# COMMUNITY CONSULTATION PLAN

## Curragh Project

**Prepared for:**

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# BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

# DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
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| 626.30083.00000-R01-v2.0 | 19 October 2022 | Emma Williams | Brad Radloff | Brad Radloff |
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# 1 Introduction

Community and stakeholder consultation and engagement is an important aspect of mine closure planning. In order to gain community and stakeholder support and consider community feedback in closure planning, early and frequent engagement will be undertaken by Coronado Curragh Pty Ltd (CCPL).

The purpose of this Community Consultation Plan is to plan, outline and record CCPL's consultation undertaken with the community and stakeholders with regard to mine closure at Curragh. This Plan will be submitted with the Progressive Rehabilitation and Closure Plan (PRCP) and meets the requirements of section 126C(1)(c)(iii) and (iv) in the *Environmental Protection Act 1994* (EP Act).

This plan includes the following:

- Objectives of consultation;
- Identification of community and stakeholders;
- Consultation methodologies;
- A future consultation plan including what information will be provided and how frequently; and
- A Consultation Register.

## 1.1 Relevant Regulations

There are multiple regulations and requirements that relate to the potential impact of mining on the surrounding community. The key legislation includes:

- Queensland Environmental Protection Act 1994;
- Commonwealth Environmental Protection and Biodiversity Act 1999;
- Queensland Coal Mining Safety and Health Act 1999 and the Coal Mining Safety and Health Regulation 2017;
- Commonwealth Fair Work Act 2009;
- Queensland Water Act 2000;
- Queensland Vegetation Management Act 1999;
- Queensland Nature Conservation Act 1992;
- Commonwealth Native Title Act;
- Queensland Heritage Act 1992;
- Queensland Aboriginal Cultural Heritage Act 2003 and Torres Strait Islander Cultural Heritage Act 2003; and
- Queensland Regional Planning Interests Act 2014.

# 2 Consultation Objectives

The objectives of this Plan and are to:

- Improve CCPL's understanding of the socio-economic impacts regarding closure and rehabilitation through engagement with the community and other stakeholders;
- Collaborate with the community to unlock ongoing value regarding mine closure opportunities and constraints through meaningful discussions on final landform, land use and infrastructure outcomes;
- Understand community issues for consideration in closure planning;
- Provide potential solutions to key closure and rehabilitation risks, perceptions and opportunities that exist in the local community;
- Share awareness of the Curragh Project and the proposed closure outcomes with the community;
- Assist and prepare the community for mine closure;
- Transition employees and contractors post mine closure;
- Manage stakeholder expectations;
- Provide a flatform for comments and feedback from the community and other stakeholders; and
- Develop a plan for how future engagement should be undertaken.

# 3 Community Profile

## 3.1 Location

The Curragh Project is located within the Central Highlands Regional Council, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton (**Figure 1**). The total mining lease area is approximately 19,650 ha.

PRCP consultation will focus on the social risks and impacts that are likely to be experienced by the communities surrounding Curragh Project and will consider both positive and negative as well as direct, indirect and cumulative risks and impacts. Therefore, the area of influence includes, but is not limited to:

- Blackwater;
- Middlemount;
- Emerald;
- Rockhampton;
- Gladstone;
- Mackay; and
- Brisbane.

Given that Blackwater is the closest town and where residential and temporary (drive in and drive out (DIDO), fly in fly out (FIFO)) accommodation is located, Blackwater will be town most directly affected by the closure of the Curragh Project.

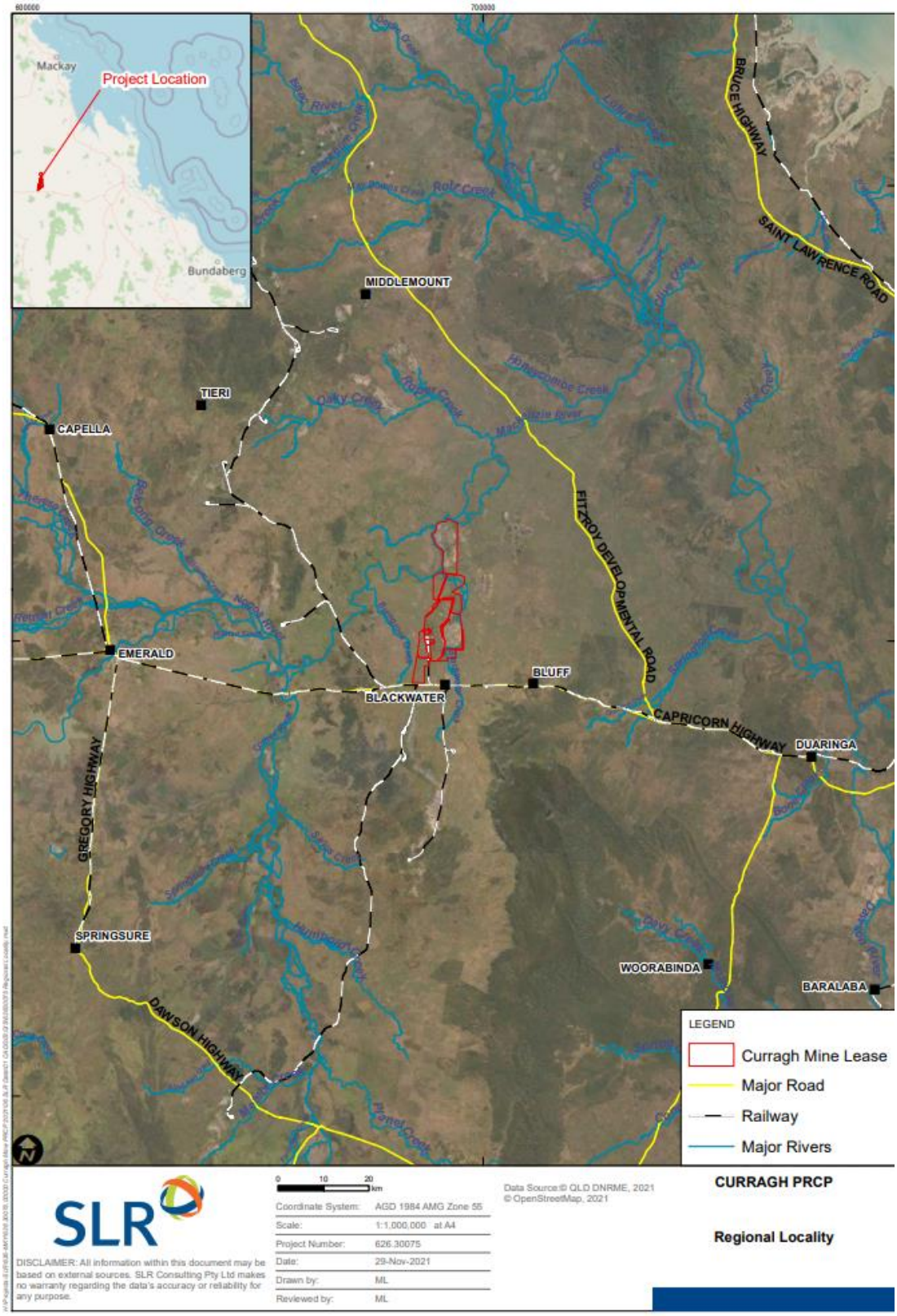



**Figure 1 Curragh Mine Regional Locality**

## 3.2 Blackwater Community

In the 2016 Census, there were 4,749 people in Blackwater with 54.9% male and 45.1% female (ABS, 2017). Aboriginal and/or Torres Strait Islander people made up 7.5% of the population. Of the employed people in Blackwater, 47.2% worked in Coal Mining.

The Blackwater settlement began with the 1877 extension of the Great Western railway line from Rockhampton and the town was gazetted in 1886 (Centre for the Government of Queensland, 2018). In the 1920s the population was approximately 80; however, coal mining sparked growth in the town.

In 1967 the first of several open-cut coal mines began production south of Blackwater, followed by the Cook Colliery in 1970 (Centre for the Government of Queensland, 2018). Gregory and Oaky Creek mines north of Blackwater began in 1979, and the Curragh Project opened in 1983. Branch railway lines serve the mines, transporting coal to Hay Point (near Mackay) or to Gladstone.

The International Coal Centre and Australian Coal Mining Museum is located at Blackwater. Besides the mining industry, Blackwater has one of the finest Japanese Gardens in the state and is located within 55 km of the Blackdown Tableland National Park (Tourism & Events Queensland, 2022).

# 4 Key Community and Stakeholders

The Department of Environment and Science (DES) have released an information sheet *Community consultation for Progressive Rehabilitation and Closure Plans* (ESR/2019/5101) which provides guidance on the community consultation requirements for the PRCP and the definition of 'community'. The information sheet states that members of the community must have a genuine interest in the underlying, adjacent or surrounding land where the mine is located. The information sheet provides the following examples of genuine interest:

- Direct impact interest (e.g. underlying and adjacent landholders);
- Cultural interest (e.g. Indigenous communities, Traditional Owners including Native Title holders);
- Heritage interest (e.g. State or Local government or relevant community groups);
- Environmental interest (e.g. State or Local government or relevant community groups);
- Recreational interest (e.g. community groups);
- Land use interest (e.g. overlapping tenure holders, agricultural entities or Local government); or
- Health interest (e.g. State or Local government, community groups).

Based on the above definition of 'community' for the purpose of the PRCP, the stakeholders relevant to the Curragh Project have been identified. A summary of the stakeholder type, organisation name and key interests has been provided in Table 1.

SLR has also assessed at what level each stakeholder requires engagement. The Spectrum of Public Participation (IAP2, 2018) is a wide used tool used to assist with the selection of the level of participation for a consultation process. The spectrum is shown below (**Figure 2**) and includes five different levels of participation.

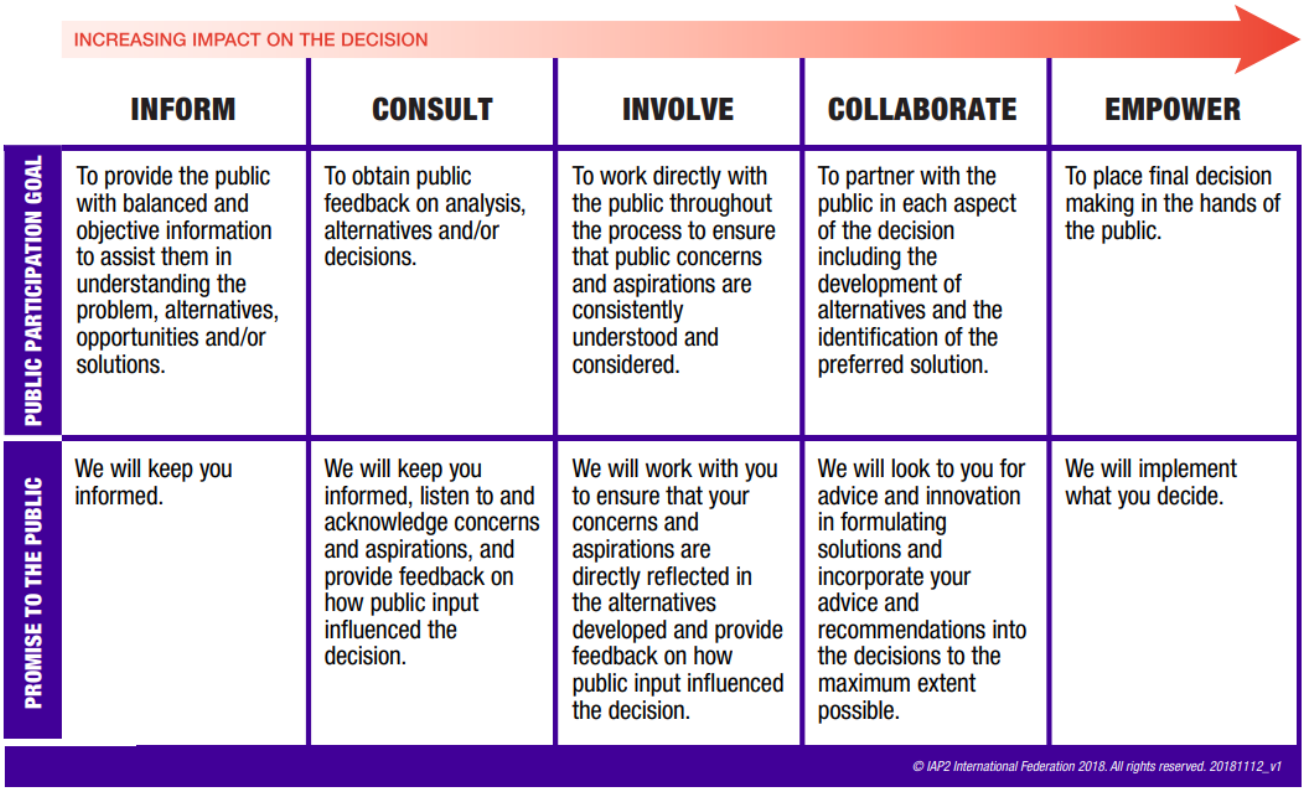



**Figure 2 IAP2 Spectrum of Public Participation (Source https://iap2.org.au/wp-content/uploads/2020/01/2018_IAP2_Spectrum.pdf)**

## Table 1 Relevant Community and Stakeholders

| Type of Stakeholder | Organisation Name | Key Interests | Level of Participation |
|---|---|---|---|
| Federal Government | Commonwealth Department of Climate Change, Energy, the Environment and Water | - Matters of National Environmental Significance<br>- Post-mining land uses<br>- Compliance with approvals<br>- Impacts to local industry | Inform |
| State Government | Department of Environment and Science | - Environmental outcomes<br>- Safe, stable, non-polluting landforms with an agreed post-mining land use | Inform, Consult and Involve |
| | Department of Resources | - Maximise utilisation of the resource<br>- Compliance with Mining Lease conditions | Inform |
| | Department of Transport and Main Roads | - Impacts on rail and road network during and following closure | Inform |
| Local Government | Central Highlands Regional Council | - Impact on local and regional employment<br>- Social impacts of population change<br>- Future sustainability of Blackwater township and associated services<br>- Effective transition of workforce and economy<br>- Post-mining land uses<br>- Consistency/impacts on local planning schemes | Inform |
| Private Landholders | A & N Goodwin | - Condition of post mining land use<br>- Impact on water resources<br>- Ongoing management requirements<br>- Use of remaining/permanent infrastructure | Inform and Consult |
| | T & M Goodwin | | |
| | A & J Acton | | |
| | P Dunne | | |
| | I & A Davidson | | |

| Type of Stakeholder | Organisation Name | Key Interests | Level of Participation |
|---|---|---|---|
| | L & N Phillipson | | |
| | J Atkinson | | |
| | J & R Warren | | |
| Community Groups and Non-Government Organisations | Fitzroy Basin Association<br>Lock the Gate Alliance<br>Environmental Defenders Office | - Impact on water resources<br>- Net positive impact on water quality post closure<br>- Environmental impact<br>- Post-mining land uses | Inform |
| Local Indigenous Groups and Cultural Heritage Groups | Nghally Ghungalu Thoonieda Aboriginal Corporation | - Connection to country<br>- Management of cultural heritage<br>- Post mining land uses | Inform and Consult |
| | Ghungalou Aboriginal Corporation | | |
| | Gaangalu Nation People | | |
| Key Suppliers | Queensland Rail, Electricity, Port Operator and Local Suppliers | - Timeline for closure<br>- Impact on their business<br>- Ongoing workforce | Inform |
| Employees | Mine employees and nominated contractors | - Current and future employment (e.g. implementing closure)<br>- Remaining mine life<br>- Redundancy and benefits<br>- Workforce transition<br>- Housing<br>- Future of community services | Inform, Consult and Involve |

# 5 Past Stakeholder Consultation

## 5.1 Curragh North EIS (2001-2003)

During the Curragh North EIS process, which concluded in 2004, a Stakeholder Consultation Plan was developed. Consultation was initially undertaken by Stanmore and continued by Wesfarmers after the sale of the Project. The consultation involved engaging multiple stakeholders including:

- Surrounding Landholders;
- Government departments;
- Local Council;
- Traditional Owners; and
- General members of the community.

A Consultation Database was established to comprehensively detail consultation undertaken, issues raised, issue topics, responses to issues, and follow-up action to address the issue.

A copy of the Stakeholder Consultation Plan and Consultation Database is provided in **Appendix A**.

**Community Consultation and Environmental Report**

A community Consultation and Environmental Report was prepared and distributed in April 2001. The report was provided to the Queensland Environmental Protection Agency (QEPA) for review and comment as well as key stakeholders and advisory bodies including surrounding landholders and Duaringa Shire Council. The Report included a Response Form for feedback, for requesting regular updates on the Project and for requesting to be placed on an Employment and Business Register.

Only three completed Response Forms were sent back to AustralAsian Resource Consultants (AARC). Two forms were from businesses primarily requested to be placed on the Employment and Business Register, and one form was from a surrounding landholder. An issue raised by two of the three respondents was concern about the loss of potential economic benefits by accommodating staff at a mine village on site instead of at Blackwater.

**Draft Terms of Reference**

An amended Draft TOR was submitted to the QEPA in June 2001. The Draft TOR was distributed to advisory bodies and stakeholders. In July 2001 the QEPA prepared and published a Terms of Reference Notice for public notification of the Draft TOR, and Stanwell Corporation Limited (SCL) provided copies of the Terms of Reference Notice to all identified affected and interested persons. At the same time the Draft TOR was made available for viewing or downloading from the Project web-site, which was linked to the QEPA web-site, so that people could access the Project web-site from the QEPA web-site.

The Draft TOR exhibition period was from Monday 9 July to Monday 20 August 2001 and comments on the Draft TOR from advisory bodies, stakeholders and other interested persons were lodged with the QEPA. In total, 14 separate submissions were received from advisory bodies, stakeholders and affected persons, and 278 issues were entered on the Consultation Database from these submissions. After the close of the exhibition period the Draft TOR comments were provided to SCL by the QEPA. SCL and AARC prepared a written summary of the comments, responses to the comments, and amended the draft TOR as a result of the comments received.

**Summary of Key Issues Raised**

As of February 2002, issues had been raised on 98 different topics. The issues relating specifically to rehabilitation and closure included:

- Final/Post mining-land use (raised 21 times);
- Final/Post-mining landform (raised 14 times);
- Final voids (raised 6 times);
- Final rehabilitation strategy (raised 14 times);
- Final voids – water quality (raised once);
- Rehabilitation monitoring (raised three times);
- Post-mining agricultural productivity (raised once); and
- Maintenance and stability of post-mining landforms (raised three times).

**Consultation with Traditional Owners**

The below local indigenous groups were also consulted:

- Nghally Ghungalu Thoonieda Aboriginal Corporation for the Ghungalu traditional owners; and
- The Ghungalou Aboriginal Corporation as representatives of the Kangalou traditional owners.

Discussions have also been held with the Birri Gubba Guntha Bimbi Sacred Sites Aboriginal Corporation for the Kabalbarra traditional owners, who claim traditional ownership to the west side of the Mackenzie River which does not form part of the Project site.

# 6 Initial PRCP Consultation

## 6.1 DES Meeting

CCPL and SLR had a PRCP pre-lodgement meeting with the DES on 1 June 2021. The primary purpose of the meeting was to confirm what land outcomes are approved in Land Outcome Documents and to agree to a PRCP submission date. The outcomes of the meeting include:

- The Curragh Project has pre-approved residual voids as Non-Use Management Areas;
- CCPL will update the Residual Void study to provide clarification on previously identified voids and to include any voids within the new Mining Leases (MLs); and
- A proposed combined Post-Mining Land Use (PMLU) of light grazing and open woodland was agreed upon.

The other key outcome of the meeting was that the PRCP for the Curragh Project would be due to DES on 21st October 2022.

## 6.2 Traditional Owners

CCPL has a quarterly meeting with the local indigenous group, Gaangalu Nation People, to discuss a number of matters as they arise. At the meeting in May 2022, SLR provided a presentation on the PRCP process and how this relates to the Curragh Complex. The key discussion items included:

- Explanation of the PRCP process and purpose and presentation of a PowerPoint which includes a description of the consultation process;
- Where the rehabilitation seeds come from and potential for supply by local Indigenous supplier;
- An overview of the nature of PRCP being progressive and reiterative as the mine life continues;
- Possibility of CCPL looking to complete fauna surveys as evidence of return of totemic species and to further support the suitability of rehabilitation;
  - CCPL requested a list of target species that can be targeted in fauna surveys; and
- Potential for returning artefacts to the land, however, this will involve a conversation with the native title applicants and consideration of what the post-mining land use will be.

In September 2023, SLR and Curragh met with the Traditional Owners, the Gaangalu Nation People, to discuss the PRCP process, the current status of the PRCP and Rehabilitation at Curragh. The following key items were discussed:

- An overview of the PRCP
- Curragh Mine Rehabilitation
- Totem Species and seed mixes
- Post Mining Land Uses
- Returning of Artefacts to rehabilitated/relinquished land

## 6.3 Underlying Landholder

On 9th August 2022, CCPL and SLR had a one-on-one meeting with an underlying landholder (property manager of Mourallyn) at Curragh North. The purpose of the meeting was to discuss the PRCP framework and how it relates to the Curragh Complex. SLR provided a presentation on the PRCP process, the proposed post-mining land uses at Curragh and the community consultation process. Key discussion points from the meeting included:

- Conversation with the landholder about how a 'grazing' land use is assessed. The landholder's advice is that this should focus on management requirements and not specific parameters such as stocking rates given that these change with changing conditions (e.g. weather, condition of pasture, etc.);
- Some of the key queries regarding the closure of Curragh included:
  - Responsibility of final voids;
  - How the land will be managed for grazing;
  - Importance of an ongoing relationship between landholders and CCPL;
  - Erosion of the land;
  - Potential for the retainment of infrastructure including areas of bare land;
- The landholder was happy for consultation to occur as required and was interested in attending larger community events and site visits; and
- It was reiterated that the land should be rehabilitated with the final land user in mind and that there should be no surprises at the time of surrender.

Peter offered to provide some guidance on grazing management strategies that he would recommend for incorporation into the rehabilitation strategy.

# 7 Consultation Plan

It is well understood that consultation and engagement relating to rehabilitation and mine closure should be undertaken over the life of the project. It is best to communicate and manage mine closure expectations so that there are no surprises when it comes time to relinquish the site. Ongoing consultation can also be used to identify opportunities such as retaining infrastructure for future use, transitioning the workforce and organising rehabilitation trials.

The PRCP Guideline requires mines to plan for when and how consultation should occur in the future. Consultation should always be meaningful and not used to simply tick a box. Some situations where consultation is recommended to occur include:

- Significant mine planning changes that result in the delay of rehabilitation or relinquishment;
- Changes to approved post-mining land uses and non-use management areas;
- When new areas of disturbance are proposed;
- Significant changes to rehabilitation methodologies;
- Large legislative changes that may impact/influence rehabilitation and closure; and
- When there may be opportunities for collaboration on rehabilitation objectives.

## 7.1 Consultation Processes

CCPL will utilise existing consultation processes wherever suitable to discuss mine closure and rehabilitation matters. However, in some cases consultation outside of these existing processes may be required. **Table 2** outlines recommended consultation processes and frequency for each stakeholder in accordance with their level of participation as per **Table 1**.

### 7.1.1 Near Neighbours Meetings

CCPL hold a bi-annual near neighbours meeting for adjacent and underlying land holders. This meeting provides an opportunity for CCPL to provide an update on relevant projects and changes as well as an opportunity for near neighbours to raise any concerns or feedback. CCPL has already used this forum to introduce the concept of PRCPs and will continue to use it for updates on rehabilitation and closure where appropriate.

### 7.1.2 Coordinating Committee Meetings

Coordinating Committee Meetings are held generally every quarter between the Gaangalu Nation People and CCPL. These meetings are used to raise any issues or concerns from the Gaangalu Nation People as well as CCPL to provide an update on projects. CCPL has already used this forum to introduce the concept of PRCPs and will continue to use it for updates on rehabilitation and closure where appropriate.

### 7.1.3 Coronado Global Resources Website

The Coronado Global Resources website is another existing resource that may be used to publish information about the rehabilitation of the Project site. The website already contains general information about the Curragh Project, surrounding community and environmental performance.

## Table 2 Consultation Plan

| Type of Stakeholder | Organisation Name | Level of Participation | Consultation Methods | Frequency | Information to be Provided |
|---|---|---|---|---|---|
| Federal Government | Commonwealth Department of Climate Change, Energy, the Environment and Water | Inform | 1. One-on-one meetings<br>2. Website<br>3. Information Sheets | 1. As required<br>2. All year round<br>3. As required | • Any impacts to MNES<br>• Project description<br>• Life of mine schedule |
| State Government | Department of Environment and Science | Inform, Consult and Involve | 1. One-on-one meetings (e.g. pre-lodgement meetings)<br>2. Website<br>3. Information Sheets<br>4. Site visits<br>5. Review of Draft documentation | 1. As required<br>2. All year round<br>3. As required<br>4. As required<br>5. As required | • Draft amendment applications<br>• Any impacts to MSES<br>• Project description<br>• Life of mine schedule<br>• Existing rehabilitation tours<br>• Rehabilitation success<br>• Post-mining land uses |
| | Department of Resources | Inform | 1. One-on-one meetings<br>2. Website<br>3. Information Sheets | 1. As required<br>2. All year round<br>3. As required | • Project description<br>• Life of mine schedule<br>• ML details |

| Type of Stakeholder | Organisation Name | Level of Participation | Consultation Methods | Frequency | Information to be Provided |
|---|---|---|---|---|---|
| | Department of Transport and Main Roads | Inform | 1. One-on-one meetings<br>2. Website<br>3. Information Sheets | 1. As required<br>2. All year round<br>3. As required | • Project description<br>• Life of mine schedule<br>• Impacts to roads |
| Local Government | Central Highlands Regional Council | Inform | 1. One-on-one meetings<br>2. Website<br>3. Information Sheets<br>4. Community Events | 1. As required<br>2. All year round<br>3. As required<br>4. As required | • Project description<br>• Life of mine schedule<br>• Post-mining land uses<br>• How to provide feedback |
| Private Landholders | A & N Goodwin | Inform and Consult | 1. One-on-one meetings<br>2. Website<br>3. Information Sheets<br>4. Site visits<br>5. Community Events<br>6. Near Neighbour Meetings<br>7. Community Newsletters | 1. As required<br>2. All year round<br>3. As required<br>4. As required<br>5. As required<br>6. Bi-Annually<br>7. Monthly | • Project description<br>• Life of mine schedule<br>• Rehabilitation success<br>• Retention of infrastructure<br>• Rehabilitation trials<br>• How to provide feedback |
| | T & M Goodwin | | | | |
| | A & J Acton | | | | |
| | P Dunne | | | | |
| | I & A Davidson | | | | |
| | L & N Phillipson | | | | |
| | J Atkinson | | | | |
| | J & R Warren | | | | |

| Type of Stakeholder | Organisation Name | Level of Participation | Consultation Methods | Frequency | Information to be Provided |
|---|---|---|---|---|---|
| Community Groups and Non-Government Organisations | Fitzroy Basin Association<br>Lock the Gate Alliance<br>Environmental Defenders Office | Inform | 1. Website<br>2. Information Sheets<br>3. Community Events | 1. All year round<br>2. As required<br>3. As required | • Project description<br>• Life of mine schedule<br>• Rehabilitation success<br>• How to provide feedback |
| Local Indigenous Groups and Cultural Heritage Groups | Nghally Ghungalu Thoonieda Aboriginal Corporation<br>Ghungalou Aboriginal Corporation<br>Gaangalu Nation People | Inform and Consult | 1. Coordinating Committee Meetings<br>2. Information Sheets<br>3. Site visits<br>4. Community Events | 1. Quarterly<br>2. As required<br>3. As required<br>4. As required | • Project description<br>• Life of mine schedule<br>• Rehabilitation success<br>• Cultural Heritage<br>• How to provide feedback |
| Key Suppliers | Queensland Rail, Electricity, Port Operator and Local Suppliers | Inform | 1. Website<br>2. Information Sheets<br>3. Community Events | 1. All year round<br>2. As required<br>3. As required | • Project description<br>• Life of mine schedule |
| Employees | Mine employees and nominated contractors | Inform, Consult and Involve | 1. Employee meetings<br>2. Website<br>3. Information Sheets<br>4. Workplace Events<br>5. Workplace Newsletters<br>6. Workshops | 1. As required<br>2. All year round<br>3. As required<br>4. As required<br>5. Monthly<br>6. As required | • Project description<br>• Life of mine schedule<br>• Workplace transition |

# 8 Community Consultation Register

A record of all closure and rehabilitation consultation undertaken must be kept in the Community Consultation Register. The register records the following information:

- Consultation date(s);
- Stakeholder or Community member name(s);
- Consultation method;
- Information provided;
- Issues raised by stakeholders/community;
- How issues have been or are intended to be considered;
- Any decisions/outcomes of the consultation; and
- Any commitments made.

A copy of the register has been provided in **Appendix B**.

# 9 References

Australian Bureau of Statistics, 2017, 2016 Census QuickStats: Blackwater, accessed on 16 February 2022, available at 2016 Census QuickStats: Blackwater (abs.gov.au).

Centre for the Government of Queensland, 2018, Blackwater, accessed on 16 February 2022, available at Blackwater | Queensland Places.

IAP2, 2018, IAP2 Spectrum of Public Participation, accessed on 17 August 2022, available at https://iap2.org.au/wp-content/uploads/2020/01/2018_IAP2_Spectrum.pdf

Tourism & Events Queensland, 2022, Blackwater, accessed on 16 February 2022, available at Blackwater (queensland.com).

# APPENDIX A

# COMMUNITY CONSULTATION PLAN (2001)

# APPENDIX B

# COMMUNITY CONSULTATION REGISTER

| Date | Stakeholders | Consultation type | Information provided | Issues raised/discussed | How issues were considered | Decisions/outcomes | Commitments |
|---|---|---|---|---|---|---|---|
| 25/09/2023 | Gaangalu Nation People | PRCP Meeting | SLR and CCPL provided a presentation and forum on the PRCP and rehabilitation undertaken at Curragh. | • Totem Species<br>• Returning of Artefacts to Rehabilitated/Relinquished Land<br>• Seed mix/list<br>• Relinquishment of land | • Further discussion required returning of artefacts to the land.<br>• Discussion surrounding involvement of GNP in provision of seed mix | • Potential for seed mix provision group to be established<br>• Wider discussion required to determine future of artefacts. | • CCPL will continue to engage with the Gaangalu Nation People |
| 14/10/2022 | Department of Environment and Science | Pre-lodgement meeting | SLR and CCPL provided a presentation on the work undertaken for the PRCP. | • Stable embankments land use<br>• Objectives of the cover design<br>• Hydrogeology technical modelling report<br>• NUMA location change | CCPL and SLR have taken away the comments made by DES and are making small changes to the PRCP to address this feedback. | The PRCP will be submitted by 21st October 2022. | The PRCP will be submitted by 21st October 2022. |
| 09/08/2022 | Underlying Landholder | One-on-one meeting with CCPL and SLR | Presentation on PRCP framework, proposed post-mining land uses and ongoing engagement process | • Rehabilitating for the final land use of grazing<br>• Final voids responsibility<br>• Erosion<br>• Retention of Infrastructure<br>• Potential grazing trials for management techniques | Peter has offered to provide information on this recommended grazing management that can be incorporated into the rehabilitation strategy at Curragh. | • Peter to provide grazing management advice<br>• CCPL to continue to engage with Peter on updates<br>• SLR and CCPL to focus on the final land user when developing PRCP<br>• Noted that the PRCP would have all infrastructure to be removed with the purpose of continuing to engage on this aspect | • CCPL will continue to engage with Peter on rehabilitation and closure<br>• Further discussion on the retainment of infrastructure post-closure to occur<br>• Peter to provide grazing management advice |
| 07/06/2022 | Department of Environment and Science | Site visit | Tour of site and update on PRCP progress | • Availability of tailings data and capping design for PRCP | Discussion with DES on weather impacting opportunities to take tailings sampling. | • DES advised CCPL to try looking at historical imagery for deposition times<br>• Provide as much information as possible in PRCP | No commitments made. |
| 10/05/2022 | Gaangalu Nation People | Quarterly Coordinating Committee Meeting | Presentation on PRCP framework, proposed post-mining land uses and ongoing engagement process | • Rehabilitation seed collection and potential for supply by local indigenous supplier<br>• Interest in CCPL completing fauna surveys as evidence of species use of area and suitability of rehabilitation<br>• Potential for returning artefacts to the land | Further discussion required for the rehabilitation monitoring and return of artefacts to the land. | • CCPL asked for a list of target species for potential fauna surveys<br>• CCPL will need to discuss the return of artefacts with native title applicants and consider the post-mining land use | • CCPL will provide the Rehabilitation Monitoring Report<br>• An update on the PRCP and return of artefacts will be provided in the next meeting |
| 17/11/2021 | Near Neighbours | Near Neighbours Meeting | Provided presentation including an introduction to PRCPs. | No issues raised. | No issues raised. | Engagement for information purposes. | No rehabilitation/closure commitments made. |
| 01/06/2021 | Department of Environment and Science | PRCP Pre-lodgement Meeting | • Site background information<br>• CCPL's interpretation of Land Outcome Documents<br>• PRCP Delivery Schedule | • Pre-approved NUMAs<br>• Inclusion of new areas as pre-approved NUMAs<br>• Combined PMLUs<br>• PRCP Delivery | • DES acknowledged that the EA allowed for the presence of voids as NUMAs<br>• The Residual Void study will need to be updated to include any additional areas<br>• DES had no issue with the combined use of open woodland and grazing | • CCPL will update the Residual Void study and submit it prior to 30 November 2021<br>• The PRCP due date of 21st October 2022 was decided | • DES to send formal transition notice in 2-4 weeks |
| 19/02/2020 | Near Neighbours | Near Neighbours Meeting | • Overview of the Curragh Extension Project and Exploration Program<br>• Drill site rehabilitation | No issues raised. | No issues raised. | Engagement for information purposes. | No rehabilitation/closure commitments made. |
| 30/08/2019 | Gaangalu Nation People | Quarterly Coordinating Committee Meeting | • Discussion on rehabilitation and cultural material<br>• Established rehabilitation areas | No issues raised. | No issues raised. | Engagement for information purposes. | No rehabilitation/closure commitments made. |

| Date | Stakeholders | Consultation type | Information provided | Issues raised/discussed | How issues were considered | Decisions/outcomes | Commitments |
|---|---|---|---|---|---|---|---|
| 2001 - 2003 | • Landholders<br>• Traditional Owners<br>• Duaringa Shire Council<br>• DNRM, Sunwater and the QEPA | • Meetings with local landholders<br>• Meetings with Traditional Owners<br>• Ongoing negotiations with Council<br>• Discussions and meetings with DNRM, Sunwater and the QEPA | • Community Consultation and Environmental Report<br>• Draft ToR<br>• EIS | Please see Appendix A for the full details of all consultation and feedback received. Items relating to mine closure and rehabilitation have been highlighted in yellow for ease of reading. | | | |

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# Permit

***Environmental Protection Act 1994***

## Environmental authority EPML00643713

*This environmental authority is issued by the administering authority under Chapter 5 of the* Environmental Protection Act 1994.

### Environmental authority number: EPML00643713

**Environmental authority takes effect on** 1 August 2022

The anniversary date of this environmental authority is 31 May each year.

The anniversary date of this environmental authority is the same day each year as the take effect date. The payment of the annual fee will be due each year on this day.

An annual return will be due each year on 01 April.

### Environmental authority holder(s)

| Name(s) | Registered address |
|---|---|
| CORONADO CURRAGH PTY LTD | Level 31, Central Plaza One 345 Queen Street BRISBANE CITY QLD 4000 |

### Environmentally relevant activity and location details

| Environmentally relevant activity/activities | Location(s) |
|---|---|
| Schedule 3 13: Mining black coal | ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171 |
| Ancillary 08 - Chemical Storage 2: Storing 50t or more of chemicals of dangerous goods class 6, division 6.1 under subsection (1)(b) | ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171 |
| Ancillary 31 - Mineral processing 2: Processing, in a year, the following quantities of mineral products, other than coke (b) more than 100,000t | ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171 |

| Environmentally relevant activity/activities | Location(s) |
|---|---|
| Ancillary 60 - Waste disposal 2: Operating a facility for disposing of, in a year, the following quantity of waste mentioned in subsection (1)(b) (b) more than 2000t but not more than 5000t | ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171 |
| Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (b-ii) more than 100 but not more than 1500EP otherwise | ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171 |

**Additional information for applicants**

Environmentally relevant activities

The description of any environmentally relevant activity (ERA) for which an environmental authority (EA) is issued is a restatement of the ERA as defined by legislation at the time the EA is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an EA as to the scale, intensity or manner of carrying out an ERA, the conditions prevail to the extent of the inconsistency.

An EA authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the EA specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that an owner or occupier of contaminated land give written notice to the administering authority if they become aware of the following:

- the happening of an event involving a hazardous contaminant on the contaminated land (notice must be given within 24 hours); or
- a change in the condition of the contaminated land (notice must be given within 24 hours); or
- a notifiable activity (as defined in Schedule 3) having been carried out, or is being carried out, on the contaminated land (notice must be given within 20 business days)

that is causing, or is reasonably likely to cause, serious or material environmental harm.

For further information, including the form for giving written notice, refer to the Queensland Government website www.qld.gov.au, using the search term ‘duty to notify’.

Take effect

Please note that, in accordance with section 200 of the EP Act, an EA has effect:

a) if the authority is for a prescribed ERA and it states that it takes effect on the day nominated by the holder of the authority in a written notice given to the administering authority-on the nominated day; or

b) if the authority states a day or an event for it to take effect-on the stated day or when the stated event happens; or

c) otherwise- one the day the authority is issued.

However, if the EA is authorising an activity that requires an additional authorisation (a relevant tenure for a resource activity, a development permit under the *Planning Act 2016* or an SDA Approval under the *State Development and Public Works Organisation Act 1971*), this EA will not take effect until the additional authorisation has taken effect.

If this EA takes effect when the additional authorisation takes effect, you must provide the administering authority written notice within 5 business days of receiving notification of the related additional authorisation taking effect.

If you have incorrectly claimed that an additional authorisation is not required, carrying out the ERA without the additional authorisation is not legal and could result in your prosecution for providing false or misleading information or operating without a valid environmental authority.



Alisha Stewart
Department of Environment and Science
Delegate of the administering authority
*Environmental Protection Act 1994*

**Date Issued*:* 1 August 2022**

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**Privacy statement**

Pursuant to section 540 of the EP Act, the Department is required to maintain a register of certain documents and information authorised under the EP Act. A copy of this document will be kept on the public register. The register is available for inspection by members of the public who are able take extracts, or copies of the documents from the register. Documents that are required to be kept on the register are published in their entirety, unless alteration is required by the EP Act. There is no general discretion allowing the Department to withhold documents or information required to be kept on the public register. For more information on the Department's public register, search 'public register' at www.qld.gov.au. For queries about privacy matters please email privacy@des.qld.gov.au or telephone 13 74 68.

**Obligations under the *Environmental Protection Act 1994***

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the Act:

- general environmental duty (section 319)
- duty to notify environmental harm (section 320-320G)
- offence of causing serious or material environmental harm (sections 437-439)
- offence of causing environmental nuisance (section 440)
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG)
- offence to place contaminant where environmental harm or nuisance may be caused (section 443)

**Other permits required**

This permit only provides an approval under the *Environmental Protection Act 1994*. In order to lawfully operate you may also require permits / approvals from your local government authority, other business units within the department and other State Government agencies prior to commencing any activity at the site. For example, this may include permits / approvals with your local Council (for planning approval), the Department of Transport and Main Roads (to access state controlled roads), the Department of Resources (to clear vegetation), and the Department of Agriculture and Fisheries (to clear marine plants or to obtain a quarry material allocation).

**Conditions of environmental authority:**

The environmentally relevant activity(ies) conducted at the location as described above must be conducted in accordance with the following site-specific conditions of approval.

This environmental authority consists of the following Schedules and Appendices:

| | |
|---|---|
| Schedule A | General |
| Schedule B | Air |
| Schedule C | Water |
| Schedule D | Regulated structures |
| Schedule E | Noise and vibration |
| Schedule F | Waste |
| Schedule G | Land |
| Schedule H | Watercourse diversions |
| Figure 1 | Release points (RP) and monitoring points (MP) on Blackwater Creek |
| Figure 2 | Release points (RP) and monitoring points (MP) on the Mackenzie River |
| Figure 3 | Curragh Mine Onsite Landfill Facility |
| Figure 4 | Approved Disturbance Area and Mine Activity Areas |
| Figure 5 | Prescribed environmental matters |
| Figure 6 | Watercourse Diversions |

## Conditions of environmental authority:

| **Agency interest: General** | |
|---|---|
| **Condition number** | **Condition** |
| **A1** | The environmental authority authorises environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm. |
| **A2** | In carrying out coal mining, disturbance of land is limited to the areas marked "Approved Disturbance Area and Mine Activity Areas" in **Figure 4**.<br>Note: *This condition relates to disturbance of land within ML700006, ML700007, ML700008 and ML700009 only*. |
| **A3** | **Prevent and /or minimise likelihood of environmental harm**<br>In carrying out the environmentally relevant activities, you must take all reasonable and practicable measures to prevent and / or to minimise the likelihood of environmental harm being caused. Any environmentally relevant activity, that, if carried out incompetently, or negligently, may cause environmental harm, in a manner that could have been prevented, shall be carried out in a proper manner in accordance with the conditions of this authority. |
| **A4** | **Maintenance of measures, plant and equipment**<br>The environmental authority holder must ensure:<br>a) install all measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority<br>b) maintain such measures, plant and equipment in a proper and efficient condition<br>c) operate such measures, plant and equipment in a proper and efficient manner<br>d) ensure all instruments and devices used for the measurement or monitoring of any parameter under any condition of this environmental authority are properly calibrated. |
| **A5** | **Monitoring and records**<br>Except where specified otherwise in another condition of this environmental authority, all monitoring records or reports required by this environmental authority must be kept for a period of not less than **five** (**5) years**. |
| **A6** | Where monitoring is a requirement of this environmental authority, ensure that a competent person(s) conducts all monitoring. |
| **A7** | **Notification of emergencies, incidents and exceptions**<br>The holder of this environmental authority must notify the administering authority by written notification within **twenty-four (24) hours**, after becoming aware of any emergency or incident which results in the release of contaminants not in accordance, or reasonably expected to be not in accordance with, the conditions of this environmental authority. |

| | |
|---|---|
| **A8** | Within **ten (10) business days** following the initial notification of an emergency or incident, or receipt of monitoring results, whichever is the latter, further written advice must be provided to the administering authority, including the following:<br>a) results and interpretation of any samples taken and analysed<br>b) outcomes of actions taken at the time to prevent or minimise unlawful environmental harm<br>c) proposed actions to prevent a recurrence of the emergency or incident. |
| **A9** | **Complaints**<br>The holder of this environmental authority must record all environmental complaints received about the mining activities including:<br>a) name, address and contact number for of the complainant<br>b) time and date of complaint<br>c) reasons for the complaint<br>d) investigations undertaken<br>e) conclusions formed<br>f) actions taken to resolve the complaint<br>g) any abatement measures implemented<br>h) person responsible for resolving the complaint. |
| **A10** | The holder of this environmental authority must, when requested by the administering authority, undertake relevant specified monitoring within a reasonable timeframe nominated or agreed to by the administering authority to investigate any complaint of environmental harm. The results of the investigation (including an analysis and interpretation of the monitoring results) and abatement measures, where implemented, must be provided to the administering authority within **ten (10) business days** of completion of the investigation, or no later than **ten (10) business days** after the end of the timeframe nominated by the administering authority to undertake the investigation. |
| **A11** | **Coal Extraction**<br>The environmental authority holder is approved for a coal extraction rate of up to **eighteen (18) million tonnes per annum (Mtpa)** of run-of-mine (ROM) coal by means of open cut mining (including highwall mining). |
| **A12** | **Exploration**<br>Exploration activities on ML700006, ML700007, ML700008 and ML700009 must be conducted in accordance with the standard conditions in the document titled '*Eligibility criteria and standard conditions for exploration and mineral development projects - Version 2*' (ESR/2016/1985). |

| **Agency interest: Air** | |
|---|---|
| **Condition number** | **Condition** |
| **B1** | **Determining Air Quality for ML700006, ML700007, ML700008 and ML700009**<br>The holder of the environmental authority must carry out a study to determine air quality background at least **six (6) months** prior to coal mining taking place on ML700006, ML700007, ML700008 and ML700009. |
| **B2** | **Dust Monitoring Plan**<br>A dust monitoring plan is to be submitted to the administrating authority at least **six (6) months** prior to coal mining taking place on ML700006, ML700007, ML700008 and ML700009.<br>This plan will include:<br>a) proposed monitoring sites for ML700006, ML700007, ML700008 and ML700009<br>b) dust monitoring sites associated with existing operations<br>c) align with monitoring methods outlined in condition **B4**. |
| **B3** | **Dust nuisance**<br>The release of dust or particulate matter or both resulting from the mining activities must not cause an environmental nuisance, at any sensitive or commercial place. |

| | |
|---|---|
| **B4** | **Dust and particulate matter monitoring**<br>The Proponent shall ensure all reasonable and feasible avoidance and mitigation measures are employed so that the dust and particulate matter emissions generated by the mining activities do not cause exceedances of the following levels when measured at any sensitive place or commercial place.<br>The environmental authority holder will respond within **twenty-eight (28) days** to any validated air quality complaints with a dust monitoring campaign, as agreed with the administrating authority, that assesses the level of nuisance with reference to the following air quality levels:<br>a) Dust deposition of 120 milligrams per square metre per day, averaged over one month, when monitored in accordance with the most recent version of Australian Standard *AS3580.10.1 Methods of sampling and analysis of ambient air – Determination of particulate matter - Deposited matter - Gravimetric method*.<br>b) A concentration of particulate matter with an aerodynamic diameter of less than 10 micrometres ($PM_{10}$) suspended in the atmosphere of 50 micrograms per cubic meter over a 24-hour averaging time, for no more than five exceedances recorded each year, when monitored in accordance with the most recent version of either:<br>*1.* Australian Standard *AS3580.9.6 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter – PM10 high volume sampler with size - selective inlet - Gravimetric method*, or<br>*2.* Australian Standard *AS3580.9.9 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM(sub)10(/sub)low volume sampler - Gravimetric method*, or<br>3. Beta attenuation monitoring (BAM) method used to calculate mass concentration of PM10 volume as per Australian Standard *AS3580.9.11Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – PM10 beta attenuation matters.*<br>c) A concentration of particulate matter suspended in the atmosphere of 90 micrograms per cubic metre over a 1 year averaging time, when monitored in accordance with the most recent version of *AS/NZS3580.9.3:2003 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - Total suspended particulate matter (TSP) - High volume sampler gravimetric method*. |
| **B5** | **Odour nuisance**<br>The release of noxious or offensive odour(s) or any other noxious or offensive airborne contaminant(s) resulting from the mining activity must not cause an environmental nuisance at any sensitive or commercial place. |
| **B6** | When requested by the administering authority, odour monitoring must be undertaken within a reasonable and practicable timeframe nominated by the administering authority to investigate any complaint (which is neither frivolous nor vexatious nor based on mistaken belief in the opinion of the authorised officer) of environmental nuisance at any sensitive or commercial place, and the results must be notified within ten business days to the administering authority following completion of monitoring. |

| **Agency interest: Water** | |
|---|---|
| **Condition number** | **Condition** |
| **C1** | **Contaminant release**<br>Contaminants that will, or have the potential to cause environmental harm must not be released directly or indirectly to any waters except as permitted under the conditions of this environmental authority. |
| **C2** | Unless otherwise permitted under the conditions of this environmental authority, the release of mine affected water to waters must only occur from the release points specified in **Table C1** and depicted in **Figure 1** and **Figure 2** attached to this environmental authority. |
| **C3** | The release of mine affected water to internal water management infrastructure that is installed and operated in accordance with a water management plan that complies with conditions **C33** to **C38** inclusive is permitted. |
| **C4** | The release of mine affected water to waters in accordance with condition **C2** must not exceed the release limits stated in **Table C2** when measured at the monitoring points specified in **Table C1** for each quality characteristic. |

**Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)**

| Release Point (RP) | Latitude (decimal degree, GDA94) | Longitude (decimal degree, GDA94) | Mine Affected Water Source and Location | Monitoring Point | Receiving waters description |
|---|---|---|---|---|---|
| RP 1 | -23.5130 | 148.8753 | Dam RD1 | Dam | Blackwater Creek |
| RP 2 | -23.5098 | 148.8868 | Various sources – release outlet to diversion channel | End of pipe | Blackwater Creek |
| RP 3 | -23.2837 | 148.8478 | Dam CN3 | Release channel downstream of pipe outlet | Mackenzie River |
| RP 4 | -23.3588 | 148.8717 | Dam CN5 | Release channel downstream of pipe outlet | Mackenzie River |
| RP 5 | -23.4522 | 148.9011 | Various sources. Outlet pipe through plug on the former Blackwater Creek channel. | Release channel downstream of pipe outlet | Blackwater Creek |
| RP 6 | -23.2615 | 148.8763 | Various sources. Outlet pipe through Mackenzie River levee | End of pipe | Mackenzie River |
| RP 7 | -23.3072 | 148.8565 | Various sources. Release outlet to Mackenzie River on pipe network | End of pipe | Mackenzie River |
| RP8 | -23.3167 | 148.8675 | Various sources, predominantly S pit. Outlet pipe through Mackenzie River levee. | Standing water at pipe inlet | Mackenzie River |
| RP9 | -23.2834 | 148.8936 | Various sources. Pumped from behind the levee to the Mackenzie | End of pipe | Mackenzie River |

**Table C2 (Mine Affected Water Release Points, Sources and Receiving Waters)**

| Quality Characteristic | Release Limits | Monitoring frequency | Comment |
|---|---|---|---|
| Electrical conductivity (µS/cm) | Release limits specified in **Table C4** for variable flow criteria. | Daily during release (the first sample must be taken within 2 hours of commencement of release) | |
| pH (pH Unit) | 6.5 (minimum)<br>9.0 (maximum) | Daily during release (the first sample must be taken within 2 hours of commencement of release) | |
| Suspended Solids (mg/L) | | Daily during release* (first sample within 2 hours of commencement of release) | Suspended solids are required to measure the performance of sediment and erosion control measures. |
| Turbidity (NTU) | Mackenzie River release points 182 NTU<br>or<br>Blackwater Creek release points 629 NTU | Daily during release* (first sample within 2 hours of commencement of release) | Turbidity is required to assess ecosystems impacts and can provide instantaneous results |

*Note: *Limit for suspended solids can be omitted if turbidity limit is included. Limit for turbidity not required if suspended solids limit included.*

| | |
|---|---|
| **C5** | a) The release of mine affected water to waters from the release points must be monitored at the locations specified in **Table C1** for each quality characteristics and at the frequency specified in **Table C2** and **Table C3**.<br><br>*Note: the administering authority will take into consideration any extenuating circumstances prior to determining an appropriate enforcement response in the event condition **C5** is contravened due to a temporary lack of safe or practical access. The administering authority expects the environmental authority holder to take all reasonable and practicable measures to maintain safe and practical access to designated monitoring locations.*<br><br>b) The holder of the environmental authority must ensure that there are no adverse impacts to the ecosystem or wetlands through overland flow for RP9. |

**Table C3 (Release Contaminant Trigger Investigation Levels, Potential Contaminants)**

| Quality Characteristic | Trigger Levels (µg/L) | Comment on Trigger Level | Monitoring Frequency |
|---|---|---|---|
| Aluminium | 55 | *For aquatic ecosystem protection, based on SMD guideline* | Commencement of release and thereafter weekly during release |
| Arsenic | 13 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Cadmium | 1 | *Based on LOR* | |
| Chromium | 1 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Copper | 4 | *80th percentile value for reference sites* | |
| Iron | 300 | *For aquatic ecosystem protection, based on low reliability guideline* | |
| Lead | 4 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Mercury | 0.2 | *For aquatic ecosystem protection, based on LOR for CV FIMS* | |
| Nickel | 11 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Zinc | 8 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Boron | 370 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Cobalt | 90 | *For aquatic ecosystem protection, based on low reliability guideline* | |
| Manganese | 1900 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Molybdenum | 34 | *For aquatic ecosystem protection, based on low reliability guideline* | |
| Selenium | 10 | *For aquatic ecosystem protection, based on LOR for ICPMS* | |
| Silver | 1 | *For aquatic ecosystem protection, based on LOR for ICPMS* | |
| Uranium | 1 | *For aquatic ecosystem protection, based on LOR for ICPMS* | |
| Vanadium | 11 | *80th percentile value for reference sites* | |
| Ammonia | 900 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Nitrate | 1100 | *For aquatic ecosystem protection, based on ambient Qld WQ Guidelines (2006) for TN* | |
| Petroleum hydrocarbons (C6-C9) | 20 | | |
| Petroleum hydrocarbons (C10- C36) | 100 | | |
| Fluoride (total) | 2000 | *Protection of livestock and short term irrigation guideline* | |
| Sodium | 180,000 | *Australian Drinking Water Guideline* | |
| Sulphate | 200,000 | *Drinking water environmental values from NHMRC 2006 guidelines or ANZECC* | |

*Note:*

*1. All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/metalloids apply if dissolved results exceed trigger.*

*2. The quality characteristics required to be monitored as per Table C3 can be reviewed once the results of two years monitoring data is available, or if sufficient data is available to adequately demonstrate negligible environmental risk, and it may be determined that a reduced monitoring frequency is appropriate or that certain quality characteristics can be removed from Table C3 by amendment.*

*3. SMD – slightly moderately disturbed level of protection, guideline refers ANZECC & ARMCANZ (2000).*

*4. LOR – typical reporting for method stated. ICPMS/CV FIMS – analytical method required to achieve LOR.*

| | |
|---|---|
| **C6** | If quality characteristics of the release exceed any of the trigger levels specified in **Table C3** during a release event, the environmental authority holder must compare the downstream results in the receiving waters to the trigger values specified in **Table C3** and:<br>1. where the trigger values are not exceeded then no action is to be taken; or<br>2. where the downstream results exceed the trigger values specified **Table C3** for any quality characteristic, compare the results of the downstream site to the data from background monitoring sites and;<br>a) if the result is less than the background monitoring site data, then no action is to be taken; or<br>b) if the result is greater than the background monitoring site data, complete an investigation in accordance with the ANZECC & ARMCANZ 2000 methodology, into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining:<br>(i) details of the investigations carried out; and<br>(ii) actions taken to prevent environmental harm.<br>Note: *Where an exceedance of a trigger level has occurred and is being investigated, in accordance with C6 2(b) of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.* |
| **C7** | If an exceedance in accordance with condition **C6 2(b)** is identified, the holder of the authority must notify the administering authority in writing within **one (1) business day** of receiving the result. |
| **C8** | **Mine Affected Water Release Events**<br>The holder must ensure a stream flow gauging station/s is installed, operated and maintained to determine and record stream flows at the locations and flow recording frequency specified in **Table C4**. |
| **C9** | Notwithstanding any other condition of this environmental authority, the release of mine affected water to waters in accordance with condition **C2** must only take place during periods of natural flow events in accordance with the receiving water flow criteria for discharge specified in **Table C4** for the release point(s) specified in **Table C1**. |

**Table C4 (Mine Affected Water Release during Flow Events)**

| Receiving waters/ stream | Release Point (RP) | Gauging station | Gauging Station Latitude (decimal degree, GDA94) | Gauging Station Longitde (decimal degree, GDA94) | Receiving Water Flow Recording Frequency | Receiving Water Flow Criteria for discharge ($m^3/s$) | Maximum release rate (for all combined RP flows) | Electrical Conductivity and Sulphate Release Limits |
|---|---|---|---|---|---|---|---|---|
| Mackenzie River | RP 3<br>RP 4#<br>RP 6<br>RP 7<br>RP 8<br>RP 9 | Bingegang tailwater gauge MP14 (Sunwater) | -23.0737 | 149.0319 | Continuous (minimum daily | **Low flow**<br>> 1 $m^3/s$ for a period of 30 days after natural flow events that exceed 30 $m^3/s$ | ≤ 0.5 $m^3/s$ | Electrical conductivity ≤ 310 µS/cm<br>Sulphate $(SO_4)^{2-}$ ≤ 200 mg/L |
| | | | | | | **Medium Flow**<br>> 30 $m^3/s$ | ≤0.18 $m^3/s$ | Electrical conductivity ≤ 3,500 µS/cm<br>Sulphate $(SO_4^{2-})$ ≤ 500 mg/L |
| | | | | | | | ≤ 0.10 $m^3/s$ | Electrical conductivity ≤ 6,000 µS/cm<br>Sulphate $(SO_4^{2-})$ ≤ 750 mg/L |
| | | | | | | **High flow**<br>> 80 $m^3/s$ | Release rate not to exceed 350 (natural) to 1 (mine affected water) dilution of the flow rate at Bingegang tailwater gauge | Electrical conductivity ≤ 7,000 µS/cm (≤ 6000 µS/cm for RP4)<br>Sulpate $(SO_4^{2-})$ ≤ 750 mg/L |
| Blackwater Creek | RP 1<br>RP 2<br>RP 5 | MP 1 | -23.5122 | 149.0319 | Continuous (minimum daily) | **Low Flow**<br><0.5 $m^3/s$ for a period of 4 weeks after natural flow events that exceed 1 $m^3/s$ | ≤ 0.5 $m^3/s$ | Electrical conductivity ≤ 680 µS/cm<br>Sulpate $(SO_4^{2-})$ ≤ 250 mg/L |
| | | | | | | **Medium Flow**<br>> 2.5 $m^3/s$ | ≤ 0.16 $m^3/s$ | Electrical conductivity ≤ 6,000 µS/cm<br>Sulpate $(SO_4^{2-})$ ≤ 500 mg/L |
| | | | | | | **High Flow**<br>> 5 $m^3/s$ | ≤ 0.18 $m^3/s$ | Electrical conductivity ≤ 10,000 µS/cm<br>Sulphate $(SO_4^{2-})$ ≤ 1000 mg/L |

*Note:*
*# Release of mine affected water from RP4 under high flow conditions (Mackenzie River) must not exceed 6,000 (µS/cm).*

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| **C10** | The release of mine affected water to waters in accordance with condition **C2** must not exceed the Electrical Conductivity and Sulphate release limits or the Maximum Release Rate (for all combined release point flows) for each receiving water flow criteria for discharge specified in **Table C4** when measured at the monitoring points specified in **Table C1**. |
| **C11** | The daily quantity of mine affected water released from each release point must be measured and recorded at the monitoring points in **Table C1**. |
| **C12** | Releases to waters must be undertaken so as not to cause erosion of the bed and banks of the receiving waters, or cause a material build up of sediment in such waters. |
| **C13** | **Notification of Release Event**<br>The environmental authority holder must notify the administering authority as soon as practicable and no later than **twenty-four (24) hours** after commencing to release mine affected water to the receiving environment. Notification must include the submission of written advice to the administering authority of the following information:<br>a) release commencement date/time;<br>b) expected release cessation date/time;<br>c) release point/s;<br>d) release volume (estimated);<br>e) receiving water/s including the natural flow rate; and<br>f) any details (including available data) regarding likely impacts on the receiving water(s).<br>Note: *Notification to the administering authority must be addressed to the Manager and Project Manager of the local Administering Authority via email or facsimile.* |
| **C14** | The environmental authority holder must notify the administering authority as soon as practicable (nominally within **twenty-four (24) hours** after cessation of a release event) of the cessation of a release notified under condition **C13** and within **twenty-eight (28) days** provide the following information in writing:<br>a) release cessation date/time;<br>b) natural flow volume in receiving water;<br>c) volume of water released;<br>d) details regarding the compliance of the release with the conditions of Agency Interest: Water of this environmental authority (i.e. contamination limits, natural flow, discharge volume);<br>e) all in-situ water quality monitoring results; and<br>f) any other matters pertinent to the water release event.<br>Note: *Successive or intermittent releases occurring within twenty-four (24) hours of the cessation of any individual release can be considered part of a single release event and do not require individual notification for the purpose of compliance with conditions C13 and C14, provided the relevant details of the release are included within the notification provided in accordance with conditions C13 and C14.* |
| **C15** | **Notification of Release Event Exceedance**<br>If the release limits defined in **Table C2** are exceeded, the holder of the environmental authority must notify the administering authority within **twenty-four (24) hours** of receiving the results. |

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| **C16** | The authority holder must, within **twenty-eight (28) days** of a release that exceeds the conditions of this authority, provide a report to the administering authority detailing:<br>a) the reason for the release;<br>b) the location of the release;<br>c) all water quality monitoring results;<br>d) any general observations;<br>e) all calculations; and<br>f) any other matters pertinent to the water release event. |
| **C17** | **Monitoring of Water Storage Quality**<br>Water storages stated in **Table C5** which are associated with the release points must be monitored for the water quality characteristics specified in **Table C6** at the monitoring locations and at the monitoring frequency specified in **Table C5**. |
| **C18** | In the event that waters storages defined in **Table C5** exceed the contaminant limits defined in **Table C6**, the holder of the environmental authority must implement measures, where practicable, to prevent access to waters by all livestock. |

**Table C5 (Water Storage Monitoring)**

| Water Storage Description | Latitude (decimal degree, GDA94) | Longitude (decimal degree, GDA94) | Monitoring Location | Frequency of Monitoring |
|---|---|---|---|---|
| Dam RD1 | -23.5130 | 148.8753 | Mixed sample taken from bank or pontoon if available | Quarterly |
| Dam CN3 | -23.2877 | 148.8492 | Mixed sample taken from bank or pontoon if available | Quarterly |
| Dam CN5 | -23.3552 | 148.8776 | Mixed sample taken from bank or pontoon if available | Quarterly |
| T Pit | -23.3047 | 148.8613 | Mixed sample taken from bank or pontoon if available | Quarterly |

**Table C6 (Onsite water storage contaminant limits)**

| Quality Characteristic | Test Value | Contaminant Limit |
|---|---|---|
| pH (pH unit) | Range | Greater than 4, less than 9[2] |
| EC (µS/cm) | Maximum | 5970[1] |
| Sulphate (mg/L) | Maximum | 1000[1] |
| Fluoride (mg/L) | Maximum | 2[1] |
| Aluminium (mg/L) | Maximum | 5[1] |
| Arsenic (mg/L) | Maximum | 0.5[1] |
| Cadmium (mg/L) | Maximum | 0.01[1] |
| Cobalt (mg/L) | Maximum | 1[1] |
| Copper (mg/L) | Maximum | 1[1] |
| Lead (mg/L) | Maximum | 0.1[1] |
| Nickel (mg/L) | Maximum | 1[1] |
| Zinc (mg/L) | Maximum | 20[1] |

*Note:*

*[1] Contaminant limit based on ANZECC & ARMCANZ (2000) stock water quality guidelines.*

*[2] Page 4.2-15 of ANZECC & ARMCANZ (2000) "Soil and animal health will not generally be affected by water with pH in the range of 4–9". Note: Total measurements (unfiltered) must be taken and analysed*

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| **C19** | **Receiving environment monitoring and contaminant trigger levels**<br>The quality of the receiving waters must be monitored at the locations specified in **Table C8** and shown in **Figure 1** and **Figure 2** for each quality characteristic and at the monitoring frequency stated in **Table C7**. |

**Table C7 (Receiving Waters Contaminant Trigger Levels)**

| Quality Characteristic | Trigger Level | Monitoring Frequency |
|---|---|---|
| pH | Blackwater Creek<br>6.5 – 9.0<br>Mackenzie River<br>6.5 - 8.5 | Daily during the release |
| Electrical Conductivity (μS/cm) | Blackwater Creek<br>720 μS/cm<br>Mackenzie River<br>400 μS/cm | |
| Suspended solids (mg/L) | Blackwater Creek<br>690 mg/L<br>Mackenzie River<br>200 mg/L | |
| Sulphate ($SO_4^{2-}$) (mg/L) | Blackwater Creek<br>250 mg/L<br>Mackenzie River<br>200 mg/L | |
| Sodium (mg/L) | Blackwater Creek<br>180 mg/L<br>Mackenzie River<br>50 mg/L | |

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| **C20** | If quality characteristics of the receiving water at the downstream monitoring points exceed any of the trigger levels specified in **Table C7** during a release event the environmental authority holder must compare the downstream results to the upstream results in the receiving waters and:<br>a) where the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action is to be taken; or<br>b) where the downstream results exceed the upstream results complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining:<br>1. details of the investigations carried out; and<br>2. actions taken to prevent environmental harm.<br>Note: *Where an exceedance of a trigger level has occurred and is being investigated, in accordance with C20(2) of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.* |

**Table C8 (Receiving Water Upstream Background Sites and Downstream Monitoring Points)**

| Monitoring Points | Receiving Waters Location Description | Latitude (decimal degree, GDA94) | Longitude (decimal degree, GDA94) |
|---|---|---|---|
| Upstream Background Monitoring Points | | | |
| Monitoring Point 1 | Blackwater Creek 800 metres upstream of RP 1 | -23.5190 | 148.8773 |
| Monitoring Point 12 | Bedford Weir Tailwater Mackenzie River 3,400 metres upstream of RP 4 | -23.3721 | 148.8414 |
| Downstream Monitoring Points | | | |
| Monitoring Point 4 | Blackwater Creek 6,000 metres downstream of RP 5 | -23.4061 | 148.9158 |
| Monitoring Point 11 (access permitting) | Mackenzie River 4,700 metres downstream of RP6 | -23.2631 | 148.9014 |
| Monitoring Point 13 | Mackenzie River downstream of RP4. | -23.3160 | 148.8678 |
| Monitoring Point 14 (alternative) | Bingegang Weir Headwater Mackenzie River approx. 40 kilometres downstream of RP 6 | -23.0737 | 149.0319 |

*Notes:*

a) *The upstream monitoring point should be within 4 km the release point.*

b) *The downstream point should not be greater than 45 km from the release point.*

c) *The data from background monitoring points must not be used where they are affected by releases from other mines.*

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| **C21** | **Receiving Environment Monitoring Program (REMP)**<br>The environmental authority holder must develop and implement a REMP to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. This must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine affected water is being discharged from the site. |

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| **C22** | The REMP must:<br>a) Assess the condition or state of receiving waters, including upstream conditions, spatially within the REMP area, considering background water quality characteristics based on accurate and reliable monitoring data that takes into consideration temporal variation (e.g. seasonality); and<br>b) Be designed to facilitate assessment against water quality objectives for the relevant environmental values that need to be protected; and<br>c) Include monitoring from background reference sites (e.g. upstream or background) and downstream sites from the release (as a minimum, the locations specified in **Table C8**); and<br>d) Specify the frequency and timing of sampling required in order to reliably assess ambient conditions and to provide sufficient data to derive site specific background reference values in accordance with the *Queensland Water Quality Guidelines* 2006. This should include monitoring during periods of natural flow irrespective of mine or other discharges; and<br>e) Include monitoring and assessment of dissolved oxygen saturation, temperature and all water quality parameters listed in **Table C2 and C3**; and<br>f) Include, where appropriate, monitoring of metals/metalloids in sediments (in accordance with ANZECC & ARMCANZ 2000, BATLEY and/or the most recent version of AS5667.*1 Guidance on Sampling of Bottom Sediments*); and<br>g) Include, where appropriate, monitoring of macro-invertebrates in accordance with the AusRivas methodology, and<br>h) Apply procedures and/or guidelines from ANZECC & ARMCANZ 2000 and other relevant guideline documents; and<br>i) Describe sampling and analysis methods and quality assurance and control; and<br>j) Incorporate stream flow and hydrological information in the interpretations of water quality and biological data. |
| **C23** | A report outlining the findings of the REMP, including all monitoring results and interpretations in accordance with conditions **C21** and **C22** must be prepared annually and made available on request to the administrating authority. This must include an assessment of background reference water quality, the condition of downstream water quality compared against water quality objectives, and the suitability of current discharge limits to protect downstream environmental values. |
| **C24** | **Water Reuse**<br>Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as farm dams or tanks, or used directly at properties owned by the environmental authority holder or a third party for the purpose of:<br>i) supplying stock water subject to compliance with the quality release limits specified in **Table C9**; or<br>ii) supplying irrigation water subject to compliance with quality release limits in **Table C10**; or<br>iii) supplying water for construction and/or road maintenance in accordance with the conditions of this environmental authority. |

**Table C9 (Stock water release limits)**

| Quality characteristic | Units | Minimum | Maximum |
|---|---|---|---|
| pH | pH units | 6.5 | 8.5 |
| Electrical Conductivity | µS/cm | N/A | 5000 |

**Table C10 (Irrigation Water Release Limits)**

| Quality characteristic | Units | Minimum | Maximum |
|---|---|---|---|
| pH | pH units | 6.5 | 8.5 |
| Electrical Conductivity | µS/cm | N/A | Site specific value to be determined in accordance with ANZECC & ARMCANZ (2000) Irrigation Guidelines |

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| **C25** | Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as dams or tanks, for the purpose of supplying water to Jellinbah Mine. The volume, pH and electrical conductivity of water transferred to Jellinbah Mine must be monitored and recorded. |
| **C26** | If the responsibility for mine affected water is given or transferred to another person in accordance with conditions **C25** or **C26:**<br>a) the responsibility for the mine affected water must only be given or transferred in accordance with a written agreement (the third party agreement); and<br>b) the third party agreement must include a commitment from the person utilising the mine affected water to use it in such a way as to prevent environmental harm or public health incidents and specifically make the persons aware of the General Environmental Duty (GED) under section 319 of the *Environmental Protection Act 1994,* environmental sustainability of the water disposal and protection of environmental values of waters; and<br>c) the third party agreement must be signed by both parties to the agreement. |
| **C27** | **Water General**<br>All determinations of water quality and biological monitoring must be:<br>a) performed by a person or body possessing appropriate experience and qualifications to perform the required measurements;<br>b) made in accordance with methods prescribed in the latest edition of the *Monitoring and Sampling Manual*;<br>Note: *Condition C28 requires the Monitoring and Sampling Manual to be followed and where it is not followed because of exceptional circumstances this should be explained and reported with the results.*<br>c) collected from the monitoring locations identified within this environmental authority, within forty-eight (48) hours of each other where possible;<br>d) carried out on representative samples; and<br>e) analysed at a laboratory accredited (e.g. NATA) for the method of analysis being used. |

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| **C28** | The release of any contaminants as permitted by this environmental authority, directly or indirectly to waters, other than internal water management infrastructure that is installed and operated in accordance with a water management plan that complies with conditions **C31** to **C36** inclusive:<br>a) must not produce any visible discolouration of receiving waters; and<br>b) must not produce any slick or other visible or odorous evidence of oil, grease or petrochemicals nor contain visible floating oil, grease, scum, litter or other objectionable matter. |
| **C29** | **Annual water monitoring reporting**<br>The following information must be recorded in relation to all water monitoring required under the conditions of this environmental authority and submitted to the administering authority in the specified format with each annual return:<br>a) the date on which the sample was taken;<br>b) the time at which the sample was taken;<br>c) the monitoring point at which the sample was taken;<br>d) the measured or estimated daily quantity of the contaminants released from all release points;<br>e) the release flow rate at the time of sampling for each release point;<br>f) the results of all monitoring and details of any exceedances with the conditions of this environmental authority; and<br>g) water quality monitoring data must be provided to the administering authority in the specified electronic format upon request. |
| **C30** | **Temporary interference with waterways**<br>Temporarily destroying native vegetation, excavating, or placing fill in a watercourse, lake or spring necessary for and associated with mining operations must be undertaken in accordance with the latest edition of the *Guideline - Activities in a watercourse, lake or spring associated with a resources activity or mining operations.* |
| **C31** | **Water Management Plan**<br>A Water Management Plan must be implemented. |
| **C32** | The Water Management Plan must:<br>a) provide for effective management of actual and potential environmental impacts resulting from water management associated with the mining activity carried out under this environmental authority; and<br>b) be developed in accordance with the guideline *Preparation of water management plans for mining activities (EM324)* and include:<br>i. a study of the source of contaminants;<br>ii. a water balance model for the site;<br>iii. a water management system for the site; iv.measures to manage and prevent saline drainage; v.measures to manage and prevent acid rock drainage; vi.contingency procedures for emergencies; and<br>iv. a program for monitoring and review of the effectiveness of the water management plan. |

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| **C33** | The Water Management Plan must be reviewed each calendar year and a report prepared by an appropriately qualified person. The report must:<br>a) assess the plan against the requirements under condition **C32**;<br>b) include recommended actions to ensure actual and potential environmental impacts are effectively managed for the coming year; and<br>c) identify any amendments made to the water management plan following the review. |
| **C34** | The holder of this environmental authority must attach to the review report required by condition **C33**, a written response to the report and recommended actions, detailing the actions taken or to be taken by the environmental authority holder on stated dates:<br>a) to ensure compliance with this environmental authority; and<br>b) to prevent a recurrence of any non-compliance issues identified. |
| **C35** | The review report required by condition **C33** and the written response to the review report required by condition **C34** must be submitted to the administering authority with the subsequent annual return under the signature of the appointed signatory for the annual return. |
| **C36** | A copy of the Water Management Plan must be provided to the administering authority on request. |
| **C37** | **Saline drainage**<br>The holder of this environmental authority must ensure proper and effective measures are taken to avoid or otherwise minimise the generation and/or release of saline drainage. |
| **C38** | **Acid rock drainage**<br>The holder of this environmental authority must ensure proper and effective measures are taken to avoid or otherwise minimise the generation and/or release of acid rock drainage. |
| **C39** | **Stormwater and water sediment controls**<br>An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented for all stages of the mining activities on the site to minimise erosion and the release of sediment to receiving waters and contamination of stormwater. |
| **C40** | **Stormwater, other than mine affected water, is permitted to be released to waters from:**<br>a) erosion and sediment control structures that are installed and operated in accordance with the Erosion and Sediment Control Plan required by condition **C39**; and<br>b) water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with conditions **C31** to **C36** inclusive, for the purpose of ensuring water does not become mine affected water. |
| **C41** | The maintenance and cleaning of any vehicles, plant or equipment must not be carried out in areas from which contaminants can be released into any receiving waters. |
| **C42** | Any spillage of wastes, contaminants or other materials must be cleaned up as quickly as practicable to minimise the release of wastes, contaminants or materials to any stormwater drainage system or receiving waters. |
| **C43** | **Sewage effluent**<br>The daily operation of the sewage treatment plant and pollution control equipment must be carried out by a person(s) with appropriate experience and/or qualifications to ensure the effective operation of that treatment system and control equipment. |

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| **C44** | Pipelines and fittings associated with the sewage treatment system must be clearly identified. |
| **C45** | All treated effluent released from the sewage treatment facilities must be monitored at the frequency and for the parameters specified in **Table C11.** |

**Table C11 (Sewage effluent quality targets)**

| Quality characteristics | Release limit | Units | Limit type | Monitoring frequency |
|---|---|---|---|---|
| 5 day Biochemical Oxygen Demand | 20 | mg/L | max | Monthly |
| pH | 6.0 to 9.0 | pH Units | range | Monthly |
| Free Chlorine Residual | 3 | mg/L | max | Monthly |
| Faecal coliforms | <1000 | Cfu/100mL[2] | max | Monthly |

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| **C46** | Treated effluent used directly from the sewage treatment facilities for dust suppression or irrigation must not exceed sewage effluent release limits defined in **Table C11**. |
| **C47** | Treated effluent used for dust suppression or irrigation must not cause spray drift or over spray to any sensitive or commercial place. |
| **C48** | Treated effluent from the sewage treatment plant must only be discharged from the authorised discharge location. |
| **C49** | Treated effluent must not be used for dust suppression or reused for irrigation so as to create a likelihood of contact or exposure to persons. |
| **C50** | Treated effluent must not be released from the site to any waters or the bed and banks of any waters. |
| **C51** | **Groundwater**<br>The holder of this environmental authority must not release contaminants to groundwater. |
| **C52** | All determinations of groundwater quality monitoring must be performed by a suitably qualified person. |
| **C53** | The holder of the environmental authority must implement a groundwater monitoring program which has been developed by a suitably qualified person. The program must be able to detect a significant change to groundwater quality values and standing water levels (consistent with the current suitability of the groundwater for domestic and agricultural use) due to activities that are part of this mining project. |
| **C54** | The holder of the environmental authority must report the results and analysis of groundwater monitoring to the administering authority on request. |
| **C55** | Groundwater affected by the mining activities must be monitored at compliance bores within the nominated geologies and minimum frequencies defined in **Table C12**. |

**Table C12 (Groundwater monitoring locations and frequency)**

| Geology | Minimum number of monitoring locations | Minimum Monitoring Frequency |
|---|---|---|
| Alluvium | 7 | 6 monthly |
| Rangal Coal Measures | 4 | 6 monthly |
| Burngrove | 2 | 6 monthly |

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| **C56** | If the groundwater contaminant trigger levels defined in **Table C13** are exceeded then the environmental authority holder must complete an investigation into the potential for environmental harm and notify the administering authority within **twenty-eight (28) days** of receiving the analysis results. An action plan to mitigate potential harm must be developed by a suitably qualified person. |

**Table C13 (Groundwater contaminant trigger levels)**

| Parameter | Unit | Trigger Levels | | | Limit Type |
|---|---|---|---|---|---|
| | | Alluvium | Rangal coal measures | Burngrove | |
| **Groundwater Level** | RL AHD (m) | Greater than 2 metre drawdown from the background level. | | | Maximum |
| **pH** | pH Units | 6.5 - 9.0 | 6.5 - 9.0 | 6.5 - 9.0 | Minimum/Maximum |
| **Electrical Conductivity** | µS/cm | TBA | TBA | TBA | Maximum |
| **Total Dissolved Solids** | mg/L | TBA | TBA | TBA | Maximum |
| **Calcium*** | mg/L | TBA | TBA | TBA | Maximum |
| **Magnesium*** | mg/L | TBA | TBA | TBA | Maximum |
| **Sodium*** | mg/L | TBA | TBA | TBA | Maximum |
| **Potassium*** | mg/L | TBA | TBA | TBA | Maximum |
| **Chloride*** | mg/L | TBA | TBA | TBA | Maximum |
| **$SO_4$*** | mg/L | TBA | TBA | TBA | Maximum |
| **$CO_3$*** | mg/L | TBA | TBA | TBA | Maximum |
| **$HCO_3$*** | mg/L | TBA | TBA | TBA | Maximum |
| **PO4** | mg/L | TBA | TBA | TBA | Maximum |
| **NO3** | mg/L | TBA | TBA | TBA | Maximum |
| **Iron** | mg/L | TBA | TBA | TBA | Maximum |
| **Aluminium** | mg/L | TBA | TBA | TBA | Maximum |
| **Arsenic** | mg/L | TBA | TBA | TBA | Maximum |
| **Mercury** | mg/L | TBA | TBA | TBA | Maximum |
| **Total Petroleum Hydrocarbons** | | | | | |
| **TPH (C6-C9)** | mg/L | TBA | TBA | TBA | Maximum |
| **TPH (C10-C14)** | mg/L | TBA | TBA | TBA | Maximum |
| **TPH (C15-C28)** | mg/L | TBA | TBA | TBA | Maximum |
| **TPH (C28-C36)** | mg/L | TBA | TBA | TBA | Maximum |

*means these cations and anions are to be monitored once/year

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| **C57** | **Determining contaminant trigger level and limit type**<br>The background groundwater quality for each geology must be determined from hydraulically isolated background bore(s) that have not been affected by any mining activities. The groundwater contaminant trigger levels and limit type as per **Table C13** must be determined and submitted to the administering authority by **1 February 2023**. |
| **C58** | **Bore construction and maintenance and decommissioning**<br>The construction, maintenance and management of groundwater bores (including background and compliance groundwater monitoring bores) must be undertaken in a manner that prevents or minimises impacts to the environment and ensures the integrity of the bores to obtain accurate monitoring. For all bores constructed after February 2015 construction and decommissioning must be in accordance with the *Manual for Minimum Construction Standard for Water Bores in Australia*. |

| **Agency interest: Regulated Structures** | |
|---|---|
| **Condition number** | **Condition** |
| **D1** | **Assessment of consequence category**<br>The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635) a*t the following times:<br>a) prior to the design and construction of the structure, if it is not an existing structure; or<br>b) prior to any change in its purpose or the nature of its stored contents. |
| **D2** | A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure. |
| **D3** | Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*. |
| **D4** | **Design and construction[1] of a regulated structure**<br>Conditions **D5** to **D9** inclusive do not apply to existing structures.<br>Note [1] : *Construction of a dam includes modification of an existing dam—refer to the definitions.* |
| **D5** | All regulated structures must be designed by, and constructed [2] under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.<br>Note [2]: *Certification of design and construction may be undertaken by different persons.* |
| **D6** | Construction of a regulated structure is prohibited unless the holder has submitted a consequence category assessment report and certification to the administering authority has been certified by a suitably qualified and experienced person for the design and design plan and the associated operating procedures in compliance with the relevant condition of this authority. |
| **D7** | Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*, and must be recorded in the Regulated Dams/Levees register. |
| **D8** | **Regulated structures** must:<br>a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635);*<br>b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of:<br>i) floodwaters from entering the regulated dam from any watercourse or drainage line; and<br>ii) wall failure due to erosion by floodwaters arising from any watercourse or drainage line.<br>c) have the floor and sides of the dam designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam. |

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| **D9** | Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that:<br>a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure;<br>b) construction of the regulated structure is in accordance with the design plan. |
| **D10** | Operation of a regulated structure, except for an existing structure, is prohibited unless:<br>a) the holder has submitted to the administering authority:<br>i) one paper copy and one electronic copy of the design plan and certification of the 'design plan' in accordance with condition **G6**;<br>ii) a set of 'as constructed' drawings and specifications;<br>iii) certification of those 'as constructed drawings and specifications' in accordance with condition **G9**;<br>iv) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan;<br>v) the requirements of this authority relating to the construction of the regulated structure have been met;<br>vi) the holder has entered the details required under this authority, into a Register of Regulated Structures; and<br>vii) there is a current operational plan for the regulated structures. |
| **D11** | For existing structures that are regulated structures:<br>a) where the existing structure that is a regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, the holder must submit to the administering authority within **twelve (12) months** of the commencement of this condition a copy of the certified system design plan including that structure; and<br>b) there must be a current operational plan for the existing structures. |
| **D12** | Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings. |
| **D13** | Conditions **D14** – **D17** inclusive only apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain – overtopping'. |
| **D14** | The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable. |
| **D15** | The holder must, as soon as practical and within **forty-eight (48) hours** of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL. |
| **D16** | The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam. |
| **D17** | The holder must record any changes to the MRL in the Register of Regulated Structures. |

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| **D18** | **Design storage allowance**<br>The holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to **1 July** of each year. |
| **D19** | By **1 November** of each year, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment systems). |
| **D20** | The holder must, as soon as possible and within **forty-eight (48) hours** of becoming aware that the regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year, notify the administering authority. |
| **D21** | The holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems. |
| **D22** | Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person. |
| **D23** | At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure. |
| **D24** | The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635). |
| **D25** | The holder must:<br>a) Within **twenty (20) business days** of receipt of the annual inspection report, provide to the administering authority:<br>i) The recommendations section of the annual inspection report; and<br>ii) If applicable, any actions being taken in response to those recommendations; and<br>b) If, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this to the administering authority within **ten (10) business days** of receipt of the request. |
| **D26** | **Transfer arrangements**<br>The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority. |

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| **D27** | **Decommissioning and rehabilitation**<br>Dams must not be abandoned but be either:<br>a) decommissioned and rehabilitated to achieve compliance with condition **D28**; or<br>b) be left in-situ for a beneficial use(s) provided that:<br>i) it no longer contains contaminants that will migrate into the environment; and<br>ii) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and<br>iii) the administering authority, the holder of the environmental authority and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies). |
| **D28** | After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria:<br>a) the landform is safe for humans and fauna;<br>b) the landform is stable with no subsidence or erosion gullies for at least **three (3) years**;<br>c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated;<br>d) not allowing for acid mine drainage; or<br>e) there is no ongoing contamination to waters (including groundwater);<br>f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001);<br>g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class;<br>h) for land that is not being cultivated by the landholder:<br>i) groundcover, that is not a declared pest species is established and self-sustaining<br>ii) vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining, and<br>iii) the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies).<br>i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within **three (3) months** of petroleum activities being completed. |
| **D29** | **Register of Regulated Structures**<br>A Register of Regulated Structures must be established and maintained by the holder for each regulated structure. |
| **D30** | The holder must provisionally enter the required information in the Register of Regulated Structures when a design plan for a regulated structure is submitted to the administering authority. |
| **D31** | The holder must make a final entry of the required information in the Register of Regulated Structures once compliance with condition **D10** and **D11** has been achieved. |
| **D32** | The holder must ensure that the information contained in the Register of Regulated Structures is current and complete on any given day. |

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| **D33** | All entries in the Register of Regulated Structures must be approved by the chief executive officer for the holder of this authority, or their delegate, as being accurate and correct. |
| **D34** | The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Structures, in the electronic format required by the administering authority. |
| **D35** | **Transitional arrangements**<br>All existing structures that have not been assessed in accordance with either the Manual or the former Manual for Assessing Hazard Categories and Hydraulic Performance of Dams must be assessed and certified in accordance with the Manual within **6 months** of amendment of the authority adopting this schedule. |
| **D36** | All existing structures must subsequently comply with the timetable for any further assessments in accordance with the Manual specified in **Table D1**, depending on the consequence category for each existing structure assessed in the most recent previous certification for that structure. |
| **D37** | **Table D1** ceases to apply for a structure once any of the following events has occurred:<br>a) It has been brought into compliance with the hydraulic performance criteria applicable to the structure under the Manual; or<br>b) It has been decommissioned; or<br>c) It has been certified as no longer being assessed as a regulated structure. |
| **D38** | Certification of the transitional assessment required by condition **D35** and **D36** (as applicable) must be provided to the administering authority within **6 months** of amendment of the authority adopting this schedule. |

**Table D1 (Transitional Hydraulic Performance Requirements for Existing Structures)**

| **Transition period required for existing structures to achieve the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Dams*** | | | |
|---|---|---|---|
| **Compliance with Criteria** | **High** | **Significant** | **Low** |
| 90% and a history of good compliance performance in last 5 years | No transition required | No transition required | No transitional conditions apply. Review consequence assessment every 7 years. |
| >70%-≤90% | Within 7 years, unless otherwise agreed with the administering authority, based on no history of unauthorised releases. | Within 10 years, unless otherwise agreed with the administering authority, based on no history of unauthorised releases. | No transitional conditions apply. Review consequence assessment every 7 years. |
| >50-≤70% | Within 5 years unless otherwise agreed with the administering authority, based on no history of unauthorised releases. | Within 7 years unless otherwise agreed with the administering authority, based on no history of unauthorised releases. | Review consequence assessment every 7 years. |
| ≤50% | Within 5 years or as per compliance requirements (e.g. TEP timing) | Within 5 years or as per compliance requirements (e.g. TEP timing) | Review consequence assessment every 5 years. |

| **Agency interest: Noise and vibration** | |
|---|---|
| **Condition number** | **Condition** |
| **E1** | **Noise limits**<br>The holder of this environmental authority must ensure that noise generated by the mining activities does not cause the criteria in **Table E1** to be exceeded at a sensitive place or commercial place. |
| **E2** | The environmental authority holder will respond within **twenty-eight (28) days** to any validated noise limit complaints with a noise monitoring campaign, as agreed with the administrating authority that assesses the level of nuisance with reference to the **Table E1** criteria. |

**Table E1 (Noise limits)**

| **Noise level dB(A)** | **7am - 6pm** | **6pm - 10pm** | **10pm - 7am** |
|---|---|---|---|
| | **Noise measured at a 'Sensitive place'** | | |
| $L_{A10, adj, 10 mins}$ | 46 | 46 | 41 |
| $L_{A1, adj, 10 mins}$ | 55 | 51 | 45 |
| | **Noise measured at a 'Commercial place'** | | |
| $L_{A10, adj, 10 mins}$ | 51 | N/A | N/A |

| **E3** | **Determining Noise limits for ML700006, ML700007, ML700008 and ML700009**<br>The holder of the environmental authority must carry out a study to determine noise limits as per **Table E2**, at least **six (6) months** prior to coal mining taking place on ML700006, ML700007, ML700008 and ML700009. |
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**Table E2 (Noise limits)**

| **Sensitive place** | | | | | | |
|---|---|---|---|---|---|---|
| **Noise level dB(A) measured as:** | **Monday to Saturday** | | | **Sunday and public holidays** | | |
| | **7am to 6pm** | **6pm to 10pm** | **10pm to 7am** | **9am to 6pm** | **6pm to 10pm** | **10pm to 9am** |
| $L_{Aeq, adj, 15 mins}$ | TBA | TBA | TBA | TBA | TBA | TBA |
| $L_{A1, adj, 15 mins}$ | TBA | TBA | TBA | TBA | TBA | TBA |
| **Commercial place** | | | | | | |
| **Noise level dB(A) measured as:** | **Monday to Saturday** | | | **Sunday and public holidays** | | |
| | **7am to 6pm** | **6pm to 10pm** | **10pm to 7am** | **9am to 6pm** | **6pm to 10pm** | **10pm to 9am** |
| $L_{Aeq, adj, 15 mins}$ | TBA | TBA | TBA | TBA | TBA | TBA |

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| **E4** | **Airblast overpressure limits**<br>The holder of this environmental authority must ensure that blasting does not cause the limits for peak particulate velocity and air blast overpressure in **Table E3** to be exceeded at a sensitive place or commercial place. |
| **E5** | The holder of the environmental authority must develop and implement a blast monitoring program to monitor compliance with **Table E3** criteria. |
| **E6** | The environmental authority holder will respond within **twenty-eight (28) days** to any validated blasting limit complaints with a blast monitoring campaign, as agreed with the administrating authority, that assesses the level of nuisance with reference to the **Table E3** criteria. |

**Table E3 (Blasting noise limits)**

| **Blasting noise limits** | **Sensitive or commercial blasting noise limits** | |
|---|---|---|
| | **7am – 6pm** | **6pm – 7am** |
| Airblast overpressure | 115dB (Linear) Peak for 9 out of 10 consecutive blasts initiated and not greater than 120dB (Linear) Peak at any time | No blasting impacts to occur |
| Ground vibration peak particulate velocity | 5mm/second peak particle velocity for 9 out of 10 consecutive blasts and not greater than 10mm/second peak particle velocity at any time. | No blasting impacts to occur |

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| **E7** | **Monitoring and reporting**<br>Noise monitoring and recording must include the following descriptor characteristics and matters:<br>a) LAN,T (where N equals the statistical levels of 1, 10 and 90 and T = time)<br>b) background noise LA90<br>c) the level and frequency of occurrence of impulsive or tonal noise and any adjustment and penalties to statistical levels<br>d) atmospheric conditions including temperature, relative humidity and wind speed and directions<br>e) effects due to any extraneous factors such as traffic noise<br>f) location, date and time of monitoring<br>g) if the complaint concerns low frequency noise, Max LpLIN,T and one third octave band measurements in dB(LIN) for centre frequencies in the 10 – 200 Hz range. |
| **E8** | The method of measurement and reporting of airblast overpressure levels must comply with the current edition of the administering authority's *Noise Measurement Manual*. |

| **Agency interest: Waste** | |
|---|---|
| **Condition number** | **Condition** |
| **F1** | **Storage of tyres**<br>Scrap tyres stored awaiting disposal or transport for take-back and recycling, or waste-to-energy options must be stored in stable stacks and at least 10 metre from any other scrap tyre storage area, or combustible or flammable material, including vegetation. |
| **F2** | All reasonable and practicable fire prevention measures must be implemented, including removal of grass and other materials within a 10 metre radius of the scrap tyre storage area. |
| **F3** | Disposing of scrap tyres resulting from the authorised activities in spoil emplacements is acceptable, provided tyres are placed as deep in the spoil as reasonably practicable. |
| **F4** | Scrap tyres resulting from the mining activities disposed within the operational land must not impede saturated aquifers or compromise the stability of the consolidated landform. |
| **F5** | **Waste management**<br>A Waste Management Plan, in accordance with the *Waste Reduction and Recycling Act 2011,* must be implemented and must cover:<br>a) describe how Curragh Coal Mine recognise and apply the waste and resource management hierarchy (*Waste Reduction and Recycling Act 2011)*;<br>b) identify characterisations of wastes generated from the project and general volume trends over the past 3 years;<br>c) a program for safe recycling or disposal of all wastes- reusing and recycling where possible;<br>d) waste commitments with auditable targets to reduce, reuse and recycle;<br>e) the waste management control strategies must consider:<br>i. the type of wastes;<br>ii. segregation of the wastes;<br>iii. storage of the wastes;<br>iv. transport of the wastes;<br>v. monitoring and reporting matters concerning the waste;<br>vi. emergency response planning; and<br>vii. disposal, reused and recycling options.<br>f) identify the potential adverse and beneficial impacts of the wastes generated;<br>g) detail the hazardous characteristics of the waste generated (if any);<br>h) cover a disposal procedure for hazardous wastes;<br>i) outline the process to be implemented to allow for continuous improvement of the waste management systems;<br>j) identify responsible staff (positions) for implementing, managing and reporting the Waste Management Plan; and<br>k) cover a staff awareness and induction program that encourages re-use and recycling. |

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| **F6** | Unless otherwise permitted by the conditions of this environmental authority or with prior approval from the administering authority and in accordance with a relevant standard operating procedure, waste must not be burnt. |
| **F7** | General waste must only be disposed of into the waste disposal trench facility of ML1878 and identified in **Figure 3**. |
| **F8** | The holder of this environmental authority may burn vegetation cleared in the course of carrying out extraction activities provided the activity does not cause environmental harm at any sensitive place or commercial place. |
| **F9** | Records must be kept for five years, and must include the following information:<br>a) date of pickup of waste;<br>b) description of waste;<br>c) cross reference to relevant waste transport documentation;<br>d) quantity of waste;<br>e) origin of the waste;<br>f) destination of the waste; and<br>g) intended fate of the waste, for example, type of waste treatment, reprocessing or disposal.<br>Note: Records of documents maintained in compliance with a waste tracking system established under the *Environmental Protection Act 1994* or any other law for regulated waste will be deemed to satisfy this condition. |
| **F10** | Records of trade and regulated wastes or material leaving the mining lease for recycling or disposal, including the final destination and method of treatment, must be in accordance with the *Waste Reduction and Recycling Act 2011.* |
| **F11** | All regulated waste received at and removed from the site must be transported by a person who holds a current authority to transport such waste under the provisions of the *Environmental Protection Act 1994*. |
| **F12** | Except as otherwise provided by the conditions of this authority, all waste removed from the site must be taken to a facility that is lawfully allowed to accept such waste under the provisions of the *Environmental Protection Act 1994*. |

| **Agency interest: Land** | |
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| **Condition number** | **Condition** |
| **G1** | **Topsoil**<br>Topsoil must be strategically stripped ahead of mining in accordance with a Topsoil Management Plan. |
| **G2** | **Preventing contaminant release to land**<br>Contaminants must not be released to land in manner which constitutes nuisance, material or serious environmental harm. |
| **G3** | **Chemicals and flammable or combustible liquids**<br>All flammable and combustible liquids, chemicals, explosives, corrosive substances, toxic substances, gases and dangerous goods must be contained within an on-site containment system and controlled in a manner that prevents environmental harm and maintained in accordance with the current version of the relevant Australian Standard. |
| **G4** | Spillage of all flammable and combustible liquids, chemicals, explosives, corrosive substances, toxic substances, gases and dangerous goods must be controlled in a manner that prevents environmental harm (other than trivial harm). |
| **G5** | All chemicals and flammable or combustible liquids stored on site that have the potential to cause environmental harm must be stored in or serviced by an effective containment system that is impervious to the materials stored and managed to prevent the release of liquids to waters or land. Where no relevant Australian Standard is available, the following must be applied:<br>a) storage tanks must be bunded so that the capacity and construction of the bund is sufficient to contain at least 110% of a single storage tank or 100% of the largest storage tank plus 10% of the second largest storage tank in multiple storage areas; and<br>b) drum storages must be bunded so that the capacity and construction of the bund is sufficient to contain at least 25% of the maximum design storage volume within the bund. |
| **G6** | **Spill kit**<br>An appropriate spill kit, personal protective equipment and relevant operator instructions/emergency procedure guides for the management of wastes, chemicals and flammable and combustible liquids associated with the activity must be kept at the site. |
| **G7** | **Infrastructure**<br>All infrastructure, constructed by or for the environmental authority holder during the licensed activities including water storage structures, must be removed from the site prior to surrender, except where agreed in writing by the post mining land owner / holder.<br>Note: *This is not applicable where the landowner / holder is also the environmental authority holder.* |
| **G8** | **Acid rock drainage and leachate management**<br>Subject to the release limits defined in Department Interest: Water, all reasonable and practicable measures must be implemented to prevent hazardous leachate being directly or indirectly released or likely to be released as a result of the activity to any groundwater or water course. |

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| **G9** | **Rehabilitation landform criteria**<br>All areas significantly disturbed by mining activities must be rehabilitated to a stable landform with a self-sustaining vegetation cover. |
| **G10** | Progressive rehabilitation must commence within three years when areas become available within the operational land. |
| **G11** | **Residual void outcome**<br>Residual voids must comply with the following rehabilitation outcomes:<br>residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority. |
| **G12** | The rehabilitation of disturbed areas and residual void investigation reports, submitted to the administrating authority in June 2012, are to be updated to incorporate rehabilitated landform criteria and residual void outcomes for ML700006, ML700007, ML700008, ML700009, **six (6) months** prior to coal mining occurring on these ML's. The rehabilitated landform criteria and residual void outcomes from these reports must be reviewed every three years, or if any amendments occur and re-submitted to the administering authority. |
| **G13** | **Erosion**<br>Rehabilitated land must:<br>a) not have a rate of soil loss that exceeds that present in representative unmined areas within the mining leases that have the same chemical and physical characteristics including slope, slope length and fire regime; and<br>b) not exhibit any signs of continued erosion greater than that exhibited on representative unmined areas within the mining leases. |
| **G14** | **Weed control**<br>Class 1 and Class 2 declared plants as listed under the Land Protection Pest and Stock Route Management Act 2002 and subordinate legislation must not be present in the rehabilitation in densities that prevent the revegetation criteria from being achieved. |
| **G15** | **Rehabilitation of Blackwater Creek diversion**<br>Rehabilitation of the Blackwater Creek diversion works must be conducted in accordance with the document EM Plan 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan. |
| **G16** | **Rehabilitation monitoring program**<br>The holder of the environmental authority must conduct a Rehabilitation Monitoring Program on a yearly basis, which must include sufficient spatial and temporal replication to enable statistically valid conclusions as established under the rehabilitation program. |
| **G17** | **Post closure management plan**<br>A post closure management plan for the site must be prepared at least **eighteen (18) months** prior to the final coal processing on site and implemented for a nominal period of:<br>a) at least **thirty (30) years** following final coal processing on site; or<br>b) a shorter period if the site is proven to be geotechnically and geochemically stable and it can be demonstrated to the satisfaction of the administering authority that no release of contaminants from the site will result in environmental harm. |

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| **G18** | The post closure management plan must include the following elements:<br>a) operation and maintenance of:<br>i. wastewater collection and reticulation systems;<br>ii. wastewater treatment systems;<br>iii. the groundwater monitoring network;<br>iv. final cover systems; and<br>v. vegetative cover.<br>b) monitoring of:<br>i. surface water quality;<br>ii. groundwater quality;<br>iii. seepage rates;<br>iv. erosion rates;<br>v. the integrity and effectiveness of final cover systems; and<br>vi. the health and resilience of native vegetation cover. |
| **G19** | **Biodiversity offsets**<br>Significant residual impacts to prescribed environmental matters, other than if the impacts were authorised by an existing authority issued before the commencement of the *Environmental Offsets Act 2014*, are not authorised under this environmental authority or the *Environmental Offsets Act 2014* unless the impacts are specified in **Table G2 – Authorised impacts to prescribed environmental matters** in the locations shown in **Figure 5 – Prescribed Environmental Matters**.<br>*Note: This condition relates to disturbance of land within Mine Activity Area 1 (ML700006 – Pit Z), Mine Activity Areas 2 (ML700007 and part ML700008 – Pit X) Mine Activity Area 3 (part ML700008 – Pit D) and Mine Activity Area 4 (ML700009 – Pit J).* |
| **G20** | Records demonstrating that each impact to a prescribed environmental matter not listed in **Table G2 - Authorised impacts to prescribed environmental matters** did not, or is not likely to, result in a significant residual impact to that matter must be:<br>a) completed by an appropriately qualified person; and<br>b) kept for the life of the environmental authority. |
| **G21** | An environmental offset made in accordance with the *Environmental Offsets Act 2014* and Queensland Environmental Offsets Policy, as amended from time to time, must be undertaken for the maximum extent of impact to each prescribed environmental matter authorised in **Table G2 - Authorised impacts to prescribed environmental matters**, unless a lesser extent of the impact has been approved in accordance with condition **G24** for staged offsets. |

**Table G2 (Authorised impacts to prescribed environmental matters)**

| Prescribed environmental matter | Maximum extent of impact | Environmental offset required | Maximum Extent of Impact – Stage 1 | Maximum Extent of Impact – Stage 2 | Maximum Extent of Impact – Stage 3 | Maximum Extent of Impact – Stage 4 |
|---|---|---|---|---|---|---|
| *Endangered regional ecosystem – 11.3.1** | *0.8ha* | *No* | *0* | *0.7* | *0* | *0.1* |
| *Endangered regional ecosystem - 11.4.7** | *10.1ha* | *No* | *6.6* | *3.5* | *0* | *0* |
| *Of concern regional ecosystem – 11.3.3** | *79ha* | *Yes* | *0* | *79.0* | *0* | *0* |
| *Remnant vegetation within a defined distance from the defining banks of a relevant watercourse*** | *30.8ha* | *Yes* | *0* | *30.8* | *0* | *0* |
| *Essential habitat for Ornamental snake* | *1.3ha* | *Yes* | *0* | *1.3* | *0* | *0* |
| *Connectivity area*** | *44.8ha* | *Yes* | *0* | *44.8* | *0* | *0* |
| *Plants that are endangered wildlife - Solanum elachophyllum* | *18.3ha* | *No* | *0* | *7.2* | *0* | *11.1* |
| *Habitat for an animal that is vulnerable wildlife – Yakka skink (Egernia rugosa)** | *10.9ha* | *No* | *6.6* | *4.2* | *0* | *0.1* |
| *Habitat for an animal that is vulnerable wildlife – Ornamental snake (Denisonia maculata)** | *79.9ha* | *No* | *0* | *79.8* | *0* | *0.1* |
| *Habitat for an animal that is vulnerable wildlife – Dunmall's snake (Furina dunmalli)** | *93.8ha* | *No* | *7.2* | *36.1* | *0* | *50.5* |
| *Habitat for an animal that is vulnerable wildlife – Eastern long-eared bat (Nyctophilus corbeni)** | *180.3ha* | *No* | *8.75* | *121* | *0* | *50.6* |
| *Habitat for an animal that is vulnerable wildlife- Large-eared pied bat (Chalinolobus dwyeri)** | *180.3ha* | *No* | *8.75* | *121* | *0* | *50.6* |
| *Habitat for an animal that is vulnerable wildlife – Squatter pigeon – (Geophaps scripta scripta)** | *97.4ha* | *No* | *8.2* | *89.1* | *0* | *0.1* |
| *Habitat for an animal that is vulnerable wildlife – Australian painted snipe (Rostratula australis)** | *75.9ha* | *No* | *0* | *75.9* | *0* | *0* |

**These prescribed environmental matters duplicate MNES values and will be conditioned for offsets by the Commonwealth*

*** Offsets for remnant vegetation within a defined distance from the defining banks of a relevant watercourse &/ or connectivity areas may be co-located within an offset site for other prescribed environmental matters or MNES values conditioned for offsets by the Commonwealth, provided the site meets the offset requirements for each matter.*

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| **G22** | The significant residual impacts to a prescribed environmental matter authorised in condition **G19** for which an environmental offset is required by condition **G21** may be carried out in stages. An environmental offset can be delivered for each stage of the impacts to prescribed environmental matters. |
| **G23** | Prior to the commencement of each stage, a report completed by an appropriately qualified person, that includes an analysis of the following must be provided to the administering authority:<br>a) for the forthcoming stage—the estimated significant residual impacts to each prescribed environmental matter; and<br>b) for the previous stage, if applicable—the actual significant residual impacts to each prescribed environmental matter, to date. |
| **G24** | The report required by condition **G23** must be approved by the administering authority before a notice of election for the forthcoming stage, if applicable, is given to the administering authority. |
| **G25** | A notice of election for the staged environmental offset referred to in condition **G24**, if applicable, must be provided to the administering authority no less than three months before the proposed commencement of that stage, unless a lesser timeframe has been agreed to by the administering authority. |
| **G26** | Within six months from the completion of the final stage of the project, a report completed by an appropriately qualified person, that includes the following matters must be provided to the administering authority:<br>a) an analysis of the actual impacts on prescribed environmental matters resulting from the final stage; and<br>b) if applicable, a notice of election to address any outstanding offset debits for the authorised impacts. |

| **Agency interest: Watercourse diversions** | |
|---|---|
| **Condition number** | **Condition** |
| **H1** | Conditions **H2** to **H7** relate to disturbance associated with coal mining on land within Mine Activity Area 1 (ML700006 – Bonnie Doon Creek diversion) and Mine Activity Area 2 (ML700007 – Minnie Creek diversion) as identified in **Figure 6 – Watercourse Diversions**. |
| **H2** | **Permanent watercourse diversions**<br>Permanent watercourse diversion, or the re-establishment of a pre-existing watercourse where a temporary watercourse diversion is being replaced, must be designed and constructed to:<br>a) incorporate natural features (including geomorphic and vegetation) present at the location of the diversion<br>b) maintain the pre-existing hydrologic characteristics of surface water and groundwater systems for the area in which the watercourse diversion is located<br>c) maintain the hydraulic characteristics of the permanent watercourse diversion that are equivalent to other local watercourses and are suitable for the area in which the diversion is located without using artificial structures that require on-going maintenance<br>d) maintain sediment transport and water quality regimes that allow the diversion to be self-sustaining, while minimising any impacts to upstream and downstream water quality, geomorphology or vegetation<br>e) Maintain equilibrium and functionality in all substrate conditions at the location of the diversion. |
| **H3** | **Temporary watercourse diversions**<br>Temporary watercourse diversions must be designed and constructed to:<br>a) Maintain the pre-existing hydrologic characteristics of surface water systems for the area in which the watercourse diversion is located<br>b) Maintain the hydraulic characteristics of the watercourse diversion that are equivalent to other local watercourses and are suitable for the area in which the diversion is located. Where structures that require on-going maintenance are used, they must not compromise the equilibrium and performance of the temporary watercourse diversion and adjoining watercourses<br>c) Maintain sediment transport and water quality regimes that minimise any impacts to upstream and downstream. |
| **H4** | **Design plan – All diversions**<br>A certified Design Plan that achieves condition **H2** for permanent watercourse diversions (i.e. Bonnie Doon Creek in Mine Activity Area 1 (ML700006) and Minnie Creek in Mine Activity Area 2 (ML700007) as identified in **Figure 6**) and condition **H3** for temporary watercourse diversions must be submitted to the administering authority at least **ten (10) business days** before commencing construction of the diversion. |
| **H5** | The certified design plan for any temporary or permanent watercourse diversion (i.e. Bonnie Doon Creek in Mine Activity Area 1 (ML700006) and Minnie Creek in Mine Activity Area 2 (ML700007) as identified on **Figure 6**) must be consistent with the functional design/s that formed a part of the application documents for this authority. |

| | |
|---|---|
| **H6** | **Construction and operation – All diversions**<br>A certified set of 'as constructed' drawings and specifications must be submitted to the administering authority within **sixty (60) business days** from the completion of construction of the temporary or permanent watercourse diversion, or re-establishment of the pre-existing watercourse. These drawings and specifications must state:<br>a) that the 'as constructed' drawings and specifications meet the original intent of the design plan for the watercourse diversion<br>b) construction of the watercourse diversion is in accordance with the design plan. |
| **H7** | **Register – All diversions**<br>The details of watercourse diversions planned and constructed under an environmental authority must be accurately recorded on the Register of Watercourse Diversions kept by the holder of the authority. An electronic copy must be provided to the administering authority on request. |

**Definitions**

Words and phrases used throughout this environmental authority are defined below. Where a definition for a term used in this environmental authority is not provided within this environmental authority, but is provided in the *Environmental Protection Act (EP Act) 1994* or subordinate legislation, the definition in the *EP Act* or subordinate legislation must be used.

**Acceptance criteria** means the measures by which the actions implemented to rehabilitate the land are deemed to be complete. The acceptance criteria indicate the success of the rehabilitation outcome or remediation of areas which have been significantly been disturbed by the mining activities. Acceptance criteria may include information regarding:

a) vegetation establishment, survival and succession;

b) vegetation productivity, sustained growth and structure development;

c) fauna colonisation and habitat development;

d) ecosystem processes such as soil development and nutrient cycling, and the recolonisation of specific fauna groups such as collembola, mites and termites which are involved in these processes;

e) microbiological studies including recolonisation by mycorrhizal fungi, microbial biomass and respiration;

f) effects of various establishment treatments such as deep ripping, topsoil handling, seeding and fertiliser application on vegetation growth and development;

g) resilience of vegetation to disease, insect attack, drought and fire; and

h) vegetation water use and effects on ground water levels and catchment yields.

**Administering authority** is the agency that administers the environmental authority provisions under the *Environmental Protection Act 1994*.

**AEP** means the Annual Exceedance Probability, which is the probability that at least one event in excess of a particular magnitude will occur in any given year.

**Airblast overpressure** means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL).

**Ambient (or total) noise** at a place, means the level of noise at the place from all sources (near and far), measured as the Leq for an appropriate time interval.

**Annual inspection report** means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan);

a) against recommendations contained in previous annual inspections reports;

b) against recognised dam safety deficiency indicators;

c) for changes in circumstances potentially leading to a change in consequence category;

d) for conformance with the conditions of this authority;

e) for conformance with the ‘as constructed’ drawings;

f) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after **31 May** each year but prior to **1 November** of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the **dam** (or network of linked containment systems);

g) for evidence of conformance with the current operational plan.

**ANZECC** means the *Australian and New Zealand Guidelines for Fresh Marine Water Quality 2000*

**Authority** means environmental authority (mining activities) under the *Environmental Protection Act 1994*.

**Appropriately qualified person** means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relative to the subject matter using the relevant protocols, standards, methods or literature.

**Assessed** or **Assess** by a suitably qualified and experienced person in relation to a hazard assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

a) exactly what has been assessed and the precise nature of that assessment;

b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;

c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

**Associated works** in relation to a dam, means:

a) operations of any kind and all things constructed, erected or installed for that dam; and

b) any land used for those operations.

**Bed and banks** for a waters, river, creek, stream, lake, lagoon, pond, swamp, wetland or dam means land over which the water of the waters, lake, lagoon, pond, swamp, wetland or dam normally flows or that is normally covered by the water, whether permanently or intermittently; but does not include land adjoining or adjacent to the bed and banks that is from time to time covered by floodwater.

**Beneficial use** in respect of dams means that the current or proposed owner of the land on which a dam stands, has found a use for that dam that is:

a) of benefit to that owner in that it adds real value to their business or to the general community,

b) in accordance with relevant provisions of the *Environmental Protection Act 1994*,

c) sustainable by virtue of written undertakings given by that owner to maintain that dam, and

d) the transfer and use have been approved or authorised under any relevant legislation.

**Biosolids** means the treated and stabilised solids from sewage.

**Blasting** means the use of explosive materials to fracture:

a) rock, coal and other minerals for later recovery; or

b) structural components or other items to facilitate removal from a site or for reuse.

**Bunded** means within bunding consistent with Australian Standard 1940.

**Certification, certifying** or **certified** by an appropriately qualified and experienced person in relation to a design plan or an annual report regarding dams/structures, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

a) exactly what is being certified and the precise nature of that certification.

b) the relevant legislative, regulatory and technical criteria on which the certification has been based;

c) the relevant data and facts on which the certification has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

d) the reasoning on which the certification has been based using the relevant data and facts, and the relevant criteria.

**Chemical** means:

a) an agricultural chemical product or veterinary chemical product within the meaning of the *Agricultural and Veterinary Chemicals Code Act 1994* (Commonwealth), or

b) a dangerous good under the Australian Code for the Transport of Dangerous Goods by Road and Rail approved by the Australian Transport Council, or

c) a lead hazardous substance within the meaning of the *Workplace Health and Safety Regulation 1997*, or

d) a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers' Advisory Council and published by the Commonwealth, or

e) any substance used as, or intended for use as:

   i) a pesticide, insecticide, fungicide, herbicide, rodenticide, nematocide, miticide, fumigant or related product, or

   ii) a surface active agent, including, for example, soap or related detergent, or

   iii) a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide, or

   iv) a fertiliser for agricultural, horticultural or garden use, or

   v) a substance used for, or intended for use for mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater, or

   vi) manufacture of plastic or synthetic rubber.

**Coal mining** means to carry on an operation for the purpose of extracting coal from its natural state and disposing of mineral in connection with, or waste substances resulting from, the extraction. This includes processes such as overburden removal, blasting, coal mining, waste rock and tailings disposal, crushing, washing and flotation and the construction activities associated with these processes. It does not include exploration activities.

**Commercial place** means a work place used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees accommodation or public roads.

**Competent person** means a person with the demonstrated skill and knowledge required to carry out the task to a standard necessary for the reliance upon collected data or protection of the environment.

**Consequence category** means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)*.

**Construction** or **constructed** in relation to a regulated structure includes building a new regulated structure and lifting or otherwise modifying an existing regulated structure, but does not include investigation and testing necessary for the purpose of preparing a design plan.

**Construction** or **constructed** in relation to watercourse diversions, is the process of building, or modifying an existing diversion, but does not include investigation and testing necessary for the purpose of preparing a design plan.

**Contaminate** means to render impure by contact or mixture.

**Contaminated** means the substance has come into contact with a contaminant.

**Contaminant** A contaminant can be:

a) a gas, liquid or solid; or

b) an odour; or

c) an organism (whether alive or dead), including a virus; or

d) energy, including noise, heat, radioactivity and electromagnetic radiation; or

e) a combination of contaminants.

**Control measure** means any action or activity that can be used to prevent or eliminate a hazard or reduce it to an acceptable level.

**Cover material** means any soil or rock suitable as a germination medium or landform armouring.

**Dam** means a land-based structure or a void that is designed to contain, divert or control flowable substances - including any substances that are thereby contained, diverted or controlled by that land-based structure or void; but does not mean a fabricated or manufactured tank or container designed to a recognised standard. In case there is any doubt, a levee dyke or bund is a dam.

**Design plan (**structures which are dams or levees**)** is a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure.

**Design plan (**watercourse diversion**)** is a document that contains the design, operation, monitoring and revegetation criteria of a watercourse diversion that addresses the outcomes stated in conditions on the environmental authority relating to the diversion. The document should include, but not be limited to:

a) required information under a functional design

b) the location, function and description of geomorphic and riparian vegetation features within the proposed watercourse diversion

c) results from hydrologic, hydraulic and sediment transportation modelling used in the design of the diversion

d) a revegetation and vegetation management plan (a revegetation plan) for the diversion

e) engineering drawings depicting the physical attributes and dimensions of the diversion

f) (if relevant) the staged development of a permanent watercourse diversion including the proposed use of temporary watercourse diversions with identified lifespans

g) all investigation and other reports relied on by the design

h) plans and specifications sufficient to complete construction and revegetation in accordance with the design.

**Design storage allowance** or **DSA** means the minimum storage required in a dam at the first of November each year in order to meet the hydraulic performance requirements.

**Development approval** means a development approval under the *Integrated Planning Act 1997* in relation to a matter that involves an environmentally relevant activity under the *Environmental Protection Act 1994*.

**Disturbance** of land includes:

a) compacting, removing, covering, exposing or stockpiling of earth

b) removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion

c) carrying out mining within a watercourse, waterway, wetland or lake

d) the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls

e) temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be removed after the mining activity has ceased

f) releasing of contaminants into the soil, or underlying geological strata.

However, the following areas are not included when calculating areas of 'disturbance':

a) areas off lease (e.g. roads or tracks which provide access to the mining lease)

b) areas previously disturbed which have achieved the rehabilitation outcomes

c) by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions)

d) areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be left by agreement with the landowner

e) disturbance that pre-existed the grant of the tenure.

**Domestic waste** means waste, other than domestic clean-up waste, green waste, recyclable waste, interceptor waste or waste discharged to a sewer, produced as a result of the ordinary use or occupation of domestic premises.

**Dwelling** means any of the following structures or vehicles that is principally used as a residence:

a) a house, unit, motel, nursing homes or other building or part of a building; or

b) a caravan, mobile home or other vehicle or structure on land; or

c) a water craft in a marina.

**Effluent** treated waste water discharged from sewage treatment plants.

**End of pipe** means the location at which water is released to waters or land.

**Environmental authority** means an environmental authority under Chapter 5 of the *Environmental Protection Act 1994.*

**Environmental authority holder** means the holder of this environmental authority.

**Environmental nuisance** is unreasonable interference or likely interference with an environmental value caused by:

a) aerosols, fumes, light, noise, odour, particles or smoke; or

b) an unhealthy, offensive or unsightly condition because of contamination; or

c) another way prescribed by regulation.

**Environmental offset** has the meaning in section 7 of the *Environmental Offsets Act 2014*.

**Equilibrium** A state where 'balance' is achieved despite changing variables.

**Environmentally relevant activity** means an environmentally relevant activity as defined under Section 18 of the *Environmental Protection Act 1994* and listed under Schedule 1 of the *Environmental Protection Regulation 1998.*

**Existing structure** means a structure that prior to when EA is issued with new dam manual conditions meets any or both of the following, a structure:

a) with a design that is in accordance with the current version of the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures and that is considerably in progress;

b) that is under considerable construction or that is constructed.

**Floodwater** means water overflowing, or that has overflowed, from waters, river, creek, stream, lake, pond, wetland or dam onto or over riparian land that is not submerged when the watercourse or lake flows between or is contained within its bed and banks.

**Flowable substance** means matter or a mixture of materials which can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension.

**Foreseeable future** is the period used for assessing the total probability of an event occurring. Permanent structures and ecological sustainability should be expected to still exist at the end of a 150 year foreseeable future with an acceptable probability of failure before that time.

**Functional design** is a document that contains 'conceptual' information about the design, operation and revegetation criteria of a watercourse diversion that addresses the outcomes stated in the conditions on the environmental authority relating to the diversion. The document should include, but not be limited to:

a) geomorphic and vegetation assessment of the existing watercourse

b) hydrologic conditions of the existing watercourse

c) the proposed watercourse diversion route

d) results from hydrologic, hydraulic and sediment transportation modelling used in the design of the diversion.

**General waste** means waste other than regulated waste.

**Hazardous waste** means a substance, whether liquid, solid or gaseous that, if improperly treated, stored, disposed of or otherwise managed, is likely to cause environmental harm.

**Hazard** in relation to a dam as defined, means the potential for environmental harm resulting from the collapse or failure of the dam to perform its primary purpose of containing, diverting or controlling flowable substances.

**Hazard category** means a category, either low significant or high, into which a dam is assessed as a result of the application of tables and other criteria in 'Manual for Assessing Hazard Categories and Hydraulic Performance of Dams'.

**Hydraulic performance** means the capacity of a regulated dam to contain or safely pass flowable substances based on the design criteria specified for the relevant consequence category in the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)*.

**Infrastructure** means water storage dams, roads and tracks, buildings and other structures built for the purpose of mining activities but does not include other facilities required for the long term management of mining impacts or the protection of potential resources. Such other facilities include dams, waste rock dumps, voids, or ore stockpiles and buildings as well as other structures whose ownership can be transferred and which have a residual beneficial use for the next owner of the operational land or the background land owner.

$L_{A10,\ adj,\ 10\ mins}$ means the A-weighted sound pressure level, (adjusted for tonal character and impulsiveness of the sound) exceeded for 10% of any 10-minute measurement period, using Fast response.

$L_{A\ 1,\ adj,\ 10\ mins}$ means the A-weighted sound pressure level, (adjusted for tonal character and impulsiveness of the sound) exceeded for 1% of any 10-minute measurement period, using Fast response

$L_{A,\ max\ adj,\ T}$ means the average maximum A-weighted sound pressure level, adjusted for noise character and measured over any 10 minute period, using Fast response.

**Lake** includes:

a) lagoon, swamp or other natural collection of water, whether permanent or intermittent; and

b) the bed and banks and any other element confining or containing the water.

**Land** in the **land schedule** of this document means land excluding waters and the atmosphere, that is, the term has a different meaning from the term as defined in the *Environmental Protection Act 1994*. For the purposes of the *Acts Interpretation Act 1954*, it is expressly noted that the term 'land' in this environmental authority relates to physical land and not to interests in land.

**Land capability** as defined in the *DME 1995 Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland*.

**Land suitability** as defined in the *DME 1995 Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland*.

**Land use** means the selected post mining use of the land, which is planned to occur after the cessation of mining operations.

**Landfill** means land used as a waste disposal site for lawfully putting solid waste on the land.

**Levee** means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of **water** or **flowable substances** at any other times.

**Mandatory reporting level** or **MRL** means a warning and reporting level determined in accordance with the criteria in the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)* published by the administering authority.

**Manual** means the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)* published by the administering authority, as amended from time to time.

**Maximum extent of impact** means the total, cumulative, residual extent and duration of impact to a prescribed environmental matter that will occur over a project's life after all reasonable avoidance and reasonable on-site mitigation measures have been, or will be, undertaken.

**Measures** includes any measures to prevent or minimise environmental impacts of the mining activity such as bunds, silt fences, diversion drains, capping, and containment systems.

**mg/L** means milligrams per litre.

**Mineral** means a substance which normally occurs naturally as part of the earth's crust or is dissolved or suspended in water within or upon the earth's crust and includes a substance which may be extracted from such a substance, and includes—

a) clay if mined for use for its ceramic properties, kaolin and bentonite;

b) foundry sand;

c) hydrocarbons and other substances or matter occurring in association with shale or coal and necessarily mined, extracted, produced or released by or in connection with mining for shale or coal or for the purpose of enhancing the safety of current or future mining operations for coal or the extraction or production of mineral oil therefrom;

d) limestone if mined for use for its chemical properties;

e) marble;

f) mineral oil or gas extracted or produced from shale or coal by in situ processes;

g) peat;

h) salt including brine;

i) shale from which mineral oil may be extracted or produced;

j) silica, including silica sand, if mined for use for its chemical properties;

k) rock mined in block or slab form for building or monumental purposes;

But does not include—

a) living matter;

b) petroleum within the meaning of the *Petroleum Act 1923*;

c) soil, sand, gravel or rock (other than rock mined in block or slab form for building or monumental purposes) to be used or to be supplied for use as such, whether intact or in broken form; or

d) water.

**'Mine affected water':**

a) means the following types of water:

i) pit water, tailings dam water, processing plant water

ii) water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the *Environmental Protection Regulation 2008* if it had not formed part of the mining activity

iii) rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water

iv) groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated

v) groundwater from the mine's dewatering activities

vi) a mix of mine affected water (under any of paragraphs i)-v) and other water.

b) does not include surface water runoff which, to the extent that it has been in contact with areas disturbed by mining activities that have not yet been completely rehabilitated, has only been in contact with:

i) land that has been rehabilitated to a stable landform and either capped or revegetated in accordance with the acceptance criteria set out in the environmental authority but only still awaiting maintenance and monitoring of the rehabilitation over a specified period of time to demonstrate rehabilitation success, or

ii) land that has partially been rehabilitated and monitoring demonstrates the relevant part of the landform with which the water has been in contact does not cause environmental harm to waters or groundwater, for example:

- areas that are been capped and have monitoring data demonstrating hazardous material adequately contained with the site
- evidence provided through monitoring that the relevant surface water would have met the water quality parameters for mine affected water release limits in this environmental authority, if those parameters had been applicable to the surface water runoff, or

iii) both.

**Minimise** is to reduce to the smallest possible amount or degree.

**Mining operations** means mining activities carried out on land over which there is a mineral development licence or mining lease under the *Mineral Resources Act 1989*.

**Modification or modifying** (see definition of 'construction')

**NATA** means National Association of Testing Authorities, Australia.

**Natural flow** means the flow of water through waters caused by nature.

**Nature** includes:

a) ecosystems and their constituent parts; and

b) all natural and physical resources; and

c) natural dynamic processes.

**Notice of election** has the meaning in section 18(2) *Environmental Offsets Act 2014*.

**Noxious** means harmful or injurious to health or physical well being.

**Offensive** means causing reasonable offence or displeasure; is disagreeable to the sense; disgusting, nauseous or repulsive, other than trivial harm.

**Operational land** means the land associated with the project for which this environmental authority has been issued.

**Operational plan** means a document that amongst other things sets out procedures and criteria to be used for operating a dam during a particular time period. The operational plan as defined herein may form part of a otherwise required in legislation.

**Palletised** means stored on a movable platform on which batteries are placed for storage or transportation.

**Peak particle velocity (ppv)** means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s).

**Permanent watercourse diversion** is a man-made structure that incorporates the geomorphologic, hydraulic, hydrologic and ecological components of a local watercourse and is designed, constructed, operated and maintained according to an engineering standard that ultimately achieves a self-sustaining watercourse able to function without features or characteristics that rely on ongoing maintenance or that impose a financial or other burden on the proponent, government or the community.

**Pre-existing watercourse** is the section of watercourse from which the flow of water will be diverted as a result of the construction and operation of a watercourse diversion.

**Prescribed environmental matters** has the meaning in section 10 of the *Environmental Offsets Act 2014*, limited to the matters of State environmental significant listed in schedule 2 of the Environmental Offsets Regulation 2014.

**Protected area** means – a protected area under the *Nature Conservation Act 1992*, or

a) a marine park under the Marine Parks Act 1992, or
b) a World Heritage Area.

**Progressive rehabilitation** means rehabilitation (defined below) undertaken progressively or a staged approach to rehabilitation as mining operations are ongoing.

**Process water** means water used or produced during the mineral development activities.

**Receiving waters** means the waters into which this environmental authority authorises releases of mine affected water.

**Recycled water** means appropriately treated effluent and urban stormwater suitable for further use.

**Reference site** (or analogue site) may reflect the original location, adjacent area or another area where rehabilitation success has been completed for a similar biodiversity. Details of the reference site may be as photographs, computer generated images and vegetation models etc.

**Register of Regulated Structures** includes**:**

a) Date of entry in the register;
b) Name of the structure, its purpose and intended/actual contents;
c) The consequence category of the dam as assessed using the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)*;
d) Dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;
e) Name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;
f) For the regulated dam, other than in relation to any levees –

i) The dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;

ii) Coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area

iii) Dam crest volume (megalitres);

iv) Spillway crest level (metres AHD).

v) Maximum operating level (metres AHD);

vi) Storage rating table of stored volume versus level (metres AHD);

vii) Design storage allowance (megalitres) and associated level of the dam (metres AHD);

viii) Mandatory reporting level (metres AHD);

g) The design plan title and reference relevant to the dam;

h) The date construction was certified as compliant with the design plan;

i) The name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;

j) Details of the composition and construction of any liner;

k) The system for the detection of any leakage through the floor and sides of the dam;

l) Dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;

m) Dates when recommendations and actions arising from the annual inspection were provided to the administering authority;

n) Dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

**Regulated dam** means any dam in the significant or high hazard category as assessed using the *Site Water Management Technical Guideline for Environmental Management of Exploration and Mining in Queensland (DME 1995)*.

**Regulated structure** means any structure in the significant or high consequence category as assessed using the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)* published by the administering authority. A regulated structure does not include:

a) a fabricated or manufactured tank or container, designed and constructed to an Australian Standard that deals with strength and structural integrity of that tank or container;

b) a sump or earthen pit used to store residual drilling material and drilling fluid only for the duration of drilling and well completion activities;

c) a flare pit.

**Regulated waste** means non-domestic waste mentioned in schedule 7 of the *Environmental Protection Regulation 1998* (whether or not it has been treated or immobilised), and includes –

a) for an element – any chemical compound containing the element; and

b) anything that has contained the waste.

**Rehabilitation** the process of reshaping and revegetating land to restore it to a stable landform.

**Release event** means a surface water discharge from mine affected water storages or contaminated areas on the licensed place.

**Representative** means a sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activities.

**Residual void** means an open pit resulting from the removal of ore and/or waste rock which will remain following the cessation of all mining activities and completion of rehabilitation processes.

**Revegetation** is the re-establishment of vegetation[1] of a species and density of cover similar to surrounding undisturbed areas or the landform that existed before mining activities on soil surfaces associated with the construction or rehabilitation of a watercourse diversion.

**Saline drainage** The movement of waters, contaminated with salts, as a result of the mining activity.

**Self sustaining** means not requiring on-going intervention and maintenance to maintain functional riverine processes and characteristics

**Sensitive place** means:

a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or

b) a motel, hotel or hostel; or

c) an educational institution; or

d) a medical center or hospital; or

e) a protected area under the *Nature Conservation Act 1992*, the *Marine Parks Act 1992* or a World Heritage Area; or

f) a public park or gardens.

Note: The definition of 'sensitive place' and 'commercial place' is based on Schedule 1 of EPP Noise. That is, a sensitive place is inside or outside on a dwelling, library and educational institution, childcare or kindergarten, school or playground, hospital, surgery or other medical institution, commercial & retail activity, protected area or an area identified under a conservation plan under Nature Conservation Act 1992 as a critical habitat or an area of major interest, marine park under Marine Parks Act 2004, park or garden that is outside of the mining lease and open to the public for the use other than for sport or organised entertainment. A commercial place is inside or outside a commercial or retail activity.

A mining camp (i.e., accommodation and ancillary facilities for mine employees or contractors or both, associated with the mine the subject of the environmental authority) is not a sensitive place for that mine or mining project, whether or not the mining camp is located within a mining tenement that is part of the mining project the subject of the environmental authority. For example, the mining camp might be located on neighbouring land owned or leased by the same company as one of the holders of the environmental authority for the mining project, or a related company. Accommodation for mine employees or contractors is a sensitive place if the land is held by a mining company or related company, and if occupation is restricted to the employees, contractors and their families for the particular mine or mines which are held by the same company or a related company.

For example, a township (occupied by the mine employees, contractors and their families for multiple mines that are held by different companies) would be a sensitive place, even if part or all of the township is constructed on land owned by one or more of the companies.

**Sewage** means the used water of person's to be treated at a sewage treatment plant.

**Spillway** means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the dam, normally under flood conditions or in anticipation of flood conditions.

**Stable** in relation to land, means land form dimensions are or will be stable within tolerable limits now and in the foreseeable future. Stability includes consideration of geotechnical stability, settlement and consolidation allowances, bearing capacity (trafficability), erosion resistance and geochemical stability with respect to seepage, leachate and related contaminant generation.

**Stormwater** means all surface water runoff from rainfall.

**Structure** means dam or levee.

**Suitably qualified and experienced person** means a person who is a Registered Professional Engineer of Queensland under the provisions of the *Professional Engineers Act 2002*, who has an **appropriate level of expertise** in the structures, geomechanics, hydrology, hydraulics and environmental impact of watercourse diversions.

An ***appropriate level of expertise*** includes:

- demonstrable competency, experience and expertise in:
    - investigation, design or construction of watercourses
    - diversions operation and maintenance of watercourse
    - geomechanics with particular emphasis on channel equilibrium, geology and geochemistry
    - hydrology with particular reference to flooding, estimation of extreme storms, water management or meteorology
    - hydraulics with particular reference to sediment transport and deposition and erosion control
    - hydrogeology with particular reference to seepage and groundwater
    - solute transport processes and monitoring thereof, or
- sufficient knowledge and experience to certify that where the **suitably qualified and experienced person** has relied on advice and information provided by other **persons with relevant expertise***:
    - they consider it reasonable to rely on that advice and information
    - the expert providing the advice and information has knowledge, competency, suitable experience and demonstrated expertise in the matters related to watercourse diversions.

***Persons with relevant expertise*** include:

- Geomorphologist: person who has demonstrated competency and relevant experience in stream geomorphology and watercourse diversions.
- Geotechnical Expert: person who has demonstrated competency and relevant experience in geotechnical assessment of soil characteristics suitable for watercourse diversions.
- Vegetation Expert: person who has demonstrated competency and relevant experience in the identification, role and function of vegetation with watercourses and adjoining floodplains, and has demonstrated competency and relevant experience in revegetation of watercourse diversions and adjoining floodplains. .
- Groundwater Expert: person who has demonstrated competency and relevant experience in groundwater systems.
- Surface Water Expert: person who has demonstrated competency and relevant experience in hydrology.

- Engineer: person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Persons Act 2002* or has similar qualifications under a respected professional registration association, and has demonstrated competency and relevant experience in design and construction of watercourse diversions.
- Soils Expert: person who has demonstrated competency and relevant experience in soil classification including the physical, chemical and hydrologic analysis of soil.

**Suitably qualified and experienced person** in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

- for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design
- for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology.

**System design plan** means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

**Temporary watercourse diversion** is a man-made structure that may incorporate geomorphologic, hydraulic, hydrologic and ecological components of a local watercourse and is designed, constructed, operated and maintained to an engineering standard that ensures the diversion does not compromise the equilibrium and performance of the diversion and adjoining watercourses. A temporary diversion is replaced by a permanent diversion, or the re-establishment of the pre existing watercourse, within the timeframe specified in the design plan.

**The Act** means the *Environmental Protection Act 1994*.

**Trivial harm** means environmental harm which is not material or serious environmental harm and will not cause actual or potential loss or damage to property of an amount of, or amounts totalling more than $5,000.

**Tolerable limits** means a range of parameters regarded as being sufficient to meet the objective of protecting relevant environmental values. For example, a range of settlement for a tailings capping, rather than a single value, could still meet the objective of draining the cap quickly, preventing pondage and limiting infiltration and percolation.

**Void** means any man-made, open excavation in the ground.

**Waste** as defined in section 13 of the *Environmental Protection Act 1994*.

**Waste and resource management hierarchy** – has the meaning provided in section 9 of the *Waste Reduction and Recycling Act 2011* and is the following precepts, listed in the preferred order in which waste and resource management options should be considered—

a) AVOID unnecessary resource consumption
b) REDUCE waste generation and disposal
c) RE-USE waste resources without further manufacturing
d) RECYCLE waste resources to make the same or different products
e) RECOVER waste resources, including the recovery of energy

f) TREAT waste before disposal, including reducing the hazardous nature of waste

g) DISPOSE of waste only if there is no viable alternative.

**Waste and resource management principles** – has the meaning provided in section 4(2)(b) of the *Waste Reduction and Recycling Act 2011* and means the:

a) polluter pays principle

b) user pays principle

c) proximity principle

d) product stewardship principle.

**Water** is defined under Schedule 4 of the *Water Act 2000.*

**Watercourse** has the meaning in Schedule 4 of the *Environmental Protection Act 1994* and means:

a) a river, creek or stream in which water flows permanently or intermittently—

i) in a natural channel, whether artificially improved or not; or

ii) in an artificial channel that has changed the course of the watercourse.

b) Watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water.

**Waste water** means used water from the activity, process water or contaminated storm water.

**Water quality** means the chemical, physical and biological condition of water.

**Waters** includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater.

**Weediness** includes weeds that are declared plants as defined under the *Land Protection (Pest and Stock Route Management) Act 2002*.

**µg/L** means micrograms per litre

**µS/cm** means micro siemens per centimetre

**Figure 1 - Release points (RP) and monitoring points (MP) on Blackwater Creek**



**Figure 2 - Release points (RP) and monitoring points (MP) on the Mackenzie River**

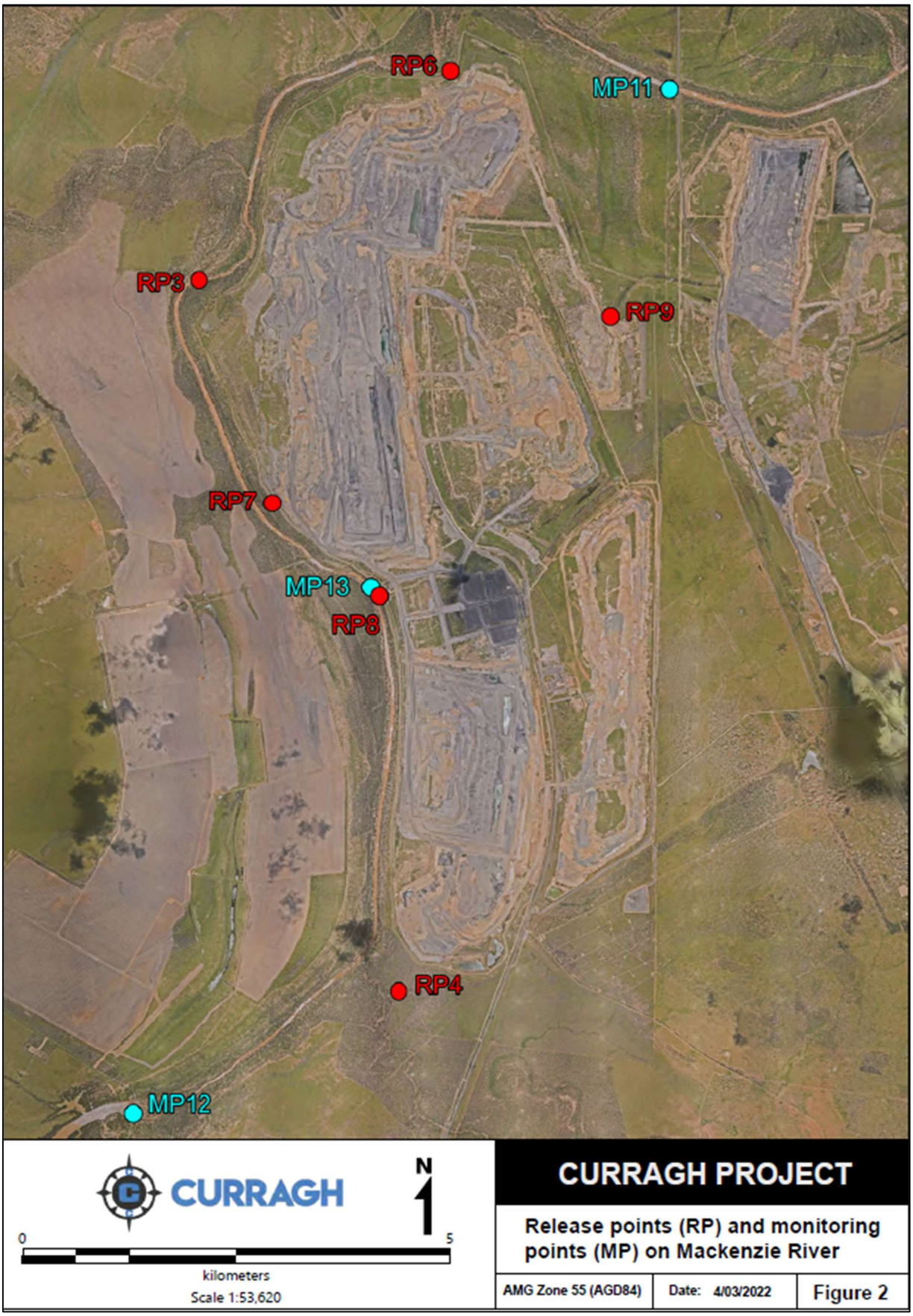


**Figure 3 – Curragh Mine Onsite Landfill Facility**



**Figure 4 – Approved Disturbance Area and Mine Activity Areas**

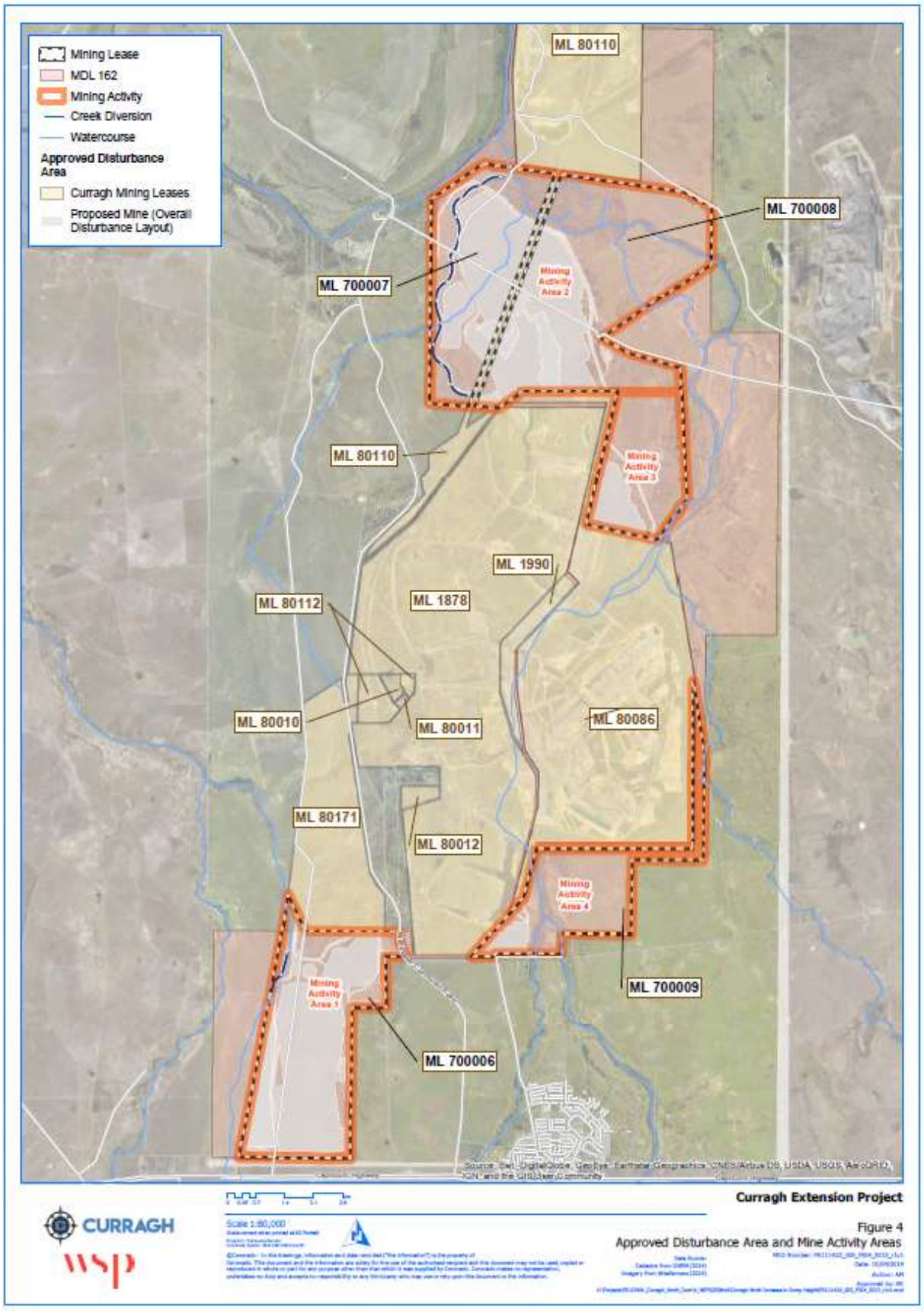


**Figure 5 – Prescribed environmental matters**

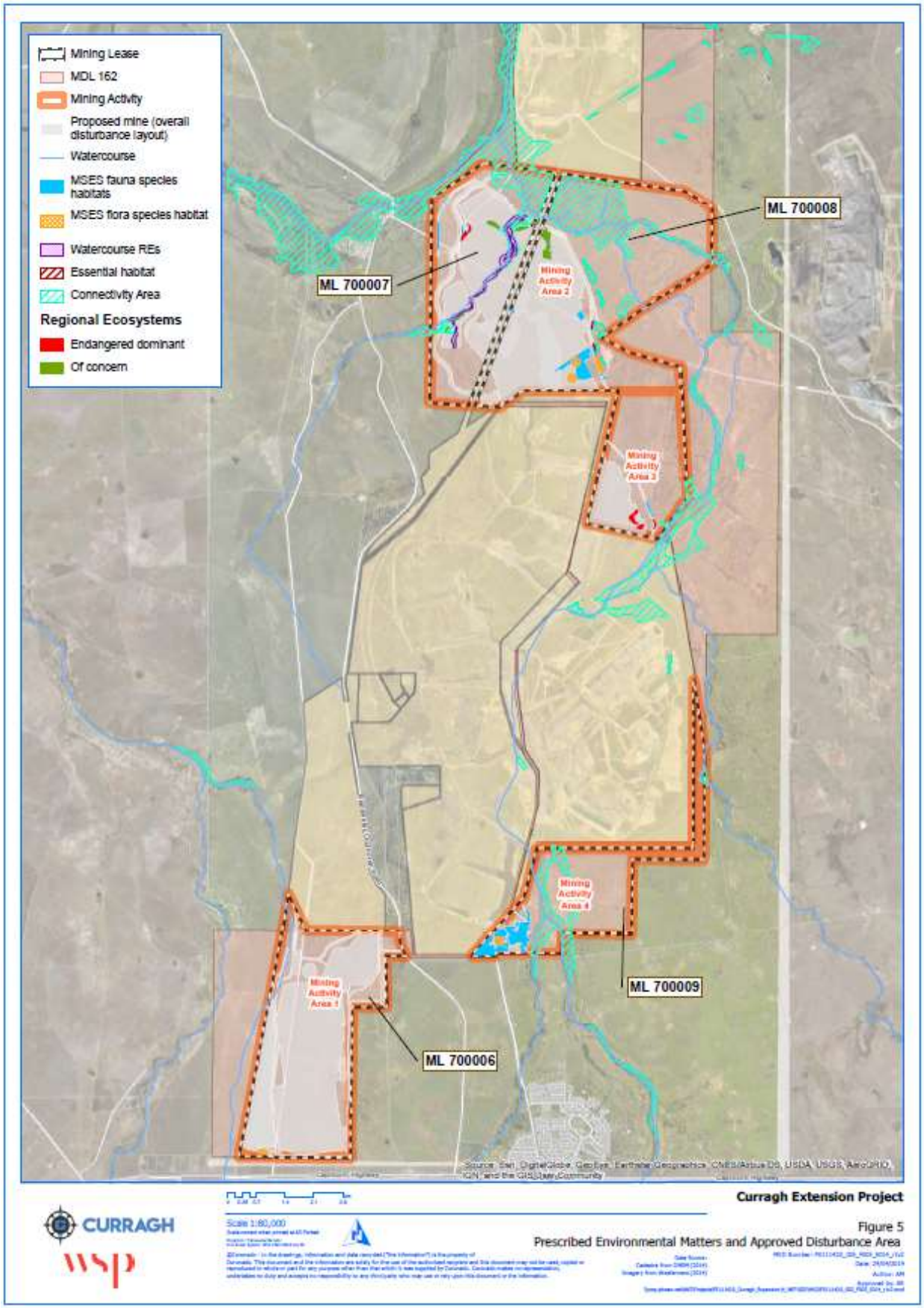
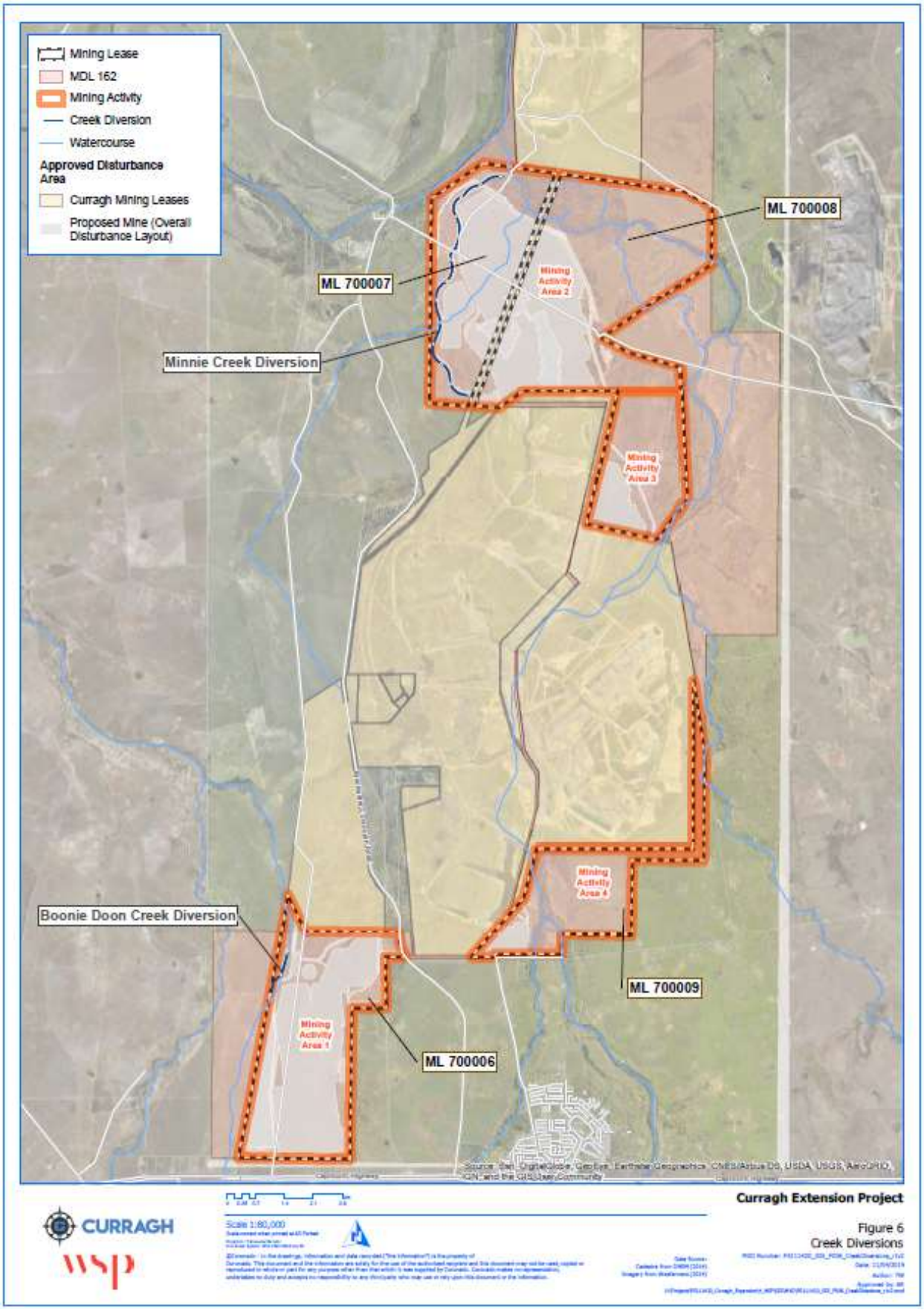


**Figure 6 – Watercourse Diversions**



**END OF PERMIT**

# BLACKWATER CREEK DIVERSION MONITORING AND MAINTENANCE PLAN

| | | | |
|---|---|---|---|
| **Document No:** | EMS PLAN 1.4 | **Version:** | 6 |
| **Applies to:** | TS | **Work Groups:** | Environment Section |
| **RELEVANT LEGISLATION** | Environmental Protection Act 1994, Biosecurity Act 2014 | | |
| | Environmental Authority EPML00643713: G17 | | |

**KEY RELATED DOCUMENTS**

| Plans | Procedures | Forms |
|---|---|---|
| EM PLAN 1.0 | EMS PROC 1.1 | EMS FORM 1.5 |
| EM PLAN 1.3 | | EMS FORM 1.6 |
| EM PLAN 1.5 | | EMS FORM 1.7 |

**DOCUMENT CONTROL**

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**REVISION HISTORY**

| Revision | Description | Date | Prepared by | Approved by |
|---|---|---|---|---|
| 1 | Creation of Document | 20/01/2014 | A Dawson-Evenhuis | E Ballot |
| 2 | Organisational changes | 30/09/2014 | S Hansen | E Ballot |
| 3 | Update to encompass EA Amendment changes | 27/08/2015 | K Reibel | E Ballot |
| 4 | Organisational Changes | 12/04/2016 | H Cooke | E Ballot |
| 5 | EA Amendment and Staff Changes | 28/06/2016 | H Cooke | E Ballot |
| 6 | Scheduled review | 13/03/2019 | K Tuart | E Ballot |

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## 1. PURPOSE

The purpose of this Maintenance and Monitoring Plan is to provide ongoing management of the Blackwater Creek Diversion (BWCD) post completion to ensure it continues to perform and meet the success criteria through to its relinquishment in 2025.

## 2. INTRODUCTION

### 2.1 Background

In 2008 approvals were granted to Wesfarmers Curragh Pty Ltd by the Department of Environment and Science (DES; previously Department of Environment and Heritage Protection, DEHP) to divert a 9.4 kilometre section of Blackwater Creek to allow the extension of mine operations to the east. The BWCD provides access to an additional 47 million tonnes of low strip coal suitable for processing into hard coking coal for export. The constructed diversion length is 10.2 kilometres and it consists of a meandering low flow channel, high flow channel, batter banks and terraces that all required rehabilitation and revegetation.

The intent of the rehabilitation is to provide a comprehensive strategy that facilitates the re-establishment of in-stream and ex-stream ecological processes within the channel. The aim of the rehabilitation is to create as much as possible, a self-sustaining system that requires minimal management in the short to medium term and no future management beyond the cessation of the mining operations. The BWCD will result in a permanent, stable and sustainable creek alignment that will provide an important ecological corridor over the entire length of the diversion.

### 2.2 Approvals

As part of the approval process several documents were referenced and provide detailed information on both construction and rehabilitation. They also include specific timeframes for reporting and key criteria for measuring success.

- NRW Integrated Planning Act Development Permit 408512 and the Water Act Development Permit 408511(both issued October 2008). Monitoring and evaluation of the performance of works must be carried out in accordance with the following documents:
  - BWCD– Vegetation and Rehabilitation Management Plan EMS-PROC-034
  - Curragh East Coal Mine – BWCD Vegetation and Rehabilitation Documentation Package.
- DERM Environmental Protection Act Environmental Authority (EA) MIN100657807(August 2008)
  - Rehabilitation of the BWCD must be conducted in accordance with the BWCD- Vegetation and Rehabilitation Management Plan EMS-PROC-034

- Rehabilitation of the BWCD must achieve as a minimum, the rehabilitation success criteria defined in the following table

Rehabilitation success criteria for BWCD (based on staged construction phase of 12 months)

| Parameter | 3 months | 6 months | 12 months | 18 months | 24 months (Diversion opening) |
|---|---|---|---|---|---|
| Cover / $m^2$ - Groundcover – Hydromulch Zones A, B & C | 30% | 50% | 75% | 75% | 75% |
| Weediness - Zones A, B & C | 15% | 10% | 5% | 5% | 5% |

- DERM Environmental Protection Act EAMIN100657807(amended November 2009)
  - H17: Rehabilitation of the BWCD must be conducted in accordance with the BWCD Revised Specification EMS-PROC-029
  - Rehabilitation of the BWCD must achieve for approval to open the diversion a minimum of seventy-five (75) per cent groundcover and have a weediness of no greater than five (5) per cent
- DEHP Environmental Protection Act EA EPML00643713 (amended November 2011)
  - H17 Rehabilitation of the BWCD Works must be conducted in accordance with BWCD Revised Rehabilitation Plan EMS-PROC-029
- DEHP Environmental Protection Act EA EPML00643713 (amended 20 March 2015)
  - H17 Rehabilitation of the BWCD Works must be conducted in accordance with the document EM PLAN 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan
- DEHP Environmental Protection Act EA EPML00643713 (amended 31 August 2015; 7 June 2016; 15 January 2019)
  - G17 Rehabilitation of the BWCD works must be conducted in accordance with the document EM Plan 1.4 Blackwater Creek diversion Monitoring and Maintenance Plan

BWCD Revised Rehabilitation Plan refers to the initial rehabilitation of the Diversion under the above conditions including the criteria required to open the diversion through to the current condition as per the EA EPML00643713.

## 3. DESIGN PRINCIPLES

The diversion channel has been designed to imitate the bed grade, channel plan form, cross-section form, and other geomorphic and habitat features of the reaches of the natural channel that the diversion will replace. Essentially the functional design aims to recreate a "natural" reach of channel that will be self-sustaining over the long term, well beyond the cessation of mining operations.

To achieve this the design aims to recreate a system as close as possible to, within the limits posed by the engineering design requirements of the diversion, the naturally occurring in stream and riparian zones in undisturbed parts of Blackwater Creek. This will aid in the establishment of natural in stream habitat, riparian and near riparian zones (riverine zones) featuring as far as practicable, locally occurring native plant species that include groundcovers, shrubs and trees.

Restoration of a diverse physical structure within the stream, and a diverse floristic structure, will see a corresponding increase in habitat diversity and an increase in faunal activity, diversity and dispersal.

A geometrically engineered diversion channel was designed by Parsons Brinckerhoff which included both low flow and high flow components divided into zones that reflect the profile attributes of the diversion.

The mandatory elements that were incorporated into the design were:

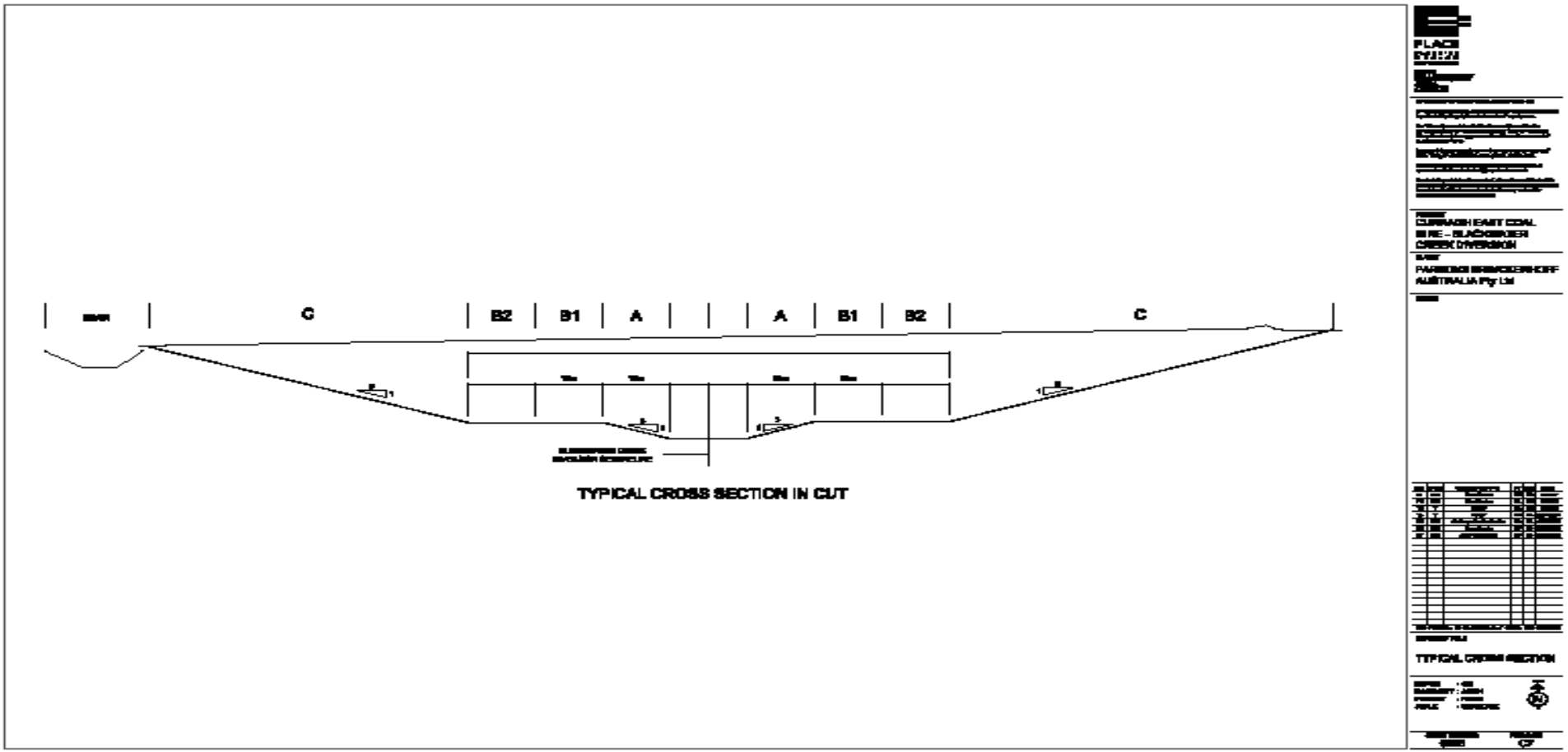
- Variations in the longitudinal and latitudinal section of the floor of stream form; and
- Strategic location of vegetation to increase habitat values and maximise bank stability.

Some amendments were made to the original rehabilitation design that was assessed as ongoing improvements and adaptations to achieve the desired outcomes.

The rehabilitation zones are referred to as:

- **Channel**: low flow channel;
- **Zone A**: low flow channel batter (1V:3H);
- **Zone B1**: high flow terrace extending up to Zone B2;
- **Zone B2**: high flow terrace extending up to Zone C; and
- **Zone C**: high flow batters (batters of 1V:3H), levees and drains extending to natural ground.

**Figure 1** Rehabilitation zones




| Doc No | Document Name | Version | Date | Doc Owner | Authorised By | Page No |
|---|---|---|---|---|---|---|
| EM PLAN 1.4 | Blackwater Creek Diversion Monitoring and Maintenance Plan | 6 | 24/04/2019 | Manager Technical Services | Manager Technical Services | 6 |

### 3.1 Planting Regimes

**Zone A – Low Flow Batter**

| | |
|---|---|
| Topsoil depth | 150mm |
| Soil ameliorant | Incorporate soil ameliorant at nominated rates to topsoil.<br>Topsoil to be left with roughened surface before hydromulch application. |
| Species types | Shallow rooted shrub and grass mix. |
| Direct planting | Nil |
| Hydromulch rate | 4 t/ha |
| Hydromulch mix | 4t/ha of hydromulch including:<br>40kg/ha grass seeds as outlined in **Table 1.**<br>1.5kg/ha native shrubs seeds as outlined in **Table 2.**<br>4t/ha of sugar cane mulch and associated guar based tackifier. |
| Irrigate | Irrigate hydromulch for grass establishment following placement, the amount of water to be applied subject to an ongoing trial and is dependent on rainfall. |

**Zone B1 – High Flow Channel Terrace**

| | |
|---|---|
| Topsoil depth | 300mm |
| Soil ameliorant | Incorporate soil ameliorant at nominated rates to topsoil.<br>Topsoil to be left with roughened surface before hydromulch application. |
| Species types | Shrubs, trees and grasses. |
| Direct planting | Install 90 x 50mm native shrub and tree **(Table 4)** for the entire area of Zone B1 @ one plant per 10m$^2$ as per planting matrix Zone B1 (including application of Terracottem in the base of each planting hole). |
| Hydromulch rate | 4 t/ha |
| Hydromulch mix | Install 4t/ha of hydromulch including:<br>4kg/ha native tree and shrubs seeds as outlined in **Table 3**<br>4t/ha of sugar cane mulch and associated guar based tackifier. |
| Irrigate | Irrigate hydromulch for establishment.<br>Install header tanks, pumps, drip tube and sprinklers for tubestock watering; and Irrigate planted tubestock to field capacity and keep plant root zone soil moisture between wilting point and field capacity. |

**Zone B2 – High Flow Channel Terrace**

| | |
|---|---|
| Notes | Zone B2 is the second section of the high flow terrace area. |
| Topsoil depth | 300mm |
| Soil ameliorant | Incorporate soil ameliorant at nominated rates to topsoil.<br>Topsoil left with roughened surface before hydromulch application. |
| Species types | Shrubs, trees and grasses. |
| Direct planting | Install 80 tubestock 90 X 50mm native shrub **(Table 4)** in each of 71 planting cells (800m$^2$). |
| Hydromulch rate | 4 t/ha |
| Hydromulch mix | Install 4t/ha of hydromulch outside the planting cells including:<br>40kg/ha cover crop, pasture grass, and native grass seed as outlined in **Table 1**.<br>4kg/ha native tree and shrubs seeds as outlined in **Table 3** (only in Chainage 8500-10250 and Chainage 0-1700).<br>4t/ha of sugar cane mulch and associated guar based tackifier.<br>Install 4t/ha of hydromulch in the planting cells including:<br>4kg/ha native shrubs and tree seeds as outlined in **Table 3**.<br>4t/ha of sugar cane mulch and associated guar based tackifier. |
| Irrigate | Irrigate hydromulch for establishment.<br>Install header tanks, pumps, drip tube and sprinklers for tubestock watering; and Irrigate planted tubestock to field capacity and keep plant root zone soil moisture between wilting point and field capacity. |

**Zone C – High Flow Batters**

| | |
|---|---|
| Topsoil depth | 150mm |
| Soil ameliorant | Incorporate soil ameliorant at nominated rates to topsoil.<br>Topsoil to be left with roughened surface before hydromulch application. |
| Species types | Shrubs, trees and grasses. |
| Direct Planting | Install 80 tubestock 90 X 50mm native trees and shrubs **(Table 4)** in each of 65 planting cells 800m$^2$. |
| Hydromulch rate | 4 t/ha |

| | |
|---|---|
| Hydromulch mix | Install 4t/ha of hydromulch outside the planting cells including:<br>40kg/ha cover crop, pasture grass, and native grass seed, outlined in **Table 1**.<br>4t/ha of sugar cane mulch and associated guar based tackifier.<br>Install 4t/ha of hydromulch in the planting cells including:<br>4kg/ha native shrubs and tree seeds as outlined in **Table 3**.<br>4t/ha of sugar cane mulch and associated guar based tackifier. |
| Erosion control | Install Jute Mesh with 150mm pins over entire zone surface. |
| Irrigate | Irrigate hydromulch for establishment.<br>Install header tanks, pumps, drip tube and sprinklers for tubestock watering; and Irrigate planted tubestock to field capacity and keep plant root zone soil moisture between wilting point and field capacity. |

**Zone C – Levees**

| | |
|---|---|
| Topsoil depth | 150mm |
| Soil ameliorant | Supply and incorporate soil ameliorant at nominated rates to topsoil.<br>Topsoil to be left with roughened surface before hydromulch application. |
| Species types | Grass. |
| Direct planting | Nil |
| Hydromulch rate | 4 t/ha |
| Hydromulch mix | Supply and install 4t/ha of hydromulch including:<br>40kg/ha cover crop, pasture grass, and native grass seed as outlined in **Table 1** on levee batters.<br>4t/ha of sugar cane mulch and associated guar based tackifier. |
| Erosion controls | Install Jute Mesh on the inside & outside batter of the levee. |

**Table 1: Grass Seeding Mix (via hydromulching)**

| Species | Common Name | Seed Mix kg/ha |
|---|---|---|
| *Bothriochloa ewartiana* | Desert bluegrass | 5 |
| | Forest bluegrass | 4 |
| *Astrebla lappacea* | Curly mitchell grass | 4 |
| *Heteropogon contortus* | Black spear grass | 5 |
| **Cynodon dactylon* | Green couch | 5 |
| **Chloris gayana* | Rhodes grass | 10 |
| **Echinochloa esculenta* | Jap millet/Wimmera ryegrass | 7 |
| TOTAL | | 40 |

**Table 2: Shrub Species Mix for Zone A (via hydromulching)**

| Species | Common Name | Seed Mix kg/ha |
|---|---|---|
| *Acacia bidwillii* (scarified) | Corkwood | 0.2 |
| *Acacia bancroftiorum* (scarified) | Bancroft's Wattle | 0.2 |
| *Acacia holosericea* (scarified) | Soapbush | 0.2 |
| *Acacia macradenia* (scarified) | Zigzag wattle | 0.2 |
| *Atalaya hemiglauca* | Whitewood | 0.1 |
| *Carrisa ovata* | Klunkerberry | 0.1 |
| *Eremophila maculata* | Fuschia Bush | 0.2 |
| *Lysiphyllum hookerii* | White flowered bauhinia | 0.2 |
| *Senna notabilis* | Cockroach Bush | 0.1 |
| TOTAL | | 1.5 |

**Table 3: Shrub and Tree Species Mix (via hydromulching)**

| Species | Common Name | Seed Mix kg/ha |
|---|---|---|
| *Acacia bidwillii* (scarified) | Corkwood | 0.1 |
| *Acacia harpophylla* | Brigalow | 0.3 |
| *Acacia salicina* (scarified) | Sally wattle | 0.3 |
| *Atalaya hemiglauca* | Whitewood | 0.1 |
| *Casaurina cristata* | Bellah | 0.2 |
| *Cassia brewsterii* | Leichhardt bean | 0.3 |
| *Corymbia tessellaris* | Moreton Bay Ash | 0.2 |
| *Eremophila maculate* | Fuschia bush | 0.1 |
| *Eucalyptus crebra* | Narrow-leafed ironbark | 0.3 |
| *E. coolabah* | Coolibah | 0.3 |
| *E. populneus* | Poplar box | 0.2 |
| *E. tereticornis* | Forest red gum | 0.3 |
| *Geijera parviflora* | Wilga | 0.1 |
| *Lysiphyllum hookerii* | White flowered bauhinia | 0.1 |
| *Melaleuca bracteata* | River tea tree | 0.1 |
| *Owenia Acidula* | Emu apple | 0.1 |
| *Erythrina vespertilio* | Bats Wing Coral | 0.1 |
| *Petalostigma pubscens* | Quinnine | 0.2 |
| *Brachychiton australis* | Kurrajong | 0.1 |
| *Lomandra longifolia* | Spiny headed mat-rush | 0.3 |
| *Melaleuca leucadendra* | Broad-leafed paperbark | 0.1 |
| *Alphitonia excels* | Red Ash | 0.1 |
| TOTAL | | 4.0 |

**Table 4: Tubestock Plant Species (direct planting)**

| Canopy | Mid Strata | Shrubs | Grasses |
|---|---|---|---|
| ***Zone B1 Planting Cells*** | | | |
| Brigalow | Ironwood | Bancroft Wattle | Mat Rush |
| Sally Wattle | Quinine Berry | Corkwood Wattle | Umbrella Grass |
| Mountain Coolibah | Sandpaper Fig | Cockroach Bush | |
| Broad-leaved Bottle Tree | Scrub Leopard Wood | | |
| Leichardt Bean | Yellow Berry Bush | | |
| Morton Bay Ash | Broad Leaved Brush Wilga | | |
| Poplar Box | Sandlewood | | |
| Queensland Blue Gum | Red Flowered Bauhinia | | |
| Yellow Wood | White Flowered Bauhinia | | |
| | River Tea Tree | | |
| | Ebony Tree | | |
| | Emu Apple | | |
| ***Zone B2 Wetlands*** | | | |
| Brigalow | Soft Aclypha | Bancroft Wattle | Mat rush |
| Sally Wattle | Quinine Berry | Corkwood Wattle | Umbrella grass |
| Coolibah | Bitter Bark | Soapbush | |
| Broad-leaved Bottle Tree | Lolly bush | Klunkerberry | |
| Poplar Box | Yellow Berry Bush | | |

| Canopy | Mid Strata | Shrubs | Grasses |
|---|---|---|---|
| Queensland Blue Gum | Creek Wilga | | |
| Yellowwood | False Sandalwood | | |
| | Red Flowered Bauhinia | | |
| | White Flowered Bauhinia | | |
| | River Tea Tree | | |
| | Ebony Tree | | |
| | Peach Bush | | |
| ***Zone B2 Planting Cells*** | | | |
| Brigalow | Ironwood | Soapbush | |
| Sally Wattle | Quinine Berry | Corkwood Wattle | |
| Mountain Coolibah | Bitter Bark | Whitewood | |
| Broad-leaved Bottle Tree | Lolly bush | Klunkerberry | |
| Leichardt Bean | Creek Wilga | | |
| Morton Bay Ash | Yellow Berry Bush | | |
| Poplar Box | False Sandalwood | | |
| Queensland Blue Gum | Sandlewood | | |
| Yellow Wood | Red Flowered Bauhinia | | |
| Narrow-leaved Red Ironbark | White Flowered Bauhinia | | |
| | Ebony Tree | | |

| Canopy | Mid Strata | Shrubs | Grasses |
|---|---|---|---|
| ***Zone C Planting Cells*** | | | |
| Brigalow | Quinine Berry | Soapbush | |
| Sally Wattle | Bitter Bark | Fuschia Bush | |
| Queensland Bottle Tree | Lolly bush | Whitewood | |
| Morton Bay Ash | Creek Wilga | Klunkerberry | |
| Poplar Box | False Sandalwood | | |
| Narrow-leaved Red Ironbark | Yellow Berry Bush | | |
| | Scrub Leopard Wood | | |
| | Sandlewood | | |
| | Red Flowered Bauhinia | | |
| | Ebony Tree | | |

### 3.2 Accelerating Construction and Revegetation Program

Construction of the diversion and its rehabilitation was originally estimated to take 24 months. Due to operational reasons it was decided to advance the construction to just over 12 months. Earthworks began in November 2008 and most works were completed by October 2009. Revegetation commenced in April 2009 and completed around late November 2009. Final works were completed in February 2010 when the original creek line was sealed via the completion of the bund adjacent to Pit B.

## 4. SUCCESS CRITERIA

Rehabilitation success criteria for diverting Blackwater Creek were that the diversion must achieve a minimum of 75% groundcover and have weediness not greater than 5%.

The establishment of adequate vegetative groundcover was deemed necessary to achieve acceptable scour resistance within the range of velocity, shear and stream power characteristics predicted. The criteria and staged response are outlined in **Table 5**. These assigned parameters aligned with the time intervals proposed for the formal assessment monitoring.

Due to the acceleration of the project, cover and weediness were still the target values which had to be achieved at the opening stage. These are considered to be the Primary Success Criteria.

**Table 5: Rehabilitation Success Criteria for Practical Completion**

| **Parameter** | **3 months** | **6 months** | **12 months** | **18 months** | **24 months** |
|---|---|---|---|---|---|
| Cover / $m^2$ - Groundcover – Hydromulch Zones A, B2 & C | 30% | 50% | 75% | 75% | 75% |
| Weediness | 15% | 10% | 5% | 5% | 5% |

Biodiversity Success Criteria were not necessary for Practical Completion but are considered necessary for proving reinstatement of biodiversity performance. **Table 6** details the long-term biodiversity outcomes.

**Table 6: Long Term Biodiversity Outcomes**

| Parameter | 3 months | 6 months | 12 months | 18 months | 24 months |
|---|---|---|---|---|---|
| Cover / $m^2$ - Groundcover – Hydromulch Zones A, B2 & C | 30% | 50% | 75% | 75% | 75% |
| Diversity - Groundcover – Hydromulch Zones A, B2 & C | ≥3 species | ≥3 species | ≥4 species | ≥5 species | ≥6 species |
| Height (Median) - (Direct Planting cells and continuous planting in Zone B1) | 20cm | 40cm | 75cm | 100cm | 125cm |
| Diversity** - (Direct Planting cells and continuous planting in Zone B1) | ≥5 species | ≥5 species | ≥7 species | ≥10 species | ≥10 species |

It is the intention that the diversion will be maintained post-opening to ensure that it complies with the long-term diversity criteria.

### 4.1 Monitoring Assessment

Three methodologies, performed concurrently, were undertaken during the construction period. Post completion monitoring is to continue utilising the primary methodology to collect and assess data relating to the ongoing success of the revegetation programme.

### Assessment Methodology

Primary Monitoring Assessment

This assessment type provides the basis for quantifying the success of the rehabilitation and achievement of milestones. This technique requires the establishment of permanent monitoring quadrates (400$m^2$) with the data generated to determine the success of the diversion revegetation.

Detailed quantification and qualification of rehabilitation success is then assessed and documented prior to completion and to determine if the criteria have been met for practical completion.

The opening criteria is based on a calculated average of 75% groundcover and <5% weediness, measured in monitoring quadrats along the diversion. These quadrats were randomly located in hydromulch areas in Zone A, Zone B2 and Zone C.

Rehabilitation success criteria to open the diversion for the hydromulched sections of each stage of the diversion are outlined in **Table 7 and 8** and the long-term rehabilitation criteria for biodiversity in both planting cells and hydromulched areas post-opening are outlined in **Table 6.**

**Table 7: Monitoring of Hydromulch Seeding Areas**

| **Hydromulch Seeding Areas** | |
|---|---|
| **Item** | **Observations to note** |
| **Quadrats** | Random quadrats of 400m$^2$ shall be staked and appropriately flagged within the hydromulched areas outside the direct planting cells.<br>One (40m x 10m) quadrat every kilometre in **Zone A** and one (20m x 20m) quadrats every kilometre in both **Zone B2** and **Zone C**.<br>These shall be assessed against opening criteria and long-term Biodiversity Outcomes (**Table 11**). |
| **Photos** | Three photos will be taken at each quadrat. All details will be recorded on a "*Primary Monitoring Assessment Template*" which will be utilised for the production of monthly reports by the Contractor to the Principal. |
| **Cover** | Within nominated quadrats a straight length of measuring tape will be laid flat upon the ground for 40m. The tape will be positioned adjacent to the centre-line of the plot. For groundcover any hydromulch which is visible beneath the tape is considered as a negative (e.g. 24.56m of hydromulch visible beneath the tape equates to 38.6% vegetative cover). |
| **Weediness** | Within each quadrat, weed cover will be expressed as a percentage of overall cover. |

**Table 8: Monitoring of Direct Planting Cells**

| **Direct Planting Cells** | |
|---|---|
| **Item** | **Observations to note** |
| **Quadrats** | Quadrats of 400m$^2$ shall be staked and appropriately flagged within the direct planting cells.<br>One (40m x 10m) quadrats every kilometre in **Zone B1** and one (20m x 20m) quadrat every kilometre in both **Zone B2** and **Zone C**.<br>These shall be assessed against the long-term Biodiversity Outcomes (**Table 12**). |
| **Height** | All direct planting cells will be initially staked prior to planting. The stake in the southwest corner of nominated planting cells shall be greater than 1,400mm in length and protrude exactly 1,000mm above the natural ground level and be painted or "flagged" in a different colour to nominate heights along the stake (e.g. 100mm, 500mm and 1000mm). This stake will be used to assess growth rates during the maintenance and monitoring periods. |
| **Cover** | Within quadrat a straight length of measuring tape will be laid flat upon the ground for 40m. The tape will be positioned adjacent to the centre-line of the plot.<br>The cover of planted trees across the tape is to be recorded (e.g. 17.54m of tape occluded from the sky because of canopy cover is equivalent to 43.85% cover).<br>Note: canopy is considered as an opaque, intact polygon. Gaps between leaves and branches of the same plant are to be acknowledged as complete cover.<br>Similarly, groundcover will be measured. Here, any hydromulch which is visible beneath the tape is considered as a negative (e.g. 24.56m of hydromulch visible beneath the tape equates to 38.6% vegetative cover). |
| **Weediness** | Within each quadrat, weed cover will be expressed as a percentage of overall cover. |
| **Attrition** | Failure of planted tube-stock will be documented. |
| **Photos** | Three photos will be taken at each nominated quadrat. All details will be recorded on a "*Primary Monitoring Assessment Template Direct Planting Cells"* which will be utilised for the production of monthly reports by the Contractor to the Principal. |

### Photographic Monitoring Points

Permanent photographic monitoring points have been established at 500m intervals along the diversion in line with the irrigation tanks on the western side of the diversion channel.

Photographs are to be taken with a high-resolution camera at intervals with the first directed northward along the edge of the high flow batter, another taken from the stake toward the base of the channel and another facing toward the south of the diversion. A photo could also be taken from the base of the channel looking toward the stake. A reference number must be visible in all photos.

### Timing of Monitoring

Primary Monitoring Assessment has been performed at a stage by stage basis prior to the opening of the diversion with the final assessment undertaken on the 11th to 16th January 2010 for practical completion (*Revegetation Implementation and Practical Completion Monitoring Report* PB Jan 2010). Since the opening of the diversion, primary monitoring has continued on a monthly basis commencing in February 2010 through to September 2011, then quarterly through to September 2013.

Primary Monitoring Assessment will continue on a yearly basis for the next 5 years until 2018 then every second year until relinquishment of the diversion in 2025. To allow for the identification of flora, monitoring will be undertaken at the most appropriate time between the months of September and March.

Tertiary Monitoring Assessment

Tertiary assessments are non-formal, visual assessments based on observing, documenting and ameliorating (or making good) matters that threaten the rehabilitation viability. This type of assessment is designed to expedite a timely and proportionate response to address issues as encountered in between the more formal monitoring process (viz. secondary and primary assessments). Designed for observation of works at commencement, during and post rehabilitation.

Secondary Monitoring Assessment

This methodology provides a framework for regular assessment of rehabilitation progression and enables prompt determination of additional requirements, problematic techniques or methodologies, plant failure or success, weed establishment and cover establishment. An acceptable maintenance action can then be applied and subsequently monitored.

Secondary assessments are formal qualitative assessments of the success of the revegetation works, set to a documented timeline. Refer to **Table 9** for schedule of monitoring activities.

**Table 9: Secondary Assessment Monitoring Schedule**

| Monitoring | Time | Maintenance Action |
|---|---|---|
| Presence of Weeds | Fortnightly | Remove weed regrowth to ensure dominance of regenerating native plants.<br>A weed exclusion zone of at least 10 metres should be maintained at the top of the high flow batter.<br>Replace hydromulch/jute matting where necessary |
| Health of Plants | Fortnightly | Replace dead or dying plants.<br>Sick plants may be an indication of stress or poor soil conditions, low nutrient levels or lack of water. |
| Signs of Regeneration | Fortnightly | Natural regeneration and new growth in previously weed infested areas is a good sign of recovery and indicates a healthy ecosystem. |
| Signs of Disturbance | Fortnightly | If a disturbance (e.g. impact from stock, native animals or insects, erosion, nutrient influx, etc.) is affecting > 10% of a revegetation area it is considered a major threat and should be mitigated. |
| Habitat Values | Annually | The site should be developing food sources (e.g. nectar and seed) and habitat (e.g. leaf litter, nesting sites) for native fauna.<br>Logs, rocks and nest boxes can be utilised to enhance fauna habitat as they become available. |
| Diversity & Structure | Annually | Replace dead or dying plants.<br>Add additional species if biodiversity is limited.<br>The site should begin to represent a natural system. It should display a diversity of native species and a natural structure incorporating canopy, mid-layer and groundcover. |

## 5. PRACTICAL COMPLETION

Primary monitoring was undertaken between November 2009 and January 2010 to determine if the success criteria had been met. All monitoring was conducted in accordance with the methodology described in 'BWCD Practical Completion and Maintenance Monitoring Sampling Protocol Draft Version B' (refer to APPENDIX A).

For practical completion monitoring and ongoing Maintenance Monitoring, sites were selected on the basis of random selection of cells. The locations were to be uniformly representative of zones, longitudinal grade and to encompass both sides of the diversion channel. The intent of the monitoring methodology was to establish a protocol that was transparent, time/cost efficient and repeatable whilst minimising simple biases which may arise between individuals conducting the sampling.

### 5.1 Results at Practical Completion

| Parameter | 3 months | 6 months | 12 months | Results | 18 months | 24 months |
|---|---|---|---|---|---|---|
| Height(median) | 300mm | 500mm | 750mm | 500mm | 1000mm | 1250mm |
| Vegetative Cover (hydromulch) | 30% | 50% | 75% | 89% | 75% | 75% |
| Weed Cover | <15% | <10% | <5% | <5% | <5% | <5% |
| Diversity (species No.) | >5 | >5 | >7 | 13 | >10 | >10 |

## 6. POST MONITORING AND MAINTENANCE

Primary Monitoring Assessment since the opening of the diversion has continued on a monthly basis commencing in February 2010 through to September 2011, then quarterly through to September 2013. Long term biodiversity provided success criteria to be achieved in successional stages up to 24months. March 2012 marked the 24months since the rehabilitation maintenance and monitoring commenced. This ongoing maintenance programme was an integral element in overcoming the adverse conditions that have affected the project by reducing stress and competition to tubestock, preventing and controlling weed outbreaks and identifying any potential problems before they could hinder the long-term success of the vegetation. Maintenance work during this period included watering, weed control, fertilising, whipper snipping grass in the monitoring plots to reduce the competition on tubestock, flood repairs and other general repairs as required.

### 6.1 Results after 24 months

Results for the month timeframe can be found in BWCD Rehabilitation Monitoring and Assessment 24-month Compliance Report – March 2012 by Lanyonscapes. A brief summary of the results against the criteria is shown below in the table.

| Parameter | 3 months | 6 months | 12 months | 18 months | 24 months | Results |
|---|---|---|---|---|---|---|
| Height (median) | 300mm | 500mm | 750mm | 1000mm | 1250mm | 1360mm |
| Vegetative Cover (hydromulch) | 30% | 50% | 75% | 75% | 75% | 96.2% |
| Weed Cover | <15% | <10% | <5% | <5% | <5% | <5% |
| Diversity (species no.) | >5 | >5 | >7 | >10 | >10 | 17 |

### 6.2 Results after 42 months

Results for the 42-month timeframe can be found in the BWCD Maintenance Progress Report – September 2013 by Lanyonscapes.

A brief summary of the results against the criteria is shown below in the table.

| Parameter | 24 months | Results at 24 months | Results at 42 months |
|---|---|---|---|
| Height (median) | 1250mm | 1360mm | 1624mm |
| Vegetative Cover (hydromulch) | 75% | 96.2% | 92% |
| Weed Cover | <5% | <5% | <5% |
| Diversity (species no.) | >10 | 17 | 17 |

## 7. FUTURE MONITORING AND MAINTENANCE

### 7.1 Timing of Monitoring

Curragh will continue to undertake the Primary Monitoring Assessment annually for the next 5 years till 2018 then every second year until relinquishment of the diversion. To allow for the identification of flora, monitoring will be undertaken at the most appropriate time between the months of September and March. A review of this plan should be conducted within 5 years of its implementation to access the data and to ensure it is performing in a manner that meets its long-term objectives.

Monitoring will continue to use the Primary Monitoring Assessment methodology to provide quantitative data and determine ongoing trends in growth, attrition, species composition and the relationship between these factors. Photo monitoring will also be undertaken at this time.

Pro formas have been developed to record this information and have been used throughout each monitoring phase. The originals are found in **APPENDIX B**.

EMS FORM 1.5 BWCD Formal Rehabilitation Assessment Template - Monitoring Sections; EMS FORM 1.6 BWCD Formal Rehabilitation Assessment Template - Photographic Monitoring; and EMS FORM 1.7 BWCD Visual Rehabilitation Assessment Template are used for ongoing monitoring and maintenance and available from Blackrock.

### 7.2 Weed treatment

The following species of weeds, as Prohibited Matter and/or Restricted Invasive Plants (Category 3) as listed under the *Biosecurity Act 2014*, will be treated within and immediately adjacent to the diversion corridor.

- *Opuntia stricta* (Prickly Pear) - Prohibited matter
- *Opuntia tomentosa* (Velvety Pear) - Prohibited Matter
- *Eriocereus martinii* (Harrisia Cactus) - Prohibited Matter
- *Bryophyllum delagonese* (Mother-of-millions) - Category 3
- *Parkinsonia aculeata* (Parkinsonia) - Category 3
- *Parthenium hysterophorus* (Parthenium) - Category 3
- *Cryptostegia grandiflora* (Rubber Vine) - Category 3

Other species will be treated in accordance with the general biosecurity obligation under the *Biosecurity Act 2014*.

Appropriate weed hygiene practices will be used to reduce the spread of weed species including washdown of all equipment and vehicles prior to entry and exit from the mine site.

Ongoing and appropriate weed treatment by a qualified specialist will be undertaken as necessary in the diversion. Weeds will be mapped on an annual basis as part of Curragh's Weed Management Plan and activities planned around the treatment of those weeds.

Management of declared weeds within the diversion will be addressed in accordance with the existing protocols outlined in EM PLAN 1.0 Land Management Plan and managed under EMS PROC 1.1 Declared Fauna and Flora Management Procedure.

### 7.3 Erosion Control and Management

Inspections of the levees and diversion are conduction on a quarterly basis, additional inspections will be required in times of rain or flow events in the creek and throughout scheduled monitoring. These will present opportunities to inspect for erosion within the diversion and implement plans for remediation.

### 7.4 Access

Cattle and unauthorised personnel & vehicles will be excluded from the revegetation area. Regular inspections will be undertaken for monitoring purpose and as part of site security and safety procedures, all other access will be restricted. Pulse grazing may be considered as part of fire management protocols to manage fuel loads and to stimulate vegetation growth.

### 7.5 Fire Management

EM PLAN 1.5 Fire Management Plan has been developed for site to manage the impacts of fire both upon infrastructure and sensitive environmental management areas. The fuel load within the diversion can present potential issues as a fire would burn with high intensity amongst the grass and damage the trees which are not all receptive to this type of fire. The management plan provides strategies to control and reduce the risk of fire both within and surrounding the diversion. The fire management plan will be updated regularly and should be referenced when undertaking any control measures.

### 7.6 Plant monitoring and replacement

Rehabilitation has been conducted according to the EM PLAN 1.3 Rehabilitation Management and Monitoring Plan and will continue to be monitored as per the Primary Monitoring Assessment. An important feature in monitoring the success is the continued growth and biodiversity trends in the data that will be collected. The goal for revegetation is to provide an ecologically sustainable diversion through restoration of midstorey and understorey structure to a condition similar to pre-disturbance conditions. Restoration of a diverse vegetation structure will see a corresponding increase in habitat diversity and result in increased faunal diversity. Assessment of fauna will also be conducted throughout the life of the diversion under the

'*Threatened Species Fauna Management Plan for within Blackwater Creek Clearance Area'* Nov 2009.

As and when the opportunity permits, woody debris will be placed within zones B and C to create additional habitat features. Should the data indicate that areas of the diversion are not performing and there is a higher than anticipated rate of attrition, steps will be taken to re-establish vegetation as per the criteria set out in EM PLAN 1.3 Rehabilitation Management and Monitoring Plan

## 8. REFERENCE DOCUMENTS

| REFERENCE | LOCATION |
|---|---|
| EMS-PROC-029 Blackwater Creek Diversion Revised Rehabilitation Plan | EMS Archive |
| EMS-PROC-034 Blackwater Creek Diversion Vegetation and Rehabilitation Management Plan Version E. Prepared for Parsons Brinckerhoff Australia Pty Ltd (March 2008) | EMS Archive |
| EM PLAN 1.0 Land Management Plan | Blackrock |
| EM PLAN 1.5 Fire Management Plan | Blackrock |
| EMS PROC 1.1 Declared Flora and Fauna Management Procedure | Blackrock |
| Lanyonscapes (March 2012) Blackwater Creek Diversion Rehabilitation Monitoring and Assessment 24-month Compliance Report | GDrive/Environment |
| Lanyonscapes (Sept 2013) Blackwater Creek Diversion Revegetation Maintenance Progress Report | GDrive/Environment |
| PLACE (Feb 2010) Revegetation Implementation and Practical Completion Monitoring Report | GDrive/Environment |
| EMS FORM 1.5 BWCD Formal Rehabilitation Assessment Template - Monitoring Sections | Blackrock |
| EMS FORM 1.6 BWCD Formal Rehabilitation Assessment Template - Photographic Monitoring | Blackrock |
| EMS FORM 1.7 BWCD Visual Rehabilitation Assessment Template | Blackrock |

## APPENDIX A

**Blackwater Creek Diversion Practical Completion and Maintenance Monitoring Sampling Protocol Draft Version B'**

# BLACKWATER CREEK DIVERSION

## Practical Completion and Maintenance Monitoring Sampling Protocol

# 1. Purpose

This document has been created to establish the methods of establishing and measuring success criteria for cover and biodiversity at PRIMARY MONITORING SITES within the Blackwater Creek Diversion (BCD). The intent of the monitoring is establish a protocol that is transparent, time/cost efficient and repeatable and which allows a consistent level of data to be collected by a variety of personnel whist minimising sample biases which *may* arise between individuals.

# 2. Monitoring Points

## 2.1 Zonation of the Works

The BCD consists of a number of planting zones namely the low flow batter (**Zone A**), the high flow terrace (**Zone B**) and the high flow batter (**Zone C**).

Planting treatments within these zones include Direct (Tubestock) Planting and Direct Seeding.

Direct (Tubestock) planting has occurred within the BCD in **Zone B1** (a continuous planting zone of trees and shrubs), **Zone B2** (a number of 80m x 20m planting cells) and **Zone C** (a number of 80m x 20m planting cells).

Direct seeding with:

- Grasses has occurred within **Zone B2** and **Zone C**;
- Grasses and shrubs has occurred within **Zone A**; and
- Trees and shrubs has occurred within **Zone B1**.

## 2.2 Monitoring Sites and Nomenclature

Monitoring points have been developed on the basis of this zonation and indicative sampling numbers provided within the *Blackwater Creek Diversion Revegetation Plan* and *Blackwater Creek Diversion Revised Revegetation Plan*.

For the Practical Completion Monitoring (and ongoing Maintenance Monitoring) sites have been selected on the basis of random selection of cells. Sites are overlapped with Downer Monitoring sites to provide a 'calibration' between the monitoring events to allow data sets to be meaningfully compared.

### *2.2.1 Direct Seeding Sites*

- **Zone A** – 18 sites (4 sites are Downer Monitoring Sites);
- **Zone B2** - 16 sites (5 sites are Downer Monitoring Sites); and
- **Zone C** – 16 site (4 sites are Downer Monitoring Sites).

Sample locations have been selected to be uniformly representative of zones, longitudinal grade of the diversion and left or right side of the diversion (when travelling downstream). They are indicated on the attached plan and described in relation to BCD chainage in **Table 1.** Direct Seeding Sites are prefixed with 'D' and sequentially numbered from chainage 0.0 (inlet end) along the alignment to chainage 10,000 (near the outlet). Contractor monitoring sampling site nomenclature has been retained for those sites.

**TABLE 1:** Direct Seeding 'D' Sample Sites

| Chainage (m) | Zone A | Zone B2 | Zone C |
|---|---|---|---|
| 0.0 – 1,000 | D1 | D2 | D3 |
| 1,001 – 2,000 | D5 | ***B9*** | D4 |
| | D38 | | D39 |
| 2,001 – 3,000 | D7 | ***B8*** | D6 |
| | ***A15*** | D9 | D8 / (***C8***) |
| 3,001 – 4,000 | D11 | ***B7*** | D10 |
| | | D12 | D13 |
| 4,001 – 5,000 | ***A11*** | D14 | ***C6*** |
| | D17 | D15 | D16 |
| 5,001 – 6,000 | ***A10*** | D18 | D19 |
| | D20 | | |
| 6,001 – 7,000 | D23 | D21 | D22 |
| | D25 | D24 | |
| 7,001 – 8,000 | D27 | ***B3*** | D26 |
| | ***A5*** | | D28 |
| 8,001 – 9,000 | D31 | D30 | D29 |
| | ***A2*** | | |
| 9,001 – 10,000 | D32 | D33 | ***C1*** |
| | D37 | D35 | D34 |
| | | D36 | |
| **Total Sites** | **18** | **16** | **16** |

Notes:
1. Emboldened number (***B9***) are Downer Monitoring Sites
2. Sample sites on the right bank are shaded red, sample sites on the left bank are shaded green

### *2.2.2 Direct Planting Sites*

- **Zone B1** – 10 sites (2 sites are Downer Monitoring Sites);
- **Zone B2** - 10 sites (2 sites are Downer Monitoring Sites); and
- **Zone C** – 10 site (3 sites are Downer Monitoring Sites).

Sample locations have been selected to be uniformly representative of zones, longitudinal grade of the diversion and left or right side of the diversion (when travelling downstream). They are indicated on the attached plan and described in relation to BCD chainage in **Table 2.** Direct Planting Sites are prefixed with 'P' and sequentially numbered from chainage 0.0 (inlet end) along the alignment to chainage 10,000 (near the outlet). Contractor monitoring sampling site nomenclature has been retained for those sites.

**TABLE 2:** Tubestock Planting 'P' Sample Sites

| Chainage (m) | Zone B1 | Zone B2 | Zone C |
|---|---|---|---|
| 0.0 – 1,000 | P1 | P2 | n/a |
| 1,001 – 2,000 | P6 | P4 | P3 |
| | | | P5 |
| 2,001 – 3,000 | P7 | P8 | P9 |
| 3,001 – 4,000 | P13 | P10 | P12 |
| | | P11 | |
| 4,001 – 5,000 | P15 | P14 | ***PC6*** |
| | | | P16 |
| 5,001 – 6,000 | ***PB4*** | ***PB5*** | D17 |
| 6,001 – 7,000 | P18 | n/a | n/a |
| 7,001 – 8,000 | P19 | n/a | ***PC3*** |
| 8,001 – 9,000 | P21 | P22 | P20 |

| | | | |
|---|---|---|---|
| | | | ***PC2*** |
| 9,001 – 10,000 | P24 | P23<br>***PB1*** | n/a |
| **Total Sites** | **10** | **10** | **10** |

Notes:
1. Emboldened number (**PB9**) are Downer Monitoring Sites
2. Sample sites on the right bank are shaded red, sample sites on the left bank are shaded green

# 3. Establishment (Target) Criteria

## 3.1 Direct Seeded Area

Target criteria (for Practical Completion and Opening of the Diversion) are 75% cover with no more than 5% weediness cover. Weeds consist of declared weeds identified within the *Blackwater Creek Diversion Revegetation Plan*, noxious weeds and any weeds deemed by the Principal to be problematic. They do not include any species endemic to the region that may be considered to be agricultural weeds.

A secondary long-term diversity criteria of 6 or more species also applies.

## 3.2 Direct (Tubestock) Planting

Target criteria are applied to direct planting area based on the date of planting. For example plants planted in March 2009, measurement of the 24 month targets would occur in March 2011. Target Criteria are outlined in **Table 3.**

**TABLE 3:** Tubestock Target Criteria ('P' Sites)

| Planting Method | Parameter | Months | | | | |
|---|---|---|---|---|---|---|
| | | 3 | 6 | 12 | 18 | 24 |
| Tubestock Planting (Direct Planting cells & continuous planting in Zone B1) | Height (Median) | 20cm | 40cm | 75cm | 100cm | 125cm |
| | Diversity** | ≥5 species | ≥5 species | ≥7 species | ≥10 species | ≥10 species |

Notes:
1. Source is *Table 11 – Longterm Biodiversity Outcomes* of the of the *Blackwater Creek Diversion Revised Revegetation Plan*

# 4. Site Establishment and Data Collection

Sampling will occur within 40 m X 10 m or 50 m X 8 m (400m$^2$) sampling quadrats.

## 4.1 'D' Sites

Within 'D' sites cover will be assessed by the line intercept method along a transect of 40 m length. Quadrats have been oriented on the attached plans to sample along and across slopes (where practical for reasons such as effective width or length of each zone).

At establishment, permanent pegs will placed to denote the transect location. Pegs will be identified with flagging tape and numbered with the respective sample site (quadrat) number. Pegs will be approximately located with a hand held GPS to facilitate later accurate survey.

In the field, data will be collected and recorded on field record sheets (attached). The following data will be collected:

1. **Botanical data and coverage along the intercept** – individual species and extent of dripline coverage will be recorded cumulatively along the length of the tape (refer **Figure 1**).

Data will be analysed to ascertain total coverage expressed as a percentage (ie 30 m of vegetation coverage along a 40 m intercept is 75% cover); extent of weeds as a percentage of cover; composition of each species expressed as a percentage of cover; and diversity. Should less than 6 species be recorded along the intercept, additional meander searches within the 400 m2 quadrat will be undertaken.

2. **Photographic log** – a photographic record of the condition of the vegetation within and surrounding the quadrat will be undertake. Photographs should be taken from the northern peg of the transect a. along the transect with tape in place; b. 45° to the left and c. 45° to the right.
3. **Incidental Observations** – observations of apparent plant health, erosion/scour in close proximity, lesser vegetation coverage nearby etc.
4. **Planting Age** – The date of direct seeding and date of establishment irrigation will be noted by post field interrogation of planting and watering records.

The field procedure is as follows:

- Record sample site and date on template;
- Pin tape to start of measured area with 150mm Jute Mesh pin;
- Lay tape in direction indicated by sample site locations;
- Measure coverage of vegetation where intercepts tape taking note of vegetation species and distances for that species where possible;
- Record measured intercepts and species types on template;
- Role up tape and remove pin.

### 4.2 'P' Sites

Within 'P' sites cover will be assessed through establishment of 40 m x 10 m quadrats within planting cells (**Zone B2** and **Zone C**) and the continuous planting zone (**Zone B1**). The corners of each quadrat will be identified with pegs (to remain in-situ), identified with flagging tape and numbered with the respective sample site (quadrat) number. Pegs will be approximately located with a hand held GPS to facilitate later accurate survey.

In the field, data will be collected and recorded on field record sheets (attached). The following data will be collected:

1. **Diversity** – the number of planted tubestock species present will be enumerated.
2. **Height** – Heights of each individual planted tubestock will be measured and related to species (eg 6 x *Eucalyptus tereticornis* Qld blue gum – 125 cm, 101cm, 98, cm, 153cm, 122cm, 125cm).
3. **Photographic log** – a photographic record of the condition of the vegetation within and surrounding the quadrat will be undertake. Photographs should be taken from the north-eastern peg of the transect a. diagonal to the south-western corner; b. 45° to the left and c. 45° to the right.
4. **Incidental Observations** – observations of apparent plant health (eg leaf yellowing, outer tip browning, scorch), erosion/scour in close proximity, lesser vegetation coverage nearby etc.
5. **Planting Age** – The date of direct seeding and date of establishment irrigation will be noted by post field interrogation of planting and watering records.

## 5. Equipment

Field Equipment required by each team undertaking the field monitoring includes the following:

- 1 x Field herbarium / field keys;
- Jewellers tags for sampling unknown species;

- 1 x Digital camera capable of taking photos >7 megapixels;
- 1 x 40m tape reel;
- 1 x 5 m tape measure;
- 1 x Clipboard;
- Field sampling record sheets;
- Timber stakes (suffient for the number of transects / quadrats if sampling for the first time);
- 1 x mallet;
- 2 x rolls of flagging tape;
- Permanent marker pen
- Pencils and eraser.

# 6. Data Analysis

### 6.1 'D' Sites

Data synthesis and analysis will provide the following information for each cell:

- Total cover expressed as a percentage;
- Individual species cover expressed percentage of total cover;
- Total weed cover expressed as a percentage;
- Analysis of dominance of cover or secondary crop;
- Species diversity.

Further analysis will occur to chart the progression of vegetative cover from cover crop to secondary crop dominance.

The total cover for the BCD will be established through identification of the mean percentage cover for all cells of the diversion. Data analysis should also indicate highest cover, lowest cover, number of cells below 75% (expressed as classes<75% but > 60%; <60% but >50%; <50% but >40%; <40%).

Data may also be synthesized and analyzed to assess coverage within individual zones (eg **Zone A, Zone B2** and **Zone C**).

### 6.21 'P' Sites

Data synthesis and analysis will provide the following information for each cell:

- Median height for each cell;
- Mean height for each species; and
- Species diversity.

Further analysis will occur to identify overall health and performance of individual species.

# FIGURES

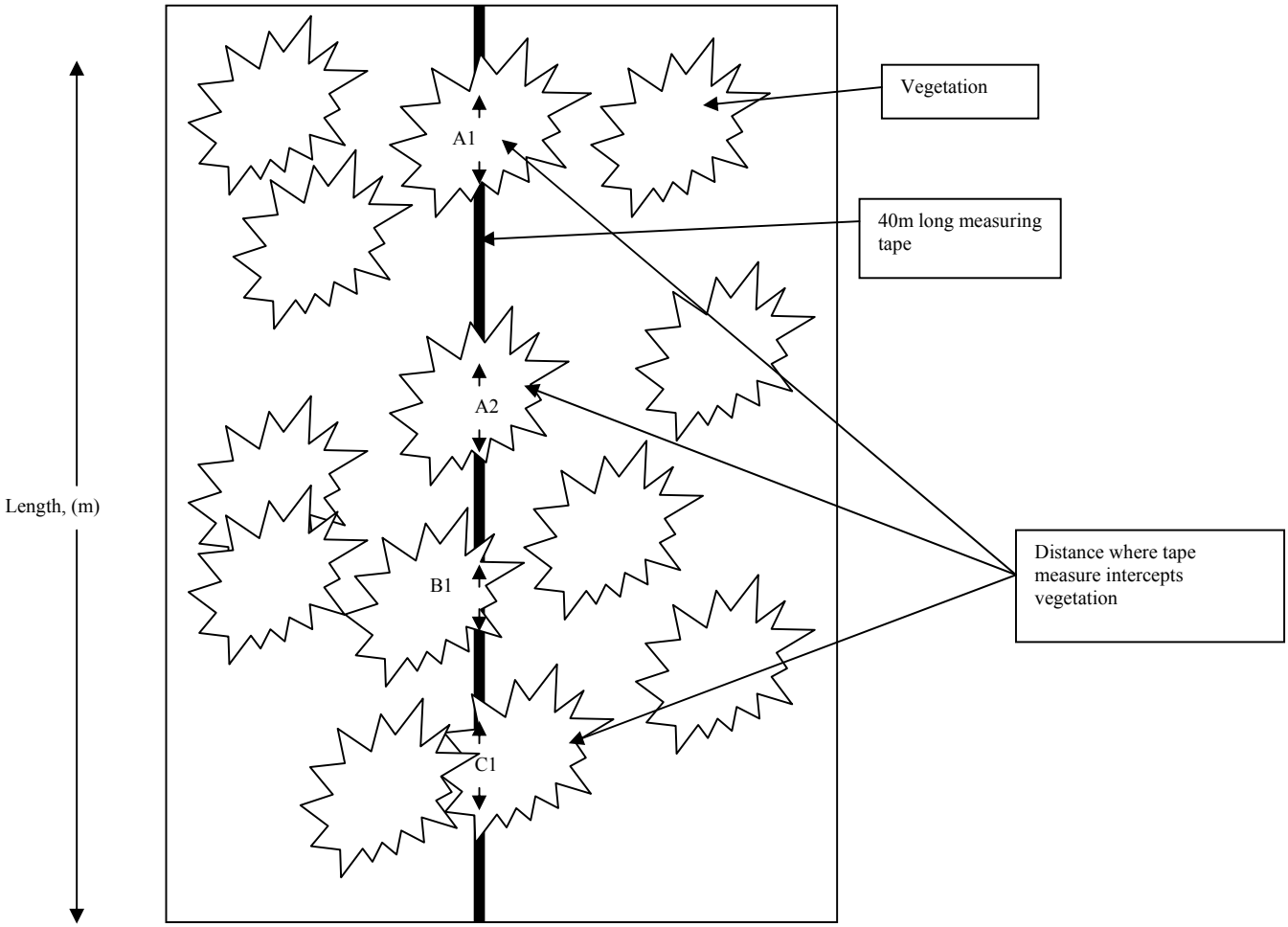



**FIGURE 1:** Line Intercept Method

The above can be analyzed thus:

Species Diversity: 3 species are present; A, B, C

Total Cover: the sum of the above vegetation intercepts is A1 – 15m + A2 – 5m + B1 – 9m +, C1-1m = 30m. Expressed as percentage of the length of tape is (30/40)*100 = 75%

Species Contribution:

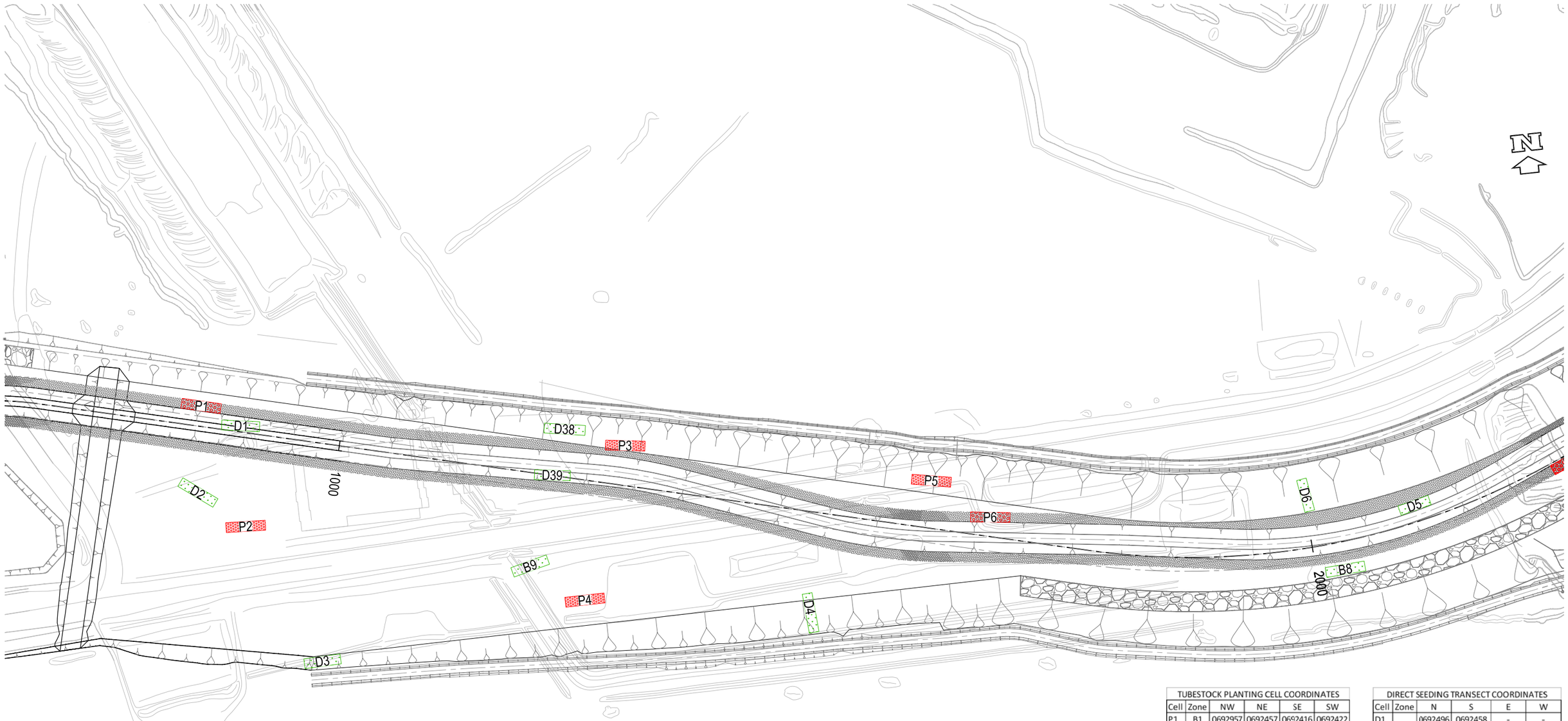
A. Rhodes grass, total line intercept 20m (A1 + A2). Therefore coverage is 50% (20/40*100).
B. Jap millet, total line intercept 7m. Coverage contribution is 22.5% (9/40*100).
C. Weed Species, total line intercept is 3m. Coverage contribution is 2.5% (3/40*100).

Trajectory:

Direct Seeding occurred August 2009. Trajectory is a transition from Cover Crop to dominance by secondary species.

**Sample Site Locations**

21321105X-SK-0070 (PLACE edit)




| TUBESTOCK PLANTING CELL COORDINATES | | | | | |
|---|---|---|---|---|---|
| Cell | Zone | NW | NE | SE | SW |
| P1 | B1 | 0692957 | 0692457 | 0692416 | 0692422 |
| | | 7398606 | 7398589 | 7398603 | 7398614 |
| P2 | B2 | 0692484 | 0692484 | 0692450 | 0692452 |
| | | 7398487 | 7398474 | 7398478 | 7398486 |
| P3 | C | 0692880 | 0692885 | 0692841 | 0692845 |
| | | 7398526 | 7398509 | 7398516 | 7398530 |
| P4 | B2 | 0692825 | 0692825 | 0692825 | 0692789 |
| | | 7398374 | 7398364 | 7398364 | 7398374 |
| P5 | C | 0693186 | 0693184 | 0693148 | 0693148 |
| | | 7398453 | 7398442 | 7398452 | 7398457 |
| P6 | B1 | 0693240 | 0693240 | 0693199 | 0693201 |
| | | 7398401 | 7398401 | 7398405 | 7398415 |

| DIRECT SEEDING TRANSECT COORDINATES | | | | | |
|---|---|---|---|---|---|
| Cell | Zone | N | S | E | W |
| D1 | | 0692496 | 0692458 | - | - |
| | | 7398580 | 7398586 | - | - |
| D2 | B2 | 0692443 | 0692410 | - | - |
| | | 7398508 | 7398533 | - | - |
| D3 | C | 0692515 | 0692552 | - | - |
| | | 7398336 | 7398337 | - | - |
| D4 | C | - | - | 0693030 | 0693032 |
| | | - | - | 7398333 | 7398304 |
| D5 | A | 0693666 | 0693635 | - | - |
| | | 7398370 | 7398361 | - | - |
| D6 | C | 0693541 | 0693546 | - | - |
| | | 7398411 | 7398378 | - | - |
| D38 | C | 0692824 | 0692783 | - | - |
| | | 7398540 | 7398547 | - | - |
| D39 | A | 0692804 | 0692768 | - | - |
| | | 7398496 | 7398501 | - | - |
| B8 | B2 | 0693601 | 0693550 | - | - |
| | | 7398317 | 7398314 | - | - |
| B9 | B2 | 0692772 | 0692735 | - | - |
| | | 7398414 | 07398405 | - | - |

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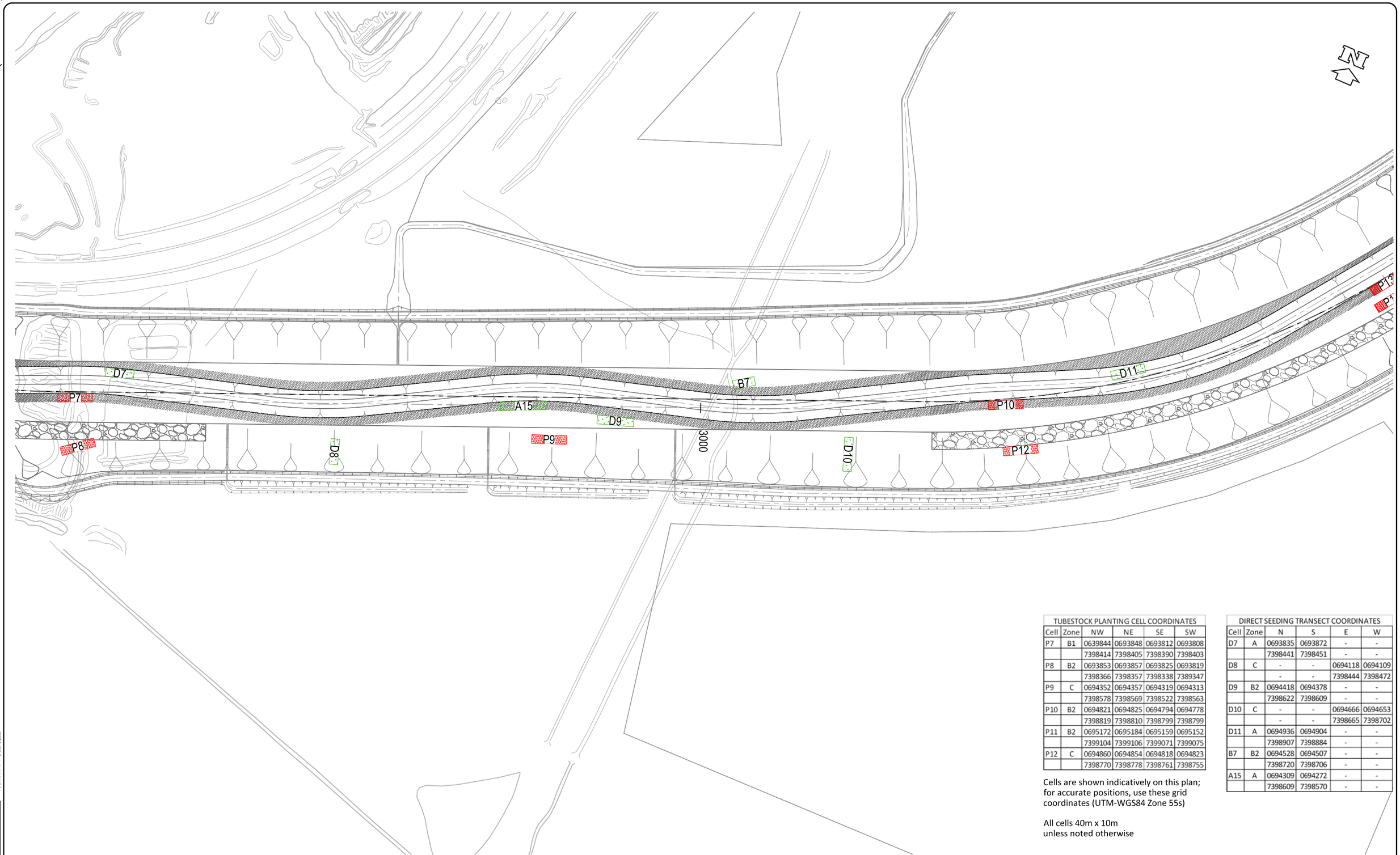
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100mm AT FULL SIZE

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2132105X-SK-0071 (PLACE edit)




TUBESTOCK PLANTING CELL COORDINATES

| Cell | Zone | NW | NE | SE | SW |
|---|---|---|---|---|---|
| P7 | B1 | 0639844 | 0693848 | 0693812 | 0693808 |
| | | 7398414 | 7398405 | 7398390 | 7398403 |
| P8 | B2 | 0693853 | 0693857 | 0693825 | 0693819 |
| | | 7398366 | 7398357 | 7398338 | 7389347 |
| P9 | C | 0694352 | 0694357 | 0694319 | 0694313 |
| | | 7398578 | 7398569 | 7398522 | 7398563 |
| P10 | B2 | 0694821 | 0694825 | 0694794 | 0694778 |
| | | 7398819 | 7398810 | 7398799 | 7398799 |
| P11 | B2 | 0695172 | 0695184 | 0695159 | 0695152 |
| | | 7399104 | 7399106 | 7399071 | 7399075 |
| P12 | C | 0694860 | 0694854 | 0694818 | 0694823 |
| | | 7398770 | 7398778 | 7398761 | 7398755 |

DIRECT SEEDING TRANSECT COORDINATES

| Cell | Zone | N | S | E | W |
|---|---|---|---|---|---|
| D7 | A | 0693835 | 0693872 | - | - |
| | | 7398441 | 7398451 | - | - |
| D8 | C | - | - | 0694118 | 0694109 |
| | | - | - | 7398444 | 7398472 |
| D9 | B2 | 0694418 | 0694378 | - | - |
| | | 7398622 | 7398609 | - | - |
| D10 | C | - | - | 0694666 | 0694653 |
| | | - | - | 7398665 | 7398702 |
| D11 | A | 0694936 | 0694904 | - | - |
| | | 7398907 | 7398884 | - | - |
| B7 | B2 | 0694528 | 0694507 | - | - |
| | | 7398720 | 7398706 | - | - |
| A15 | A | 0694309 | 0694272 | - | - |
| | | 7398609 | 7398570 | - | - |

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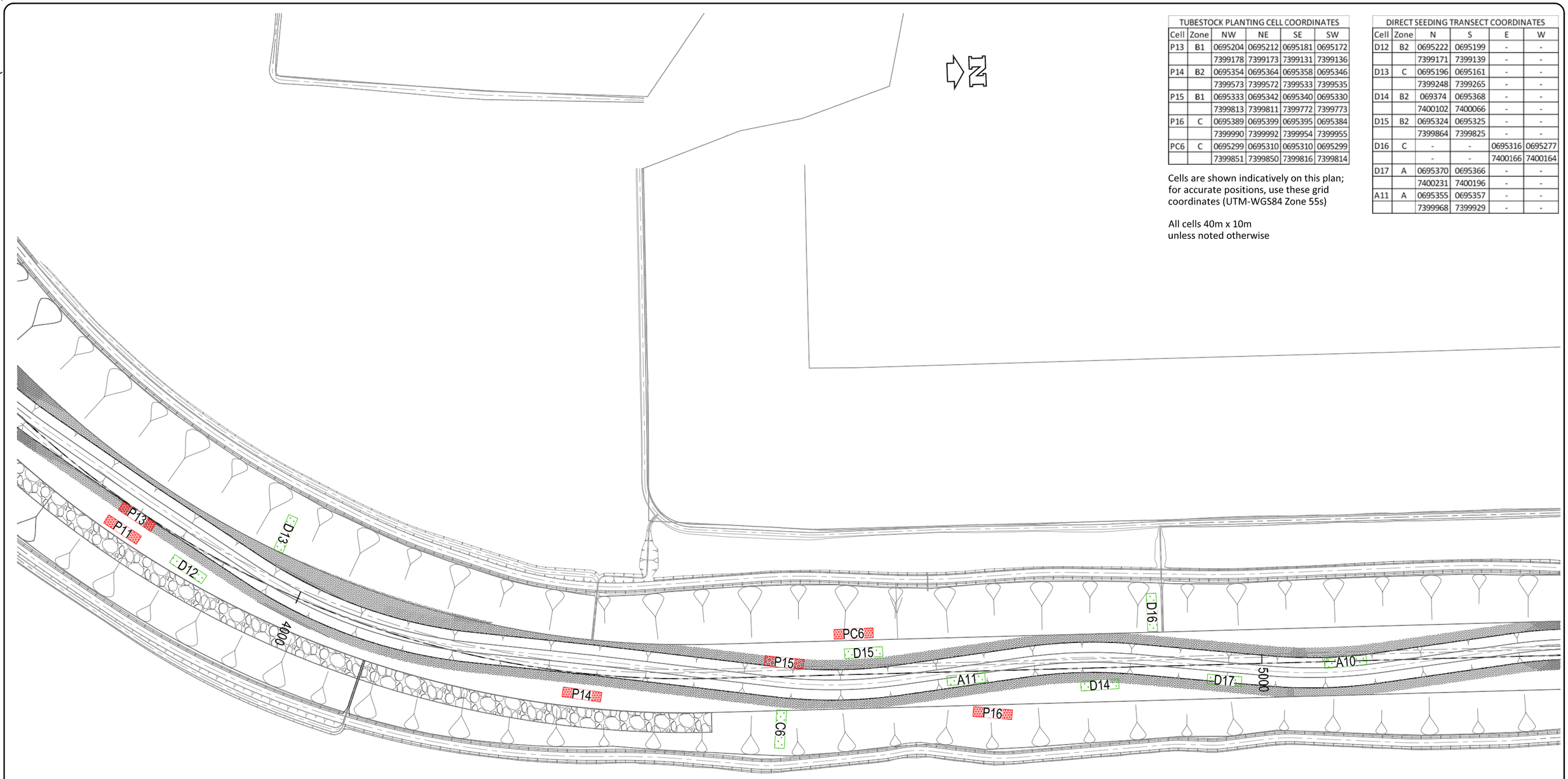
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| 2132105X | SK | 0071 | |

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2132105X-SK-0072 (PLACE edit)




TUBESTOCK PLANTING CELL COORDINATES

| Cell | Zone | NW | NE | SE | SW |
|---|---|---|---|---|---|
| P13 | B1 | 0695204 | 0695212 | 0695181 | 0695172 |
| | | 7399178 | 7399173 | 7399131 | 7399136 |
| P14 | B2 | 0695354 | 0695364 | 0695358 | 0695346 |
| | | 7399573 | 7399572 | 7399533 | 7399535 |
| P15 | B1 | 0695333 | 0695342 | 0695340 | 0695330 |
| | | 7399813 | 7399811 | 7399772 | 7399773 |
| P16 | C | 0695389 | 0695399 | 0695395 | 0695384 |
| | | 7399990 | 7399992 | 7399954 | 7399955 |
| PC6 | C | 0695299 | 0695310 | 0695310 | 0695299 |
| | | 7399851 | 7399850 | 7399816 | 7399814 |

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DIRECT SEEDING TRANSECT COORDINATES

| Cell | Zone | N | S | E | W |
|---|---|---|---|---|---|
| D12 | B2 | 0695222 | 0695199 | - | - |
| | | 7399171 | 7399139 | - | - |
| D13 | C | 0695196 | 0695161 | - | - |
| | | 7399248 | 7399265 | - | - |
| D14 | B2 | 069374 | 0695368 | - | - |
| | | 7400102 | 7400066 | - | - |
| D15 | B2 | 0695324 | 0695325 | - | - |
| | | 7399864 | 7399825 | - | - |
| D16 | C | - | - | 0695316 | 0695277 |
| | | - | - | 7400166 | 7400164 |
| D17 | A | 0695370 | 0695366 | - | - |
| | | 7400231 | 7400196 | - | - |
| A11 | A | 0695355 | 0695357 | - | - |
| | | 7399968 | 7399929 | - | - |

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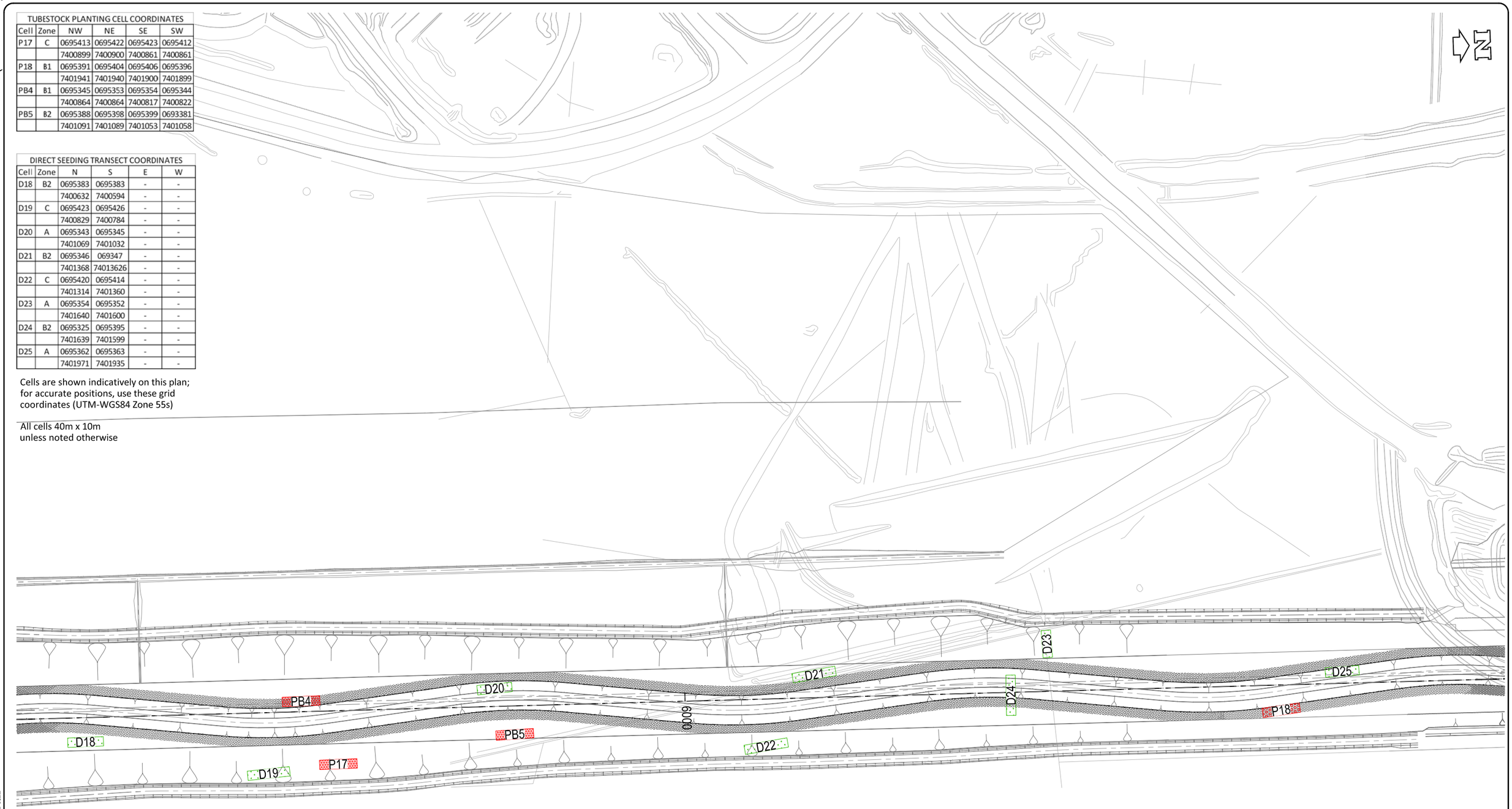
2132105X-SK-0073 (PLACE edit)

| TUBESTOCK PLANTING CELL COORDINATES | | | | | |
|---|---|---|---|---|---|
| Cell | Zone | NW | NE | SE | SW |
| P17 | C | 0695413 | 0695422 | 0695423 | 0695412 |
| | | 7400899 | 7400900 | 7400861 | 7400861 |
| P18 | B1 | 0695391 | 0695404 | 0695406 | 0695396 |
| | | 7401941 | 7401940 | 7401900 | 7401899 |
| PB4 | B1 | 0695345 | 0695353 | 0695354 | 0695344 |
| | | 7400864 | 7400864 | 7400817 | 7400822 |
| PB5 | B2 | 0695388 | 0695398 | 0695399 | 0693381 |
| | | 7401091 | 7401089 | 7401053 | 7401058 |

| DIRECT SEEDING TRANSECT COORDINATES | | | | | |
|---|---|---|---|---|---|
| Cell | Zone | N | S | E | W |
| D18 | B2 | 0695383 | 0695383 | - | - |
| | | 7400632 | 7400594 | - | - |
| D19 | C | 0695423 | 0695426 | - | - |
| | | 7400829 | 7400784 | - | - |
| D20 | A | 0695343 | 0695345 | - | - |
| | | 7401069 | 7401032 | - | - |
| D21 | B2 | 0695346 | 069347 | - | - |
| | | 7401368 | 74013626 | - | - |
| D22 | C | 0695420 | 0695414 | - | - |
| | | 7401314 | 7401360 | - | - |
| D23 | A | 0695354 | 0695352 | - | - |
| | | 7401640 | 7401600 | - | - |
| D24 | B2 | 0695325 | 0695395 | - | - |
| | | 7401639 | 7401599 | - | - |
| D25 | A | 0695362 | 0695363 | - | - |
| | | 7401971 | 7401935 | - | - |

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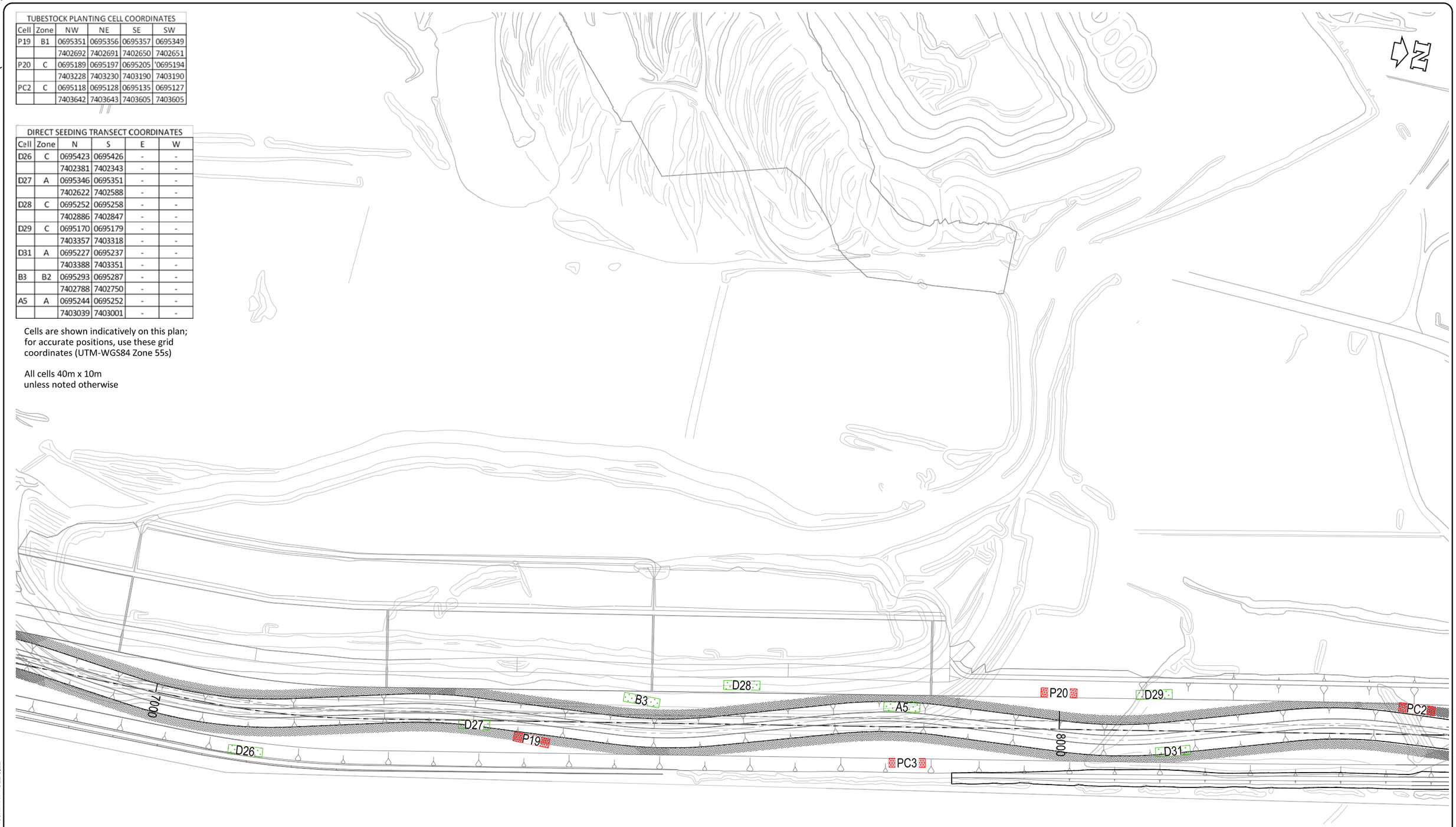
2132105X-SK-0074 (PLACE edit)

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|---|---|---|---|---|---|
| Cell | Zone | NW | NE | SE | SW |
| P19 | B1 | 0695351 | 0695356 | 0695357 | 0695349 |
| | | 7402692 | 7402691 | 7402650 | 7402651 |
| P20 | C | 0695189 | 0695197 | 0695205 | '0695194 |
| | | 7403228 | 7403230 | 7403190 | 7403190 |
| PC2 | C | 0695118 | 0695128 | 0695135 | 0695127 |
| | | 7403642 | 7403643 | 7403605 | 7403605 |

| DIRECT SEEDING TRANSECT COORDINATES | | | | | |
|---|---|---|---|---|---|
| Cell | Zone | N | S | E | W |
| D26 | C | 0695423 | 0695426 | - | - |
| | | 7402381 | 7402343 | - | - |
| D27 | A | 0695346 | 0695351 | - | - |
| | | 7402622 | 7402588 | - | - |
| D28 | C | 0695252 | 0695258 | - | - |
| | | 7402886 | 7402847 | - | - |
| D29 | C | 0695170 | 0695179 | - | - |
| | | 7403357 | 7403318 | - | - |
| D31 | A | 0695227 | 0695237 | - | - |
| | | 7403388 | 7403351 | - | - |
| B3 | B2 | 0695293 | 0695287 | - | - |
| | | 7402788 | 7402750 | - | - |
| A5 | A | 0695244 | 0695252 | - | - |
| | | 7403039 | 7403001 | - | - |

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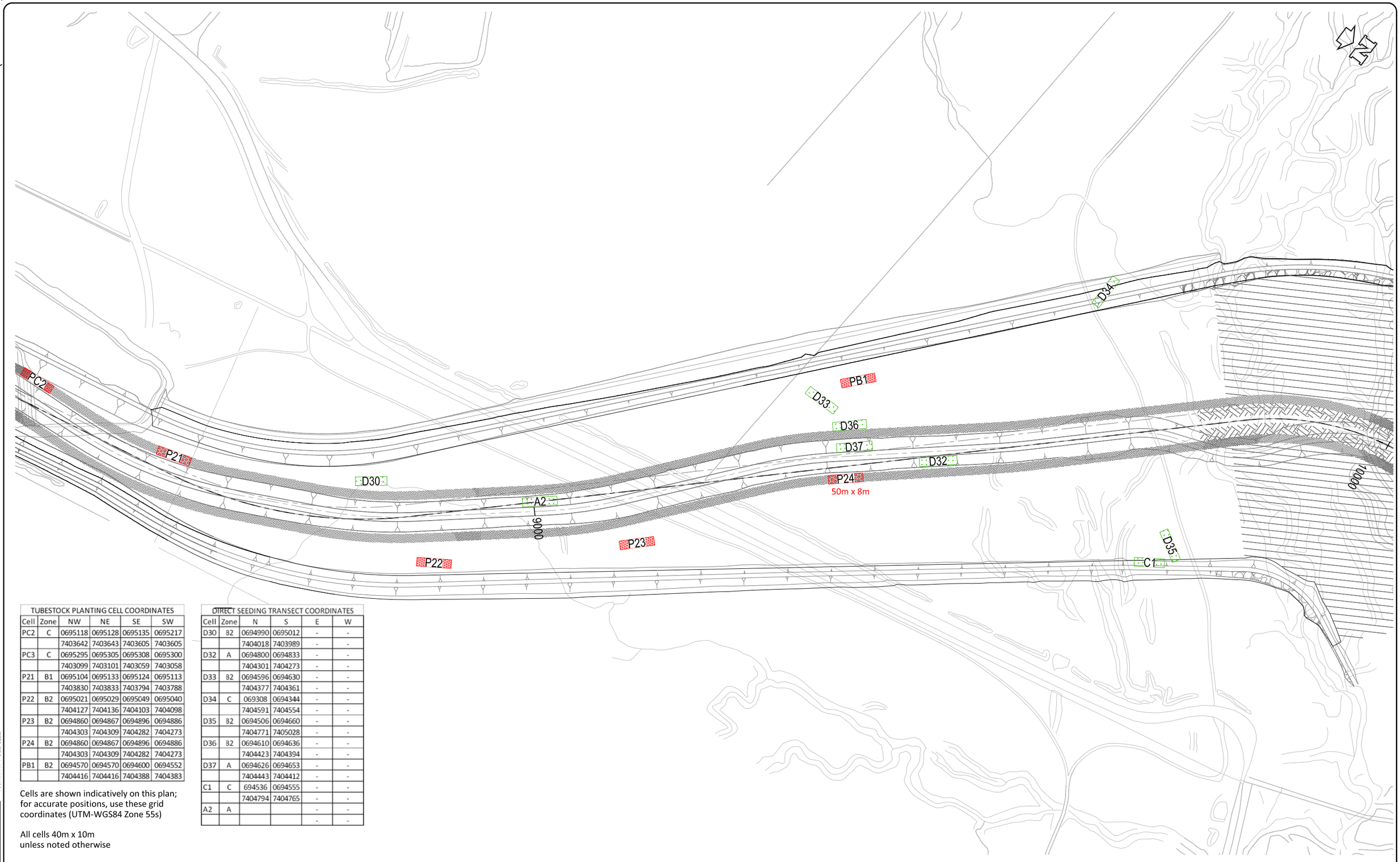
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2132105X-SK-0075 (PLACE edit)




TUBESTOCK PLANTING CELL COORDINATES

| Cell | Zone | NW | NE | SE | SW |
|---|---|---|---|---|---|
| PC2 | C | 0695118 | 0695128 | 0695135 | 0695217 |
| | | 7403642 | 7403643 | 7403605 | 7403605 |
| PC3 | C | 0695295 | 0695305 | 0695308 | 0695300 |
| | | 7403099 | 7403101 | 7403059 | 7403058 |
| P21 | B1 | 0695104 | 0695133 | 0695124 | 0695113 |
| | | 7403830 | 7403833 | 7403794 | 7403788 |
| P22 | B2 | 0695021 | 0695029 | 0695049 | 0695040 |
| | | 7404127 | 7404136 | 7404103 | 7404098 |
| P23 | B2 | 0694860 | 0694867 | 0694896 | 0694886 |
| | | 7404303 | 7404309 | 7404282 | 7404273 |
| P24 | B2 | 0694860 | 0694867 | 0694896 | 0694886 |
| | | 7404303 | 7404309 | 7404282 | 7404273 |
| PB1 | B2 | 0694570 | 0694570 | 0694600 | 0694552 |
| | | 7404416 | 7404416 | 7404388 | 7404383 |

DIRECT SEEDING TRANSECT COORDINATES

| Cell | Zone | N | S | E | W |
|---|---|---|---|---|---|
| D30 | B2 | 0694990 | 0695012 | - | - |
| | | 7404018 | 7403989 | - | - |
| D32 | A | 0694800 | 0694833 | - | - |
| | | 7404301 | 7404273 | - | - |
| D33 | B2 | 0694596 | 0694630 | - | - |
| | | 7404377 | 7404361 | - | - |
| D34 | C | 069308 | 0694344 | - | - |
| | | 7404591 | 7404554 | - | - |
| D35 | B2 | 0694506 | 0694660 | - | - |
| | | 7404771 | 7405028 | - | - |
| D36 | B2 | 0694610 | 0694636 | - | - |
| | | 7404423 | 7404394 | - | - |
| D37 | A | 0694626 | 0694653 | - | - |
| | | 7404443 | 7404412 | - | - |
| C1 | C | 694536 | 0694555 | - | - |
| | | 7404794 | 7404765 | - | - |
| A2 | A | | | - | - |
| | | | | - | - |

Cells are shown indicatively on this plan; for accurate positions, use these grid coordinates (UTM-WGS84 Zone 55s)

All cells 40m x 10m unless noted otherwise

PLAN
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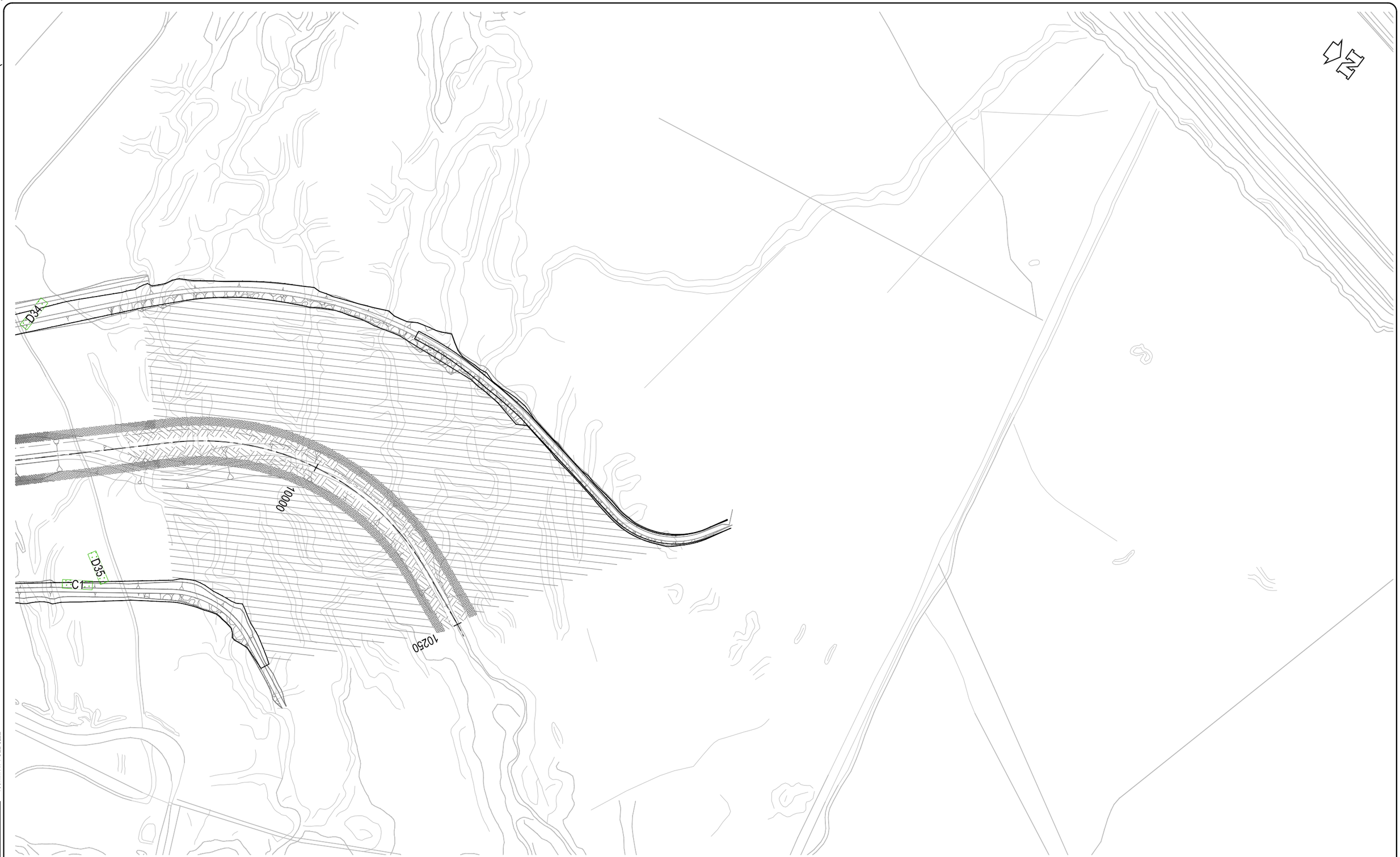
PROJECT
BLACKWATER CREEK DIVERSION
VEGETATION MONITORING LOCATIONS
PLAN
SHEET 6 OF 7

| PROJECT No. | DISCIPLINE | NUMBER | REV. |
|---|---|---|---|
| 2132105X | SK | 0075 | |

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CLIENT

PROJECT
BLACKWATER CREEK DIVERSION
VEGETATION MONITORING LOCATIONS
PLAN
SHEET 7 OF 7

| PROJECT No. | DISCIPLINE | NUMBER | REV. |
|---|---|---|---|
| 2132105X | SK | 0076 | |

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## APPENDIX B

### Proformas for conducting Primary Monitoring Assessment

**Blackwater Creek Diversion**
Practical Completion and Maintenance Phase Monitoring Version A

| | | |
|---|---|---|
| Date: | Chainage: | 40 m line intercept: Y / N |
| Site Number: | Photos: | 40 x 10 m quad: Y / N |
| Samplers: | Zone | L Bank or R bank:* |
| GPS Co-ordinates (UTM): | | |

* - view downstream

| **Vegetation Intercept (cm) *Height (cm)*** | **Species** | **Vegetation Intercept (cm) *Height (cm)*** | **Species** |
|---|---|---|---|
| | | | |
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**Summary**

| **Total Intercept Distance (m)** | **Species (Rank in order of dominance)** | **Total Intercept Distance (m)** | **Species** |
|---|---|---|---|
| | 1. | | 11. |
| | 2. | | 12. |
| | 3. | | 13. |
| | 4. | | 14. |
| | 5. | | 15. |
| | 6. | | 16. |
| | 7. | | 17. |
| | 8. | | 18. |
| | 9. | | 19. |
| | 10. | | 20. |

**Diversity (Additional species) if extended Quadrate is used**

| | |
|---|---|
| 1. | 6. |
| 2. | 7. |
| 3. | 8. |
| 4. | 9. |
| 5. | 10. |

**Notes:**

Weeds:

Dieback / illness

| | | |
|---|---|---|
| Tree height | Median (m): | Mean (m) |
| Groundcover: | of 40 m | % |
| Cover crop: | of 40 m | % |
| Weeds: | of 40 m | % |
| Attrition | of 40 m | % |

# CURRAGH PROJECT

## Concept Residual Void Assessment

**Prepared for:**

Coronado Curragh Pty Ltd



**SLR Ref: 626.30075.00000-R01**
**Version No: -v2.0**
**November 2021**

# PREPARED BY

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# BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

# DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
|---|---|---|---|---|
| 626.30075.00000-R01-v2.0 | 30 November 2021 | Emma Williams | Brad Radloff | Brad Radloff |
| 626.30075.00000-R01-v1.0 | 29 November 2021 | Emma Williams | Brad Radloff | |
| | | | | |

# EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Coronado Curragh Pty Ltd (CCPL) to update the Conceptual Residual Void Assessment (CRVA) for the Curragh Project. The aim of this report is to satisfy the Environmental Authority (EA) Condition G14 which requires an updated to the CRVA to incorporate rehabilitated landform criteria and residual void outcomes for new mining leases (MLs) ML700006, ML700007, ML700008 and ML700009.

The updated CRVA is being submitted with the intention of being considered a Land Outcome Document (LOD) under the definition in section 750 of the Environmental Protection Act 1994. The Updated CRVA is a document made under a condition of the EA and has been provided to the administering authority on 30 November 2021, if a notice of insufficiency is not received within 20 business days, the updated CRVA will meet the requirements for a LOD.

SLR have developed the following residual void objectives based on relevant legislation and policy, the statutory requirements of the EA and best practice:

1. Safe for humans, livestock and native fauna;
2. Geotechnically and erosionally stable;
3. Does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself; and
4. The extent of residual voids is minimised as much as practicable.

As part of this CRVA update a flood assessment, groundwater assessment, void water balance model and geotechnical stability assessment has been undertaken. The intent of these studies is to assist in defining the final land outcome for residual voids and to provide input into the finalisation of the proposed final landform. The outcomes of the studies are summarised below.

Conservative flood modelling of the 0.1% Annual Exceedance Probability (AEP) event was undertaken for the Curragh Project. The flood modelling shows that with the inclusion of a long-term stable embankment around the residual voids, flood inundation of the voids will not occur. The maximum flood levels from the modelling will be used to further refine the final landform design for the stable embankments.

SLR updated the existing numerical model from Parsons Brinckerhoff in 2016 to be extended over a wider area and to include a post-mining recovery simulation. The preliminary numerical modelling assessment found that the residual voids will act as local groundwater ‘sinks’. The residual drawdown in the Mackenzie River Alluvium to the west of Curragh North will generally be in the order of 1 to 2 m. Based on the geological data reviewed, it appears that the equilibrium void lake levels are generally well below the level of alluvium and the base of weathering which are potential preferential flow paths for seepage.

# EXECUTIVE SUMMARY

SLR developed a void water balance model using Goldsim software which includes groundwater inputs from the above study and surface water inputs. The water balance modelling shows that residual void water levels are expected to range from 26 mAHD to 132 mAHD with water depths of 14 m to 74 m. Salinity in all voids increases over time until reaching saturation (37,313 µS/cm) after approximately 20 to 30 years. The results indicate that the mine is not a net accumulator of water after approximately 100 years when the equilibrium water levels are reached. The final water levels remain below the spill level and the voids are unlikely to overtop in the 99$^{th}$ percentile climate scenario.

A Slope Stability Analysis has been undertaken by Raine Associates (RA) for the preliminary final landform provided by CCPL as well as a number of alternative landform options. The factor of safety for all landform options were determined and compared against the acceptable design criteria of >1.5 static factor of safety and >1.1 dynamic factor of safety. All landforms had a factor of safety higher than the design criteria indicating that the final landform is considered safe and geotechnically stable.

The erosional stability of the Tertiary highwall has been assessed against existing rehabilitation trials and literature. Further work is required to determine the final slope angles of the Tertiary highwall and stable embankment with consideration to the outputs of the flood model.

With consideration to all of the above information, SLR recommends that the Permian highwall and maximum void water level be considered a non-use management area and that the void low wall, Tertiary highwall and stable embankment have a post-mining land use of open pasture and woodland.

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# 1 Introduction

## 1.1 Purpose

Coronado Curragh Pty Ltd (CCPL) engaged SLR Consulting Australia Pty Ltd (SLR) to update the Concept Residual Void Assessment (CRVA) for Curragh Mine Complex (Curragh Project). The last version of the CRVA was developed in 2012 by AECOM.

The purpose of this CRVA update is to identify the location, and area of all proposed voids, the post-mining land outcome for each of these voids and the work to be undertaken between now and the submission of the Curragh Progressive Rehabilitation and Closure Plan (PRCP). All residual voids are approved with post mining land uses of conservation/grazing post-mining land use for the low walls and a non-use management area for the pit lakes/highwalls.

This assessment will address condition G13 and condition G14 of the Environmental Authority (EA) EPML00643713, outline appropriate outcomes to meet these conditions and demonstrate how these measures can be achieved through ongoing rehabilitation and landform stabilisation at the end of the economic life of each void.

It is intended that this report will be considered a Land Outcome Document (LOD) under the definition in section 750 of the *Environmental Protection Act 1994* (EP Act). The purpose of a LOD is to be able to transition pre-approved land outcomes into the new PRCP framework without further assessment. Under the PRCP Guideline, a LOD includes:

a) An EA;

b) A document made under a condition of an EA that:

   i. Relates to the management or rehabilitation of land (e.g. rehabilitation and closure plan or residual void management plan); and

   ii. Was provided to the administering authority, and had not been superseded, before 30 November 2018; and

   iii. Before 15 January 2019, the administering authority had not notified the EA holder that the document was insufficient.

c) a document made under a condition of an EA that:

   i. Relates to the management or rehabilitation of land (e.g. rehabilitation and closure plan or residual void management plan); and

   ii. Was provided to the administering authority between 20 November 2019 and 30 November 2021; and

   iii. Within 20 business days after receiving the document, the administering authority had not notified the EA holder that the document was insufficient.

d) A report evaluating an EIS under section 34D of the SDPWO Act;

e) An EIS assessment Report; or

f) A written agreement between the EA holder and the State that is in force on 30 November 2018.

It should be noted that LODs are treated in a hierarchy as outlined above. Therefore, the 2012 version of the CRVA would be considered higher on the hierarchy than this updated version as it was provided to the administering authority before 30 November 2018 and did not receive a notice of insufficiency. As mentioned above, the specific purpose of this update to the CRVA is to include five additional pits which were not included in the original version. The land outcomes for the voids identified in the 2012 version have not changed although it is noted that the extent and location of the voids has been updated to account for changes in the landform design and mine planning. This update of the CRVA will provide further clarification on the land outcomes for all planned voids for the Curragh Project.

This updated CRVA has been submitted to DES by 30th November 2021; and therefore, may qualify as a LOD under section 750 of the EP Act. In order to be a sufficient LOD under Condition G14 of the EA, the CRVA must include rehabilitated landform criteria and residual void outcomes both of which are addressed in Section 8 of this report.

## 1.2 Report Terminology

There have been numerous definitions and interpretations of 'residual void' made in the wider mining industry and therefore SLR would like to clarify the definitions and terminologies used in this report.

For the purposes of this assessment the term 'residual void' refers to the final landform area associated with a mined pit after closure and is not the proposed final land use. The residual void will include the low wall, highwall and pit bottom regardless of the proposed land outcome or use.

The proposed final land use will be referred to as either a post-mining land use (PMLU) or non-use management area (NUMA) in order to be consistent with the PRCP framework terminology and reduce any confusion.

## 1.3 Project Description

Curragh Project is approved under EA EPML00643713 and operated by CCPL, a wholly owned subsidiary of Coronado Global Resources. The Curragh Project consists of Curragh Main, Curragh East, Curragh West, Curragh Extension and Curragh North mining leases.

Curragh Project is located within the Central Highlands Regional Council, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton (**Figure 1-1**). The total mining lease area is approximately 19,650 ha.

The mine is an open cut operation producing a variety of coking, PCI and steaming coal products for both export and domestic market. The operation is a mix of dragline and truck and shovel. The annual run of mine (ROM) production is approximately 18 million tonnes per annum (Mtpa).

Operations at Curragh first commenced in 1983. The projected life of the Curragh Project is currently predicted to 2041.

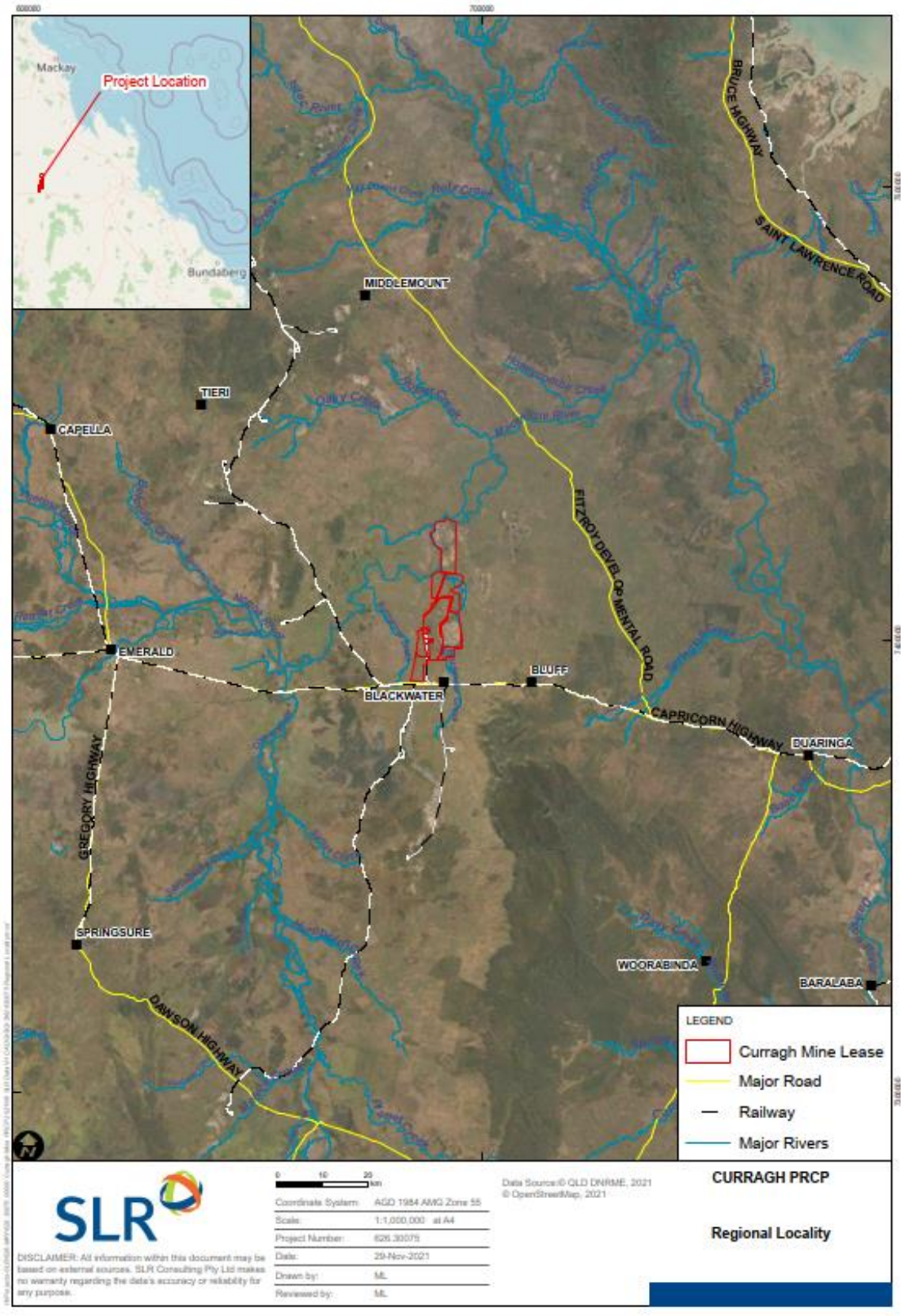



**Figure 1-1 Regional Locality**

The mine infrastructure and activities on site includes:

- Exploration drilling;
- Clearing vegetation;
- Stripping and stockpiling of topsoil material;
- Explosives;
- Mining;
- Coal processing and stockpiling;
- Tailings and coarse reject disposal;
- Coal stockpiling, train loading and transport via conveyor and rail;
- Rehabilitation of disturbed land;
- Water management;
- Levees and regulated dam management;
- Blackwater Creek Diversion;
- Facilities and Infrastructure;
- Waste management;
- Sewage treatment;
- Mechanical workshops;
- Storage of fuels, oils and chemicals; and
- Village accommodation.

CCPL is required to submit a PRCP for Curragh Project by 21st October 2022.

# 2 Relevant Legislation, Regulations and Policies

## 2.1 Environmental Authority

The Curragh Project operates under EA EPML00643713. Conditions G13 and G14 apply to residual voids.

Condition G13 states:

*Residual voids must comply with the following rehabilitation outcomes:*

*(a) residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority.*

Condition G14 states:

*The rehabilitation of disturbed areas and residual void investigation reports submitted to the administrating authority in June 2012 are to be updated to incorporate rehabilitated landform criteria and residual void outcomes for ML700006, ML700007, ML700008, ML700009, six (6) months prior to coal mining occurring on these ML's. The rehabilitated landform criteria and residual void outcomes from these reports must be reviewed every three years, or if any amendments occur and re-submitted to the administering authority.*

## 2.2 Mined Land Rehabilitation Policy

The Mined Land Rehabilitation Policy is a joint departmental policy between the Department of Environment and Science, the Department of Natural Resources and Mines and Queensland Treasury. The Policy presents Queensland Government's position on mine rehabilitation and is the basis of the changes made through the MERFP Act.

The Policy states that, "land disturbed by mining is considered to be rehabilitated when it can be demonstrated it is safe, stable, does not cause environmental harm, and is able to sustain the post-mining land use approved in the PRCP (referred to as 'stable condition'). An area of land that does not sustain a post-mining land use (referred to as a 'non-use management area') may be approved if best practice management can be demonstrated, and:

- Rehabilitating the area would cause greater environmental risk than not rehabilitating, or
- The environmental risks from the area are localised, and the cost of rehabilitation would be so excessive as to not be in the public interest."

The Policy also introduces the prohibition of final voids situated wholly or partly in a floodplain. This Policy is not intended to be applied to residual voids already approved in a LOD.

## 2.3 Environmental Protection Act 1994

The amendments to the EP Act requiring mines with site-specific EAs to have a PRCP, came into effect on 1 November 2019. The EP Act states the legislative information requirements for the rehabilitation planning part (section 126C) and PRCP schedule (section 126D). The EP Act also details the assessment process for the approval of a proposed PRCP.

The EP Act contains transitional provisions relating to existing site-specific mines. During the three-year transition period, DES will issue notices to existing mines requiring them to develop and submit a proposed PRCP by a specific date (no less than six months from issuing the notice). The transitional provisions also state that existing approvals may be translated into the proposed PRCP without additional assessment or public notification. Final voids approved in a land outcome document are exempt from the prohibition of a final void in a floodplain and the requirement for a public interest evaluation for a NUMA.

## 2.4 Environmental Protection Regulation 2019

The Environmental Protection Regulation 2019 (EP Regulation) includes PRCP objectives and performance outcomes (schedule 8A) the administering authority must consider when approving a PRCP. The EP Regulation also contains additional requirements for deciding the extent of a floodplain (0.1% Annual Exceedance Probability (AEP)) for the purposes of prohibiting a final void within a floodplain.

## 2.5 PRCP Guideline

The PRCP Guideline (ESR/2019/4964, V2.00, Effective 17th March 2021) is a statutory guideline made under section 550 of the EP Act and includes additional information requirements the administering authority deems necessary or desirable within a PRCP.

The PRCP Guideline provides information about the assessment process for a PRCP, information requirements for the PRCP, relevant post-approval processes and transitional provisions. The PRCP Guideline stipulates the detailed technical information that is expected to be included in a proposed PRCP.

# 3 Residual Void Objectives and Locations

## 3.1 Residual Void Objectives

For residual voids to be relinquished by CCPL, the residual void outcomes describe the key attributes for residual voids at CCPL and thus the underlying principles for closure criteria to be met in a cost effective and timely manner to facilitate relinquishment.

Residual void objectives are described below and the following sections of this report outline how these objectives can be achieved through landform stabilisation and rehabilitation.

The objectives are based on relevant legislation and policy, the statutory requirements of the EA and best practice. The long-term objectives for residual voids are:

1. Safe for humans, livestock and native fauna;
2. Geotechnically and erosionally stable;
3. Does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself; and
4. The extent of residual voids is minimised as much as practicable.

The below sections present the residual void design and describe residual void assumptions and results for landform design and land use studies. Studies undertaken include economic, geotechnical, groundwater and surface water, concept flood barrier / stable embankment design and erosion. Flood modelling and design for the concept flood barrier / stable embankment is presented firstly followed by the detailed studies in the proposed void design.

### 3.1.1 Factors Affecting Void Behaviour

To understand how the outcomes will be achieved, factors affecting void behaviour must first be understood. The factors which have been considered in this CRVA include:

- Climate;
- Void configuration, including depth, length and spoil landform;
- Topography and catchment areas;
- Effectiveness of rehabilitation, including preventing erosion and regrowth of vegetation;
- Water quality including amount of salts / salinity potential;
- Groundwater inflows and outflows;
- Adjoining land use; and
- Scale of activity.

## 3.2 Residual Void Locations

The Curragh Project consists of multiple mining leases including:

- ML80110;
- ML700006;
- ML80112;
- ML80011;
- ML80123;
- ML80086;
- ML80171;
- ML80012;
- ML700009;
- ML80010;
- ML1878;
- ML700008;
- ML700007; and
- ML1990.

Condition G14 of the EA requires the residual void investigation report to be updated (this document) to incorporate rehabilitated landform criteria and residual void outcomes for ML700006, ML700007, ML700008 and ML700009 six months prior to coal mining commencing. The proposed voids located with the expansion mining leases are Pit X, Pit Y and Pit Z. All residual voids across the Curragh Project are shown in **Figure 3-1**.

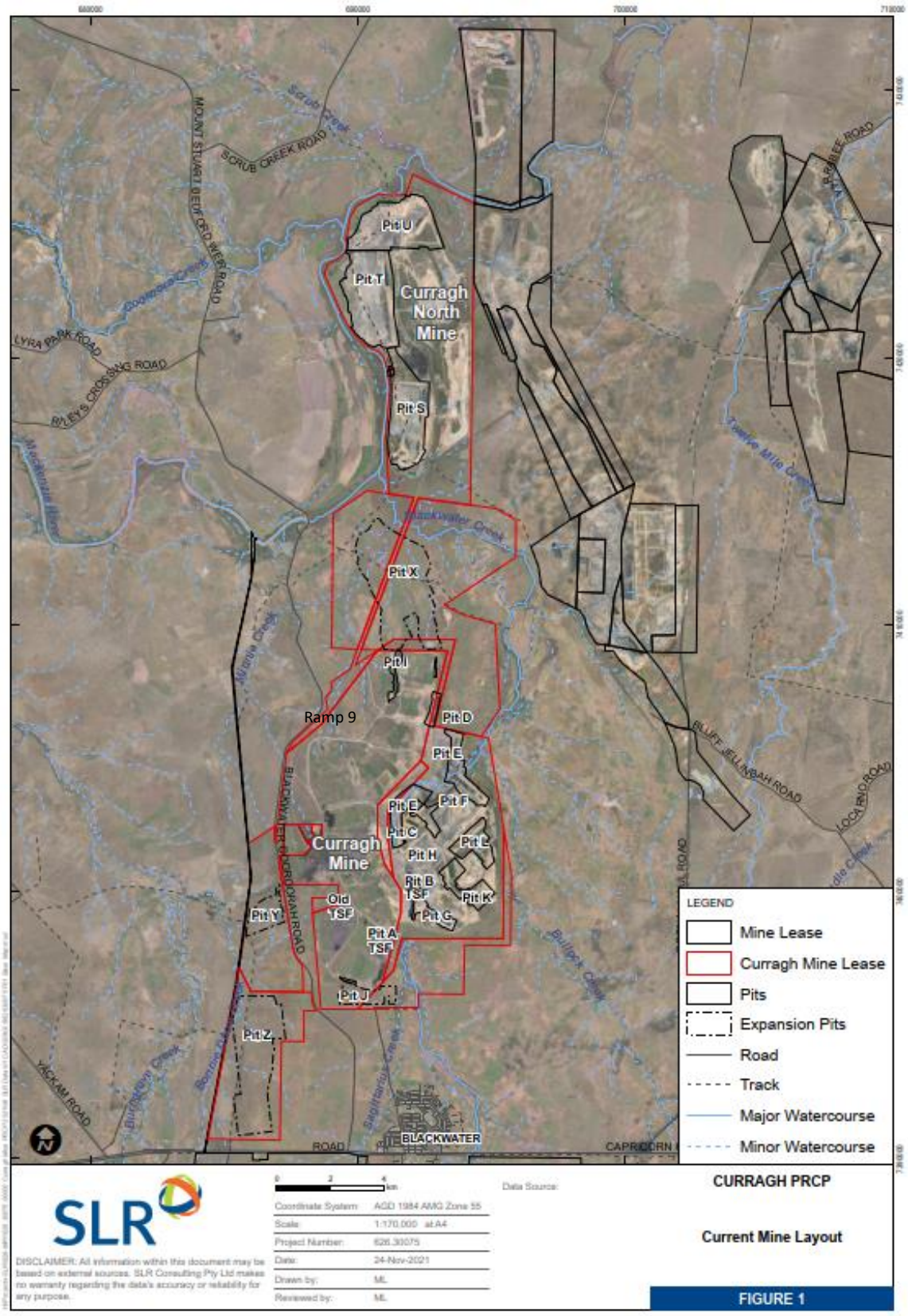



**Figure 3-1 Pit Layout at End of Mining**

# 4 Residual Void Flood Assessment

SLR has undertaken preliminary flood modelling of the floodplain surrounding the Curragh Project to assist in design levels for the concept flood barriers for proposed residual voids. The Preliminary Flood Model Report has been provided in **Appendix A**.

The flood modelling was undertaken to estimate 0.1% Annual Exceedance Probability (AEP) flood event for the relevant watercourses which impact the Curragh Project. The intent of the assessment is to understand the locations and dimensions of the flood barrier (long-term stable embankment) required to protect the nominated residual voids from flood influx. For planning purposes, the model has adopted a high level of conservatism by using the most conservative (i.e. largest) flow estimate derived from the flood frequency analysis (FFA). Therefore, the flood modelling results in a conservatively high volume of floodwater over the floodplain rather than stored within the waterway banks providing the worst case flood level estimates.

## 4.1 Site Hydrology

The mine extends across the floodplain of the Mackenzie River and its tributaries (**Figure 4-1**), the Mackenzie River being the main watercourse in the area and a major tributary of the Fitzroy River. The Mackenzie River forms at the confluence of the Nogoa and Comet rivers, 30km west of Blackwater. The total catchment area of Mackenzie River to Bingegang Weir, 25km downstream of the mine, is approximately 51,000 square km. To the north west of the mine the Mackenzie River floodplain is relatively flat, with the current course of the river meandering through an alluvial tract between approximately 3 km to 8 km in width.

The main tributary of Mackenzie River in the study area is Blackwater Creek, which flows in a northerly direction to the east of Curragh Main via a major diversion around Pits J, K, L, F, and E. Blackwater Creek is naturally ephemeral although at its upstream end, it flows due to intermittent discharge of treated effluent from Blackwater Wastewater Treatment Plant (WTP) into Sagittarius Creek between Blackwater and the mine (PB, 2016).

Blackwater Creek is highly modified having been diverted several times to accommodate mining at Curragh. The current Blackwater Creek diversion is a 9 km long engineered drainage structure made of compacted earth vegetated with grasses and shrubs. The discharge from Blackwater WTP is observed along the extent of the diversion although not north of the diversion (PB, 2016).

Just downstream of the diversion around Curragh Main and to the east of the proposed Pit X Blackwater Creek becomes an ephemeral braided channel system.

Tributaries of Blackwater Creek include Taurus Creek, Sagittarius Creek, Minnie Creek and Bullock Creek, all of which are ephemeral. Minnie Creek flows through the proposed Pit X area and will be subject to a 5.3 km diversion near its confluence with Blackwater Creek plus a 2.9 km diversion of one of its unnamed tributaries around the western side of the pit prior to the commencement of mining in this area (PB, 2016).

Other tributaries of Mackenzie River in the Project area include Burngrove Creek. A tributary of Burngrove Creek is Bonnie Doon Creek, which flows in a northerly direction to the west of proposed Pit Z and will be subject to a diversion. Both Burngrove Creek and Bonnie Doon Creek are ephemeral.

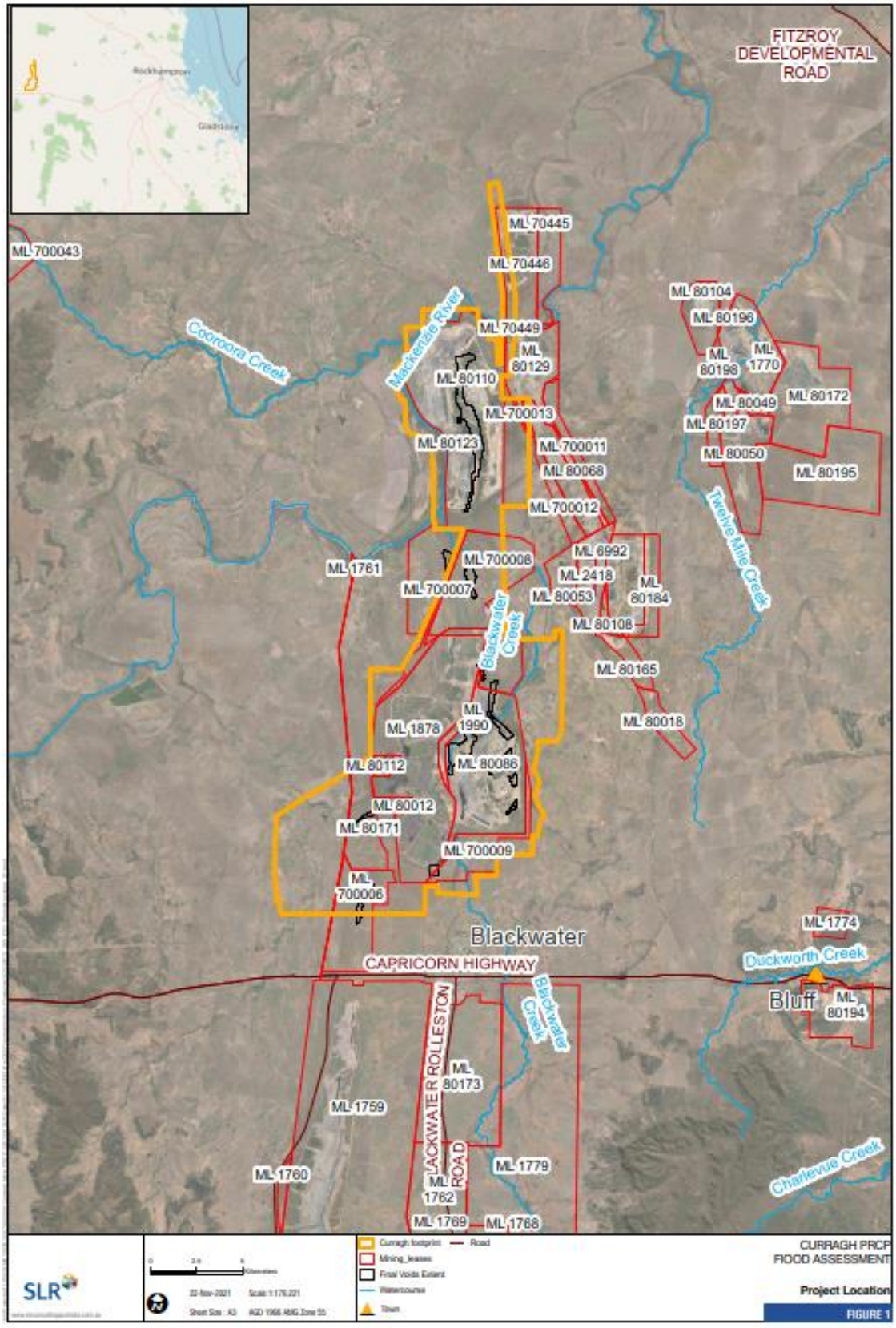



**Figure 4-1 Curragh Project Watercourses**

## 4.2 Methodology

A hydrologic assessment was undertaken to provide flow estimates to the hydraulic model. The aim is to estimate the maximum peak flows for 0.1% AEP flood event of various watercourses in relation to the proposed residual voids. To achieve this, a flood frequency analysis (FFA) was undertaken using recorded streamflow data sourced from the Department of Regional Development, Manufacturing and Water (DRDMW). There are no flow gauges in the immediate vicinity of Curragh Project; however, several current and historic gauges are located in the wider catchment. A frequency analysis was undertaken of the annual flood maxima series for each gauge. The details of the FFA are provided in **Appendix A**. The hydrologic inputs for the hydraulic model are:

- For the Mackenzie River immediately upstream of Curragh Project - 1% AEP event of 12,777 $m^3/s$, and the 0.1% AEP event of 54,393 $m^3/s$;
- For Blackwater Creek and Minnie Creek - 1% AEP event of 2,702 $m^3/s$ and a 0.1% AEP event of 4,290 $m^3/s$; and
- For Burngrove Creek - 1% AEP event of 1,182 $m^3/s$ and the 0.1% AEP event of 1,876 $m^3/s$.

A hydraulic model was developed for the purpose of assessing the post-mining flood extent. The industry standard hydrodynamic modelling software TUFLOW (Build 2020-10-AA) was utilised for the 2D hydraulic modelling. Details of the model setup and methodology are provided in **Appendix A**.

## 4.3 Assumptions

Broad assumptions in regard to the following elements have been made through the development of the hydraulic model, as follows.

- The flood model has been developed based on inflows derived through a FFA approach. Numerous gauges were used along the Mackenzie River and its tributaries. The assessment shows a lack of convergence in the results. Specifically, the FFA showed estimates of the 0.1% AEP event at each gauge could vary by an order of magnitude. It is thought that this could be due to factors such as floodplain storage, artificial features such as dams and levees, short record lengths and gauge rating curve accuracy. Therefore, the most conservative flow estimate has been adopted. Detailed assessment into the estimate of a 0.1% AEP event for the catchment will be required prior to presentation of results in the PRCP.
- Flow estimates have been applied to the hydraulic model as a steady state inflow. This is a conservative approach as the effects of floodplain storage are removed. The flow estimates were applied as inflows into the model until inflows and outflows were equal.
- Flow estimates for tributaries of the Mackenzie River, such as Blackwater Creek, has been determined through a FFA on donor gauges scaled to the applicable catchment area. As above, the most conservative assessment was applied however this will need to be investigated further prior to understanding flood modelling for the PRCP.
- No assessment of coincident flooding between the Mackenzie River and other tributaries was carried out. Although in reality, flood peaks in Blackwater Creek could potentially occur at a different time to the peak in the Mackenzie River, it was assumed that the flood peak occurred at the same time, providing a conservative approach to estimate the peak water levels.

- The hydraulic model has been largely based on SRTM data due to the limited extent of available Lidar. SRTM data for the site has a vertical accuracy of +/-5-10m. Hydro-enforced SRTM was not used due to the inaccurate representation of waterway cross-sectional area when compared to available LiDAR data. A terrain surface was developed using the residual void landform, 1m Lidar and SRTM with some connectivity along the Mackenzie River provided through the use of artificial terrain manipulation.
- No artificial devices such as weirs were modelled in the hydraulic model.
- No bathymetric data for Mackenzie River was available and therefore not incorporated in the model.
- All roughness values were determined by review of aerial photography. No site visit or verification of the assessment was carried out.
- No infrastructure such as bridges or the like were included in the hydraulic model.

## 4.4 Results

The results of the TUFLOW model are illustrated for the 0.1% AEP flood event and shown in **Figure 4-2**, **Figure 4-3** and **Figure 4-4**. These figures show that all residual voids within the Curragh Project are not subject to flood inundation due to the current diversion of Blackwater Creek and the stable embankments defined as part of the proposed final landform.

The modelled results show that a residual void landform can effectively use spoil dumps and long-term stable embankments to protect the residual voids from flood ingress. SLR adjusted the provided residual void landform along the existing Blackwater Creek diversion and between X Pit and Curragh North to provide additional protection. Modelled results for the 0.1% AEP flood event show:

- Landform heights of up to 141 mAHD plus freeboard are likely to be required North of X Pit; and
- Blackwater Creek diversion should allow for flood levels up to 162.5 mAHD.

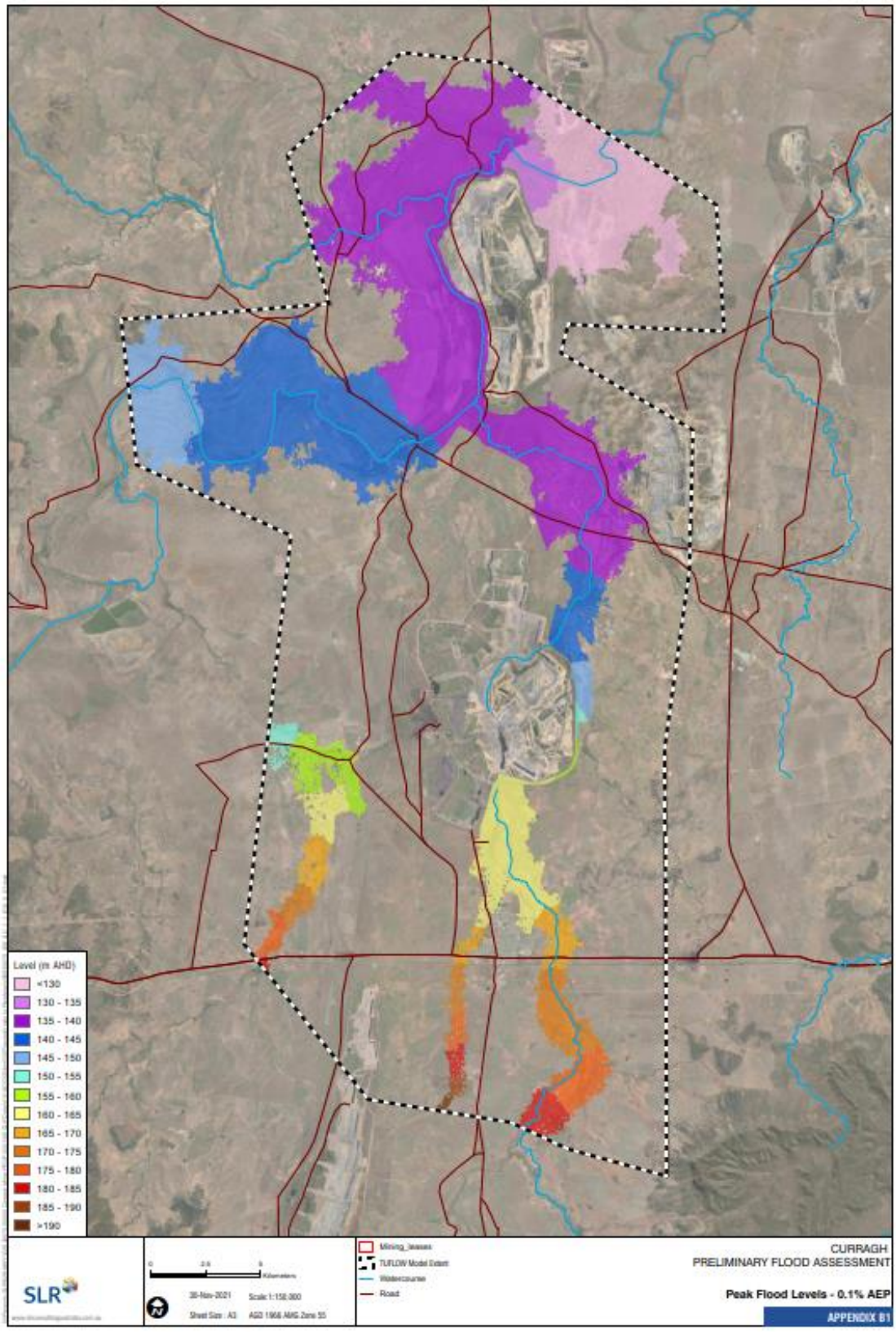



**Figure 4-2 Peak Flood levels 0.1% AEP event**

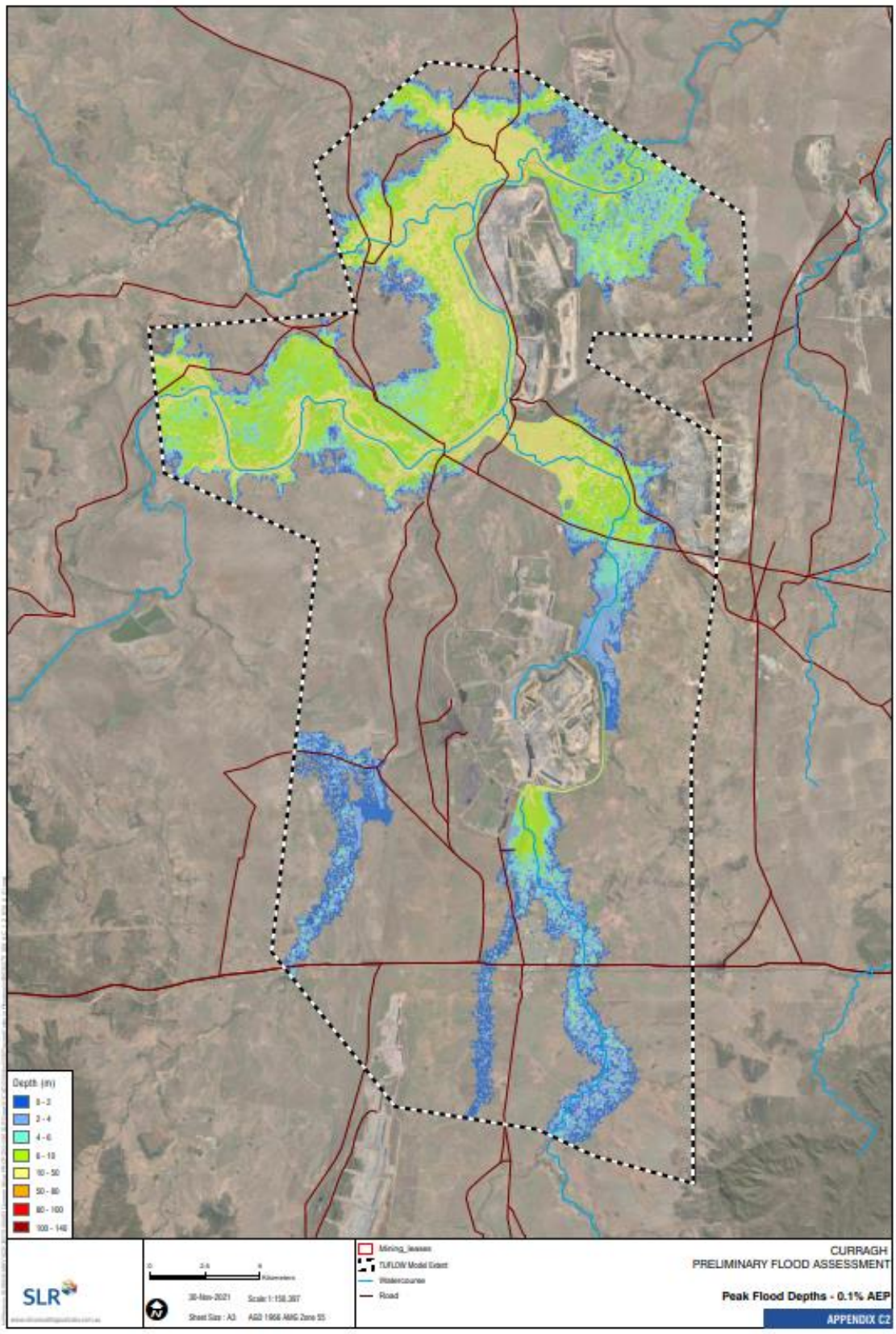



**Figure 4-3 Peak flood depths 0.1% AEP event**

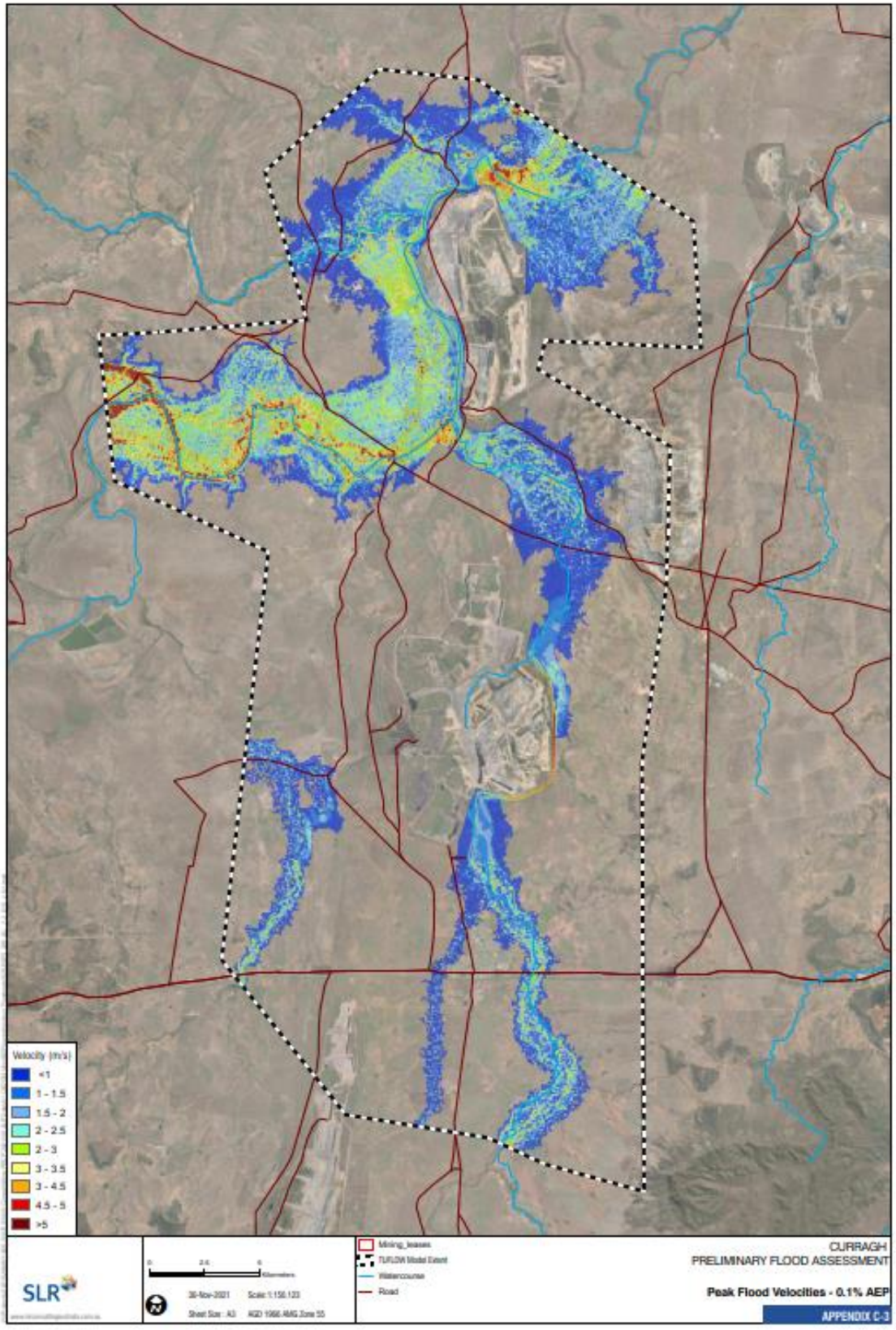



**Figure 4-4 Peak flood velocities 0.1% AEP event**

A summary of the modelled 0.1% AEP flood levels and velocities for the floodplain around the residual voids is provided in **Table 4-1** and shown in **Figure 4-5**.

### Table 4-1 Maximum Surface Level Elevations and Velocities

| Measurement Point | Indicative Water Level 0.1% AEP event (m AHD) | Average Velocity (m/s) |
|---|---|---|
| 1 | 130.37 | 2.1 – 5.3 |
| 2 | 140.58 | 1.8 – 3.9 |
| 3 | 140.57 | 1.8 – 3.9 |
| 4 | 140.57 | 1.1 – 3.7 |
| 5 | 140.58 | 0.7 – 2.9 |
| 6 | 142.32 | 0.6 -2.6 |
| 7 | 145.19 | 1.5 - 5 |
| 8 | 148.9 | 2 - 4.5 |
| 9 | 152.12 | 0.8 - 5.4 |
| 10 | 156.94 | 1.5 - 4 |
| 11 | 162.67 | 0.5 – 2.5 |
| 12 | 160.05 | 0.5 – 1.7 |
| 13 | 165.89 | 0.5 – 1.7 |
| 14 | 170.39 | 0.5 – 3.9 |

Flood velocities can be substantial through areas where the floodplain is constrained. Velocities are significant in the Blackwater Creek diversion, due to the confinement of the creek flows. However, the diversion is an existing infrastructure and is considered stable in its current form.

Velocities are typically 3 - 4.5 m/s which will cause some erosion to the long-term stable embankment and appropriate treatment will be required. It should be noted that the hydraulic model utilised steady state inflows and this area is affected by backwater from the Mackenzie River. As such, velocities may be greater if Blackwater Creek is in flood with lower tailwater levels observed in the Mackenzie River. The Mackenzie River experiences velocities of greater than 6 m/s within the river banks adjacent to Curragh North, however velocities reduce to less than 2 m/s adjacent to the landform.

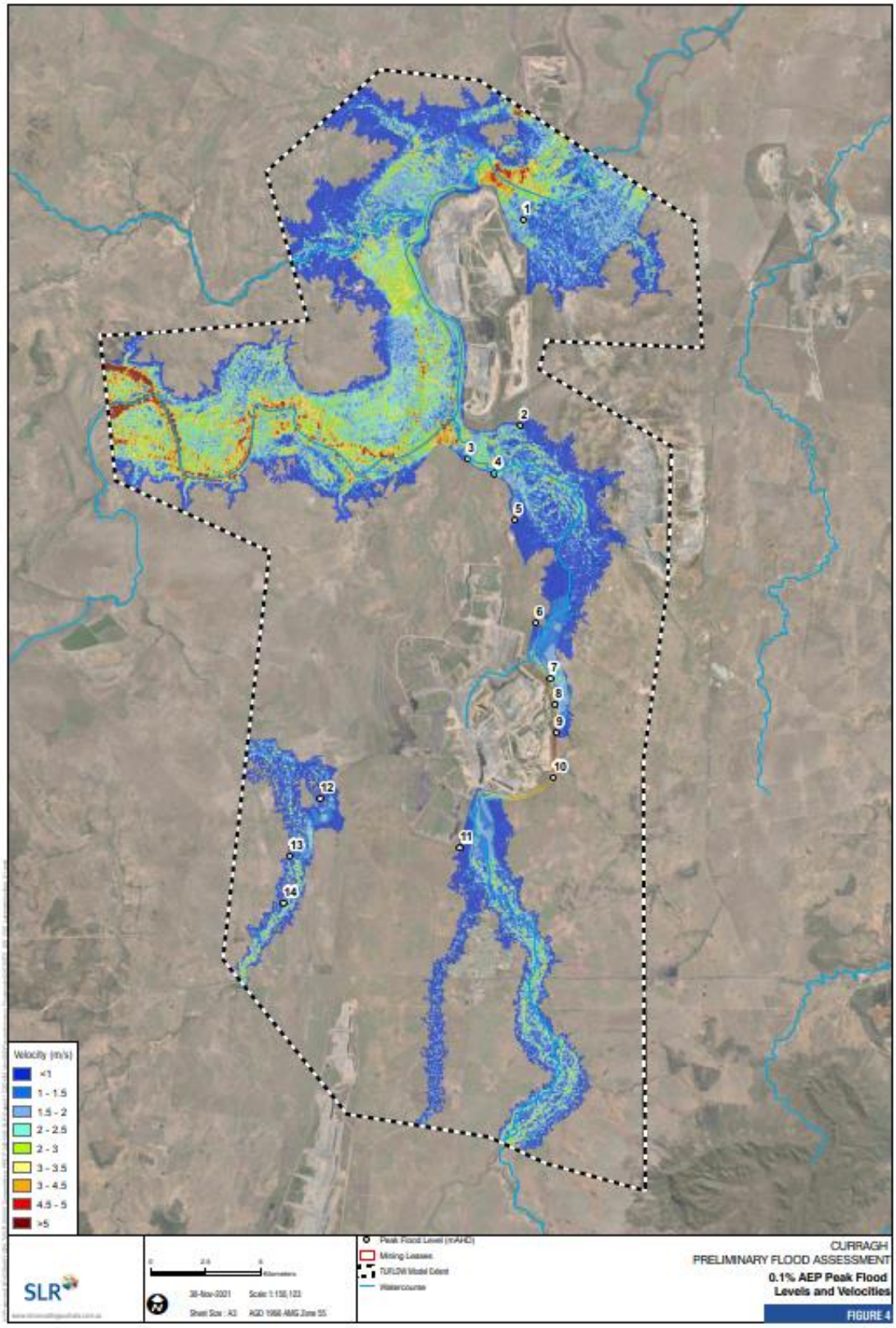



**Figure 4-5 Measurement Points**

## 4.5 Conclusions and Recommendations

The conservative flood modelling undertaken shows that the residual voids will not be inundated with flood water due to the Mackenzie River including Blackwater Creek and associated diversion with long-term stable embankments acting as a flood barrier. It is important to note that even if the residual void locations were to change the flood waters will still not inundate the voids as the proposed flood barriers provide protection to the whole mining area in a 0.1% AEP event.

It should be noted that the intention of the preliminary flood modelling is to help inform the development and finalisation of the post-mining landform design. A more detailed flood assessment for the final landform is recommended for the PRCP submission. The following recommendations for further work have been identified through the process of the flood modelling:

- Undertake ongoing monitoring of the Blackwater Creek diversion in accordance with legislative requirements will determine if any works are required to maintain the stability of the landform in this area;
- Investigate the erosion protection requirements for the long-term stable embankment and final landform design with consideration to the peak flood velocities;
- Obtain additional landform data, including LiDAR and bathymetric data, to develop a more refined assessment of the post-mining flood impacts; and
- Update the flood model to meet the detailed requirements of the PRCP Guideline.

# 5 Residual Void Hydrogeology

SLR have reviewed the existing groundwater, climate, geology, surface water and topography data available for Curragh Project and developed a Groundwater Technical Report (**Appendix B**) to support this CRVA. The objectives of the Groundwater Technical Report are to understand the post-closure groundwater regime around the mine and to:

- Present an understanding of the hydrogeological setting of the mine including potential groundwater receptors;
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by CCPL to understand whether the final voids act as groundwater sinks or sources; and
- Understand the long-term effect of the proposed post mining landform on local groundwater levels i.e. the residual drawdown, and post-mining groundwater flux.

## 5.1 Conceptual Hydrogeological Model

Section 2 of the Groundwater Technical Report outlines the information for the Conceptional Hydrogeological Model (CHM) including:

- Topography and land use;
- Climate;
- Hydrology;
- Geology; and
- Groundwater monitoring data.

The surface geology across the study area (based on the 1:100,000 mapping), is presented in **Figure 5-1** and the regional (solid) geology is presented in **Figure 5-2.**

The study area is underlain by Permian to Quaternary sediments located within a gently folded and faulted sequence of the Bowen Basin. The Permo-Triassic sediments dip eastward and include the Triassic Rewan Formation and the underlying Permian Blackwater Group, which includes the Rangal Coal Measures, Burngrove Formation and Fair Hill Formation. The Triassic strata are overlain by unconsolidated Quaternary alluvium associated with creeks, rivers and floodplains and the poorly consolidated Tertiary sediments of the Duaringa and Emerald formations. The Back Creek Group underlies the Blackwater Group and forms the basement of the area.

The stratigraphic sequence underlying the study area is presented in **Table 5-1** and summarised below.

### Table 5-1 Regional Stratigraphy

| Age | Group | Stratigraphic Unit | Description |
|---|---|---|---|
| Quaternary | | Alluvium | Soils, unconsolidated silts, sands, gravels and clays, |
| Cenozoic (Tertiary) | | Duaringa Formation/ Emerald Formation | Claystone, siltstone, sandstone, conglomerate (often poorly consolidated), lignite, basalt |
| Triassic | Mimosa | Rewan Formation | Mudstone, interbeds of lithic sandstone. |
| Upper Permian | Blackwater Group | Rangal Coal Measures | Coal seams calcareous sandstone, calcareous shale, mudstone, calcareous tuff in places. Main coal seams include Aries, Castor, Pollux, Orion, Pisces. |
| | | Burngrove Formation | Siltstone, carbonaceous shales and mudstone, fine lithic sandstone, calcareous lithic and feldspathic sandstone, tuffaceous shales and thin coal seams. |
| | | Fair Hill Formation | Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal |
| Permian | Back Creek Group | Macmillan Formation | Interbedded mudstone and sandstone, prominent dark grey basal unit. |

Extensive exploration drilling at Curragh and neighbouring mines was analysed by PB to develop a detailed understanding of the geology in the vicinity of the mine for the 2016 expansion project. This included the development of detailed conceptual cross sections which have been reproduced in Figures 7 to 10 (PB, 2016). The cross-sections show the geology of the study area and the progression of mining as of August 2015 and were developed using LiDAR, drill hole data and the mine geological model as well as exploration data for neighbouring mines obtained from Queensland Globe.

The locations of the cross-sections (which are shown on **Figure 5-2**), comprise a north-south long section (A-A' **Figure 5-3**), and three east-west long sections (B-B' **Figure 5-4**, C-C' **Figure 5-5**, and D-D' **Figure 5-6**)

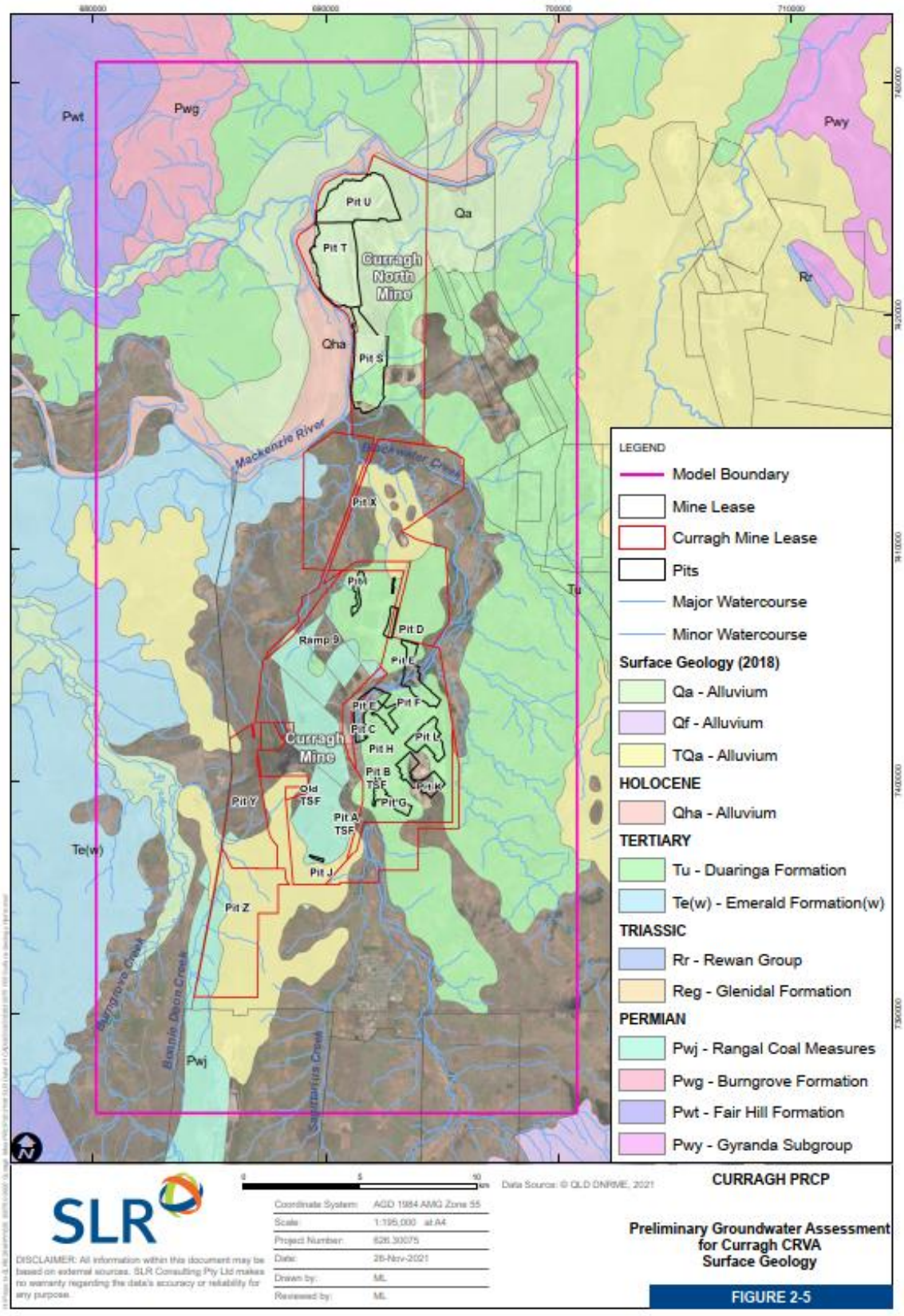



**Figure 5-1 Surface Geology**

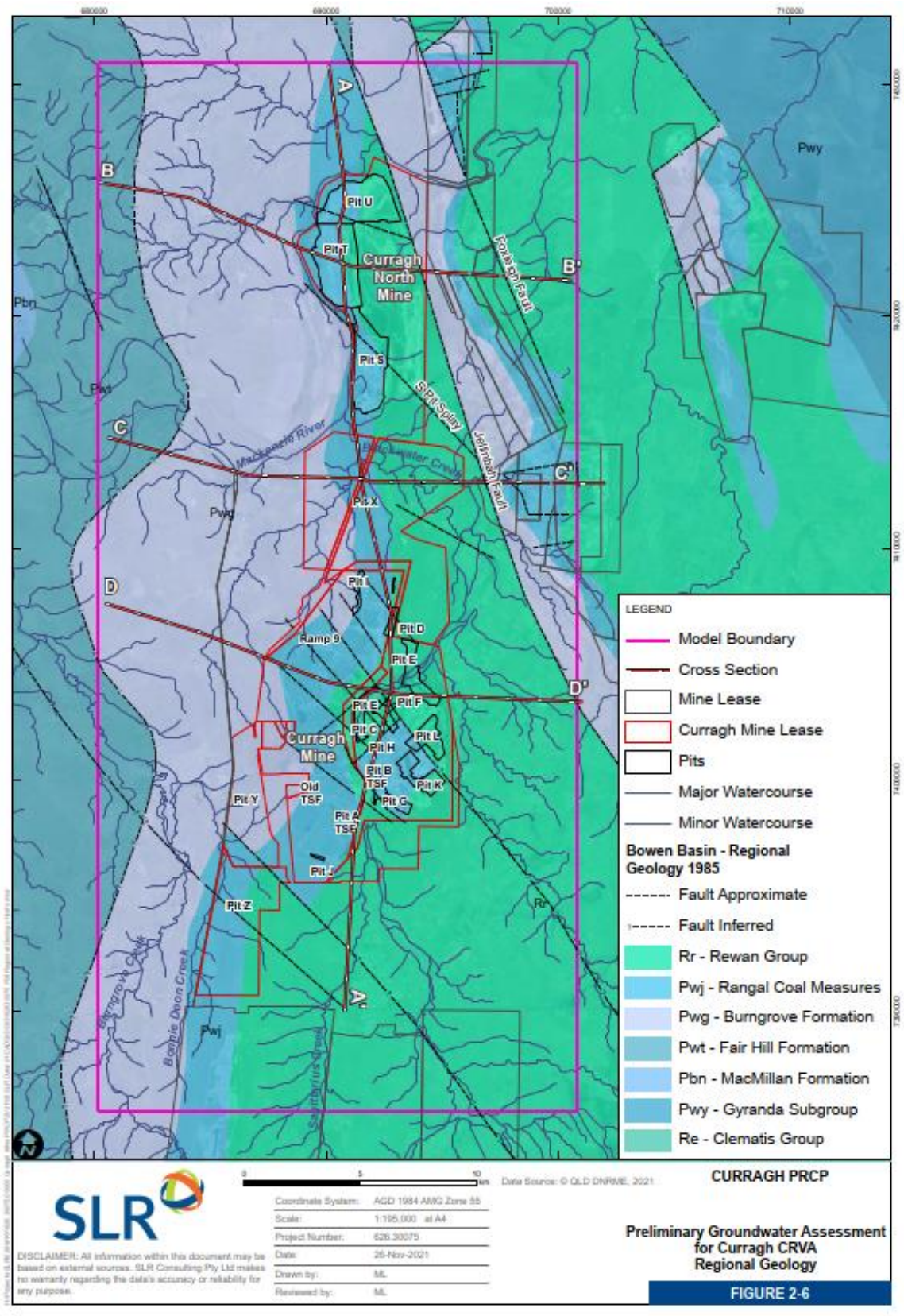



**Figure 5-2 Regional Geology**

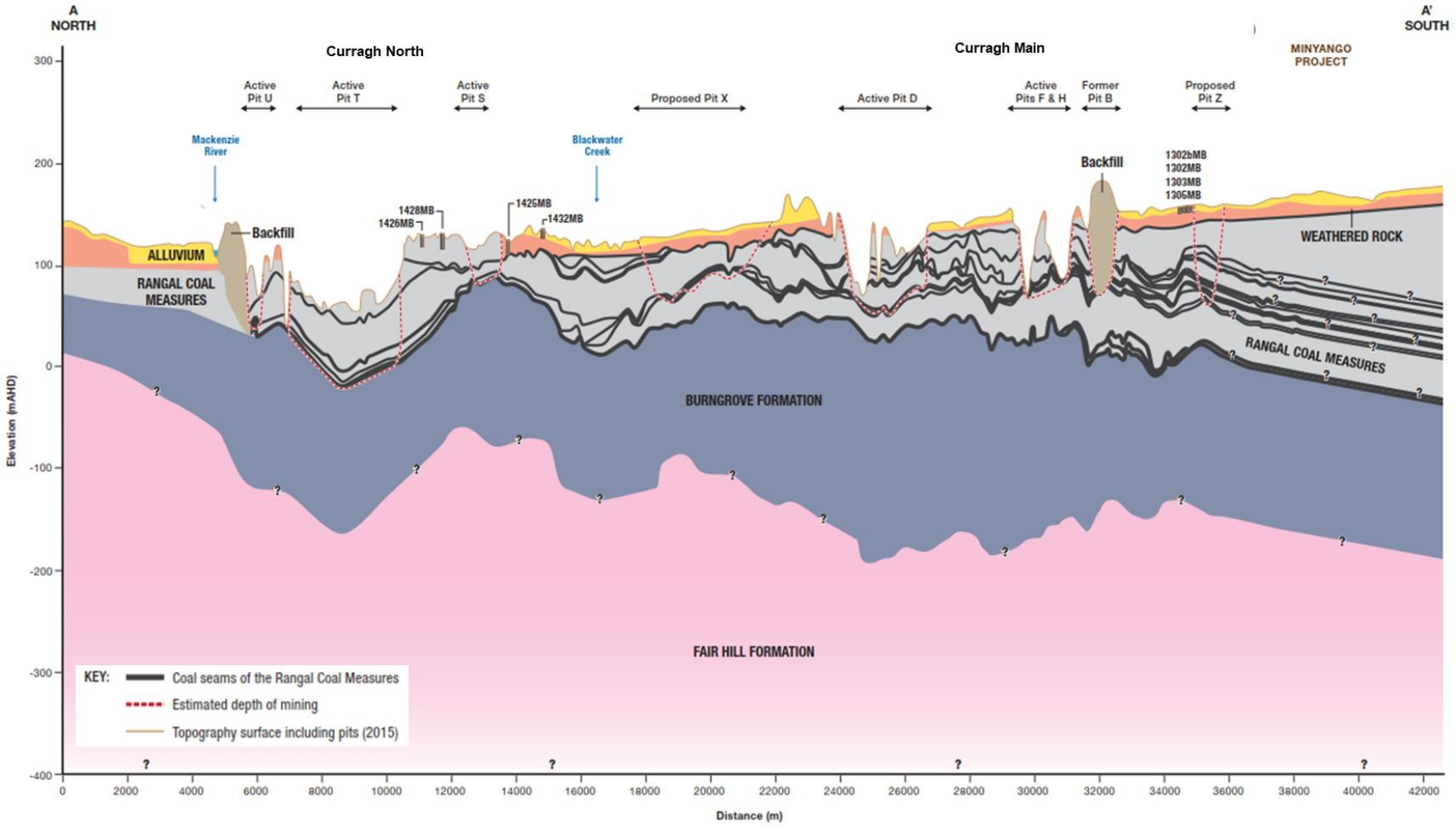



**Figure 5-3 Conceptual geological cross-section A-A' (PB, 2016)**

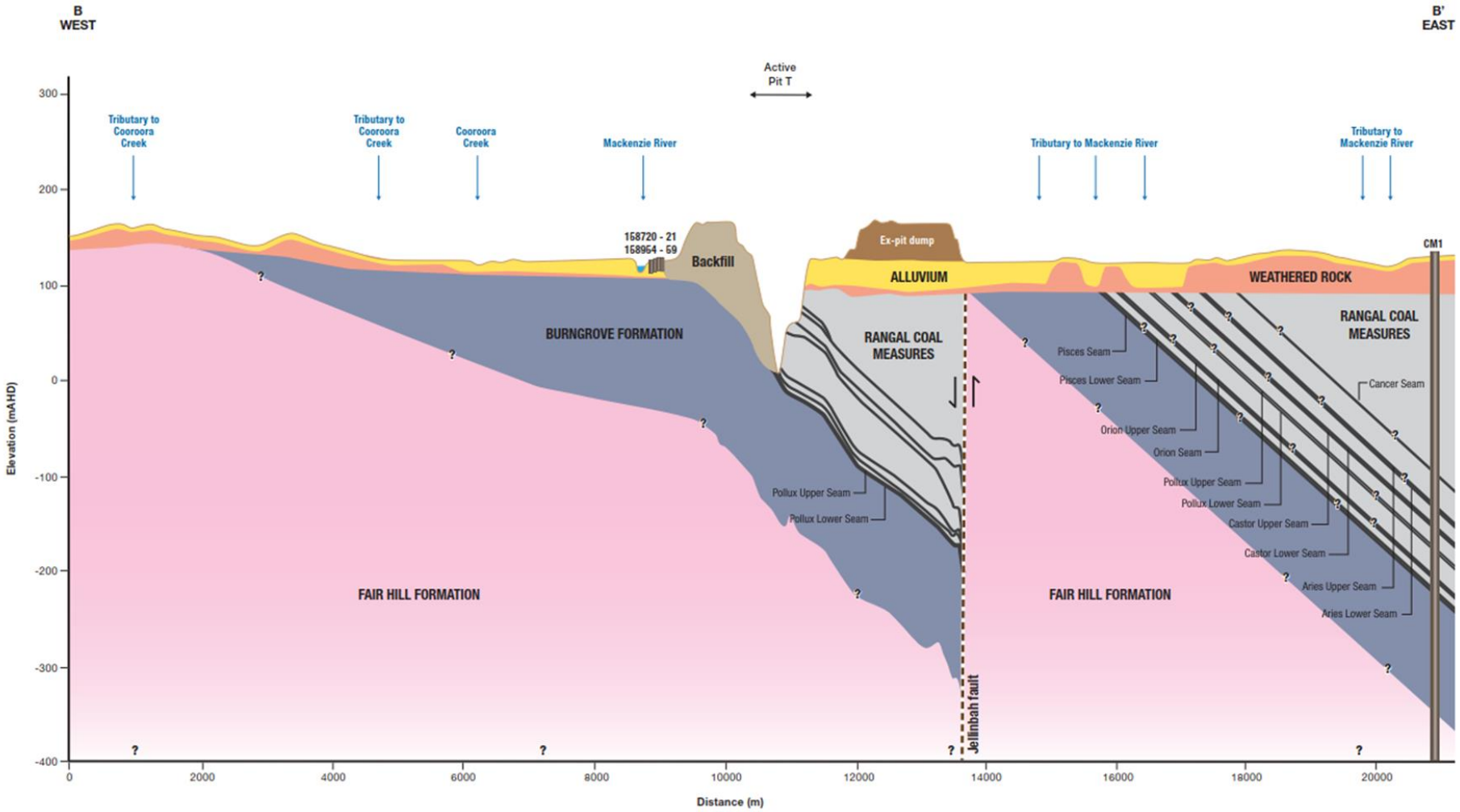



**Figure 5-4 Conceptual geological cross-section B-B' (PB, 2016)**

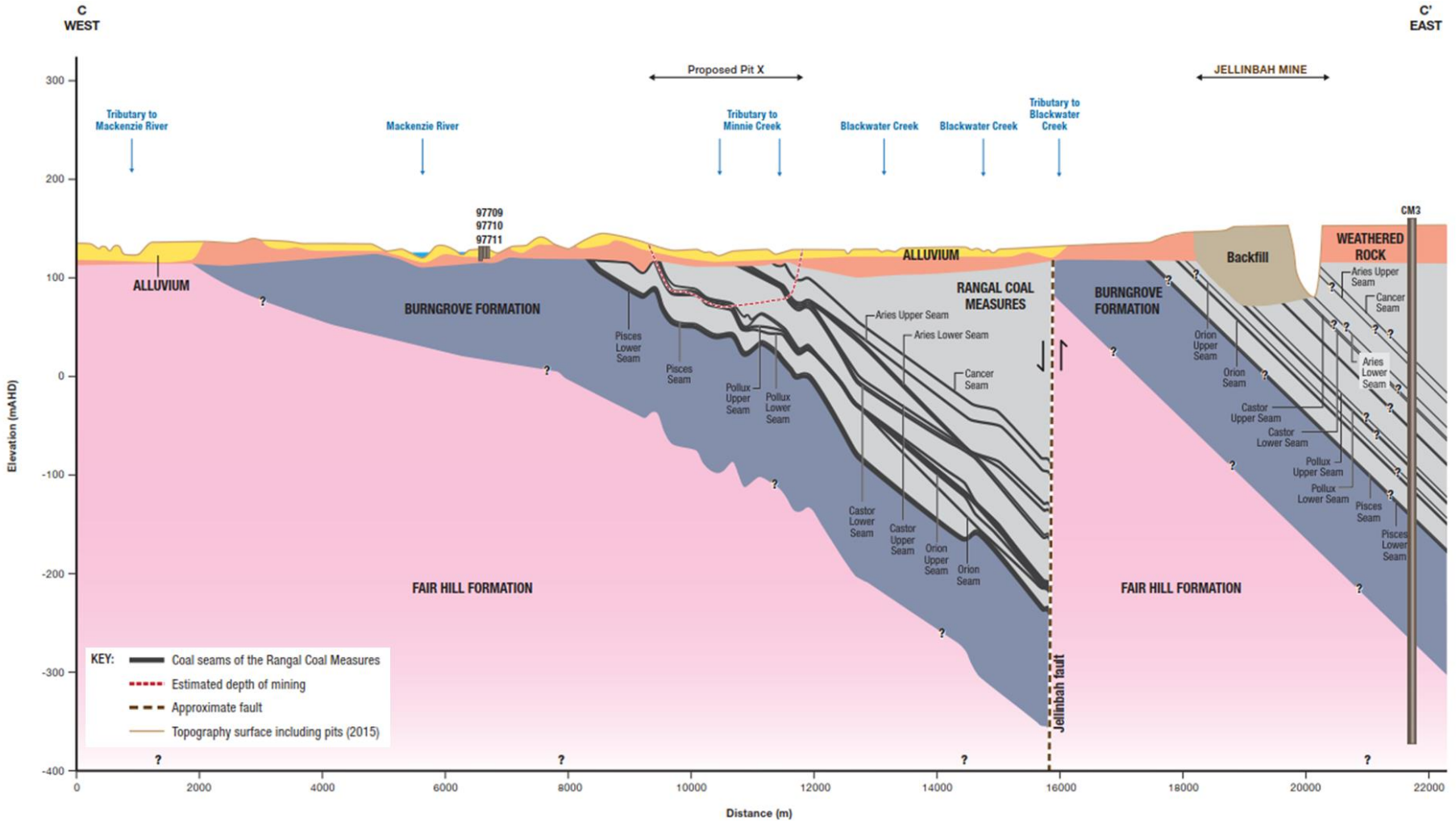



**Figure 5-5 Conceptual geological cross-section C-C' (PB, 2016)**

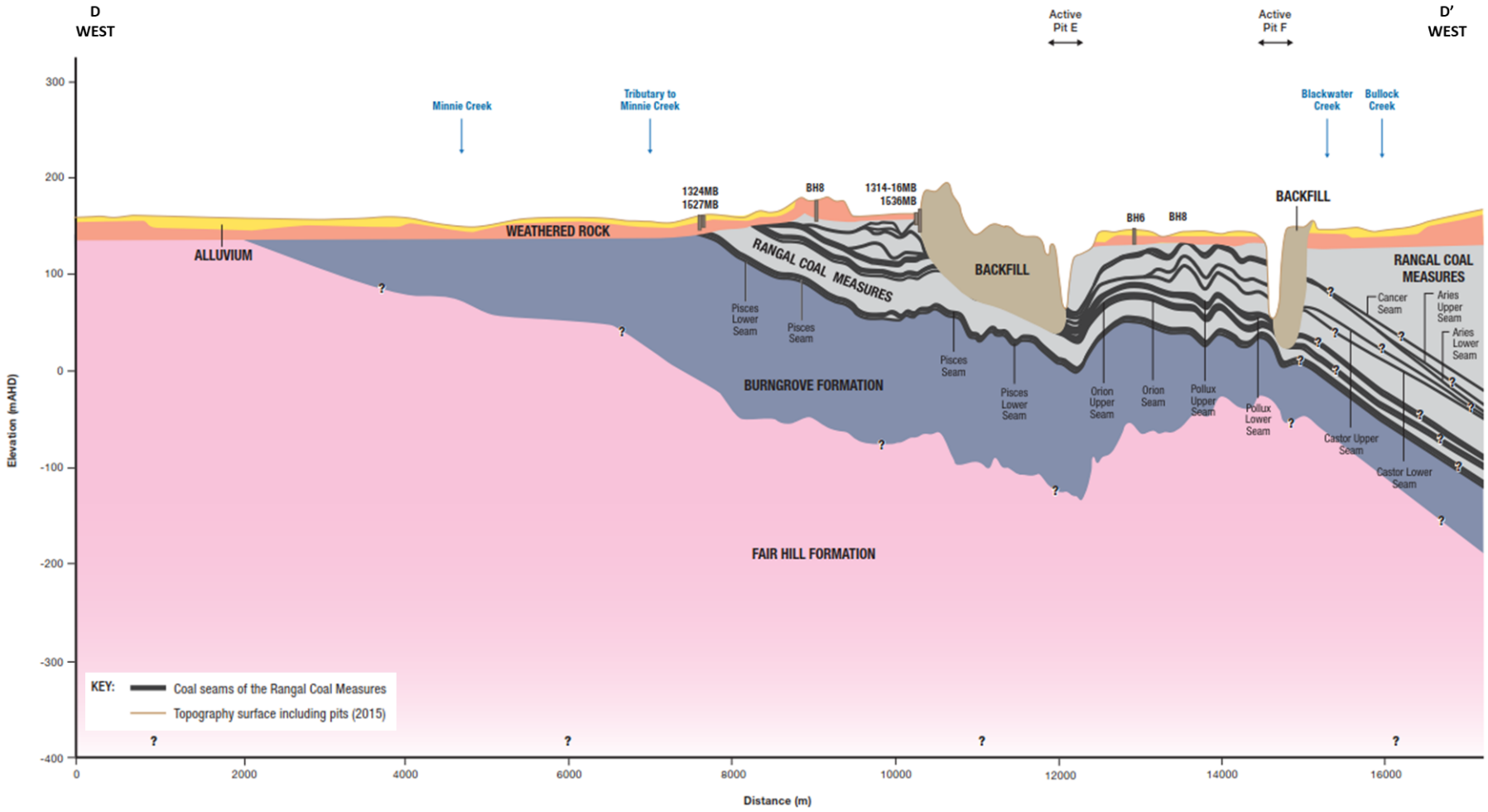



**Figure 5-6 Conceptual geological cross-section D-D' (PB, 2016)**

The main hydrostratigraphic units in the vicinity of the mine are described below, from the shallowest to the deepest/oldest:

- **Alluvium** – up to 30m thick in the north associated with the floodplain / channel deposits of the Mackenzie River. Thinner (up to 12 m), near extension Pit X and comprises clay, sand and gravel units. At Curragh Main and southern extension Pits up to 10 m thick but generally much thinner and predominantly clay and silt. The alluvium is dry in many areas. Unconfined water bearing sand and gravel may occur at the base of the alluvial sequence around Curragh North near proposed Pit X but it is considered unlikely to be significantly water bearing where it occurs in the south of the mine.
- **Regolith** - unconsolidated surface layer of weathered rock which may provide a preferential flow pathway for groundwater. Occurs across the Project area at thicknesses between 5 and 15 m. Includes weathered residual rocks of the Duaringa and Emerald formations, Rewan Formation, Rangal Coal Measures and Burngrove Formation in areas of outcrop and sub-cropping alluvium. Variable permeability.
- **Cenozoic** (Tertiary Duaringa and Emerald formations) - Occurs around Curragh Main extension Pits X and D. Comprises cemented sands and gravels and sandstones, siltstones and mudstones. Water bearing zones may occur in more permeable layers, unconfined to semi-confined.
- **Rewan Group** - is a regional aquitard comprising mudstones interbedded with siltstone and fine to medium grained labile sandstone.
- **Rangal Coal Measures** - Occurs along the strike of the mine and is overlain to the east by the Rewan. Groundwater flow is primarily within the coal seams (via interconnected cleats and fractures), which are confined by low permeability overburden and interburden. The coal measures are highly faulted resulting in "compartmentalisation" with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of flow. Faults themselves may form barriers to flow or provide conduits.
- **Burngrove Formation** – outcrops/subcrops to the west of the mine dipping east below the Rangal Coal Measures. Groundwater flow occurs primarily via the coal seams and fractured sandstone units with low permeability siltstone and claystone forming aquitards. As with the RCM sequence is considered to be highly faulted with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of groundwater flow. This Formation is considered the basement for the purposes of this assessment.

There are four registered bores within 3 km of Curragh Project. One of these bores is owned by the Central Highlands Regional Council, located at the campground near Bedford Weir, and they have indicated that the groundwater is relatively saline.

## 5.2 Numerical Hydrogeological Model

SLR has updated the original numerical groundwater model for Curragh Project which was developed in 2016 by Parsons Brinckerhoff for Wesfarmers Resources Pty Ltd. The original model was constructed and calibrated for the Curragh Extension Project assessment and was independently reviewed and audited by HydroSimulations in 2016. For this this study the 2016 model temporal datasets have been extended and a post-mining recovery simulation has been added with detailed final void modelling, to estimate effect of mine closure on the local groundwater regime.

The primary objective of this work is to identify groundwater related issues potentially resulting from the closure of the Curragh Project and secondarily, to lay the foundations for a more detailed assessment of potential groundwater issues at the complex as part of the closure planning process. The key objectives of this modelling exercise have been to:

- Update the model datasets and verify the model calibration;
- Update the mine progression in line with the current mine plan;
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by Coronado to understand whether the final voids act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post mining landform on local groundwater levels by comparing the long term post closure case to a null case (no mining activity).

The updates to the model included:

- Extending the rainfall in the model to include the latest climate measurements;
- Extending the calibration data set to include the latest groundwater level measurements and recalibrate the model;
- Recalibrating the model to include depth-dependent hydraulic conductivity in the Rangal Coal Measures;
- Updating the mine progression plan in the model, to include all foreseeable future mining at Curragh Project;
- Updating the temporal discretisation to include the recovery model; and
- Setting up the recovery model to include proposed residual voids at the end of foreseeable mining at Curragh Project.

Further information on the numerical model is provided in **Appendix B**.

## 5.3 Results

Post mining impacts were investigated with a recovery model, commencing at the end of active mining. A preliminary transient recovery model consisting of 16 time slices (each time slice set to 300-years) was developed to assess the relationship between the final voids' lake elevations and groundwater inflow. The net groundwater flux has been calculated as a cumulative void flux for each area at Curragh Project (Curragh North, X Pit, Curragh Main, Y Pit and Z Pit) (**Figure 5-7**) to account for interaction between the adjacent voids within each area. The simulated average groundwater flux at the end of the model run time (2133) for each residual void area, including throughflow from spoil and groundwater take from the Rangal Coal Measures, are presented in **Table 5-2**.

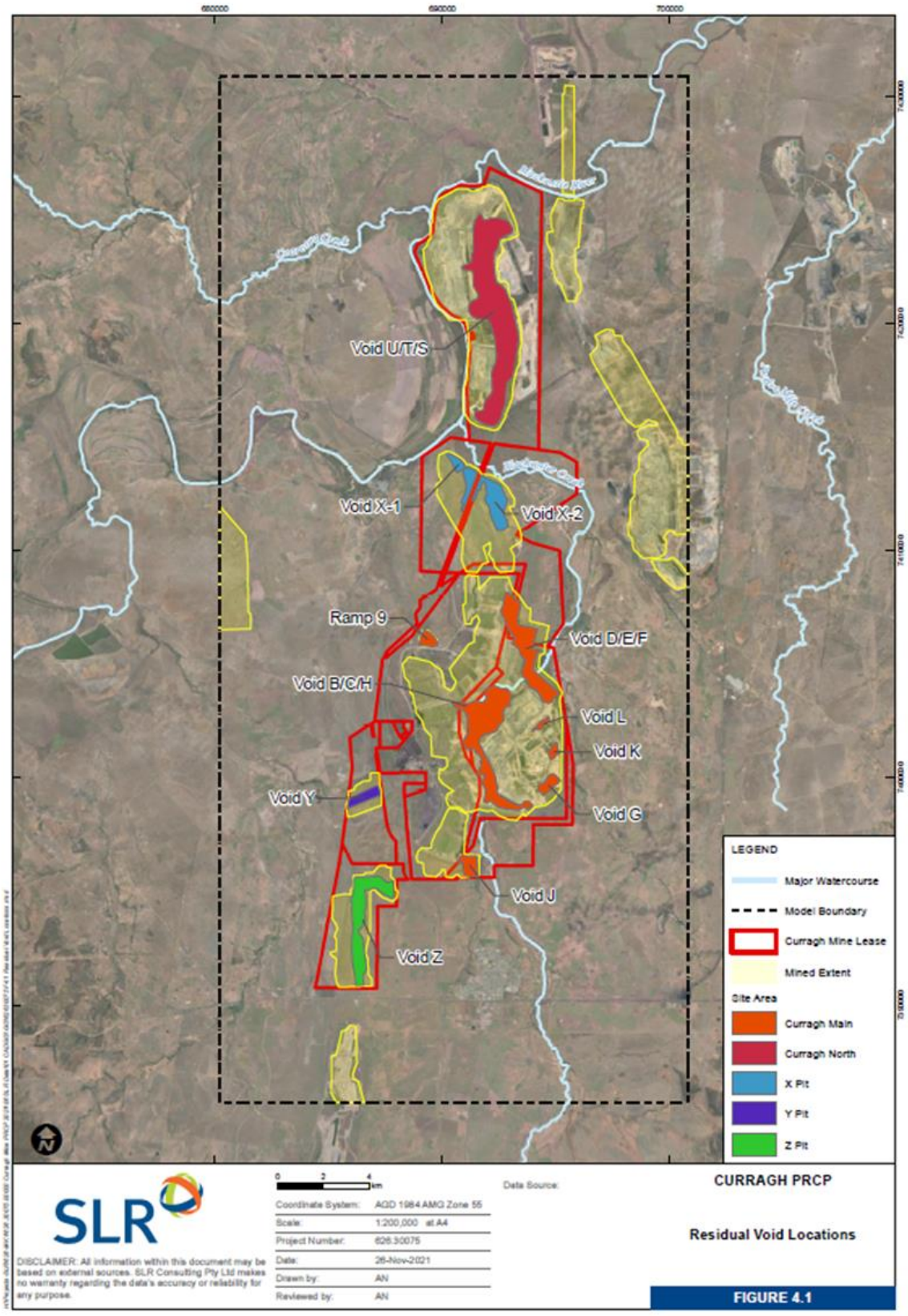



**Figure 5-7 Hydrogeologic Residual Void Groups**

## Table 5-2 Post-Mining Equilibrium Residual Void Summary

| Curragh Area: | | Curragh N | X Pit | | Curragh Main | | | | | | | Y Pit | Z Pit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Void*: | | U/T/S | Void 1 | Void 2 | D/E/F | B/C/H | L | K | G | J | Ramp 9 | Y | Z |
| Final landform minimum elevation used in the numerical model (mAHD) | | -48 | 78 | 34 | 26 | 41 | 92 | 65 | 64 | 93 | 77 | 116 | 78 |
| Post-mining equilibrium void lake level (mAHD), the final lake levels were derived from the surface water model. | | 26 | 101 | 69 | 63 | 83 | 113 | 105 | 79 | 132 | 91 | 131 | 115 |
| Void lake salinity (uS/cm), as predicted by the water balance model.** | ~10 years | 27,578 | 28,650 | 16,174 | 36,828 | 23,045 | 20,530 | 23,445 | 33,100 | 19,951 | 29,754 | 28,954 | 37,296 |
| | ~30 years | 37,313 | 37,274 | 32,568 | 37,313 | 37,181 | 36,416 | 37,308 | 37,288 | 31,496 | 37,313 | 37,313 | 37,313 |
| | ~200 years | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 |
| Net groundwater flux to void at equilibrium (total flux including inflow draining from the spoil and groundwater inflow from the RCM, ML/day) | | 4.82 | 0.49 | | 1.75 | | | | | | | 0.11 | 1.00 |

* The residual voids have been grouped where a void may act as a source of water to an adjacent void, but where collectively they act as a groundwater sink.
** 37,313 µS/cm is the maximum salinity limit set in the surface water balance model (SLR 2021)

An equilibrium groundwater flux of 4.82 ML/day was predicted at Curragh North, where the minimum elevation of the final landform is 74 m lower than the other voids. The relative depth of the residual void at Curragh North is likely accountable for the higher predicted groundwater flux to the void in this area. Equilibrium total groundwater flux to the voids in Curragh North Pit, X Pit, Curragh Main, Y Pit and Z Pit are predicted to be 4.82, 0.49, 1.75, 0.11 and 1.00 ML/day respectively, indicating all simulated voids are predicted to be groundwater sinks with positive net groundwater flow into the voids. The simulated fluxes to the voids in the groundwater model are consistent with groundwater fluxes in the surface water model developed for simulating final landforms for Curragh Mine (SLR, 2021).

The predicted post-mining water table at equilibrium (end of recovery) is shown in **Figure 5-8**. Hydraulic gradients at equilibrium indicate an overall flow direction toward residual voids at Curragh Main and Curragh North. All residual voids show hydraulic heads decreasing with proximity to the void, indicating all voids are predicted to act as local groundwater sinks.

Predicted drawdown figures (**Figure 5-9** and **Figure 5-10**) show where residual drawdown impacts are predicted to exceed 1 m. **Figure 5-9** presents the residual drawdown just within the alluvium at post-mining equilibrium. Predicted recovered heads in the alluvium west of Curragh North show residual drawdowns of 1 to 2 m extending up to 3 km from mined pits at Curragh North although drawdowns at the very edge of the voids are higher (5-10 m). **Figure 5-10** presents the residual drawdown of the water table at post-mining equilibrium.

To investigate the potential movement of groundwater to or from the voids and spoil at post-mining equilibrium, the post-mining water table predicted for the end of recovery was used to infer potential flow pathways in and around the spoil at each area of mining. Particle tracking was used together with the post-mining water table to predict groundwater movement relative to the voids and areas of spoil. Particles are “dropped” on the post mining equilibrium water table and allowed to track down hydraulic gradient from their starting position. **Figure 5-11** shows the inferred flow pathways around the residual voids interpreted from the particle tracking simulation at post-mining equilibrium. The flow paths from the outer edges of the voids or spoil dumps informed by the recovered head levels indicate groundwater flow is toward each of the residual voids hence none of the voids are likely to act as sources to the groundwater system.

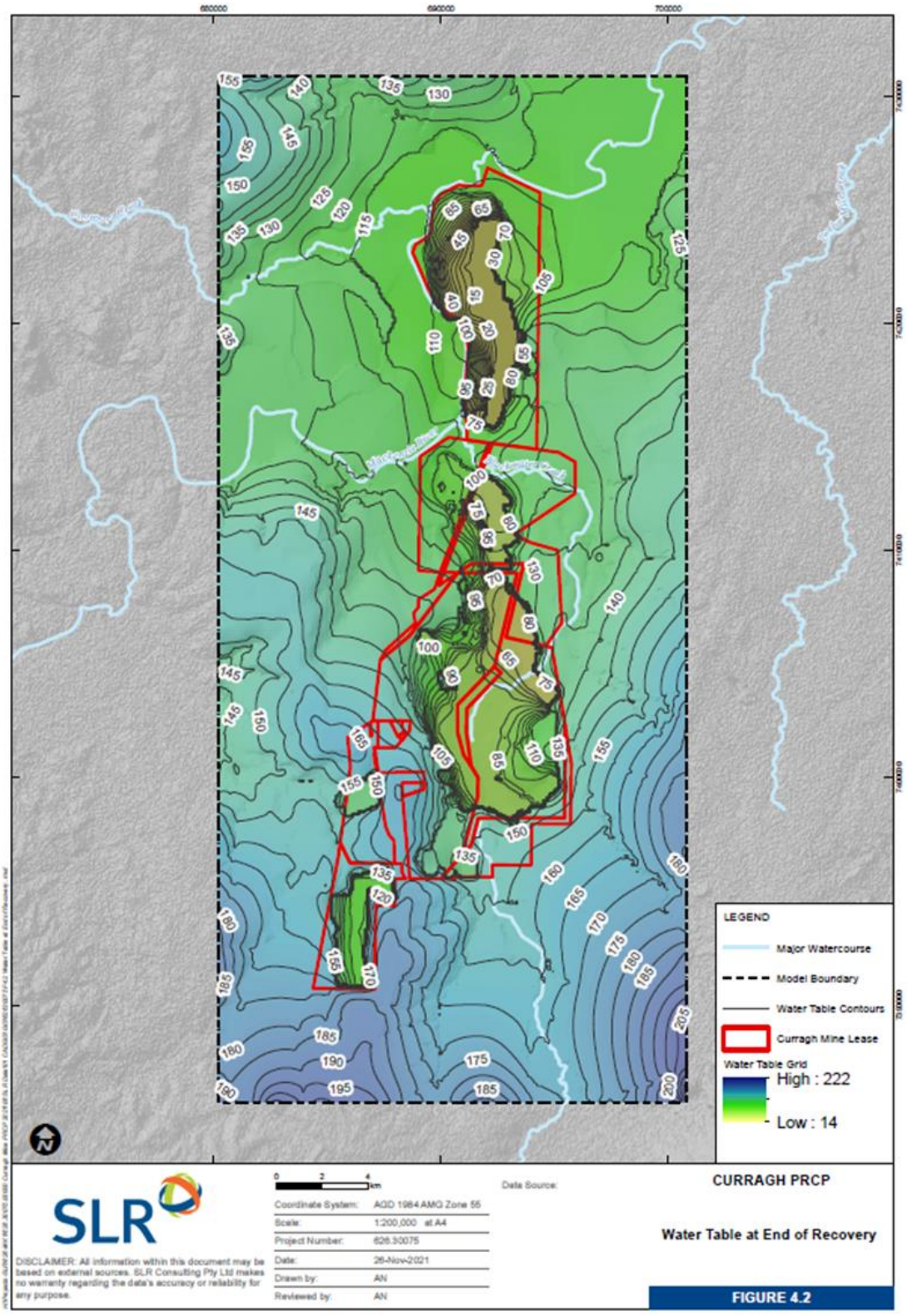



**Figure 5-8 Predicted Water Table at End of Recovery**

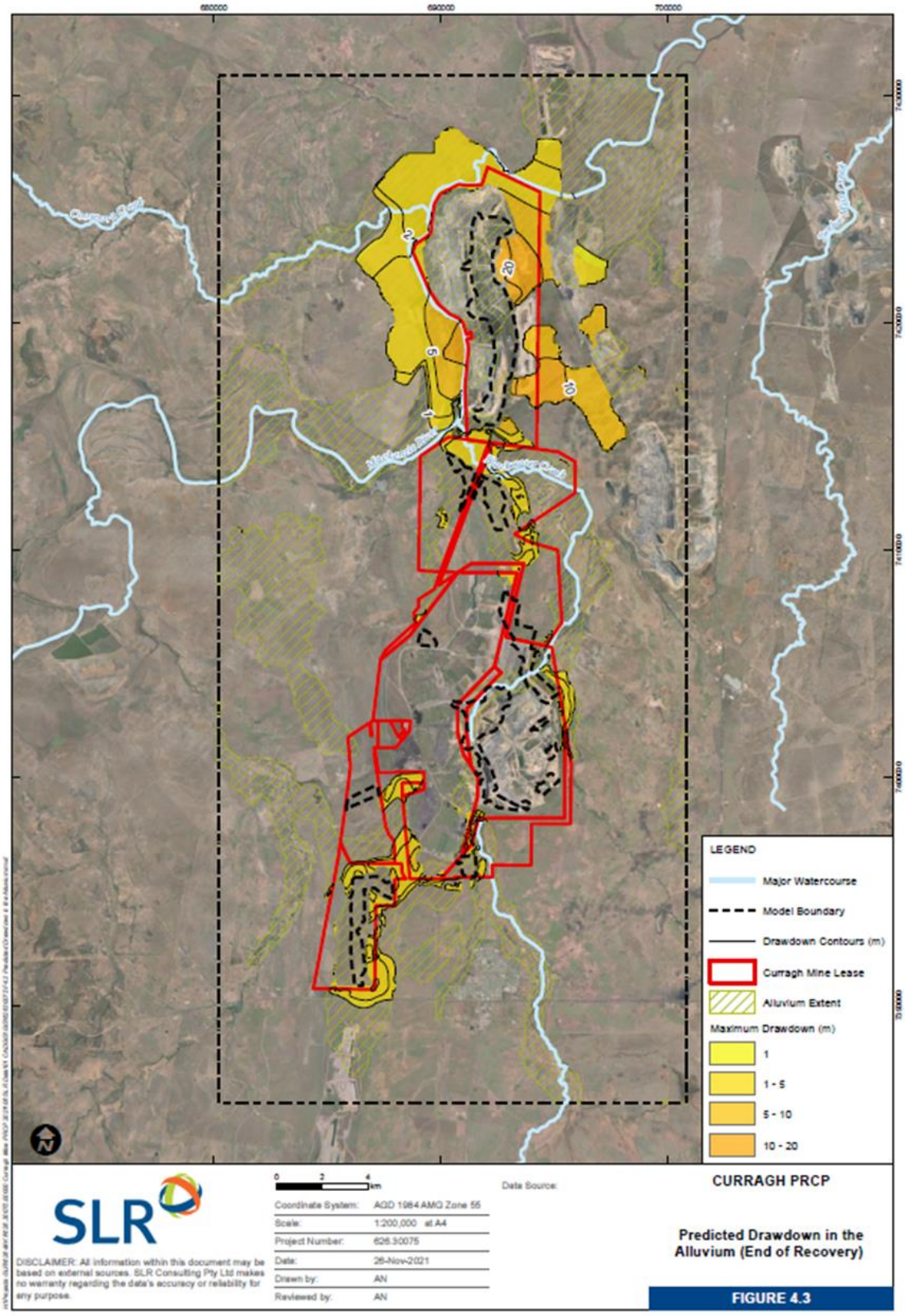



**Figure 5-9 Predicted Residual Drawdown in Alluvium at End of Recovery**

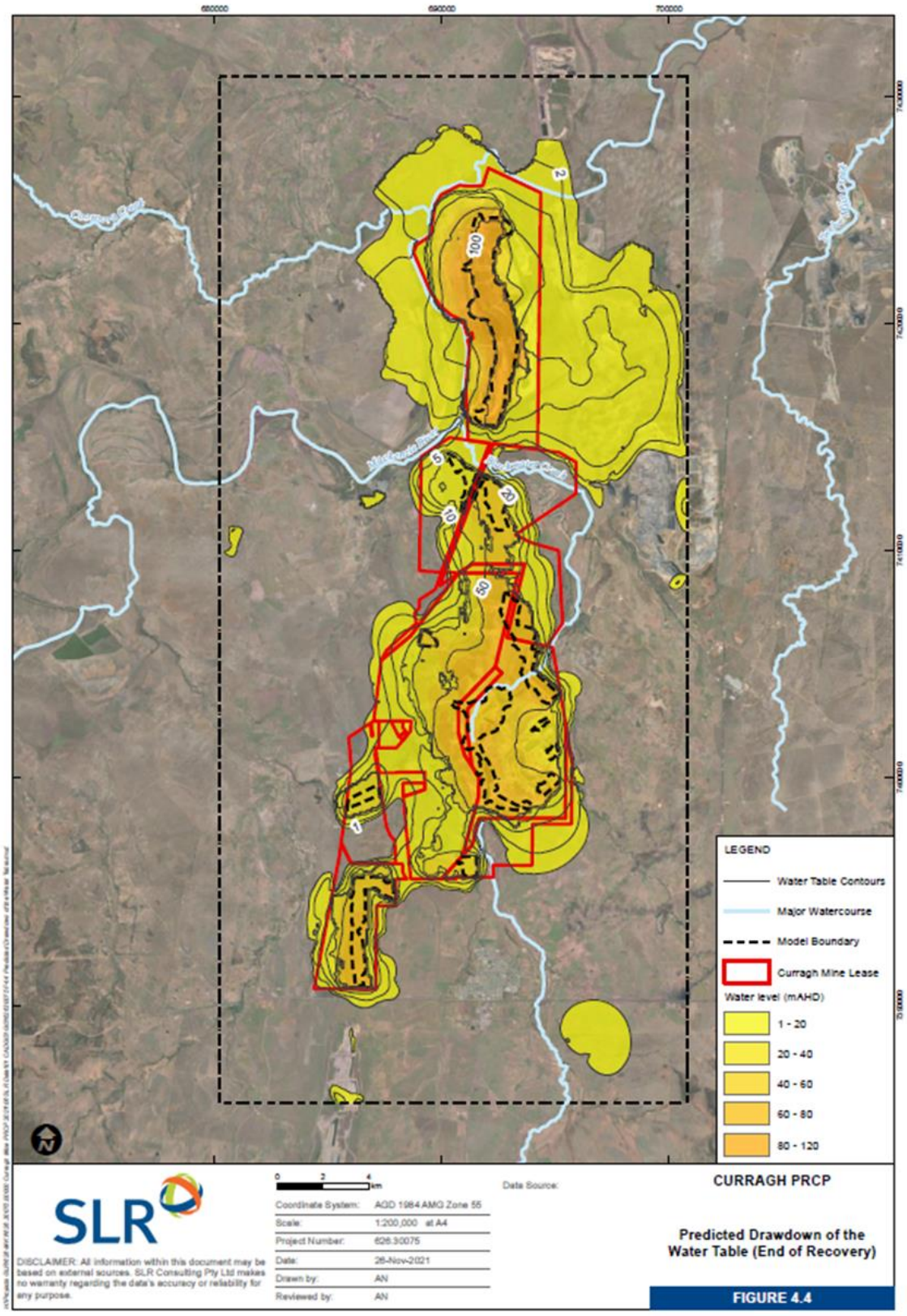



**Figure 5-10 Predicted Residual Water Table Drawdown at End of Recovery**

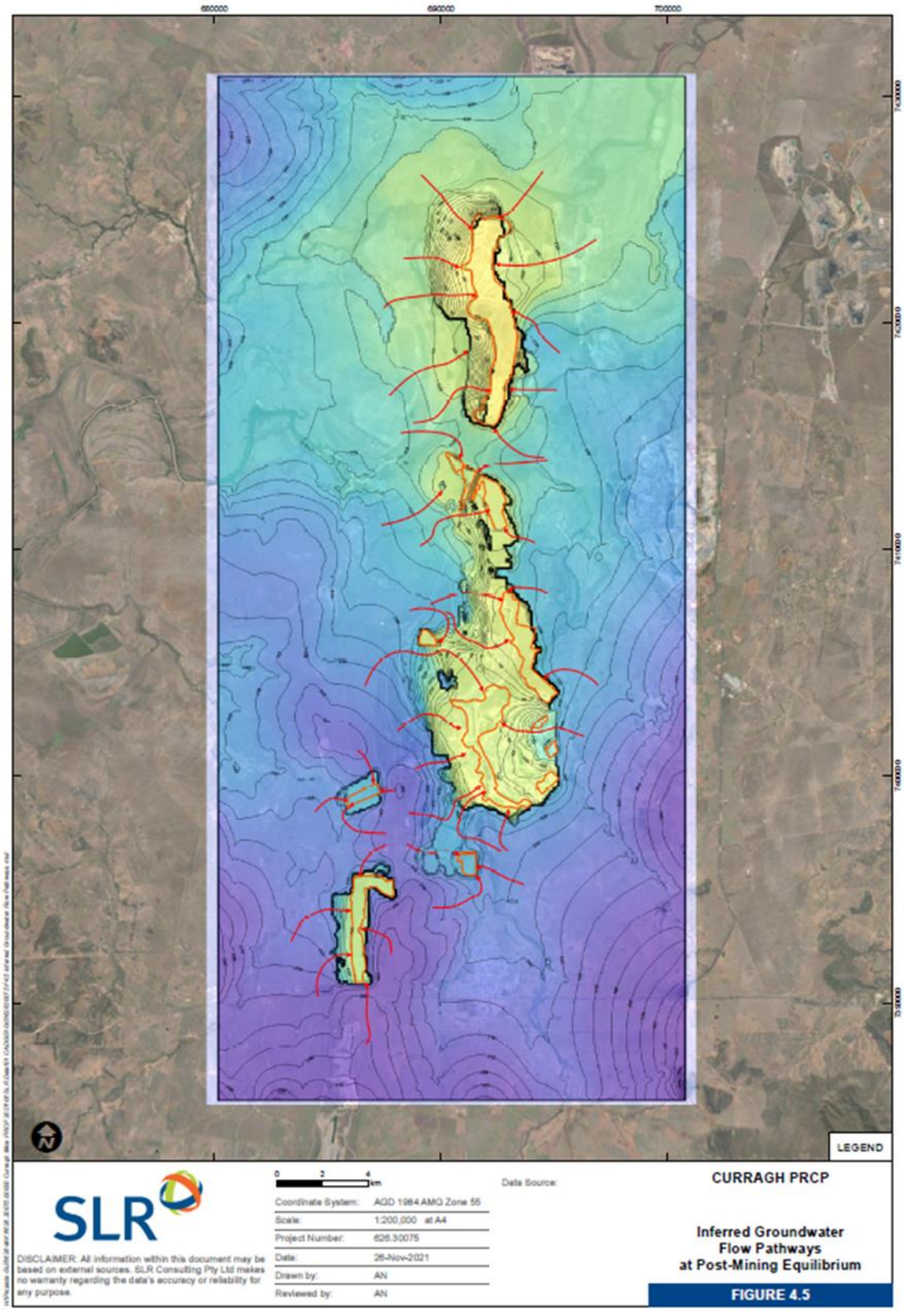



**Figure 5-11 Inferred Groundwater Flow Pathways at Post-mining Equilibrium**

## 5.4 Conclusions and Recommendations

The following key conclusions are drawn from the preliminary numerical modelling assessment of the post-mining groundwater environment at the Curragh Project:

- The numerical modelling indicates that lakes will form within the residual voids of the proposed final landform. These lakes will act as local groundwater 'sinks' with groundwater within mining disturbed areas (including the Pit A and B TSFs) migrating towards these sinks;

- Post-mining residual drawdown in the Mackenzie River Alluvium to the west of Curragh North will generally be in the order of 1-2m (but up to 10m near the mine voids), noting that the Mackenzie River is regarded as a "losing" watercourse with pre-mining groundwater levels in the alluvium 4-5 m below the river stage in the vicinity of the mine;

- Based on the geological data reviewed for this preliminary assessment (limited for the extension areas), it appears that equilibrium void lake levels are generally well below the level of alluvium and base of weathering (potential preferential pathways for outward seepage of water from the void lakes); and

- Post-mining, the total estimated "groundwater" inflow to all voids is approximately 8.2 ML/d although the majority of this is water derived from infiltration to the spoil and drainage into the void lake rather than inflow from the Rangal Coal Measures or Alluvium.

A more detailed assessment of the post-closure groundwater related issues with refined modelling is recommended for the PRCP submission. Section 5.3 of the Groundwater Report (**Appendix B**) details the key modelling update recommendations for the detailed groundwater assessment.

# 6 Residual Void Water Balance

SLR has developed a residual void water balance model (WBM) for the Curragh Project to determine the final void water level and quality of the residual voids. The details of the WBM are provided in **Appendix C**. The WBM has considered both surface water and groundwater inflows derived from the recovery groundwater model mentioned above.

## 6.1 Water Balance Modelling

As stated above there are 12 residual voids expected at the end of mine life, these voids have been listed below with multiple pits grouped where hydrologically linked for the purpose of the WBM:

- Curragh North: Void U/T/S;
- Curragh Main: Void D/E/F, Void B/C/H, Void L, Void K, Void G, Void J, Ramp 9; and
- Expansion Areas: Void X (1 and 2), Void Y, Void Z.

The WBM has been developed using GoldSim software package to assess the long-term void water level and water quality at Curragh Project. The model simulates daily changes in the volumes of stored water in response to inflows (rainfall, groundwater) and outflows (evaporation and controlled releases/overflows). The WBM was run for daily time step over 200-year simulation period, represented by 500 climate sequences, allowing the model to assess long term water levels, quality and risk of overflow for each void.

The input data includes catchment areas for each residual void (or group of voids), stage storage relationships, climate data including probabilistic rainfall and evaporation, runoff, groundwater inflow and water quality. The details of each input is outlined in **Appendix C**.

## 6.2 Results

### 6.2.1 Residual Void Water Levels

The WBM was predicted to stabilise after approximately 100 years to the approximate levels for the median condition shown in **Table 6-1**. It is noted that some individual voids within the WBM reached equilibrium level from approximately 20 years. Graphical representations of the results for each residual void are provided in **Appendix C.**

**Table 6-1 Residual Void Water Level Summary**

| Void | Residual Void Level (50%ile) (mAHD) | Depth (m) | Spillway (mAHD) | Surface Area (ha) |
|---|---|---|---|---|
| Void U/T/S | 26 | 74 | 120 | 286.5 |
| Void D/E/F | 63 | 36 | 135 | 63.5 |
| Void B/C/H | 83 | 42 | 154 | 109.3 |
| Void L | 116 | 24 | 135 | 17.2 |
| Void K | 107 | 42 | 135 | 8.5 |
| Void G | 79 | 14 | 135 | 9.2 |

| Void | Residual Void Level (50%ile) (mAHD) | Depth (m) | Spillway (mAHD) | Surface Area (ha) |
|---|---|---|---|---|
| Void J | 132 | 39 | 152 | 20.2 |
| Ramp 9 | 91 | 14 | 147 | 17.1 |
| Void X – 1 | 101 | 23 | 120 | 23.2 |
| Void X – 2 | 69 | 35 | 120 | 49.4 |
| Void Y | 131 | 15 | 160 | 19.6 |
| Void Z | 115 | 37 | 164 | 72.3 |

The relative size of external catchment to the void footprint results in water levels that stabilise well below the indicative spill level with evaporative losses balancing inflows into the voids. A similar trend in water level is seen across all the residual voids. Water depths range from 14 m to 74 m within the voids for median conditions (50$^{th}$ percentile). During dry climatic conditions (5$^{th}$ percentile) water levels are approximately 2 m to 13 m lower. During very wet (99$^{th}$ percentile) climatic conditions the water level increases by 3 m to 20 m depending on the void and generally causes greater fluctuation in the equilibrium water level. Final water levels range from 9 m to 88 m below the indicative spill levels and are not expected to overtop.

### 6.2.2 Residual Void Water Quality

Water within the residual voids becomes highly saline throughout the simulation. This was not unexpected due to the high salinity of groundwater in the region and the assumption that no salt is lost from the system via evaporation. Within the WBM, salinity is capped at a maximum EC of 37,313 µS/cm which is equivalent to the point where the concentration of salt becomes high enough that the solution is saturated and any additional salt will precipitate out of solution. Salinity in all voids increases over time until reaching saturation after approximately 20 to 30 years.

The average salinity of the voids throughout the simulation period are provided in **Table 6-2**. Graphical representations of the results for each residual void are provided in **Appendix C.**

**Table 6-2 Average Stage Salinity (EC µS/cm)**

| Void | Year 10 | Year 30 | Year 200 |
|---|---|---|---|
| Void U/T/S | 27,578 | 37,313 | 37,313 |
| Void D/E/F | 36,828 | 37,313 | 37,313 |
| Void B/C/H | 23,045 | 37,181 | 37,313 |
| Void L | 20,880 | 32,696 | 37,313 |
| Void K | 22,333 | 37,292 | 37,313 |
| Void G | 33,100 | 37,288 | 37,313 |
| Void J | 19,951 | 31,496 | 37,313 |
| Ramp 9 | 29,754 | 37,313 | 37,313 |
| Void X – 1 | 28,650 | 37,274 | 37,313 |
| Void X – 2 | 16,174 | 32,568 | 37,313 |

| Void | Year 10 | Year 30 | Year 200 |
|---|---|---|---|
| Void Y | 28,954 | 37,313 | 37,313 |
| Void Z | 37,296 | 37,313 | 37,313 |

## 6.3 Conclusions

At Curragh Project the residual void water levels are expected to range from 26 mAHD to 132 mAHD with water depths of 14 m to 74 m. The results indicate that the mine is not a net accumulator of water after approximately 100 years when the equilibrium water levels are reached. The final water levels remain below the spill level and the voids are unlikely to overtop in the 99$^{th}$ percentile climate scenario.

A significantly high concentration of salt is expected to accumulate within the residual voids. The elevated salinity of the groundwater inflows input a high level of salt into the voids which is not lost from the system via evaporation. The salinity of the voids is expected to exceed that of the groundwater and form highly concentrated solution. Although poor quality, water within the voids is not expected to interact with surrounding surface water given the final water levels.

# 7 Residual Void Geotechnical and Erosion Stability

## 7.1 Preliminary Landform Design

Geotechnical and geological information to support the possibility of adverse fault orientations and interactions relative to pitwall geometries and locations, and/or fault related rock mass shearing failures occurring is limited for most voids as the mining either hasn't commenced yet or not proceeded to the final void location. In order to provide a conservative approach on the residual void surface area and long-term void water level, the preliminary final landform has proposed a design which is appropriate for fault related rock mass shearing and/or adversely oriented structures – a standard overall slope of <22 degrees with a maximum slope of <45 degrees for the highwall side.

Landform cross sections (**Figure 7-1** and **Figure 7-2**) showing the different scenarios are shown in section 4 of **Appendix D**. The landform design options included in the geotechnical analysis are listed in **Table 7-1**. Some of the alternative options include a highwall angle of < 65 degrees.

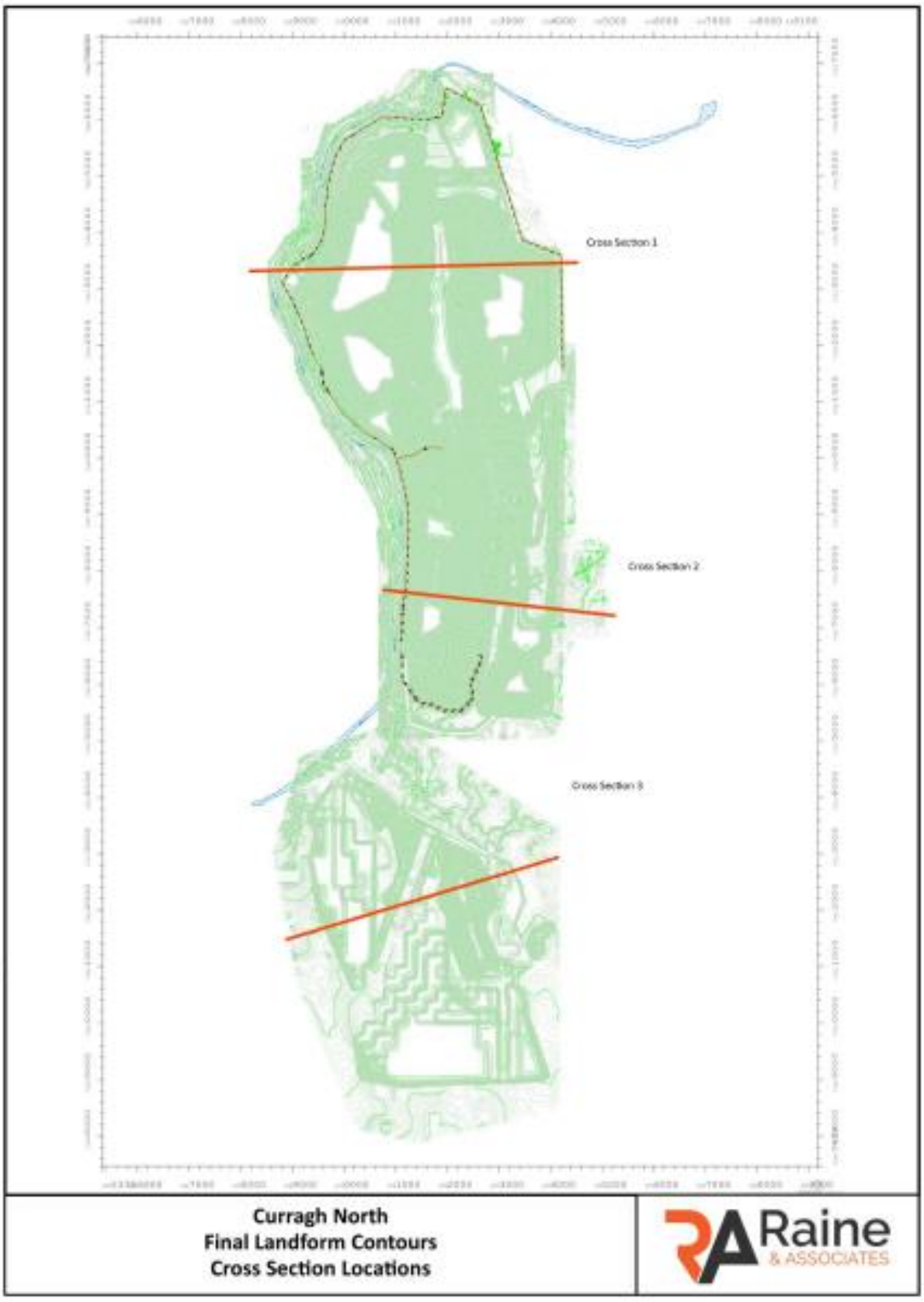



**Figure 7-1 Curragh North Landform Cross Sections (Raine Associates, 2021)**

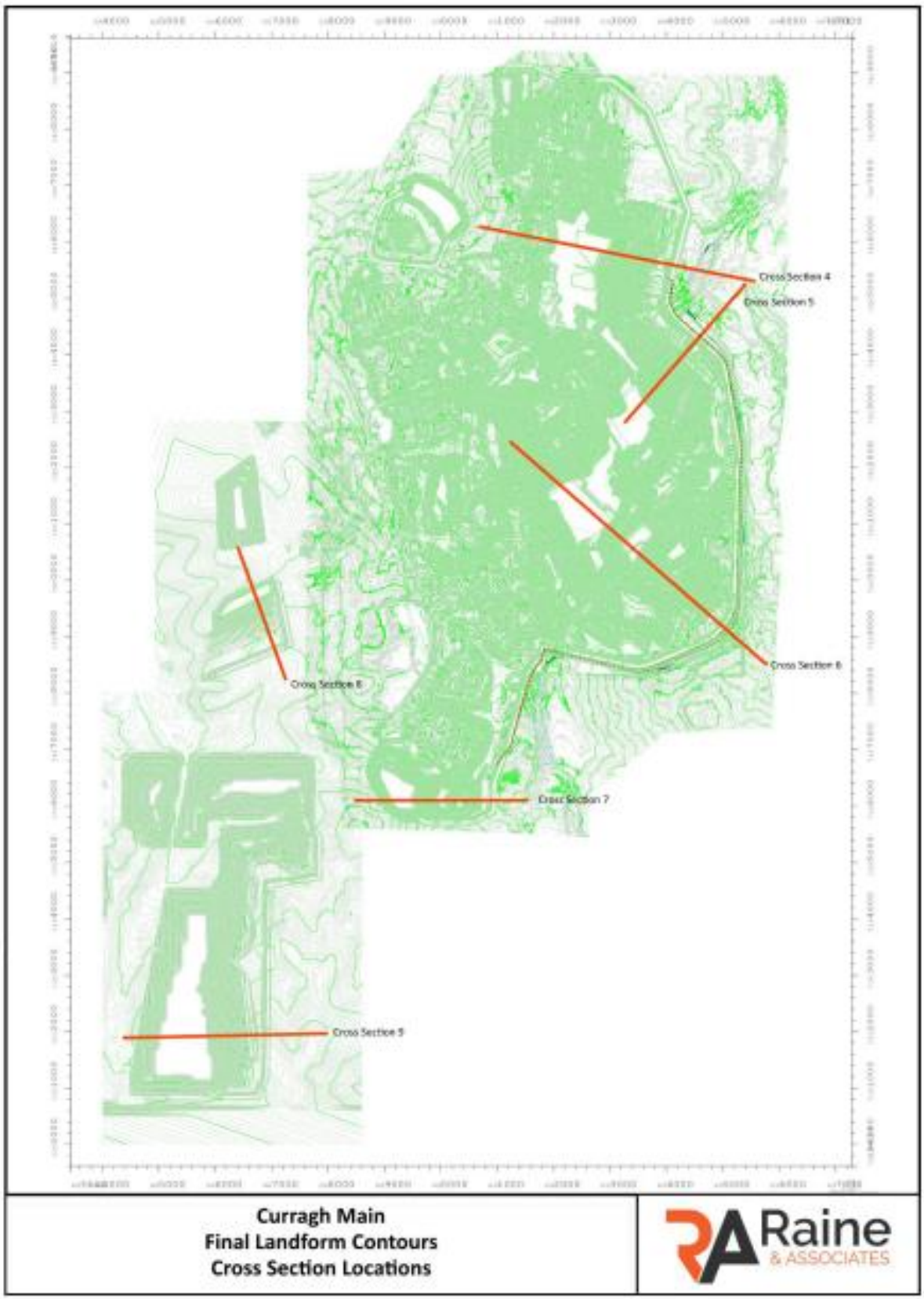



**Figure 7-2 Curragh Main Landform Cross Sections (Raine Associates, 2021)**

### Table 7-1 Cross section landform option descriptions

| Cross Section | Number | Scenario |
|---|---|---|
| U Pit | 1 | Planned Final Landform Option – Highwall Side |
| S Pit South | 2 | Planned Final Landform Option – Highwall Side |
| | | Planned Final Landform Option – Lowwall Side |
| X Pit | 3 | Planned Final Landform Option – Highwall Side |
| D Pit | 4 | Planned Final Landform Option – Highwall Side |
| | | Alternative Final Landform Option – Highwall Side |
| | | Alternative Final Highwall Reshaped Final Slope Option – Highwall Side |
| F Pit | 5 | Planned Final Landform Option – Highwall Side |
| | | Alternative Final Highwall Reshaped Final Slope Option – Highwall Side |
| | | Planned Final Landform Out Board Slope |
| | | Planned Final Landform Option – Lowwall Side |
| K Pit | 6 | Planned Final Landform Option – Highwall Side |
| | | Alternative Final Landform Option – Highwall Side |
| | | Alternative Final Highwall Reshaped Final Slope Option – Highwall Side |
| J Pit | 7 | Planned Final Landform Option – Highwall Side |
| | | Planned Final Highwall Reshaped Final Slope - Highwall Side |
| Y Pit | 8 | Planned Final Landform Option – Highwall Side |
| | | Planned Final Highwall Reshaped Final Slope - Highwall Side |
| Z Pit | 9 | Planned Final Landform Option – Highwall Side |
| | | Planned Final Highwall Reshaped Final Slope - Highwall Side |

The cross section of Pit D has been shown below (**Figure 7-3**) to demonstrate the different scenarios.

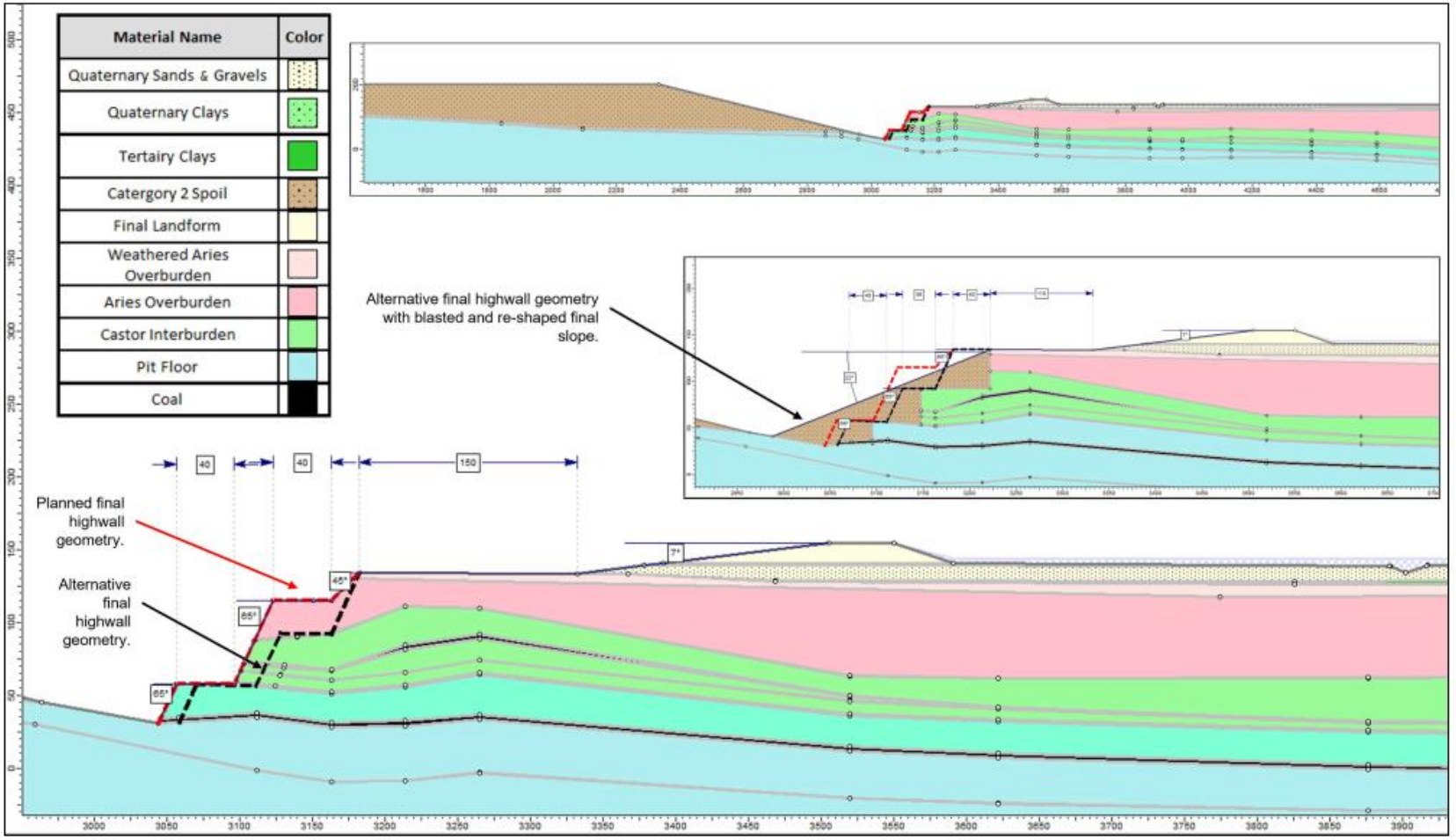



**Figure 7-3 D Pit Cross Section (Raine Associates, 2021)**

### 7.1.1 Long-term Stable Flood Barrier Embankment

As Curragh Project is located on a floodplain, an indicative cross section of the long-term stable embankment has been designed to prevent flood water ingress into the residual voids. The embankment design has been based on the B Pit embankment section developed from the B Pit Tailings Storage Facility Design Plan (Golders, 2017). A conceptual embankment design is shown in **Figure 7-4** with parameters outlined in **Table 7-2**. Stable embankments based on this concept and constructed to heights to provide freeboard to protect residual voids against the 0.1% AEP flood event are being incorporated into the final landform design for Curragh.

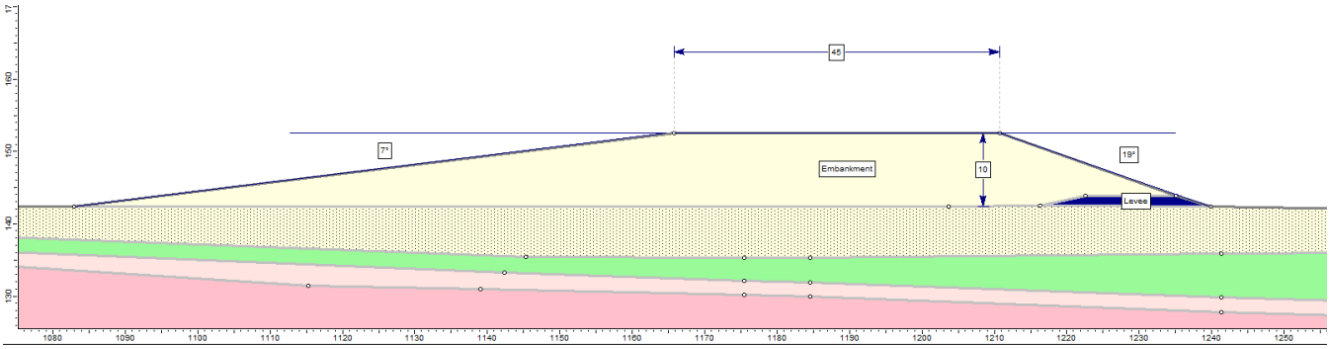



**Figure 7-4 Stable Embankment Conceptual Design (Raine Associates, 2021)**

**Table 7-2 Indicative Stable Embankment Standard Parameters**

| Parameter | Value |
|---|---|
| Height | 10 m (actual will be 0.1% AEP plus 1 m freeboard) |
| Top width | 45 m (actual to be determined during design) |
| Water facing slope | <19° (actual to be long term stable to erosion and flood scour) |
| Residual void facing slope | 7° (actual to be long term stable to erosion) |

The outcomes of the flood model will be incorporated into the updated landform design for the PRCP to ensure flood water does not enter residual voids.

## 7.2 Geotechnical Stability

Raine Associates (2021) (Appendix D) have undertaken a slope stability analysis on the Curragh preliminary final landform highwall designs using two-dimensional limit equilibrium methods and Rocscience's proprietary software SLIDE 2.0. Nine cross-sections across the preliminary landform have been analysed with this method.

A minimum factor of safety (FoS) of 1.5 for static conditions and 1.1 for dynamic conditions (i.e. potential impacts of earthquakes) have been adopted as design acceptance criteria for this analysis. A summary of the slope stability analysis is presented in **Table 7-3**.

### Table 7-3 Slope Stability Analysis Results

| Cross Section | Scenario | Estimated Static FoS | Estimated Dynamic FoS |
|---|---|---|---|
| U Pit | Planned Final Landform Option – Highwall Side | 1.8 | 1.7 |
| S Pit South | Planned Final Landform Option – Highwall Side | 1.8 | 1.7 |
| | Planned Final Landform Option – Lowwall Side | 1.7 | 1.6 |
| X Pit | Planned Final Landform Option – Highwall Side | 1.8 | 1.7 |
| D Pit | Planned Final Landform Option – Highwall Side | 2.4 | 2.3 |
| | Alternative Final Landform Option – Highwall Side | 3.2 | 2.7 |
| | Alternative Final Highwall Reshaped Final Slope Option – Highwall Side | 1.6 | 1.5 |
| F Pit | Planned Final Landform Option – Highwall Side | 1.9 | 1.8 |
| | Alternative Final Highwall Reshaped Final Slope Option – Highwall Side | 1.8 | 1.7 |
| | Planned Final Landform Out Board Slope | 1.7 | 1.6 |
| | Planned Final Landform Option – Lowwall Side | 2.9 | 2.6 |
| K Pit | Planned Final Landform Option – Highwall Side | 2.5 | 2.4 |
| | Alternative Final Landform Option – Highwall Side | 3.2 | 3.1 |
| | Alternative Final Highwall Reshaped Final Slope Option – Highwall Side | 1.7 | 1.6 |
| J Pit | Planned Final Landform Option – Highwall Side | 1.7 | 1.6 |
| | Planned Final Highwall Reshaped Final Slope - Highwall Side | 1.6 | 1.5 |
| Y Pit | Planned Final Landform Option – Highwall Side | 2.7 | 2.5 |
| | Planned Final Highwall Reshaped Final Slope - Highwall Side | 2.0 | 1.9 |
| Z Pit | Planned Final Landform Option – Highwall Side | 1.8 | 1.7 |
| | Planned Final Highwall Reshaped Final Slope - Highwall Side | 1.6 | 1.5 |

As shown in the above table, all scenarios at all pits were able to meet the minimum FoS for both the static and dynamic conditions.

## 7.3 Erosion Stability

### 7.3.1 Tertiary Highwall

Multiple waste characterisation reports and results have been reviewed for the highwall Tertiary spoil. The magnesium/calcium ratio and the exchangeable sodium percentage soil characterisation results indicate the Tertiary alluvium samples have a greater susceptibility to dispersion and erosion than Quaternary or Permian materials. To address this, standard slopes of 7 degrees have been included for sodic Tertiary materials in the preliminary final landform.

Curragh Project was involved in a rehabilitation trial relating to the impact of vegetative cover and slope on runoff, erosion and water quality for both topsoil and spoil cover material (Carroll *et al*., 2000) over mined spoil within overburden areas. The trial involved a number of topsoil and spoil plots at different slopes with different vegetation covers, the experimental design is shown in **Figure 7-5**.

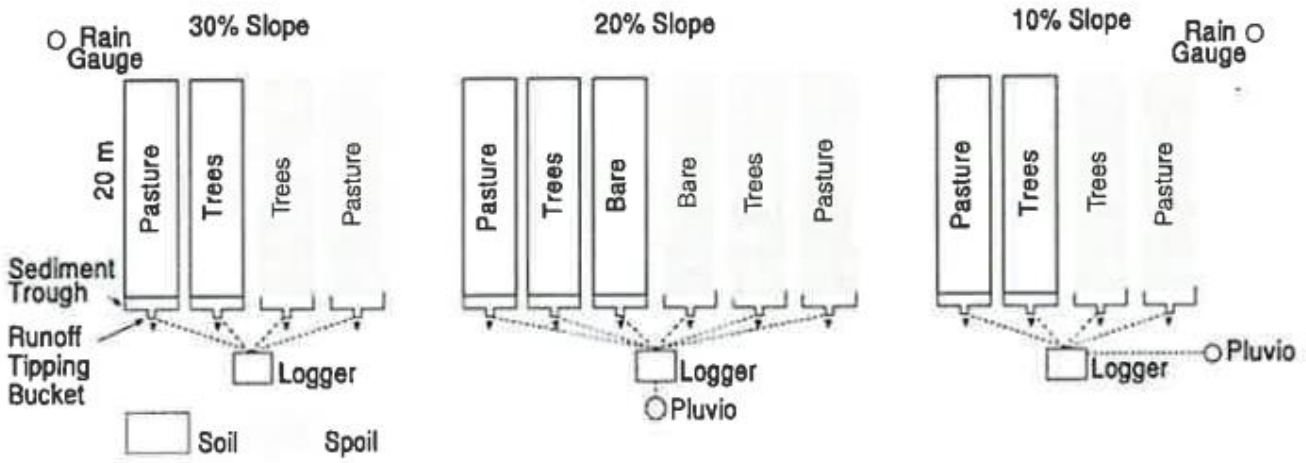



**Figure 7-5 Experimental design (Carroll *et al*., 2000)**

The exchangeable sodium percentage (ESP) for the Curragh soil had a mean of 7 % and the spoil had a mean of 28 %. The chemical characterisation data for the spoil material indicates the spoil is Tertiary spoil rather than Permian. Generally, material with an ESP of > 6 % is considered slightly sodic and dispersive whereas materials < 6 % are considered non-dispersive.

The results of an erosion study on topsoil on tertiary spoil and bare tertiary spoil at Curragh Project are shown in **Figure 7-6**. It is generally considered that 5 t/ha/yr of sediment loss is reasonable for stable vegetated natural landforms. None of the spoil trials were able to achieve a sediment loss of < 5 t/ha/yr across the different scenarios, due to the natural crusting characteristics and presumably low vegetation covers achieved in the Tertiary spoil plots. This suggests that even with vegetation cover dispersive Tertiary spoil without a material cover would be too erosive as a natural landform surface. The pasture on topsoil plots at Curragh showed that over a six year period sediment loss reduced significantly, with all slopes (30 %, 20 % and 10 %) presenting under 5 t/ha/yr in years 5 and 6 indicating that topsoiling Tertiary spoil was an effective method of rehabilitating Tertiary spoil even at steeper slopes.

The rehabilitation trials suggest that vegetating the Tertiary dispersive spoil alone will not be sufficient in reducing erosion and sediment runoff to an appropriate level. The application of topsoil and pasture seed as a cover for the dispersive spoil appears, from the trials, to reduce the sediment loss to an appropriate rate. Another option which is not included in the rehabilitation trial would be to apply a non-dispersive spoil as a rock mulch on the dispersive spoil and seed the area with native trees and shrubs.

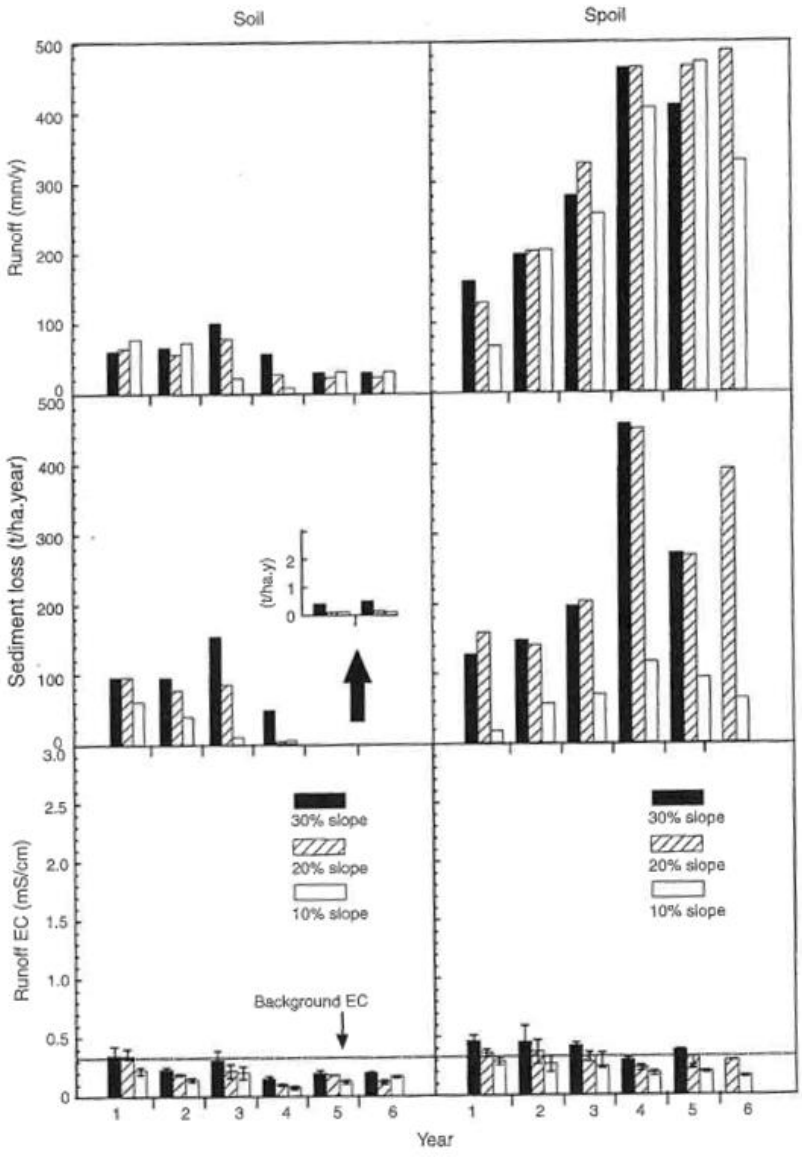



**Figure 7-6 Curragh annual runoff, sediment loss, and average runoff EC (with standard error) for soil and spoil pasture plots on 10, 20 and 30% slope over six years**

### 7.3.2 Stable Embankment

As stated above, the preliminary stable embankment design was based on the B Pit tailings embankment design by Golders (2017). The preliminary stable embankment design was formulated with the intent to test the structure height against the flood modelling extent and depth. Flood modelling of the conservative 0.1% AEP event has been completed including flood depths and velocities. These velocities will have to be tested against the material of the stable embankment and the proposed slope angle of 19 degrees.

It is likely that this slope will have to be reviewed due to some of the velocities modelled and that erosion protection for the embankment is further investigated. A potential option for enhancing the erosional stability of the embankment could be rock armouring.

## 7.4 Rehabilitation Method Options

### 7.4.1 Highwall Rehabilitation Strategies

The ACARP study undertaken by PW Baker & Assoc. Pty Ltd (2006) identifies 11 rehabilitation strategies for highwalls. SLR have identified Strategy 3, 5 and 6 as being relevant to the preliminary final landform and alternative highwall options at Curragh Project.

Strategy 5 represents the landform design where the geology is stable and a factor of safety >1.5 is achievable with the highwall left mostly as is. Strategy 3 represents the landform design for faulted ground where there is the potential for failures and therefore in order to meet a factor of safety >1.5 the slopes must be battered. Strategy 5 most closely aligns with the preliminary landform design option in un-faulted ground and leaves the Permian highwall generally as is with an average angle of 65 degrees and 7 degrees in the Tertiary. Strategy 5 includes leaving the Permian highwall as is and laying back the Tertiary to 30% (16.7 degrees) slope, cover with 2 m of Permian material, topsoil and seed (**Figure 7-7**). In all landform scenarios assessed for Curragh Project the Tertiary highwall is shaped to a slope of 7 degrees. It's uncertain at this stage what cover and vegetation will be applied to the Tertiary spoil, however the option presented in Strategy 5 could be a consideration pending cost and material availability.

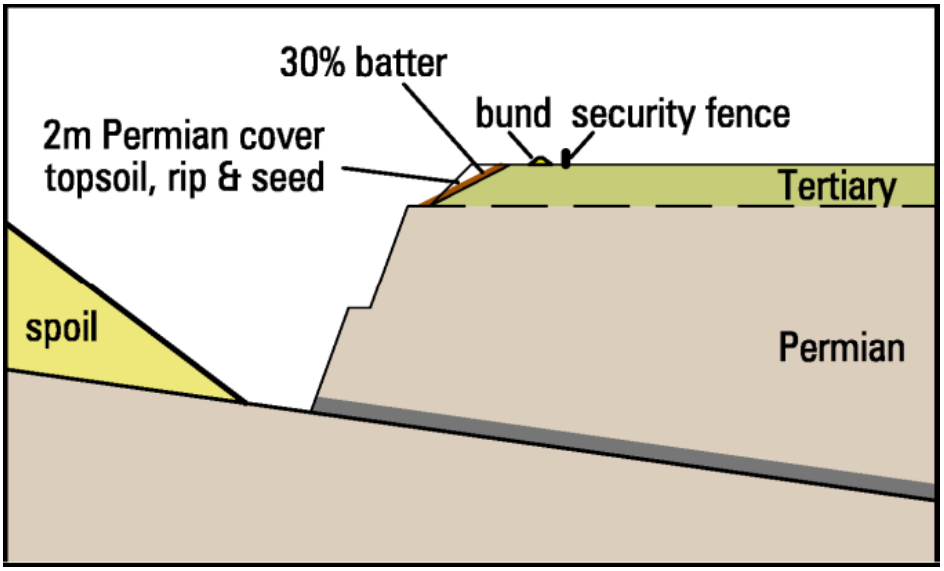



**Figure 7-7 Strategy 5 (PW Baker & Assoc. Pty Ltd, 2006)**

Strategy 3 has been used as a basis for the residual void landform design at Curragh Project in faulted ground with an overall angle of 22 degrees in the Permian and 7 degrees in the Tertiary (in some pits this is the planned landform and in others it's an alternative landform). Strategy 3 involves throw blasting the Permian and Tertiary highwall to the toe of the residual void, then aerial seeding and fertiliser (**Figure 7-8**). A bund and fencing are included in all three strategies identified. This methodology reduces the risk of highwall failure and there is the potential for vegetation growth on the blasted highwall but the surface area of the highwall is increased.

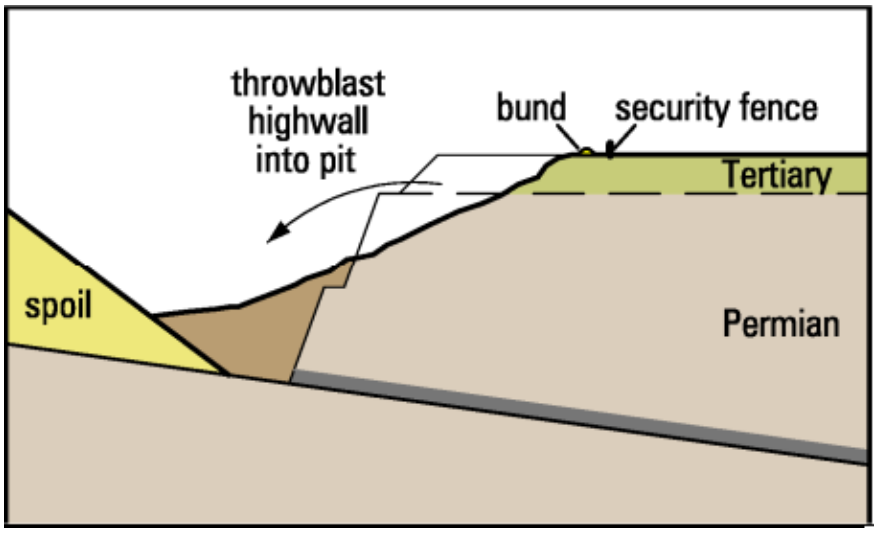



**Figure 7-8 Strategy 3 (PW Baker & Assoc. Pty Ltd, 2006)**

## 7.5 Conclusions and Recommendations

The Slope Stability Analysis has shown that in all scenarios tested the factor of safety was above the accepted design criteria and therefore considered structurally safe. While some rehabilitation trials and other site and regional studies have been undertaken on erosion, further work is required to confirm the proposed landform slopes for the Tertiary highwall and stable embankment.

The following recommendations are made in relation to finalising the post-mining landform:

- The construction of the final landform designs, including cut-fill volumes, are to be reviewed and developed;
- An erosional assessment is necessary to confirm the maximum slope angles for the various soil strength materials (including spoil materials). The final landform designs, and if deemed necessary the slope stability analysis, are to be updated based on the outcomes of the erosion assessment;
- Further assess the cover options of topsoil and non-dispersive spoil cover on the Tertiary material including material availability, effectiveness and potential land uses of the area;
- Geological, geotechnical and hydrogeological data collection programs for the final pitwalls are to be developed and implemented to inform the detailed design process;
- The hydrogeological and hydrological models should be developed, and an associated groundwater investigation program implemented;
- Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels in the alluvial soil profile;
- As the final landform designs are progressed, and additional geological, geotechnical, hydrogeological and/or hydrological data is obtained, more detailed and extensive slope stability analysis may be required. This should include assessment of all slope geometries, remnant pitwalls and final voids. It is recommended that detailed design include probabilistic slope stability analysis;
- Review the embankment design, material and cover based on the results of the flood modelling; and
- Confirm the rehabilitation methodology for the final landform design.

# 8 Residual Void Outcomes and Criteria

## 8.1 Residual Void Constraints

When considering the final land outcomes for residual voids any regulatory, physical, chemical and economic constraints should be considered.

An objective of this CRVA update is to have this document accepted as a LOD and therefore have the residual void outcomes in this document transitioned into the PRCP without further assessment or restriction. The EP Act states that final voids on floodplains are prohibited and therefore must have a post-mining land use. This restriction does not apply to LODs and therefore SLR has proceeded with the assumption that the residual voids at Curragh Project may be left on a floodplain with best practices in place to prevent flood water ingress.

The residual void water balance modelling showed that all residual voids at Curragh Project have a highly saline water quality after only 30 years (>30,000 µS/cm). There are certain aquatic species that are able to habitat water of this salinity (such as Bony Bream, Rainbows, algal species) but other uses such as stock or irrigation are not suitable.

The slopes of the Permian highwalls in the preliminary final landform have a slope between 22 and 63 degrees depending on the geological stability. The landform will consist of interconnecting benches which is relatively safe to humans, stock and native fauna. As mentioned in **section 6.2.1** of this report, there is a significant space from the top of the highwall to the waterbody and SLR is recommending the installation of bunds, fencing and signage to prevent access to the steeper highwalls.

This report has focussed on the environmental and regulatory constraints of residual voids but it should also be mentioned that there is also an economic constraint for the final land outcomes of residual voids.

## 8.2 Residual Void Outcomes

The PRCP framework has two categories of final land outcomes: (1) post-mining land use (PMLU) or (2) non-use management area (NUMA). A NUMA is an area of land that cannot be rehabilitated to a stable condition after all activities have ended. The definition of stable condition is outlined in section 111A of the EP Act as:

> *Land is in a stable condition if-*
>
> *a) the land is safe and structurally stable; and*
>
> *b) there is no environmental harm being caused by anything on or in the land; and*
>
> *c) the land can sustain a post-mining land use.*

A post-mining land use is defined in the EP Act as the purpose for which land will be used after all activities have ended.

The residual void objectives in **section 3.1** of this report include safe and structurally stable and does not cause serious environmental harm except for the existence of the void itself. Therefore, the determining factor as to whether the residual voids can meet stable condition is whether the land can sustain a PMLU.

As mentioned above, the void water quality is not appropriate for stock watering or irrigation but may be appropriate for some aquatic species. The suitability of void water for aquatic habitat requires further investigation in order to confirm the feasibility of this use. Given the potential safety hazard of the highwall and water storage which will be restricted by the installation of fencing and signage, this rehabilitation strategy does not support a PMLU.

The void low wall, Tertiary highwall and stable embankment are all at appropriate slope angles to be considered safe and stable and therefore likely able to sustain a PMLU consistent with the surrounding area. While further erosion work is required to confirm that the stable embankment and Tertiary highwall will have an acceptable level of erosion, this will be reviewed as part of the PRCP.

Therefore, it is SLRs recommendation that the Permian Highwall and maximum void water level be considered as a NUMA and the void low wall have a PMLU of light grazing and open woodland, as shown in **Figure 8-1** and **Figure 8-2**. Given that the low wall, Tertiary highwall and stable embankment are considered able to achieve a PMLU, the criteria and further land outcomes and objectives for these areas is contained within the Rehabilitation Monitoring and Management Plan.

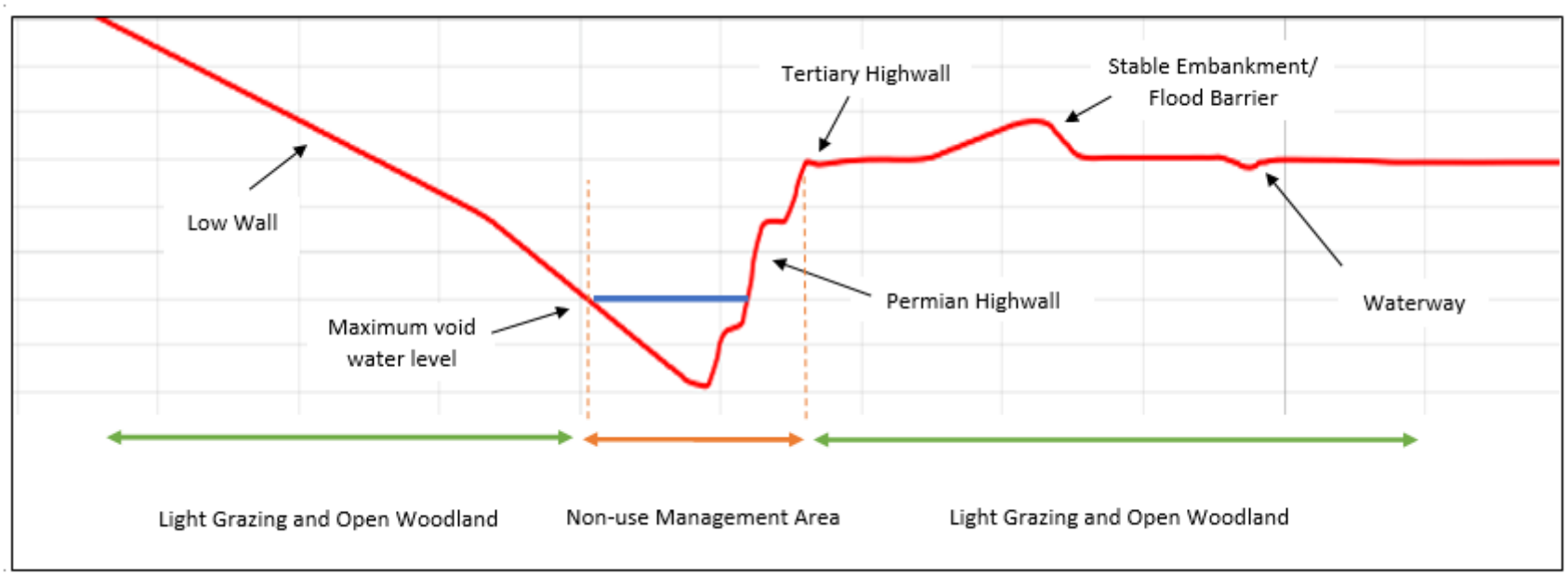



**Figure 8-1 Conceptual Residual Void Cross Section with Land Outcomes**

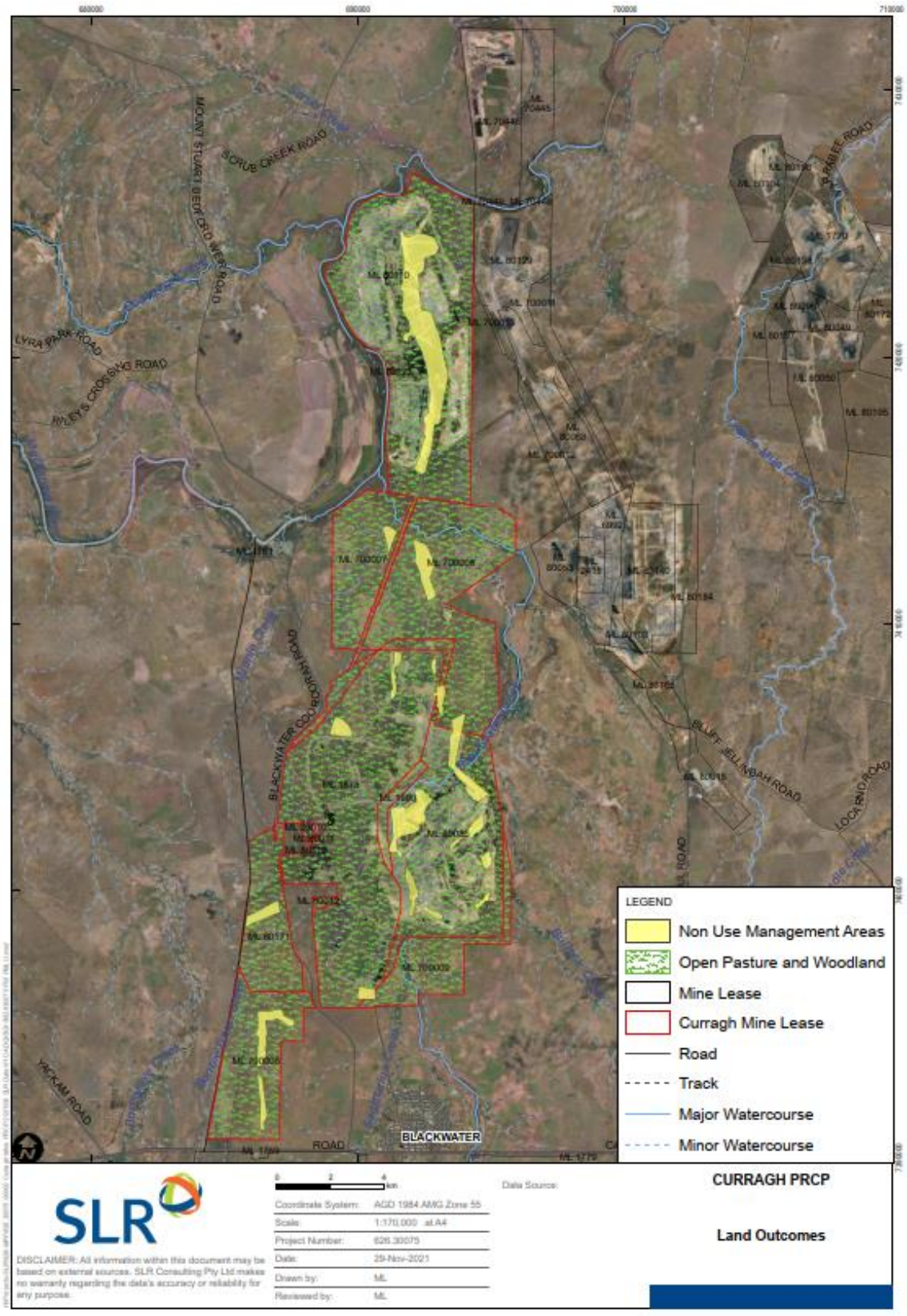



**Figure 8-2 Curragh Project Proposed Land Outcomes**

## 8.3 Non-use Management Areas

Based on the above technical information and assessment, the Curragh Project will have proposed NUMAs. SLR has attempted to reduce the extent of NUMA and maximise the area with a proposed PMLU by only including the maximum void water level and the highwall. It should be noted that the below areas and locations are based on the preliminary landform design which is subject to change before the PRCP is submitted.

The preliminary NUMAs for the whole Curragh Project are detailed in **Table 8-1**.

**Table 8-1 Preliminary NUMA Areas**

| Pit | NUMA Area (ha) | NUMA Average Depth (m) |
|---|---|---|
| Pit S, T and U | 637 | 26 |
| Pit D and F | 202 | 63 - 113 |
| Pit G, H and I | 259 | 83 |
| Pit L | 19 | 105 |
| Pit K | 13 | 79 |
| Ramp 9 | 40 | 91 |
| Pit J | 28 | 132 |
| Pit X | 125 | 69 |
| Pit Y | 48 | 131 |
| Pit Z | 128 | 115 |

## 8.4 NUMA Criteria

SLR have developed completion criteria for the proposed NUMAs (**Table 8-2**) using the technical studies undertaken and detailed above. It should be noted that this criterion is only applicable to the Permian Highwall and maximum void water level. The void low wall, Tertiary highwall and embankment have criteria outlined in the RMMP.

**Table 8-2 NUMA Criteria**

| Objective | Criteria | Justification |
|---|---|---|
| Safe for humans, livestock and native fauna | Static Factor of Safety >1.5<br>Dynamic Factor of Safety >1.1 | Factor of safety design criteria is recommended in the Geotechnical Report (**Appendix D**). |
| | Certification from an appropriately qualified person that the residual void is safe to humans and livestock | Example from PRCP Guideline. |
| | Installation of fencing and signage where required. | The installation of fencing and signage would be confirmed in the PRCP once the final landform has been finalised. |
| Geotechnically and erosionally stable | The final landform does not form rill erosion of >30 cm. | This is a standard criteria for demonstrating erosional stability. |

| Objective | Criteria | Justification |
|---|---|---|
| | Permian highwalls battered to a geotechnically stable slope. | As recommended in Geotechnical Report. Where fault related rock mass shearing and/or adversely orientated structures are interpreted or inferred final walls may have to be constructed as softwalls at 22 degrees. |
| | Certification from an appropriately qualified person that the residual void is geotechnically and erosionally stable. | Example from PRCP Guideline. |
| Does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself | Construction of a stable, long-term embankment which prevents the ingress of flood water into the residual voids. | The embankment will protect the voids from interacting with the floodplain. The Flood Model Report in **Appendix A** provides the minimum height for the embankment based on very conservative flood modelling. This height may be reviewed based on more detailed flood modelling recommended as part of the PRCP. |
| | Saline void water will not spill or seep into the surrounding environment at a concentration that will cause environmental harm. | The void water balance modelling shows that the voids are highly unlikely to spill. Groundwater modelling demonstrates that the voids are likely to act as sinks and not contaminate the surrounding environment. |
| | Certification from an appropriately qualified person that the residual void does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself. | Similar example from PRCP Guideline. |

### 8.4.1 Minimisation of Residual Void Area

**Table 8-3** shows a comparison of the 2012 proposed residual voids and the 2021 preliminary NUMA areas. This shows that the area which could be interpreted as a NUMA in the PRCP has been reduced in this version of the CRVA. This was achieved by reviewing the parameters of what is considered a 'NUMA' and optimising the PMLU for the low wall and Tertiary highwall.

### Table 8-3 Residual Voids / NUMA Areas 2012 vs 2021

| Domain | 2012 CRVA Residual Void Area (ha) | 2021 CRVA NUMA Area (ha) |
|---|---|---|
| Curragh Main | 1,096 | 561 |
| Curragh North | 646 | 637 |
| Pit X | - | 125 |
| Pit Y | - | 48 |
| Pit Z | - | 128 |
| **Total** | **1,742** | **1,499** |

# 9 Conclusions and Recommendations

This report has reviewed the proposed residual voids as presented in the preliminary final landform design provided by CCPL. The CRVA has been updated to include additional EA approved voids located in the Curragh extension leases (Pits X, Y and Z) and the updated residual void location for existing voids. The intent of this CRVA is to be approved as a Land Outcome Document with the purpose of transitioning the residual void land outcomes in this report to the PRCP.

This report includes a flood assessment, groundwater assessment, void water balance and geotechnical stability analysis of the proposed preliminary landform. The intent of these studies was to provide input into the preliminary landform design which can then be updated and improved upon for the PRCP submission.

The CRVA established four key objectives for residual voids which are outlined below.

1. *Safe for humans, livestock and native fauna.*

The final highwall landform for all voids, as well as optional alternative landforms, were assessed for slope stability. All landforms assessed had a factor of safety above the adopted design criteria, >1.5 for static conditions and >1.1 for dynamic conditions. This means that there is an acceptable factor of safety for the highwalls.

The residual void WBM found that there was a significant space between the top of the highwall and the long-term water level which may indicate that the water is not easily accessible and therefore may not be safe for human and/or animal interaction. To address this SLR has proposed that the installation of fencing and signage should be considered, and the extent required confirmed in the PRCP.

2. *Geotechnically and erosionally stable.*

The slope stability analysis using the factor of safety can also be used for assessing the geotechnical stability of the final landform. All landforms assessed had a factor of safety above the adopted design criteria, >1.5 for static conditions and >1.1 for dynamic conditions; hence, all landforms are considered geotechnically stable.

Erosion trials have been undertaken at Curragh Project previously for Tertiary spoil. These trials and literature have been reviewed and considered in the erosion assessment of the landform. Further work is required in order to confirm the proposed final landform now that results from the floodplain modelling have been provided.

3. *Does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself.*

The residual void water balance model was used to determine residual void water levels and water quality. The 99$^{th}$ percentile water levels predicted for all voids were well under the spill level; and therefore, the high salinity water contained within the residual voids is unlikely to spill into the surrounding environment.

The groundwater assessment showed that the residual voids are likely to act as sinks and therefore not seep into the surrounding environment.

4. *The extent of residual voids is minimised as much as practicable.*

The extent of the residual voids from the 2012 version of this document has been significantly reduced, by approximately 300 ha, even though this assessment includes an additional five pits. The reduction in residual void classified as NUMA has been achieved by proposing a PMLU for the void low wall and Tertiary highwall.

SLR recommends that the Permian highwall and maximum void water level extent have a land outcome of NUMA. This is due to the safety hazards presented by these areas and hence the exclusion which constrains any potential use. It is acknowledged that further work is required for the PRCP submission; however, the preliminary information presented in this assessment is considered sufficient for the land outcome decision. It is recommended that the proposed residual void land outcomes and criteria presented in this report be transitioned into the PRCP where appropriate.

# 10 References

Carroll et al., 2000, Impact of vegetative cover and slope on runoff, erosion, and water quality for field plots on a range of soil and spoil materials on central Queensland coal mines, Aust. J. Soil Res., 38, 313-327

Golders, 2017, B Pit Tailings Storage Facility Design Plan

Parsons Brinkerhoff (PB), 2016, Curragh Extension Project – Groundwater Technical Report (2172652H-WAT-REP-002 RevB)

PW Baker & Assoc. Pty Ltd, 2006, Rehabilitation of Highwalls, ACARP Report C14048

# APPENDIX A

# FLOOD MODEL REPORT

# CURRAGH MINE

## Conceptual Residual Void Assessment
## Preliminary Flood Impact

**Prepared for:**

Coronado Curragh Pty Ltd
Blackwater, QLD, 4717

**SLR Ref: 626.30075-R01**
**Version No: -v1.0**
**November 2021**

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# BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

# DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
|---|---|---|---|---|
| 626.30075-R01-v1.0 | 27 November 2021 | Nicole Bichel | Michael Della | Emma Williams |
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# 1 Introduction

## 1.1 Scope of Work

SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to undertake floodplain modelling of the floodplain surrounding the Curragh Complex. The modelling was undertaken to assist in determining the stability and flood immunity requirements of the proposed residual voids.

Due to the preliminary nature of the assessment, a conservative approach to determining maximum flood levels for the 0.1% Annual Exceedance Probability (AEP) was taken. The key tasks carried out were:

- Estimate the maximum peak flows on the relevant tributaries in the site using flood frequency analysis (FFA);
- Develop a hydraulic model for the purpose of identifying flood risk posed to the proposed voids for 0.1% AEP flood event and developing final landform condition, based on available terrain data; and
- Produce a report detailing the methodology and findings of the above assessments, including all relevant mapping of flood extents, levels, and depths in relation to the proposed residual voids and long-term stable embankments.

## 1.2 Project Information

The mine is an open cut coal mine located in the Bowen Basin, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton in Central Queensland. The Curragh Complex has been operating since 1983 and covers an area of approximately 19,650 ha. The project location is illustrated in **Figure 1**.

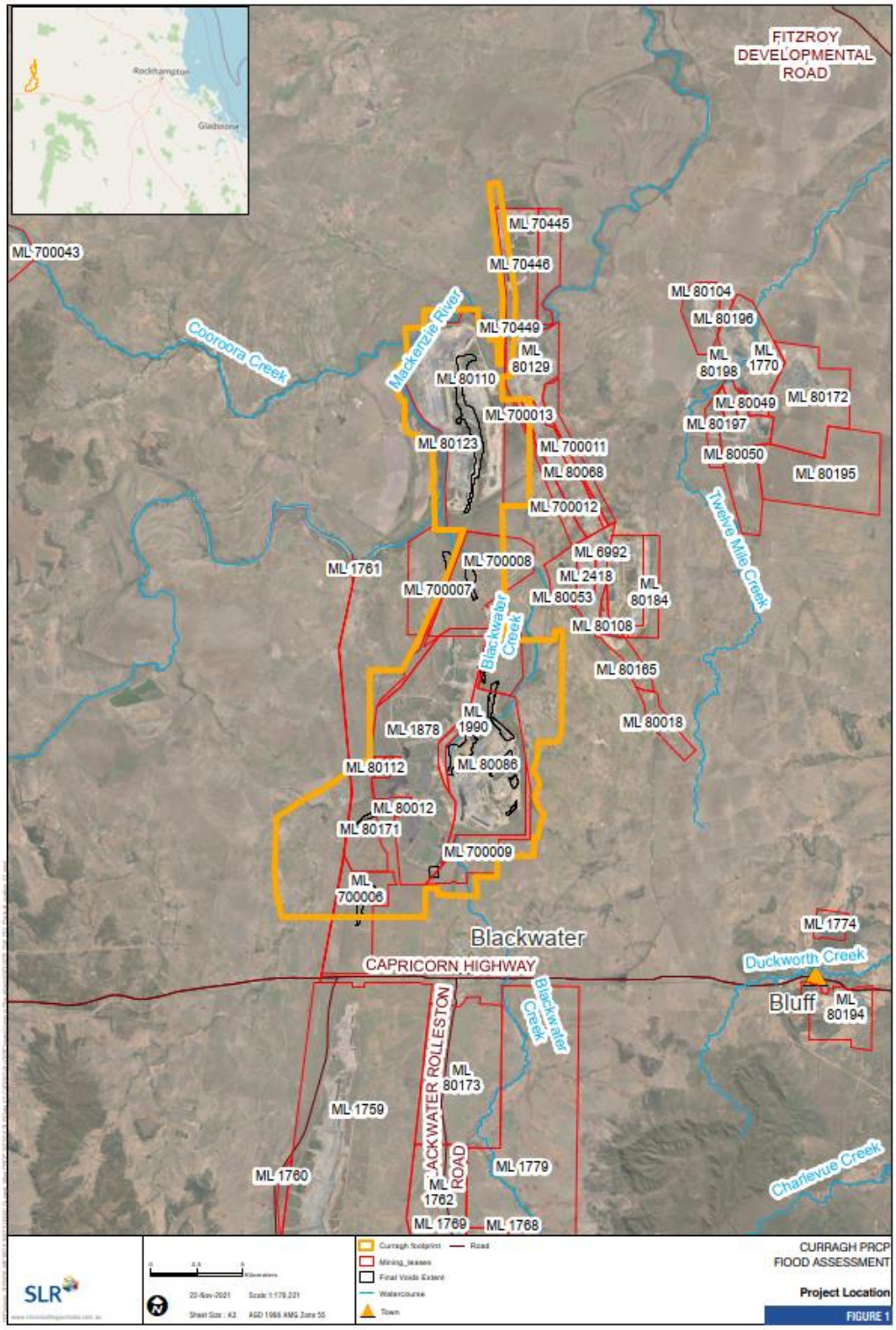



**Figure 1. Project Location**

## 1.3 Relevant Documentation

This assessment was undertaken cognisant of the following guidelines and documentation:

- *Environmental Protection Act 1994*;
- Environmental Protection Regulation 2019;
- 'Guideline – Progressive Rehabilitation and Closure Plans', Department of Environment and Science, March 2021 (PRCP Guideline);
- 'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains', Department of Environment and Science, March 2020 (Voids in Flood Plains Information Sheet); and
- 'Australian Rainfall and Runoff (2019)' (ARR).

The assessment undertaken is preliminary in nature due to the immaturity of the residual void design surface. This assessment is focused on quantifying the flood risk to enable to appropriate assessments to be carried out for the Progressive Rehabilitation and Closure Plan (PRCP) in the future. As such, in accordance with the guidelines stated above, the flood assessment has been undertaken for the residual void landform only to understand the flood risk and stability of the landform. No assessment of the pre-mining landform has been carried out. Further details pertaining to the limitations of the assessment are provided in Section 1.4 of this report.

## 1.4 Assumptions and Limitations

This flood assessment has relied upon information which was received from the client and other sources. SLR has assumed that information provided is accurate and ,except where noted, SLR has not verified the accuracy of the information provided.

This report has been prepared for the purposes of gaining a preliminary understanding of the magnitude of a 0.1% AEP flood event for the relevant watercourse which impacts on the Curragh Complex. The intent of the assessment is to understand the extent that a long-term stable embankment would be required to protect the nominated residual voids from flood influx. As such, a level of conservatism has been built into the model, primarily through adoption of the most conservative flow estimate derived by the FFA and lack of creek and waterway definition. This results in a conservative volume of floodwater being conveyed on the floodplain rather than within the waterway banks, providing an overall conservative estimate of flood levels.

- The flood model has been developed based on inflows derived through a FFA approach. Numerous gauges were used along the Mackenzie River and its tributaries. The assessment shows a lack of convergence in the results. Specifically, the FFA showed estimates of the 0.1% AEP event at each gauge could vary by an order of magnitude. It is thought that this could be due to factors such as floodplain storage, artificial features such as dams and levees, short record lengths and gauge rating curve accuracy. Therefore, the most conservative flow estimate has been adopted. Detailed assessment into the estimate of a 0.1% AEP event for the catchment will be required prior to presentation of results in the PRCP.

- Flow estimates have been applied to the hydraulic model as a steady state inflow. This is a conservative approach as the effects of floodplain storage are removed. The flow estimates were applied as inflows into the model until inflows and outflows were equal.

- Flow estimates for tributaries of the Mackenzie River, such as Blackwater Creek, has been determined through a FFA on donor gauges scaled to the applicable catchment area. As above, the most conservative assessment was applied however this will need to be investigated further prior to understanding flood modelling for the PRCP.

- No assessment of coincident flooding between the Mackenzie River and other tributaries was carried out. Although in reality, flood peaks in Blackwater Creek could potentially occur at a different time to the peak in the Mackenzie River, it was assumed that the flood peak occurred at the same time, providing a conservative approach to estimate the peak water levels.

- The hydraulic model has been largely based on SRTM data due to the limited extent of available Lidar. SRTM data for the site has a vertical accuracy of +/-5-10m. Hydro-enforced SRTM was not used due to the inaccurate representation of waterway cross-sectional area when compared to available LiDAR data. A terrain surface was developed using the residual void landform, 1m Lidar and SRTM with some connectivity along the Mackenzie River provided through the use of artificial terrain manipulation.

- No artificial devices such as weirs were modelled in the hydraulic model.

- No bathymetric data for Mackenzie River was available and therefore not incorporated in the model.

- All roughness values were determined by review of aerial photography. No site visit or verification of the assessment was carried out.

- No infrastructure such as bridges or the like were included in the hydraulic model.

A more refined assessment of the flood impact will be required prior to submission of the PRCP to meet the data and modelling requirements outlined in the PRCP guideline.

This report should be read in full and no excerpts are to be taken as representative of the findings. This report has been prepared on behalf of CCPL and we accept no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

## 1.5 Definitions and Terminology

The following definitions and abbreviations apply to the report.

**Table 1 Report Definitions**

| Term | Definition |
|---|---|
| Annual Exceedance Probability (AEP) | The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a flood level of 3.5 mAHD has an AEP of 1% or 1 in 100 (or 1:100), it means that there is a 1% chance (i.e., a 1 in 100 chance) of a flood level of 3.5 mAHD (or larger) occurring in any one year<br>(see also average recurrence interval). |
| Australian Height Datum (AHD) | National survey datum corresponding approximately to mean sea level. |

| Term | Definition |
|---|---|
| Average Recurrence Interval (ARI) | The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. ARI is another way of expressing the likelihood of occurrence of a flood event (see also annual exceedance probability). |
| Catchment | The catchment at a particular point is the area of land that drains to that point. |
| Design flood | A hypothetical flood representing a specific likelihood of occurrence (for example the 1% AEP probability flood). |
| Discharge | The rate of flow of water measured in terms of volume over time (i.e., the amount of water moving past a point). Discharge and flow are interchangeable. |
| DEM | Digital Elevation Model – a three-dimensional model of the ground surface. |
| Flood | Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences. |
| Flood Frequency Analysis | An analysis of historical flood records to determine estimates of design flood flows. |
| Floodplain | Land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood (PMF) event. |
| Flood Storage | Floodplain areas that are important for the temporary storage of floodwaters during a flood |
| Floodway | A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood. |
| Historical Flood | A flood which has occurred in the past. |
| Hydrograph | A graph showing how a river or creek's discharge or water level changes with time. |
| Hydrology | The term given to the study of the rainfall-runoff process in catchments. |
| Levee | Operational mine protection device. |
| Long-term stable embankment | Landform feature which may protect residual voids from flood ingress, is not a regulated structure. |
| Peak flood level, flow or velocity | The maximum flood level, flow or velocity occurring during a flood event at a particular location. |
| Pit | Operational open cut mine pit/void |
| Probability | A statistical measure of the likely frequency or occurrence of flooding |
| Residual void | Post closure landform design term. |
| Runoff | The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek. |
| Velocity | The speed at which floodwater are moving. |
| Water level | Same as flood level. |

**Table 2 Report Abbreviations**

| Abbreviation | Term |
|---|---|
| 1D/2D | One dimensional / two dimensional |
| AEP | Annual Exceedance Probability |
| AHD | Australian Height Datum |
| ARI | Average Recurrence Interval |
| ARR2019 | Australian Rainfall and Runoff 2019 |
| BoM | Bureau of Meteorology |
| CCPL | Coronado Curragh Pty Ltd |
| CRVA | Concept Residual Void Assessment |
| Curragh Complex | Curragh Mine Complex "the mine" |
| DEM | Digital Elevation Model |
| km | Kilometres |
| $m^3/s$ | Cubic Metres per second |
| mAHD | Elevation in metres relative to the Australian Height Datum |

# 2 Available Data

The following data was supplied or accessed for development of the hydraulic model.

- Residual void landform (supplied as 0.5m contours);
- 1m LiDAR provided as x,y,z points;
- Shuttle Radar Topography Mission (SRTM) terrain data – sourced from Geoscience Australia for the hydraulic model extent where LiDAR wasn't available; and
- Aerial photography was sourced from Queensland Globe and was used to determine roughness of land uses within the floodplain extent.

# 3 Hydrologic Assessment

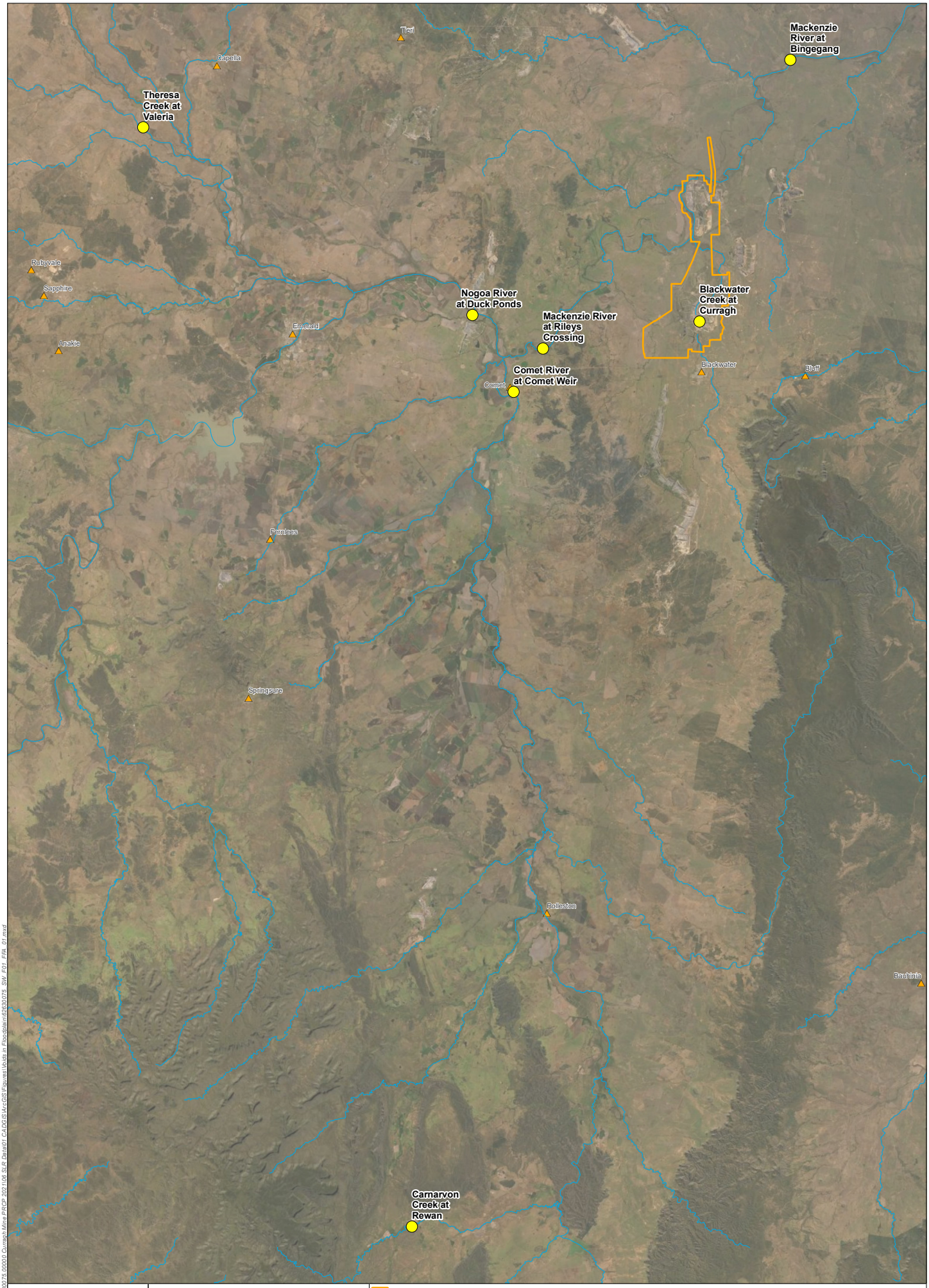
## 3.1 Stream Gauges

A hydrologic assessment was undertaken to provide flow estimates to the hydraulic model. The aim is to estimate the maximum peak flows for 0.1% AEP flood event of various watercourses in relation to the proposed voids. To achieve this, a flood frequency analysis was undertaken using recorded streamflow data sourced from the Department of Regional Development, Manufacturing and Water (DRDMW). Both the 1% and 0.1% AEP maximum peak flows are presented below, although this assessment utilised the 0.1% AEP event only.

There are no flow gauges in the immediate vicinity of the Curragh Complex. However, there are several current and historic gauges in the wider catchment. The gauges used in the assessment are provided below in Table 3 and have been used to estimate the maximum peak flows in the area of interest. Locations of the gauges are provided in Figure 2.

**Table 3. Flood Frequency Analysis Locations within the Fitzroy Catchment**

| Site Name | Site No. | Years of Record | Catchment Area ($km^2$) |
|---|---|---|---|
| Mackenzie River at Bingegang | 130106A | 50 | 50,860 |
| Mackenzie River at Riley's Crossing | 130113A | 17 | 45,040 |
| Nogoa River at Duck Ponds | 130219A | 26 | 27,130 |
| Comet River at Comet Weir | 130501A & 130504A/B | 99 | 16,460 |
| Blackwater Creek at Curragh (Historic 1973-2009) | 130108A & 130108B | 37 | 777 |
| Theresa Creek at Valeria | 130210A | 50 | 4,421 |
| Carnarvon Creek at Rewan | 130509A | 36 | 351 |




SLR
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0 2.5 5
Kilometers

30-Nov-2021 Scale: 1:620,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Curragh footprint
Watercourse
Town
Gauge Locations

CURRAGH
PRELIMINARY FIOOD ASSESSMENT
**FFA Sites**

**FIGURE 2**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CADGIS\ArcGIS\Figures\Data in Floodplain\626.30075_SW_F01_FFA_01.mxd

The two gauges on the Mackenzie River were selected for the analysis, being Mackenzie River at Rileys Crossing (130113A) and Mackenzie River at Bingegang (130106A).

The Bingegang site is located approximately 44 km north-west of Curragh Mine and has an upstream catchment area of 50,860 km$^2$ and has a continuous streamflow record of 50 years commencing in 1971. The Mackenzie River at Rileys Crossing is located approximately 75 km upstream of Bingegang and less than 30 km west of Currah Mine. The gauge has an upstream catchment area of 45,040 km$^2$ and has a continuous streamflow record of 17 years commencing in 2004.

Mackenzie River flows have also been continuously recorded at Nogoa River at Duck Ponds since 1993. This site has a catchment area of 27,130 km² and includes Lake Maraboon and Fairbairn Dam, which was completed in 1972. Fairbairn Dam has a significant impact on the flood response of the Mackenzie River (WRM, 2018) and therefore all observed flows from the gauge are representative of the impact Fairburn Dam has on reducing peak flood flows downstream.

The Comet River at Comet Weir gauge is 35 km south-west of Curragh Mine with a catchment area of 16,460 km$^2$. The current streamflow record commenced in 2002 providing 19 years of data. Two historic sites are also located in a proximal location. The historic Comet Weir site operated between 1919 and 1973, with the Comet Weir Inflow site between 1971 and 1994. Although this latter site has a catchment area of 40 km² less than the other two sites, the annual flood maxima for overlapping periods is similar. As such, these three records have been combined for this flood frequency assessment. It should be noted, however, that this site can be affected by backwater from the Mackenzie River (WRM, 2018)

Two gauges on Blackwater Creek were located toward the southern end of Curragh Mine, prior to the Creek's diversion around the eastern side of the mine. Combined, these two gauges provide a continuous streamflow record of 37 years with an upstream catchment area of 777 km².

The Theresa Creek gauge is approximately 100 km to the north-west of Curragh Mine. The continuous streamflow record for this site commenced in 1971 (50 years), with a gap in the record between February 2001 and February 2003. With these three years excluded, a total of 47 years of data was available for use from the Theresa Creek gauge.

The Carnarvon Creek gauge is located 170 km south-east of Curragh Mine. The streamflow record for this site has 36 years of data (commencing 1985). This is also the smallest catchment used in the assessment (351 km$^2$).

## 3.2 Flood Frequency Analysis

A frequency analysis was undertaken of the annual flood maxima series for each gauge. Three types of statistical distribution (Gumbel, Log Pearson III (LP3) and GEV) are assessed for how well they modelled the annual flood maxima series. As is standard practice, the frequency analyses are performed on a 12-month water year commencing 1 October, such that only the largest flood in each complete year was plotted, and the most appropriate statistical distribution was fitted to those annual values. The results of the FFA are shown in Appendix A.

For all gauges, a LP3 flood frequency distribution provided the best fit to the annual maximum data series. For each gauge, low flow outliers and incomplete years were excluded from the data series using the Grubbs Beck Test method prior to fitting the distribution.

It was assumed that any additional missing data have no significant effect on the results of the analysis. It should be noted that no additional quality control has been undertaken on these data specific to this project.

The 1% AEP and 0.1% AEP flows for each catchment are presented in **Table 4**. The Mackenzie River at Rileys Crossing gauge has a relatively short record (<20 years) which is generally not considered sufficient to derive 1% AEP and 0.1% AEP design events, as evident by the significantly over-estimated design flows at this site (**Table 4**). Consequently, the Rileys Crossing site is not used for any further analysis.

For comparison, 1% AEP Quantile Regression estimates have also been determined. These are significantly different to those derived from the flood frequency assessment, partly due to the Quantile Regression approach not explicitly accounting for the attenuating effects of large storage dams in the catchments.

**Table 4. Flood Frequency Assessment and Quantile Regression (QR) Estimates**

| Site Name | Site No. | Quantile Regression (QR) | Regional Flood Frequency Method (RFFE) | Flood Frequency Analysis (FFA) | |
|---|---|---|---|---|---|
| | | 1 in 100 AEP (cumecs) | 1 in 100 AEP (cumecs) | 1 in 100 AEP (cumecs) | 1 in 1000 AEP (cumecs) |
| Mackenzie River at Bingegang | 130106A | 27,665 | 27,800 | 12,777 | 54,393 |
| Mackenzie River at Rileys Crossing | 130113A | 22,853 | 11,200 | 29,870 | 263,559 |
| Nogoa River at Duck Ponds | 130219A | 16,805 | 8,310 | 9,040 | 36,412 |
| Comet River at Comet Weir | 130501A & 130504B | 12,066 | 6,080 | 4,138 | 8,750 |
| Blackwater Creek at Curragh (Historic 1973-2009) | 130108A & 130108B | 1,616 | 809 | 824 | 1,391 |
| Theresa Creek at Valeria | 130210A | 5,408 | 1,340 | 4,508 | 12,690 |
| Carnarvon Creek at Rewan | 130509A | 1,123 | 2,960 | 855 | 1,358 |

## 3.3 Area scaling of flood flows for ungauged catchments

To understand the flood flows that may be experienced in the immediate vicinity of the Curragh Complex, an assessment of flows for ungauged creeks was also required. Blackwater Creek flows through the Curragh Mine, its confluence with Minnie Creek just to the north before it discharges to the Mackenzie River. Adjacent to the Blackwater Creek catchment is Burngrove Creek to the west. Both are considered here for understanding the potential peak flows that may be experienced at Curragh Mine.

There are no flow records for Burngrove Creek or Minnie Creek, and the combined flow record for Blackwater Creek ended in 2009. This means that some significant flow events are not recorded; namely the event in 2011. Donor gauges were investigated based on similar catchment area and topography and proximity to the mine. Carnarvon Creek at Rewan and Theresa Creek at Valeria in addition to the Blackwater gauge were investigated for use. These two sites were chosen because they provide relatively long records (36 and 47 years respectively), and their catchment areas are comparable to the catchment areas of the tributaries around Curragh Mine.

For these three sites, design flows were estimated by scaling the Carnarvon Creek at Rewan and Theresa Creek at Valeria records as a function of area and the outputs compared. The results of the FFA scaling factors and resultant scaled flows are provided below in **Table 5, Table 6** and **Table 7.**

**Table 5. Estimated design flows for Blackwater Creek and donor gauges.**

| Site Name | Site No. | Quantile Regression (QR) | Regional Flood Frequency Method (RFFE) | Flood Frequency Analysis (FFA) | |
|---|---|---|---|---|---|
| | | 1 in 100 AEP (cumecs) | 1 in 100 AEP (cumecs) | 1 in 100 AEP (cumecs) | 1 in 1000 AEP (cumecs) |
| Blackwater Ck | 130108A&B | 1,616 | 809 | 824 | 1,391 |
| Carnarvon Ck | 130509A | 1,123 | 1,340 | 855 | 1,358 |
| Theresa Ck | 130210A | 5,408 | 2,960 | 4,508 | 12,690 |

**Table 6. Scaling factors used to derive AEP event flows in the vicinity of Curragh Mine**

| Site name | Catchment Area ($km^2$) | Scaling Factor Theresa Creek (4,421$km^2$) | Scaling Factor Carnarvon Creek (351$km^2$) |
|---|---|---|---|
| Blackwater Creek at Mackenzie River (includes Minnie Creek) | 1,109 | 0.251 | 3.16 |
| Burngrove Creek at Mackenzie River | 485 | 0.1097 | 1.38 |

**Table 7. Scaled design flows for Blackwater Creek and Burngrove Creek Catchments.**

| Site Name | 1 in 100 QR AEP | 1 in 100 AEP (cumecs) | 1 in 1000 AEP (cumecs) |
|---|---|---|---|
| **Blackwater Creek at Mackenzie River** | **2,053** | | |
| Scaled using Theresa Creek | | 1,131 | 3,183 |
| Scaled using Carnarvon Creek | | 2,702 | 4,290 |
| **Burngrove Creek at Mackenzie River** | **1,214** | | |
| Scaled using Theresa Creek | | 495 | 1,392 |
| Scaled using Carnarvon Creek | | 1,182 | 1,876 |

The resulting flood flow estimates around Curragh Mine are presented in Table 7Error! Reference source not found.. Flows in Blackwater Creek derived by scaling the Carnarvon Creek AEP flows, are estimated to be 2,702 $m^3/s$ for the 1% AEP event and 4,290 $m^3/s$ for the 0.1% AEP event. These are significantly less when scaling the Theresa Creek flows, reducing the 1% AEP to 1,131 $m^3/s$ and the 1 in 1000 AEP to 3,183 $m^3/s$.

Similarly, for Burngrove Creek the 1% AEP event is estimated as 1,181 $m^3/s$ and 1,876 $m^3/s$ for the 1% AEP and 0.1% AEP events by scaling the Carnarvon Creek flows. Scaling the Theresa Creek records results in lower AEP design flows.

The Carnarvon Creek scaled flows are, however, comparable to the 1% AEP flow estimated using the Quantile Regression approach, which resulted 2,053 $m^3/s$ for the Blackwater Creek and 1,214 $m^3/s$ in Burngrove Creek.

## 3.4 Discussion

For the purpose of understanding the potential flood flows in the vicinity of Curragh Mine, the above analyses have been used to estimate the 1% AEP and 0.1% AEP in the Mackenzie River, Blackwater Creek (including Minnie Creek) and Burngrove Creek. An earlier report by WRM (2018) estimates a 0.1% AEP flow of 17,200 $m^3/s$, near the confluence of Blackwater Creek and the Mackenzie River, which included a mixture of modelled and modified rating curve peak discharges from various sites.

In this study, the flow in the Mackenzie River has been estimated using the Bingegang site, which has 50 years of record. There is only a 10% increase in catchment area between the Curragh Mine and Bingegang, so provides some conservatism in the approach. The 1% AEP for this site is 12,777 $m^3/s$, increasing to 54,393 $m^3/s$ for the 0.1% AEP event.

The closer site of Rileys Crossing only has 17 years of record and therefore provides a less reliable estimation of design flows. Despite a combined 99-year record for the Comet River, the site can be affected by backwater from the Mackenzie River making it less reliable to use in this instance.

For the Blackwater and Burngrove catchments, the design flows from Carnarvon Creek and Theresa Creek were scaled to provide estimates for these two catchments. These two sites were chosen because they are more comparable in size to the smaller tributary catchments around Curragh Mine. The Theresa Creek at Valeria site offers a longer record for flood frequency analysis, but area scaling of this record resulted in lower design flows overall. Although some distance from the Curragh Mine, the Carnarvon Creek site has 36 years of data including significant events since 2009 and are comparable with Quantile Regression estimates. As such, the scaled flows from this latter site are used to estimate the potential design flows around the Curragh Mine.

In summary, the following hydrologic inputs to the hydraulic model for the Curragh mine have been adopted.

- The Mackenzie River at Bingegang was used to estimate design flows in the Mackenzie River immediately upstream of Curragh Mine. With some adjustment for uncertainty the 1% AEP event was estimated as 12,777 $m^3/s$, and the 0.1% AEP was estimated as 54,393 $m^3/s$.
- As there were no gauges on the waterways in the immediate vicinity of the Curragh Mine, the scaled Carnarvon Creek flows were applied. These flows indicate a 1% AEP event of 2,702 $m^3/s$ and a 0.1% AEP event of 4,290 $m^3/s$ in Blackwater Creek (including Minnie Creek). For Burngrove Creek, the 1% AEP flow was 1,182 $m^3/s$ and the 0.1% AEP flow was 1,876 $m^3/s$.

# 4 Hydraulic Modelling

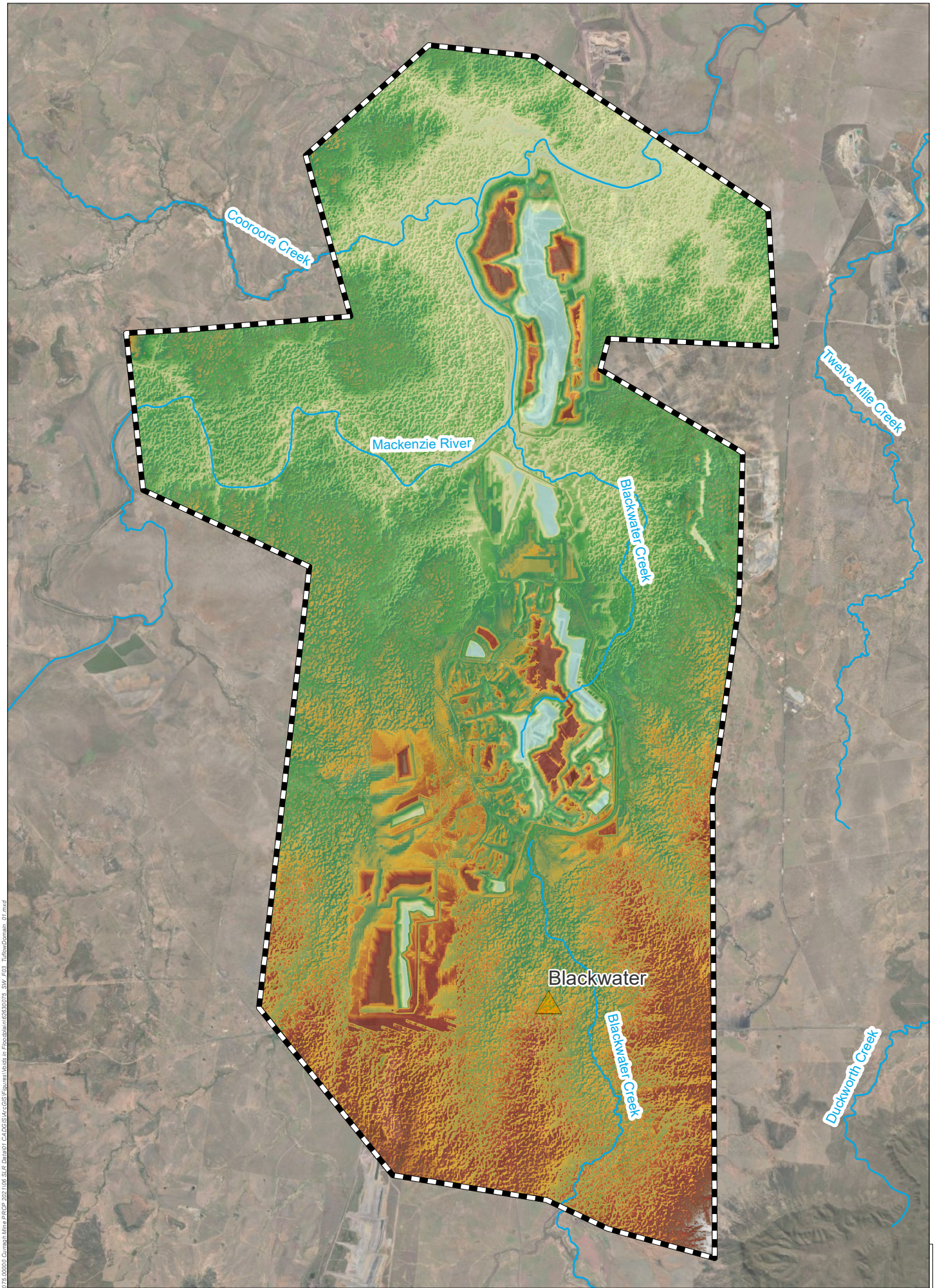
## 4.1 Software

A hydraulic model was developed for the purpose of assessing the post-mining flood extent. The industry standard hydrodynamic modelling software TUFLOW (Build 2020-10-AA) was utilised for the 2D hydraulic modelling. The TUFLOW Heavily Parallelised Compute (HPC) solution scheme was adopted in this project to minimise the model simulation time. Details of the model setup, methodology and results are provided in the following sections.

## 4.2 Topography

The residual void DEM as detailed below was utilised as the topography for the hydraulic modelling. A grid cell size of 20 metres was adopted for the model. The model domain and DEM data are shown in **Figure 3**.

Post-mining contour data was processed into a 5-metre spaced Digital Elevation Model (DEM). To create the residual void landform used in the floodplain modelling, the processed residual void DEM (which incorporated available 1m LiDAR) was overlaid on 1-second SRTM Derived DEM topographic data from Geoscience Australia. A long-term stable embankment has been incorporated into the residual void landform to provide flood immunity to the residual voids.




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TUFLOW Model Extent

Watercourse

Model DEM (mAHD)
High : 344.268
Low : 90

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**TUFLOW DEM and Model Extent**

**FIGURE 3**

H:\Projects-SLR\626-MKY\626.30375.00000 Curragh Mine PRCP 20211106 SLR Data\01 CADGIS\ArcGIS\Figures\Data in Flood\data\n626x30375_SW_F03_TuflowDomain_01.mxd

## 4.3 Hydraulic Roughness

The hydraulic roughness for the model was adopted based on available Queensland Globe aerial imagery and the model landform. The adopted land use types are consistent with the current catchment characteristics. The Manning's roughness values adopted for the various land use types in the assessment are shown in **Table 8.**

**Table 8. TUFLOW Manning's n Values**

| Land use | Manning's n |
|---|---|
| Creek | 0.06 |
| Waterways | 0.025 |
| Grassland | 0.04 |
| Light Scrub | 0.05 |
| Thick Scrub | 0.08 |
| Mining and rehabilitated area | 0.05 |
| Urban | 0.2 |

## 4.4 Inflows

Inflows were applied to the hydraulic model as steady state discharges based on the Flood Frequency Analysis discussed in **Section 3.** The hydrographs were applied as total inflow boundaries via 2D boundary condition lines for the Mackenzie River, Blackwater Creek, Burngrove Creek, and Sagittarius Creek on the model domain as shown in **Figure 3**.

## 4.5 Downstream Boundaries

The downstream boundary for the TUFLOW model was positioned on Burngrove Creek on the western side and Mackenzie River on the northern boundary of the site. A stage-discharge relationship was applied as the tailwater condition for the 2D model domain, with the water surface gradient equivalent to the ground surface slope in the vicinity of the boundaries. Based on the post-mining landform data the slope of 0.004% to 0.2% was used for the boundary locations. Downstream boundaries are shown in **Figure 3Error! Reference source not found.**.

# 5 Results

The intent of the flood modelling was to determine whether the residual void landform was stable and sufficient to prevent ingress to any of the residual voids. The results of the TUFLOW model are illustrated for the 0.1% AEP flood event and are provided in **Appendix B**.

The results show that all residual voids within the Curragh Complex are not subject to flood inundation due to the current diversion of Blackwater Creek and the stable landforms defined as part of the residual void landform. The surface water elevations and velocities are presented in **Appendix B**Error! Reference source not found.**.**

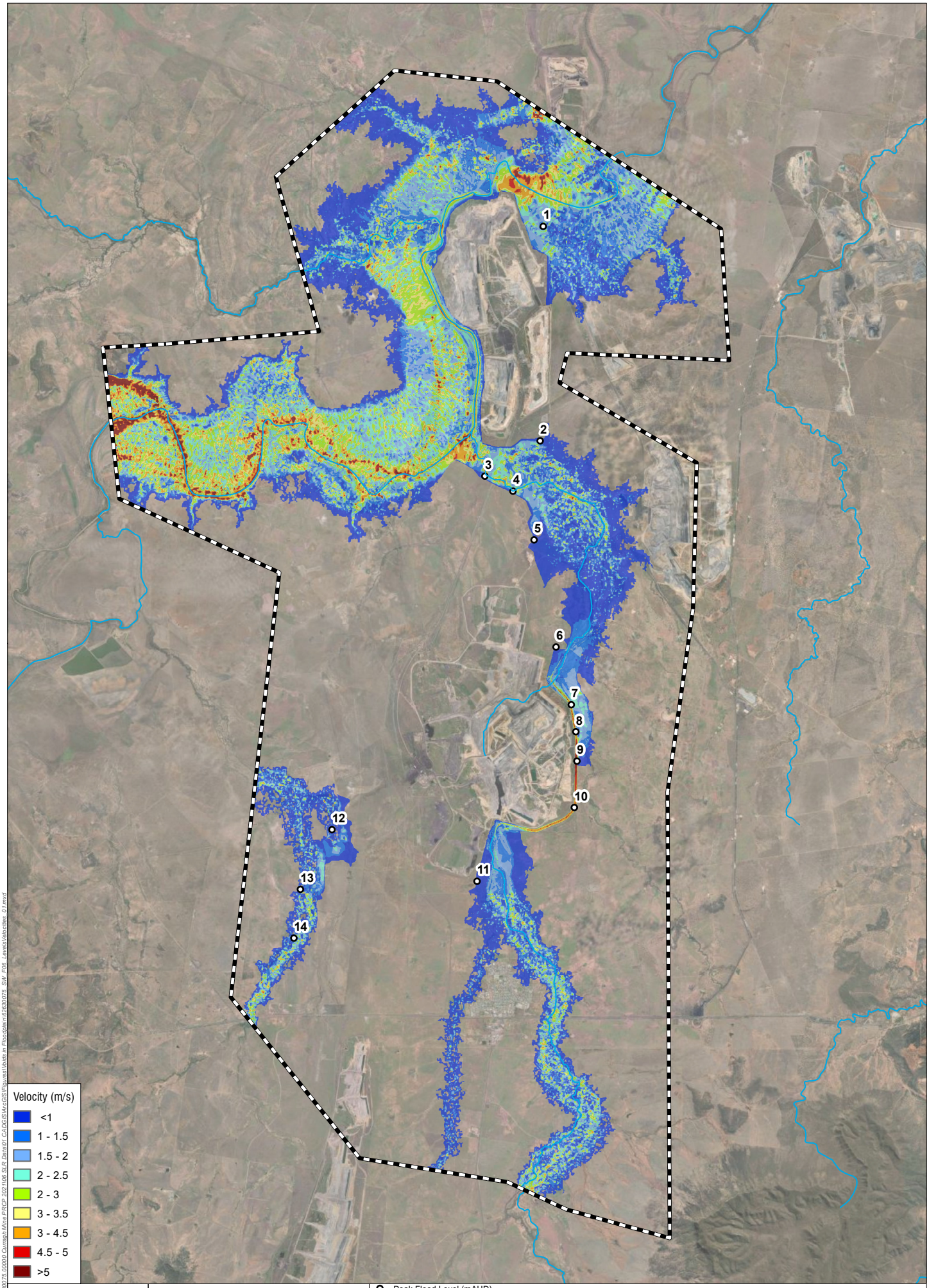
The modelled results show that a residual void landform can effectively use spoil dumps and long-term stable embankments to protect the residual voids from flood ingress. SLR adjusted the provided residual void landform along the existing Blackwater Creek diversion and between X Pit and Curragh North to provide additional protection. Modelled results for the 0.1% AEP flood event show:

- Landform heights of up to 141 mAHD plus freeboard are likely to be required North of Pit X.
- Blackwater Creek diversion should allow for flood levels up to 162.5 mAHD.

A summary of the modelled 0.1% AEP flood levels and velocities for each of the residual voids is provided in **Table 9** and
Figure 4.

### Table 9. Maximum Surface Water Elevations

| Void Name | Indicative Water Level 0.1% AEP event (m AHD) | Average Velocity (m/s) |
|---|---|---|
| 1 | 130.37 | 2.1 – 5.3 |
| 2 | 140.58 | 1.8 – 3.9 |
| 3 | 140.57 | 1.8 – 3.9 |
| 4 | 140.57 | 1.1 – 3.7 |
| 5 | 140.58 | 0.7 – 2.9 |
| 6 | 142.32 | 0.6 -2.6 |
| 7 | 145.19 | 1.5 - 5 |
| 8 | 148.9 | 2 - 4.5 |
| 9 | 152.12 | 0.8 - 5.4 |
| 10 | 156.94 | 1.5 - 4 |
| 11 | 162.67 | 0.5 – 2.5 |
| 12 | 160.05 | 0.5 – 1.7 |
| 13 | 165.89 | 0.5 – 1.7 |
| 14 | 170.39 | 0.5 – 3.9 |




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Peak Flood Level (mAHD)
Mining Leases
TUFLOW Model Extent
Watercourse

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**0.1% AEP Peak Flood Levels and Velocities**

FIGURE 4

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\ArcGIS\Figures\Vols in Floodplain\626300075_SW_F06_Levels Velocities_01.mxd

Flood velocities can be substantial through areas where the floodplain is constrained. Velocities are significant in the Blackwater Creek diversion, due to the confinement of the creek flows. That being said, the diversion is an existing infrastructure and is considered stable in its current form. Ongoing monitoring of the diversion in accordance with legislative requirements will determine if any works are required to maintain the stability of the landform in this area.

Velocities are typically 3 - 4.5m/s which will cause some erosion to the long-term stable embankment and appropriate treatment will be required. It should be noted that the hydraulic model utilised steady state inflows and this area is affected by backwater from the Mackenzie River. As such, velocities may be greater if Blackwater Creek is in flood with lower tailwater levels observed in the Mackenzie River. Further investigation of this element to confirm the erosion protection requirements will be required as part of the PRCP submission.

The Mackenzie River experiences velocities of greater than 6 m/s within the river banks adjacent to Curragh North, however velocities reduce to less than 2 m/s adjacent to the landform. Again, further investigation of velocities upon refinement of the hydraulic model will be required for the PRCP to show the landform is stable when subjected to high velocity flood flows.

It should also be noted the current hydraulic model does not take into account any further modifications to the floodplain due to the progression of mining on adjacent mining leases outside the control of CCPL. Further assessment of how mine development on the floodplain adjacent to Curragh Complex should be undertaken to determine whether any of the impacts (flood level or velocity) are exacerbated.

# 6 Conclusion

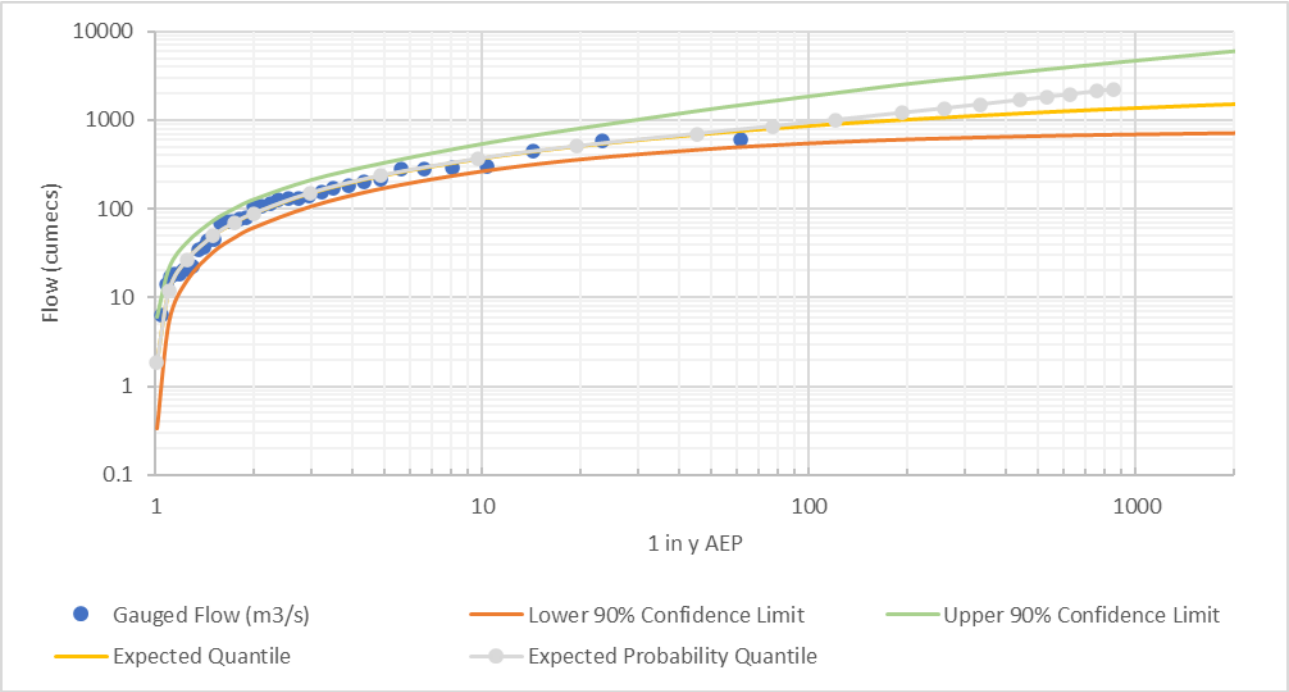
A flood assessment was carried out to determine the maximum flood level for a 0.1% AEP flood event for the floodplain which Curragh Complex spans.

Due to the limitations and assumptions detailed in Section 1.4, a conservative approach to determining flood levels was undertaken. The assessment found that with some adjustments to the long-term stable embankment proposed, the residual voids are not impacted by ingress of floodwater. The flood assessment has been based on a conservative estimate of estimated flood flows, however a full assessment of the flood risk to the site in accordance with the PRCP guidelines is required prior to submission of the PRCP.

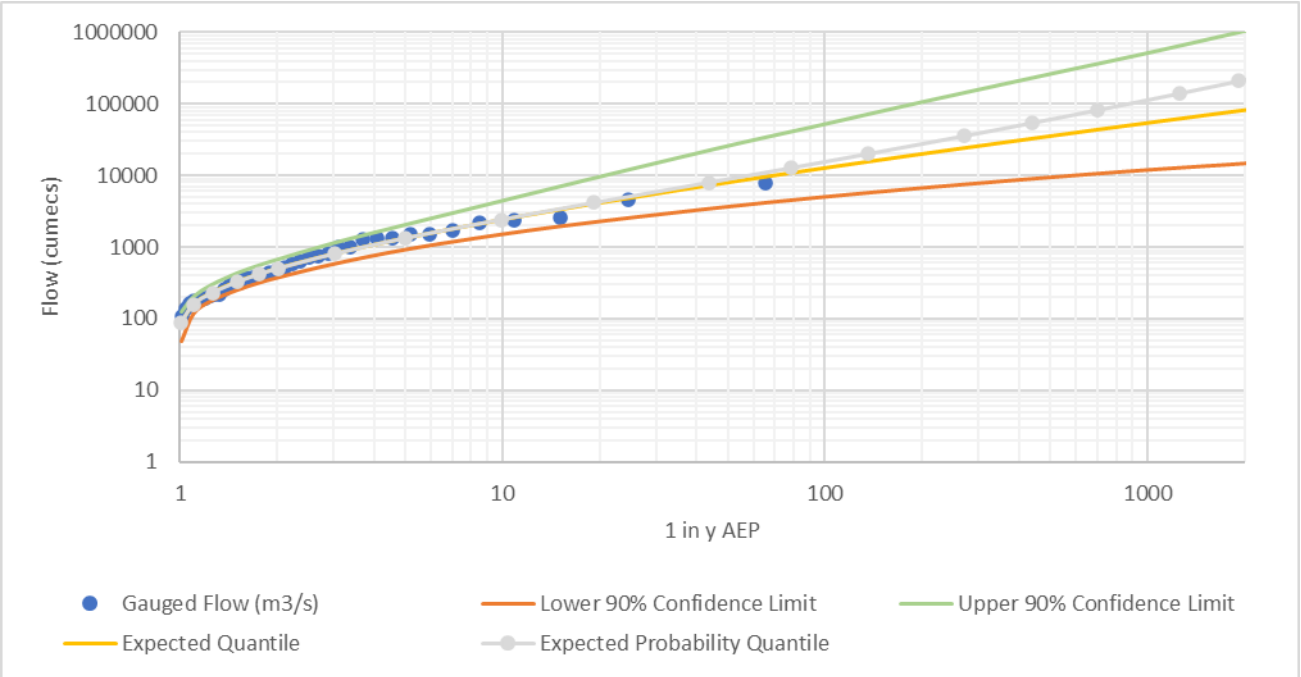
Furthermore, due to the narrowing of the floodplain, some areas specifically north of Pit X and to the west and north of Curragh North experience flood velocities which are excessive and will require treatment of the residual void landform to prevent scour. It is recommended that an erosion assessment be carried out once the flood modelling results have been refined and prior to the submission of the PRCP.

# APPENDIX A

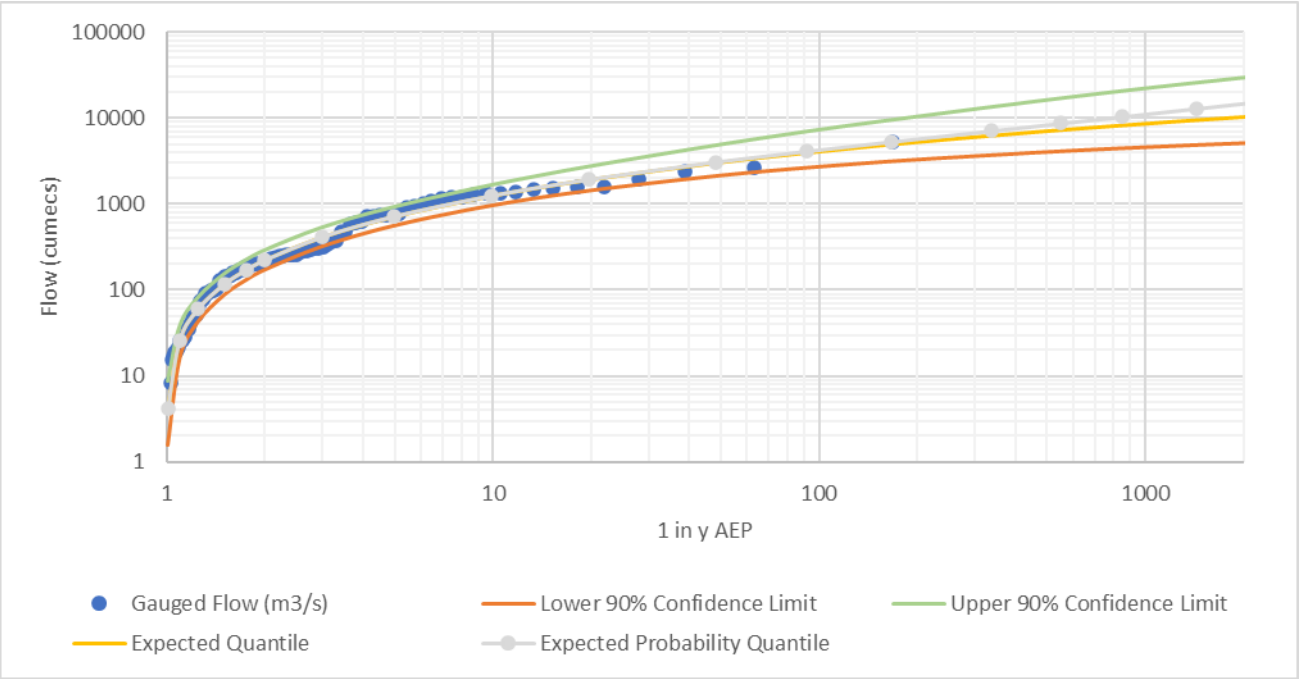
Flood Frequency Analysis (FFA) results



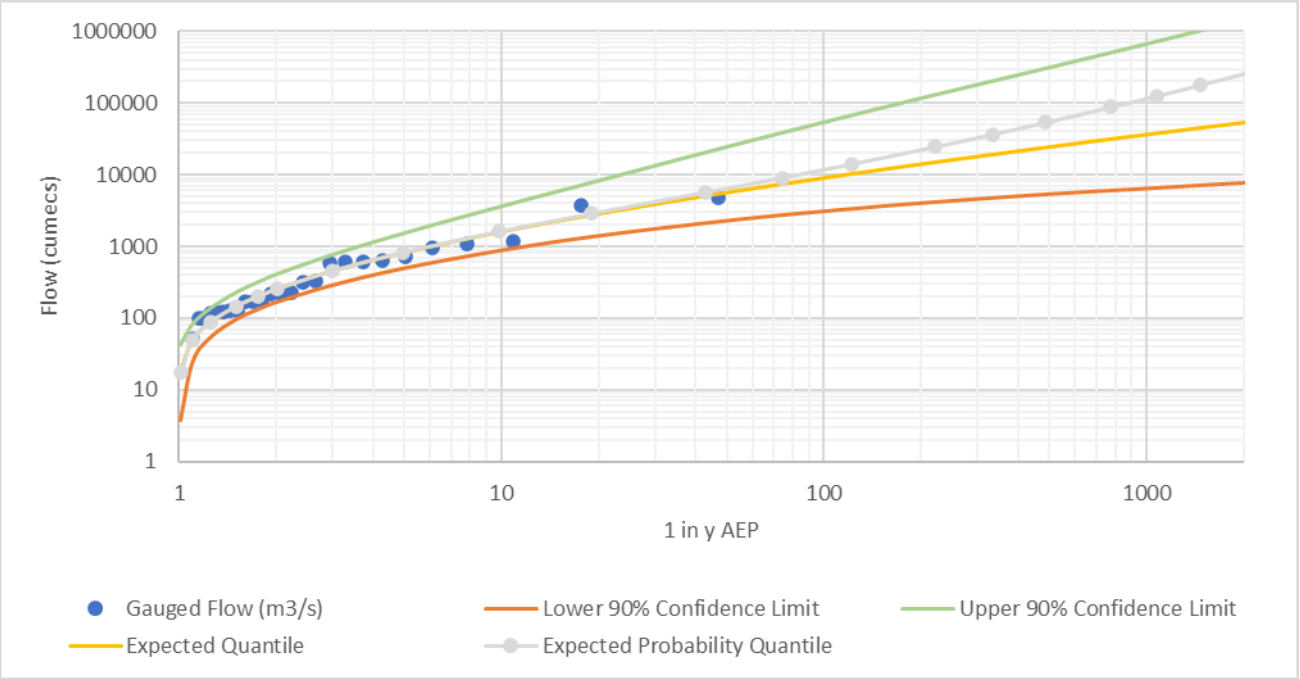

Carnarvon Creek at Rewan



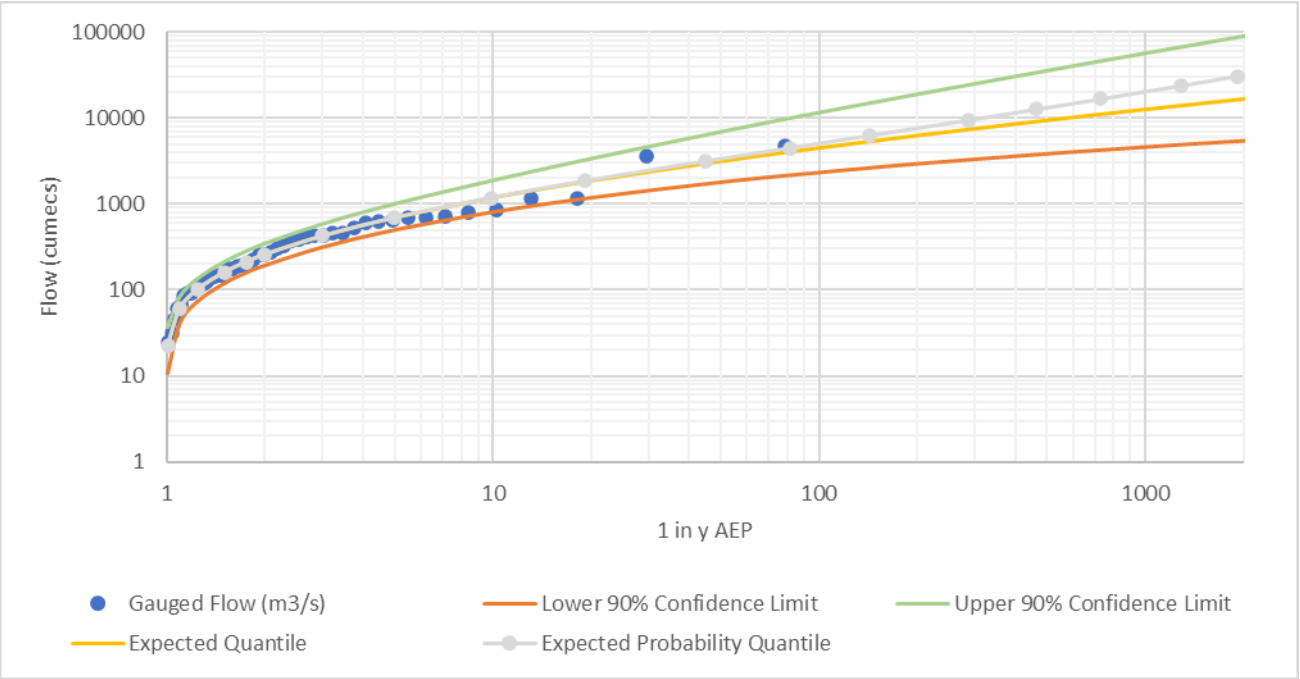

Mackenzie River at Bingegang




Comet River at Comet Weir



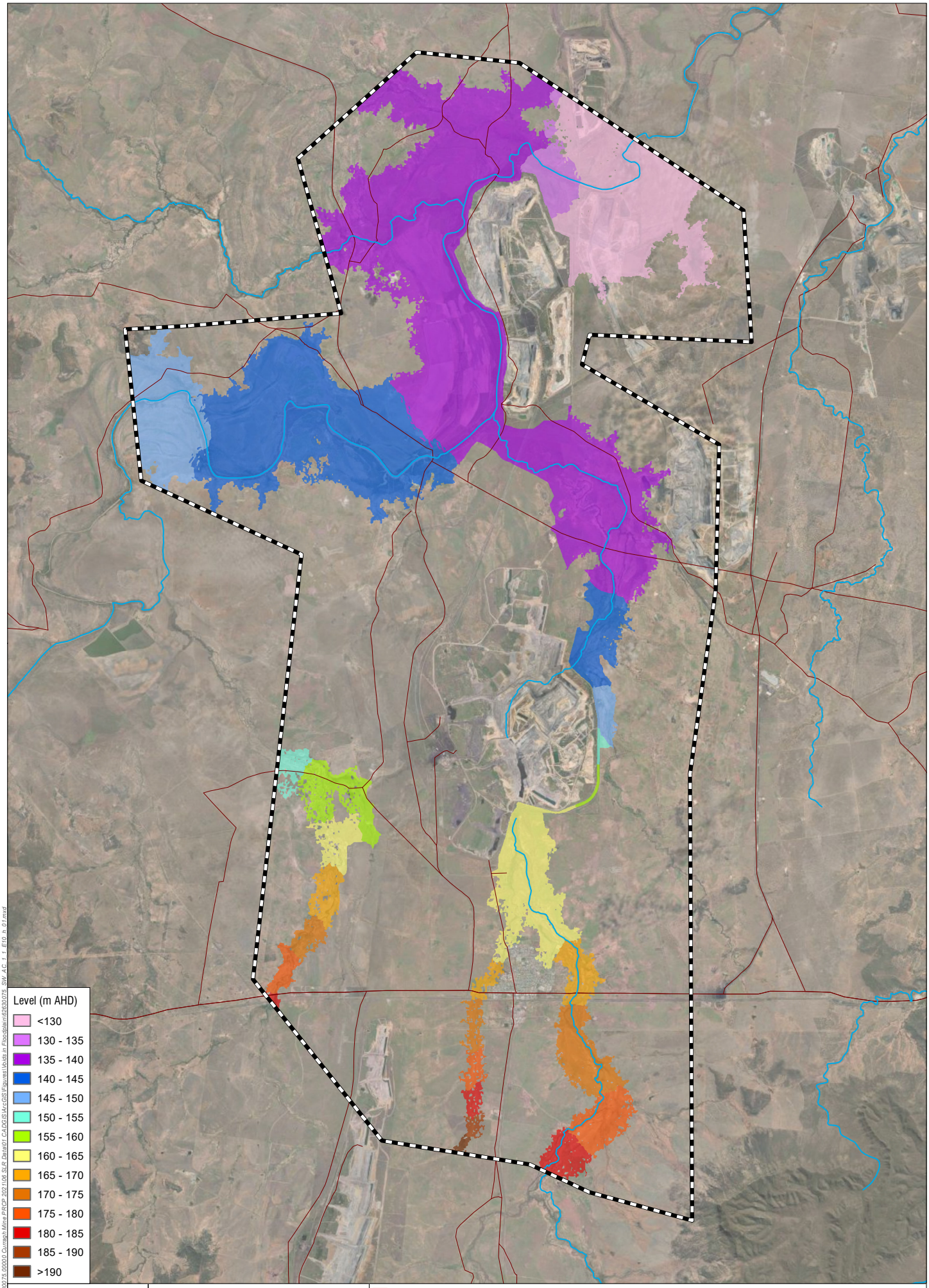

Nogoa River at Duck Ponds




Theresa Creek at Valeria

# APPENDIX B

Hydraulic Model Results




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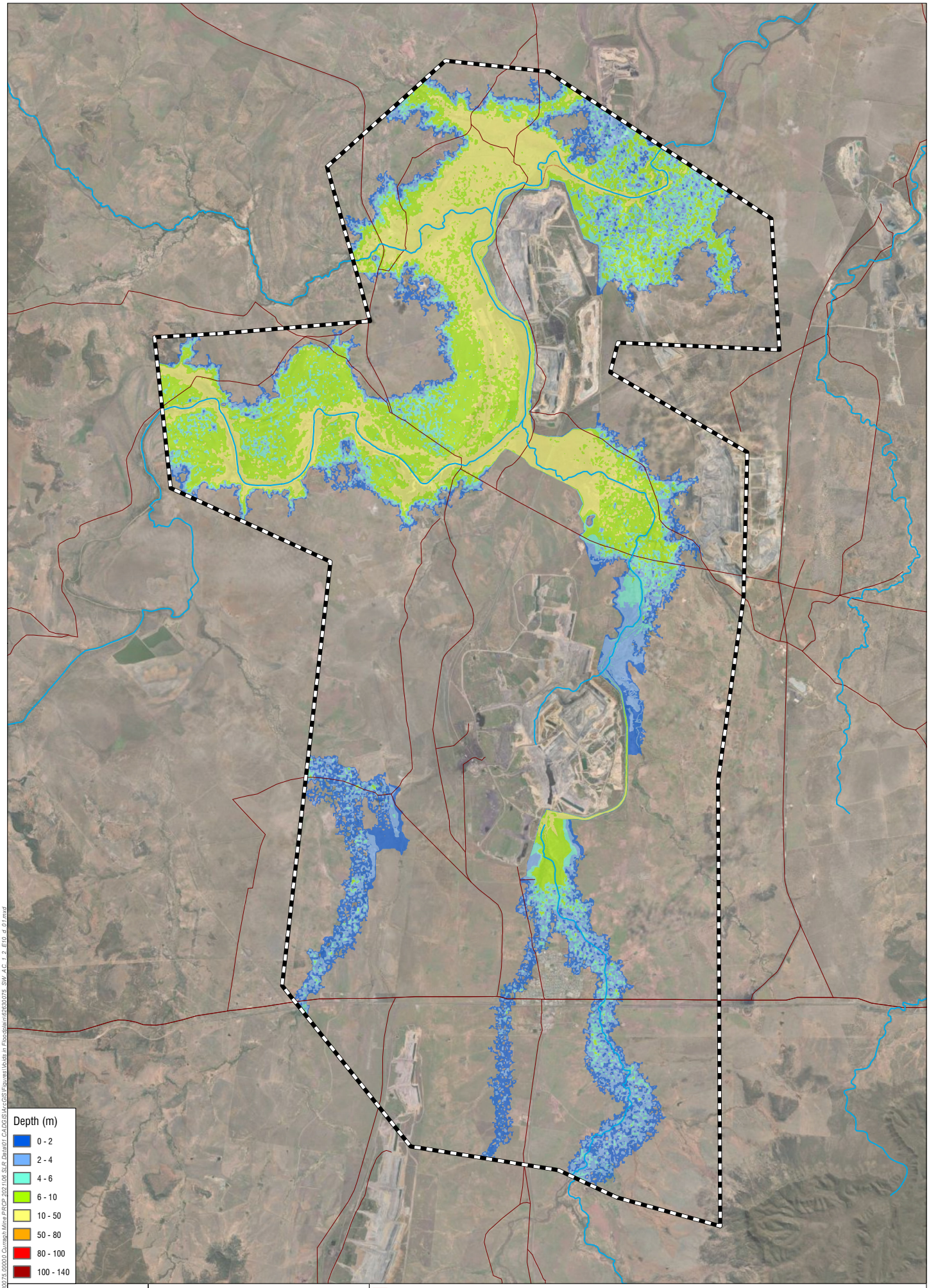
Mining_leases
TUFLOW Model Extent
Watercourse
Road

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PRELIMINARY FLOOD ASSESSMENT

**Peak Flood Levels - 0.1% AEP**

**APPENDIX B1**

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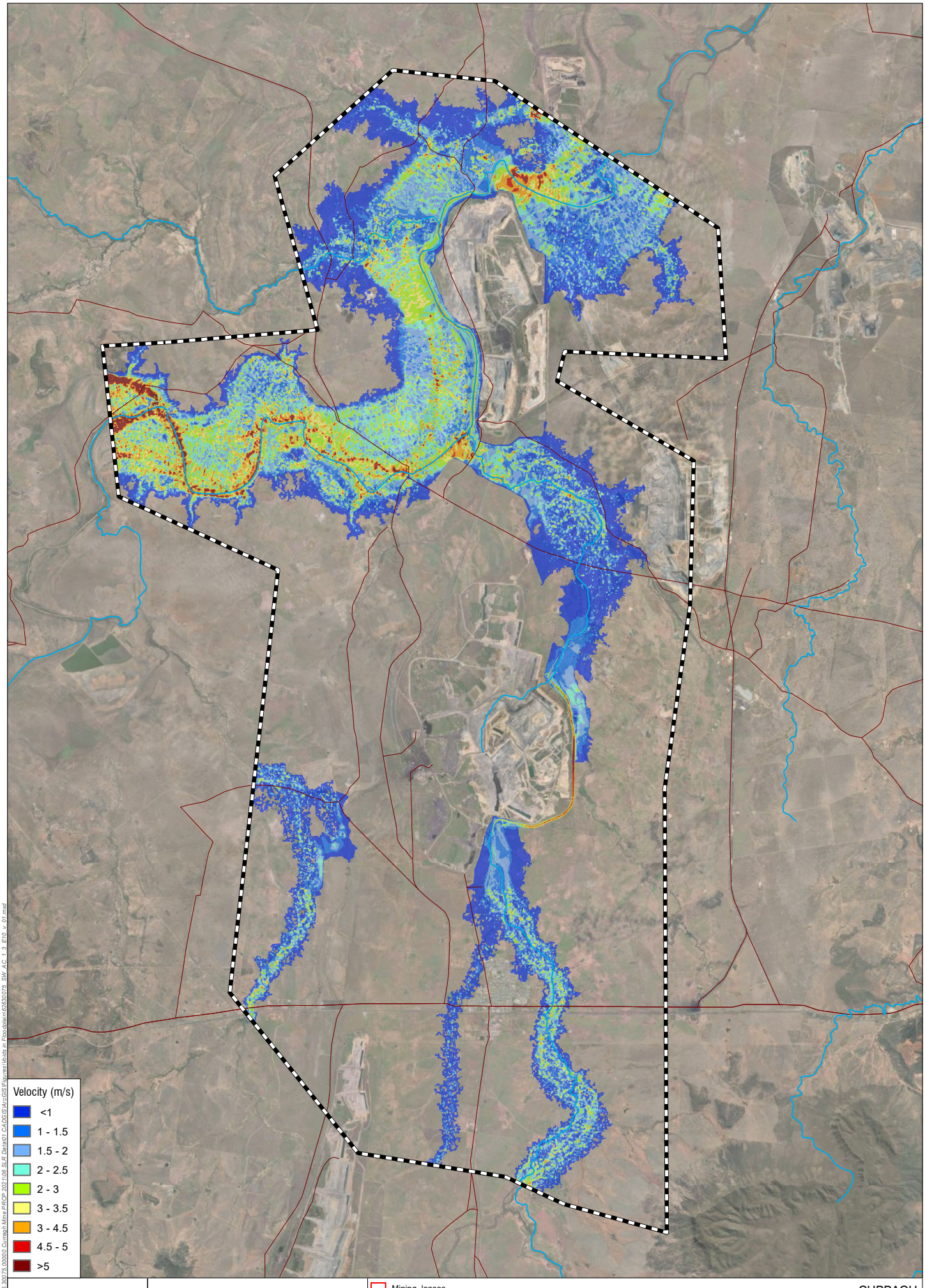
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TUFLOW Model Extent
Watercourse
Road

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PRELIMINARY FLOOD ASSESSMENT

**Peak Flood Depths - 0.1% AEP**

APPENDIX C2

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Mining_leases

TUFLOW Model Extent

Watercourse

Road

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**Peak Flood Velocities - 0.1% AEP**

**APPENDIX C-3**

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# APPENDIX B

# GROUNDWATER REPORT

# CURRAGH MINE COMPLEX

## Concept Residual Void Assessment
## Groundwater Technical Appendix

Prepared for:
Coronado Curragh Pty Ltd
Blackwater, QLD, 4717

SLR Ref: 626.30075.00000 -R01
Version No: -v0.1
November 2021

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# BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

# DOCUMENT CONTROL

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|---|---|---|---|---|
| 626.30075.00000 -R01-v1.0 | 28 November 2021 | Dariarne Edwards<br>Arash Mohajeri<br>John Barlow | Brian Rask<br>John Barlow | Brian Rask<br>Emma Williams |
| | | | | |

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## APPENDICES

Appendix A Groundwater Quality
Appendix B Calibration Average Residuals
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# 1 Introduction

In September 2021 SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to provide a Concept Residual Void Assessment (CRVA) for the Curragh Mine Complex (the mine). In support of the CRVA a groundwater assessment of the mine and final landforms has been undertaken including two key components, a conceptual hydrogeological model and numerical groundwater modelling. The objective of the groundwater assessment in support of the CRVA is to understand the post closure groundwater regime around the mine, and specifically to:

- present an understanding of the hydrogeological setting of the mine including potential groundwater receptors
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by Coronado to understand whether the final voids act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post mining landform on local groundwater levels i.e., the residual drawdown, and post-mining groundwater flux.

This groundwater assessment presents a preliminary assessment of the hydrogeological aspects of the mine closure primarily to support the CRVA submission in November 2021. A more detailed groundwater assessment will be prepared to support the Progressive Rehabilitation Closure Plan (PRCP) for the mine.

This preliminary assessment is based substantially on the Groundwater Technical Report prepared for Wesfarmers Resources Pty Ltd by WSP in support of the Curragh Extension Project (WSP 2016). The WSP assessment presents a comprehensive hydrogeological conceptualisation for the mine and the results of predictive numerical groundwater modelling. The WSP report, and specifically the numerical groundwater modelling, was peer reviewed by HydroSimulations (2016), and the 2016 model has been used as the basis for the numerical modelling completed for this assessment.

Section 2 of this report presents a summary of the hydrogeological setting of the mine and conceptual hydrogeological model drawing on the groundwater assessment prepared by WSP in 2016 for the mine expansion. Section 3 presents an overview of the numerical groundwater model setup and development, including model calibration and prediction. Section 4 describes the post closure modelling and groundwater recovery including the long term post-closure groundwater levels compared to pre mining conditions i.e., the residual drawdown. Conclusions, recommendations, and limitations are presented in Section 5.

# 2 Conceptual Hydrogeological Model

## 2.1 Physical Setting

The Curragh Mine is located in Central Queensland within the Fitzroy Basin in an area dominated by grazing, farming and coal mining. The mine extends across an area from approximately 3 km to 35 km north of the township of Blackwater, with an additional expansion pit (Pit Z) located 5km to the WNW of Blackwater. Neighbouring mines include Blackwater to the southwest of Blackwater Township, Mackenzie South located approximately 2.5 km east of Curragh and Jellinbah Central located approximately 5.5 km east of Curragh.

Figure 2-1shows the mine location in the context of the local area, drainage, surrounding mines, topography as well as the general mine layout and pit configuration.

The site is broadly divided into Curragh North (Pits S, T, U and associated spoil dumps); Curragh Main (Pits A & B (both TSFs), C, D, E, F, G, and H), and the expansion areas (Pits X, Y, Z, J and Ramp 9), where mining has not yet commenced. Mining at Curragh is projected to end in 2038.

### 2.1.1 Topography and land use

The land surrounding the mine is typically gently undulating and comprises the floodplain of Mackenzie River. The topography of the area is dominated by the major drainage features (Mackenzie River and tributaries), creek lines, and the open cut pits and spoil dumps of Curragh Mine and neighbouring mines. Topography and drainage near the Project area is shown on Figure 2-1.

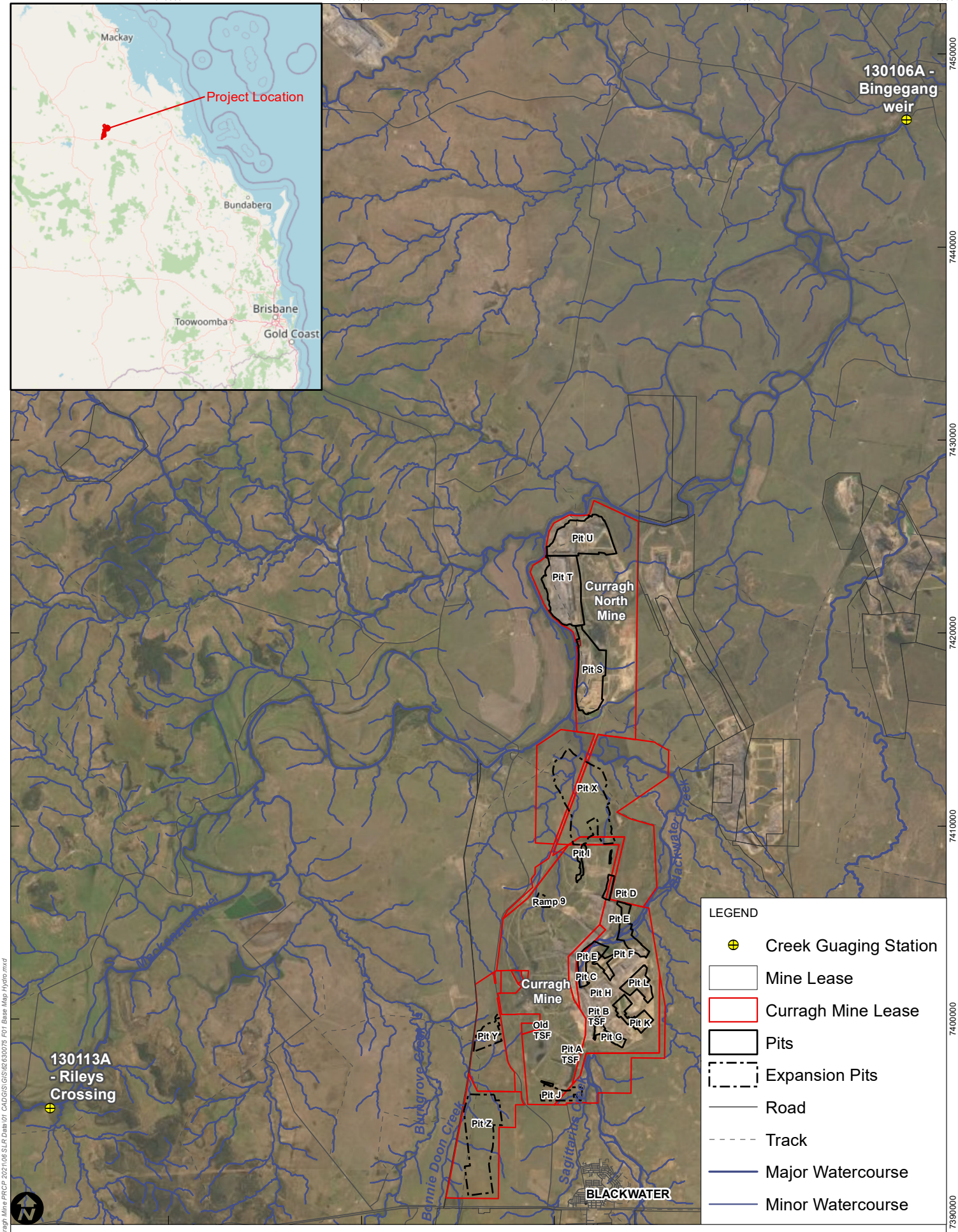
Aside from the Township of Blackwater and the surrounding mines land use is rural with large areas predominantly turned over to livestock grazing with some dryland cropping and minor irrigated cropping adjacent to Mackenzie River.

### 2.1.2 Climate

The climate of the region is subtropical with the highest rainfall and evaporation occurring from October through till March (BoM, 2021). Historical climate data was obtained for the period January 1900 to September 2021 from the Scientific Information for Landowners (SILO) database (Queensland Government, 2021) for the location of the Project area (latitude -23.5, longitude 148.9). Table 2-1 outlines the total monthly average rainfall and evaporation. The data shows that the total potential average annual evaporation (2,054 mm/yr) is almost four times annual rainfall (565 mm/yr). The high annual evaporation rates are strongly related to seasonal temperatures (Figure 2-2).

Table 2-1 Total Monthly Rainfall and Evaporation (January 1900 to August 2021)

| Average Total Monthly (mm) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall | 93 | 88 | 58 | 30 | 29 | 29 | 24 | 16 | 21 | 42 | 56 | 80 | 565 |
| Evaporation | 229 | 184 | 190 | 151 | 118 | 94 | 103 | 132 | 173 | 214 | 226 | 240 | 2,054 |




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| Coordinate System: | AGD 1984 AMG Zone 55 |
| Scale: | 1:250,000 at A4 |
| Project Number: | 626.30075 |
| Date: | 26-Nov-2021 |
| Drawn by: | ML |
| Reviewed by: | ML |

**Preliminary Groundwater Assessment for Curragh CRVA**
**Curragh Mine location and layout**

**FIGURE 2-1**

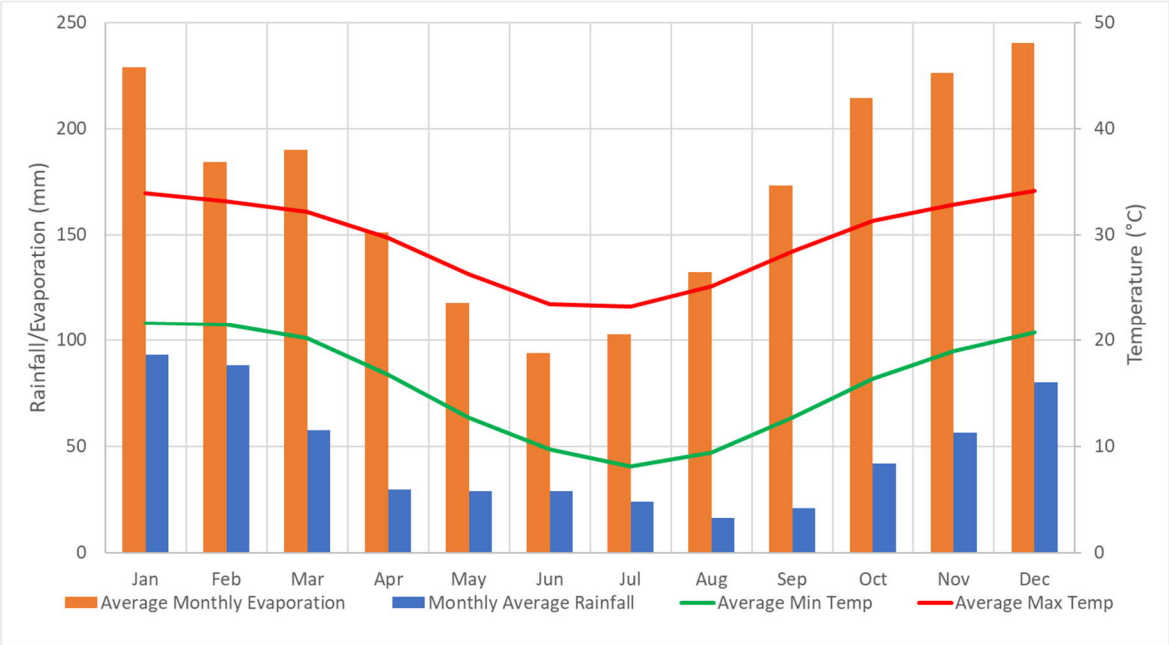



Figure 2-2 Average Monthly Evaporation, Rainfall and Temperature (January 1900 to August 2021)

In order to assess recent rainfall distribution into a historical context, the cumulative rainfall departure (CRD) was calculated for the data period 1900 to 2021 (Figure 2-3). The CRD is a summation of difference between the actual monthly rainfall compared to the average monthly for the same period. A rising slope in the CRD indicates periods of rainfall above the long term average (e.g., 2010 to 2012), and a falling slope indicates periods when rainfall is below the long term average (e.g., 1999 to 2007). Rainfall volumes over more recent years of the record (2017 to 2021) have been lower than average, as is indicated by the falling slope in the CRD.

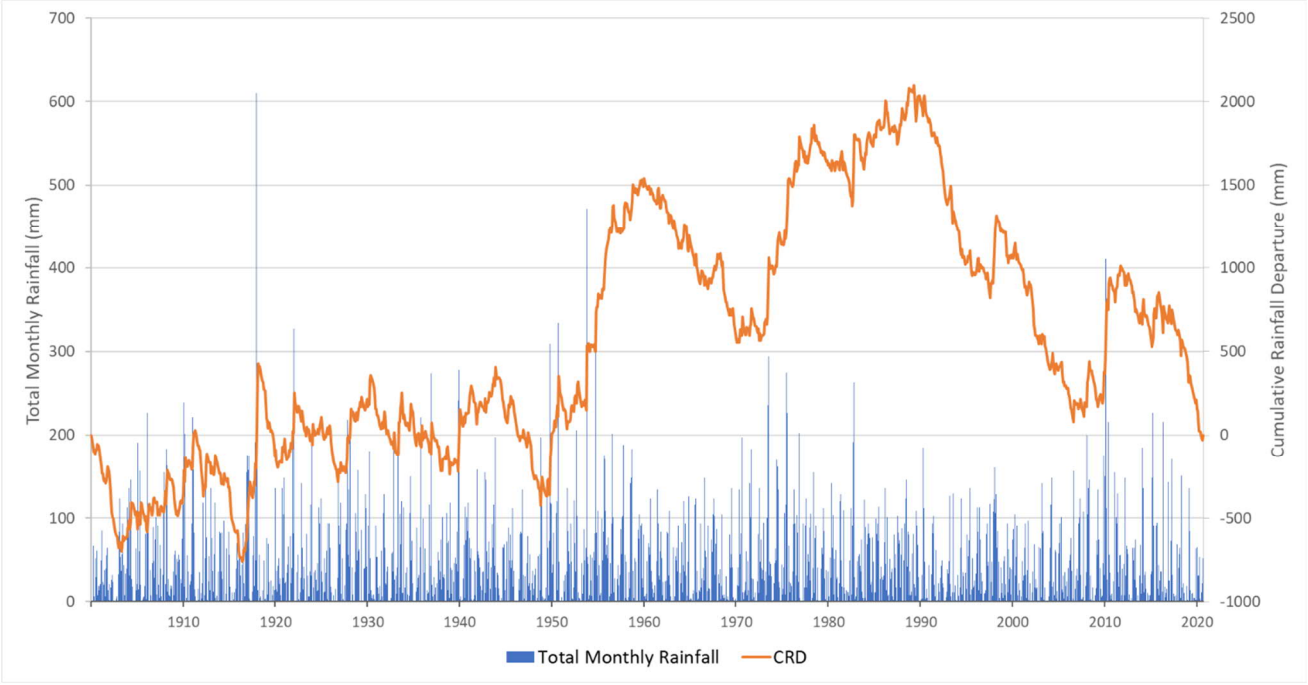



Figure 2-3 Cumulative Rainfall Departure and Total Monthly Rainfall (1900-2021)

Since the start of mining in 1983 the area has generally seen lower than average rainfall except for the remainder of the 1980s and significant wet seasons in late 1998 and 2010/11.

### 2.1.3 Hydrology

#### 2.1.3.1 Mackenzie River

The mine extends across the floodplain of the Mackenzie River and its tributaries, the Mackenzie River being the main watercourse in the area and a major tributary of the Fitzroy River. The Mackenzie River forms at the confluence of the Nogoa and Comet rivers, 30km west of Blackwater. The total catchment area of Mackenzie River to Bingegang Weir, 25km downstream of the mine, is approximately 51,000 square km. To the northwest of the mine the Mackenzie River floodplain is a relatively flat, with the current course of the river meandering through an alluvial tract between approximately 3 to 8 km in width.

Fairbairn Dam located upstream on the Nogoa River approximately 80km WSW of Blackwater stores 1,300 gigalitres (GL) when full. Releases from the dam maintain levels downstream so that various towns, mines and irrigators can be supplied. This regulation of the Mackenzie River has altered the natural flow regime.

Figure 2-4 presents flow duration curves for the gauge at Riley's Crossing (130113A) 25km west of Blackwater, and for Bingegang weir (130106A) 25km north-west (downstream) of the northern extent of the mine. The data indicates that higher flows mostly driven by rainfall over the catchment naturally result in increasing flows downstream with Bingegang recording higher flows than Riley's Crossing upstream when flows at both gauges are above ~200 ML/d. Below ~200 ML/d the effects of river regulation by releases from Fairburn Dam and downstream extraction / losses appear to be apparent with perennial flow recorded at Riley's Crossing whilst downstream at Bingegang there appears to be no flow over the weir 70% of the time.

The main tributaries of Mackenzie River in the study area include Blackwater Creek, Burngrove Creek, Cooroora Creek and Scrub Creek.

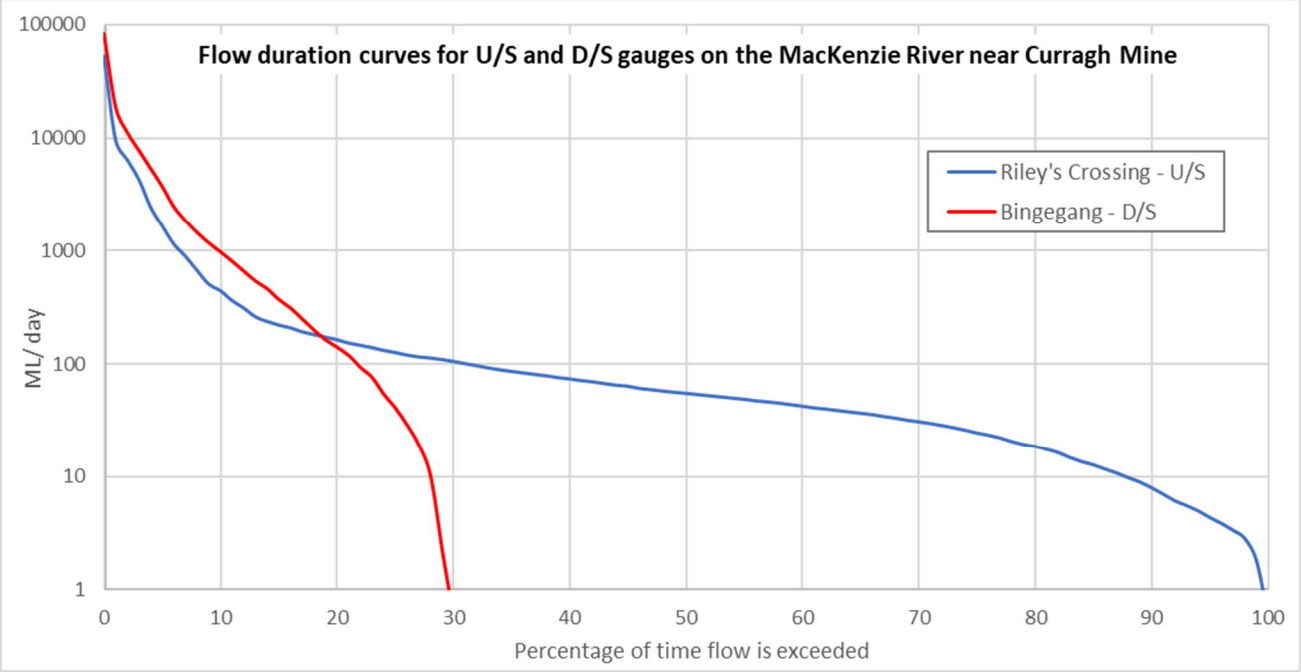


Figure 2-4 Flow Duration Curves for Gauging Stations on the Mackenzie River in the Vicinity of Curragh Mine (Nov 2013 – Oct 2021)

#### 2.1.3.2 Blackwater Creek and tributaries

The main tributary of Mackenzie River in the study area is Blackwater Creek, which flows in a northerly direction to the east of Curragh Main via a major diversion around Pits J, K, L, F, and E. Blackwater Creek is naturally ephemeral although at its upstream end, it constantly flows due to discharge of treated effluent from Blackwater Wastewater Treatment Plant into Sagittarius Creek between Blackwater and the mine (PB 2016).

Blackwater Creek is highly modified having been diverted several times to accommodate mining at Curragh. The current Blackwater Creek diversion is a 9 km long engineered drainage structure made of compacted earth vegetated with grasses and shrubs. The discharge from Blackwater WTP is observed along the extent of the diversion although not north of the diversion (PB 2016).

Just downstream of the diversion around Curragh Main and to the east of the proposed Pit X Blackwater Creek becomes an ephemeral braided channel system.

Tributaries of Blackwater Creek include Taurus Creek, Sagittarius Creek, Minnie Creek and Bullock Creek, all of which are ephemeral. Minnie Creek flows through the proposed Pit X area and will be subject to a 5.3 km diversion near its confluence with Blackwater Creek plus a 2.9 km diversion of one of its unnamed tributaries around the western side of the pit prior to the commencement of mining in this area (PB 2016).

#### 2.1.3.3 Burngrove Creek and tributaries

Other tributaries of Mackenzie River in the Project area include Burngrove Creek. A tributary of Burngrove Creek is Bonnie Doon Creek, which flows in a northerly direction to the west of proposed Pit Z and will be subject to a diversion. Both Burngrove Creek and Bonnie Doon Creek are ephemeral.

### 2.1.4 Geology

The surface geology across the study area (based on the 1:100,000 mapping), is presented in Figure 2-5 and the regional (solid) geology is presented in Figure 2-6

The study area is underlain by Permian to Quaternary sediments located within a gently folded and faulted sequence of the Bowen Basin. The Permo-Triassic sediments dip eastward and include the Triassic Rewan Formation and the underlying Permian Blackwater Group, which includes the Rangal Coal Measures, Burngrove Formation and Fair Hill Formation. The Triassic strata are overlain by unconsolidated Quaternary alluvium associated with creeks, rivers and floodplains and the poorly consolidated Tertiary sediments of the Duaringa and Emerald formations. The Back Creek Group underlies the Blackwater Group and forms the basement of the area.

The stratigraphic sequence underlying the study area is presented in Table 2-2 and summarised below.

#### 2.1.4.1 Quaternary and Tertiary alluvium

Alluvium associated with the main watercourses of the Mackenzie River and Blackwater Creek (and their tributaries) is present across much of the extension areas as much of Curragh North.

In the proposed Pit X area, exploration drilling indicates the alluvium is typically less than 12m thick and predominantly comprised of clay with occasional channel sand and gravel lenses at depth. Alluvium in the vicinity of proposed Pit J and Pit Z is generally thin (typically 2m but up to 4m) and comprised of clay and silt. Alluvium occurs in the southeast corner of proposed Pit D extension and is typically less than 2m (and up to 10m) and comprised of clay and sand (WSP 2016).

Floodplain alluvium associated with the Mackenzie River occurs extensively at Curragh North and exhibits an overall fining upwards sequence and significant lateral variability with an average thickness of 18 - 20m. Drilling data indicates the alluvium may be up to 35 m thick and the base of the alluvium is deepest close to the Mackenzie River (WSP 2016).

Table 2-2 Regional Stratigraphy

| Age | Group | Stratigraphic Unit | Description |
|---|---|---|---|
| Quaternary | | Alluvium | Soils, unconsolidated silts, sands, gravels and clays, |
| Cenozoic (Tertiary) | | Duaringa Formation/ Emerald Formation | Claystone, siltstone, sandstone, conglomerate (often poorly consolidated), lignite, basalt |
| Triassic | Mimosa | Rewan Formation | Mudstone, interbeds of lithic sandstone. |
| Upper Permian | Blackwater Group | Rangal Coal Measures | Coal seams calcareous sandstone, calcareous shale, mudstone, calcareous tuff in places. Main coal seams include Aries, Castor, Pollux, Orion, Pisces. |
| | | Burngrove Formation | Siltstone, carbonaceous shales and mudstone, fine lithic sandstone, calcareous lithic and feldspathic sandstone, tuffaceous shales and thin coal seams. |
| | | Fair Hill Formation | Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal |
| Permian | Back Creek Group | Macmillan Formation | Interbedded mudstone and sandstone, prominent dark grey basal unit. |

### 2.1.4.2 Cenozoic sediments

The Duaringa Formation is present in the proposed Pit X and Pit D extension areas and outcrop extensively in the north, east and south of the study area. In the north of the study area the Cenozoic sediments have been eroded by the Mackenzie River. The Emerald Formation is present in the western section of the proposed Pit X area and outcrop in the west of the study area (WSP 2016).

The Cenozoic sediments consists of interbedded stiff to hard clayey sands, gravels and thick beds of ferruginous clays of medium to high plasticity. They are fluvial and colluvial in origin and partially consolidated. The sequence unconformably overlies Permian coal measures with an indistinct boundary due to the clay rich and ferruginous composition of both horizons caused by in-situ weathering (WSP 2016).

### 2.1.4.3 Triassic sediments

The Rewan Formation overlies the Rangal Coal Measures and outcrops / subcrops directly east of the mined areas. It typically comprises thinly interbedded mudstones, lithic sandstones and siltstones. Drilling in the Minyango mine area recorded Rewan Formation up to 350m thick with a depth of weathering between 30 and 70 m (WSP 2016).

#### 2.1.4.4 Permian sediments

The Permian Rangal Coal Measures (RCM) is the uppermost sequence in the Blackwater Group and comprises predominantly fine grained to occasionally medium grained lithic sandstone, siltstone, mudstone, carbonaceous mudstone and coal.

The RCM contain seams of high quality PCI coal, high quality medium-to-low ash coals suitable for prime coking coal, anthracite and semi-anthracite, and high energy thermal coals. The Cancer, Aries, Castor, Pollux, Orion and Pisces seams within the RCM are mined at Curragh. The strata generally dip to the east at less than 3°, with dips increasing locally in fault zones. The Rangal Coal Measures outcrop / subcrop in Curragh North and Curragh Main areas. The Rangal Coal Measures also subcrop east (the upthrow side) of the Jellinbah Fault where they are extracted at Jellinbah Mine (WSP 2016).

The boundary between the Burngrove Formation and the overlying RCM is the Yarrabee Tuff Bed, a distinctive marker horizon. The tuff lies between the target Pisces seam in the RCM and the Pisces Lower seam. The upper part of the Burngrove Formation (below the Yarrabee Tuff Bed and Pisces Lower seam), comprise dark grey to grey mudstones grading to siltstones. The Burngrove Formation outcrops/subcrops in the proposed Pit X, Y and Z locations and to the west of Curragh Mine (WSP 2016).

The Fair Hill Formation underlies the Burngrove Formation and outcrops/subcrops to the west of the mine. The formation comprises lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff and tuffaceous mudstone and includes the Fort Cooper Coal Measures.

The upper Permian sediments are weathered. The depth of weathering in the study area is approximately 14 metres below ground level (mbgl), except where Quaternary erosion and deposition has resulted in the replacement of Permian sediments by Quaternary alluvium. Where this occurs deeper weathering up to 35 mbgl is observed (WSP 2016).

### 2.1.5 Structural geology

The mine is located within an area of the Bowen Basin subject to faulting and gentle folding. The study area lies on the eastern limb of the Comet Ridge, adjacent to the Folded Zone within the Bowen Basin. This ridge was formed over an existing basement platform, creating a regional anticlinal structure with low amplitude and gentle folds (WSP 2016).

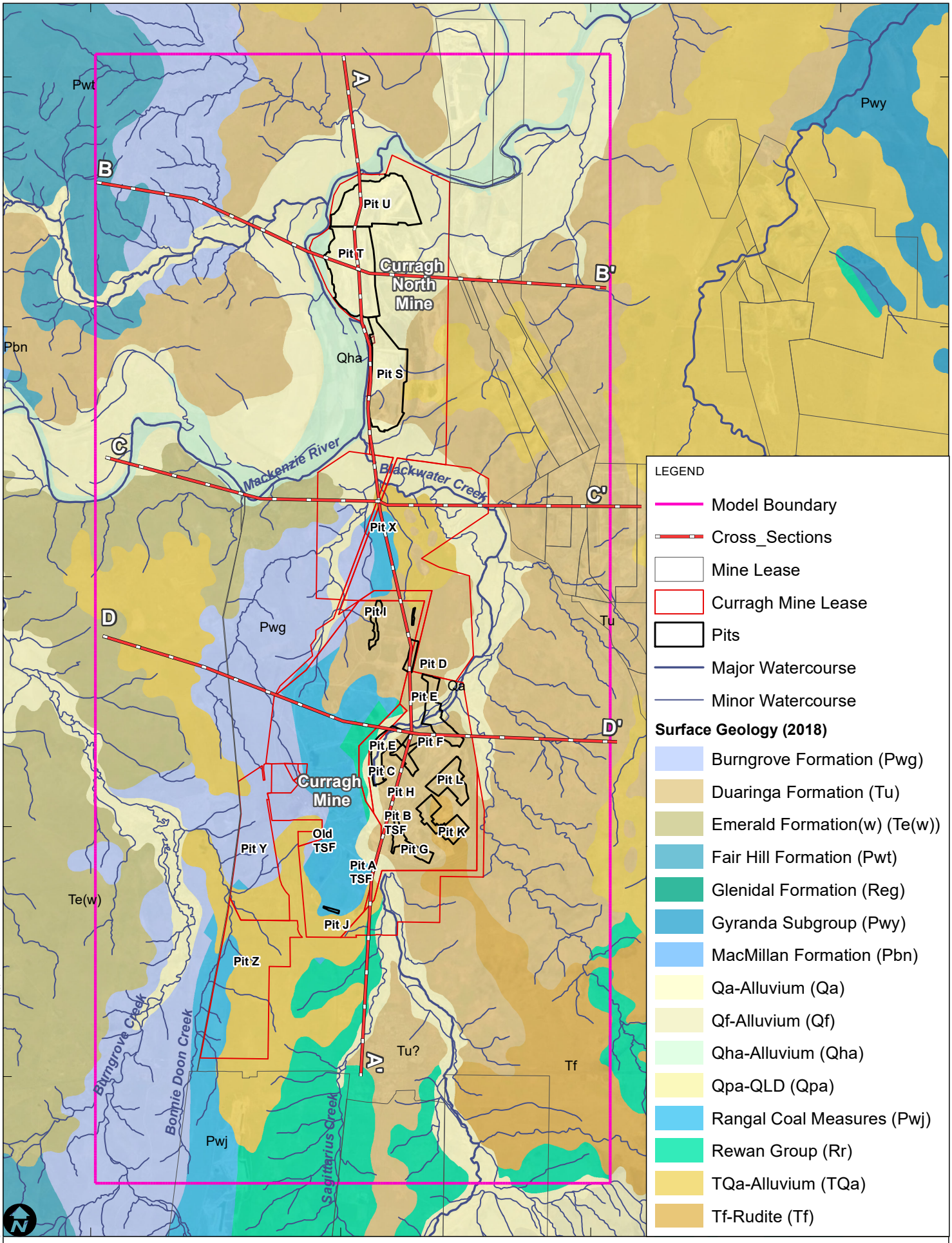
The NNW-SSE trending Jellinbah Fault is located directly east of Curragh North and approximately 5 km east of Curragh Main. It is the major fault structure in the Curragh Mine region. The fault has an approximate vertical displacement of 120 m brining the RCM back up to depths that allows the Jellinbah Mine to target the associated coal seams (WSP 2016).

The RCM in the vicinity of the mine have been affected by low angle thrust faulting from the north-east and results in seam displacements up to 20 m vertically. Fault deformation has resulted in seam thinning, seam repetitions and absenting occurring throughout the Curragh Mine (PB 2016).

#### 2.1.5.1 Geological Cross-sections

Extensive exploration drilling at Curragh and neighbouring mines was analysed by PB to develop a detailed understanding of the geology in the vicinity of the mine for the 2016 expansion project. This included the development of detailed conceptual cross sections which have been reproduced in Figures 7 to 10 (PB 2016). The cross-sections show the geology of the study area and the progression of mining as of August 2015 and were developed using LiDAR, drill hole data and the mine geological model as well as exploration data for neighbouring mines obtained from Queensland Globe.

The locations of the cross-sections (which are shown on Figure 2-5), comprise a north-south long section (A-A' Figure 2-7), and three east-west long sections (B-B' Figure 2-8, C-C' Figure 2-9, and D-D' Figure 2-10)




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| Reviewed by: | ML |

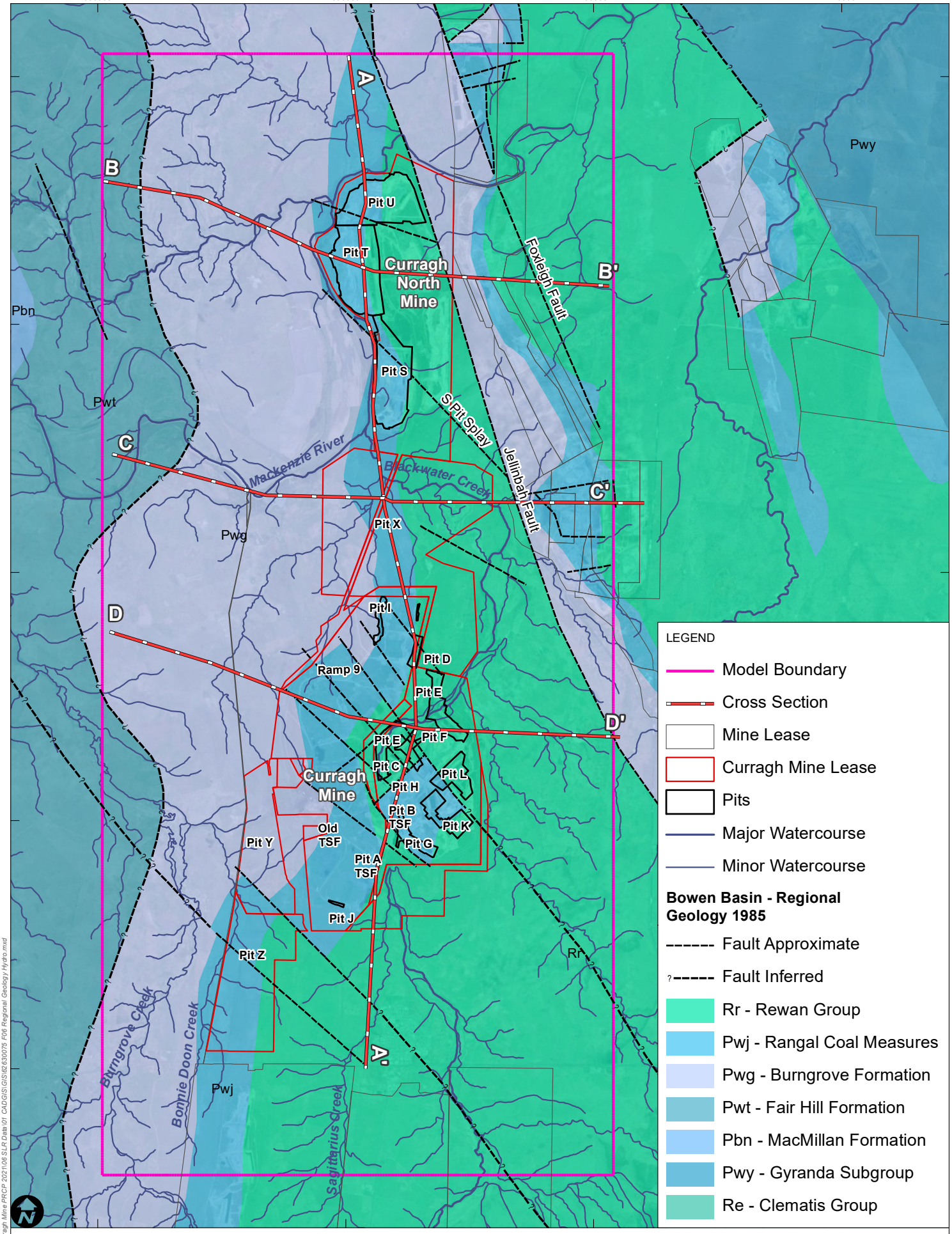
**CURRAGH PRCP**

**Preliminary Groundwater Assessment for Curragh CRVA Surface Geology**

**FIGURE 2-5**

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**CURRAGH PRCP**

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| Reviewed by: | ML |

**Preliminary Groundwater Assessment for Curragh CRVA Regional Geology**

**FIGURE 2-6**

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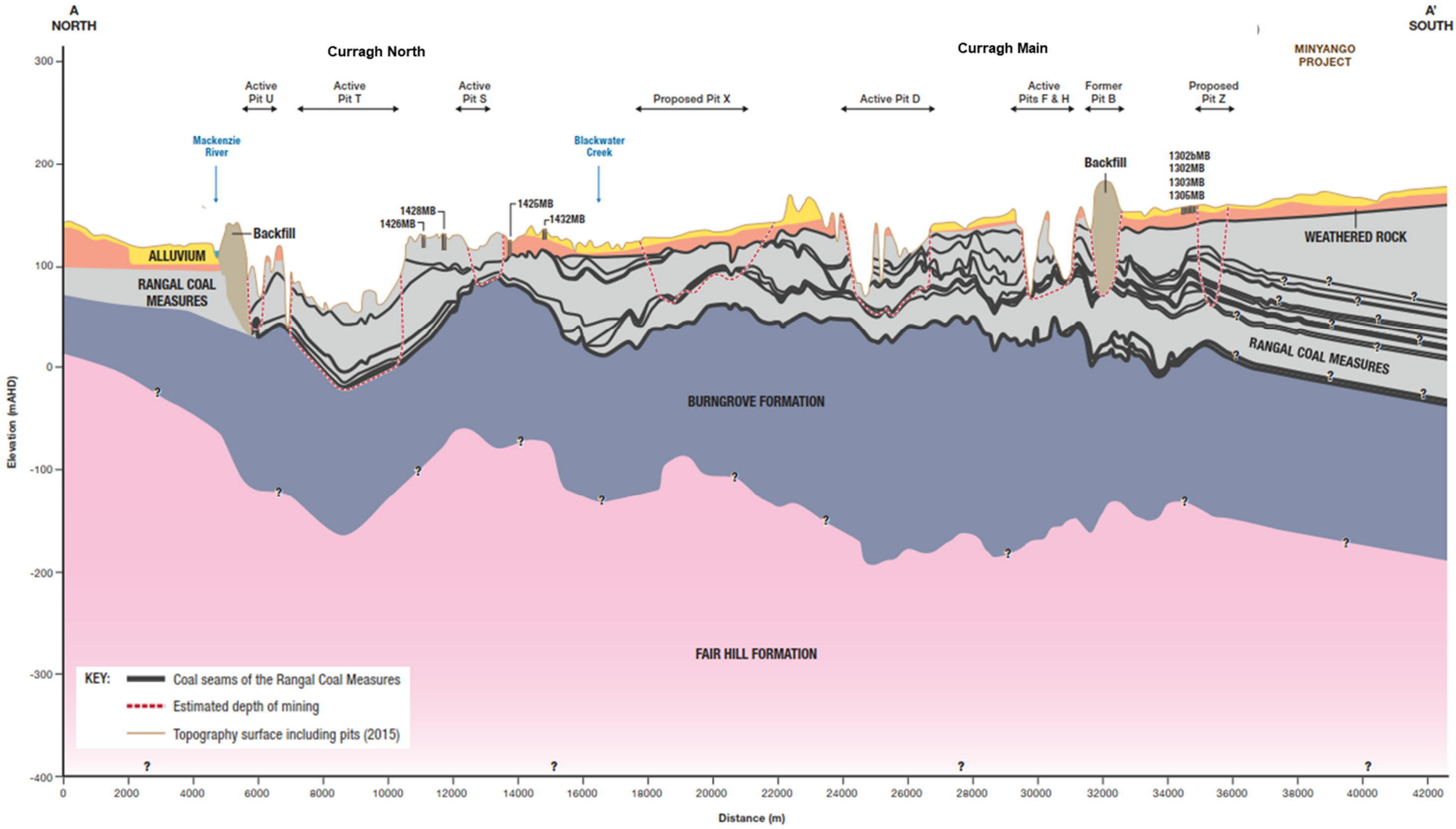



Figure 2-7 Conceptual geological cross-section A-A' (from PB, 2016)

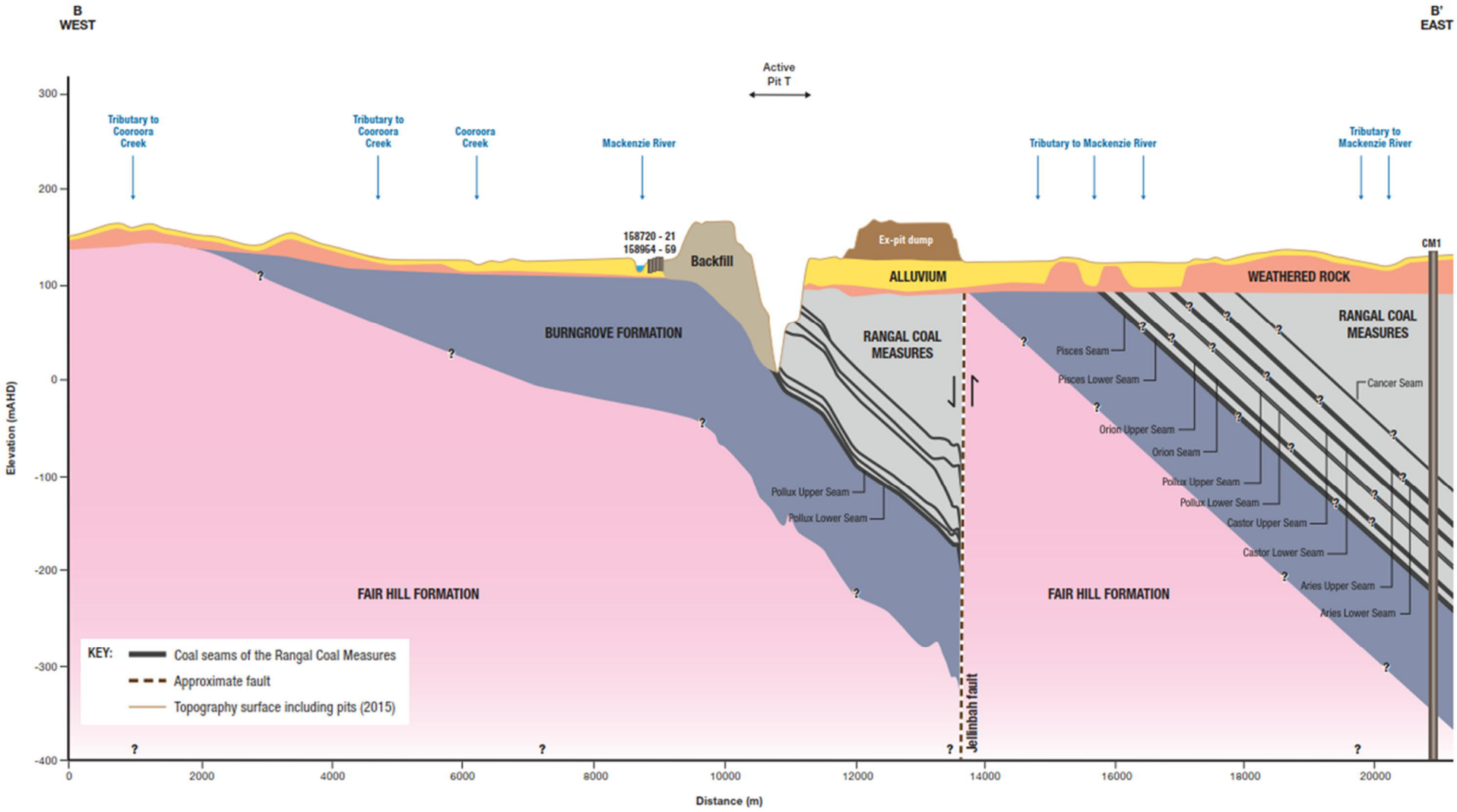



Figure 2-8 Conceptual geological cross-section B-B' (from PB, 2016)

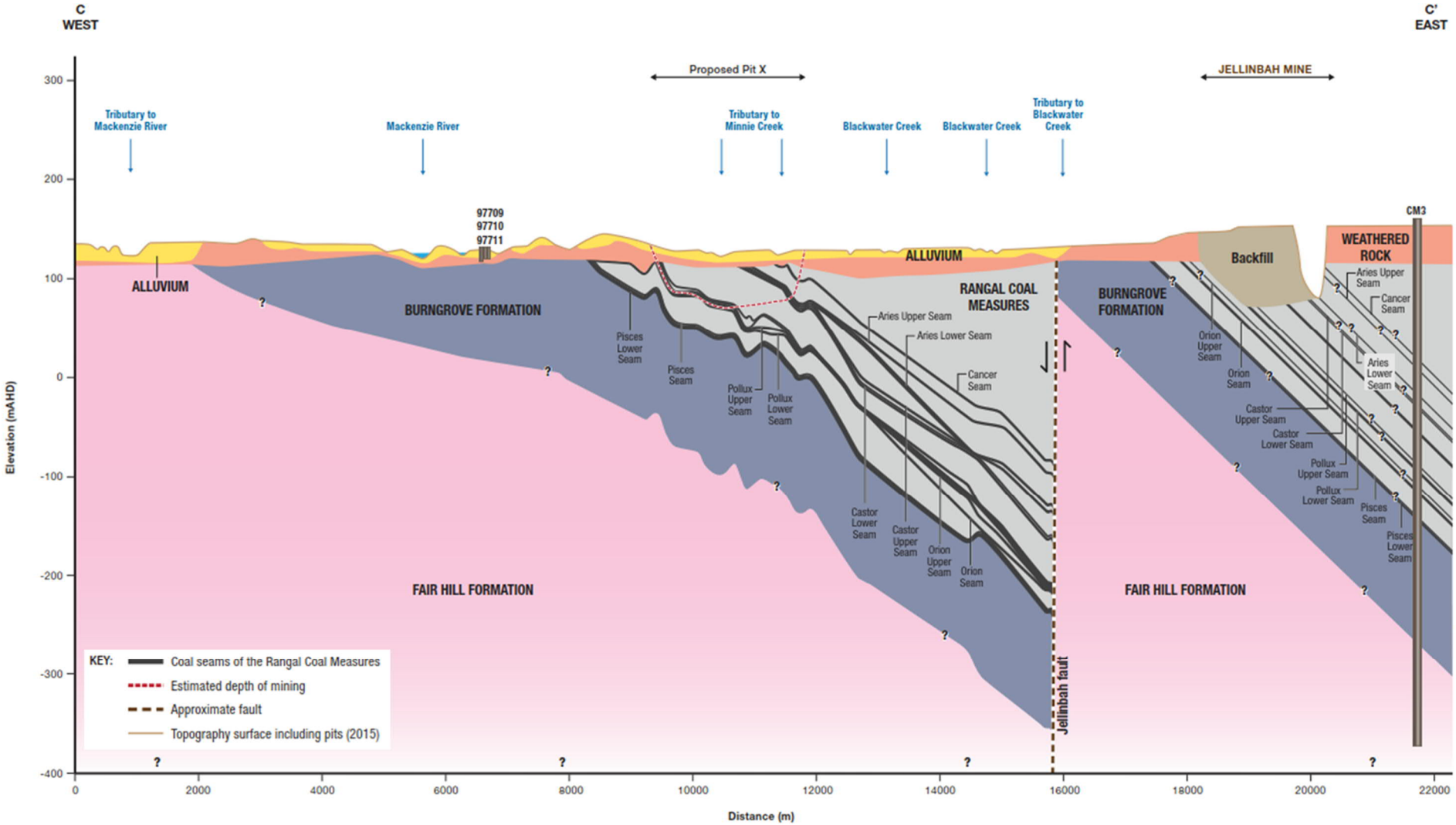



Figure 2-9 Conceptual geological cross-section C-C' (from PB, 2016)

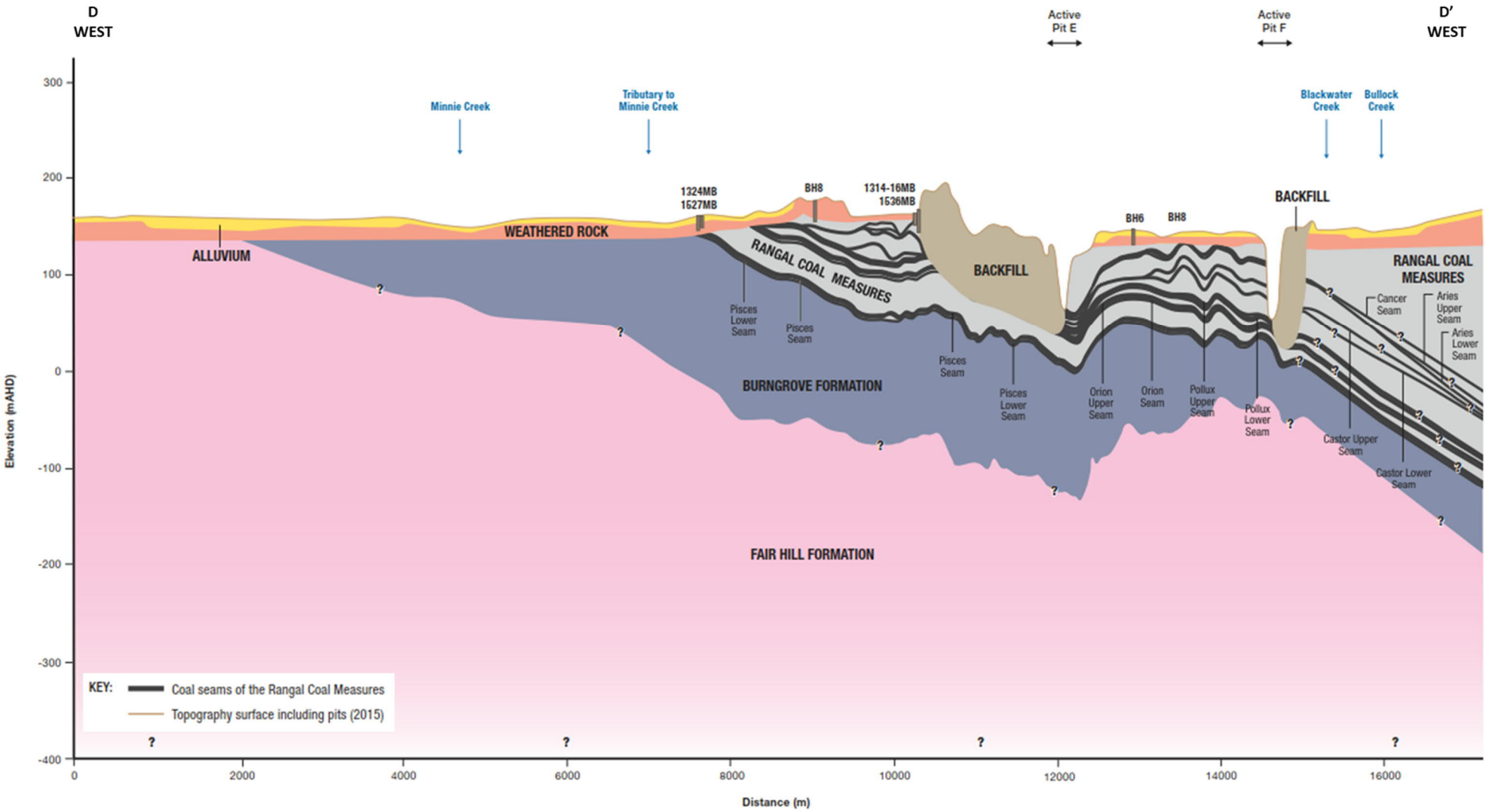



Figure 2-10 Conceptual geological cross-section D-D' (from PB, 2016)

## 2.2 Groundwater Monitoring Data

### 2.2.1 Groundwater Monitoring Network

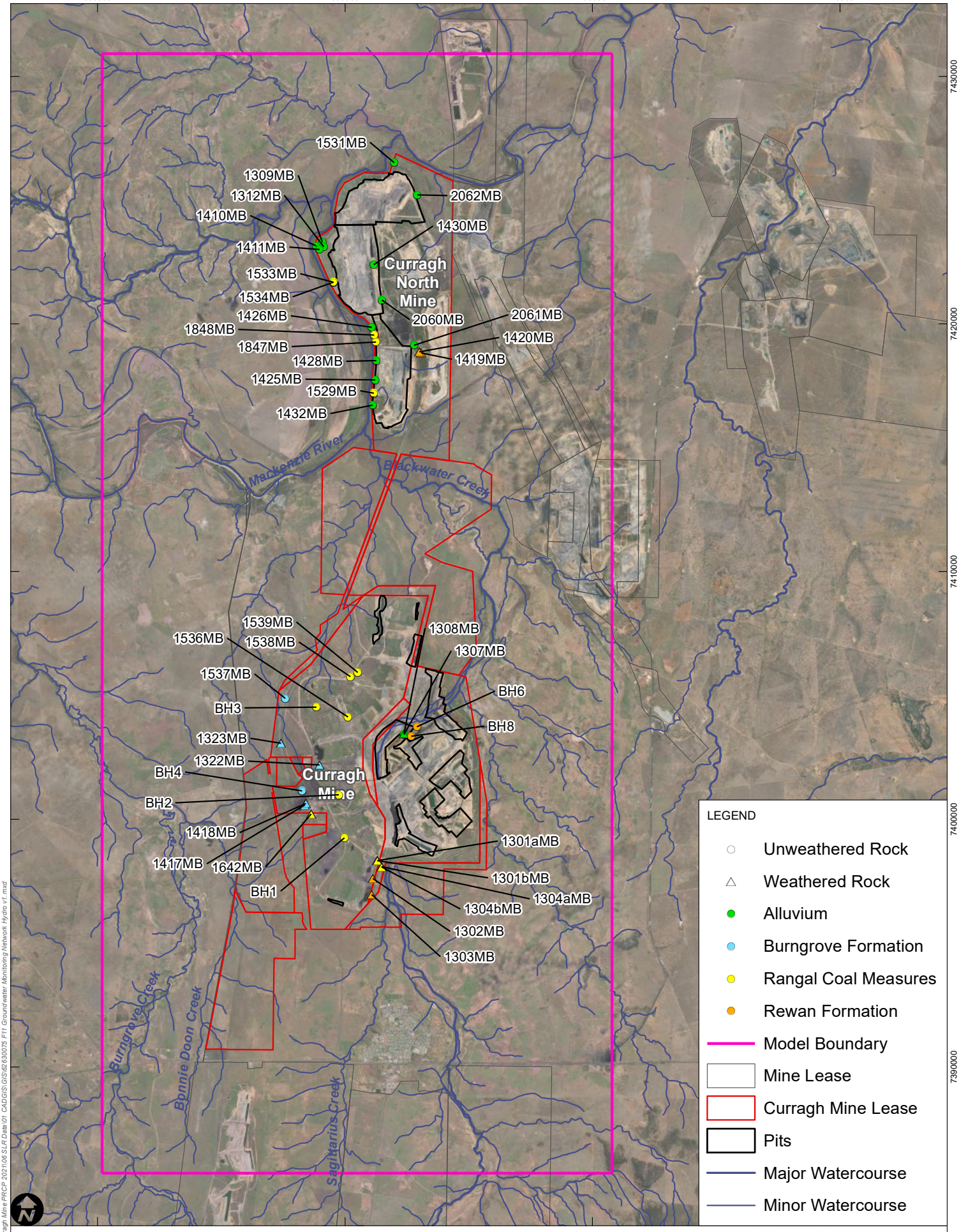
The groundwater monitoring network at Curragh Mine has progressively developed since the 1990s. The available monitoring data indicates that there are 36 bores from which data is currently collected with 22 used for groundwater quality monitoring and 23 used for groundwater level monitoring. The monitoring bore network for the mine is shown in Figure 2-11. Details of the monitoring bores, including bore construction, target formation and date of installation, are provided in Table 2-3.

Groundwater monitoring bores across the mine have been installed in the alluvium, Duaringa Formation, Rewan Formation, Rangal Coal Measures and the Burngrove Formation, with emphasis on water bearing units. The network has been designed to improve the understanding of the hydrogeological conditions in the area surrounding the mine and identify impacts associated within mining operations. Monitoring bore locations have been chosen to:

- provide spatial coverage across the area
- provide hydrogeological data on the range of formations and hydrogeological environments
- identify potential impacts to sensitive features such as groundwater dependent ecosystems (GDEs) and areas of potential surface water-groundwater interaction
- detect changes in groundwater conditions due to seepage from site infrastructure, including tailings storage facilities (TSFs), landfills, fuel farms and water storage dams
- establish a baseline of undisturbed groundwater conditions so that trigger levels can be developed to detect impacts associated with mining.

The Groundwater Monitoring Plan for the site identifies three categories of monitoring bore:

- compliance bores - monitored to assess potential impacts from mining activity on sensitive receptors
- reference bores - monitored to establish baseline groundwater conditions so that appropriate trigger levels for the detection of impacts associated with mining can be developed
- observation bores - monitored to improve the understanding of the hydrogeological conditions in the area surrounding the mine.




Data Source: © QLD DNRME, 2021

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data \01 CAD\GIS\GIS\626.30075 F11 Groundwater Monitoring Network Hydro v1.mxd

SLR

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| | |
|---|---|
| Coordinate System: | AGD 1984 AMG Zone 55 |
| Scale: | 1:195,000 at A4 |
| Project Number: | 626.30075 |
| Date: | 26-Nov-2021 |
| Drawn by: | ML |
| Reviewed by: | ML |

**CURRAGH PRCP**

**Preliminary Groundwater Assessment for Curragh CRVA Groundwater monitoring network**

**FIGURE 2-11**

## Table 2-3 Groundwater Monitoring Bores

| Bore | Easting | Northing | Ground RL (mAHD) | Screen Depth (mbgl) | Formation description | Date installed | Location | Available data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Water Quality | Water Level |
| Alluvium | | | | | | | | | |
| 1307MB* | 692378 | 7403433 | 143.16 | 4 – 7 | Alluvium | 08-07-2013 | Dam A | no | yes |
| 1308MB* | 692387 | 7403452 | 143.30 | 10 – 14 | Alluvium / weathered Tertiary (Duaringa Fm.) | 09-07-2013 | Dam A | no | no |
| 1309MB” | 689082 | 7423302 | 124.43 | 12 – 18 | Alluvium | 10-07-2013 | CN3 (between pit and Mackenzie R) | yes | yes |
| 1312MB* | 689148 | 7423118 | 125.93 | 11 – 17 | Alluvium | 11-07-2013 | CN3 (between pit and Mackenzie R) | yes | yes |
| 1426MB” | 691085 | 7419864 | 128.79 | 12 – 26 | Alluvium | 25-11-2014 | S Pit West - below levee north | yes | yes |
| 1428MB* | 691266 | 7418518 | 127.9 | 13 – 26 | Alluvium | 26-11-2014 | S Pit West - below levee central | no | no |
| 1531MB* | 691987 | 7426518 | 125.53 | 21 – 27 | Alluvium | 16-07-2015 | U Pit extension - north near levee | yes | yes |
| 1533MB” | 689529 | 7421689 | 132.36 | 21 – 27 | Alluvium | 15-07-2015 | T Pit - West levee | no | no |
| 1410MB” | 688842 | 7423144 | 126.05 | 10 – 18 | Alluvium | 27-11-2014 | CN3 | yes | yes |
| 1430MB* | 691169 | 7422399 | 127.56 | 22 – 27 | Alluvium | 21-11-2014 | T Pit - East (palaeochannel) | no | no |
| 1432MB* | 691123 | 7416724 | 134.75 | 2 – 5 | Alluvium | 25-11-2014 | S Pit Tertiary Ridge | no | no |
| 1411MB” | 688974 | 7423011 | 128.23 | 9 – 20 | Alluvium | 21-11-2014 | CN3 | yes | yes |
| 1425MB | 691229 | 7417747 | 125.12 | 16 – 19 | Alluvium | 24-11-2014 | S Pit West - below levee south | no | yes |
| 2060MB | 691488.4 | 7420977 | 123.88 | 18 – 24 | Alluvium | - | Dam A | no | yes |
| 2061MB | 692800.1 | 7419144 | 129.75 | 26.5 – 32.5 | Alluvium | - | Dam A | no | yes |
| 2062MB | 692921.8 | 7425213 | 123.77 | 13 – 19 | Alluvium | - | Dam A | no | yes |
| Tertiary | | | | | | | | | |
| 1301aMB* | 691313 | 7398339 | 151.83 | 4 – 11 | Tertiary (weathered) | 06-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1302MB* | 691118 | 7397611 | 153.64 | 3 – 6 | Tertiary (weathered) | 05-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1303MB* | 691086 | 7396966 | 156.9 | 3 – 6 | Tertiary (weathered) | 05-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1304aMB* | 691481 | 7398090 | 153.35 | 6 – 9 | Tertiary (weathered) | 04-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1419MB^ | 693083 | 7418830 | 137.96 | 1.2 – 15 | Tertiary (weathered Duaringa Fm.) | 19-11-2014 | Curragh North Fuel Farm | yes | no |
| 1420MB” | 693004 | 7418881 | 138.43 | 1.2 - 15 | Tertiary (weathered Duaringa Fm.) | 20-11-2014 | Curragh North Fuel Farm | yes | no |

| Bore | Easting | Northing | Ground RL (mAHD) | Screen Depth (mbgl) | Formation description | Date installed | Location | Available data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Water Quality | Water Level |
| Rewan Formation | | | | | | | | | |
| BH6* | 692902 | 7403743 | 141.98 | n/a | Rewan Fm | n/a | Dam A and B | no | no |
| BH8* | 692678 | 7403357 | 142.90 | n/a | Rewan Fm | n/a | Dam A | no | no |
| Rangal Coal Measures | | | | | | | | | |
| BH1" | 689978 | 7399250 | 157.70 | n/a | RCM | n/a | Crib hut 3 | yes | no |
| BH2" | 689746 | 7400993 | 169.8 | n/a | RCM | n/a | R5 landfill | yes | no |
| BH3" | 688846 | 7404539 | 176.52 | n/a | RCM | n/a | R8 landfill | yes | no |
| 1301bMB* | 691308 | 7398335 | 151.69 | 14 – 18 | RCM (weathered) | 06-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1304bMB* | 691481 | 7398084 | 153.33 | 14 – 17 | RCM (weathered) | 02-07-2013 | New TSF (formerly Pit A R2) | yes | yes |
| 1529MB" | 691161 | 7417212 | 123.81 | 33 – 39 | RCM | 17-07-2015 | S Pit West - below levee south | yes | yes |
| 1534MB^ | 689540 | 7421687 | 132.52 | 27 – 33 | RCM | 13-07-2015 | T Pit - West levee | yes | yes |
| 1536MB" | 690116 | 7404141 | 148.504 | 35.5 – 41.5 | RCM | 02-07-2015 | Landfill - east | yes | yes |
| 1538MB^ | 690217 | 7405768 | 153.18 | 73 – 79 | RCM | 29-06-2015 | Ramp 10/11 | yes | yes |
| 1539MB* | 690523 | 7405931 | 152.2 | 53 – 59 | RCM | 03-07-2015 | Ramp 10/11 - second site | yes | yes |
| 1642MB | 688631 | 7400213 | 174.587 | 1.4 – 18.5 | RCM (weathered) | n/a | | no | yes |
| 1847MB | 691245.7 | 7419276 | 129.169 | 76.5 – 85.5 | RCM (Pisces) | n/a | | no | yes |
| 1848MB | 691184.3 | 7419553 | 128.902 | 85 – 94.5 | RCM (Pisces) | n/a | | no | yes |
| Burngrove Formation | | | | | | | | | |
| BH4" | 688260 | 7401147 | 170.19 | n/a | Burngrove Fm. | n/a | CHPP landfill | yes | no |
| 1322MB* | 688976 | 7402204 | 162.69 | 2 – 25 | Burngrove Fm. (weathered) | 26-07-2013 | Down gradient of industrial process area | no | yes |
| 1323MB^ | 687417 | 7403078 | 164.44 | 11 – 25 | Burngrove Fm. (weathered) | 25-07-2013 | Up gradient of mining ops | yes | yes |
| 1417MB^ | 688376 | 7400592 | 175.56 | 1.2 – 15 | Burngrove Fm. (weathered) | 18-11-2014 | Curragh Fuel Farm | yes | no |
| 1418MB" | 688428 | 7400647 | 175.56 | 1.2 – 16 | Burngrove Fm. (weathered) | 18-11-2014 | Curragh Fuel Farm | yes | no |
| 1537MB^ | 687589 | 7404885 | 157.71 | 30.5 – 36.5 | Burngrove Fm. (coal seam) | 27-06-2015 | SAR | yes | yes |

*Observation bore, ^Reference bore, "Compliance bore

## 2.3 Hydrogeology

### 2.3.1 Hydrostratigraphy

The main hydrostratigraphic units in the vicinity of the mine are described below, from the shallowest to the deepest/oldest:

- Alluvium – up to 30m thick in the north associated with the floodplain / channel deposits of the Mackenzie River. Thinner (up to 12 m), near extension Pit X and comprises clay, sand and gravel units. At Curragh Main and southern extension Pits up to 10 m thick but generally much thinner and predominantly clay and silt. The alluvium is dry in many areas. Unconfined water bearing sand and gravel may occur at the base of the alluvial sequence around Curragh North near proposed Pit X, but it is considered unlikely to be significantly water bearing where it occurs in the south of the mine.
- Regolith - unconsolidated surface layer of weathered rock which may provide a preferential flow pathway for groundwater. Occurs across the Project area at thicknesses between 5 and 15 m. Includes weathered residual rocks of the Duaringa and Emerald formations, Rewan Formation, Rangal Coal Measures and Burngrove Formation in areas of outcrop and sub-cropping alluvium. Variable permeability.
- Cenozoic (Tertiary Duaringa and Emerald formations) - Occurs around Curragh Main extension Pits X and D. Comprises cemented sands and gravels and sandstones, siltstones and mudstones. Water bearing zones may occur in more permeable layers, unconfined to semi-confined.
- Rewan Group - is a regional aquitard comprising mudstones interbedded with siltstone and fine to medium grained labile sandstone.
- Rangal Coal Measures - Occurs along the strike of the mine and is overlain to the east by the Rewan. Groundwater flow is primarily within the coal seams (via interconnected cleats and fractures), which are confined by low permeability overburden and interburden. The coal measures are highly faulted resulting in “compartmentalisation” with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of flow. Faults themselves may form barriers to flow or provide conduits.
- Burngrove Formation – outcrops/subcrops to the west of the mine dipping east below the Rangal Coal Measures. Groundwater flow occurs primarily via the coal seams and fractured sandstone units with low permeability siltstone and claystone forming aquitards. As with the RCM sequence it is considered to be highly faulted with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of groundwater flow. This Formation is considered the basement for the purposes of this assessment.

#### 2.3.1.1 Alluvium

The alluvium is comprised of coarse sands, gravels, silt, and clay. Groundwater present within the sand and gravel units is generally regarded as unconfined. Floodplain alluvium associated with the Mackenzie River and Blackwater Creek occurs extensively across Curragh North and the northern part of the extension Pit X.

For the 2016 expansion project hydrogeological assessment PB undertook a review of bore logs from the exploration drilling program which identified that Curragh North is underlain by a paleochannel system of significant thickness (12 - 30 m), predominantly comprising sand and gravel. The Pit X extension area is underlain by a thinner alluvial sequence (typically less than 12 m) predominantly comprising clay with sand and gravel lenses, generally occurring at depth. The alluvium in the southern areas of the mine is generally thin (<10m but typically much thinner) and comprised predominantly of clay and silt (PB 2016).

The Mackenzie River channel has migrated across the floodplain over time resulting in coarse sediments (sands and gravels) being deposited as point bar/channel lenses with overlying finer floodplain sediments. There is significant lateral variability and discontinuity in the coarser alluvial deposits which is likely to control/limit connectivity to the Mackenzie River (PB 2016). The permeability of the sands and gravels horizons within the alluvium will be variable and depend on the fines (silt/clay) content.

Groundwater studies undertaken at Curragh North prior to the commencement of mining found the majority of monitoring bores installed in alluvium were dry. Where intersected, groundwater occurred within coarse basal sands and gravels (PB 2016).

Potential impacts from mining activities will depend on intersection of the alluvium by mining and connectivity between pits and watercourses via the alluvium with the main receptors being landholder bores and GDEs.

#### 2.3.1.2 Rangal Coal Measures

Coal seams are typically the most permeable horizons within the Rangal Coal Measures and are considered fractured rock aquifers with groundwater flow occurring via joints and cleats. The coal measures have also been extensively faulted which is likely to restrict flow through the coal seams due to the lateral discontinuity. The faults themselves may present barriers to flow or provide pathways for groundwater flow.

To the east of the mining activity the coal seam aquifers are confined by the interburden layers of low permeability shale, siltstone and mudstone.

#### 2.3.1.3 Burngrove Formation

The Burngrove Formation comprises an interbedded fractured rock aquifer system with water bearing units comprising fractured or weathered sandstone and coal seams. These fractured rock aquifer units are confined by low permeability sequences of siltstone, mudstone and tuff. The fractured rock aquifers are heterogeneous in properties and distribution over their spatial extent.

### 2.3.2 Groundwater Levels and Flow Direction

Groundwater level data was provided by the mine for late 2015 onward and is presented in hydrographs below for the alluvium, RCM and Burngrove Formation. Earlier groundwater level data presented in the 2016 PB groundwater assessment for the mine expansion is also described below.

#### 2.3.2.1 Alluvium

The alluvium associated with Mackenzie River is dry in many areas and where water is present, it generally occurs in coarse paleochannel deposits at the base of the alluvium. Perched groundwater in sand and gravel lenses within low permeability fines (silt and clay) has also been recorded in previous investigations (PB, 2016).

Pre-mining groundwater levels in the alluvium at Curragh North were generally 18 to 22 mbgl with groundwater levels recorded since commencement of mining ranging from approximately 16 to 26 mbgl (PB, 2016).

The alluvium associated with Blackwater Creek in the southern area of the mine is dry in many areas.

More recent groundwater level data for the alluvium is presented in Figure 2-12. The data appears to show clear responses to rainfall variations through 2016 and 2017 and a slight declining trend (in line with low rainfall since early 2018), apparent in some bores.

Most of the current alluvial monitoring is focused on the Mackenzie River alluvial deposits directly west of Curragh North. The only current alluvial monitoring south of this is at 1307MB within Curragh Main with the alluvial groundwater level reflecting the higher elevation of this area.

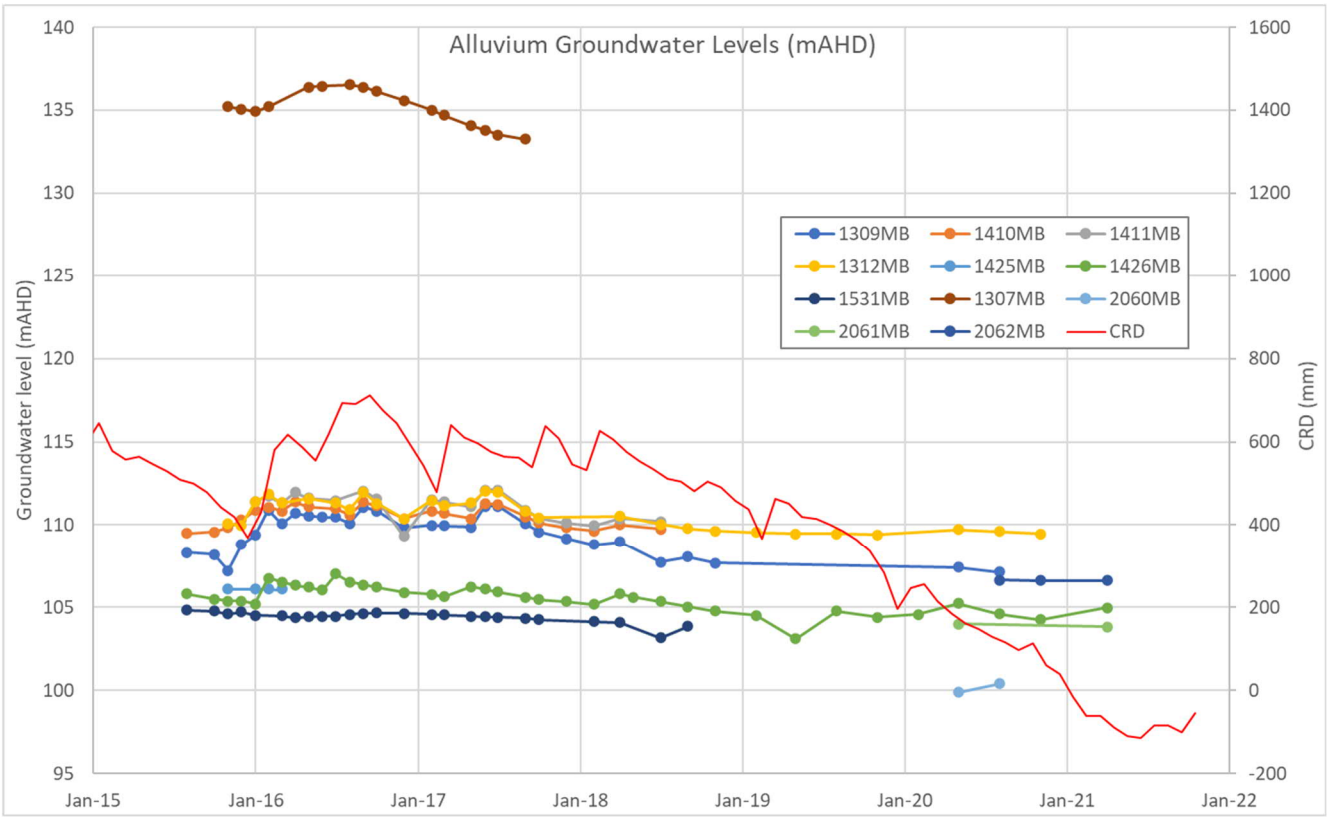



Figure 2-12 Alluvium Groundwater Levels and Cumulative Rainfall Departure

Overall, the alluvial groundwater levels clearly reflect a northerly flow direction along the Mackenzie River west of Curragh North. The 2016 PB assessment numerical modelling indicated that groundwater flow in the alluvium followed topography and drainage lines to the north and northeast. Data for 1309MB and 1312MB for July 2013 to the end of 2015 is consistent with subsequent data obtained from these bores.

#### 2.3.2.2 Rangal Coal Measures

Monitoring of the Pisces seam at Curragh North prior to the commencement of mining indicated pressure heads of 0 to 78 m above the seam. Groundwater levels in RCM outcrop areas were observed to respond to rainfall variations seen in the CRD and groundwater level recovery was also observed at some locations where mining progression had moved away from certain bores (PB, 2016).

Prior to mining, groundwater flow direction in the Permian strata was to the north-east at a very gentle gradient of 1 in 400 (Douglas Partners 2014). Since commencement of mining, groundwater flow direction in the Permian strata has been influenced locally by dewatering in the active pit areas of Curragh and Jellinbah mines.




Figure 2-13 RCM Groundwater Levels and Cumulative Rainfall Departure

Recent groundwater level monitoring data for RCM bores is presented in Figure 2-13 and generally shows very steady levels with little or no response to the CRD although several bores show slight declining trends from 2017 onward in line with lower than average rainfall although this may also be due to the influence of mining. Bore 1743MB shows a rising trend from 2017 onward, contrary to the CRD. This bore is located to the east of the Pit A TSF and south of Pit B TSF and screened at shallow depth (14-17 m bgl). It is possible that the rising groundwater level trend in this bore relates to the filling of the adjacent TSFs.

### 2.3.2.3 Burngrove Formation

Groundwater levels recorded in the Burngrove Formation since commencement of mining have ranged from approximately 6 to 29 mbgl with shallow bores in unconfined outcrop areas showing levels that correspond to long term rainfall trends. (PB, 2016).

Recent groundwater level monitoring data for the four bores installed in the Burngrove Formation are presented in Figure 2-14 All four bores are installed on the west side of Curragh Main to depths of less than 35m bgl. 1417MB shows a slight declining trend over time and possibly some response to the CRD over this period. 1537MB and to a lesser extent 1322MB show a slight rising trend over the monitoring period, possibly due to the progression of mining activity away from these locations. Recovery responses may also be somewhat masked by lower than average rainfall over the monitoring period.

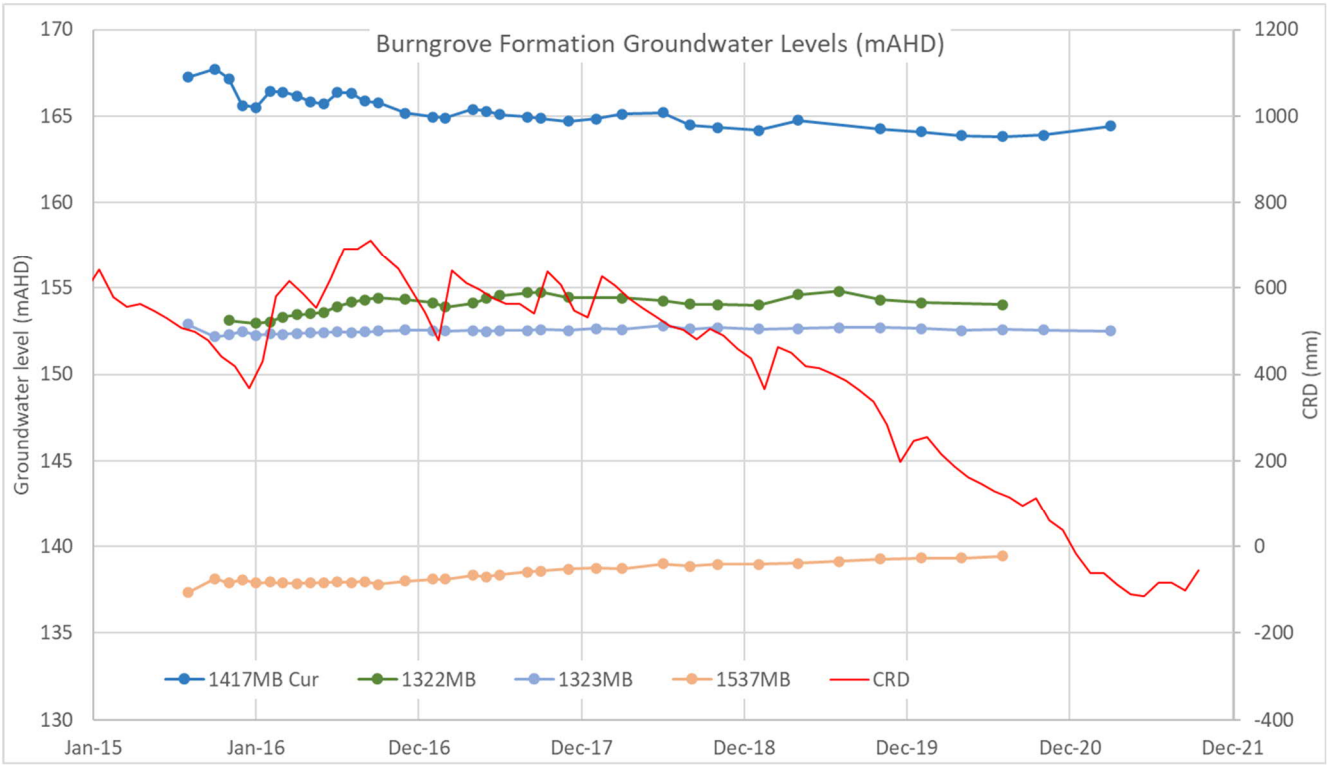



Figure 2-14 Burngrove Formation Groundwater Levels and Cumulative Rainfall Departure

### 2.3.3 Pre-mining groundwater flow

Modelled pre-mining heads are presented in

Figure 3-4 and show a generally northerly flow of groundwater across the southern area of the model domain, turning more towards the north-east in the northern part of the domain, essentially aligned with the Mackenzie River which flows in the same direction.

### 2.3.4 Effects of faulting on groundwater flow

As well as the larger mapped faults referred to in Section 2.1.5, the many minor faults will be present throughout the Permian strata.

A seismic survey across an area approximately 4x4km directly south of Blackwater was completed for the Minyango Project in 2011 (Velseis, 2012). The aim was to map the roof of the Aries and Pollux seams, mapping structures / faulting including characterisation of displacement, orientation and fault type. A total of 709 structural features were interpreted within the 16 sq km survey area for all seams.

Most structures (faults) interpreted from the survey were high angle with two main faulting trends identified striking either NNW-SSE or approximately E-W. No dominant fault type was identified with a similar number of faults characterised as reverse, normal and undefined. Many of the structures classified as undefined appear as if they may have been reactivated as they display both normal and reverse characteristics. The largest vertical displacements interpreted across the Aries and Pollux seams were 53.5m and 38m respectively. However, most faults interpreted across both horizons had displacements of less than 15m.

The high degree of faulting within the Rangal Coal Measures identified locally by the Velseis survey will have will have resulted in “compartmentalisation” with the faulting juxtaposing the more permeable coal seams against interburden. This will limit the coal seams exposed in the pit highwalls from acting as continuous pathways for potential seepage migration with abrupt discontinuation of seams where they are displaced by faulting against lower permeability interburden.

faulting around Curragh is likely to have resulted in strong compartmentalisation within the coal measures although it is likely that while some faults act as barriers to flow others may act as conduits.

### 2.3.5 Hydraulic Properties

Hydraulic property data obtained from the Curragh site and surrounding mines and other relevant sources for the key formations of interest was collated by PB for the 2016 Curragh expansion project and has been reproduced in Table 2-4.

The parameter ranges presented in Table 2-4 indicates the highly variable hydraulic conductivity in the alluvium depending on the silt / clay content. The coal seams within the Rangal Coal Measures exhibit variably moderate permeability, and typically significantly higher than the interburden strata.

## Table 2-4 Hydraulic Parameter Estimates (reproduced from PB, 2016)

| Age / Formation | Lithology | Kh (m/d) | Kv (m/d) | Ss ($m^{-1}$) | Sy | Source | Project | Source |
|---|---|---|---|---|---|---|---|---|
| Quaternary Alluvium | Mackenzie River alluvium - silty clay | 0.0009 – 0.001 | | | | Falling head test | Curragh North | 1 |
| | Mackenzie River alluvium - sand | 0.09 – 9 | | | | Falling head test | Curragh North | 1 |
| | Mackenzie River alluvium - sand/gravel | 0.9 – 9 | | | | Falling head test | Curragh North | 1 |
| | Mackenzie River alluvium - gravel | 10 | | | | Constand rate test | Mackenzie South | 2 |
| | Blackwater Creek alluvium | 0.4 | | | | Rising head test | Minyango | 3 |
| | Blackwater Creek alluvium | 0.6 | 0.018 | | | Calibrated model parameters | Minyango | 3 |
| | Floodplain/ river alluvium | 1 – 40 | 0.1 – 2 | 0.0005 | 0.05 – 0.18 | Calibrated model parameters | Arrow Energy | 7 |
| | Not specified0.00 | 100 | 10 | 0.001 | 0.25 | Unknown | Ensham Central | 6 |
| | Not specified | 0.7 – 1.5 | | 0.0001 | | Unknown | Barabala North | 13 |
| | Not specified | 10 | 1 | | 0.2 | | Millenium expansion | 8 |
| | Not specified | 0.088 – 0.38 | | 0.00001 | | Unknown | Caval Ridge | 9 |
| | Not specified | 10 | 1 | 0.00005 | 0.1 | Unknown | Springsure Creek | 11 |
| Tertiary | Duaringa Fm. - unspecified | 0.05 | 0.005 | 0.00005 | 0.12 | Calibrated model parameters | Arrow Energy | 7 |
| | | 0.6 | 0.018 | | | | Minyango | 3 |
| | Weathered – sandy gravels | 0.9 | | | | Unknown | Curragh North | 1 |
| | Weathered – claystone / cemented strata | 0.43 | | | | Unknown | Curragh North | 1 |
| Triassic Rewan Fm. | Sedimentary strata | 0.00075 | 0.0000001 | 0.00005 | 0.05 | Calibrated model parameters | Arrow Energy | 7 |
| | | 0.00015 – 0.055 | | | | Falling head tests | Minyango | 3 |
| | | 0.0009 | 0.000054 | | | Calibrated model parameters | Minyango | 3 |
| | | 0.00001 – 0.0001 | 0.000001 – 0.00001 | 0.000001 | 0.005 | Unknown | Ensham Central | 6 |
| | | 0.1 | 0.00001 | 0.000005 | 0.05 | Unknown | Daunia | 10 |

| Age / Formation | Lithology | Kh (m/d) | Kv (m/d) | Ss ($m^{-1}$) | Sy | Source | Project | Source |
|---|---|---|---|---|---|---|---|---|
| | | 0.0001 | 0.0000007 | 0.00001 | 0.01 | Unknown | Springsure Creek | 11 |
| | | 0.000007 | | | | Calibrated model parameters | Carmichael | 12 |
| Permian Rangal Coal Measures | Overlying units | 0.04 | 0.001 | | | Packer tests | Curragh North | 1 |
| | Fractured coal | 0.009 – 0.09 | | | | Packer tests | Curragh North | 1 |
| | Intact coal | 0.017 | | | | Packer tests | Curragh North | 1 |
| | Aries coal seam | 0.003 | | | | Falling head test | Minyango | 3 |
| | | 0.14 | | | | Drill stem test | Minyango | 4 |
| | Aries / Castor coal seam | 0.00014 | | | | Packer leak-off test | Cook Colliery | 5 |
| | Castor coal seam | 0.06 | | | | Drill stem test | Minyango | 4 |
| | Pollux coal seam | 0.017 | | | | Drill stem test | Minyango | 4 |
| | | 0.9 | | | | Constant rate test | Mackenzie South | 2 |
| | Pisces coal seam | 0.003 | | | | Drill stem test | Minyango | 4 |
| | Interburden | 0.0001 | $1 \times 10^{-8}$ | $8.5 \times 10^{-6}$ | 0.05 | Calibrated model parameters | Arrow Energy | 7 |
| | | 0.00009 | $1.8 \times 10^{-6}$ | | | Calibrated model parameters | Minyango | 3 |
| | | 0.1 | | $5 \times 10^{-6}$ | 0.05 | Unknown | Daunia | 10 |
| | | 0.001 | 0.00001 | 0.00001 | 0.01 | Unknown | Springsure Creek | 11 |
| Permian Burngrove | Coal and interburden | 0.00044 | $8.8 \times 10^{-6}$ | 0.00005 | 0.12 | Calibrated model parameters | Minyango | 3 |
| | | 0.000009 | $9.9 \times 10^{-7}$ | | | Calibrated model parameters | | |
| Permian Fair Hill Fm. | Fort Cooper coal seams (Virgo/ Leo/ Aquarius) | 0.000017 | | | | Packer leak-off test | Cook Colliery | 5 |

1 Minserve (1998), cited in Parsons Brinckerhoff (2003), 2 ERM (2002), cited in AGE (2006), 3 AGE (2013a), 4 Polymetra (2009), cited in AGE (2013a), 5 North Queensland Energy (1993), cited in AGE (2013a), 6 AGE (2006), cited in HydroSimulations (2014), 7 Ausenco-Norwest (2012), 8 Matrix Plus (2010), 9 URS (2009), cited in HydroSimulations (2014), 10 BHP Billiton Mitsubishi Alliance, cited in HydroSimulations (2014), 11 CDM Smith (2013), cited in HydroSimulations (2014), 12 GHD (2013), 13 JBT (2012), cited in HydroSimulations (2014)

### 2.3.6 Groundwater Quality

Groundwater quality data has been provided for the bores listed in Table 2-5 and which are shown on Figure 2-11. Data is generally available from late 2015 onward with limited data provided from before this time. Historically, groundwater quality monitoring was undertaken infrequently from 1997 to 2012 with the frequency increasing thereafter. Samples were analysed for electrical conductivity (EC), pH, major ions, nutrients, dissolved metals and hydrocarbons and water quality statistics for selected analytes are shown in Table 2-6.

Table 2-5 Currently available groundwater quality data

| Screened Formation | Bore ID | Data availability | |
|---|---|---|---|
| | | From | To |
| Alluvium | 1309MB | 28-10-2015 | 01-04-2020 |
| Alluvium | 1312MB | 03-10-2019 | 03-10-2019 |
| Alluvium | 1426MB | 30-10-2015 | 10-11-2020 |
| Alluvium | 1531MB | 28-10-2015 | 13-05-2020 |
| Alluvium | 1410MB | 03-03-2016 | 29-06-2018 |
| Alluvium | 1411MB | 28-04-2016 | 11-06-2019 |
| Tertiary (weathered) | 1301aMB | 30-01-2020 | 06-01-2021 |
| Tertiary (weathered) | 1302MB | 03-10-2019 | 07-01-2021 |
| Tertiary (weathered) | 1303MB | 03-10-2019 | 07-01-2021 |
| Tertiary (weathered) | 1304aMB | 18-09-2013 | 13-06-2016 |
| Tertiary (weathered Duaringa Fm.) | 1419MB | 06-08-2015 | 28-06-2018 |
| Tertiary (weathered Duaringa Fm.) | 1420MB | 30-12-2016 | 20-06-2017 |
| RCM | BH1 | 26-06-2000 | 09-11-2020 |
| RCM | BH2 | 09-02-2000 | 16-11-2020 |
| RCM | BH3 | 09-02-2000 | 11-11-2020 |
| RCM (weathered) | 1301bMB | 03-10-2019 | 06-01-2021 |
| RCM (weathered) | 1304bMB | 04-09-2013 | 06-01-2021 |
| RCM | 1529MB | 06-08-2015 | 10-11-2020 |
| RCM | 1534MB | 06-08-2015 | 09-12-2020 |
| RCM | 1536MB | 16-04-2018 | 14-05-2020 |
| RCM | 1538MB | 19-08-2015 | 11-11-2020 |
| RCM | 1539MB | 29-10-2015 | 20-08-2018 |
| Burngrove Fm. | BH4 | 09-02-2000 | 09-12-2020 |
| Burngrove Fm. (weathered) | 1323MB | 07-01-2014 | 09-11-2020 |
| Burngrove Fm. (weathered) | 1417MB | 05-08-2015 | 09-11-2020 |
| Burngrove Fm. (weathered) | 1418MB | 22-06-2015 | 11-11-2020 |
| Burngrove Fm. (coal seam) | 1537MB | 30-10-2015 | 10-11-2020 |

Table 2-6 Groundwater quality (recent data) for the Mackenzie River Alluvium, Rangal Coal Measures and Burngrove Formation at Curragh

| Analyte | 95% Species protection for freshwater [1] | Livestock (ANZECC) | ADWG [A] | Groundwater Quality Objectives for the Fitzroy River Basin | | | | | | Mackenzie River Alluvium | | | | Tertiary | | | | Rangal Coal Measures | | | | Burngrove Fm. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Deep (Zone 34) | | | Shallow (Zone 13) | | | | | | | | | | | | | | | | | | |
| | | | | 20th | 50th | 80th | 20th | 50th | 80th | No. | 20th | 50th | 80th | No. | 20th | 50th | 80th | No. | 20th | 50th | 80th | No. | 20th | 50th | 80th |
| pH | - | - | 6.5 – 8.5 [C] | 7.4 | 7.8 | 8.03 | 7.5 | 8.0 | 8.3 | 45 | 6.92 | 7.19 | 7.65 | 17 | 7.33 | 7.51 | 7.71 | 122 | 7.1 | 7.4 | 7.7 | 82 | 7.31 | 7.59 | 7.91 |
| TDS | - | See Table 2-7 | 600 [C] | | | | | | | 34 | 334 | 378 | 640 | 25 | 1,132 | 2,350 | 9,596 | 134 | 1,090 | 8,434 | 9,674 | 114 | 2242 | 4710 | 8366 |
| EC (µS/cm) | - | - | | 3,419 | 6,100 | 16,000 | 630 | 1,150 | 2,509 | 45 | 484.6 | 573 | 3468 | 17 | 1,702 | 3,290 | 13,420 | 118 | 1,620 | 14,250 | 16,000 | 80 | 5718 | 10900 | 14560 |
| Aluminium (mg/L) | 0.055 | 5 | 0.2 [C] | | | | | | | 34 | 0.01 | 0.01 | 0.01 | 25 | 0.01 | 0.01 | 0.024 | 139 | 0.01 | 0.01 | 0.019 | 116 | 0.01 | 0.01 | 0.01 |
| Arsenic (mg/L) | 0.013 | 0.5 | 0.01 | | | | | | | 34 | 0.001 | 0.003 | 0.0104 | 25 | 0.001 | 0.001 | 0.0016 | 138 | 0.001 | 0.001 | 0.005 | 118 | 0.001 | 0.001 | 0.001 |
| Antimony (mg/L) | 0.009 | - | 0.003 | | | | | | | 32 | 0.001 | 0.001 | 0.001 | 14 | 0.001 | 0.001 | 0.001 | 64 | 0.001 | 0.001 | 0.001 | 78 | 0.001 | 0.001 | 0.001 |
| Boron (mg/L) | 0.37 | 5 | 4 | | | | | | | 0 | | | | 1 | | 0.87 | | 23 | 0.938 | 1.10 | 1.36 | 11 | 0.63 | 0.78 | 0.85 |
| Cadmium (mg/L) | 0.0002 | 0.01 | 0.002 | | | | | | | 0 | | | | 1 | | 0.0001 | | 23 | 0.0001 | 0.0001 | 0.0001 | 11 | 0.0001 | 0.0001 | 0.0001 |
| Calcium (mg/L) | - | 1,000 | - | 46 | 145 | 442 | 21 | 40 | 73 | 15 | 34.8 | 41 | 51 | 8 | 142 | 150 | 182 | 128 | 70 | 130 | 170 | 59 | 74 | 110 | 212 |
| Chloride (mg/L) | - | - | 250 [C] | 753 | 1,900 | 5,505 | 30 | 110 | 400 | 21 | 49 | 67 | 771 | 14 | 1,895 | 2,800 | 4,356 | 139 | 1,292 | 4,300 | 5,140 | 86 | 580 | 2000 | 4060 |
| Chromium (mg/L) | 0.0033 (CrIII) | 1 | 0.05 (as CrVI) | | | | | | | 0 | | | | 1 | | 0.001 | | 23 | 0.001 | 0.016 | 0.0268 | 11 | 0.001 | 0.006 | 0.013 |
| Cobalt (mg/L) | 0.0014 | 1 | - | | | | | | | 0 | | | | 1 | | 0.001 | | 23 | 0.001 | 0.001 | 0.0068 | 11 | 0.001 | 0.001 | 0.001 |
| Copper (mg/L) | 0.0014 | 0.4 (sheep) 1 (cattle) 5 (pigs & poultry) | 2 | 0.017 | 0.030 | 0.030 | 0.000 | 0.010 | 0.030 | 0 | | | | 1 | | 0.001 | | 23 | 0.0014 | 0.004 | 0.006 | 11 | 0.001 | 0.004 | 0.005 |
| Iron (mg/L) | - | not sufficiently toxic | 0.3 [C] | 0.000 | 0.050 | 0.246 | 0.00 | 0.01 | 0.04 | 34 | 0.376 | 2.12 | 5.82 | 25 | 0.05 | 0.05 | 0.554 | 138 | 0.05 | 0.17 | 1.2 | 119 | 0.05 | 0.05 | 0.29 |
| Lead (mg/L) | 0.0034 | 0.1 | 0.01 | | | | | | | 0 | | | | 1 | | 0.001 | | 25 | 0.001 | 0.001 | 0.001 | 13 | 0.001 | 0.001 | 0.001 |
| Magnesium (mg/L) | - | 2,000 | - | 35 | 115 | 491 | 21 | 54 | 119 | 9 | 14 | 18 | 21.4 | 10 | 198 | 296 | 335 | 67 | 51 | 148 | 400 | 42 | 47 | 100 | 483 |
| Mercury (mg/L) | 0.0006 | 0.002 | 0.001 | | | | | | | 28 | 0.0001 | 0.0001 | 0.0001 | 18 | 0.0001 | 0.0001 | 0.0005 | 131 | 0.0001 | 0.0001 | 0.0005 | 104 | 0.0001 | 0.0001 | 0.0001 |
| Manganese (mg/L) | 1.9 | not sufficiently toxic | 0.5 | 0.000 | 0.050 | 0.291 | 0.00 | 0.01 | 0.02 | 0 | | | | 1 | | 1.2 | | 23 | 0.022 | 0.19 | 0.634 | 11 | 0.23 | 0.27 | 0.3 |
| Nickel (mg/L) | 0.011 | 1 | 0.02 | | | | | | | 0 | | | | 1 | | 0.003 | | 38 | 0.0044 | 0.008 | 0.013 | 17 | 0.0012 | 0.003 | 0.005 |
| Potassium (mg/L) | | - | | | | | | | | 21 | 3 | 4 | 6 | 13 | 7.5 | 11 | 12 | 82 | 6 | 8 | 13 | 60 | 2 | 5 | 11 |
| Selenium (mg/L) | 0.005 | 0.02 | 0.01 | | | | | | | 33 | 0.01 | 0.01 | 0.01 | 19 | 0.01 | 0.01 | 0.01 | 112 | 0.01 | 0.01 | 0.01 | 103 | 0.01 | 0.01 | 0.01 |
| Silver (mg/L) | 0.00005 | - | 0.1 | | | | | | | 0 | | | | 1 | | 0.001 | | 23 | 0.001 | 0.001 | 0.0016 | 11 | 0.001 | 0.001 | 0.001 |
| Sodium (mg/L) | - | - | 180 [2] | 480 | 1100 | 2565 | 56 | 135 | 326 | 21 | 36 | 42 | 648 | 13 | 1,800 | 2,100 | 2,700 | 135 | 1,400 | 2,600 | 3,336 | 85 | 580 | 1150 | 1890 |
| $SO_4$ (mg/L) | - | 1,000 | 250 [C] | 25 | 138 | 398 | 5 | 24 | 125 | 21 | 5 | 48 | 150 | 14 | 599 | 1,100 | 1,690 | 140 | 3 | 529 | 801 | 87 | 28 | 194 | 398 |
| Uranium (mg/L) | ID | 0.2 | 0.017 | | | | | | | 0 | | | | 1 | | 0.005 | | 23 | 0.001 | 0.007 | 0.008 | 11 | 0.001 | 0.001 | 0.001 |
| Zinc (mg/L) | 0.008 | 20 | 3 | 0.010 | 0.025 | 0.317 | 0.000 | 0.015 | 0.050 | 0 | | | | 1 | | 0.024 | | 23 | 0.0038 | 0.012 | 0.0246 | 11 | 0.005 | 0.014 | 0.02 |
| Total Hardness as CaCO3 (mg/L) | - | - | 200 [C] | 359 | 919 | 3,208 | 145 | 350 | 650 | 18 | 140 | 192 | 576 | 9 | 352 | 403 | 444 | 65 | 232 | 830 | 980 | 52 | 396 | 651 | 797 |

Metals concentrations presented for groundwater are dissolved, greyed out values for groundwater quality represent method detection limits

1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) - for dissolved metals and metalloids, guideline value relates to slightly-moderately disturbed systems, 95% species protection.

2 Natural component of water - guideline value is taste threshold.

A ADWG are recommended guidelines for human consumption of water (i.e. post-treatment), NHMRC (2011)

ID - insufficient data

C Aesthetic guideline / Insufficient data to set a guideline value based on health considerations.

Table 2-7 Total dissolved solids (mg/L) - livestock water quality guidelines and groundwater quality

| Livestock | Low range | Medium range | High range |
|---|---|---|---|
| Beef Cattle | 0 – 4,000 | 4,000 – 5,000 | 5,000 – 10,000 |
| Dairy Cattle | 0 – 2,400 | 2,400 – 4,000 | 4,000 – 7,000 |
| Sheep | 0 – 4,000 | 4,000 – 10,000 | 10,000 – 13,000 |
| Horses | 0 – 4,000 | 4,000 – 6,000 | 6,000 – 7,000 |
| Pigs | 0 – 4,000 | 4,000 – 6,000 | 6,000 – 8,000 |
| Poultry | 0 – 2,000 | 2000 – 3,000 | 3,000 – 4,000 |
| Formation | 20$^{th}$ %ile | 50$^{th}$ %ile | 80$^{th}$ %ile |
| Mackenzie Alluvium | 334 | 378 | 640 |
| Tertiary | 1,132 | 2,350 | 9,596 |
| Rangal Coal Measures | 1,090 | 8,434 | 9,674 |
| Burngrove Fm. | 2242 | 4710 | 8366 |

Low range - No adverse effects expected
Medium Range - Animals may have initial reluctance to drink, but stock should adapt without loss of production.
High range - Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually.

To provide a broad picture of groundwater quality in the vicinity of the mine Table 2-6 and Table 2-7 presents water quality statistics (20$^{th}$, 50$^{th}$ and 80$^{th}$ percentiles) for each of the main formations monitored together with the following relevant water quality guidelines:

- Livestock drinking water guidelines (ANZECC, 2000) – given the rural agricultural setting of the mine the stock watering guidelines are considered relevant to assessing local groundwater values.
- Australian Drinking Water Guidelines (ANZECC, NRMMC 2011) – given the rural setting of the mine and the potential presence of local stock and domestic bores the drinking water guidelines are considered relevant to assessing local groundwater values.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) – these guidelines, originating from the ANZECC & ARMCANZ (2000) water quality guidelines, provide guideline values for the protection of fresh and marine water habitats. The values selected from this guidance relates to slightly-moderately disturbed freshwater systems for 95% species protection. These guidelines are considered relevant for protection of the Mackenzie River and its tributaries.
- Groundwater Quality Objectives for the Fitzroy River Basin (Zone 13 & 34) (DEHP 2011) - These guidelines are intended to be protective of surface waters where there is the potential for groundwater surface water interaction i.e., groundwater quality should not compromise identified EVs and WQOs for those waters. This guidance groundwater quality objectives i.e., background groundwater quality statistics that should be maintained for groundwaters, for 44 zones and depths (shallow and deep) across the Fitzroy Basin. The mine lies within Zone 13 which is categorised as Low-Moderate salinity alluvial groundwater – reflective of the Mackenzie River Alluvium. In addition, guideline values for Zone 34 (deep) have been included which is regarded as saline groundwater and considered more representative of deeper groundwater within the RCM and Burngrove Formation.

A summary of general groundwater quality compared these to guideline values is presented below.

- Livestock drinking water guidelines (ANZECC, 2000) – except for sulphate in Tertiary strata at the 50th and 80th percentile none of the guideline values for stock watering in Table 2-6 are exceeded in any lithology even at the 20th percentile. TDS is considered separately in Table 2-7:
    - Mackenzie River Alluvium – Salinity is suitably low for stock watering.
    - Tertiary – salinity is generally low and suitable for most stock although higher salinities are observed around the 80th percentile rendering it suitable for beef cattle and sheep only.
    - RCM – salinity is elevated with concentrations around the 50th percentile becoming unsuitable for more salt sensitive livestock. Maximum TDS significantly exceeds the high range guidelines for livestock
    - Burngrove Formation - salinities around the 50th percentile concentration are generally still suitable for all but the most sensitive livestock (poultry and dairy cattle) but increase to similar concentrations seen in the Tertiary and RCM at the 80th percentile. Maximum TDS significantly exceeds the high range guidelines for livestock
- Australian Drinking Water Guidelines (ANZECC, NRMMC 2011) – groundwater quality in the Mackenzie River Alluvium to the west of Curragh North is considered generally suitable for drinking water based on chemical quality noting the exceedances below. The composition of groundwater in the Tertiary, RCM, and Burngrove Fm. Is considered unsuitable for drinking water, primarily due to its generally high salinity. The following exceedances of guideline values are noted:
    - Mackenzie River Alluvium - The (aesthetic) guidelines for TDS, Na and total hardness are exceeded at the 80th percentile and the (aesthetic) guideline for Fe is exceeded at all percentiles. In addition, the guideline for As is fractionally exceeded at the 80th percentile.
    - Tertiary - The (aesthetic) guidelines for TDS, Cl, Na, SO4 and hardness are exceeded at the 20th percentile. In addition, the guidelines for Al, As and Fe are exceeded at the 80th percentile and one analysis for Mn also exceeds the guideline.
    - RCM - The (aesthetic) guidelines for TDS, Cl, Na and hardness are exceeded at the 20th percentile, and SO4 at the 50th percentile. In addition, the guidelines for As, Fe and Mn are exceeded at the 80th percentile.
    - Burngrove Formation - The (aesthetic) guidelines for TDS, Cl, Na and hardness are exceeded at the 20th percentile, and SO4 at the 80th percentile.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) – 95% species protection. With regard to the potential impacts on surface water ecosystems local groundwater the following exceedances identified:
    - Mackenzie River Alluvium – none of the guideline values are exceeded at the 20th percentile.
    - Tertiary – The guideline for B and Zn is exceeded although the sample count for these analytes is just 1.
    - RCM - The guideline for B is exceeded at the 20th percentile; Cr, Cu and Zn at the 50th percentile and, Co, K and Ag at the 80th percentile.
    - Burngrove Formation - The guideline for B is exceeded at the 20th percentile; Cu and Zn at the 50th percentile and, Cr at the 80th percentile.

- Groundwater Quality Objectives for the Fitzroy River Basin (Zone 13 & 34) (DEHP 2011) - These guidelines are intended to be protective of surface waters where there is the potential for groundwater - surface water interaction. The Mackenzie River Alluvium has been compared to Zone 13 (shallow) guidelines which are intended for low salinity alluvial groundwater. The Tertiary, RCM and Burngrove Formation groundwater has been compared to guidelines for Zone 34 (deep) which are considered more appropriate for the deeper geology across the mine:
    - Mackenzie River Alluvium – pH (groundwater slightly lower than the 20$^{th}$ %ile guideline); and exceedances for EC (80$^{th}$ %ile), Ca (20$^{th}$ and 50$^{th}$ %iles), Fe (20$^{th}$, 50$^{th}$ and 80$^{th}$ %iles), Na (80$^{th}$ %ile), and SO4 (50$^{th}$ and 80$^{th}$ %iles).
    - Tertiary – pH (groundwater slightly lower than the 20$^{th}$ %ile guideline); and exceedances for Ca (20$^{th}$ and 50$^{th}$ %iles), Mg (20$^{th}$ and 50$^{th}$ %iles), Mn (20$^{th}$, 50$^{th}$ and 80$^{th}$ %iles), Na and SO4 (20$^{th}$, 50$^{th}$ and 80$^{th}$ %iles).
    - RCM - pH (groundwater slightly lower than the 20$^{th}$ and 50$^{th}$ %ile guideline); and exceedances for Fe (50$^{th}$ and 80$^{th}$ %iles), Mg (20$^{th}$ %ile), Mn, Na and SO4 (20$^{th}$, 50$^{th}$ and 80$^{th}$ %iles).
    - Burngrove Formation - pH (groundwater slightly lower than the 20$^{th}$ %ile guideline); and exceedances for EC (20$^{th}$ and 50$^{th}$ %iles), Fe (80$^{th}$ %ile), Mg (20$^{th}$ %iles), Mn (20$^{th}$, 50$^{th}$ and 80$^{th}$ %iles), Na and SO4 (50$^{th}$ and 80$^{th}$ %iles).

For bores with sufficient data on major ion chemistry, the mean major ion concentrations have been plotted on a Piper Diagram (Figure 2-15), to determine key differences in the hydrochemical facies of groundwater sampled from different strata. The Piper Plot displays individual bores colour coded for the different formations: Mackenzie River Alluvium (yellow), Tertiary (red), RCM (grey) and Burngrove Formation (green).

The fresher groundwater of the Mackenzie River Alluvium (yellow), fall within the Mg-HCO3 field while the RCM bores plot mostly within the Na-Cl field as does groundwater sampled from the Burngrove Formation. The two bores screened in the Tertiary plot separately in the Na-Cl field and the adjacent mixed Ca-Mg-Cl field.

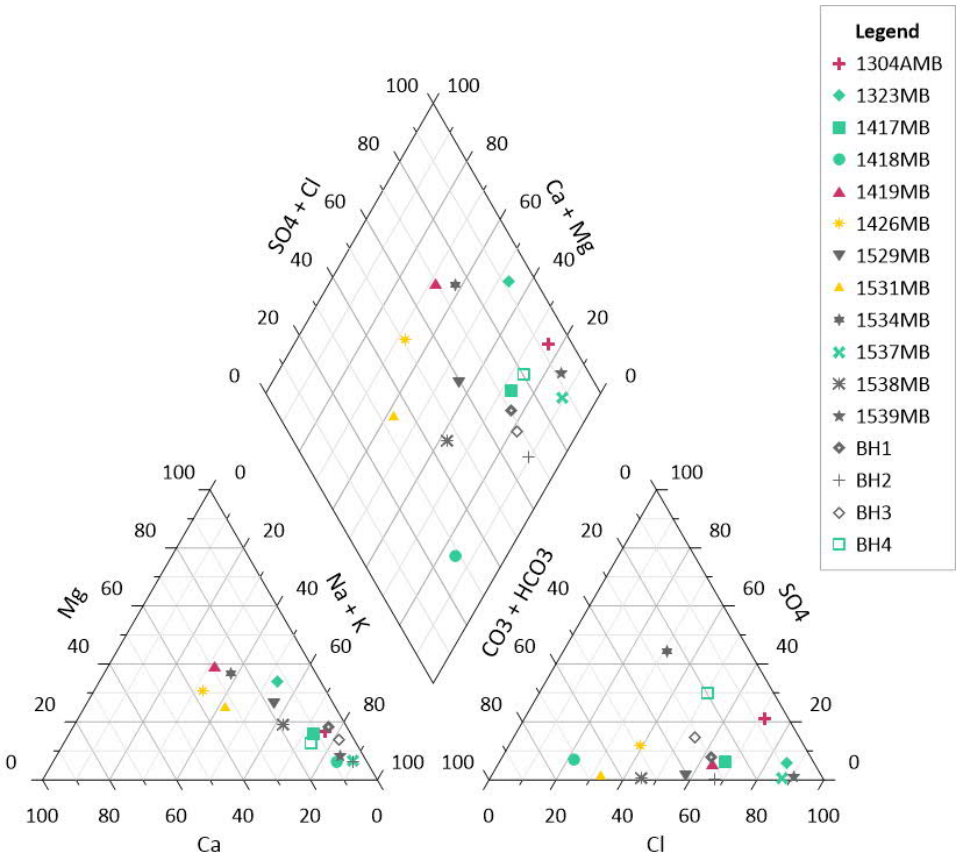



Figure 2-15 Piper plot of groundwater major ion chemistry

## 2.3.7 Groundwater Recharge and Discharge

### 2.3.7.1 Recharge

Recharge of the alluvial aquifers occurs via stream flow, particularly during periods of high flow and flooding, as well as via rainfall infiltration. Most creeks in the region are ephemeral, although flow in the Mackenzie River is controlled by releases from Fairbairn Dam and the upper reach of Blackwater Creek flows due to discharge from the Blackwater Wastewater Treatment Plant. These streams may provide a constant source of recharge to the underlying alluvial and weathered rock groundwater systems. Groundwater studies undertaken at Curragh North prior to the commencement of mining found the alluvium was dry in many areas which may be related to clays and silts in the upper part of the alluvial profile restricting direct recharge and streamflow infiltration (PB 2003).

In the initial phases of mining at Pit S at Curragh North in late 2014, conceptual understanding was that Mackenzie River may provide recharge to the alluvium with a hydraulic gradient in the alluvium towards Pit S (Douglas and Partners, 2014). However, the 2016 PB assessment indicates that very minor inflow from the alluvium in the wall buttress on the Mackenzie River side of the pit has been observed and no change in water levels in Mackenzie River during mining (PB 2016). This may be due to the disconnected nature of the permeable channel deposits and the presence of clay and silt layers limiting the connectivity between the alluvium and mining operations directly east of the Mackenzie River at Curragh North (PB 2016).

From a review of available monitoring data Parsons Brinckerhoff (2003) identified a limited response in alluvial groundwater levels to rainfall events and subsequent river level rises and suggest this was due to the monitored alluvial groundwater being perched, and the high fines content of the alluvial sand and gravel lenses.

Following a review of alluvial bore logs between the Mackenzie River and proposed Pit X, and Blackwater Creek and proposed extension Pits D and J which identified a relatively high proportion of clay, PB (2016) again suggest that recharge to alluvium in these areas may be limited.

Recharge to the aquifer units within the RCM and Burngrove Formation is likely to occur predominantly through rainfall infiltration in outcrop areas, and via vertical leakage, particularly where coal seams subcrop permeable alluvium. Some recharge may also occur via stream flow where formations outcrop / subcrop along creek lines, for example where the RCM outcrops Bonnie Doon Creek.

#### 2.3.7.2 Discharge

The major discharge from the RCM in the vicinity of the mine is direct inflow to the mine pits. Regional groundwater flow is also a discharge mechanism with the general direction of groundwater flow being toward the north-east.

Evapotranspiration from the water table is also a significant discharge mechanism in areas where the water table is shallow and within the rooting depth of vegetation.

The BOM GDE Atlas indicates that Mackenzie River, Blackwater Creek and Cooroora Creek have a moderate potential for groundwater interaction. There is potential that groundwater in alluvium may discharge to Mackenzie River at times, particularly during the wet season when groundwater levels may rise. This is discussed further below.

Local extraction of groundwater by landholders is also a discharge mechanism although this appears to be limited in the vicinity of the mine (Section 2.4.2).

Other streams in the study area, including Blackwater Creek, Minnie Creek, Sagittarius Creek and Bonnie Doon Creek, are considered unlikely to receive baseflow from groundwater. This is consistent with site observations which indicate these streams are dry during the dry season and only flow following rainfall runoff during the wet season (PB 2016).

### 2.3.8 Surface Water Groundwater Interaction

#### 2.3.8.1 Mackenzie River (including Cooroora Creek)

The Mackenzie River is the main watercourse in the vicinity of the mine with regulation and releases from Fairburn Dam having altered the natural flow regime. Cooroora Creek is a tributary of Mackenzie River to the west of Curragh North.

##### 2.3.8.1.1 Occurrence of groundwater

Groundwater studies undertaken by Parsons Brinckerhoff (2003) at Curragh North prior to the commencement of mining found that most monitoring bores installed in alluvium were dry. Where water was present in monitoring bores, it occurred within the basal palaeochannel deposits of gravel and coarse sands.

#### 2.3.8.1.2 Pre-mining groundwater levels

Groundwater studies undertaken by Parsons Brinckerhoff (2003) at Curragh North prior to the commencement of mining included installation of a groundwater monitoring network in the Mackenzie River alluvium and monitoring levels in the Mackenzie River.

Monitoring was undertaken from November 2001 to May 2003 at three alluvial bores located immediately adjacent to Mackenzie River (near current Pit U and Pit T). Hydrographs for these bores and levels in the Mackenzie River are presented in Figure 2-16 and show that groundwater levels in the alluvium were 3-5 m below the Mackenzie River stage. The monitoring also shows that high flow events captured in the monitoring data with river stage increases of over 1m had little or no impact on groundwater levels in the neighbouring alluvial groundwater bores. The data was interpreted as an indication that prior to mining at Curragh North, there was limited leakage from the river to the alluvium, and no discharge of groundwater from the alluvium to the river.

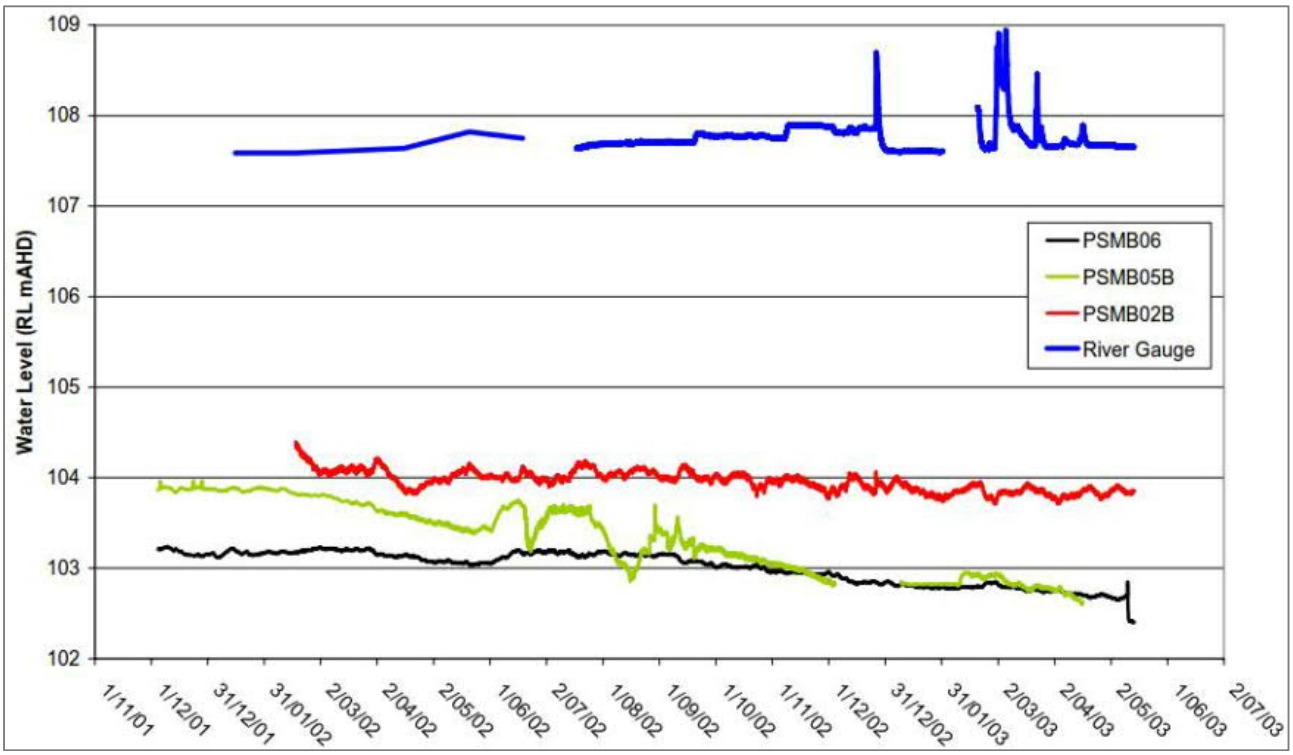



Figure 2-16 Mackenzie River stage and Mackenzie alluvium groundwater levels (reproduced from AGE, 2006)

Groundwater monitoring undertaken for the Mackenzie South Project observed a similar relationship with groundwater levels in an alluvial bore (MSP0203), immediately adjacent to the Mackenzie River 4.2 m below the river stage prior to the commencement of mining (AGE, 2006). It is noted that the monitoring undertaken for the Curragh North and Mackenzie South projects was undertaken during a period of low rainfall.

#### 2.3.8.1.3 Observations of mining adjacent to the river

Curragh North pits (S, T and U) experience inflows from the alluvium, which, in this area is relatively thick and comprised of sand and gravel. Average daily inflow from the alluvium to these pits is estimated to be 3.5 Ml/d (40 l/s), with the bulk of this inflow occurring at Pit U (3 Ml/d) (PB 2016).

A review of inflows to Pit S by Douglas Partners (2014) indicated that at the start of mining in late 2014, inflows were observed from sand and gravel at the base of the alluvium. Curragh Mine also reported that saturated alluvium was encountered in Pit S at approximately 5 to 10 mbgl with initial inflow/dewatering rates of approximately 6.5 Ml/day (PB 2016).

Two months after mining started in Pit S, the alluvium on the western pit face adjacent to Mackenzie River was dewatered and the majority of inflow was observed from the east pit face and monitoring bores screened to the base of the alluvium between the Mackenzie River and Pit S were dry or recorded water levels near the base (PB 2016).

Site observations of limited seepage from west buttress wall of Pit S suggest there is limited hydraulic connection between the Mackenzie River and the alluvium intersected in Pit S. This may be due to low permeability alluvial silt and clay between the river and pit, combined with low permeability riverbed material. Curragh Mine personnel have observed that pit inflows have not changed in relation to changing water levels in the Mackenzie River or wet season rainfall conditions (PB 2016).

#### 2.3.8.1.4 Riverbed materials

Inspection of the Mackenzie River by AGE (2006) immediately downstream of Curragh North, found the material exposed in the banks to be clay bound gravels suggesting the Mackenzie River stream bed is of relatively low permeability, limiting seepage of water from the river to the alluvium. Similar stream bed materials were observed in the Nogoa River upstream, where a detailed study of connectivity between the river and underlying alluvium was undertaken for Ensham Mine (AGE, 2006). The study involved installation of 23 monitoring bores in alluvium along both sides of the Nogoa River and excavation of pits in the stream bed and showed that there was no connection between the alluvium and river (AGE, 2006). The findings of this study were supported by investigations undertaken by the Queensland government on the Nogoa River floodplain which concluded 'it is unlikely that there is any connection between the river system and groundwater. Groundwater is restricted to the deeper section of the alluvium and there are large tracts of dry alluvium' (cited in AGE 2006).

### 2.3.8.2 Blackwater Creek

Blackwater Creek is a tributary of Mackenzie River. It is a highly modified system having undergone three previous channel alterations due to Curragh Mine workings including a 9.4 km diversion in 2010.

The field investigation program for the Minyango project found the Blackwater Creek alluvium was only saturated in areas where there is a significant thickness of deeper alluvial sediment (AGE 2013). Within the study area, the Blackwater Creek alluvium forms a relatively thin heterogeneous system, with lenses of poorly connected clean sand separated by lower permeability clayey facies and bedrock highs (PB 2016). The constant flow in the upstream section of Blackwater Creek is understood to be from the Blackwater Wastewater Treatment Plant (WTP) which discharges effluent via Sagittarius Creek.

Depth to groundwater (based the PB 2016 calibrated numerical groundwater model) indicates that Blackwater Creek is unlikely to receive baseflow from groundwater, with groundwater levels more than three metres below the stream bed. This is supported by observation of the downstream end of Blackwater Creek being dry except following rainfall.

Blackwater Creek was conceptualised by PB in 2016 to be a losing stream that is disconnected from the water table.

## 2.4 Groundwater Related Values

### 2.4.1 Groundwater dependent ecosystems (GDEs)

A Groundwater Dependent Ecosystem (GDE) is one in which the plant and/ or animal community is dependent on the availability of groundwater to maintain its structure and function. The BoM Groundwater Atlas (BoM, 2021) indicates areas of primarily low potential terrestrial GDEs / IDEs (inflow dependent ecosystems associated with the riparian corridor of the Mackenzie River and, to a lesser extent, Blackwater Creek (Figure 2-17). These terrestrial GDEs are vegetation ecosystems that rely on the subsurface presence of groundwater.

The 2016 PB assessment (due to its objective of assessing impacts associated with expansion), considered the potential for impacts on GDEs in considerable detail. The area of potential subsurface GDEs was assumed to be restricted to areas of saturated alluvium based on the results from the numerical groundwater modelling. It was also assumed that within the areas of saturated alluvium that groundwater dependence was related to the depth to the water table and vegetation rooting depth. The following criteria were used to refine the areas of likely and potential subsurface GDEs in the vicinity of the site:

- Where field verified and Queensland Herbarium mapped regional ecosystems associated with likely and potential GDEs intersected with modelled areas of saturated alluvium
- depth to groundwater within the area of saturated alluvium:
    - High – depth to groundwater within saturated alluvium <10 m
    - Possible – depth to groundwater within saturated alluvium between 10 and 20 m
    - Unlikely – depth to groundwater within saturated alluvium >20 m.

The assessment (PB, 2016) identified that much of the reach of the Mackenzie River and Cooroora Creek (tributary of the Mackenzie), within the model domain, and the northern reaches of Blackwater Creek, had a high potential to host terrestrial GDEs along the riparian corridor with a likely depth to groundwater of <10 m.

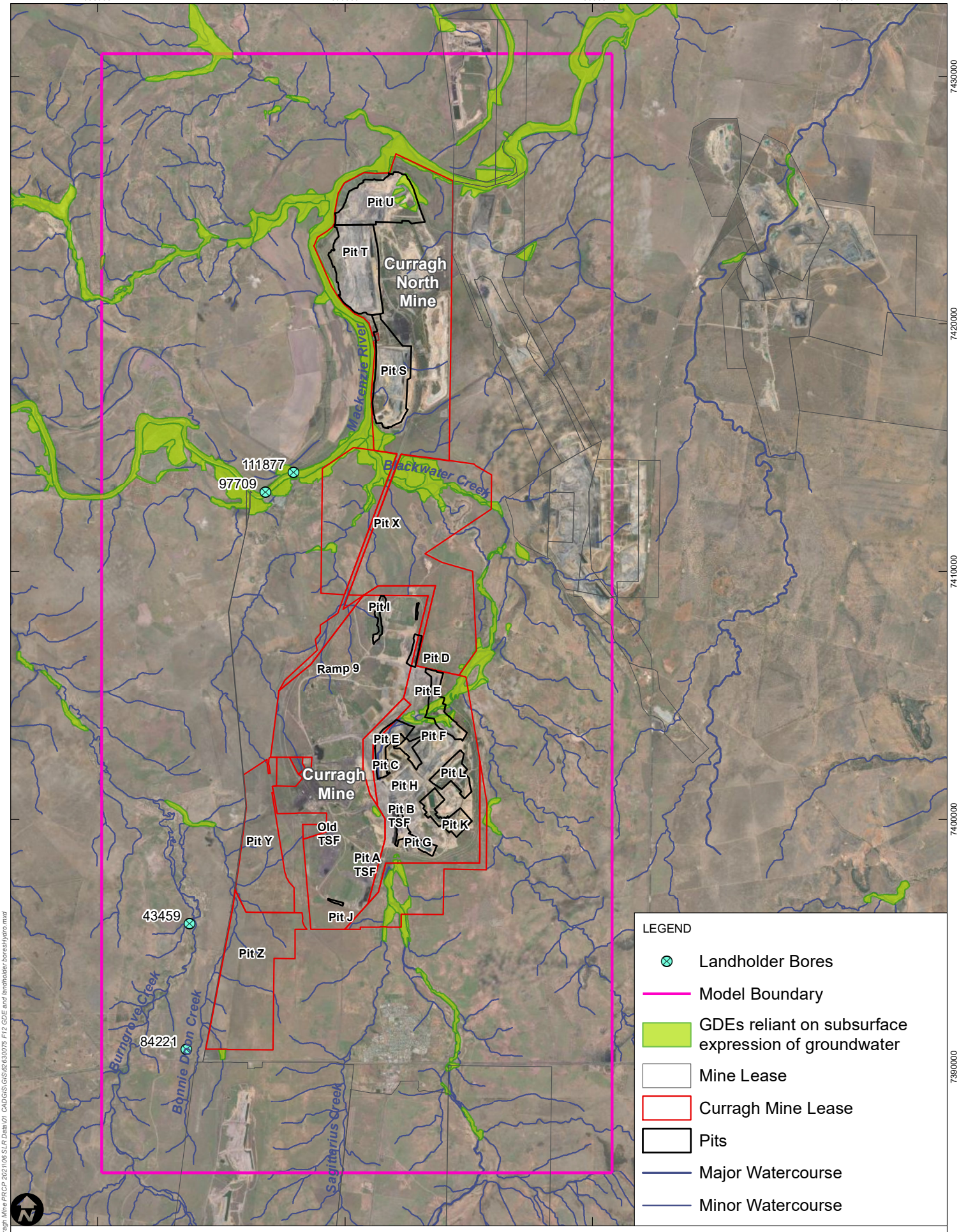
### 2.4.2 Local groundwater use

There are four registered bores within 3km of Curragh mining operations (existing or proposed); details are presented in Table 2-8 and their locations are shown on Figure 2-17.

Table 2-8 Registered bores within 3km of Curragh mining operations

| RN | | Depth (m) | SWL (mbgl) | Water quality | Yield (L/s) | Installed |
|---|---|---|---|---|---|---|
| 43459 | - | - | - | - | - | - |
| 84221 | Burngrove Formation | 31 | 30 | salty | 0.12 | 1988 |
| 97709 | - | 57 | 13 | Fresh | 3.2 | 1998 |
| 111877 | Mackenzie River Alluvium | 23 | 15 | | | 2002 |

RN111877 is owned by Central Highlands Regional Council and located at the campground approximately 150 m south of Bedford Weir on the Mackenzie River. The Council have indicated the bore is used to irrigate grass near and in the toilet block at the campground and that the groundwater is relatively saline. The bore is used to fill a 45,000 L tank 2 to 3 times each week (PB, 2016).




H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data \01 CADGIS\GIS\626.630075 F12 GDE and landholder boresHydro.mxd

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|---|---|
| Coordinate System: | AGD 1984 AMG Zone 55 |
| Scale: | 1:195,000 at A4 |
| Project Number: | 626.30075 |
| Date: | 26-Nov-2021 |
| Drawn by: | ML |
| Reviewed by: | ML |

**CURRAGH PRCP**

**Preliminary Groundwater Assessment for Curragh CRVA Landholder bores and GDEs**

**FIGURE 2-17**

# 3 Numerical Groundwater Modelling

## 3.1 Model History and Current Objectives

A numerical groundwater model for Curragh Mine was developed in 2016 by Parsons Brinckerhoff for Wesfarmers Resources Pty Ltd. The model was constructed and calibrated with the primary objective of quantifying the potential impacts of the Curragh Extension Project on groundwater resources and associated environmental values. The model was independently peer reviewed and audited by HydroSimulations in 2016. The peer review found the modelling design, model calibration and predictions to be fit for the purpose of quantifying impacts from proposed mining for the Curragh Extension Project.

The 2016 model has been provided to SLR Consulting by CCPL and has been updated for use in this preliminary assessment of post-closure groundwater related issues at the mine. For this study the 2016 model temporal datasets have been extended and a post-mining recovery simulation has been added with detailed final void modelling, to estimate the effect of mine closure on the local groundwater regime.

The primary objective of this work is to identify groundwater related issues potentially resulting from the closure of the Curragh Complex and secondarily, to lay the foundations for a more detailed assessment of potential groundwater issues at the complex as part of the closure planning process. The key objectives of this modelling exercise have been to:

- Update the model datasets and verify the model calibration;
- Update the mine progression in line with the current mine plan;
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by Coronado to understand whether the final voids act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post mining landform on local groundwater levels by comparing the long term post closure case to a null case (no mining activity).

The 2016 study classified the model as a Class 2 confidence level (HydroSimulations, 2016). The objective of the updates was to enable the groundwater model to continue to reliably simulate the existing and future groundwater conditions at Curragh Complex at a regional scale. The updates to the model included:

- Extending the rainfall in the model to include the latest climate measurements;
- Extending the calibration data set to include the latest groundwater level measurements and recalibrate the model;
- Recalibrating the model to include depth-dependent hydraulic conductivity in the Rangal Coal Measures;
- Updating the mine progression plan in the model, to include all foreseeable future mining at Curragh Complex;
- Updating the temporal discretisation to include the recovery model; and
- Setting up the recovery model to include proposed residual voids at the end of foreseeable mining at Curragh Complex.

Based on the model confidence level classification from the 2016 study and relevant updates to the model, the updated model remains a Class 2 confidence level.

## 3.2 Model Design Summary

### 3.2.1 Model Code

MODFLOW-USG (Panday *et al.* 2013) was used as the model code. MODFLOW-USG is the latest version of industry standard MODFLOW code and was determined to be appropriate and the most suitable modelling code for accomplishing the model objectives., therefore the model software remains unchanged from the Curragh Model (Parsons Brinckerhoff, 2016).

SLR used MODFLOW-USG to update and re-run the model.

### 3.2.2 Model Extent and Mesh Design

The model geometry including the grid and layering have been left unchanged from the 2016 groundwater model update by Parsons Brinckerhoff.

Model extent and mesh design have been carried over from the existing Curragh Model (Parsons Brinckerhoff, 2016) developed on behalf of Wesfarmers Resources Pty Ltd for the Curragh Extension Project. No changes to model extent or mesh design were necessary to adopt the Curragh Model for use at the Project. The model domain is presented in Figure 3-1.

The model domain encompasses the Project and is elongated in a north to south direction, covering all historical and future mining operations at Curragh Mine. The model domain is 20.6 km x 45.2 km, with a structured grid of cell size 100 m x 100 m. Where layers are discontinuous, cells were defined as no-flow cells using the BAS package. There are 93,112 cells in each of the 10 model layers, resulting in a total of 931,120 cells.

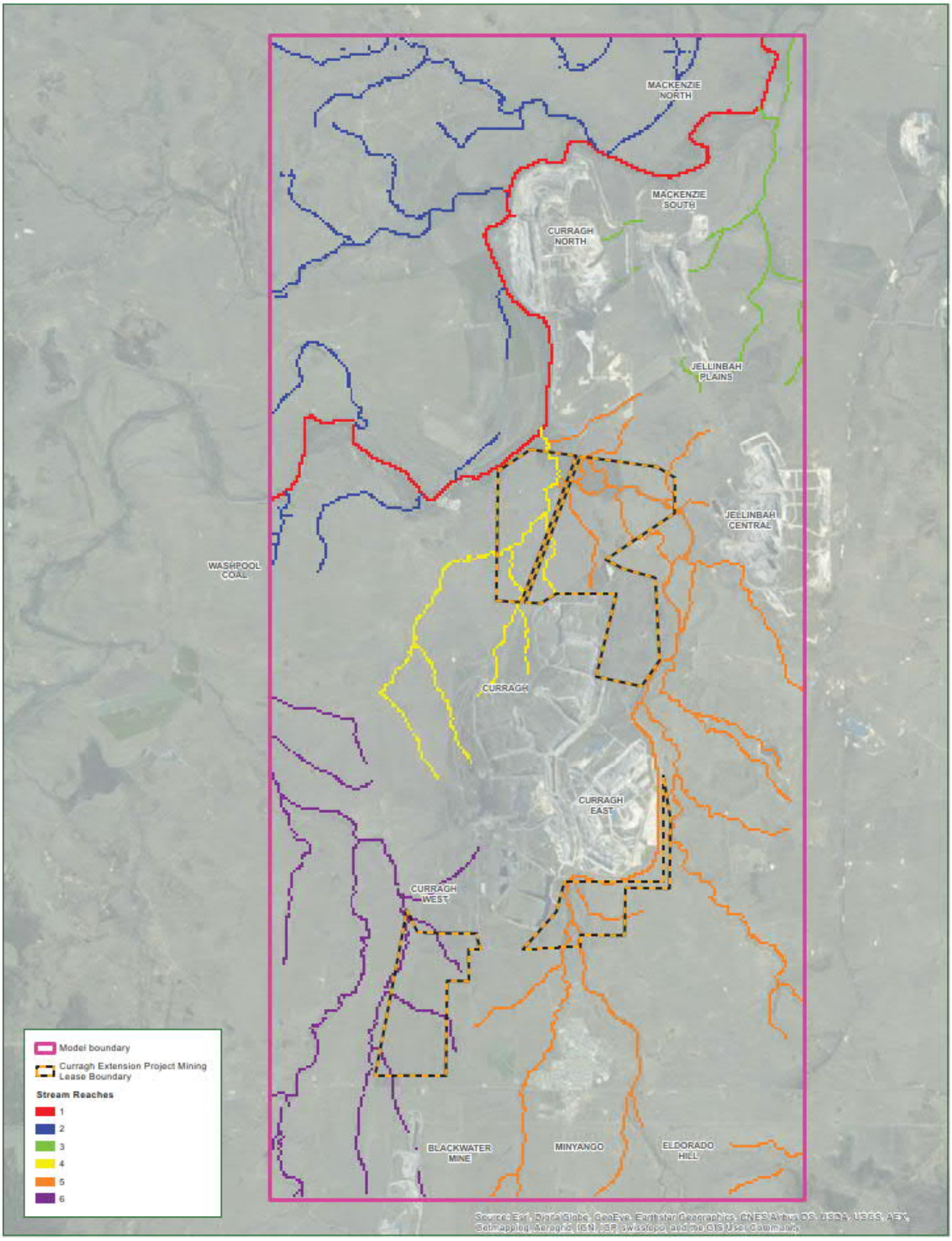



Figure 3-1 Model Domain (Parson Brinckerhoff, 2016)

As discussed in Parsons Brinckerhoff (2016), topography within the Project area of the model domain has been defined using Curragh Mine LiDAR data, beyond the extents of which high quality DEM data was used.

The model domain is discretised into 10 layers, as listed in Table 3-1. Model layer extents (lateral and vertical) have been defined using the Curragh Mine VULCAN database, with the support of exploration data from Queensland Globe for geological extent beyond the Curragh Mine area.

As discussed in Parsons Brinckerhoff (2016), the hydrogeological units represented in the model have been simplified based on hydraulic properties in order to minimise model run time while maintaining sufficient conceptual detail. The Rangal Coal Measures (RCM) are represented over three model layers, with coal seams aggregated into upper, middle and lower RCM seams. The RCM layers are not present to the western and eastern extents of the model domain where dipping of geological strata and thrusting have resulted in outcropping of the Burngrove Formation.

The modelling of faults in the model has not been updated from the Curragh Model. Included in the model are major regional faults and smaller scale local faults identified in the Curragh Extension Project hydrogeological conceptual model. The Jellinbah Fault, a regional thrust fault running in a north-westerly direction to the east of the Project resulting in up to 400 m of displacement, has been incorporated into the model through the offset of model layer elevations. Conceptual cross-sections developed using site LiDAR and drill hole data are included in the Groundwater Technical Report for the Curragh Extension Project (Parsons Brinckerhoff, 2016) and detail the structural geology of the model domain.

### Table 3-1 Model Layers and Thicknesses

| Model Layer | Formation | Unit | Average Thickness (m) | Maximum Thickness (m) |
|---|---|---|---|---|
| 1 | Alluvium | Surface cover | 9.2 | 54.7 |
| 2 | Weathered rock | Tertiary and minor Triassic Clematis, weathered Permian | 15.3 | 67.8 |
| 3 | Rewan Formation and RCM overburden | Triassic sandstone, siltstone, mudstone | 72.6 | 520.1 |
| 4 | Upper RCM seams | Cancer, Aries, Castor seams | 2.3 | 12.1 |
| 5 | RCM interburden | Sandstone, siltstone | 18.2 | 84.5 |
| 6 | Middle RCM seams | Pollux (upper and lower), Orion (upper and lower) | 2.3 | 12.1 |
| 7 | RCM interburden | Sandstone, siltstone | 11.0 | 69.4 |
| 8 | Lower RCM seams | Pisces seam | 1.9 | 17.0 |
| 9 | Burngrove Formation | Sandstone, siltstone, mudstone, coal seams | 120.2 | 357.1 |
| 10 | Fair Hill Formation | Sandstone, mudstone, coal seams | 500.0 | 750.5 |

### 3.2.3 Temporal discretisation

The simulated time period in the original model (PB, 2016) starts at 1983, with a steady-state stress period to represent the pre-mining conditions, followed by 11 transient stress periods of 3 years representing historical mining at Curragh Complex. The predictive period comprised 26 transient annual stress periods and a final 100-year stress period, ending in 2142. The temporal discretisation of the model has been updated from that originally used in the Curragh Model, to allow for an extension of the mining period to 2048.

The transient calibration model was based on temporal data at bi-annual intervals from the end of the steady state calibration (January 1983) until December 2020. Together, the initial steady-state and transient calibration comprise 17 stress periods. Table 3-2 summarises the calibration model stress periods and simulated timing of active mining. The predictive part of the model comprises annual stress periods, starting from January 2021 until January 2048. The predictive model stress period setup is detailed in Table 3-3, alongside simulated mine-timings.

## Table 3-2 Calibration Model Stress Period Setup

| Calibration Period | Interval | Stress Period | Date (from) | Date (to) | Mackenzie (North & South) (OC) | Curragh North (OC) | Jellinbah (Plains & Central) (OC) | Washpool Coal (OC) | Curragh (OC) | Curragh East (OC) | Blackwater (OC) | Eldorado Hill (UG) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Steady-state | | 1 | Steady-state | | | | | | | | | |
| Transient | Bi-annual | 2 | 01/01/1983 | 31/12/1985 | | | | | x | | | x |
| | Bi-annual | 3 | 01/01/1986 | 31/12/1988 | | | | | x | | | x |
| | Bi-annual | 4 | 01/01/1989 | 31/12/1991 | x | | x | | x | | | x |
| | Bi-annual | 5 | 01/01/1992 | 31/12/1994 | x | | x | | x | | | x |
| | Bi-annual | 6 | 01/01/1995 | 31/12/1997 | x | | x | | x | | | x |
| | Bi-annual | 7 | 01/01/1998 | 31/12/2000 | x | | x | | x | | x | x |
| | Bi-annual | 8 | 01/01/2001 | 31/12/2003 | x | x | x | | x | x | x | x |
| | Bi-annual | 9 | 01/01/2004 | 31/12/2006 | x | x | x | | x | x | x | x |
| | Bi-annual | 10 | 01/01/2007 | 31/12/2009 | x | x | x | | x | x | | x |
| | Bi-annual | 11 | 01/01/2010 | 31/12/2012 | x | x | x | | x | x | | x |
| | Bi-annual | 12 | 01/01/2013 | 31/12/2015 | x | x | x | | x | x | | x |
| | Annual | 13 | 01/01/2016 | 31/12/2016 | x | x | x | | x | x | | x |
| | Annual | 14 | 01/01/2017 | 31/12/2017 | x | x | x | x | x | x | | x |
| | Annual | 15 | 01/01/2018 | 31/12/2018 | x | x | x | x | x | x | | x |
| | Annual | 16 | 01/01/2019 | 31/12/2019 | x | x | x | x | x | x | | |
| | Annual | 17 | 01/01/2020 | 31/12/2020 | x | x | x | x | x | x | | |

## Table 3-3 Predictive Model Stress Period Setup

| Predictive Interval | Stress Period | Date (from) | Date (to) | Mackenzie (North & South) (OC) | Curragh North (OC) | Jellinbah (Plains & Central) (OC) | Curragh (OC) | Curragh East (OC) | Curragh West (OC) |
|---|---|---|---|---|---|---|---|---|---|
| Annual | 18 | 01/01/2021 | 31/12/2021 | x | x | x | x | x | |
| Annual | 19 | 01/01/2022 | 31/12/2022 | x | x | x | x | x | x |
| Annual | 20 | 01/01/2023 | 31/12/2023 | x | x | x | x | x | x |
| Annual | 21 | 01/01/2024 | 31/12/2024 | x | x | x | x | x | x |
| Annual | 22 | 01/01/2025 | 31/12/2025 | x | x | x | x | x | x |
| Annual | 23 | 01/01/2026 | 31/12/2026 | x | x | x | x | x | x |
| Annual | 24 | 01/01/2027 | 31/12/2027 | x | x | x | x | x | x |
| Annual | 25 | 01/01/2028 | 31/12/2028 | x | | x | x | x | x |
| Annual | 26 | 01/01/2029 | 31/12/2029 | x | | x | x | x | x |
| Annual | 27 | 01/01/2030 | 31/12/2030 | x | | x | | x | x |
| Annual | 28 | 01/01/2031 | 31/12/2031 | x | | x | | x | x |
| Annual | 29 | 01/01/2032 | 31/12/2032 | x | | x | | x | x |
| Annual | 30 | 01/01/2033 | 31/12/2033 | x | | x | | x | x |
| Annual | 31 | 01/01/2034 | 31/12/2034 | x | | x | | x | x |
| Annual | 32 | 01/01/2035 | 31/12/2035 | x | | x | | x | x |
| Annual | 33 | 01/01/2036 | 31/12/2036 | x | | x | | | x |
| Annual | 34 | 01/01/2037 | 31/12/2037 | x | | x | | | x |
| Annual | 35 | 01/01/2038 | 31/12/2038 | x | | x | | | |
| Annual | 36 | 01/01/2039 | 31/12/2039 | x | | x | | | |
| Annual | 37 | 01/01/2040 | 31/12/2040 | x | | | | | |
| Annual | 38 | 01/01/2041 | 31/12/2041 | x | | | | | |
| Annual | 39 | 01/01/2042 | 31/12/2042 | | | | | | |
| Annual | 40 | 01/01/2043 | 31/12/2043 | | | | | | |
| Annual | 41 | 01/01/2044 | 30/12/2044 | | | | | | |
| Annual | 42 | 01/01/2045 | 31/12/2045 | | | | | | |
| Annual | 43 | 01/01/2046 | 31/12/2046 | | | | | | |
| Annual | 44 | 01/01/2047 | 31/12/2047 | | | | | | |

### 3.2.4 Model Stresses and Boundary Conditions

Stresses and boundary conditions used in the model have been adopted from the Curragh Model (Parsons Brinckerhoff, 2016) and included:

- Rainfall Recharge: MODFLOW recharge package (RCH) was used to simulate groundwater recharge in the model. The model applied recharge in six zones across the model domain according to surface geology. The model assigned a proportion of annual rainfall to each of the zones, estimated through chloride mass balance and the calibration process. Recharge rates applied in the Curragh Model are presented in Parsons Brinckerhoff (2016).
- Evapotranspiration: MODFLOW evapotranspiration package (EVT) was used to simulate evapotranspiration in the model. The long-term average, annual, actual evapotranspiration for the Curragh Mine area is approximately 650 mm (Parsons Brinckerhoff, 2016). Evapotranspiration for the model domain was set to 50% of this annual actual rate with an extinction depth of 3 m.
- Fixed head boundaries: MODFLOW general head boundary package (GHB) was used to apply fixed heads. A general head boundary condition was applied to cells along the north, south, east and west boundaries of the model, setting groundwater levels to 4.5 m below the top of Layer 1 to represent approximate effects of neighbouring mines on the groundwater regime.
- Rivers: MODFLOW river package (RIV) and MODLFOW drain package (DRN) were used to simulate surface drainage in the model. The model included the Mackenzie River and some tributaries of Mackenzie River, including Blackwater Creek. The Mackenzie River was represented at a constant level using the RIV package, with stage elevations defined as the lowermost elevation (from Curragh Mine LiDAR) within each 100 m cell. The smaller tributaries to the Mackenzie River were represented using the DRN package, with drain stage elevations also defined using minimum elevations from the Curragh Mine LiDAR data.
- Mining: MODFLOW drain package (DRN) was used to simulate historical and future open pit mining and underground mining with the model domain.

For the purpose of this study, SLR updated the RCH package with the latest rainfall data until January 2021. No changes were made to historical mining at surrounding sites. The simulated future mine progression in the model was primarily based on the 2016 study. Some changes were made to the simulated mine progression at Curragh Mine to reflect historical mining that occurred after 2016, and updates to future mine progression plans.

## 3.3 Model Recalibration

Transient calibration was previously undertaken on the existing Curragh Model (Parsons Brinckerhoff, 2016), and has been used as a starting point for re-calibration of the updated model. Automated calibration utility PEST ++ (Doherty 2019) and manual calibration were used to match the available transient water level data.

The 2016 calibration included 328 data points from 39 sites. The recalibration update consisted of an additional 687 data points from new and existing sites. The updated calibration data set includes all available groundwater measurements recorded from August 1997 until June 2021. In all, 1015 target heads were established for 69 bores from the following sites:

- Jellinbah Coal Mine: 19 groundwater level observations sites;
- Minyango Project: 3 groundwater level observations sites;

- Curragh Mine: 46 groundwater monitoring bores located across the Curragh, Curragh East and Curragh North mining areas; and
- Other bores: 1 water resource investigation bore.

Groundwater bores used for the calibration were weighted as 1 each in the calibration where data was considered reliable. Curragh monitoring bores BH1, BH3 and BH4 were weighted as 0.5, and BH2 and BH5 were weighted as 0.1, consistent with the weighting applied in the calibration of the existing Curragh Model (PB, 2016), reflective of data reliability. Bore 1314MB was removed from the calibration as the observed data indicated significant measurements errors. The observation points and their average residuals are presented in Appendix B.

The hydraulic properties (horizontal and vertical conductivity, specific yield and specific storage), and recharge rates were adjusted during the transient recalibration to provide best match between the measurements and model simulated heads. Manual parameter adjustment was undertaken to ensure the calibrated parameters were consistent with the conceptual understanding of the hydrogeological system. Vertical hydraulic conductivity was calibrated as a factor of horizontal conductivity ($K_V/K_H$). Reduced vertical hydraulic conductivity is typically observed due to sedimentary layering throughout the sequence, and by aggregation of strata in a numerical model.

### 3.3.1 Calibration Statistics

One of the industry standard methods to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. This is done by assessing the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). A root mean square (RMS) is expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2\right]^{0.5}$$

Where:

- n = number of measurements
- $h_o$ = observed water level
- $h_m$ = simulated water level

RMS is considered to be the best measure of error, if errors are normally distributed. The weighted RMS error for the calibrated model is 5.3 m.

The acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head change in the system is small, the errors are only a small part of the overall model response. Scaled RMS (SRMS) error is the RMS divided by the range of measured heads. The weighted SRMS is 5.5% which indicates a good calibration well within the Australian guideline indicator of 10% SRMS error (MDBC, 2001; Barnett *et al*., 2012).

Figure 3-2 shows the observed and simulated groundwater levels graphically for all bores used in the calibration. The current model shows a consistent match to the observations when compared to the Parsons Brinckerhoff (2016) model calibration, which showed a weighted RMS of 3.8 m and weighted SRMS of 5.8%.

Figure 3-3 shows the distribution of calibration residuals. As shown in the figure, all calibration residuals for calibration data points are within ± 20 m. A negative residual represents an over estimation of water levels, while a positive residual represents an underestimate. Figure 3-3 indicates that in general, the model tends to over-predict groundwater levels.

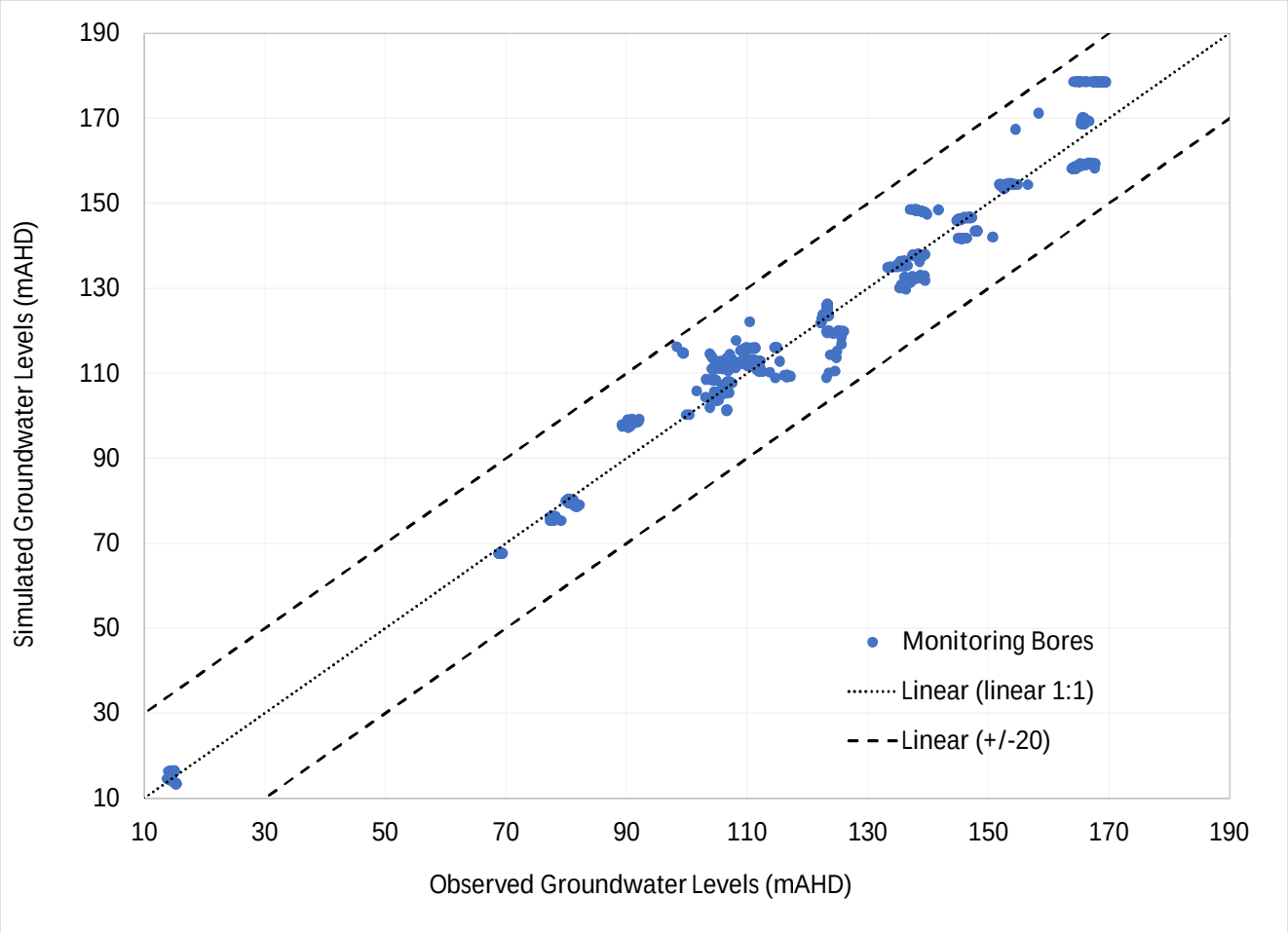



Figure 3-2 Calibration Scattergram – Modelled vs Observed Groundwater Levels (All Bores)

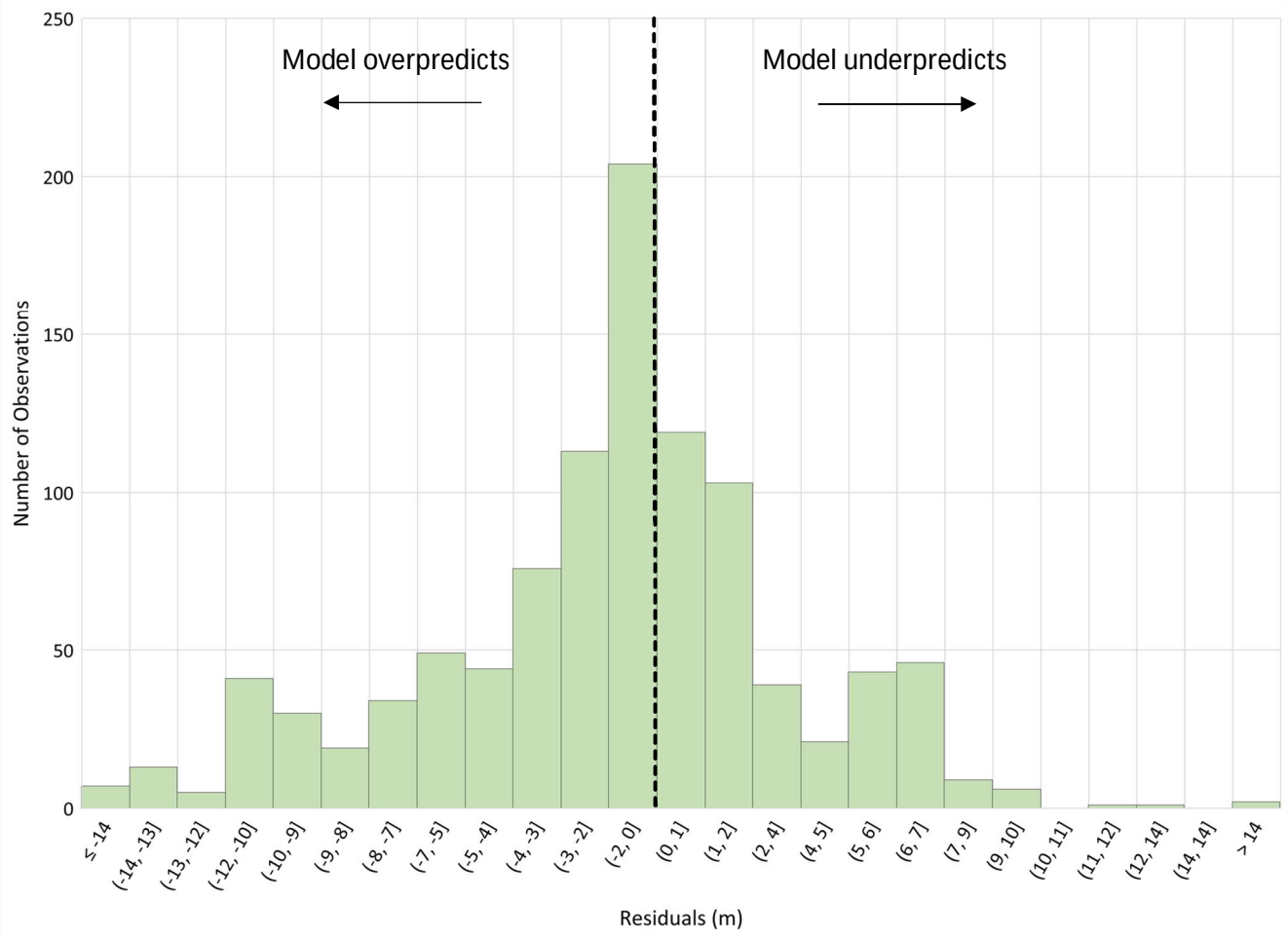



Figure 3-3 Calibration Residual Histogram Scattergram

The overall transient calibration statistics are presented in Table 3-4. As shown in the table, all calibration targets are calibrated within ±20 m of the observed measurements. This provides an indication of sufficient fit for the regional dataset; however, further discussion on the fit between modelled and observed trends is included in Section 3.3.2.

Table 3-5 shows the average calibration residual and absolute average residual per model layer. The residual is the difference between the measured and the modelled water level at each bore. Table 3-5 shows an overall overestimation of water levels in the model layers across the model domain. The table shows Layer 5 has the largest average residual, and Layer 3 has the largest absolute average residual.

## Table 3-4 Calibration Statistics

| Statistic | Value |
|---|---|
| Sum of Squares (m2) | 25242.96 |
| Mean of Squares (m) | 28.10 |
| Square Root of Mean of Squares (RMS) (m) | 5.30 |
| Scaled Root Mean Square (SRMS) (%) | 5.50 |
| Root Mean Fraction Square (RMFS) (%)* | 3.87 |
| Scaled Root Mean Fraction Square (SRMFS) (%) ** | 5.31 |
| Sum of Residuals (m) | 3742.29 |
| Mean Residual (m) | 3.65 |
| Scaled Mean Residual (%) | 3.79 |
| Coefficient of Determination (tend to unity) | 1.02 |
| Targets within ±2m | 457 |
| Targets within ±5m | 706 |
| Targets within ±20m | 1015 |

*RMFS represents the sample standard deviation of the differences between predicted values and observed values as a fraction of the observed value expressed as a percentage.

** SRMFS scales the RMFS error by the ratio of the mean observed value to the range of the observed values expressed as a percentage.

## Table 3-5 Average Residual by Model Layer

| Model Layer | Formation | Unit | Average Residual (m) | Average Absolute Residual (m) | Number of Observation Targets | Number of bores |
|---|---|---|---|---|---|---|
| 1 | Alluvium | Surface cover | -1.70 | 2.45 | 294 | 27 |
| 2 | Weathered rock | Tertiary and minor Triassic Clematis, weathered Permian | 1.81 | 2.78 | 136 | 9 |
| 3 | Rewan/RCM overburden | Triassic sandstone, siltstone, mudstone | 3.19 | 6.51 | 34 | 7 |
| 4 | Upper RCM seams | Cancer, Aries, Castor seams | - | - | - | - |
| 5 | RCM interburden | Sandstone, siltstone | -3.62 | 5.10 | 104 | 9 |
| 6 | Middle RCM seams | Pollux (upper and lower), Orion (upper and lower) | - | - | - | - |
| 7 | RCM interburden | Sandstone, siltstone | -2.90 | 4.11 | 68 | 3 |
| 8 | Lower RCM seams | Pisces seam | - | - | - | - |
| 9 | Burngrove Formation | Sandstone, siltstone, mudstone, coal seams | -2.17 | 4.26 | 379 | 14 |
| 10 | Fair Hill Formation | Sandstone, mudstone, coal seams | - | - | - | - |

### 3.3.2 Calibration Fit

#### 3.3.2.1 Groundwater levels

This section provides discussion on the modelled to observed groundwater level trends (calibration hydrographs) for key bores across the Curragh Complex. Calibration hydrographs, showing the fit between modelled and observed groundwater levels are presented in Appendix C. As shown by the hydrographs, in general, the model has replicated the groundwater transient trends in the bores.

Reproducing historical changes in groundwater levels at Curragh Complex required accurate data for mining intervals (spatial extent and depth), backfilling and voids water level as well as the screening depth interval (or targeted geological unit) for each bore. In many cases, this information was incomplete or not available. Considering these limitations, the response to the historical mining at Curragh Complex were reasonably simulated in most bores around the historical mining areas. This includes bores such as 1301MB, 1302MB, 1303MB, 1304MB, 1307MB and 1308MB.

Within the mine area, the model overpredicts or underpredicts groundwater levels by approximately 5 to 7 m when comparing to the observed groundwater levels in the Rangal Coal Measures. This can be seen in the calibration hydrographs for bores 1534MB, 1536MB, 1847MB and 1848MB.

Water levels in the alluvium and regolith in the vicinity of the mine are generally well represented and are within 5m of the measured water level. This can be seen in a number of monitoring bores, including 1312MB, 1322MB, 1410MB, 1411MB and BH8A.

Groundwater levels in regional bores to the far north and south of the model domain are overestimated by 10 to 15 m. Only one measurement is available for each bore located to the north. These bores target the alluvium (158166 and 158209), the RCM (158171, 158207, 158208, 158210, MIN_MB2 and MIN_MB4) and the Burngrove Formation (13010010). The difference in groundwater level between observed and simulated likely relate to the simplification of the geological units into discrete model layers away from the project area, where limited data is available.

#### 3.3.2.2 Mine Pit Inflows

Parsons Brinckerhoff (2016) calibration data set included measured inflows. The model calculated the volume of water removed by mining based on hydraulic properties and gradients, not by direct user input. The calibration was undertaken to match the magnitude of water being removed based on observations.

Simulated model inflows were compared against observed inflows in the calibration data set. There were no additional inflow measurements available after 2016. Table 3-6 summarises the average observed and simulated inflows to the mine workings over the 2016 model update calibration period.

Overall, the model provides a reasonable fit to measured pit inflows for 2016. The modelled pit inflows are underpredicted at Curragh North pit U, and overpredicted at the Curragh East pits and Curragh North pit T and S.

Table 3-6 Mine Pit Inflows

| | Curragh East (C, D, E, F, H pits) | Curragh North (U pit) | Curragh North (T pit) | Curragh North (S pit) |
|---|---|---|---|---|
| Total Measured Inflow (ML/d) | 0.46 | 5.60 | 1.00 | 0.60 |
| Modelled Inflow (ML/d) | 1.20 | 3.57* | 2.34* | 0.93 |

*Average pit inflow rate taken from 2002 to 2016.

### 3.3.3 Water Balance

The water balance for the steady-state and transient calibration simulations are presented in Table 3-7 and Table 3-8, respectively. The water balance for the steady-state model indicates that recharge was the largest net inflow contributor to the model (10.72 ML/d). In the transient simulation, the largest net contribution to the model was also recharge (10.28 ML/d). Regional net groundwater inflows were 3.03 and 5.81 ML/day for the steady state and transient runs respectively, indicating that groundwater leaves the model domain through this boundary.

Net outflows of 6.86 ML/d (steady state) and 4.59 ML/d (transient) from the model occur due to baseflow seepage to the Mackenzie River (i.e. surface water and groundwater interaction in the Mackenzie River). This is the largest component of outflow from the model during steady state calibration. Also contributing to outflow from the groundwater system is evapotranspiration (6.90 and 5.40 ML/d outflow for the steady state and transient simulations, respectively). The mass balance error for the steady state and transient calibrations are 0.00 %, within the error threshold recommended by the Australian Groundwater Modelling Guidelines (Barnett et al., 2012), and indicating the model is stable and achieves an accurate numerical solution.

Table 3-7 Steady State Model Mass Balance

| Component | Inflow (ML/day) | Percent of Total Inflow (%) | Outflow (ML/day) | Percent of Total Inflow (%) |
|---|---|---|---|---|
| Recharge (RCH) | 10.72 | 62.46 | - | - |
| ET (from GW) (EVT) | - | - | 6.90 | 40.17 |
| SW-GW Interaction (RIV) * | 2.65 | 15.44 | 9.51 | 55.38 |
| Regional GW Flow (GHB) | 3.79 | 22.10 | 0.76 | 4.45 |
| Mines (DRN) | - | - | - | - |
| Storage | - | - | - | - |
| Total | 17.17 | 100.00 | 17.17 | 100.00 |

## Table 3-8 Transient Model Water Balance

| Component | Inflow (ML/day) | Percent of Total Inflow (%) | Outflow (ML/day) | Percent of Total Inflow (%) |
|---|---|---|---|---|
| Recharge (RCH) | 10.28 | 29.23 | - | - |
| ET (from GW) (EVT) | - | - | 5.40 | 15.34 |
| SW-GW Interaction (RIV) * | 3.51 | 9.99 | 8.10 | 23.03 |
| Regional GW Flow (GHB) | 6.44 | 18.30 | 0.63 | 1.79 |
| Mines (DRN) | - | - | 15.11 | 42.96 |
| Storage | 14.95 | 42.49 | 5.94 | 16.89 |
| Total | 35.18 | 100.00 | 35.18 | 100.00 |

### 3.3.4 Calibrated Hydraulic Parameters

Table 3-9 summarises the calibrated values for horizontal and vertical hydraulic conductivity used in the model.

Table 3-9 Calibrated Hydraulic Parameters

| Model Layer | Formation | Unit | Horizontal Hydraulic Conductivity (m/day)* | Anisotropy Kz/Kx |
|---|---|---|---|---|
| 1 | Alluvium | Gravel | 1.50E+01 | 2.46E-01 |
| | Alluvium | Sand/clay | 8.22E-01 | 1.67E-02 |
| | Alluvium | Clay | 1.30E+00 | 1.00E-02 |
| | Regolith | Rewan Formation (weathered) | 5.20E-03 | 3.15E-02 |
| | Regolith | Rangal Coal Measures (weathered) | 2.26E-02 | 3.48E-01 |
| | Regolith | Bungrove and Fair Hill Formation (weathered) | 1.64E+00 | 7.05E-02 |
| 2 | Regolith | Weathered rock | 1.24E-01 | 4.74E-02 |
| 3 | Rewan Formation | Triassic sandstone, siltstone, mudstone | 3.13E-03 | 1.47E-02 |
| 4 | RCM Upper Seams | Cancer, Aries, Castor seams | 4.89E-04 | 2.19E-01 |
| 5 | RCM Interburden | Sandstone, siltstone | 1.21E-04 | 5.11E-02 |
| 6 | RCM Middle Seams | Pollux (upper and lower), Orion (upper and lower) | 2.31E-03 | 1.56E-02 |
| 7 | RCM Interburden | Sandstone, siltstone | 3.62E-01 | 1.00E-02 |
| 8 | RCM Lower Seam | Pisces seam | 1.00E+00 | 3.48E-02 |
| 9 | Burngrove Formation | Sandstone, siltstone, mudstone, coal seams | 7.78E-05 | 9.22E-02 |
| 10 | Fair Hill Formation | Sandstone, mudstone, coal seams | 4.81E-04 | 4.06E-01 |

Note: * upper hydraulic conductivity derived from depth of 20 m below surface and using depth formula

The hydraulic conductivity of the Permian interburden material and coal seams in the model reduces with depth in order to reflect field observations. The hydraulic conductivity of the interburden/overburden and coal seam layers decreases with depth according to Equation 1 (exponential):

Coal/Interburden: $HC = HC_0 \times e(-0.012 \times depth)$ (Eq. 1)

Where:

- HC is horizontal hydraulic conductivity at specific depth;
- $HC_0$ is horizontal hydraulic conductivity at depth of 0 m (intercept of the curve);
- depth is depth of the floor of the layer (thickness of the cover material);
- slope is a term representing slope of the formula (steepness of the curve).

$HC_0$ was estimated in the calibration. It varies for the coal seams and for the interburden and overburden units in the model. The final calibrated parameters used in the existing Curragh Model are consistent with the range of field and literature derived hydraulic parameters compiled for the conceptual model in the Groundwater Technical Report for the Curragh Extension Project (Parsons Brinckerhoff, 2016).

### 3.3.5 Calibrated Storage Properties

Table 3-10 summarises the calibrated values for specific storage and specific yield.

Table 3-10 Calibrated Storage Parameters

| Model Layer | Formation | Unit | Specific Yield | Specific Storage SS ($m^{-1}$) |
|---|---|---|---|---|
| 1 | Alluvium | Gravel | 5.00E-02 | 1.32E-06 |
| | Alluvium | Sand/clay | 9.70E-02 | 3.30E-06 |
| | Alluvium | Clay | 2.35E-03 | 1.00E-05 |
| | Regolith | Rewan Formation (weathered) | 5.90E-03 | 2.99E-06 |
| | Regolith | Rangal Coal Measures (weathered) | 2.11E-02 | 1.00E-05 |
| | Regolith | Bungrove and Fair Hill Formation (weathered) | 1.00E-03 | 7.97E-06 |
| 2 | Regolith | Weathered rock | 5.00E-02 | 1.00E-05 |
| 3 | Rewan Formation | Triassic sandstone, siltstone, mudstone | 8.27E-03 | 4.57E-06 |
| 4 | RCM Upper Seams | Cancer, Aries, Castor seams | 1.00E-02 | 4.43E-07 |
| 5 | RCM Interburden | Sandstone, siltstone | 6.55E-03 | 4.47E-06 |
| 6 | RCM Middle Seams | Pollux (upper and lower), Orion (upper and lower) | 3.91E-03 | 1.00E-07 |
| 7 | RCM Interburden | Sandstone, siltstone | 1.12E-03 | 1.14E-07 |
| 8 | RCM Lower Seam | Pisces seam | 6.67E-03 | 3.97E-06 |
| 9 | Burngrove Formation | Sandstone, siltstone, mudstone, coal seams | 2.68E-03 | 4.24E-07 |
| 10 | Fair Hill Formation | Sandstone, mudstone, coal seams | 1.58E-03 | 1.00E-07 |

### 3.3.6 Calibrated Recharge

Recharge is predominantly through direct rainfall infiltration through the soil profile, and along the ephemeral drainage lines. The rate of recharge infiltration depends on the location, topography and geology at each model cell. Initial estimates of recharge were adopted from the previous Curragh Model (Parsons Brinckerhoff, 2016). As discussed in Section 3.2.4, the MODFLOW-USG recharge package simulated diffuse rainfall recharge across the model domain. For the steady state simulation, the model calculated the recharge rate as a percentage of long-term annual rainfall (1.55 mm/year) for each geological unit outcropping at the surface and for the transient simulation, the model calculated the recharge rate as a percentage of actual annual rainfall. The model then adjusted these initial percentages through the calibration process. Table 3-11 presents the calibrated recharge rate to each geological unit in the model.

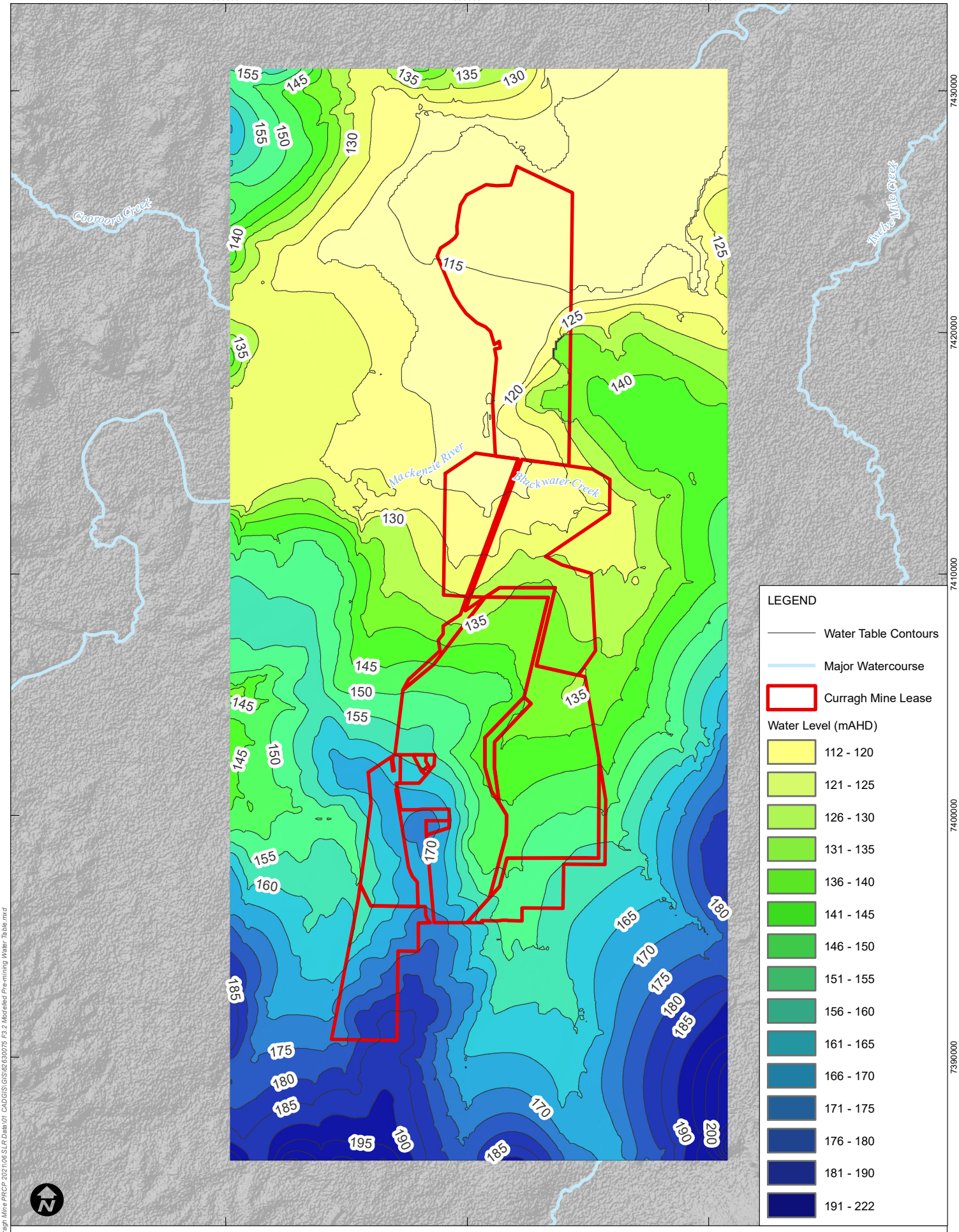
Table 3-11 Calibrated Rainfall Recharge

| Model Geology Zone | (mm/year) | % Annual Rainfall | CMB Estimated (mm/year) |
|---|---|---|---|
| Alluvium | 0.0028 | 0.18 | 5.5 |
| Alluvium (Sand and Clay) | 0.0543 | 3.51 | - |
| Alluvium (Clay) | 0.0774 | 5.00 | - |
| Weathered Rock (Rewan) | 0.0002 | 0.01 | 0.38 |
| Weathered Rock | 0.0077 | 0.50 | 0.50 |
| Weathered Rock (Fairhill and Burngrove) | 0.0003 | 0.02 | 0.38 |
| Fresh Spoil Emplacement | 0.0155 | 1.00 | - |
| Mine Void | 0.0000 | 0.00 | - |

### 3.3.7 Calibrated Pre-Mining Groundwater Levels

Figure 3-4 show the calibrated pre-development water table. Water table is the shallowest groundwater below surface regardless of geological unit. As shown in Figure 3-4, the simulated water levels reflect the flow regime prior to commencement of any mining within the model domain and indicate a general flow of groundwater towards the north-west discharging through the RIV boundary condition at the northern boundary of the model. The simulated water table reflect the surface topography.

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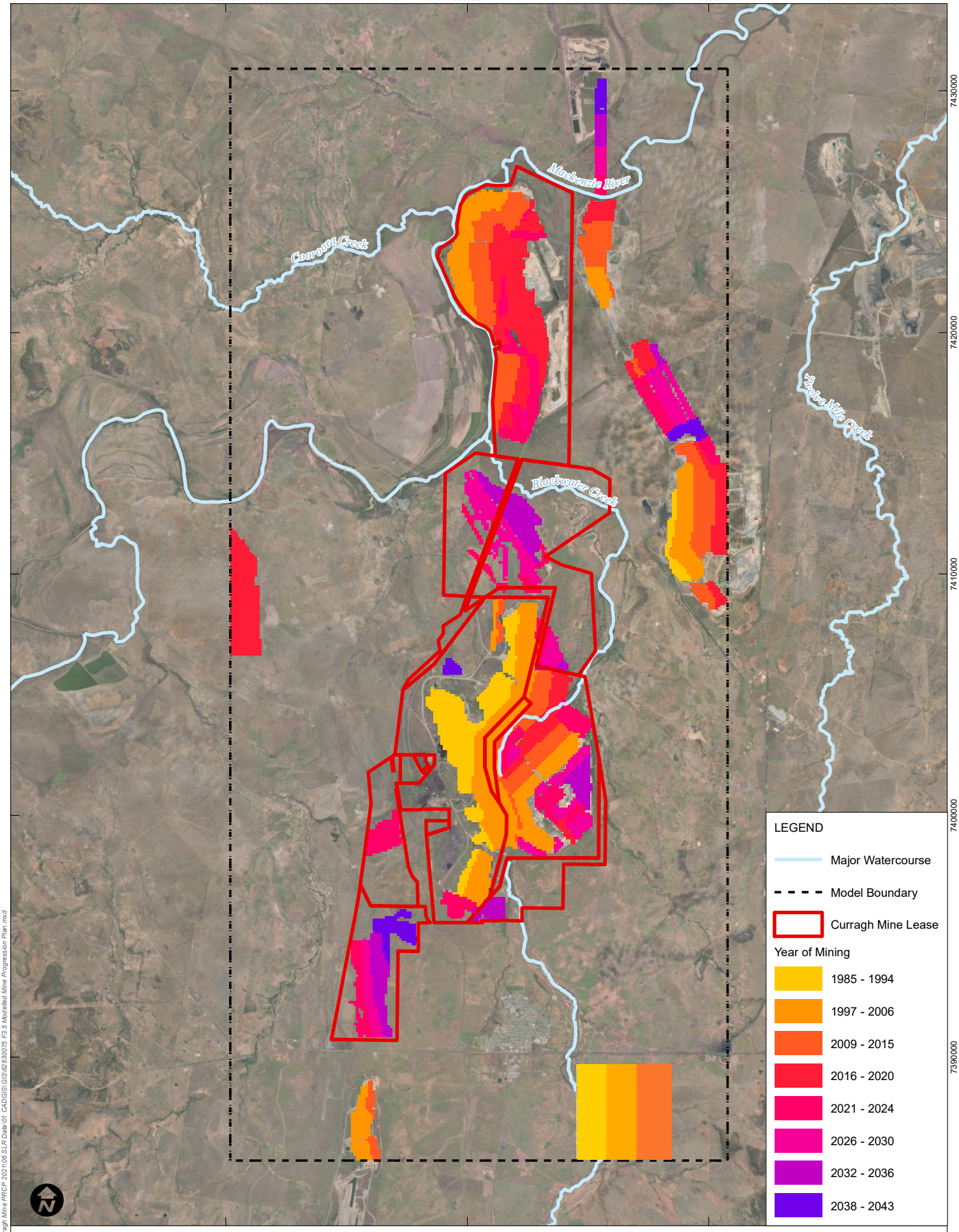
**Preliminary Groundwater Assessment for Curragh CRVA**
**Modelled Pre-mining Water Table**
**(End of Steady State Simulation)**

**FIGURE 3-4**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CADGIS\GIS\626.30075 F3.2 Modelled Pre-mining Water Table.mxd

## 3.4 Predictive Model

Transient predictive modelling was used to simulate the proposed mining at Curragh (the expansion Pits X, Y, Z, J D and Ramp 9), as well as mining at other approved and foreseeable mines within the model domain. The predictive model stress period setup is detailed in Section 3.2.3, and the simulated predictive mine progression for the Project is presented spatially in Figure 3-5.




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**Preliminary Groundwater Assessment for Curragh CRVA Modelled Mine Progression**

**FIGURE 3-5**

All mining areas included in the model were simulated using the MODFLOW Drain (DRN) package. A nominally high drain conductance of 100 square metres per day ($m^2$/day) was applied to drain cells to simulate rapid removal of water from the system. Drain cells simulating mining were projected down to the base of the target coal seams. A one-year operational window was assumed for mine cells at the Project, after which time the drains were removed and the MODFLOW Time Varying Materials (TVM) package was used to assign spoil properties to the cells.

The model cell properties were updated to spoil properties guided by operational mine plans. Horizontal hydraulic conductivity of 0.3 m/day and vertical hydraulic conductivity of 0.1 m/day is applied to the spoil. The storage parameters used for the spoil were a specific yield of 0.05 and a storage coefficient of $1.0 \times 10^{-5}$ $m^{-}$.

### 3.4.1 Predictive Water Balance

The water balance for the predictive simulation is presented in Table 3-12. The water balance for the predictive model indicates that recharge was the largest net inflow contributor to the model (11.01 ML/d). Regional groundwater inflow and outflow are 13.37 and 0.33 ML/day respectively, indicating that groundwater enters the model domain through this boundary.

The largest net contributor to outflow from the model during the predictive simulation were the drain cells, used to simulate mining activity and groundwater flux from minor tributaries (12.55 ML/d). A net outflow of 1.24 ML/d from the model occurs due to baseflow seepage to the Mackenzie River. Also contributing to outflow from the groundwater system was evapotranspiration (3.24 ML/d outflow). The mass balance error for the predictive calibration is 0.00 %.

Table 3-12 Predictive Model Water Balance

| Component | Inflow (ML/day) | Percent of Total Inflow (%) | Outflow (ML/day) | Percent of Total Inflow (%) |
|---|---|---|---|---|
| Recharge (RCH) | 11.01 | 24.85 | - | - |
| ET (from GW) (EVT) | - | - | 3.24 | 7.32 |
| SW-GW Interaction * | 4.62 | 10.43 | 5.86 | 13.22 |
| Regional GW Flow (GHB) | 13.37 | 30.15 | 0.33 | 0.74 |
| Mines (DRN) | - | - | 12.55 | 28.32 |
| Storage | 15.32 | 34.57 | 22.34 | 50.40 |
| Total | 44.32 | 100.00 | 44.32 | 100.00 |

* The other tributaries or drainage lines in the model are set as drains to the groundwater system and do not result in any recharge.

### 3.4.2 Predicted Mine Inflows

Average modelled pit inflows were calculated as time weighted averages for Project drain cells, for the predictive simulation period (2021-2039). The total inflow rates predicted for Curragh Mine range from 0.33 to 4.28 ML/day, with an average predicted inflow rate of 1.36 ML/day The average total pit inflow rate predicted by the model is reasonably consistent with the average total inflow of 0.97 ML/day predicted by the existing Curragh Model (Parsons Brinckerhoff, 2016). The additional pit inflow predicted by the updated model is likely attributable to changes in the Curragh Mine progression plan since 2016.

# 4 Recovery Model

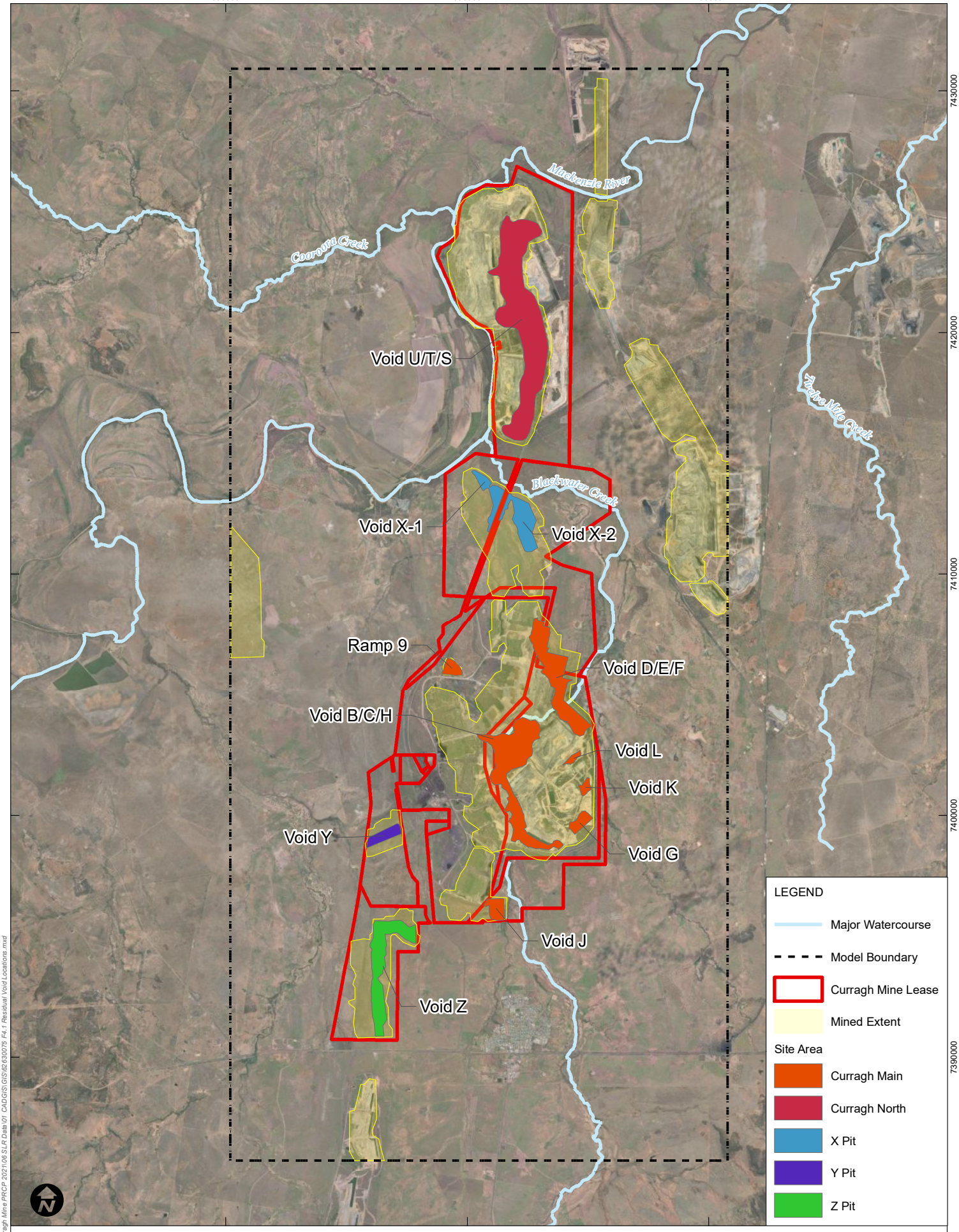
## 4.1 Recovery Model Setup

The location of the final voids at Curragh Complex are provided in Figure 4-1.

Post mining impacts were investigated with a recovery model, commencing at the end of active mining. A preliminary transient recovery model consisting of 16 time slices (each time slice set to 300-years) was developed to assess the relationship between the final voids' lake elevations and groundwater inflow. At the start of the recovery model, all model drain cells were removed and the properties of the final void cells were converted to values representative of a void. The void cells were assigned high horizontal and vertical hydraulic conductivities (1000 m/day) and storage parameters based on the compressibility of water (specific yield of 1.0, storage coefficient of $5.0 \times 10^{-6}$ $m^{-1}$), to simulate free water movement within the void. This approach is often referred to as a 'high-K' lake. A constant head boundary condition was used to simulate increasing lake elevations in each of the final voids over the recovery period and the resultant groundwater inflows – lake level curve for each of the final voids during recovery were incorporated in the site water balance model for the Project's surface water modelling (SLR, 2021).

The pit lake recovery level and timings were predicted by the surface water balance modelling. These elevation and recovery timing derived from the surface water modelling was replicated within the numerical groundwater model using the time variant constant head boundary condition. The model predicted water levels in the final voids to reach equilibrium conditions after approximately 20 to 50 years, dependent on void structure and interaction with the regional groundwater system. Void recovery graphs in each of the voids over the recovery period are presented in Appendix D.

A summary of predictions from the recovery model, including final void water levels (at equilibrium) are presented in Section 4.2.




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**Preliminary Groundwater Assessment for Curragh CRVA**

**Residual Void Locations**

**FIGURE 4.1**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data \01 CAD\GIS\GIS\626.30075 F4.1 Residual Void Locations.mxd

## 4.2 Post-mining Equilibrium

Simulated post-mining groundwater fluxes to the final voids at equilibrium conditions were extracted for both scenarios using MODFLOW-USG ZONBUD utility. The net groundwater flux has been calculated as a cumulative void flux for each area at Curragh Complex (Curragh North, X Pit, Curragh Main, Y Pit and Z Pit) to account for interaction between the adjacent voids within each area. The simulated average groundwater takes at the end of recovery (2133) at each of the site areas are presented in Table 4-1.

The groundwater takes presented in Table 4-1 are total groundwater takes, including throughflow from spoil and groundwater take from the Rangal Coal Measures (RCM). An equilibrium groundwater flux of 4.82 ML/day was predicted at Curragh North, where the minimum elevation of the final landform is 74 m lower than the other voids. The relative depth of the residual void at Curragh North is likely accountable for the higher predicted groundwater flux to the void in this area. Equilibrium total groundwater flux to the voids in Curragh North Pit, X Pit, Curragh Main, Y Pit and Z Pit are predicted to be 4.82, 0.49, 1.75, 0.11 and 1.00 ML/day respectively, indicating all simulated voids are predicted to be groundwater sinks with positive net groundwater flow into the voids. The simulated fluxes to the voids in the groundwater model are consistent with groundwater fluxes in the surface water model developed for simulating final landforms for Curragh Mine (SLR, 2021).

Based on the geological data reviewed for this preliminary assessment (which is limited for the extension areas), it appears that equilibrium void lake levels are generally well below the level of alluvium and base of weathering (Table 4-1). If these levels were exceeded, the alluvium and weathered rock profile could potentially present preferential pathways for outward seepage of water from the void lakes.

The predicted water salinity results presented in Table 4-1 have been derived from the preliminary surface water modelling of residual voids (SLR,2021). The predicted salinities indicate that the void lakes should stabilise at approximately 37,000 µS/cm after 200 years.

## Table 4-1 Post-Mining Equilibrium Residual Void Summary

| Curragh Area: | | Curragh N | X Pit | | Curragh Main | | | | | | | Y Pit | Z Pit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Void[1]: | | U/T/S | Void 1 | Void 2 | D/E/F | B/C/H | L | K | G | J | Ramp 9 | Y | Z |
| Final landform minimum elevation used in the numerical model (mAHD) | | -48 | 78 | 34 | 26 | 41 | 92 | 65 | 64 | 93 | 77 | 116 | 78 |
| Post-mining equilibrium void lake level (mAHD), the final lake levels were derived from the surface water model. | | 26 | 101 | 69 | 63 | 83 | 113 | 105 | 79 | 132 | 91 | 131 | 115 |
| Approximate base of weathering / alluvium elevation (mAHD) | | 100 | 110 | 115 | 120 | 130 | 130* | 130* | 135* | 140* | 120 | 135* | 150 |
| Void lake salinity (uS/cm), as predicted by the water balance model.[2] | ~10 years | 27,578 | 28,650 | 16,174 | 36,828 | 23,045 | 20,530 | 23,445 | 33,100 | 19,951 | 29,754 | 28,954 | 37,296 |
| | ~30 years | 37,313 | 37,274 | 32,568 | 37,313 | 37,181 | 36,416 | 37,308 | 37,288 | 31,496 | 37,313 | 37,313 | 37,313 |
| | ~200 years | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 | 37,313 |
| Net groundwater flux to void at equilibrium (total flux including inflow draining from the spoil and groundwater inflow from the RCM, ML/day) | | 4.82 | 0.49 | | 1.75 | | | | | | | 0.11 | 1.00 |

Notes:
1 The residual voids have been grouped where a void may act as a source of water to an adjacent void, but where collectively they act as a groundwater sink.
2 37,313 µS/cm is the maximum salinity limit set in the surface water balance model (SLR 2021)
* Approximate elevation of base of weathering estimated from available data.

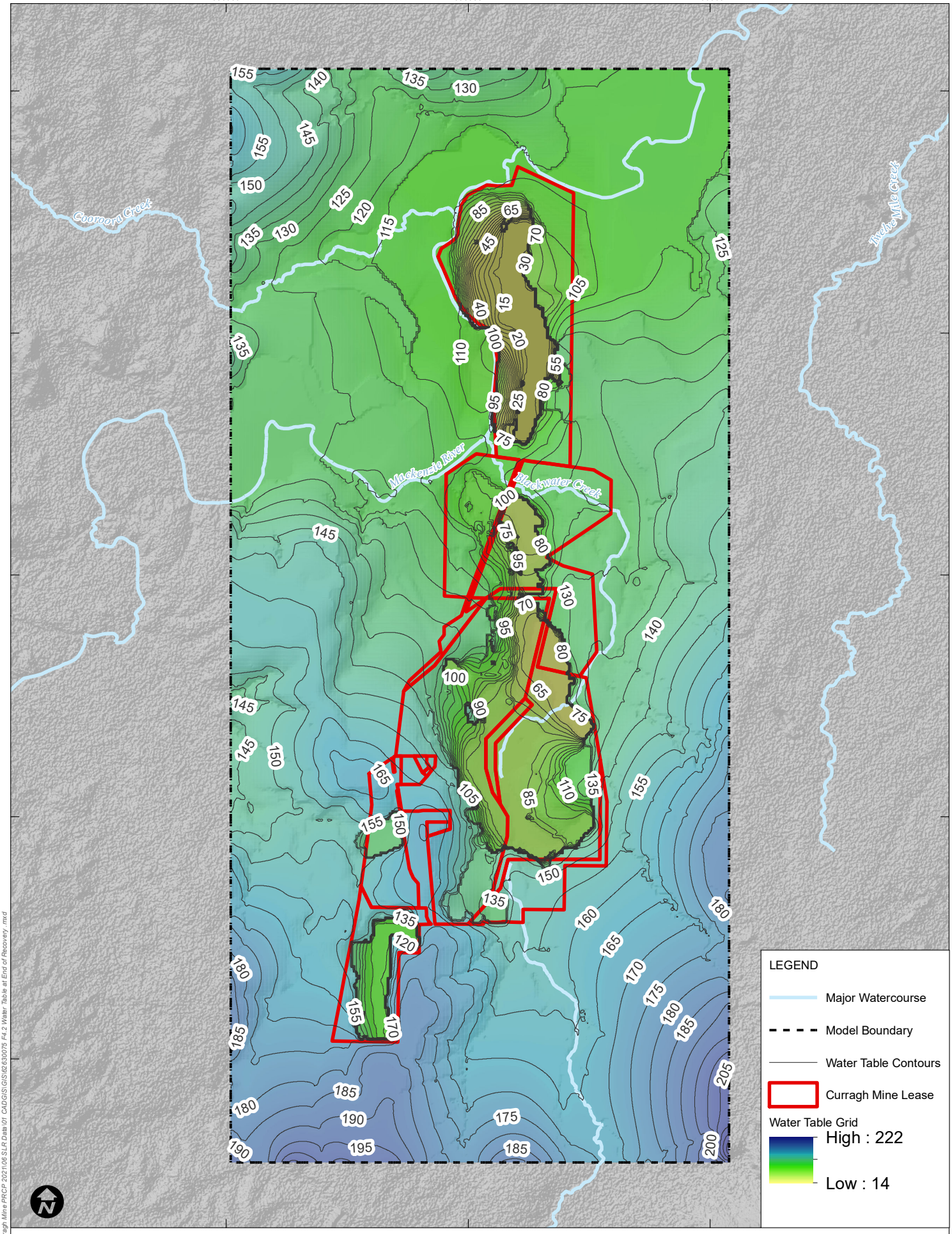
## 4.3 Post-mining Gradients and Residual Drawdown

The predicted post-mining water table at equilibrium (end of recovery) is shown in Figure 4-2. Hydraulic gradients at equilibrium indicate an overall flow direction toward residual voids at Curragh Main and Curragh North. All residual voids show hydraulic heads decreasing with proximity to the void, indicating all voids are predicted to act as local groundwater sinks.

Residual drawdown refers to the remaining drawdown impact associated with mining at Curragh Complex and is obtained by comparing the difference predicted equilibrium post-closure groundwater levels at Curragh Complex against a 'null-mining' model scenario. The 'null-mining' model run does not include any historical or future mining at Curragh Complex but all other stresses and boundary conditions remain unchanged from the model simulating mining at Curragh Complex. The residual drawdown is essentially a comparison of groundwater levels between a mining and closure scenario, and a no mining scenario.

Predicted drawdown figures (Figure 4-3 and Figure 4-4) show where residual drawdown impacts are predicted to exceed 1 m. Figure 4-3 presents the residual drawdown just within the alluvium at post-mining equilibrium. Predicted recovered heads in the alluvium west of Curragh North show residual drawdowns of 1 to 2 m extending up to 3 km from mined pits at Curragh North although drawdowns at the very edge of the voids are higher (5-10 m). Figure 4-4 presents the residual drawdown of the water table at post-mining equilibrium.

To investigate the potential movement of groundwater to or from the voids and spoil at post-mining equilibrium, the post-mining water table predicted for the end of recovery was used to infer potential flow pathways in and around the spoil at each area of mining. Particle tracking was used together with the post-mining water table to predict groundwater movement relative to the voids and areas of spoil. Particles are "dropped" on the post mining equilibrium water table and allowed to track down hydraulic gradient from their starting position. Figure 4-5 shows the inferred flow pathways around the residual voids interpreted from the particle tracking simulation at post-mining equilibrium. The flow paths from the outer edges of the voids or spoil dumps informed by the recovered head levels indicate groundwater flow is toward each of the residual voids hence none of the voids are likely to act as sources to the groundwater system. Although the tailings storage facilities (Pit A and Pir B TSFs), have not been modelled explicitly for this preliminary assessment, the particle tracking indicates that groundwater flow around the TSFs would move into towards the residual voids at Curragh Main.




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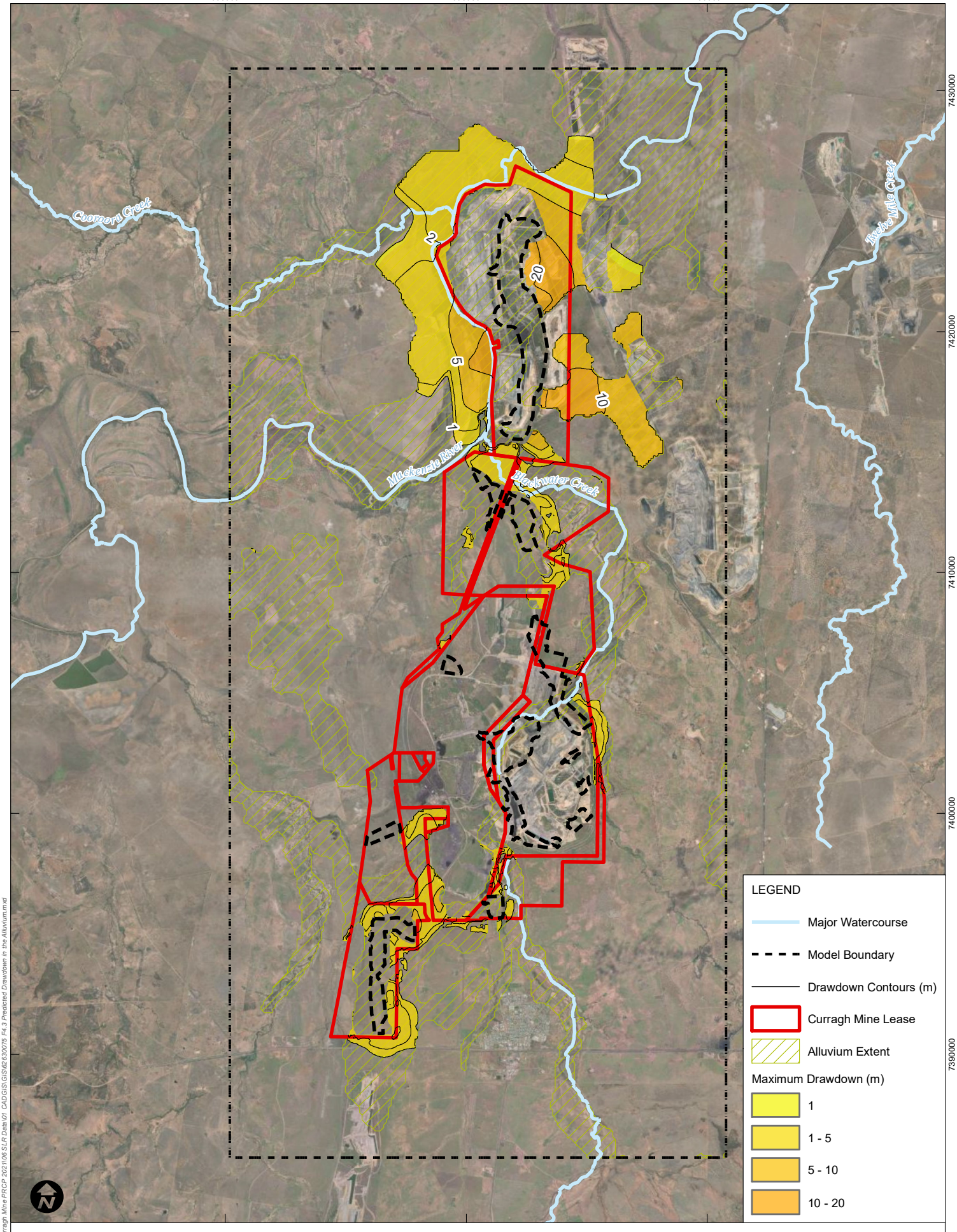
**CURRAGH PRCP**

**Preliminary Groundwater Assessment for Curragh CRVA**

**Water Table at End of Recovery**

**FIGURE 4-2**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20210106 SLR Data\01 CAD\GIS\GIS\626.30075 F4.2 Water Table at End of Recovery .mxd




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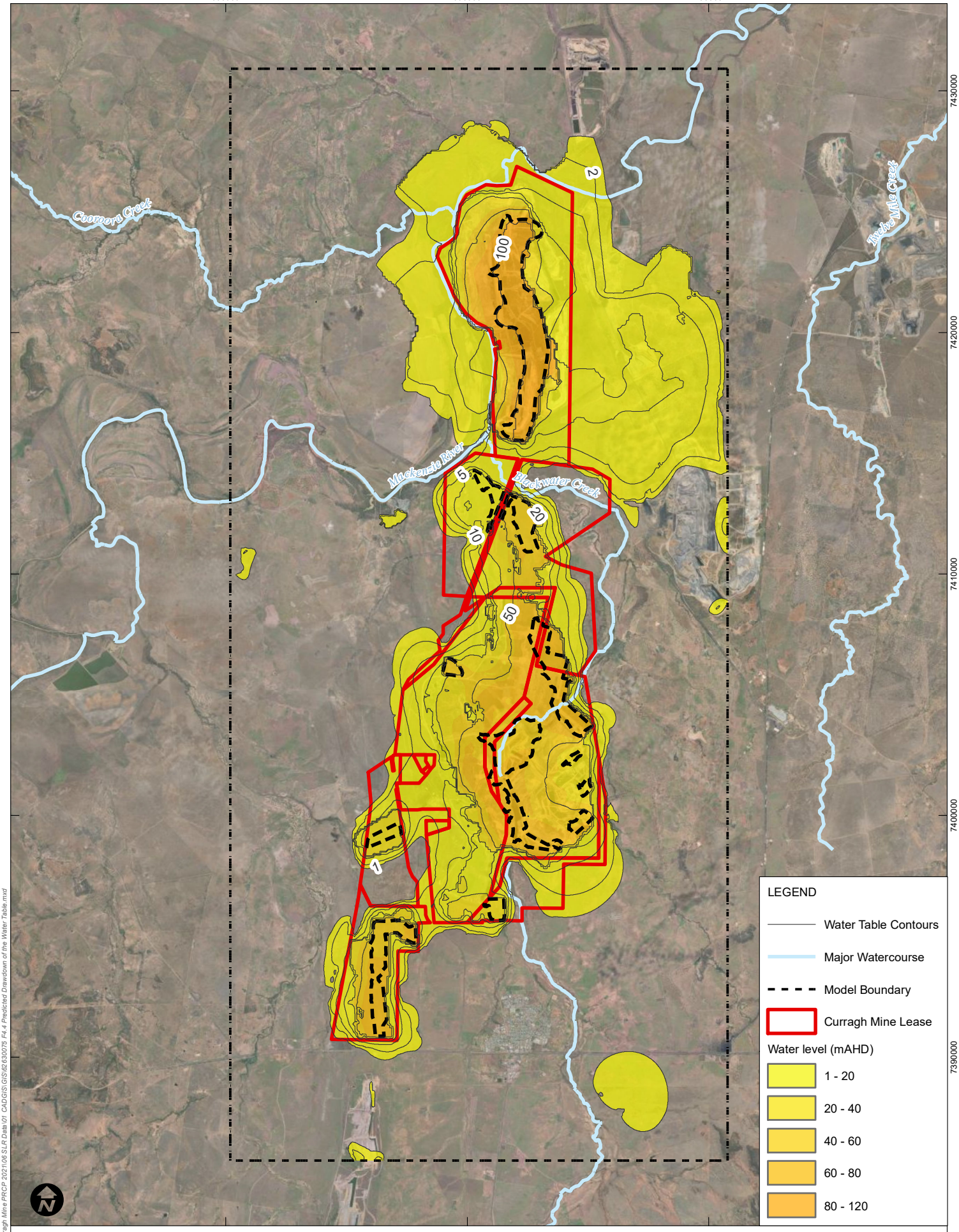
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**Preliminary Groundwater Assessment for Curragh CRVA**

**Predicted Drawdown in the Alluvium (End of Recovery)**

**FIGURE 4.3**




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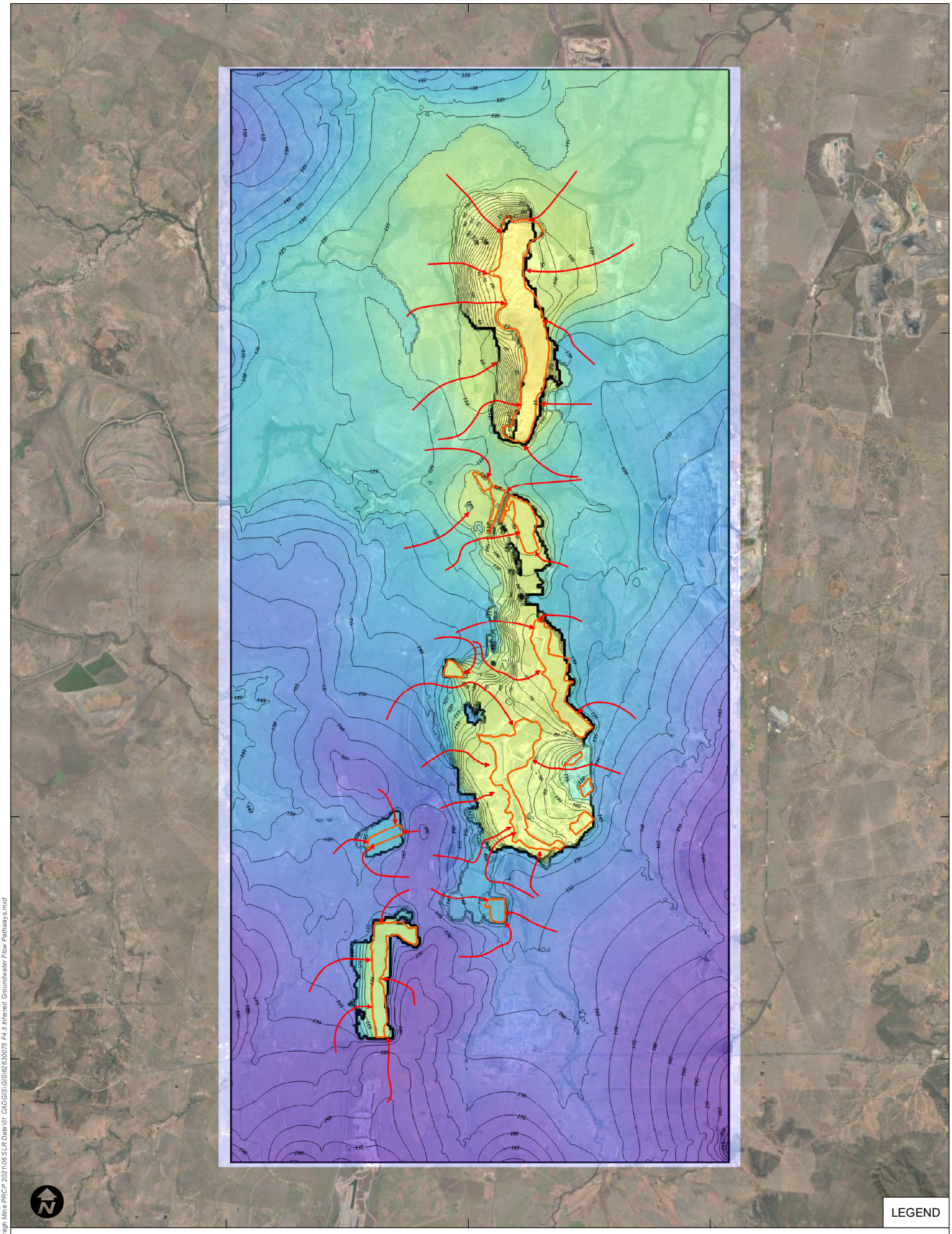
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**Preliminary Groundwater Assessment for Curragh CRVA**

**Predicted Drawdown of the Water Table (End of Recovery)**

**FIGURE 4-4**




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**Preliminary Groundwater Assessment for Curragh CRVA**

**Inferred Groundwater Flow Pathways at Post-Mining Equilibrium**

**FIGURE 4-5**

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# 5 Conclusions and Recommendations

## 5.1 Conclusions

The numerical groundwater model updated for Curragh Complex achieved the modelling objectives, as outlined in Section 3.1. Model calibration statistics are within suggested guidelines (MDBC, 2001) and mass balance errors remain at 0%, through the model calibration and predictive modelling. The groundwater model was updated to considers all available data to date, including an updated mine plan for some of the pits. The model, therefore, serves as a useful tool to represent the transient groundwater conditions within the Curragh Complex area, over the life of the mine. The following key conclusions are drawn from the preliminary numerical modelling assessment of the post-mining groundwater environment at the Curragh Complex:

- The numerical modelling indicates that lakes will form within the residual voids of the proposed final landform. These lakes will act as local groundwater 'sinks' with groundwater within mining disturbed areas (including the Pit A and B TSFs) migrating towards these sinks.
- Post-mining residual drawdown in the Mackenzie River Alluvium to the west of Curragh North will generally be in the order of 1-2m (but up to 10m near the mine voids), noting that the Mackenzie River is regarded as a "losing" watercourse with pre-mining groundwater levels in the alluvium 4-5m below the river stage in the vicinity of the mine (Section 2.3.8.1).
- Based on the geological data reviewed for this preliminary assessment (limited for the extension areas), it appears that equilibrium void lake levels are generally well below the level of alluvium and base of weathering (potential preferential pathways for outward seepage of water from the void lakes).
- Post-mining, the total estimated "groundwater" inflow to all voids is approximately 8.2 Ml/d although the majority of this is water derived from infiltration to the spoil and drainage into the void lake rather than inflow from the Rangal Coal Measures or Alluvium.

## 5.2 Model Limitations

It is important to note that groundwater models have inherent uncertainties which should be quantified and reduced where required and possible. The limitations and uncertainty associated with the model are discussed below. The IESC *Uncertainty analysis – Guidance for groundwater modelling within a risk management framework* (2018) identifies four key sources of scientific uncertainty affecting groundwater model simulations:

- Structural/conceptual.
- Parameterisation.
- Measurement error.
- Scenario uncertainties.

These four sources of scientific uncertainty have been qualitatively assessed with regards key aspects of the Curragh Mine groundwater model, as presented in Table 5-1.

Overall, the model is considered fit for purpose to achieve the objectives of the preliminary groundwater assessment outlined in Section 1 based on the data provided and the project timeframe. In case of future versions of the model including the PRCP assessment, updates should be conducted to further refine the model. The table includes actions to verify if aspects of the model are currently fit for purpose, as well as recommendations to improve the model for the PRCP.

Table 5-1 Groundwater Model and Data Limitations and Recommended updates for more Detailed Assessment of Closure

| Type | Part | Status | Comment |
|---|---|---|---|
| Structural/ Conceptual | Grid and Model Extent | Fit for purpose. Improvements required. | • The model has a structured 100 m x 100 m cell grid that includes the site, neighbouring mines and drainage features.<br>• Further modelling of closure should consider developing an unstructured grid that can allow efficiency and flexibility with detailed cell refinement around the final voids, the tailings and along drainage features such as Mackenzie River.<br>• The model extent should be reviewed and revised if necessary for the PRCP assessment. |
| | Layers | Fit for purpose of preliminary assessment. Improvement required. | • The top of layer 1 should be updated using the latest site LiDAR.<br>• Representation of alluvium and regolith should be refined based on CSIRO and available geology.<br>• Verify extent of modelled alluvium matches observed extent of alluvium near pits, along Mackenzie River.<br>• The model structure should be refined based on the site latest geology model and the model vertical resolution should be revisited and refined if necessary. Comparison between the model layers and drill hole information indicates some discrepancy in the model layers. Changes required could be verified by comparing the current site geological model surfaces to the groundwater model layers.<br>• The MODFLOW-USG pinch out option should be used to allow discontinuous geology units to be better represented in the model (e.g. outcrop, or cross geological faults). |
| | Conceptualisation – Geological Structure | Fit for purpose of preliminary assessment. Improvement may be required. | • The structure of the geology is based on site and regional geological mapping. No geological structures (i.e. faults) have been included in the model other than through layer displacements from site geological models.<br>• Faults are known in the region, and review of latest site-specific data (if available) is recommended. |
| | Conceptualisation – GDEs | Fit for purpose of preliminary assessment. Improvement may be required. | • Most recent information on where GDE's may be located (i.e. ecological sites) is required to ensure the local groundwater regime relevant to the GDE is adequately understood and captured in the model. |

| Type | Part | Status | Comment |
|---|---|---|---|
| | Conceptualisation – Surface Water Groundwater Interactions | Fit for purpose of preliminary assessment. Verification required. | • The RCM outcrop / subcrop in Curragh North and Curragh Main areas. The RCM also subcrop east (the upthrow side) of the Jellinbah Fault where they are extracted at Jellinbah Mine. The vertical connectivity between where the coal seam occurs at subcrop near alluvium and surface water features such as Mackenzie River tributaries should be verified in the future version of the model and refined if necessary. |
| | Conceptualisation – Saturated Extent of Alluvium and Regolith | Fit for purpose of preliminary assessment. Future improvements maybe be required. | • The model slightly under or over-predicts groundwater levels in alluvium, but generally within 5 m of observed levels.<br>• Additional monitoring points may be required to verify the presence/absence of groundwater in the Alluvium at key locations i.e. west of Curragh North.<br>• Any additional data or study on alluvium extent and thickness at Curragh Complex should be reviewed and captured (where relevant) in future updates of the model. Such improvements are not critical for the preliminary assessment for the CRVA. |
| Parameterisation | Hydraulic Conductivity – Depth Dependence | Fit for purpose of preliminary assessment. Future improvements may be required. | • Limited site specific hydraulic conductivity data (horizontal and to a lesser extent vertical) obtained in 1998. The data shows a general decline in hydraulic conductivity with depth that is replicated in the model.<br>• Additional data (if available) should be utilised to verify and update the modelled change with depth, and to refine model calibration and predictions. |
| | Spoil and Tailings Properties | Fit for purpose of preliminary assessment. Future improvements may be required. | • No site-specific data is available for the spoil and tailings. Spoil properties were adopted from existing studies.<br>• Measurements of spoil and tailings hydraulic properties should be carried out and utilised to verify and refine the model calibration and predictions in the future version of the model. |

| Type | Part | Status | Comment |
|---|---|---|---|
| | Rivers | Fit for purpose of preliminary assessment. Future improvements required. | • Mackenzie River stage height is assigned a long term annual average level assumed in the previous version of the model.<br>• Future versions of the model should refine model time slices to allow river stage heights that are changed temporally in the historical calibration model based on observed levels from gauges with the average quarterly levels assumed in the predictive model.<br>• No site-specific information on surface water discharge, flow monitoring or water storage has been included in the model but should be considered for inclusion in further modelling work.<br>• Blackwater Creek and other minor tributaries within the vicinity of Curragh Complex are ephemeral and only flow briefly after rainfall. Therefore, river stage height of zero was assigned to these watercourses in the model. |
| | Recharge | Fit for purpose | • Recharge zonation is based on mapped surface geology and calibrated recharge rates. Soil mapping and site water quality data could be further utilised to base recharge rates. |
| Measurement Error | Observation Data Quality | Fit for purpose of preliminary. Future improvements required. | • Require further review of bore construction details, target geology and monitoring methodology to reliably apply to the groundwater model. |
| | Landholder Bore Data Quality | Fit for purpose | • Further detailed review of impacts at the locations of landholder bores should be undertaken with the updated model for PRCP |
| | Temporal spread | Fit for purpose of preliminary. Future improvements may be required. | • Timeseries water level data from the site as well as the neighbouring mines (Minyango, Jellinbah) for the alluvium and Permian coal measures.<br>• Future versions of the model could be designed with refined model time slices to allow climate seasonality and temporal behaviour of the groundwater system to be simulated in the model. |
| Scenario Uncertainties Future stresses/ conditions | Calibration | Fit for purpose of preliminary. Future improvements may be required. | • A transient calibration model set up in existing model. The model was calibrated to observed groundwater levels (1983-2021) and observed mine inflows (2015).<br>• Using shorter time slices in the model would allow climate seasonality to be better represented in the model.<br>• The model calibration could be further refined with more recent data on mine inflows. |

| Type | Part | Status | Comment |
|---|---|---|---|
| | Predictive | Fit for purpose of preliminary. Future improvements may be required. | • Model captures open cut mining progression and timing at Curragh Complex, based on the 2016 model with a few areas updated based on the most recent data.<br>• The model also includes future mining at surrounding mines based on publicly available data and the information from the previous version of the model.<br>• The simulated mining progression and the timing for the pits I will require an update to match with the actual mine progression. This may require extension or changes to the predictive model timing. |
| | Sensitivity and uncertainty | Fit for purpose of preliminary. Future improvements may be required. | • Predictive uncertainty analysis was conducted on the previous version of the model and is not considered necessary for the purpose of this preliminary assessment for the CRVA.<br>• Additional work to test the uncertainty of the model parameters may be required. This includes differences in the properties spoil properties and hydraulic properties of the in-situ strata. As well the influence of streamflow and recharge on model predictions and recovery. |

## 5.3 Recommendations

A more detailed assessment of post-closure groundwater related issues with refined modelling will be completed for the Curragh Mine PRCP. Based on the work completed for this preliminary assessment, and Table 5-1, the following key recommendations are made for the detailed groundwater assessment and refinement of the numerical model:

- More detailed evaluation of the interaction between the voids and alluvial groundwater, particularly in relation to the Mackenzie River Alluvium, should be undertaken;
- A more detailed estimation of net groundwater flux from the Rangal Coal Measures to each of the residual voids should be completed (excluding drainage of infiltration through the spoil to the voids).
- Assessment of the final landform for the tailings storage facilities, using site specific information on the tailings (permeability and water quality), and the potential for contaminant migration from the TSFs;
- Assessment of other potential sources of contamination such as landfills and fuel storage sites;
- More detailed assessment of final pit lake levels against the base of weathering / alluvium, particularly for the voids with the highest predicted equilibrium lake levels; and,
- Assessment of the effect of the Mackenzie River flooding on groundwater ingress to the voids via the alluvium / weathered rock.

In relation to updates to the numerical groundwater model required to investigate the effects of closure of the Curragh Mine on the local groundwater environment we recommend that:

- The existing conceptual model should be reviewed and refined using the latest data and observations and relevant updates made to the representation within the numerical model;
- The model geological layering should be revised based on the latest site geological model including any new information on the depth, nature and extent of the Mackenzie River Alluvium;
- The Mackenzie River should be represented using the latest data including a channel depth should be applied to replicate the incised nature of the river;
- The simulated mining in the model should be refined to represent the actual historical mining and the latest proposed future mine progression. The timing of events such as in-pit spoil emplacement within the open-cut pits and tailing emplacement should be captured in the model as accurately as possible. Any conductivity test on spoil and tailings and, the tailings fill elevation should be included in the model;
- The model design should be updated to an unstructured grid and the layering should also use the “pinch out” option of MODFLOW-USG where required to model the geology more accurately;
- Any new field data available on the horizontal and vertical hydraulic conductivity for the main stratigraphic units should be used to update the model. There is currently limited data on storage parameters, which influences predicted groundwater fluxes and the extent of residual drawdown. The revision of model parameterisation would be calibrated using PEST (parameter estimation function), and constrained by site data and documented ranges for Bowen Basin stratigraphy; and,
- Climate data should be updated from SILO, and stress period timing aligned with site climate seasonality. Recharge rates should be calibrated, and the bounds set based on available site water quality data and historical modelling.

# 6 References

Ausenco-Norwest, 2012. Groundwater Model, Northern Bowen Basin Regional Model Impact Predictions, Queensland, Australia. Prepared for Arrow Energy Pty Ltd. Available at: http://www.arrowenergy.com.au/__data/assets/pdf_file/0018/3870/Appendix- Model-Technical-Report.pdf.

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A., 2012. Australian Groundwater Modelling Guidelines. Waterlines Report Series No. 82, June 2012.

AGE 2006. Ensham Central Project EIA - Groundwater Impact Assessment. Prepared for Hansen Consulting, cited in HydroSimulations, Baralaba North Continued Operations (BNCOP) for Cockatoo Coal Ltd, April 2014.

AGE, 2013. Minyango Project Groundwater. Proj G1562. Report for Hansen Bailey. April 2013.

Bureau of Meteorology (BOM). (2021). Map of Climate Zones Australia. Retrieved August 20, 2021, from http://www.bom.gov.au/climate/how/newproducts/images/zones.shtml

Doherty, J., 2010. PEST - Model Independent Parameter Estimation. User Manual 5th Edition. Watermark Numerical Computing.

Douglas Partners 2014. Report on S Pit Groundwater Study Review, Curragh Coal Mine via Blackwater, Central Queensland, Project 80724.00, November 2014.

HydroSimulations, 2016. Curragh Extension Project Groundwater Model: Final Review (Ref: HC2016/26).

MDBC (Middlemis, H., Merrick, N., and Ross, J.), 2001. Murray-Darling Basin Commission – Groundwater Flow Modelling Guideline. Report for MDBC. January 2001.

Parsons Brinckerhoff 2003. Curragh North Coal Mine – Hydrology, flooding and groundwater report, Project No. 2132105A-PR001Ebt (Appendix G of Curragh North Mine Environmental Impact Statement). August 2003.

Parsons Brinkerhoff (PB), 2016. Curragh Extension Project – Groundwater Technical Report (2172652H-WAT-REP-002 RevB)

Queensland Government. (2021). *Scientific Land Owners (SILO) database – Australian climate data from 1889 to yesterday*. Retrieved August, 23, 2021, from https://www.longpaddock.qld.gov.au/silo/point-data/

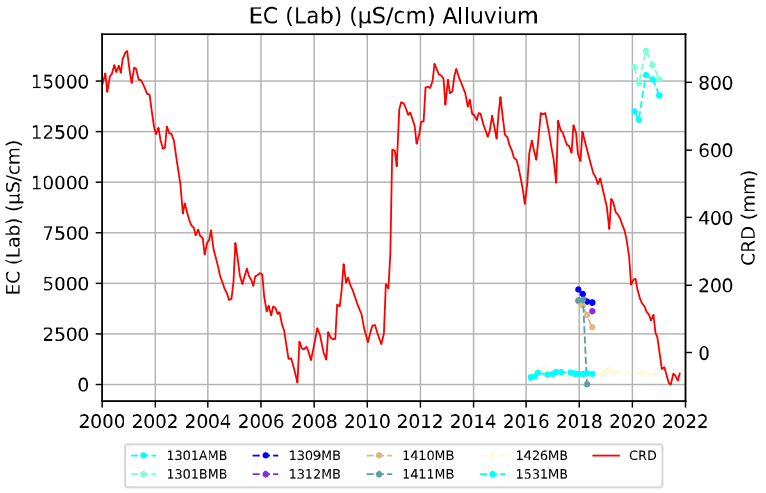
Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., and Hughes, J.D., 2013., MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: USGS Techniques and Methods 6-A45.

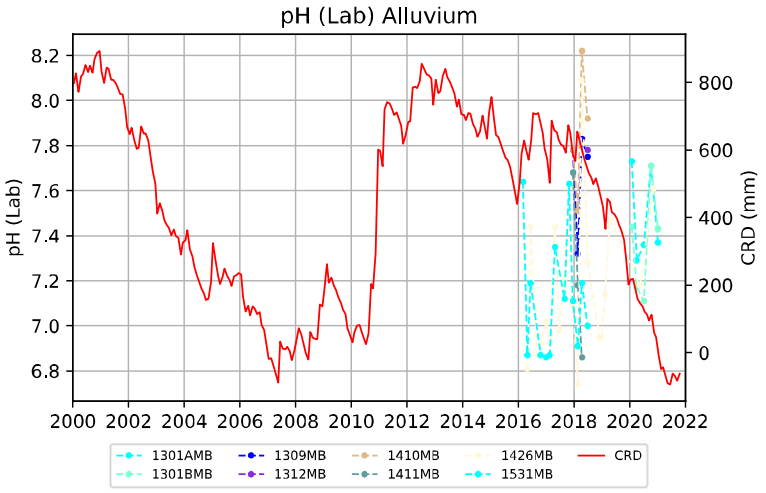
SLR, 2021. Curragh Mine Complex, Residual Void Modelling, November 2021.

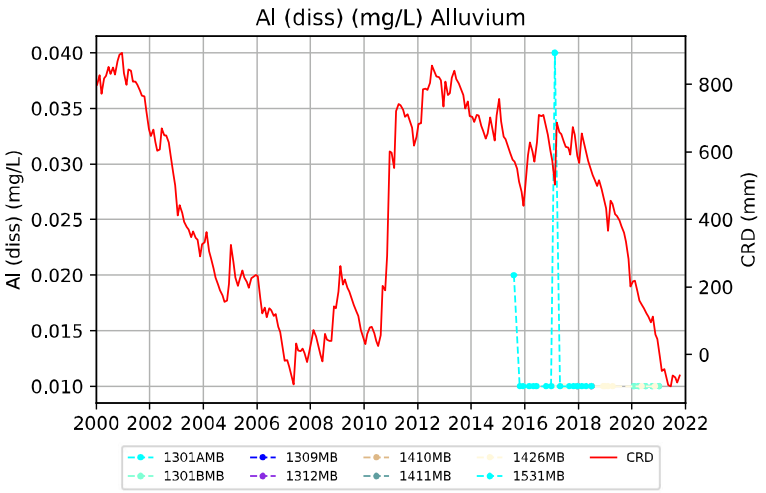
Velseis Processing Pty Ltd (2012). 2011 Minyango 3D Seismic Survey, Minyango Project Area, Qld. Final Report, Interpretation and Data Processing.

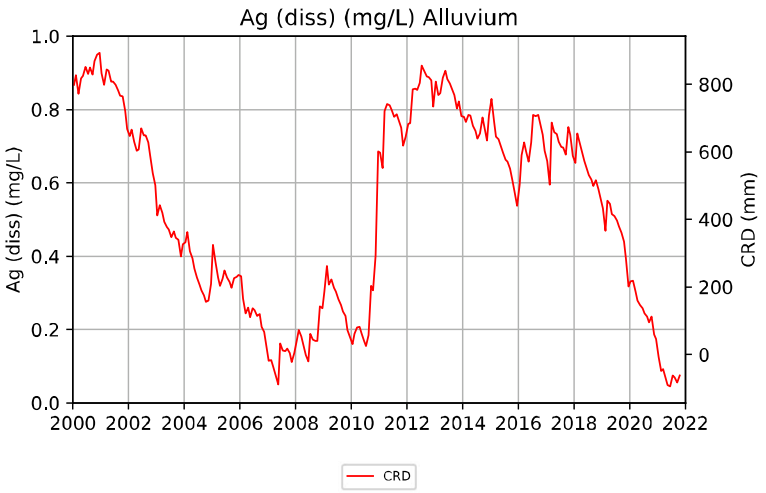
# APPENDIX A

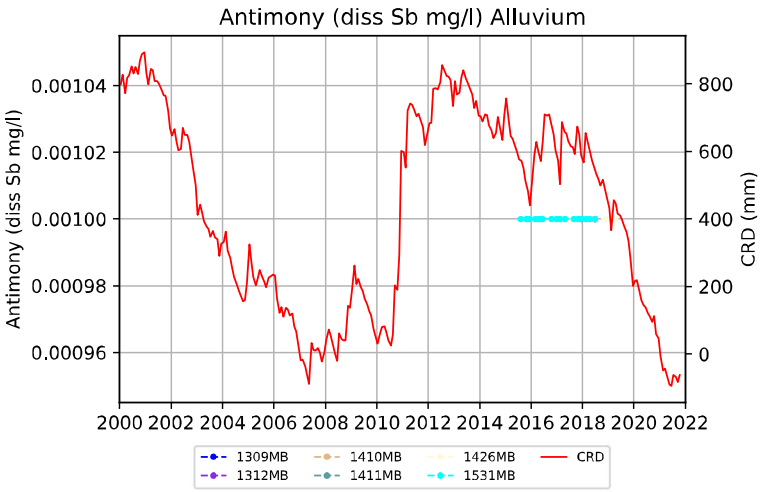
## Groundwater quality charts

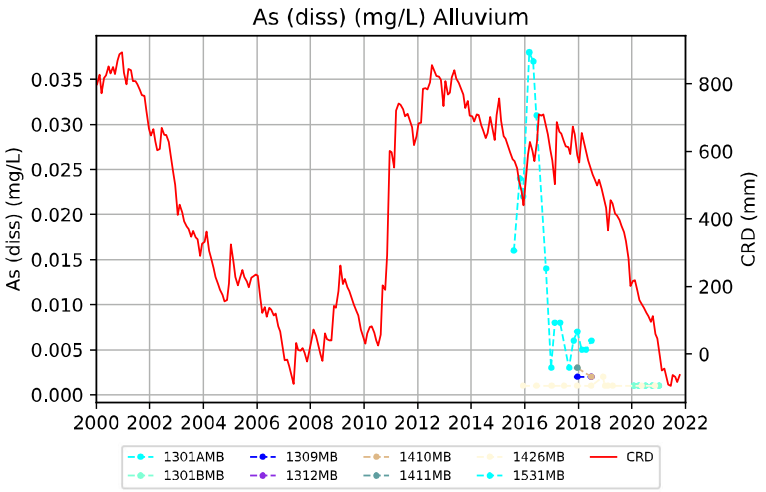

EC (Lab) (µS/cm) Alluvium
EC (Lab) (µS/cm)
CRD (mm)
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1531MB
CRD

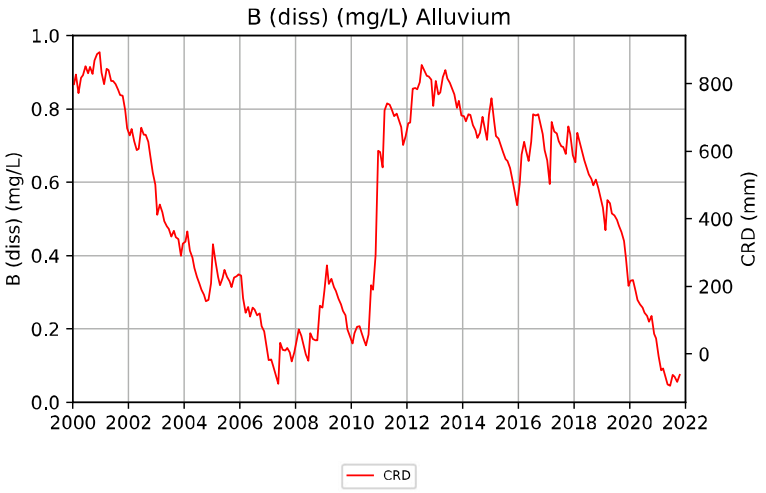

pH (Lab) Alluvium
pH (Lab)
CRD (mm)
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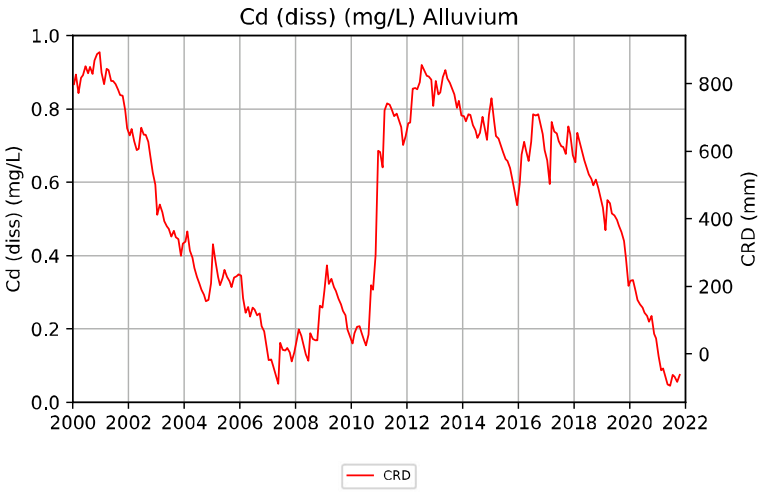

Al (diss) (mg/L) Alluvium
Al (diss) (mg/L)
CRD (mm)
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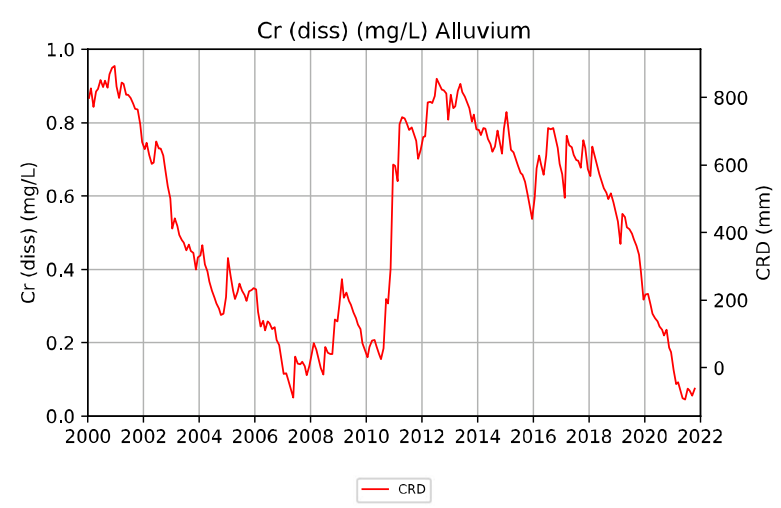

Ag (diss) (mg/L) Alluvium
Ag (diss) (mg/L)
CRD (mm)
CRD

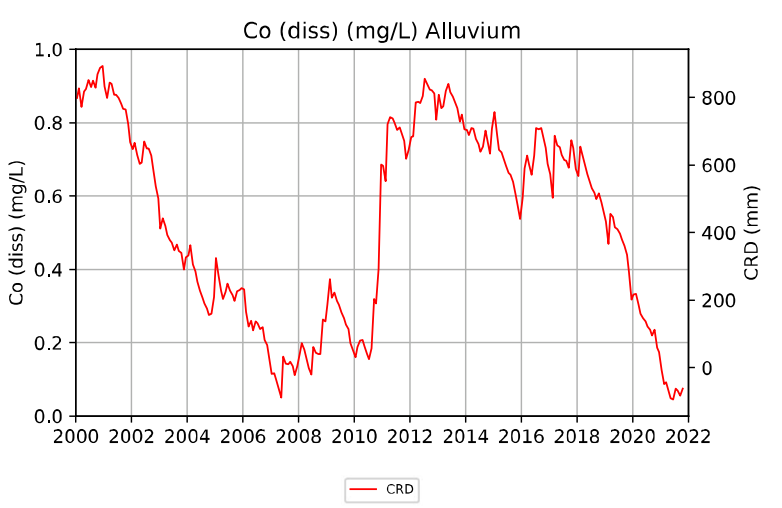

Antimony (diss Sb mg/l) Alluvium
Antimony (diss Sb mg/l)
CRD (mm)
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CRD

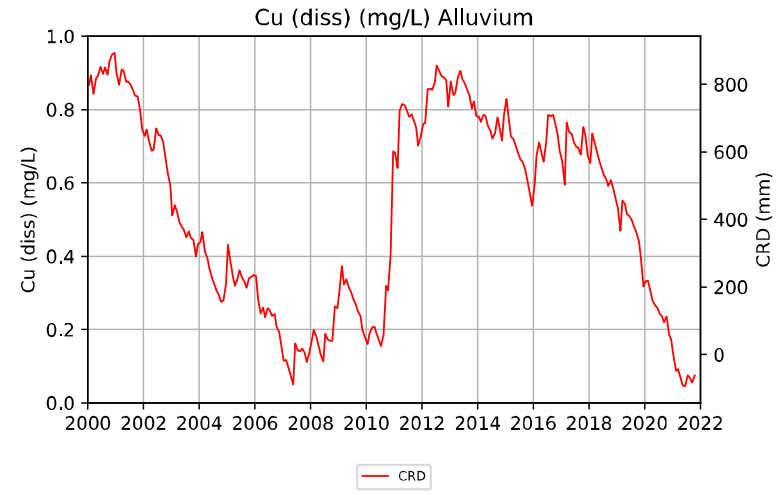

As (diss) (mg/L) Alluvium
As (diss) (mg/L)
CRD (mm)
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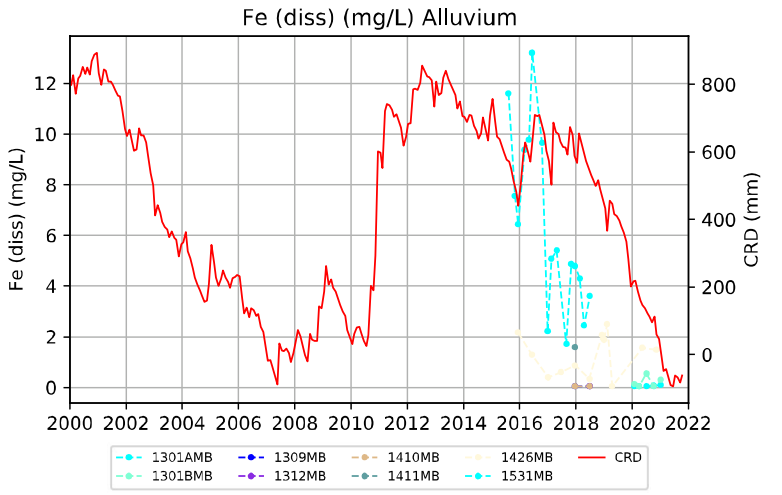

B (diss) (mg/L) Alluvium
B (diss) (mg/L)
CRD (mm)
CRD

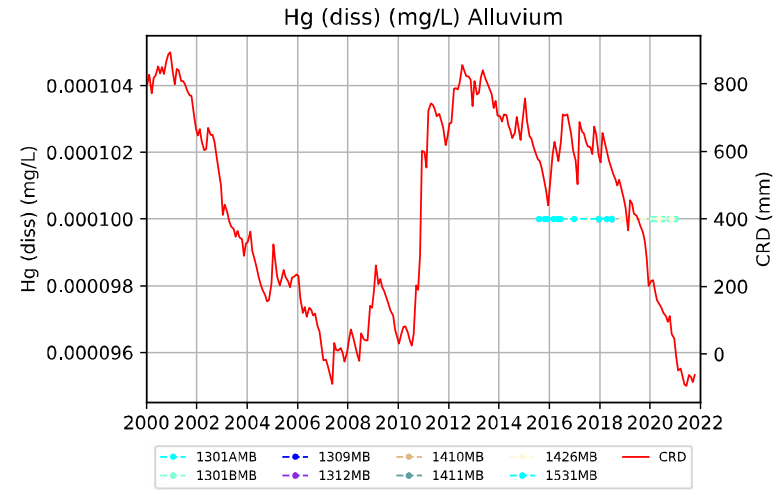

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Cd (diss) (mg/L)
CRD (mm)
CRD

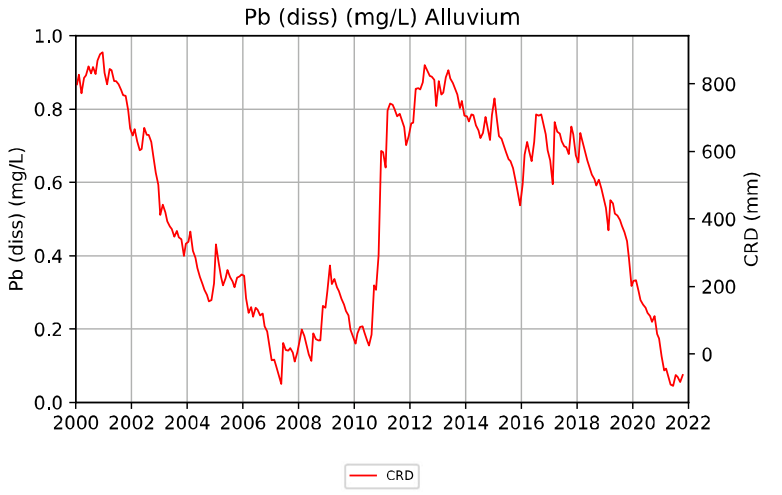

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Cr (diss) (mg/L)
CRD (mm)
CRD

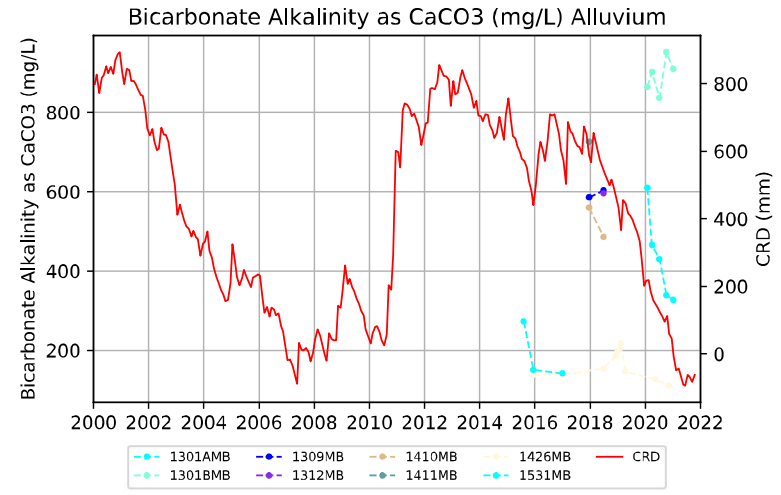

Co (diss) (mg/L) Alluvium
Co (diss) (mg/L)
CRD (mm)
CRD

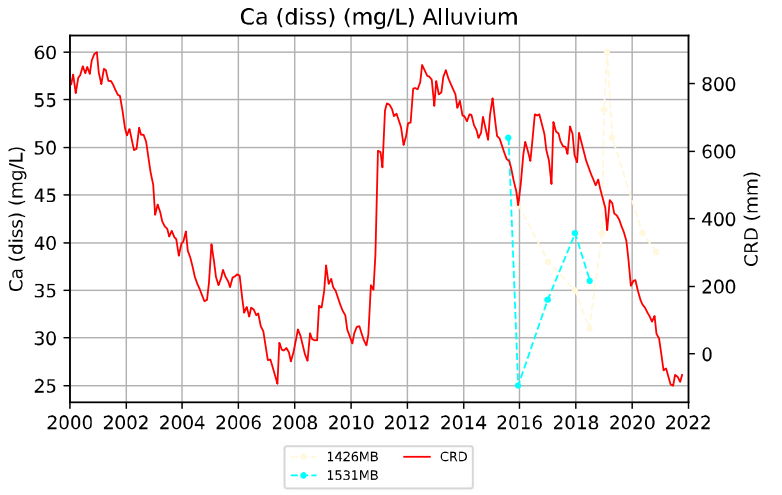

Cu (diss) (mg/L) Alluvium
Cu (diss) (mg/L)
CRD (mm)
CRD

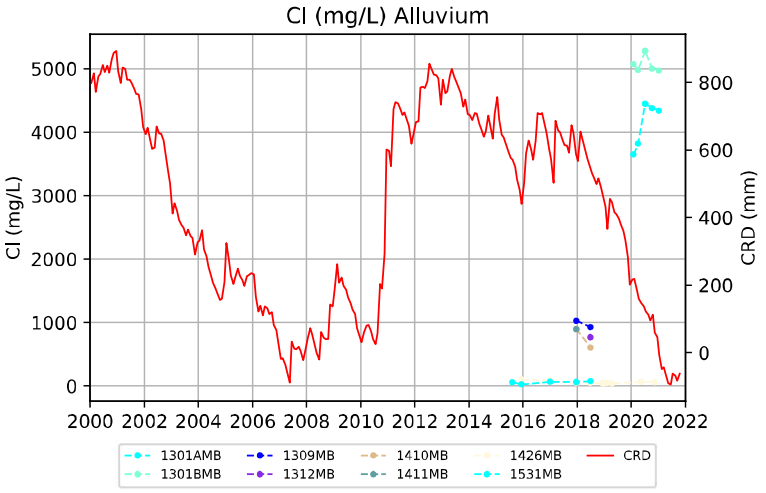

Fe (diss) (mg/L) Alluvium
Fe (diss) (mg/L)
CRD (mm)
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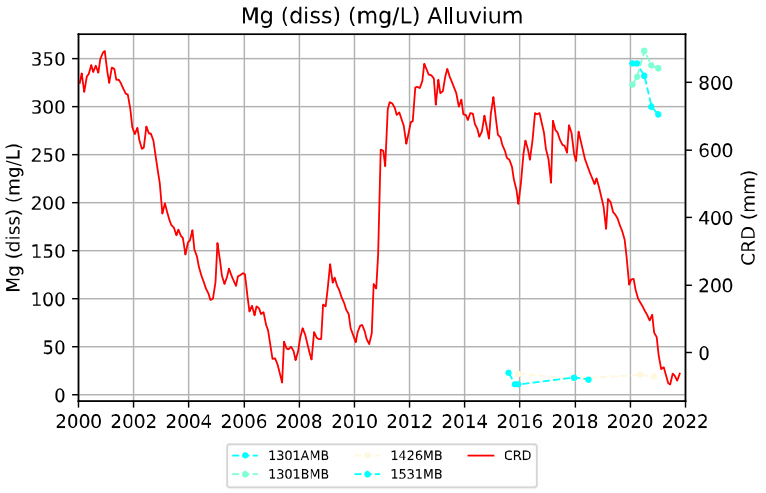

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Hg (diss) (mg/L)
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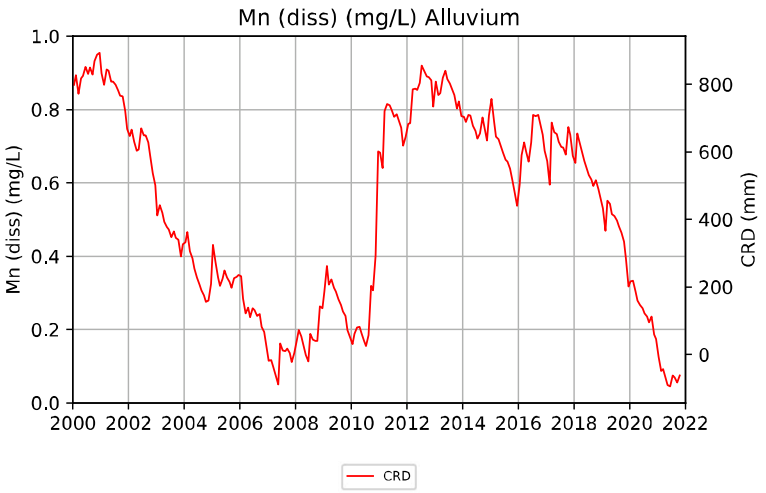

Pb (diss) (mg/L) Alluvium
Pb (diss) (mg/L)
CRD (mm)
CRD

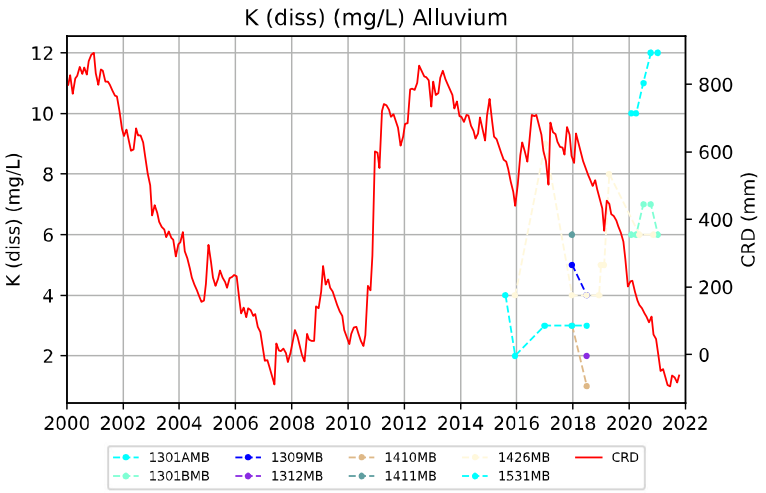

Bicarbonate Alkalinity as CaCO3 (mg/L) Alluvium
Bicarbonate Alkalinity as CaCO3 (mg/L)
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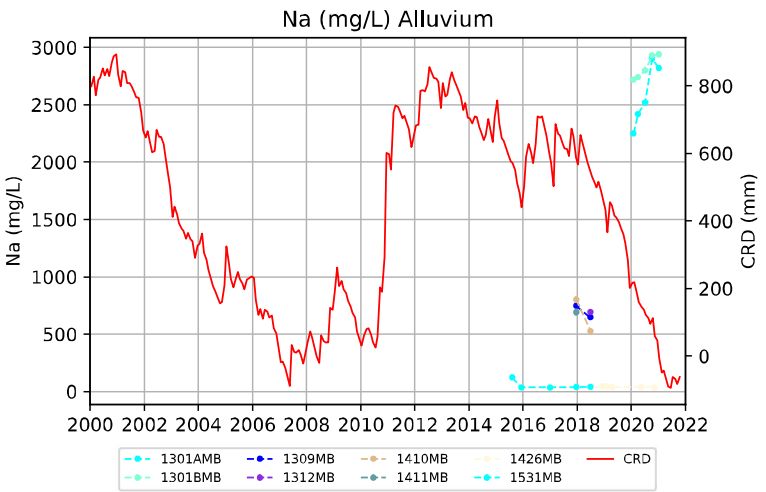

Ca (diss) (mg/L) Alluvium
Ca (diss) (mg/L)
CRD (mm)
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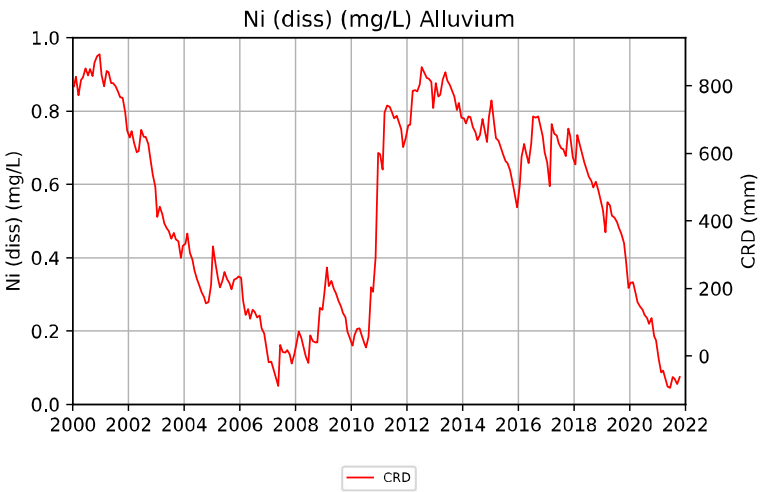

Cl (mg/L) Alluvium
Cl (mg/L)
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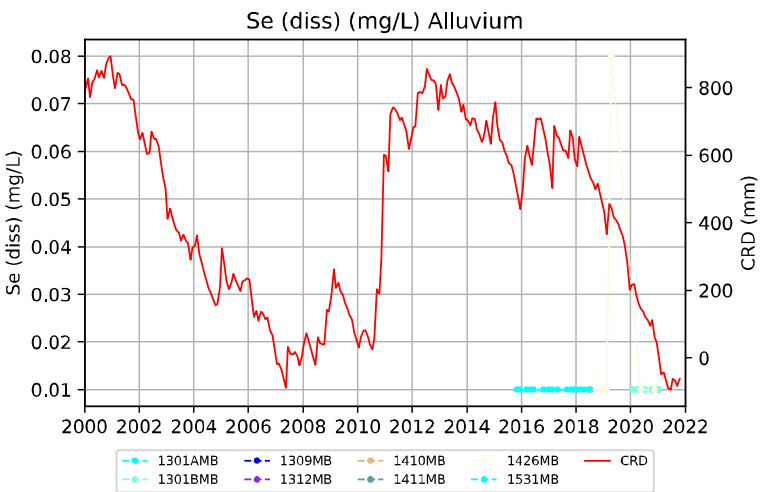

Mg (diss) (mg/L) Alluvium
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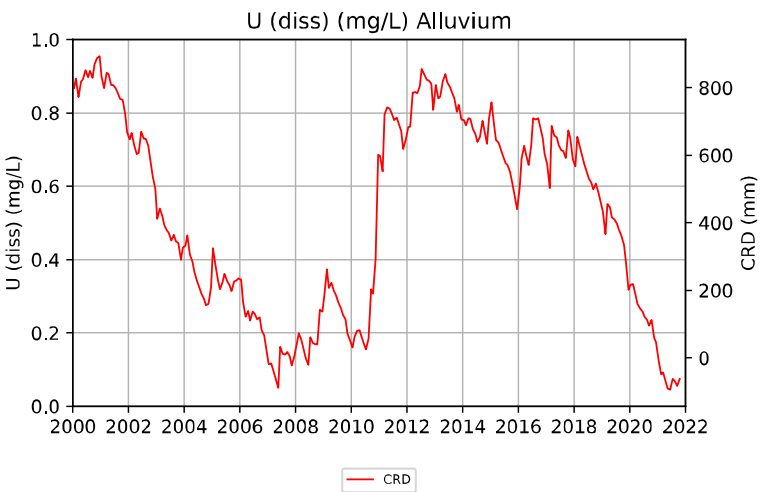

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Mn (diss) (mg/L)
CRD (mm)
CRD

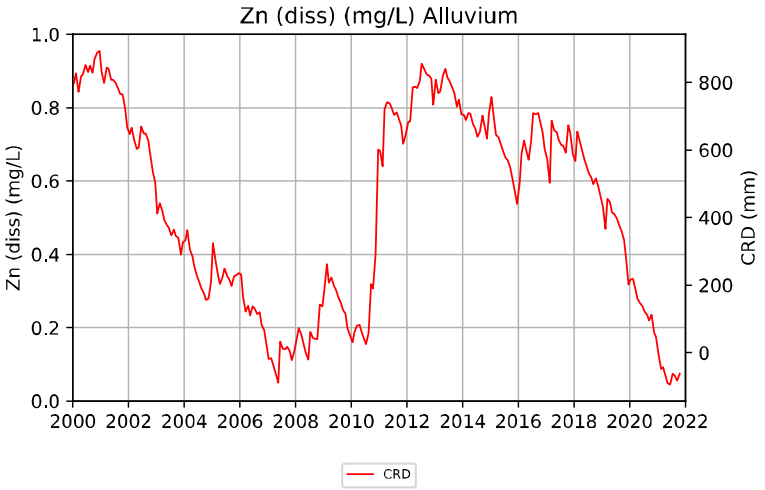

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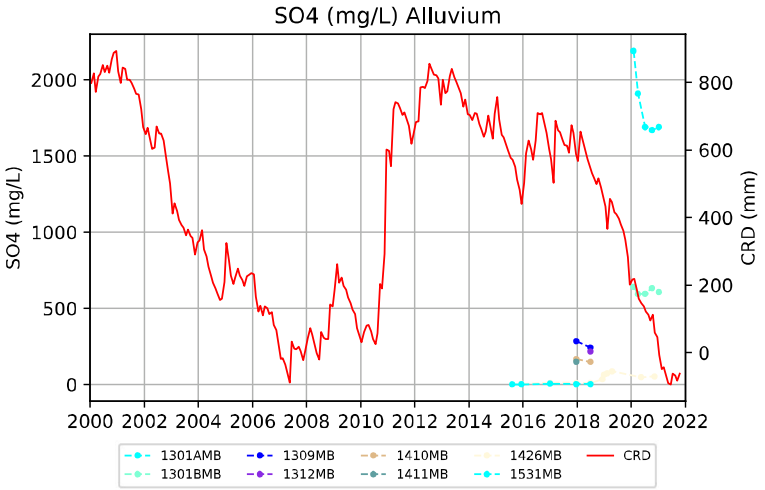

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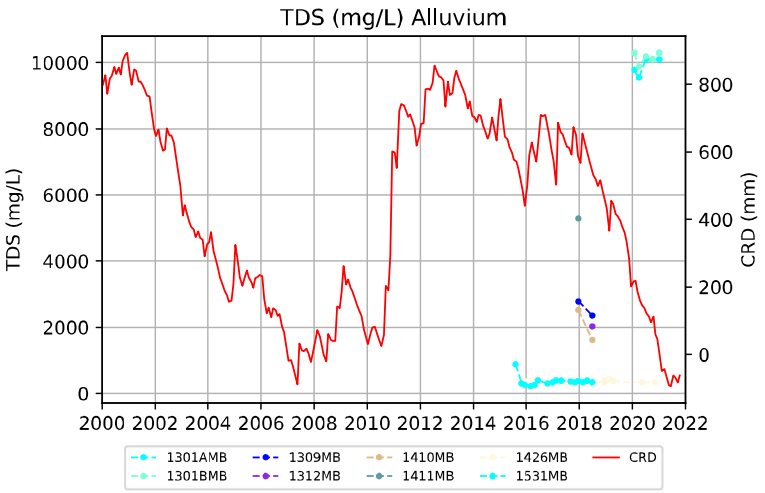

Ni (diss) (mg/L) Alluvium
Ni (diss) (mg/L)
CRD (mm)
CRD

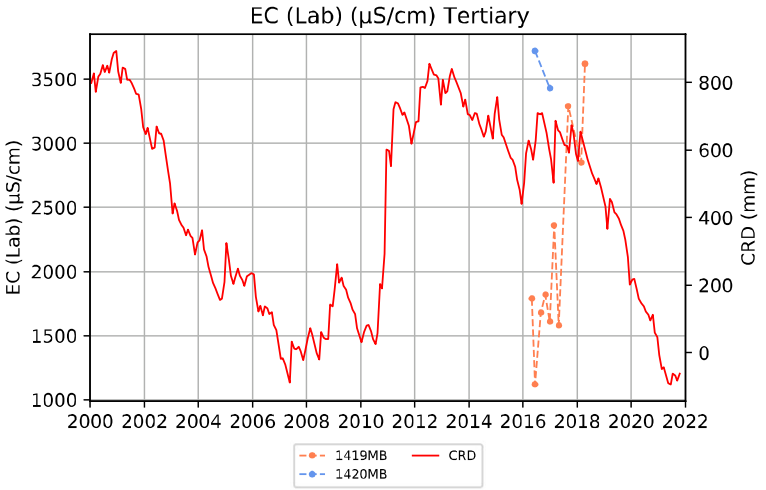

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Se (diss) (mg/L)
CRD (mm)
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1531MB
CRD

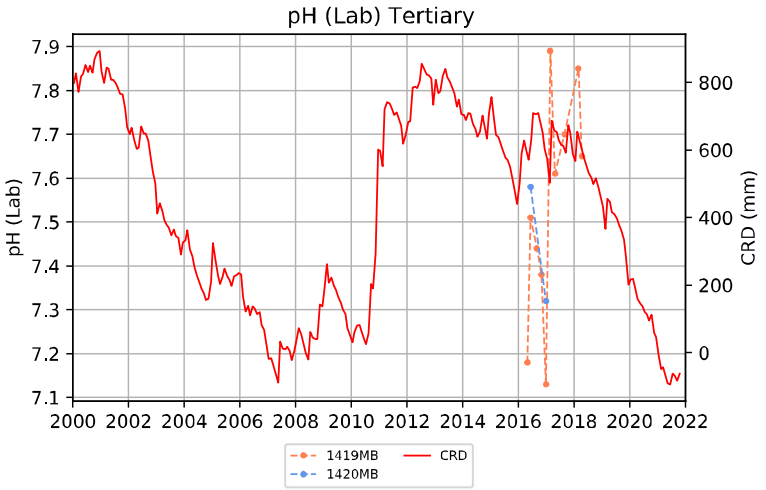

U (diss) (mg/L) Alluvium
U (diss) (mg/L)
CRD (mm)
CRD

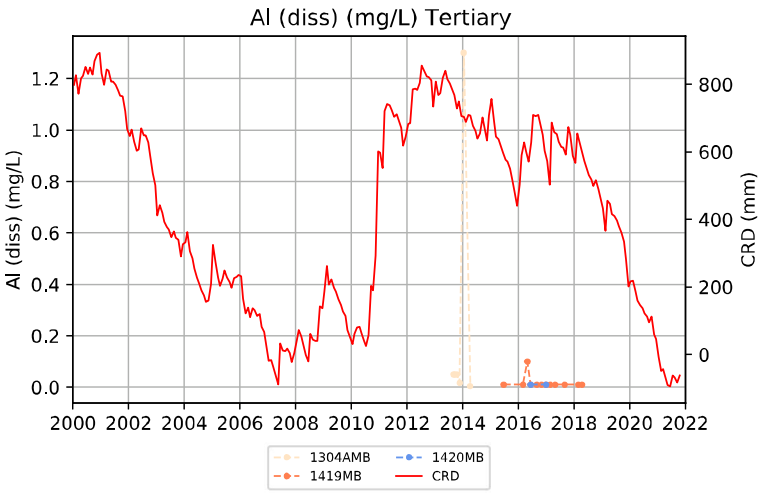

Zn (diss) (mg/L) Alluvium
Zn (diss) (mg/L)
CRD (mm)
CRD

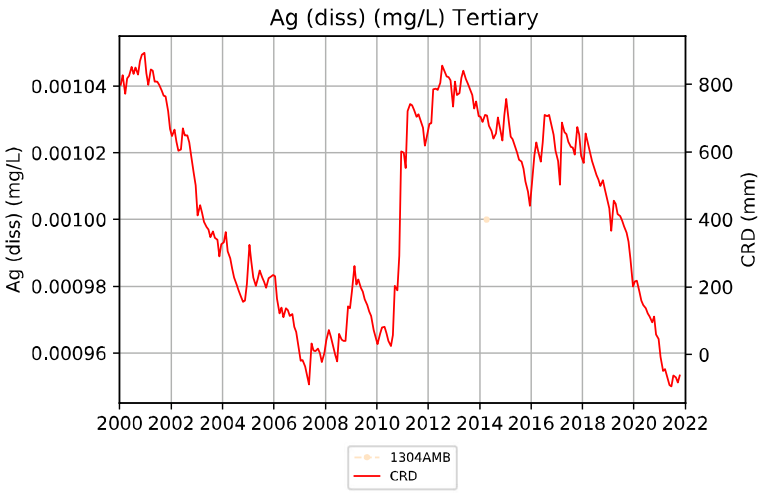

SO4 (mg/L) Alluvium
SO4 (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

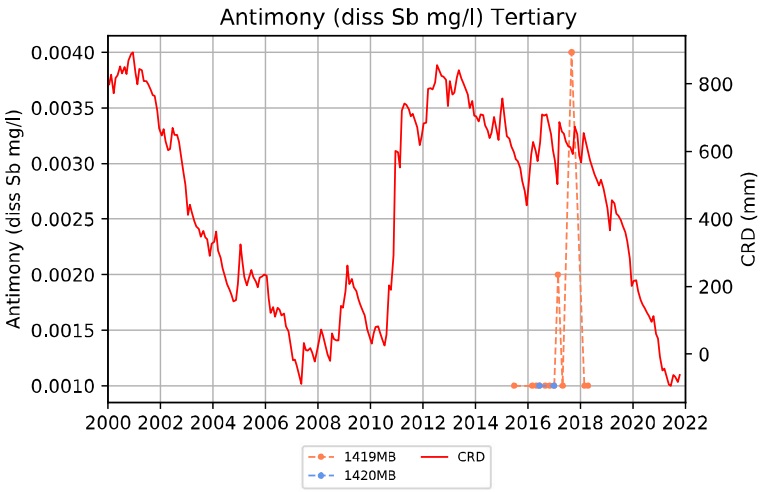

TDS (mg/L) Alluvium
TDS (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

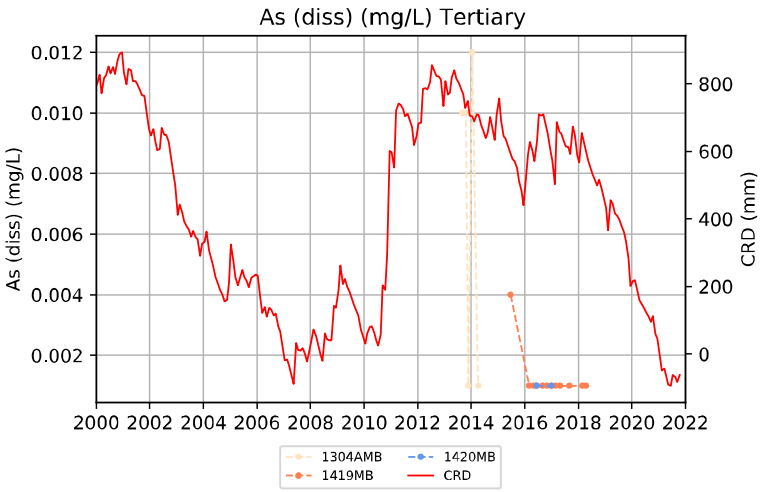

EC (Lab) (µS/cm) Tertiary
EC (Lab) (µS/cm)
CRD (mm)
1419MB
1420MB
CRD

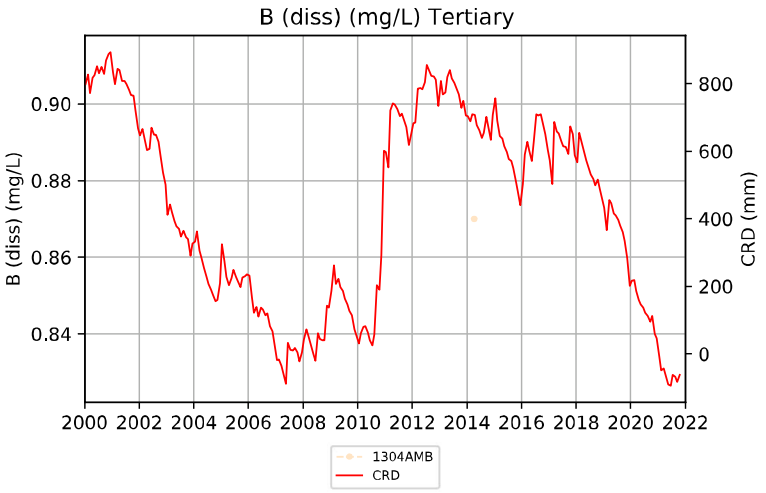

pH (Lab) Tertiary
pH (Lab)
CRD (mm)
1419MB
1420MB
CRD

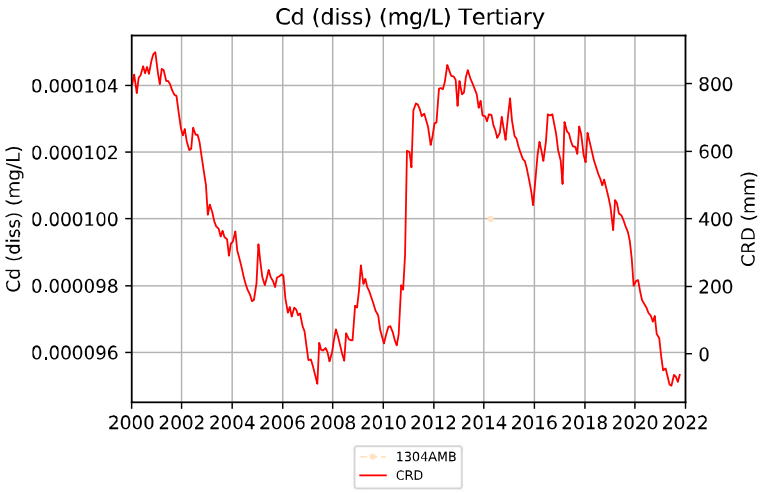

Al (diss) (mg/L) Tertiary
Al (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

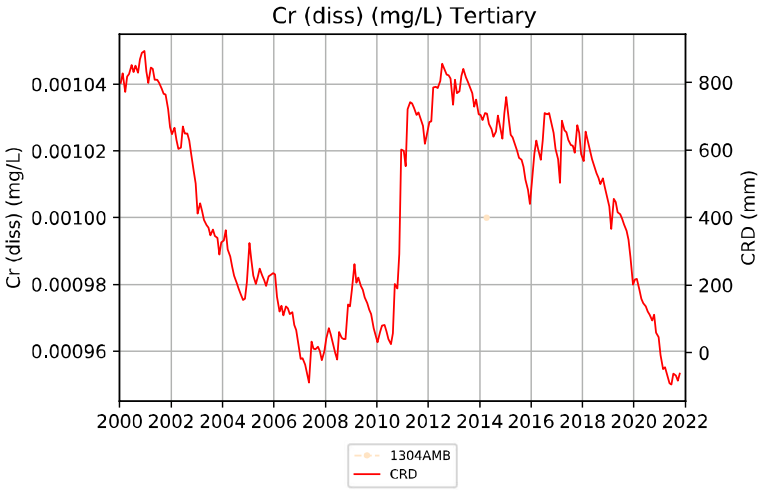

Ag (diss) (mg/L) Tertiary
Ag (diss) (mg/L)
CRD (mm)
1304AMB
CRD

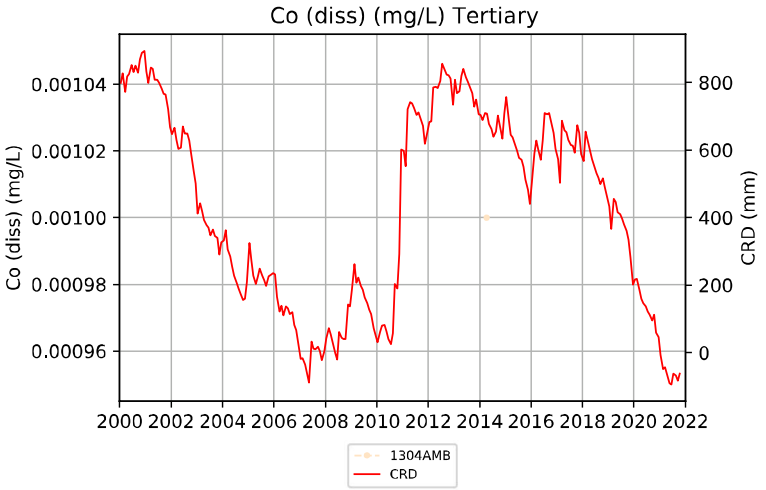

Antimony (diss Sb mg/l) Tertiary
Antimony (diss Sb mg/l)
CRD (mm)
1419MB
1420MB
CRD

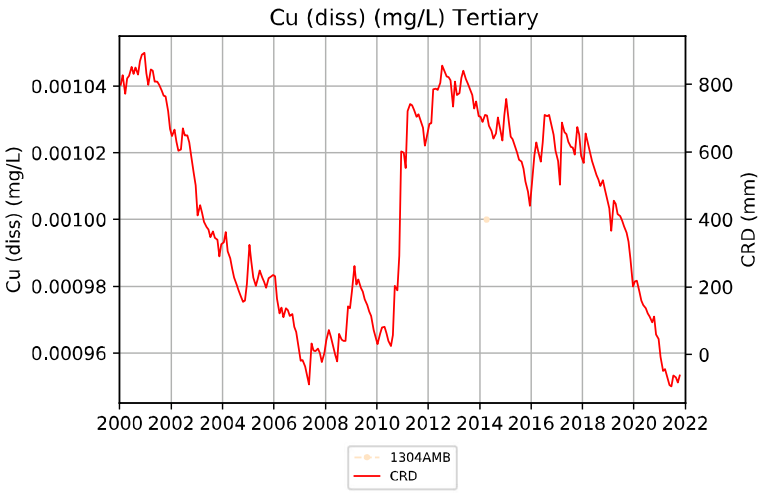

As (diss) (mg/L) Tertiary
As (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

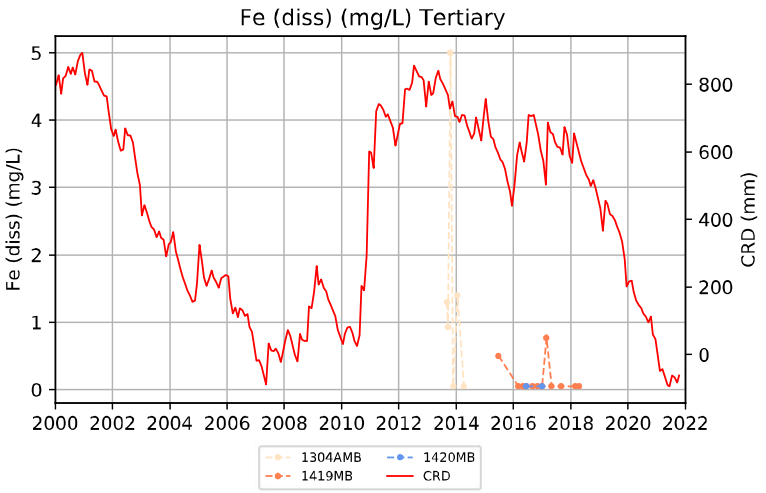

B (diss) (mg/L) Tertiary
B (diss) (mg/L)
CRD (mm)
1304AMB
CRD

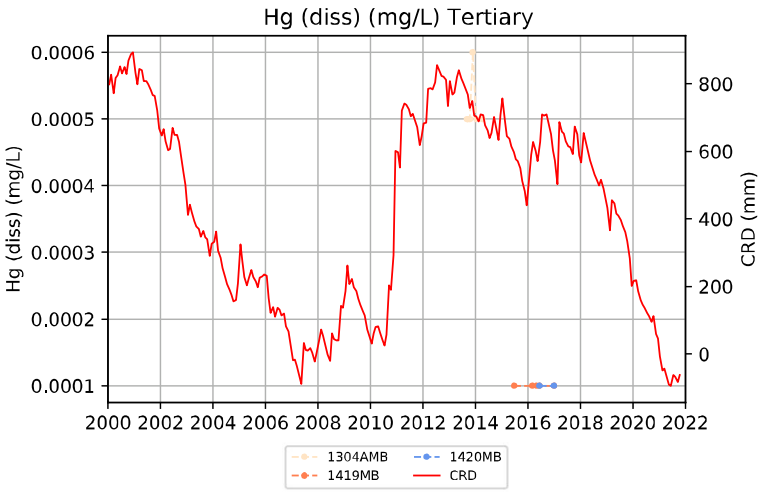

Cd (diss) (mg/L) Tertiary
Cd (diss) (mg/L)
CRD (mm)
1304AMB
CRD

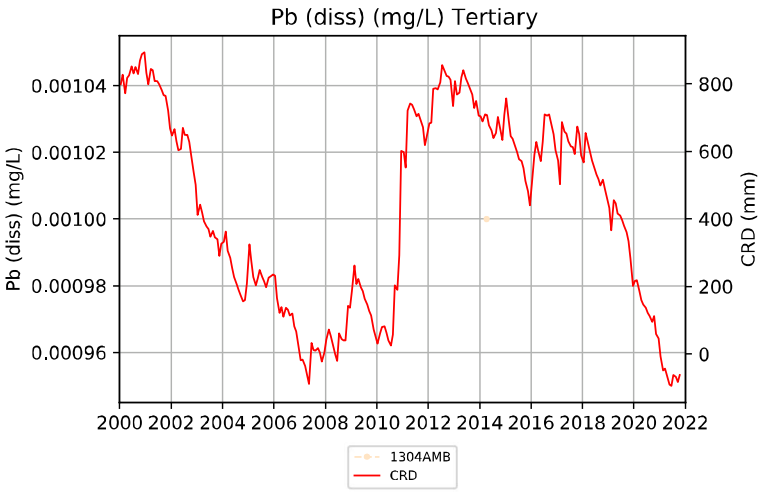

Cr (diss) (mg/L) Tertiary
Cr (diss) (mg/L)
CRD (mm)
1304AMB
CRD

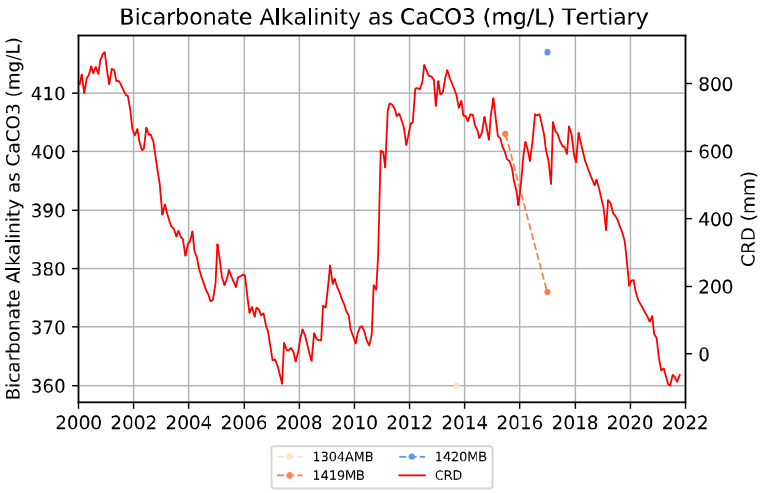

Co (diss) (mg/L) Tertiary
Co (diss) (mg/L)
CRD (mm)
1304AMB
CRD

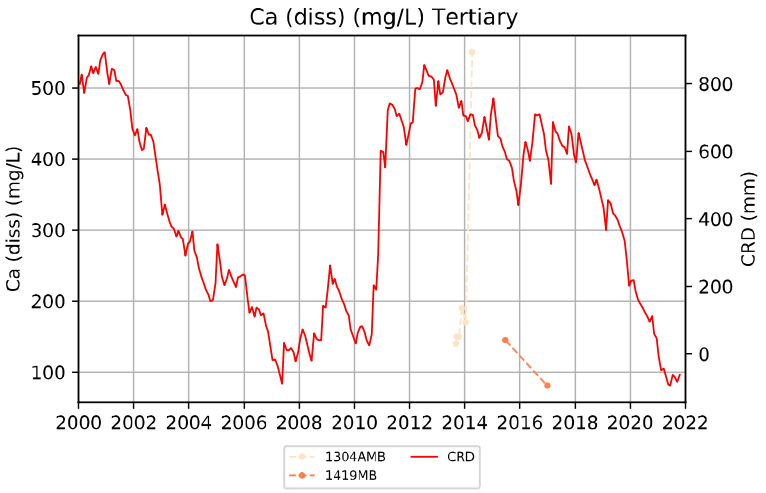

Cu (diss) (mg/L) Tertiary
Cu (diss) (mg/L)
CRD (mm)
1304AMB
CRD

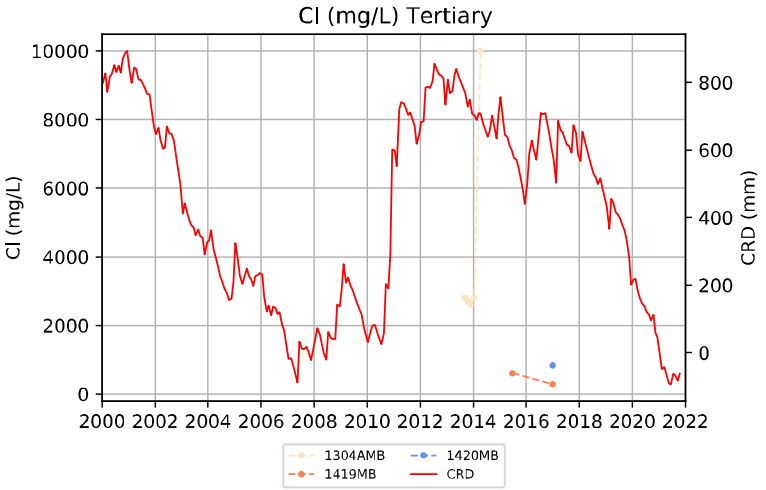

Fe (diss) (mg/L) Tertiary
Fe (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

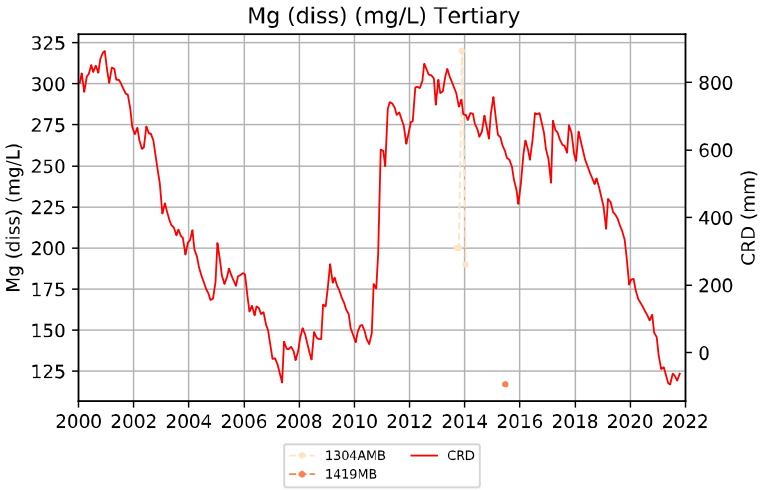

Hg (diss) (mg/L) Tertiary
Hg (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

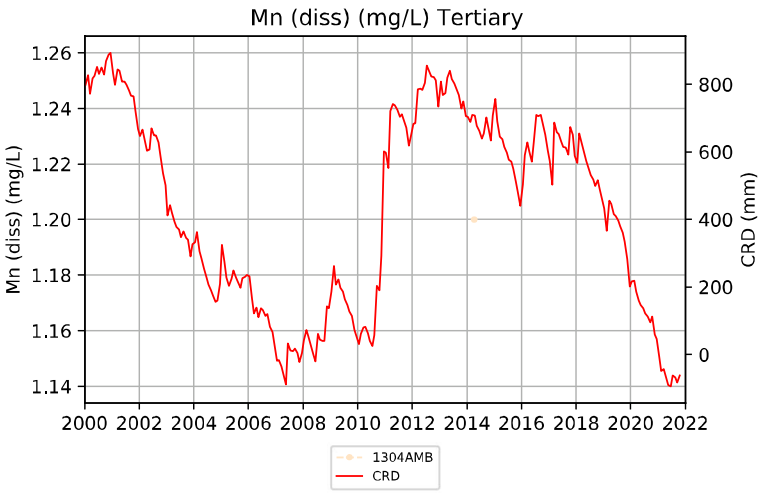

Pb (diss) (mg/L) Tertiary
Pb (diss) (mg/L)
CRD (mm)
1304AMB
CRD

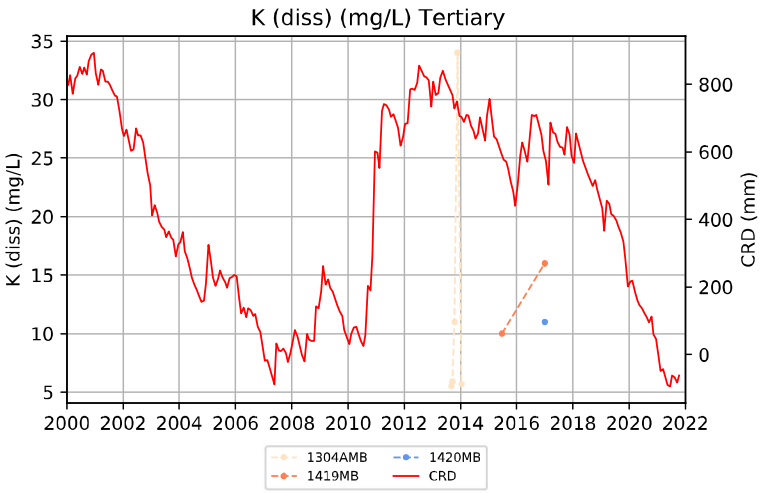

Bicarbonate Alkalinity as CaCO3 (mg/L) Tertiary
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

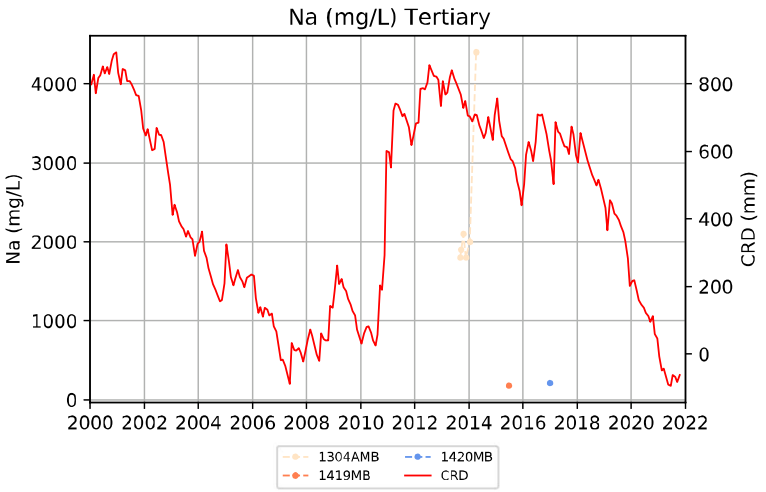

Ca (diss) (mg/L) Tertiary
Ca (diss) (mg/L)
CRD (mm)
1304AMB
CRD
1419MB

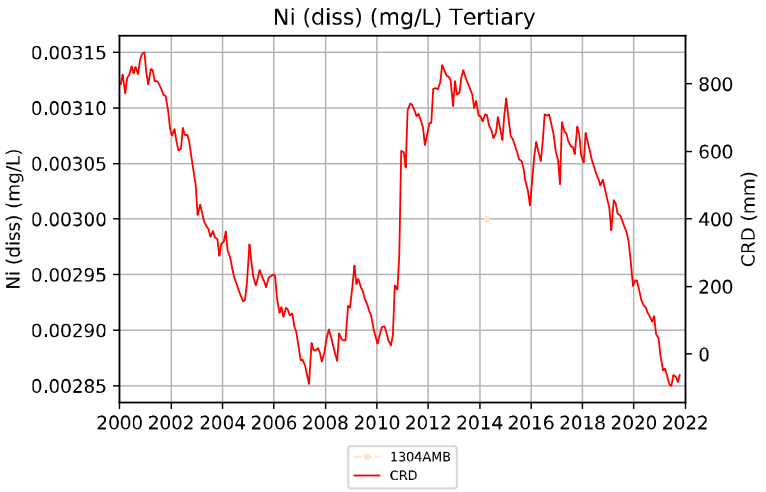

Cl (mg/L) Tertiary
Cl (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

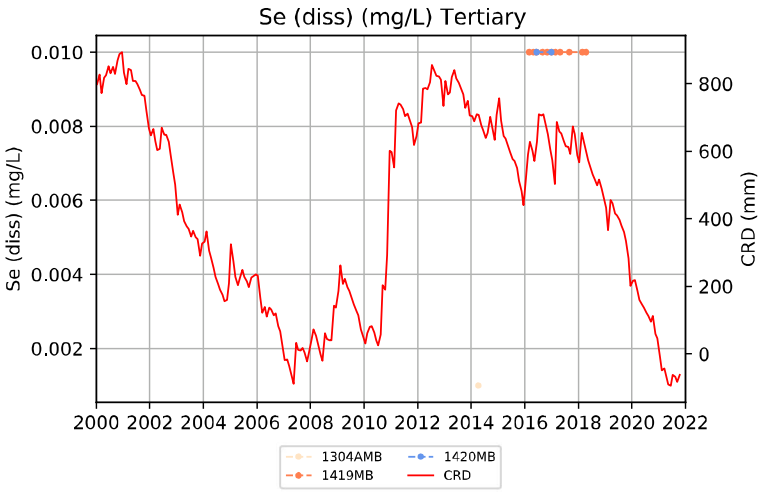

Mg (diss) (mg/L) Tertiary
Mg (diss) (mg/L)
CRD (mm)
1304AMB
CRD
1419MB

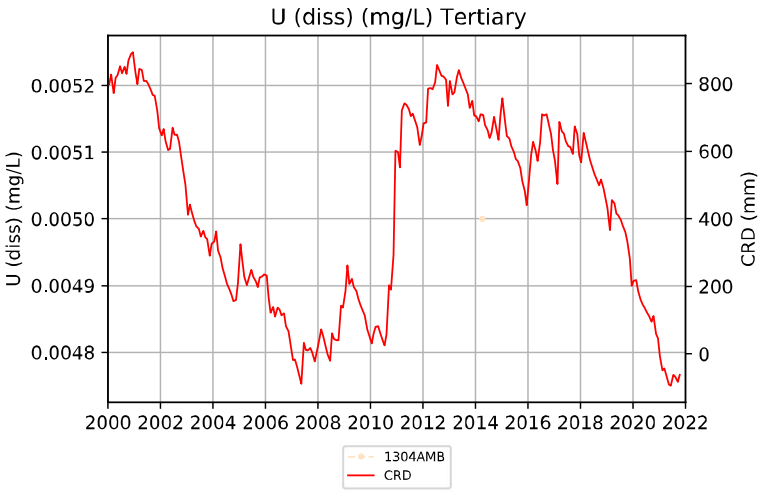

Mn (diss) (mg/L) Tertiary
Mn (diss) (mg/L)
CRD (mm)
1304AMB
CRD

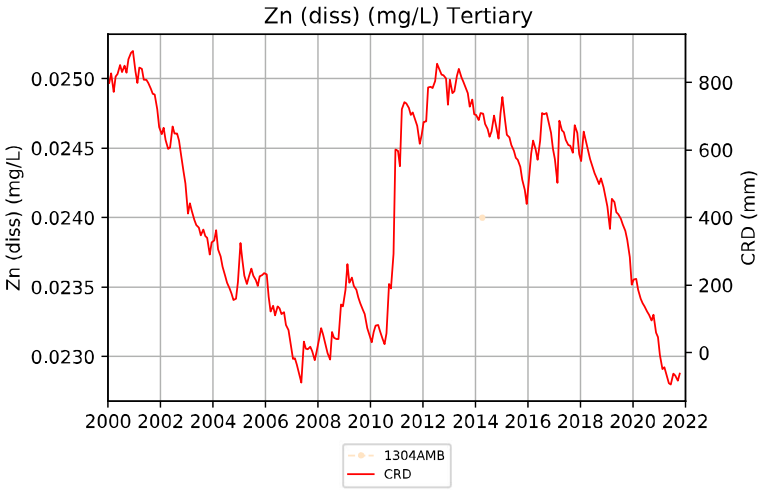

K (diss) (mg/L) Tertiary
K (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

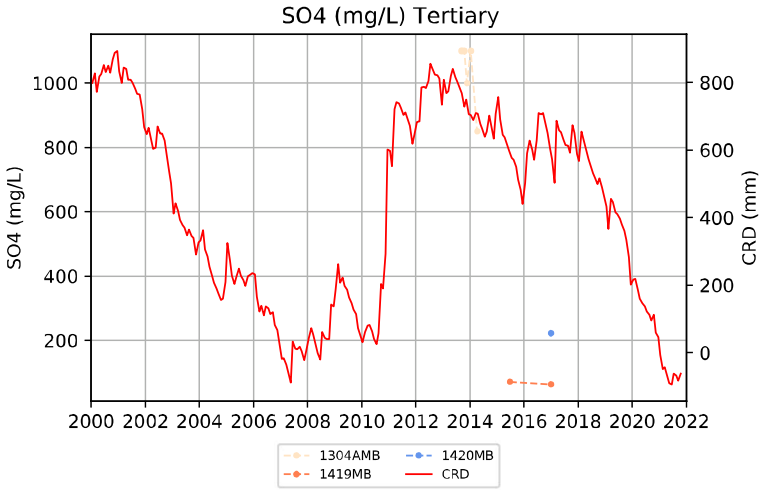

Na (mg/L) Tertiary
Na (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

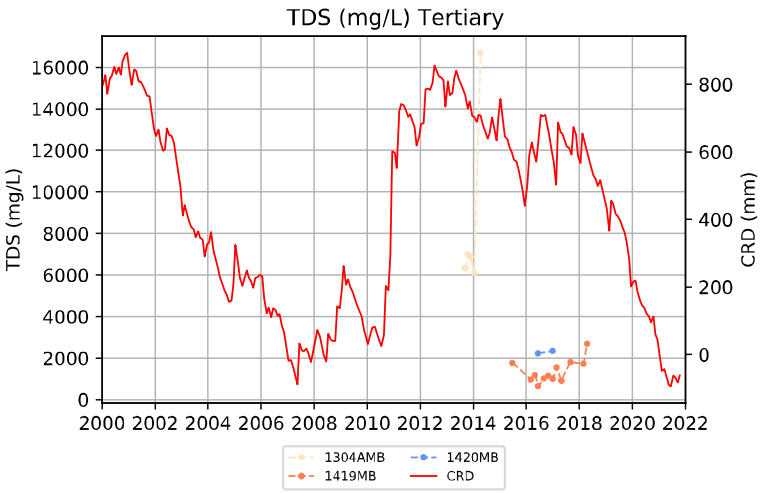

Ni (diss) (mg/L) Tertiary
Ni (diss) (mg/L)
CRD (mm)
1304AMB
CRD

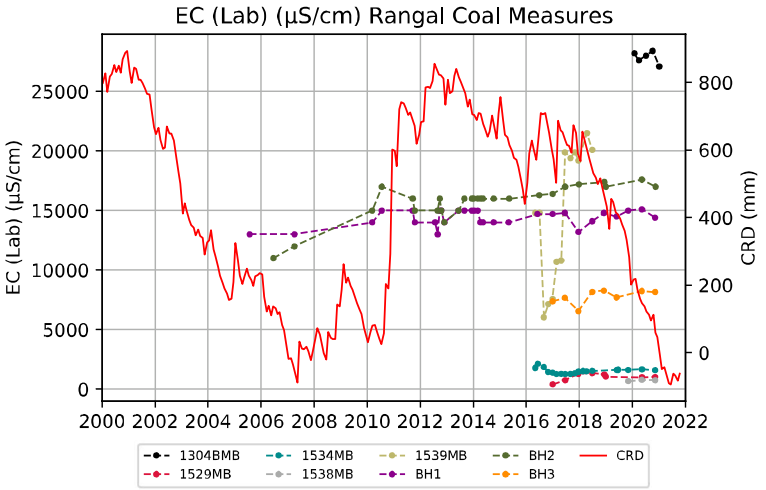

Se (diss) (mg/L) Tertiary
Se (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

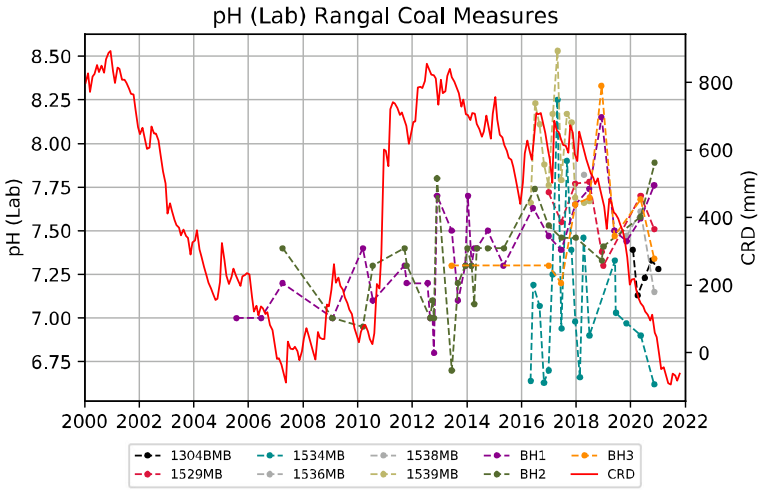

U (diss) (mg/L) Tertiary
U (diss) (mg/L)
CRD (mm)
1304AMB
CRD

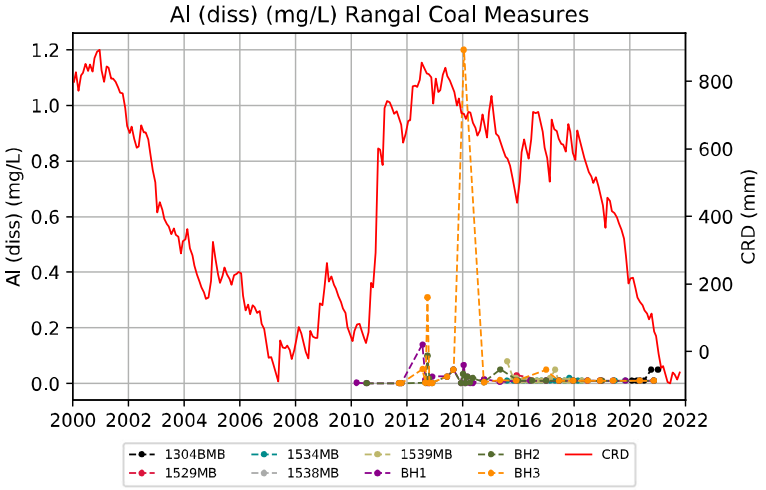

Zn (diss) (mg/L) Tertiary
Zn (diss) (mg/L)
CRD (mm)
0.0250
0.0245
0.0240
0.0235
0.0230
800
600
400
200
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
1304AMB
CRD

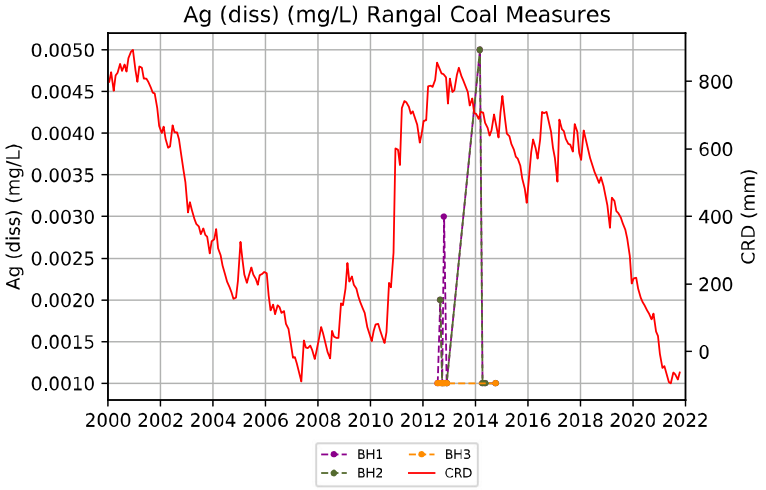

SO4 (mg/L) Tertiary
SO4 (mg/L)
CRD (mm)
1000
800
600
400
200
800
600
400
200
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
1304AMB
1420MB
1419MB
CRD

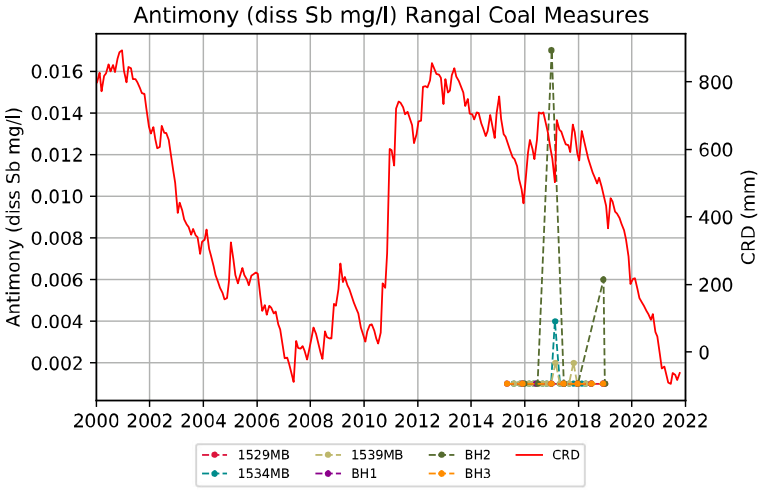

TDS (mg/L) Tertiary
TDS (mg/L)
CRD (mm)
16000
14000
12000
10000
8000
6000
4000
2000
0
800
600
400
200
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
1304AMB
1420MB
1419MB
CRD

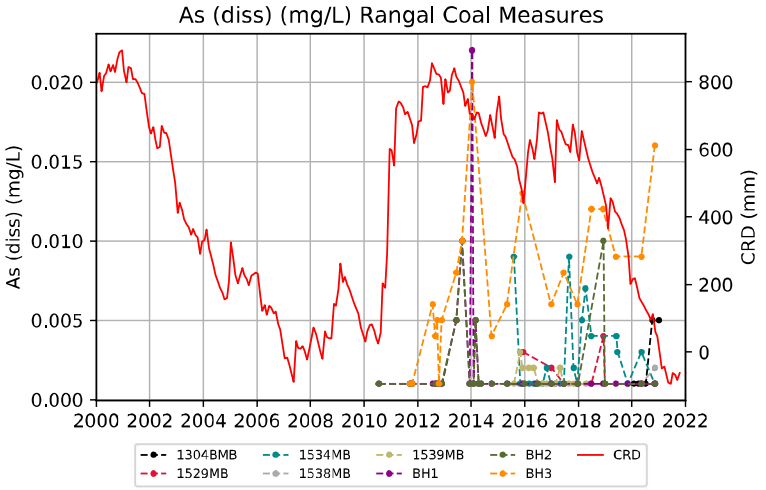

EC (Lab) (µS/cm) Rangal Coal Measures
EC (Lab) (µS/cm)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

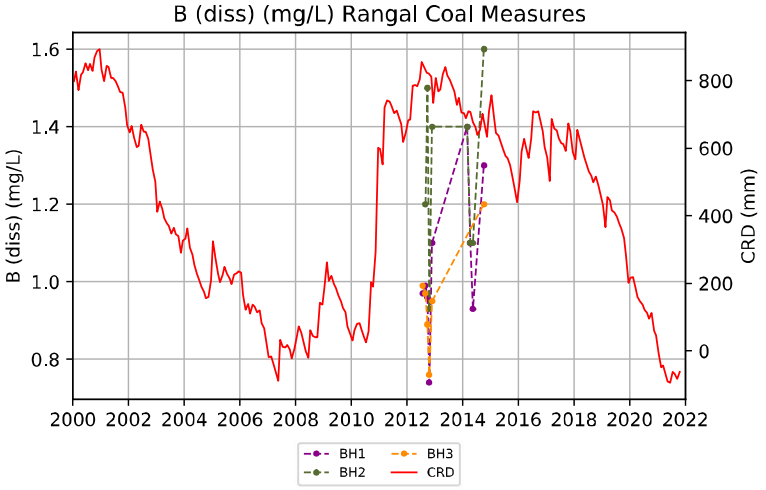

pH (Lab) Rangal Coal Measures
pH (Lab)
CRD (mm)
1304BMB
1529MB
1534MB
1536MB
1538MB
1539MB
BH1
BH2
BH3
CRD

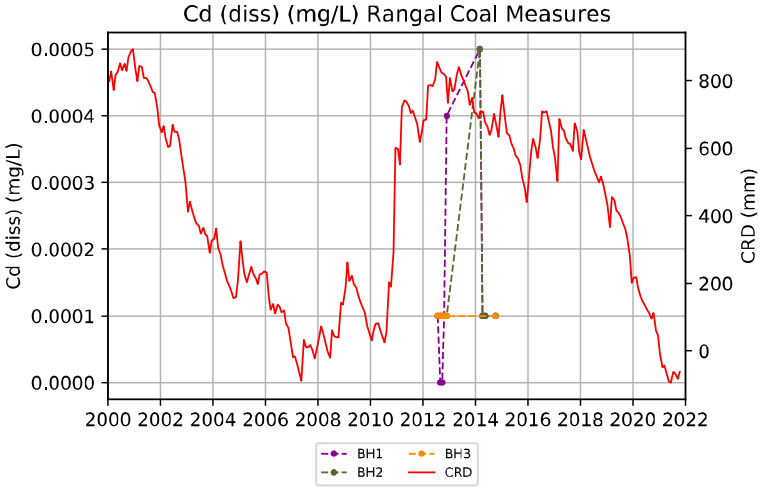

Al (diss) (mg/L) Rangal Coal Measures
Al (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

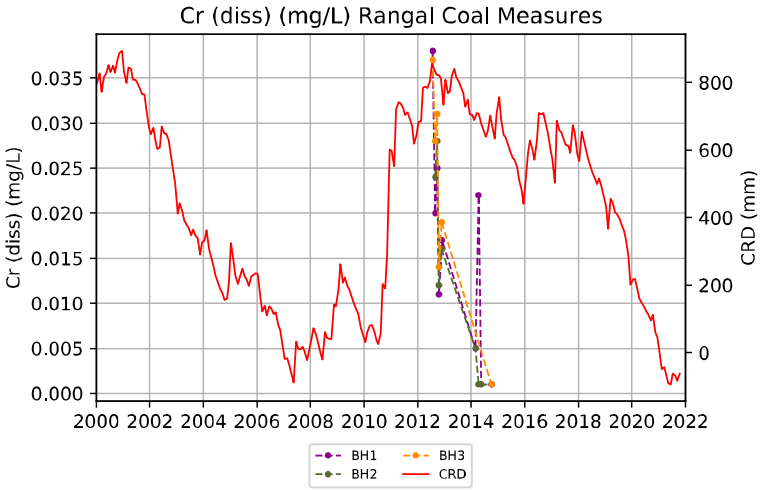

Ag (diss) (mg/L) Rangal Coal Measures
Ag (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

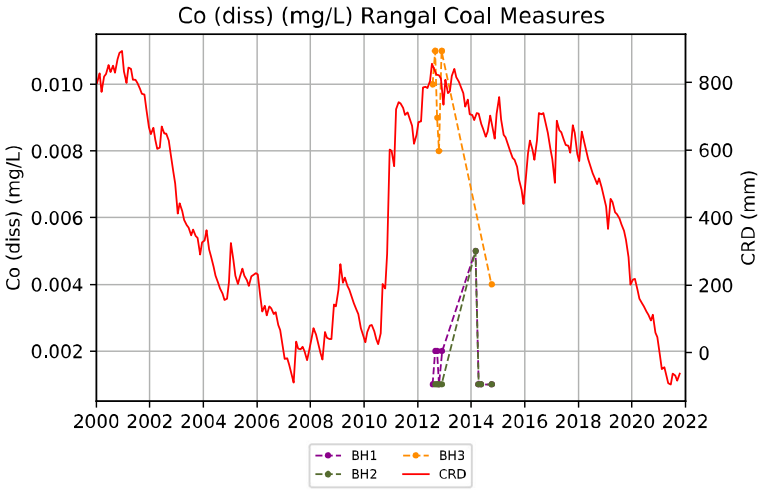

Antimony (diss Sb mg/l) Rangal Coal Measures
Antimony (diss Sb mg/l)
CRD (mm)
1529MB
1534MB
1539MB
BH1
BH2
BH3
CRD

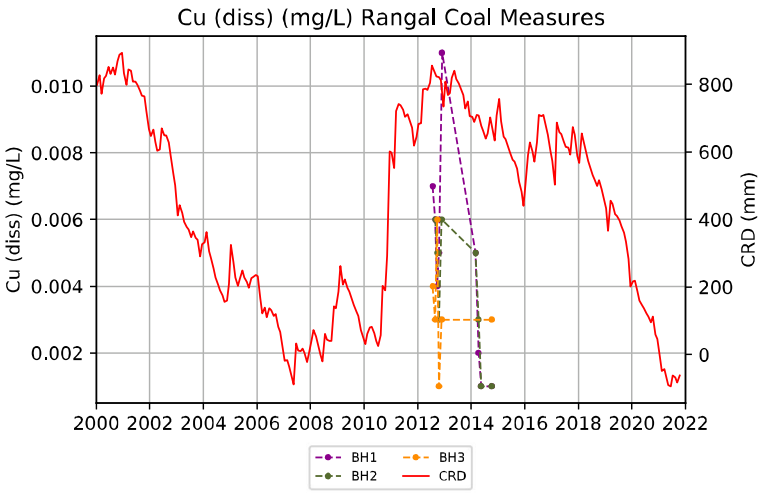

As (diss) (mg/L) Rangal Coal Measures
As (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

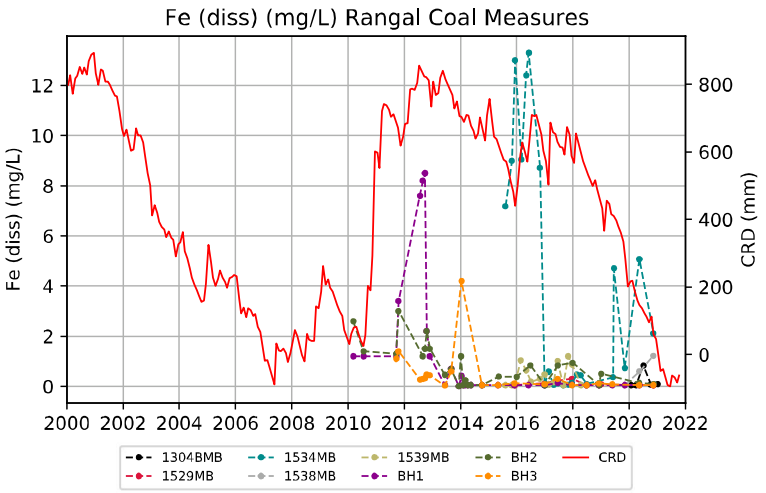

B (diss) (mg/L) Rangal Coal Measures
B (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

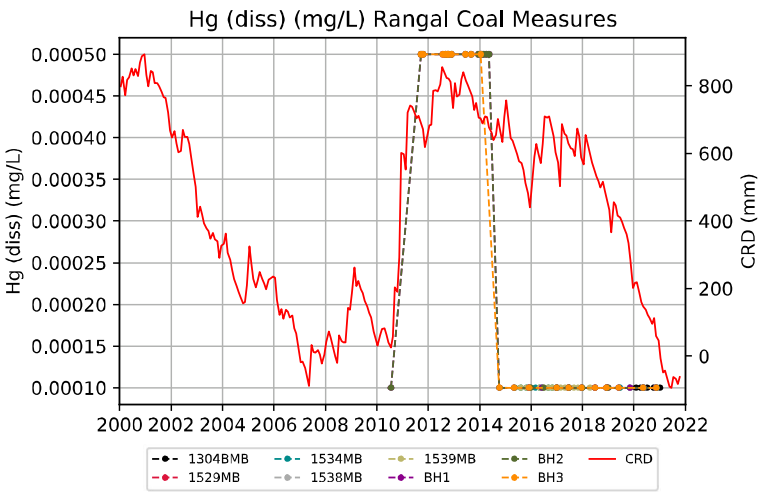

Cd (diss) (mg/L) Rangal Coal Measures
Cd (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

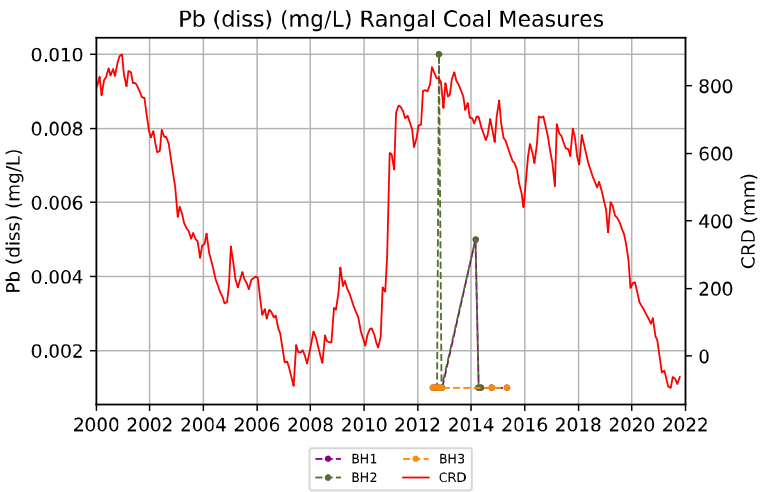

Cr (diss) (mg/L) Rangal Coal Measures
Cr (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

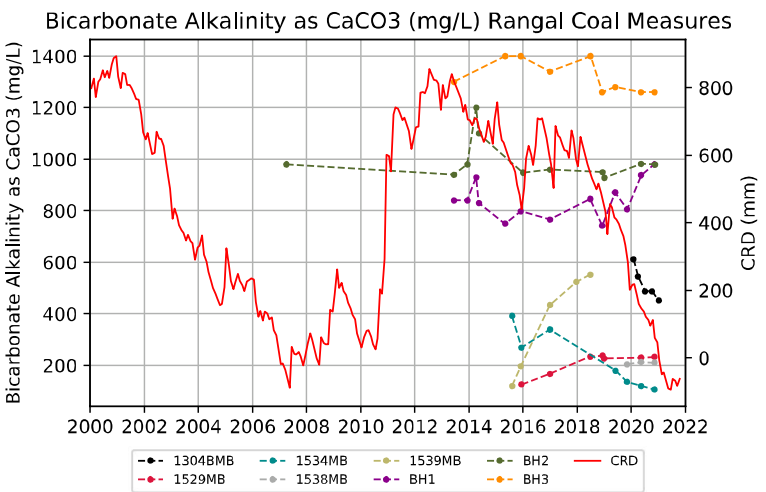

Co (diss) (mg/L) Rangal Coal Measures
Co (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

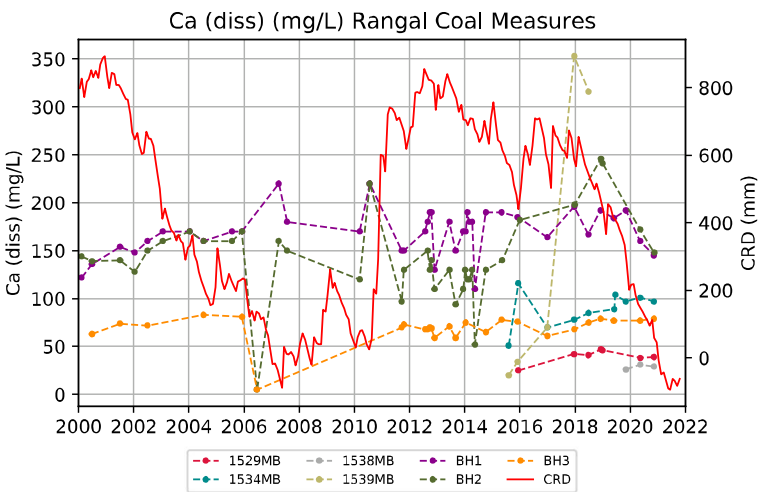

Cu (diss) (mg/L) Rangal Coal Measures
Cu (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

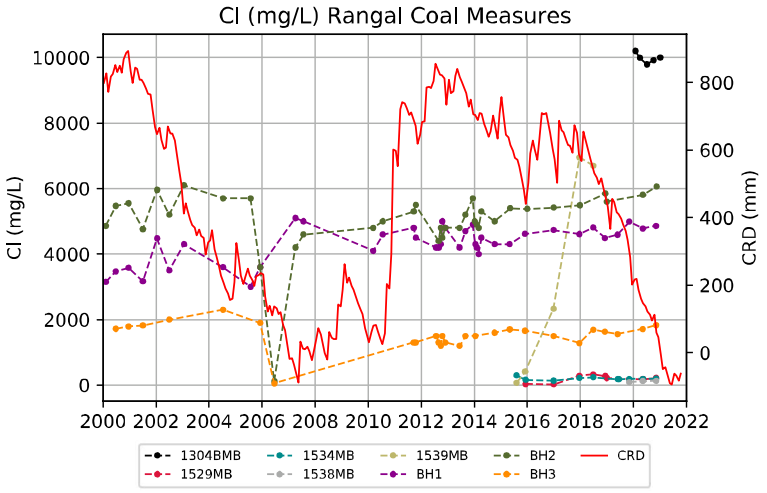

Fe (diss) (mg/L) Rangal Coal Measures
Fe (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

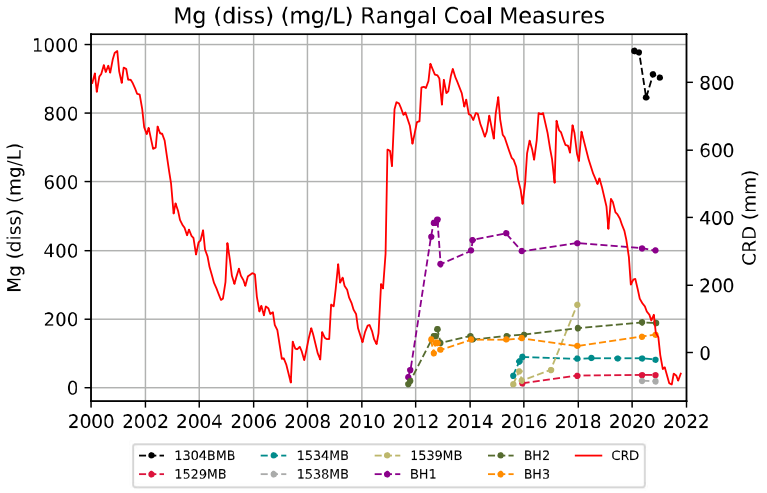

Hg (diss) (mg/L) Rangal Coal Measures
Hg (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

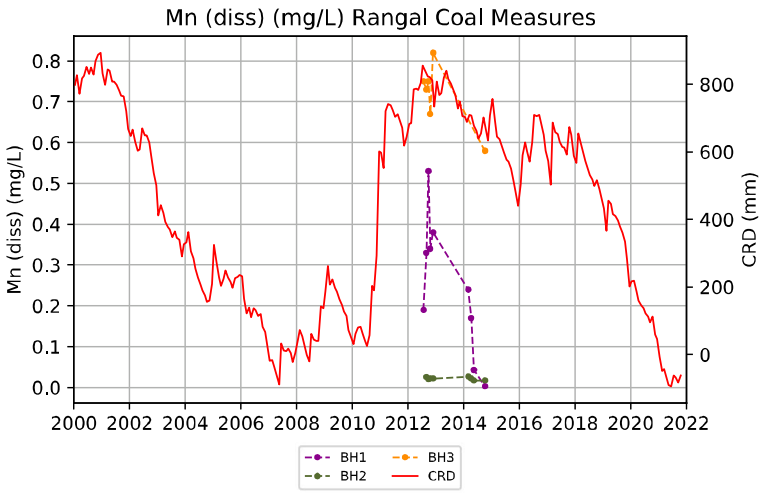

Pb (diss) (mg/L) Rangal Coal Measures
Pb (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

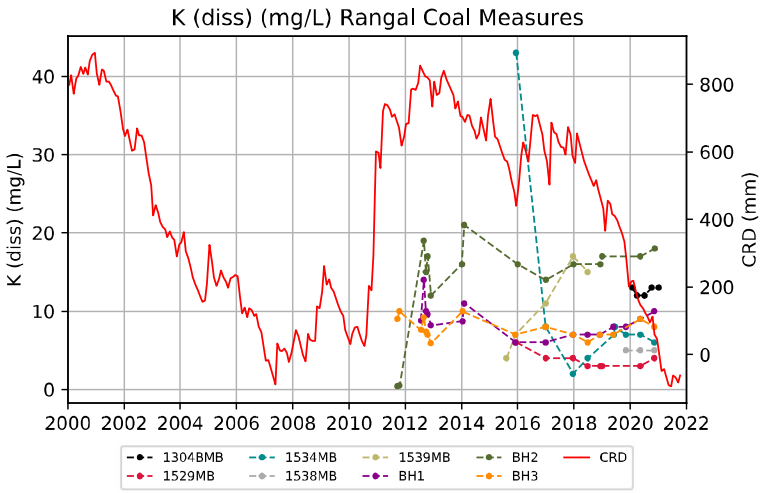

Bicarbonate Alkalinity as CaCO3 (mg/L) Rangal Coal Measures
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

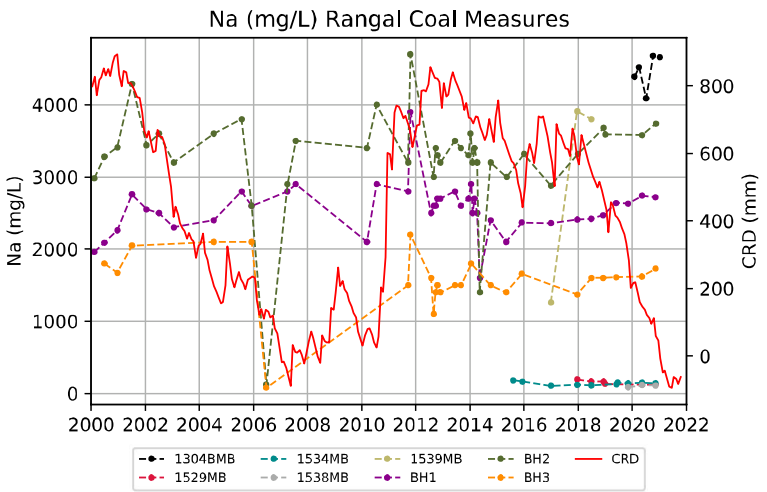

Ca (diss) (mg/L) Rangal Coal Measures
Ca (diss) (mg/L)
CRD (mm)
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

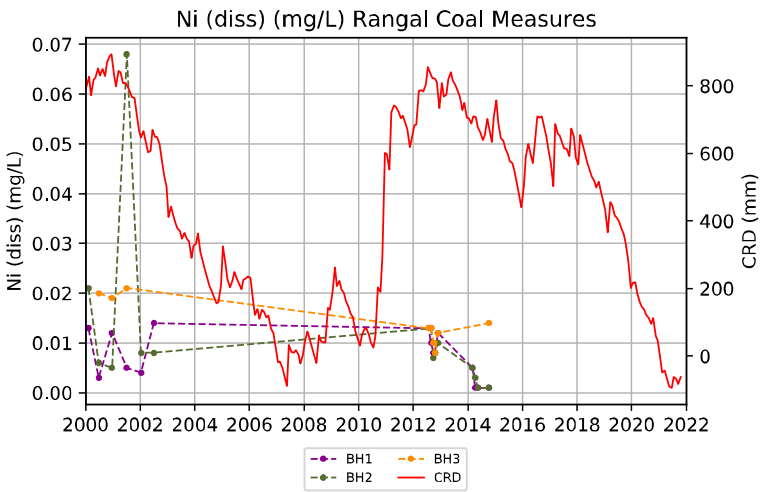

Cl (mg/L) Rangal Coal Measures
Cl (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

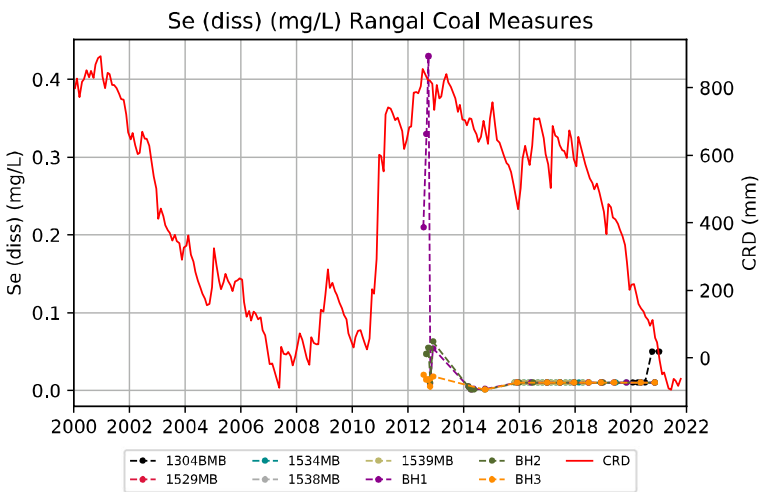

Mg (diss) (mg/L) Rangal Coal Measures
Mg (diss) (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

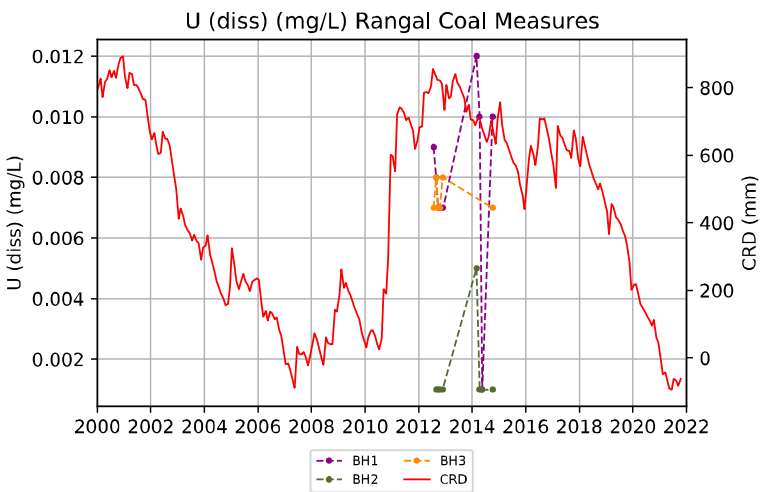

Mn (diss) (mg/L) Rangal Coal Measures
Mn (diss) (mg/L)
CRD (mm)
BH1
BH3
BH2
CRD

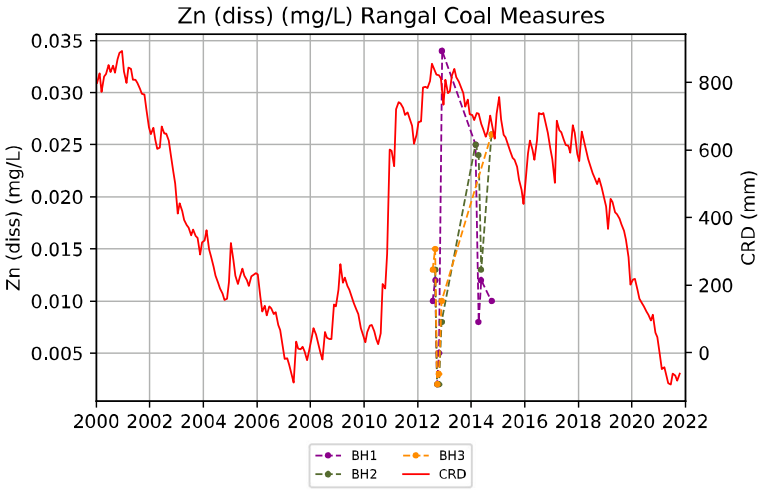

K (diss) (mg/L) Rangal Coal Measures
K (diss) (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

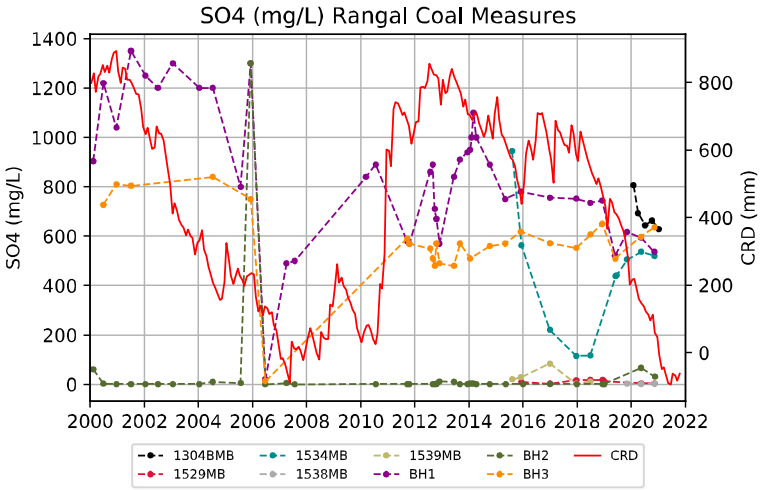

Na (mg/L) Rangal Coal Measures
Na (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

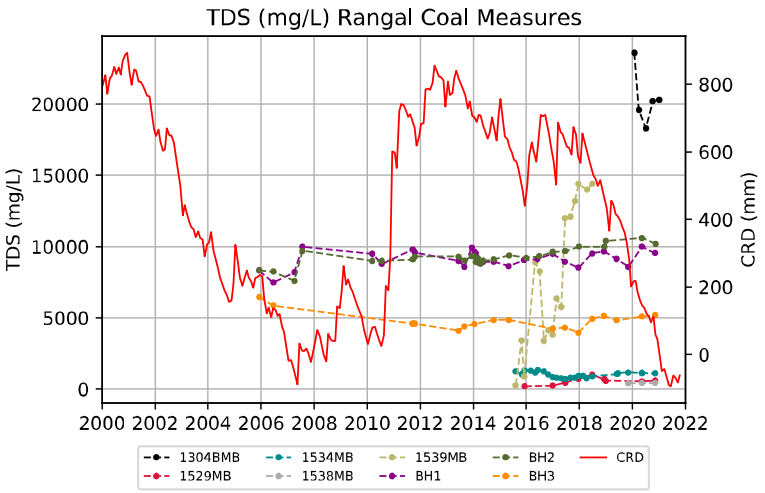

Ni (diss) (mg/L) Rangal Coal Measures
Ni (diss) (mg/L)
CRD (mm)
BH1
BH3
BH2
CRD

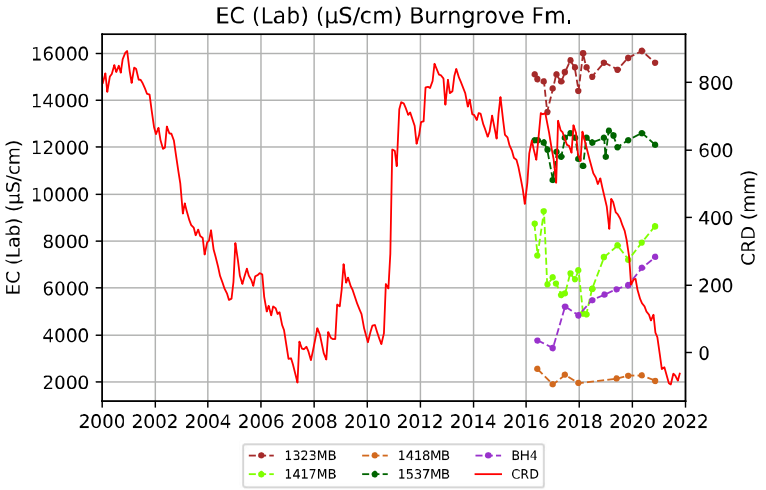

Se (diss) (mg/L) Rangal Coal Measures
Se (diss) (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

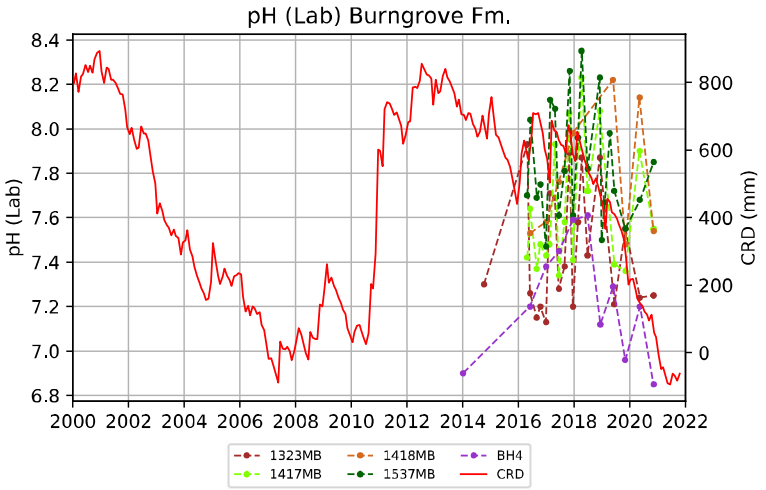

U (diss) (mg/L) Rangal Coal Measures
U (diss) (mg/L)
CRD (mm)
BH1
BH3
BH2
CRD

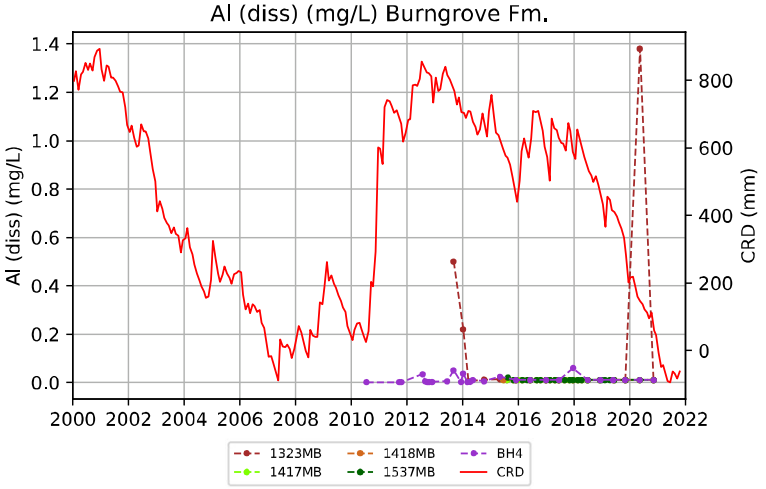

Zn (diss) (mg/L) Rangal Coal Measures
Zn (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

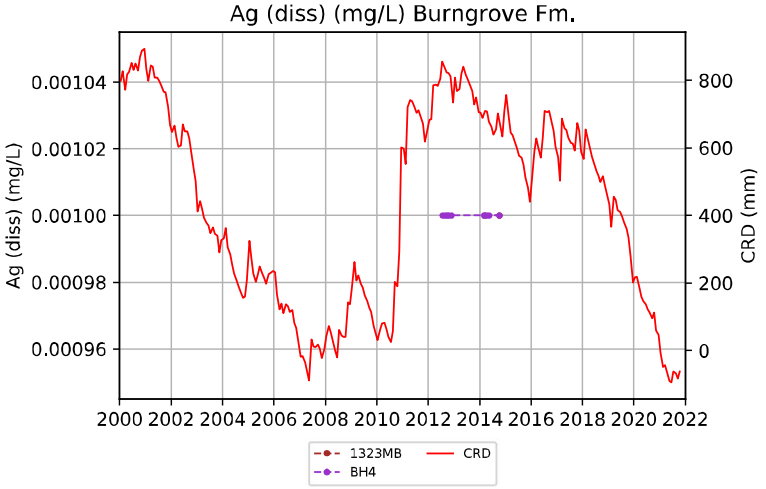

SO4 (mg/L) Rangal Coal Measures
SO4 (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

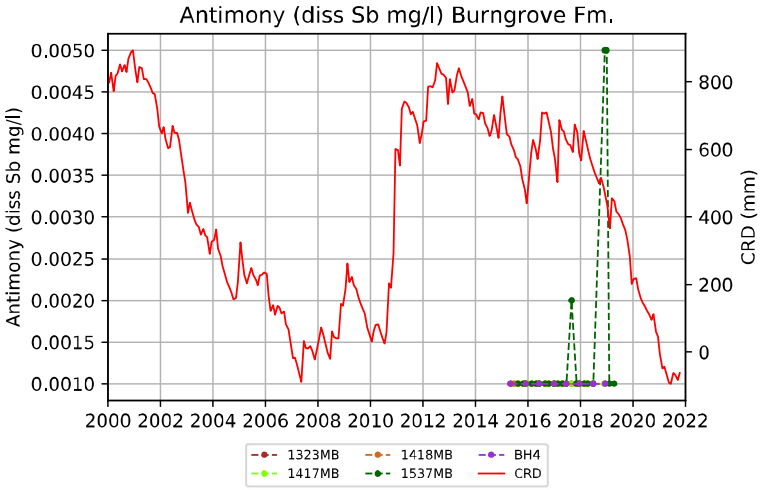

TDS (mg/L) Rangal Coal Measures
TDS (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

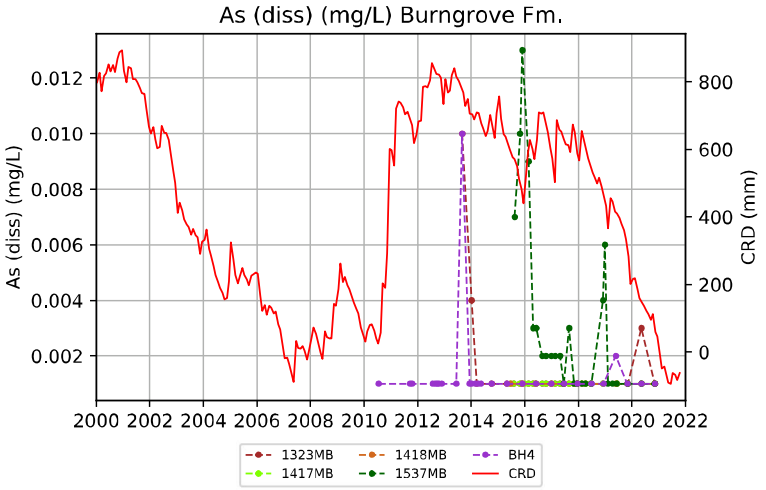

EC (Lab) (µS/cm) Burngrove Fm.
EC (Lab) (µS/cm)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

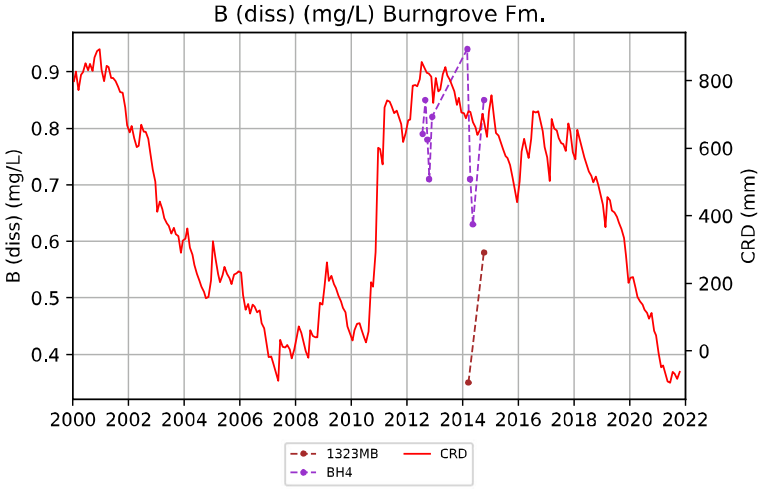

pH (Lab) Burngrove Fm.
pH (Lab)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

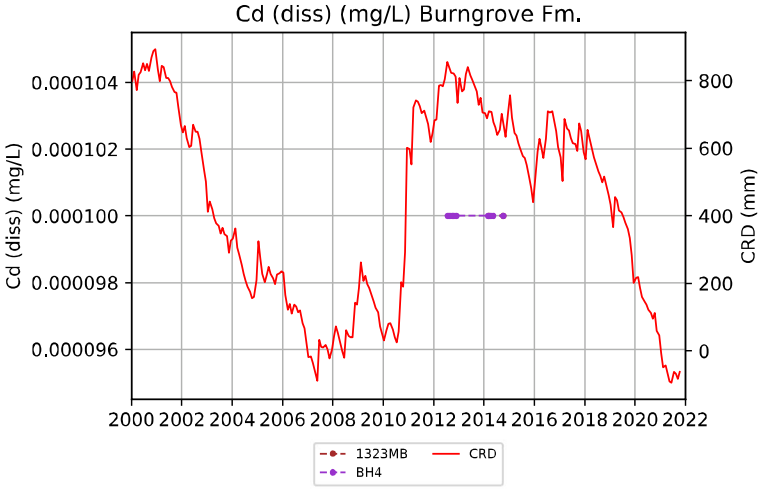

Al (diss) (mg/L) Burngrove Fm.
Al (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

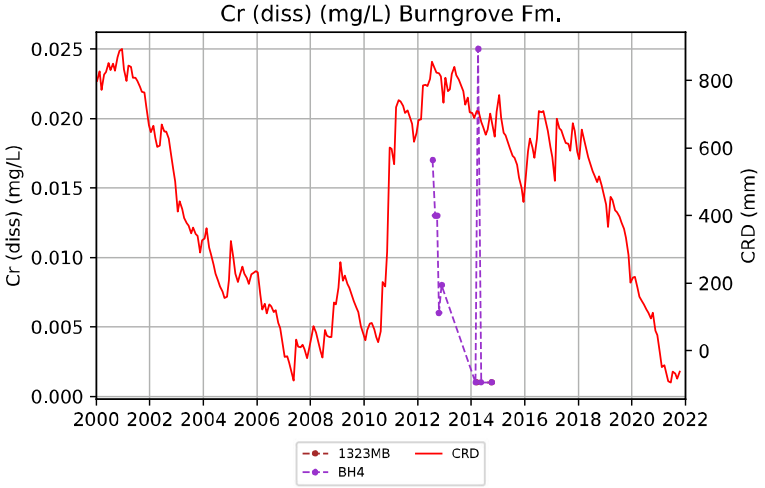

Ag (diss) (mg/L) Burngrove Fm.
Ag (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

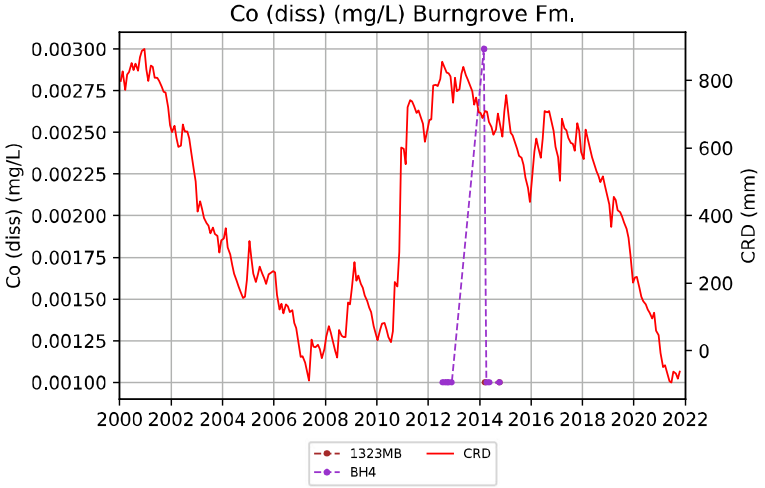

Antimony (diss Sb mg/l) Burngrove Fm.
Antimony (diss Sb mg/l)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

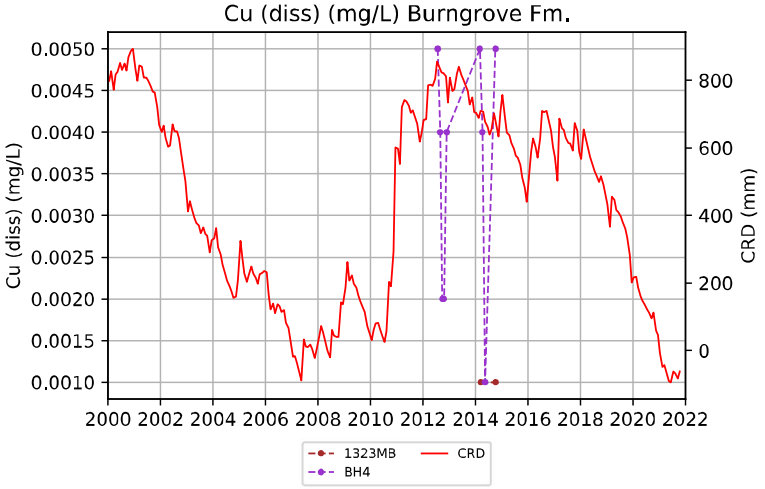

As (diss) (mg/L) Burngrove Fm.
As (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

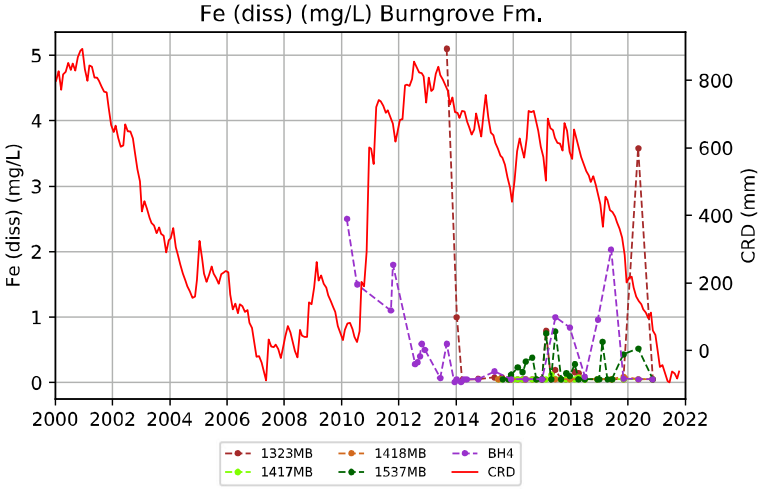

B (diss) (mg/L) Burngrove Fm.
B (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

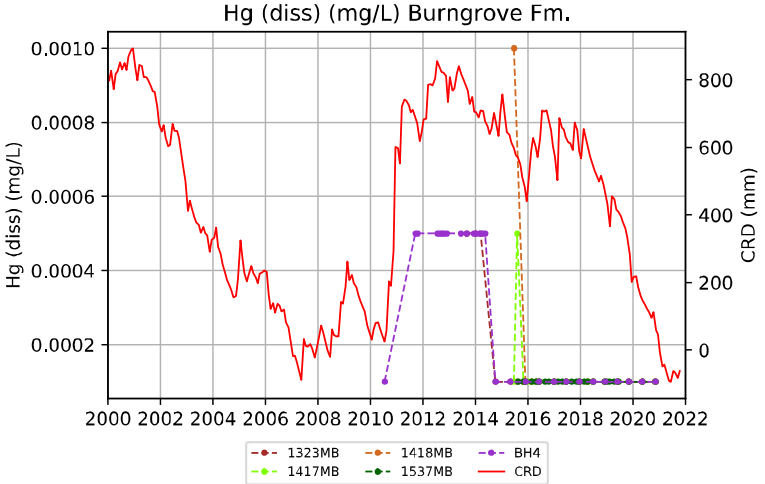

Cd (diss) (mg/L) Burngrove Fm.
Cd (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

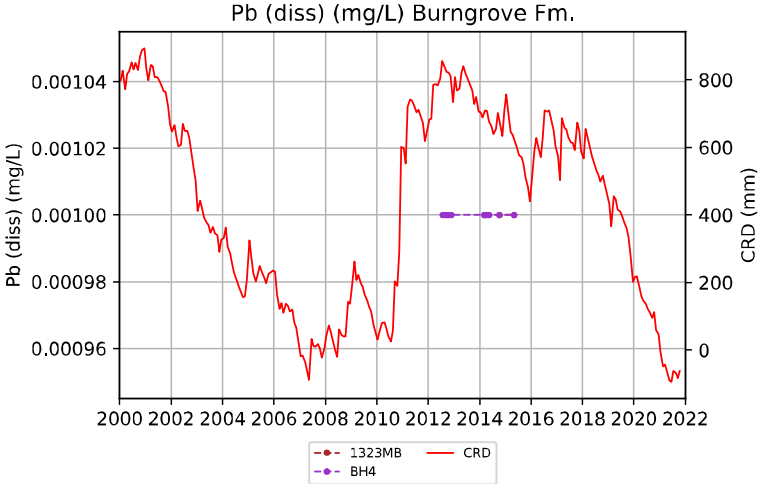

Cr (diss) (mg/L) Burngrove Fm.
Cr (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

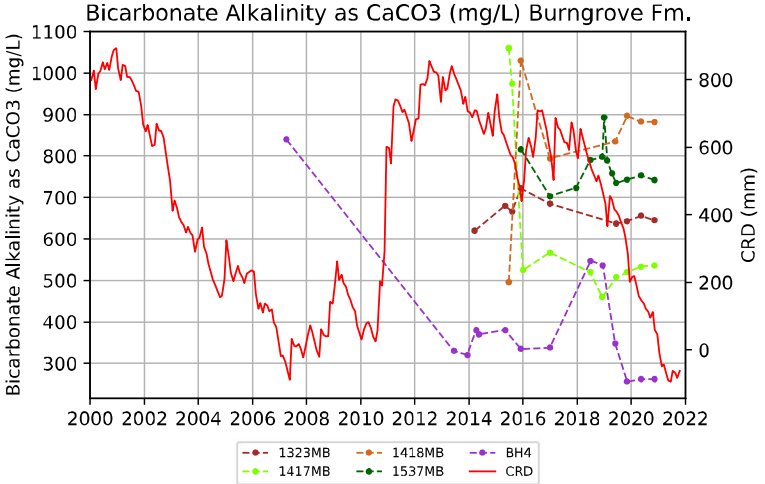

Co (diss) (mg/L) Burngrove Fm.
Co (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

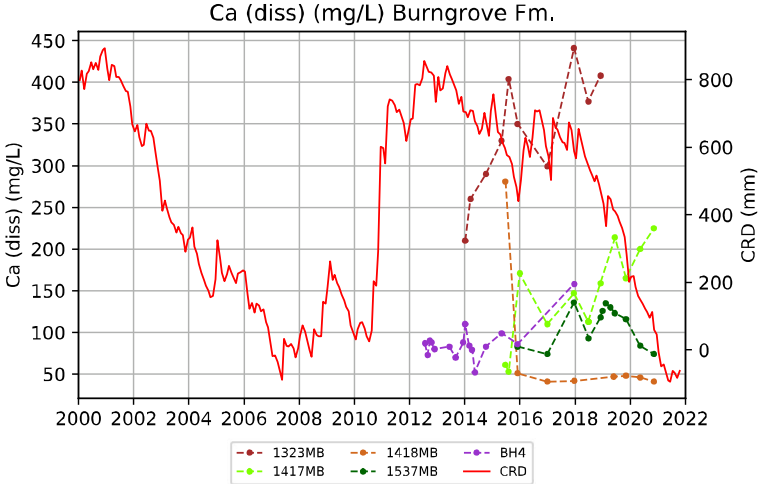

Cu (diss) (mg/L) Burngrove Fm.
Cu (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

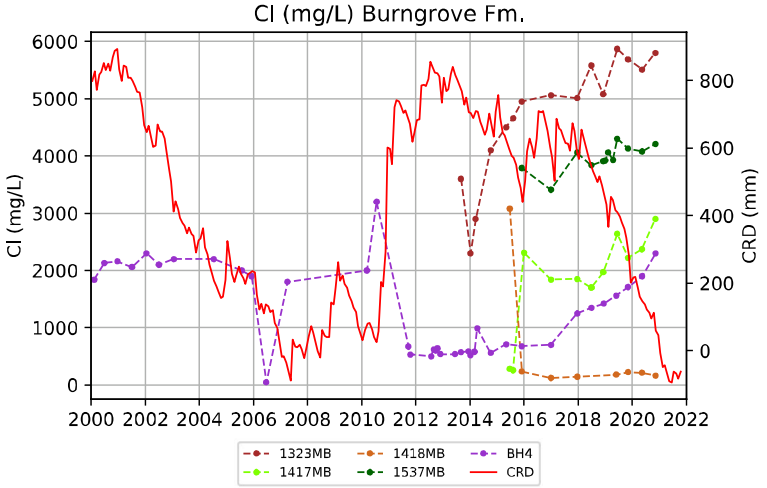

Fe (diss) (mg/L) Burngrove Fm.
Fe (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

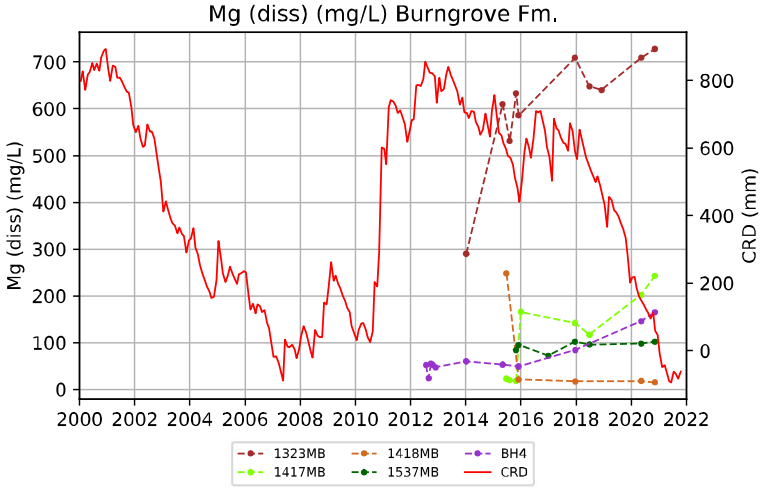

Hg (diss) (mg/L) Burngrove Fm.
Hg (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

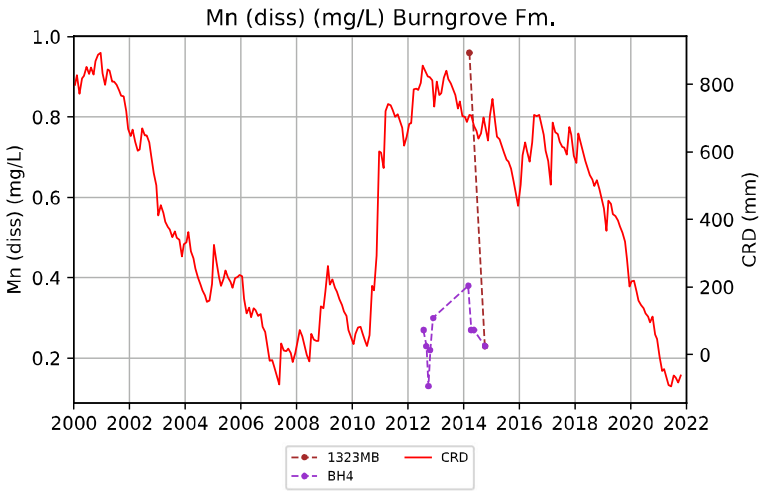

Pb (diss) (mg/L) Burngrove Fm.
Pb (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

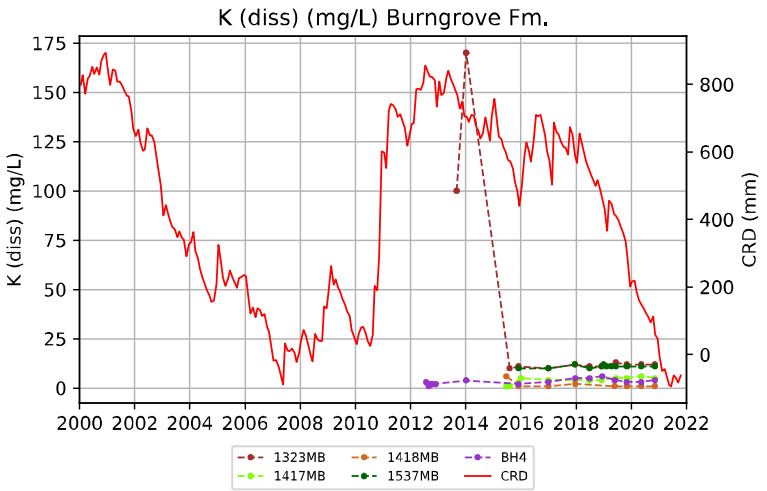

Bicarbonate Alkalinity as CaCO3 (mg/L) Burngrove Fm.
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

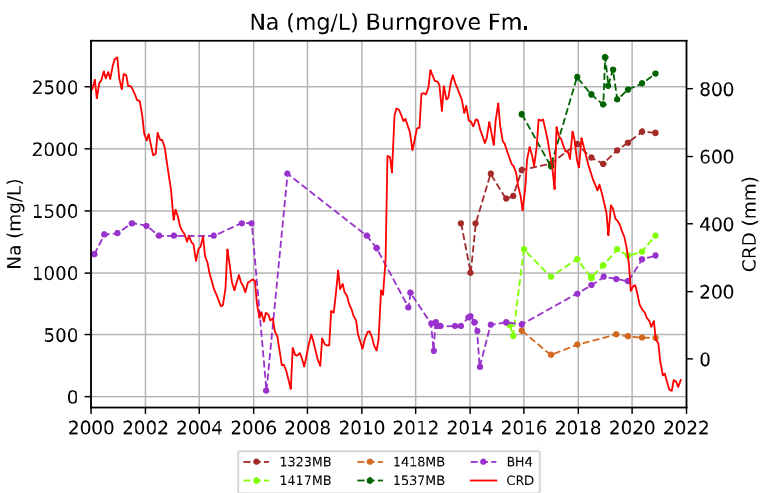

Ca (diss) (mg/L) Burngrove Fm.
Ca (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

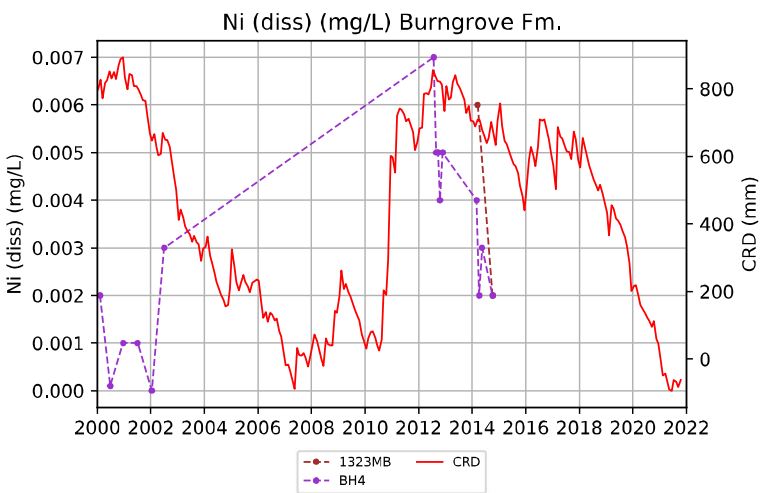

Cl (mg/L) Burngrove Fm.
Cl (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

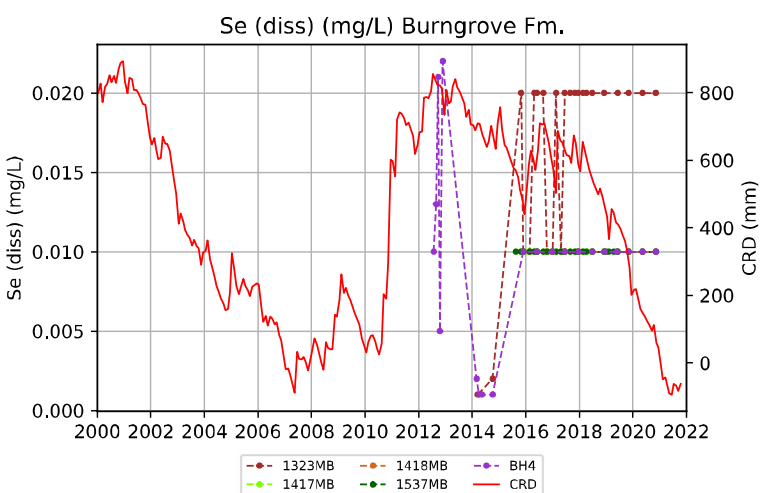

Mg (diss) (mg/L) Burngrove Fm.
Mg (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

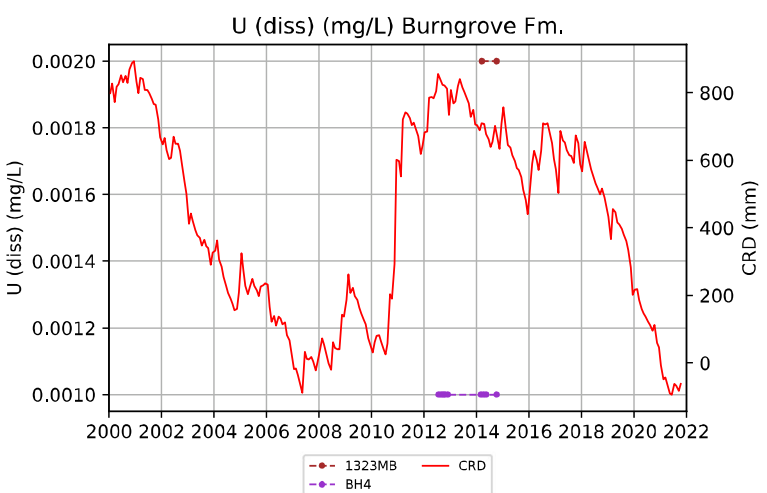

Mn (diss) (mg/L) Burngrove Fm.
Mn (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

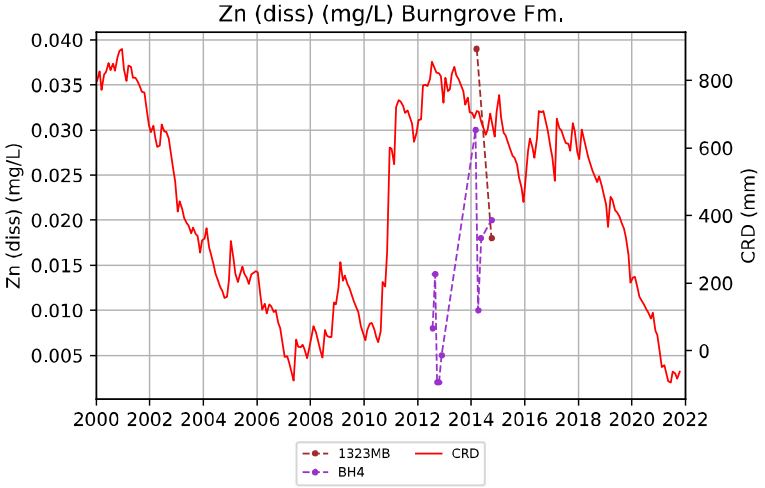

K (diss) (mg/L) Burngrove Fm.
K (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

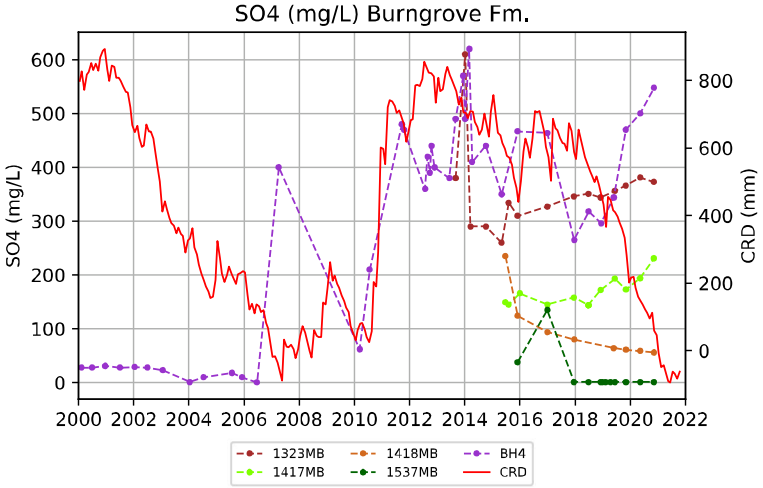

Na (mg/L) Burngrove Fm.
Na (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

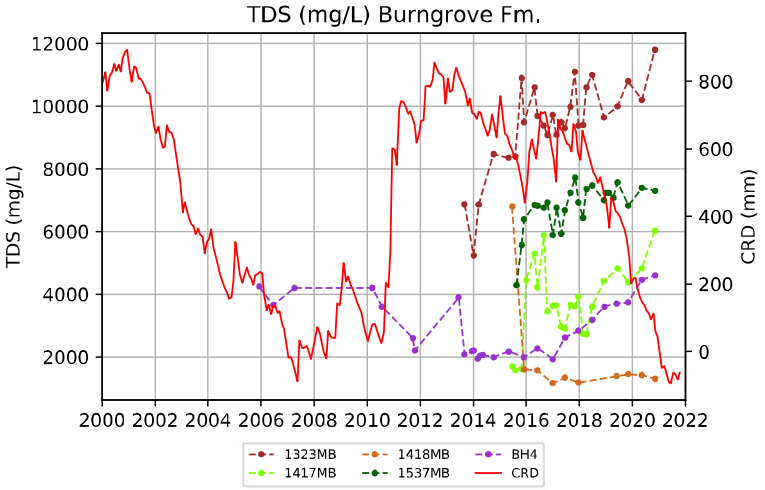

Ni (diss) (mg/L) Burngrove Fm.
Ni (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4


Se (diss) (mg/L) Burngrove Fm.
Se (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD


U (diss) (mg/L) Burngrove Fm.
U (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

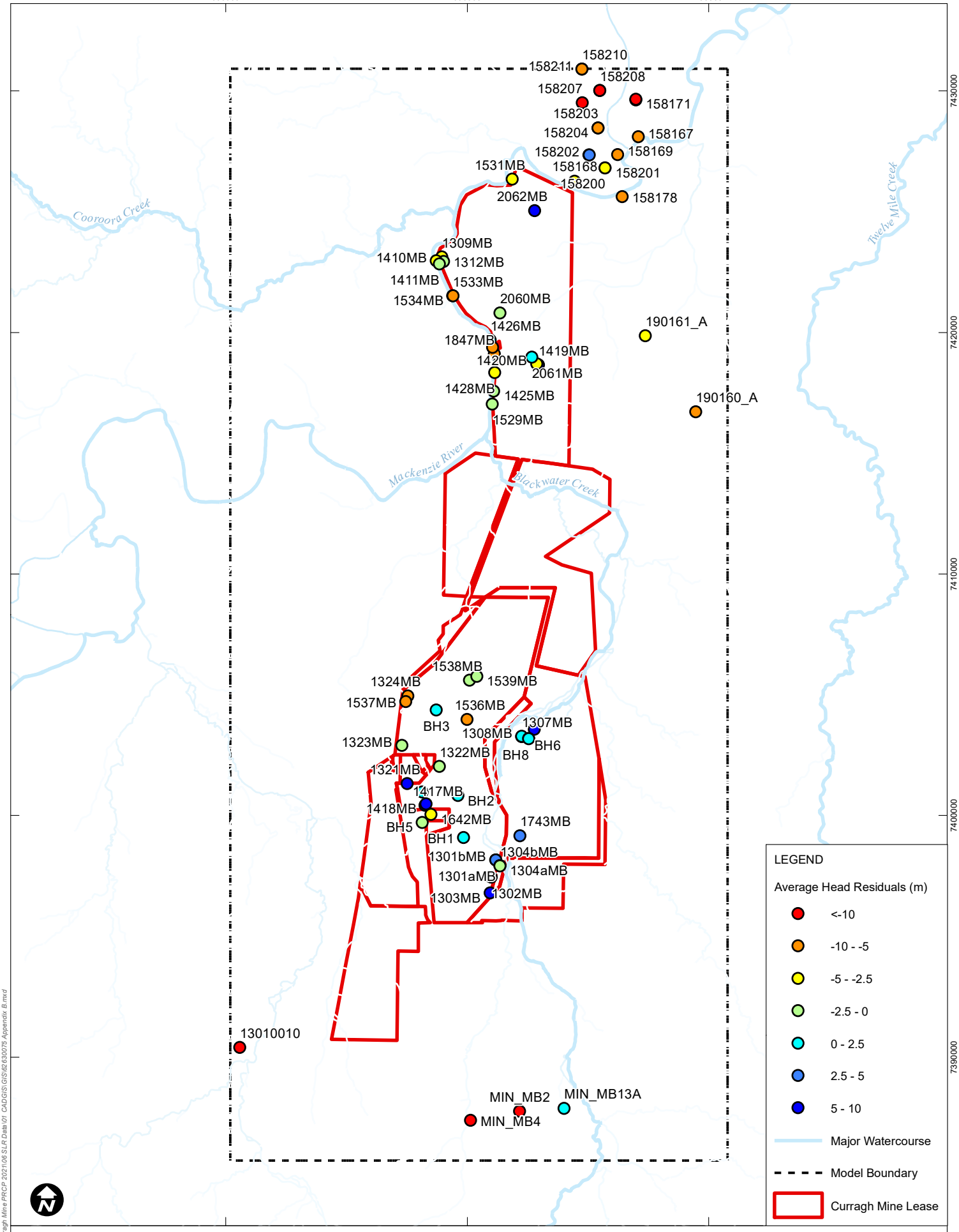

Zn (diss) (mg/L) Burngrove Fm.
Zn (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4


SO4 (mg/L) Burngrove Fm.
SO4 (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD


TDS (mg/L) Burngrove Fm.
TDS (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

# APPENDIX B

## Calibration Average Residuals




SLR

DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.

0 2 4 km

| | |
|---|---|
| Coordinate System: | AGD 1984 AMG Zone 55 |
| Scale: | 1:200,000 at A4 |
| Project Number: | 626.30075 |
| Date: | 26-Nov-2021 |
| Drawn by: | AN |
| Reviewed by: | AN |

Data Source:

# CURRAGH PRCP

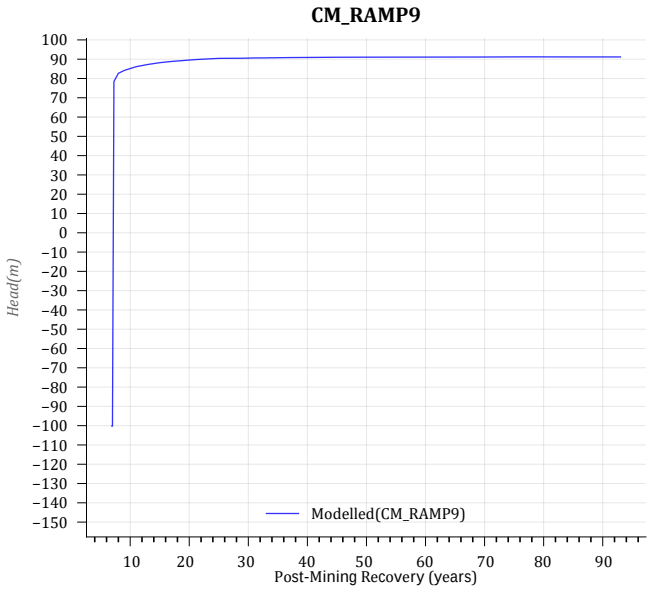
## Calibration Residuals

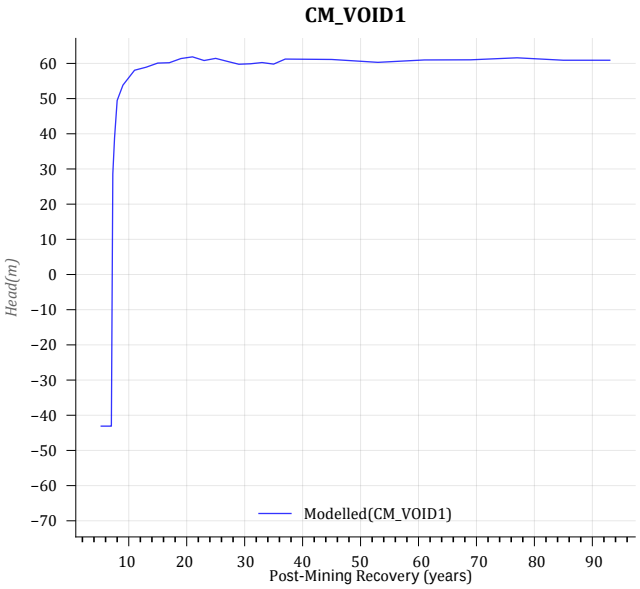
**APPENDIX B**

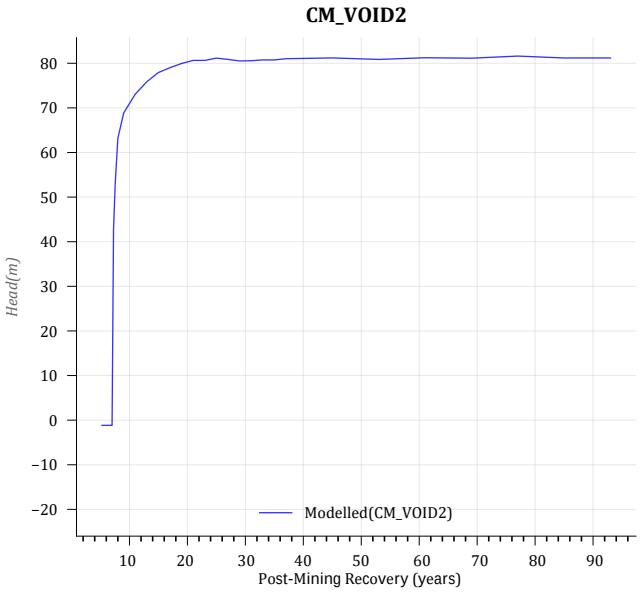
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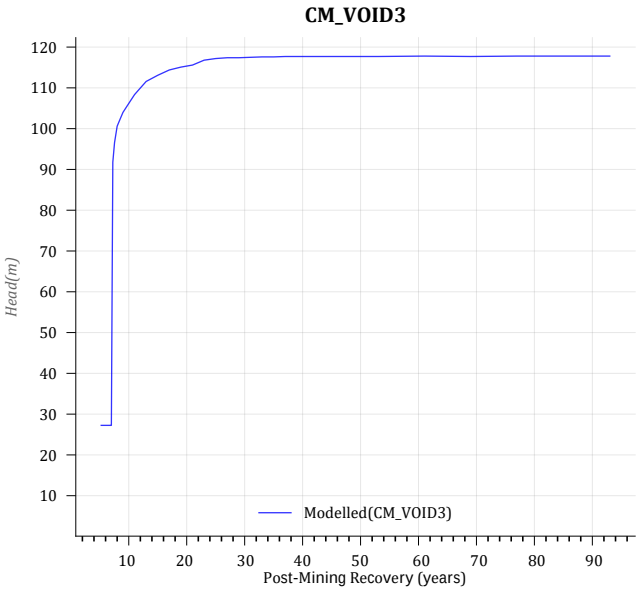
# APPENDIX C

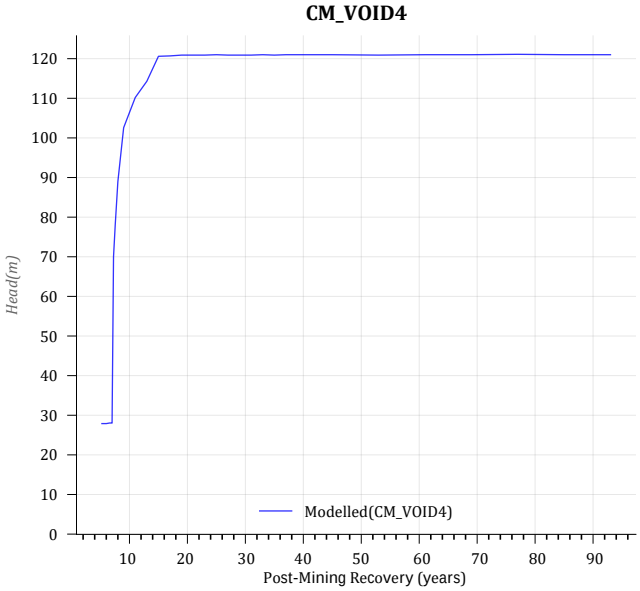
## Calibration Hydrographs

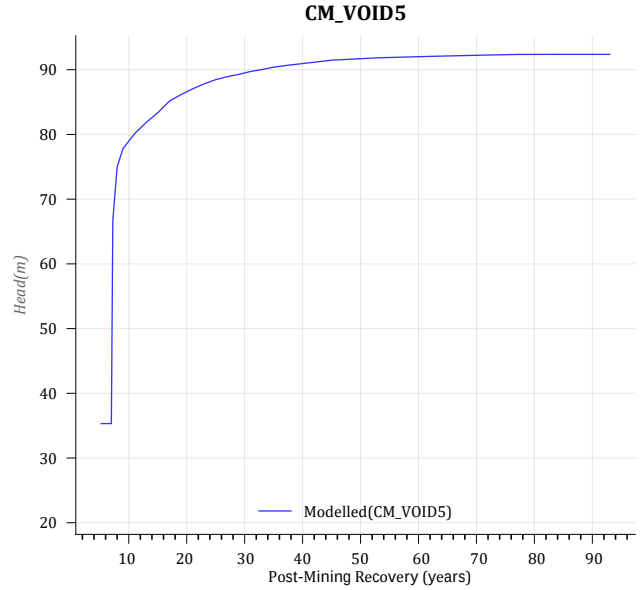

CM_RAMP9
Head(m)
Post-Mining Recovery (years)
Modelled(CM_RAMP9)

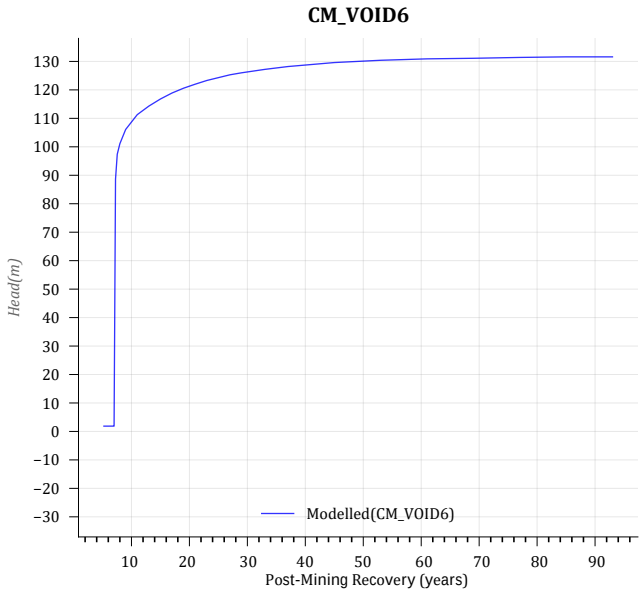

CM_VOID1
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID1)

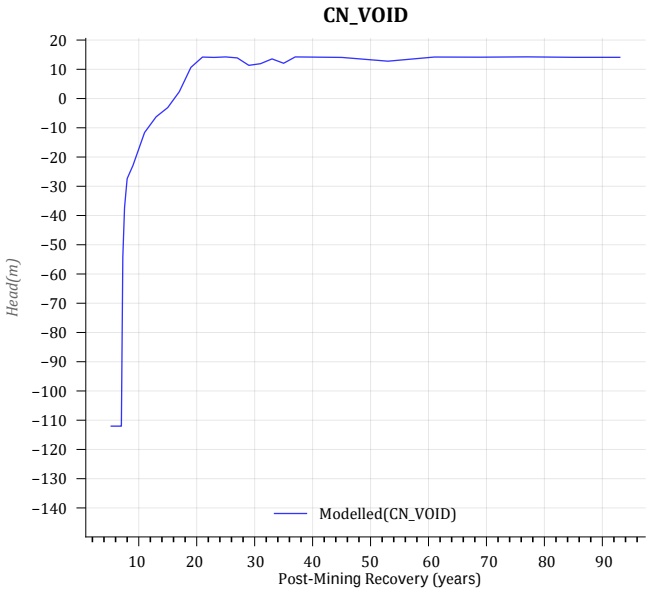

CM_VOID2
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID2)

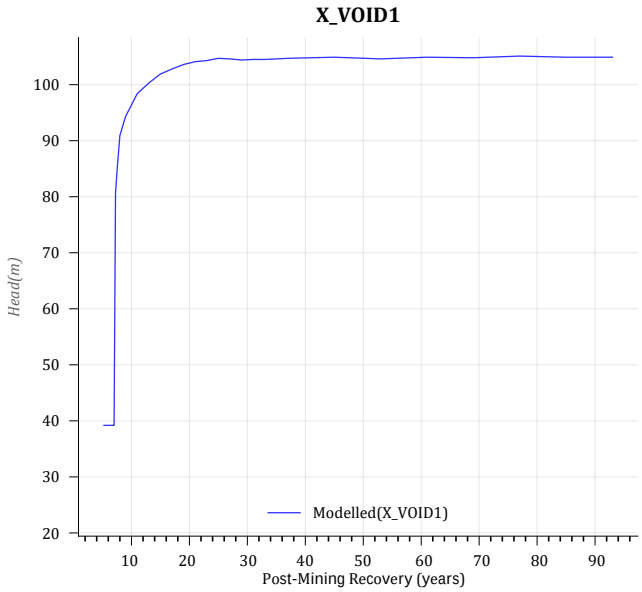

CM_VOID3
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID3)

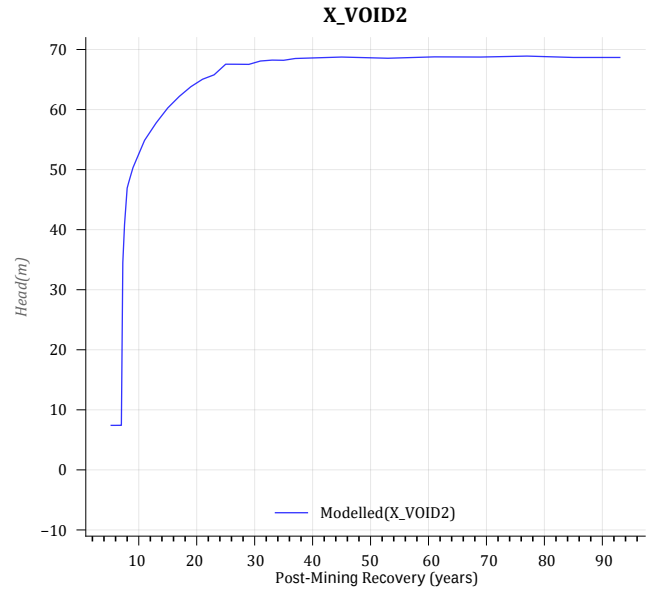

CM_VOID4
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID4)

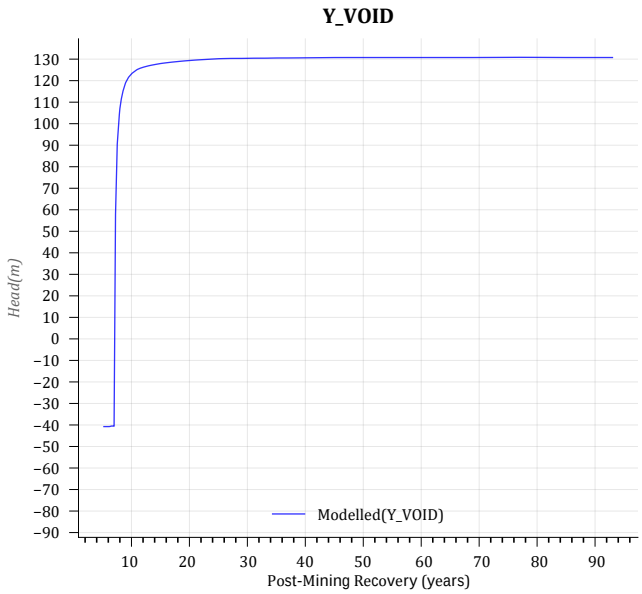

CM_VOID5
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID5)

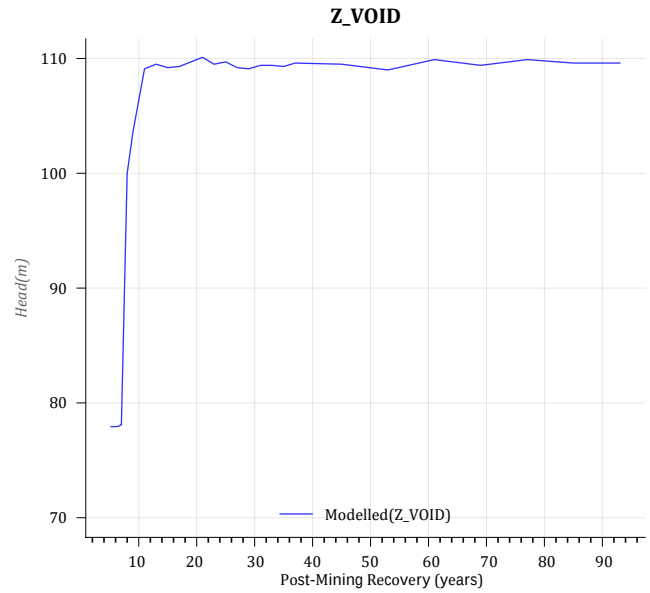

CM_VOID6
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID6)


CN_VOID
Head(m)
Post-Mining Recovery (years)
Modelled(CN_VOID)


X_VOID1
Head(m)
Post-Mining Recovery (years)
Modelled(X_VOID1)

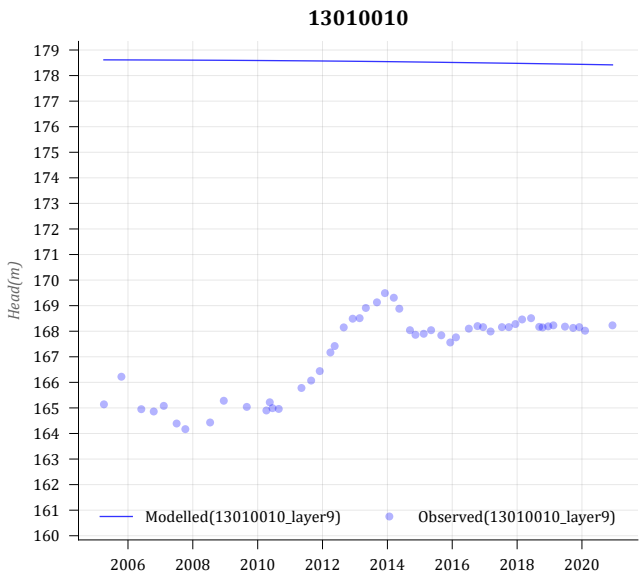

X_VOID2
Head(m)
Post-Mining Recovery (years)
Modelled(X_VOID2)

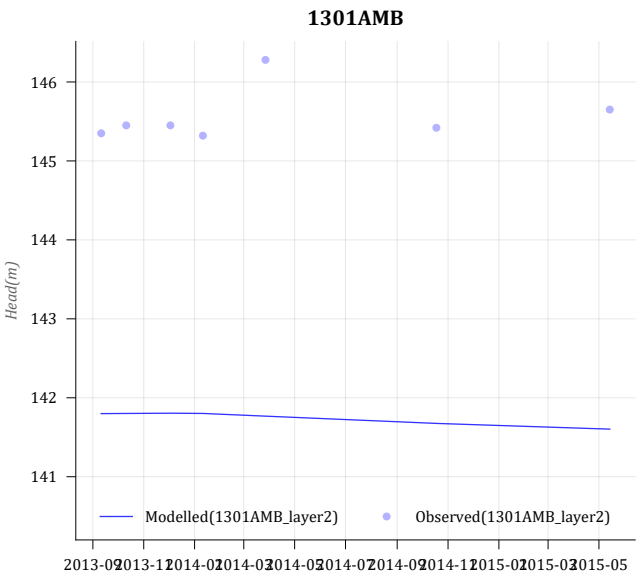

Y_VOID
Head(m)
Post-Mining Recovery (years)
Modelled(Y_VOID)

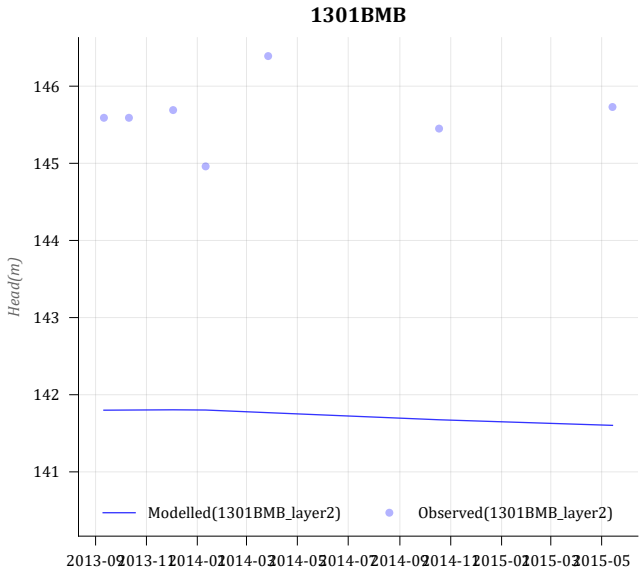

Z_VOID
Head(m)
Post-Mining Recovery (years)
Modelled(Z_VOID)

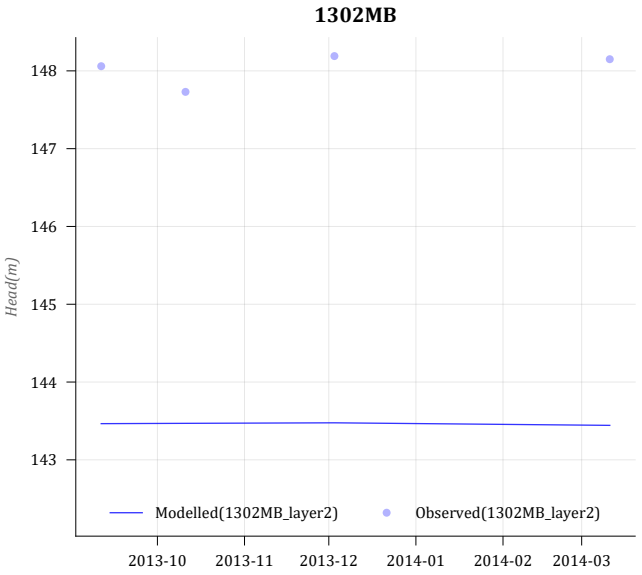
# APPENDIX D

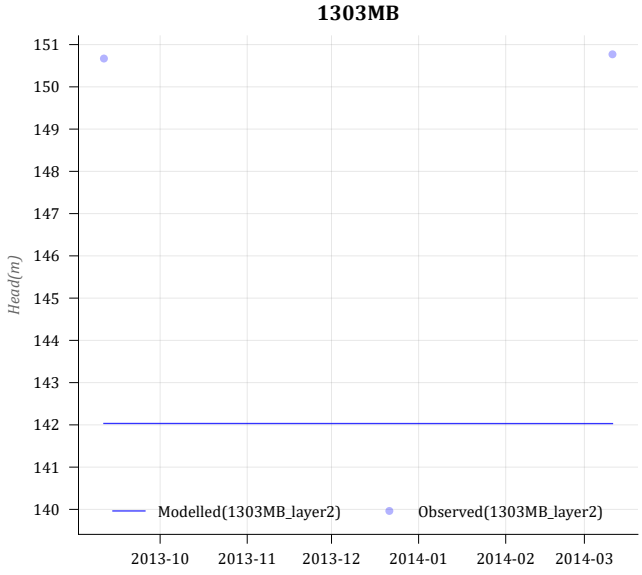
## Post Mining Recovery Hydrographs

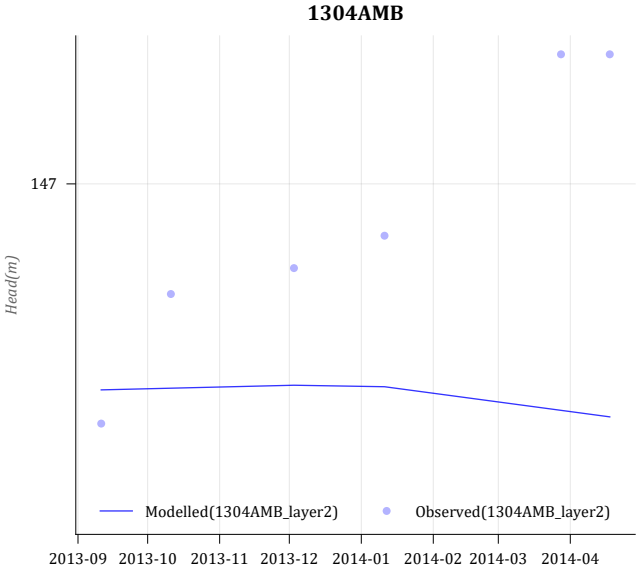

13010010
Head(m)
Modelled(13010010_layer9)
Observed(13010010_layer9)

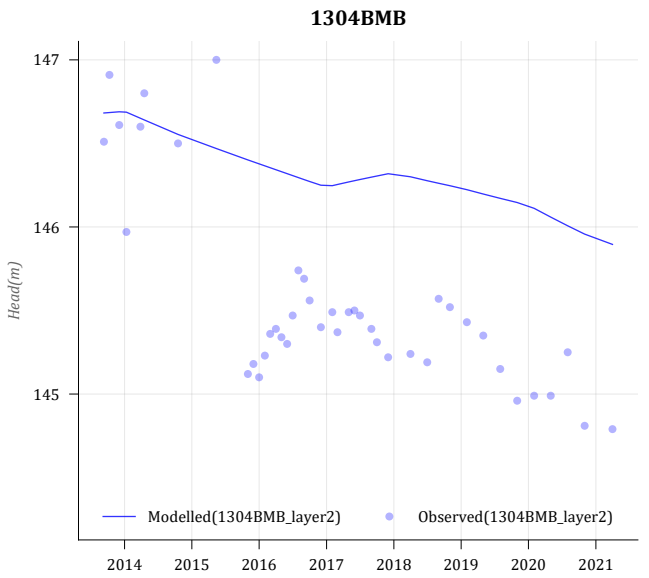

1301AMB
Head(m)
Modelled(1301AMB_layer2)
Observed(1301AMB_layer2)

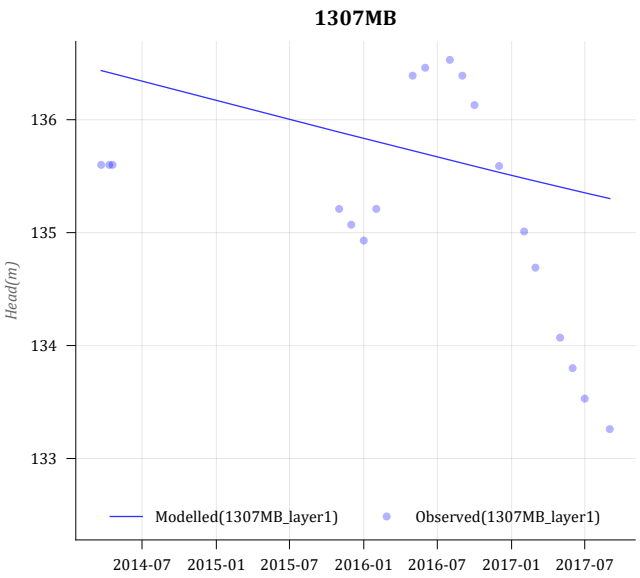

1301BMB
Head(m)
Modelled(1301BMB_layer2)
Observed(1301BMB_layer2)

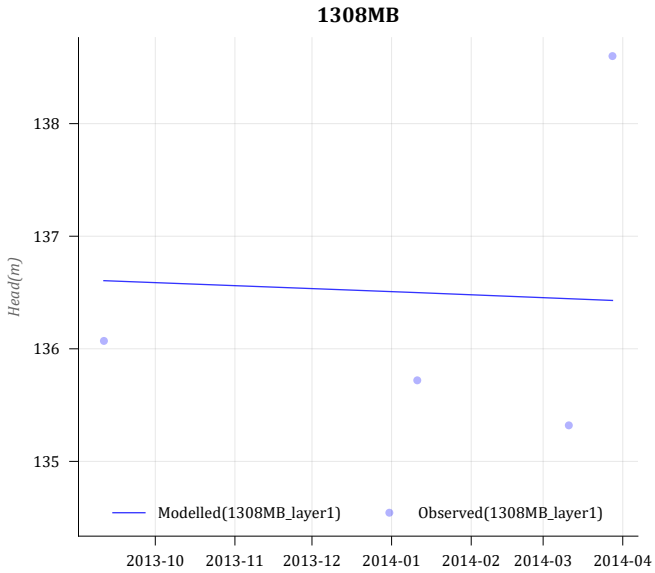

1302MB
Head(m)
Modelled(1302MB_layer2)
Observed(1302MB_layer2)

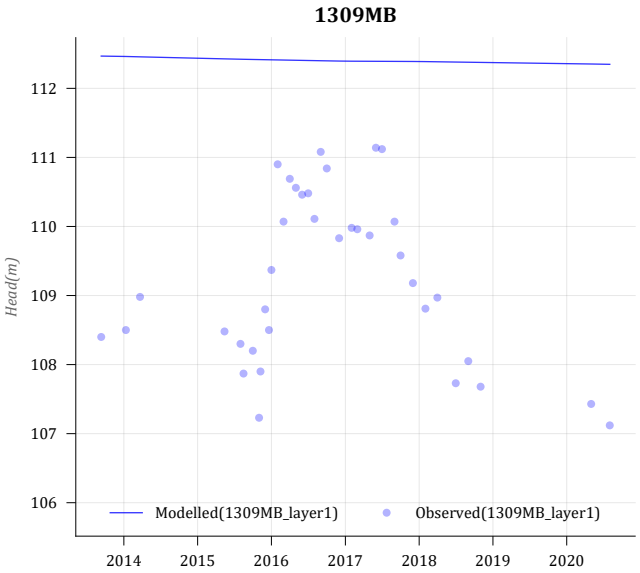

1303MB
Head(m)
Modelled(1303MB_layer2)
Observed(1303MB_layer2)

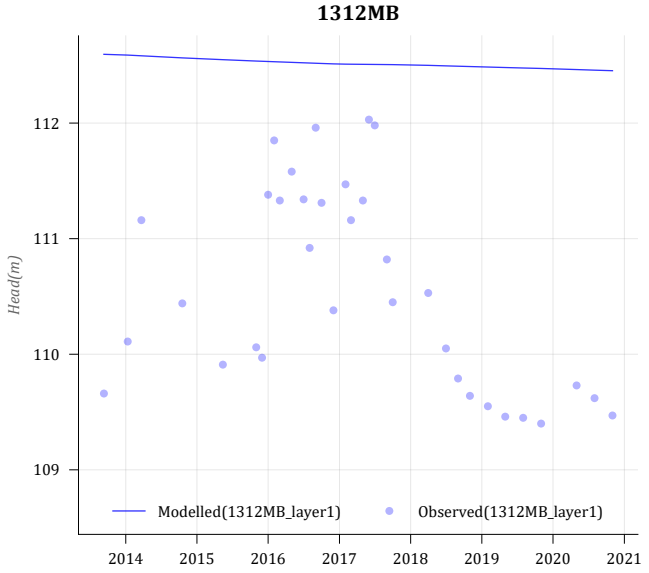

1304AMB
Head(m)
Modelled(1304AMB_layer2)
Observed(1304AMB_layer2)

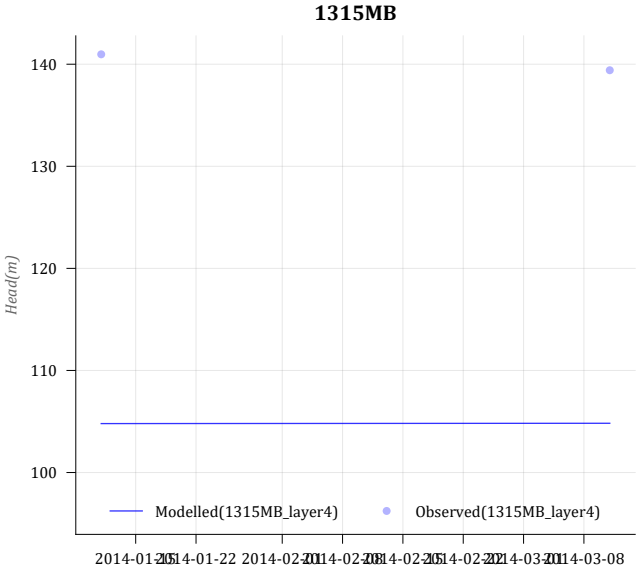

1304BMB
Head(m)
147
146
145
Modelled(1304BMB_layer2)
Observed(1304BMB_layer2)
2014
2015
2016
2017
2018
2019
2020
2021

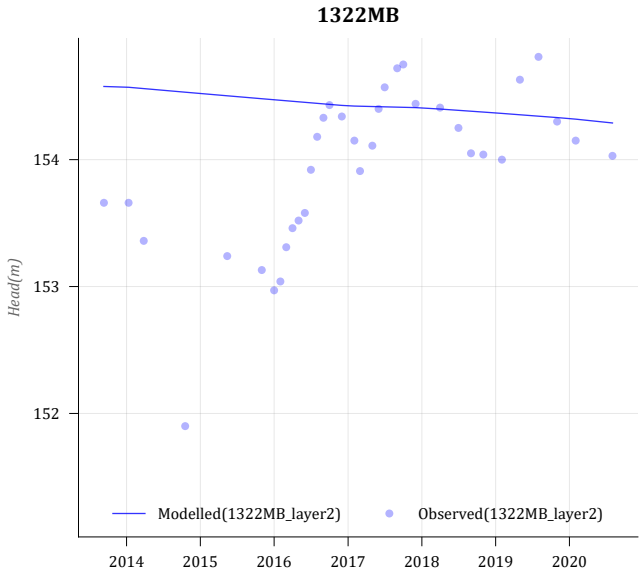

1307MB
Head(m)
136
135
134
133
Modelled(1307MB_layer1)
Observed(1307MB_layer1)
2014-07
2015-01
2015-07
2016-01
2016-07
2017-01
2017-07

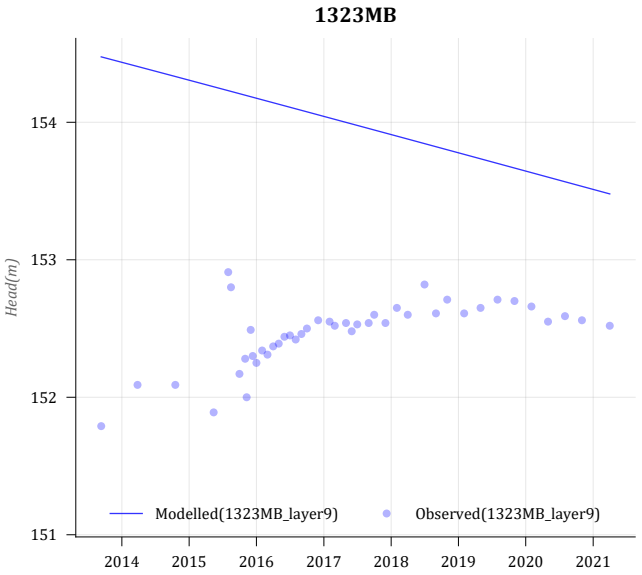

1308MB
Head(m)
138
137
136
135
Modelled(1308MB_layer1)
Observed(1308MB_layer1)
2013-10
2013-11
2013-12
2014-01
2014-02
2014-03
2014-04

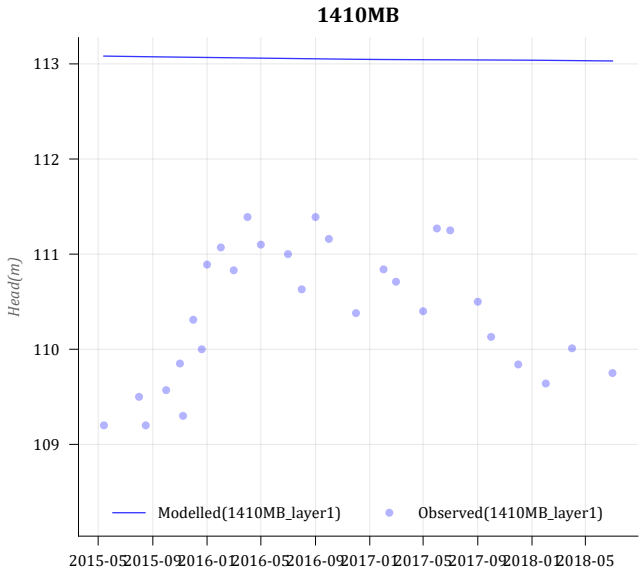

1309MB
Head(m)
112
111
110
109
108
107
106
Modelled(1309MB_layer1)
Observed(1309MB_layer1)
2014
2015
2016
2017
2018
2019
2020

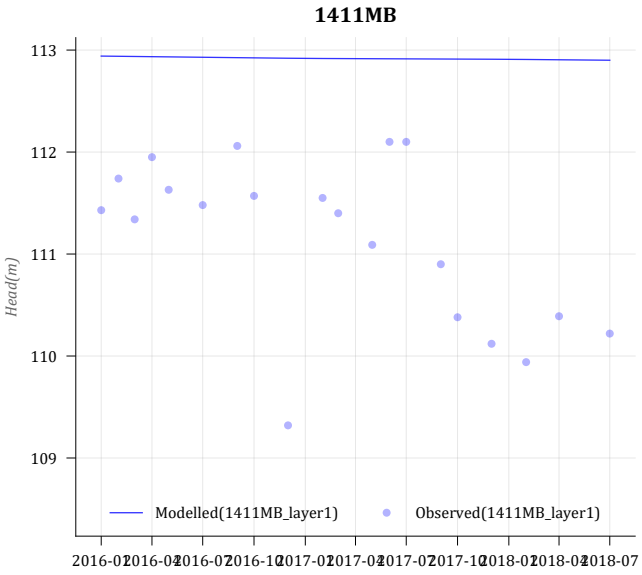

1312MB
Head(m)
112
111
110
109
Modelled(1312MB_layer1)
Observed(1312MB_layer1)
2014
2015
2016
2017
2018
2019
2020
2021

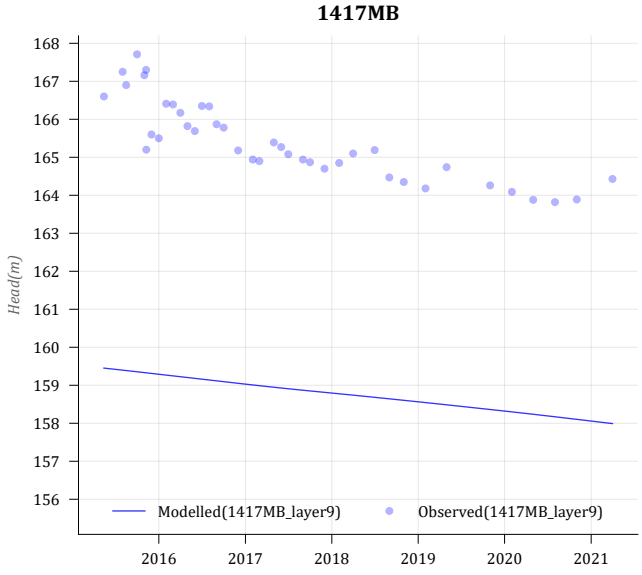

1315MB
Head(m)
140
130
120
110
100
Modelled(1315MB_layer4)
Observed(1315MB_layer4)
2014-01-15
2014-01-22
2014-02-01
2014-02-08
2014-02-15
2014-02-22
2014-03-01
2014-03-08

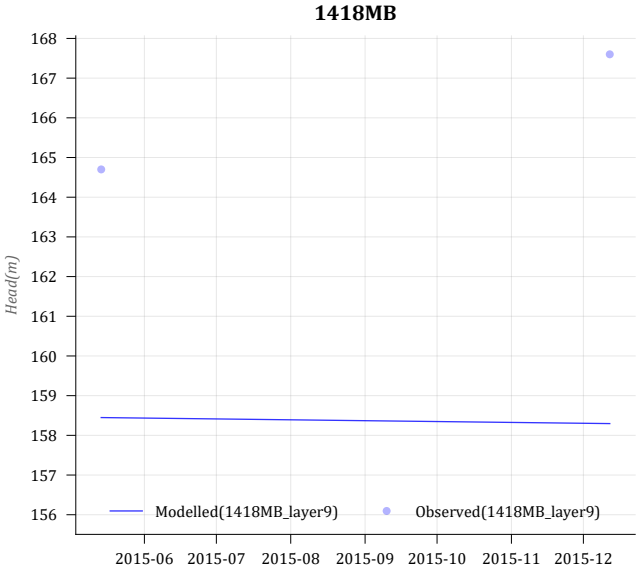

1322MB
Head(m)
154
153
152
Modelled(1322MB_layer2)
Observed(1322MB_layer2)
2014
2015
2016
2017
2018
2019
2020

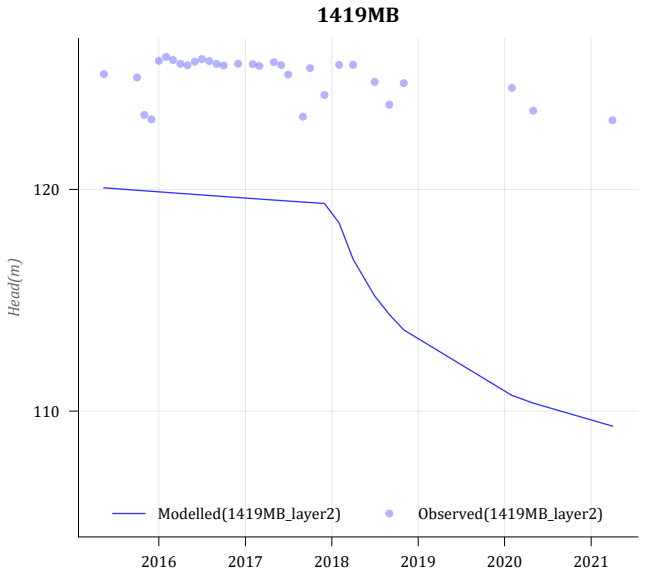

1323MB
Head(m)
154
153
152
151
Modelled(1323MB_layer9)
Observed(1323MB_layer9)
2014
2015
2016
2017
2018
2019
2020
2021

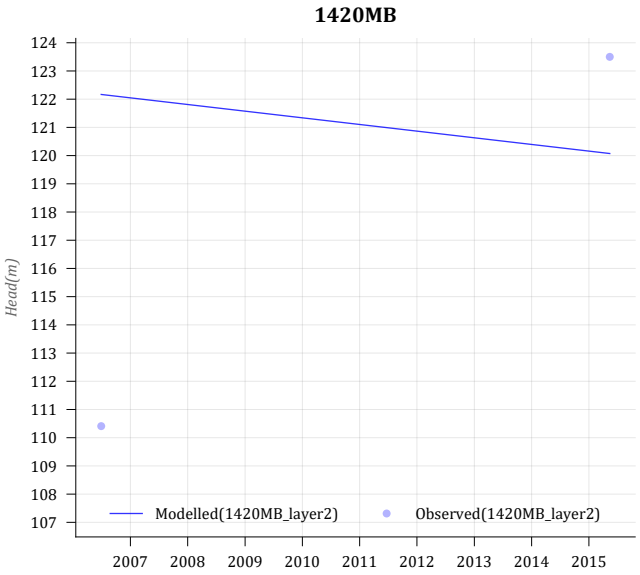

1410MB
Head(m)
113
112
111
110
109
Modelled(1410MB_layer1)
Observed(1410MB_layer1)
2015-05
2015-09
2016-01
2016-05
2016-09
2017-01
2017-05
2017-09
2018-01
2018-05

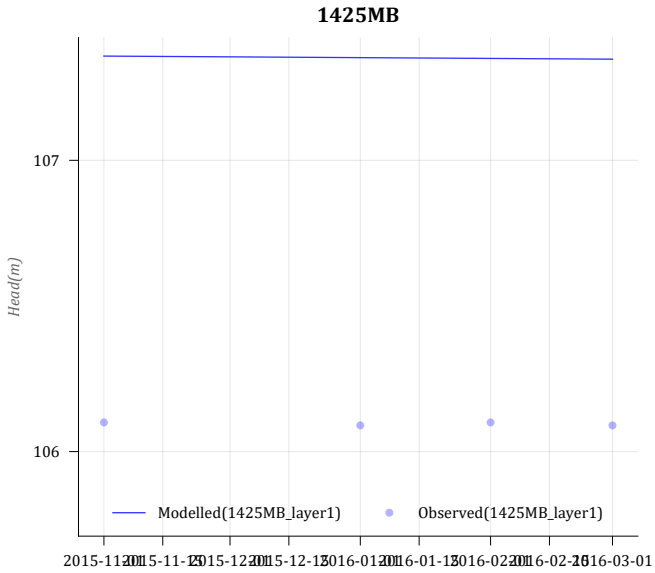

1411MB
Head(m)
113
112
111
110
109
Modelled(1411MB_layer1)
Observed(1411MB_layer1)
2016-01
2016-04
2016-07
2016-10
2017-01
2017-04
2017-07
2017-10
2018-01
2018-04
2018-07

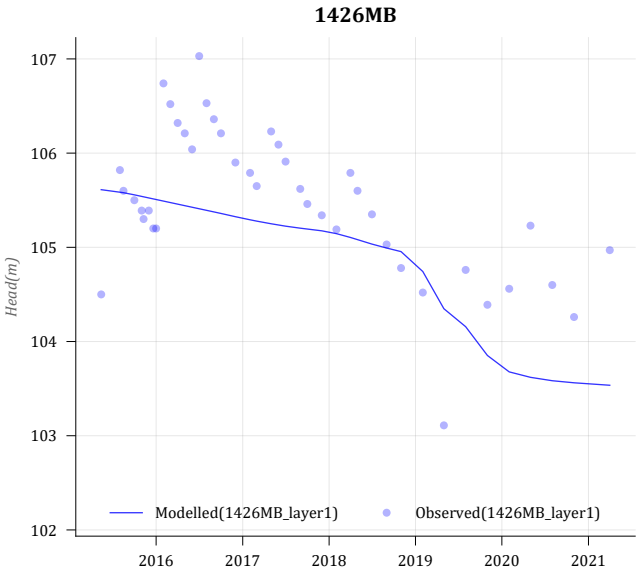

1417MB
Head(m)
168
167
166
165
164
163
162
161
160
159
158
157
156
Modelled(1417MB_layer9)
Observed(1417MB_layer9)
2016
2017
2018
2019
2020
2021

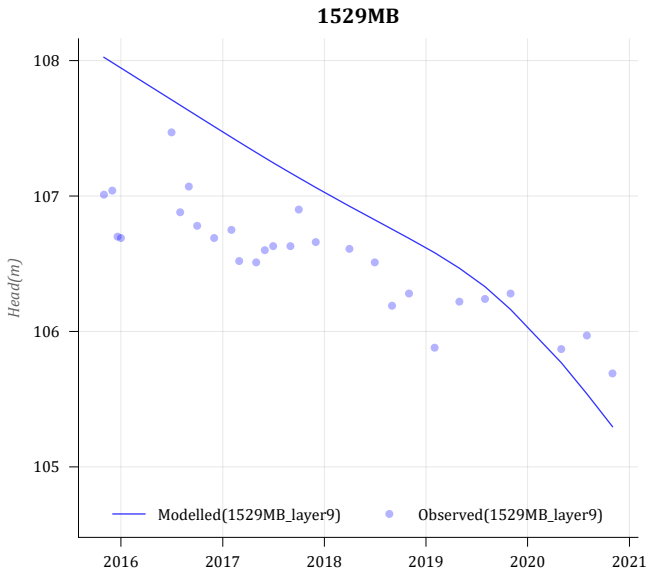

1418MB
Head(m)
168
167
166
165
164
163
162
161
160
159
158
157
156
Modelled(1418MB_layer9)
Observed(1418MB_layer9)
2015-06
2015-07
2015-08
2015-09
2015-10
2015-11
2015-12

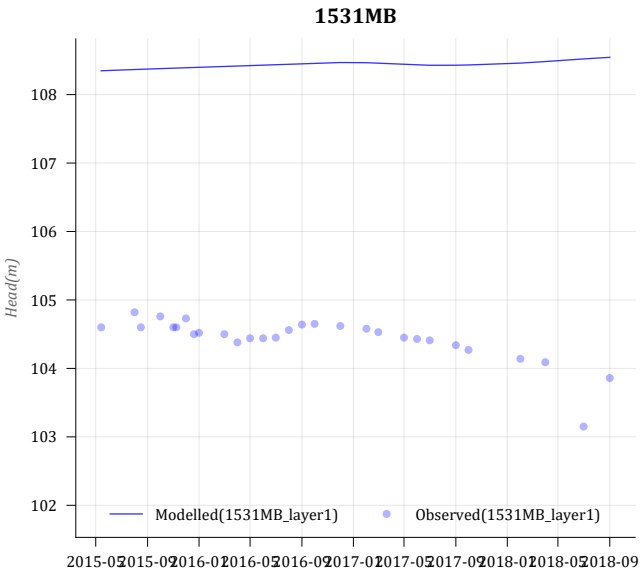

1419MB
Head(m)
120
110
Modelled(1419MB_layer2)
Observed(1419MB_layer2)
2016
2017
2018
2019
2020
2021

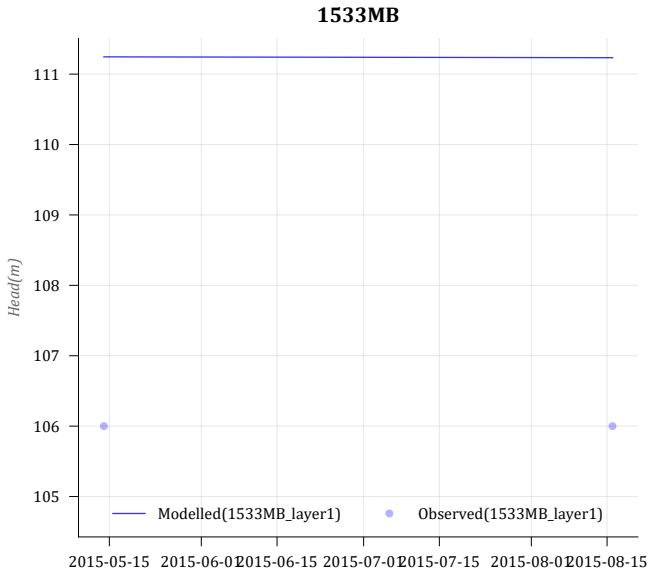

1420MB
Head(m)
124
123
122
121
120
119
118
117
116
115
114
113
112
111
110
109
108
107
Modelled(1420MB_layer2)
Observed(1420MB_layer2)
2007
2008
2009
2010
2011
2012
2013
2014
2015

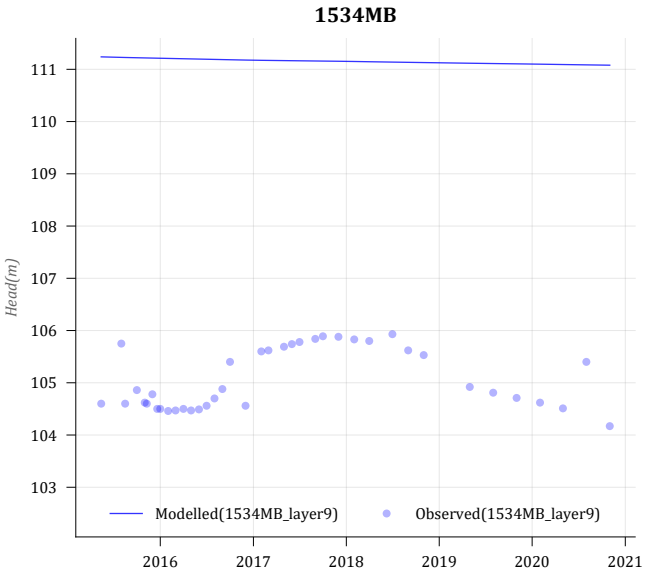

1425MB
Head(m)
107
106
Modelled(1425MB_layer1)
Observed(1425MB_layer1)
2015-11-01
2015-11-15
2015-12-01
2015-12-15
2016-01-01
2016-01-15
2016-02-01
2016-02-15
2016-03-01

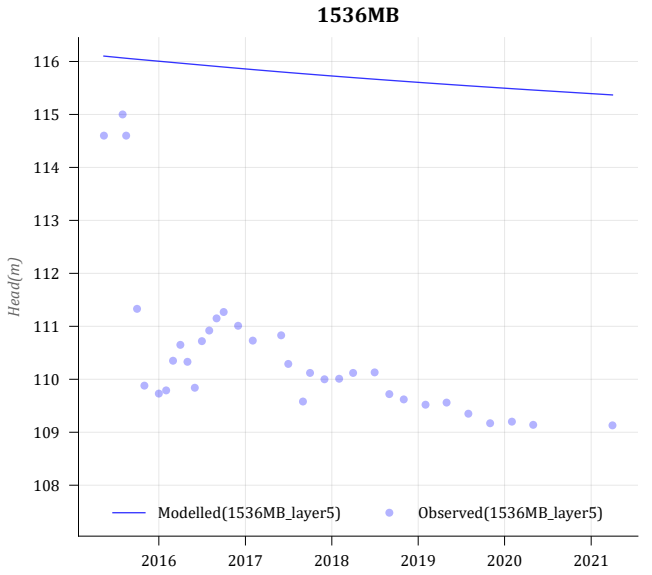

1426MB
Head(m)
107
106
105
104
103
102
Modelled(1426MB_layer1)
Observed(1426MB_layer1)
2016
2017
2018
2019
2020
2021

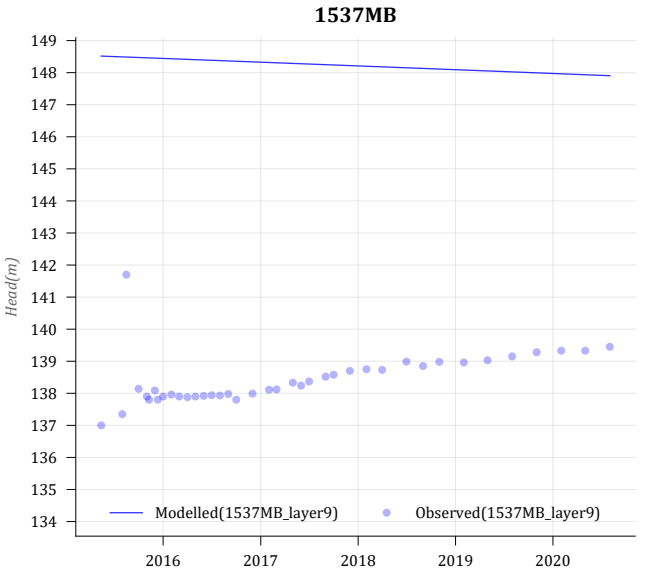

1529MB
Head(m)
108
107
106
105
Modelled(1529MB_layer9)
Observed(1529MB_layer9)
2016
2017
2018
2019
2020
2021

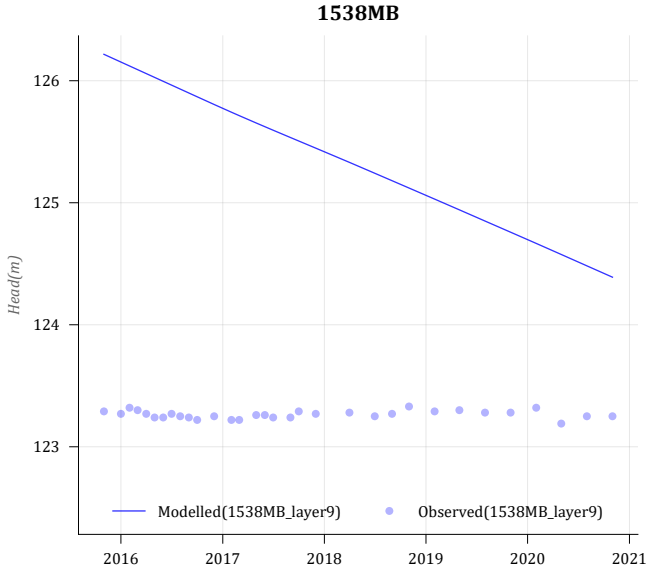

1531MB
Head(m)
108
107
106
105
104
103
102
Modelled(1531MB_layer1)
Observed(1531MB_layer1)
2015-05
2015-09
2016-01
2016-05
2016-09
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09

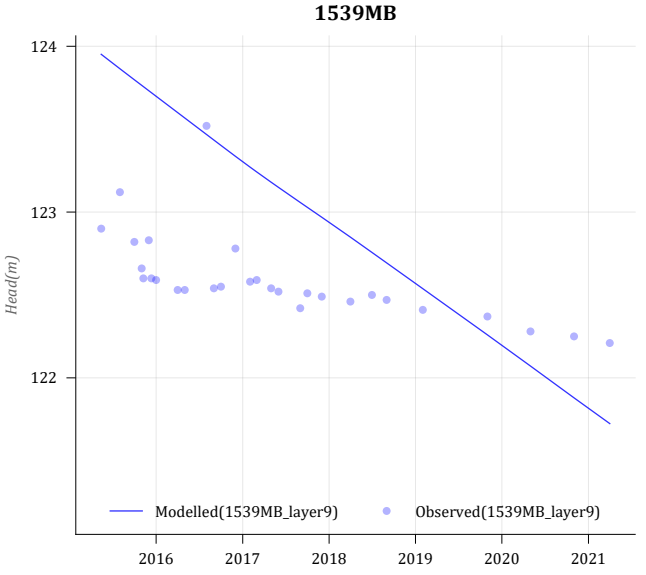

1533MB
Head(m)
111
110
109
108
107
106
105
2015-05-15
2015-06-01
2015-06-15
2015-07-01
2015-07-15
2015-08-01
2015-08-15
Modelled(1533MB_layer1)
Observed(1533MB_layer1)

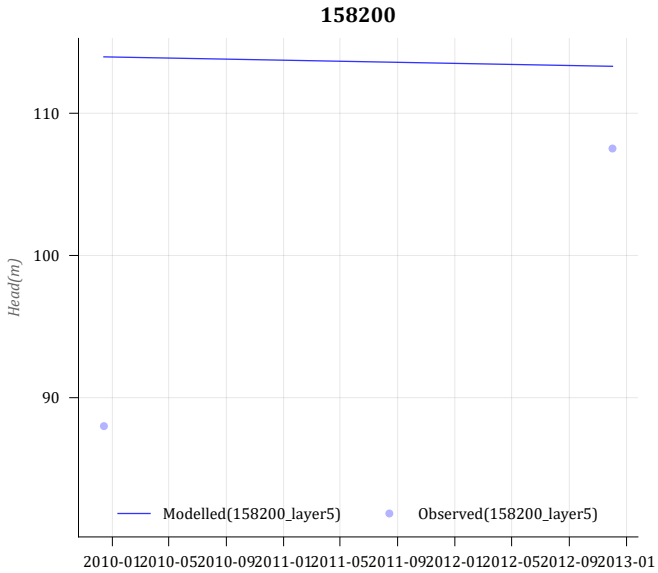

1534MB
Head(m)
111
110
109
108
107
106
105
104
103
2016
2017
2018
2019
2020
2021
Modelled(1534MB_layer9)
Observed(1534MB_layer9)

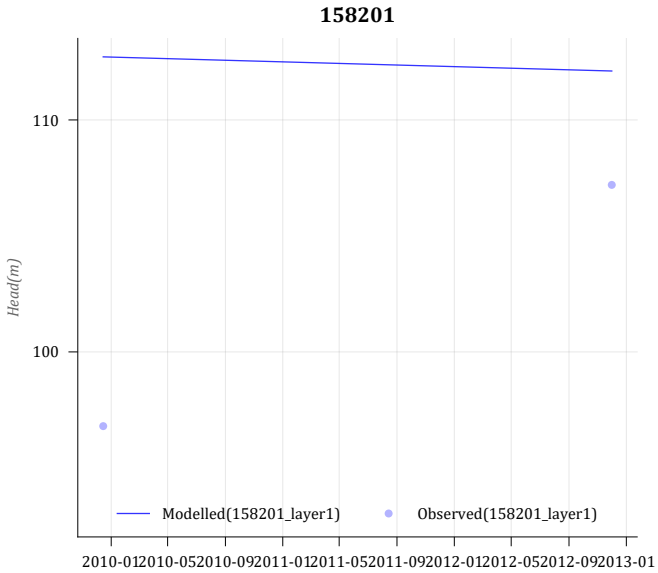

1536MB
Head(m)
116
115
114
113
112
111
110
109
108
2016
2017
2018
2019
2020
2021
Modelled(1536MB_layer5)
Observed(1536MB_layer5)

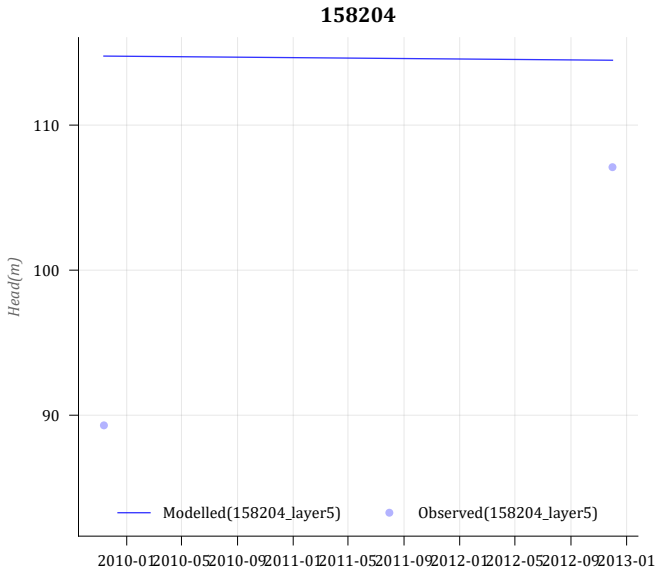

1537MB
Head(m)
149
148
147
146
145
144
143
142
141
140
139
138
137
136
135
134
2016
2017
2018
2019
2020
Modelled(1537MB_layer9)
Observed(1537MB_layer9)

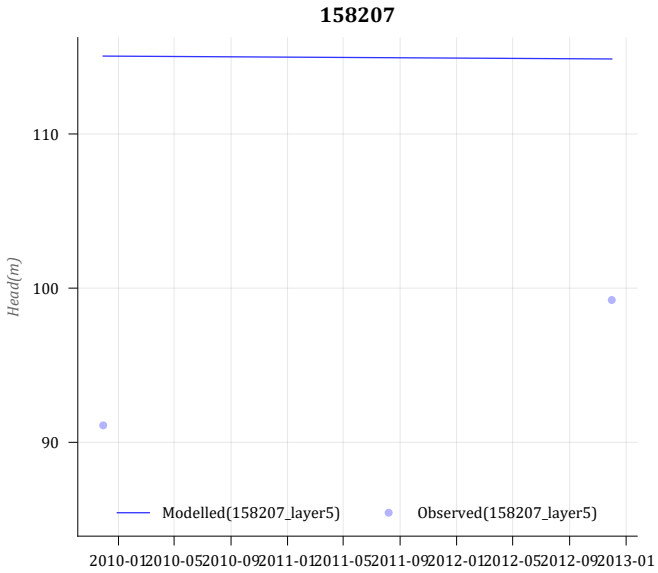

1538MB
Head(m)
126
125
124
123
2016
2017
2018
2019
2020
2021
Modelled(1538MB_layer9)
Observed(1538MB_layer9)

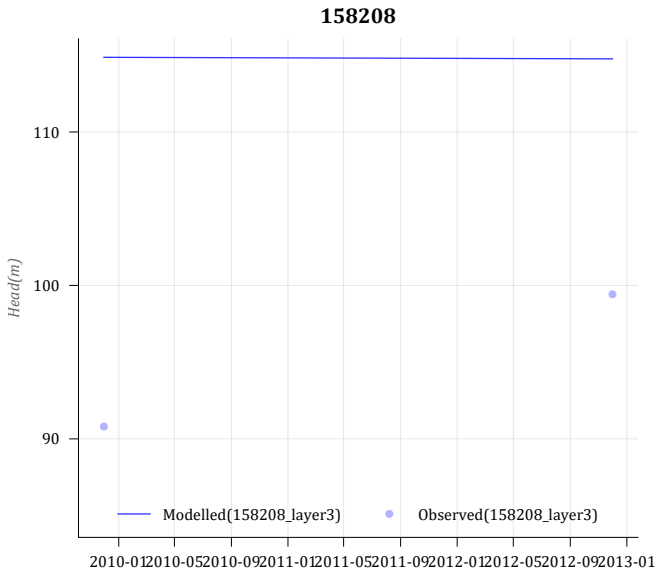

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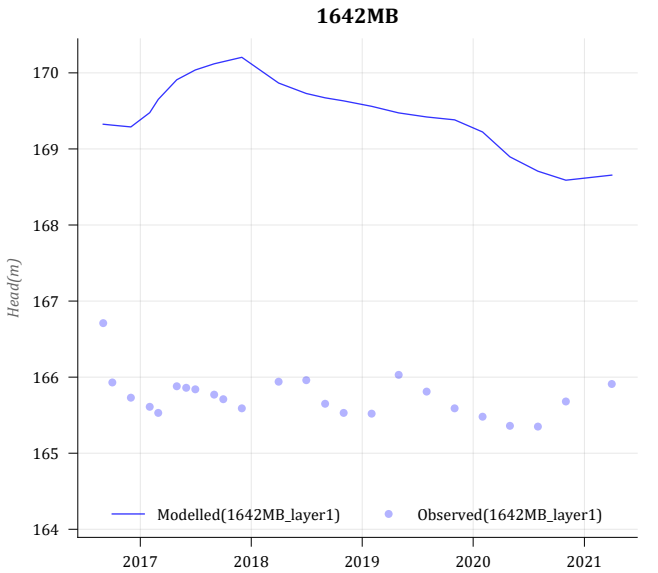

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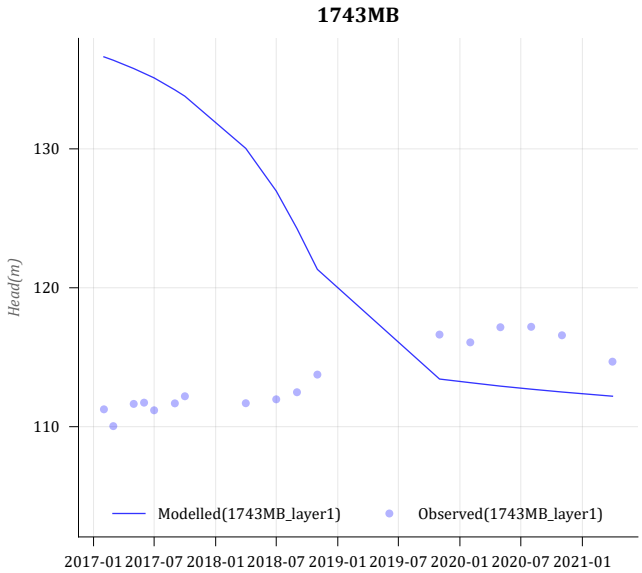

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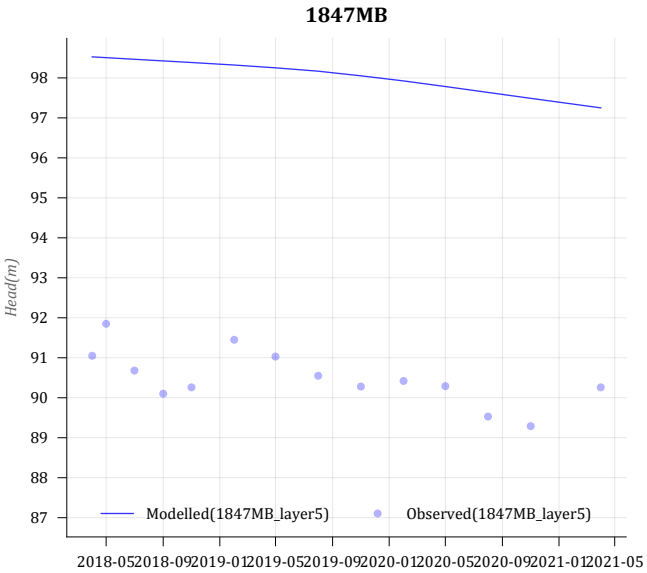

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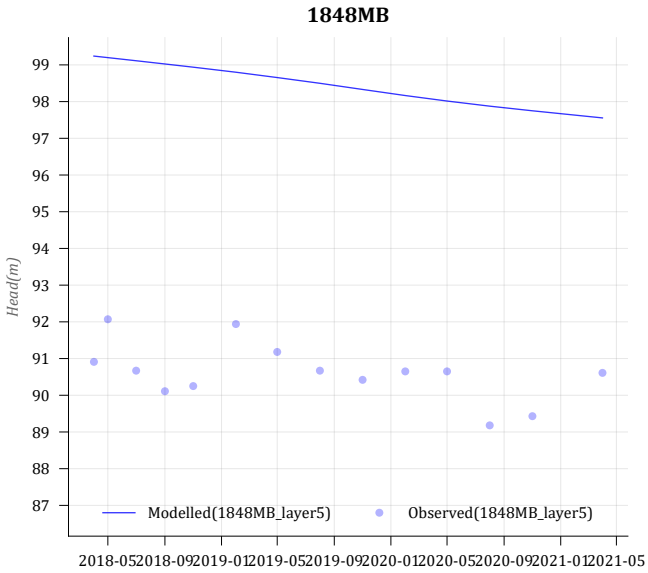

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165
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2019
2020
2021

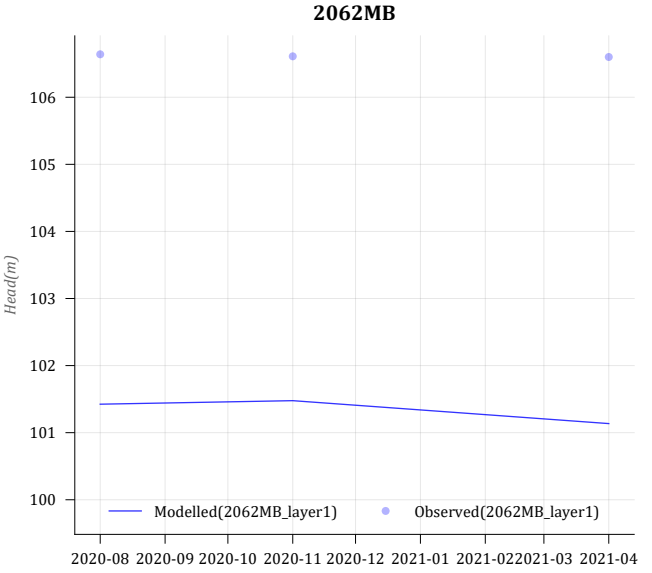

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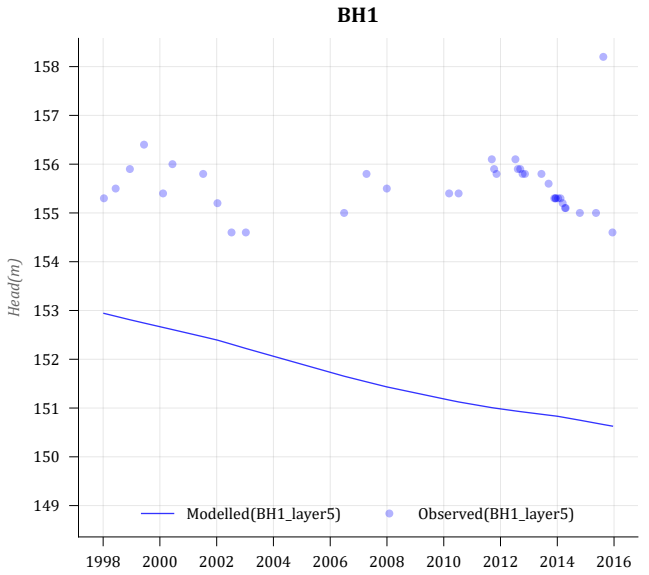

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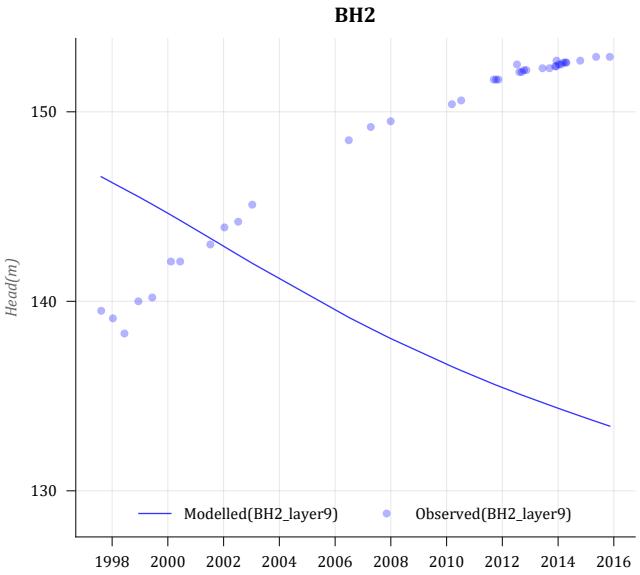

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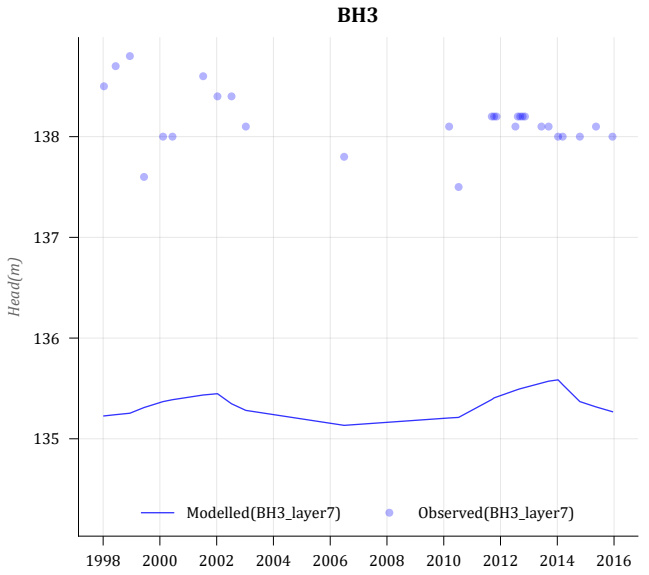

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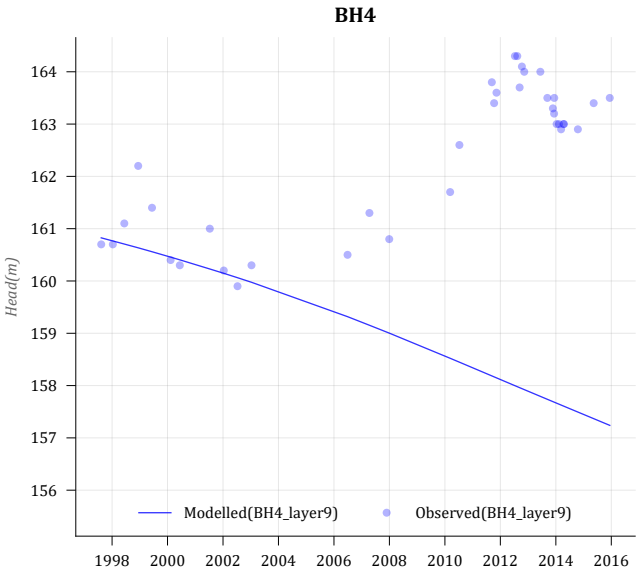

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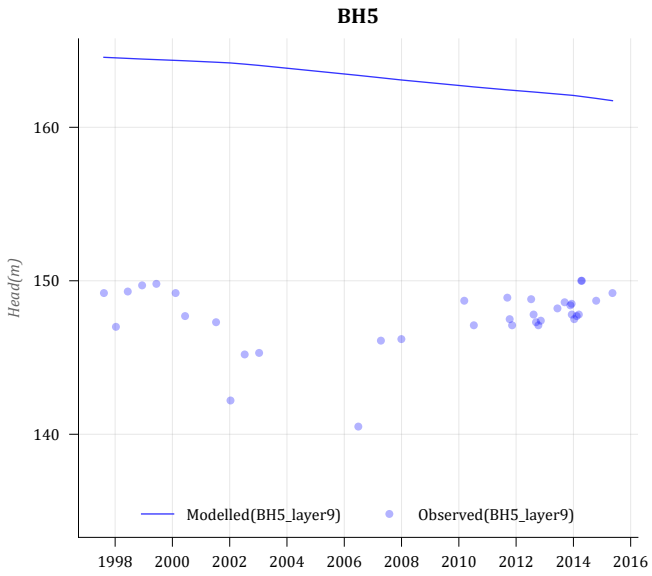

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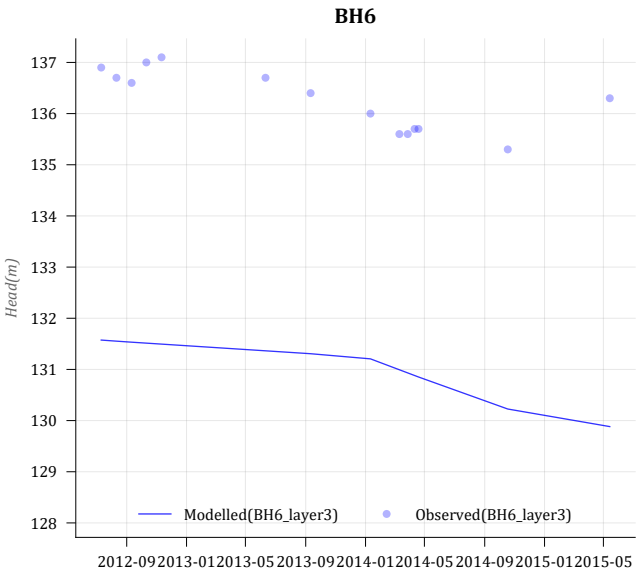

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2012
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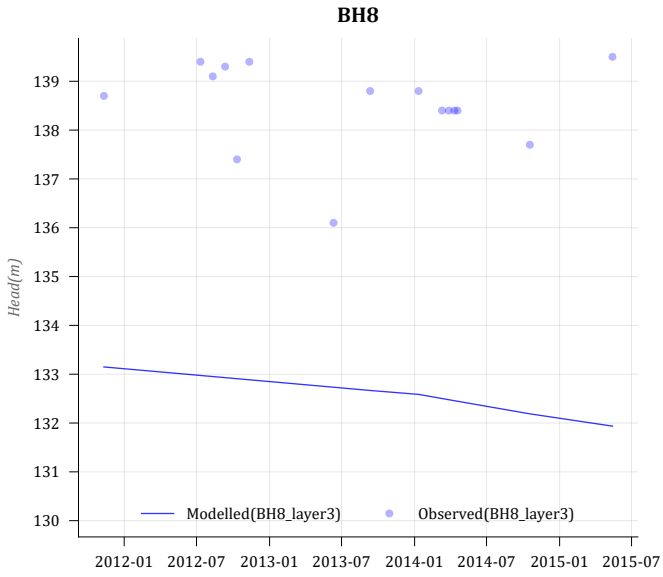

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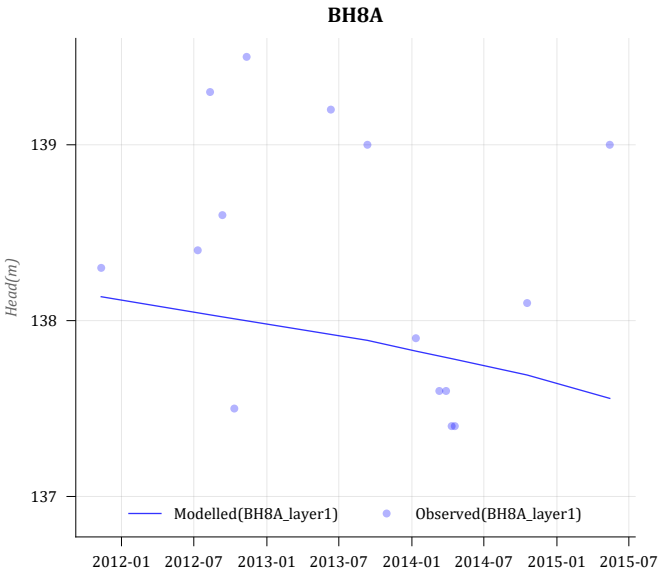

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BH4
Head(m)
164
163
162
161
160
159
158
157
156
Modelled(BH4_layer9)
Observed(BH4_layer9)
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BH5
Head(m)
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130
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2015-05


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Head(m)
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2013-01
2013-07
2014-01
2014-07
2015-01
2015-07

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# APPENDIX C

# VOID WATER BALANCE REPORT

# CURRAGH MINE COMPLEX

## Residual Void Modelling

**Prepared for:**

Coronado Curragh Pty Ltd
Blackwater,
QLD, 4717



**SLR Ref: 626.30075-R01**
**Version No: -v2.0**
**November 2021**

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# BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

# DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
|---|---|---|---|---|
| 626.30075-R01-v2.0 | 29 November 2021 | Emily Curtis | Nicole Bichel | Nicole Bichel |
| 626.30075-R01-v1.0 | 26 November 2021 | Emily Curtis | Nicole Bichel | Nicole Bichel |
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## APPENDICES

Appendix A Stage Storage Curves
Appendix B Residual Void Water Levels
Appendix C Residual Void Water Quality

# 1 Introduction

SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to provide a Concept Residual Void Assessment (CRVA) for the Curragh Mine Complex (the mine). In support of the CRVA a Residual Void Water Balance Model (WBM) for the mine and has been developed to determine the final water level and quality of the residual voids.

## 1.1 Scope of works

The scope of work includes the development of a surface water final void model which accounts for the modelled groundwater inflows derived from the recovery groundwater model.

An iterative modelling process is required between the groundwater numerical model and the WBM to develop a groundwater inflow relationship for the final void. The final void model then provides long-term estimate of water level and salt concentration for the void stored water while the groundwater recovery model allows estimating post-closure (equilibrium) groundwater levels, potential areas of seepage and discharge to creeks.

This report covers the WBM development. For further information regarding the groundwater numerical model can be found in the Concept Residual Void Groundwater Technical Appendix (SLR, 2021).

## 1.2 Residual Voids

Following closure of the mine, 12 residual void areas are expected to remain. The arrangement of these voids for the purpose of the WBM are listed below with multiple pits grouped where hydrologically linked.

- Curragh North: Void U/T/S
- Curragh Main: Void D/E/F, Void B/C/H, Void L, Void K, Void G, Void J, Ramp 9; and
- Expansion Areas: Void X (1 and 2), Void Y, Void Z.

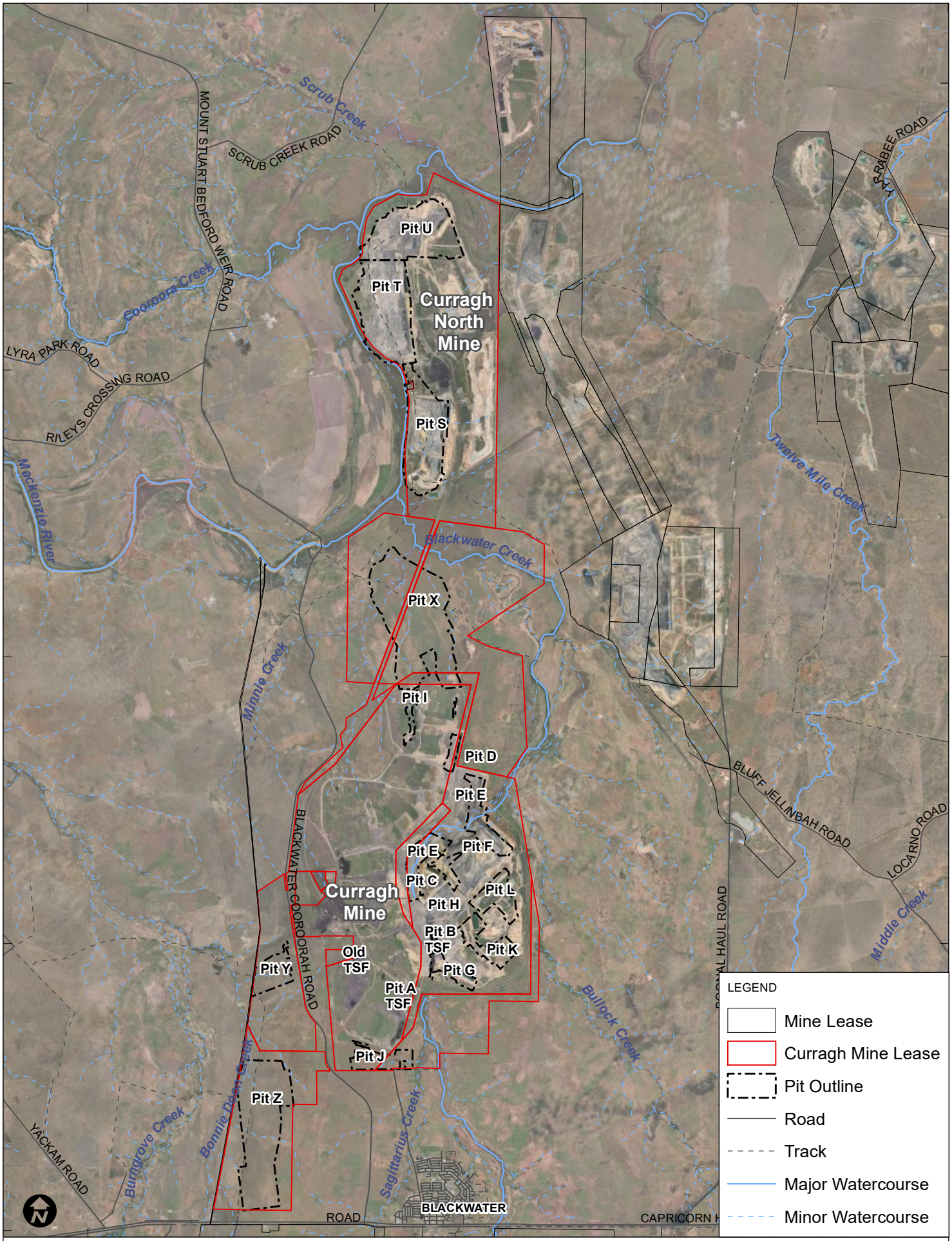
The assessed voids are shown in **Figure 1-1**.

## 1.3 Supplied Data

The following data was provided by CCPL to SLR to complete the assessment

- A final landform as separate designs for Curragh main, Curragh North and Void X, Y and Z. The final void designs were provided in dxf format as 0.5m contours.
- 1m Lidar data for the existing site (dated 2021).

Anticipated groundwater inflow volumes and associated water quality was derived from the numerical groundwater report.




SLR

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0 2 4 km

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| Project Number: | 626.30075 |
| Date: | 24-Nov-2021 |
| Drawn by: | ML |
| Reviewed by: | ML |

Data Source:

**CURRAGH PRCP**

**Current Mine Layout**

**FIGURE 1.1**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\GIS\626.630075 F01 Base Map.mxd

# 2 Water Balance Modelling

A Water Balance Model (WBM) was developed using Goldsim software package to assess the long-term water level and water quality was of the residual voids following closure of CCPL.

The model simulates daily changes in the volumes of stored water in response to inflows (rainfall, groundwater) and outflows (evaporation and controlled releases/overflows). The WBM was run for daily time step over 200-year simulation period, represented by 500 climate sequences, allowing the model to assess long term water levels, quality and risk of overflow for each void.

## 2.1 Catchment Areas

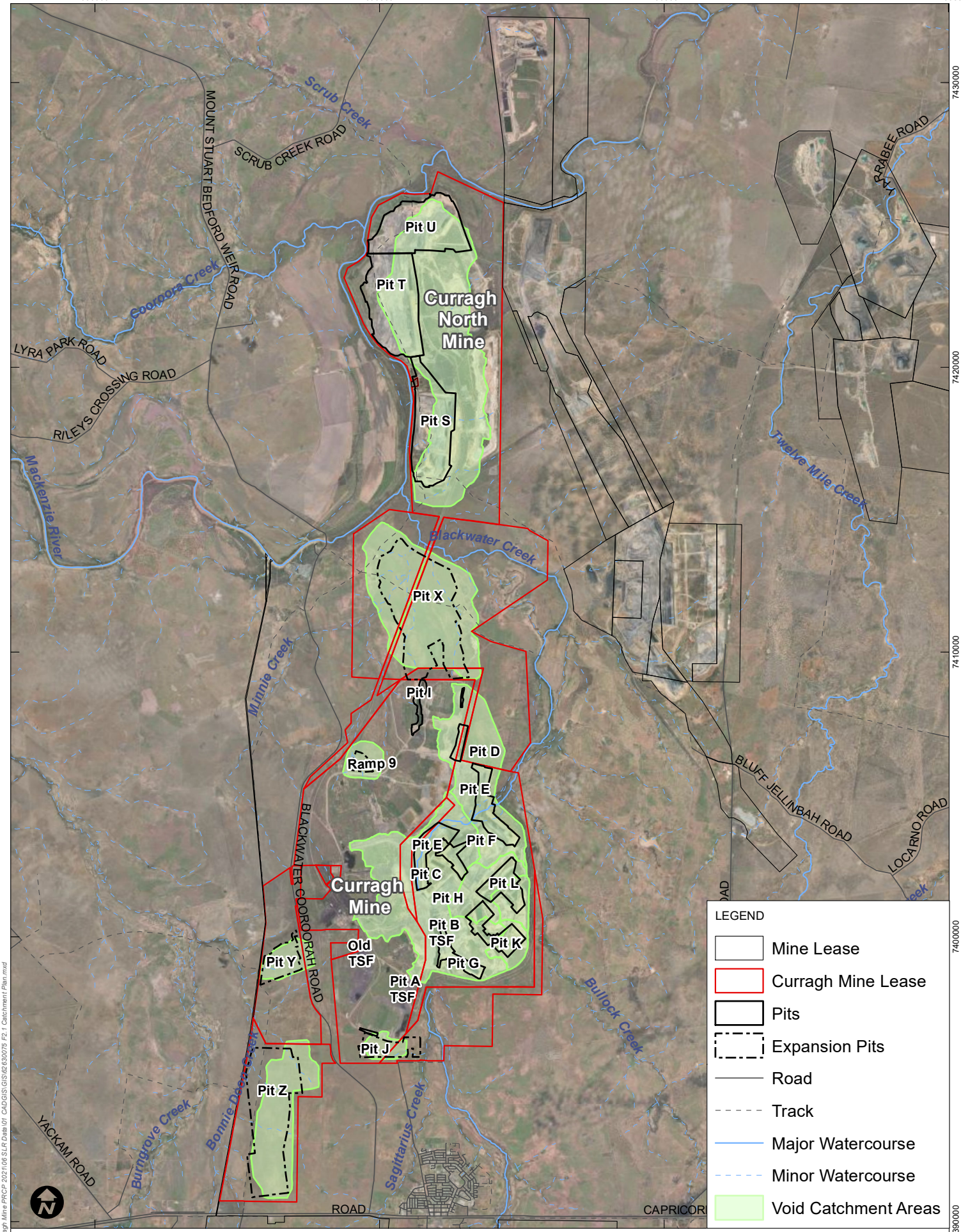
The catchment configurations for the residual voids at the mine were determined based on the final landform contours provided by CCPL. The residual void catchments consist primarily of rehabilitated spoil dumps, with an elevated stable landform constructed around the perimeter prevent external catchment and flood ingress into the voids. A summary of the catchment breakdown is provided in **Table 1.** The catchments are shown in **Figure 2-1 Catchment Plan** .

**Table 1 Catchment Summary**

| Curragh Area | Residual Void | Residual Void Footprint (ha) | Catchment Area (ha) |
|---|---|---|---|
| Curragh North | Void U/T/S | 1105.6 | 1334.4 |
| Curragh Main | Void D/E/F | 347.5 | 648.6 |
| | Void B/C/H | 673.7 | 1227.1 |
| | Void L | 63.1 | 287.2 |
| | Void K | 35.6 | 129.0 |
| | Void G | 45.2 | 107.4 |
| | Void J | 40.9 | 69.3 |
| | Ramp 9 | 45.4 | 104.4 |
| X Pit | Void X – 1 | 90.9 | 458.2 |
| | Void X – 2 | 169.0 | 764.6 |
| Y Pit | Void Y | 64.0 | 117.9 |
| Z Pit | Void Z | 295.6 | 426.0 |

## 2.2 Stage Storage Relationship

The stage storage surface area curves were derived from the final landform contours, provided by CCPL. Void depths range from 42m to 168m with inverts from -48m AHD to 116 m AHD. Residual void stage storage surface area relationship for each residual void is provided in **Appendix A**.




H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\626.30075 F2.1 Catchment Plan.mxd

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| Date: | 26-Nov-2021 |
| Drawn by: | AN |
| Reviewed by: | AN |

Data Source:

**CURRAGH PRCP**

**Catchment Plan**

**FIGURE 2.1**

## 2.3 Climate

Long term historical climate data has been collected by the Bureau of Meteorology (BoM) for the New Caledonia station (035132) at -23.429, 148.927 for 1900 to 2020 and was sourced from the Scientific Information for Land Owners (SILO) data drill as a Patch Point Data set. The Patch Point Data provides infilling of any missing data from nearby gauges based on relationships developed between the overlapping records of each gauge.

A summary of the annual average climate data is given in **Figure 2-2**.

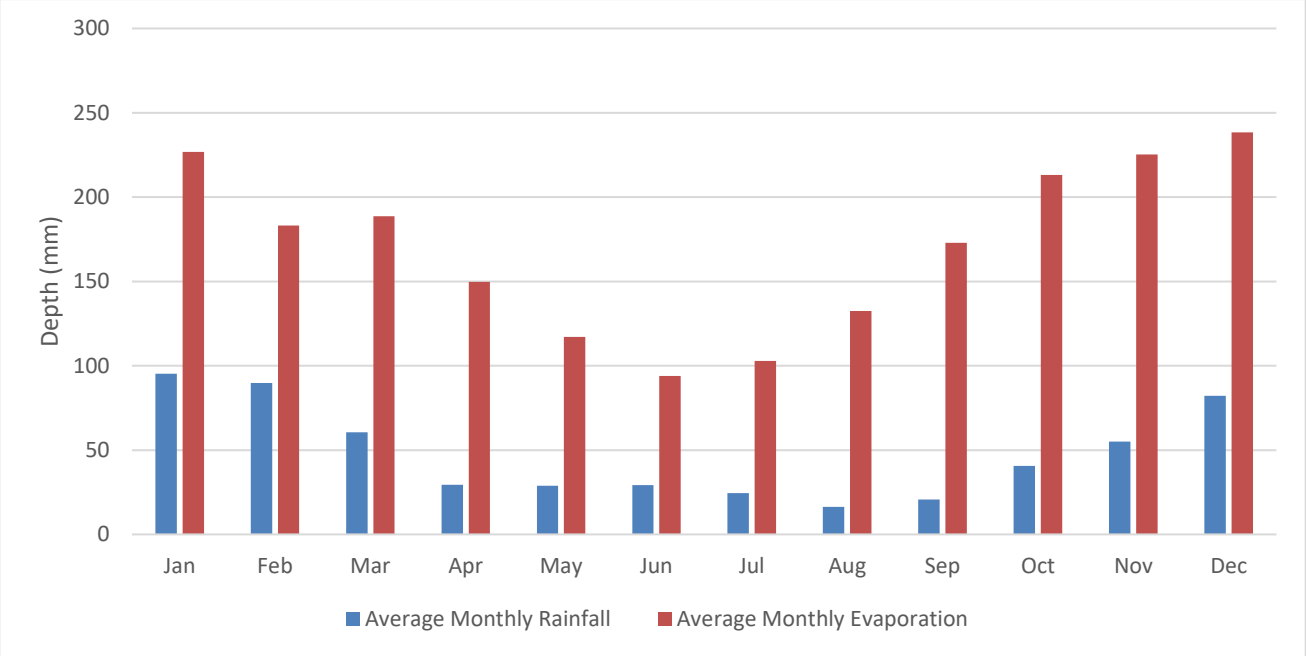



**Figure 2-2 Long Term Average Rainfall and Evaporation**

The average annual rainfall in the region (BoM Station 035132) is approximately 572mm, with the distribution of monthly rainfall shown in **Figure 2-2**. Rainfall is greatest during the summer months December to February, with 47% of annual rainfall occurring over these months. The highest monthly average rainfall total is 95mm in January, and the driest month is August with an average rainfall of 16mm.

The site experiences large water loss year-round, with an average annual evaporation for the site of 2,044mm. On a monthly basis, maximum evaporation occurs later in the year (October to December). During the dryer months evaporation is significantly lower, with the lowest total typically occurring in June. **Figure 2-2** summaries the average evaporation for all moths of the year for the site.

### 2.3.1 Probabilistic Rainfall

Probabilistic rainfall was generated for the WBM. The purpose of the probabilistic rainfall generation is to develop a wide range of climate sequences based on the recorded rainfall data of the area. These sequences have the same statistical characteristics of the historical data set for a range of parameters including mean, variance, skew, and the number of wet days or dry days. The 500 sequences of probabilistic data are summarised as exceedance probabilities. Some sequences may be wetter or dryer than others in order to account for the variability of the climate which may occur following establishment of the residual voids. The probabilistic rainfall data replicated the seasonality of the rainfall data.

The probabilistic rainfall data was generated from the historical data using the eWater CRC Stochastic Climate Library (SCL). Data was generated from 500 replicates of 120 years (from 1900 to 2020 as consistent with the available historical data record) of daily rainfall data for in accordance with the SCL Manual. Probabilistic rainfall at 200 years length were generated. The generated data was found to be representative of the historical record within acceptable tolerances for key statistics.

Comparison of the probabilistic data and the historical rainfall record for the annual rainfall totals is shown in **Figure 2-3**. Review of **Figure 2-3** shows the model simulates a range greater than that of the recorded historical rainfall data but the median (50$^{th}$ percentile) of the results are aligned.

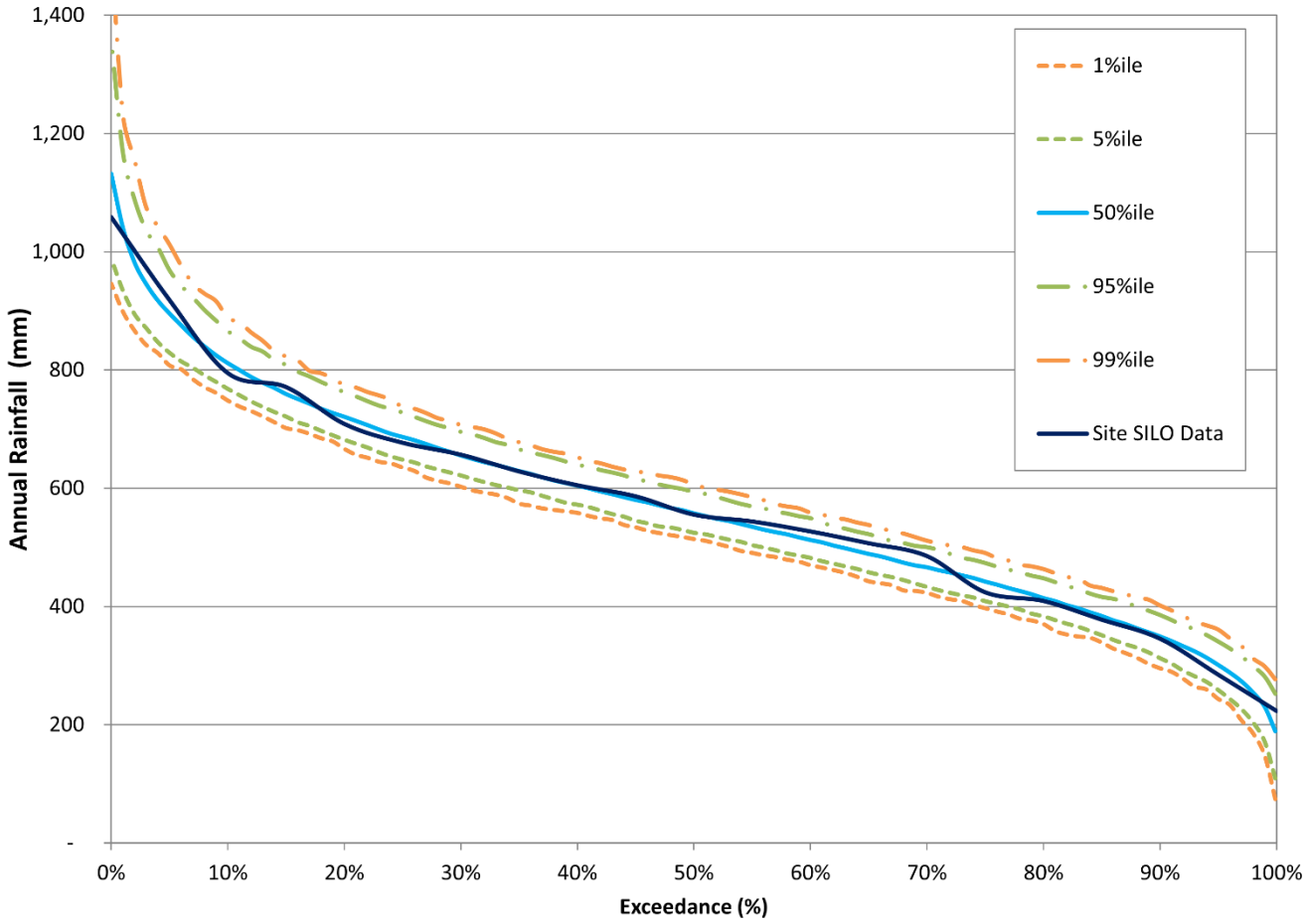



**Figure 2-3 Comparison of Historical and Probabilistic Data**

### 2.3.2 Evaporation

The evaporation rates in the model were sourced from the SILO. For the WBM, monthly averages were used as the evaporation data for the area is limited. The extended evaporation records available in SILO consisted of infilled data from monthly averages (rather than daily records from other gauges) for the period prior to gauge readings. This is most likely due to the limited available data for infilling. **Table 2** outlines the adopted lake evaporation rates and pan factor. Pan factors have been determined using the Morton Lake Evaporation.

**Table 2 Adopted Monthly Evaporation Rates**

| Month | Evaporation (mm/d) | Pan Factor |
|---|---|---|
| January | 7.3 | 0.90 |
| February | 6.5 | 0.93 |
| March | 6.1 | 0.90 |
| April | 5.0 | 0.89 |
| May | 3.8 | 0.86 |
| June | 3.1 | 0.84 |
| July | 3.3 | 0.87 |
| August | 4.3 | 0.88 |
| September | 5.8 | 0.87 |
| October | 6.9 | 0.88 |
| November | 7.5 | 0.89 |
| December | 7.7 | 0.89 |

## 2.4 Runoff Modelling

The WBM utilises the Australian Water Balance Model (AWBM) rainfall runoff module to calculate the rainfall and runoff inflows in each catchment. There are two AWBM modules in the WBM representing the runoff response for the following land use types:

- Void; and
- Rehabilitation.

The rainfall is converted to runoff using the Australian Water Balance Model (AWBM), illustrated in **Figure 2-4**. This runoff can be split into two forms:

1. Surface runoff which travels overland to the destination; or
2. Sub-surface which travels through the ground to reach the destination.

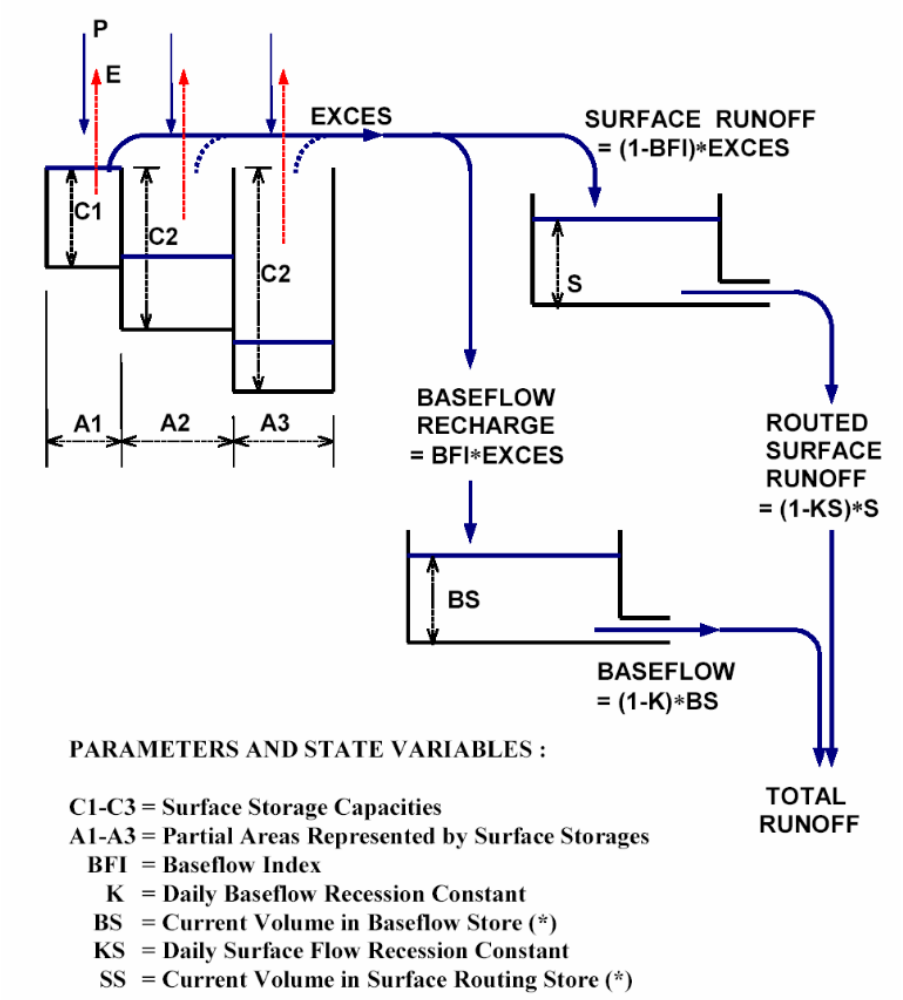



**Figure 2-4 AWBM Rainfall Runoff Model**

AWBM parameters were adopted based on values derived in the area for similar projects and are considered suitable for use in this assessment. A summary of the AWBM parameters used for different catchment types are presented in **Table 3**.

**Table 3 Adopted AWBM Parameters**

| Parameter | Abb | Landuse | |
|---|---|---|---|
| | | Void | Rehabilitation |
| Small storage capacity (mm) | C1 | 10 | 11 |
| Medium storage capacity (mm) | C2 | 25 | 60 |
| Large storage capacity (mm) | C3 | 50 | 130 |
| Small partial area portion | A1 | 0.134 | 0.134 |
| Medium partial area portion | A2 | 0.433 | 0.433 |
| Large partial area portion | A3 | 0.433 | 0.433 |
| Baseflow Index | BFI | 0.1 | 0.35 |

| Parameter | Abb | Landuse | |
|---|---|---|---|
| | | Void | Rehabilitation |
| Baseflow recession | K | 0.6 | 0.6 |
| Daily streamflow recession | KS | 0.1 | 0.1 |

## 2.5 Groundwater Inflow

Groundwater inflows into the WBM were derived from the groundwater model developed for the CRVA in the and provided as a relationship between water level and inflow (SLR, 2021). This was modelled as an inflow in the WBM and were calculated daily based on the current water level in the void as predicted by the WBM.

Further information relating to derived groundwater inflows can be found in Section 4.2 of the Concept Residual Void Groundwater Technical Appendix (SLR, 2021).

## 2.6 Water Quality

The water balance model was developed to include a high-level salt balance to track both the quantity and quality of water on-site. The salt balance tracks the water quality in all of the inflows into the voids and subsequent effects from evaporation and releases on the storage water quality. The water quality values are presented in **Table 4**Error! Reference source not found.. These adopted values are consistent with those adopted for other Queensland mine sites.

Based on groundwater monitoring data at the mine, an EC of 12,500 µS/cm was adopted as the average salinity concentration of groundwater inflows. Salinity parameters for surface runoff were determined based on prior experience in the area.

Adopted water quality parameters are summarised in **Table 4**.

**Table 4 Adopted Salinity Generation Parameters**

| Inflow | Salinity (EC) (µS/cm) |
|---|---|
| Void | 3000 |
| Rehabilitation | 250 |
| Groundwater Inflow | 12,500 |

The above salinity values are converted to a concentration in milligrams per litre using an average multiplication factor of 0.67 (Measuring Salinity DERM, June 2007) to quantify the mass of salt transferred in the model.

# 3 Results

The WBM was run for a range of rainfall conditions to allow for the calculation of percentiles of the final void levels. These percentiles represent the results range due to variability in climate. The results of the WBM focus on the 5$^{th}$, 50$^{th}$ and 99$^{th}$ percentile. This represents the dry, median and very wet climatic condition. The 99$^{th}$ percentile result is used to assess the risk of overflow of the voids.

## 3.1 Residual Void Water Levels

The WBM was predicted to stabilise after approximately 100 years to the approximate levels for the median condition shown in **Table 5**. It is noted that some individual voids within the WBM reached equilibrium level from approximately 20 years. Graphical representations of the results for each residual void are provided in **Appendix B.**

**Table 5 Residual Void Water Level Summary**

| Void | Residual Void Level (50%ile) (mAHD) | Depth (m) | Surface Area (ha) |
|---|---|---|---|
| Void U/T/S | 26 | 74 | 286.5 |
| Void D/E/F | 63 | 36 | 63.5 |
| Void B/C/H | 83 | 42 | 109.3 |
| Void L | 113 | 21 | 13.9 |
| Void K | 107 | 42 | 8.5 |
| Void G | 79 | 14 | 9.2 |
| Void J | 132 | 39 | 20.2 |
| Ramp 9 | 91 | 14 | 17.1 |
| Void X – 1 | 101 | 23 | 23.2 |
| Void X – 2 | 69 | 35 | 49.4 |
| Void Y | 131 | 15 | 19.6 |
| Void Z | 115 | 37 | 72.3 |

The relative size of external catchment to the void footprint results in water levels that stabilise well below the indicative spill level with evaporative losses balancing inflows into the voids. A similar trend in water level is seen across all the residual voids. Water depths range from 14m to 74m within the voids for median conditions (50$^{th}$ percentile). During dry climatic conditions (5$^{th}$ percentile) water levels are approximately 2m to 13m lower. During very wet (99$^{th}$ percentile) climatic conditions the water level increases by 3m to 20m depending on the void and generally causes greater fluctuation in the equilibrium water level. Final water levels range from 9m to 88m below the indicative spill levels and are not expected to overtop.

## 3.2 Water Quality

Water within the residual voids becomes highly saline throughout the simulation. This was not unexpected due to the high salinity of groundwater in the region and the assumption that no salt is lost from the system via evaporation. Within the WBM salinity is capped at a maximum EC of 37,313 µS/cm which is equivalent to the point where the concentration of salt becomes high enough that the solution is saturated and any additional salt will precipitate out of solution. Salinity in all voids increases over time until reaching saturation after approximately 20 to 30 years.

The average salinity of the voids throughout the simulation period are provided in **Table 6**. Graphical representations of the results for each residual void are provided in **Appendix C.**

**Table 6 Average Stage Salinity (EC µS/cm)**

| | Year 10 | Year 30 | Year 200 |
|---|---|---|---|
| Void U/T/S | 27,578 | 37,313 | 37,313 |
| Void D/E/F | 36,828 | 37,313 | 37,313 |
| Void B/C/H | 23,045 | 37,181 | 37,313 |
| Void L | 17,843 | 34,498 | 37,313 |
| Void K | 22,333 | 37,292 | 37,313 |
| Void G | 33,100 | 37,288 | 37,313 |
| Void J | 19,951 | 31,496 | 37,313 |
| Ramp 9 | 29,754 | 37,313 | 37,313 |
| Void X – 1 | 28,650 | 37,274 | 37,313 |
| Void X – 2 | 16,174 | 32,568 | 37,313 |
| Void Y | 28,954 | 37,313 | 37,313 |
| Void Z | 37,296 | 37,313 | 37,313 |

# 4 Conclusions

At Curragh Complex the residual void water levels are expected to range from 26mAHD to 132mAHD with water depths of 14m to 74m. The results indicate that the mine is not a net accumulator of water after approximately 100 years when the equilibrium water levels are reached. The final water levels remain below the spill level and the voids are unlikely to overtop in the 99 percentile climate scenario.

A significantly high concentration of salt is expected to accumulate within the residual voids. The elevated salinity of the groundwater inflows input a high level of salt into the voids which is not lost from the system via evaporation. The salinity of the voids is expected to exceed that of the groundwater and form highly concentrated solution. Although poor quality, water within the voids is not expected to interact with surrounding surface water given the final water levels.

# APPENDIX A

Stage Storage Curves

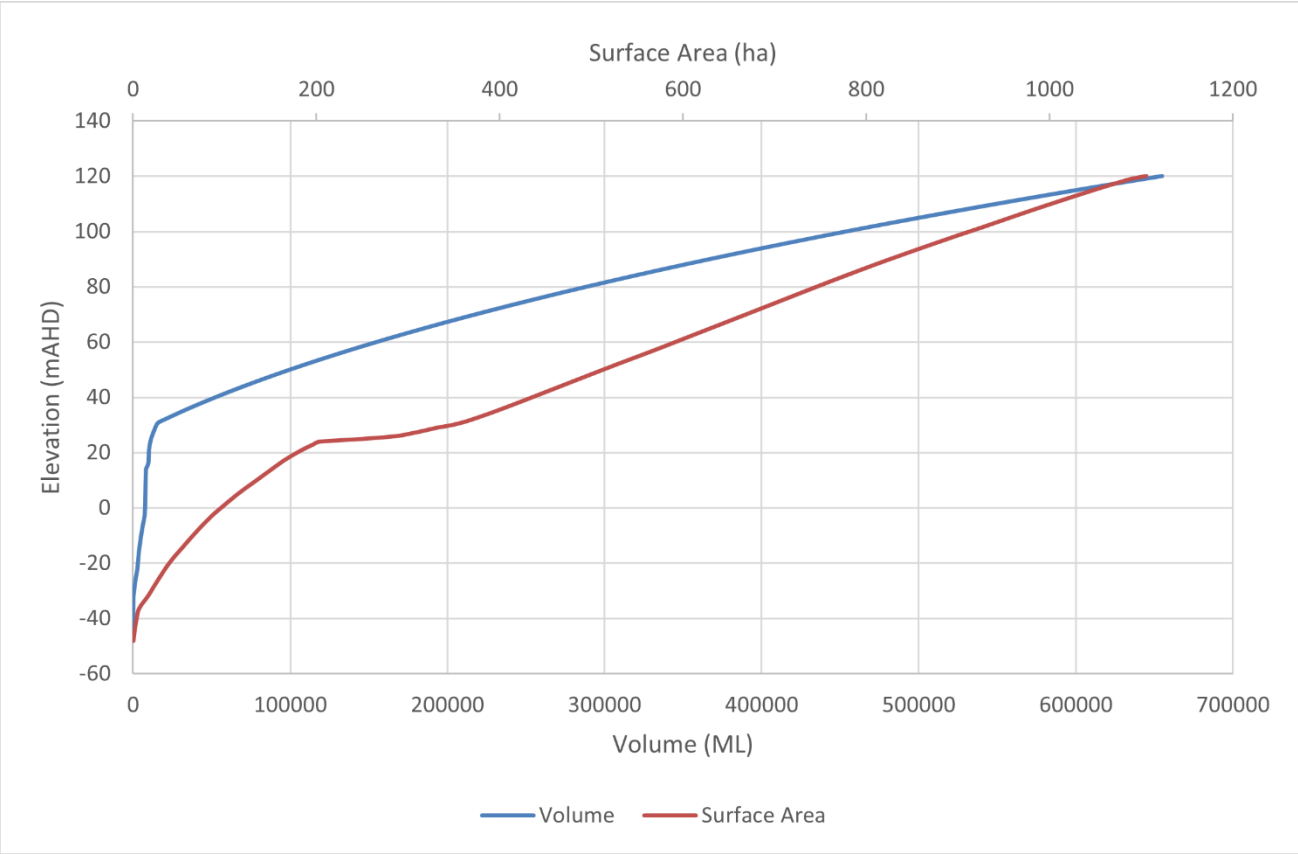



**Figure 1A** - Curragh North: Void U/T/S

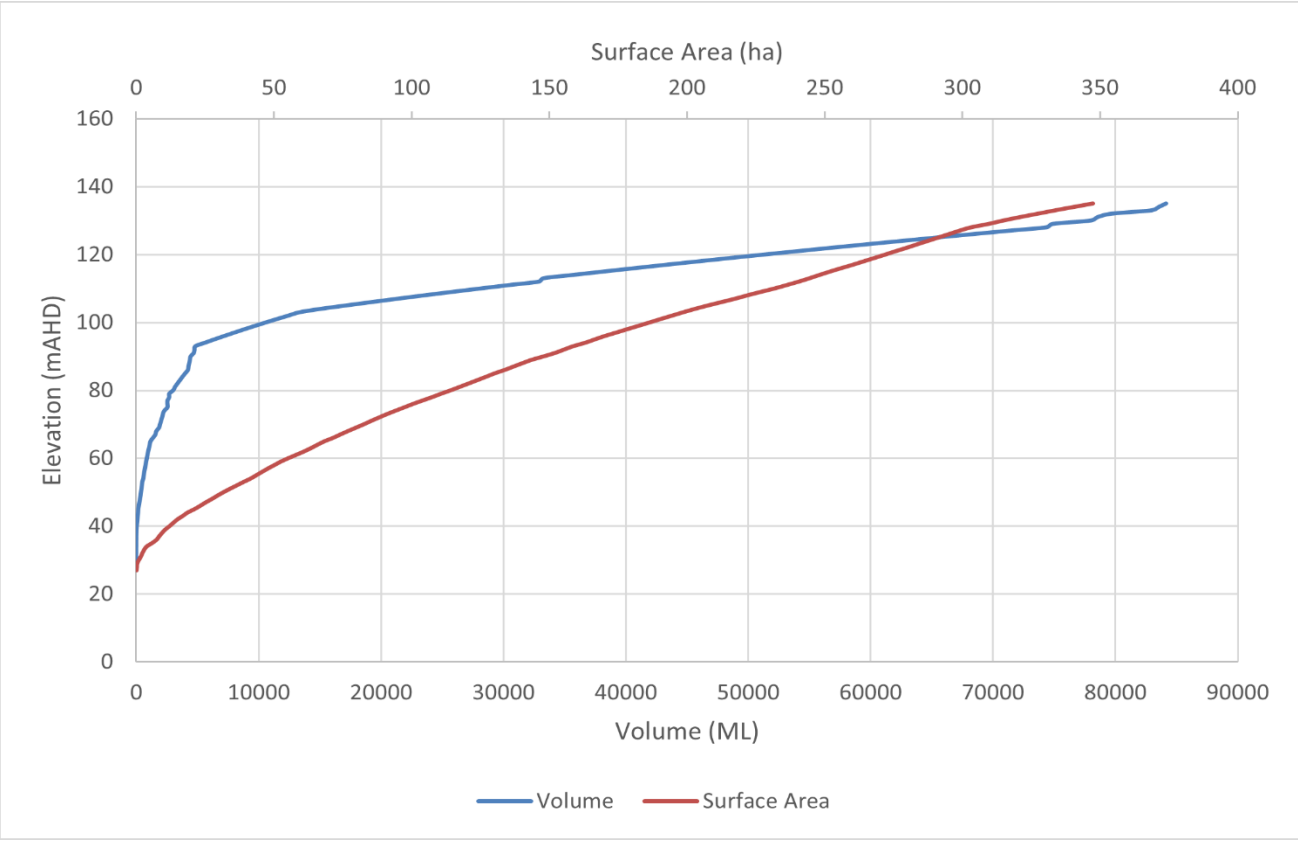



**Figure 2A** - Curragh Main: Void D/E/F

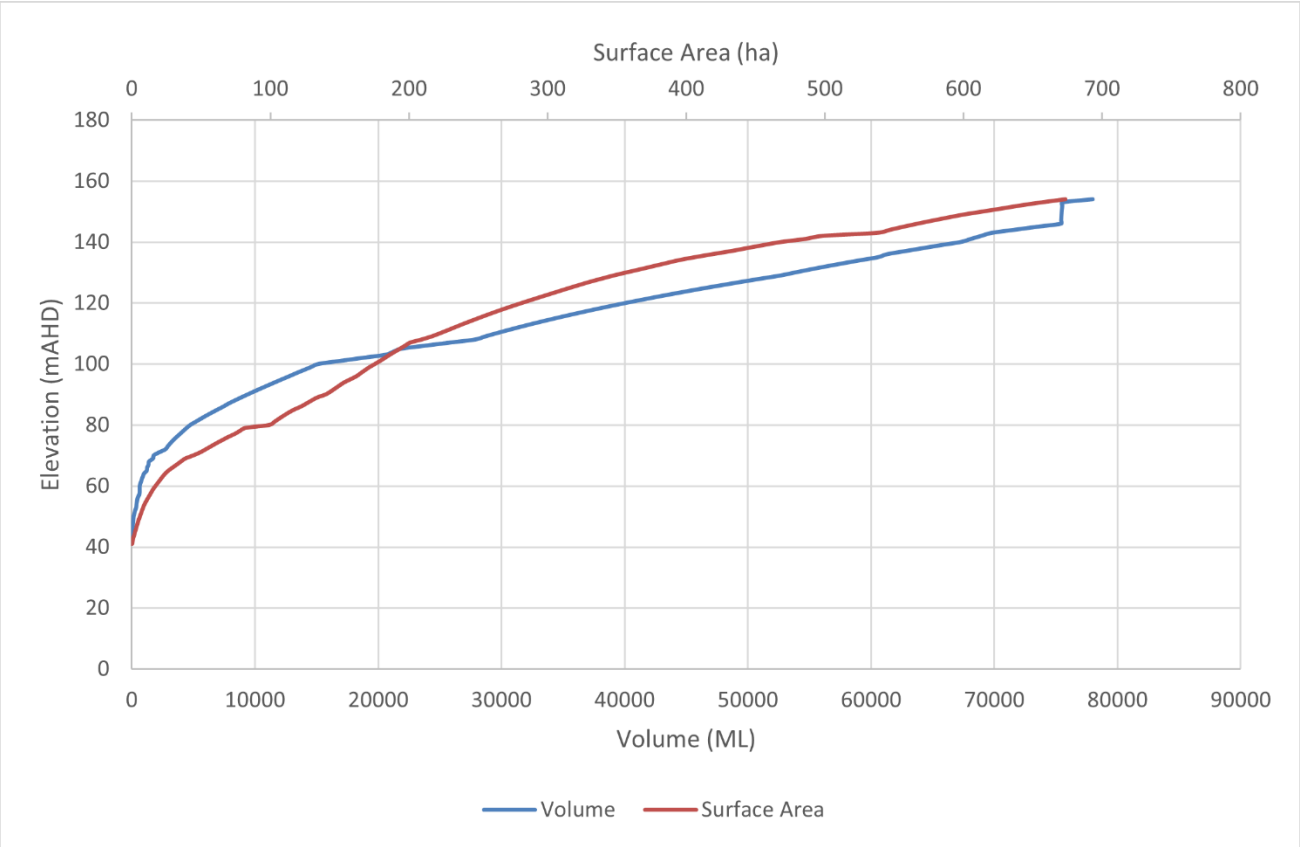



**Figure 3A** - Curragh Main: Void B/C/H

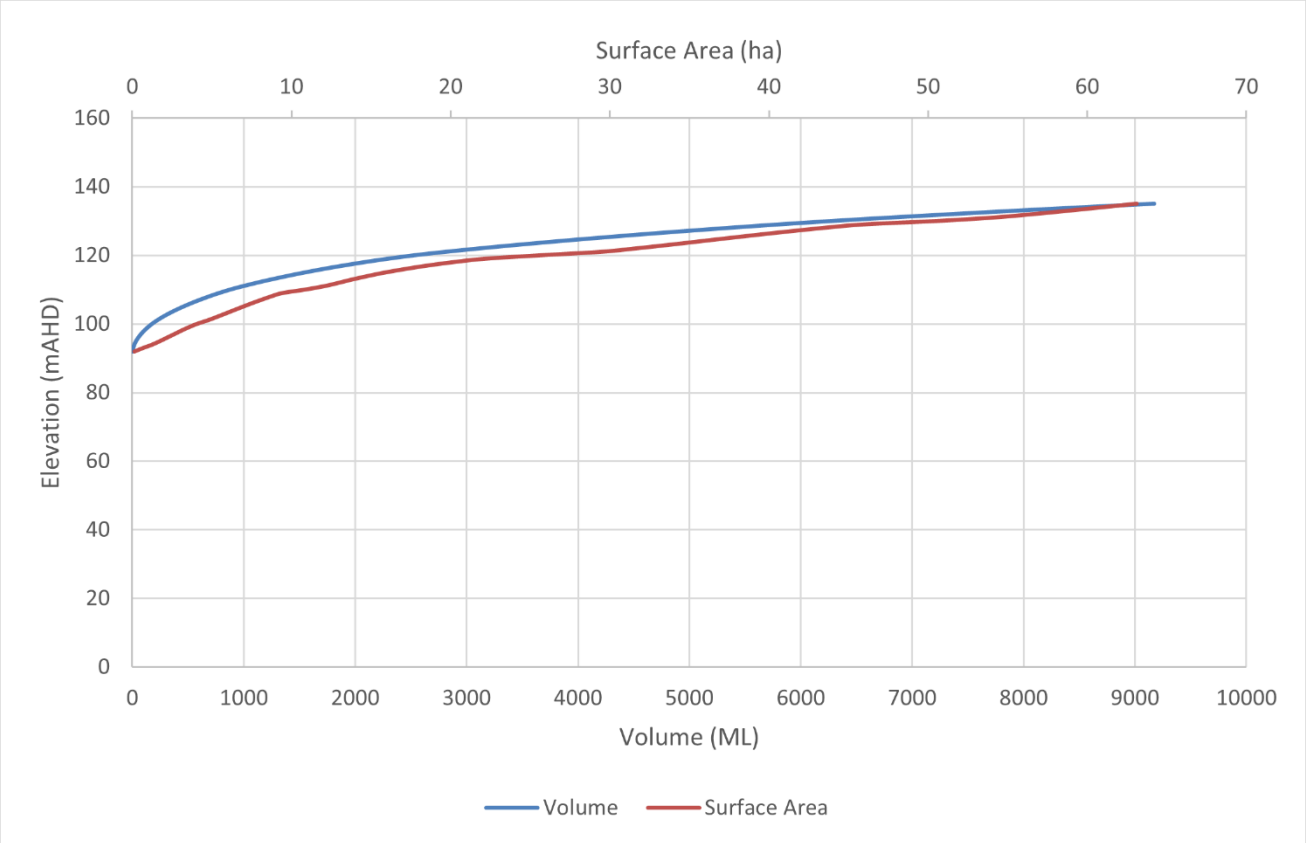



**Figure 4A** - Curragh Main: Void L

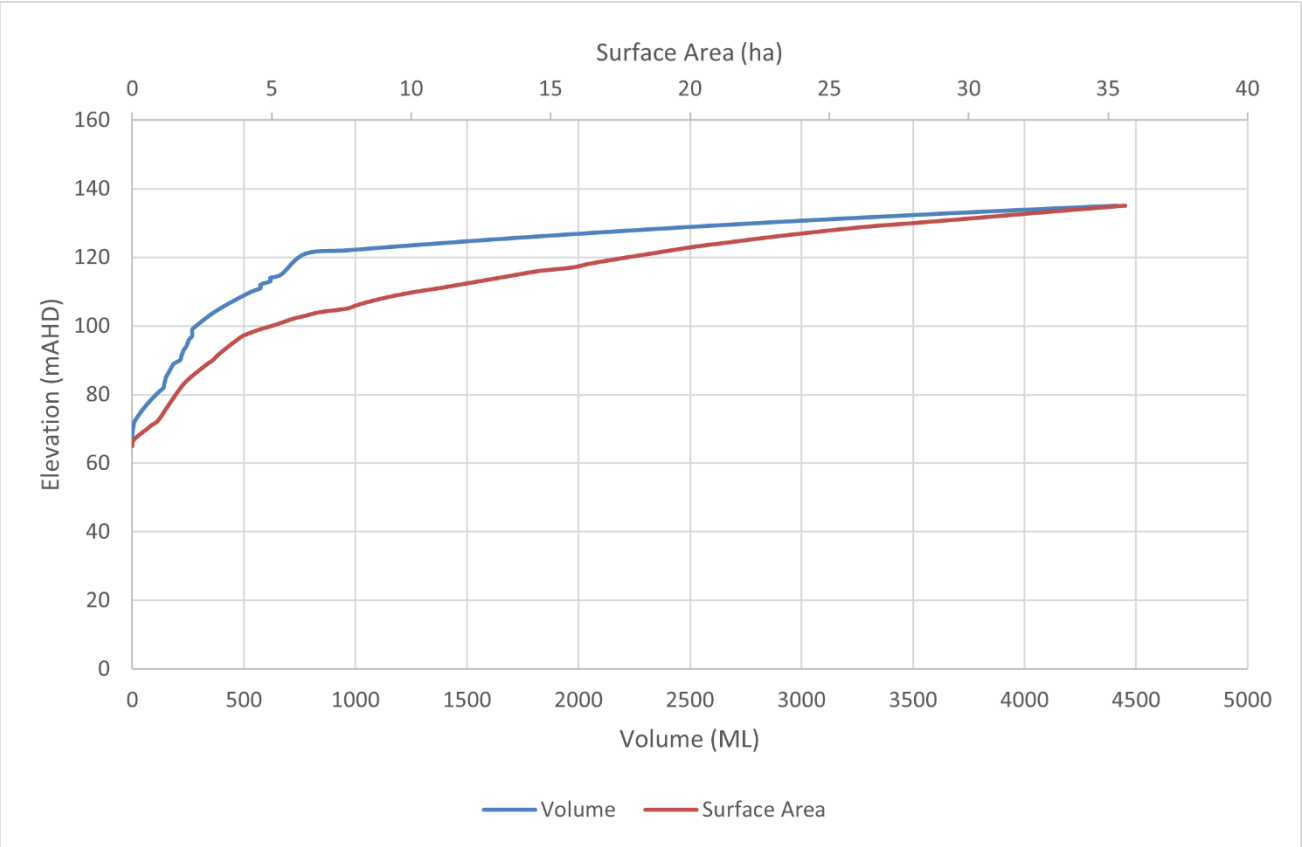



**Figure 5A** - Curragh Main: Void K

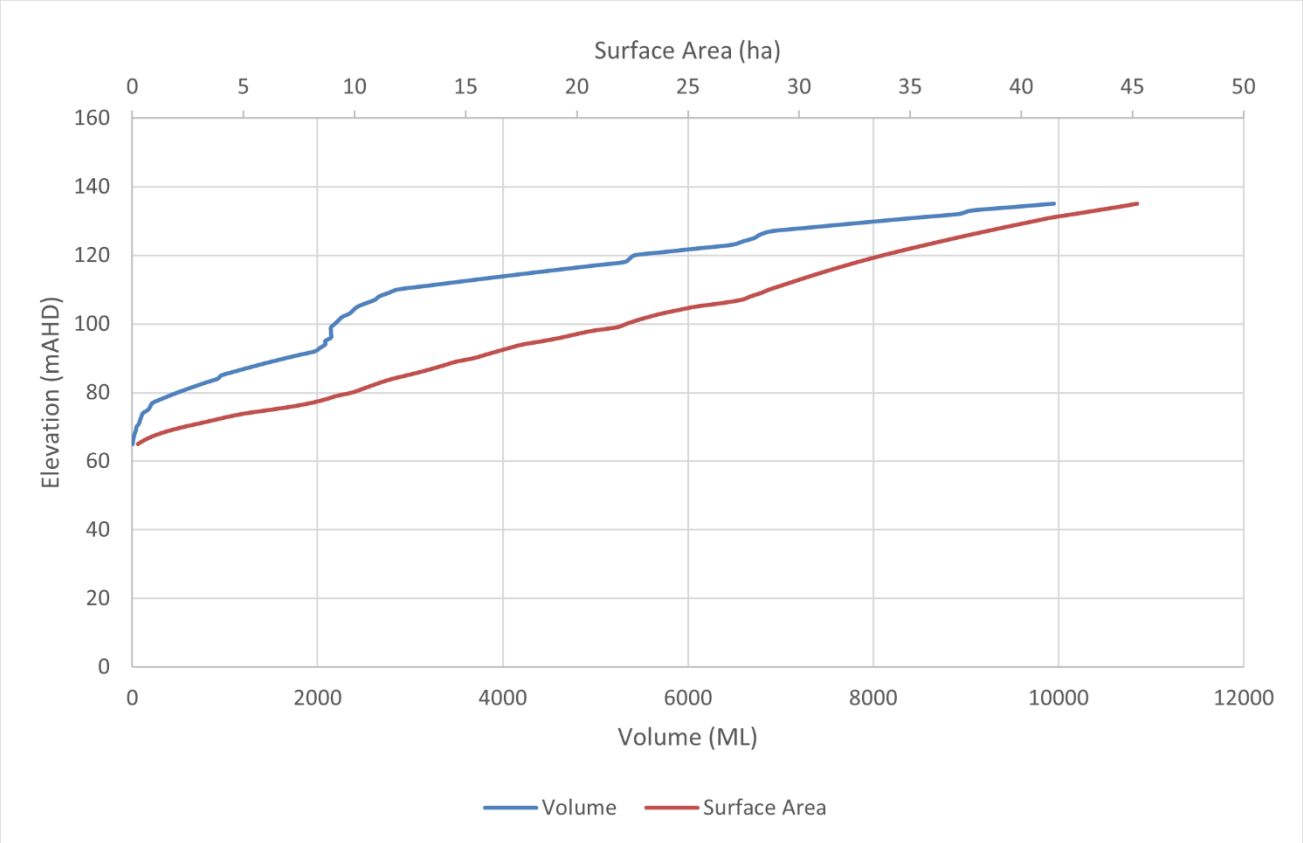



**Figure 6A** - Curragh Main: Void G

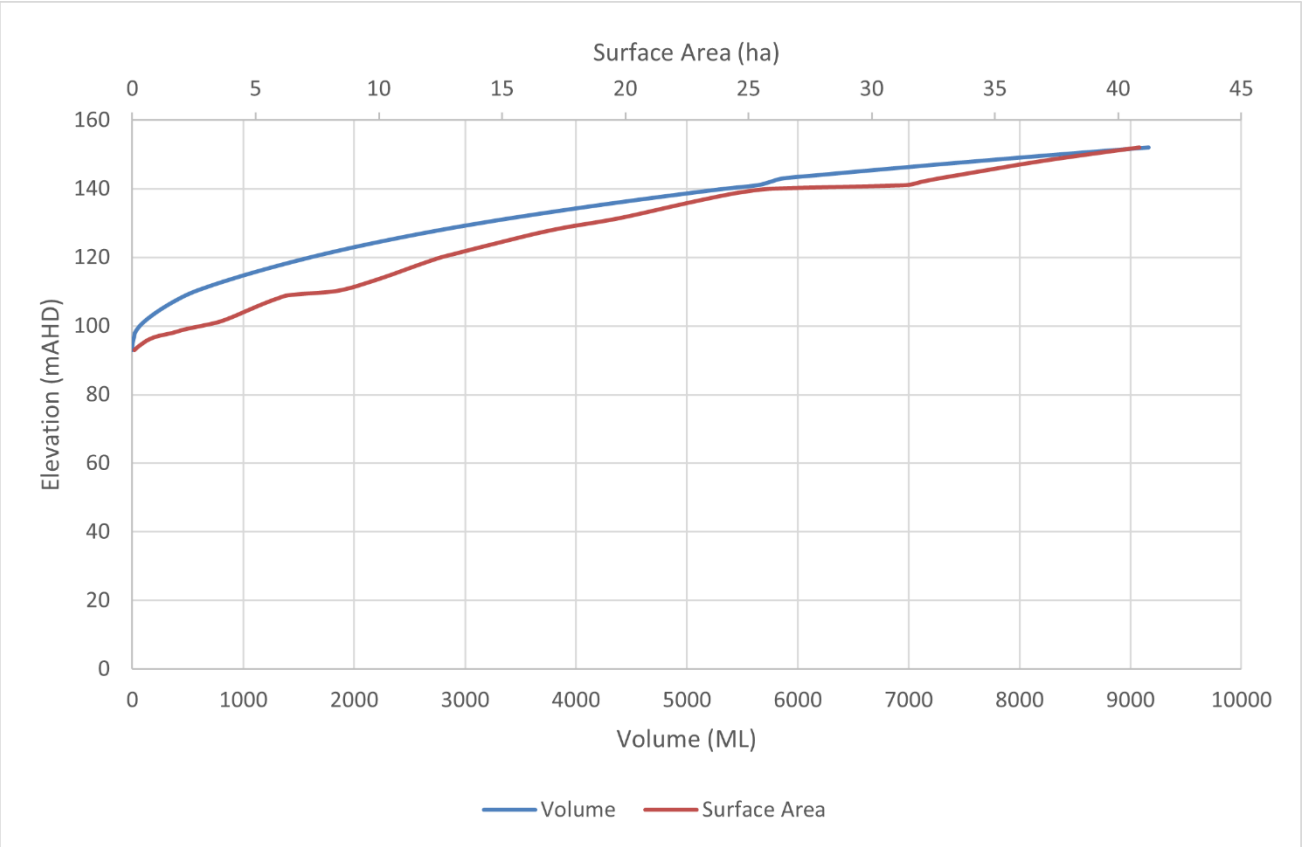



**Figure 7A** - Curragh Main: Void J

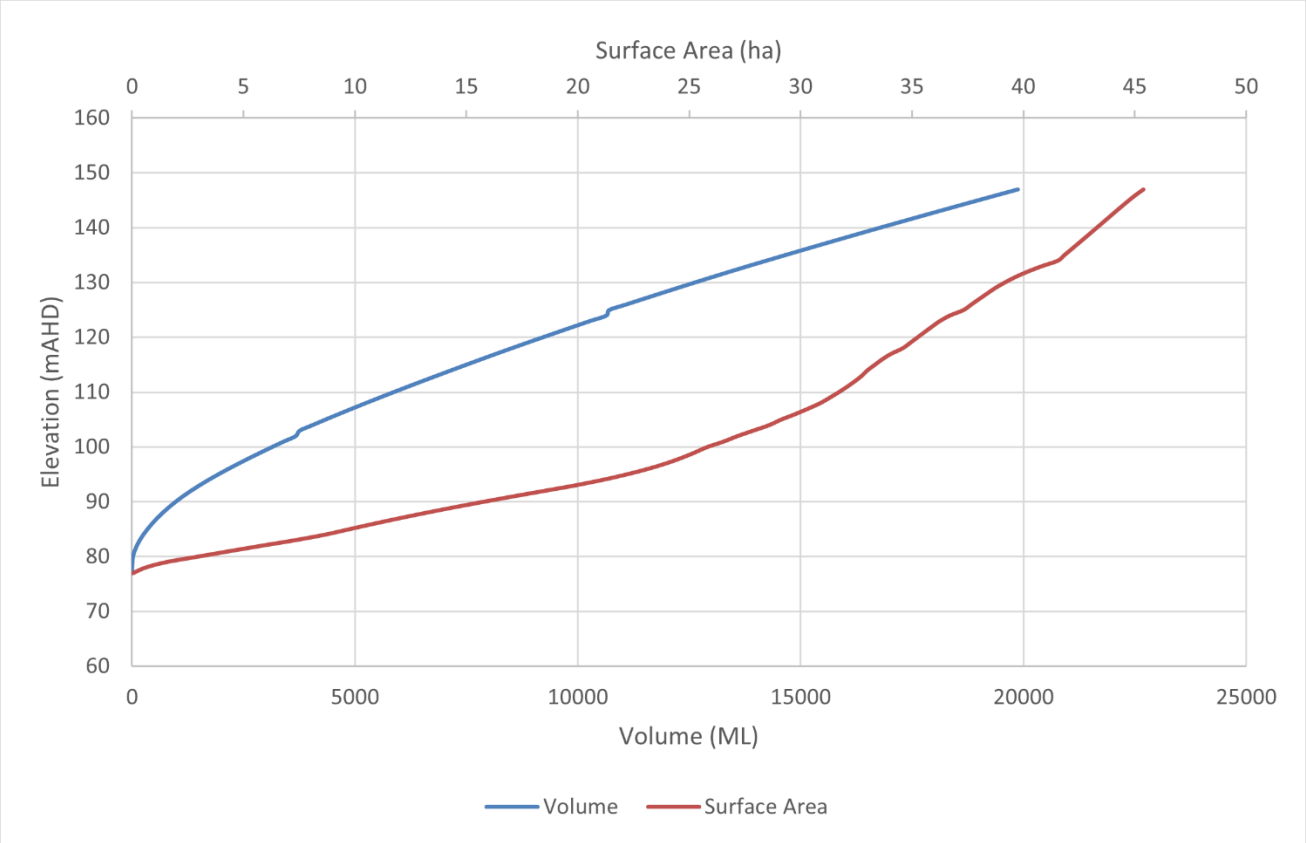



**Figure 8A** - Curragh Main: Void Ramp 9

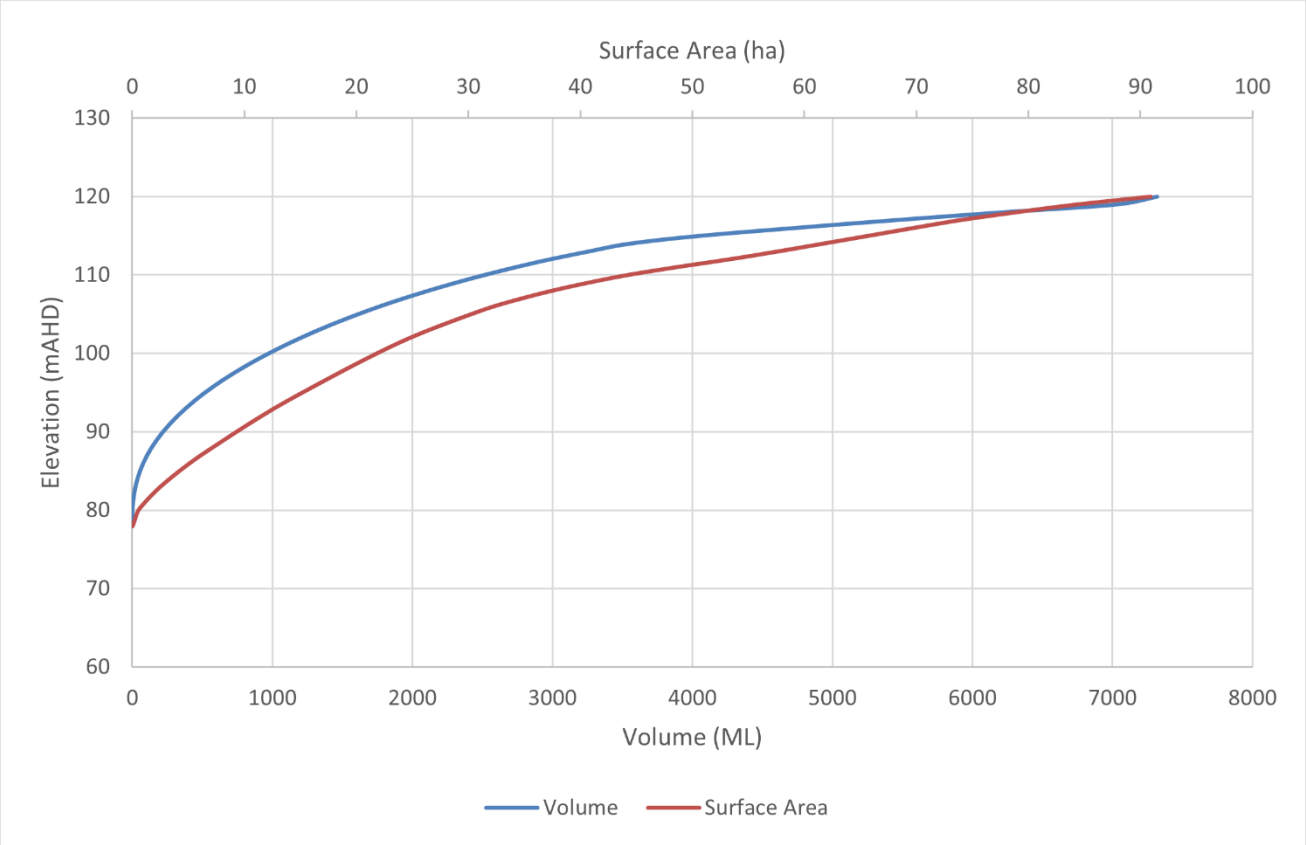



**Figure 9A** - Void X – 1

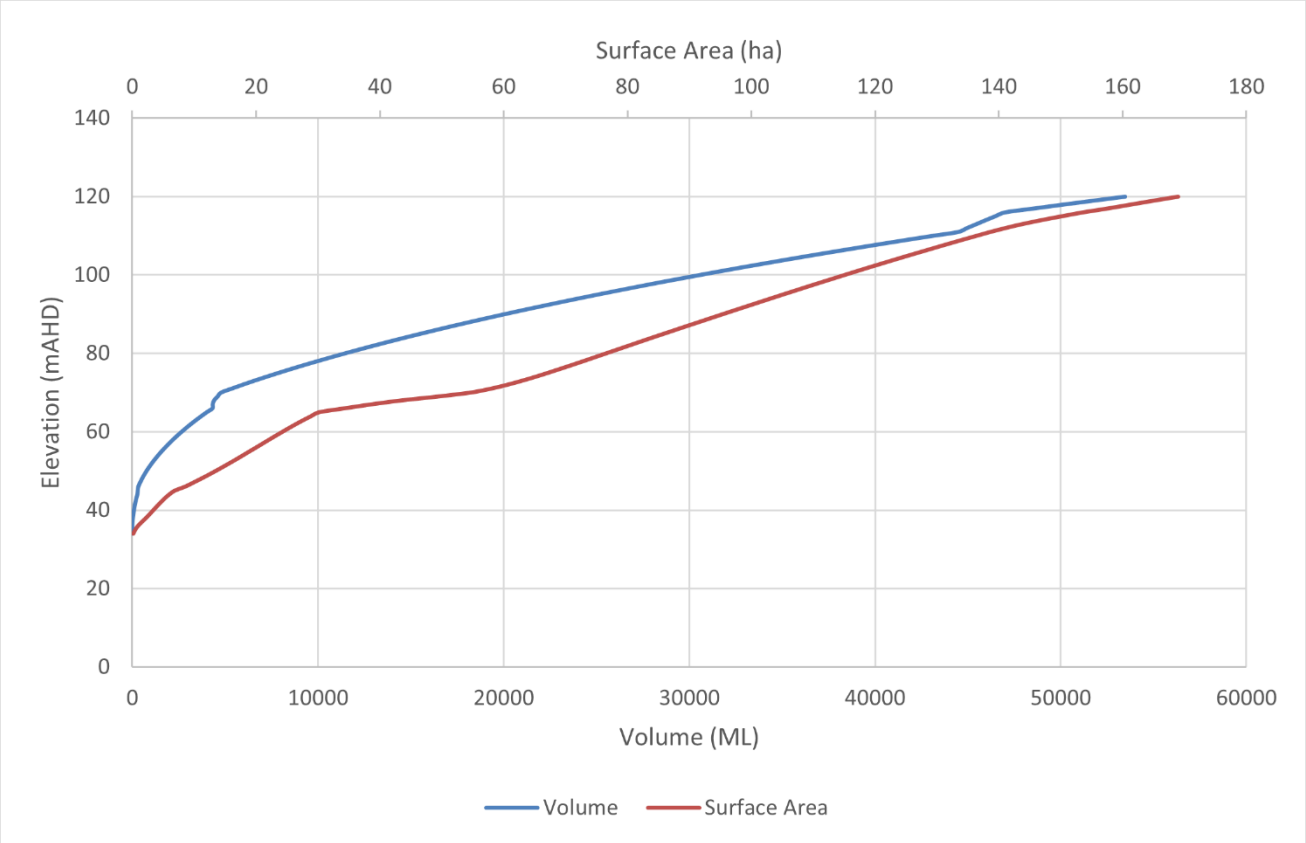



**Figure 10A** – Void X – 2

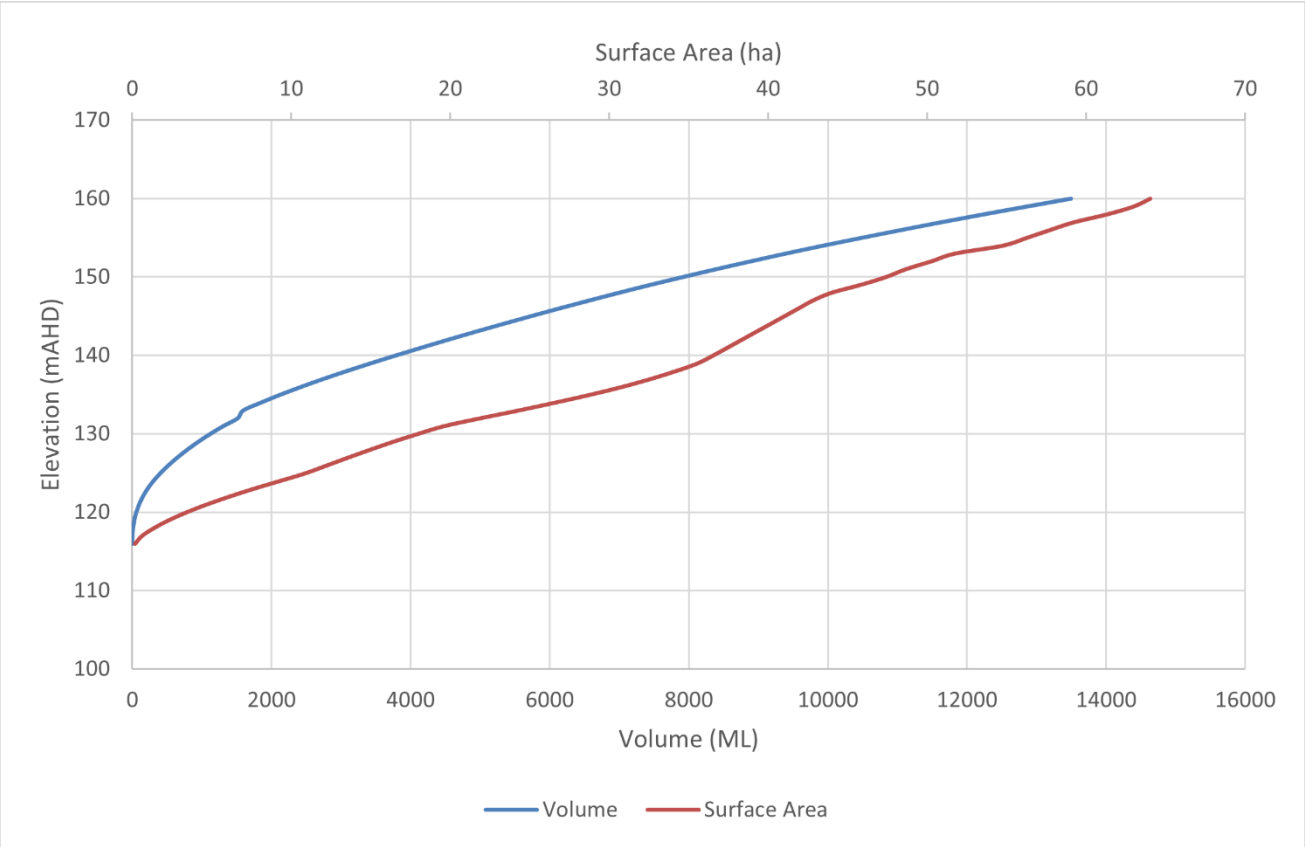



**Figure 11A** – Void Y

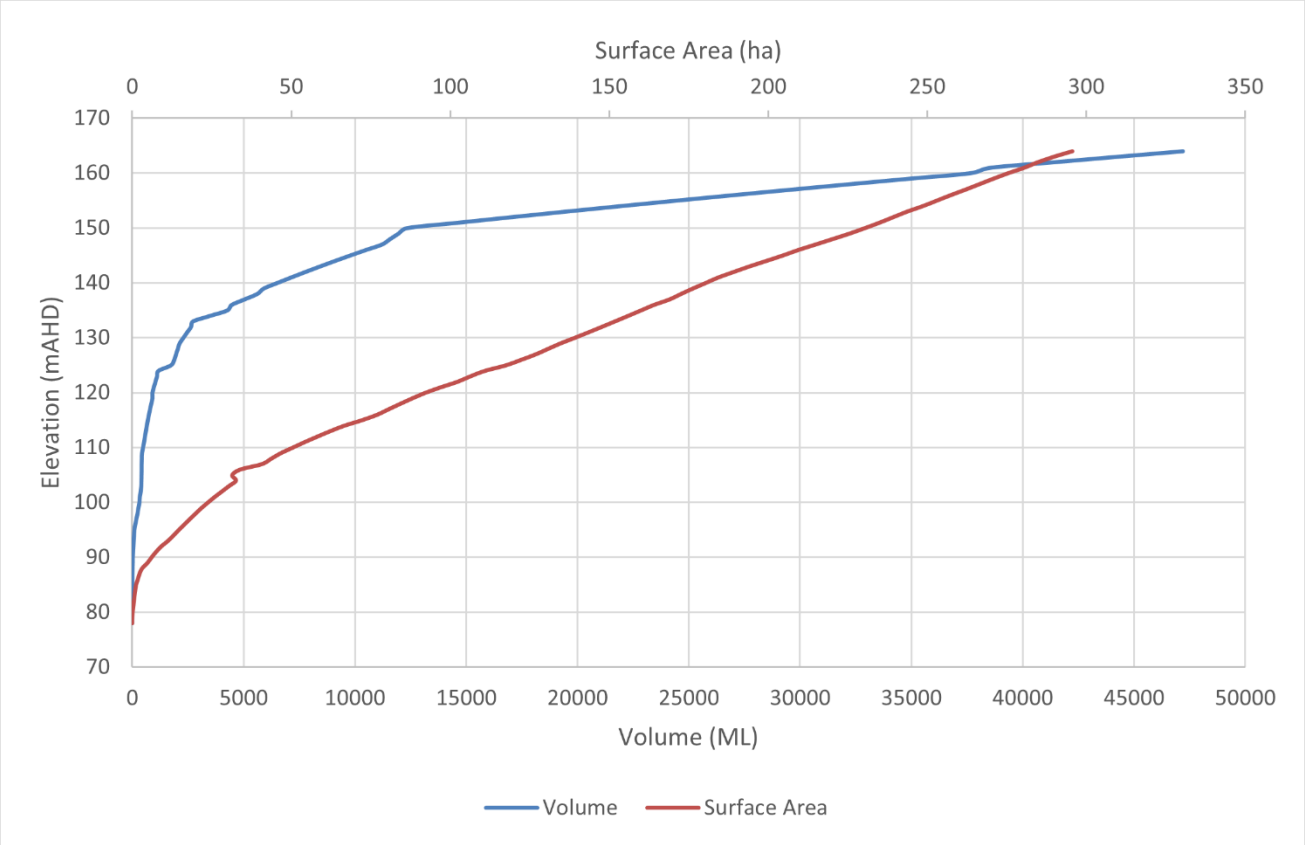



**Figure 12A** – Void Z

# APPENDIX B

Residual Void Water Levels

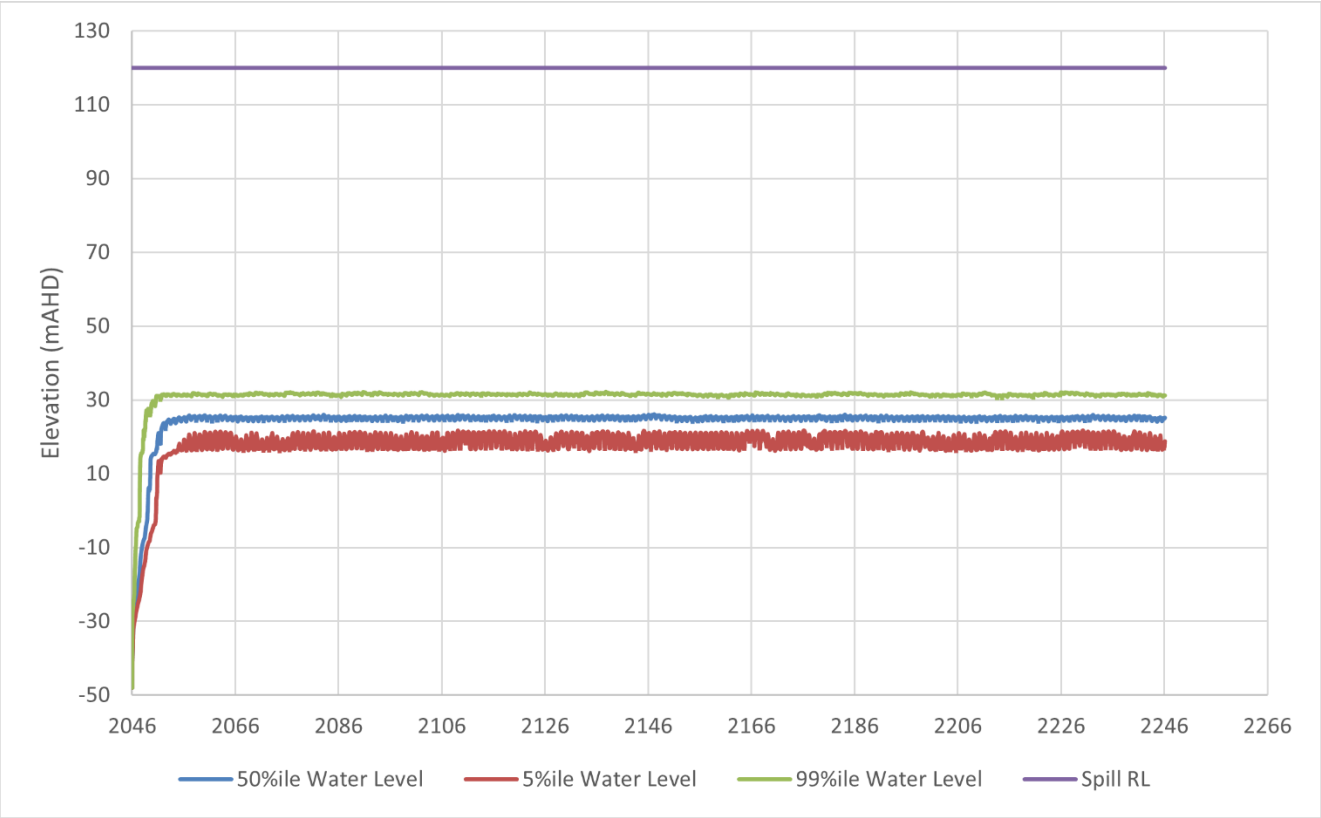



**Figure 1B** – Curragh North: Void U/T/S Final Water Level

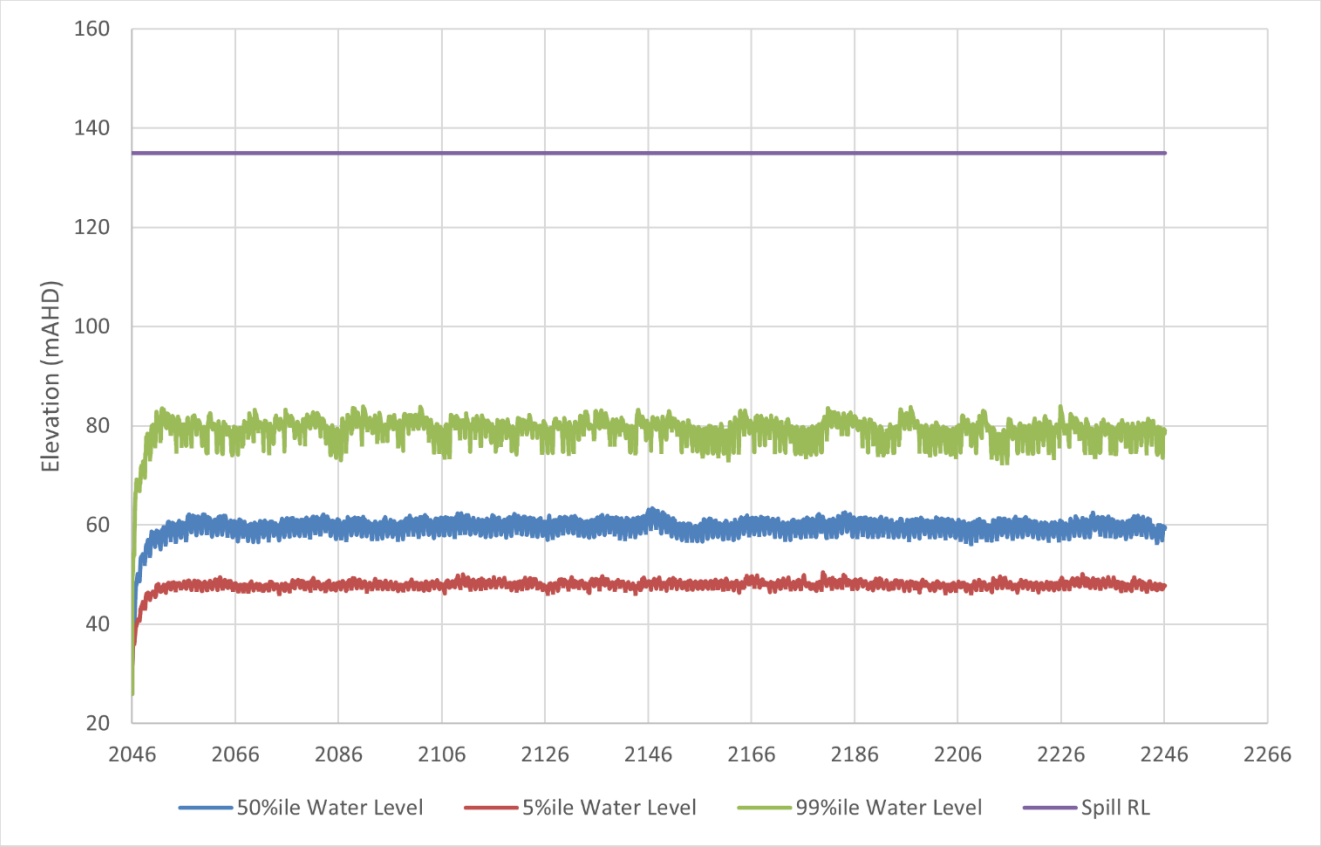



**Figure 2B** – Curragh Main: Void D/E/F Final Water Level

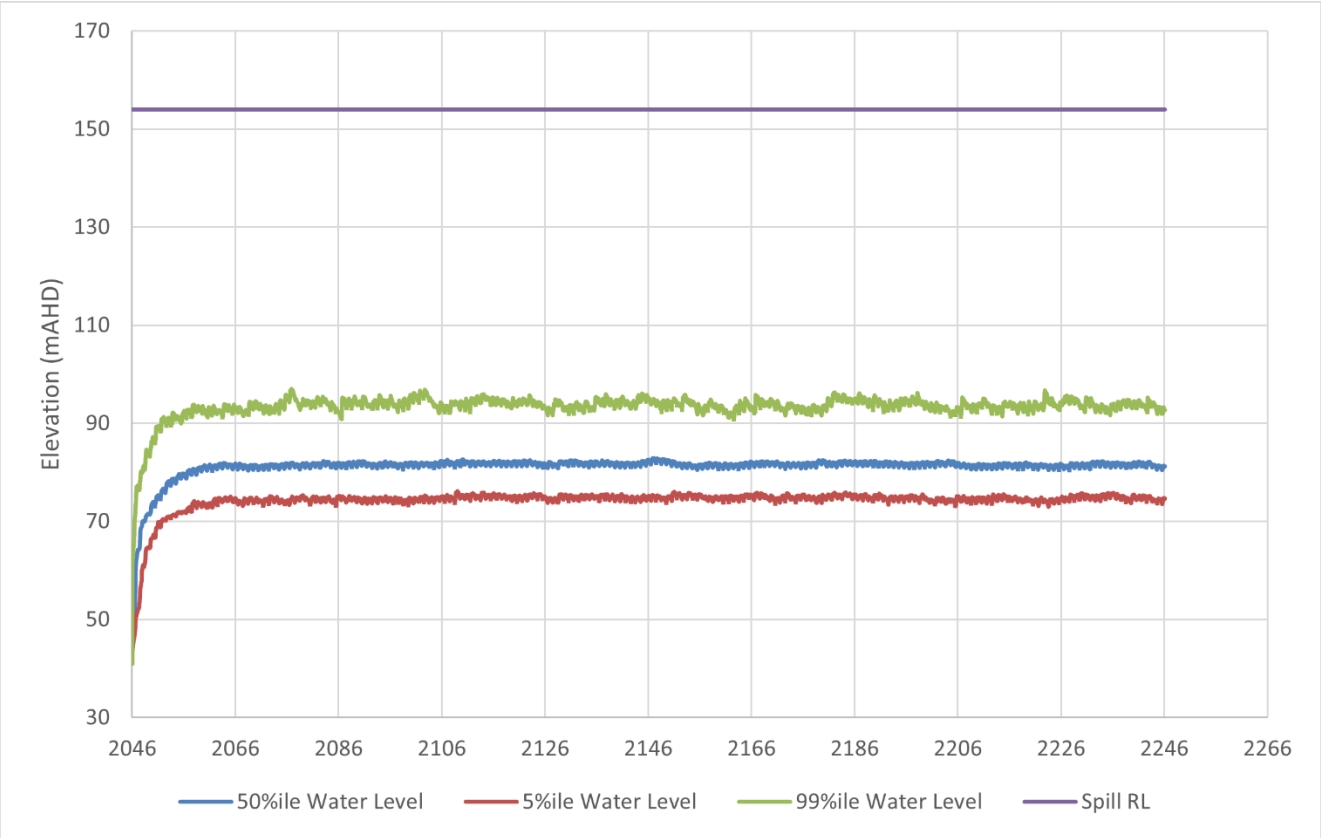



**Figure 3B** - Curragh Main: Void B/C/H Final Water Level

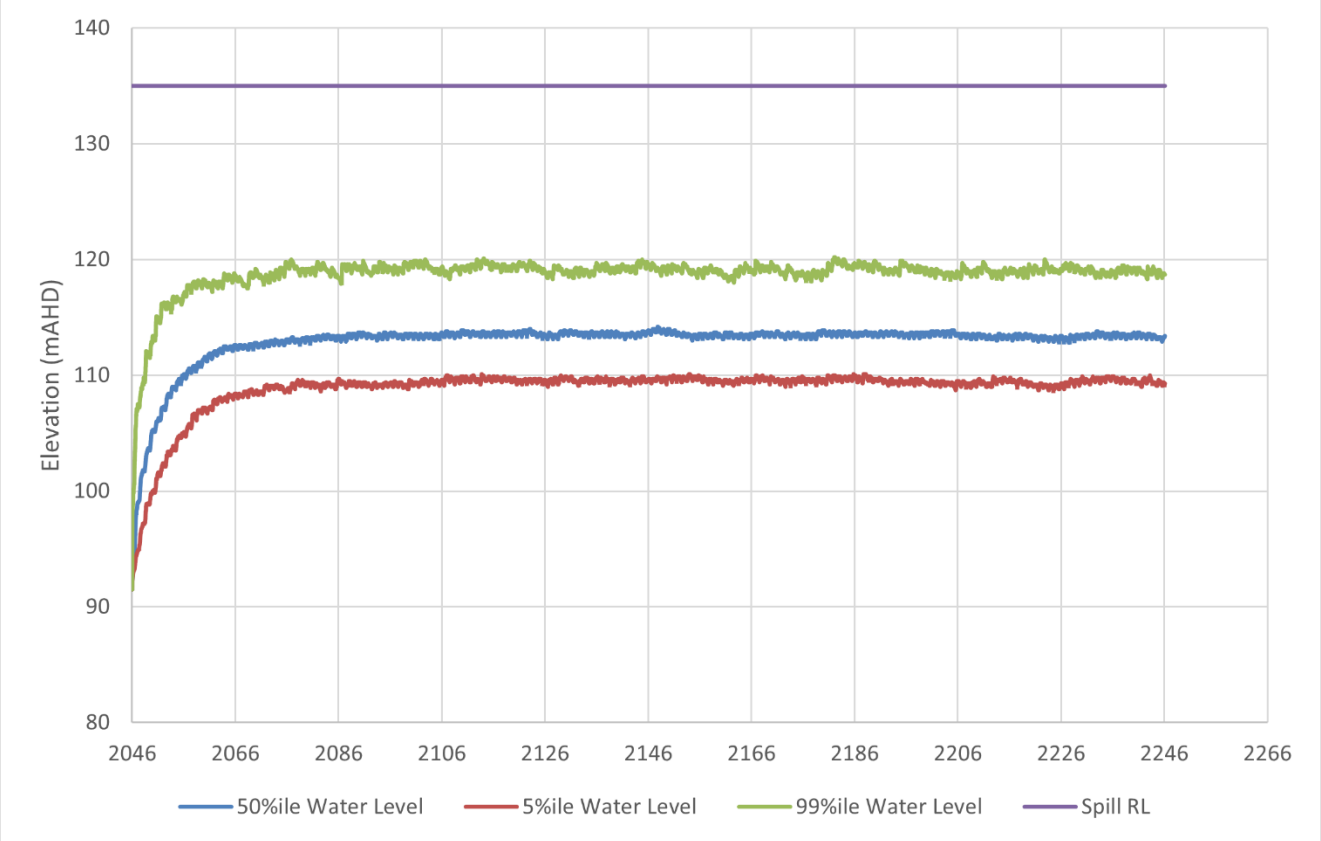



**Figure 4B** - Curragh Main: Void L Final Water Level

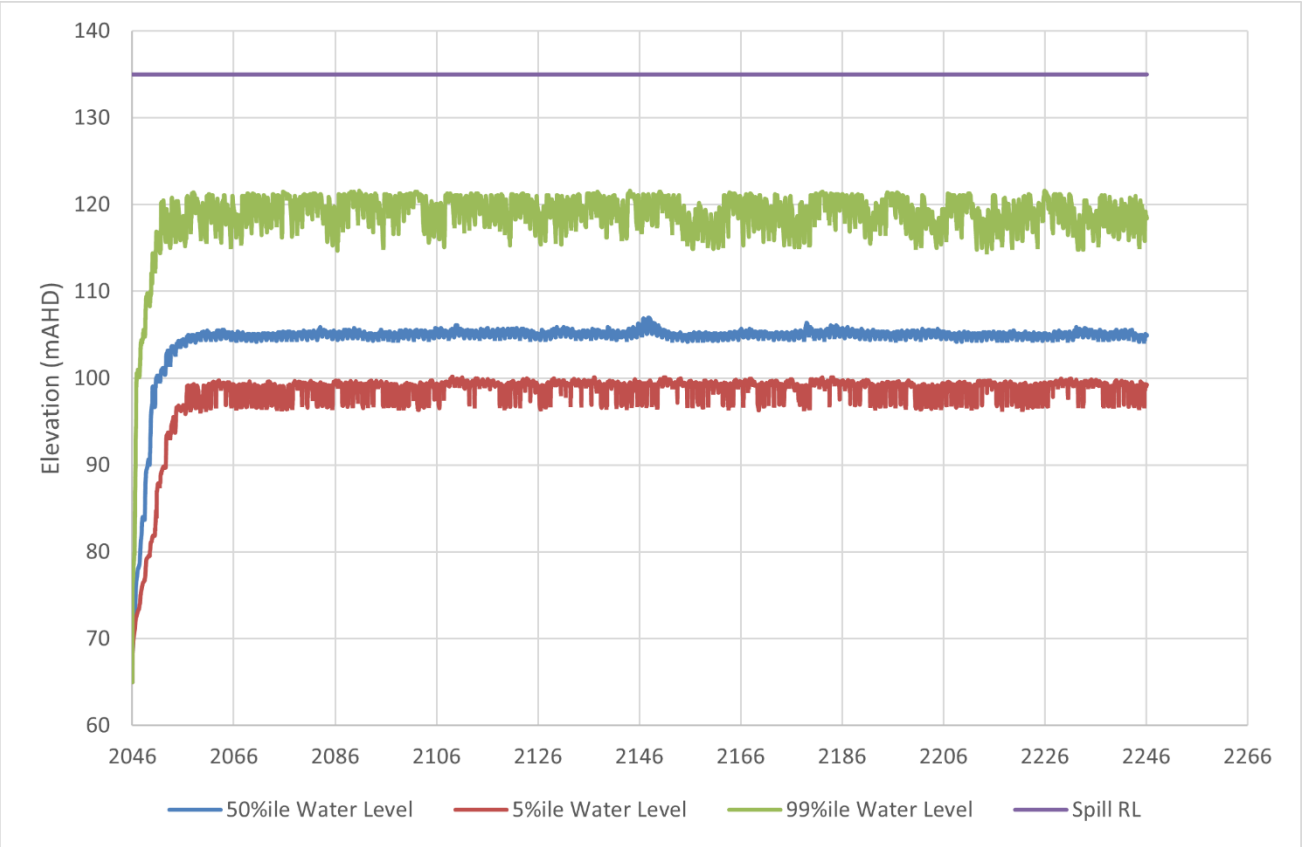



**Figure 5B** - Curragh Main: Void K Final Water Level

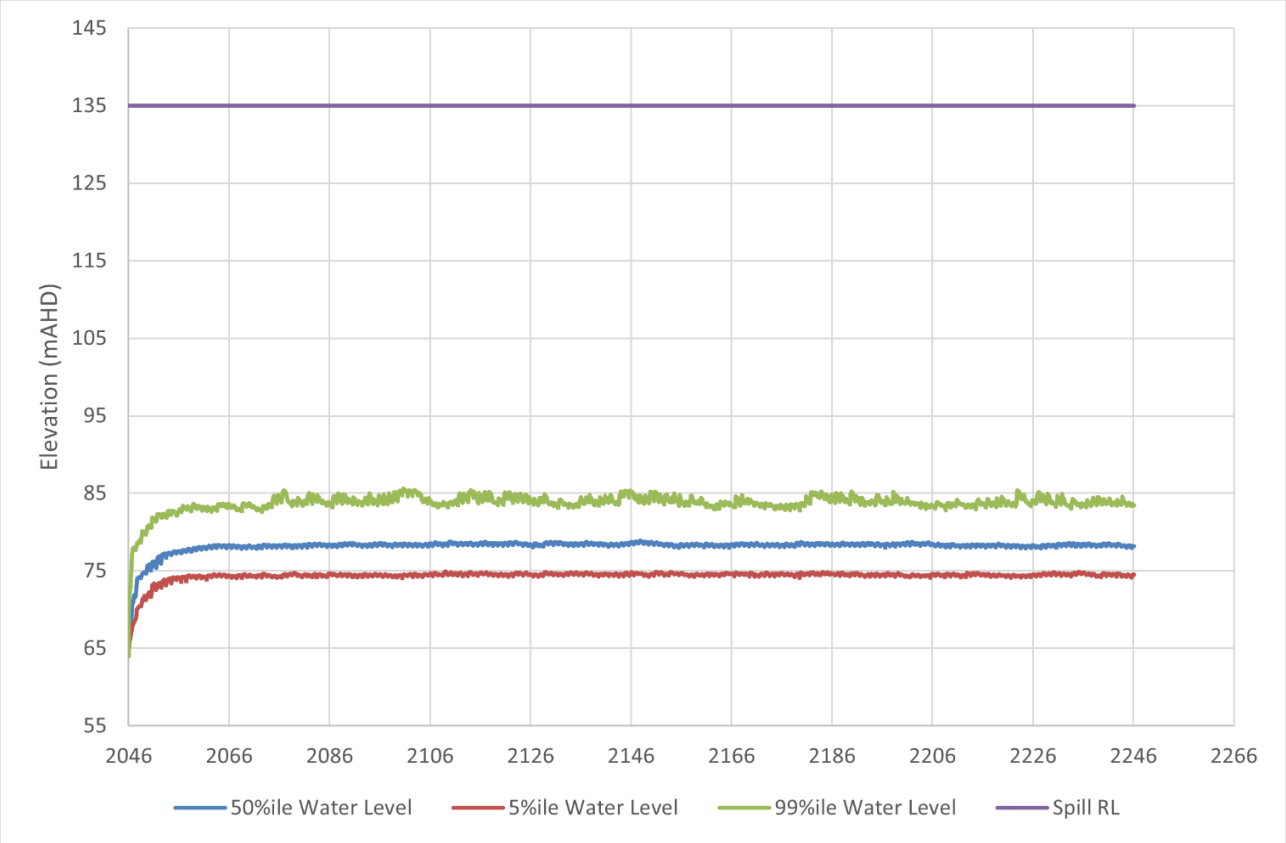



**Figure 6B** - Curragh Main: Void G Final Water Level

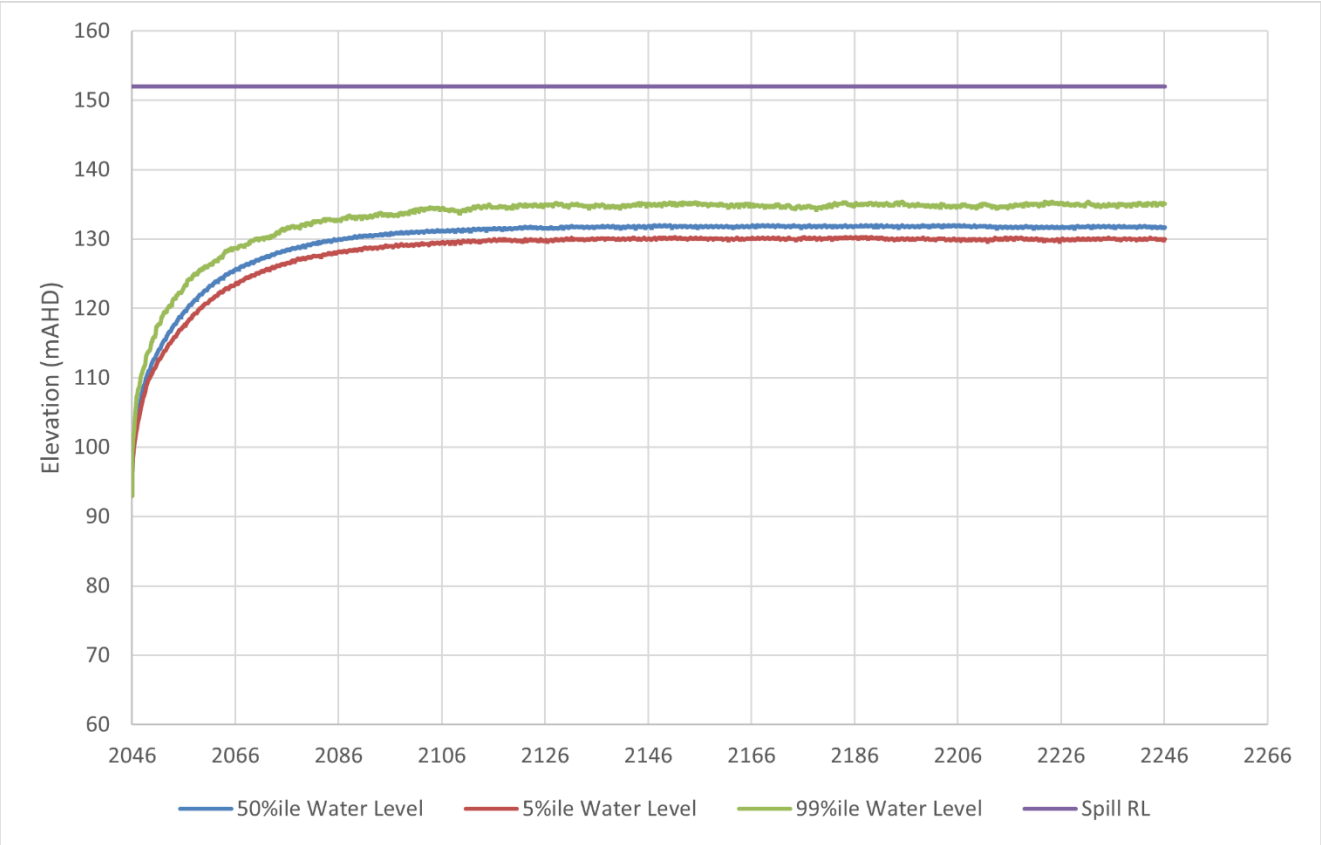



**Figure 7B** - Curragh Main: Void J Final Water Level

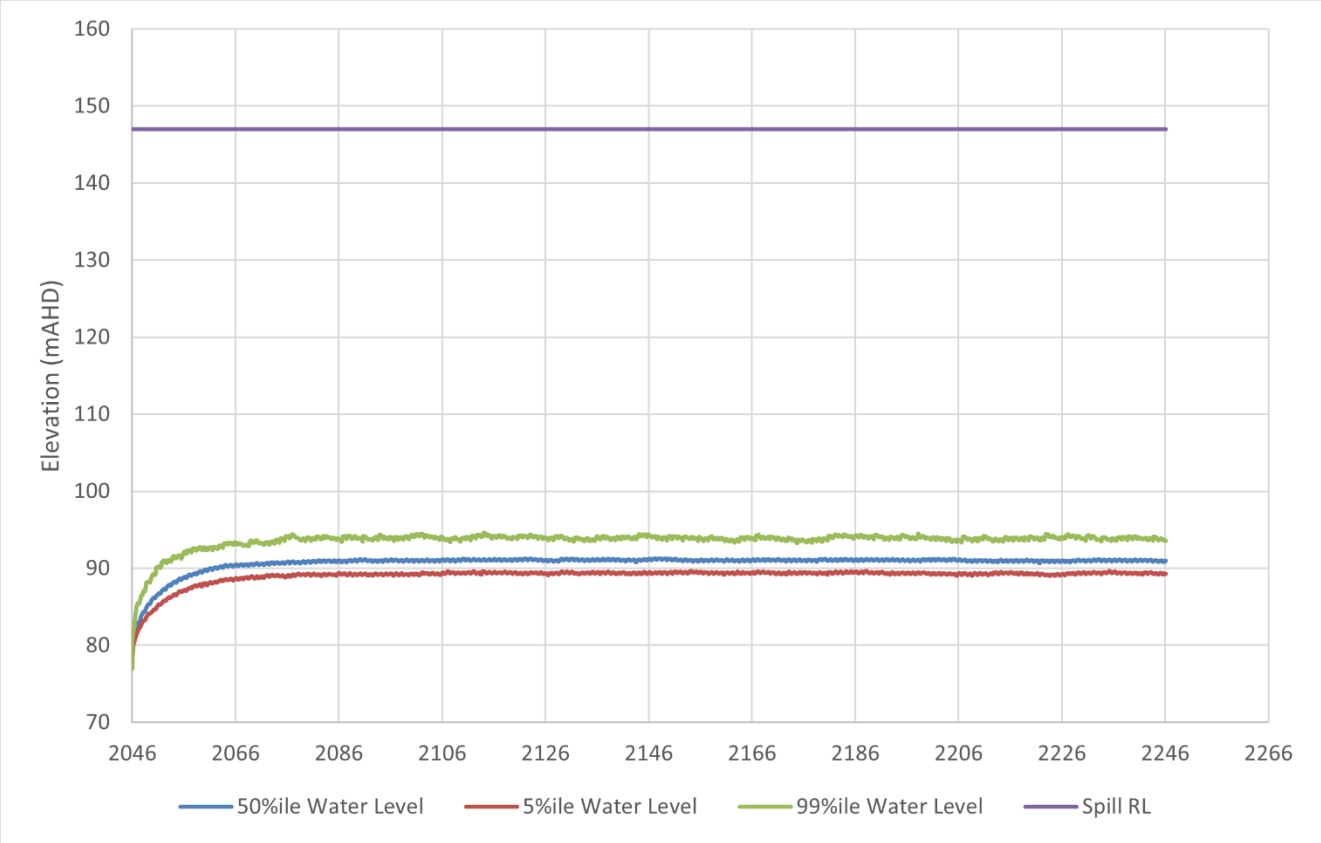



**Figure 8B** - Curragh Main: Void Ramp 9 Final Water Level

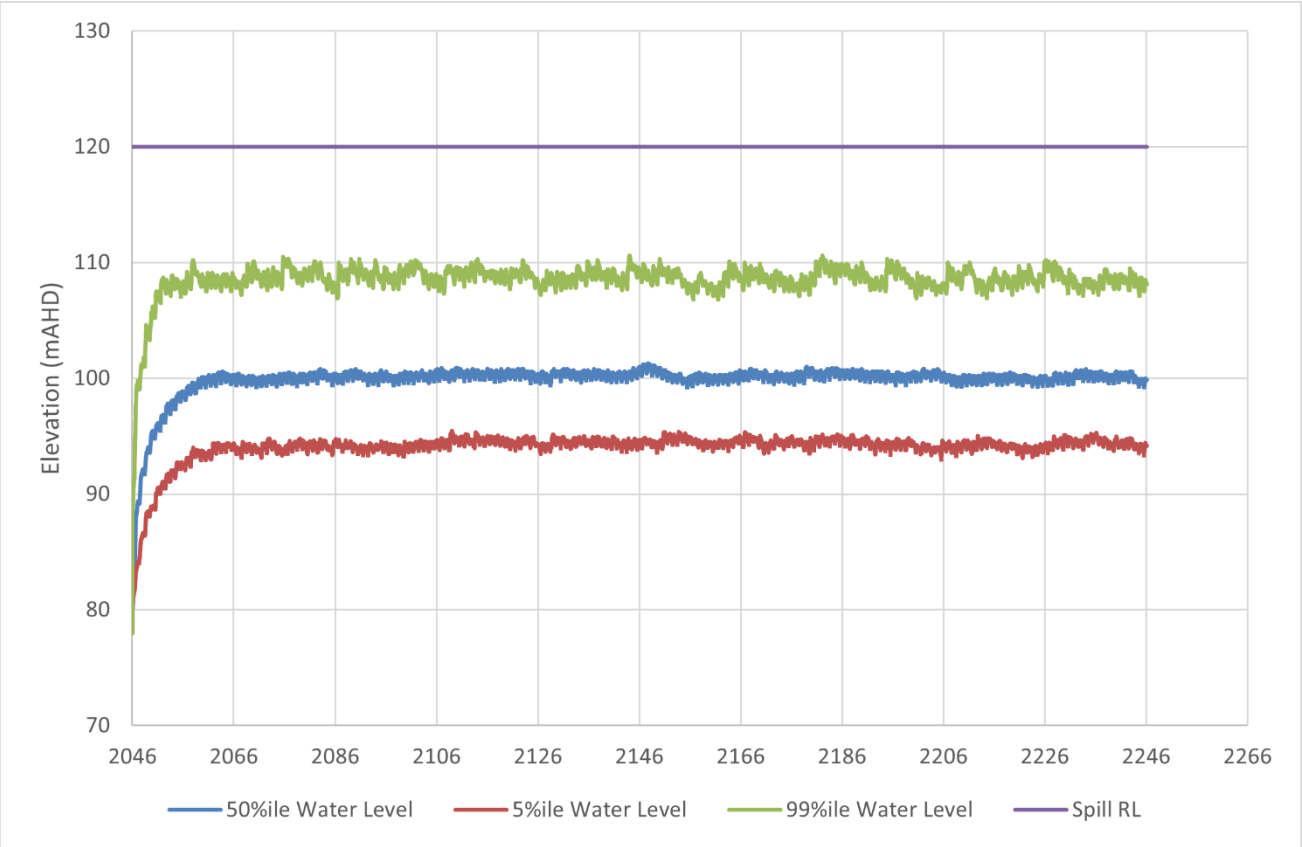



**Figure 9B** - Void X – 1 Final Water Level

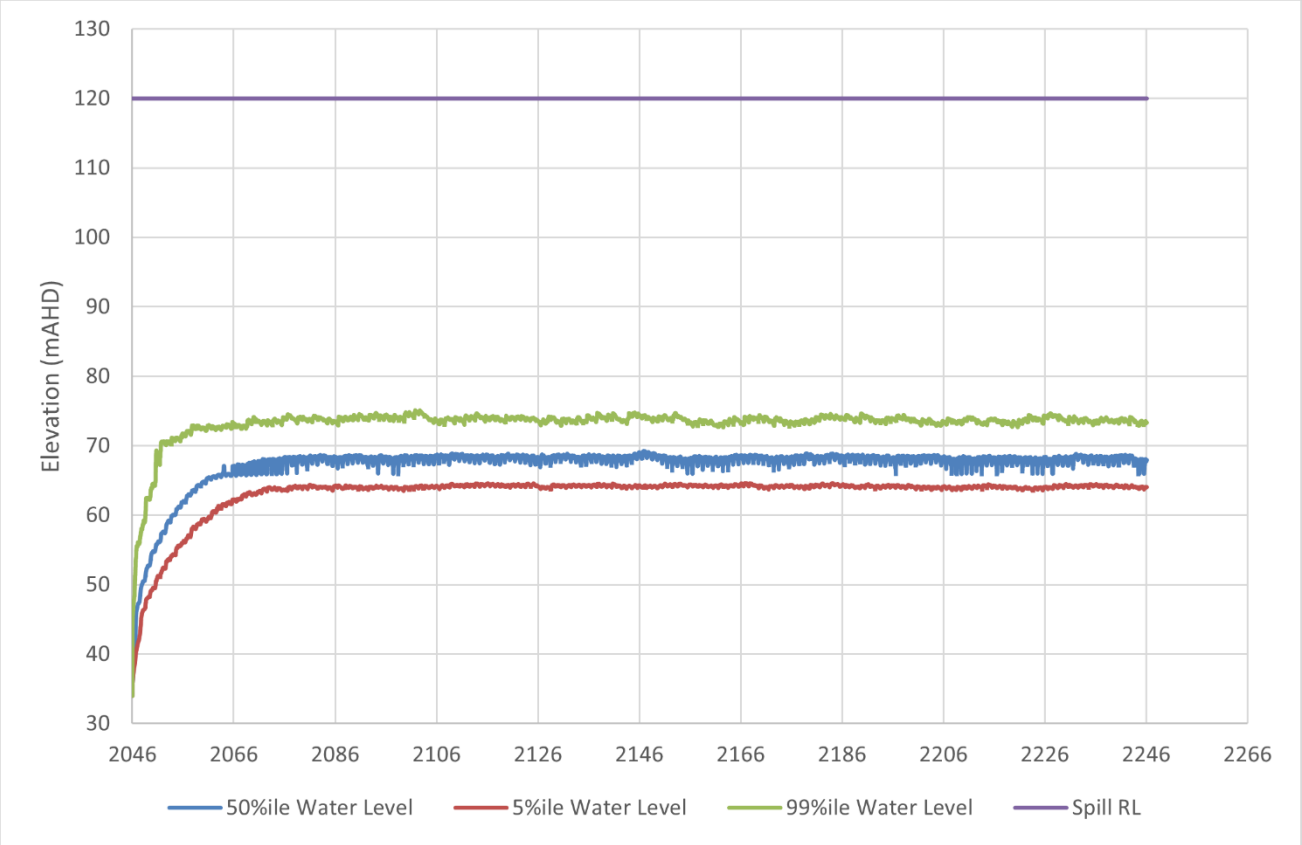



**Figure 10B** - Void X – 2 Final Water Level

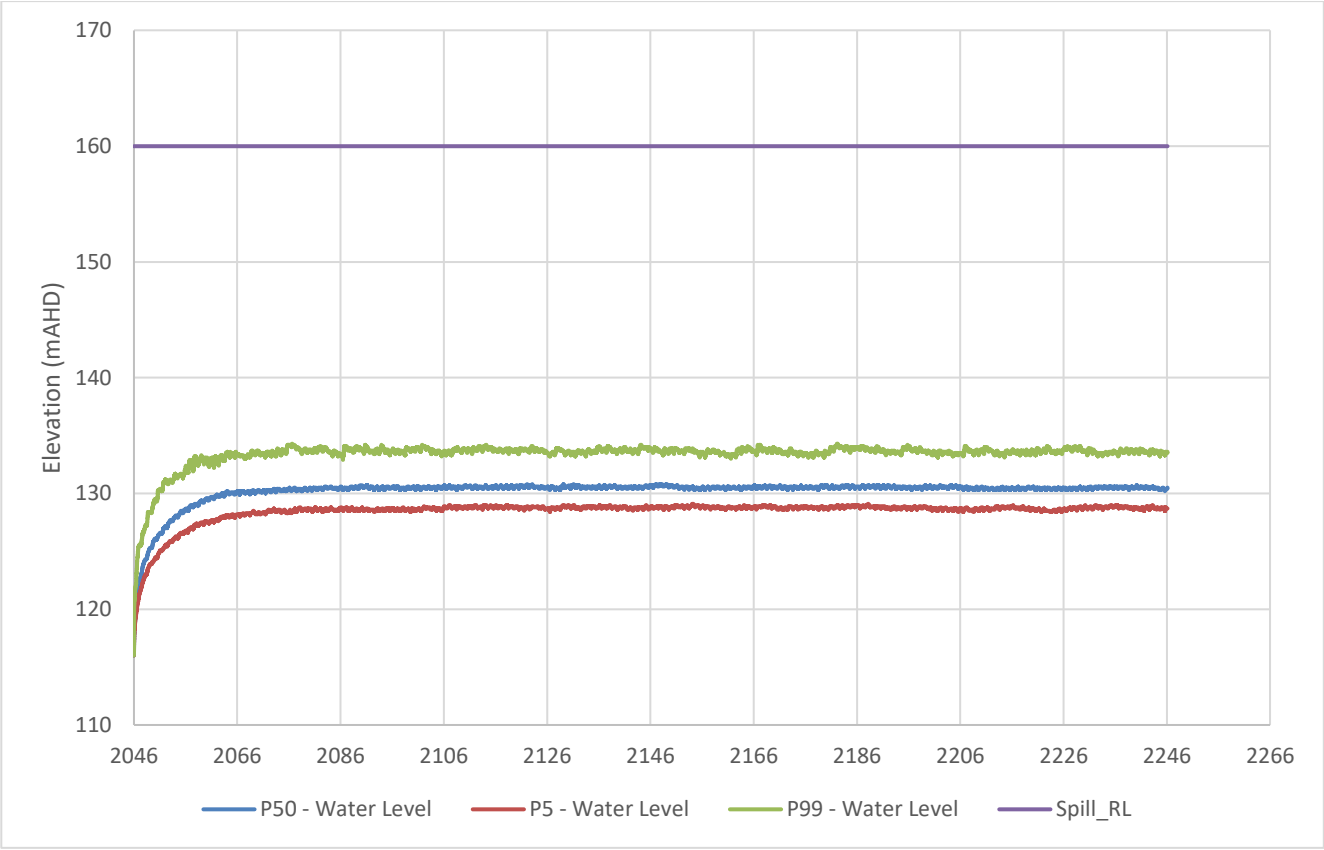



**Figure 11B** - Void Y Final Water Level

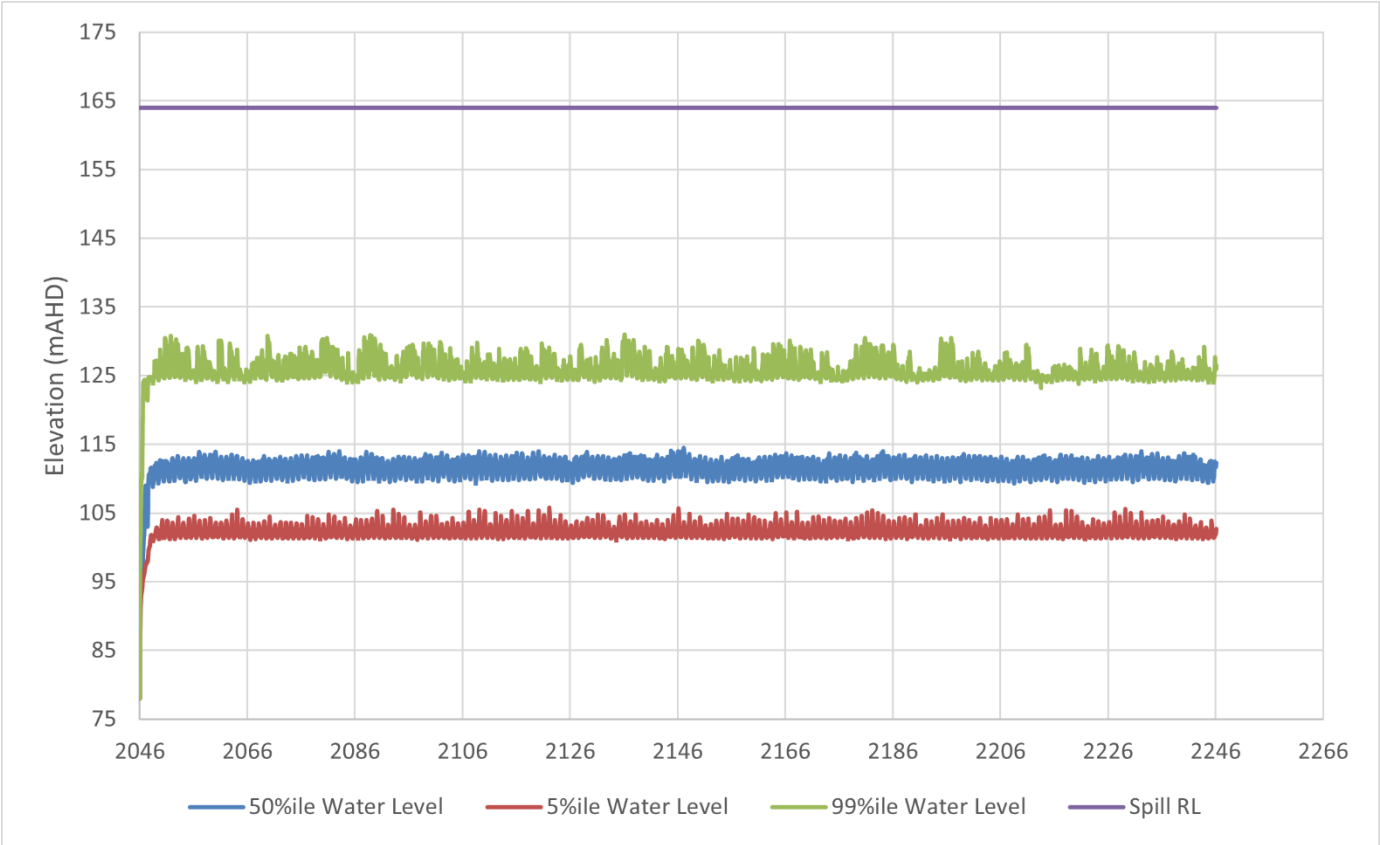



**Figure 12B** - Void Z Final Water Level

# APPENDIX C

Residual Void Water Quality

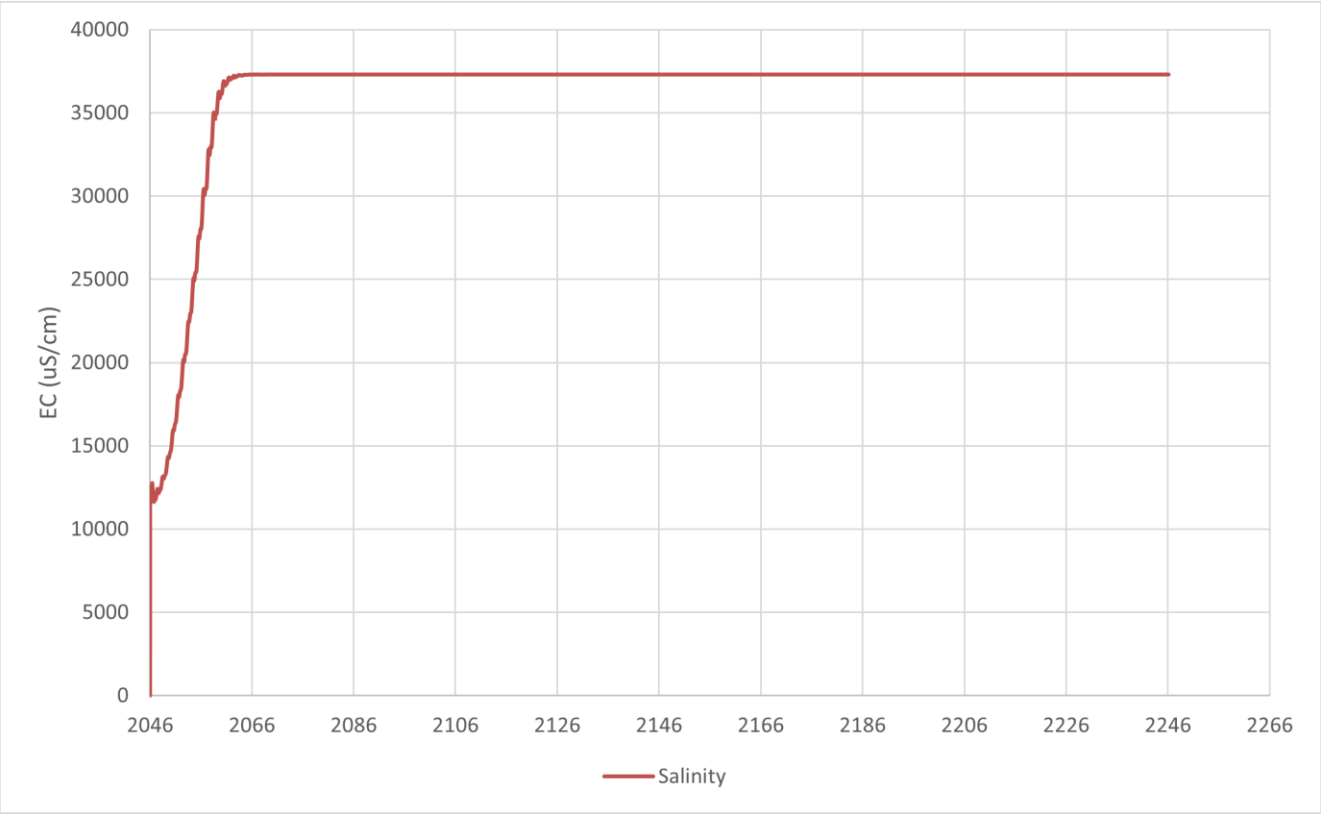



**Figure 1C** – Curragh North: Void U/T/S Water Quality

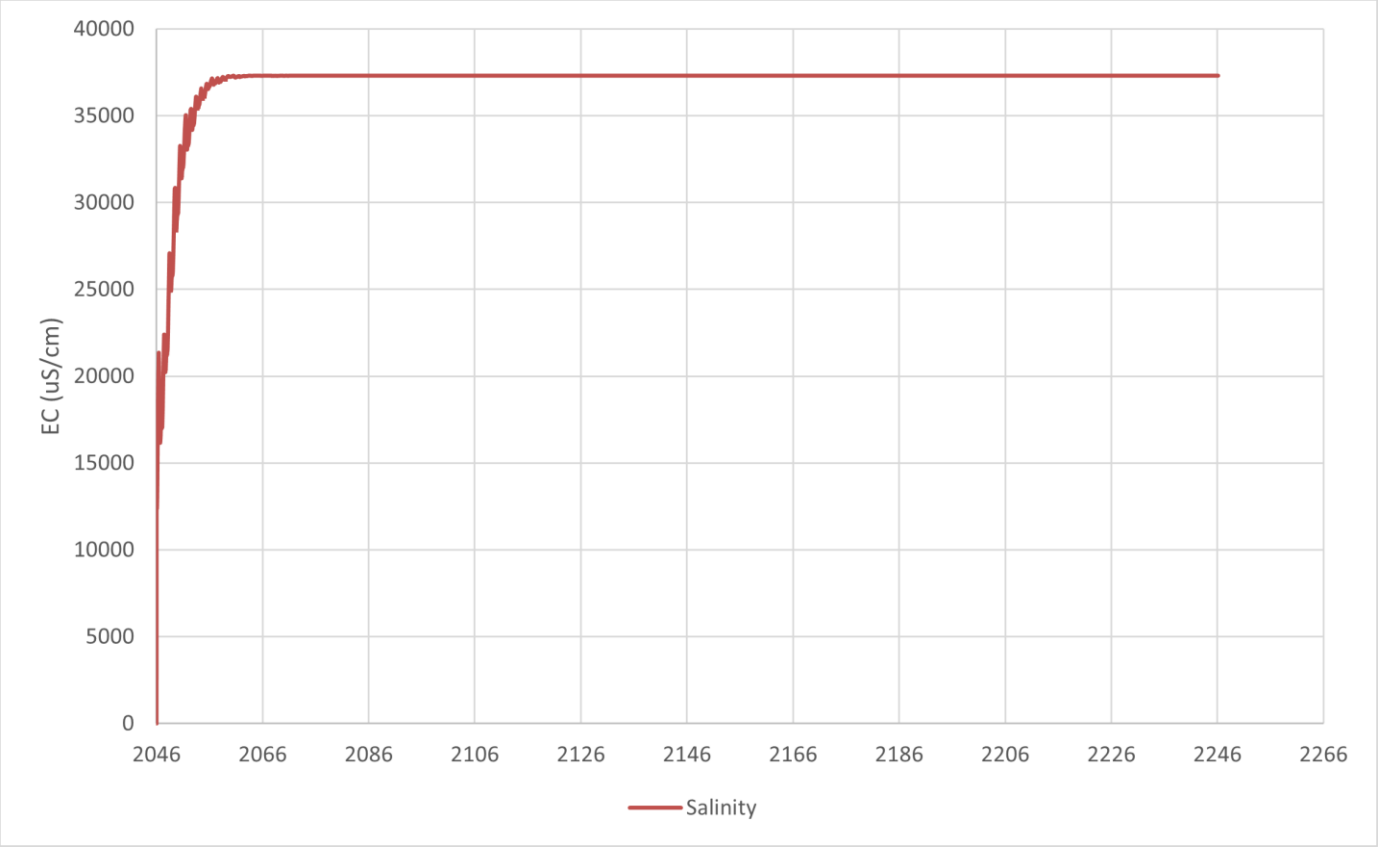



**Figure 2C** – Curragh Main: Void D/E/F Water Quality

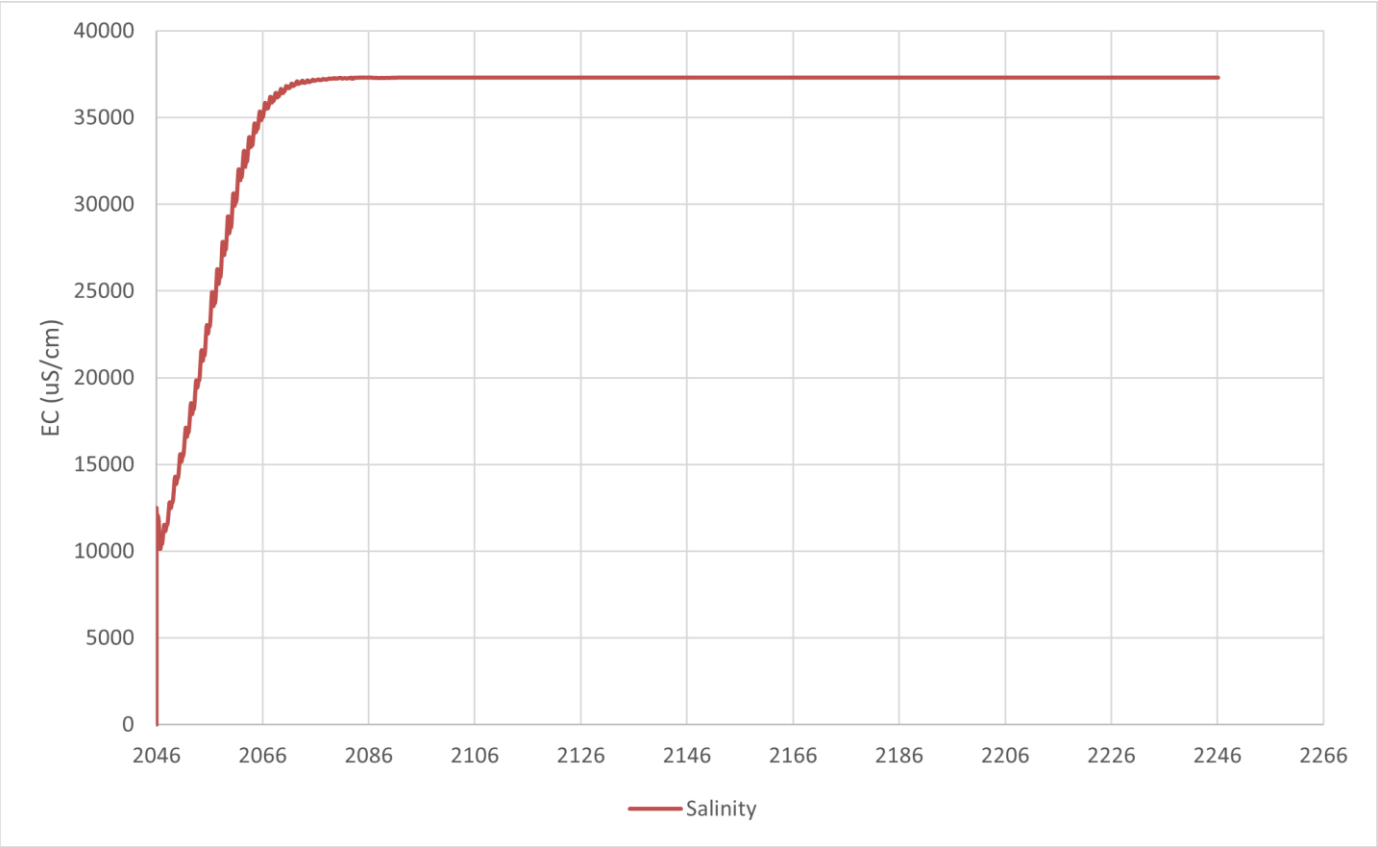



**Figure 3C** – Curragh Main: Void B/C/H Water Quality

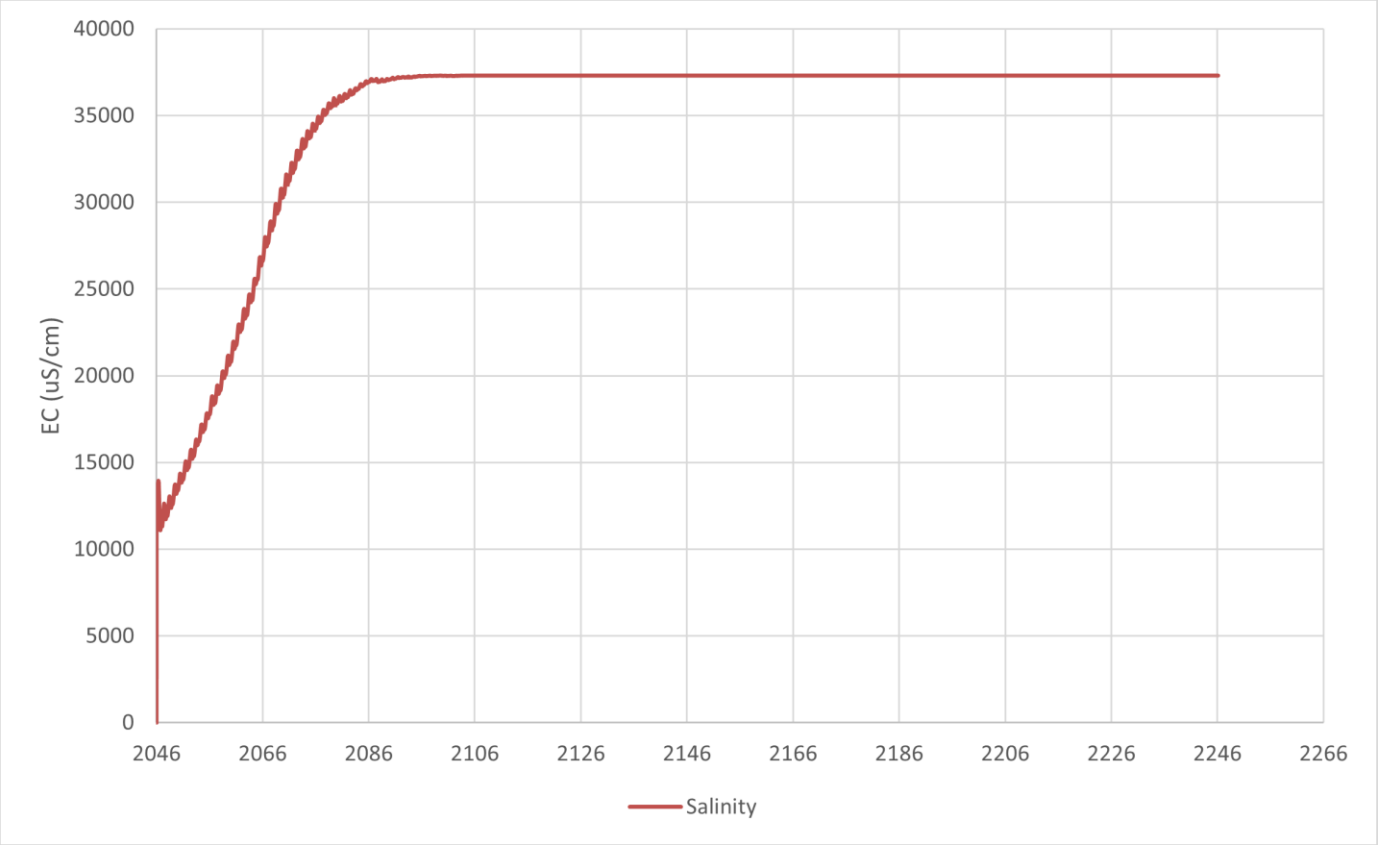



**Figure 4C** – Curragh Main: Void L Water Quality

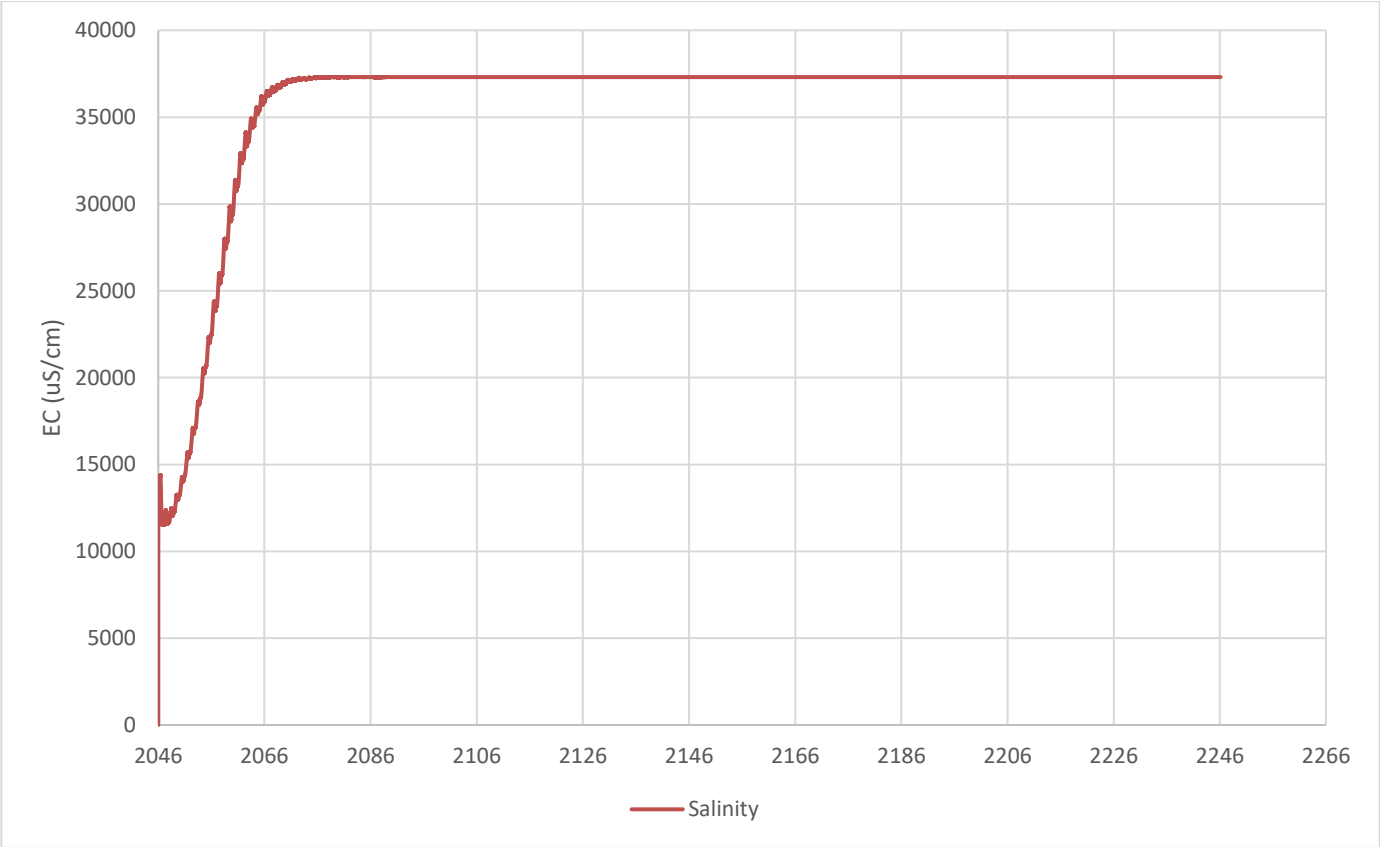



**Figure 5C** – Curragh Main: Void K Water Quality

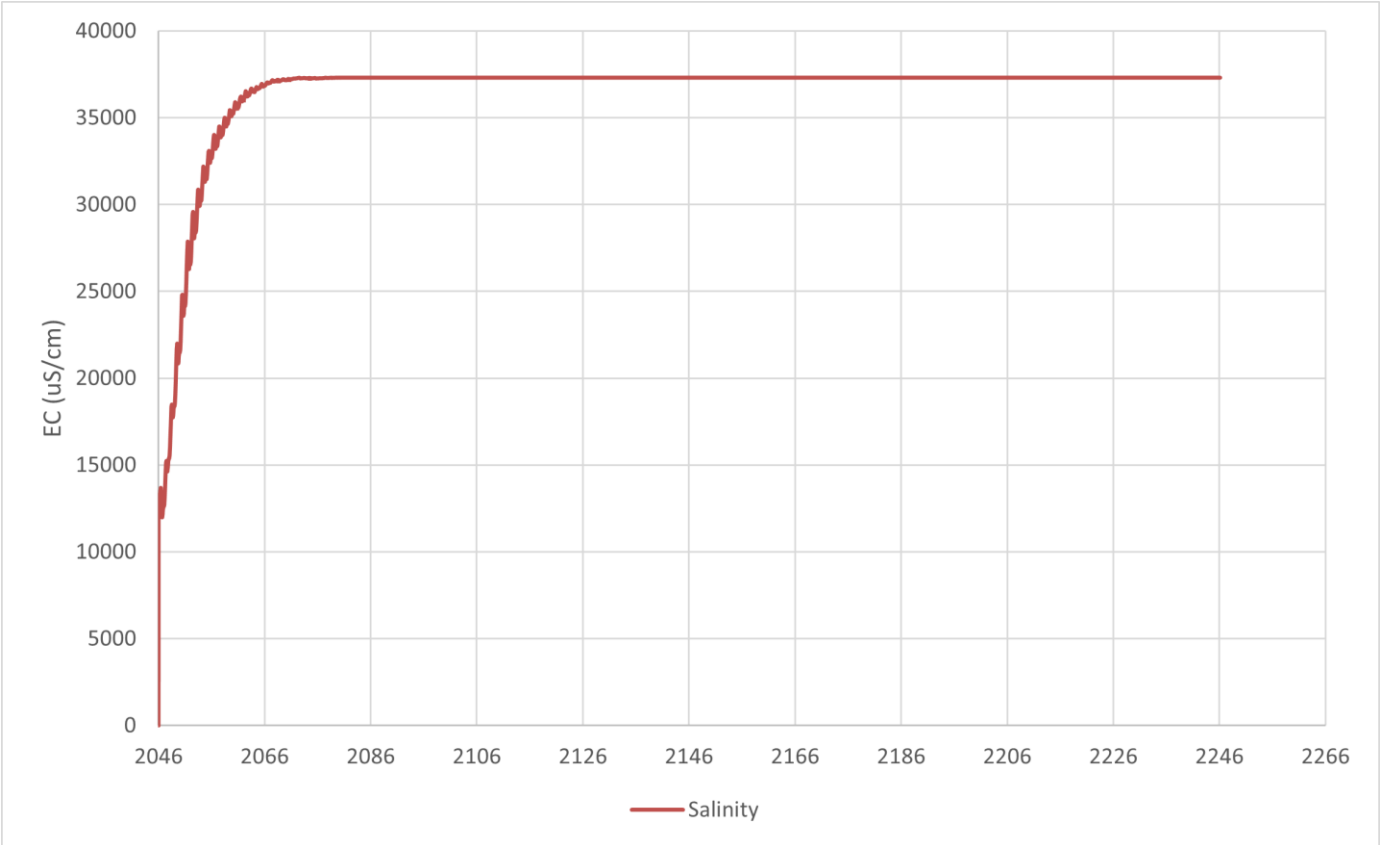



**Figure 6C** – Curragh Main: Void G Water Quality

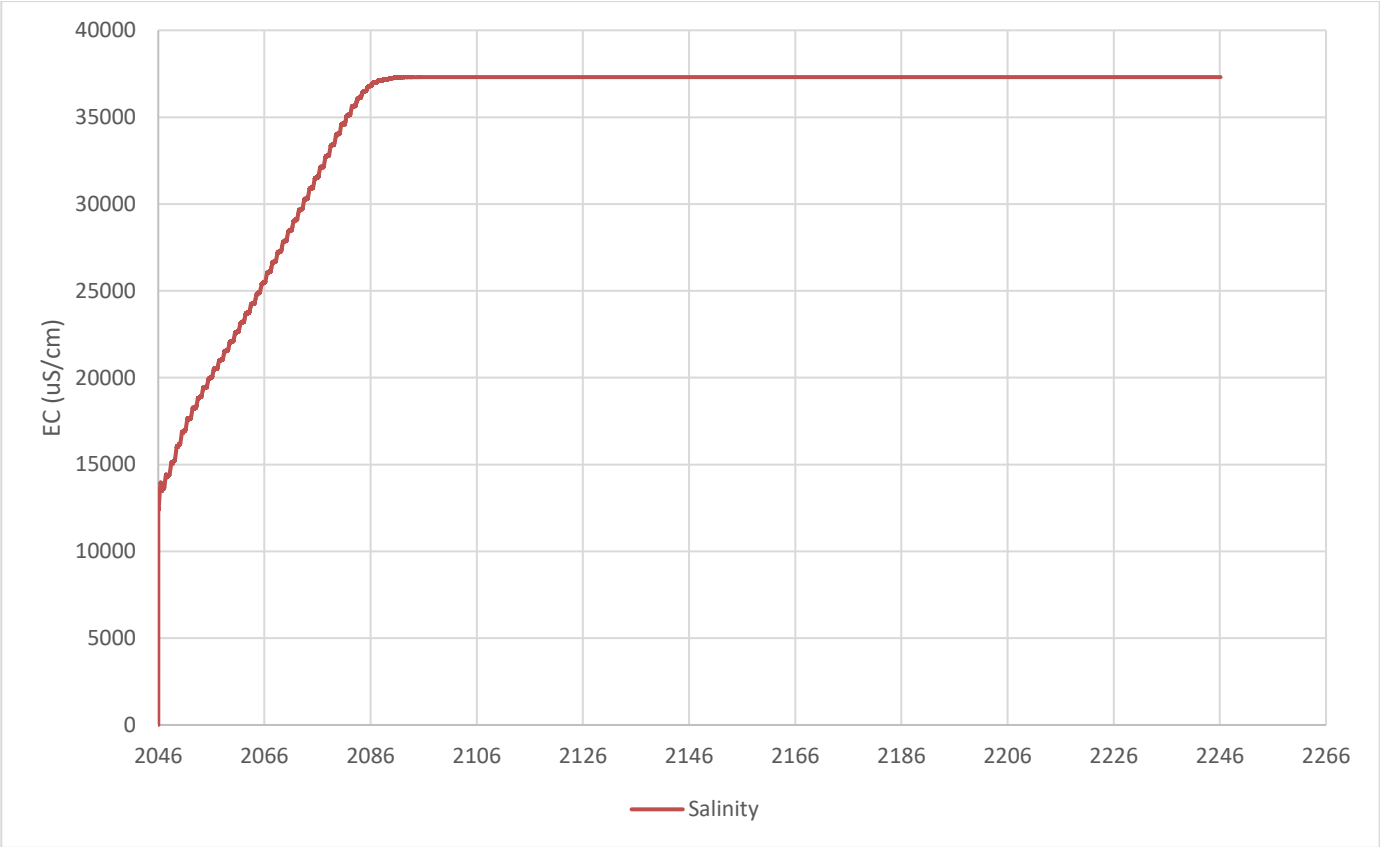



**Figure 7C** – Curragh Main: Void J Water Quality

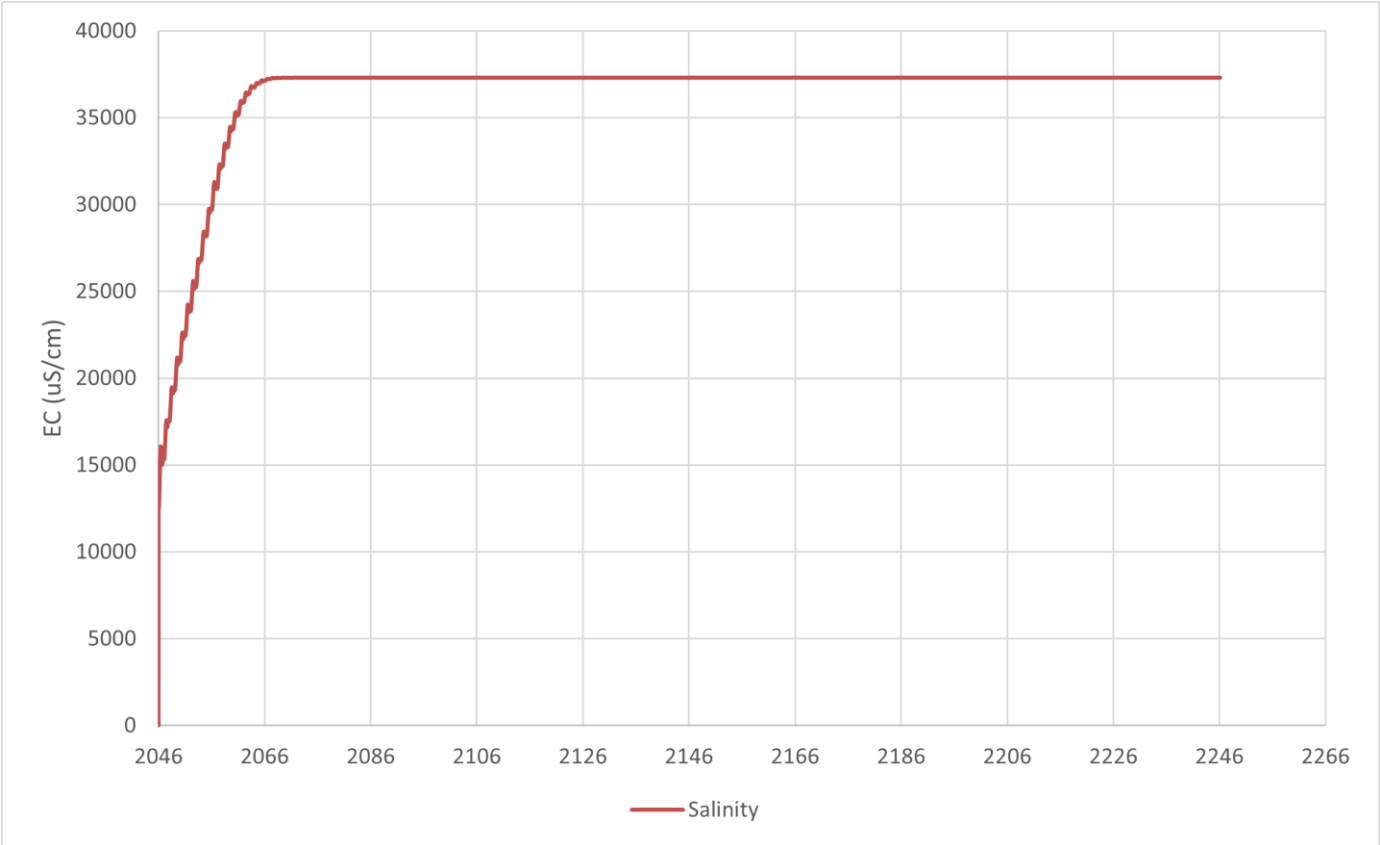



**Figure 8C** – Curragh Main: Void Ramp 9 Water Quality

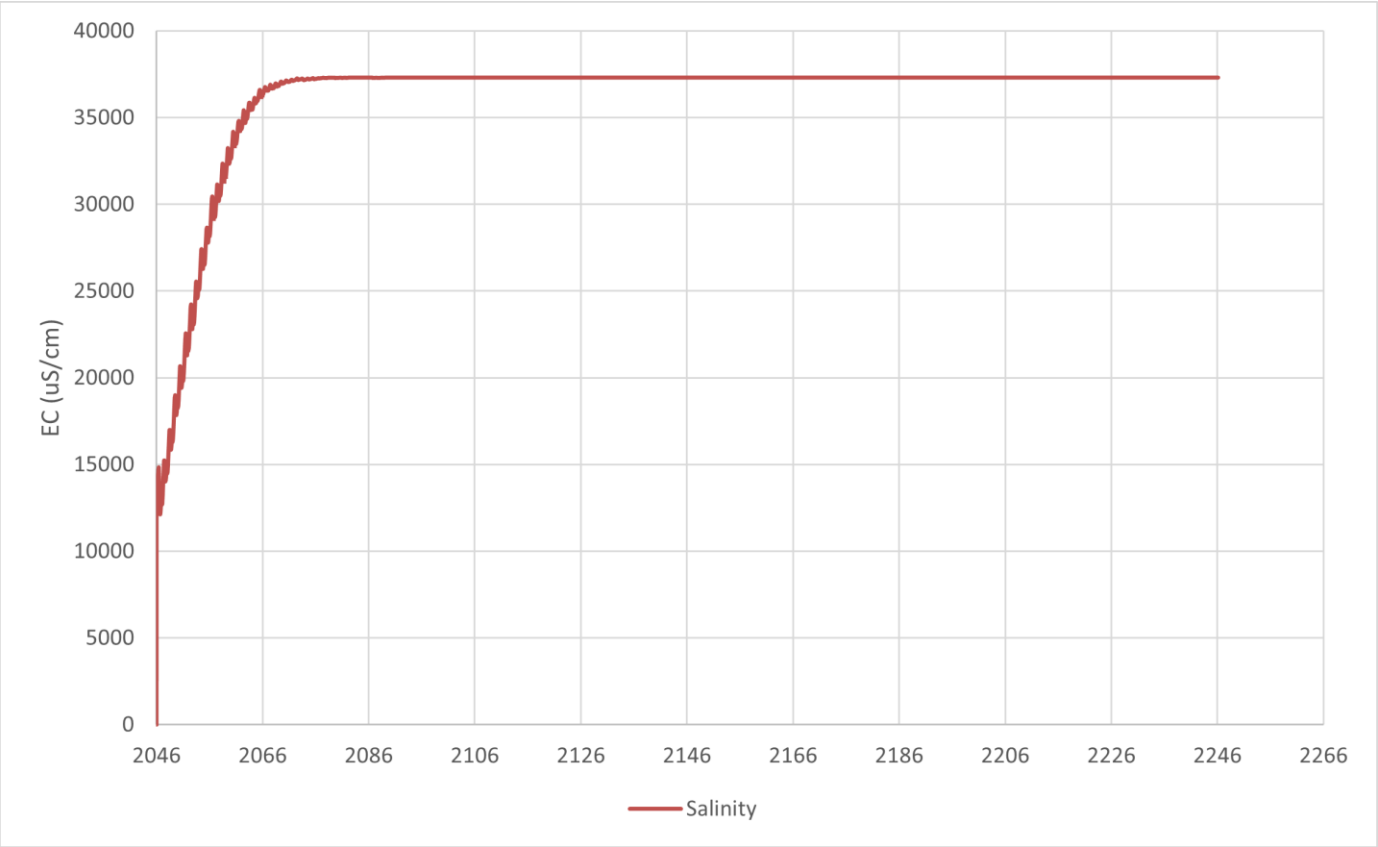



**Figure 9C** – Void X – 1 Water Quality

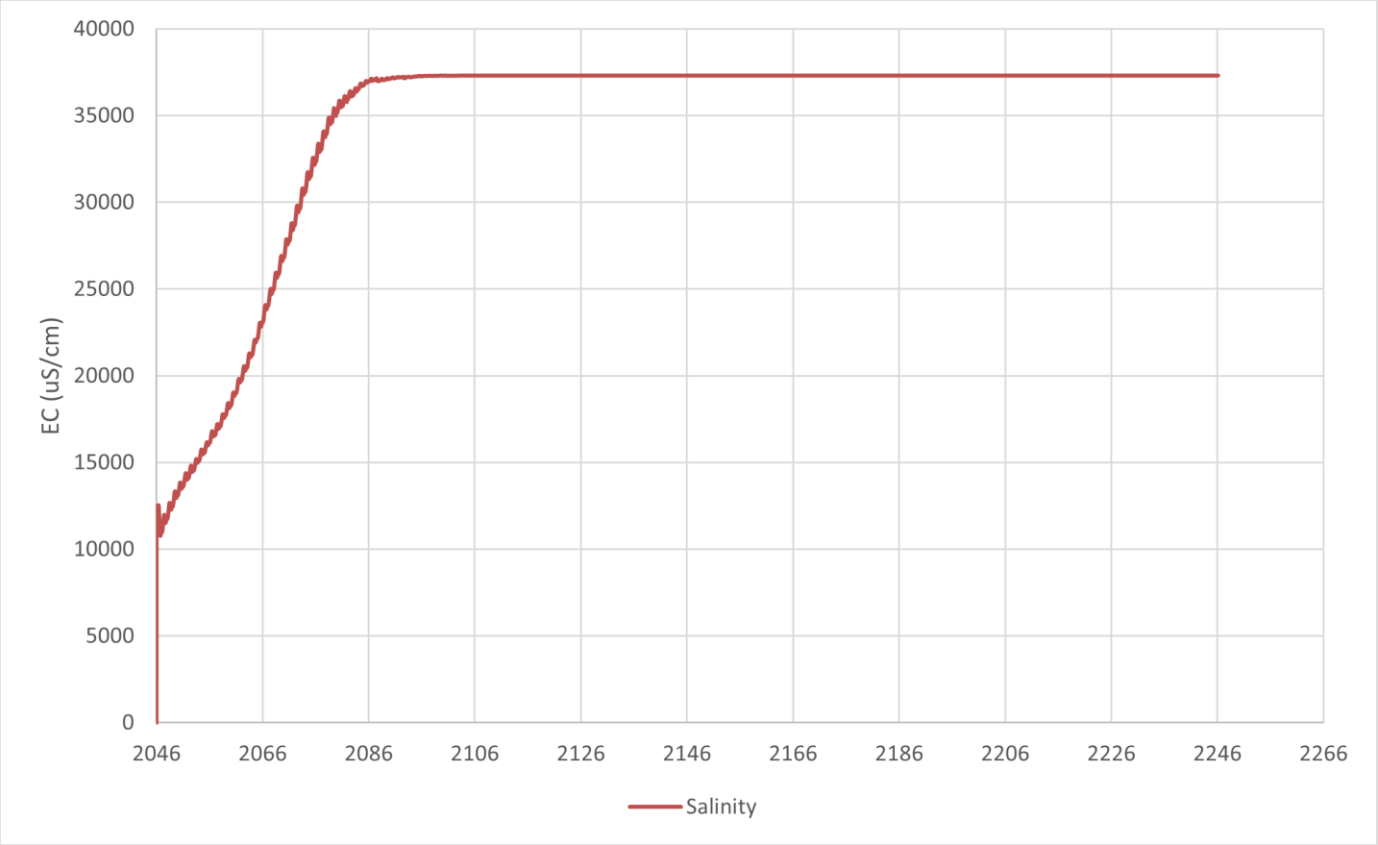



**Figure 10C** – Void X – 2 Water Quality

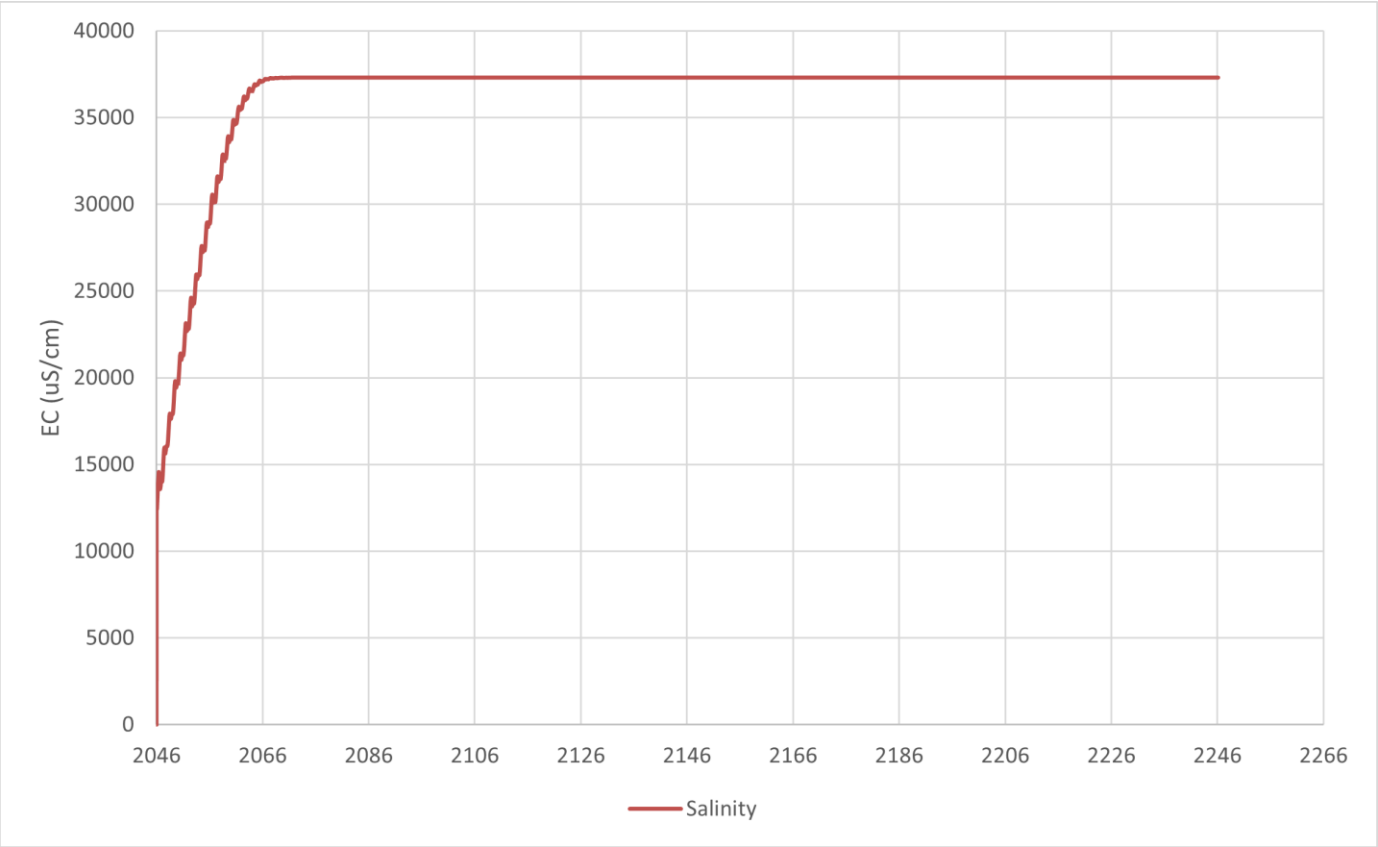



**Figure 11C** – Void Y Water Quality

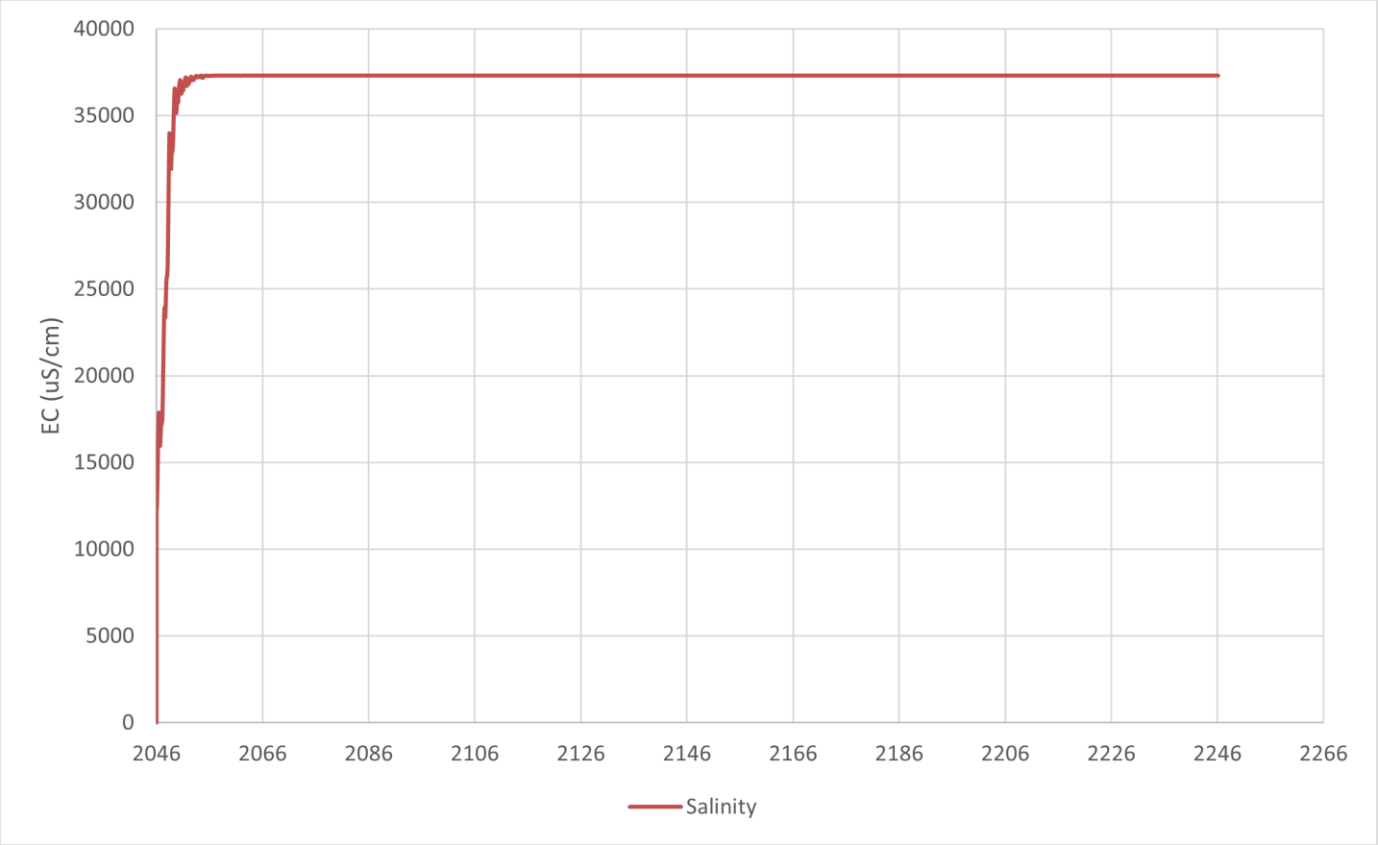



**Figure 12C** – Void Z Water Quality

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# APPENDIX D

# INITIAL GEOTECHNICAL SLOPE STABILITY ANALYSIS

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# Curragh Mine
# Final Landform Design

## Initial Geotechnical Slope Stability Analysis

**Prepared for:**

Curragh Mine
Blackwater
QLD 4717
AUSTRALIA

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# Appendices

Appendix A – Limit Equilibrium Slope Stability Analysis Outputs
Appendix B – Design Risk & Opportunities Register

# 1. Introduction

This report has been prepared by Raine & Associates (R&A) for Coronado Curragh Pty Ltd (CCPL) in relation to their Curragh Coal Mine (Curragh). This report presents the results of initial two-dimensional limit equilibrium slope stability analyses undertaken by R&A in relation to the final landform designs developed for Curragh.

## 1.1 Purpose

The purpose of this report is to assist CCPL, as part of the Curragh Planning System (CPS), identify, assess, manage, and document pre-emptively, potential geotechnical hazards associated with the longer-term slope stability of the Curragh final landform designs.

Qualifications and Limitations associated with the work presented in this report are provided in Section 8.

## 1.2 Available Data

The following data was made available by CCPL (Table 1-1).

*Table 1-1 Supplied Data*

| Data Name and Format | Supplier | Comment |
|---|---|---|
| 20200922.dhd | CCPL | Vulcan dataset of Geobank Output |
| CN Pit 20211101.dxf | CCPL | DXF contour model of the Curragh North final landforms |
| X Pit 20211030.dxf | CCPL | DXF contour model of the X Pit final landform |
| Y Pit 20211101.dxf | CCPL | DXF contour model of the Y Pit final landform |
| Z Pit 20211030.dxf | CPPL | DXF contour model of the Z Pit final landform |
| CM Pit 20211103b 2m.dxf | CCPL | DXF contour model of the Curragh Main final landforms, using 2m contours |
| CM Pit 20211103b half m.dxf | CCPL | DXF contour model of the Curragh Main final landforms, using 0.5m contours |
| CN Mining Surface 20211102.dxf | CCPL | DXF model of the Curragh North final mining surface, prior to remediation |
| 2020Aug_LT_WOA_PublishedMOdel | CCPL | Life of Mine grids, inclusive of all coal seams and unconformable |
| Ramp 9 | CCPL | A directory of Vulcan layers for Ramp 9, inclusive of powerlines, infrastructure, permanent roads, waterways and pit shell |
| 210621.dhd.isix & .isis | CCPL | Borehole database for all of Curragh |
| 0684-08-C1_FloorStudyDesignReport.pdf | WRM | Flood study for northern levee design – Jellinbah Mackenzie North Pit |
| 211014 – pit shell plus dumps 0.5m contours.dxf | CCPL | DXF contour model of Y Pit final pit shell, including dumps, using 0.5m contours |
| 211014 – void and footprint outlines.dxf | CCPL | DXF model of void and footprint outlines for Y Pit |
| 1532295-052-R-Rev3-PitB-Design-Plan FINAL 20171124.pdf | CCPL | B Pit tailings storage facility design plan |

| Data Name and Format | Supplier | Comment |
|---|---|---|
| 2172961A-GEO-REP-002 RevB.pdf | CCPL | Geotechnical investigation and assessment for capping, Curragh Coal Mine – Old Tailings Dam Rehabilitation |
| AGD84_AMG_Z55_Curragh_2107_Submission | CCPL | Registered images and topographic models from Curragh's survey department – Current as at July 2021 |
| AGD84_AMG_Z55_Curragh_2108_Submission | CCPL | Registered images and topographic models from Curragh's survey department – Current as at August 2021 |
| 1911.stat.blackwater.creek.arch_d | CCPL | Vulcan layer outlining Blackwater Creek |
| 1911.stat.levee.arch_d | CCPL | Vulcan layer outlining the current position of levees |
| 1911.stat.mackenzie.river.arch_d | CCPL | Vulcan layer outlining the Mackenzie River |
| FW_ Hydraulic conductivities (email) | SLR | Hydraulic Permeabilities |
| 1in1000_E009_Waterlevel_Curragh.pdf | SLR | Flood levels |

### 1.3 References

The slope stability analyses presented in this report reference the following documents:

- R&A Report: *RA002_201706_02_Rev0 Slope Stability Analysis for Out of Pit Dumps_Rev0*, dated November 2017;
- Hawley, M. and Cunning, J. (2017), *Guidelines for Mine Waste Dump and Stockpile Design*, CSIRO;
- Martin, D. and Stacey, P., (2018) *Guidelines for Open Pit Slope Design* in Weak Rocks, CSIRO;
- Read, J. and Stacey, P., (2009) *Guidelines for Open Pit Slope Design*, CSIRO; and,
- Simmons, J. and McManus, D. (2004), *Shear Strength Framework for Design of Dumped Spoil Slopes for Open Pit Coal Mines*.

### 1.4 Safe Design

As noted in Section 1.1, the purpose of this report is to help CCPL, as part of the CPS, identify, assess, manage and document pre-emptively, potential geotechnical hazards associated with the longer-term slope stability of the Curragh final landform designs.

As a result, it is necessary that this report conforms with the legislated reporting requirements under the Qld Work Health & Safety Act 2011, the Work Health & Safety Regulation 2011 and the Coal Mining Safety and Health Act 1999. As part of this obligation R&A recommend and encourage that discussions, design reviews and risk workshops be undertaken in relation to the final landform designs considered in this report (Appendix B).

## 2. Geological Conditions, Structural Analysis and Interpretation

The Curragh Coal Mine is located approximately 30 km north of the town of Blackwater in Central Queensland's Bowen Basin and is comprised of two active mining areas, which are referred to as Curragh Main and Curragh North.

Curragh is located on the western flank of the Bowen Basin and resides in the Upper Blackwater Group, which comprises of the Rangal Coal Measures, the Burngrove Formation and the Fair Hill Formation. In general, the Rangal Coal Measures are mined at Curragh. These deposits are comprised of grey mudstone and siltstone, light grey fine-grained sandstone and the productive coal seams of Cancer, Aries, Castor, Pollux, Orion and Pisces. Mining of the Burngrove Formation coal seams is also being considered. The local basin coal seam stratigraphy is presented in Figure 2-2.

Locally, the Aries and Castor Coal Seams, and the Pollux, Orion, and Pisces Coal Seams are observed to coalesce. Where the Aries and Castor Coal Seams coalesce, they are named the Mammoth Seam (Figure 2-1). The Mammoth Coal Seam is observed in the footprint of the current S-Pit Main and S-Pit South mining areas. Where the Pollux, Orion, and Pisces Coal Seams coalesce, they are named the Mackenzie Seam (Figure 2-1). The Mackenzie Seam (sometimes also referred to as the Pisces Seam) is mined at Curragh North and is directly underlain by the Yarrabee Tuff and Pisces Lower Coal Seam.

Curragh is located adjacent to the northwest trending Jellinbah Thrust Belt, which is believed to exhibit vertical stratigraphic throws in the order of 100's of metres. The dominant geological structures at Curragh are observed to be north-northwest to south-southeast trending thrusts faults crosscut by younger transcurrent and normal faults.

Zones of significant rock mass and coal seam shearing are likely in the vicinity of larger-scale faults. These zones are characterised by extensive shearing, repeating and/or stripping of stratigraphic units and represent areas of structural and geological complexity. Pitwall design revisions are often implemented at Curragh to mitigate the risks associated with geological faults and pitwall stability.

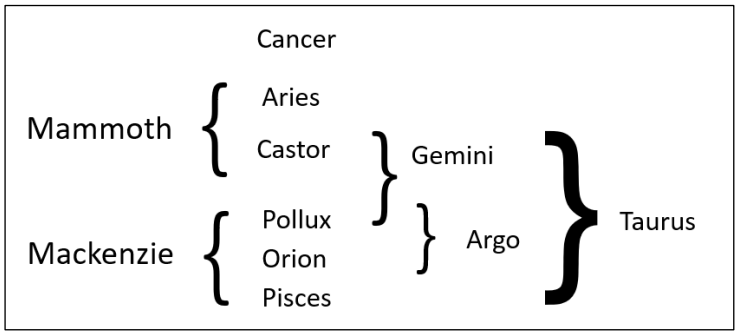



*Figure 2-1 Rangal Coal Measure coalesces naming convention (Curragh Geology Training Manual, CCPL)*

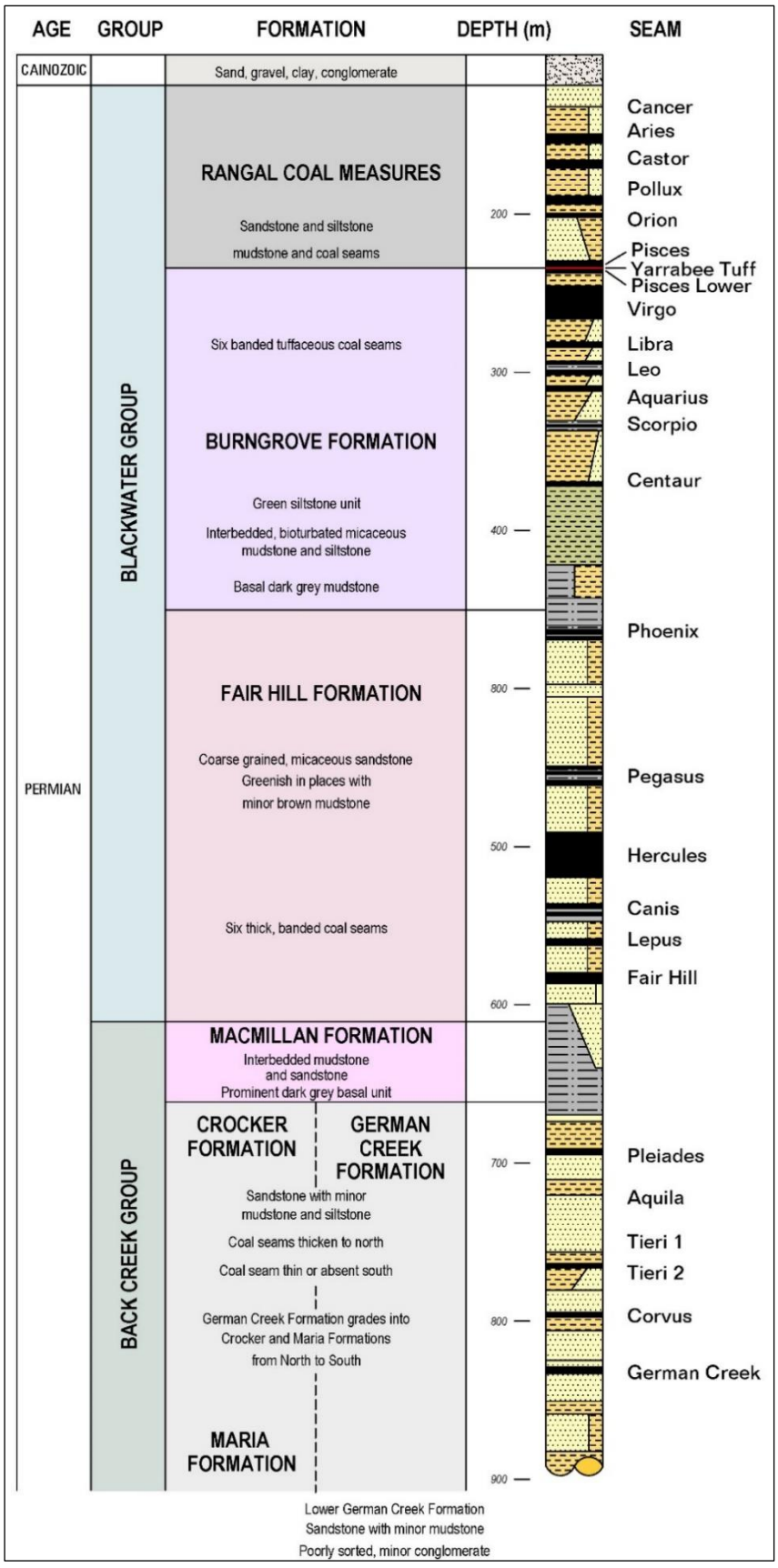



*Figure 2-2 Coal Seam Stratigraphy (Curragh Geology Training Manual, CCPL)*

## 2.1 Quaternary and Tertiary Lithology

The alluvial soil materials observed at Curragh are comprised of Quaternary Sands, Gravels and Clays, and Tertiary Clays and Sandy Clays.

## 2.2 Permian Interburden Lithology

The Permian stratigraphy observed at Curragh Main is comprised predominately of the Rangal Coal Measures, generally consisting of coal, sandstone, siltstone, claystones, and carbonaceous units (refer to Table 2-1).

*Table 2-1 General Permian Material Classifications – Curragh Main*

| Material Name | Material Description |
|---|---|
| Siltstones, Sandstones, Claystones and Carbonaceous Units | Interlaminated and bedded siltstone and sandstones with occasional mudstone and / or carbonaceous units occurring in the Aries Overburden, Castor Interburden, Pollux Interburden and Orion Interburdens. |
| Coal | Black coal. |

The Permian stratigraphy observed in Curragh North generally consists of coal, sandstone, and siltstone, with occasional mudstone and carbonaceous units, and stratigraphically continuous tuffaceous layers (i.e. Yarrabee Tuff and Tuff Lower; refer to Table 2-2).

*Table 2-2 General Permian Material Classifications – Curragh North*

| Material Name | Material Description |
|---|---|
| Siltstones & Sandstones | Interlaminated and bedded siltstone and sandstone with occasional mudstone and/or carbonaceous units occurring in the Aries Overburden, Castor Interburden and Mackenzie Interburden. |
| Massive Sandstones | Massive to thickly bedded sandstone, typically medium to coarse grained occurring predominately in the Mackenzie Interburden. |
| Coal | Black coal. |
| Yarrabee Tuff | Stratigraphically continuous tuffaceous layer. |
| Tuff Lower | Stratigraphically continuous tuffaceous layer located approximately 1m to 2m below the Yarrabee Tuff. |
| Burngrove Formation | Sandstone and siltstone residing in the pit floor. |

## 2.3 Seismic Risk

The Geoscience Australia Earthquake Hazard Maps (Earthquake Hazard Maps) present peak ground acceleration (response spectral period of 0.01 seconds) on rock expected for a 50 year return period, in units of *g*, evaluated for the geometric mean of the horizontal components.

For Curragh, the following have been obtained from the Earthquake Hazard Maps (Figure 2-3 and Figure 2-4):

- Exceedance probability of 10% in 50 years = 0.0-0.005g; and
- Exceedance probability of 2% in 50 years = 0.0-0.02g.

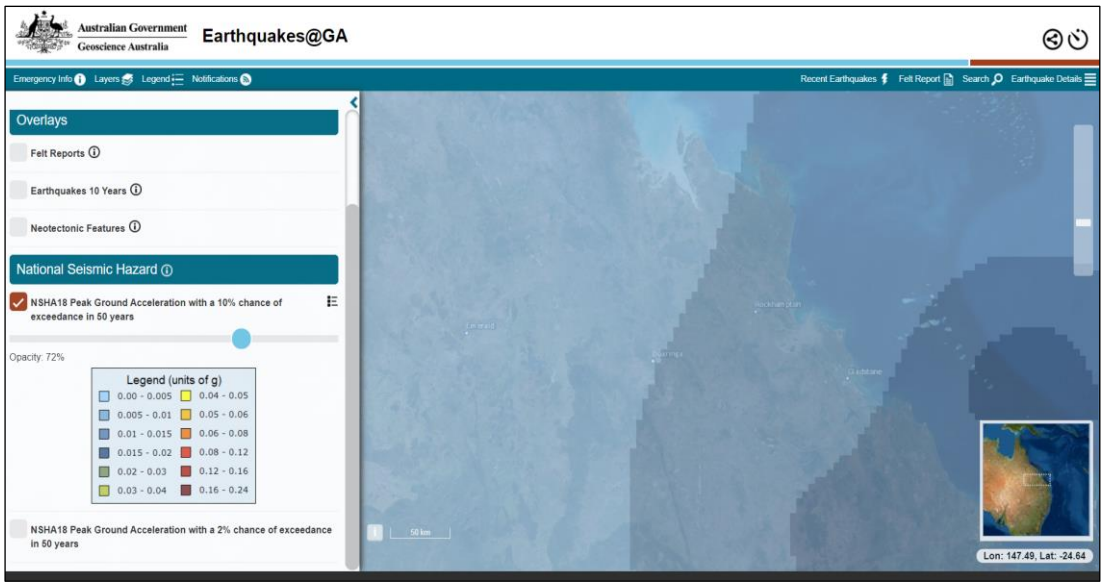



*Figure 2-3 Geoscience Australia Earthquake Hazard Map - 10% chance of exceedance in 50 years*

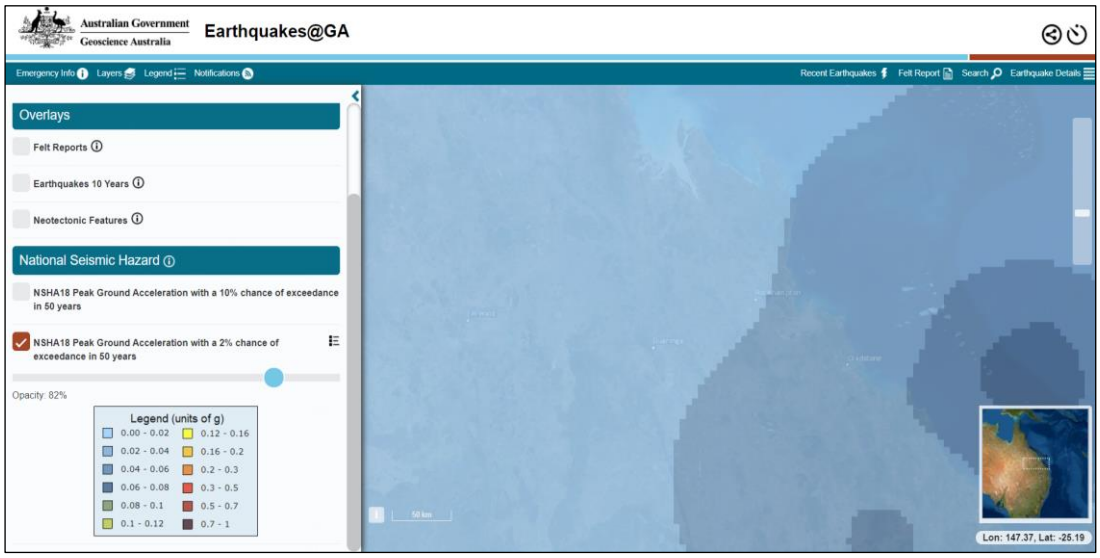



*Figure 2-4 Geoscience Australia Earthquake Hazard Map - 2% chance of exceedance in 50 years*

## 2.4 Predicted Flood Levels

Predicted flood levels for a 1:1000 AEP flood have been provided by SLR Consulting Australia Pty Ltd (SLR) and are outlined in Table 2-3. Refer to Section 4 of this report for Section locations and orientations.

*Table 2-3 Supplied Flood Levels for selected section locations*

| Section | Flood Level (AGD66) | Section | Flood Level (AGD66) |
|---|---|---|---|
| Section 1 | 137.62 mAHD | Section 6 | 156.6 mAHD |
| Section 2 | 140.0 mAHD | Section 7 | 162.7 mAHD |
| Section 3 | 140.5 mAHD | Section 8 | Dry |
| Section 4 | 142.7 mAHD | Section 9 | Dry |
| Section 5 | 143.4 mAHD | - | - |

# 3. Geotechnical Laboratory Data

## 3.1 Soil Test Results

Laboratory test results for soil and alluvial materials utilised in these works were obtained from the following sources:

- The Minserve Group Pty Ltd (1998), Jellinbah Station Project (CN) Report. The following data were obtained from this report:
    - 4 Emerson Class Tests;
    - 21 Atterberg Limits Test Results; and,
    - 25 Particle Size Distribution Test Results.
- Golder Associates Pty Ltd (2012), Design Report Curragh U, S & T Pit Levee Raising Report. The following data were obtained from this report:
    - 44 CPT Profiles (located in the vicinity of the S-Pit and T-Pit South levee);
    - 26 Emerson Class Tests;
    - 38 Atterberg Limits Test Results; and,
    - 40 Particle Size Distribution Test Results.
- Drilling through alluvial soils and weathered rock in S-Pit South (2016):
    - 11 Atterberg Limits Test Results; and,
    - 6 Particle Size Distribution Test Results.
- Grab samples obtained from exposed alluvial materials in S-Pit and S-Pit South (2018 and 2019):
    - 10 Emerson Class Tests;
    - 17 Atterberg Limits Test Results; and,
    - 17 Particle Size Distribution Test Results.

Atterberg Limits, and Particle Size Distribution test data are presented in Figure 3-1, Figure 3-2 and Figure 3-3. Laboratory certificates and associated reports are provided on the CCPL systems.

## 3.2 Rock Core Laboratory Test Results

Uniaxial Compressive Strength data obtained from cored boreholes drilled at Curragh are provided in Table 3-1 and Table 3-2. Direct shear test results for the Yarrabee Tuff are provided in Figure 3-4. Laboratory certificates are provided on the CCPL system.

*Table 3-1 Summary of Uniaxial Compressive Strength Data Available for Curragh Main*

| Material Unit | Lithology | Mean Strength (UCS) | No of Samples |
|---|---|---|---|
| Aries Overburden | Siltstones, Sandstones, Mudstones & Carbonaceous Materials | 15.73 | 55 |
| Castor Interburden | Siltstones, Sandstones, Mudstones & Carbonaceous Materials | 17.96 | 38 |
| Pollux Interburden | Siltstones, Sandstones, Mudstones & Carbonaceous Materials | 23.59 | 59 |
| Virgo Interburden | Sandstones & Siltstones | 17.75 | 10 |
| Coal | Black Coals | 7.13 | 12 |
| Yarrabee Tuff | Tuff | 25.30 | 5 |
| Pit Floor | Sandstone, Siltstone & Carbonaceous Materials | 28.69 | 49 |

*Table 3-2 Summary of Uniaxial Compressive Strength Data Available for Curragh North*

| Material Unit | Lithology | Mean Strength (UCS) | No of Samples |
|---|---|---|---|
| Aries Overburden | Siltstones, Sandstones, Mudstones, Claystones & Carbonaceous Materials | 24.24 | 109 |
| Castor Interburden | Siltstones, Sandstones & Carbonaceous Materials | 27.61 | 21 |
| Mackenzie Interburden | Siltstones, Sandstone, Carbonaceous Materials & Massive Sandstone | 26.87 | 162 |
| Aries, Castor & Mackenzie Seams | Black Coals | 6.92 | 15 |
| Yarrabee Tuff | Tuff | 15.61 | 3 |
| Pit Floor | Sandstone, Siltstone & Carbonaceous Materials | 28.69 | 43 |

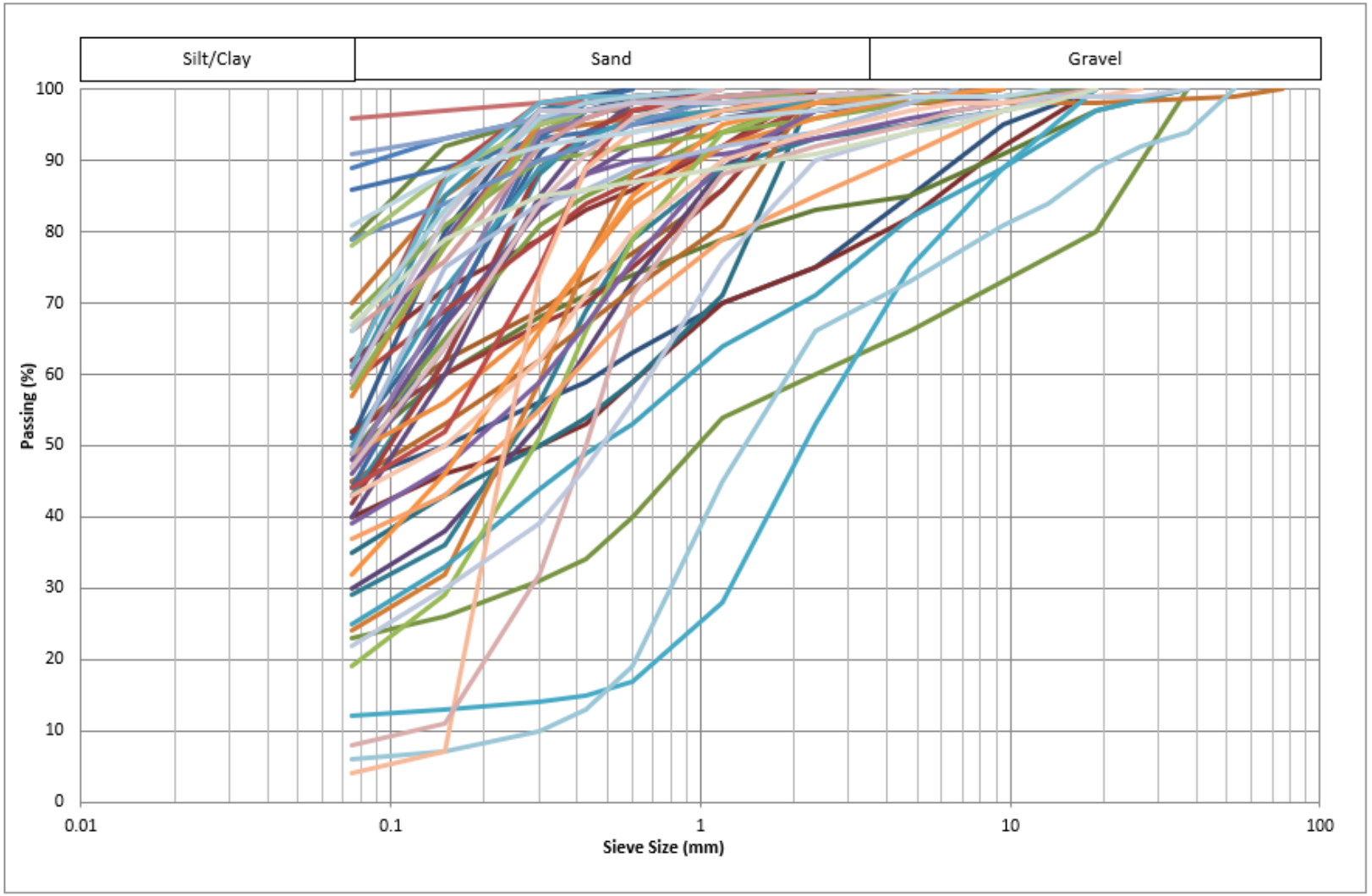



*Figure 3-1 Particle Size Distribution Chart – Quaternary Soil Materials*

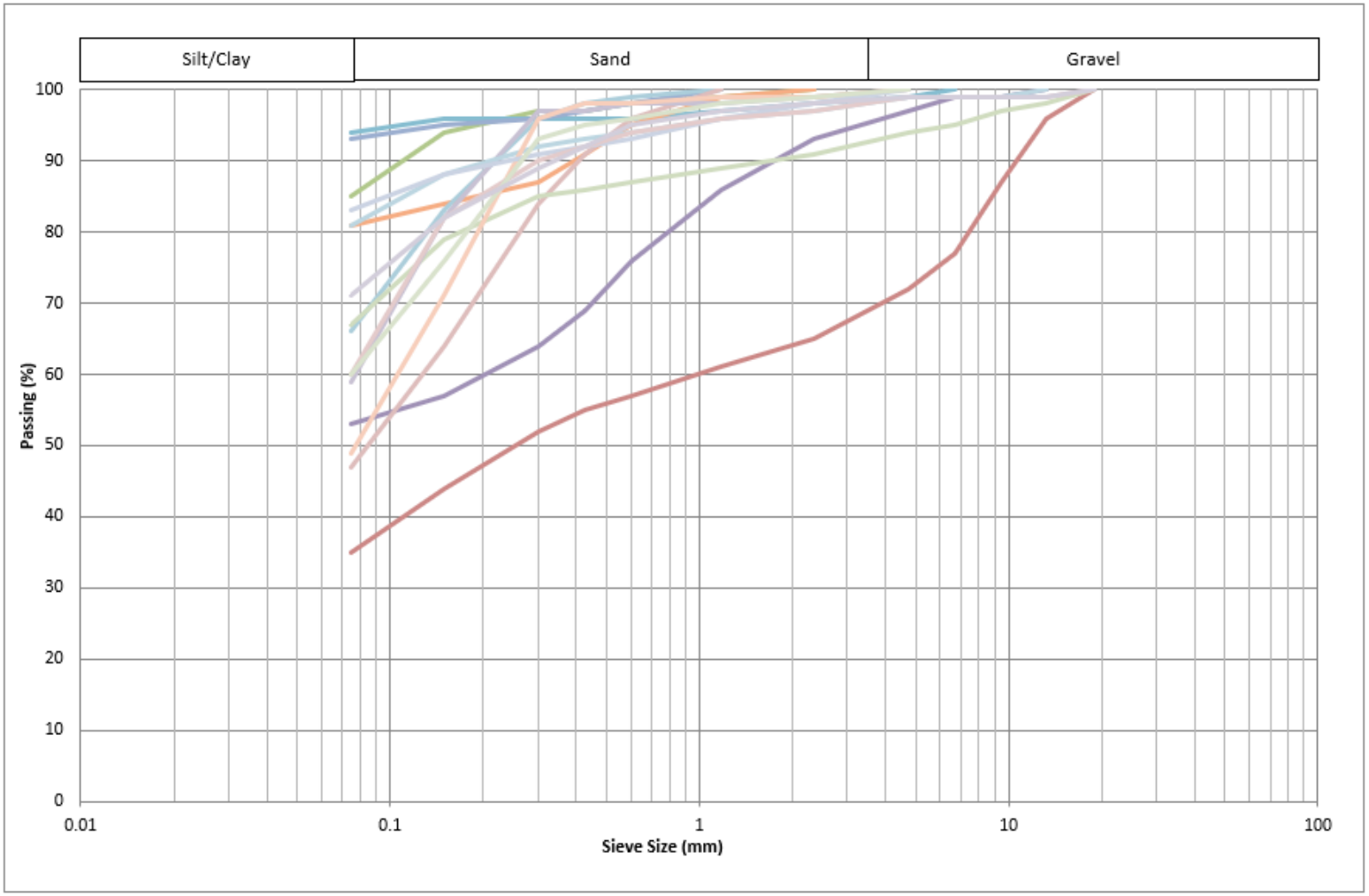



*Figure 3-2 Particle Size Distribution Chart – Tertiary Soil Materials*

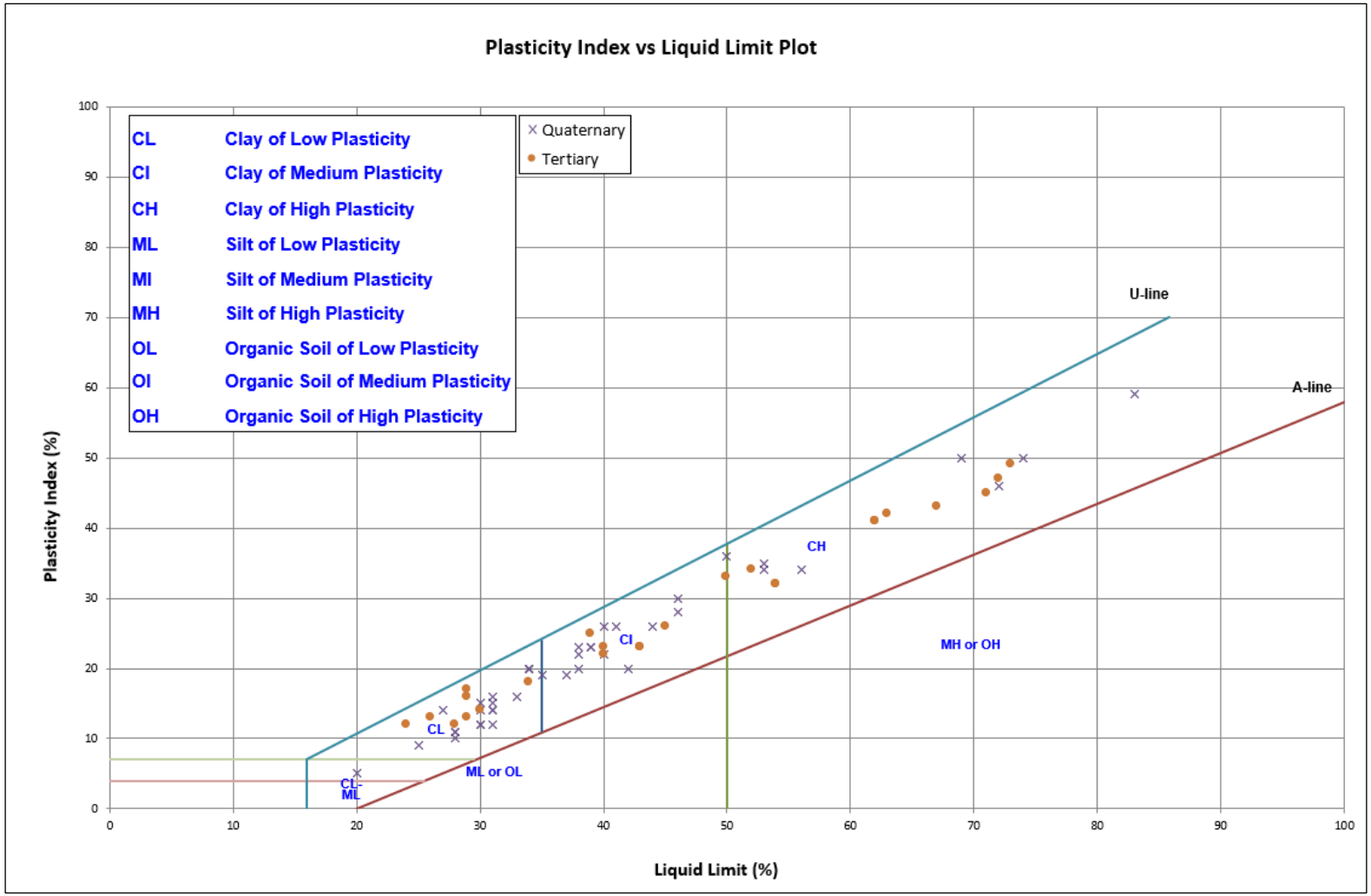



*Figure 3-3 Casagrande Chart – Quaternary & Tertiary Clays*

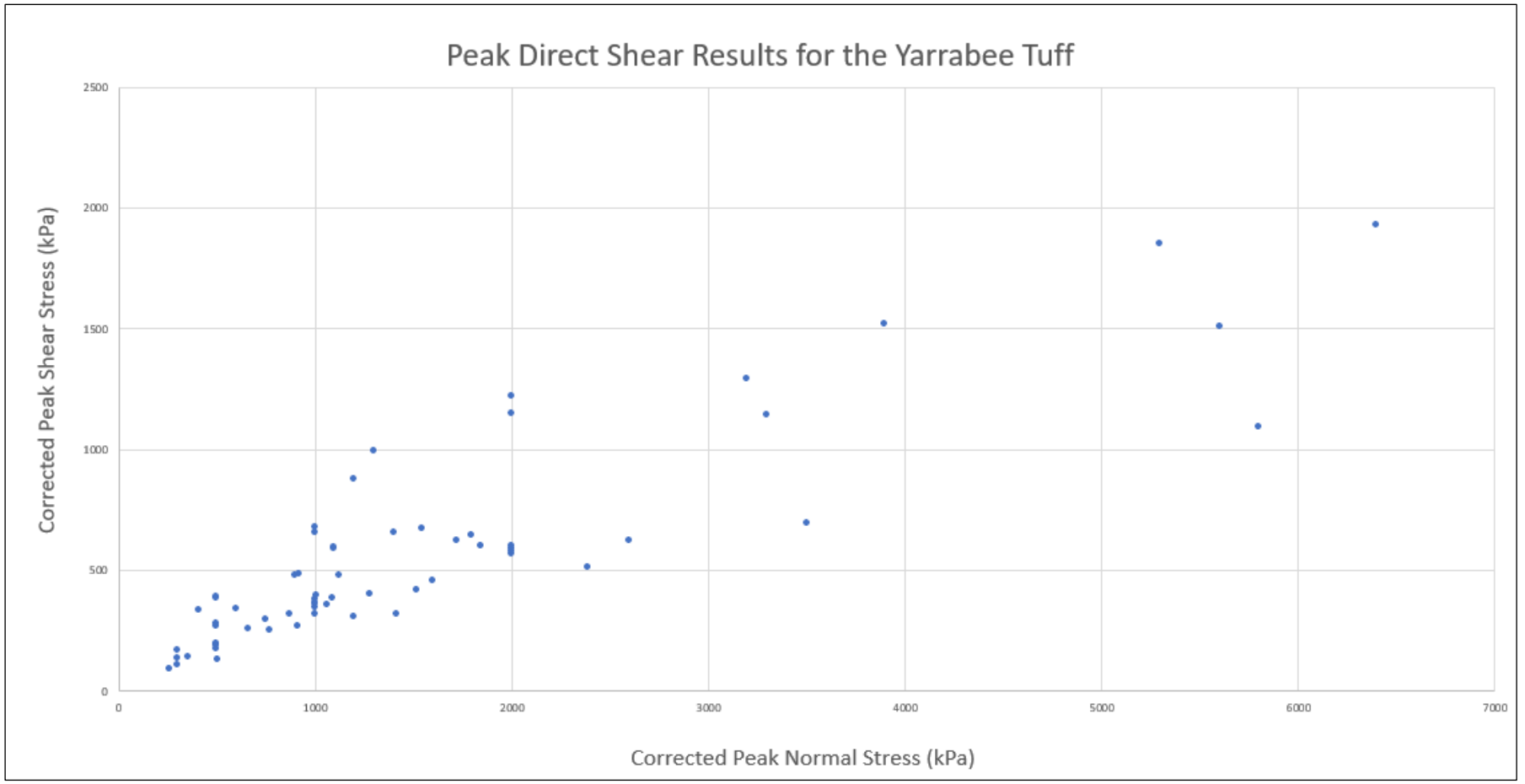



*Figure 3-4 Peak Direct Shear Data for the Yarrabee Tuff at Curragh*

# 4. Final Landform Designs

The final landform designs, which form the basis for this works, have been provided by CCPL (refer to Section 1.2).

As noted in Section 2, pitwall design revisions are often developed and implemented to mitigate the risks associated with geological faults and pitwall stability. As a result, where the current final landform design comprises remnant pitwalls alternative pitwall design options are presented for consideration. These alternative options provide some contingency for the possibility that adverse ground conditions, including geological faults, could be encountered at the planned final pitwall locations.

To account for the flood levels supplied for X-Pit the supplied final landform surface has been raised by approximately 10m for the purpose of the analyses presented in this report.

The following cross-sections and scenarios have been considered (refer to Figure 4-1 to Figure 4-11):

- Section 1 U-Pit Cross Section;
- Section 2 S-Pit South Cross Section;
- Section 3 X-Pit Cross Section;
- Section 4 D-Pit Cross Section;
- Section 5 F-Pit South Cross Section;
- Section 6 K-Pit Cross Section;
- Section 7 J-Pit Cross Section;
- Section 8 Y-Pit Cross Section; and,
- Section 9 Z-Pit Cross Section.

The adopted geotechnical ground model scenarios are provided in Table 4-1.

*Table 4-1 Adopted Ground Model Scenarios*

| Cross Section | Scenario |
|---|---|
| **Section 1: U-Pit** | Planned Final Landform Option - Highwall Side |
| **Section 2: S-Pit South** | Planned Final Landform Option - Highwall Side |
| | Planned Final Landform Option - Lowwall Side |
| **Section 3: X-Pit** | Planned Final Landform Option - Highwall Side |
| **Section 4: D-Pit** | Planned Final Landform Option - Highwall Side |
| | Alternative Final Landform Option - Highwall Side |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side |

| Cross Section | Scenario |
|---|---|
| **Section 5: F-Pit South** | Planned Final Landform Option - Highwall Side |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side |
| | Planned Final Landform Out Board Slope |
| | Planned Final Landform Option - Lowwall Side |
| **Section 6: K-Pit** | Planned Final Landform Option - Highwall Side |
| | Alternative Final Landform Option - Highwall Side |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side |
| **Section 7: J-Pit** | Planned Final Landform Option - Highwall Side |
| | Planned Final Highwall Re-Shaped Final Slope - Highwall Side |
| **Section 8: Y-Pit** | Planned Final Landform Option - Highwall Side |
| | Planned Final Highwall Re-Shaped Final Slope - Highwall Side |
| **Section 9: Z-Pit** | Planned Final Landform Option - Highwall Side |
| | Planned Final Highwall Re-Shaped Final Slope - Highwall Side |

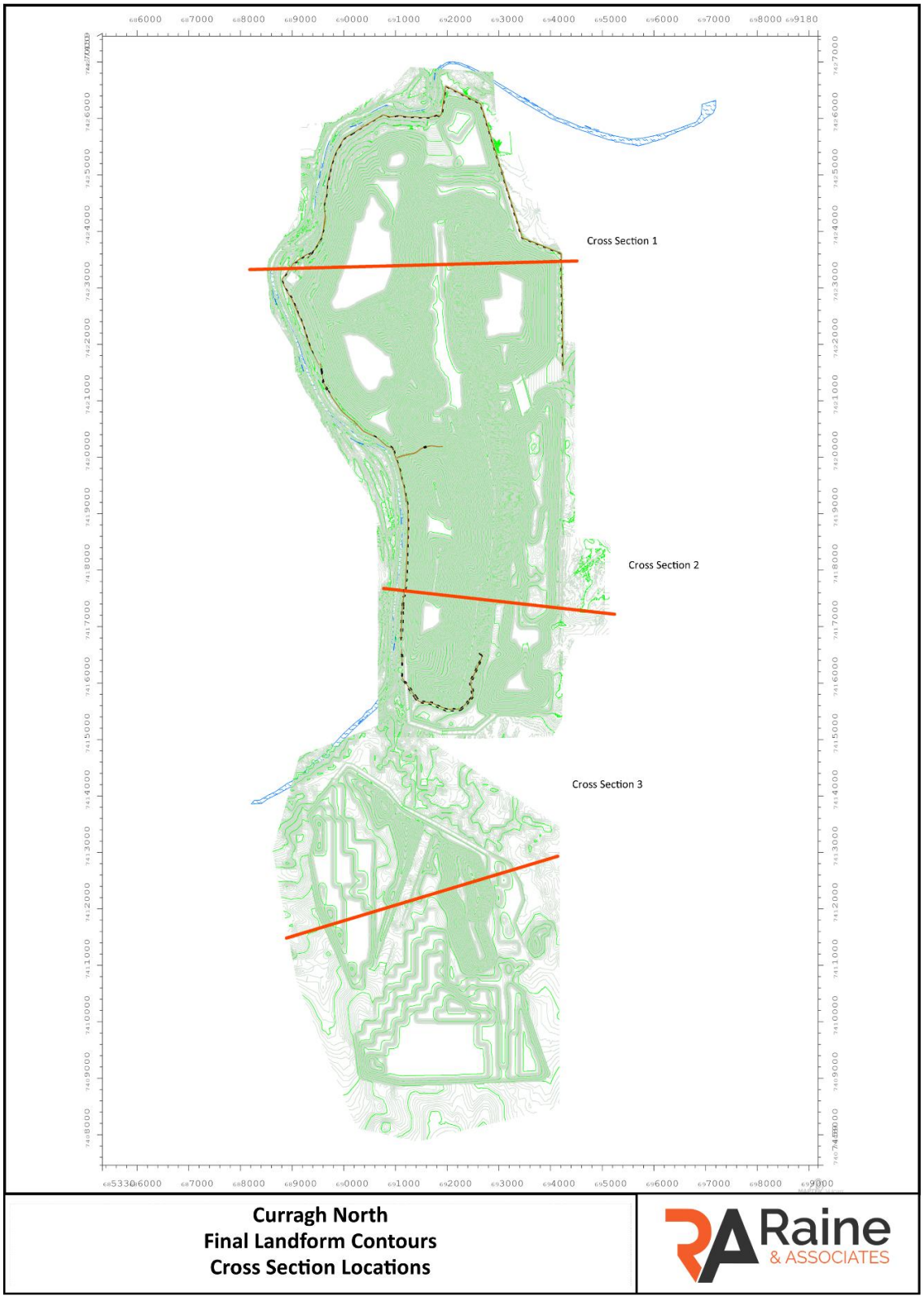



*Figure 4-1 Curragh North Final Landform & Cross Section Locations*

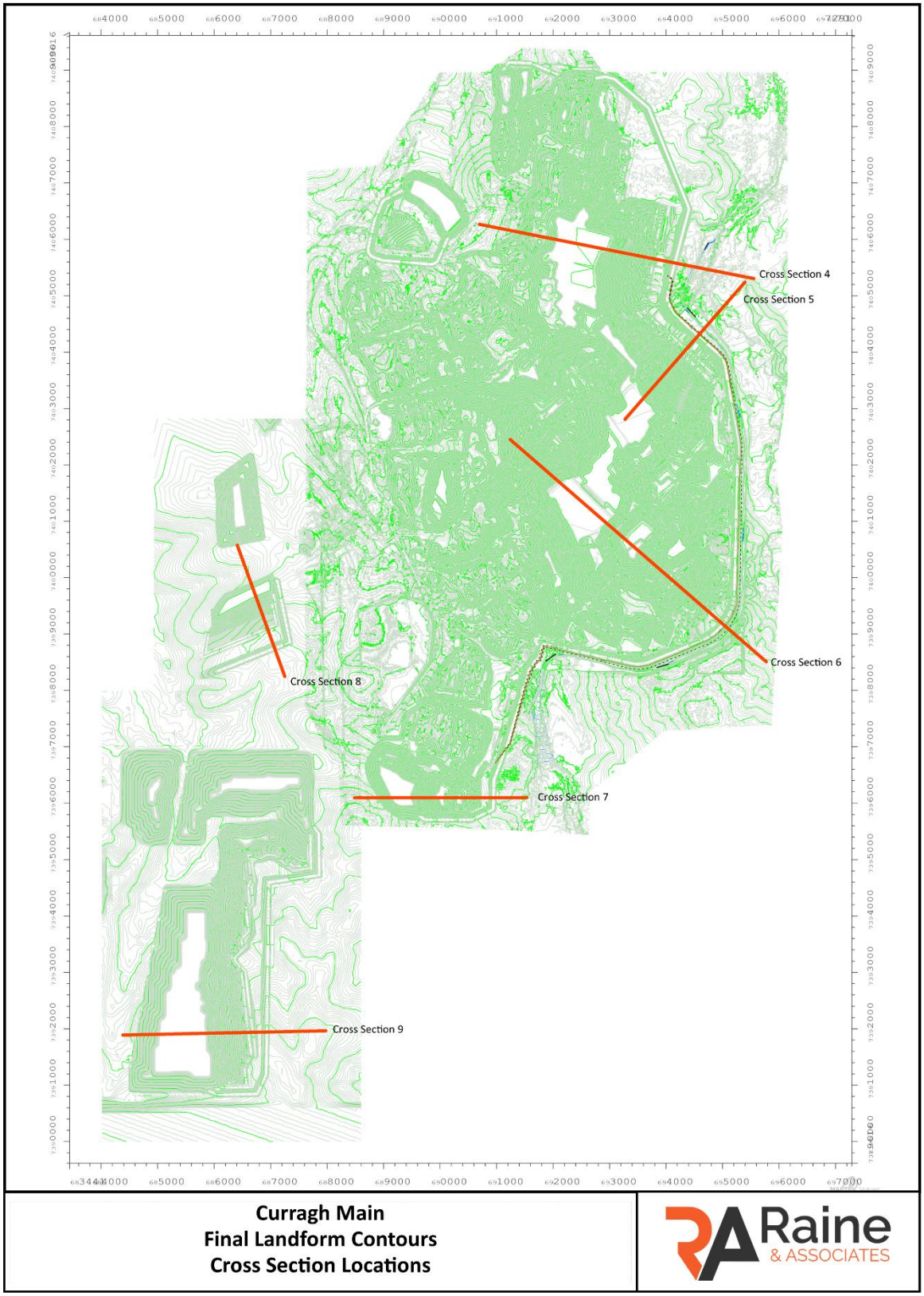



*Figure 4-2 Curragh Main Final Landform& Cross Section Locations*

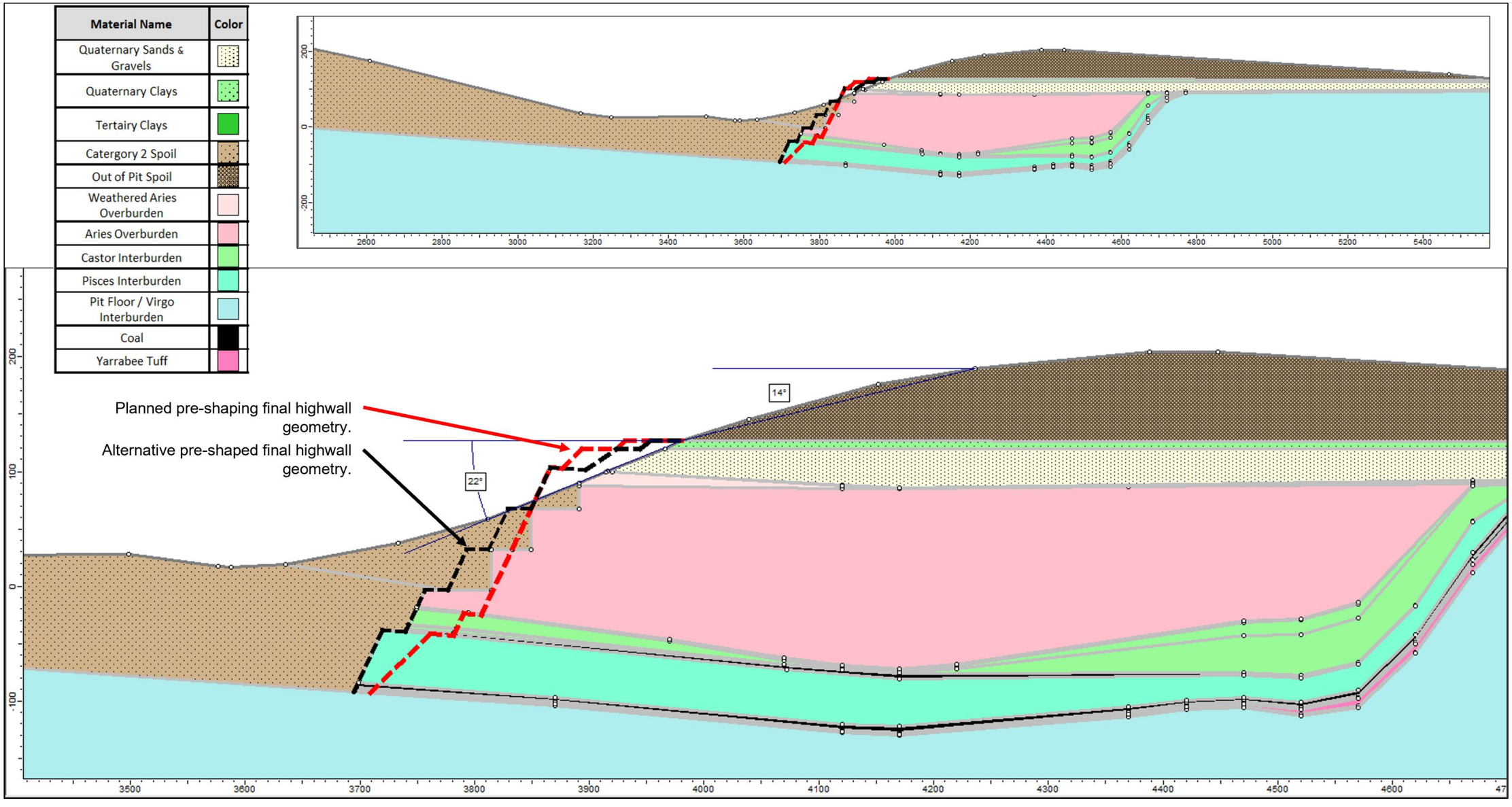



*Figure 4-3 Cross Section 1 – Curragh North U-Pit*

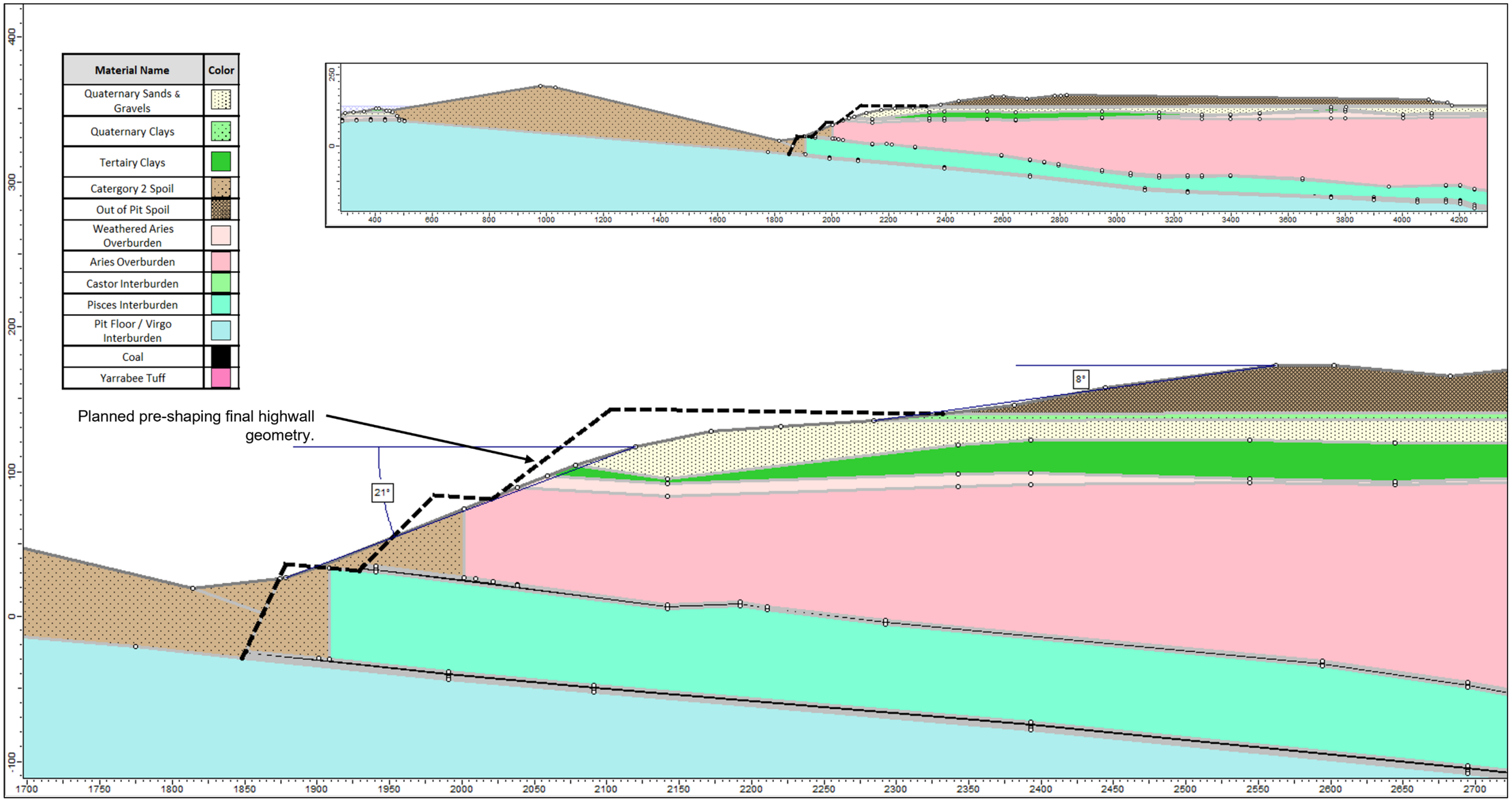



*Figure 4-4 Cross Section 2 – Curragh North S-Pit South*

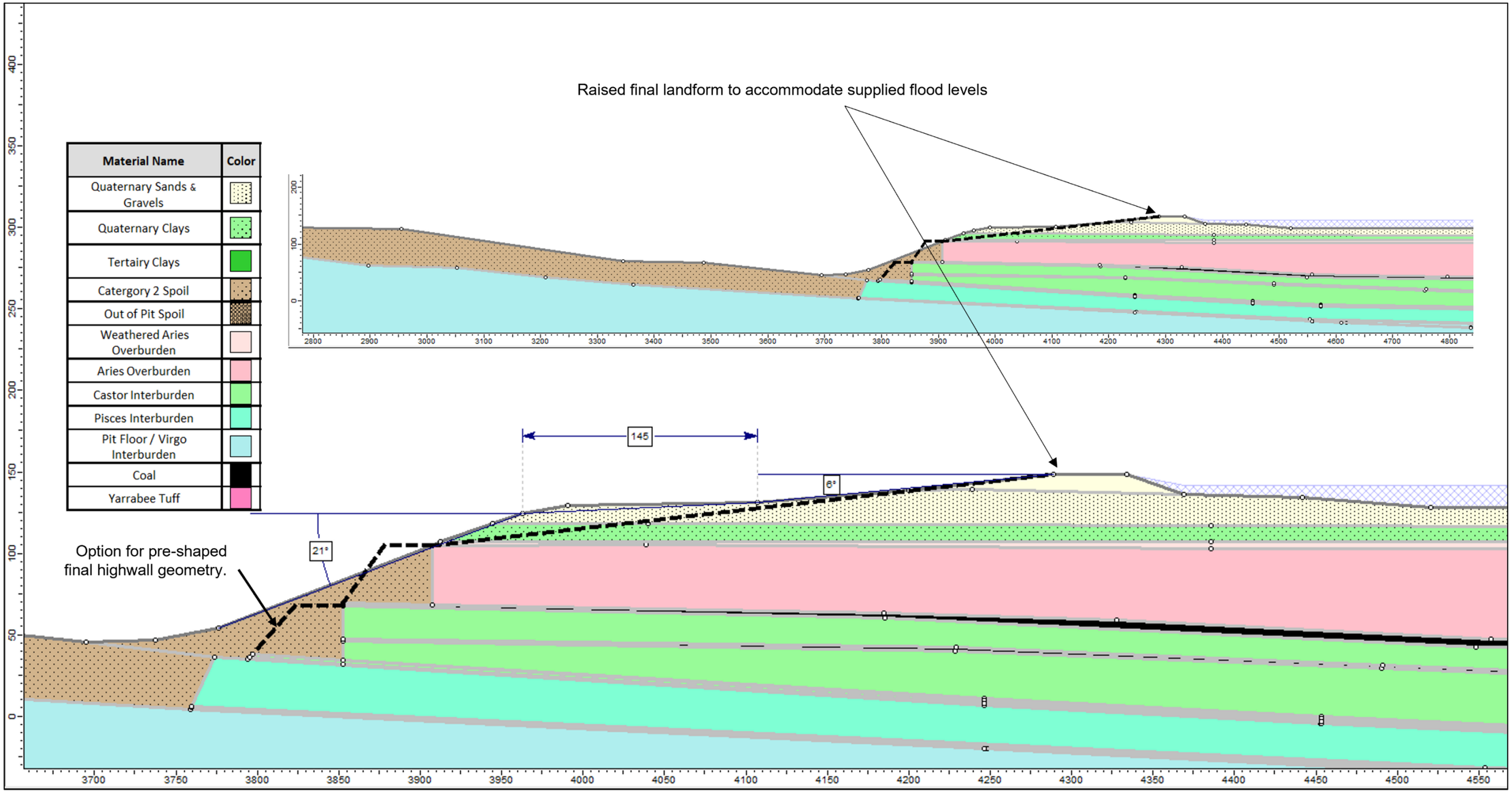



*Figure 4-5 Cross Section 3 – X-Pit*

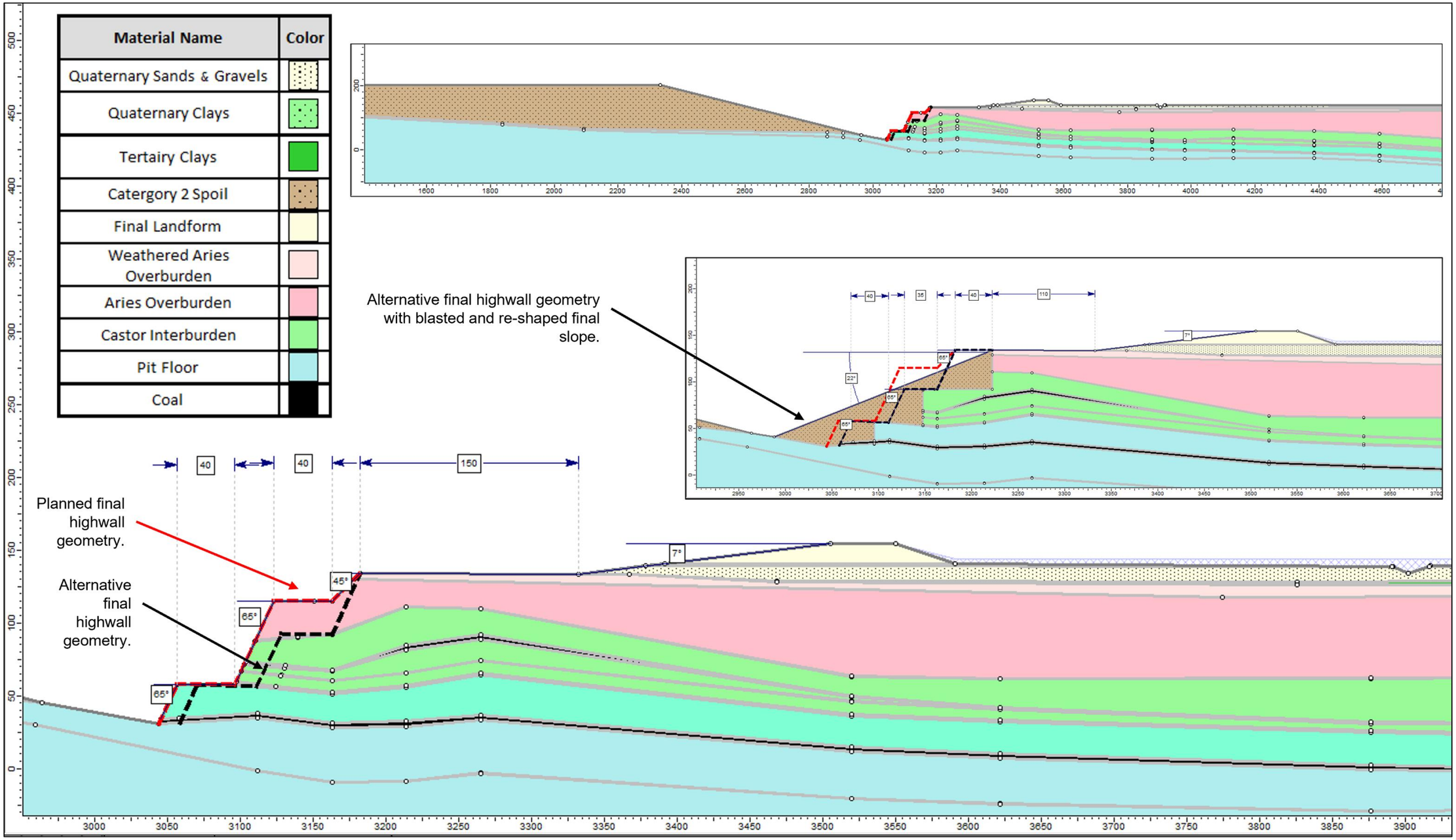



*Figure 4-6 Cross Section 4 – Curragh Main D-Pit*

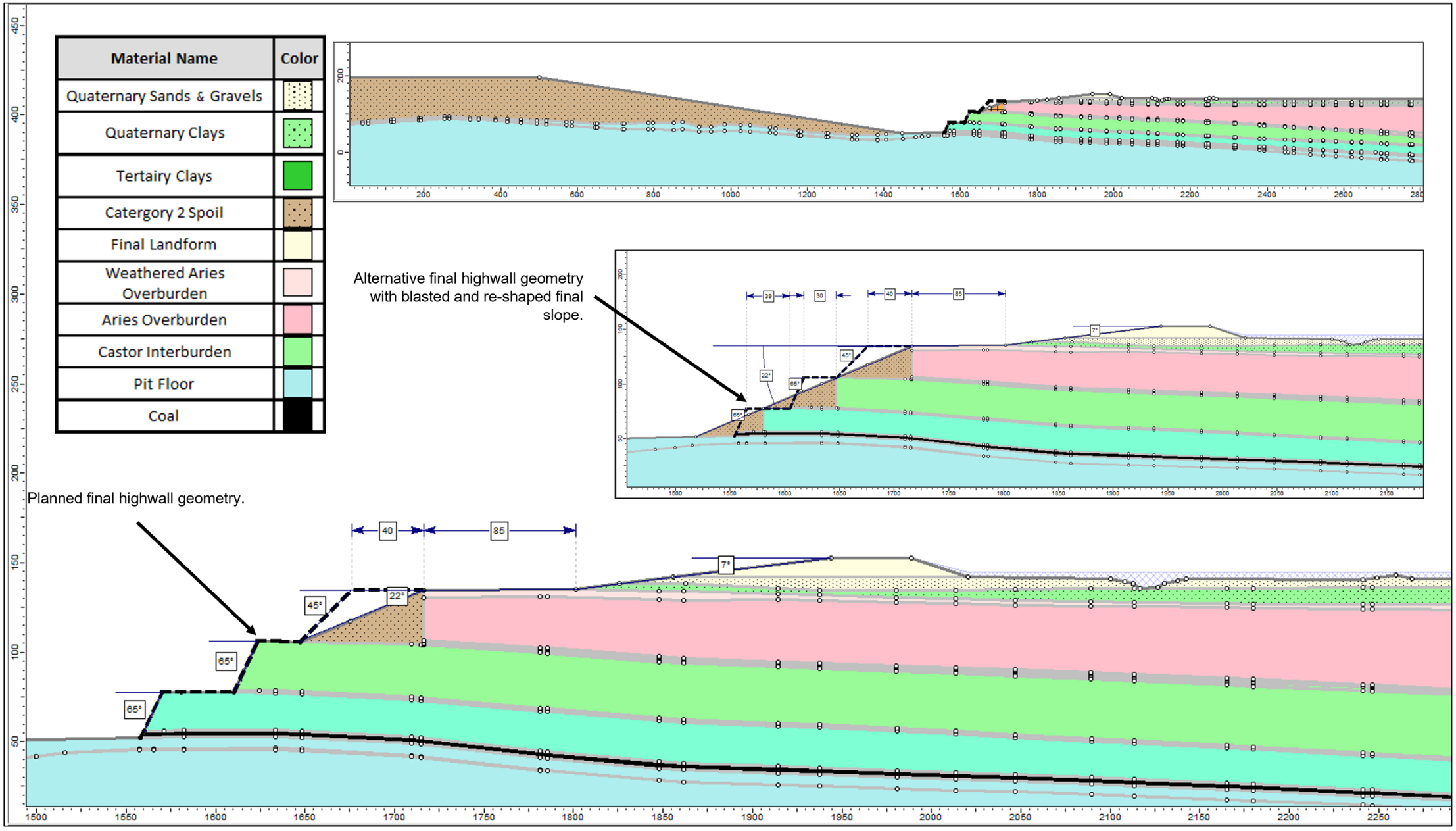



*Figure 4-7 Cross Section 5 – Curragh Main F-Pit*

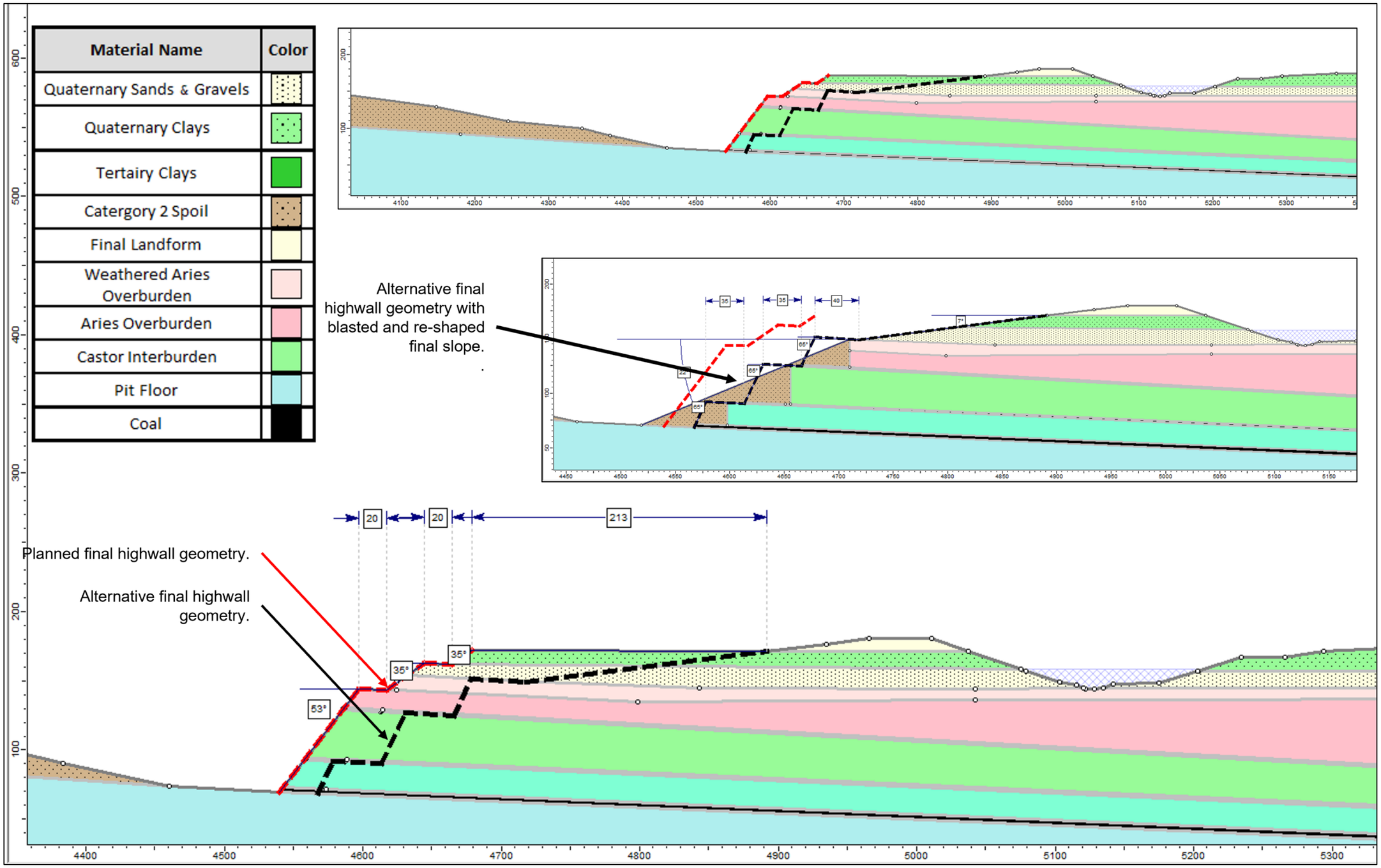



*Figure 4-8 Cross Section 6 – Curragh Main K-Pit*

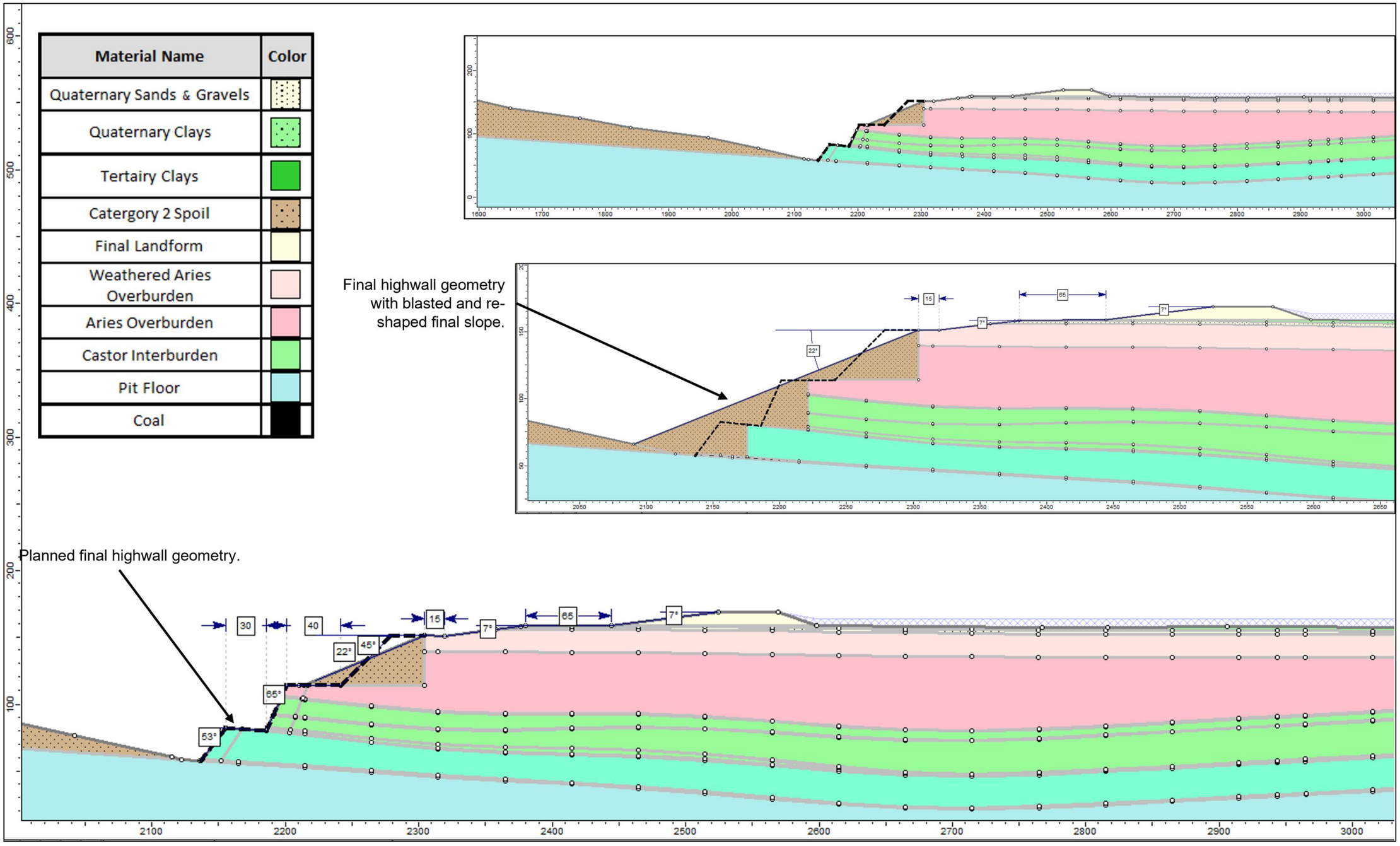
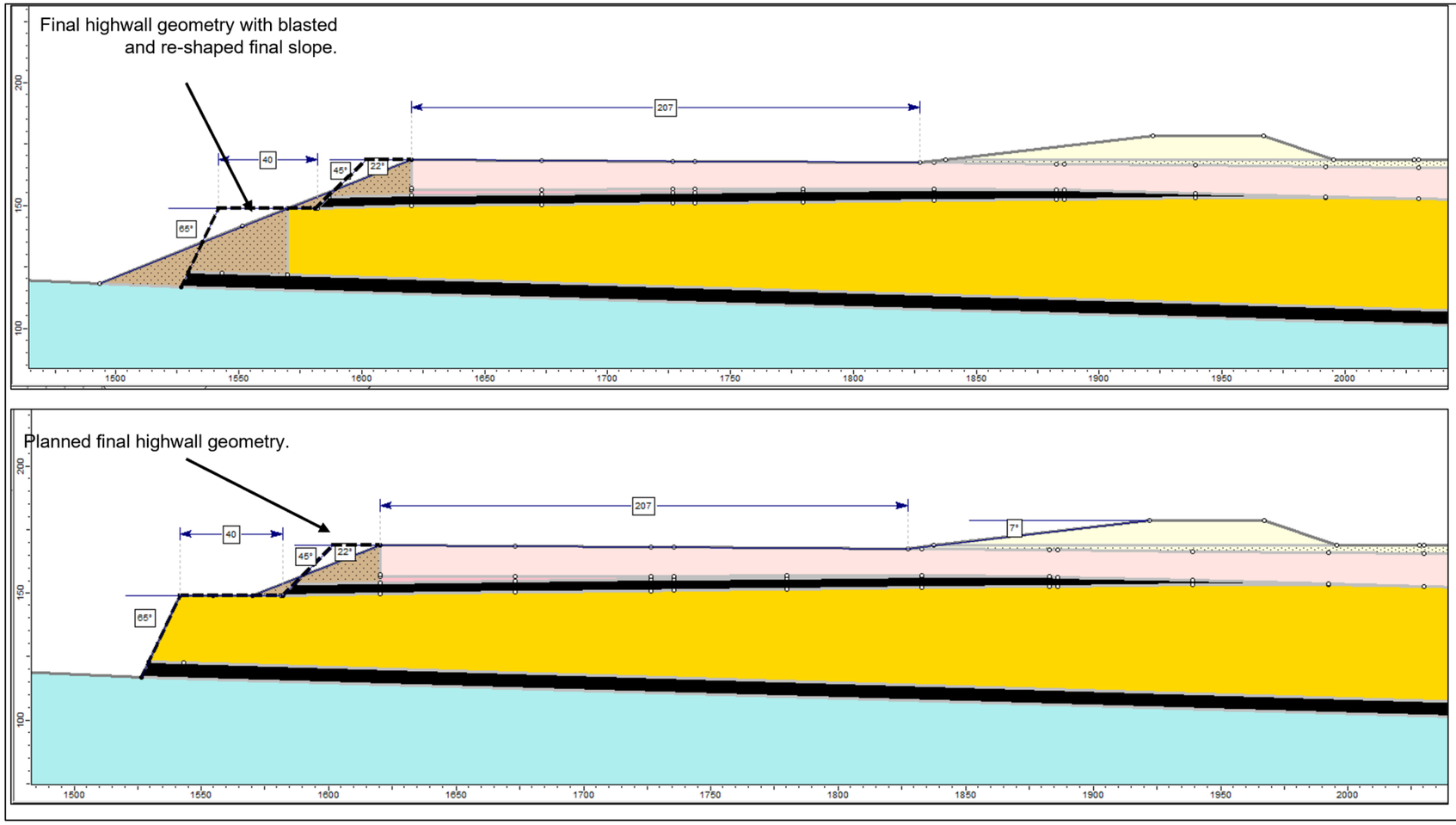



*Figure 4-9 Cross Section 7 – Curragh Main J-Pit*




| Material Name | Color |
|---|---|
| Quaternary Sands & Gravels | |
| Catergory 2 Spoil | |
| Final Landform | |
| Weathered Aries Overburden | |
| Aries Overburden | |
| Pit Floor | |
| Coal | |
| Virgo Interburden | |

*Figure 4-10 Cross Section 8 – Y-Pit*

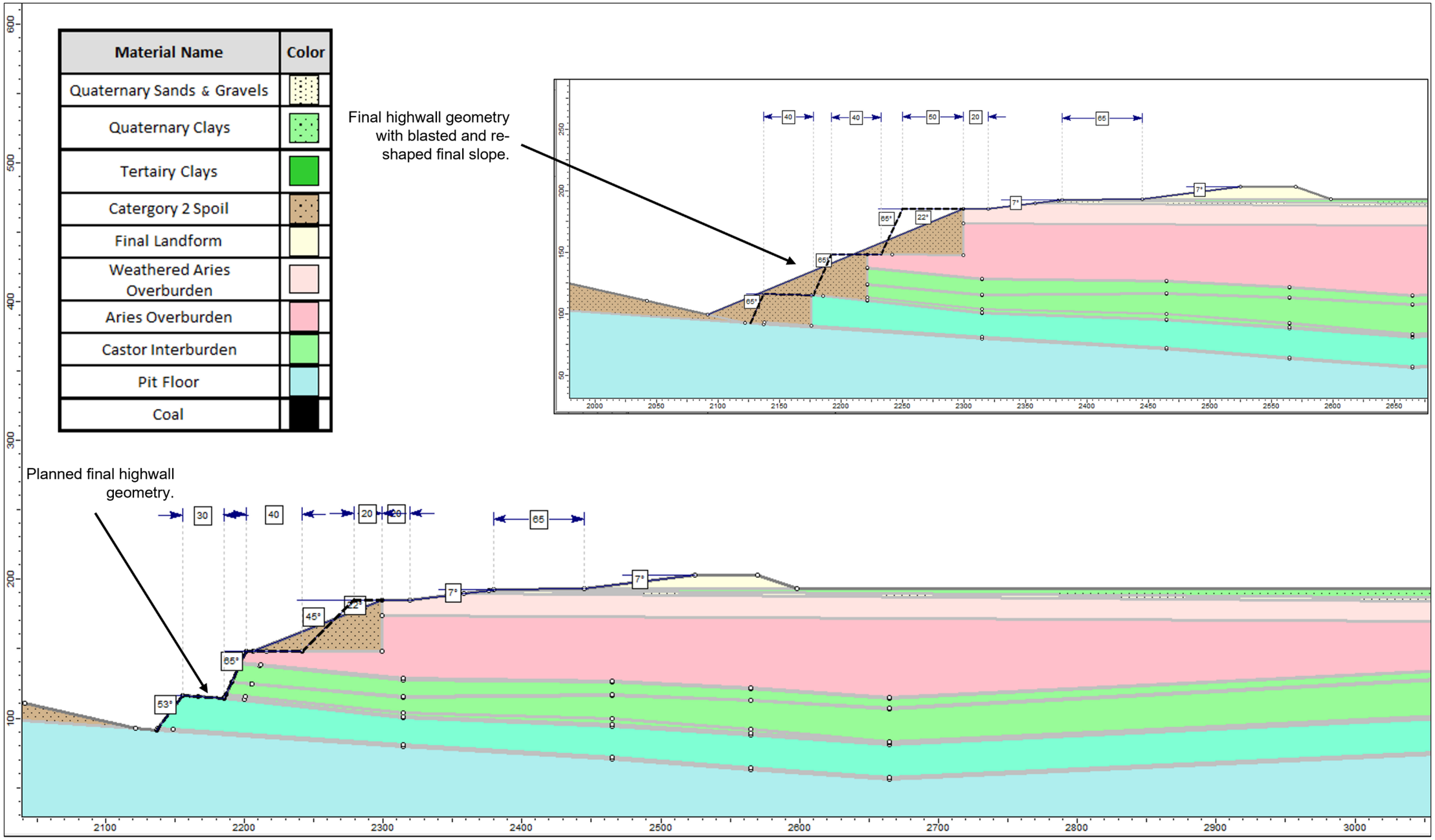



*Figure 4-11 Cross Section 9 – Z-Pit*

# 5. Slope Stability Analysis – Adopted Methodology

## 5.1 Adopted Geotechnical Ground Models

The adopted geotechnical ground models have been developed in Rocscience's proprietary software SLIDE 2.0 (SLIDE) and are based on the supplied final landform designs, flood levels and geological, geotechnical and hydrogeological data.

Two-dimensional limit equilibrium slope stability analysis has been completed for nine (9) cross-section final landform slope geometries, which are presented in Section 4.

## 5.2 Material Parameters

### 5.2.1 Spoil Dump Material Parameters

### 5.2.2 In-Pit Spoil Dumps

In general, the dragline spoil is observed to consist of spoil materials derived from fresh to weathered Permian rock. In considering the data presented in Simmons and McManus (2004) Hawley and Cunning (2017), and site observations, the spoil materials have been classified as Category 2 Spoil (refer to Figure 5-1 and Figure 5-2).

The truck dump terraces, which form the upper portions of the in-pit dumps, are considered to comprise materials similar to those described in Section 5.2.3 below.

### 5.2.3 Out-of-Pit Spoil Dumps

The out-of-pit dump composition appears to be highly variable with the following material types observed:

- Sands and Gravels;
- Clayey Sands;
- Low to High Plasticity Clays, Silty Clays and Sandy Clays; and,
- Highly Weathered to Slightly Weathered Permian Rock.

The adopted material strength parameters (Table 5-1) for the out-of-pit dump spoil have been taken from the following report:

- *RA002_201706_02_Rev0 Slope Stability Analysis for Out of Pit Dumps_Rev0*, dated November 2017.

*Table 5-1 Adopted Out-of-Pit Spoil Dump Material Parameters*

| Material Name | Unit Weight (kN/m3) | Apparent Cohesion (kPa) | Friction Angle (°) |
|---|---|---|---|
| **Spoil Dump Materials** | 18 | 3 | 28 |

Table 1
**Shear Strength Parameters for Categories and Mobilisation Modes**
*(Parameter standard deviations in italicised parentheses)*

| Category | Unsaturated | | | Saturated | | | Remoulded |
|---|---|---|---|---|---|---|---|
| | γ (kN/m³) | c' (kPa) | ϕ' (deg) | γ (kN/m³) | c' (kPa) | ϕ' (deg) | c'=0 kPa, ϕ' (deg) |
| 1 | 18 *(1)* | 20 *(10)* | 25 *(2.5)* | 20 *(1)* | 0 *(0)* | 18 *(3)* | 18 *(1.5)* |
| 2 | 18 *(1)* | 30 *(15)* | 28 *(3)* | 20 *(1)* | 15 *(7.5)* | 23 *(2.5)* | 18 *(1.5)* |
| 3 | 18 *(1)* | 50 *(15)* | 30 *(2)* | 20 *(1)* | 20 *(10)* | 25 *(2.5)* | 18 *(1.5)* |
| 4 | 18 *(1)* | 50 *(15)* | 35 *(2.5)* | 20 *(1)* | 0 *(0)* | 30 *(1.5)* | 28 *(2)* |

*Figure 5-1 Shear Strength Parameters for Categories and Mobilisation Modes (Simmons & McManus, 2004).*

Table 2
**Spoil Categories and Attributes**

| CATEGORY | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| **Description Attributes** | **Weighting** *(excl. Age)* | Fine-grained clay-rich high plasticity | Fine-grained low plasticity with larger clasts | Larger clasts with fine matrix, low plasticity | Large blocks, minor fines, minor slaking |
| **Predominant Particle Size** | 3/31=**9.7%** *(11.6%)* | Clay | Sand | Gravel | Cobbles |
| **Consistency: cohesive cohesionless** | 7/31=**22.6%** *(26.9%)* | Soft to Firm Loose | Stiff Med. Dense | Hard Dense | XLS+ rock Very Dense |
| **Structure** | 7/31=**22.6%** *(26.9%)* | Matrix only | Matrix supported | Framework supported | Framework only |
| **Liquid Limit** | 9/31=**29.0%** *(34.6%)* | High (>50) | Intermediate (35 – 50) | Low (20 – 35) | Not Plastic (<20) |
| **Age** | 5/31=**16.1%** | 0 - 2y | 2 - 10y | 10 - 30y | >30y |

*( Note: XLS+ rock refers to rock of extremely low strength, or higher)*

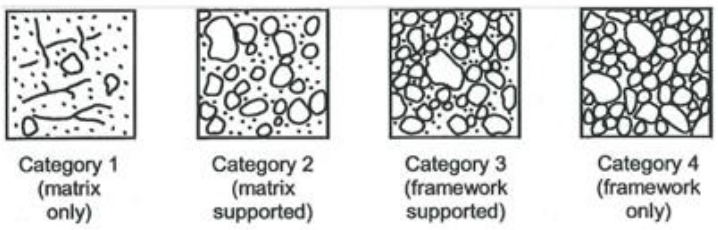



Figure 6 Spoil structure control ranking (use with Table 2)

*Figure 5-2 Spoil Categories and Attributes (Simmons and McManus, 2004).*

## 5.3 In-Situ Alluvial Material Parameters

### 5.3.1 Alluvial Clays

The material strength parameters adopted for in-situ clays have been based on available Atterberg Limits test data available for Curragh. Mesri (1993) calculations were undertaken to develop the material parameters presented in Table 5-2 and Table 5-3.

which represent a curved Mohr-Coulomb failure envelope, with friction angle reducing with increasing normal stress.

*Table 5-2 Adopted Clay Material Parameters – Quaternary Clays*

| Normal Stress (kPa) | Shear Stress (kPa) |
|---|---|
| 0.5 | 0.9 |
| 2 | 2.7 |
| 5 | 5.8 |
| 10 | 10.3 |
| 20 | 18.3 |
| 50 | 39.1 |
| 100 | 69.6 |
| 150 | 97.4 |
| 225 | 136.4 |
| 300 | 173.2 |
| 400 | 219.9 |
| 1000 | 470.5 |

*Table 5-3 Adopted Clay Material Parameters – Tertiary Clays*

| Normal Stress (kPa) | Shear Stress (kPa) |
|---|---|
| 0.5 | 1.5 |
| 2 | 4.3 |
| 5 | 8.6 |
| 10 | 14.5 |
| 20 | 24.4 |
| 50 | 48.5 |
| 100 | 81.6 |
| 150 | 110.7 |
| 225 | 150.0 |
| 300 | 186.1 |
| 400 | 230.9 |
| 1000 | 459.1 |

### 5.3.2 Alluvial Sands and Gravels

Consideration has been given to available laboratory test data and the observed pitwall performance associated with these materials. Adopted material strengths for the Sands and Gravels are provided in Table 5-4.

*Table 5-4 Adopted Sand Material Parameters*

| Material Name | Unit Weight (kN/m3) | Apparent Cohesion (kPa) | Friction Angle (°) |
|---|---|---|---|
| **Sands & Gravels** | 18 | 0 | 35 |

## 5.4 Permian Rock Mass Strength

The rock mass strength parameters presented in Table 5-8 and Table 5-9 have been developed from available geological and geotechnical data (i.e. geotechnical borehole data and laboratory test data) and field observations using Rocscience's proprietary software RocData incorporating disturbance factors (D) of 0 and 0.7, for a non-blast affected and a blast affect rock mass, respectively

### 5.4.1 Coal Material Strength

The adopted Coal material strength parameters were obtained from Martin & Stacey (2018) (Table 5-5).

*Table 5-5 Adopted Coal Material Strength Parameters*

| Material | Unit Weight | Apparent Cohesion (kPa) | Friction Angle (°) |
|---|---|---|---|
| **Coal** | 15 | 35 | 35 |

### 5.4.2 Tuff Material Strength

The adopted tuff material strength parameters are presented in Table 5-6 and have been derived from available direct shear test results.

*Table 5-6 Adopted Tuff Material Strength Parameters*

| Material | Unit Weight | Apparent Cohesion (kPa) | Friction Angle (°) |
|---|---|---|---|
| **Yarrabee Tuff** | 24 | 50 | 23 |

### 5.4.3 Adopted Hydraulic Conductivity

Adopted hydraulic conductivity values are presented in Table 5-7 and were provided by SLR for the presented analysis.

*Table 5-7 Adopted hydraulic conductivity values for the considered material types*

| Material Name | Hydraulic Conductivity | |
|---|---|---|
| | $K_h$ (m/s) | $K_v/K_h$ (factor) |
| **Quaternary Sands & Gravels** | $1.509x10^{-5}$ | 0.0167 |
| **Quaternary Clays** | $9.516x10^{-6}$ | 0.0167 |
| **Tertiary Clays** | $3.617x10^{-8}$ | 0.0147 |
| **Weathered Permian Rock** | $1.894x10^{-5}$ | 0.0474 |
| **Permian Rock** | $9.00x10^{-10}$ | 0.0922 |
| **Coal Seams** | $2.679x10^{-8}$ | 0.0156 |
| **Spoils** | $1.736x10^{-4}$ | 0.246 |

*Table 5-8 General Rock Mass Strength Parameters – Curragh Main*

| Parameter | Weathered Permian | Aries Overburden | Castor Interburden | Pollux Interburden | Pit Floor | Virgo Interburden |
|---|---|---|---|---|---|---|
| Unit Weight | 22 | 24 | 24 | 24 | 24 | 24 |
| Rock Strength (MPa) | 3.62 | 15.73 | 17.96 | 23.59 | 23.96 | 16.85 |
| GSI* | 50 | 65 | 65 | 65 | 70 | 70 |
| Mi | 7 | 7 | 7 | 10 | 10 | 10 |
| D | 0 | 0 | 0 | 0 | 0 | 0 |
| Apparent Cohesion (kPa) | 87 | 549 | 537 | 633 | 1704 | 534 |
| Friction Angle (°) | 36 | 44 | 44 | 49 | 36 | 51 |
| **Parameter** | Weathered Permian | Aries Overburden | Castor Interburden | Pollux Interburden | Pit Floor | Virgo Interburden |
| Unit Weight | 22 | 24 | 24 | 24 | 24 | 24 |
| Rock Strength (MPa) | 3.62 | 15.73 | 17.96 | 23.59 | 23.96 | 16.85 |
| GSI* | 50 | 65 | 65 | 65 | 70 | 70 |
| Mi | 7 | 7 | 7 | 10 | 10 | 10 |
| D | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Apparent Cohesion (kPa) | 58 | 309 | 364 | 437 | - | 372 |
| Friction Angle (°) | 28 | 39 | 39 | 44 | - | 47 |

*GSI is based on available geotechnical borehole data (Figure 5-3).

*Table 5-9 General Rock Mass Strength Parameters – Curragh North*

| Parameter | Weathered Permian | Aries Overburden | Castor Interburden | Pisces Interburden | Pit Floor |
|---|---|---|---|---|---|
| Unit Weight | 22 | 24 | 24 | 24 | 24 |
| Rock Strength (MPa) | 2.1 | 24.24 | 27.61 | 26.87 | 28.69 |
| GSI* | 50 | 65 | 65 | 65 | 70 |
| Mi | 7 | 7 | 7 | 10 | 10 |
| D | 0 | 0 | 0 | 0 | 0 |
| Apparent Cohesion (kPa) | 49 | 637 | 485 | 692 | 2040 |
| Friction Angle (°) | 36 | 47 | 42 | 49 | 36 |
| Parameter | **Weathered Permian** | **Aries Overburden** | **Castor Interburden** | **Pisces Interburden** | **Pit Floor** |
| Unit Weight | 22 | 24 | 24 | 24 | 24 |
| Rock Strength (MPa) | 2.1 | 24.24 | 27.61 | 26.87 | 28.69 |
| GSI* | 50 | 65 | 65 | 65 | 70 |
| Mi | 7 | 7 | 7 | 10 | 10 |
| D | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Apparent Cohesion (kPa) | 33 | 414 | 740 | 473 | - |
| Friction Angle (°) | 29 | 42 | 46 | 45 | - |

*GSI is based on available geotechnical borehole data (Figure 5-3).

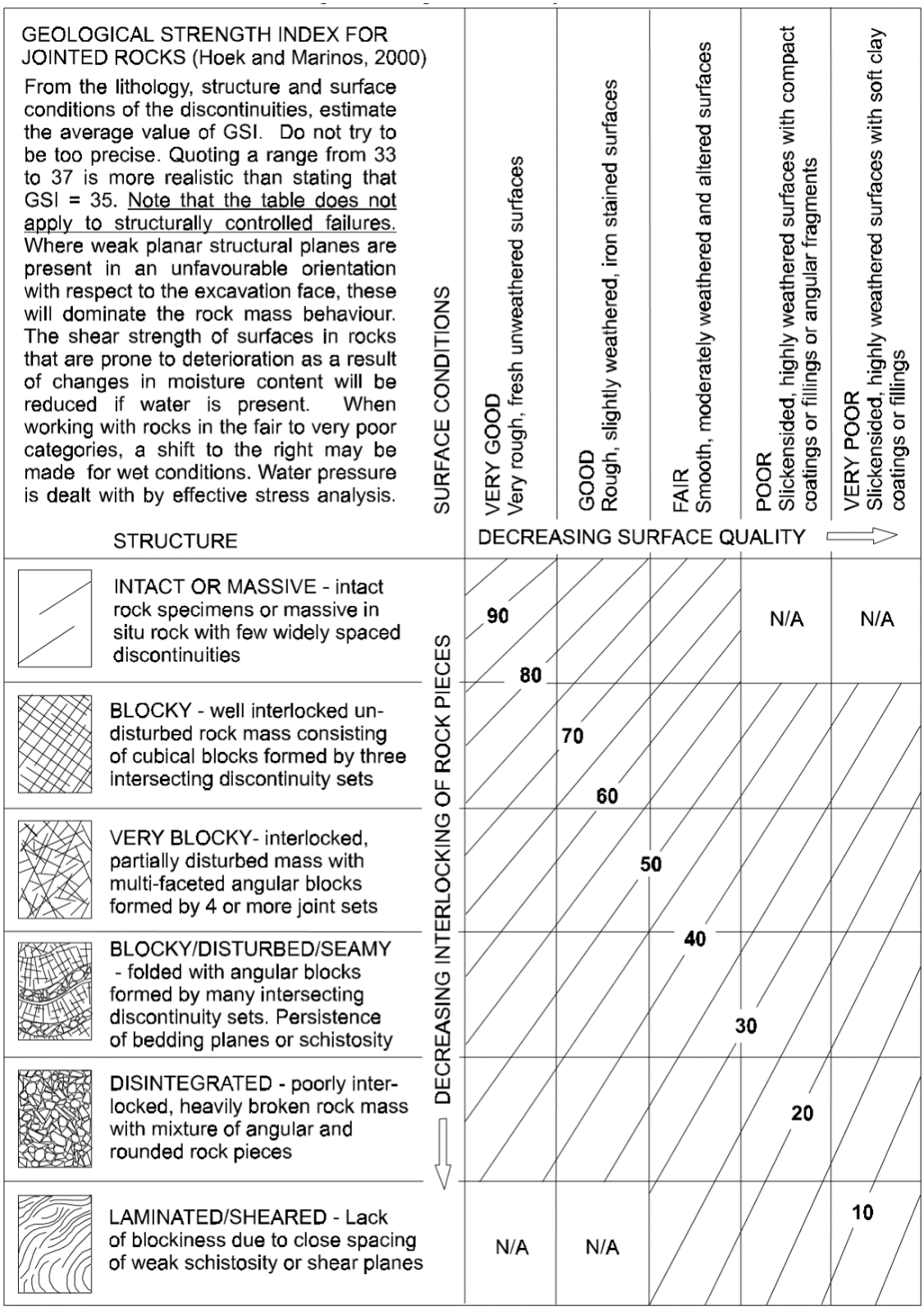



*Figure 5-3 Summary of GSI classifications (Hoek and Marinos, 2000)*

## 5.5 Adopted Slope Stability Analysis Methodology

Deterministic slope stability analysis, using two-dimensional limit equilibrium methods and Rocscience's proprietary software SLIDE 2.0 (SLIDE), has been undertaken for the nine (9) selected cross-section locations through the supplied final landform designs for Curragh.

The following assumptions, comments and qualifications are made in relation to the analyses completed:

- Static and dynamic scenarios have been considered. To consider the potential impacts of earthquakes (i.e. dynamic scenarios) a peak ground acceleration (g) of 0.02 has been applied, equivalent to an event with an exceedance probability of 2% in 50 years (refer to Section 2.3).
- For design acceptance criteria, a minimum factor of safety (FoS) of 1.5 for static conditions and 1.1 for dynamic conditions have been adopted for these analyses;
- The Spencer method has been adopted for these analyses;
- The Path Search search method has been adopted for these analyses;
- The slope stability analysis considers Global Stability of the slope;
- For the purpose of these analyses a slope angle of 7-degrees in the soil materials has been assumed. It is understood that this is to help prevent and minimise surface erosion, rather than to maintain long term stability of the relevant final landform slopes;
- A Disturbance (D) Factor of 0.7 has been applied when determining Hoek-Brown material parameters for a blast affect Permian rock mass;
- A Disturbance (D) Factor has been applied to a width equal to approximately half the bench height, where the final landform comprises final excavated pitwall geometries in the Permian rock;
- The analysis of final excavated pitwall geometries in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s);
- Groundwater and surface water can have a significant and adverse impact on the stability of pitwalls and must therefore be appropriately understood and considered. Limited groundwater and/or hydrogeological information is available.
    - The Steady State FEA tool provided in SLIDE has been utilised to model groundwater movement and hydrostatic pressures through the materials based on the adopted ground models, for the assumed water levels and adopted material hydraulic conductivities (Table 5-7).
    - Flood levels have been adopted as per Section 2.4. A 1m freeboard was added to the provided flood levels for the presented analysis. Values were converted to the CCPL mine grid coordinate system prior to use.
    - The final voids have been assumed to be dry for the presented analyses.
    - Perched water tables have not been considered.

# 6. Slope Stability Analysis Results

The analysis results for the critical failure surfaces analysed are provided in Table 6-1 to Table 6-9. Analysis outputs are provided in Appendix A.

*Table 6-1 Analysis Results for the Adopted Geotechnical Ground Models -Section 1 U-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Section 1: U-Pit** | Planned Final Landform Option - Highwall Side | 1.8 | 1.7 |

*Table 6-2 Analysis Results for the Adopted Geotechnical Ground Models -Section 2 S-Pit South*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Section 2: S-Pit South** | Planned Final Landform Option - Highwall Side | 1.8 | 1.7 |
| | Planned Final Landform Option - Lowwall Side | 1.7 | 1.6 |

*Table 6-3 Analysis Results for the Adopted Geotechnical Ground Models -Section 3 X-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Section 3: X-Pit** | Planned Final Landform Option - Highwall Side | 1.8 | 1.7 |

*Table 6-4 Analysis Results for the Adopted Geotechnical Ground Models -Section 4 D-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Section 4: D-Pit** | Planned Final Landform Option - Highwall Side | 2.4 | 2.3 |
| | Alternative Final Landform Option - Highwall Side | 3.2 | 2.7 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.6 | 1.5 |

*Table 6-5 Analysis Results for the Adopted Geotechnical Ground Models -Section 5 F-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Section 5: F-Pit South** | Planned Final Landform Option - Highwall Side | 1.9 | 1.8 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.8 | 1.7 |
| | Planned Final Landform Out Board Slope | 1.7 | 1.6 |
| | Planned Final Landform Option - Lowwall Side | 2.9 | 2.6 |

*Table 6-6 Analysis Results for the Adopted Geotechnical Ground Models -Section 6 K-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Section 6: K-Pit** | Planned Final Landform Option - Highwall Side | 2.5 | 2.4 |
| | Alternative Final Landform Option - Highwall Side | 3.2 | 3.1 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.7 | 1.6 |

*Table 6-7 Analysis Results for the Adopted Geotechnical Ground Models -Section 7 J-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Section 7: J-Pit** | Planned Final Landform Option - Highwall Side | 1.7 | 1.6 |
| | Planned Final Highwall Re-Shaped Final Slope - Highwall Side | 1.6 | 1.5 |

*Table 6-8 Analysis Results for the Adopted Geotechnical Ground Models -Section 8 Y-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Section 8: Y-Pit** | Planned Final Landform Option - Highwall Side | 2.7 | 2.5 |
| | Planned Final Highwall Re-Shaped Final Slope - Highwall Side | 2.0 | 1.9 |

*Table 6-9 Analysis Results for the Adopted Geotechnical Ground Models -Section 9 Z-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Section 9: Z-Pit** | Planned Final Landform Option - Highwall Side | 1.8 | 1.7 |
| | Planned Final Highwall Re-Shaped Final Slope - Highwall Side | 1.6 | 1.5 |

# 7. Discussion and Recommendations

Two-dimensional limit equilibrium slope stability analysis has been completed with the estimated static and dynamic Factors of Safety (FoS) for the critical failure surface analysed presented for CCPL's consideration. The estimated FoS should only be used as a general guide for assessing potential geotechnical hazards and risks associated with the longer-term stability of the final landform designs.

Deterministic analysis results for the final landform designs, based on the adopted ground models and analysis methodology and assumptions, indicate that the final landform designs meet the adopted design acceptance criteria (Section 5.5).

It must be noted that the material parameters used in these analyses are consistent with those currently used for in-pit slope design. These are typically based on mean strength parameters, which lead to relatively high probabilities of failure when uncertainty is considered. For example, Table 9.7 in Read & Stacey (2009) suggests that for in-pit slope design a factor of safety of 1.5 may have a Probability of Failure (PoF) of up to 10 or 15%, and a factor of safety of 1.6 still has a PoF of up to 8%. These are unlikely to be acceptable in areas to which the public has access, where a factor of safety of 1.5 is expected to have a much lower PoF as a result of the use of more conservative design parameters. It is therefore necessary for CCPL to confirm that the adopted FoS are acceptable.

Past pitwall performance at Curragh indicates that geological structures are a key factor requiring consideration as part of the design process and CPS. The analysis of sections that include remnant pitwalls in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s). Where adverse fault orientations and interactions, relative to pitwall geometries and locations are present, the planned final pitwall geometries (as provided) may not be appropriate for CCPLs long-term final landform stability requirements. In such cases alternative design options such as the construction of softwalls in blasted Permian rock may be required. Due to potential surface erosion mitigation requirements and in order to meet the adopted design acceptance criteria for long-term slope stability, it may be necessary to re-shape softwalls to reduce slope angles. A re-shaped slope angle of approximately 22-degrees has been considered in the analysis undertaken for ground models that consider re-shaping of softwalls constructed in blasted Permian rock. The associated cut-fill balance of these options is to be further investigated as detailed design works are completed.

The ability to identify geological fault locations and geometries accurately for the final pitwall is limited by existing data coverage and density. Fault interpretations and geotechnical ground models for final pitwalls are to be developed as mining progresses and/or additional geology and geotechnical data is collected and obtained.

To consider the provided flood levels for X-Pit the proposed final landform has been raised by approximately 10m for the purpose of these analyses.

The slope stability analyses presented in this document should be reviewed and updated when new geological, geotechnical and/or hydrogeological data becomes available or as material changes are made to existing data or the design options are developed.

The following recommendations are provided in relation to detailed design of the final landforms:

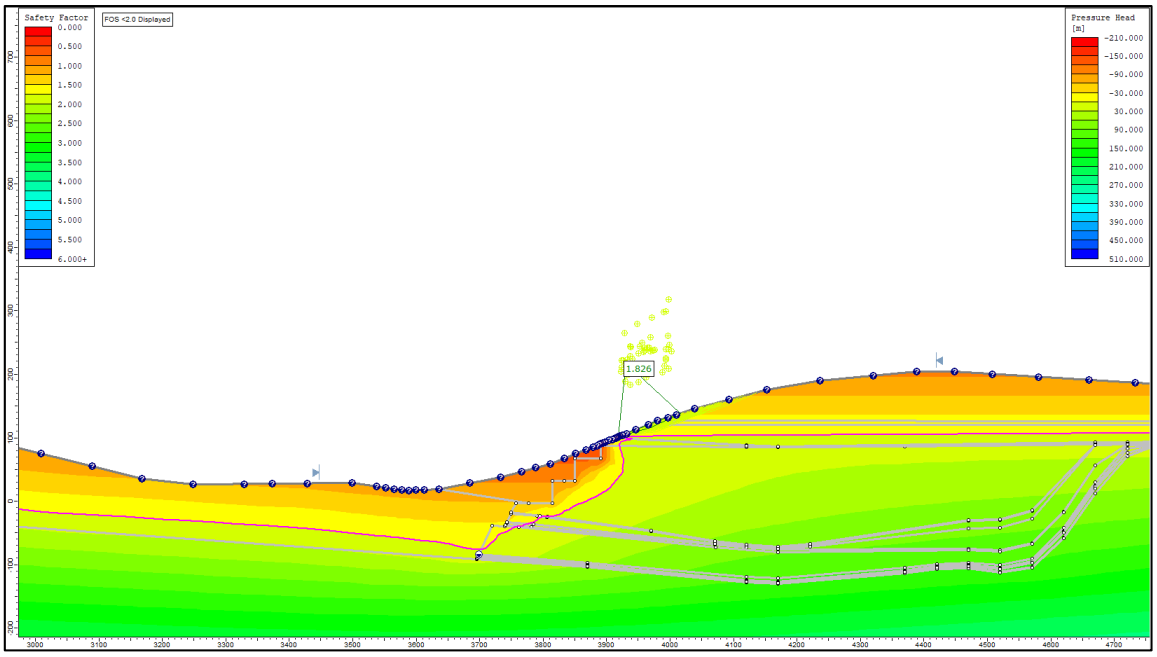
- The construction of the final landform designs, including cut-fill volumes, are to be reviewed and developed;
- An erosional assessment is necessary to confirm the maximum slope angles for the various soil strength materials (including spoil materials). The final landform designs, and if deemed necessary the slope stability analysis, are to be updated based on the outcomes of the erosion assessment;
- Geological, geotechnical and hydrogeological data collection strategies for the final pitwalls are to be developed and implemented to inform the detailed design process;
- The hydrogeological and hydrological models should be developed, and an associated groundwater investigation program implemented;
- Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels in the alluvial soil profile; and,
- As the final landform designs are progressed, and additional geological, geotechnical, hydrogeological and/or hydrological data is obtained, more detailed and extensive slope stability analysis may be required. This should include assessment of all slope geometries, remnant pitwalls and final voids. It is recommended that detailed design include probabilistic slope stability analysis.

## 8. Qualification

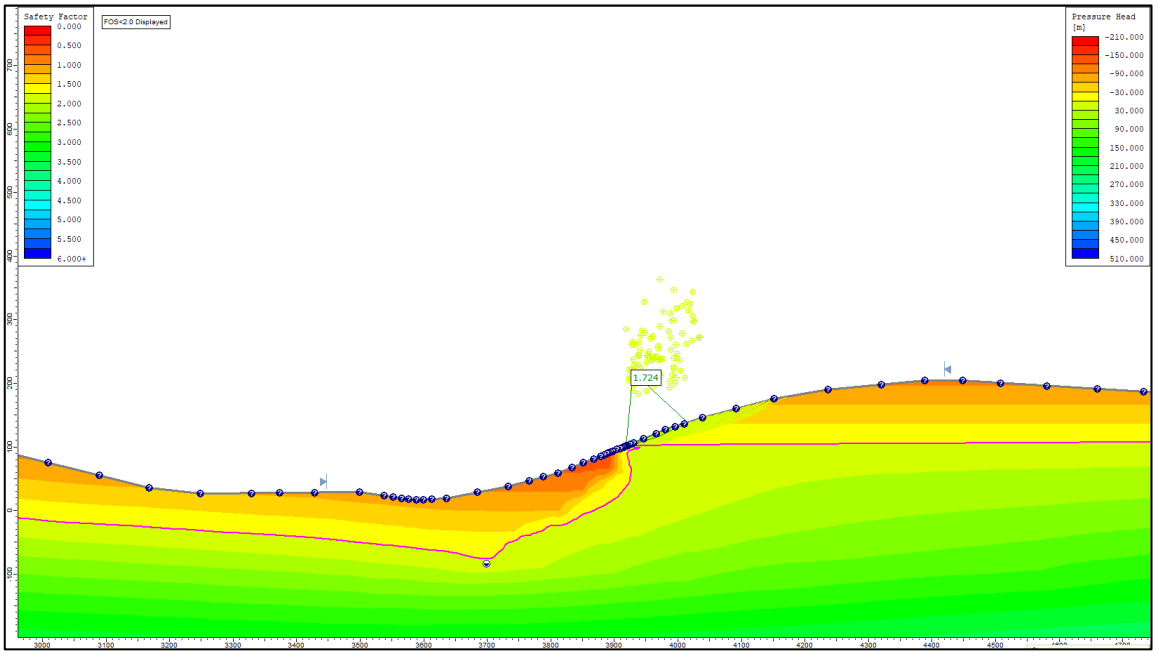
The following qualifications are made in relation to the analysis and recommendations presented in this report:

- This document has been prepared by R&A for CCPL and may only be used and relied upon by CCPL for the purpose agreed between R&A and CCPL as set out in relevant sections of this memorandum. R&A otherwise disclaims responsibility to any person other than CCPL arising in connection with this memorandum.
- It has been assumed that all data supplied by CCPL is true and accurate and that all available and relevant data has been supplied. R&A has not independently verified or validated the data supplied by CCPL and does not accept liability in connection with unverified information, including errors and omissions in this document which were caused by errors or omissions in that information.
- The outputs, opinions, conclusions and recommendations provided in this document are based on the adopted geotechnical ground models and analysis methods. The adopted geotechnical ground models presented in this report may be constrained by available data type, density and accuracy. Therefore there is potential for interpreted ground conditions to vary from those assumed in the adopted ground models. R&A assume that CCPL will undertake detailed design and risk analysis for the design option part of the design process.
- No geotechnical investigations or laboratory testing have been commissioned or undertaken as part of this work.
- The groundwater levels and phreatic surfaces adopted as per data supplied by SLR.
- If the content of this document, including the adopted methods and terminology, is unclear or not fully understood clarification should be sort.
- If it is known, or subsequently becomes known, that any of the qualifications, assumptions or interpretations made in this memorandum are incorrect, R&A must be notified immediately, and the applicability of the slope stability analysis and any associated recommendations reviewed. If considered necessary, the slope stability analysis and report may need to be updated.

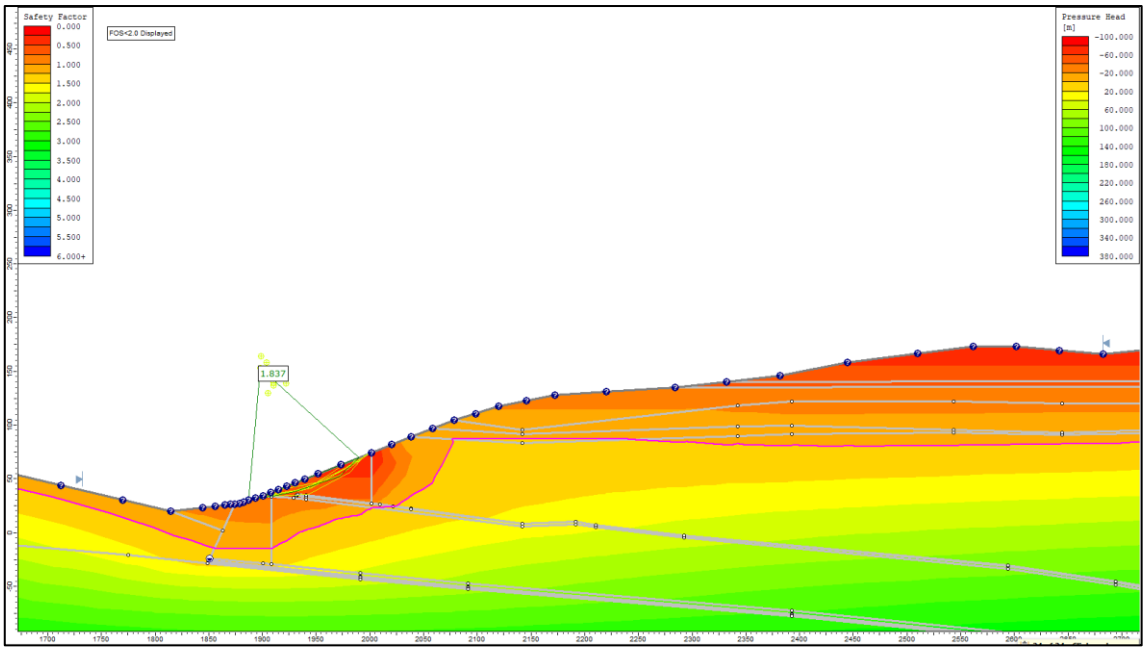
# **Appendix A** – Limit Equilibrium Slope Stability Analysis Outputs



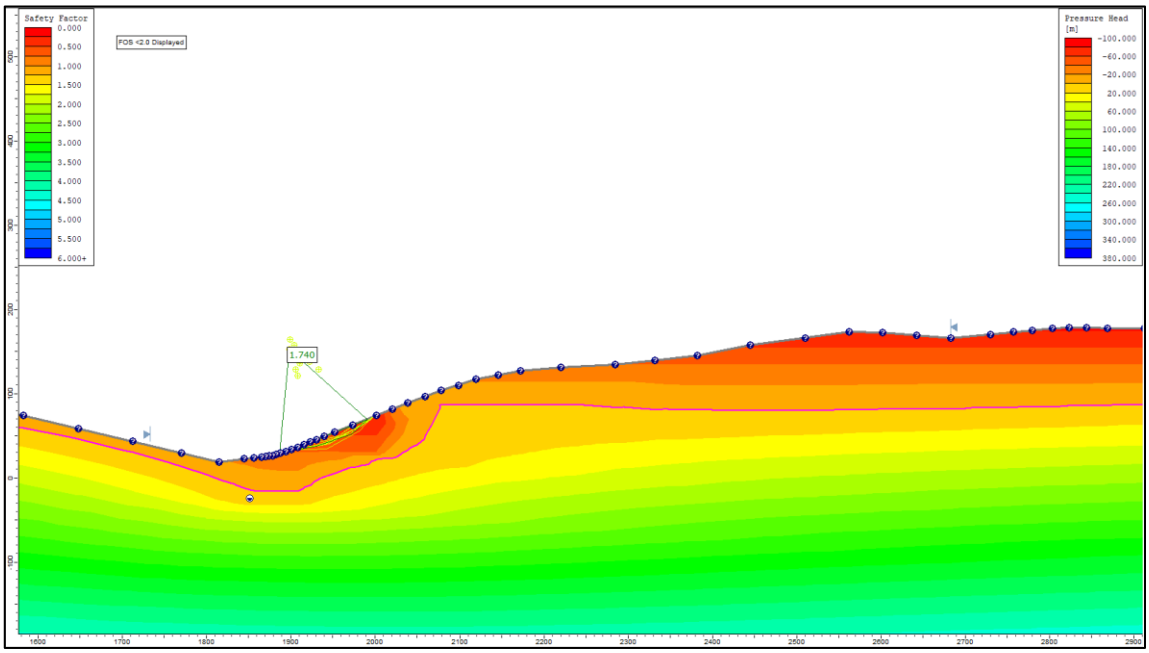

*Appendix A 1 Cross Section 1 – Curragh North U-Pit - Static*



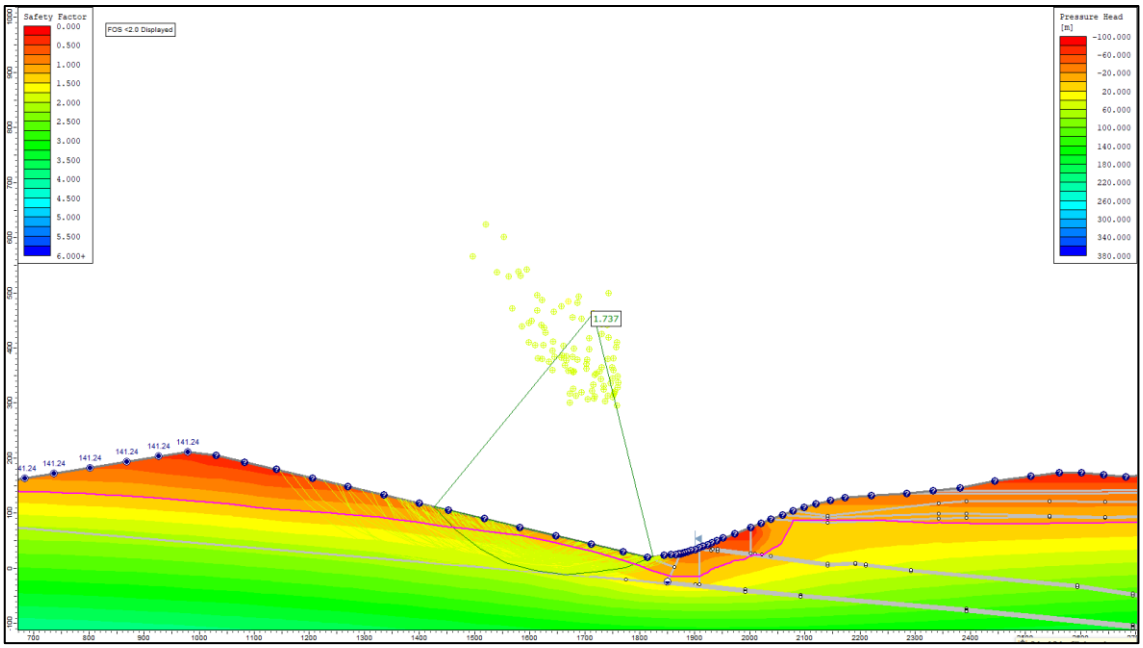

*Appendix A 2 Cross Section 1 – Curragh North U-Pit - Dynamic*



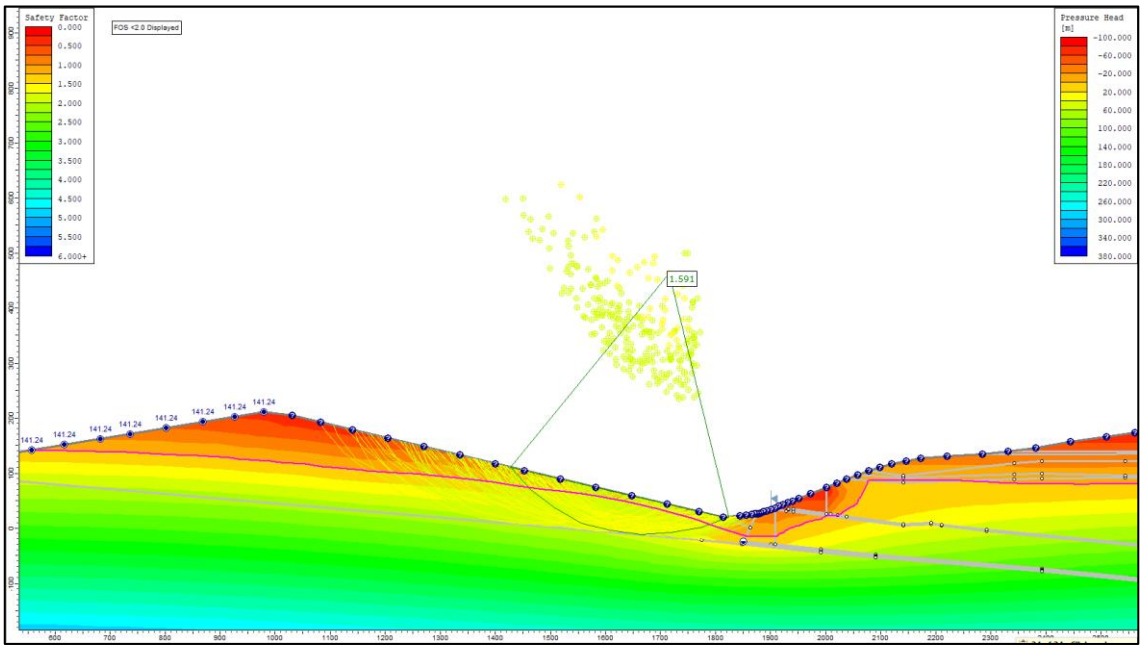

*Appendix A 3 Cross Section 2 – Curragh North S-Pit South - Static*



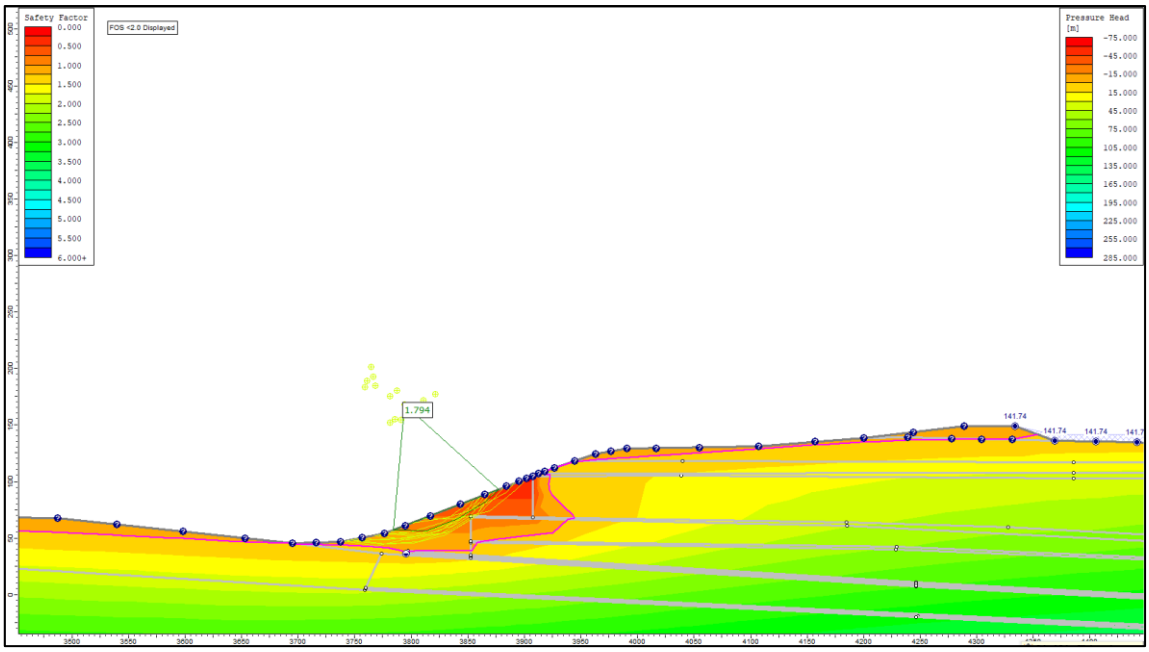

*Appendix A 4 Cross Section 2 – Curragh North S-Pit South - Dynamic*



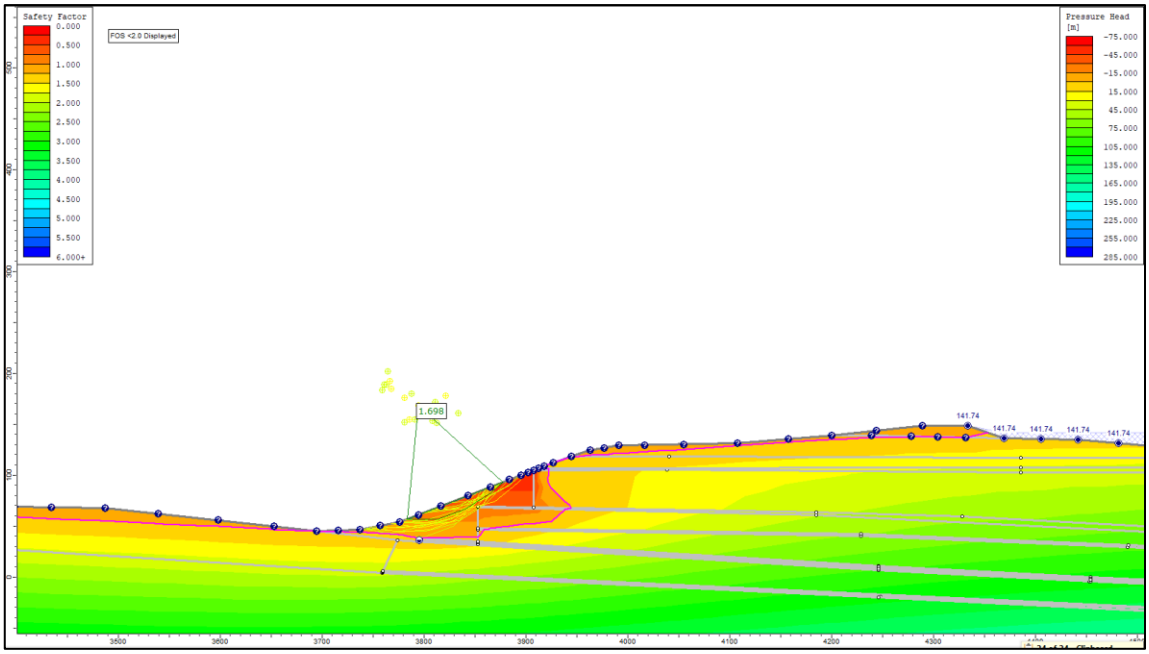

*Appendix A 5 Cross Section 2 – Curragh North S-Pit South Lowwall – Static*



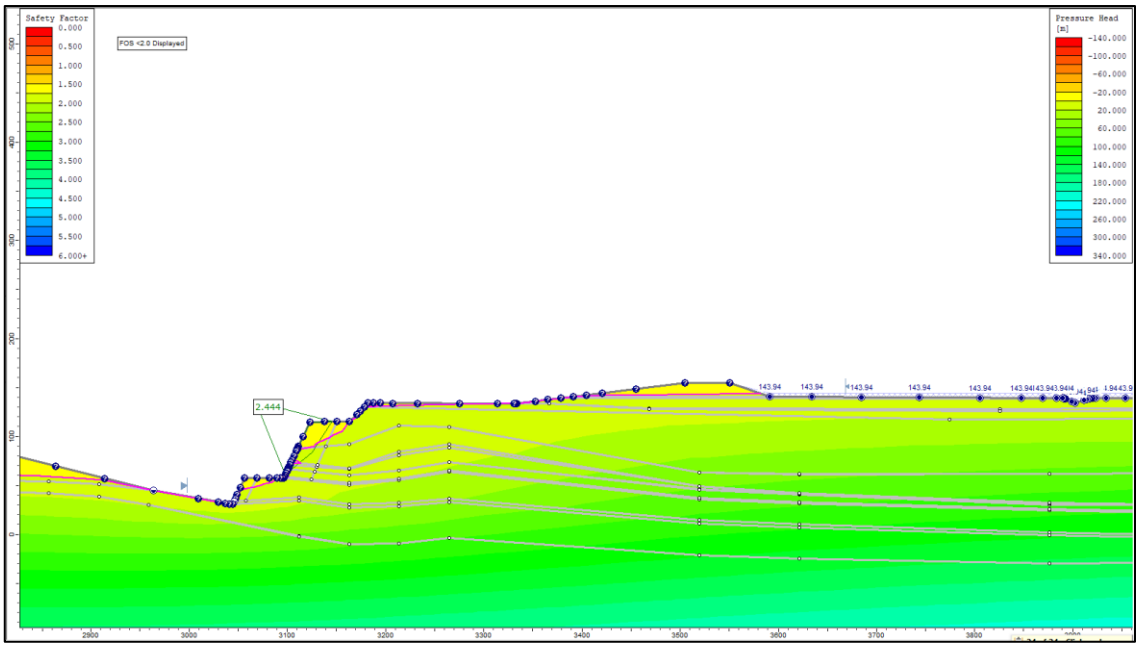

*Appendix A 6 Cross Section 2 – Curragh North S-Pit South Lowwall - Dynamic*



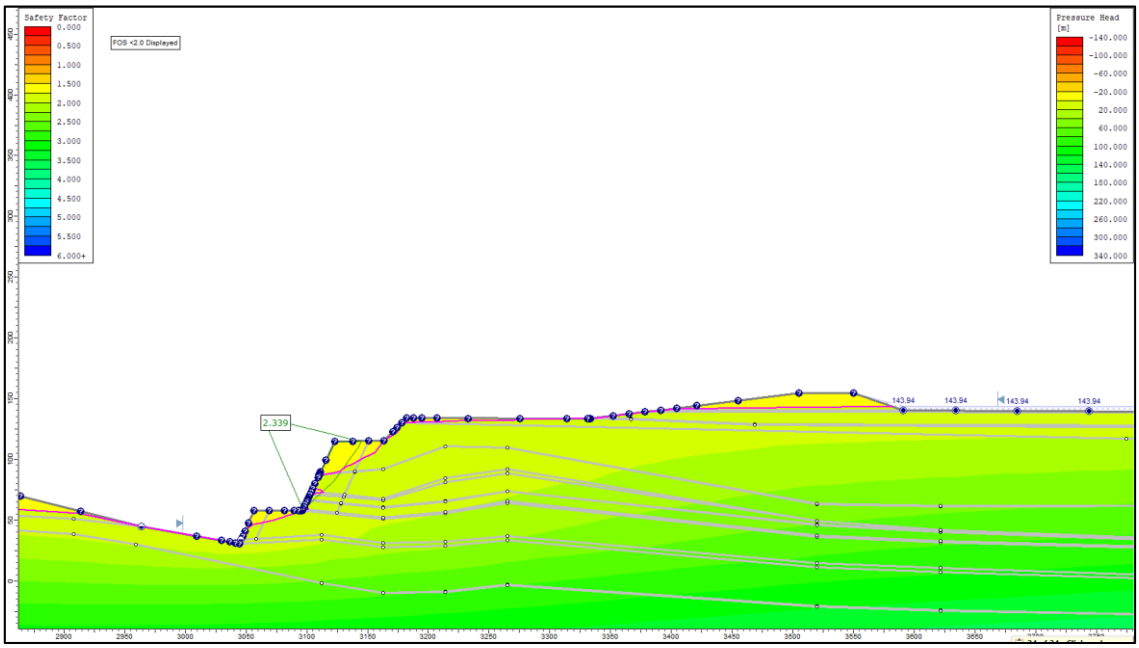

*Appendix A 7 Cross Section 3 – X-Pit – Raised final landform to accommodate supplied flood levels - Static*



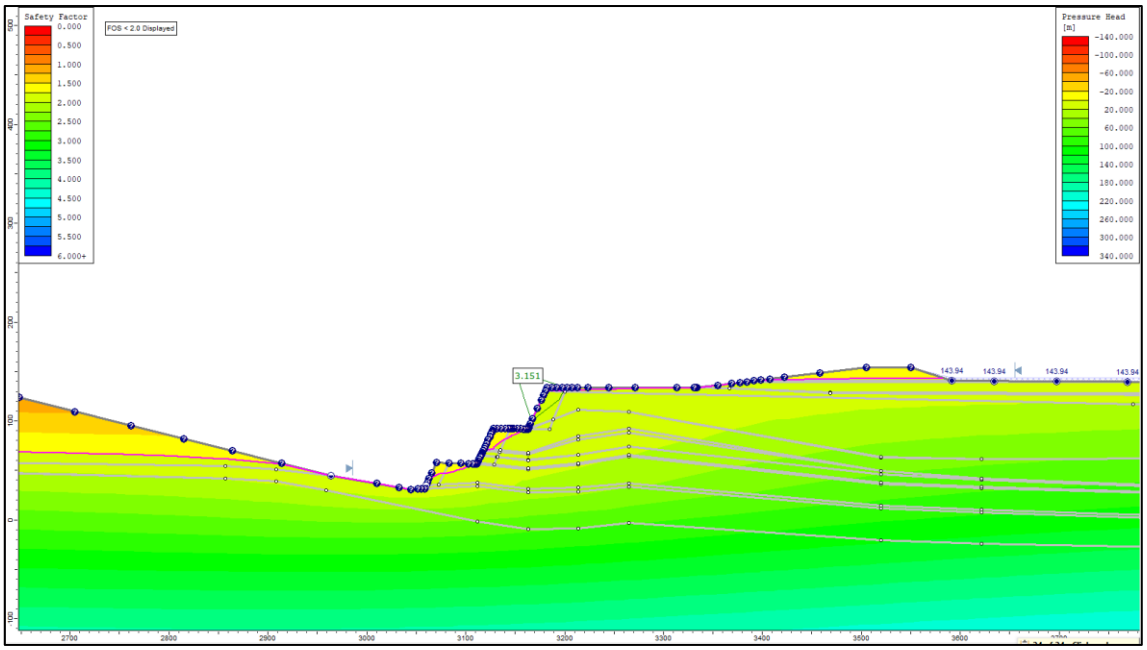

*Appendix A 8 Cross Section 3 – X-Pit – Raised final landform to accommodate supplied flood levels - Dynamic*



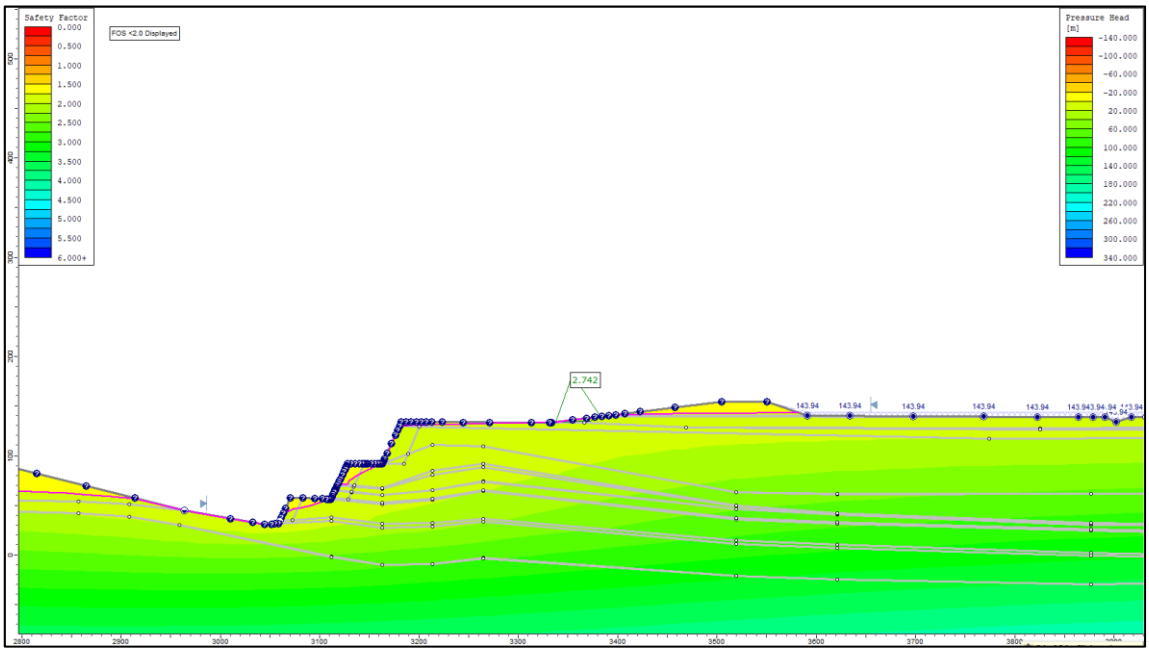

*Appendix A 9 Cross Section 4 – Curragh Main D-Pit - Static*



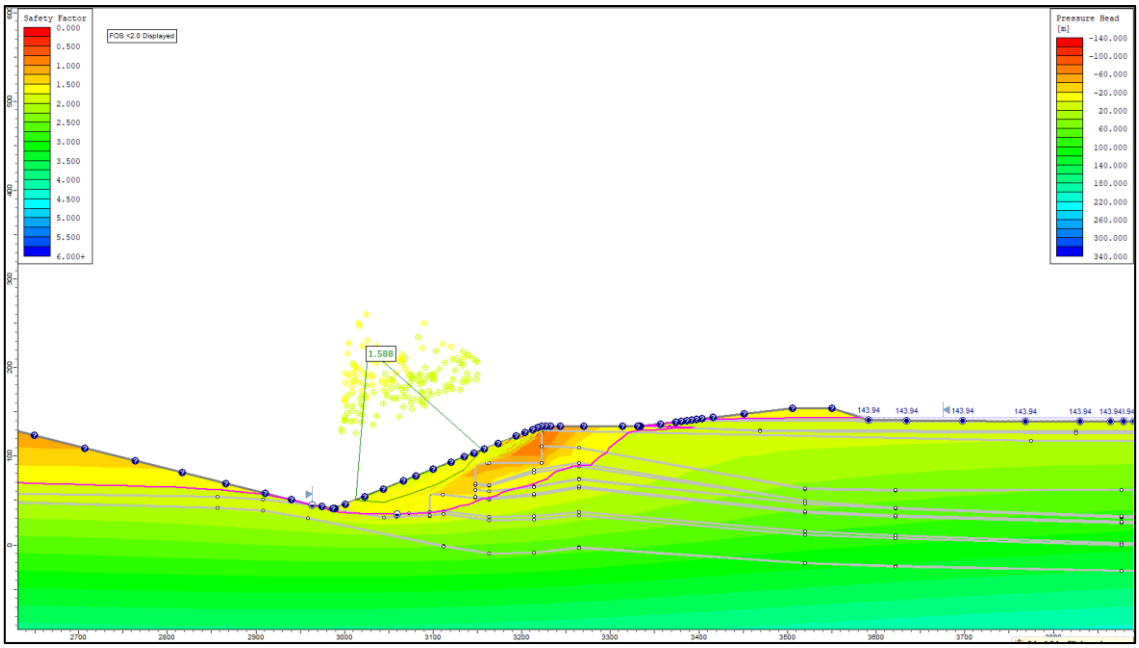

*Appendix A 10 Cross Section 4 – Curragh Main D-Pit - Dynamic*



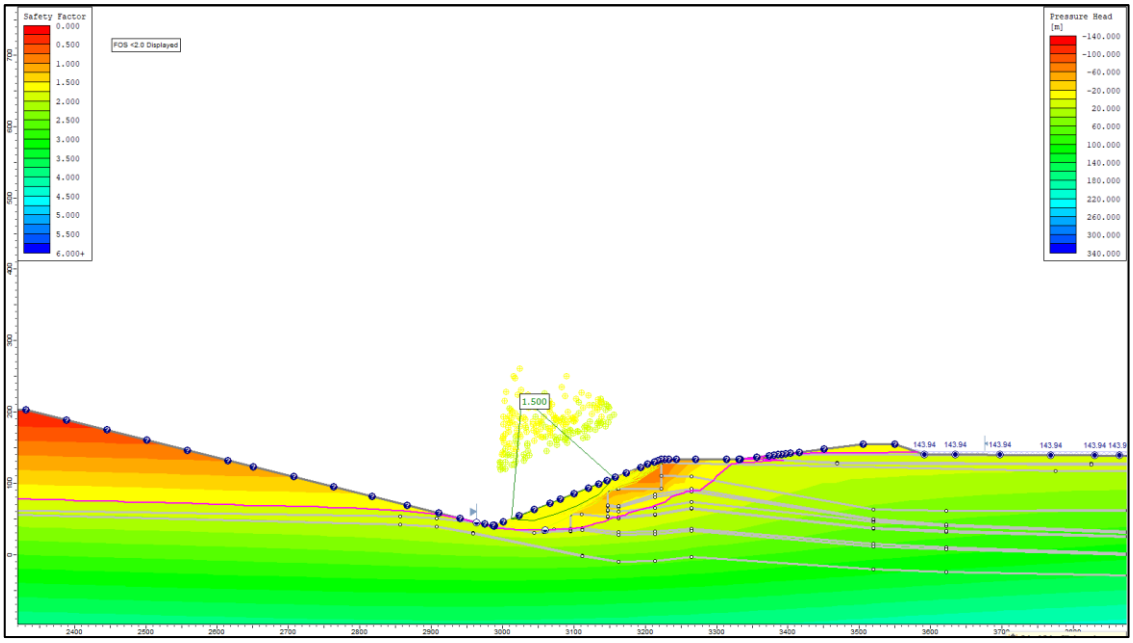

*Appendix A 11 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry – Static*



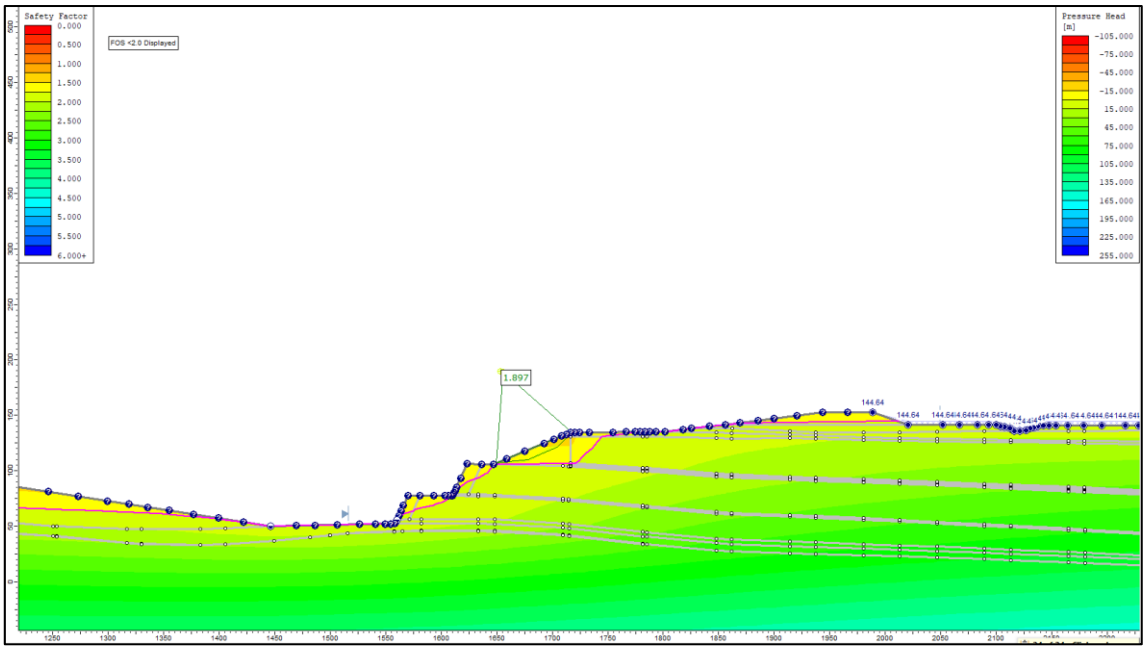

*Appendix A 12 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry – Dynamic*



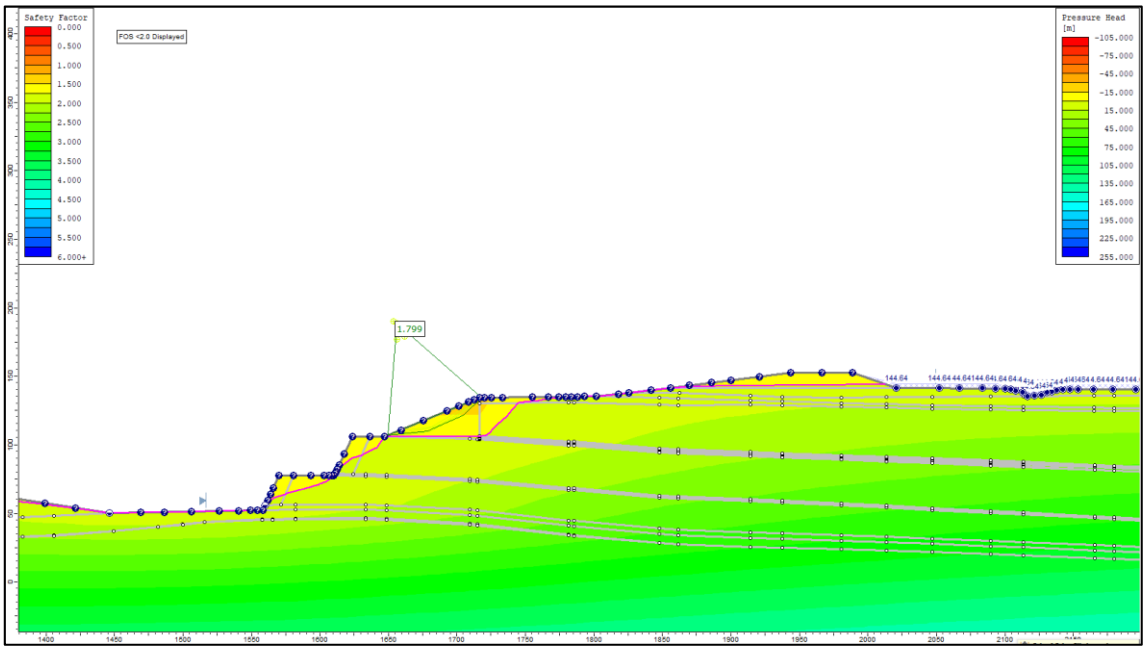

*Appendix A 13 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Static*



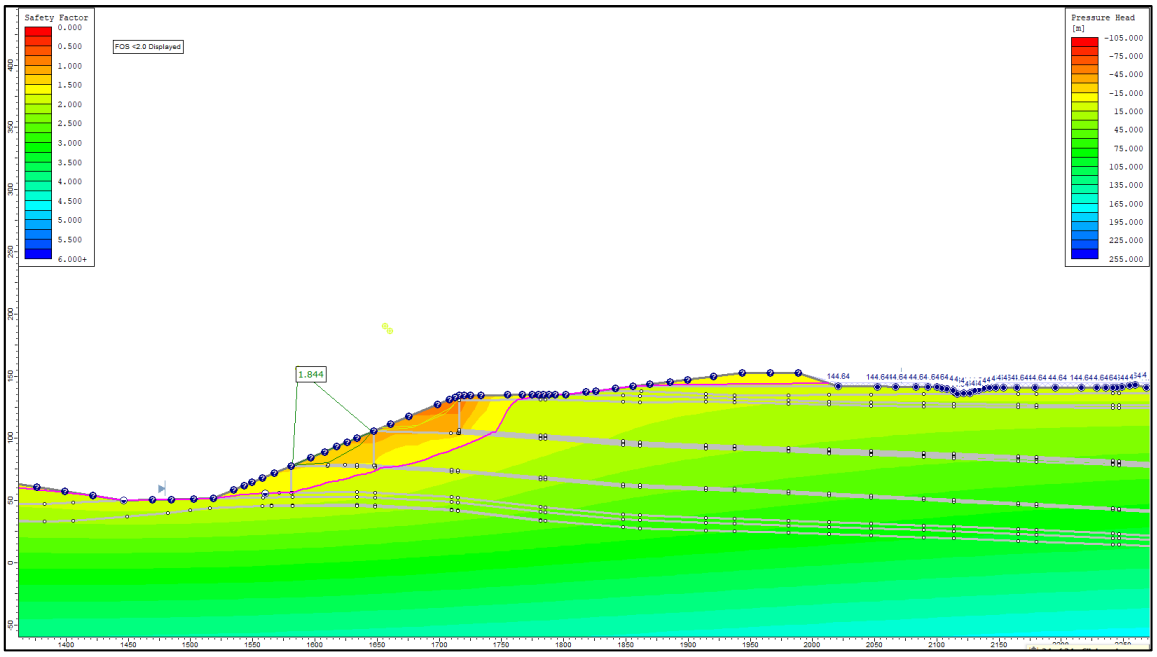

*Appendix A 14 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Dynamic*



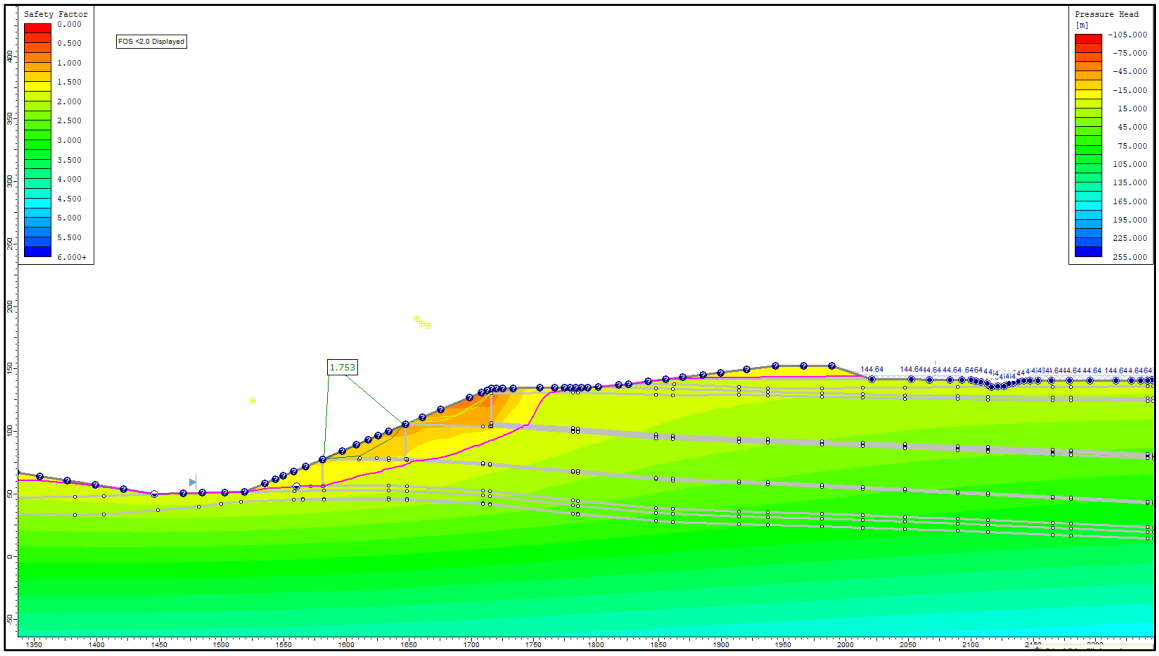

*Appendix A 15 Cross Section 5 – Curragh Main F-Pit - Static*



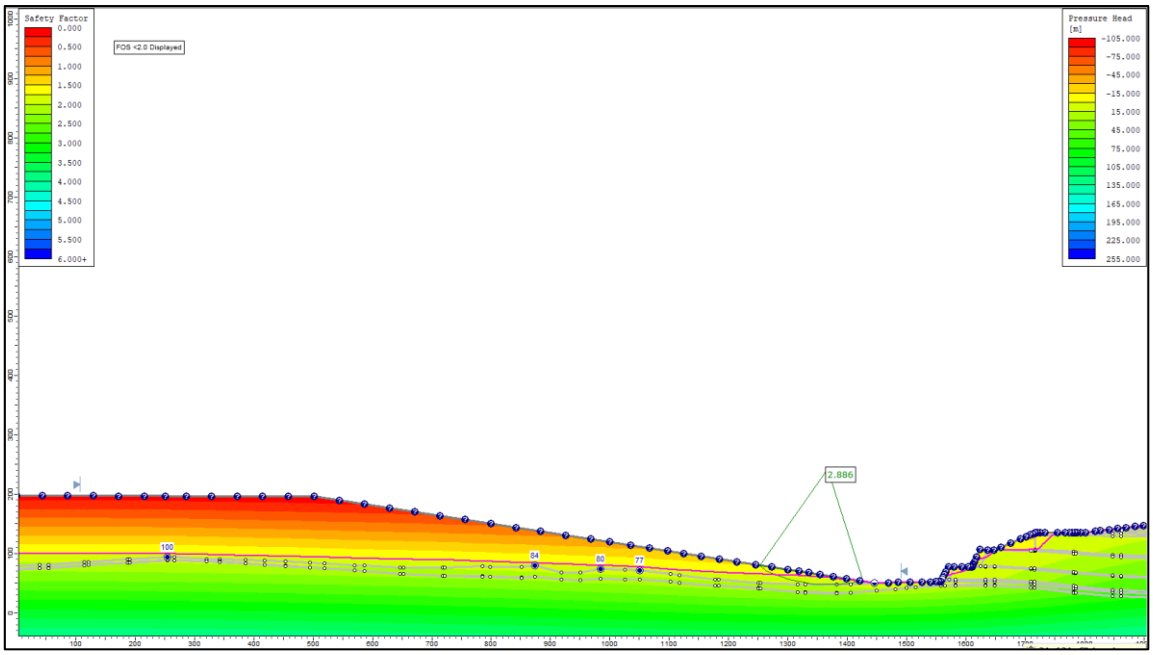

*Appendix A 16 Cross Section 5 – Curragh Main F-Pit - Dynamic*



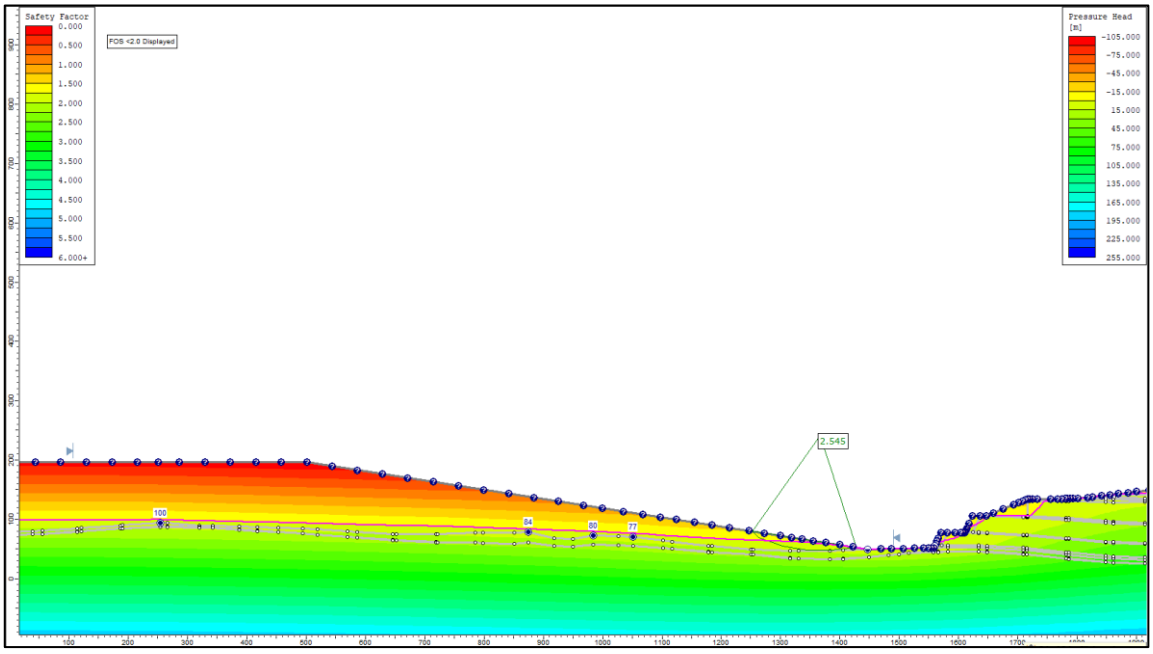

*Appendix A 17 Cross Section 5 – Curragh Main F-Pit Final highwall geometry with blasted and re-shaped final slope – Static*



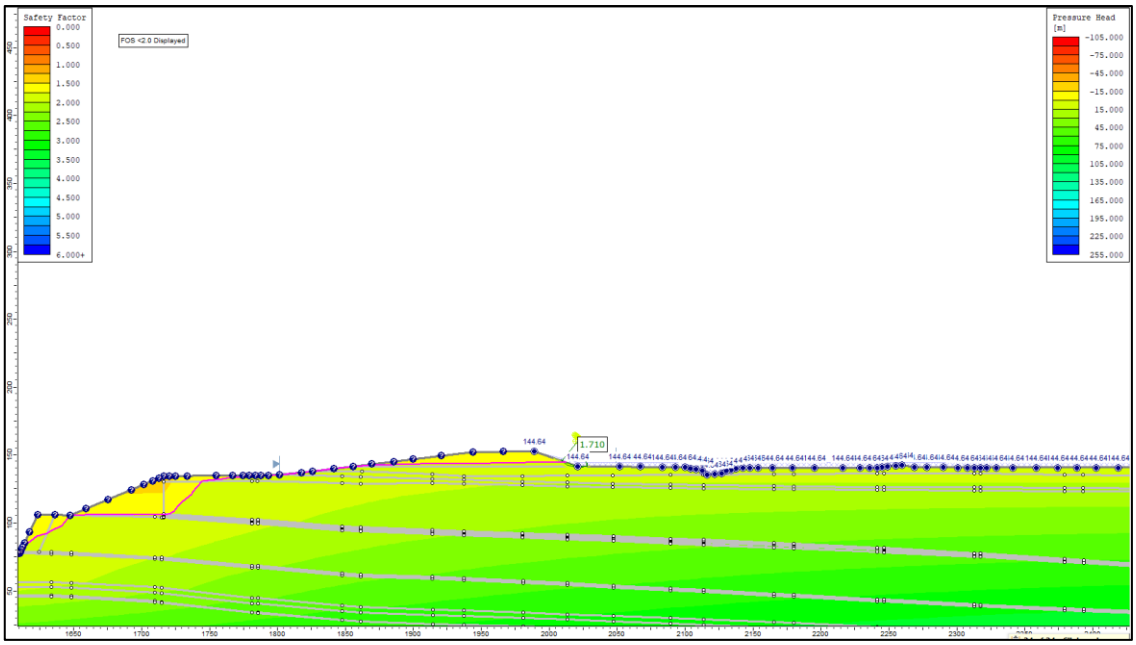

*Appendix A 18 Cross Section 5 – Curragh Main F-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic*



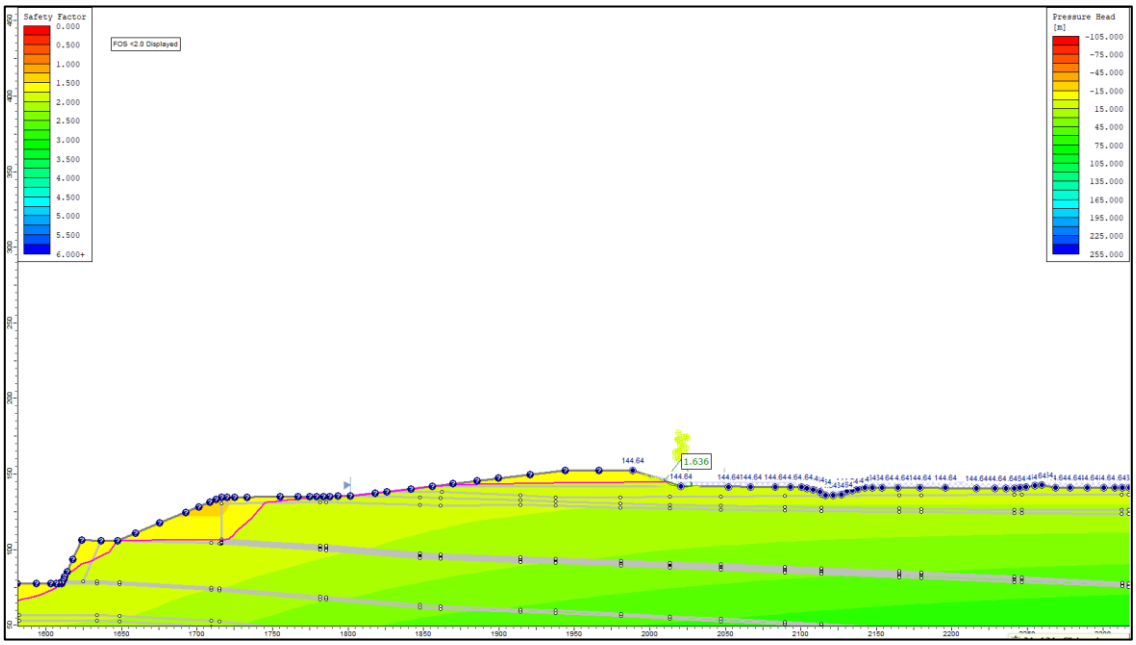

*Appendix A 19 Cross Section 5 – Curragh Main F-Pit Lowwall - Static*



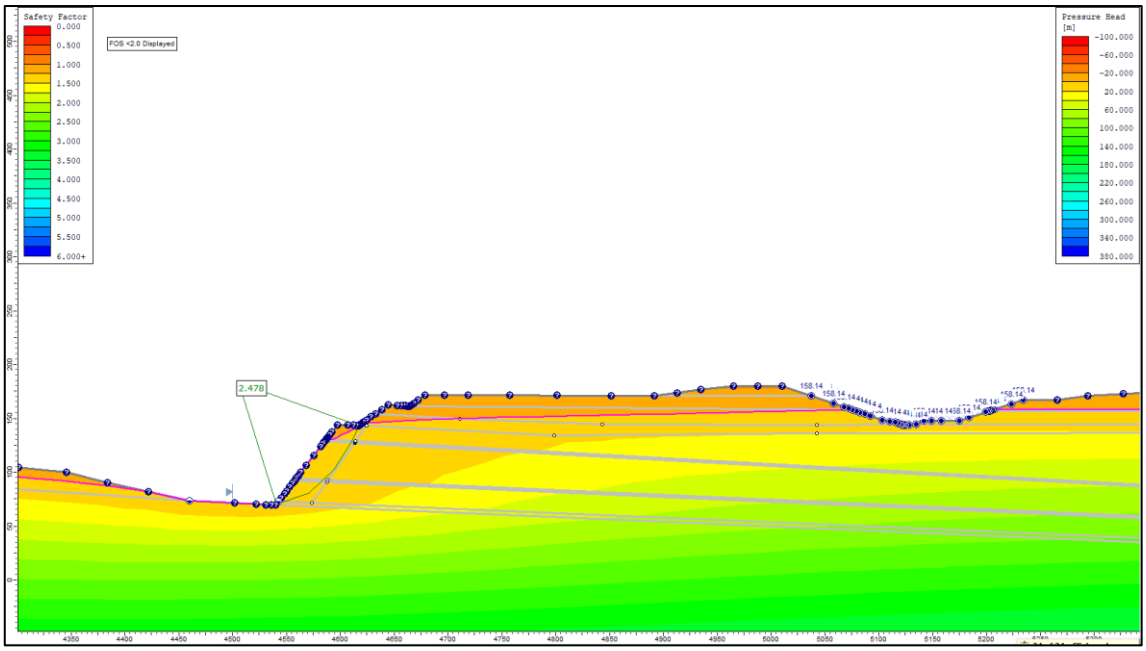

*Appendix A 20 Cross Section 5 – Curragh Main F-Pit Lowwall – Dynamic*



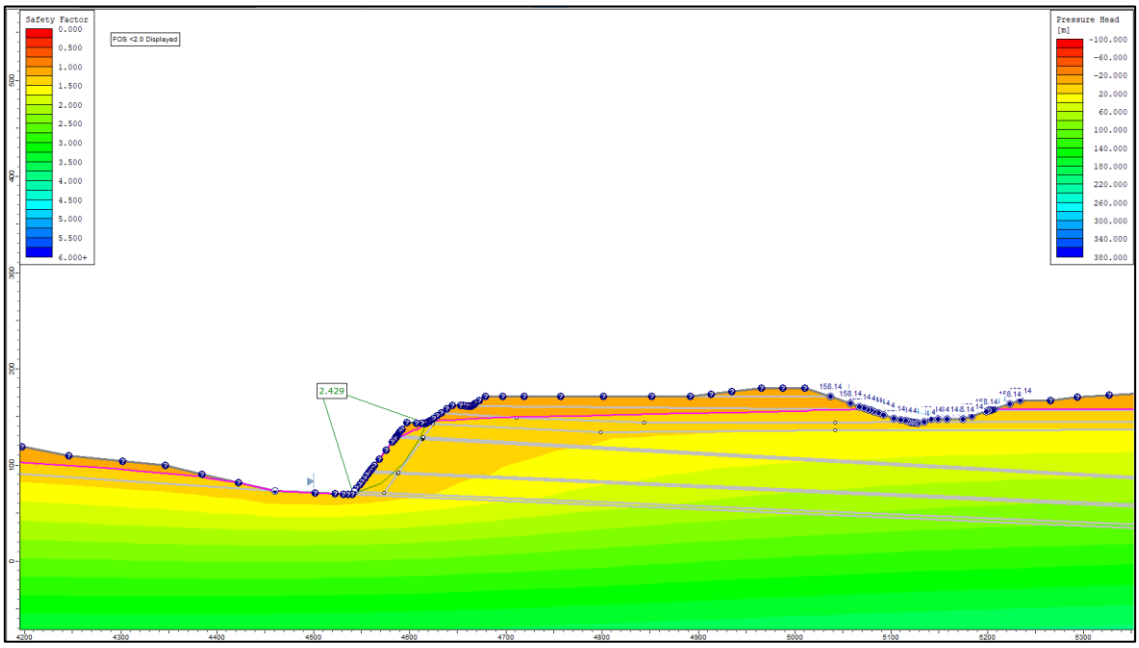

*Appendix A 21 Cross Section 5 – Curragh Main F-Pit Final Landform Out Board Slope - Static*



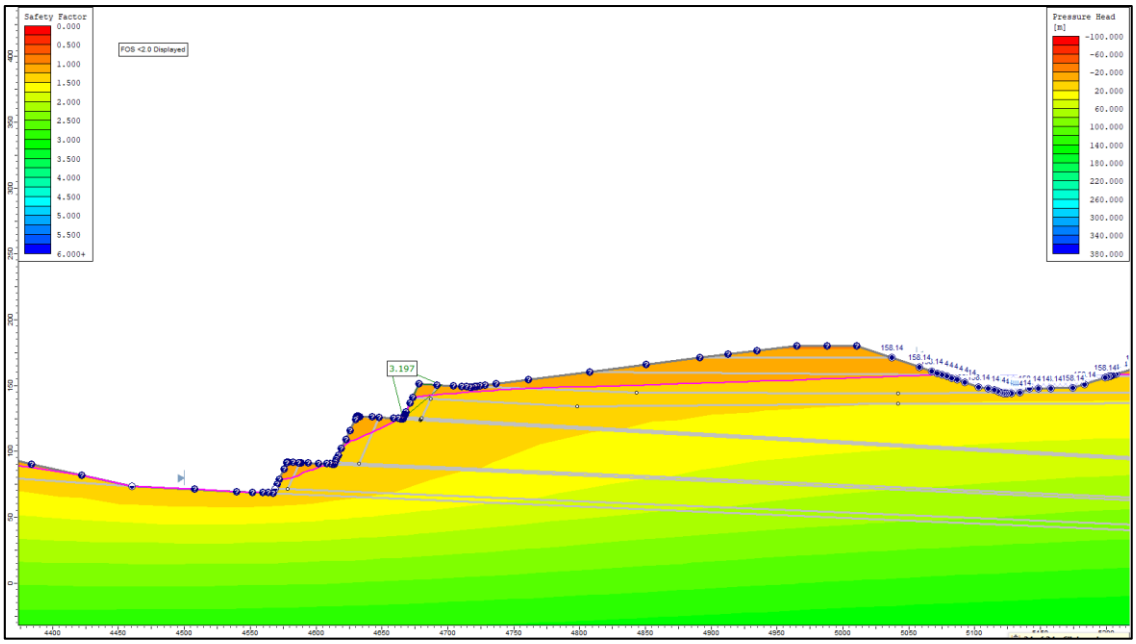

*Appendix A 22 Cross Section 5 – Curragh Main F-Pit Final Landform Out Board Slope - Dynamic*



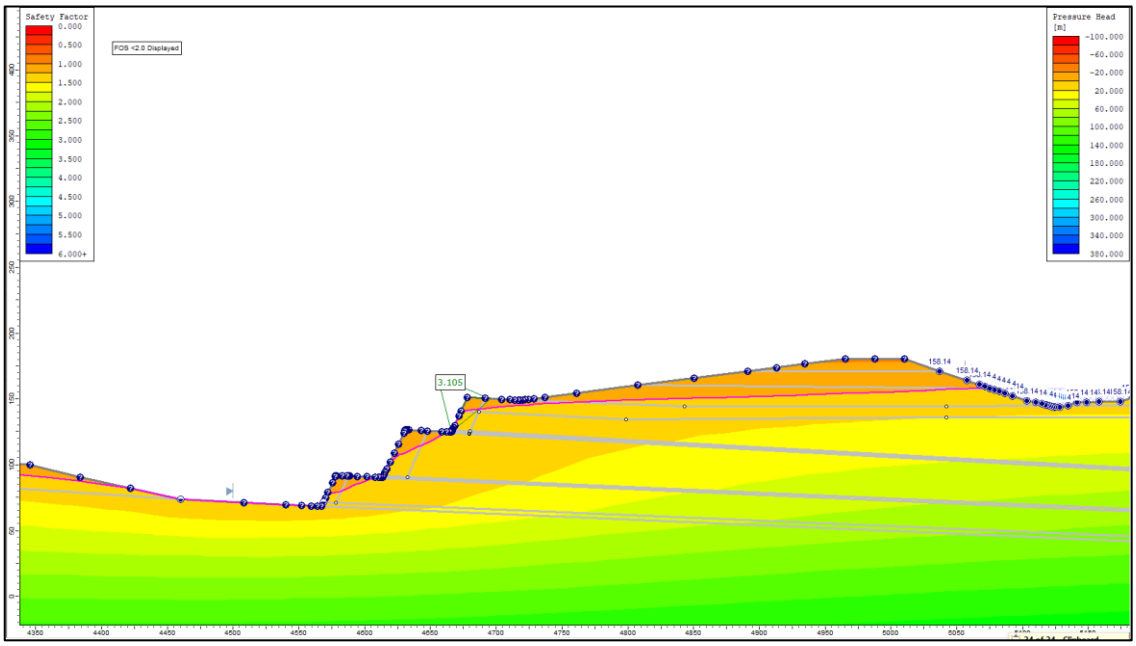

*Appendix A 23 Cross Section 6 – Curragh Main K-Pit - Static*



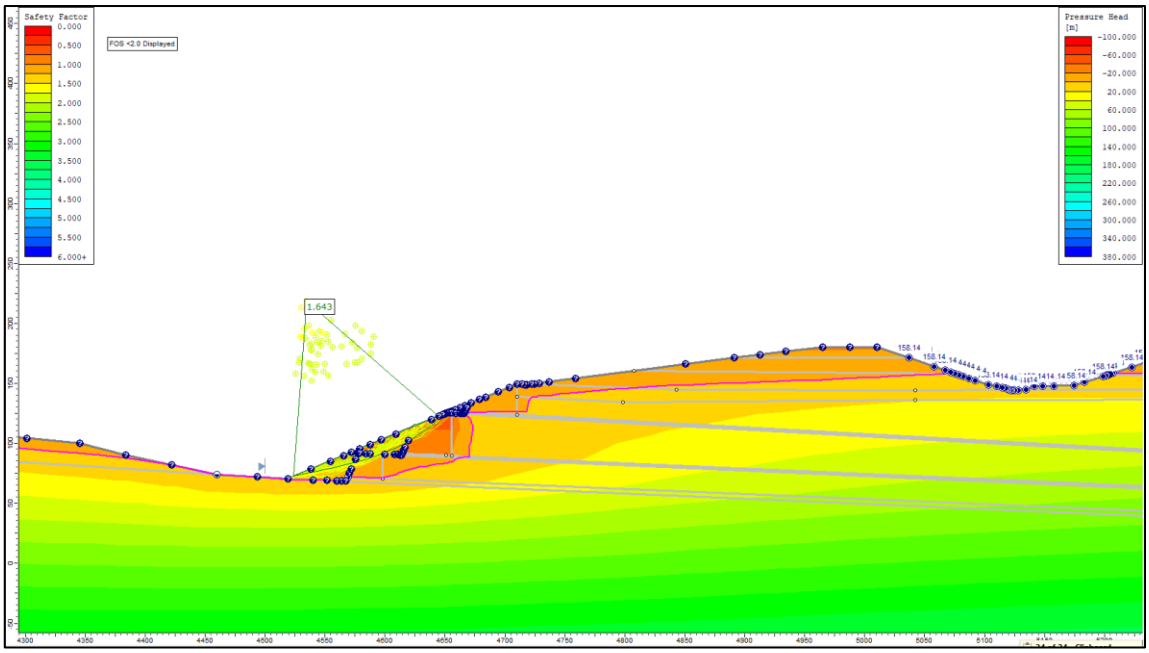

*Appendix A 24 Cross Section 6 – Curragh Main K-Pit - Dynamic*



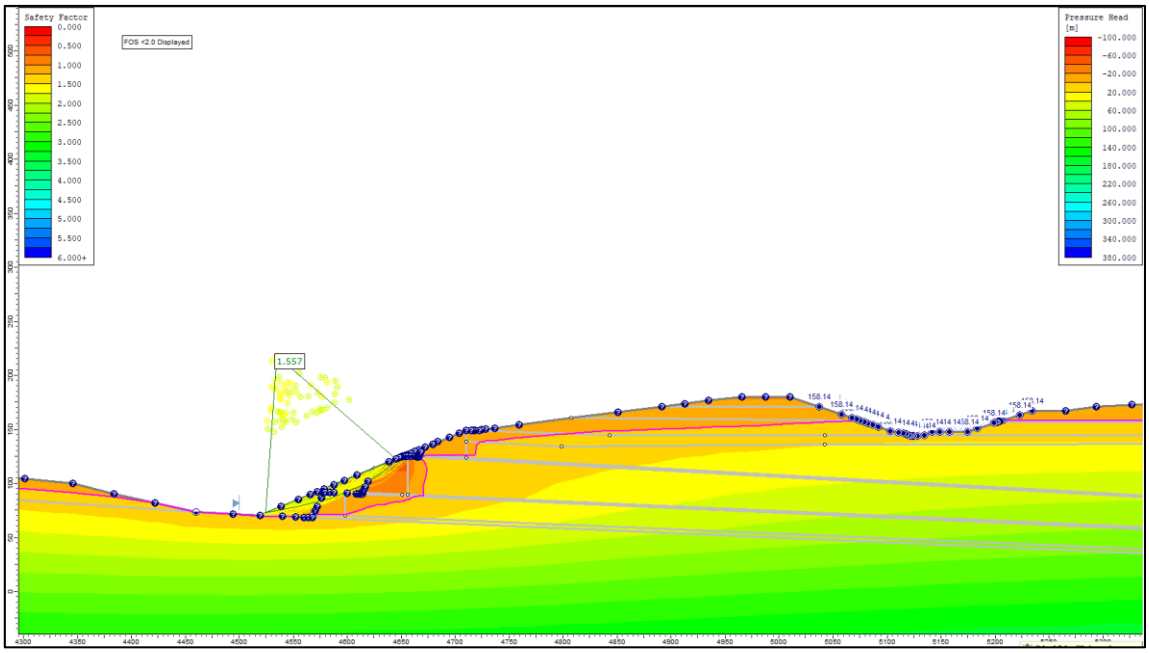

*Appendix A 25 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry – Static*



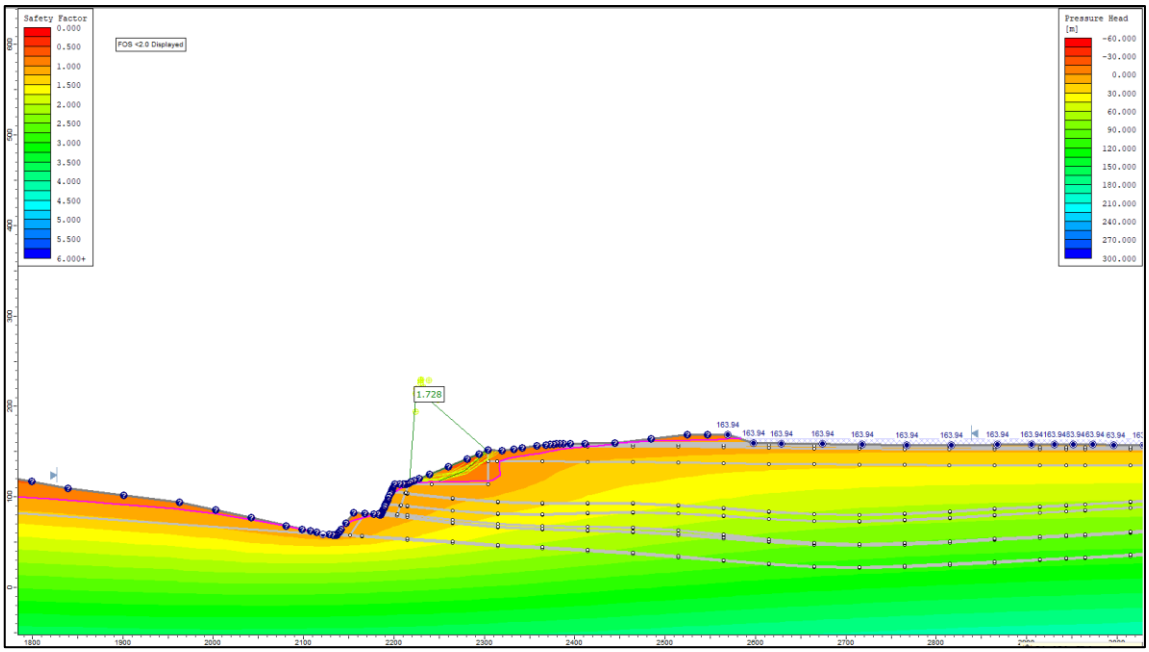

*Appendix A 26 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry – Dynamic*



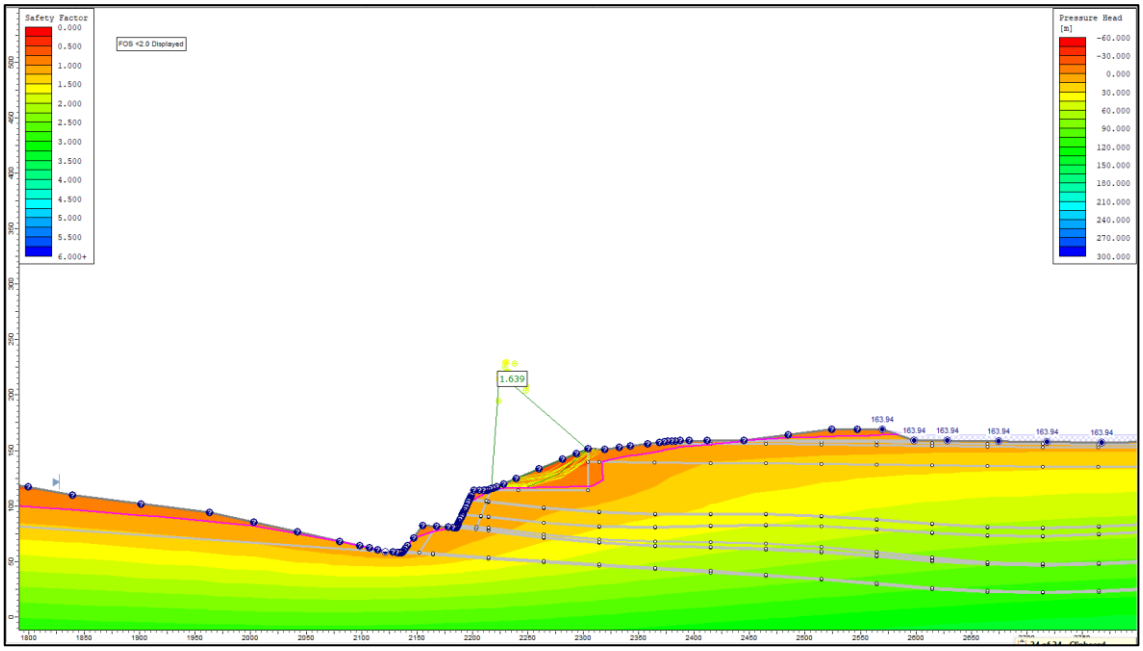

*Appendix A 27 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Static*



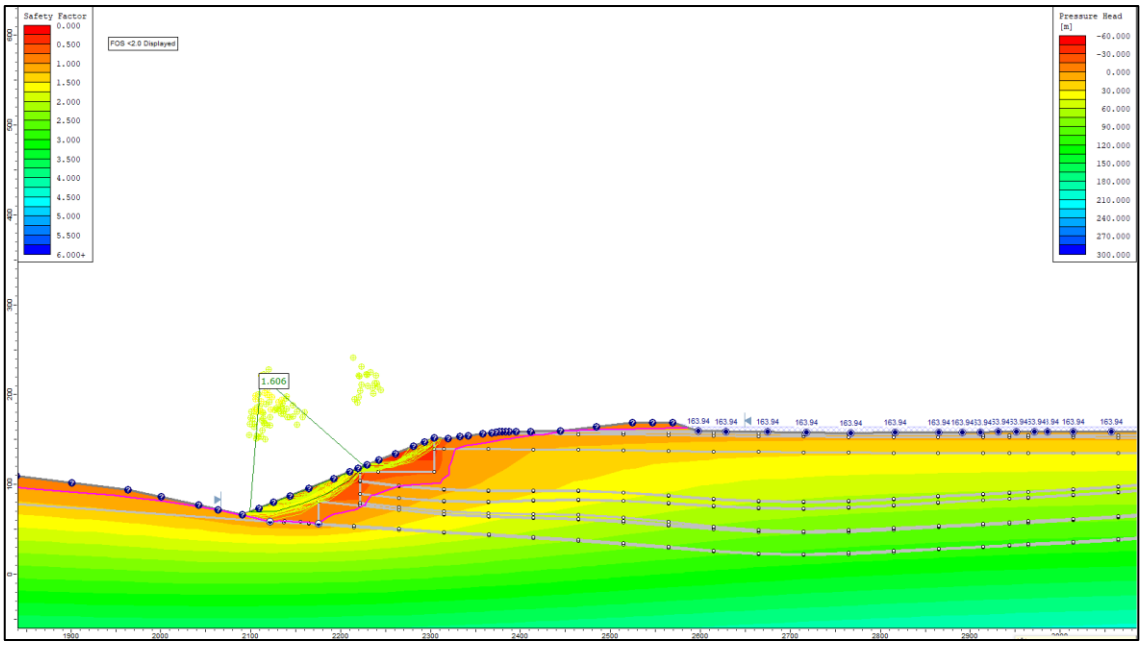

*Appendix A 28 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Dynamic*



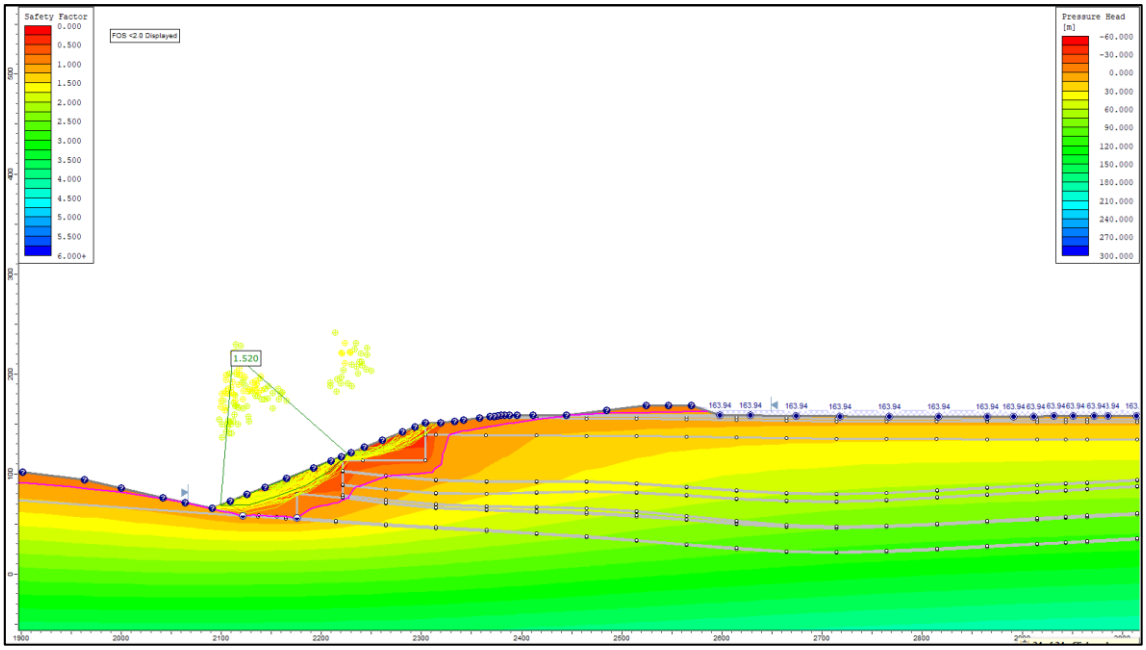

*Appendix A 29 Cross Section 7 – Curragh Main J-Pit - Static*



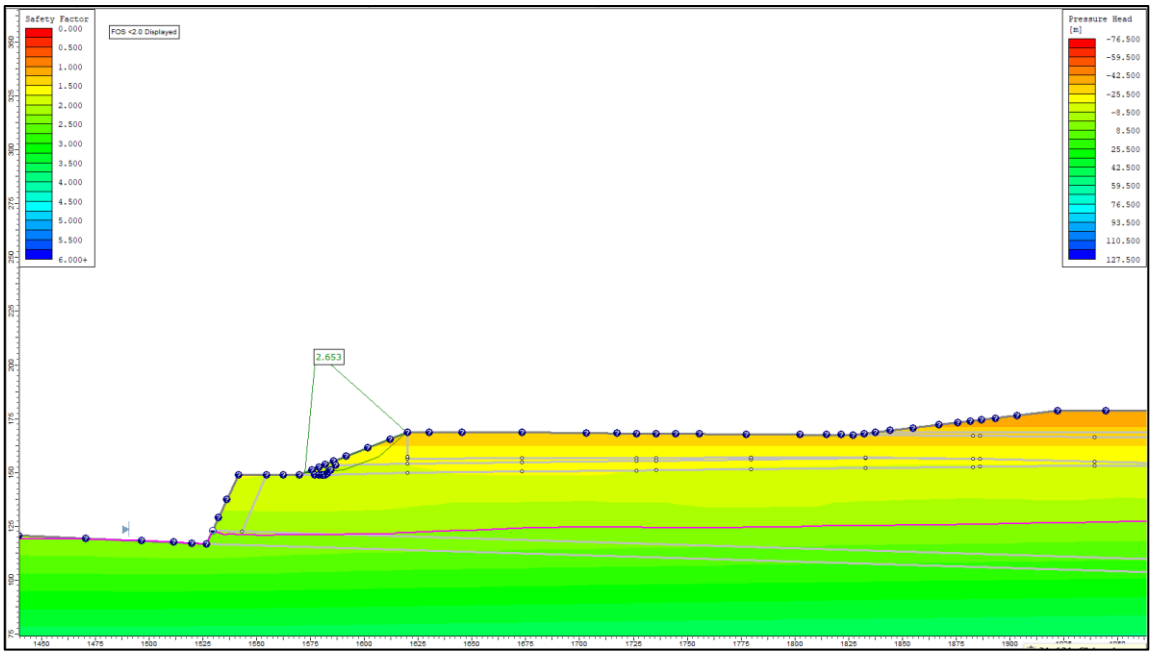

*Appendix A 30 Cross Section 7 – Curragh Main J-Pit - Dynamic*



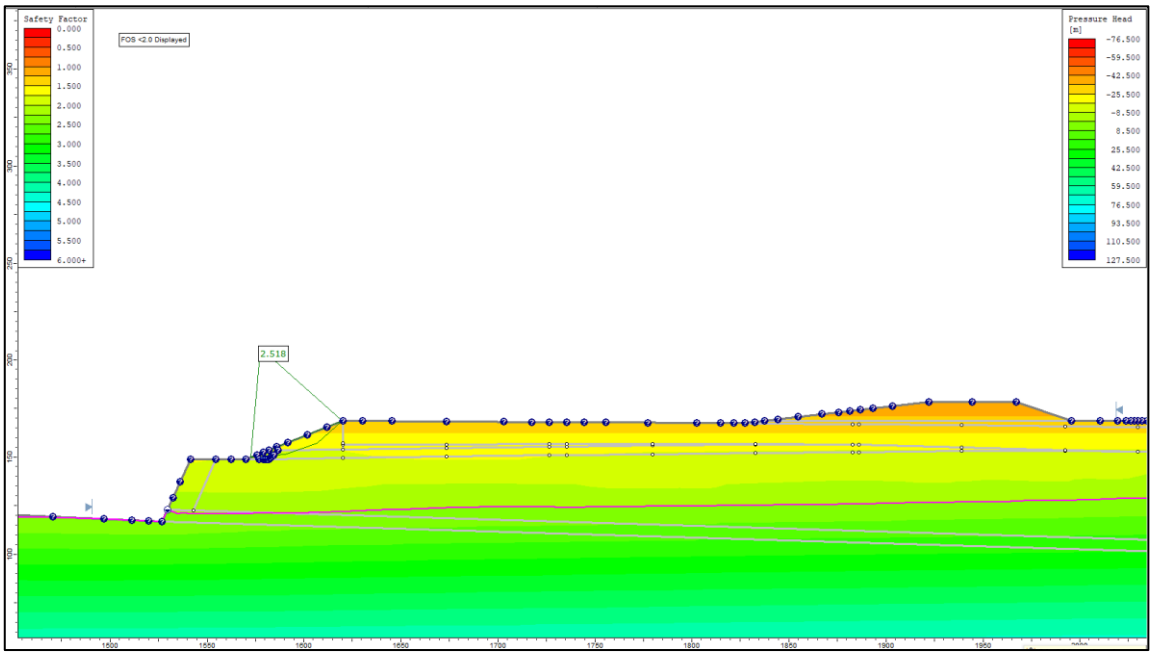

*Appendix A 31 Cross Section 7 – Curragh Main J-Pit Final highwall geometry with blasted and re-shaped final slope – Static*



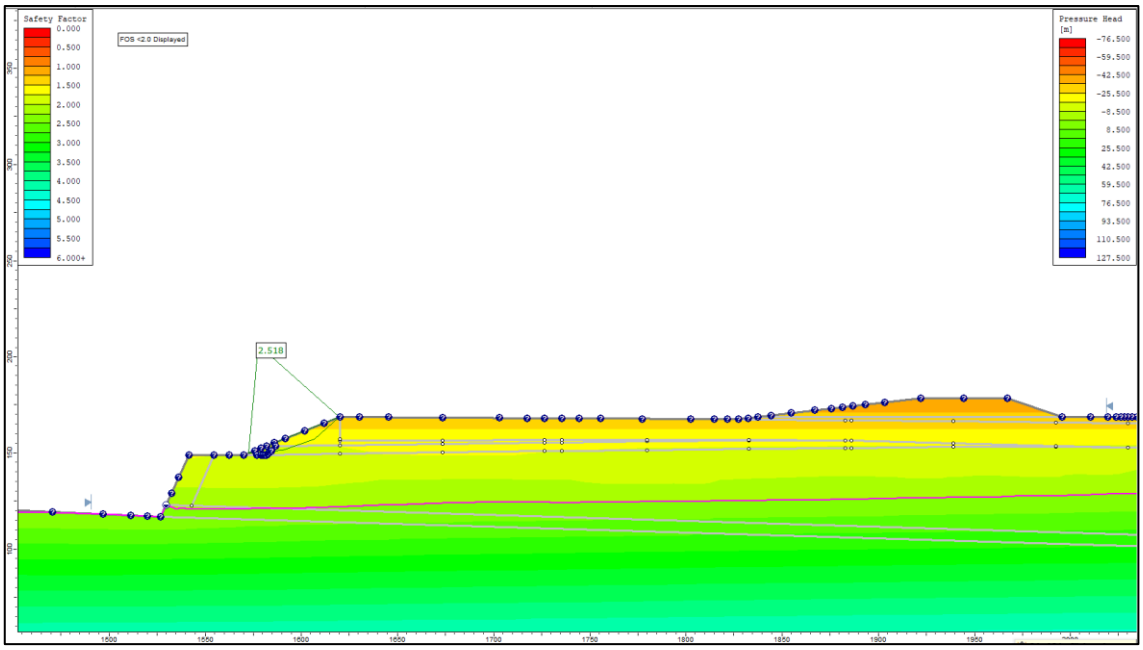

*Appendix A 32 Cross Section 7 – Curragh Main J-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic*



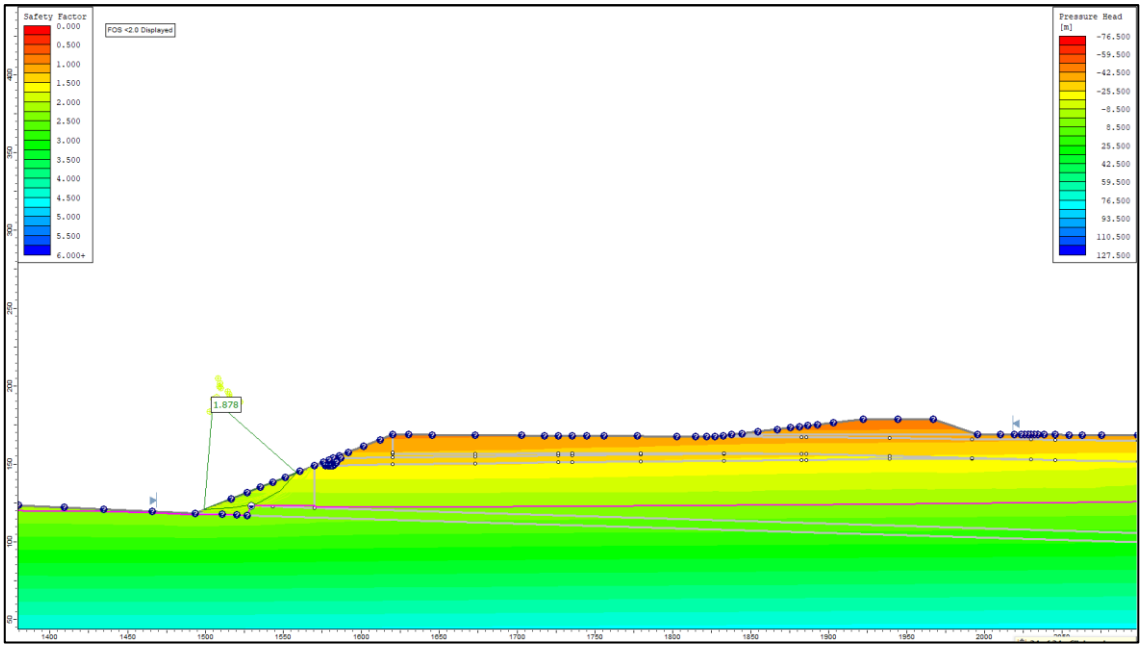

*Appendix A 33 Cross Section 8 – Curragh Main Y-Pit - Static*



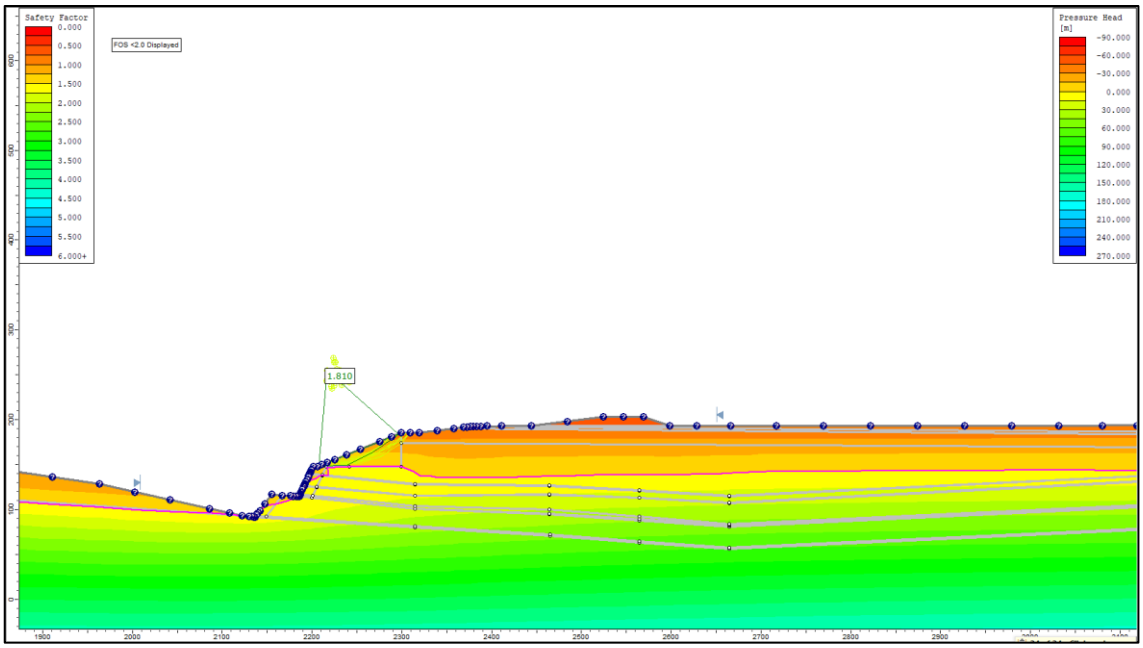

*Appendix A 34 Cross Section 8 – Curragh Main Y-Pit - Dynamic*



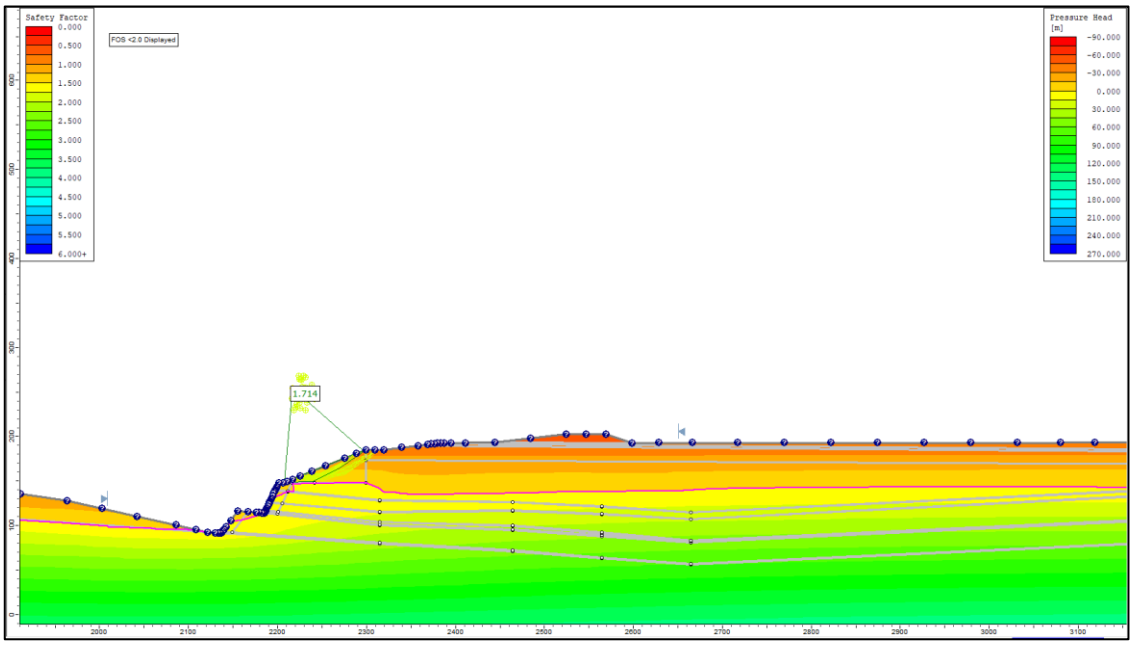

*Appendix A 35 Cross Section 8 – Curragh Main Y-Pit Final highwall geometry with blasted and re-shaped final slope – Static*



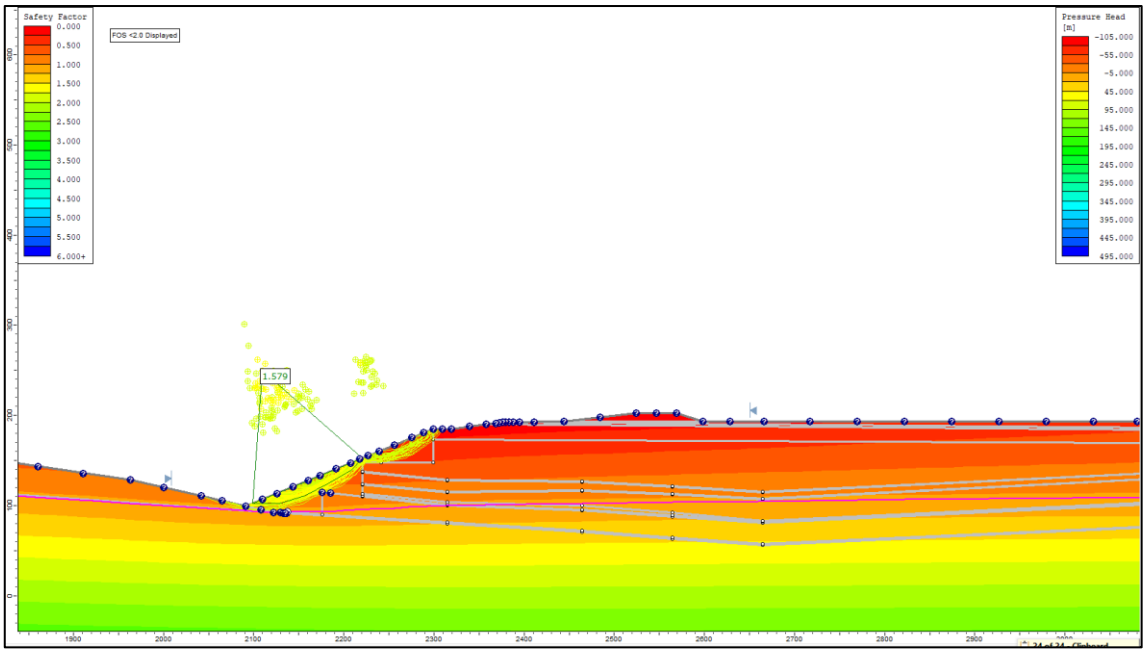

*Appendix A 36 Cross Section 8 – Curragh Main Y-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic*



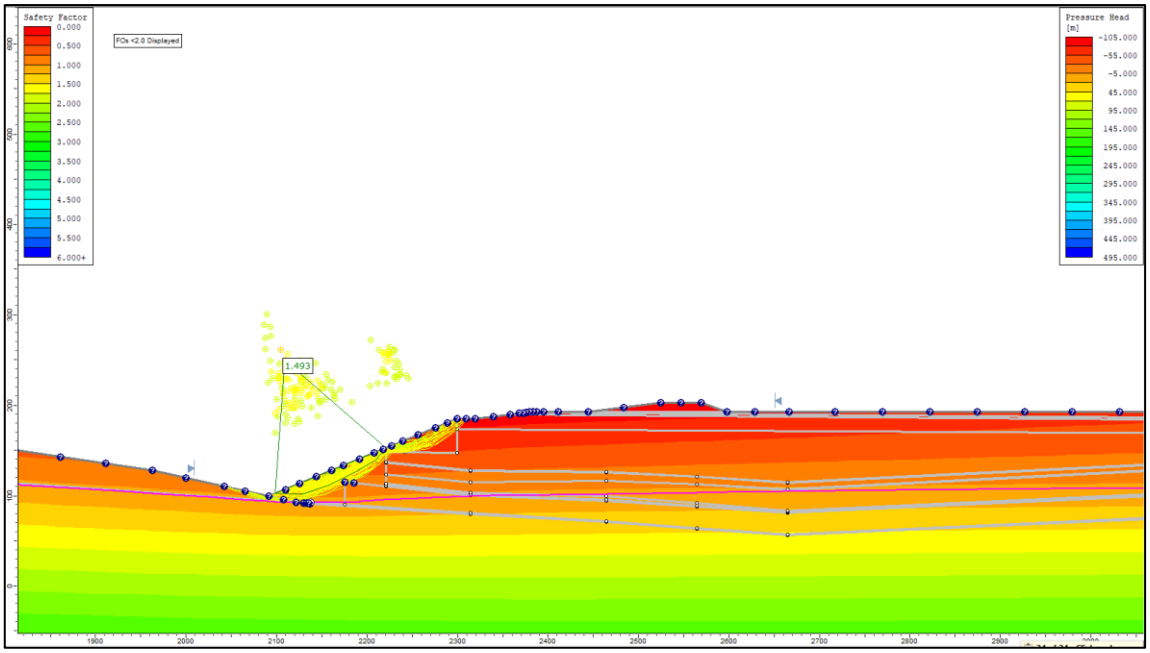

*Appendix A 37 Cross Section 9 – Curragh Main Z-Pit - Static*




*Appendix A 38 Cross Section 9 – Curragh Main Z-Pit - Dynamic*




*Appendix A 39 Cross Section 9 – Curragh Main Z-Pit Final highwall geometry with blasted and re-shaped final slope – Static*




*Appendix A 40 Cross Section 9 – Curragh Main Z-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic*

# **Appendix B** – Design Risk & Opportunities Register

| Item | Risk Scenario | Actions & Recommendations |
|---|---|---|
| 1 | Geological and geotechnical risk and uncertainty:<br>• Variations in the geological and structural models resulting in changes to adopted lithological unit, unit thicknesses, geological structures (i.e. faults, joints etc.), rock mass conditions, material properties etc. impacting the final landform design option include pitwall crest and toe limits. | Geological and geotechnical data collection programs for the final pitwalls are to be developed and implemented.<br>An erosion assessment is completed to define the required slope angles for the soil strength materials and inform the design development. The proposed final landform is to be updated based on the outcomes of the erosion study. |
| 2 | Hydrogeological and hydrological risk and uncertainty:<br>• Variations in the hydrogeological and hydrological models resulting in changes to adopted lithological unit hydraulic properties, changes in groundwater levels, changes in flood water level etc. impacting the final landform design option. | The hydrogeological and hydrological models should be developed, and an associated ground water investigation program implemented, to further inform the slope stability analysis.<br>Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels. |
| 3 | Variations to the proposed final landform design options arising from:<br>• Variations in the geological and structural model;<br>• Variations in the hydrogeological and hydrological models;<br>• Outcomes of erosion studies;<br>• Changes to or limitations in the final pitwall construction methodology, crest and toe locations, and availability of materials. | The proposed final landform design option construction methodologies, and design options are developed.<br>Undertake detailed design work to develop final pitwall construction methodologies. |

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| **B** | **MGaughan** | | **MRaine** | | **23/11/2021** |
| **0** | **MGaughan** | | **MRaine** | | **25/11/2021** |
| **1** | **MGaughan** | | **MRaine** | | **30/11/2021** |

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# REHABILITATION MANAGEMENT AND MONITORING PLAN

| | | | |
|---|---|---|---|
| **Document No:** | EM PLAN 1.3 | **Version:** | 6 |
| **Applies to:** | ALL | **Work Groups:** | Mining, Environment |
| **RELEVANT LEGISLATION** | Environmental Protection Act 1994 | S126C, S126D, S318Z | |
| | Environmental Authority EPML00643713: | A4, D27–D28, G10-G12, G17-G19 | |

**KEY RELATED DOCUMENTS**

| Plans | Procedures | Forms |
|---|---|---|
| EM PLAN 1.0 | EMS PROC 1.3 | |
| EM PLAN 1.1 | EMS PROC 1.5 | |
| EM PLAN 1.2 | EMS PROC 1.6 | |

**DOCUMENT CONTROL**

| | Title | Name | Signature |
|---|---|---|---|
| **Prepared by:** | Environmental Specialist | Amanda Dawson-Evenhuis | |
| **Reviewed by:** | Environmental Superintendent | Kim Tuart | |
| **Approved by:** | Manager Technical Services | Michael Bailey | |
| **Next Review Date:** | **This document is scheduled for review 3 years from the Approval Date** | | |

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|---|---|---|---|---|
| 1 | Creation of Document | 07/2012 | Amanda Dawson-Evenhuis | Ken Dunlop |
| 2 | Review and Update of Document | 07/05/2014 | Amanda Dawson-Evenhuis | Elmien Ballot |
| 3 | Basic review and update to encompass ES amendment | 30/06/2015 | Amanda Dawson-Evenhuis | Elmien Ballot |
| 4 | Organisational Changes and EA Amendment | 28/06/2016 | Helen Cooke | Elmien Ballot |
| 5 | Incorporation of rehabilitation requirements for heightened spoil dumps at Curragh North | 24/09/2019 | Steve Lyngcoln, Principal Ecologist, WSP | Elmien Ballot |
| 6 | Review and Update of Document | 30/11/2021 | Howard Rogers, Principal Ecologist, WSP | Kim Tuart |

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# 1. LEGISLATIVE CONTEXT

## 1.1 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) is the key legislation for environmental management and protection in Queensland. The EP Act establishes a general environmental duty and a duty to notify environmental harm that applies to all persons and corporations.

The following sections of the EP Act are the key requirements for operations prior to closure:

- Chapter 5, Section 126C and 126D covers the requirements for a Progressive Rehabilitation and Closure Plan (PRCP), which provides for a rehabilitation program for land disturbed or proposed to be disturbed under each relevant lease; and the proposed amount of financial assurance (FA) for the environmental authority for the plan period;
- in November 2020 Curragh transitioned to the estimated rehabilitation cost (ERC) calculator. The ERC period for which the ERC is in force is between 3 November 2020 to 2 November 2022; and
- Section 318Z deals with progressive rehabilitation and certification.

## 1.2 Curragh Mine Environmental Authority

The Curragh Project operates under Environmental Authority (EA) EPML00643713, issued by Department of Environment and Science (DES) under Chapter 5 of the EP Act. Rehabilitation plans are captured in each ERC submission.

This Rehabilitation Management and Monitoring Plan has been developed to provide a framework and strategy for site rehabilitation work and has been developed to meet the legislative requirements under the EA. The following EA conditions are covered in this plan for landform, erosion and weed control:

### Rehabilitation landform criteria

G10 All areas significantly disturbed by mining activities must be rehabilitated to a stable landform with a self-sustaining vegetation cover.

G11 Progressive rehabilitation must commence within three years when areas become available within the operational land.

G12 Areas that are, or are becoming, available for rehabilitation must be identified in the current Plan of Operations.

G13 and G14 relate to Residual Voids and are not addressed in this plan but covered specifically in the Concept Residual Void Assessment (CRVA).

### Erosion

G15 Rehabilitated land must:

a. not have a rate of soil loss that exceeds that present in representative unmined areas within the mining leases that have the same chemical and physical characteristics including slope, slope length and fire regime; and

b. not exhibit any signs of continued erosion greater than that exhibited on representative unmined areas within the mining leases.

## Weed control

G16 Class 1 and Class 2 declared plants as listed under the *Land Protection Pest and Stock Route Management Act 2002* and subordinate legislation must not be present in the rehabilitation in densities that prevent the revegetation criteria from being achieved.

## Rehabilitation of Blackwater Creek diversion

G17 The rehabilitation of the Blackwater Creek diversion which is addressed in EM PLAN 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan.

## Rehabilitation monitoring program

G18 The holder of the environmental authority must conduct a Rehabilitation Monitoring Program on a yearly basis, which must include sufficient spatial and temporal replication to enable statistically valid conclusions as established under the rehabilitation program.

G19 Upon commencement, a Rehabilitation Management and Monitoring Program must be developed describing:

a. how the rehabilitation objectives will be achieved; and

b. verification of rehabilitation success.

G20 and G21 relate to Post-Closure Management Plan and are not addressed in this plan.

## 2. INTRODUCTION

The Curragh Project is an open cut coal mine located approximately 200 kilometres west by road from Rockhampton and approximately six kilometres north of the town of Blackwater (Figure 1), within the Central Highlands Regional Council. It is located within the catchment of the Dawson / Fitzroy River drainage, which contains a number of ephemeral waterways such as Blackwater Creek and Sagittarius Creek (WBM, 2000). These waterways drain north and north-west to the Mackenzie River. The Dawson / Fitzroy system has been subjected to several direct and indirect pressures associated with the advent of agricultural practices and mining operations in the wider Bowen Basin.

The Curragh Project has been operating since 1983. In March 2018, Coronado Curragh Pty Ltd (CCPL) was acquired by Coronado Global Resources from previous operators, Wesfarmers Curragh Pty Ltd (WCPL). WCPL had managed the Curragh Project between 2000 and 2018, after the operation was purchased from ARCO and Mitsui.

The Curragh East Mine had been approved in 2000, extending the mine life to 2016. In 2003, WCPL won the competitive tender to develop an allocated section of the Curragh North Mine. Curragh North Mine commenced operation in 2004, extending the life of the Curragh Project to 2025.

In 2008, Curragh obtained approval to divert Blackwater Creek to the eastern edge of the Curragh East Mine mining lease, allowing WCPL to access the reserves located under the current creek alignment once the diversion was open. A pit west of the Curragh main operation, Curragh West, was approved in July 2015, effective 1 August 2015. This area has not yet been developed.

In 2016 WCPL converted parts of MDL162 to ML700006, ML700007, ML700008 and ML700009, increasing the total area and the life of the project past 2038.

In 2018, CCPL acquired “The Stanwell Reserved Area” at Curragh North, further increasing the life of the Curragh Project past 2042.

The Curragh Project open cut mine produces a variety of coking, PCI and steaming coal products for both export and domestic markets. CCPL holds a long-term domestic coal supply contract with Stanwell Corporation which is largely supplied by washed secondary product.

The Curragh Project comprises circa 19,650 hectares (Ha) of Mining Leases (MLs). The scale of the Curragh Project makes CCPL a significant landholder in the Central Highlands region. With a variety of historical and current land uses within the local and regional catchment CCPL recognises the importance of responsible land management.

To date a total of 1,545 hectares (Ha) of land has been rehabilitated using the techniques and processes described within this management plan.

Much of the criteria and techniques have been developed as results of extensive research and monitoring carried out at Curragh since 1990. Research work is considered a vital component of Curragh’s continual improvement process, the purpose of which is to understand key aspects of the rehabilitated ecosystem, improving rehabilitation techniques and determining whether the resulting vegetation and fauna communities will be sustainable and fulfil their ecosystem functions over the long term.

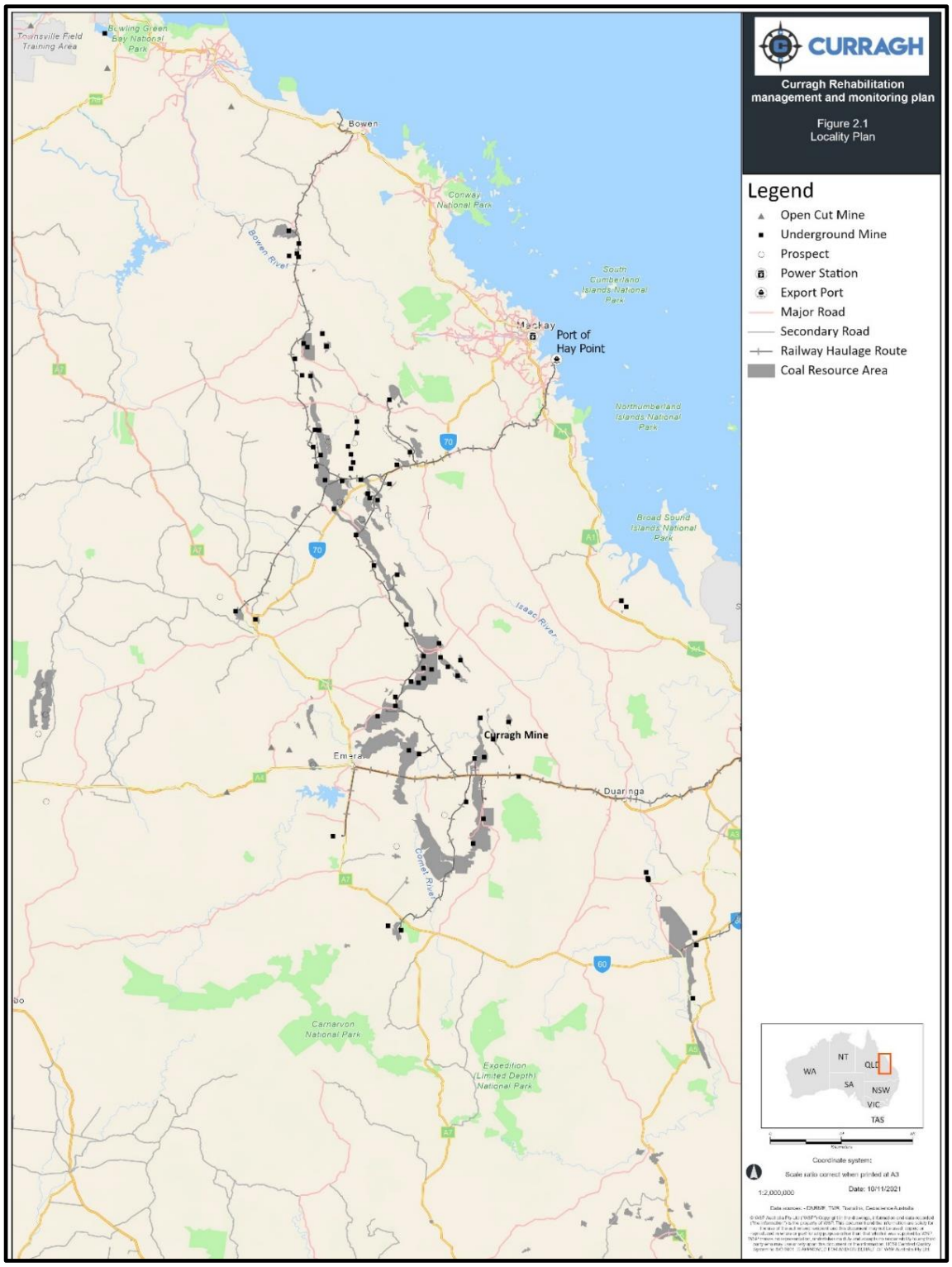



**Figure 1:** Locality map.

## 2.1 Background

Immediately prior to the commencement of open cut mining in the Curragh Project area the predominant land use was grazing and raising cattle. The area to the west of Blackwater Creek was comprised of beef cattle raising and mixed beef cattle/grain production systems (Hollingsworth, 1979). To the east of Blackwater Creek, beef cattle operations were carried out over approximately 80% of the land. This activity resulted in a major portion of the land area being significantly modified.

Overall, pre-mining land use consisted of beef cattle grazing (85%), conservation (11%) and disturbed areas (4%). The Curragh Project area conservation status before mining was Class 3. In addition, there is evidence of small-scale underground mining having taken place within parts of the lease area to the west of Blackwater Creek.

## 2.2 Rehabilitation Objectives

The rehabilitation objectives for the Curragh Project are:

i. To achieve a self-sustaining open pasture and woodland, capable of supporting both native fauna and pasture for light intensity grazing that requires minimal on-going maintenance.

ii. To ensure the land disturbed by mining activities will be made stable.

iii. Maintain downstream water quality at an acceptable standard consistent with ambient water quality conditions.

To avoid land degradation, grazing should be of a light intensity only. Light grazing is a condition with less than 30% grass utilization to produce slaughter steers. A 30% pasture utilization is considered the maximum to maintain land condition without degradation (Bowen and Chudleigh, 2017).

The basic elements essential to the attainment of these objectives are landform stability, topsoil management, revegetation, and control of run-off water. These objectives incorporate specific short-term and long-term objectives.

## 2.3 Short-Term Objectives

Short-term rehabilitation objectives including landform stabilisation, erosion control, and revegetation works aim:

i. To minimise clearing/vegetation disturbance consistent with operational requirements.

ii. To utilise coarse woody debris on rehabilitation area as habitat, where possible.

iii. To rehabilitate areas of disturbance no longer required for mining related operations in accordance with the Rehabilitation Management and Monitoring Plan.

iv. To apply soil (topsoil/subsoil) to the final landform based on material availability and post mining land use.

v. To stabilise all earthworks, drainage lines and disturbed areas required for mine-related activities to minimise erosion and sedimentation.

vi. To control pests, feral animals and noxious weeds.

vii. To implement fire management trials for the site.

viii. To reduce the visibility of activities from adjacent properties and the local road network, where appropriate.

### 2.3.1 Long-Term Objectives

Long-term rehabilitation objectives including achieving stable self-sustaining open pasture and woodland, capable of supporting both native fauna and pasture for light intensity grazing that requires minimal on-going maintenance aim:

i. To establish low maintenance, geotechnically stable, safe and vegetated landforms which blends in with the surrounding natural landscape and is acceptable to stakeholders.

ii. To control pests including feral animals and weeds.

iii. To monitor rehabilitation success in terms of physical and biological parameters.

iv. To decommission and remove all project-related infrastructure not required for the future use of final land use stakeholders.

v. To remediate any contaminated land.

vi. To re-establish open woodland and pasture capable of supporting both native fauna and pasture for light intensity grazing commensurate with land capability. Where land capability is low the emphasis will be on the re-establishment of woodland habitat).

vii. To relinquish Blackwater Creek back to the authorities by meeting its closure criteria.

## 2.4 Post-mine Land Capability

The post-mine land capability is likely to differ from the pre-mine land capability in places given the approximate 25% increase on in situ volume as a result of swell from mining activity that has taken place i.e. the land profile will be more undulating than pre-mining. However, with the exception of voids and slopes associated with voids; land capability will allow for a similar type (with decreased grazing intensity) of land use that occurred prior to mining.

It is expected that extensive areas of open predominantly native woodland will be nature positive, even though structure and species composition may differ from remnant Regional Ecosystems. The predominance of pasture grasses in the rehabilitated lands will allow for light grazing. Light grazing, while allowing for a return to the pre-mining land use should also minimise the risk of erosion and is considered compatible with nature positive outcomes, provided grazing levels as determined by pasture monitoring are not exceeded.

The main post-mine differences in land use capability will include:

- spoil slopes where the slope angle on average exceed the slope of the original topography;
- final voids where remnant high walls and end walls may be left; and
- infrastructure retained as agreed by stakeholders.

## 2.5 Rehabilitation Commitments

The following rehabilitation commitments have been adopted:

i. Infrastructure will be decommissioned unless arrangements have been made with underlying stakeholders.

ii. Landform design that will emulate the natural drainage and slopes in the mining area, where possible.

iii. Landform morphology will be developed and implemented to ensure an integrated final landform.

iv. Water and erosion will be managed though use of the appropriate water management structures e.g. contour banks, rock lining on waterways.

v. Final void studies will be continuously undertaken and updated during operations and prior to mine closure to ensure baseline data is available for updating the final void modelling. The baseline data will be inclusive of water and periodic soil monitoring.

vi. All final voids, including pits and ramps not backfilled, will be made safe with persons and stock excluded.

vii. Hydro-geological studies of tailings dams will be undertaken once operational life is reached to inform final rehabilitation design.

viii. Deep ripping of spoil/topsoil in conjunction with seeding will be utilised to minimise erosion.

ix. Revegetation will be surveyed on a regular basis as defined in Section 7 and maintenance will be carried out to meet rehabilitation success criteria.

x. Revegetation will be carried out predominantly using a seeder to broadcast seed.

xi. A rehabilitation schedule will be implemented and maintained.

xii. Rehabilitation areas will be restricted for access.

xiii. Haul roads and hardstand areas will be rehabilitated by removal of contaminated material and ripping of compacted areas, topsoiling and seeding.

### 2.5.1 Decommissioning of Infrastructure

The decommissioning and final rehabilitation will occur on a staged basis over several years. Where written agreement has not been obtained with stakeholders for infrastructure to remain, the rehabilitation will include:

- the treatment of exploration disturbance and drill holes according to the DES ESR-2016-1985 Eligibility criteria and standard conditions for exploration and mineral development projects—V2;
- the removal of buildings and structures;
- the breaking up and covering of concrete slabs and or/coal stockpile areas with a suitable depth of inert material;
- the removal of redundant roads by removal of contaminated material before ripping and seeding; and
- mine affected water management structures will be assessed for contamination and treated in accordance with specialist advice.

### 2.5.2 Post-mine Land Suitability

Based on current information, post-mine suitability at Curragh Project could sustain an open pasture woodland capable of supporting both native fauna and light intensity grazing. The only areas unable to be rehabilitated to a post mining land use will be the final voids and residual walls (Non-Use Mining Areas - NUMAs) identified in the CRVA as shown in Figure 2.

### 2.5.3 Post-mine Land Use

To achieve the Post Mining Land Use (PMLU), rehabilitation will include the use of a species mix incorporating exotic and native pasture grasses and native woodland species as discussed in Section 3.7 noting that the native woodland species seed mix may vary from year to year depending on seed availability and ongoing reviews of species performance to achieve the land use objectives.

### 2.5.4 Post-mine Landform

In general, visual amenity impacts will remain during the life of the mine. Out of pit spoil stockpiles will remain in the post-mining landform. The visual impacts of these stockpiles will be minimised through progressive rehabilitation activities, including revegetation.

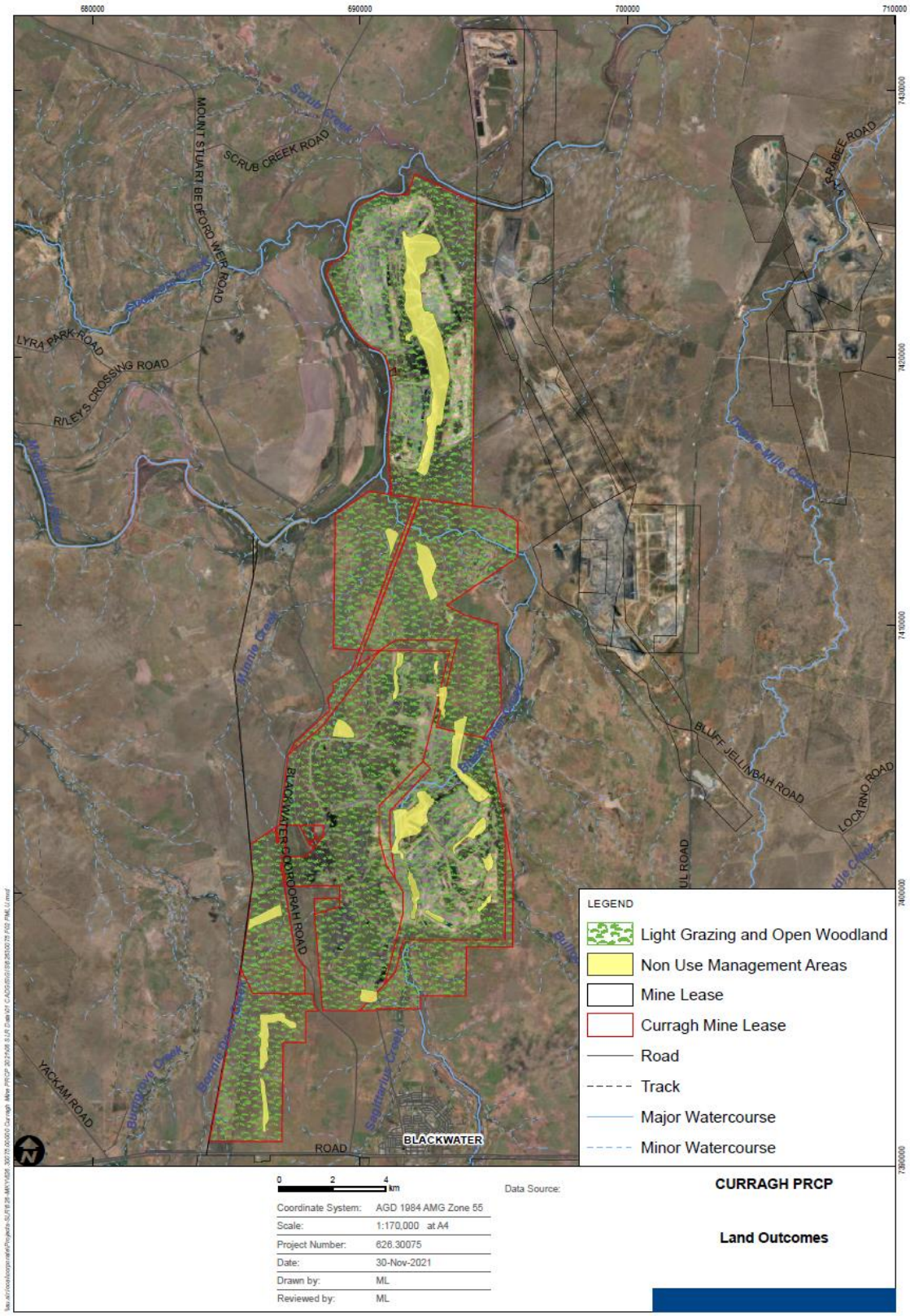



**Figure 2:** PLMU and NUMA Map.

# 3. REHABILITATION MANAGEMENT STRATEGY

The rehabilitation strategy is built around five benchmarks as follows:

- areas re-contoured (reshaped to final grade);
- areas topsoiled;
- areas seeded (ripped and seeded, irrespective of germination success);
- areas established (vegetation has established, although minor reseeding/ erosion repairs may be necessary); and
- areas successfully rehabilitated and certified (compliance with rehabilitation success criteria).

Conceptually re-contouring will occur circa 36 months after cessation of coal mining and re-topsoiling activities will complete 48 months after cessation of mining.

In general, all available (re-contoured and topsoiled) areas are seeded in October/November and February/March of each year. Seeding may also occur at other times to take advantage of predicted weather patterns.

## 3.1 Slope angles

The maximum slope criteria to be achieved by rehabilitation is provided in Table 1. Treatment proposed for voids and void ramps is discussed further in the Concept Residual Voids Assessment document (CRVA).

**Table 1**: Slope Criteria for Rehabilitation.

| | **Slope Criteria** |
|---|---|
| **Boxcut spoil** | Typical slope 14%, Maximum slope 16% |
| **Strip spoil** | Typical slope 10%, Maximum slope 16% |
| **Out of Pit** | Typical slope 12%, Maximum slope 16% |
| **Final void** | As described in the CRVA document |
| **Haulage ramps** | Typical Slope 22%-27% |
| | Dip direction at coal dip 5%-9% |

The Curragh Project will, throughout the life of the operation, continue to trial rehabilitation for varying slope angles within the ranges shown in Table 1 to identify the most appropriate treatment at each slope angle. This excludes Curragh North Spoil Dumps where near term trials are considering slopes of greater than 16 %. If monitoring proves that the rehabilitation of slope angles greater than 10 % (and greater than 16 % for Curragh North spoil dumps) are not performing, then suitable control strategies will be implemented, and design criteria will be modified accordingly.

## 3.2 Slope Length

For simplicity in design and construction, straight slopes, with a constant gradient are targeted for spoil reshaping at the Curragh Project. Straight slopes require their slope length to be limited to avoid runoff water velocity increasing above the erosive threshold. The criteria for the slope angle/length relationship adopted are provided in Table 2**.**

**Table 2:** Slope Length.

| Slope % | Slope ratio (v:h) | Length Between Benches (m) |
|---|---|---|
| **6** | 1:17 | 115 |
| **8** | 1:12 | 105 |
| **10** | 1:10 | 90 |
| **12** | 1:8 | 80 |
| **14** | 1:7 | 70 |
| **16** | 1:6 | 55 |
| **18** | 1:5.5 | 45 |
| **25** | 1:4 | As required (not<45) |

## 3.3 Contour Banks

Contour banks are earthen water management structures constructed at intervals down a slope to intercept run off and safely channel it into stable waterways. Contour banks reduce effective slope length and intercept the runoff before it can concentrate into an erosive force. Contour banks also trap sediment from overland flow. Contour banks are typically constructed on re-contoured spoil to minimise erosion.

CCPL will continue to produce a landform design that will emulate the natural drainage and slopes in the mining area, where possible. Landform design will incorporate natural and engineered structures to minimise erosion.

Contour bank design parameters would typically include consideration of:

- low gradient design of circa 0.5% along the flow alignment;
- low flow velocities, typically >1.0 m/sec (for nil vegetation case);
- adequate topsoil coverage (200-300 mm);
- bank invert left bare, no topsoil; and
- up slope bank face <1:2, down slope face <1:3.

Contour banks less than 400m long are built to a standard dimension of 1m high of spoil, plus a 200-300 mm topsoil cover.

Contour banks effectively minimise erosion on slopes but tend to produce concentrated high velocity flows at their discharge end. Contour banks are therefore arranged to discharge into a strategically placed energy dissipation basin or waterway.

Some waterways may require rock armouring due to the high flow velocities encountered. At Curragh Project, the Ishbash equation has been used to determine optimum rock size as appropriate.

If contour banks are left to remain in the longer term, after the establishment of a vegetative cover, they may increasingly be at risk of overtopping. This failure could cause a concentration of flow to occur and commencement of gully erosion. Consequently, after establishment of adequate vegetative cover, the potential will be assessed as to whether the contour banks will be removed to avoid that possibility. Removal could be carried out by a variety of methods depending on the height of the bank and its manner of construction.

## 3.4 Contamination Source Rehabilitation

Rehabilitation of the tailings dam will be in accordance with the technical Guideline for Tailings Management and the Guideline for Rehabilitation Requirements for Mining Lease Projects and subject to detailed hydro-geological studies at the appropriate time. For in-pit tailings storage, rehabilitation methods are expected to be the same as for the tailings dam.

## 3.5 Topsoil Management

The Curragh Project has an active topsoil management procedure (EMS PROC 1.3) to provide guidance for the ongoing management of topsoil and to ensure topsoil is managed as an important resource. This document provides direction for the management of topsoil from its removal, storage and its placement as part of the rehabilitation strategy. As outlined in Curragh Project's regulatory framework under the Environmental Authority EPML00643713 and EM PLAN 1.1 Topsoil Management Plan.

## 3.6 Deep Ripping

Deep ripping and the use of a winged tyne (Figure 3) after shaping has been completed, is required to improve rainfall/run-off infiltration, and to decrease erosion. The winged tyne facilitates improved sub soil loosening without having to drag a larger tyne through the soil profile.

Deep ripping is carried out to a depth of 60–75 cm with the rip-lines oriented across the slope at a gradient of 0.5% (1h: 200v) off the contour. The dozer operator uses the graded banks, which are also at 0.5% gradient, for alignment guidance. Deep ripping is carried out in conjunction with the seeding operation.



**Figure 3**: A winged tyne in use at Curragh.

## 3.7 Revegetation

The objective of revegetation is threefold:

i. To stabilise the re-contoured ground.

ii. To fit in and complement the surrounding flora and habitat.

iii. To enhance or increase species diversity.

Revegetation is predominantly carried out by seeding. which appears to perform better than tube stock planting, which has a high mortality rate.

## 3.8 Seeding

The seed mix employed at Curragh Project includes native Eucalypts, Acacias, other native shrubs and tree species, native grasses, exotic grasses and a range of legumes. A typical seed mix is provided in Table 3: . The seed mix is improved from year to year based on the results of the annual rehabilitation monitoring. The current seed mix (2019 – 2022 has an increased richness of other trees and shrubs to better reflect species present in the reference sites.

For 2019 to 2020 the combined seed mix included seven species of Acacia, six species of Eucalyptus, six native grass species, 12 species of other trees and shrubs, one legume species and three exotic pasture grass species.

**Table 3:** Past and Recent Seeding Mix**.**

| **Acacias** | **2011** | **2019/2022** | ***Native Grasses*** | **2011** | **2019/2022** |
|---|---|---|---|---|---|
| *Acacia bancroftii* | x | | *Astrebla lappacea* | x | |
| *Acacia complanata* | x | | *Astrebla squarrosa* | | x |
| *Acacia cretata* | x | | *Bothriochloa bladhii* | | x |
| *Acacia decora* | | x | *Cynodon dactylon* | x | |
| *Acacia excelsa* | | x | *Dichanthium serecium* | x | |
| *Acacia harpophylla* | x | x | *Digitaria didactyla* | x | |
| *Acacia holosericea* | x | x | *Digitaria sericeum* | | x |
| *Acacia macradenia* | x | | *Heteropogon contortus* | x | x |
| *Acacia rhodoxylon* | | x | *Paspalidium caespitosum* | x | |
| *Acacia salicina* | x | | *Themeda australis* | x | x |
| *Acacia saligna* | x | | **Introduced / Exotic Grasses** | | |
| *Acacia shirleyi* | | x | *Bothriochloa insculpta* | | x |
| *Acacia stenophylla* | x | | *Cenchrus ciliaris* | x | |
| *Acacia victoriae* | | x | *Chloris gayana* | x | x |
| **Eucalyptus** | | | *Echinochloa esculenta* | | x |
| *Corymbia citriodora variegata* | | x | *Panicum coloratum* | x | |
| *Eucalyptus camaldulensis* | x | | *Panicum maximum* | x | |
| *Eucalyptus cambageana* | x | x | *Urochloa mosambicensis* | x | |
| *Eucalyptus citriodora* | x | | **Legumes** | | |
| *Eucalyptus crebra* | x | x | *Cassia brewsteri* | | x |
| *Eucalyptus drepanophylla* | x | | *Chamaecrista rotundifolia* | x | |
| *Eucalyptus longirostrata* | x | | *Clitoria ternatea* | x | |
| *Eucalyptus populnea* | x | x | *Stylosanthes hamata* | x | |
| *Eucalyptus punctata* | x | | *Stylosanthes scabra* | x | |
| *Eucalyptus tereticornis* | x | x | | | |
| *Eucalyptus thozetiana* | x | x | | | |
| **Other Trees / Shrubs** | | | | | |
| *Atalaya hemiglauca* | x | x | | | |
| *Brachychiton rupestris* | x | x | | | |
| *Carissa ovata* | | x | | | |
| *Casuarina crista* | x | | | | |
| *Eremophila maculata* | | x | | | |
| *Erythrina vespertilio* | | x | | | |
| *Geijera parviflora* | | x | | | |
| *Lysiphyllum carronii* | x | x | | | |
| *Lysiphyllum hookeri* | | x | | | |
| *Owenia acidula* | | x | | | |
| *Petalostigma pubescens* | | *x* | | | |
| *Pittosporum angustifolium* | | *x* | | | |
| *Salt Bush Mix* | | *x* | | | |
| *Senna artemisioides* | *x* | | | | |
| *Senna notabilis* | *x* | | | | |

## 3.9 Rehabilitation Schedule for Heightened Spoil Dumps at Curragh North

Issues and risks that may affect the success and performance of revegetation on increased slope angles include:

- soil erosion and landform stability;
- adequacy of current species mixes for final landform and land use; and
- vegetation establishment on steeper slopes >16%.

Consequently, the following measures will be trialled for rehabilitation of the steeper slopes associated with the heighted Curragh North spoil dumps.

### 3.9.1 Erosion and landform stability

#### Contour banks / slope breaks

On the steeper slopes associated with the heighted spoil dumps at Curragh North, the regularity of contour banks and/or slope breaks will be increased (to approximately 55m apart for vegetated slopes up to 20%). The adequacy of these additional contour banks and slope breaks for maintaining erosion and landform stability, will be assessed through erosion and landform stability monitoring as outlined below.

#### Erosion analysis

For the heighted spoil dumps at Curragh North, field-based erosion monitoring will be undertaken at the same time as rehabilitation monitoring. Evidence of erosion will be assessed in accordance with the Australian Soil and Land Survey Field Handbook (National Committee on Soil and Terrain 2009) and includes:

a. type of erosion (wind, water, scald, sheet, rill, gully, tunnel and mass movement)

b. state of erosion (active, partially stabilised or stabilised)

c. severity of erosion (dependent upon type of erosion present – present/absent and if present either minor, moderate, severe or very severe)

d. for gullies - the depth and width of erosion

e. opportunistic identification of all areas of significant erosion encountered outside of the assessment areas.

#### Landform stability

Landform stability of the rehabilitation on the heightened spoil dumps will be assessed using current Light Detection and Ranging (LiDAR) data and remote sensing software to generate 1m digital elevation models (DEMs) of the landform. DEMs from previous years will be compared to assess stability as it relates to identifying areas of settlement, deposition, subsidence and erosion.

The DEM slope analysis will also be used to assess the as built landform against the landform design criteria with a maximum slope of 16% for the out of pit (OoP) dump slope tying into the final landform and with in-pit dump slopes of up to 27% for the internal rehabilitation batters.

Annual erosion and landform stability monitoring will enable early detection of instability of rehabilitated slopes >16%, particularly areas that may be developing deep rills or gullies and/or areas that are either subsiding or where run off is settling. Early detection will enable targeted rework as required to maintain overall landform stability.

### 3.9.2 Species mix

The following measures will be implemented to improve rehabilitation success on steeper slopes associated with the heightened spoil dumps at Curragh North:

- establishment of additional vegetation reference sites in surrounding vegetation communities on steep slopes (i.e. > 16%) to improve species data and vegetation data to inform rehabilitation on the steeper slopes;
- tree, shrub and grass species representative of the surrounding vegetation will be included in the species mix for steeper slopes; and
- to establish short-term groundcover, a cover crop such as millet or oats will be included with the revised native tree, shrub and grass seed mix.

### 3.9.3 Vegetation establishment on steeper slopes

The current rehabilitation method includes deep ripping, with the use of a winged tyne and direct seeding. For steeper slopes, (>16%) there is an increased risk of erosion. To reduce this risk, rehabilitation is focused on establishing a high ground cover to reduce rainfall impact on soils and on establishing deeper roots to stabilise slopes. To improve native tree and shrub establishment on steeper slopes all areas of rehabilitation that have been adequately topsoiled are seeded with the revised native species mix (outlined above).

In areas of rehabilitation lacking suitable topsoil, consideration will be given to hydro mulching slopes >16% to improve vegetation establishment to achieve >50% cover with revised species mix in less than one year to reduce the risk of erosion.

When preparing the soils for direct seeding, consideration will be given to the constraints associated with the material below the depth of ripping (i.e. poor structure from sodicity or subsoil salinity). The addition of soil ameliorants such as lime or gypsum or alternatively a calcium based soil conditioner in combination with recalcitrant carbon-based soil conditioner, a biologically active fertiliser blend including soil bacteria and mycorrhizal fungi developed for rehabilitation, and a soil binder product may be required to stabilise the soil prior to direct seeding and ripping.

## 4. COMPLETION CRITERIA

The EPA (2008) Guideline 18 and DES Guideline (ESR/2016/1875) on the rehabilitation requirements for mining projects provides assistance to mining companies when defining rehabilitation goals, objectives and setting appropriate completion criteria. This guideline details how the regulator will assess whether progressive or final rehabilitation is successful and eligible for sign off.

Assessment is based on different land management units called 'domains' which contain their own specific goals, objectives and indicators that can be monitored and measured to demonstrate that the completion criteria have been satisfied. Four broad rehabilitation goals are required for rehabilitation of areas disturbed by mining. These goals are presented in Table 4.

**Table 4:** General rehabilitation goals and objectives of areas disturbed by mining (EPA 2008, DES 2016).

| Rehabilitation Goal | Possible Rehabilitation Objective |
|---|---|
| **Long-term safety** | The site is safe for humans and animals (including stock and wildlife), now and in the foreseeable future. |
| **Non-polluting material** | Hazardous material adequately managed. |
| | Acid mine drainage (if any) will not cause serious environmental harm. |
| | Polluted/ contaminated water will be contained on-site. |
| **Stable landform** | Very low probability of landform slumping, subsidence, slippage or rock falls with serious consequences to people, animals and/or the environment. |
| | Landform design achieves appropriate erosion rates. |
| | Vegetation cover to minimise erosion |
| **Sustainable land use** | Soil properties that support and will continue to support proposed post-mine land use. |
| | Specified self-sustaining vegetation and habitat established. |
| | Specified water body with low risk of environmental harm established. |
| | Land use with comparable management requirements to similarly used non- mined land established. |

## 4.1 Pre-Mine Landform, Land Use, Habitat and Vegetation

The pre-mine landforms of the mining leases to the west of Blackwater Creek, the area's major drainage system, were gently undulating plains and lowlands with a mild gradient to the east over most of the area towards the creek, with mainly gentle 2-5% slopes (Coffey et al. 1979 in Orr and Bell 1990). A similar profile was exhibited to the east of the creek, but with gradients to the west and northwest. The predominant soil type is brown cracking clay soil which is associated with sandstone parent materials. Cattle grazing and minor grain production was the main land use.

As a result of land clearing activities prior to mining, only small areas of the original vegetation remain on the mine site (Coffey et al. 1979 in Orr and Bell 1990). These remnants were mainly Brigalow (Acacia harpophylla) communities with eucalypt species relatively uncommon. Several other native tree/shrub species were reported to be common to most communities, such as Carissa ovata, Geijera parviflora, Eremophila mitchellii and Acacia rhodoxylon. These native remnant habitats support a diverse fauna assemblage, including rare and threatened fauna species (See Section 5.6.1).

## 4.2 Final Landform and Land Use

Previous RMMPs for the Curragh Project have addressed three "Domains" consistent with the EPA's Guideline 18 on land disturbance types:

i. Domain 1, areas have been disturbed by mining activities i.e. reshaped spoil, roads and infrastructure suitable for an open woodland ecosystem with a slope range of <16 percent.

ii. Domain 2, areas which have been areas where water carrying capacity was required i.e. tailings storage facilities, tailings embankments & mine site ramps and will be suitable for open grassland with a slope range of <25 percent.

iii. Domain 3, will be all the active pit voids.

More specific land use description for each domain is shown in Table 5 which has been sourced from a combination of references including EPA Guideline 18 (2008), DES Guideline (ESR/2016/1875), Curragh Mine EMOS (2002), annual monitoring reports of the Curragh Project rehabilitation sites and a range of other draft plans regarding completion criteria.

Domain 3 is addressed in the CRVA.

**Table 5:** Proposed domains based on land use description for final land disturbance types.

| Domain | Disturbance Type | Post Mine land Description | Maximum Slope (%) |
|---|---|---|---|
| **1** | Borrow Pits | Light grazing and open woodland | 10 |
| | Long Term Infrastructure | Light grazing and open woodland | 0.5 |
| | Main Haul Road | Light grazing and open woodland | 6 |
| | Short Term Infrastructure | Light grazing and open woodland | 0.5 |
| | Reject Dumps (e.g. out of pit) | Open woodland | 16 |
| | Topsoil Stripped | Light grazing and open woodland | 0.5 |
| | Available Strip Spoil | Light grazing and open woodland | 10 |
| **2** | Tailings Embankment | Open Grassland | 22 |
| | Tailings | Open Grassland | 0.5 |
| | Deferred Rehab (e.g. Ramps) | Open Grassland | 22 |

## 4.3 Completion Criteria for Domains 1 and 2

Proposed completion criteria for Domains 1 and 2 and given in Tables 6 and 7 respectively.

**Table 6:** Curragh completion criteria for Rehabilitation of Disturbed Lands in Domain 1.

| Goal | Objective | Parameter/Indicator | Completion Criteria |
|---|---|---|---|
| **Safety** | The site is safe for humans and animals (including stock and wildlife), now and in the foreseeable future. | Safety assessment of slopes that are >16% and >5 m in height (if any) | • Certification in rehabilitation report that slopes, including graded banks, waterways, and rock lined waterways are safe. Predictions/ risk assessment to be made about future safety. |
| | | Exposure to and availability of heavy metals and other toxic materials (selection will be made based on relevance to site) | • Certification in rehabilitation report that soil, spoil and other cover materials are safe with details of predicted future changes. |
| | | Technical design of landform | • Engineer's certification of construction and maintenance to specified geotechnical design performance. |
| | | Low risk of fire | • Site management planning provide adequate measures for fire risk reduction (e.g. minimise accumulation of dry matters or other potential fuels for fire). |
| **Non-polluting** | Hazardous material/ contaminated land adequately managed. | Results of site contaminated land assessment report | • Contaminated sites remediated and removed from DES Environmental Management Register or Contaminated Land Register.<br>• Tarmac, padding, footing, hardstand removed from site unless otherwise agreed with landholder(s).<br>• Evidence that all infrastructures are removed from site except where agreed in writing by the post mining landowner/holder. |
| | Polluted/ contaminated water will be contained on-site. | Downstream groundwater/ surface water monitoring. | • Certification that drainage structures and sediment dams are effective in controlling surface water runoff, and minimising quantities of polluted water and containing it on site.<br>• Certification that monitoring data meet specified criteria relevant to potential contaminants. |
| | | Geochemical and hydrological minimisation of spoil | • Documented evidence that geochemical and hydrological minimisation of soil material has been incorporated into design of spoil dumps. |
| | | | • Evidence that appropriate risk assessment has been undertaken and control measures are in place. |
| **Stable landform** | Very low probability of landform slumping with serious consequences to people, animals and/or the environment | Past record of slope failure/slumping | • Evidence that appropriate risk assessment was undertaken, and control measures are in place to prevent recurrence. |
| | | Slope Range | • Evidence in rehabilitation report that relevant EA conditions have been complied with according to – Landform Design (Table 5). |
| | Landform design achieves appropriate erosion rates | Engineered structures to control water flow | • Documented evidence that drainage structures are in place as per design requirements and functioning effectively. |
| | Vegetation ground cover to minimise erosion | Vegetation type and density | • Evidence that the vegetation type and density are of species suited to the spoil/waste composition, slope, aspect, climate and other factors, and that the measured erosion rates meet the limits set (Only relevant to stability where root systems are a major control of erosion). |
| | | Foliage cover | • Evidence that the average percent vegetative ground cover on both topsoil and spoil ≥50%. |
| | | Leaf litter, humus, depth of growing medium | • Evidence of litter breakdown and the development of humus. |
| **Sustainable land use** | **Ecosystem definition:**<br>Area accomplishes and remains as a healthy open woodland, capable of supporting both native fauna and pasture for light intensity grazing. | | |
| | Specified self-sustaining vegetation and habitat established. | Key Species Presence | Evidence in rehabilitation monitoring reports of the following:<br>• Tree canopy cover (combined canopy and sub-canopy). Preliminary value to be determined from 2021 monitoring.<br>• Presence of at least 1 *Eucalyptus* species.<br>• Presence of at least 2 *Acacia* species. |
| | | Native species recruitment | • Evidence of second-generation recruitment of tree/shrub species. |
| | | Absence of weed species | • Certification that Class 2 declared pest plants are successfully managed in a weed management program. |
| | | Fauna presence | • Evidence of active use of rehabilitated site by native fauna (e.g. bird nests, scats, etc.). |

| Goal | Objective | Parameter/Indicator | Completion Criteria |
|---|---|---|---|
| | Soil properties support and will continue to support proposed post- mine land use. | Chemical properties (e.g. pH, salinity, nutrients, trace elements) of topsoil and other subsoil/growth medium for vegetation. | Evidence in rehabilitation reporting that topsoil and spoil chemistry satisfies the following:<br>• Soil salinity content is <800 dS/m with the aim of attaining <400 dS/m.<br>• Soil pH is between 5.5 and 9.<br>• Soil Exchangeable Sodium Percentage (ESP) is <15%. |
| | | Physical properties (e.g. type, colour, texture, coherence, water infiltration, stability, etc.). | • Topsoil strips returned to a depth of >100 mm on spoil dumps.<br>• Surface ripped before revegetated where appropriate.<br>• Physical properties to be achieved to within 2 standard deviations of that in reference sites and determined by soil testing. |
| | | Biological properties (e.g. nutrient cycling, microbial biomass, litter bags etc.). | • Evidence that nutrient accumulation and recycling processes are occurring by the presence and decomposition of a litter layer. |

**Table 7:** Curragh completion criteria for Rehabilitation of Disturbed Lands in Domain 2**.**

| Goal | Objective | Parameter/Indicator | Completion Criteria |
|---|---|---|---|
| ***Safe*** | The site is safe for humans and animals (including stock and wildlife), now and in the foreseeable future. | Safety assessment of slopes that are >22% and >5 m in height | • Certification in rehabilitation report that slopes are safe. Predictions/ risk assessment to be made about future safety. |
| | | Exposure to and availability of heavy metals and other toxic materials (selection will be made based on relevance to site) | • Certification in rehabilitation report that TSF cover and Ramp material is safe with details of predicted future changes. |
| | | | • Leaching tests meet specified guideline values (using standard protocols such as US EPA Toxic Characteristic Leaching Procedure). |
| | | Technical design of landform | • Engineers certification of construction and maintenance to specified geotechnical design performance. |
| | | Low risk of fire | • Site management planning provide adequate measures for fire reduction (e.g. minimise accumulation of dry matter). |
| | | Performance of Fencing | • Certification that fencing meets required safety standards and prevents stock from accessing TSF and Ramp slopes |
| ***Non-polluting*** | Hazardous material is adequately managed. | Technical design of capping | • Engineer's certification of construction and maintenance to design performance.<br>• Cover for TSFs comprises a minimum of 1.5 m of insert cover material, must be sufficient to break capillary rise of solutes.<br>• No acid leachate. |
| | Polluted/ contaminated water will be contained on-site. | Downstream groundwater/ surface water monitoring | • Certification that drainage structures and sediment dams are effective in controlling surface water runoff, and minimising quantities of polluted water and containing it on site.<br>• Certification that monitoring data meet specified criteria relevant to potential contaminants. |
| ***Stable landform*** | Very low probability of landform slumping with serious consequences to people, animals and/or the environment | Past record of slope failure/slumping | • Evidence that appropriate risk assessment was undertaken and control measures are in place to prevent recurrence. |
| | | Slope Range | • Evidence in rehabilitation report that relevant EA conditions have been complied with according to – Landform Design (Table 5). |
| | | Geotechnical, geochemical and hydrological studies of existing slopes and TSFs | • Documented evidence that appropriate risk assessment has been undertaken and control measures are in place for existing TSFs.<br>• Evidence that results of geotechnical, hydrological and geochemical assessment have been incorporated into design of TSFs as final landforms.<br>• No mass failure of slopes.<br>• Ramp walls not backfilled exhibit long-term geotechnical stability. |
| | Landform design achieves appropriate erosion rates | Engineered structures to control water flow | • Documented evidence that drainage structures are in place as per design requirements and functioning effectively. |
| | | Foliage Cover | • Evidence that the average percent vegetative ground cover on both topsoil and spoil ≥50%. |
| | Vegetation Cover to Minimise Erosion | Leaf Litter, Humus, depth of Growing Medium | • Evidence of litter breakdown and the development of humus. |
| ***Sustainable land use*** | **Ecosystem definition:**<br>Area accomplishes and remains as a healthy open grassland, capable of supporting pasture for light intensity grazing | | |
| | Specified self-sustaining vegetation and habitat established. | Key Species Presence | • Presence of native grass and pasture species. |
| | | Species Recruitment | • Evidence of second-generation recruitment of desirable pasture/legume species |
| | | Absence of weed species | • Certification that Class 2 declared pest plants are successfully managed in weed management programs. |
| | | Fauna presence | • Evidence of active use of rehabilitated site by native fauna (e.g. bird nests, scats, etc.). |
| | Soil properties support and will continue to support proposed post- mine land use. | Chemical properties (e.g. pH, salinity, nutrients, trace elements) of topsoil and other subsoil/growth medium for vegetation | Evidence in rehabilitation reporting that topsoil chemistry satisfies the following:<br>• Soil salinity content is <800 dS/m with the aim of attaining <400 dS/m.<br>• Soil pH is between 5.5 and 9.<br>• Soil Exchangeable Sodium Percentage (ESP) is <15%. |

| Goal | Objective | Parameter/Indicator | Completion Criteria |
|---|---|---|---|
| | | Physical properties (e.g. type, colour, texture, coherence, water infiltration, stability etc.) | • Topsoil strips returned to a depth of >100 mm.<br>• Physical properties to be achieved to within 2 standard deviations of that in reference sites and determined by soil testing. |
| | | Biological properties (e.g. nutrient cycling, microbial biomass etc.) | • Evidence that nutrient accumulation and recycling processes are occurring by the presence and decomposition of a litter layer. |
| | Land use is established with comparable management requirements to similarly used un-mined land. | Achieves agreed stocking capacity/capability on agreed areas (potential for erosion/damage to slopes which may be fenced off). | • Use of rehabilitated land meets specified yield (e.g. 75% of un-mined land). |

### 4.3.1 Goal: Safety

The completion criteria for the safety aspect of the site are adopted from Guideline 18 (EPA 2008) and ensure that the slope, spoil and supporting structures are safe for humans and animals in the long-term and that there is a low risk of fire on the site.

### 4.3.2 Goal: Non-Polluting

The criteria for this rehabilitation goal ensure that the water leaving the site is not polluted or contaminated and the drainage structures and sediment dams are functioning effectively.

### 4.3.3 Goal: Stable Landform

#### Slope range

The slope range for various disturbed lands are meant to ensure that the rehabilitated spoil dumps comply with design requirements and function effectively. The suggested vegetation type and density of species are suited to the various landform and climate factors.

#### Foliage cover

An erosion rate of less than 1 tonne/hectare/year can be achieved at the Curragh Project on slopes less than 20%, provided surface vegetative cover reaches more than 50% (Caroll et al. 2003). Since this level of cover is achievable on rehabilitated sites over a short period of time (3 – 4 years) as shown in Figure 4, this value was adopted as the completion criteria for foliage cover in Domain 1. Figure 4 indicates that 50% vegetation cover (including litter cover) could be reached in as little as three years after seeding on topsoil media, and generally between six and ten years on spoil media.

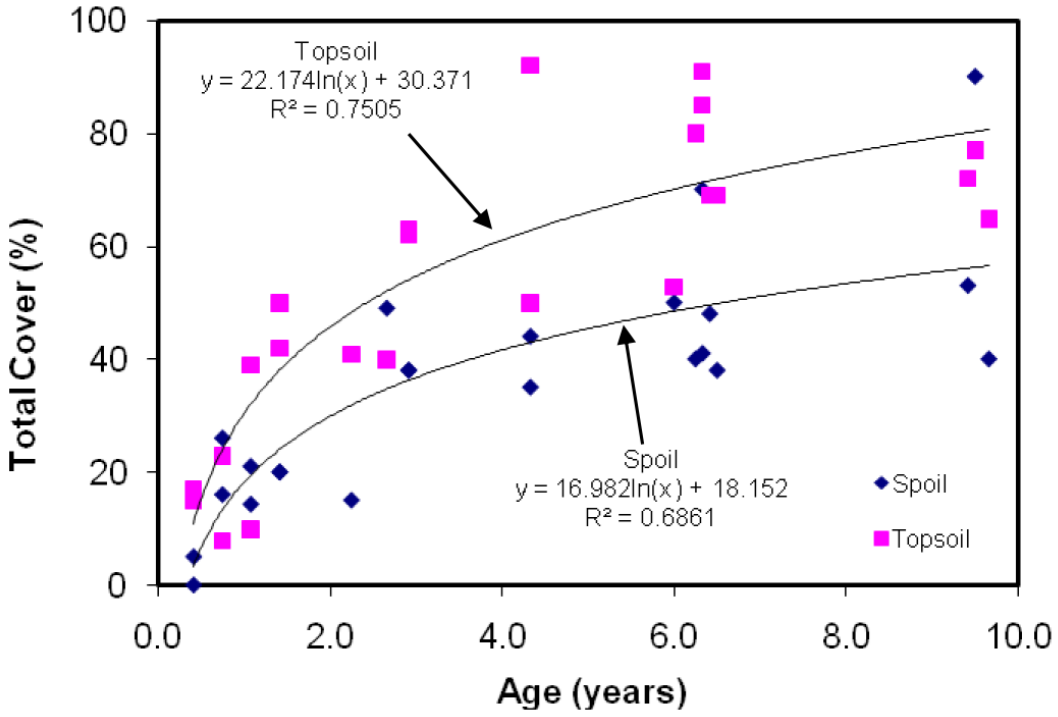



**Figure 4:** Vegetation covers by ages of rehabilitation at Curragh rehabilitation sites (as yearly monitored by CMLR-UQ from 2002 until 2007).

### 4.3.4 Goal: Sustainable Land use

Evidence of sustainable land use is determined from vegetation and habitat attributes and soil chemical properties.

Previously native tree and shrub species density was listed as a potential criterion, this has been replaced by canopy cover (combined canopy and sub-canopy cover). Provisional canopy cover targets will be determined from the 2021 monitoring data. Other land use criteria include the presence of key native species, the presence of native woody species recruitment, the absence of Class 2 declared weeds, and the presence of native fauna.

Soil EC and pH values follow a similar format to Guideline 18 and values are specific to Curragh based on 10 years of monitoring as well as previous studies completed on reference sites. Rehabilitated sites with topsoil have a lower mean pH, electrical conductivity (EC) and exchangeable sodium percentage (ESP) than sites with spoil growing media (Table 8).

**Table 8**: Range of soil chemical properties in different rehabilitation media.

| Media | Range of values in rehabilitation | | |
|---|---|---|---|
| | **pH** | **EC (uS/cm)** | **ESP** |
| **Topsoil** | 7.7 – 8.8 | 94 – 757 | 0 – 8.4 |
| **Spoil** | 7.2 – 9.3 | 57 – 1568 | 0 – 9.2 |

### 4.3.5 Curragh North heighted spoil dumps success criteria

From a landform stability perspective, success criteria for the Curragh North heightened spoil dumps relates to a lack of evidence of instability associated with major rill and gully erosion and/or subsidence.

From a vegetation perspective, it is important that there is a minimum of 50% total cover including litter. From a vegetation performance perspective, the current reference sites are not suitable for assessing the performance of rehabilitation on steeper slopes >16%, therefore additional reference sites for native vegetation on slopes >16% will be established. Whilst it is unlikely there may be suitable reference sites in surrounding native vegetation on slopes >16% it is recommended that a “best on offer” reference site is considered in surrounding native vegetation.

Completion criteria for rehabilitation on the steep slopes will be aligned with achieving performance of vegetation that shows a trajectory towards achieving vegetation structural attributes such as tree canopy heights and canopy cover and species richness associated with reference communities.

In the absence of suitable reference sites, consideration will be given to taking completion criteria for tree canopy heights, canopy cover and ground cover from existing benchmark data for associated broad vegetation groups on steeper slopes >16% from the broader sub-region surrounding the mine.

# 5. REHABILITATION MONITORING

## 5.1 Introduction

The overall aim of the 2021-2025 program is to provide Curragh Project with accurate information about the performance and development of its rehabilitation over time.

Within this broad aim there are number of specific objectives:

i. To measure the density, richness and condition of canopy, shrub (overstorey) and shrub (understory) woody species established on rehabilitated land using plot-based methods, and to benchmark the results against completion criteria.

ii. To measure species richness in the rehabilitation and compare against completion criteria.

iii. To accurately assess foliage projective cover (FPC), canopy cover (canopy cover is the combined cover of the canopy and sub-canopy), shrub cover and ground cover across rehabilitated areas using plot-based methods and to assess against completion criteria.

iv. Assessment of slope stability, erosion 'hotspots' or slumping across the site using LiDAR.

v. To determine if any relationships exist between biophysical parameters, such as substrate quality, soil moisture and rainfall patterns at the time of sowing, and rehabilitation success.

### 5.1.1 Methodology

The methodology for the 2021 - 2025 program has been updated in this document to better align with more contemporary methodologies and to increase efficiency. However, the methods will still enable the same rehabilitation metrics to be assessed, quantified and compared for assessment against rehabilitation success criteria and ultimately progressive certification and relinquishment.

### 5.1.2 Site Selection

The extended five-year 2021 - 2025 program is based on monitoring at ages 1, 2, 3, 5, 7 and 10 years. From age 10, sites are monitored at five year intervals until certification.

Reference sites were selected and measured in October 2011, and these will be revisited in 2021 to capture any temporal variation and provide ongoing feedback to the completion criteria process. The 2021 - 2025 rehabilitation schedule is provided in Section 7 together with a summary of monitoring, establishment year (seeding) and rehabilitation performance.

### 5.1.3 Traditional Transect Based Assessment

A modified transect-based approach will continue at Curragh to provide continuity with previous monitoring of rehabilitation on site and to inform remotely sensed imagery interpretation. For 2021 - 2025, the method has been modified to focus on collecting data suitable for the current rehabilitation success criteria

### 5.1.4 Sites less than one year old

For sites less than one year old the following are recorded;

- plant species richness – native, pasture species and weeds;
- percentage cover; and
- rill and gully erosion.

A walk through of the site is undertaken to record all native and weed species observed across representative area of the site, ensuring variation across the site is assessed, e.g. areas of woodland species, pasture grasses, weedy areas and any area where there are obvious differences in vegetation cover. Following this, a representative location towards the centre of the site is chosen and a 1m x 1m quadrat is randomly placed in the four compass directions (north, east, south and west).

The species assemblage (including declared weeds) and the following groundcover percentages within the quadrats are recorded. Rill and gully formation are also noted and where significant gullies are forming a GPS waypoint is recorded so that gully stability can be assessed over time (Figure 5).

This assessment is undertaken for each site with a minimum of four quadrat samples per 10 hectares provided the site is relatively homogeneous. If there is substantial variation in vegetation cover across a site, the site will be stratified so that an additional four quadrats will be sampled for each strata, e.g. high cover areas, low cover areas, weed dominated areas.

For each quadrat the following are recorded:

- native grasses;
- non-native grasses;
- native forbs and others;
- woody species (saplings);
- non-native forbs and others; and
- bare ground/rock.

### 5.1.5 Sites greater than one year old

At each new site, three transects of 50m x 14m running downslope will be established and permanently marked for future re-assessment. At each (new and established) transect assessments are undertaken in 50m x 14m, 50m x 8m, 50m x 4m and in 1m x 1m quadrats (listed in Table 9), with the following parameters assessed:

- species richness – total number of different species in each life form layer as described in the BioCondition Methodology (Eyre et al., 2015);
- coarse woody debris – total length in metres of all woody debris over 0.5m length and 0.1m diameter; and
- tree species recruitment – regeneration of canopy and sub-canopy species.

**Table 9:** Data attributes collected in different quadrats.

| 50m x 4m quadrats | 1m x 1m quadrats |
|---|---|
| Canopy cover, sub-canopy cover and shrub layer cover using the line intercept method along the transect centre line. Cover is recoded for each layer where it intercepts the tape measure laid out along the centre line | Native perennial grass cover, native other grass, native forbs and other species (non-grass), native shrubs (<1m height), non-native grass, non-native forbs and shrubs, litter, rock, bare ground and cryptograms. |
| stem counts identified into groupings – Eucalypt/Corymbia, Acacia, Other (tree), Shrub based on final life form, i.e. a young Eucalypt in the shrub layer is still recorded as a tree | |
| estimate of the mean height of the sub-canopy and shrub layer based on field measurements | |
| number of large trees. A large tree will be determined based on comparison with the relevant reference sites and measured against a DBH threshold | |

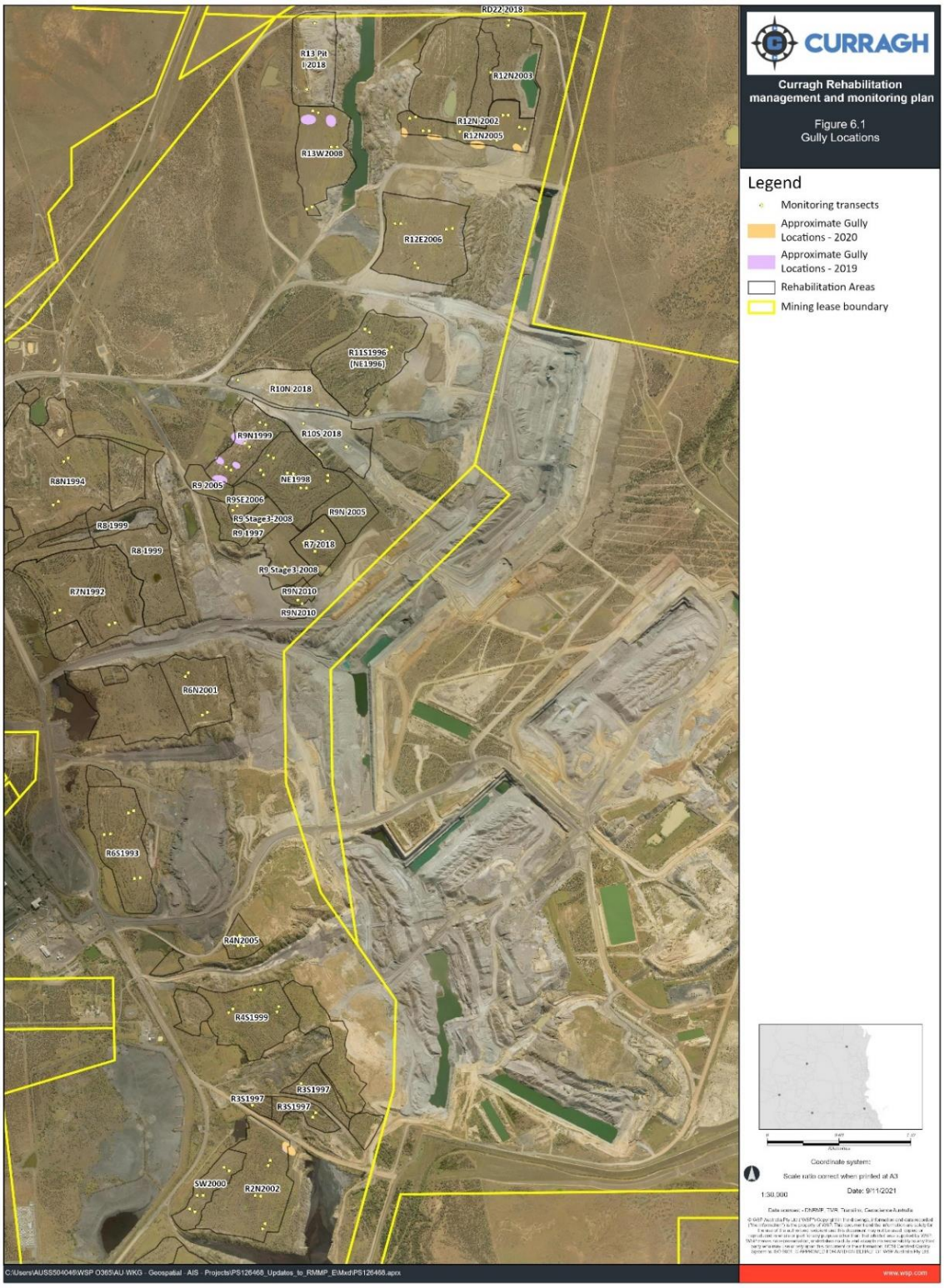



**Figure 5:** Gully Locations.

### 5.1.6 Soil Sampling

Soil sampling (0-10cm) at both ends of the transect on newly revegetated sites (or problem sites) across topsoil / spoil media for analysis of EC, pH and nutrient characteristics.

## 5.2 Reference Sites

Reference sites were established in remnant vegetation in 2011 as a requirement of the Environmental Authority (2011). The reference communities provide a basis for the generation and progressive review of the rehabilitation success criteria and form a part of the ongoing annual vegetation monitoring program at the Curragh Project.

## 5.3 The Use of Reference Communities

Guideline Mining (formally Guideline 18) (DERM 2011) suggests for the rehabilitation objective of establishing a native ecosystem, that unmined native reference communities may be used to guide criteria. Comparisons to the reference community can be used as an indirect indicator of how sustainable the rehabilitated ecosystem is likely to be. However, the selection of appropriate reference sites to which rehabilitated sites can be compared is a particular challenge within the mining industry. Typically, mining will alter the landscape to such an extent that the geology, soil physical and chemical profile and hydrology no longer resemble the unmined landscapes. Reddell and Hopkins (1994) also highlight the need to recognise the constraints associated with rehabilitating a heavily disturbed site and comparing it to a native, 'undisturbed' ecosystem.

Some guidelines on the selection of reference sites have been proposed, with Ruiz- Jaen and Aide (2005) suggesting that reference sites should:

- occur within the same life zone, close to the project; and
- should be exposed to similar natural disturbance regimes.

This allows for natural changes in vegetation to be identified over time, minimising the unknown variation within rehabilitated sites. Ruiz-Jaen and Aide (2005) also recommend that a number of reference communities need to be selected due to the natural variation within individual sites.

In many cases, mined land rehabilitation efforts have included seed mixes that only partially resemble the suite of species found within a reference community, as has been the case at Curragh Project. In these instances, it is highly unrealistic to expect the rehabilitation of the site to result in a vegetation community identical to that of a reference site (Erskine et al. 2008).

In these situations, reference sites can be used as a guide to spatial and temporal changes, as opposed to specific vegetation and soil parameters. Comparisons of indicators that can be safely made between rehabilitation and reference sites include ground cover and erosion, plant life form composition (e.g. the proportion of vines, herbs, trees and grasses), tree heights and seedling presence, soil nutrient levels and litter cover (Erskine 2008).

### 5.3.1 Reference site establishment and general descriptions

The Curragh Project is surrounded by a number of land uses, many of which are highly disturbed including grazing and agricultural land. The Regional Ecosystem (RE) Mapping (Queensland Herbarium 2009) indicates that vegetation within the mine leases and surrounding the mine is largely non-remnant, having been cleared for cropping and pasture. However, pre-clearing RE's list a large majority of the site as being RE 11.4.9 (Acacia harpophylla shrubby open forest) and a mixture of Acacia and Eucalypt dominated woodland / open forest. The RE maps have been utilised to locate and select appropriate reference sites.

In November 2011, three Eucalypt dominated vegetation communities were selected as reference sites:

i. RE: 11.10.12 Poplar Box Woodland.

ii. RE: 11.4.2 Napunyah Woodland (Gravel Pit).

iii. RE: 11.4.8 Dawson Gum Woodland.

The selected sites represent self-sustaining native ecosystems. Monitoring data from these sites is used to determine quantifiable vegetation attributes to assist in the development of completion criteria for rehabilitation at the Curragh Project. However, it is not expected that the rehabilitation will replicate the species composition or stand structure of the reference site communities.

Reference site selection was based on:

- remnant and representative vegetation types in the area;
- slopes, landforms and soil capability similar to the rehabilitation on the mine;
- A range of vegetation structure and cover from sparse to dense, and woodland to open forest; and
- access by field staff.

The location and extent of the Poplar Box Woodland and the Napunyah Woodland communities are mapped in Figure 6. Descriptions and GPS coordinates are provided in Table 10. Note the Dawson Gum Woodland reference site is no longer present due to mine expansion.

Further details of the vegetation attributes and soil characteristics of the reference sites, and comparison with monitoring data from the rehabilitation sites are provided in Appendix 2.

**Table 10:** Locations of permanently marked monitoring transects located within reference communities within the Curragh Project area.

| Description | RE | Site | Transect | Start Points (AGD84) | | Finish Points (AGD84) | |
|---|---|---|---|---|---|---|---|
| | | | | Northing | Easting | Northing | Easting |
| **Poplar Box Woodland** | 11.10.12 | REF PB1 | 1 | 7399259 | 695458 | 7399269 | 695507 |
| **Poplar Box Woodland** | 11.10.12 | REF PB 2 | 2 | 7399207 | 695489 | 7399212 | 695538 |
| **Napunyah Woodland (Gravel Pit)** | 11.4.2 | REF GP1 | 1 | 7410458 | 693172 | 7410491 | 693134 |
| **Napunyah Woodland (Gravel Pit)** | 11.4.2 | REF GP2 | 2 | 7410602 | 693141 | 7410575 | 693100 |
| **Dawson Gum Woodland*** | 11.4.8 | REF EC 1 | 1 | 7405776 | 693938 | 7405792 | 693891 |
| **Dawson Gum Woodland*** | 11.4.8 | REF EC 2 | 2 | 7405689 | 693963 | 7405734 | 693945 |

*no longer present due to mine expansion

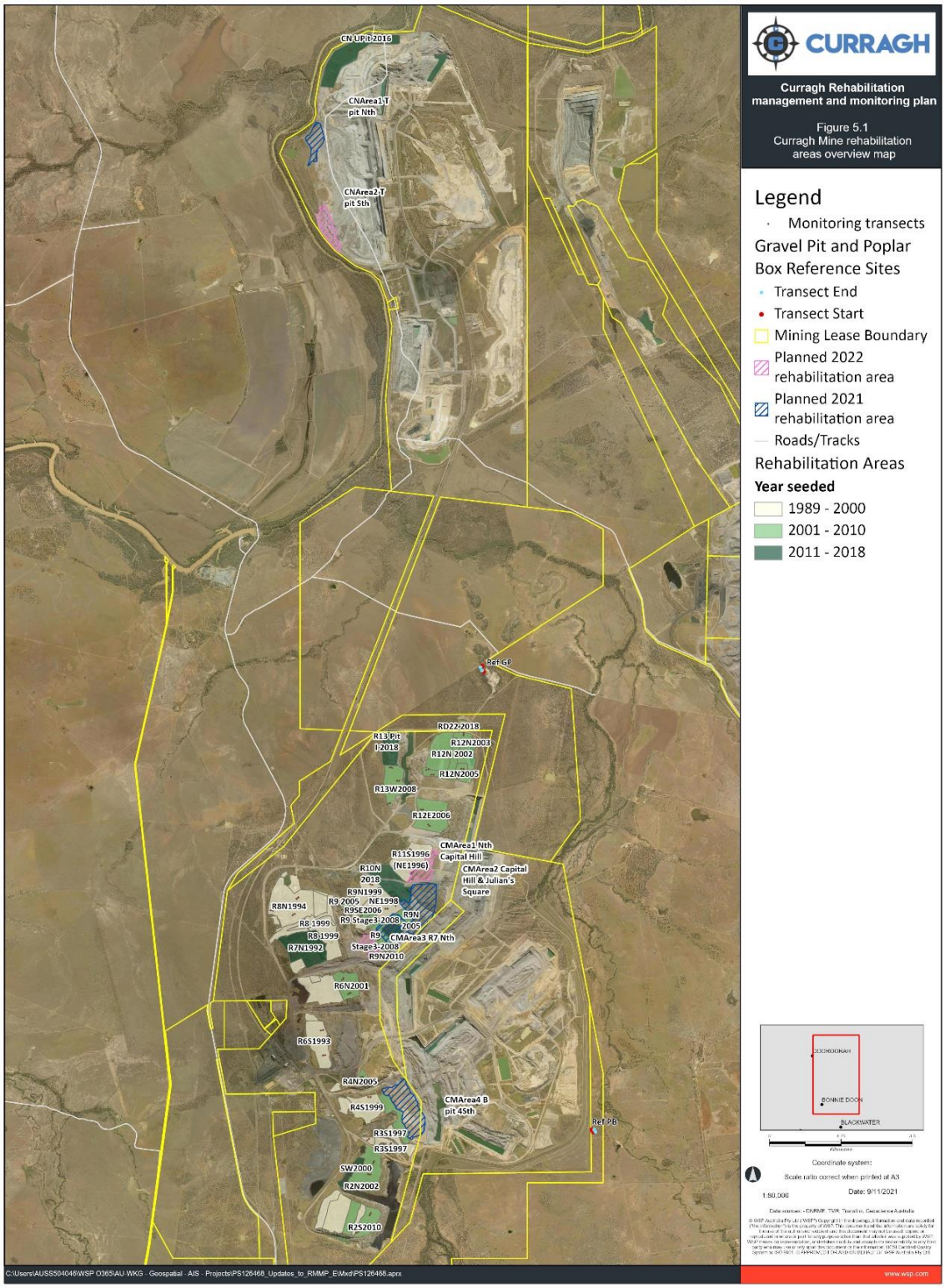



**Figure 6:** Curragh Project rehabilitation areas overview map.

## 5.4 Pasture Monitoring

Pasture monitoring will be undertaken to determine the dry season yield per hectare to determine the potential safe stocking capacity that will avoid land degradation. This assessment method is based on collecting pasture samples from 0.5m x 0.5m quadrats along each 50m monitoring transect as follows:

- select one of the five ground cover quadrat locations at random along each transect;
- harvest the grass from a 0.5m x 0.5m quadrat; The quadrat should be located adjacent to the centre line i.e., for quadrat one where ground cover is measured in a 1m x 1m quadrat at 9m to 10 m, the pasture monitoring quadrat should be located at 9m – 9.5m;
- using battery operated shears cut the herbage (grass & herbs) to within approximately 1cm of the ground level and bag all the harvested material in a large labelled paper bag. Note that if there are large amounts of old dead herbage (typically grey in colour) it should be separated from the sample and discarded to prevent over estimation of the pasture mass;
- determine the nett (wet) weight of each sample (nett weight = sample weight minus the bag weight. If the quadrat has no grass cover and this is not representative of the transect, another quadrat should be selected at random. The average weight of the two samples is entered in the final spreadsheet;
- sub-sample each of the 'wet' sample quadrats. The sub-sample should be of mostly leafy material since this is mostly what cattle feed on. Incorporating stem material will result in potentially artificially high nett weights;
- measure the wet weight of each of the five sub-samples in grams;
- oven dry the sub-sample (samples will be dried for 48 hours at approximately 70-80°C using a dehydrator);
- weigh the oven dried sub-sample (in grams);
- calculate dry matter percentage of the sub-sample;
- use this dry matter percentage figure to determine the dry matter weight of each quadrat;
- calculate the equivalent dry matter weight for each quadrat for one hectare (kg dry matter/hectare); and
- determine dry season pasture budget to provide a guide for the appropriate stocking rate for the proposed light grazing land use (for an example: Dry season pasture budget: a guide for stocking rates - FutureBeef).

Trials may be needed to determine the appropriate threshold for light grazing on rehabilitated landforms to prevent degradation of rehabilitated landforms, which is important for informing for post relinquishment grazing. For unmined land 30% use of pasture is considered the maximum sustainable land use to avoid degradation in Central Queensland (Bowen and Chudleigh, 2017). This equates to a stocking rate of approximately 0.6 steers per hectare or less for productive pastures. For rehabilitated mined lands the threshold is likely to be less to minimise land degradation, and associated erosion due to the sodic nature of some of the spoil material.

## 5.5 State and Transition Model

To determine the overall rehabilitation status for each transect, and to identify if rework, maintenance or ongoing monitoring is required, a simplified State and Transition Model will be used. The State and Transition Model identifies key landform and ecosystem changes in relation to the rehabilitation success criteria that have implications for management that can be easily mapped in relation to the potential management requirements, rework, maintenance and monitoring.

The states of rehabilitation are initially based on the rehabilitation success criteria that are ordered in a logical sequence to reflect progressive changes in ecosystem rehabilitation. These will be reviewed based on the 2021 rehabilitation monitoring. An example of potential rehabilitation age indicators is provided in Table 11 and the associated state and transition age model is provided in Figure 7. The applicability of the age indicators and age model will be trialled and refined from the 2021 monitoring.

**Table 11:** Rehabilitation transitional age indicators.

| Indicator | Transitional Age |
|---|---|
| **Stability** | 1 |
| **Ground cover** | 3 |
| **Percentage of native tree species (excluding Brigalow)** | 5 |
| **Native tree species density** | 7 |
| **Stem count of each native tree species (biodiversity) / Foliage Projective Cover (FPC) of native species** | 10 |

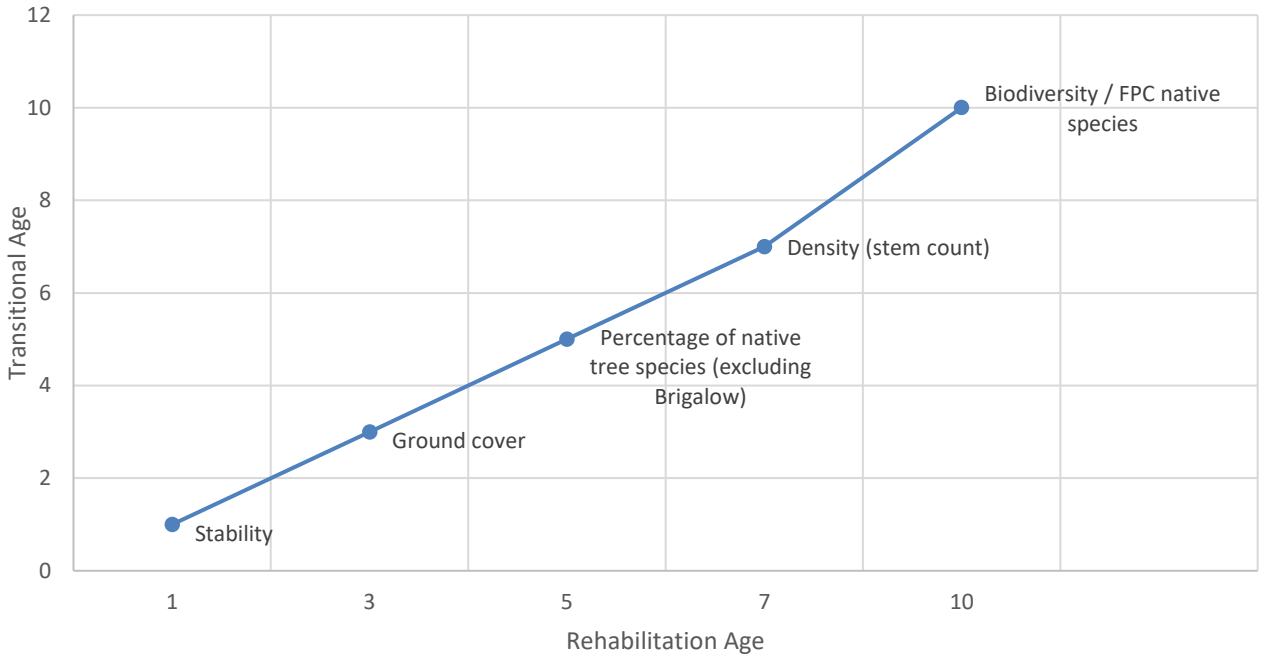



**Figure 7:** State and Transition Age Model.

A site that is not performing will fall below the line in the age model. For example, a 10-year-old site that does not meet the ground cover requirements will retain a transitional age of three, even if all other indicators have been met. Examples of compliant and non-compliant sites is provided in Figure 8.**Error! Reference source not found.** with different transitional age indicators.

A site that has attained the final stage of the transition age model has met all the performance monitoring criteria and would be recommended for progressive certification and relinquishment. A site that is not performing well will be recommended for rework, maintenance, or just to continue ongoing monitoring. The rehabilitation status and accompanying management action is provided in Table 12.

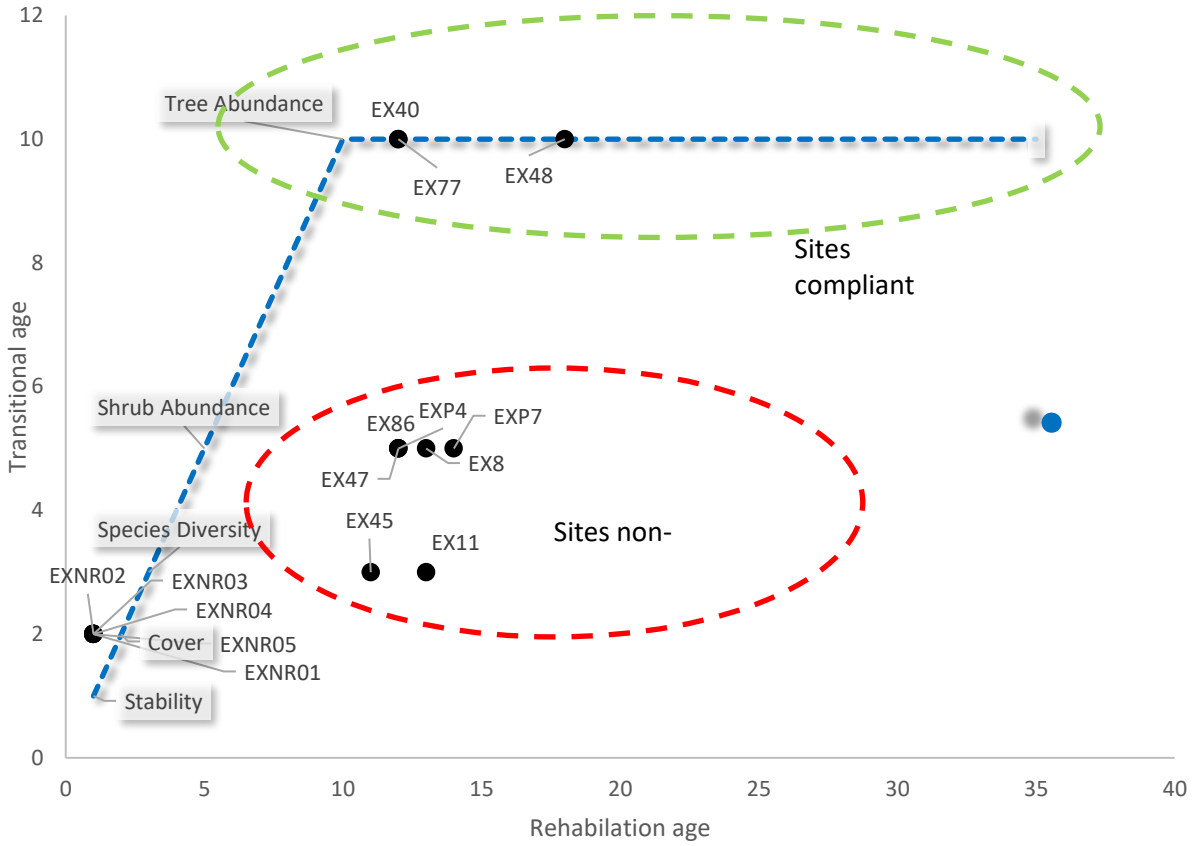



**Figure 8:** State and Transition Age Model Example.

**Table 12:** Rehabilitation Status.

| Rehabilitation status | Recommended action |
|---|---|
| **Rework** | Major works associated with reshaping landforms and gully remediation |
| **Maintenance** | Minor works associated with gully remediation, groundcover maintenance, reseeding and planting |
| **Monitor** | Site is on a trajectory towards completion criteria and requires ongoing monitoring |
| **Acceptable** | Site meets all performance criteria. Recommend for progressive certification |

## 5.6 Additional Monitoring and Control Measures

### 5.6.1 Flora and Fauna Protection

The pre-mining flora and fauna areas west of Blackwater Creek for Curragh Mine were reported by Hollingsworth (1979). For areas east of Blackwater Creek, pre-mining flora and fauna were reported by EH&S (1998) and ERM (2000b).

A three-season sampling program by the Central Queensland University (1994- 1996) surveyed areas for vertebrate fauna. Two hundred and twenty species of terrestrial vertebrates were identified including 149 bird, 23 mammal, 36 reptile (12 snakes and 24 lizards) and 12 frog species. Aquatic vertebrates were not targeted although the report by the Central Queensland University (1994-1996) mentions four species.

The pre-mining flora and fauna at areas for Curragh North Mine were reported during the EIS studies. Three flora and fauna surveys were undertaken during 1998, 2002 and 2003.

A total of 198 fauna species were observed or recorded including 14 butterflies, 15 amphibians, 22 reptiles, 120 birds and 27 mammals were identified.

The following species of conservation significance were recorded for the Curragh Project:

i. Brigalow Scaly-Foot Lizard (Paradelma orientalis) (no longer listed).

ii. Ornamental Snake (Denisonia maculata).

iii. Squatter Pigeon (Geophaps scripta scripta).

iv. Little Pied Bat (Chalinolobus picatus). (no longer listed).

Six vegetation communities were identified:

i. Fringing Red River Gum, tall woodland on alluvial plains.

ii. Open Coolabah, woodland with a predominately grassy under storey.

iii. Brigalow woodland and Yellowwood.

iv. Poplar Box and Dallachys Gum open woodland.

v. Lemon scented Gum woodland with Rosewood.

vi. Open grassland with Scattered Trees.

The main areas of conservation significance which have been identified:

i. Mackenzie River Riparian Vegetation.

ii. Brigalow community in the northern section of the Curragh Project.

iii. Brigalow community in the central section of the Curragh Project.

iv. Brigalow community in the southern section of the Curragh Project.

v. Poplar Box community in the eastern section of the Curragh Project.

The declared plants known to exist on the lease include:

i. Parthenium weed.

ii. Parkinsonia.

iii. Harrisia Cactus.

iv. Mother of Millions.

v. Rubbervine.

Fauna and flora surveys were carried out in late 2007 covering the area of the existing creek alignment and proposed Blackwater Creek diversion.

The assessment identified:

- a total of 108 fauna species including 71 birds, 19 mammals, 13 reptiles and 5 amphibians;
- five regional ecosystems (REs) as occurring within Curragh East Mine (ML 80086). Of these RE 11.3.1 and 11.4.9a are listed as Endangered under the Queensland Vegetation Management Act 1999 (VM Act) and the Commonwealth Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act) while 11.4.12 is also listed as Endangered under the VM Act;
- a total of 271 species of plant within the study area of which 41 (15 %) were introduced; and
- seven species of 'declared plants' under the Queensland Land Protection (Pest and Stock-route Management) Act 2002 during the field surveys for Curragh Project.

### 5.6.2 Declared Plants and Feral Animals

Weeds are an increasing cost to local graziers and the wider community. All Curragh mining leases are in close proximity to surrounding pastoralists. The potential impact from weeds is high and can include a loss of production, difficulty in establishment of rehabilitation, failure to meet completions criteria and degraded aesthetic qualities. The declared plants known to exist on the lease include Parthenium weed, Parkinsonia, Harrisia Cactus, Mother of Millions and Rubbervine. Local feral animals include pigs, cats and dogs and are a significant issue for the wider community. Feral animals including pigs, foxes, hares and cats are also particularly detrimental to native flora and fauna.

### 5.6.3 Description of Environmental Value

The environmental values to be protected or enhanced are:

- managing endangered and threatened ecosystems to ensure biodiversity values are retained;
- enhancing knowledge and data relating to all native fauna in the local area, with a particular focus on the species classified as threatened under the EPBC Act and/or NC Act; and
- managing declared pests and declared weeds to maximise the enduring value of the land.

### 5.6.4 Environmental Protection Objective

Objectives for the management of conservation values include:

- not introducing new weed species and preventing the spread of existing weed species;
- the protection of on-site flora and fauna;
- re-introducing flora and fauna to the mined area by undertaking a staged rehabilitation program;
- control of feral animal populations on site; and
- minimising the impact of mining on identified significant ecosystems.

### 5.6.5 Potential Impacts

Potential impacts on fauna and flora species may include:

- loss of habitat for the Brigalow Scaly-foot Lizard, Ornamental Snake, Squatter Pigeon and Little Pied Bat through clearing activities;
- fragmentation of the population and interception to dispersal / movement along existing corridors;
- an increase in weeds that may alter the structure of habitat and therefore reduce the quality of habitat

currently inhabited; and

- feral animals attracted to the Curragh Project.

### 5.6.6 Control Measures

Control measures include:

- the mine site weed eradication program is part of the Central Highlands Regional Council weed control strategy. Company or contractor vehicles are washed before leaving site. A specially designed wash down facility with under-body sprays is located at the Curragh Project industrial area. Contractor equipment is checked before being allowed onsite. Contractor equipment, if used in an infested weed area, is washed down before being transported away from the area;
- trees are to be inspected for fauna presence prior to removal where the potential for fauna presence exists and where inspections have not been undertaken for previous mining operations. Detected individuals will be flushed out or relocated prior to clearance; and
- in the event of any sick, injured or displaced animals being located during clearing activities, the Queensland Department of Environment and Science will be contacted when required.

### 5.6.7 Ongoing Surveys

Surveys will be carried out on an ongoing basis to gauge the occurrence, diversity and stability of flora and fauna species, and to determine appropriate directions for the progressive integration of mined areas into the surrounding ecosystems.

### 5.6.8 Weed Treatment Declared Plants and Feral Animal Control

Integrated weed and pest management is practised. Weed control methods include mechanical removal, herbicides and fire. A long term-approach to weed management is required to control weeds. A weed control management plan identifying locations of weeds by species is maintained and updated. Weed management as described in the following EMS documents are the basis of the annual weed control program.

*Reference: EM PLAN 1.0 Land Management Plan* and *EMS PROC 1.1 Declared Fauna and Flora Management Procedure.*

### 5.6.9 Vegetation Clearing

Prior to clearance of trees, areas are to be inspected for fauna presence detected individuals will be flushed out and/or relocated.

*Reference: EM PLAN 1.0 Land Management Plan*

### 5.6.10 Regional Ecosystems

The Curragh Project supports five environmental management areas (Figure 9). These areas are requirements of conditions of approval under two separate referrals under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

These environmental management areas and the relevant referrals involve:

i. Curragh North Coal Mine (EPBC 2003/1096)
   a. *Brigalow Management Area* (55 hectares) – Condition 2
   b. *Brigalow Rehabilitation Area* (37 hectares) – Condition 2
   c. *Transport Corridor Management Area* (17 hectares) – Condition 1

ii. Blackwater Creek Diversion and Coal Mine (EPBC 2007/3925)
   *a. Northern Brigalow Area (44.9 hectares) – Condition 1*

*b. Northern Brigalow Revegetation Area (21.4 hectares) – Condition 1*

Management plans have been prepared outlining the management actions to be undertaken to maintain and enhance the environmental values of each of these areas. These management plans have been combined into the Consolidated Environmental Management Plan (CEMP).

The management actions include measures to control weeds and pest animals, livestock and site access, erosion and sediment controls, fire management, methods for seed stock collection and planting techniques, as well as fauna management.

The CEMP also outlines a monitoring and reporting framework for noting the condition of each environmental management area over time.

### 5.6.11 Blackwater Creek Diversion

The rehabilitation plan for the Blackwater Creek diversion includes success criteria for the creek diversion, and ongoing monitoring requirements to ensure a stable and sustainable creek alignment is established and maintained.

Refer to document Place Design 'Blackwater Creek Diversion EMS-PROC-034 (Blackwater Creek Diversion – Vegetation and Rehabilitation Management Plan (2008)', for additional background information on rehabilitation design principles andoriginal process and the current EM PLAN 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan.

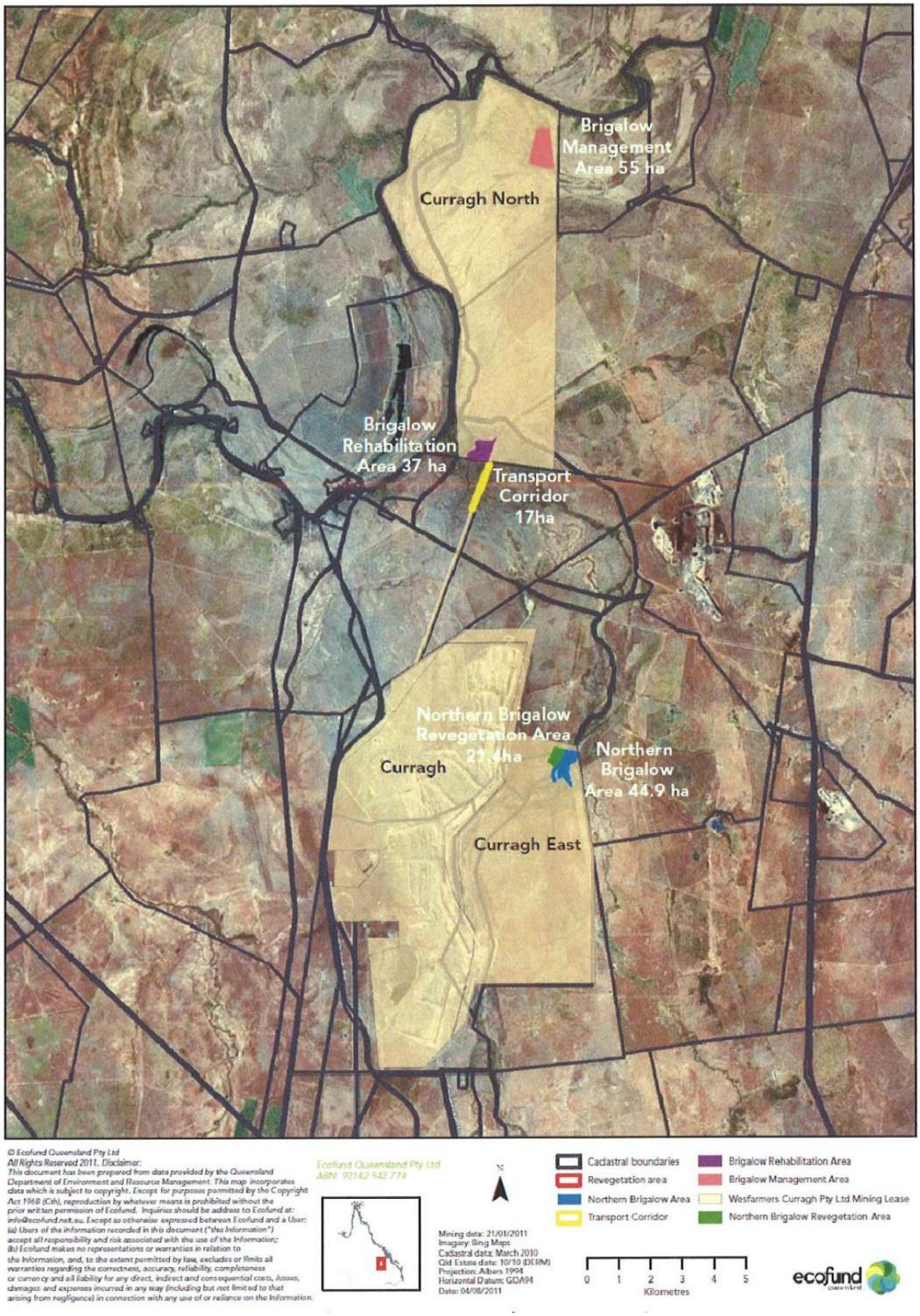



**Figure 9:** Curragh Mine Environmental Management Areas.

## 6. PROGRESSIVE CERTIFICATION

Curragh undertakes progressive targeted rehabilitation monitoring to identify rehabilitation areas that are performing at a level adequate to enable Coronado to apply for progressive certification. This involves targeted monitoring using the standard rehabilitation monitoring procedures as outlined in EMS PROC 1.6 Rehabilitation Monitoring Procedure.

The monitoring results are assessed against the completion criteria for the relevant domain (See section 4.3), based on a landform level assessment and a transect based assessment (Table 13,

Table 14 and Table 15).

**Table 13:** Safe, stable and non-polluting rehabilitated landform completion criteria performance matrix.

| Performance Criteria | Completion criteria | |
|---|---|---|
| | **Not yet conforming** | **Acceptable** |
| Slope >10% with a maximum slope 16% unstable | Yes | **No** |
| Slope ≤ 10% with a maximum slope 16% stable | No | **Yes** |
| Landform design achieves appropriate erosion rates. Engineered structures to control water flow | No | **Yes** |
| Signs of continued erosion greater than that exhibited on representative unmined areas within the mining leases (i.e. active gully erosion) | Yes | **No** |
| Certification that Class 2 declared pest plants are successfully managed by weed management program | No | **Yes** |
| Fauna presence (Evidence of active use of rehabilitated site by native fauna (e.g. bird nests, scats, etc.) | No | **Yes** |

**Table 14:** Light grazing and open woodland completion criteria performance matrix Domain 1.

| Performance Criteria | Completion criteria | |
|---|---|---|
| | **Not yet conforming** | **Acceptable** |
| Tree canopy cover (%) (combined canopy and sub-canopy)<br>*Preliminary value to be determined from 2021 monitoring* | TBA | **TBA** |
| Key Species Presence:<br>• at least 1 *Eucalyptus* species<br>• at least 2 *Acacia* species | No | **Yes** |
| Evidence of second-generation recruitment of native tree/shrub species | No | **Yes** |
| Mean ground cover requirement (≥50% total cover) | <50% | **≥50%** |
| Evidence of litter breakdown and nutrient recycling | No | **Yes** |
| Evidence in rehabilitation reporting that topsoil and spoil chemistry satisfies the following:<br>• soil salinity content is <800 µS/m with the aim of attaining <400 µS/m<br>• soil pH is between 5.5 and 9<br>• soil Exchangeable Sodium Percentage (ESP) is <15%. | No | **Yes** |

**Table 15:** Open grassland completion criteria performance matrix Domain 2.

| Performance Criteria | Completion criteria | |
|---|---|---|
| | **Not yet conforming** | **Acceptable** |
| Use of rehabilitated land meets specified yield<br>*Preliminary value to be determined from 2021 monitoring* | TBA | **TBA** |
| Presence of native grass and pasture species | No | **Yes** |
| Evidence of second-generation recruitment of native tree/shrub species | No | **Yes** |
| Mean ground cover requirement (≥50% total cover) | <50% | **≥50%** |
| Evidence of litter breakdown and nutrient recycling | No | **Yes** |
| Evidence in rehabilitation reporting that topsoil and spoil chemistry satisfies the following:<br>• soil salinity content is <800 µS/m with the aim of attaining <400 µS/m<br>• soil pH is between 5.5 and 9<br>• soil Exchangeable Sodium Percentage (ESP) is <15%. | No | **Yes** |

## 7. REHABILITATION MONITORING SCHEDULE 2021 – 2025

The proposed five rehabilitation monitoring schedule for 2021 – 2025 is presented in Table 16. The schedule is based on monitoring at age ≤1, 2, 3, 5, 7 and 10 years. After age 10 monitoring occurs at five-year intervals. Monitoring up to age one is based on a rapid assessment. From age one onwards permanent monitoring transects are established for newly rehabilitated areas.

A map of the existing monitoring sites is provided in Figure 10.

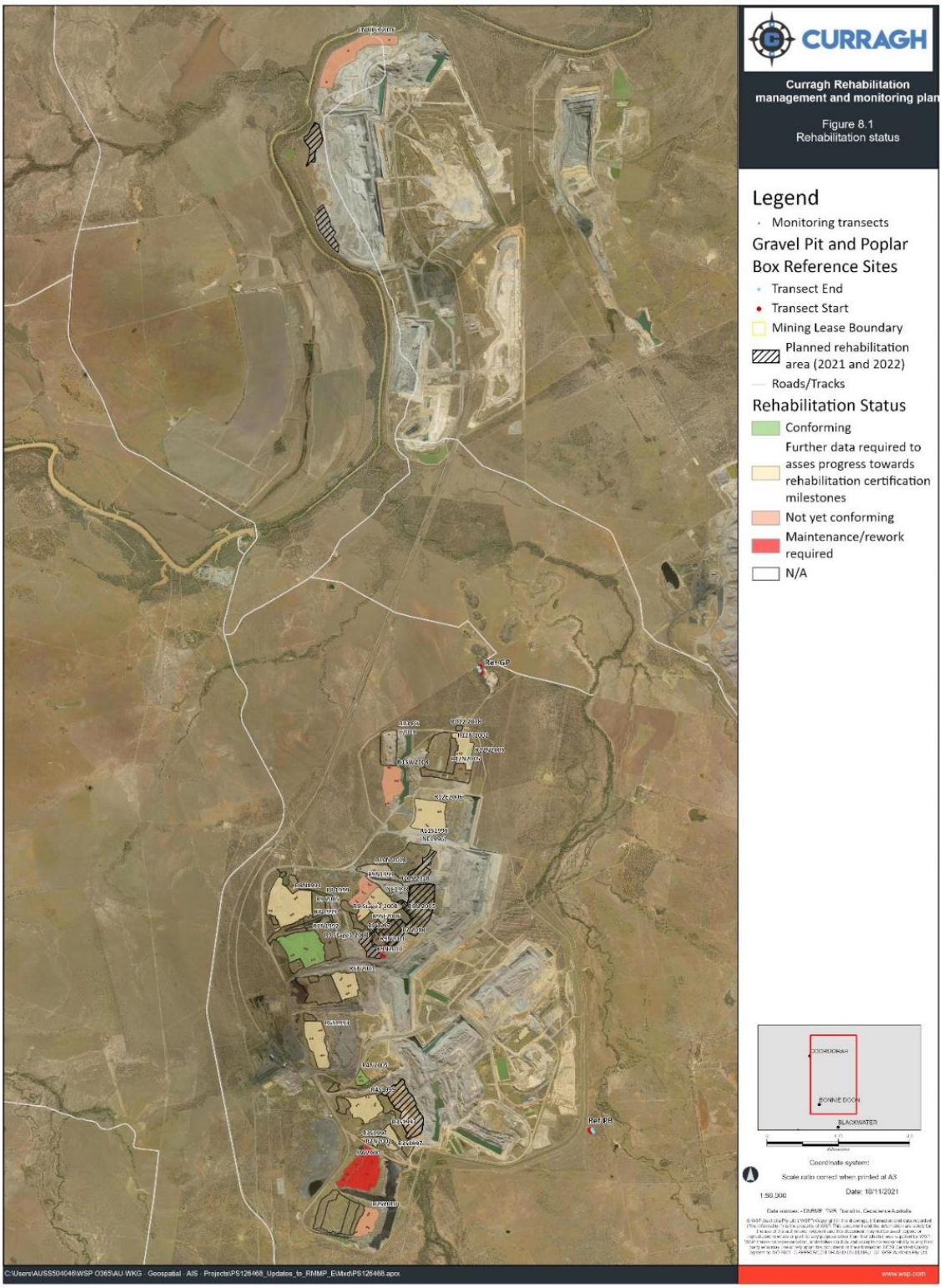



**Figure 10:** Rehabilitation status.

**Table 16:** Rehabilitation monitoring schedule 2021 – 2005.

| Site Name | Site ID | Easting* | Northing* | Rehab Year | Years Monitored | Age 2021 | Site Establishment | Rehab Status | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference Gravel Pit** | REF GP1 | 7410641 | 693284 | | 2011, 2014, 2016, 2019, 2020 | | Existing | - | | | | | |
| **Reference Poplar Box** | REF PB1 | 7399441 | 695571 | | 2011, 2014, 2016, 2019, 2020 | | Existing | - | | | | | |
| **Reference *E. cambageana*^** | REF EC | - | - | | 2011, 2014, 2016 | | Mined | - | - | - | - | - | - |
| **`Ramp 7 1992** | R71992 | | | 1992 | | 29 years | Existing | Conforming | | Year 30 | | | |
| **Ramp 7 North 1992** | R7N1992 | 7403663 | 689371 | 1992 | 2015, 2020 | 29 years | Existing | Further data required | | Year 30 | | | |
| **Ramp 6 South 1993** | R6S1993 | 7401938 | 689510 | 1993 | 2013, 2017 | 28 years | Existing | Further data required | | | Year 30 | | |
| **Ramp 8 North 1994** | R8N1994 | 7404794 | 688956 | 1994 | 2013 | 27 years | Existing | Further data required | | | | Year 30 | |
| **Ramp 11 South 1996** | R11S1996 | 7406310 | 691604 | 1996 | 2002, 2005, 2009, 2012 | 25 years | Existing | Further data required | Year 25 | | | | |
| **Ramp 3 South 1997** | R3S1997 | 7399131 | 691031 | 1997 | 2003, 2006, 2015 | 24 years | Existing | Further data required | | Year 25 | | | |
| **North East 1998** | NE1998 | 7405171 | 690778 | 1998 | 2002, 2004, 2007, 2011, 2015 | 23 years | Existing | Further data required | | | Year 25 | | |
| **Ramp 4 South 1999** | R4S1999 | 7400149 | 690756 | 1999 | 2003, 2005, 2008, 2012 ,2016 | 22 years | Existing | Not yet conforming | | | | Year 25 | |
| **Ramp 9 North 1999** | R9N1999 | 7405495 | 690667 | 1999 | 2003, 2005, 2008, 2012 ,2016,2019 | 22 years | Existing | Not yet conforming | | | | Year 25 | |
| **South West 2000** | SW2000 | 7398280 | 690024 | 2000 | 2002, 2006, 2009, 2013, 2019, 2020 | 21 years | Existing | Further data required | | | | | Year 25 |
| **Ramp 6 North 2001** | R6N2001 | 7402852 | 690187 | 2001 | 2004, 2007 ,2010,2017 | 20 years | Existing | Not yet conforming | Year 20 | | | | |
| **Ramp 2 North 2002** | R2N2002 | 7398741 | 690667 | 2002 | 2003, 2005, 2008, 2015, 2019, 2020 | 19 years | Existing | Further data required | | Year 20 | | | |
| **Ramp 12 North 2003** | R12N2003 | 7409104 | 692811 | 2003 | 2004, 2006, 2009 | 18 years | Existing | Not yet conforming | | | Year 20 | | |
| **Ramp 12 North 2005 (fresh)** | R12N2005 (fresh) | 7408055 | 692700 | 2005 | 2005, 2006,2008, 2020 | 16 years | Existing | Not yet conforming | | | | | Year 20 |
| **Ramp 12 North 2005 (old)** | R12N2005 (old) | 7408277 | 692018 | 2005 | 2005, 2006,2008, 2020 | 16 years | Existing | Conforming | | | | | Year 20 |
| **Ramp 4 North 2005** | R4N2005 | 7400708 | 690468 | 2005 | 2012,2013,2019, 2020 | 16 years | Existing | Further data required | | | | | Year 20 |
| **Ramp 12 East 2006** | R12E2006 | 7407302 | 691878 | 2006 | 2007, 2009, 2010 | 15 years | Existing | Not yet conforming | Year 15 | | | | |
| **Ramp 9 South East 2006** | R9SE2006 | 7404699 | 690426 | 2006 | 2007, 2009, 2010 | 15 years | Existing | Further data required | Year 15 | | | | |
| **Ramp 13 West 2008** | R13W2008 | 7407465 | 691132 | 2008 | 2008, 2019 | 13 years | Existing | Further data required | | | Year 15 | | |
| **Ramp 9 Stage 3 2008** | R9Stage3 2008 | 7404134 | 690827 | 2008 | 2008, 2016 | 13 years | Existing | Further data required | | | Year 15 | | |
| **Western dump Curragh North 3** | Western dump CN3 | | | 2009 | n/a | 12 years | Existing | Further data required | | | | Year 15 | |
| **Ramp 2 South 2010** | R2S2010 | 7397000 | 690246 | 2010 | 2012, 2020 | 11 years | Existing | Further data required | | | | | Year 15 |
| **Ramp 9 North 2010** | R9N2010 | 7403948 | 690903 | 2010 | 2011, 2020 | 11 years | Existing | Not yet conforming | | | | | Year 15 |
| **Blackwater Creek Diversion** | Blackwater Creek Diversion | - | - | 2011 | 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2020 | 10 years | Existing | Not yet conforming | | Biennial monitoring | | Biennial monitoring | |

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| Site Name | Site ID | Easting* | Northing* | Rehab Year | Years Monitored | Age 2021 | Site Establishment | Rehab Status | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ramp 12 South 2014** | R12S2014 | | | 2014 | n/a | 6 years | Existing | Further data required | Year 7 | | | Year 10 | |
| **KyberPass Ramp 4 North** | KyberPass R4N | | | 2014 | n/a | 6 years | Existing | Not yet conforming | Year 7 | | | Year 10 | |
| **Curragh North U Pit 2016** | CN UPIT2016 | | | 2016 | 2020 | 5 years | Existing | Further data required | Year 5 | | Year 7 | | |
| **Ramp 7 2018** | R72018 | | | 2018 | 2020 | 3 years | Existing | Not yet conforming | Year 3 | | Year 5 | | Year 7 |
| **Ramp 10 North 2018** | R10N2018 | | | 2018 | 2020 | 3 years | Existing | Not yet conforming | Year 3 | | Year 5 | | Year 7 |
| **Ramp 10 South 2018** | R10S2018 | | | 2018 | 2020 | 3 years | Existing | Not yet conforming | Year 3 | | Year 5 | | Year 7 |
| **Ramp 13 Pit 1 2018** | R13Pit1 2018 | | | 2018 | 2020 | 3 years | Existing | Not yet conforming | Year 3 | | Year 5 | | Year 7 |
| **Ramp D22 2018** | RD22 2018 | | | 2018 | 2018 | 3 years | Existing | n/a | Year 3 | | Year 5 | | Year 7 |
| **Ramp 3 South 2018** | R3S2018 | | | 2018 | n/a | 3 years | Existing | Not yet conforming | Year 3 | | Year 5 | | Year 7 |
| **Ramp 4 South B Pit** | R4S B Pit | - | - | 2021 | - | - | Proposed | - | | Year 1 | Year 2 | Year 3 | |
| **Capital Hill and Julian's Square** | Capital Hill and Julian's Square | - | - | 2021 | - | - | Proposed | - | | Year 1 | Year 2 | Year 3 | |
| **Nth Capital Hill** | North Capital Hill | - | - | 2021 | | - | Proposed | - | | Year 1 | Year 2 | Year 3 | |
| **T pit North Curragh North** | T Nth CN | - | - | 2021 | - | - | Proposed | - | | Year 1 | Year 2 | Year 3 | |
| **T pit South Curragh North** | T Sth CN | - | - | 2022 | - | - | Proposed | - | | | Year 1 | Year 2 | Year 3 |
| **Ramp 7 North** | R7Nth | - | - | 2022 | | - | Proposed | - | | | Year 1 | Year 2 | Year 3 |

*Easting and Northing coordinates are derived from the start of Transect 1 (T1) for each site.

^REF EC has been disturbed by mining and no longer exists.

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# 8. RESEARCH AND DEVELOPMENT

Curragh maintains a strong commitment to rehabilitation research and development to refine rehabilitation methods, achieve rehabilitation success and ensure eventual bond release. Past research projects are listed here and are summarised in Appendix 3.

## 8.1 Previous Research Programs

Previous research programs conducted by WCPL include:

i. Mine rehabilitation erosion stage III (biophysical adjunct).
ii. Establishment of trees on topsoil.
iii. Soil micro-biology.
iv. Soil substitutes and native ecosystem development.
v. Establishment of native understorey.
vi. Terrestrial flora/fauna success criteria.
vii. Aquatic flora/fauna success factors.
viii. Risk assessment of rehabilitation stability.
ix. Tailing dam hydrogeology.

## 9. REFERENCES


ANZECC. (2000) Australian Guidelines for Fresh and Marine Water Quality 2000. National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council, Canberra, ACT.

Baiquni, H. & McKenna, P. (2008) Curragh Coal Mine Rehabilitation Monitoring 2007 assessment. Final report to Curragh Queensland Mining Ltd. Centre for Mined land Rehabilitation, University of QLD. 24pp.

Bowen, D. (1996) Personal Communication. Centre for Mined Land Rehabilitation, The University of Queensland, St. Lucia, QLD.

Bowen, M.K. & Chudleigh, F. (2017). Productivity and profitability of a range of alternative steer growth paths resulting from manipulating the pasture feed base in central Queensland – a modelling approach. Department of Agriculture and Fisheries.

Carroll, C., Merton, L. and Berger, P. (2000). Impact of vegetative cover and slope on runoff, erosion, and water quality for field plots on a range of soil and spoil materials on central Queensland coal mines. *Australian Journal of Soil Research* 38, 313-327.

Carroll, C. & Tucker, A. (2000). Effects of pasture cover on soil erosion and water quality on central Queensland coal mine rehabilitation. *Tropical Grasslands* 34, 254- 262.

Carroll, C., Tucker, A., Burger, P. & Pink, L (2003) Sustainability indicators for coal mine rehabilitation. 2003 Curragh Final Report. QLD Natural Resources and Mines. 35pp

Central Queensland Cultural Heritage Management Pty Ltd, (June 2000), Curragh East Levee Bank Mitigation program, Summary Report of Field Work.

C.Q.M.L. (1996) Environmental Sampling Procedures Manual, Curragh Project, March 1991. Curragh Queensland Mining Limited, Blackwater, QLD.

Curragh Queensland Mining Ltd (2007) Curragh Project Plan of Operations, 1 July 2007 – 30 June 2008.

C.Q.U. (1996) Fauna of Curragh Coal Mine Blackwater Central Queensland. Centre for Land and Water Resource Development, Central Queensland University, Rockhampton, QLD.

CCPL EM PLAN 1.0 Land Management Plan

CCPL. EM PLAN 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan

CCPL EMS PROC 1.1 Declared Fauna and Flora Management Procedure

Department of the Environment and Heritage 2006, *EPBC Act Policy Statement*

*1.1 Significant Impact Guidelines,* Department of the Environment and Heritage, Canberra.

Curragh Queensland Mining Ltd, (2002), Curragh Project Environmental Management Overview Strategy, October 2002.

Department of Environment and Science, Guideline: Rehabilitation requirements for mining resources activities (ESR/2016/1875).

Department of Natural Resources and Mines, Central West Water Management and Use Regional Guideline: Watercourse Diversions – Central Queensland Mining Industry. Queensland Government.

EGI (1993), Geochemistry of Overburden and Implications for its Disposal, Curragh East Development Area.

EH&S Systems (1998), Description of Existing Environment, Curragh East Project,Brisbane.

Elsol, J. and Fletcher, G. (1995) Vegetation Studies - Curragh Queensland Mining Limited. Land Reclamation Services Pty Ltd, Emerald, QLD.

Emmerton, B. (1993) Characterisation of Dragline Dumped Spoil, Curragh Project. Land Reclamation Services Pty Ltd, Emerald, QLD.

EPA (2008) Rehabilitation requirements for mining projects. Guideline: Mining 18. http://www.epa.qld.gov.au/publications/p01673aa.pdf/Rehabilitation_requirements_ for_mining_projects.pdf

ERM (2000a), Curragh East Initial Advice Statement, Environmental Resources Management, Brisbane.

ERM (2000b) Curragh East Project Flora and Fauna Studies, Environmental Resources Management, Brisbane.

ERM (2000c) Curragh East Project Land Suitability Assessment, Environmental Resources Management, Brisbane.

ERM (2000d) Curragh East Project Weed Survey, Environmental Resources Management, Brisbane.

ERM (2000f) Curragh East Project Community Outcomes Report, Environmental Resources Management, Brisbane.

Franks, A., J. (2002). The ecological consequences of Buffel Grass Cenchrus ciliaris establishment within remnant vegetation of Queensland. Pacific Conservation Biology; 2002; 8, 2;

Hall, R. (2008) Soil Essentials Managing Your Farms Primary Asset. Landlinks Press 182 pp

Haydock, K.P. and Shaw, N.H. (1975). The comparative yield method for estimating dry matter yield of pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry* 15, 663-670.

Hollingsworth P. and Associated Consultants. (1979) Preliminary Impact Assessment May 1979, Evaluation of the Coal Resources in Authority to Prospect 217C Curragh.

Land Reclamation Services Pty Ltd. (1984) Reclamation Planning Curragh Project Blackwater, Queensland. Emerald, QLD.

Land Reclamation Services Pty Ltd. (1990) Curragh Project Soil Survey. Emerald, QLD.

Land Reclamation Services, (1994), Selection of Native Species to Develop Natural Ecosystems on Open Cut Coal Mines in the Central Queensland Region Fletcher, G., LRS Pty Ltd, Emerald.

Land Reclamation Services, (1995), Vegetation Studies - Curragh Queensland Mining Limited., L Elsol, J, and Fletcher, G, LRS Pty Ltd, Emerald.

Longworth and McKenzie Pty Ltd. (1987) Curragh Tailings Dam Stage 3 - Construction Manual. Brisbane, QLD.

L'Oste-Brown, S (2007) Fieldwork summary report (No. 1) for the survey and mitigation of 2007 priority areas 2 & 5 (Curragh Main) and the survey and mitigation of 2007 priority areas 10-12 (Curragh East), September 2007, 20 September 2007.

Place Design (2008) Blackwater Creek Diversion Vegetation and Rehabilitation Management Plan. WCPL document no. EMS-PROC-034.

Stuart Miller & Associates, (1984), Waste Management and Rehabilitation Studies,Overburden Geochemical Investigations, Birchgrove, NSW.

Stuart Miller & Associates, (1990), Geochemical Characterisation of Course Rejects & Tailings, Balmian, NSW.

McKenna, P. & Baiquni, H (2008) Curragh Coal Mine Rehabilitation Monitoring 2008 assessment. Final report to Curragh Queensland Mining Ltd. Centre for Mined land Rehabilitation, University of QLD. 89pp.

McKenna, P. & Vickers, H (2009) Curragh Coal Mine Rehabilitation Monitoring 2009 assessment. Final report to Curragh Queensland Mining Ltd. Centre for Mined land Rehabilitation, University of QLD. 76pp.

Mulligan, D.R. and Bell, L.C. (1991). Tree and Shrub Growth on Land Rehabilitated After Mining at Curragh Coal Mine. Department of Agriculture, The University of Queensland, St. Lucia, QLD.

Orr, M.S. and Bell, L.C. (1990) Strategies for Site Stabilisation and Native Species Regeneration at the Curragh Open-Cut Coal Mine. Department of Agriculture, The University of Queensland, St. Lucia, QLD.

Orr, M.S, (1993), Strategies for Native Species Establishment at the Curragh Open-Cut Coal Mine, Central Queensland., University of Queensland, Brisbane.

PB (2007) Blackwater Creek Diversion Terrestrial Ecology Assessment. December2007, Brisbane

PB (2008) Addendum 1 to Blackwater Creek Diversion Hydrology and Hydraulic Report, February 2007, Brisbane.

Queensland Herbarium (2009). Regional Ecosystem Description Database (REDD). Version 6.0b Updated November 2009, (Department of Environment and Resource Management: Brisbane).

Rayment, G.E. and Higginson, F.R. (1992). *Australian laboratory handbook of soil and water chemical methods.* Inkata Press, Sydney.

Rosser, J., Swartz, G.L., Dawson, N.M. and Briggs, H.S. (1974) A Land Capability Classification for Agricultural Purposes. Division of Land Utilisation Technical Bulletin No. 14, Queensland Department of Primary Industries.

Scanlan, J.C., McKeon, G.M., Day, K.A., Mott, J.J. and Hinton, A.W. (1996). Estimating safe capacities in extensive cattle grazing properties within tropical semi- arid woodlands of north-eastern Australia. *Rangeland journal* 16, 64-76.

University of Queensland, Centre for Mined Land Rehabilitation, (1989), Strategies for Site Stabilisation and Native Species Regeneration at the Curragh Open-Cut Coal Mine - Progress Report.

University of Queensland, Centre for Mined Land Rehabilitation, (1991), Tree and Shrub Growth on Land Rehabilitated after Mining at Curragh Coal Mine.

University of Queensland, Centre for Mined Land Rehabilitation, (1993a), Strategies and Techniques for the Establishment of a Self-Sustaining Native Ecosystem on Mined Land at the Curragh Open-Cut Coal Mine.

University of Queensland, Centre for Mined Land Rehabilitation, (1993b), Assessment of Seed Content of Vacuum Collected Topsoil Litter Samples from Native Vegetation near Curragh.

University of Queensland, Centre for Mined Land Rehabilitation, (1998), Strategiesand Techniques for the Establishment of a Self-Sustaining Native Ecosystem on Mined Land at the Curragh Open-Cut Coal Mine, A summary of monitoring and investigation 1995-1998.

University of Queensland, Centre for Mined Land Rehabilitation (2000), InoculatingMycorrhizal Fungi into Mine Soils, Curragh Project, AMIRA Project P257B, Final Report.

WBM (2000), An investigation of the vertebrate fauna and habitat values of Curragh Project.

Willcocks, J. (1993). Climate. In *Farming Systems for Downs and Brigalow Soils in Central Queensland.* Proceedings of a workshop held at Emerald Pastoral College, September 1991 (Eds A.L. Garside, B.J. Radford and A.J. Carr.). Dept. Primary Industries, Brisbane.

WSP 2021, Coronado Curragh Offset Strategy. Curragh Extension Project EPBC 2015/7508.

## APPENDIX 1 – Curragh Project Spoil and Soil Characterisation

In order to meet requirements under the Curragh Project Environmental Authority (Permit Number: EPML00643713) a rehabilitation management plan must be developed that specifies soil and spoil characteristics.

Appendix 1 summarises data gathered in the previous surveys of the Curragh, Curragh East and Curragh North mining tenements and makes recommendations on further spoil and soil analysis regimes that may be required to meet condition outlined in the Environmental Authority.

### Previous Investigations

Previous soil and spoil investigation have been undertaken in all areas that are to be disturbed by mining activities.

### Curragh Soil

A soil study by Land Reclamation Services (1990) identified 7 soil mapping units in the Curragh Project area. Table A1.1 gives a brief description of the soil units described by Land Reclamation Services and outlines the soils suitability for rehabilitation (Figure A1.1 shows the locality of the soil units). Care should be taken when using the table as 'there is considerable variation within these mapping units' and hence a more intensive survey should be completed before topsoil stripping commences.

**Table A1.1:** Curragh Soils and Suitability for Rehabilitation.

| Soil Description | Suitability for Rehabilitation |
|---|---|
| **Red brown melon hole clays** | • Top 10cm chemically suitable for Rehab<br>• Lower horizons are dispersive and have high chloride concentration<br>• Melon hole relief makes striping top layer without contamination from lower horizons impossible<br>• Therefore, this soil is not suitable for rehabilitation |
| **Red brown non-cracking clays** | • Top 20cm are suitable for rehabilitation<br>• Lower horizons are dispersive and have moderate chloride concentrations<br>• Topsoil should be carefully stripped to 20cm |
| **Grey brown cracking clays** | • High chloride concentrations throughout the profile<br>• All horizons are potentially dispersive<br>• Recommended that this soil is not used in rehabilitation |
| **Grey brown cracking clays over calcareous material** | • Well-structured cracking clay with low chlorides and dispersivity to at least 60cm<br>• Soil should be stripped to 60cm depth<br>• 0–30cm should be stockpiled separately to 30-60cm |
| **Red brown cracking clays – acid sub soil** | • Only the top 20cm is chemically suitable for rehabilitation |
| **Mixed clays and texture contrast soils** | • Only the top 15cm is suitable for rehabilitation<br>• Lower horizons consist of impervious clays which are dispersive |
| **Red texture contrast soils** | • Only the A horizon should be used for rehabilitation as the lower clays are impervious and dispersive<br>• Therefore, only the top 15cm should be stripped and stockpiled for rehabilitation |

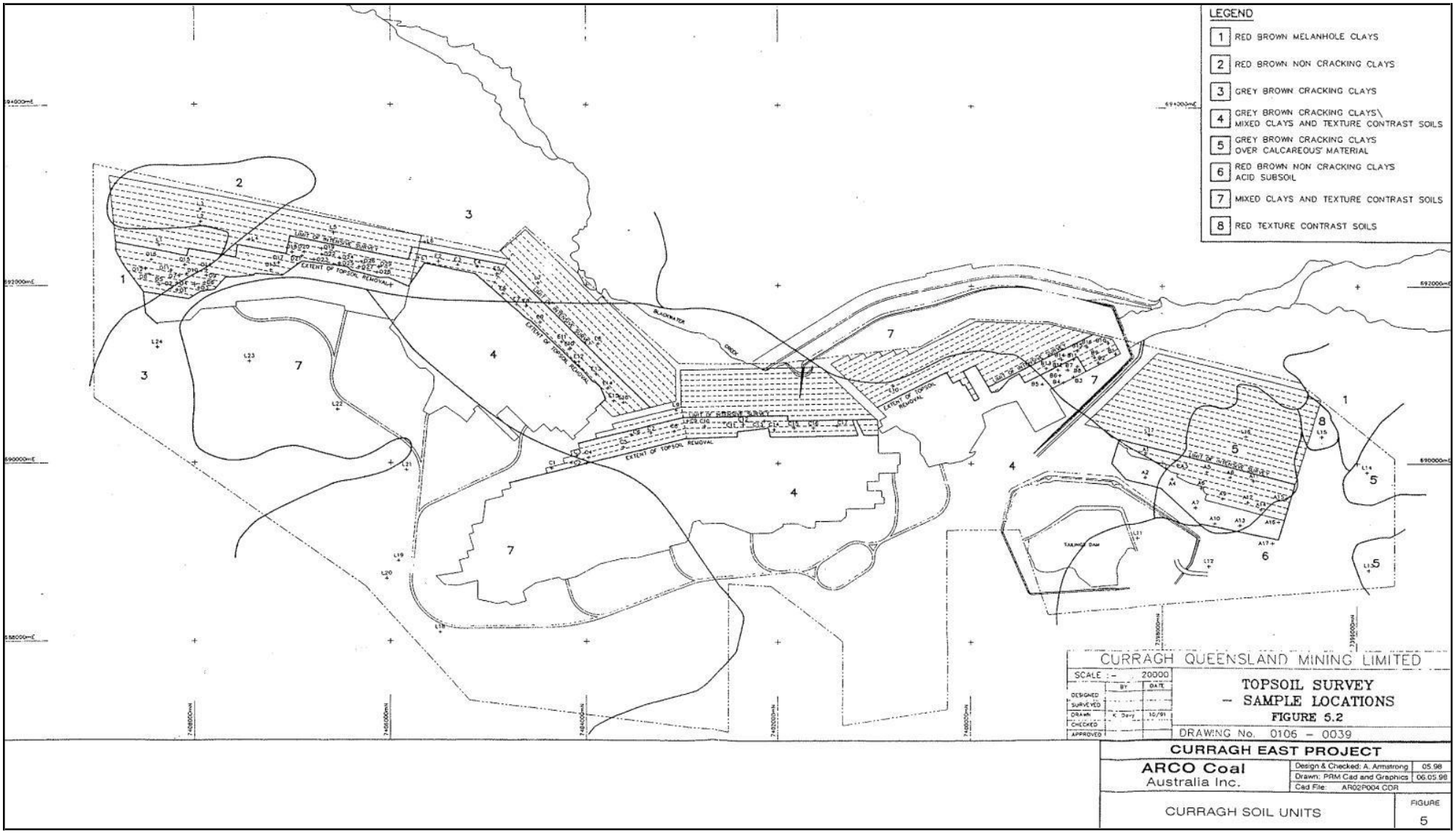



**Figure A1.1:** Curragh Soil Types.

## Spoil

Various Spoil studies have been completed in the vicinity of the main Curragh area. Below is a brief description of the findings from each report.

## Stuart Miller and Associates

Stuart Miller and Associates (1984) completed field and laboratory investigation to characterise overburden and identify management techniques that may be required to maximise rehabilitation success and preserve water quality. This report focuses on overburden samples taken from pits C and E (formerly known as pit E east) as well parts of Pits B and D. The results show that:

- the total sulphur content of samples ranged from 0.03 to 2.8%;
- the ANC is high in all samples – and hence sufficient to neutralise acid produced by oxidation of sulphur;
- the thin (<0.5m) inter burden layer between the Aries/Castor and Pollux seams is acid forming in places but shouldn't prove problematic in rehabilitation, provided that this strata is mixed with other layers;
- spoils were moderately to highly saline and were highly sodic; and
- coal seams are potentially acid forming and hence rejects generated from this area may be acidic in nature.

## Land Reclamation Services

Land Reclamation Service completed a survey of dragline dumped spoil in 1993, 81 grab samples were analysed for pH and EC, with results from these samples used to select 41 samples for further analysis. The in-situ and laboratory results have shown that the majority of spoil is saline and sodic:

- Of the 81 grab samples only 6 returned an acidic pH with;
    - one of these samples came from coal reject material;
    - four samples contained oxidised coal material; and
    - one clay and grey shale material with slight acidity was found between ramps 7 and 8.

In addition to the dragline spoil sampling Land Reclamation Services also completed analysis of overburden chips from 5 drill holes within the mining lease. The samples were analysed for pH and EC (on a 1:5) and results show that:

- in general, weathered materials (ranging from 333 to 2270 µS/cm) appear to have higher salinities than that unweathered materials (EC between 293 and 945 µS/cm); and
- the majority of the chip samples were strongly alkaline with the exception being some near surface clay samples from the northern area of the Lease.

## HLA-Envirosciences Pty Ltd

HLA-Envirosciences completed pH and NAG analysis on 20 samples from 5 bore holes in March 1998. Of the twenty samples only two had an acidic pH and a NAG of >0.1. The details of these two samples are shown below:

- sample 98137-13100 was taken from between the base of weathering and the Aries roof, a pH of 3.4 and NAG of 12.9 kg/t was recorded; and
- sample 98143-13118 was taken between Aries floor and Castor Roof, a pH of 2.9 and NAG of 4.5kg/t.

Unfortunately, the HLA report does not contain the location of the bore holes and hence this data may be of little use. Curragh East

## Soils

A description of the existing environment of the Curragh East Project Area was completed by Environment Health and Safety Systems (1998). Soil samples were taken from 17 sites and soils were described in sufficient detail to classify into mapping units (Figure A1.2). In general, the report shows that:

- soil sample analyses show that the soils of the project area are poorly to moderately fertile;
- soils are potassium and nitrogen are deficient;
- soils are calcium and magnesium are moderately deficient; and
- sodicity of soils is low although deeper layers may prove more problematic.

In addition to the soil units already described in the Curragh Soil section the following soil units are also described in the (1998) report as existing in the Curragh East area:

## Variable Texture Contrast Soils

Occur on the eastern and north-eastern part of the Curragh East area and are characterised by coarse textured sandy clay loams to sandy clay over-lying coarsely structured alkaline clay subsoil. The soils are associated with the ridge running north/south over the Curragh East area and support a range of vegetation from tall Poplar Box forest to short mixed forest.

## Cracking Clays over Alluvial Parent Material

This mapping unit is associated with the undisturbed section of the Blackwater Creek streambed. This cracking heavy clay forms a deep layer over an alluvial parent material, the dark brown to grey soil has a coarse blocky structure and ranges from acid to neutral in the upper 0.5 metres to strongly alkaline below this depth.

Rehabilitation suitability for these two-soil mapping unit is not given in the Environment Health and Safety Systems report

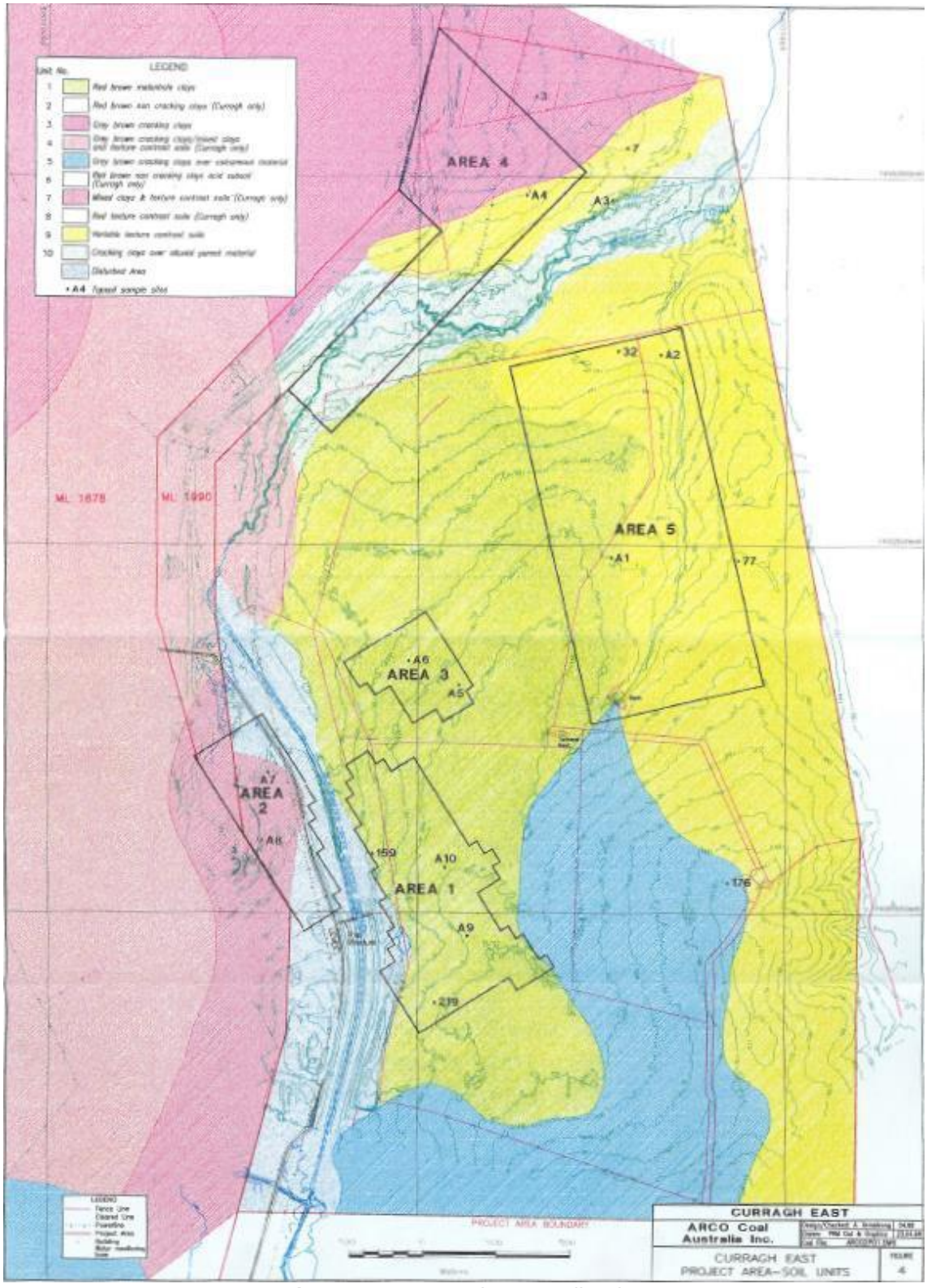



**Figure A1.2:** Curragh East Soil Units.

## Spoil

As part of the Curragh East Project, Environmental Geochemistry International (EGI) was commissioned to investigate the Acid Forming Potential (AFP) and environmental geochemistry of the overburden in the Curragh East project area. Curragh Project personal supplied the EGI laboratory with 119 samples from varying depths within 16 drill holes. All samples were analysed for total sulphur content and ANC with subsequent calculations to determine NAPP being made. Selected samples then underwent Net Acid Generation NAG testing and a multi element analysis.

From the analysis the following conclusions were drawn:

- all samples had low sulphur contents (<0.01 to 0.36%), the samples with the greater than 0.15% Sulphur were almost exclusively from the roof or floor of the Aries and Castor seems;
- ANC were typically moderate to high, and generally increased with sample depth;
- in most cases the ANC is at least 20-times the acid production potential;
- NAPP results were all negative and therefore all samples are classified as non-acid forming;
- overburden is slightly to moderately enriched with Silver, Arsenic and Selenium; however concentrations are below levels which would limit rehabilitation of the overburden after mining.
- spoil was found to be generally sodic in nature; and
- 'The potential for generation of acidic leachates in all types of spoil from the Curragh East area is extremely low.'

## Curragh North Soils

As part of the EIS process, AustralAsian Resource Consultants Pty Ltd (AARC) was commissioned to complete a *Supplementary Topsoil Survey for the Curragh North Mining Lease* (AARC 2004). The report used results from soil samples taken in previous surveys (1996, 1998 and 2003, 61 samples in total). As well as data taken from the analysis of 88 sites sampled in November 2003 by the consultants (Figure A1.3). Soil test results were statistically analysed by AARC with the relative levels of various parameters used to categorise soil against criteria provided in the Land Suitability Assessment Techniques Guideline (Department of Minerals and Energy 1995).

The AARC report concludes that:

- the Curragh North Project area contains 6 distinct soil types;
- the soil types have been mapped into 4 distinct management units (Figure A1.3); and
- each land management until has distinctive management requirements and is only suited to particular land uses (Table A1.2).

**Table A1.2:** Suitability of soil types for grazing and broad acre cropping – prior to mining activities (adapted from AARC 2004).

| Management Unit | Grazing Suitability | | Broadacre Cropping Suitability | | Area to be disturbed (hectares) | % of disturbed area |
|---|---|---|---|---|---|---|
| | Class | Limitations | Class | Limitations | | |
| **Dee** | 3 | Suitable for grazing with moderate limitations.<br>Requires moderate inputs to ensure sustainable land use | 3 | Suitable for rain fed broadacre cropping with moderate limitations.<br>Requires moderate inputs to ensure sustainable use | 1371.5 | 29.7 |
| **Callide** | 2 | Suitable for grazing with minor limitations. May require minor changes in management to ensure sustainable use. | 3 | Suitable for rain fed broadacre cropping with moderate limitations.<br>Requires moderate inputs to ensure sustainable use | 1865.9 | 40.4 |
| **Maculata** | 3 | Suitable for grazing with moderate limitations.<br>Requires moderate inputs to ensure sustainable land use | 3 | Suitable for rain fed broadacre cropping with moderate limitations.<br>Requires moderate inputs to ensure sustainable use | 275.8 | 6.0 |
| **Oombabee r** | 4 | Suitable for grazing with severe limitations.<br>Requires significant inputs to ensure sustainable land use. | 4 | Suitable for rain fed broadacre cropping with severe limitations.<br>Requires significant inputs to ensure sustainable land use. | 1100.1 | 23.8 |

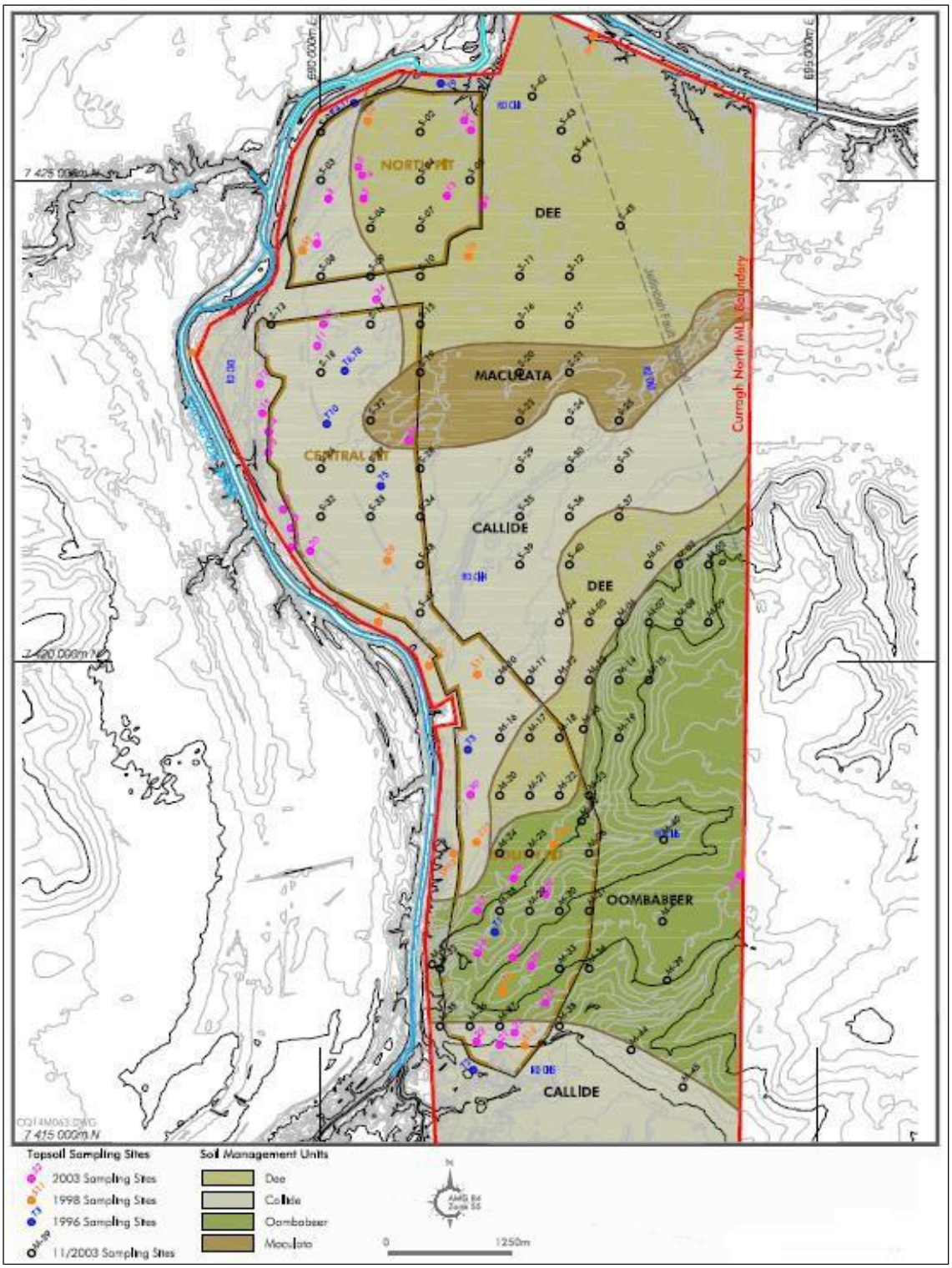



**Figure A1.3:** Location of soil sampling points and soil management units.

## Spoil

As part of the Curragh North Project EIS, AARC was commissioned to compile an Overburden Characterisation Report (OCR) of the Curragh North project Site. AARC used analytical results from 33 overburden samples in order to "identify and evaluate potential management issues associated with the handling of overburden material at the Project site".

The following conclusions were drawn:

- acid Neutralising Capacity (ANC) and Net Acid Production Potential (NAPP) results have indicated AMD is unlikely to develop to be a management issue;
- sodicity levels for the overburden material are sufficiently high to warrant placement below the root zone;
- salinity levels are not sufficiently high to adversely affect plant growth; and
- ongoing characterisation of overburden is recommended to refine management strategies on an operational level.

## 2009 Spoil Sampling Regime

In 2009 Curragh Environmental personal undertook sampling of mine spoil from Curragh, Curragh East and Curragh North to further assess the risk of AMD. An experimental process outlined by Watling *et al.* was used; this involved measuring field pH ($pH_F$) and field pH peroxide ($pH_{FOX}$) on sub-samples of mine spoil.

The Guidelines for Sampling an Analysis of Lowland Acid Sulfate Soils in Queensland (Ahern *et al.* 1998) were used to interpret the experimental results. The guidelines use a combination of three factors to deduce a positive field sulphide identification, namely "a reaction with hydrogen peroxide, a much lower $pH_{FOX}$ than field $pH_F$ (ΔpH) and the actual value of $pH_{FOX}$.

In addition to field investigations, 11 samples were sent to a NATA accredited laboratory for further analysis. Results from both the field assessment and laboratory analysis are shown below:

The field assessment results were:

- one sample had a slightly acidic pHF (6.3 from the Permian material on the CN Eastern Spoil Dump) with the remaining samples returning pHF of between 7.4 and 9.4;
- three Samples had a ΔpH > 1 they were from mine spoils located on the CN Eastern Spoil Dump (both Tertiary and Permian material) and the CN levee access road;
- only two samples returned an acidic pHFOX (Tertiary and Permian materials from the Eastern Spoil Dump); and
- field assessment results indicate that the Permian material on the CN Eastern Spoil Dump has the highest PASS potential, as the pHFOX was 2.7 and the ΔpH was 3.6.

The laboratory analysis results were:

- pH of samples was alkaline, ranging from 7.8 to 9.4;
- as per the field assessment two samples returned an acidic pHOX these samples were the two samples from the eastern spoil dump;
- the Net Acid Generation (NAG) was <0.5 kg(H2SO4)/tonne for all except one sample, ESD2 (Permian Material) had a NAG of 3.5 kg(H2SO4)/tonne;
- acid Neutralisation Capacity ranged from 6.1 to 67 kg (H2SO4)/tonne for the 11 samples; and
- the Nett Acid Generation Potential (inc. ANC) was negative for all samples, suggesting that the samples have enough ANC to prevent acid generation.

## CONCLUSIONS AND RECOMMENDATIONS

### Spoil Acidity

Previous reports suggest that future spoil sampling may be required to facilitate successful spoil placement if isolated areas of PASS are discovered. A detailed spoil sampling regime should be developed in conjunction with a suitably qualified consultant, so spoil can be categorised prior to mining. Taking spoil samples during the exploration drilling program would allow enough time for samples to be analysed and an appropriate strategic placement plan to be developed if Potential Acid Sulphate Soil (PASS) were discovered. Using the exploration drill to obtain these samples would also allow for some synergies regarding project costing.

### Sodicity and Salinity

Previous spoil characterisation reports indicate that the spoils in the Curragh and Curragh East lease areas are saline and sodic in nature. At Curragh North salinity is not sufficiently high to affect plant growth but sodicity is high enough to consider selective placement of spoils or amelioration techniques.

### Soil Curragh North

The supplementary topsoil survey for the Curragh North Mining Lease (AARC 2004) Supplies a reasonably detailed map of soil management units. This map should be used by environmental personnel when advising on topsoil stripping (through the permit to disturb system) as each management unit should be stripped and stockpiled separately. The separate stockpiling of different management units would allow for the best management of each soil class once rehabilitation commenced. Once topsoil has been stockpiled it is important that relevant information is recorded into the topsoil database so as data relating to the stockpile can be easily recalled when rehabilitation works begin.

### Curragh and Curragh East

Preliminary topsoil surveys of the Curragh and Curragh East give a good broad description of the soils in these areas. Higher resolution topsoil mapping would be required to optimise topsoil stripping and stockpiling techniques. To facilitate this, it is advisable that further topsoil sampling and categorisation should take place well in advance of mining activities.

## REFERENCES


Ahern, C.R., Ahern, M.R., and Powell, B. (1998) Guidelines for Sampling and Analysis of Lowland Acid Sulphate Soils (ASS) in Queensland

Austral Asian Resource Consultants (2003) Curragh North Project - Environmental Impact Statement

Austral Asian Resource Consultants (2004) Supplementary Topsoil Survey for the Curragh North Mining Lease

Environmental Geochemistry International (1993) Curragh Queensland Mining – Curragh East Development Area: Geochemistry of Overburden and Implications for its Disposal

Environment Health and Safety Systems (1998) Description of Existing Environment Curragh East Project

HLA-Envirosciences (1998) Soil Analysis: Net Acid Generation and pH Curragh Mine Queensland

Land Reclamation Services (1990) Curragh Mine Soil Survey

Land Reclamation Services (1993) Characterisation of Dragline Dumped Spoil – Curragh Mine

Stuart Miller and Associates (1984) Curragh Queensland Mining Limited, Waste Management and Rehabilitation Studies Overburden Geochemical Investigations

Walting, K.M., Ahern, C.R, Hey, K.M., Acid Sulfate Soil Field pH Tests

## APPENDIX 2 – Vegetation Reference Sites

### Reference Site 1: Poplar Box Woodland (REF PB)

### Regional Ecosystem: 11.10.12

**RE Description:** *Eucalyptus populnea* woodland on medium to coarse-grained sedimentary rocks (QLD Herbarium 2009).

The two REF PB transects are located in a remnant patch of *Eucalyptus populnea* open woodland on the southern area of the western boundary fence (Figure A2.1) run in an easterly direction away from the lease boundary. This is a sparse open woodland to a height of 15m with a sparse mid storey of *Eremophila spp.* and *Atalaya hemiglauca*. The ground layer is dominated by Buffel (*Cenchrus ciliaris*) and native grasses such as *Aristida spp.* and *Chrysopogon fallax*. The area has undergone recent rill and sheet erosion and there were many bare patches noted. Upon examination of the UAV images obtained at the time of monitoring, the area is obviously part of a larger easterly facing drainage line. Areas of remnant Poplar Box off the western and south western boundary had undergone extensive medium-high intensity fuel reduction burning in the weeks prior to the assessment in 2011.

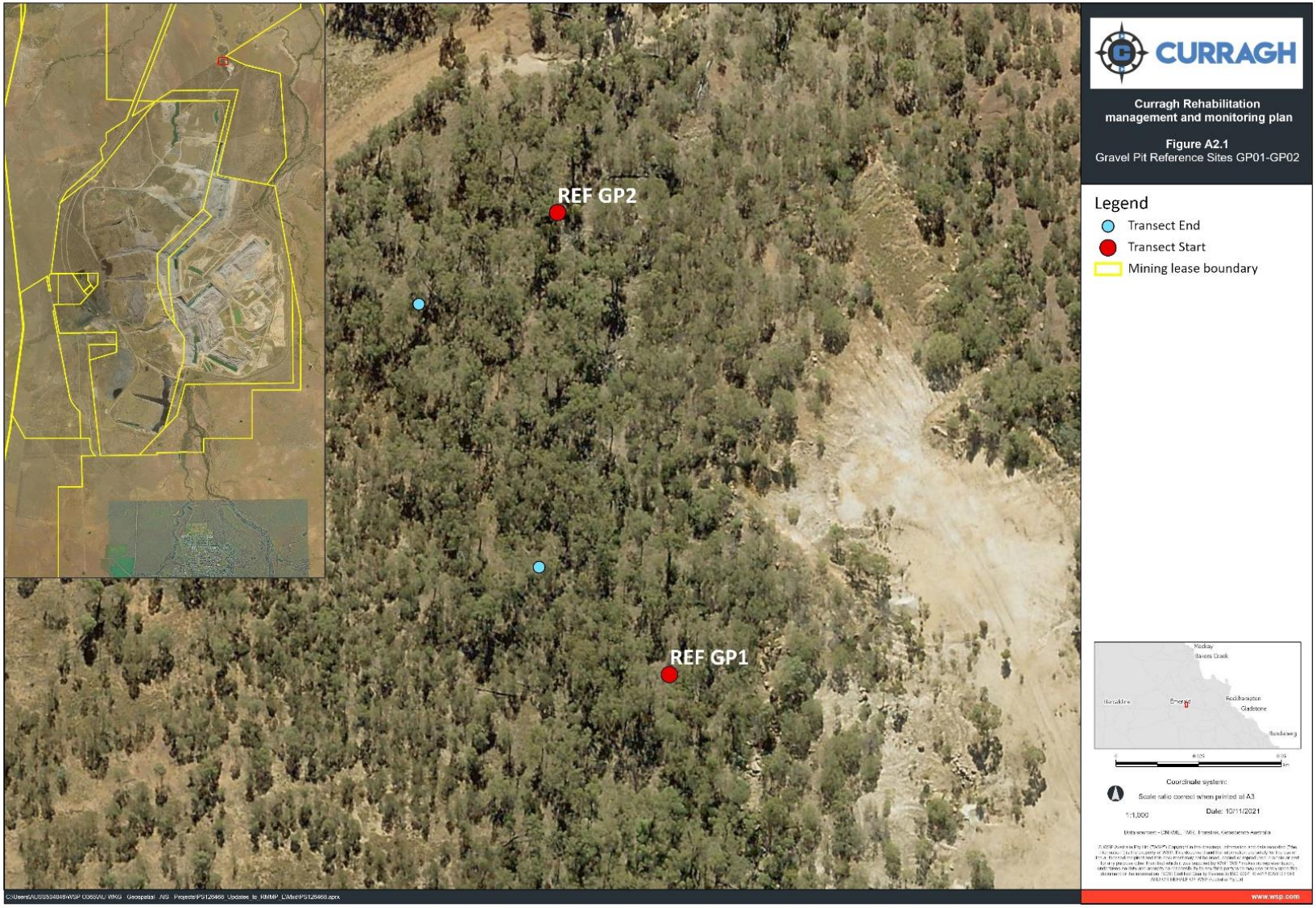



**Figure A2.1:** Poplar Box Reference Sites PB01-PB02.

## Reference Site 2: Napunyah Woodland Gravel Pit (REF GP)

## Regional Ecosystem: 11.4.2

**RE Description:** *Eucalyptus* spp. and/or *Corymbia* spp. grassy or shrubby woodland on Cainozoic clay plains.

The two REF GP transects are located to the north of the mine boundary in the area known as the 'gravel pit' which is an old quarry (Figure A2.2). Surrounding the quarry is a remnant patch of *Eucalyptus thozetiana* woodland which grades into *Acacia harpophylla* woodland on the lower slopes. This general area was the location of the original reference sites listed in Curragh EMOS 2002 as 'Site C', however the exact location of the 2002 plots is unknown. The current transects are positioned within the area dominated by *Eucalyptus thozetiana* before the community grades into *Acacia harpophylla. Eucalyptus thozetiana* forms a dominant moderate-dense canopy to a height of 15m, while the sparse midlayer consists of the shrub species *Carissa ovata*, *Croton phebalioides*, and *Erythroxylum australe*. Groundlayer is a dense combination of native grasses such as *Paspalidium spp*., *Aristida spp*., and *Leptochloa decipiens ssp. decipiens*. Historical timber harvesting is evident with cut timbers noted, and the area has obviously undergone considerable disturbance as a result of the quarry workings.

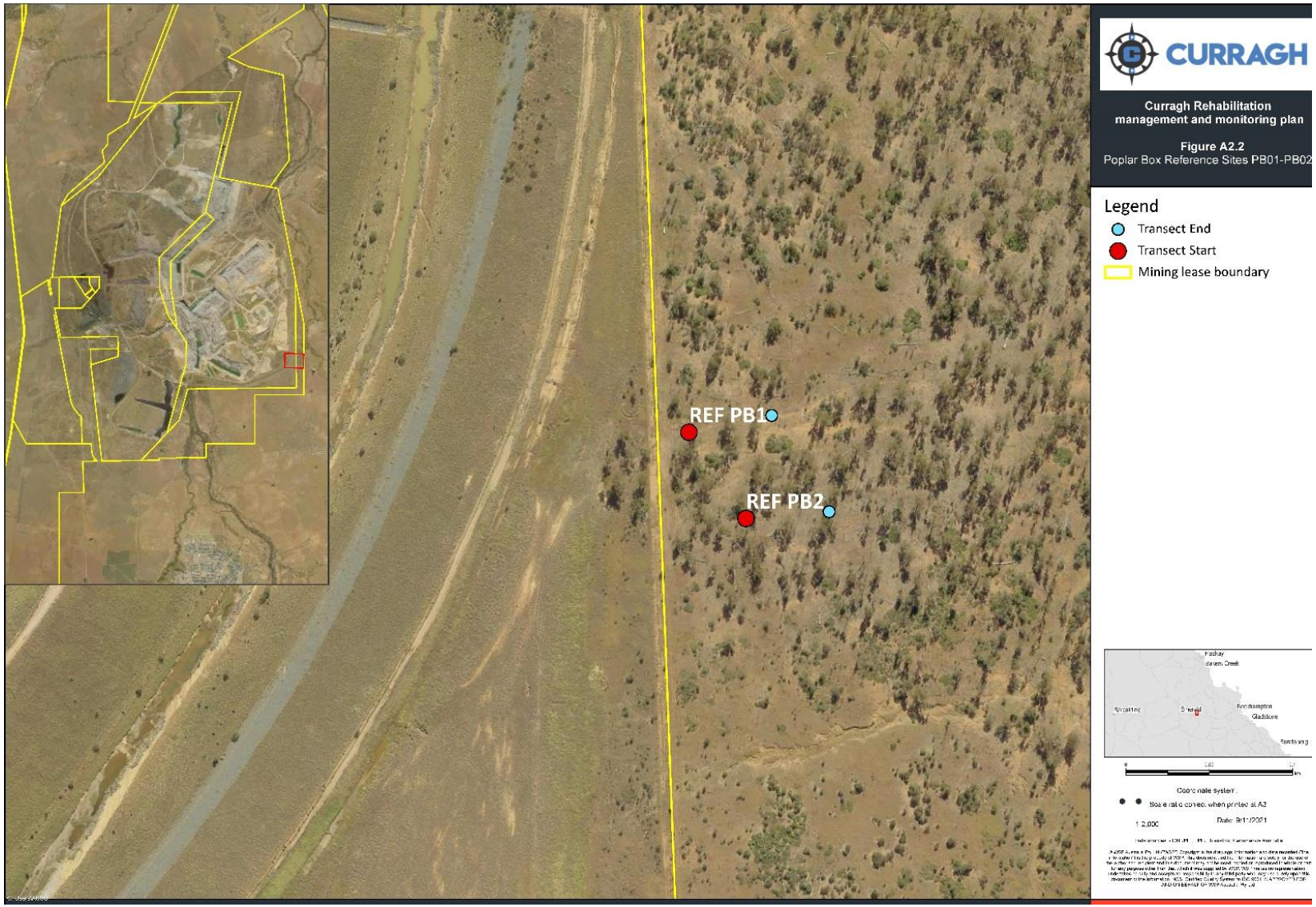



**Figure A2.2:** Gravel Pit Reference Sites GP01-GP02

**Reference Site 3:**

**Regional Ecosystem: 11.4.8**

**RE Description:** *Eucalyptus cambageana* woodland to open forest with Ac*acia harpophylla* or A*. argyrodendron* on Cainozoic clay plains.

The two REF EC transects are located within a small patch of remnant *Eucalyptus cambageana woodland* within the mine lease on the northwestern boundary. The open canopy is dominated by *Eucalyptus cambageana* and *Acacia harpophylla* to a height of 12m, with some sparse, older dead *Eucalyptus cambageana* stags present. The mid layer is composed of *Carissa ovata*, *Eremophila mitchellii* and *Alectryon diversifolius* in a moderate to sparse density. The moderate to dense groundlayer is dominated by patches of Buffel Grass (*Pennisetum ciliare*) and other grasses such as *Paspalidium spp.*, *Aristida spp.* and *Enteropogon unispiceus* are more dominant in areas of dense Brigalow canopy shading

This reference site is no longer in use due to mine progression in the area.

## A2.1 Methods – Vegetation assessment

The methods used followed previous methods employed when assessing rehabilitated sites at Curragh Project.

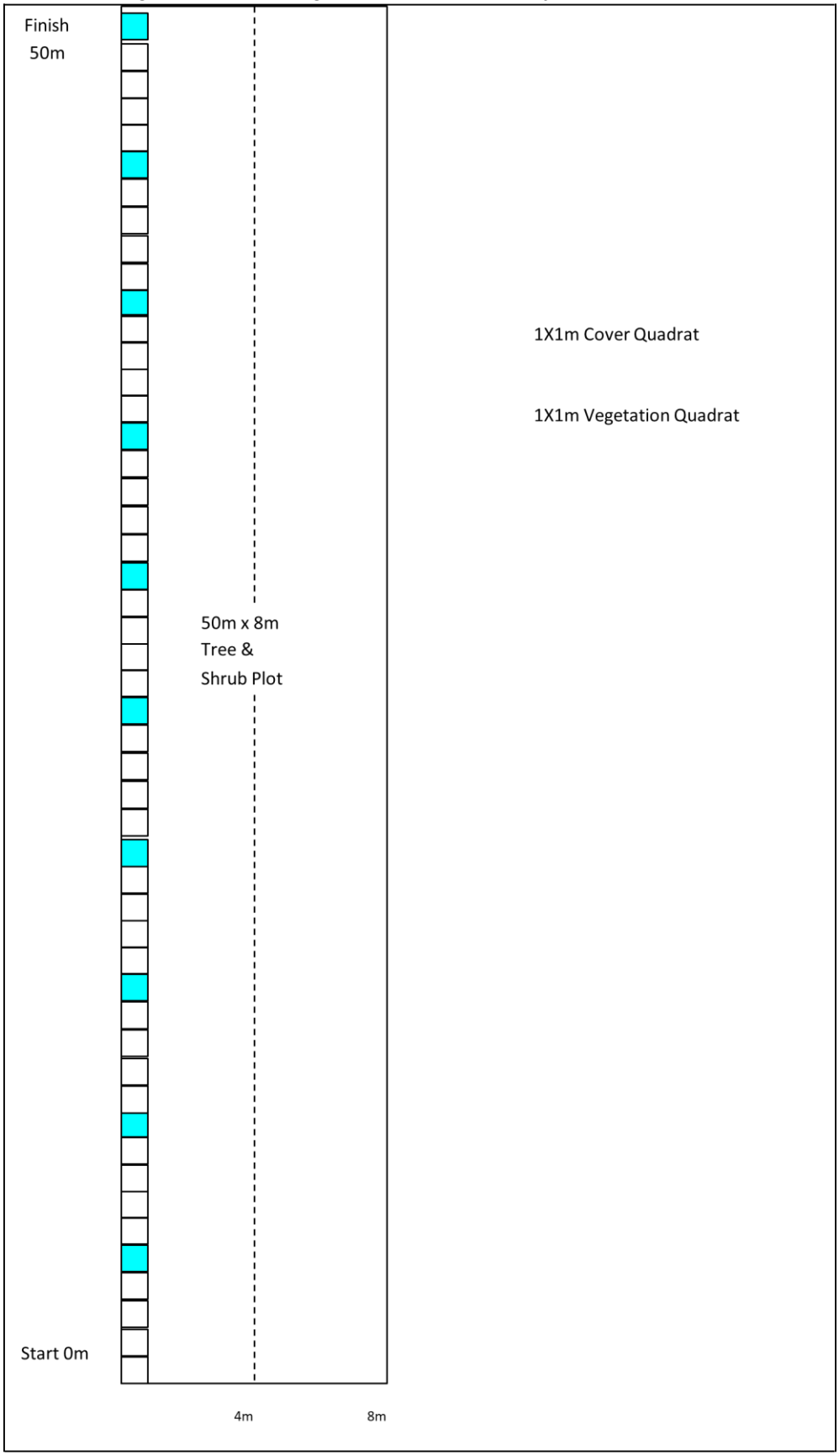
A measuring tape was extended along each of the 50m transects, and the number and height of woody tree and shrub species were recorded for each of 50 (1m x 1m) quadrats located along the right-hand side of the tape. Any forbs (herbaceous and sub shrub) and grass species present in each quadrat were also recorded. Tree and shrub species and heights were also recorded in an area of 7m x 50m immediately adjacent to the 1m x 1m quadrats, in 5m x 10m sections. Individuals within 4m of the measuring tape were recorded separately to enable future comparisons with previous data. Grass and herbaceous species present but not already encountered in the 1m quadrats were also recorded in this way. Thus, species richness was assessed for 1200m$^2$ at each site, comprising 3 x 400m$^2$ areas (Figure A2.3).

At one metre intervals along the transect, foliage projective cover (FPC) was assessed for the cover of canopy vegetation (>2m), understorey vegetation (0.5-2m), and ground vegetation (<0.5m), noting at each interval if the vegetation cover was by native grass (n), introduced grass (i), shrub (s) or tree (t). At each metre interval groundcover was also assessed for bare, rock, litter or vegetation. This resulted in measures of vegetation in three strata (canopy, understorey and ground layer) at each point along the transect, and four categories of soil surface cover at each point along the transect.

At 5m intervals along each transect ground cover characteristics (live standing material, detached or fallen litter, and rock) were visually assessed within the 1m x 1m quadrats (*i.e*. a total of 10 quadrat locations for the whole 50m transect), used for recording species presence detailed above. The proportion of bare ground was also assessed by default. The proportional contribution to total standing cover from up to three of the most prevalent species was recorded.

Photographs were taken from both ends of transect as a permanent visual record of the development of the site providing an interesting visual snapshot of the changes that are occurring over time.

**Figure A2.3:** Diagram of monitoring methods conducted by CMLR at Reference sites 2011.



### A2.1.1 Soil sampling and analysis

At each transect, two surface (0-10cm) soil samples was collected, one at each end of the transect. All samples were air-dried, ground to pass through a 2mm sieve and initially analysed for pH and electrical conductivity (EC) to determine the occurrence of any significant differences in soil characteristics. The samples were analysed according to methods described in Rayment and Higginson (1992). Total N and Total C are measured by combustion in an automated LECO CNS Analyser. Unlike in previous years, samples for C analysis were not pre-treated with 5 M HCl to remove any inorganic carbonates present (Method 6B3) and hence only Total C values are provided in this report. Available P was determined by ICPAES following 0.5 M $NaHCO_3$ (1:30) extraction (Method 9B1). Exchangeable cations (Ca, Mg, K and Na) were analysed by ICPAES following alcoholic 1 M $NH_4Cl$ extraction, with pre- treatment to remove soluble salts (Method 15A2). Cation exchange capacity (CEC), a measure of soil ability to hold nutrients, and exchangeable sodium percentage (ESP), indicating how prone a soil is to dispersion and structural problems, were calculated from exchangeable cations data. Chloride was determined colorimetrically using a Pharmacia Ultrospec 2000 spectrophotometer on 1:10 soil solution extracts in 0.1 M nitric acid (Method 5A2), and extractable S by ICPAES from 1:5 soil solution extracts in 0.01M calcium monophosphate (Method 10B3).

### A2.1.2 Site characteristics

At each site, general descriptions of the area were recorded, including dominant vegetation for each strata, evidence of grazing, clearing, erosion or any other disturbance. Average slope gradient, the angle between the beginning and the end of transect, was measured using a hand-held clinometer.

## A2.2 Survey results

### A2.2.1 Vegetation

### Species Richness

Species richness across the three reference sites ranged from 18 (REF PB), 25.5 (REF EC) to 26 (REF GP). Figure A2.4 a) and b) details the richness for each site with a breakdown of the lifeforms, indicating that grass species are making up a significant proportion of the richness component at REF EC and REF GP, while tree species makes up a higher proportion at REF PB.

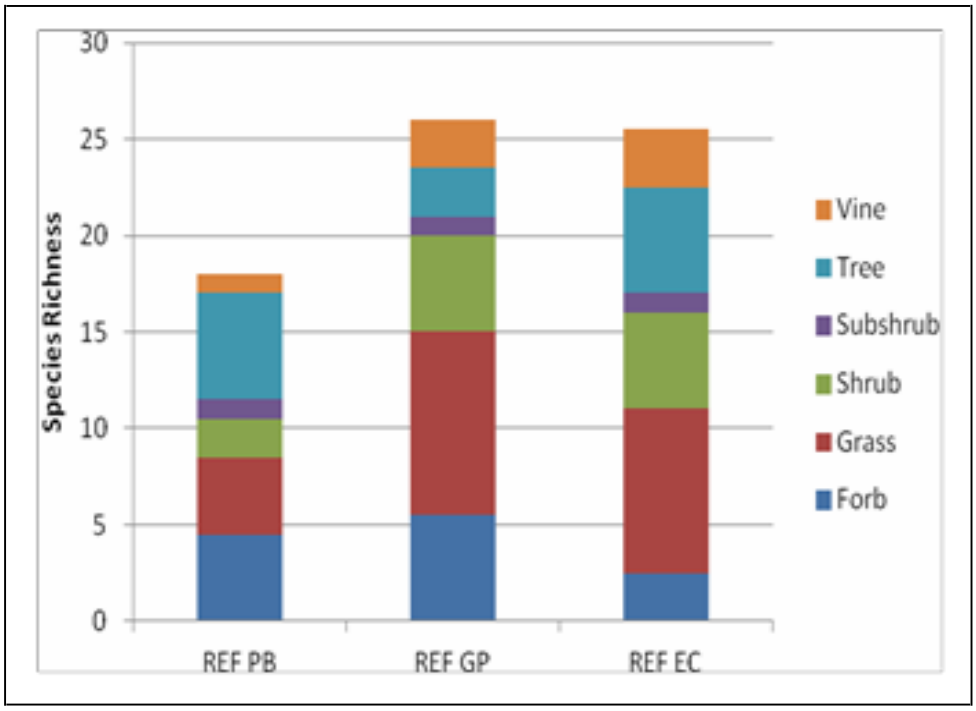



**Figure A2.4 a:** Species richness lifeforms recorded within three native sites in 2011. Lifeform richness as a proportion.

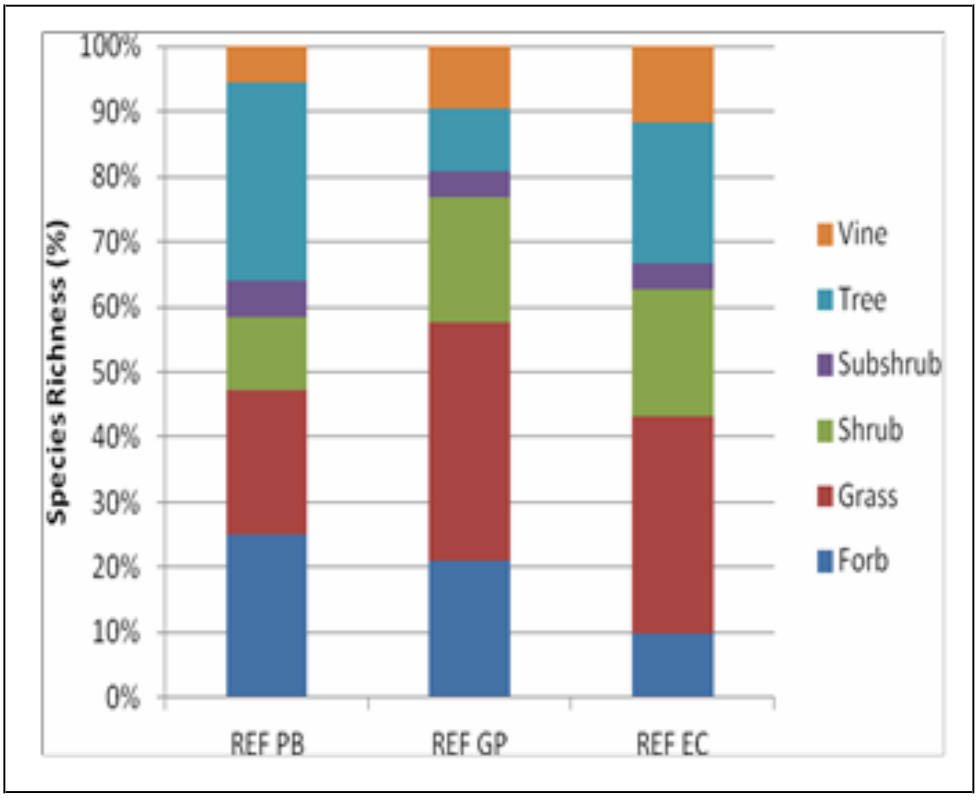



**Figure A2.5 b:** Species richness as a percentage (calculated as an average from two transects within each area (400m2).

### A2.2.2 Tree & shrub density and heights

The total tree density at the reference sites ranged from 400 (REF PB), 425 (REF GP) to 775 (REF EC). A breakdown of Eucalypts, Acacias and 'Other' tree species is provided in Figure A2.6 The high proportion of Acacias at REF EC represents a high number of *Acacia harpophylla* (Brigalow) individuals, while the high number of 'Other' tree species at REF PB reveals a relatively high number of species such as *Atalaya hemiglauca* (Whitewood), *Eremophila* spp, and *Ventilago viminalis* (Supple Jack). The dominance of *Eucalyptus thozetiana* is demonstrated by the high number of Eucalypts at REF GP.

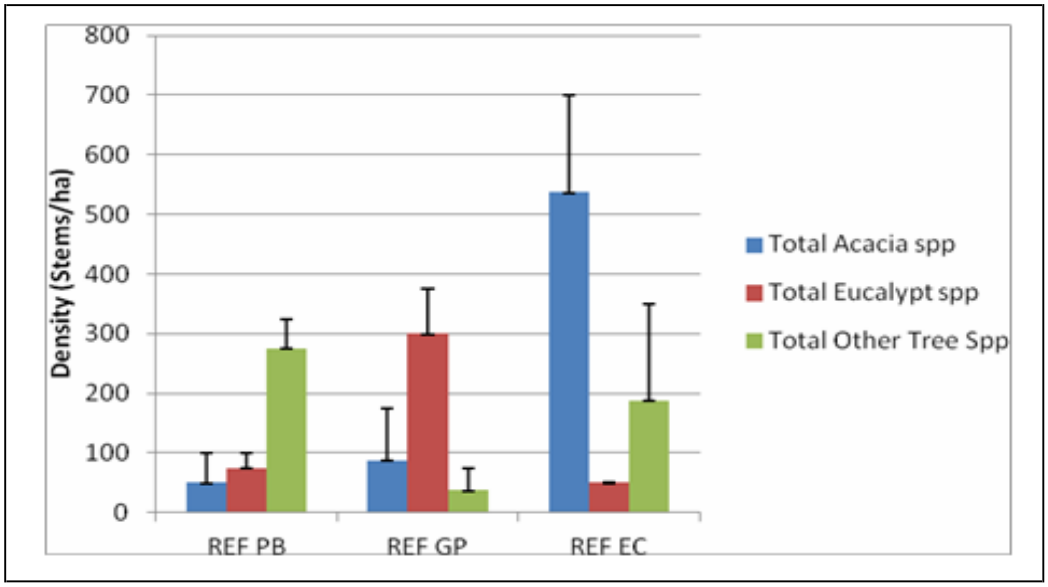



**Figure A2.6:** Tree densities at three reference sites monitored at Curragh, November 2011. Data taken from sum of 2 transects (800m$^2$).

Analysis of height class shows that the greatest densities are found in the <2m category with REF GP and REF EC dominated by shrubs such as *Carissa ovata* and *Indigophora brevidens*, while REF PB is dominated by Other Tree species such as *Atalaya hemiglauca* and *Eremophila spp*. At all reference sites, Eucalypt species are dominant in the >10 m height class representing the dominant canopy species for each site (Figure A2.7). These charts indicate that structurally the reference sites have a sparse to moderate upper storey, a sparse midstory and moderate to dense ground layer.

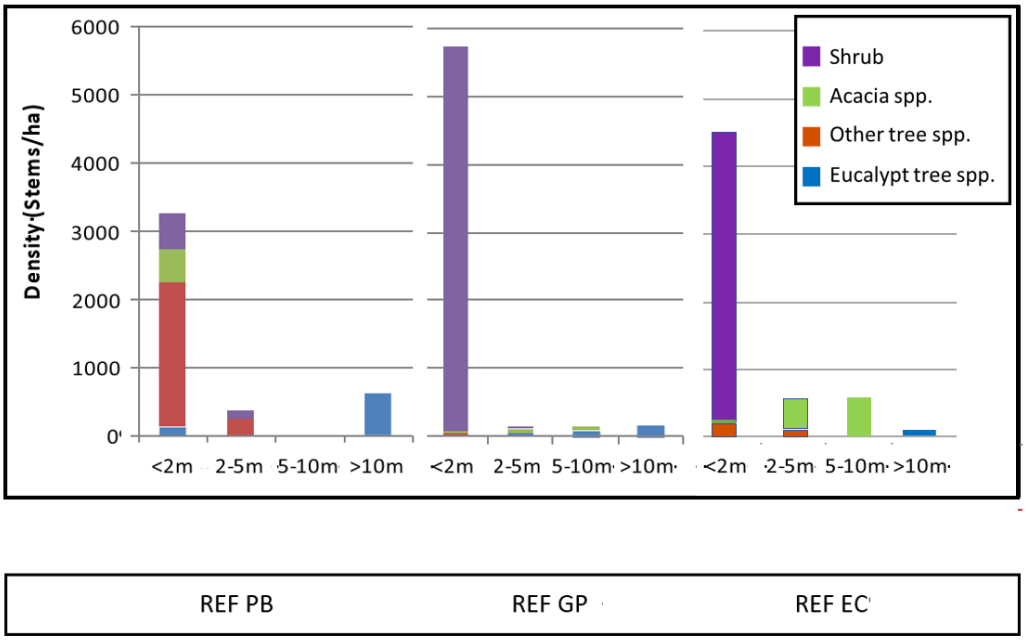



**Figure A2.7:** Height class density plots for three reference sites monitored November 2011, Curragh Project. Data taken from sum of 2 transects (800m$^2$).

### A2.2.3 Cover

Foliage projective cover across the three reference communities shows the variation observed, with canopy cover REF GP (66%), REF EC (46%) and REF PB (16%). Ground cover was dominated by introduced grasses (mostly Buffel) at REF PB with a cover score of over 70%, while the ground layer was dominated by mostly native grasses at REF GP (53%) and at REF EC a mixture of introduced grass (39%) and shrubs (28%). Mid layer was largely absent at REF PB with small contributions by shrubs and trees at the other two reference sites (Figure

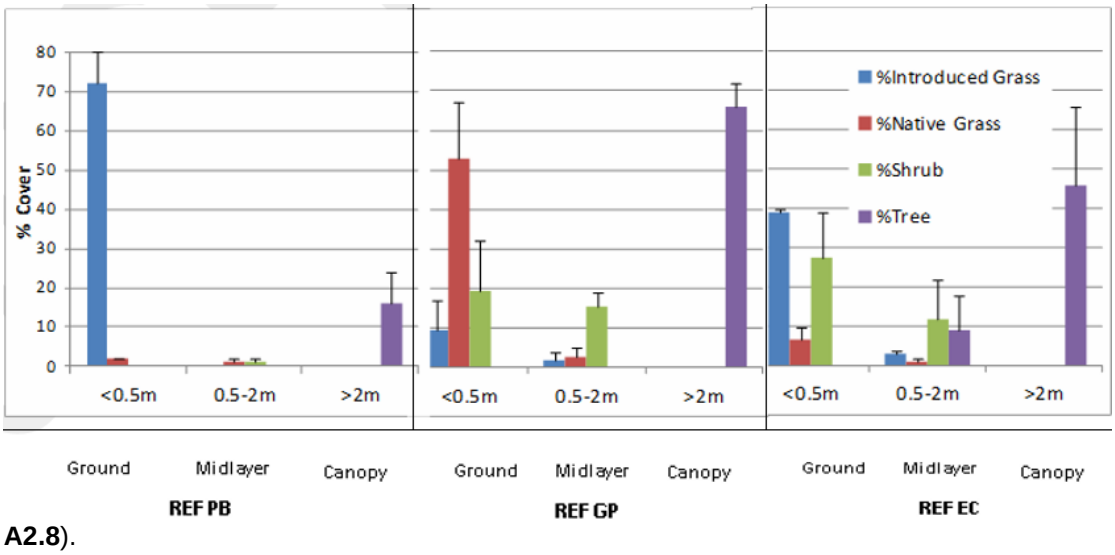



**Figure A2.8**).

**Figure A2.8:** Foliage Projective Cover (FPC) along 50m transect. Each reference site is a coverage of two transects.

Cover measurements from the quadrat assessment shows that the quadrats are dominated by standing vegetation (60%); litter contributes a large proportion of the cover component at REF GP (33%) and REF EC (30%), while bare earth contributes a significant cover component of 27% at REF PB (Figure A2.9).

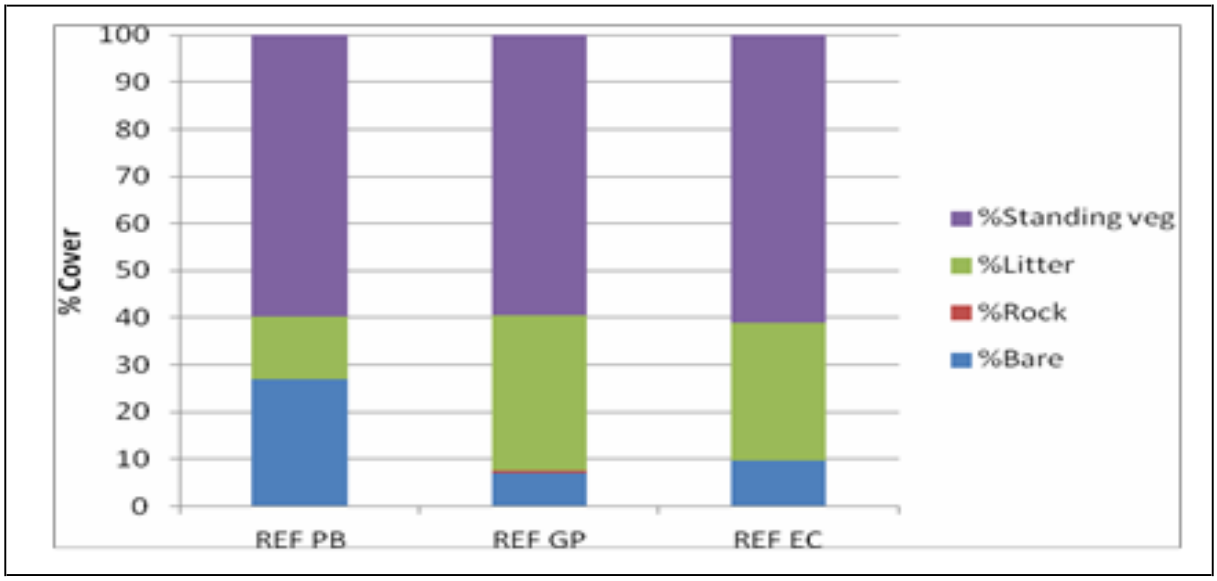



**Figure A2.9:** Quadrat Cover for the three reference sites. Each reference site is an average of two transects.

### A2.2.4 Soil Properties

Site-specific soil data taken across all reference sites from November 2011 is provided in sodic. Table A2.1 For sampling and analysis methods please refer to Section A2.1.1.

The topsoil across all monitored sites is generally considered to be non-saline, neutral (pH) and non-sodic. Table A2.1: Soil results (0-10cm) from monitoring from each transect at the three reference sites. Values are an average of two samples, one taken at the start and one at the end of each transect.

**Table A2.1** Soil results from monitoring.

| Parameter | REF PB1 | REF PB2 | REF GP1 | REF GP2 | REF EC1 | REF EC2 |
|---|---|---|---|---|---|---|
| **EC (uS/cm) (1:5 $H_20$)** | 18.32 | 21.01 | 68.10 | 66.57 | 121.40 | 78.87 |
| **pH** | 7.12 | 7.15 | 6.83 | 7.11 | 6.55 | 6.67 |
| **Total C (%Wt)** | 1.00 | 1.34 | 2.58 | 3.49 | 2.55 | 2.83 |
| **Total N (%Wt)** | 0.05 | 0.09 | 0.16 | 0.21 | 0.17 | 0.18 |
| **Cl (mg/kg)** | 11.25 | 7.38 | 68.81 | 35.14 | 53.59 | 18.61 |
| **Available P (mg/kg)** | 7.07 | 8.05 | 29.55 | 32.28 | 26.74 | 44.11 |
| **$SO_4$-S (mg/kg)** | 6.47 | 5.64 | 14.15 | 14.27 | 13.57 | 13.12 |
| **Ca (cmol(+)/kg)** | 2.69 | 4.49 | 5.68 | 7.08 | 13.31 | 14.07 |
| **K (cmol(+)/kg)** | 0.36 | 0.58 | 0.80 | 1.06 | 0.67 | 1.40 |
| **Mg (cmol(+)/kg)** | 0.89 | 1.13 | 3.28 | 2.75 | 1.49 | 1.68 |
| **Na (cmol(+)/kg)** | 0.19 | 0.19 | 0.24 | 0.26 | 0.23 | 0.18 |
| **CEC (calculated)** | 4.12 | 6.39 | 10.00 | 11.15 | 15.70 | 17.33 |
| **Cu (mg/kg)** | 0.33 | 0.49 | 1.04 | 1.09 | 0.88 | 0.92 |
| **Fe (mg/kg)** | 24.72 | 36.21 | 43.64 | 51.26 | 45.72 | 64.17 |
| **Mn (mg/kg)** | 8.54 | 13.17 | 4.96 | 5.45 | 15.65 | 22.99 |
| **Zn (mg/kg)** | 0.99 | 0.51 | 3.19 | 4.99 | 2.38 | 3.46 |

Total N values are considered low-medium across topsoil media while levels of sulphate-sulphur ($SO_4$-S) vary across the sites with REF PB considered to be low while REF GP and REF EC are at medium levels. Similarly, for available phosphorus, REF PB is considered low while REF GP and REF EC are at medium levels. All soils were low-moderate for CEC values, with PB in particular showing values that indicate a susceptible and fragile reduced soil structure.

The relative proportions of cations across the sites indicate that REF PB is well balanced; REF GP demonstrates low, but not deficient calcium levels, while REF EC is low, but not deficient in magnesium (Figure A2.10.)

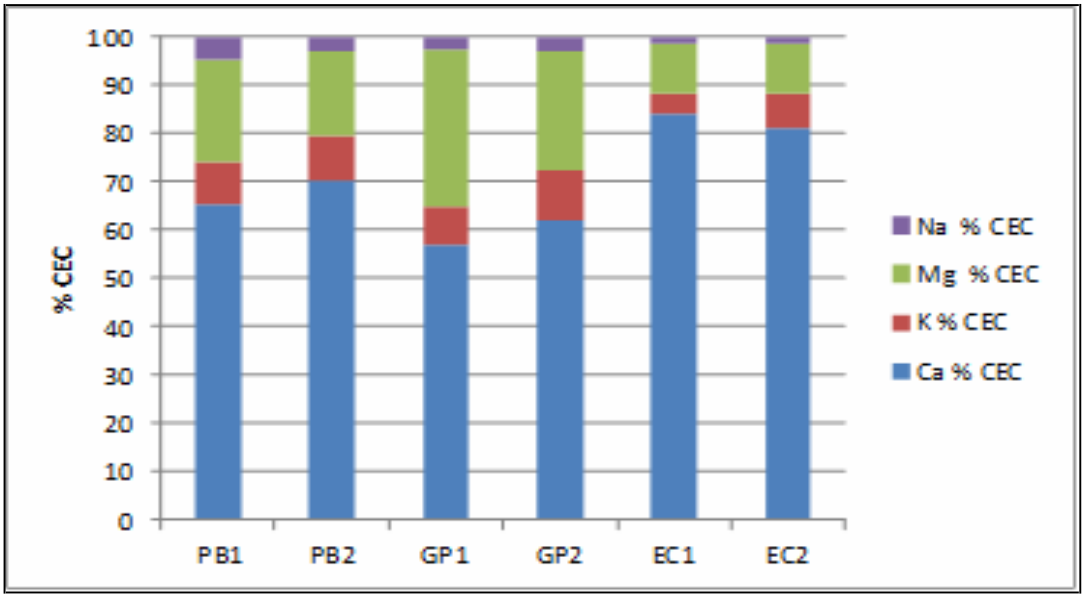



**Figure A2.10:** Relative proportions of cations across each transect. Values are an average of two samples.

### A2.2.5 Rainfall Patterns for 2020

Annual rainfall totals from 1983-2020 recorded on site at the Curragh Project are shown in Figure A2.11. With an average rainfall of 530 mm (1983-2020), the 2020 rainfall represents a total rainfall just under the long-term average.

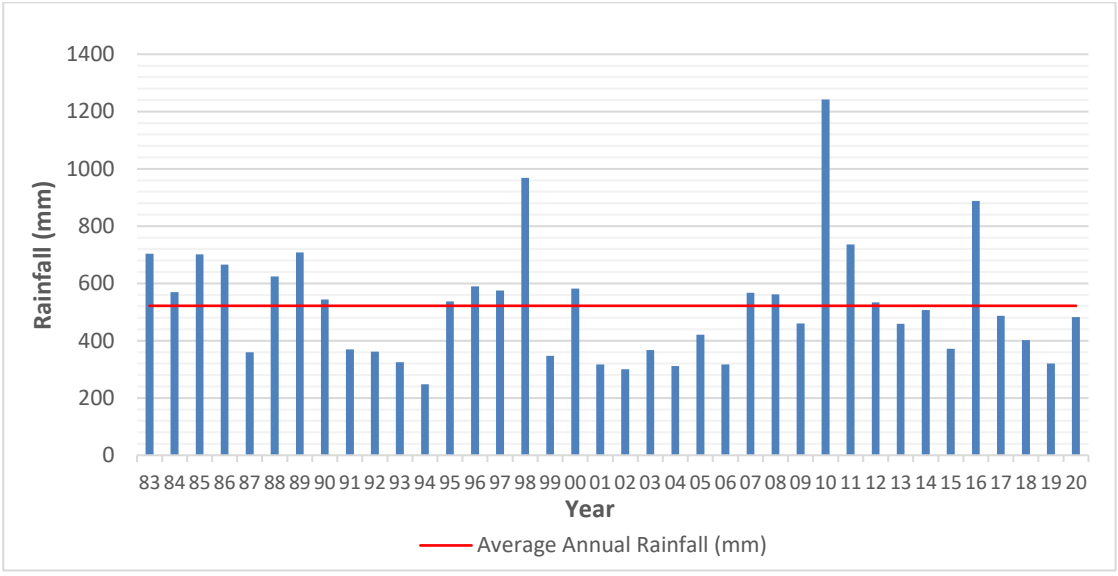



**Figure A2.11:** Annual rainfall totals recorded at Curragh Project 1983-2020 Red line indicates Curragh Project long term average.

Monthly rainfall totals recorded at the Curragh mine site in 2020 are shown in Figure A2.12. The majority of the monthly rainfall actually fell in January, February and October (95 – 98 mm) compared with the long-term average of 43.6mm.

Daily weather data throughout 2011 provides daily values for the parameters expressed in the monthly summary in Figure A2.12.

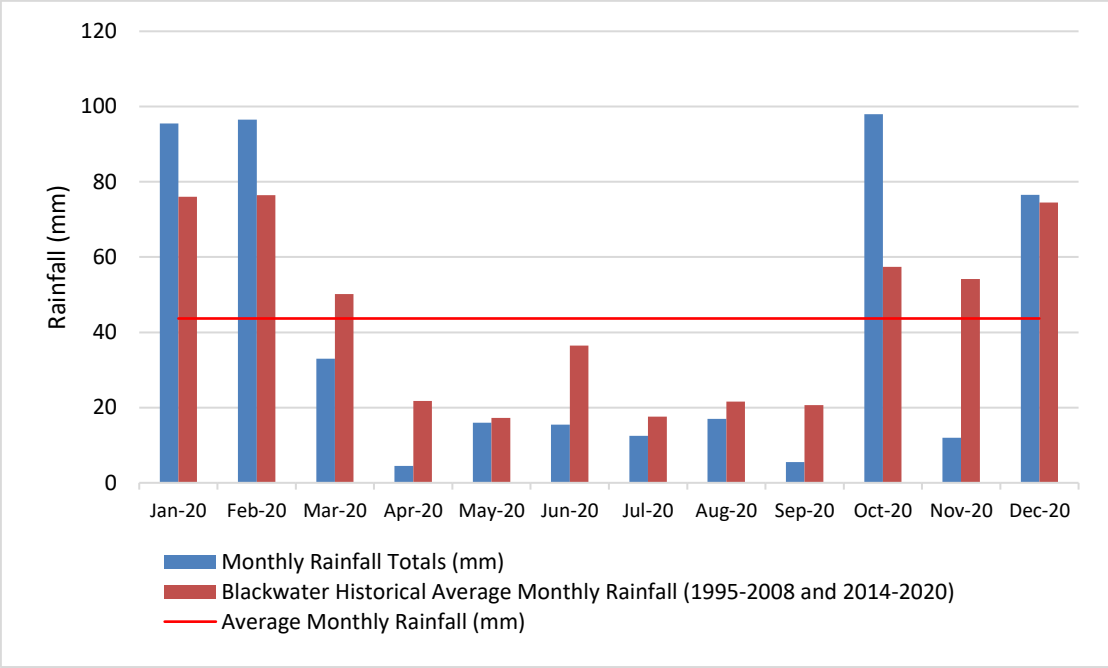



**Figure A2.12:** Monthly rainfall totals for the year 2020 recorded at Curragh Project against Blackwater average.

## A2.3 Comparison with Curragh rehabilitation data

### A2.3.1 Species Richness

The relationship between reference sites, rehabilitation age and species richness (all species) from 1996 - 2010 is illustrated in Figure A2.13. The majority of rehabilitated sites have been monitored on three separate occasions and many sites show an initial decline in species richness before stabilising or slightly increasing over time. A general decline in richness could be attributed to the establishment and subsequent cover dominance of grass species such as *Cenchrus ciliaris* which are able to successfully out compete other understory species and is known to compete out native species (Franks 2002). Species richness in the reference communities are high in comparison to the rehabilitated sites with REF GP and REF EC recording the highest values (0.07 and 0.06 species/$m^2$ respectively) while REF PB showed a significantly lower richness of 0.05 species/$m^2$.

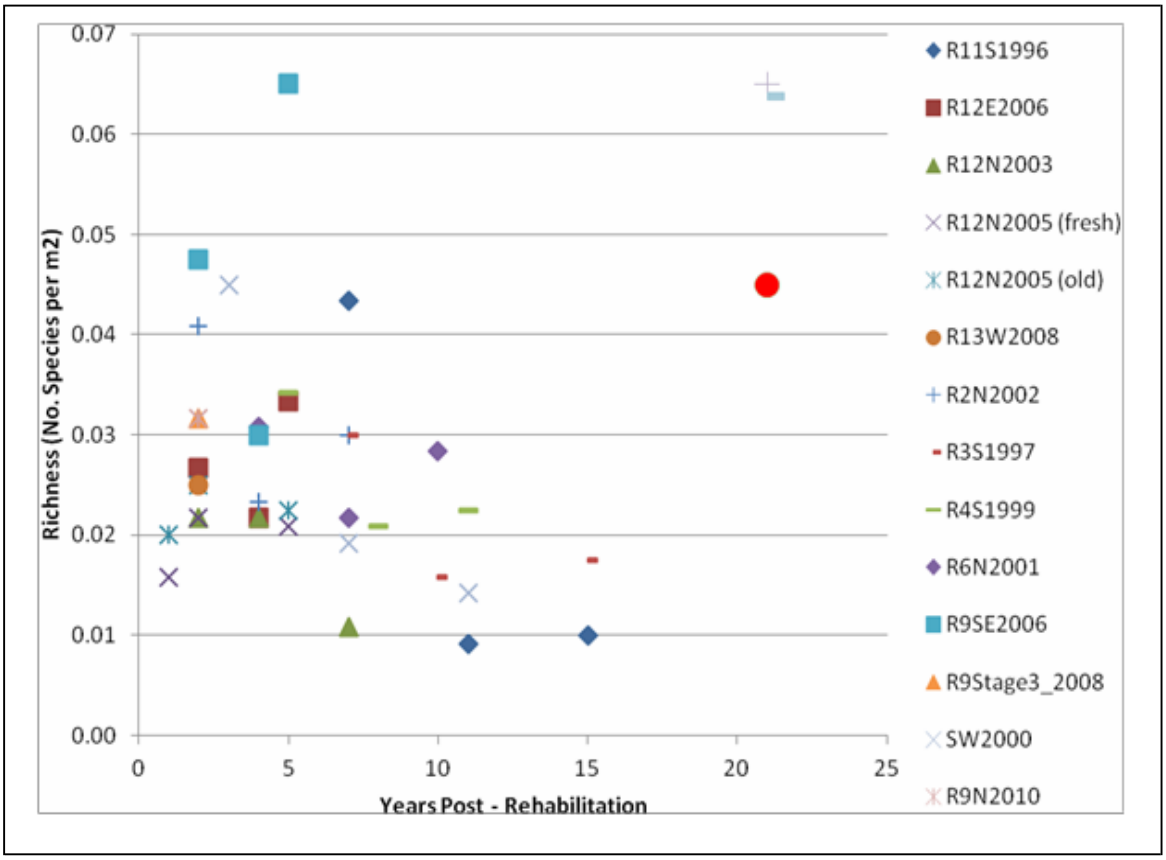



**Figure A2.13:** The relationship between species richness (all species) for rehabilitated and native sites. Values are numbers of species per $m^2$.

Still to be provided as part of this assessment is:

- Comparisons of native, introduced and exotic richness between sites; and
- PRIMER MDS analysis between rehab vs reference sites.

### A2.3.2 Tree & Shrub Density

The chrono sequence of tree and shrub density data for each rehabilitated site against values for the reference communities REF EC, REF GP and REF PB is provided in Figure A2.14 (a, b, c, d & e). Most rehabilitated sites show a general trend of increasing density over time with the best performing sites being R3S1997, R11S1996 and NE1998. Many of the rehabilitated sites are trending towards values obtained within the reference communities with REF EC being an obvious outlier at 1112.5 stems per ha (Figure A2.14a). While *Acacia harpophylla* (Brigalow) was only present at two native sites REF EC and REF GP and one rehabilitated site (R3S1997), the removal of this species from the data demonstrates its dominance, particularly at site REF EC (reduced to 225 stems per ha) (Figure A2.14b). Many rehabilitated sites are on a trajectory towards Acacia densities (Figure A2.14d) (note this figure includes Brigalow)), however Eucalypt (Figure A2.14c) and shrub (Figure A2.14e) densities in the reference communities are significantly higher than those found within the rehab sites, particularly shrub densities which were off the chart for the sites REF EC (4525 stems per ha) and REF GP (5640 stems per ha). This result shows the significant density of understorey species such as *Carissa ovata, Alectryon diversifolius, Indigophora spp.* etc. found within the native communities and subsequently lacking in the rehabilitated sites, most likely due to the competitive dominance of grass species such as Buffel and poor seed germination and success of understorey species within rehabilitated sites.

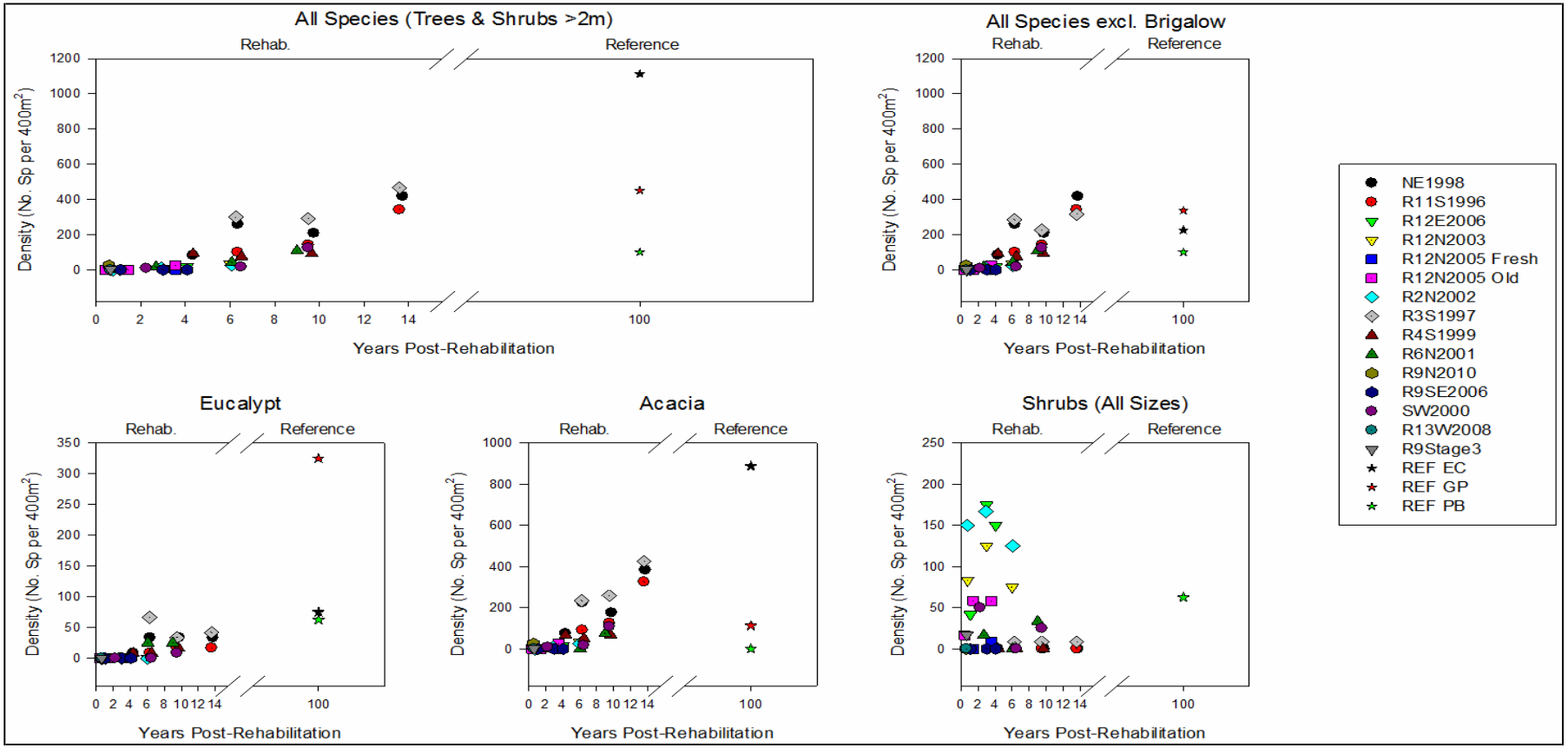



**Figure A2.14:** The relationship between tree and shrub density on rehabilitated sites vs native sites. a) All Species>2m, b) All Species>2m excluding *Acacia harpophylla* (Brigalow), c) Eucalypt density >2m, d) Acacia density>2m and e) Shrubs (all sizes). Each data point represents average numbers of individuals per 400 $m^2$ (8mX50m transect).

### A2.3.3 Vegetative Cover

Monitoring data for the past ten years consistently shows that total vegetative cover tends to increase over time for both media levelling off as the sites approach 14 years of age. Topsoiled areas generally show a greater per cent cover as compared to the spoil media due largely to management practices of sowing faster growing pasture species in the topsoil media and tree & shrub species in the spoil media. The chemical and physical characteristics of the topsoil media are also more favourable to faster growing ground cover species. The inclusion of reference site data indicates that rehabilitated areas are on a trajectory towards, and in some cases surpassing values obtained in the reference sites (Figure A2.15). Trend lines indicate that topsoiled media could achieve reference site values within 10 years, while spoil media may take between 15-20 years.

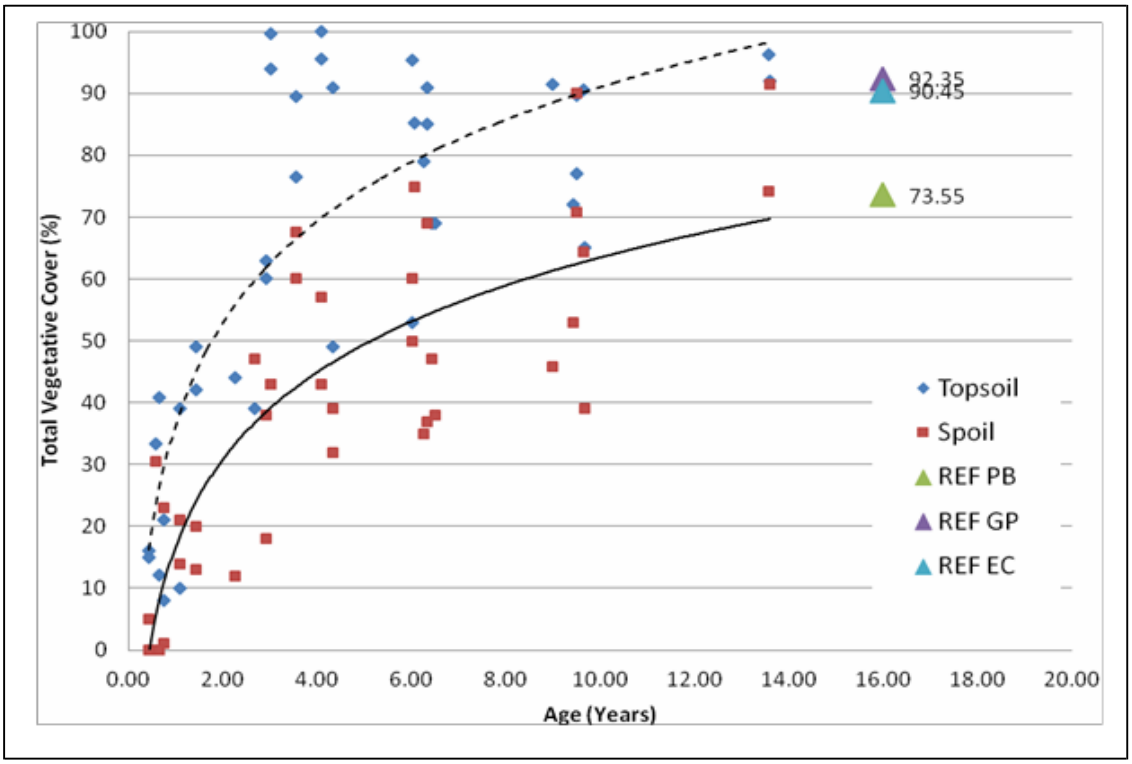



**Figure A2.16:** Cover development with rehabilitation age at Curragh Project on replaced topsoil and spoil compared with values from reference communities. Data are from 2002 until 2011 monitoring campaigns.

Data showing further comparisons such as litter cover between sites is currently being processed and will be provided within the review of this document. Note that this is cover measured through quadrat method only. Cover analysis by FPC as reported earlier has *not* traditionally occurred on rehabilitated sites at Curragh. This method will however be included in the extended monitoring period so that future comparisons can be made on the structural variability between reference and rehabilitated communities.

# APPENDIX 3 – Past Research and Development Projects

## A3.1 Completed research programs

Final Void Research – to allow planning for closure to be undertaken on the basis of sound understanding of final void hydrology and post-closure processes. (AECOM, 2012)

The use of high resolution remote sensed imagery generated via GPS- guided Unmanned Aerial Vehicles (UAVs) to assist ground-based assessments. Centre for Mined Land Rehabilitation, University of Queensland (CMLR-UQ), 2002-2016

Develop success criteria from ongoing monitoring of reference and rehabilitated areas. CMLR-UQ, 2002-2016

Measuring Rehabilitation Responses to Fire: Implications for long term resilience and mine closure. CMLR-UQ, 2015-2017

## A3.2 Other relevant research

### A3.2.1 Mine Rehabilitation Erosion Process

An industry wide erosion research program: "Post-Mining Landscape Parameters for Erosion And Water Quality Control" managed by the Centre for Mined Land Rehabilitation, CMLR, at the University of Queensland commenced in 1992 (ACARP C4011). The program investigated soil erosion processes and water quality issues relating to mine rehabilitation. It is a Queensland coal industry research program aiming to develop erosion prediction models for use in post mining landform design as well as a better understanding of water quality issues.

The project was sponsored by 15 open cut coalmines in Central Queensland, including Curragh. Onsite environmental officers as well as researchers fromthe University of Queensland, the University of Newcastle, ACIRL and the DNR, (formally DPI), provided technical expertise. The program was due to be completed by the end of 1997, although further funding allowed it to continue into year 2002.

### A3.2.2 Mine Rehabilitation Erosion Stage II

An extension to ACARP 4011, this project (ACARP 1629), undertaken by the Department of Natural Resources, focused on the long-term monitoring of erosion and water quality from rehabilitated land. Biophysical indicators for rehabilitation and the effect or reject on enhancing infiltration and vegetative growth were investigated.

### A3.2.3 Mine Rehabilitation Erosion Stage III (biophysical adjunct)

Central Queensland University undertook a *Pilot study investigating the use of invertebrate assemblages to gauge rehabilitation success*. Samples were taken from 3 reference sites, 5 contour strip sites, 3 full soil sites and 3 early rehabilitation sites. The assessment indicated that the older contour strip sites were following a similar successional pathway and showed similar grouping characteristics to reference sites. At the order taxonomic level, contour strip sites had a similar order composition to reference sites.

### A3.2.4 Establishment of Trees on Topsoil

Land Reclamation Services set up an herbicide/cultivation trial at Curragh Mine in 1992. Its aim was to determine the advantages and costs of applying various herbicide/cultivation treatments to topsoil areas to overcome Buffel competition and establish native species.

This project was affected by the drought and because it was never completed, the outcomes were inconclusive. The progress of the uniformly topsoiled rehabilitation area between Ramps 1 and 2, established as part of this project, is monitored.

### A3.2.5 Soil Micro-Biology

Curragh was a member company that supported the AMIRA project: “Soil Microbiology for Rehabilitation P257A conducted by the University of Western Australia, 1991-1994”. It focused on defining soil microbiology at a range of mine sites, specifically the presence and benefits of mycorrhizal fungi. A number of Curragh natural isolates were identified and used for pot and greenhouse cultivation, refinements of inoculation production and storage techniques and assessment of stockpiled topsoil health from mycorrhiza bioassays and microbial biomass measurement.

Curragh sponsored an extension to the above AMIRA project: “Inoculating VA Mycorrhizal Fungi into Mine Soils P257B”, specifically targeting methods of cost-effective introduction of isolates into mine soil. The first field trial at Curragh commenced in May 1997 and concluded in February 2000.

### A3.2.6 Soil Substitutes and native Ecosystem Development

The CMLR (University of Qld) undertook a project entitled “Soil Substitutes and Native Ecosystem Development at the Curragh Open-Cut Coal Mine”. Two main sub-programs cover the issues encompassed:

*Properties of Coarse Coal Reject* - Laboratory and glasshouse studies examining the chemical, physical and microbiological properties of a range of coarse coal reject samples to assess their short- and long-term impacts on native species establishment, native community sustainability, and the surrounding groundwater environments in general.

*Monitoring of Media, Vegetation and Ecosystem Development* – measurement of the growth, nutritional and ecological status of existing rehabilitation and natural control areas. Field sampling and surveys, followed by laboratory analyses, were undertaken to supplement data previously collected from Curragh as well as aid in the development of rehabilitation success indicators. A significant proportion of the project is devoted to the study of litter fauna and decomposition within an area not previously focused on.

Reports on outcomes include UQ CMLR (1991), UQ CMLR (1993a), UQ CMLR (1993b) and UQ CMLR (1998). The University of Central Queensland conducted a further study of invertebrates during May 1999. Seventeen sites were studied including Reference Site B. The results suggest that the Contour Strip plots are showing similar assemblages of invertebrates to each other but distinct from the Reference sites.

### A3.2.7 Establishment of Native Understorey

Curragh has been successful in establishing upper storey trees and shrubs and also pasture grasses. Current and future efforts are also being directed into the development of native understorey flora and fauna. The CMLR commenced a research project which remains uncompleted; however, Curragh has continued introducing *Acacia cretata* and *Acacia ampliceps*, two native understorey species, since the beginning of 1999.

## A3.3 Terrestrial Flora/Fauna Success Criteria

An assessment of terrestrial flora and fauna success criteria was carried out by WBM in February 2000. The object of the research was to identify success factors evident in reference sites around Curragh, and contrast these with similar factors in spoil rehabilitation.

## A3.4 Aquatic Flora/Fauna Success Factors

In conjunction with field tests detailed in Section 7, WBM undertook surveys of water ponds (2 in rehabilitation, 1 in a retention dam, 1 in a natural creek site and 1 in a creek diversion site) to establish success indicators for aquatic species.

## A3.5 Risk Assessment of Rehabilitation Stability

A University of Queensland administered ACARP project (C8039), comprising a risk assessment model of rehabilitation geomorphology and final land use stability, has used Curragh Mine as a reference site, among a

number of others in the Bowen Basin.

### A3.6 Tailings Dam Hydrogeology Study

In March 2000, negotiations commenced on a study of tailings dam hydrogeology, as the first steps towards fulfilling closure requirements discussed in Section 7. ACARP C9030, a general stability study across Bowen Basin mines, is programmed for February 2000 to year 2003.

# PROGRESSIVE REHABILITATION AND CLOSURE PLAN

## Curragh Project
## Erosion Risk Assessment

**Prepared for:**

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SLR Ref: 630.30341-R01
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# BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

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# DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
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## APPENDICES

Appendix A: Sample Site Logs
Appendix B: Certificate of Analysis

# 1 Introduction

The Curragh Project is located within the Central Highlands Regional Council, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton. The total mining lease area is about 19,650 ha.

The Curragh Project consists of:

- Curragh Central (Pit X-west);
- Curragh Central Extended (Pit X-east & Pit D);
- Curragh Extended (Pit J);
- Curragh South (Pit Z);
- Curragh West (Pit Y);
- Curragh East (Pit A-C, Pit E—I, Pit K-L); and
- Curragh North (Pit s, Pit T and Pit U).

The Curragh Project is an open cut operation producing a variety of coking, PCI and steaming coal products for both the export and domestic markets. The operation is a mix of dragline and truck and shovel fleets. The site is predominantly divided into mining areas 'Curragh Main' and the more recent 'Curragh North'. Curragh Main consists of Curagh East, West and Extended and mining commenced in this area in approximately 1983. Curragh North is a satellite mining operation which commenced operations in 2005 and is connected to Curragh Main by a haul road for supply and servicing and a conveyor for coal transport to the Curragh Main Coal Handling and Preparation Plant (CHPP).

The approved annual run of mine (ROM) production is 18 million tonnes per annum (Mtpa). Coal extraction has been ongoing since 1983, entirely through surface mining methods. Coal is transported from the mine to Gladstone via the Central Rail Line also known as the Blackwater Line. The Project is currently estimated to run until 2044.

# 2 Objectives

The objectives of the erosion assessment are as follows:

- Calculate the soil erodibility (K) factors for the topsoil, subsoil and spoil material.
- Determine appropriate cover management (C) and support practice (P) factors from local and international literature.
- Calculate the rainfall erosivity (R) factor for the site.
- Calculate soil loss (A) for a set of slope angles (as provided by the landform design engineer) for the proposed final landform.
- Provide guidance / recommendations on optimal waste rock dump slope angles and cover management based on soil loss estimates.

# 3 Methodology

## 3.1 Methods of data analysis

The **Revised Universal Soil Loss Equation (RUSLE)** is used to determine long term safe, stable and non-polluting landform design at OCC. RUSLE is commonly used to predict the long term, average, annual soil loss from sheet and rill flow under specific management conditions. The predicted losses are empirically derived. Given that the RUSLE takes into consideration all major components likely to affect erosion, it is the most widely used soil loss predictive tool available. Inputs include rainfall erosivity, soil erodibility, slope length, gradient, erosion control practices, ground cover and management. The output is the predicted average annual soil loss per unit area. The estimated annual soil loss expected is based on the following equation (USDA-ARS, 2016):

$$A = R \times K \times LS \times C \times P \qquad \text{Eq. 1}$$

where, A = computed spatial average soil loss (ton per hectare per year (t ha−1.yr-1)), R is the rainfall-runoff erosivity factor, K is the soil erodibility factor, LS = topographic factor, C is the cover management factor (unitless) and P is the support practice factor.

For the rainfall erosivity (R-factor) the value determined for Emerald as per the IECA (2009) *Best Practice Erosion and Sediment Control* was used. The soil erodibility was determined from representative soil and spoil samples collected from Curragh Main and Curragh North. Laboratory estimation of the K-factor considers the topsoil soil organic matter, very fine sand, silt, soil structure and permeability. The slope length and gradients were sourced from the maximum values specified in the Curragh Rehabilitation Plan (Curragh, 2019).

## 3.2 Data source

A summary of the input data is provided in the below table.

**Table 1. Description of data sources for soil loss estimation for Curragh Project**

| RUSLE Input parameter | Description |
|---|---|
| Soil erodibility<br>K-factor | Laboratory results for K-factors are available for soil and spoil samples collected from Curragh Main and Curragh North. Spoil samples are subdivided into Permian and Quaternary spoil. |
| Rainfall erosivity<br>R-factor | The annual erosivity factor was determined from the IECA (2008) *Best Practice Erosion & Sediment Control. Book 2 – Appendices A-G* Table E1. |
| Slope % & slope length<br>LS-factor | Slope length and gradients were based on the maximum slope criteria specified in the Curragh Rehabilitation Plan (2019) Table 2. |
| Cover management<br>C-factor | Cover management was based on guidance provided in the Curragh Rehabilitation Plan (2019) and additional cover management practices were included where required. |
| Support practices<br>P-factor | The P factor was sourced from the IECA (2008) *Best Practice Erosion & Sediment Control. Book 2 – Appendices A-G* Table E11. |

# 4 Results and discussion

## 4.1 Soil erodibility (K-factor)

The K-factor is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Soil texture is the principal component affecting K-factor, but soil structure, organic matter and profile permeability also contribute.

SLR provided Curragh with a topsoil and spoil sampling plan. Samples were collected from 20 selected topsoil and 20 spoil stockpiles. Details of the sample sites are provided in **Appendix A.** All the samples were submitted to a NATA accredited laboratory for testing including determination of the K-factor. The laboratory certificates are provided in **Appendix B.**

### 4.1.1 Topsoil

Detailed information on the soil mapping units is provided in the Curragh Topsoil Management Plan. Multiple soil characterisation studies have been undertaken at Curragh, Curragh East and Curragh North:

- Soil study for the original Curragh Project by LRA (1990) identified 7 soil mapping units in the Curragh mine area.
- Additional mapping at Curragh East was undertaken by EHSS (1998) where two additional mapping units were identified.
- A soil survey of the Curragh North Project site was conducted by ARC (2003) which included the results of previous investigations. Four mapping units were identified at Curragh North.

Samples were collected from topsoil stockpiles at Curragh North and Curragh Main. Topsoil samples generally have a smaller range of K-factors compared to the spoil. The median K-factors were used in the RUSLE and are provided in **Table 4**.

**Table 2 K-factors topsoil**

| Site area | Number of sites | Median K-factor |
|---|---|---|
| Curragh North | 10 | 0.021 |
| Curragh Main | 9 | 0.028 |

K-factor for Curragh North is lower than Curragh Main indicating that topsoil material from Curragh North is less erodible.

### 4.1.2 Spoil

Overburden at the project site can be characterised by three main types of material as shown in **Table 3** (AARC, 1999).

**Table 3 Overburden summary (AARC, 1999)**

| Rock type | Description |
|---|---|
| Quaternary alluvium | A mixture of brown clay and silt, and sand and river gravel |
| Tertiary alluvium | Reddish claystone with sub-rounded gravels and claystone matrices |

| Rock type | Description |
|---|---|
| Permain Rangal Coal Measures | A broadly fining upward sequence of fine-grained sandstone, siltstone and mudstone |

Characteristically, Tertiary material is yellow/brown in colour, has high proportions of silt and clay and is alkaline and sodic. Tertiary materials experience a marked loss of strength when they are wet up. Because of the composition and moisture-sensitivity, many Tertiary materials are prone to instability and severe erosion. Permian material is characterised by grey colours. Compared to Tertiary materials, Permain materials contain less clay, is similarly alkaline and less sodic (ACARP, 2006).

Previous spoil characterisation reports indicate that the spoils in the Curragh and Curragh East lease areas are saline and sodic in nature. At Curragh North, salinity is not sufficiently high to affect plant growth but sodicity is high enough to consider selective placement of spoils or amelioration.

The median K-factor was used in the RUSLE. The K-factor was adjusted for inclusion of surface stone cover as per the methodology provided by Panagos *et al.* (2014). The K-factors calculated for individual lithologies are provided in **Table 4**.

**Table 4 K-factors spoil**

| Site area | Lithology | Number of sites | Median K-factor | Adjusted K-factor ($K_{st}$) |
|---|---|---|---|---|
| Curragh North | Permian | 7 | 0.034 | 0.025 |
| | Tertiary | 1 | 0.037 | 0.027 |
| | Quaternary | 1 | 0.023 | 0.017 |
| Curragh Main | Permian | 5 | 0.034 | 0.025 |
| | Tertiary | 1 | 0.022 | 0.016 |
| | Quaternary | 5 | 0.019 | 0.014 |

K-factors for the Permian spoil from both sites are equal to 0.025 with values for Quaternary materials also similar for both sites (CN is 0.017 and CM is 0.014). There is a marked difference in the K-factors for Tertiary spoil from the two sites. Only one Tertiary sample was tested for each site. Based on information from previous studies (see **Section 4.1.2**) the higher of the two values will be used to determine the soil loss on Tertiary spoil. The following K-factors will be used to represent the spoil types in the RUSLE:

- Tertiary spoil 0.027
- Permian spoil 0.025
- Quaternary spoil 0.017.

## 4.2 Rainfall erosivity (R-factor)

The rainfall erosivity factor, R, is a measure of the ability of rainfall to cause erosion. It is a constant parameter based on the location of the site. The erosivity factor for Emerald (1,804) from the IECA (2008) *Best Practice Erosion & Sediment Control. Book 2 – Appendices A-G* Table E1 was used.

## 4.3 Cover management (C-factor)

The cover factor, C, is the ratio of soil loss from land under specified crop or mulch conditions to the corresponding loss from continuously tilled, bare soil.

The Curragh Rehabilitation Plan (2019) includes the following guidance in terms of cover management practices:

- Revegetation will be carried out by seeding which appears to perform better than tube stock
- Vegetation species mix will include Eucalypts, Acacias, other native shrubs and tree species, native grasses, exotic grasses and range of legumes
- Potential use of straw mulch with cover crop.

In addition to the above rehabilitation, heightened spoil dumps at Curragh North may require the following cover management practices:

- Contour banks approximately 55 m apart for vegetated slopes up to 20%
- Cover crop such as millet or oats will be included with revised native tree, shrub and seed mix
- Consideration of hydromulch on slopes >16% to improve vegetation establishment to achieve >50% cover in less than one year.

An additional cover management tool to be evaluated is the application of stone with a cover crop on embankments where slope gradients of 34.4% are proposed.

The C-factors used in the RUSLE are outlined in **Table 5.**

**Table 5 C-factors**

| Description | C-factor | Source |
|---|---|---|
| Newly established grass cover no canopy (0%) | 1.0 | IECA (2008) Table E8 |
| Newly established grass cover no canopy (20%) | 0.45 | IECA (2008) Table E8 |
| Newly established grass cover no canopy (40%) | 0.2 | IECA (2008) Table E8 |
| Newly established grass cover no canopy (50%) | 0.15 | Calculated based on graph of data presented in IECA (2008) Table E8 |
| Newly established grass cover no canopy (60%) | 0.10 | IECA (2008) Table E8 |
| Newly established grass cover no canopy (80%) | 0.03 | IECA (2008) Table E8 |
| Hydromulch | 0.07 | IECA (2008) Table E6 |
| Cover crop with 2.5 t/ha straw mulch | 0.20 | IECA (2008) Table E8 |
| Cover crop with 3.8 t/ha straw mulch | 0.12 | IECA (2008) Table E8 |
| Cover crop with 330 t/ha stone | 0.05 | IECA (2008) Table E8 |
| Cover crop with 600 t/ha stone | 0.02 | IECA (2008) Table E8 |

## 4.4 Support Practice (P-factor)

The erosion control practice factor, P, is the ratio of soil loss with a nominated surface condition ploughed up and down the slope. It is reduced by practices that reduce both the velocity of runoff and the tendency of runoff to flow directly downhill. P-factor was selected given that mined landforms are largely unconsolidated materials.

Section 2.5 of the Curragh Rehabilitation Plan (2019) includes the following adopted support practice:

*Deep ripping of spoil/topsoil in conjunction with seeding will be utilised to minimise erosion*.

Therefore, a K-factor of 0.8 is applied in the RUSLE, corresponding to 'Ripped - Loose soil to 300 mm Depth' in accordance with the IECA Guideline.

## 4.5 Topographic factor (LS factor)

The LS-factor describes the combined effect of slope length and gradient on soil loss. It is the ratio of soil loss per unit area at any site to the corresponding loss from a specific experimental plot of known length and gradient.

Slope length and gradients were based on the maximum slope criteria specified in the Curragh Rehabilitation Plan (2019) Table 2 and the Curragh Concept Residual Void Assessment (SLR, 2021). The LS associated with the slope length and gradients were determined using the LS lookup table provided in *Queensland Landform Erosion Risk Evaluation for Pit Void Closure Planning - Desktop Review and Void Landform Guidelines* (Landloch, 2016).

**Table 6 LS factors (Curragh, 2019) and (SLR, 2021)**

| Slope % | Slope length (m) | LS (Landloch, 2016) |
|---|---|---|
| 6 | 115 | 1.06 |
| 8 | 105 | 1.45 |
| 10 | 90 | 1.93 |
| 12 | 80 | 2.44 |
| 14 | 70 | 2.94 |
| 16 | 55 | 3.06 |
| 18 | 45 | 3.24 |
| 25 | 45 | 5.68 |
| 35 | 31 | 6.07 |

## 4.6 Estimated Soil Loss (A-factor)

There is currently no broad agreement on what constitutes an 'acceptable rate of erosion' on a rehabilitated landform. Spatial data available from CSIRO (2020) provide estimates of broad scale and in situ soil erosion in Australia. The soil erosion estimate provided for the Curragh site range from 0.026 to 31.4 t/ha/y which can be interpreted as low to high based on the Food and Agricultural Organisation (FAO) soil loss classes in **Table 7** (Teng, et al., 2016)**.** The Curragh Rehabilitation Plan specifies that a soil loss of <1 t/ha/yr on slopes less than 20% with 50% vegetative cover can be obtained in 3-4 years. The RUSLE parameters used to calculate this soil loss were not available and as such the FAO soil loss classes were adopted to inform acceptable soil loss criteria for Curragh.

The low-risk soil loss threshold range applicable for an agricultural setting is estimated at 5 to 12 t/ha/yr. According to the DRI *Guidelines for Rehabilitation of Central Queensland Coal Mines* (DRI, undated) post mining landforms should be designed so that lost sediment will be less than 20 t/ha/yr and preferably less than 12.5 t/ha/yr.

A target average erosion rate of <12 t/ha/yr (very low or low) has been adopted for this study.

**Table 7 FAO soil loss classes after Bergma et al (1991)**

| Soil loss (t/ha/yr) | Class |
|---|---|
| < 5 | very low |
| 5 – 12 | low |
| 12 – 25 | moderate |
| 25 – 60 | high |
| 60 – 150 | very high |
| > 150 | extremely high |

The results of the RUSLE calculations are provided in **Table 8** for Permian, Quaternary and Tertiary spoil and **Table 9** for topsoil from Curragh North and Curragh Main. The results indicate the following:

- Stable 16% slope gradients can be achieved on all spoil types by applying hydromulch
- Permian and Quaternary spoil with 16% slope gradients will be stable once 50% cover is established
- Tertiary spoil will only be stable when at least 80% cover is established
- Spoil stability is increased as a result of stone fragments which provide additional cover
- Stone cover offer the best protection against erosion with soil losses classified as very low to low where this is applied
- Topsoil from Curragh North is less erodible and will reach a low annual soil loss once 60% cover is established
- Stable slopes of >25 % can be achieved when cover crops are used with stone mulch
- Topsoil from Curragh Main is more erodible and gentler slopes should be considered.

## Table 8 Soil loss (t/ha/yr) spoil

| Lithology | | | Slope angle (%) | 35% | 25% | 18% | 16% | 14% | 12% | 10% | 8% | 6% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Slope length (m) | 31 | 45m | 45m | 55m | 70m | 80m | 90m | 105m | 115m |
| | Cover management | | | | | Calculated annual soil loss (t/ha/yr) | | | | | | |
| Permian | Newly established grass cover no canopy | 0 | | 219.0 | 204.9 | 116.9 | 110.4 | 106.1 | 88.0 | 69.6 | 52.3 | 38.2 |
| | | 20 | | 98.6 | 92.2 | 52.6 | 49.7 | 47.7 | 39.6 | 31.3 | 23.5 | 17.2 |
| | | 40 | | 43.8 | 41.0 | 23.4 | 22.1 | 21.2 | 17.6 | 13.9 | 10.5 | 7.6 |
| | | 50 | | 32.9 | 30.7 | 17.5 | 16.6 | 15.9 | 13.2 | 10.4 | 7.8 | 5.7 |
| | | 60 | | 21.9 | 20.5 | 11.7 | 11.0 | 10.6 | 8.8 | 7.0 | 5.2 | 3.8 |
| | | 80 | | 6.6 | 6.1 | 3.5 | 3.3 | 3.2 | 2.6 | 2.1 | 1.6 | 1.1 |
| | Hydromulch | | | 15.3 | 14.3 | 8.2 | 7.7 | 7.4 | 6.2 | 4.9 | 3.7 | 2.7 |
| | Cover crop with 2.5 t/ha straw mulch | | | 43.8 | 41.0 | 23.4 | 22.1 | 21.2 | 17.6 | 13.9 | 10.5 | 7.6 |
| | Cover crop with 3.8 t/ha straw mulch | | | 26.3 | 24.6 | 14.0 | 13.2 | 12.7 | 10.6 | 8.4 | 6.3 | 4.6 |
| | Cover crop with 330 t/ha stone | | | 11.0 | 10.2 | 5.8 | 5.5 | 5.3 | 4.4 | 3.5 | 2.6 | 1.9 |
| | Cover crop with 600 t/ha stone | | | 4.4 | 4.1 | 2.3 | 2.2 | 2.1 | 1.8 | 1.4 | 1.0 | 0.8 |
| Quaternary | Newly established grass cover no canopy | 0 | | 148.9 | 139.4 | 79.5 | 75.1 | 72.1 | 59.9 | 47.4 | 35.6 | 26.0 |
| | | 20 | | 67.0 | 62.7 | 35.8 | 33.8 | 32.5 | 26.9 | 21.3 | 16.0 | 11.7 |
| | | 40 | | 29.8 | 27.9 | 15.9 | 15.0 | 14.4 | 12.0 | 9.5 | 7.1 | 5.2 |
| | | 50 | | 22.3 | 20.9 | 11.9 | 11.3 | 10.8 | 9.0 | 7.1 | 5.3 | 3.9 |
| | | 60 | | 14.9 | 13.9 | 7.9 | 7.5 | 7.2 | 6.0 | 4.7 | 3.6 | 2.6 |
| | | 80 | | 4.5 | 4.2 | 2.4 | 2.3 | 2.2 | 1.8 | 1.4 | 1.1 | 0.8 |
| | Hydromulch | | | 10.4 | 9.8 | 5.6 | 5.3 | 5.0 | 4.2 | 3.3 | 2.5 | 1.8 |
| | Cover crop with 2.5 t/ha straw mulch | | | 29.8 | 27.9 | 15.9 | 15.0 | 14.4 | 12.0 | 9.5 | 7.1 | 5.2 |
| | Cover crop with 3.8 t/ha straw mulch | | | 17.9 | 16.7 | 9.5 | 9.0 | 8.7 | 7.2 | 5.7 | 4.3 | 3.1 |
| | Cover crop with 330 t/ha stone | | | 7.4 | 7.0 | 4.0 | 3.8 | 3.6 | 3.0 | 2.4 | 1.8 | 1.3 |
| | Cover crop with 600 t/ha stone | | | 3.0 | 2.8 | 1.6 | 1.5 | 1.4 | 1.2 | 0.9 | 0.7 | 0.5 |
| Tertiary | Newly established grass cover no canopy | 0 | | 236.5 | 221.3 | 126.3 | 119.2 | 114.6 | 95.1 | 75.2 | 56.5 | 41.3 |
| | | 20 | | 106.4 | 99.6 | 56.8 | 53.7 | 51.6 | 42.8 | 33.8 | 25.4 | 18.6 |
| | | 40 | | 47.3 | 44.3 | 25.3 | 23.8 | 22.9 | 19.0 | 15.0 | 11.3 | 8.3 |
| | | 50 | | 35.5 | 33.2 | 18.9 | 17.9 | 17.2 | 14.3 | 11.3 | 8.5 | 6.2 |
| | | 60 | | 23.7 | 22.1 | 12.6 | 11.9 | 11.5 | 9.5 | 7.5 | 5.7 | 4.1 |
| | | 80 | | 7.1 | 6.6 | 3.8 | 3.6 | 3.4 | 2.9 | 2.3 | 1.7 | 1.2 |
| | Hydromulch | | | 16.6 | 15.5 | 8.8 | 8.3 | 8.0 | 6.7 | 5.3 | 4.0 | 2.9 |
| | Cover crop with 2.5 t/ha straw mulch | | | 47.3 | 44.3 | 25.3 | 23.8 | 22.9 | 19.0 | 15.0 | 11.3 | 8.3 |
| | Cover crop with 3.8 t/ha straw mulch | | | 28.4 | 26.6 | 15.2 | 14.3 | 13.7 | 11.4 | 9.0 | 6.8 | 5.0 |
| | Cover crop with 330 t/ha stone | | | 11.8 | 11.1 | 6.3 | 6.0 | 5.7 | 4.8 | 3.8 | 2.8 | 2.1 |
| | Cover crop with 600 t/ha stone | | | 4.7 | 4.4 | 2.5 | 2.4 | 2.3 | 1.9 | 1.5 | 1.1 | 0.8 |

## Table 9 Soil loss (t/ha/yr) topsoil

| Lithology | | | Slope angle (%) | 35% | 25% | 18% | 16% | 14% | 12% | 10% | 8% | 6% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Slope length (m) | 31 | 45m | 45m | 55m | 70m | 80m | 90m | 105m | 115m |
| | Cover management | | | | | Calculated annual soil loss (t/ha/yr) | | | | | | |
| Curragh North | Percentage newly established grass cover no canopy | 0 | | 184.0 | 172.1 | 98.2 | 92.7 | 89.1 | 73.9 | 58.5 | 43.9 | 32.1 |
| | | 0.2 | | 82.8 | 77.5 | 44.2 | 41.7 | 40.1 | 33.3 | 26.3 | 19.8 | 14.5 |
| | | 0.4 | | 36.8 | 34.4 | 19.6 | 18.5 | 17.8 | 14.8 | 11.7 | 8.8 | 6.4 |
| | | 0.5 | | 27.6 | 25.8 | 14.7 | 13.9 | 13.4 | 11.1 | 8.8 | 6.6 | 4.8 |
| | | 0.6 | | 18.4 | 17.2 | 9.8 | 9.3 | 8.9 | 7.4 | 5.8 | 4.4 | 3.2 |
| | | 0.8 | | 5.5 | 5.2 | 2.9 | 2.8 | 2.7 | 2.2 | 1.8 | 1.3 | 1.0 |
| | Hydromulch | | | 12.9 | 12.1 | 6.9 | 6.5 | 6.2 | 5.2 | 4.1 | 3.1 | 2.2 |
| | Cover crop with 2.5 t/ha straw mulch | | | 36.8 | 34.4 | 19.6 | 18.5 | 17.8 | 14.8 | 11.7 | 8.8 | 6.4 |
| | Cover crop with 3.8 t/ha straw mulch | | | 22.1 | 20.7 | 11.8 | 11.1 | 10.7 | 8.9 | 7.0 | 5.3 | 3.9 |
| | Cover crop with 330 t/ha stone | | | 9.2 | 8.6 | 4.9 | 4.6 | 4.5 | 3.7 | 2.9 | 2.2 | 1.6 |
| | Cover crop with 600 t/ha stone | | | 3.7 | 3.4 | 2.0 | 1.9 | 1.8 | 1.5 | 1.2 | 0.9 | 0.6 |
| Curragh Main | Percentage newly established grass cover no canopy | 0 | | 245.3 | 229.5 | 130.9 | 123.7 | 118.8 | 98.6 | 78.0 | 58.6 | 42.8 |
| | | 0.2 | | 110.4 | 103.3 | 58.9 | 55.6 | 53.5 | 44.4 | 35.1 | 26.4 | 19.3 |
| | | 0.4 | | 49.1 | 45.9 | 26.2 | 24.7 | 23.8 | 19.7 | 15.6 | 11.7 | 8.6 |
| | | 0.5 | | 36.8 | 34.4 | 19.6 | 18.5 | 17.8 | 14.8 | 11.7 | 8.8 | 6.4 |
| | | 0.6 | | 24.5 | 23.0 | 13.1 | 12.4 | 11.9 | 9.9 | 7.8 | 5.9 | 4.3 |
| | | 0.8 | | 7.4 | 6.9 | 3.9 | 3.7 | 3.6 | 3.0 | 2.3 | 1.8 | 1.3 |
| | Hydromulch | | | 17.2 | 16.1 | 9.2 | 8.7 | 8.3 | 6.9 | 5.5 | 4.1 | 3.0 |
| | Cover crop with 2.5 t/ha straw mulch | | | 49.1 | 45.9 | 26.2 | 24.7 | 23.8 | 19.7 | 15.6 | 11.7 | 8.6 |
| | Cover crop with 3.8 t/ha straw mulch | | | 29.4 | 27.5 | 15.7 | 14.8 | 14.3 | 11.8 | 9.4 | 7.0 | 5.1 |
| | Cover crop with 330 t/ha stone | | | 12.3 | 11.5 | 6.5 | 6.2 | 5.9 | 4.9 | 3.9 | 2.9 | 2.1 |
| | Cover crop with 600 t/ha stone | | | 4.9 | 4.6 | 2.6 | 2.5 | 2.4 | 2.0 | 1.6 | 1.2 | 0.9 |

# 5 Model limitations

The following limitations of the RUSLE model are noted:

- The RUSLE model was formulated based on soil erosion studies on agricultural land in the USA and when applied to different climate regimes and land cover conditions it may lead to over- or under-prediction of actual average annual soil loss
- RUSLE ideally requires long-term data to develop the parameters for climate (R factor) and erodibility (K factor) for locations and soils outside the USA
- RUSLE estimates soil loss through sheet and rill erosion, but not from other types of erosion (gully, channel, bank, or from mass wasting events such as landslides)
- The model also does not account for deposition, extent of outcrops or soil depth
- Given the absence of long-term data for some factors (R and P factors in particular), the model relies on expert opinion. The RUSLE estimates average annual soil loss by sheet and rill erosion on those portions of landscape profiles where erosion, but not deposition is occurring.
- The RUSLE provides a high-level indication of landform performance.
- The RUSLE is not a Landform Evolution Model (LEM) but provides sufficient guidance to compare the performance of final landform construction (slope length and grade) and stabilization/amelioration methods (hydromulching, cover crops etc.).
- The rainfall erosivity factor does not consider individual storm or extreme weather events but presents an average over the year
- The rate of soil loss provided may vary significantly depending upon climate patterns, climate change and storm events particularly when the ground is bare.
- Incorporation of soil ameliorants (eg. gypsum on dispersive materials) may further improve stability and, therefore reduce predicted soil loss. Beneficial use of soil ameliorants have not been included in the calculated outcomes. RUSLE does not account for incorporation of ameliorants and the potential reduction in K-factors.

# 6 References

AARC. (1999). *Waste Characterisation Report.*

ACARP. (2006). *Rehabilitation of Highwalls ACARP Project C14048.*

ARC. (2004). *Supplementary Topsoil Survey for the Curragh North Mining Lease.* Austrlasian Resource Consultants.

Curragh. (2019). *Rehabilitation Management and Monitoring Plan. EM PLan 1.3. Version 6.* Curragh.

DRI. (undated). *Guidelines for Rehabilitation of Central Queensland Coal Mines.* Brisbane: Department of Resource Industries.

FAO. (2022, 07 25). *Food and Agriculture Organisation of the United States*. Retrieved from Land & Water: https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/zh/c/1236444/

IECA. (2008). *Best Practice Erosion & Sediment Control. Book 2 Appendices A - G.* Australasia: International Erosion Control Association.

Landloch. (2016). QLD Landform Erosion Risk Evaluation for Pit Void Closure Planning - Desktop Review and Void Landform Guidelines. Newcastle, Queensland, Australia.

LRS. (1990). *Curragh Mine Soil Survey.* Land Reclamation Services Pty Ltd.

Panagos, P., Meusburger, K., Ballbio, C., Borelli, P., & Alewell, C. (2014). Soil erodibility in Europe: A high-resolution dataset based on LUCAS. *Science of the Total Environment, 479-480*, 189-200.

SLR. (2021). *Curragh Project Concept Residual Void Assessment.* Mackay, QLD: SLR Consulting Australia Pty Ltd.

Teng, H., Viscarra Rossel, R., Shi, Z., Behrens, T., Chappell, A., & Bui, E. (2016). Assimilating satellite imagery and visible-near infrared spectroscopy to model and map soil loss by water erosion in Australia. *Environmental Modelling & Software, 77*, 156-167.

USDA-ARS. (2016, 08 13). *Revised Universal Soil Loss Equation*. Retrieved from USDA Agricultural Research Service U.S. Department of Agriculture: https://www.ars.usda.gov/southeast-area/oxford-ms/national-sedimentation-laboratory/watershed-physical-processes-research/docs/revised-universal-soil-loss-equation-106-current-version/

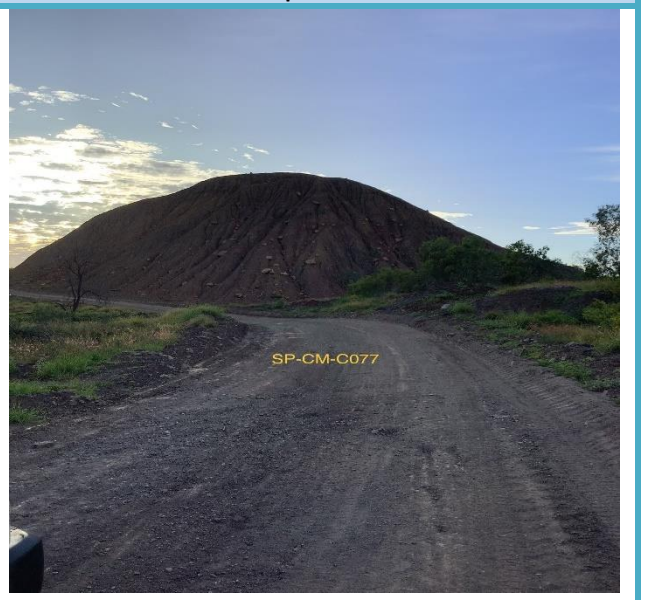
# Appendix A:

## Sample Site Logs

| Sample Photo | | Sample Photo | | Sample Photo | |
|---|---|---|---|---|---|
|  | |  | |  | |
| **Site information** | | **Site information** | | **Site information** | |
| **Material Type** | Spoil | **Material Type** | Spoil | **Material Type** | Spoil |
| **Sample ID** | SP-CN-C418 | **Sample ID** | SP-CN-C16 | **Sample ID** | SP-CM-C07 |
| **Sample date** | 02-08-2022 | **Sample date** | 02-08-2022 | **Sample date** | 02-08-2022 |
| **Coordinates** | 55k 0693826 / 7419717 | **Coordinates** | 55k 0693298 / 7416586 | **Coordinates** | 55K 0692819 / 7407579 |
| **Project Location** | Curragh North | **Project Location** | Curragh North | **Project Location** | Curragh Main |
| **Stockpile dominant lithology** | Permian Rangal coal measures/Quaternary alluvium mix | **Stockpile dominant lithology** | Quaternary Alluvium | **Stockpile dominant lithology** | Quaternary / tertiary alluvium |
| **Dominant surface rock** | Coal stone/sandstone | **Dominant surface rock** | Sandstone | **Dominant surface rock** | Sandstone |
| **Surface rock >60mm** | >10% | **Surface rock >60mm** | >10% | **Surface rock >60mm** | >10% |
| **Vegetation** | 0% | **Vegetation** | 0% | **Vegetation** | 0-2% |
| **Surface Condition** | Weathered slopes with heavy rill erosion evident | **Surface Condition** | No vegetation present. Heavy rill erosion evident on slopes. | **Surface Condition** | Weathered surface. Active rill erosion. Some surface crusting |
| **Texture** | Sand/Sandy Loam | **Texture** | Sand | **Texture** | Sand. Borderline sandy loam. |
| **Signs of salinity** | No vegetation present. Dark, wet, greasy patches. Clear water pooled nearby. | **Signs of salinity** | Bare patches of soil. Wet, dark, greasy patches. | **Signs of salinity** | Bare patches of soil. Salt tolerable plant species present |
| **Signs of sodicity** | Nil | **Signs of sodicity** | Surface crusting. Cloudy water in puddles. Hard/dense subsoil. | **Signs of sodicity** | Some surface crusting. Soapy feel to sample when wetting. |
| **Consistence strength** | Weak/Firm | **Consistence strength** | Loose/very friable | **Consistence strength** | Friable |
| **Consistence stickiness** | Sligh | **Consistence stickiness** | Non-sticky | **Consistence stickiness** | Non-sticky |
| **Slope** | 30% | **Slope** | 36% | **Slope** | 36% |

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| **Material Type** | Spoil | **Material Type** | Spoil | **Material Type** | Spoil |
| **Sample ID** | SP-CM-C126 | **Sample ID** | SP-CM-C042 | **Sample ID** | SP-CM-C152 |
| **Sample date** | 01-08-2022 | **Sample date** | 01-08-2022 | **Sample date** | 01-08-2022 |
| **Coordinates** | 55k 0692183 / 7404550 | **Coordinates** | 55k 0690452 / 7404134 | **Coordinates** | 55k 0694176 / 74021634 |
| **Project Location** | Curragh Main | **Project Location** | Curragh Main | **Project Location** | Curragh East |
| **Stockpile dominant lithology** | Quaternary Alluvium | **Stockpile dominant lithology** | Permian rangal coal measures | **Stockpile dominant lithology** | Permian rangal coal measures / quaternary alluvium mix |
| **Dominant surface rock** | Nil | **Dominant surface rock** | Coalstone | **Dominant surface rock** | Sandstone/coal stone mix |
| **Surface rock >60mm** | 0% | **Surface rock >60mm** | 2-10% | **Surface rock >60mm** | >10% |
| **Vegetation** | 0-2% | **Vegetation** | 50% | **Vegetation** | 5% |
| **Surface Condition** | Not Provided | **Surface Condition** | Stable surface. Evidence of minor rill erosion | **Surface Condition** | Heavy presence of active rill erosion. |
| **Texture** | Silty Loam | **Texture** | Sandy Loam | **Texture** | Sand |
| **Signs of salinity** | Evidence of vegetation dieback | **Signs of salinity** | Bare patches of soil | **Signs of salinity** | Bare patches of soil. Growth of salt tolerant plant species. |
| **Signs of sodicity** | Poor water infiltration. Poor crop growth. Crusting on surface. | **Signs of sodicity** | Hard subsoil | **Signs of sodicity** | Poor vegetation growth. Some surface crusting. |
| **Consistence strength** | Firm | **Consistence strength** | Loose | **Consistence strength** | Firm |
| **Consistence stickiness** | Sticky | **Consistence stickiness** | Non-sticky | **Consistence stickiness** | Sticky |
| **Slope** | 45% | **Slope** | 35% | **Slope** | 45% |

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| **Material Type** | Spoil | **Material Type** | Spoil | **Material Type** | Spoil |
| **Sample ID** | SP-CM-C100 | **Sample ID** | SP-CM-C38/38 | **Sample ID** | SP-CM-C077 |
| **Sample date** | 01-08-2022 | **Sample date** | 01-08-2022 | **Sample date** | 01-08-2022 |
| **Coordinates** | 55K 0690921 / 740118432 | **Coordinates** | 55K 0688902 / 7396824 | **Coordinates** | 55k 0688902 / 73968243 |
| **Project Location** | Curragh Main | **Project Location** | Curragh East | **Project Location** | Curragh Main |
| **Stockpile dominant lithology** | Permian rangal coal measures | **Stockpile dominant lithology** | Permian rangal coal measures | **Stockpile dominant lithology** | Permian dominant with tertiary mix |
| **Dominant surface rock** | Sandstone | **Dominant surface rock** | Sandstone/coal stone mix | **Dominant surface rock** | Permian/sandstone |
| **Surface rock >60mm** | >10% | **Surface rock >60mm** | >10% | **Surface rock >60mm** | >10% |
| **Vegetation** | 0.4 | **Vegetation** | >5% | **Vegetation** | 0 |
| **Surface Condition** | Evidence of moderate rill and piping erosion. | **Surface Condition** | Little vegetation. Coal present. Weathered surface. | **Surface Condition** | No vegetation growth. Heavy rill erosion |
| **Texture** | Sand | **Texture** | Sandy loam/borderline sand | **Texture** | Silty Loam |
| **Signs of salinity** | Bare patches of soil | **Signs of salinity** | Bare surface. Patches of salt bush. Salt crust in some spots. | **Signs of salinity** | Surface completely bare of vegetation |
| **Signs of sodicity** | Dense subsoil | **Signs of sodicity** | Poor vegetation growth. Surface crusting. | **Signs of sodicity** | Surface crusting. Dense subsoil. Soapy feel when wetting. |
| **Consistence strength** | Loose | **Consistence strength** | Very friable | **Consistence strength** | Very friable |
| **Consistence stickiness** | Non-sticky | **Consistence stickiness** | Slightly sticky | **Consistence stickiness** | Non-sticky |
| **Slope** | 32% | **Slope** | 31% | **Slope** | 38% |

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| **Material Type** | Spoil | **Material Type** | Spoil | **Material Type** | Spoil |
| **Sample ID** | SP-CN-C369/370 | **Sample ID** | SP-CN-CN93 | **Sample ID** | SP-CN-CN320 |
| **Sample date** | 02-08-2022 | **Sample date** | 04-08-2022 | **Sample date** | 04-08-2022 |
| **Coordinates** | 55k 0694122 / 7417627 | **Coordinates** | 55K 0691906 / 7423051 | **Coordinates** | 55k 0692073 / 7422194 |
| **Project Location** | Curragh North | **Project Location** | Curragh North | **Project Location** | Curragh North |
| **Stockpile dominant lithology** | Permian spoil, coalstone dominant | **Stockpile dominant lithology** | Tertiary Alluvium | **Stockpile dominant lithology** | Quaternary alluvium |
| **Dominant surface rock** | Coalstone | **Dominant surface rock** | Claystone | **Dominant surface rock** | Sand / river gravel |
| **Surface rock >60mm** | 0-2% | **Surface rock >60mm** | 2-10% | **Surface rock >60mm** | >10% |
| **Vegetation** | 25% | **Vegetation** | 15% | **Vegetation** | 5% |
| **Surface Condition** | Stable surface. Minimal erosion evident. Some grass vegetation. | **Surface Condition** | Heavy rill erosion. Some tree & grass vegetation. | **Surface Condition** | Very little vegetation. Minor rill erosion. |
| **Texture** | Sand | **Texture** | Sandy loam | **Texture** | Sand |
| **Signs of salinity** | Bare patches of soil | **Signs of salinity** | Bare patches of soil. Salt tolerant species present. | **Signs of salinity** | Bare patches of soil. Dieback of some species evident. |
| **Signs of sodicity** | Poor vegetation growth. Poor water infiltration. Hard subsoil. | **Signs of sodicity** | Poor vegetation growth. | **Signs of sodicity** | Cloudy water in nearby puddle. Surface crusting. |
| **Consistence strength** | Loose | **Consistence strength** | Very friable | **Consistence strength** | Loose |
| **Consistence stickiness** | Non-sticky | **Consistence stickiness** | Sticky | **Consistence stickiness** | Non-sticky |
| **Slope** | 34% | **Slope** | 30% | **Slope** | 32% |

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| **Material Type** | Spoil | **Material Type** | Spoil | **Material Type** | Spoil |
| **Sample ID** | SP-CN-CN342 | **Sample ID** | SP-CN-CN413 | **Sample ID** | SP-CN-CN334 |
| **Sample date** | 04-08-2022 | **Sample date** | 04-08-2022 | **Sample date** | 03-08-2022 |
| **Coordinates** | 55K 0690064 / 7422367 | **Coordinates** | 55K 0689752 / 7421690 | **Coordinates** | 55k 0692011 / 7425941 |
| **Project Location** | Curragh North | **Project Location** | Curragh North | **Project Location** | Curragh North |
| **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Permian. Coalstone/Shale dominant | **Stockpile dominant lithology** | Permian |
| **Dominant surface rock** | Riverstone/siltstone/shale | **Dominant surface rock** | Coalstone / shale | **Dominant surface rock** | Coalstone / shale |
| **Surface rock >60mm** | >10% | **Surface rock >60mm** | >10% | **Surface rock >60mm** | >10% |
| **Vegetation** | Nil | **Vegetation** | 5% | **Vegetation** | il |
| **Surface Condition** | Nil vegetation. Evidence of active rill erosion. | **Surface Condition** | Heavy rill erosion. Most surface rocks >100m. Little vegetation | **Surface Condition** | New spoil dump. No signs of active rill erosion |
| **Texture** | Sand | **Texture** | Sandy loam | **Texture** | Sandy loam |
| **Signs of salinity** | Dark greasy patches. | **Signs of salinity** | Bare patches of soil | **Signs of salinity** | New dump (no signs) |
| **Signs of sodicity** | No vegetation. Some surface crusting. | **Signs of sodicity** | Poor vegetation growth. Surface crusting. Dense subsoil. | **Signs of sodicity** | New dump (no signs) |
| **Consistence strength** | Loose | **Consistence strength** | Very friable | **Consistence strength** | Loose / very friable |
| **Consistence stickiness** | Non-sticky | **Consistence stickiness** | Sticky | **Consistence stickiness** | Slightly sticky |
| **Slope** | 30% | **Slope** | 25% | **Slope** | 38% |

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| **Material Type** | Spoil | **Material Type** | Spoil | **Material Type** | Spoil |
| **Sample ID** | SP-CN-CN364 | **Sample ID** | SP-CM-C051 | **Sample ID** | SP-CN-CN223 |
| **Sample date** | 02-08-2022 | **Sample date** | 02-08-2022 | **Sample date** | Not Provided |
| **Coordinates** | 55k 0691659 / 7417538 | **Coordinates** | 55K 0689735 / 7400989 | **Coordinates** | 55K 0691737 / 7418661 |
| **Project Location** | Curragh North | **Project Location** | Curragh Main | **Project Location** | Curragh North |
| **Stockpile dominant lithology** | Permian | **Stockpile dominant lithology** | Permian | **Stockpile dominant lithology** | Permian |
| **Dominant surface rock** | Shale | **Dominant surface rock** | Sandstone / coalstone mix | **Dominant surface rock** | Coalstone / shale |
| **Surface rock >60mm** | >10% | **Surface rock >60mm** | Nil | **Surface rock >60mm** | >10% |
| **Vegetation** | Nil | **Vegetation** | Nil | **Vegetation** | Nil |
| **Surface Condition** | Rill erosion evident. Nil vegetation | **Surface Condition** | Heavy rill erosion. Nil vegetation | **Surface Condition** | Nil vegetation. Minimal rill erosion. New dump |
| **Texture** | Sand | **Texture** | Silty loam | **Texture** | Fine Clay |
| **Signs of salinity** | Nil vegetation | **Signs of salinity** | Bare patches of soil. Surface salt crust in some places | **Signs of salinity** | Nil |
| **Signs of sodicity** | Hard subsoil | **Signs of sodicity** | Slight surface crusting | **Signs of sodicity** | Nil |
| **Consistence strength** | Very firm | **Consistence strength** | Very friable | **Consistence strength** | Friable |
| **Consistence stickiness** | Slightly sticky | **Consistence stickiness** | Slightly sticky | **Consistence stickiness** | Slightly sticky |
| **Slope** | 40% | **Slope** | 45% | **Slope** | 35% |

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| **Material Type** | Spoil | **Material Type** | Spoil | **Material Type** | Topsoil |
| **Sample ID** | SP-CM-C142 | **Sample ID** | SP-CM-C10 | **Sample ID** | TS-CM-C07 |
| **Sample date** | 05-08-2022 | **Sample date** | 01-08-2022 | **Sample date** | 02-08-2022 |
| **Coordinates** | Not Provided | **Coordinates** | 55k 0691489/7406642 | **Coordinates** | 55k 0693129 / 7407704 |
| **Project Location** | Curragh Main | **Project Location** | Curragh Main | **Project Location** | Curragh Main |
| **Stockpile dominant lithology** | Tertiary spoil dominant | **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium |
| **Dominant surface rock** | Claystone/siltstone | **Dominant surface rock** | Permian/sandstone mix | **Dominant surface rock** | Dark grey shale |
| **Surface rock >60mm** | >10% | **Surface rock >60mm** | >10% | **Surface rock >60mm** | 0-2% |
| **Vegetation** | 20% | **Vegetation** | 20% | **Vegetation** | 95% |
| **Surface Condition** | Hard rocky surface. Minimal erosion. Established and mature trees and some grass. | **Surface Condition** | Weathered surface. Evidence of intensifying rill erosion. | **Surface Condition** | Stable. Well established buffel grass. |
| **Texture** | sand | **Texture** | Sand | **Texture** | Sandy Loam |
| **Signs of salinity** | Bare patches of soil. | **Signs of salinity** | Salt tolerant plant species are dominant. Areas/patches of bare soil. | **Signs of salinity** | Nil |
| **Signs of sodicity** | Poor grass growth. Dense/hard subsoil | **Signs of sodicity** | Surface crusting. Hard subsoil | **Signs of sodicity** | Nil |
| **Consistence strength** | Firm | **Consistence strength** | Very firm | **Consistence strength** | Very friable |
| **Consistence stickiness** | Sticky | **Consistence stickiness** | Slightly sticky | **Consistence stickiness** | Sticky |
| **Slope** | 18% | **Slope** | 12% | **Slope** | Flat |

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| **Material Type** | Topsoil | **Material Type** | Topsoil | **Material Type** | Topsoil |
| **Sample ID** | TS-CM-C10 | **Sample ID** | TS-CM-C126 | **Sample ID** | TS-CM-C042 |
| **Sample date** | 01-08-2022 | **Sample date** | 01-08-2022 | **Sample date** | 01-08-2022 |
| **Coordinates** | 55k 0691401 / 7406704 | **Coordinates** | 55k 0691865 / 7405070 | **Coordinates** | 55k 0690139 / 7405150 |
| **Project Location** | Curragh Main | **Project Location** | Curragh Main | **Project Location** | Curragh Main |
| **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium |
| **Dominant surface rock** | Nil | **Dominant surface rock** | Nil | **Dominant surface rock** | Nil |
| **Surface rock >60mm** | Nil | **Surface rock >60mm** | Nil | **Surface rock >60mm** | Nil |
| **Vegetation** | 95% | **Vegetation** | 50% | **Vegetation** | 95% |
| **Surface Condition** | Stable surface. Well established buffel grass. | **Surface Condition** | Well established vegetation. Minimal signs of erosion. | **Surface Condition** | Established vegetation. No signs of active erosion. |
| **Texture** | Loam | **Texture** | Silty Loam | **Texture** | Silty Loam |
| **Signs of salinity** | Nil | **Signs of salinity** | Heavy presence of saltbush. | **Signs of salinity** | Nil |
| **Signs of sodicity** | Nil | **Signs of sodicity** | Surface crusting. | **Signs of sodicity** | Nil |
| **Consistence strength** | Friable | **Consistence strength** | Friable | **Consistence strength** | Very friable |
| **Consistence stickiness** | Sticky | **Consistence stickiness** | Very Sticky | **Consistence stickiness** | Sticky |
| **Slope** | Flat | **Slope** | Flat | **Slope** | Flat |

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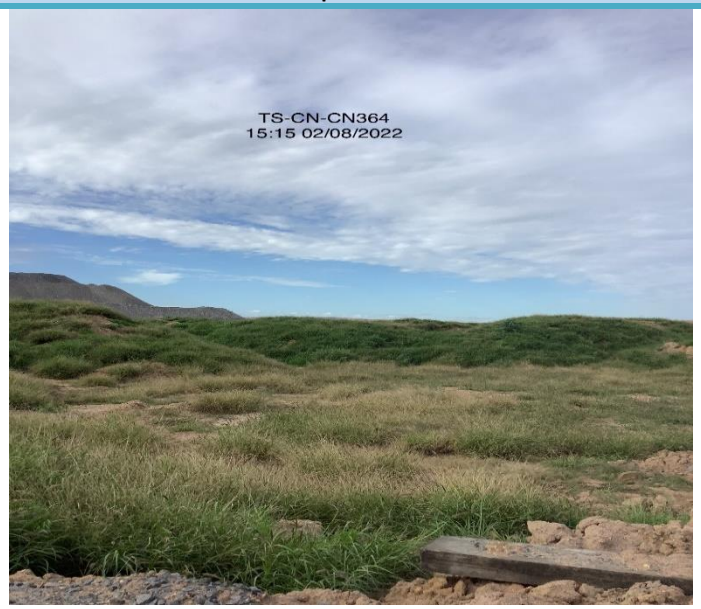
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| **Material Type** | Topsoil | **Material Type** | Topsoil | **Material Type** | Topsoil |
| **Sample ID** | TS-CM-C152 | **Sample ID** | TS-CM-C100 | **Sample ID** | TS-CM-C38/38 |
| **Sample date** | 01-08-2022 | **Sample date** | 01-08-2022 | **Sample date** | 01-08-2022 |
| **Coordinates** | 55K 0694472 / 7402527 | **Coordinates** | 55k 0691006 / 7401101 | **Coordinates** | 55K 0688902 / 7396824 |
| **Project Location** | Curragh East | **Project Location** | Curragh Main | **Project Location** | Curragh East |
| **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium |
| **Dominant surface rock** | Nil | **Dominant surface rock** | river gravel | **Dominant surface rock** | river gravel |
| **Surface rock >60mm** | Nil | **Surface rock >60mm** | 2-10% | **Surface rock >60mm** | 0-2% |
| **Vegetation** | 95% | **Vegetation** | 35-40% | **Vegetation** | 95% |
| **Surface Condition** | Established buffel grass. Stable surface | **Surface Condition** | Evidence of minor rill erosion. | **Surface Condition** | Established buffel grass. Some localized Parkinsonia. |
| **Texture** | Silty Loam | **Texture** | Loam | **Texture** | Silty Loam |
| **Signs of salinity** | Nil | **Signs of salinity** | Nil | **Signs of salinity** | Nil |
| **Signs of sodicity** | Nil | **Signs of sodicity** | Nil | **Signs of sodicity** | Hard/dense subsoil |
| **Consistence strength** | Friable | **Consistence strength** | Very friable | **Consistence strength** | Firm |
| **Consistence stickiness** | Sticky | **Consistence stickiness** | Sticky | **Consistence stickiness** | Slightly sticky |
| **Slope** | Nil | **Slope** | Flat | **Slope** | Flat |

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| **Material Type** | Topsoil | **Material Type** | Topsoil | **Material Type** | Topsoil |
| **Sample ID** | TS-CM-C077 | **Sample ID** | TS-CN-CN93 | **Sample ID** | TS-CN-CN320 |
| **Sample date** | 01-08-2022 | **Sample date** | 04-08-2022 | **Sample date** | 04-08-2022 |
| **Coordinates** | 55K 0688902 / 7396824 | **Coordinates** | 55k 0691842 / 7423036 | **Coordinates** | 55K 0691995 / 7422159 |
| **Project Location** | Curragh Main | **Project Location** | Curragh North | **Project Location** | Curragh North |
| **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium |
| **Dominant surface rock** | river gravel | **Dominant surface rock** | Siltstone | **Dominant surface rock** | Nil |
| **Surface rock >60mm** | 2-10% | **Surface rock >60mm** | 0-2% | **Surface rock >60mm** | Nil |
| **Vegetation** | 80% | **Vegetation** | 80% | **Vegetation** | 95% |
| **Surface Condition** | Well established grass vegetation. Some bare patches | **Surface Condition** | Established tree & grass vegetation. Some bare patches & surface cracking. | **Surface Condition** | Established grass & tree vegetation. No evidence of active erosion. |
| **Texture** | Clayey loam | **Texture** | Silty Loam | **Texture** | Silty Loam |
| **Signs of salinity** | Nil | **Signs of salinity** | Bare patches of soil | **Signs of salinity** | Nil |
| **Signs of sodicity** | Nil | **Signs of sodicity** | Surface cracking | **Signs of sodicity** | Nil |
| **Consistence strength** | Very friable | **Consistence strength** | Firm | **Consistence strength** | Firm |
| **Consistence stickiness** | Non-sticky | **Consistence stickiness** | Slightly sticky | **Consistence stickiness** | Slightly sticky |
| **Slope** | 0.25 | **Slope** | Flat | **Slope** | Flat |

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| **Material Type** | Topsoil | **Material Type** | Topsoil | **Material Type** | Topsoil |
| **Sample ID** | TS-CN-CN342 | **Sample ID** | TS-CN-CN413 | **Sample ID** | TS-CN-CN334 |
| **Sample date** | 04-08-2022 | **Sample date** | 04-08-2022 | **Sample date** | 03-08-2022 |
| **Coordinates** | 55k 0689436 / 7422656 | **Coordinates** | 55k 0689676 / 7421754 | **Coordinates** | 55K 0692385 / 7426088 |
| **Project Location** | Curragh North | **Project Location** | Curragh North | **Project Location** | Curragh North |
| **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium |
| **Dominant surface rock** | Siltstone | **Dominant surface rock** | Nil | **Dominant surface rock** | River gravel |
| **Surface rock >60mm** | 0-2% | **Surface rock >60mm** | Nil | **Surface rock >60mm** | 0-2% |
| **Vegetation** | 80% | **Vegetation** | 95% | **Vegetation** | 90% |
| **Surface Condition** | Established vegetation. Some bare patches | **Surface Condition** | Established grass vegetation. No signs of active erosion. | **Surface Condition** | Established vegetation. Evidence of minor rill erosion |
| **Texture** | Silty Loam | **Texture** | Sandy loam | **Texture** | Clayey loam |
| **Signs of salinity** | Bare patches of soil. | **Signs of salinity** | Nil | **Signs of salinity** | Nil |
| **Signs of sodicity** | Nil | **Signs of sodicity** | Nil | **Signs of sodicity** | Dense subsoil. Surface cracking in some areas. |
| **Consistence strength** | Firm | **Consistence strength** | Very friable | **Consistence strength** | Firm |
| **Consistence stickiness** | Slightly sticky | **Consistence stickiness** | Slightly sticky | **Consistence stickiness** | sticky |
| **Slope** | Flat | **Slope** | Flat | **Slope** | Flat |

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| **Material Type** | Topsoil | **Material Type** | Topsoil | **Material Type** | Topsoil |
| **Sample ID** | TS-CN-CN223 | **Sample ID** | TS-CN-CN364 | **Sample ID** | TS-CM-C051 |
| **Sample date** | 02-08-2022 | **Sample date** | 02-08-2022 | **Sample date** | 02-08-2022 |
| **Coordinates** | 55K 0691320 / 7419798 | **Coordinates** | 55k 0691478 / 7416979 | **Coordinates** | 55k 0689187 / 7401020 |
| **Project Location** | Curragh North | **Project Location** | Curragh North | **Project Location** | Curragh Main |
| **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium |
| **Dominant surface rock** | River gravel | **Dominant surface rock** | River gravel | **Dominant surface rock** | Nil |
| **Surface rock >60mm** | 0-2% | **Surface rock >60mm** | 0-2% | **Surface rock >60mm** | Nil |
| **Vegetation** | 95% | **Vegetation** | 95% | **Vegetation** | 95% |
| **Surface Condition** | Established vegetation. No evidence of active erosion. | **Surface Condition** | Established vegetation. No evidence of active erosion. | **Surface Condition** | Established grass vegetation. No evidence of active erosion. |
| **Texture** | Loam | **Texture** | Sandy loam | **Texture** | Loam |
| **Signs of salinity** | Nil | **Signs of salinity** | Nil | **Signs of salinity** | Nil |
| **Signs of sodicity** | Nil | **Signs of sodicity** | Nil | **Signs of sodicity** | Nil |
| **Consistence strength** | friable | **Consistence strength** | Weak | **Consistence strength** | Very friable |
| **Consistence stickiness** | Slight / sticky | **Consistence stickiness** | Non-sticky | **Consistence stickiness** | Slightly sticky |
| **Slope** | Flat | **Slope** | Flat | **Slope** | Flat |

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| **Material Type** | Topsoil | **Material Type** | Topsoil | **Material Type** | Topsoil |
| **Sample ID** | TS-CN-CN369/370 | **Sample ID** | TS-CM-C142 | **Sample ID** | TS-CN-C16 |
| **Sample date** | 02-08-2022 | **Sample date** | 05-08-2022 | **Sample date** | 02-08-2022 |
| **Coordinates** | 55K 0693817 / 7417549 | **Coordinates** | None given | **Coordinates** | 55k 0692264 / 7414818 |
| **Project Location** | Curragh North | **Project Location** | Curragh Main | **Project Location** | Curragh North |
| **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Quaternary alluvium | **Stockpile dominant lithology** | Topsoil |
| **Dominant surface rock** | Nil | **Dominant surface rock** | river gravel | **Dominant surface rock** | Nil |
| **Surface rock >60mm** | Nil | **Surface rock >60mm** | Nil | **Surface rock >60mm** | Nil |
| **Vegetation** | 95% | **Vegetation** | 95% | **Vegetation** | 95% |
| **Surface Condition** | Established grass vegetation. No evidence of active erosion. | **Surface Condition** | Established grass and tree vegetation. No signs of active erosion. | **Surface Condition** | Well established buffel grass. No signs of erosion. Near 100% vegetation cover. |
| **Texture** | Sandy loam | **Texture** | Sandy loam | **Texture** | Silty Loam |
| **Signs of salinity** | Nil | **Signs of salinity** | Nil | **Signs of salinity** | Nil |
| **Signs of sodicity** | Dense subsoil | **Signs of sodicity** | Nil | **Signs of sodicity** | Nil |
| **Consistence strength** | Very friable | **Consistence strength** | Friable | **Consistence strength** | Friable |
| **Consistence stickiness** | Non sticky / slightly sticky | **Consistence stickiness** | Slightly sticky | **Consistence stickiness** | Sticky |
| **Slope** | Flat | **Slope** | Flat | **Slope** | Flat |

# Appendix B:

## Certificate of Analysis

# GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No. N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | Method | Sample 1 SP-CN-C418 | Sample 2 SP-CN-C16 | Sample 3 SP-CM-C07 | Sample 4 SP-CM-C10 | Sample 5 SP-CM-C126 | Sample 6 SP-CM-C042 | Sample 7 SP-CM-C152 | Sample 8 SP-CM-C100 | Sample 9 SP-CM-C38/38 | Sample 10 SP-CM-C077 | Sample 11 SP-CN-C369/370 | Sample 12 SP-CN-CN93 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Job No.* | *N2045/1* | *N2045/2* | *N2045/3* | *N2045/4* | *N2045/5* | *N2045/6* | *N2045/7* | *N2045/8* | *N2045/9* | *N2045/10* | *N2045/11* | *N2045/12* |
| **Emerson Dispersion Class** | *Emerson Aggregate Test (EAT)* | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 2 |
| **Total Organic Carbon (%C)** | *HCL treatment- LECO Analyser* | 0.56 | 0.24 | 0.32 | 2.12 | 2.17 | 1.27 | 0.48 | 0.23 | 1.37 | 0.96 | 17.20 | 0.25 |
| **Organic Matter (%)** | *** Calculation* | 0.96 | 0.41 | 0.55 | 3.65 | 3.73 | 2.18 | 0.83 | 0.40 | 2.36 | 1.65 | 29.58 | 0.43 |
| **K Factor** | *Revised Universal Soil Loss Equation (RUSLE)* | 0.058 | 0.016 | 0.022 | 0.022 | 0.039 | 0.037 | 0.034 | 0.034 | 0.025 | 0.022 | 0.028 | 0.043 |
| **K Factor + 20% (EAT Class 1&2 soils only)** | *Revised Universal Soil Loss Equation (RUSLE)* | 0.070 | 0.019 | 0.026 | 0.027 | 0.047 | 0.044 | 0.041 | 0.041 | 0.030 | 0.026 | .. | 0.052 |

**Notes:**

1. All results as dry weight DW - samples were dried at 40 oC for 24-48 h prior to crushing and analysis.
2. Methods from Rayment and Lyons, Soil Chemical Methods - Australasia.
3. K Factor determined for RUSLE; Organic matter calculation as per RUSLE - where the TOC > 4% the 4% value has been used to determine K Factor; K Factor determined using client provided information for structure and permeability.
4. Analysis conducted between sample arrival date and reporting date.
5. ** NATA accreditation does not cover the performance of this service.
6. .. Denotes not requested.
7. This report is not to be reproduced except in full.
8. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.edu.au/eal or on request).
9. Results relate only to the samples tested.
10. This report was issued on 14/10/2022 and replaces the previous report issued on 5/10/2022. The K Factor + 20% has been corrected for EAT Class 2 soils.



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Graham Lancaster (Nata signatory)
Laboratory Manager

## GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No. N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | Method | Sample 13 SP-CN-CN320 | Sample 14 SP-CN-CN342 | Sample 15 SP-CN-CN413 | Sample 16 SP-CN-CN334 | Sample 17 SP-CN-CN364 | Sample 18 SP-CM-C051 | Sample 19 SP-CN-CN223 | Sample 20 SP-CM-C142 | Sample 21 TS-CM-C077 | Sample 22 TS-CM-C142 | Sample 23 TS-CM-C100 | Sample 24 TS-CM-C051 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Job No.* | *N2045/13* | *N2045/14* | *N2045/15* | *N2045/16* | *N2045/17* | *N2045/18* | *N2045/19* | *N2045/20* | *N2045/21* | *N2045/22* | *N2045/23* | *N2045/24* |
| **Emerson Dispersion Class** | *Emerson Aggregate Test (EAT)* | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 4 | 3 | 4 | 2 | 4 |
| **Total Organic Carbon (%C)** | *HCL treatment- LECO Analyser* | 0.15 | 0.31 | 1.15 | 16.10 | 1.03 | 2.62 | 0.89 | 0.89 | 1.35 | 6.09 | 1.06 | 2.77 |
| **Organic Matter (%)** | *** Calculation* | 0.26 | 0.53 | 1.98 | 27.69 | 1.77 | 4.51 | 1.53 | 1.53 | 2.32 | 10.47 | 1.82 | 4.76 |
| **K Factor** | *Revised Universal Soil Loss Equation (RUSLE)* | 0.006 | 0.008 | 0.042 | 0.028 | 0.029 | 0.020 | 0.022 | 0.022 | 0.021 | 0.019 | 0.018 | 0.016 |
| **K Factor + 20% (EAT Class 1&2 soils only)** | *Revised Universal Soil Loss Equation (RUSLE)* | 0.007 | .. | 0.050 | 0.034 | 0.035 | 0.024 | 0.026 | .. | .. | .. | 0.022 | .. |

**Notes:**

1. All results as dry weight DW - samples were dried at 40 oC for 24-48 h prior to crushing and analysis.
2. Methods from Rayment and Lyons, Soil Chemical Methods - Australasia.
3. K Factor determined for RUSLE; Organic matter calculation as per RUSLE - where the TOC > 4% the 4% value has be
4. Analysis conducted between sample arrival date and reporting date.
5. ** NATA accreditation does not cover the performance of this service.
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9. Results relate only to the samples tested.
10. This report was issued on 14/10/2022 and replaces the previous report issued on 5/10/2022. The K Factor + 20%



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Graham Lancaster (Nata signatory)
Laboratory Manager

## GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No. N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | Method | Sample 25 TS-CM-C042 | Sample 26 TS-CM-C07 | Sample 27 TS-CM-C10 | Sample 28 TS-CM-C38/38 | Sample 29 TS-CM-C152 | Sample 30 TS-CN-C16 | Sample 31 TS-CN-CN364 | Sample 32 TS-CN-CN223 | Sample 33 TS-CN-CN342 | Sample 34 TS-CN-CN413 | Sample 35 TS-CN-CN334 | Sample 36 TS-CN-CN93 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Job No.* | *N2045/25* | *N2045/26* | *N2045/27* | *N2045/28* | *N2045/29* | *N2045/30* | *N2045/31* | *N2045/32* | *N2045/33* | *N2045/34* | *N2045/35* | *N2045/36* |
| **Emerson Dispersion Class** | *Emerson Aggregate Test (EAT)* | 4 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 3 |
| **Total Organic Carbon (%C)** | *HCL treatment- LECO Analyser* | 1.69 | 1.51 | 1.53 | 1.28 | 1.17 | 1.60 | 0.47 | 0.87 | 1.23 | 0.74 | 1.26 | 1.92 |
| **Organic Matter (%)** | *** Calculation* | 2.91 | 2.60 | 2.63 | 2.20 | 2.01 | 2.75 | 0.81 | 1.50 | 2.12 | 1.27 | 2.17 | 3.30 |
| **K Factor** | *Revised Universal Soil Loss Equation (RUSLE)* | 0.021 | 0.034 | 0.021 | 0.029 | 0.030 | 0.018 | 0.020 | 0.026 | 0.032 | 0.026 | 0.024 | 0.022 |
| **K Factor + 20% (EAT Class 1&2 soils only)** | *Revised Universal Soil Loss Equation (RUSLE)* | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |

**Notes:**

1. All results as dry weight DW - samples were dried at 40 oC for 24-48 h prior to crushing and analysis.
2. Methods from Rayment and Lyons, Soil Chemical Methods - Australasia.
3. K Factor determined for RUSLE; Organic matter calculation as per RUSLE - where the TOC > 4% the 4% value has be
4. Analysis conducted between sample arrival date and reporting date.
5. ** NATA accreditation does not cover the performance of this service.
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9. Results relate only to the samples tested.
10. This report was issued on 14/10/2022 and replaces the previous report issued on 5/10/2022. The K Factor + 20%



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Graham Lancaster (Nata signatory)
Laboratory Manager

## GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No. N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | Method | Sample 37 TS-CN-CN320 | Sample 38 TS-CN-CN369/370 | Sample 39 TS-CM-C26 |
|---|---|---|---|---|
| | *Job No.* | *N2045/37* | *N2045/38* | *N2045/39* |
| **Emerson Dispersion Class** | *Emerson Aggregate Test (EAT)* | 3 | 3 | 2 |
| **Total Organic Carbon (%C)** | *HCL treatment- LECO Analyser* | 1.20 | 0.42 | 1.12 |
| **Organic Matter (%)** | *** Calculation* | 2.06 | 0.72 | 1.93 |
| **K Factor** | *Revised Universal Soil Loss Equation (RUSLE)* | 0.028 | 0.015 | 0.030 |
| **K Factor + 20% (EAT Class 1&2 soils only)** | *Revised Universal Soil Loss Equation (RUSLE)* | .. | .. | 0.036 |

**Notes:**

1. All results as dry weight DW - samples were dried at 40 oC for 24-48 h prior to crushing and analysis.
2. Methods from Rayment and Lyons, Soil Chemical Methods - Australasia.
3. K Factor determined for RUSLE; Organic matter calculation as per RUSLE - where the TOC > 4% the 4% value has be
4. Analysis conducted between sample arrival date and reporting date.
5. ** NATA accreditation does not cover the performance of this service.
6. .. Denotes not requested.
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9. Results relate only to the samples tested.
10. This report was issued on 14/10/2022 and replaces the previous report issued on 5/10/2022. The K Factor + 20%



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Graham Lancaster (Nata signatory)
Laboratory Manager

## GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 soil samples supplied by SLR Consulting Australia Pty Ltd on 25th August, 2022 - Lab Job No. N2045
Analysis requested by Michelle Papenfus. Job Ref SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| SAMPLE ID | Lab Code | MOISTURE CONTENT (% of water in sample) | GRAVEL > 2 mm (% of total oven-dry equivalent) | COARSE SAND 200-2000 µm (0.2-2.0 mm) (% of total oven-dry equivalent) | FINE SAND 100-200 µm (0.1-0.2 mm) (% of total oven-dry equivalent) | V. FINE SAND 20 - 100 µm (0.02-0.1 mm) (% of total oven-dry equivalent) | SILT 2-20 µm ISSS (% of total oven-dry equivalent) | CLAY < 2 µm (% of total oven-dry equivalent) |
|---|---|---|---|---|---|---|---|---|
| SP-CN-C418 | N2045/1 | 8.2% | 17.3% | 4.5% | 3.2% | 26.6% | 27.4% | 20.9% |
| SP-CN-C16 | N2045/2 | 8.0% | 5.3% | 32.4% | 3.6% | 8.4% | 4.0% | 46.3% |
| SP-CM-C07 | N2045/3 | 11.2% | 10.9% | 7.3% | 4.7% | 18.6% | 17.5% | 41.0% |
| SP-CM-C10 | N2045/4 | 9.6% | 2.4% | 7.5% | 7.6% | 28.2% | 15.2% | 39.2% |
| SP-CM-C126 | N2045/5 | 9.8% | 0.7% | 3.4% | 3.0% | 31.4% | 32.8% | 28.7% |
| SP-CM-C042 | N2045/6 | 9.2% | 22.8% | 6.8% | 5.5% | 22.1% | 18.8% | 24.1% |
| SP-CM-C152 | N2045/7 | 7.6% | 3.0% | 10.8% | 6.4% | 20.3% | 23.6% | 35.8% |
| SP-CM-C100 | N2045/8 | 8.8% | 15.5% | 21.1% | 13.4% | 17.2% | 11.5% | 21.3% |
| SP-CM-C38/38 | N2045/9 | 9.9% | 15.5% | 23.4% | 6.7% | 17.8% | 17.3% | 19.3% |
| SP-CM-C077 | N2045/10 | 12.1% | 5.0% | 6.8% | 3.0% | 14.0% | 33.5% | 37.8% |
| SP-CN-C369/370 | N2045/11 | 13.0% | 51.7% | 4.1% | 0.5% | 5.9% | 17.1% | 20.8% |
| SP-CN-CN93 | N2045/12 | 11.5% | 0.5% | 4.8% | 13.6% | 44.3% | 10.1% | 26.7% |
| SP-CN-CN320 | N2045/13 | 6.4% | 8.6% | 60.2% | 5.2% | 8.8% | 3.2% | 13.9% |
| SP-CN-CN342 | N2045/14 | 6.5% | 20.9% | 41.2% | 6.8% | 11.2% | 4.2% | 15.7% |
| SP-CN-CN413 | N2045/15 | 11.3% | 14.2% | 13.7% | 5.9% | 28.1% | 19.1% | 19.0% |
| SP-CN-CN334 | N2045/16 | 8.3% | 31.1% | 13.2% | 3.2% | 14.1% | 19.1% | 19.3% |
| SP-CN-CN364 | N2045/17 | 4.5% | 24.9% | 24.1% | 5.6% | 16.7% | 10.9% | 17.7% |
| SP-CM-C051 | N2045/18 | 13.7% | 3.2% | 9.6% | 3.1% | 12.1% | 34.7% | 37.2% |
| SP-CN-CN223 | N2045/19 | 12.9% | 24.8% | 29.6% | 6.7% | 9.1% | 10.7% | 19.0% |
| SP-CM-C142 | N2045/20 | 12.3% | 47.0% | 23.6% | 3.1% | 6.4% | 6.5% | 13.4% |
| TS-CM-C077 | N2045/21 | 14.2% | 5.4% | 9.5% | 9.8% | 17.9% | 9.9% | 47.5% |
| TS-CM-C142 | N2045/22 | 16.0% | 13.9% | 15.1% | 5.9% | 17.2% | 8.1% | 39.9% |
| TS-CM-C100 | N2045/23 | 17.0% | 0.5% | 10.8% | 7.6% | 15.7% | 14.6% | 50.9% |
| TS-CM-C051 | N2045/24 | 16.3% | 6.7% | 9.7% | 7.9% | 28.4% | 8.3% | 39.1% |
| TS-CM-C042 | N2045/25 | 21.4% | 1.4% | 3.8% | 4.2% | 12.8% | 18.0% | 59.8% |
| TS-CM-C07 | N2045/26 | 15.8% | 1.6% | 3.3% | 5.9% | 25.7% | 21.0% | 42.5% |
| TS-CM-C10 | N2045/27 | 18.5% | 0.7% | 11.5% | 6.6% | 22.4% | 3.2% | 55.7% |
| TS-CM-C38/38 | N2045/28 | 12.6% | 3.0% | 17.1% | 11.1% | 21.4% | 9.7% | 37.8% |
| TS-CM-C152 | N2045/29 | 13.2% | 0.1% | 17.1% | 13.3% | 18.3% | 13.5% | 37.7% |
| TS-CN-C16 | N2045/30 | 23.2% | 0.3% | 2.1% | 1.4% | 8.0% | 19.3% | 69.0% |
| TS-CN-CN364 | N2045/31 | 3.4% | 8.7% | 57.9% | 6.9% | 14.8% | 1.5% | 10.2% |
| TS-CN-CN223 | N2045/32 | 9.3% | 0.0% | 41.6% | 8.7% | 21.4% | 5.6% | 22.8% |
| TS-CN-CN342 | N2045/33 | 11.0% | 0.4% | 22.2% | 10.7% | 25.0% | 9.3% | 32.4% |
| TS-CN-CN413 | N2045/34 | 9.4% | 0.0% | 37.5% | 12.4% | 26.7% | 3.2% | 20.2% |
| TS-CN-CN334 | N2045/35 | 21.0% | 0.1% | 1.3% | 3.2% | 27.6% | 9.0% | 58.9% |
| TS-CN-CN93 | N2045/36 | 21.2% | 0.6% | 2.6% | 1.5% | 11.1% | 25.0% | 59.1% |
| TS-CN-CN320 | N2045/37 | 18.6% | 0.2% | 5.7% | 3.9% | 23.5% | 16.0% | 50.7% |
| TS-CN-CN369/370 | N2045/38 | 5.6% | 2.9% | 58.7% | 7.5% | 13.7% | 3.6% | 13.6% |
| TS-CM-C26 | N2045/39 | 20.2% | 1.1% | 5.2% | 5.7% | 15.7% | 14.9% | 57.4% |

**Note:**

1. The Hydrometer Analysis method was used to determine the percentage sand, silt and clay,
modified from SOP meth004 (California Dept of Pesticide Regulation), using method of Gee & Bauder (1986)," &
in Methods of Soil Analysis. Part 1 Agron. Monogr. 9 (2nd Ed). Klute, A., American Soc. of Agronomy Inc., Soil Sci. Soc. America Inc., Madison WI: 383-411.
2. The texture classification was based on the hydrometer results and the appropriate texture triangle.
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4. This report is not to be reproduced except in full.
5. This report was issued on 05/10/2022.



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Graham Lancaster (Nata signatory)
Laboratory Manager

## GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 soil samples supplied by SLR Consulting Australia Pty Ltd on 25th August, 2022 - Lab Job No. N2045
Analysis requested by Michelle Papenfus. Job Ref SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| SAMPLE ID | Lab Code | MOISTURE CONTENT (% of water in sample) | COARSE SAND 200-2000 µm (0.2-2.0 mm) (% < 2 mm oven-dry equivalent) | FINE SAND 100-200 µm (0.1-0.2 mm) (% < 2 mm oven-dry equivalent) | V. FINE SAND 20 - 100 µm (0.02-0.1 mm) (% < 2 mm oven-dry equivalent) | SILT 2-20 µm (% < 2 mm oven-dry equivalent) | CLAY < 2 µm (% < 2 mm oven-dry equivalent) |
|---|---|---|---|---|---|---|---|
| SP-CN-C418 | N2045/1 | 8.2% | 5.5% | 3.9% | 32.2% | 33.2% | 25.3% |
| SP-CN-C16 | N2045/2 | 8.0% | 34.2% | 3.8% | 8.9% | 4.3% | 48.9% |
| SP-CM-C07 | N2045/3 | 11.2% | 8.2% | 5.3% | 20.8% | 19.7% | 46.0% |
| SP-CM-C10 | N2045/4 | 9.6% | 7.7% | 7.8% | 28.9% | 15.5% | 40.1% |
| SP-CM-C126 | N2045/5 | 9.8% | 3.4% | 3.1% | 31.6% | 33.0% | 28.9% |
| SP-CM-C042 | N2045/6 | 9.2% | 8.7% | 7.1% | 28.6% | 24.3% | 31.2% |
| SP-CM-C152 | N2045/7 | 7.6% | 11.1% | 6.6% | 20.9% | 24.3% | 37.0% |
| SP-CM-C100 | N2045/8 | 8.8% | 25.0% | 15.9% | 20.3% | 13.6% | 25.2% |
| SP-CM-C38/38 | N2045/9 | 9.9% | 27.7% | 7.9% | 21.1% | 20.5% | 22.8% |
| SP-CM-C077 | N2045/10 | 12.1% | 7.1% | 3.1% | 14.7% | 35.3% | 39.7% |
| SP-CN-C369/370 | N2045/11 | 13.0% | 8.5% | 1.0% | 12.1% | 35.3% | 43.1% |
| SP-CN-CN93 | N2045/12 | 11.5% | 4.9% | 13.7% | 44.5% | 10.1% | 26.8% |
| SP-CN-CN320 | N2045/13 | 6.4% | 65.9% | 5.7% | 9.6% | 3.5% | 15.2% |
| SP-CN-CN342 | N2045/14 | 6.5% | 52.1% | 8.6% | 14.2% | 5.3% | 19.8% |
| SP-CN-CN413 | N2045/15 | 11.3% | 16.0% | 6.8% | 32.8% | 22.3% | 22.1% |
| SP-CN-CN334 | N2045/16 | 8.3% | 19.1% | 4.6% | 20.4% | 27.8% | 28.1% |
| SP-CN-CN364 | N2045/17 | 4.5% | 32.1% | 7.5% | 22.2% | 14.6% | 23.6% |
| SP-CM-C051 | N2045/18 | 13.7% | 10.0% | 3.2% | 12.5% | 35.8% | 38.5% |
| SP-CN-CN223 | N2045/19 | 12.9% | 39.4% | 8.9% | 12.1% | 14.2% | 25.3% |
| SP-CM-C142 | N2045/20 | 12.3% | 44.5% | 5.9% | 12.0% | 12.2% | 25.3% |
| TS-CM-C077 | N2045/21 | 14.2% | 10.0% | 10.3% | 18.9% | 10.5% | 50.3% |
| TS-CM-C142 | N2045/22 | 16.0% | 17.6% | 6.8% | 20.0% | 9.4% | 46.3% |
| TS-CM-C100 | N2045/23 | 17.0% | 10.9% | 7.6% | 15.7% | 14.6% | 51.1% |
| TS-CM-C051 | N2045/24 | 16.3% | 10.4% | 8.5% | 30.4% | 8.9% | 41.9% |
| TS-CM-C042 | N2045/25 | 21.4% | 3.9% | 4.3% | 13.0% | 18.2% | 60.6% |
| TS-CM-C07 | N2045/26 | 15.8% | 3.3% | 6.0% | 26.1% | 21.4% | 43.2% |
| TS-CM-C10 | N2045/27 | 18.5% | 11.6% | 6.6% | 22.5% | 3.2% | 56.0% |
| TS-CM-C38/38 | N2045/28 | 12.6% | 17.7% | 11.4% | 22.0% | 10.0% | 38.9% |
| TS-CM-C152 | N2045/29 | 13.2% | 17.1% | 13.4% | 18.3% | 13.5% | 37.7% |
| TS-CN-C16 | N2045/30 | 23.2% | 2.1% | 1.4% | 8.0% | 19.3% | 69.2% |
| TS-CN-CN364 | N2045/31 | 3.4% | 63.4% | 7.5% | 16.2% | 1.7% | 11.2% |
| TS-CN-CN223 | N2045/32 | 9.3% | 41.6% | 8.7% | 21.4% | 5.6% | 22.8% |
| TS-CN-CN342 | N2045/33 | 11.0% | 22.3% | 10.8% | 25.1% | 9.3% | 32.6% |
| TS-CN-CN413 | N2045/34 | 9.4% | 37.5% | 12.4% | 26.7% | 3.2% | 20.3% |
| TS-CN-CN334 | N2045/35 | 21.0% | 1.3% | 3.2% | 27.6% | 9.0% | 58.9% |
| TS-CN-CN93 | N2045/36 | 21.2% | 2.7% | 1.5% | 11.2% | 25.2% | 59.4% |
| TS-CN-CN320 | N2045/37 | 18.6% | 5.7% | 3.9% | 23.5% | 16.0% | 50.8% |
| TS-CN-CN369/370 | N2045/38 | 5.6% | 60.4% | 7.7% | 14.1% | 3.7% | 14.0% |
| TS-CM-C26 | N2045/39 | 20.2% | 5.1% | 1.3% | 29.3% | 12.4% | 51.9% |

**Note:**

1. The Hydrometer Analysis method was used to determine the percentage sand, silt and clay,
modified from SOP meth004 (California Dept of Pesticide Regulation), using method of Gee & Bauder (1986)," &
in Methods of Soil Analysis. Part 1 Agron. Monogr. 9 (2nd Ed). Klute, A., American Soc. of Agronomy Inc., Soil Sci. Soc. America Inc., Madison WI: 383-411.
2. The texture classification was based on the hydrometer results and the appropriate texture triangle.
3. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (see EAL website: scu.edu.au/eal).
4. This report is not to be reproduced except in full.
5. This report was issued on 05/10/2022.

Environmental Analysis Laboratory, Southern Cross University,
Tel. 02 6620 3678, website: scu.edu.au/eal



checked: .....
Graham Lancaster (Nata signatory)
Laboratory Manager

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ABN: 41 995 651 524

# AGRICULTURAL SOIL ANALYSIS REPORT

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No.N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | | | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | SP-CN-C418 | SP-CN-C16 | SP-CM-C07 | SP-CM-C10 | SP-CM-C126 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | | Method reference | N2045/1 | N2045/2 | N2045/3 | N2045/4 | N2045/5 |
| | Phosphorus (mg/kg P) | | **Rayment & Lyons 2011 - 9B2 (Colwell) | 10 | 4.9 | 5.6 | 8.2 | 8.2 |
| | Nitrate Nitrogen (mg/kg N) | | **Inhouse S37 (KCl) | 0.8 | 0.8 | 9.6 | 6.6 | 9.6 |
| | pH | | Rayment & Lyons 2011 - 4A1 (1:5 Water) | 9.5 | 8.9 | 8.7 | 9.5 | 8.3 |
| | Electrical Conductivity (dS/m) | | Rayment & Lyons 2011 - 3A1 (1:5 Water) | 0.143 | 0.178 | 1.977 | 0.500 | 2.674 |
| | Exchangeable Calcium | (cmol+/kg) | Rayment & Lyons 2011 - 15D3 (Ammonium Acetate) | 10 | 3.1 | 18 | 15 | 6.4 |
| | | (kg/ha) | | 4,588 | 1,409 | 8,001 | 6,801 | 2,854 |
| | | (mg/kg) | | 2,048 | 629 | 3,572 | 3,036 | 1,274 |
| | Exchangeable Magnesium | (cmol+/kg) | | 8.8 | 3.9 | 8.6 | 8.6 | 8.6 |
| | | (kg/ha) | | 2,395 | 1,059 | 2,330 | 2,332 | 2,341 |
| | | (mg/kg) | | 1,069 | 473 | 1,040 | 1,041 | 1,045 |
| | Exchangeable Potassium | (cmol+/kg) | | 0.31 | <0.12 | 0.13 | 0.14 | 0.30 |
| | | (kg/ha) | | 272 | <112 | 115 | 125 | 262 |
| | | (mg/kg) | | 121 | <50 | 51 | 56 | 117 |
| | Exchangeable Sodium | (cmol+/kg) | | 1.4 | 1.8 | 11 | 5.7 | 13 |
| | | (kg/ha) | | 734 | 940 | 5,896 | 2,926 | 6,553 |
| | | (mg/kg) | | 328 | 420 | 2,632 | 1,306 | 2,925 |
| | Exchangeable Aluminium | (cmol+/kg) | **Inhouse S37 (KCl) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | | (kg/ha) | | 1.1 | 1.8 | 1.1 | 1.4 | 1.3 |
| | | (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Exchangeable Hydrogen | (cmol+/kg) | **Rayment & Lyons 2011 - 15G1 (Acidity Titration) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | | (kg/ha) | | <1 | <1 | <1 | <1 | <1 |
| | | (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Effective Cation Exchange Capacity (ECEC) (cmol+/kg) | | **Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg) | 21 | 9.0 | 38 | 30 | 28 |
| | Calcium (%) | | **Base Saturation Calculations - Cation cmol+/kg / ECEC x 100 | 49 | 35 | 47 | 51 | 23 |
| | Magnesium (%) | | | 42 | 43 | 23 | 29 | 31 |
| | Potassium (%) | | | 1.5 | 1.1 | 0.35 | 0.48 | 1.1 |
| | Sodium - ESP (%) | | | 6.9 | 20 | 30 | 19 | 45 |
| | Aluminium (%) | | | 0.03 | 0.10 | 0.01 | 0.02 | 0.02 |
| | Hydrogen (%) | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Calcium/Magnesium Ratio | | **Calculation: Calcium / Magnesium (cmol+/kg) | 1.2 | 0.81 | 2.1 | 1.8 | 0.74 |

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# AGRICULTURAL SOIL ANALYSIS REPORT

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No.N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
|---|---|---|---|---|---|---|
| | Sample ID: | SP-CN-C418 | SP-CN-C16 | SP-CM-C07 | SP-CM-C10 | SP-CM-C126 |
| | Crop: | soil | soil | soil | soil | soil |
| | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/1 | N2045/2 | N2045/3 | N2045/4 | N2045/5 |
| | Zinc (mg/kg) | Rayment & Lyons 2011 - 12A1 (DTPA) | 0.9 | <0.5 | <0.5 | <0.5 | 19.3 |
| | Manganese (mg/kg) | | 3 | 1 | 4 | 2 | 3 |
| | Iron (mg/kg) | | 18 | 2 | 3 | 3 | 8 |
| | Copper (mg/kg) | | 3.0 | 0.2 | 0.4 | 0.4 | 8.7 |
| | Boron (mg/kg) | **Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$) | 0.23 | 1.19 | 1.89 | 0.97 | 0.81 |
| | Total Carbon (%) | Inhouse S4a (LECO Trumac Analyser) | 0.63 | 0.29 | 0.63 | 2.30 | 2.17 |
| | Total Nitrogen (%) | | 0.09 | 0.03 | 0.05 | 0.14 | 0.15 |
| | Total Phosphorus (mg/kg) | Rayment & Lyons 2011 - 17C1 Aqua Regia | 793 | 73 | 305 | 579 | 436 |
| | Chloride (mg/kg) | **Rayment & Lyons 2011 - 5A3a | 561 | 148 | 1,672 | 647 | 1,687 |
| | pH | **Rayment & Lyons 2011 - 4B4 ($CaCl_2$) | 8.2 | 8.0 | 8.3 | 8.6 | 7.9 |
| | Emerson Aggregate Test (EAT) | **AS1289.3.8.1-2017 | 2 | 2 | 2 | 2 | 2 |

**Notes:**

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 cmol$_+$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer SCU.edu.au/eal/t&cs).
17. This report was issued on 5/10/2022 and replaces the report published 14/09/2022. Total carbon data has been amended.

NATA
WORLD RECOGNISED ACCREDITATION
Accreditation No. 14960
Accredited for compliance with ISO/IEC 17025 - Testing

*Quality Checked: Kris Saville*
*Agricultural Co-Ordinator* KS

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## AGRICULTURAL SOIL ANALYSIS REPORT

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Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | | | Sample 6 | Sample 7 | Sample 8 | Sample 9 | Sample 10 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | SP-CM-C042 | SP-CM-C152 | SP-CM-C100 | SP-CM-C38/38 | SP-CM-C077 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/6 | N2045/7 | N2045/8 | N2045/9 | N2045/10 |
| | Phosphorus (mg/kg P) | **Rayment & Lyons 2011 - 9B2 (Colwell) | 5.9 | 6.2 | 10 | 5.6 | 9.2 |
| | Nitrate Nitrogen (mg/kg N) | **Inhouse S37 (KCl) | 0.8 | 7.1 | 0.8 | 1.4 | 24.5 |
| | pH | Rayment & Lyons 2011 - 4A1 (1:5 Water) | 9.8 | 8.8 | 9.4 | 10.0 | 9.2 |
| | Electrical Conductivity (dS/m) | Rayment & Lyons 2011 - 3A1 (1:5 Water) | 0.222 | 3.221 | 0.117 | 0.420 | 0.738 |
| | Exchangeable Calcium (cmol+/kg) | Rayment & Lyons 2011 - 15D3 (Ammonium Acetate) | 14 | 10 | 8.9 | 10 | 16 |
| | Exchangeable Calcium (kg/ha) | | 6,062 | 4,694 | 4,007 | 4,652 | 7,148 |
| | Exchangeable Calcium (mg/kg) | | 2,706 | 2,096 | 1,789 | 2,077 | 3,191 |
| | Exchangeable Magnesium (cmol+/kg) | | 14 | 9.2 | 6.5 | 6.3 | 6.1 |
| | Exchangeable Magnesium (kg/ha) | | 3,817 | 2,494 | 1,773 | 1,728 | 1,658 |
| | Exchangeable Magnesium (mg/kg) | | 1,704 | 1,113 | 791 | 771 | 740 |
| | Exchangeable Potassium (cmol+/kg) | | 0.30 | 0.15 | 0.14 | 0.17 | 0.14 |
| | Exchangeable Potassium (kg/ha) | | 259 | 134 | 126 | 151 | 121 |
| | Exchangeable Potassium (mg/kg) | | 116 | 60 | 56 | 67 | 54 |
| | Exchangeable Sodium (cmol+/kg) | | 2.5 | 17 | 3.3 | 4.0 | 4.9 |
| | Exchangeable Sodium (kg/ha) | | 1,276 | 8,498 | 1,685 | 2,040 | 2,503 |
| | Exchangeable Sodium (mg/kg) | | 569 | 3,794 | 752 | 911 | 1,117 |
| | Exchangeable Aluminium (cmol+/kg) | **Inhouse S37 (KCl) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | Exchangeable Aluminium (kg/ha) | | 1.0 | 1.4 | 1.2 | <1 | <1 |
| | Exchangeable Aluminium (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Exchangeable Hydrogen (cmol+/kg) | **Rayment & Lyons 2011 - 15G1 (Acidity Titration) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | Exchangeable Hydrogen (kg/ha) | | <1 | <1 | <1 | <1 | <1 |
| | Exchangeable Hydrogen (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Effective Cation Exchange Capacity (ECEC) (cmol+/kg) | **Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg) | 30 | 36 | 19 | 21 | 27 |
| | Calcium (%) | **Base Saturation Calculations - Cation cmol+/kg / ECEC x 100 | 45 | 29 | 47 | 50 | 59 |
| | Magnesium (%) | | 46 | 25 | 35 | 30 | 23 |
| | Potassium (%) | | 0.98 | 0.42 | 0.76 | 0.83 | 0.51 |
| | Sodium - ESP (%) | | 8.2 | 45 | 17 | 19 | 18 |
| | Aluminium (%) | | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 |
| | Hydrogen (%) | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Calcium/Magnesium Ratio | **Calculation: Calcium / Magnesium (cmol+/kg) | 0.96 | 1.1 | 1.4 | 1.6 | 2.6 |

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| | | | Sample 6 | Sample 7 | Sample 8 | Sample 9 | Sample 10 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | SP-CM-C042 | SP-CM-C152 | SP-CM-C100 | SP-CM-C38/38 | SP-CM-C077 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/6 | N2045/7 | N2045/8 | N2045/9 | N2045/10 |
| | Zinc (mg/kg) | Rayment & Lyons 2011 - 12A1 (DTPA) | <0.5 | <0.5 | <0.5 | 0.8 | <0.5 |
| | Manganese (mg/kg) | | 0 | 0 | 1 | 2 | 2 |
| | Iron (mg/kg) | | 1 | <0.5 | 2 | 4 | 2 |
| | Copper (mg/kg) | | 0.1 | <0.1 | 0.2 | 0.2 | 0.5 |
| | Boron (mg/kg) | **Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$) | 0.35 | 1.17 | 0.47 | 0.29 | 0.78 |
| | Total Carbon (%) | Inhouse S4a (LECO Trumac Analyser) | 2.30 | 0.54 | 0.23 | 2.04 | 1.63 |
| | Total Nitrogen (%) | | 0.11 | 0.06 | 0.06 | 0.09 | 0.11 |
| | Total Phosphorus (mg/kg) | Rayment & Lyons 2011 - 17C1 Aqua Regia | 784 | 540 | 165 | 656 | 1,065 |
| | Chloride (mg/kg) | **Rayment & Lyons 2011 - 5A3a | 669 | 2,001 | 794 | 168 | 544 |
| | pH | **Rayment & Lyons 2011 - 4B4 ($CaCl_2$) | 8.3 | 8.4 | 7.7 | 8.3 | 8.4 |
| | Emerson Aggregate Test (EAT) | **AS1289.3.8.1-2017 | 2 | 2 | 2 | 2 | 2 |

**Notes:**

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil resu
10. Conversions for 1 cmol$_c$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
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17. This report was issued on 5/10/2022 and replaces the report published 14/09/2022. Total ca

*Quality Checked: Kris Saville*
*Agricultural Co-Ordinator* KS

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| | | | Sample 11 | Sample 12 | Sample 13 | Sample 14 | Sample 15 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | SP-CN-C369/370 | SP-CN-CN93 | SP-CN-CN320 | SP-CN-CN342 | SP-CN-CN413 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | | Method reference | N2045/11 | N2045/12 | N2045/13 | N2045/14 | N2045/15 |
| | Phosphorus (mg/kg P) | | **Rayment & Lyons 2011 - 9B2 (Colwell) | 38 | 20 | 6.9 | 12 | 6.9 |
| | Nitrate Nitrogen (mg/kg N) | | **Inhouse S37 (KCl) | 0.8 | 0.7 | <0.1 | <0.1 | 0.7 |
| | pH | | Rayment & Lyons 2011 - 4A1 (1:5 Water) | 5.7 | 9.2 | 9.2 | 3.4 | 9.3 |
| | Electrical Conductivity (dS/m) | | Rayment & Lyons 2011 - 3A1 (1:5 Water) | 0.118 | 0.180 | 0.036 | 1.336 | 0.122 |
| | Exchangeable Calcium | (cmol+/kg) | Rayment & Lyons 2011 - 15D3 (Ammonium Acetate) | 6.2 | 11 | 2.2 | 6.4 | 12 |
| | | (kg/ha) | | 2,799 | 5,098 | 999 | 2,854 | 5,382 |
| | | (mg/kg) | | 1,250 | 2,276 | 446 | 1,274 | 2,403 |
| | Exchangeable Magnesium | (cmol+/kg) | | 6.7 | 6.3 | 2.4 | 3.9 | 7.6 |
| | | (kg/ha) | | 1,837 | 1,727 | 662 | 1,056 | 2,064 |
| | | (mg/kg) | | 820 | 771 | 296 | 471 | 921 |
| | Exchangeable Potassium | (cmol+/kg) | | 0.20 | 0.28 | <0.12 | <0.12 | 0.26 |
| | | (kg/ha) | | 178 | 241 | <112 | <112 | 226 |
| | | (mg/kg) | | 79 | 108 | <50 | <50 | 101 |
| | Exchangeable Sodium | (cmol+/kg) | | 0.24 | 2.2 | 0.47 | 0.30 | 0.69 |
| | | (kg/ha) | | 125 | 1,141 | 241 | 152 | 354 |
| | | (mg/kg) | | 56 | 510 | 108 | 68 | 158 |
| | Exchangeable Aluminium | (cmol+/kg) | **Inhouse S37 (KCl) | 0.19 | <0.01 | <0.01 | 2.8 | 0.03 |
| | | (kg/ha) | | 37 | 1.6 | <1 | 571 | 6.9 |
| | | (mg/kg) | | 17 | <1 | <1 | 255 | 3.1 |
| | Exchangeable Hydrogen | (cmol+/kg) | **Rayment & Lyons 2011 - 15G1 (Acidity Titration) | 0.18 | <0.01 | <0.01 | 1.2 | <0.01 |
| | | (kg/ha) | | 4.0 | <1 | <1 | 28 | <1 |
| | | (mg/kg) | | 1.8 | <1 | <1 | 12 | <1 |
| | Effective Cation Exchange Capacity (ECEC) (cmol+/kg) | | **Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg) | 14 | 20 | 5.2 | 15 | 21 |
| | Calcium (%) | | **Base Saturation Calculations - Cation cmol+/kg / ECEC x 100 | 45 | 56 | 43 | 43 | 58 |
| | Magnesium (%) | | | 49 | 31 | 47 | 26 | 37 |
| | Potassium (%) | | | 1.5 | 1.4 | 0.83 | 0.29 | 1.3 |
| | Sodium - ESP (%) | | | 1.8 | 11 | 9.0 | 2.0 | 3.3 |
| | Aluminium (%) | | | 1.3 | 0.04 | 0.07 | 19 | 0.17 |
| | Hydrogen (%) | | | 1.3 | 0.00 | 0.00 | 8.4 | 0.00 |
| | Calcium/Magnesium Ratio | | **Calculation: Calcium / Magnesium (cmol+/kg) | 0.92 | 1.8 | 0.91 | 1.6 | 1.6 |

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10 Kings Road NEW LAMBTON NSW 2305

| | Parameter | Method reference | Sample 11 SP-CN-C369/370 soil SLR Consulting Australia Pty Ltd N2045/11 | Sample 12 SP-CN-CN93 soil SLR Consulting Australia Pty Ltd N2045/12 | Sample 13 SP-CN-CN320 soil SLR Consulting Australia Pty Ltd N2045/13 | Sample 14 SP-CN-CN342 soil SLR Consulting Australia Pty Ltd N2045/14 | Sample 15 SP-CN-CN413 soil SLR Consulting Australia Pty Ltd N2045/15 |
|---|---|---|---|---|---|---|---|
| | Zinc (mg/kg) | Rayment & Lyons 2011 - 12A1 (DTPA) | 0.6 | <0.5 | <0.5 | 1.0 | 2.7 |
| | Manganese (mg/kg) | | 18 | 2 | 1 | 8 | 2 |
| | Iron (mg/kg) | | 20 | 3 | 2 | 16 | 9 |
| | Copper (mg/kg) | | 0.9 | 0.4 | 0.2 | 0.1 | 2.5 |
| | Boron (mg/kg) | **Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$) | 0.26 | 0.69 | <0.1 | 0.27 | 0.19 |
| | Total Carbon (%) | Inhouse S4a (LECO Trumac Analyser) | 17.20 | 0.25 | 0.15 | 0.31 | 1.36 |
| | Total Nitrogen (%) | | 0.53 | 0.03 | 0.03 | 0.04 | 0.10 |
| | Total Phosphorus (mg/kg) | Rayment & Lyons 2011 - 17C1 Aqua Regia | 761 | 469 | 109 | 183 | 510 |
| | Chloride (mg/kg) | **Rayment & Lyons 2011 - 5A3a | 66 | 59 | 15 | 43 | 16 |
| | pH | **Rayment & Lyons 2011 - 4B4 ($CaCl_2$) | 5.2 | 8.3 | 8.2 | 3.3 | 8.5 |
| | Emerson Aggregate Test (EAT) | **AS1289.3.8.1-2017 | 4 | 2 | 2 | 4 | 2 |

**Notes:**

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
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11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Condit
17. This report was issued on 5/10/2022 and replaces the report published 14/09/2022. Total ca

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*Agricultural Co-Ordinator* KS

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ABN: 41 995 651 524

## AGRICULTURAL SOIL ANALYSIS REPORT

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No.N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | | | Sample 16 | Sample 17 | Sample 18 | Sample 19 | Sample 20 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | SP-CN-CN334 | SP-CN-CN364 | SP-CM-C051 | SP-CN-CN223 | SP-CM-C142 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | | Method reference | N2045/16 | N2045/17 | N2045/18 | N2045/19 | N2045/20 |
| | Phosphorus (mg/kg P) | | **Rayment & Lyons 2011 - 9B2 (Colwell) | 20 | 13 | 21 | 15 | 6.9 |
| | Nitrate Nitrogen (mg/kg N) | | **Inhouse S37 (KCl) | 0.8 | 6.3 | 9.1 | 4.7 | 1.3 |
| | pH | | Rayment & Lyons 2011 - 4A1 (1:5 Water) | 9.5 | 9.7 | 9.1 | 9.5 | 9.1 |
| | Electrical Conductivity (dS/m) | | Rayment & Lyons 2011 - 3A1 (1:5 Water) | 0.273 | 0.426 | 0.696 | 0.194 | 0.108 |
| | Exchangeable Calcium | (cmol+/kg) | Rayment & Lyons 2011 - 15D3 (Ammonium Acetate) | 7.5 | 10 | 16 | 9.8 | 30 |
| | | (kg/ha) | | 3,366 | 4,541 | 7,346 | 4,416 | 13,680 |
| | | (mg/kg) | | 1,503 | 2,027 | 3,279 | 1,971 | 6,107 |
| | Exchangeable Magnesium | (cmol+/kg) | | 5.5 | 6.0 | 9.8 | 7.7 | 5.3 |
| | | (kg/ha) | | 1,485 | 1,646 | 2,662 | 2,085 | 1,446 |
| | | (mg/kg) | | 663 | 735 | 1,188 | 931 | 645 |
| | Exchangeable Potassium | (cmol+/kg) | | 0.19 | 0.25 | 0.16 | 0.24 | 0.14 |
| | | (kg/ha) | | 166 | 215 | 138 | 213 | 123 |
| | | (mg/kg) | | 74 | 96 | 62 | 95 | 55 |
| | Exchangeable Sodium | (cmol+/kg) | | 2.8 | 3.6 | 5.0 | 1.9 | 0.64 |
| | | (kg/ha) | | 1,425 | 1,872 | 2,589 | 975 | 330 |
| | | (mg/kg) | | 636 | 836 | 1,156 | 435 | 147 |
| | Exchangeable Aluminium | (cmol+/kg) | **Inhouse S37 (KCl) | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 |
| | | (kg/ha) | | <1 | <1 | <1 | <1 | 2.6 |
| | | (mg/kg) | | <1 | <1 | <1 | <1 | 1.1 |
| | Exchangeable Hydrogen | (cmol+/kg) | **Rayment & Lyons 2011 - 15G1 (Acidity Titration) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | | (kg/ha) | | <1 | <1 | <1 | <1 | <1 |
| | | (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Effective Cation Exchange Capacity (ECEC) (cmol+/kg) | | **Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg) | 16 | 20 | 31 | 20 | 37 |
| | Calcium (%) | | **Base Saturation Calculations - Cation cmol+/kg / ECEC x 100 | 47 | 50 | 52 | 50 | 83 |
| | Magnesium (%) | | | 34 | 30 | 31 | 39 | 15 |
| | Potassium (%) | | | 1.2 | 1.2 | 0.50 | 1.2 | 0.38 |
| | Sodium - ESP (%) | | | 17 | 18 | 16 | 9.6 | 1.8 |
| | Aluminium (%) | | | 0.02 | 0.02 | 0.00 | 0.01 | 0.03 |
| | Hydrogen (%) | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Calcium/Magnesium Ratio | | **Calculation: Calcium / Magnesium (cmol+/kg) | 1.4 | 1.7 | 1.7 | 1.3 | 5.7 |

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39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No.N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | | | Sample 16 | Sample 17 | Sample 18 | Sample 19 | Sample 20 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | SP-CN-CN334 | SP-CN-CN364 | SP-CM-C051 | SP-CN-CN223 | SP-CM-C142 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/16 | N2045/17 | N2045/18 | N2045/19 | N2045/20 |
| | Zinc (mg/kg) | Rayment & Lyons 2011 - 12A1 (DTPA) | 5.8 | 3.5 | <0.5 | 0.7 | <0.5 |
| | Manganese (mg/kg) | | 12 | 8 | 0 | 1 | 4 |
| | Iron (mg/kg) | | 30 | 16 | <0.5 | 2 | 5 |
| | Copper (mg/kg) | | 3.2 | 2.1 | <0.1 | 0.2 | 0.2 |
| | Boron (mg/kg) | **Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$) | 0.16 | 0.32 | 0.91 | 0.36 | 0.18 |
| | Total Carbon (%) | Inhouse S4a (LECO Trumac Analyser) | 18.50 | 1.67 | 3.23 | 1.25 | 1.71 |
| | Total Nitrogen (%) | | 0.45 | 0.09 | 0.14 | 0.07 | 0.06 |
| | Total Phosphorus (mg/kg) | Rayment & Lyons 2011 - 17C1 Aqua Regia | 655 | 617 | 897 | 626 | 1,550 |
| | Chloride (mg/kg) | **Rayment & Lyons 2011 - 5A3a | 71 | 156 | 273 | 62 | 34 |
| | pH | **Rayment & Lyons 2011 - 4B4 ($CaCl_2$) | 8.8 | 8.4 | 8.5 | 8.1 | 8.2 |
| | Emerson Aggregate Test (EAT) | **AS1289.3.8.1-2017 | 2 | 2 | 2 | 2 | 4 |

**Notes:**

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil resu
10. Conversions for 1 cmol$_+$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
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| | | | Sample 21 | Sample 22 | Sample 23 | Sample 24 | Sample 25 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | TS-CM-C077 | TS-CM-C142 | TS-CM-C100 | TS-CM-C051 | TS-CM-C042 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | | Method reference | N2045/21 | N2045/22 | N2045/23 | N2045/24 | N2045/25 |
| | Phosphorus (mg/kg P) | | **Rayment & Lyons 2011 - 9B2 (Colwell) | 12 | 7.2 | 17 | 13 | 8.5 |
| | Nitrate Nitrogen (mg/kg N) | | **Inhouse S37 (KCl) | 9.6 | 1.8 | 25.6 | 95.7 | 11.0 |
| | pH | | Rayment & Lyons 2011 - 4A1 (1:5 Water) | 8.9 | 8.5 | 8.9 | 8.4 | 8.8 |
| | Electrical Conductivity (dS/m) | | Rayment & Lyons 2011 - 3A1 (1:5 Water) | 0.177 | 0.075 | 0.375 | 0.301 | 0.142 |
| | Exchangeable Calcium | (cmol+/kg) | Rayment & Lyons 2011 - 15D3 (Ammonium Acetate) | 27 | 30 | 24 | 38 | 41 |
| | | (kg/ha) | | 11,980 | 13,323 | 10,805 | 17,041 | 18,426 |
| | | (mg/kg) | | 5,348 | 5,948 | 4,824 | 7,608 | 8,226 |
| | Exchangeable Magnesium | (cmol+/kg) | | 6.9 | 7.6 | 7.8 | 2.6 | 9.4 |
| | | (kg/ha) | | 1,872 | 2,063 | 2,130 | 721 | 2,565 |
| | | (mg/kg) | | 836 | 921 | 951 | 322 | 1,145 |
| | Exchangeable Potassium | (cmol+/kg) | | 0.51 | 0.35 | 0.45 | 1.1 | 0.76 |
| | | (kg/ha) | | 444 | 302 | 390 | 941 | 669 |
| | | (mg/kg) | | 198 | 135 | 174 | 420 | 299 |
| | Exchangeable Sodium | (cmol+/kg) | | 1.5 | 0.53 | 3.4 | 0.49 | 0.78 |
| | | (kg/ha) | | 765 | 272 | 1,731 | 251 | 404 |
| | | (mg/kg) | | 341 | 121 | 773 | 112 | 180 |
| | Exchangeable Aluminium | (cmol+/kg) | **Inhouse S37 (KCl) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | | (kg/ha) | | 1.4 | <1 | <1 | <1 | <1 |
| | | (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Exchangeable Hydrogen | (cmol+/kg) | **Rayment & Lyons 2011 - 15G1 (Acidity Titration) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | | (kg/ha) | | <1 | <1 | <1 | <1 | <1 |
| | | (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Effective Cation Exchange Capacity (ECEC) (cmol+/kg) | | **Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg) | 36 | 38 | 36 | 42 | 52 |
| | Calcium (%) | | **Base Saturation Calculations - Cation cmol+/kg / ECEC x 100 | 75 | 78 | 67 | 90 | 79 |
| | Magnesium (%) | | | 19 | 20 | 22 | 6.3 | 18 |
| | Potassium (%) | | | 1.4 | 0.91 | 1.2 | 2.5 | 1.5 |
| | Sodium - ESP (%) | | | 4.2 | 1.4 | 9.4 | 1.2 | 1.5 |
| | Aluminium (%) | | | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| | Hydrogen (%) | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Calcium/Magnesium Ratio | | **Calculation: Calcium / Magnesium (cmol+/kg) | 3.9 | 3.9 | 3.1 | 14 | 4.4 |

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Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

| | | | Sample 21 | Sample 22 | Sample 23 | Sample 24 | Sample 25 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | TS-CM-C077 | TS-CM-C142 | TS-CM-C100 | TS-CM-C051 | TS-CM-C042 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/21 | N2045/22 | N2045/23 | N2045/24 | N2045/25 |
| | Zinc (mg/kg) | Rayment & Lyons 2011 - 12A1 (DTPA) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| | Manganese (mg/kg) | | 6 | 4 | 5 | 4 | 3 |
| | Iron (mg/kg) | | 9 | 3 | 9 | 7 | 7 |
| | Copper (mg/kg) | | 1.6 | 0.7 | 1.3 | 0.7 | 1.2 |
| | Boron (mg/kg) | **Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$) | 0.55 | 0.41 | 0.98 | 0.31 | 0.54 |
| | Total Carbon (%) | Inhouse S4a (LECO Trumac Analyser) | 1.48 | 6.69 | 1.10 | 4.29 | 1.69 |
| | Total Nitrogen (%) | | 0.12 | 0.22 | 0.10 | 0.25 | 0.13 |
| | Total Phosphorus (mg/kg) | Rayment & Lyons 2011 - 17C1 Aqua Regia | 388 | 513 | 259 | 464 | 360 |
| | Chloride (mg/kg) | **Rayment & Lyons 2011 - 5A3a | 32 | 30 | 290 | 69 | 20 |
| | pH | **Rayment & Lyons 2011 - 4B4 ($CaCl_2$) | 8.0 | 7.7 | 8.1 | 7.8 | 8.0 |
| | Emerson Aggregate Test (EAT) | **AS1289.3.8.1-2017 | 3 | 4 | 2 | 4 | 4 |

**Notes:**

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil resu
10. Conversions for 1 cmol$_c$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
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| | | | Sample 26 | Sample 27 | Sample 28 | Sample 29 | Sample 30 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | TS-CM-C07 | TS-CM-C10 | TS-CM-C38/38 | TS-CM-C152 | TS-CN-C16 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | | Method reference | N2045/26 | N2045/27 | N2045/28 | N2045/29 | N2045/30 |
| | Phosphorus (mg/kg P) | | **Rayment & Lyons 2011 - 9B2 (Colwell) | 8.2 | 6.9 | 10 | 7.9 | 27 |
| | Nitrate Nitrogen (mg/kg N) | | **Inhouse S37 (KCl) | 4.2 | 3.8 | 4.2 | 3.1 | 2.7 |
| | pH | | Rayment & Lyons 2011 - 4A1 (1:5 Water) | 8.9 | 8.8 | 9.1 | 8.8 | 8.9 |
| | Electrical Conductivity (dS/m) | | Rayment & Lyons 2011 - 3A1 (1:5 Water) | 0.127 | 0.141 | 0.154 | 0.103 | 0.156 |
| | Exchangeable Calcium | (cmol+/kg) | Rayment & Lyons 2011 - 15D3 (Ammonium Acetate) | 26 | 28 | 25 | 23 | 34 |
| | | (kg/ha) | | 11,473 | 12,692 | 11,266 | 10,179 | 15,405 |
| | | (mg/kg) | | 5,122 | 5,666 | 5,029 | 4,544 | 6,877 |
| | Exchangeable Magnesium | (cmol+/kg) | | 7.7 | 9.9 | 4.9 | 5.1 | 10 |
| | | (kg/ha) | | 2,097 | 2,686 | 1,342 | 1,392 | 2,825 |
| | | (mg/kg) | | 936 | 1,199 | 599 | 621 | 1,261 |
| | Exchangeable Potassium | (cmol+/kg) | | 0.43 | 1.5 | 0.41 | 0.38 | 0.91 |
| | | (kg/ha) | | 378 | 1,291 | 357 | 335 | 801 |
| | | (mg/kg) | | 169 | 576 | 160 | 150 | 358 |
| | Exchangeable Sodium | (cmol+/kg) | | 1.9 | 0.56 | 1.4 | 0.22 | 1.5 |
| | | (kg/ha) | | 979 | 291 | 711 | 111 | 784 |
| | | (mg/kg) | | 437 | 130 | 317 | 50 | 350 |
| | Exchangeable Aluminium | (cmol+/kg) | **Inhouse S37 (KCl) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | | (kg/ha) | | <1 | <1 | <1 | <1 | <1 |
| | | (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Exchangeable Hydrogen | (cmol+/kg) | **Rayment & Lyons 2011 - 15G1 (Acidity Titration) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | | (kg/ha) | | <1 | <1 | <1 | <1 | <1 |
| | | (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Effective Cation Exchange Capacity (ECEC) (cmol+/kg) | | **Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg) | 36 | 40 | 32 | 28 | 47 |
| | Calcium (%) | | **Base Saturation Calculations - Cation cmol+/kg / ECEC x 100 | 72 | 70 | 79 | 80 | 73 |
| | Magnesium (%) | | | 22 | 25 | 15 | 18 | 22 |
| | Potassium (%) | | | 1.2 | 3.7 | 1.3 | 1.3 | 1.9 |
| | Sodium - ESP (%) | | | 5.3 | 1.4 | 4.3 | 0.76 | 3.2 |
| | Aluminium (%) | | | 0.01 | 0.01 | 0.00 | 0.02 | 0.01 |
| | Hydrogen (%) | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Calcium/Magnesium Ratio | | **Calculation: Calcium / Magnesium (cmol+/kg) | 3.3 | 2.9 | 5.1 | 4.4 | 3.3 |

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| | | | Sample 26 | Sample 27 | Sample 28 | Sample 29 | Sample 30 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | TS-CM-C07 | TS-CM-C10 | TS-CM-C38/38 | TS-CM-C152 | TS-CN-C16 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/26 | N2045/27 | N2045/28 | N2045/29 | N2045/30 |
| | Zinc (mg/kg) | Rayment & Lyons 2011 - 12A1 (DTPA) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| | Manganese (mg/kg) | | 5 | 6 | 5 | 8 | 4 |
| | Iron (mg/kg) | | 11 | 7 | 7 | 5 | 7 |
| | Copper (mg/kg) | | 1.3 | 2.0 | 1.1 | 1.0 | 1.1 |
| | Boron (mg/kg) | **Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$) | 0.66 | 0.61 | 0.93 | 0.48 | 0.96 |
| | Total Carbon (%) | Inhouse S4a (LECO Trumac Analyser) | 1.59 | 1.57 | 1.36 | 1.20 | 1.63 |
| | Total Nitrogen (%) | | 0.14 | 0.14 | 0.11 | 0.12 | 0.14 |
| | Total Phosphorus (mg/kg) | Rayment & Lyons 2011 - 17C1 Aqua Regia | 211 | 212 | 161 | 187 | 657 |
| | Chloride (mg/kg) | **Rayment & Lyons 2011 - 5A3a | 16 | 16 | 19 | 4.6 | 15 |
| | pH | **Rayment & Lyons 2011 - 4B4 ($CaCl_2$) | 7.9 | 8.0 | 8.2 | 8.0 | 8.1 |
| | Emerson Aggregate Test (EAT) | **AS1289.3.8.1-2017 | 3 | 4 | 3 | 4 | 4 |

**Notes:**

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil resu
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11. Conversions to kg/ha = mg/kg x 2.24
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| | | | Sample 31 | Sample 32 | Sample 33 | Sample 34 | Sample 35 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | TS-CN-CN364 | TS-CN-CN223 | TS-CN-CN342 | TS-CN-CN413 | TS-CN-CN334 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/31 | N2045/32 | N2045/33 | N2045/34 | N2045/35 |
| | Phosphorus (mg/kg P) | **Rayment & Lyons 2011 - 9B2 (Colwell) | 8.2 | 38 | 58 | 41 | 49 |
| | Nitrate Nitrogen (mg/kg N) | **Inhouse S37 (KCl) | 1.3 | 81.4 | 10.0 | 3.5 | 5.7 |
| | pH | Rayment & Lyons 2011 - 4A1 (1:5 Water) | 8.8 | 7.5 | 7.6 | 8.4 | 8.3 |
| | Electrical Conductivity (dS/m) | Rayment & Lyons 2011 - 3A1 (1:5 Water) | 0.066 | 0.259 | 0.079 | 0.072 | 0.090 |
| | Exchangeable Calcium (cmol+/kg) | Rayment & Lyons 2011 - 15D3 (Ammonium Acetate) | 6.6 | 10 | 13 | 11 | 21 |
| | Exchangeable Calcium (kg/ha) | | 2,942 | 4,615 | 5,727 | 4,933 | 9,642 |
| | Exchangeable Calcium (mg/kg) | | 1,314 | 2,060 | 2,557 | 2,202 | 4,304 |
| | Exchangeable Magnesium (cmol+/kg) | | 0.93 | 3.3 | 5.4 | 2.4 | 9.3 |
| | Exchangeable Magnesium (kg/ha) | | 254 | 893 | 1,460 | 646 | 2,543 |
| | Exchangeable Magnesium (mg/kg) | | 113 | 398 | 652 | 288 | 1,135 |
| | Exchangeable Potassium (cmol+/kg) | | <0.12 | 0.44 | 0.99 | 0.36 | 0.62 |
| | Exchangeable Potassium (kg/ha) | | <112 | 381 | 864 | 316 | 540 |
| | Exchangeable Potassium (mg/kg) | | <50 | 170 | 386 | 141 | 241 |
| | Exchangeable Sodium (cmol+/kg) | | 0.12 | 0.54 | 0.36 | 0.17 | 1.3 |
| | Exchangeable Sodium (kg/ha) | | 60 | 278 | 187 | 87 | 652 |
| | Exchangeable Sodium (mg/kg) | | 27 | 124 | 83 | 39 | 291 |
| | Exchangeable Aluminium (cmol+/kg) | **Inhouse S37 (KCl) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | Exchangeable Aluminium (kg/ha) | | <1 | <1 | <1 | <1 | <1 |
| | Exchangeable Aluminium (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Exchangeable Hydrogen (cmol+/kg) | **Rayment & Lyons 2011 - 15G1 (Acidity Titration) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | Exchangeable Hydrogen (kg/ha) | | <1 | <1 | <1 | <1 | <1 |
| | Exchangeable Hydrogen (mg/kg) | | <1 | <1 | <1 | <1 | <1 |
| | Effective Cation Exchange Capacity (ECEC) (cmol+/kg) | **Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg) | 7.7 | 15 | 19 | 14 | 33 |
| | Calcium (%) | **Base Saturation Calculations - Cation cmol+/kg / ECEC x 100 | 85 | 71 | 66 | 79 | 66 |
| | Magnesium (%) | | 12 | 23 | 28 | 17 | 29 |
| | Potassium (%) | | 1.5 | 3.0 | 5.1 | 2.6 | 1.9 |
| | Sodium - ESP (%) | | 1.5 | 3.7 | 1.9 | 1.2 | 3.9 |
| | Aluminium (%) | | 0.05 | 0.02 | 0.01 | 0.02 | 0.01 |
| | Hydrogen (%) | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Calcium/Magnesium Ratio | **Calculation: Calcium / Magnesium (cmol+/kg) | 7.0 | 3.1 | 2.4 | 4.6 | 2.3 |

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## AGRICULTURAL SOIL ANALYSIS REPORT

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| | | | Sample 31 | Sample 32 | Sample 33 | Sample 34 | Sample 35 |
|---|---|---|---|---|---|---|---|
| | | Sample ID: | TS-CN-CN364 | TS-CN-CN223 | TS-CN-CN342 | TS-CN-CN413 | TS-CN-CN334 |
| | | Crop: | soil | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/31 | N2045/32 | N2045/33 | N2045/34 | N2045/35 |
| | Zinc (mg/kg) | Rayment & Lyons 2011 - 12A1 (DTPA) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| | Manganese (mg/kg) | | 3 | 6 | 6 | 4 | 6 |
| | Iron (mg/kg) | | 12 | 12 | 9 | 4 | 10 |
| | Copper (mg/kg) | | 0.4 | 0.5 | 0.8 | 0.5 | 0.9 |
| | Boron (mg/kg) | **Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$) | 0.35 | 0.39 | 0.36 | 0.31 | 1.05 |
| | Total Carbon (%) | Inhouse S4a (LECO Trumac Analyser) | 0.47 | 0.87 | 1.23 | 0.77 | 1.28 |
| | Total Nitrogen (%) | | 0.05 | 0.08 | 0.09 | 0.06 | 0.09 |
| | Total Phosphorus (mg/kg) | Rayment & Lyons 2011 - 17C1 Aqua Regia | 138 | 356 | 432 | 439 | 405 |
| | Chloride (mg/kg) | **Rayment & Lyons 2011 - 5A3a | 10 | 124 | 38 | 11 | 11 |
| | pH | **Rayment & Lyons 2011 - 4B4 ($CaCl_2$) | 8.2 | 7.1 | 7.0 | 7.8 | 7.4 |
| | Emerson Aggregate Test (EAT) | **AS1289.3.8.1-2017 | 3 | 4 | 3 | 3 | 3 |

**Notes:**

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil resu
10. Conversions for 1 cmol$_+$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Condit
17. This report was issued on 5/10/2022 and replaces the report published 14/09/2022. Total ca

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Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
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| | | | Sample 36 | Sample 37 | Sample 38 | Sample 39 |
|---|---|---|---|---|---|---|
| | | Sample ID: | TS-CN-CN93 | TS-CN-CN320 | TS-CN-CN369/370 | TS-CM-C26 |
| | | Crop: | soil | soil | soil | soil |
| | | Client: | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/36 | N2045/37 | N2045/38 | N2045/39 |
| | Phosphorus (mg/kg P) | **Rayment & Lyons 2011 - 9B2 (Colwell) | 26 | 58 | 16 | 20 |
| | Nitrate Nitrogen (mg/kg N) | **Inhouse S37 (KCl) | 0.7 | 0.9 | 1.2 | 4.4 |
| | pH | Rayment & Lyons 2011 - 4A1 (1:5 Water) | 8.9 | 8.1 | 7.7 | 9.0 |
| | Electrical Conductivity (dS/m) | Rayment & Lyons 2011 - 3A1 (1:5 Water) | 0.123 | 0.088 | 0.035 | 0.266 |
| | Exchangeable Calcium (cmol+/kg) | Rayment & Lyons 2011 - 15D3 (Ammonium Acetate) | 23 | 19 | 2.9 | 24 |
| | Exchangeable Calcium (kg/ha) | | 10,251 | 8,334 | 1,288 | 10,810 |
| | Exchangeable Calcium (mg/kg) | | 4,576 | 3,720 | 575 | 4,826 |
| | Exchangeable Magnesium (cmol+/kg) | | 12 | 8.0 | 1.2 | 8.6 |
| | Exchangeable Magnesium (kg/ha) | | 3,192 | 2,187 | 336 | 2,352 |
| | Exchangeable Magnesium (mg/kg) | | 1,425 | 976 | 150 | 1,050 |
| | Exchangeable Potassium (cmol+/kg) | | 0.51 | 1.3 | 0.29 | 0.57 |
| | Exchangeable Potassium (kg/ha) | | 445 | 1,176 | 250 | 497 |
| | Exchangeable Potassium (mg/kg) | | 199 | 525 | 112 | 222 |
| | Exchangeable Sodium (cmol+/kg) | | 1.7 | 0.76 | 0.11 | 3.5 |
| | Exchangeable Sodium (kg/ha) | | 883 | 392 | 57 | 1,819 |
| | Exchangeable Sodium (mg/kg) | | 394 | 175 | 26 | 812 |
| | Exchangeable Aluminium (cmol+/kg) | **Inhouse S37 (KCl) | <0.01 | <0.01 | <0.01 | <0.01 |
| | Exchangeable Aluminium (kg/ha) | | <1 | <1 | <1 | <1 |
| | Exchangeable Aluminium (mg/kg) | | <1 | <1 | <1 | <1 |
| | Exchangeable Hydrogen (cmol+/kg) | **Rayment & Lyons 2011 - 15G1 (Acidity Titration) | <0.01 | <0.01 | <0.01 | <0.01 |
| | Exchangeable Hydrogen (kg/ha) | | <1 | <1 | <1 | <1 |
| | Exchangeable Hydrogen (mg/kg) | | <1 | <1 | <1 | <1 |
| | Effective Cation Exchange Capacity (ECEC) (cmol+/kg) | **Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg) | 37 | 29 | 4.5 | 37 |
| | Calcium (%) | **Base Saturation Calculations - Cation cmol+/kg / ECEC x 100 | 62 | 65 | 64 | 65 |
| | Magnesium (%) | | 32 | 28 | 27 | 23 |
| | Potassium (%) | | 1.4 | 4.7 | 6.3 | 1.5 |
| | Sodium - ESP (%) | | 4.7 | 2.6 | 2.5 | 9.6 |
| | Aluminium (%) | | 0.00 | 0.00 | 0.01 | 0.00 |
| | Hydrogen (%) | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Calcium/Magnesium Ratio | **Calculation: Calcium / Magnesium (cmol+/kg) | 1.9 | 2.3 | 2.3 | 2.8 |

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| | | Sample 36 | Sample 37 | Sample 38 | Sample 39 |
|---|---|---|---|---|---|
| Sample ID: | | TS-CN-CN93 | TS-CN-CN320 | TS-CN-CN369/370 | TS-CM-C26 |
| Crop: | | soil | soil | soil | soil |
| Client: | | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd | SLR Consulting Australia Pty Ltd |
| | Parameter | Method reference | N2045/36 | N2045/37 | N2045/38 | N2045/39 |
| | Zinc (mg/kg) | Rayment & Lyons 2011 - 12A1 (DTPA) | 0.6 | <0.5 | <0.5 | <0.5 |
| | Manganese (mg/kg) | | 2 | 5 | 5 | 5 |
| | Iron (mg/kg) | | 6 | 11 | 8 | 9 |
| | Copper (mg/kg) | | 1.1 | 0.9 | 0.4 | 1.2 |
| | Boron (mg/kg) | **Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$) | 0.85 | 0.67 | 0.34 | 1.38 |
| | Total Carbon (%) | Inhouse S4a (LECO Trumac Analyser) | 2.17 | 1.20 | 0.42 | 1.27 |
| | Total Nitrogen (%) | | 0.11 | 0.09 | 0.05 | 0.09 |
| | Total Phosphorus (mg/kg) | Rayment & Lyons 2011 - 17C1 Aqua Regia | 726 | 492 | 278 | 309 |
| | Chloride (mg/kg) | **Rayment & Lyons 2011 - 5A3a | 25 | 8.4 | 19 | 82 |
| | pH | **Rayment & Lyons 2011 - 4B4 ($CaCl_2$) | 8.1 | 7.4 | 7.1 | 8.3 |
| | Emerson Aggregate Test (EAT) | **AS1289.3.8.1-2017 | 3 | 3 | 3 | 2 |

**Notes:**

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia*. CSIRO Publishing: Collingwo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil resu
10. Conversions for 1 $cmol_c/kg$ = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
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17. This report was issued on 5/10/2022 and replaces the report published 14/09/2022. Total ca

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# CURRAGH MINE PRCP

## Groundwater Technical Appendix

**Prepared for:**
Coronado Curragh Pty Ltd
Blackwater, QLD, 4717



SLR Ref: 626.30075.00000 -R01
Version No: -v2.0
September 2022

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# BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

# DOCUMENT CONTROL

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|---|---|---|---|---|
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## APPENDICES

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# 1 Introduction

In September 2021 SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to provide a Progressive Rehabilitation and Closure Plan (PRCP) for the Curragh Mine Complex (the mine). In support of the PRCP a groundwater assessment of the mine and final landforms has been undertaken including two key components, a conceptual hydrogeological model and numerical groundwater modelling. The objective of the groundwater assessment is to understand the post closure groundwater regime around the mine, and specifically to:

- present an understanding of the hydrogeological setting of the mine including potential groundwater receptors
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by Coronado to understand whether the final voids act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post mining landform on local groundwater levels i.e., the residual drawdown, and post-mining groundwater flux.

This assessment is based partly on the Groundwater Technical Report prepared for Wesfarmers Resources Pty Ltd by WSP prepared for approval of the Curragh Extension Project (WSP 2016). The WSP assessment includes a comprehensive hydrogeological conceptualisation for the mine which was peer reviewed by HydroSimulations (2016). A new numerical model has been developed for the site by SLR as part of the PRCP submission and includes the proposed expansion pits as well as incorporating the final landforms that were designed in 2021 for the Concept Residual Void Assessment (SLR 2021).

**Section 2** of this report presents a summary of the hydrogeological setting of the mine and conceptual hydrogeological model. **Section 3** presents an overview of the numerical groundwater model setup and development, including model calibration and prediction. **Section 4** describes the post closure modelling and groundwater recovery including the long term post-closure groundwater levels compared to pre mining conditions i.e., the residual drawdown. Conclusions, recommendations, and limitations are presented in **Section 5**.

# 2 Conceptual Hydrogeological Model

## 2.1 Physical Setting

The Curragh Mine is located in Central Queensland within the Fitzroy Basin in an area dominated by grazing, farming and coal mining. The mine extends across an area from approximately 3 km to 35 km north of the township of Blackwater, with one of the proposed expansion pits (Pit Z) located 5km to the WNW of Blackwater. Neighbouring mines include Blackwater to the southwest of Blackwater Township, Mackenzie South located approximately 2.5 km east of Curragh and Jellinbah Central located approximately 5.5 km east of Curragh.

**Figure 2-1** shows the mine location in the context of the local area, drainage, surrounding mines, topography as well as the general mine layout and pit configuration.

The site is broadly divided into Curragh North (Pits S, T, U and associated spoil dumps); Curragh Main (Pits A & B (both TSFs), C, D, E, F, G, H and I), and the expansion areas (Pits X, Y, Z, J and Ramp 9), where mining has not yet commenced. Mining at Curragh is projected to end in 2038.

### 2.1.1 Topography and land use

The land surrounding the mine is typically gently undulating and partly sits within the floodplain of Mackenzie River. The topography of the area is dominated by the major drainage features (Mackenzie River and tributaries), ephemeral drainage lines, and the open cut pits and spoil dumps of Curragh Mine and neighbouring mines. Topography and drainage near the Project area is shown on **Figure 2-1**.

Aside from the Township of Blackwater to the south of Curragh, and the surrounding mines, land use is rural with large areas predominantly turned over to livestock grazing with some dryland cropping and minor irrigated cropping adjacent to Mackenzie River.

### 2.1.2 Climate

The climate of the region is subtropical with the highest rainfall and evaporation occurring from October through till March (BoM, 2021). Historical climate data was obtained for the period January 1900 to September 2021 from the Scientific Information for Landowners (SILO) database (Queensland Government, 2021) for the location of the Project area (latitude -23.5, longitude 148.9). **Table 2-1** outlines the total monthly average rainfall and evaporation. The data shows that the total potential average annual evaporation (2,054 mm/yr) is almost four times annual rainfall (565 mm/yr). The high annual evaporation rates are strongly related to seasonal temperatures (**Figure 2-2**).

**Table 2-1 Total Monthly Rainfall and Evaporation (January 1900 to August 2021)**

| Average Total Monthly (mm) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall | 93 | 88 | 58 | 30 | 29 | 29 | 24 | 16 | 21 | 42 | 56 | 80 | 565 |
| Evaporation | 229 | 184 | 190 | 151 | 118 | 94 | 103 | 132 | 173 | 214 | 226 | 240 | 2,054 |

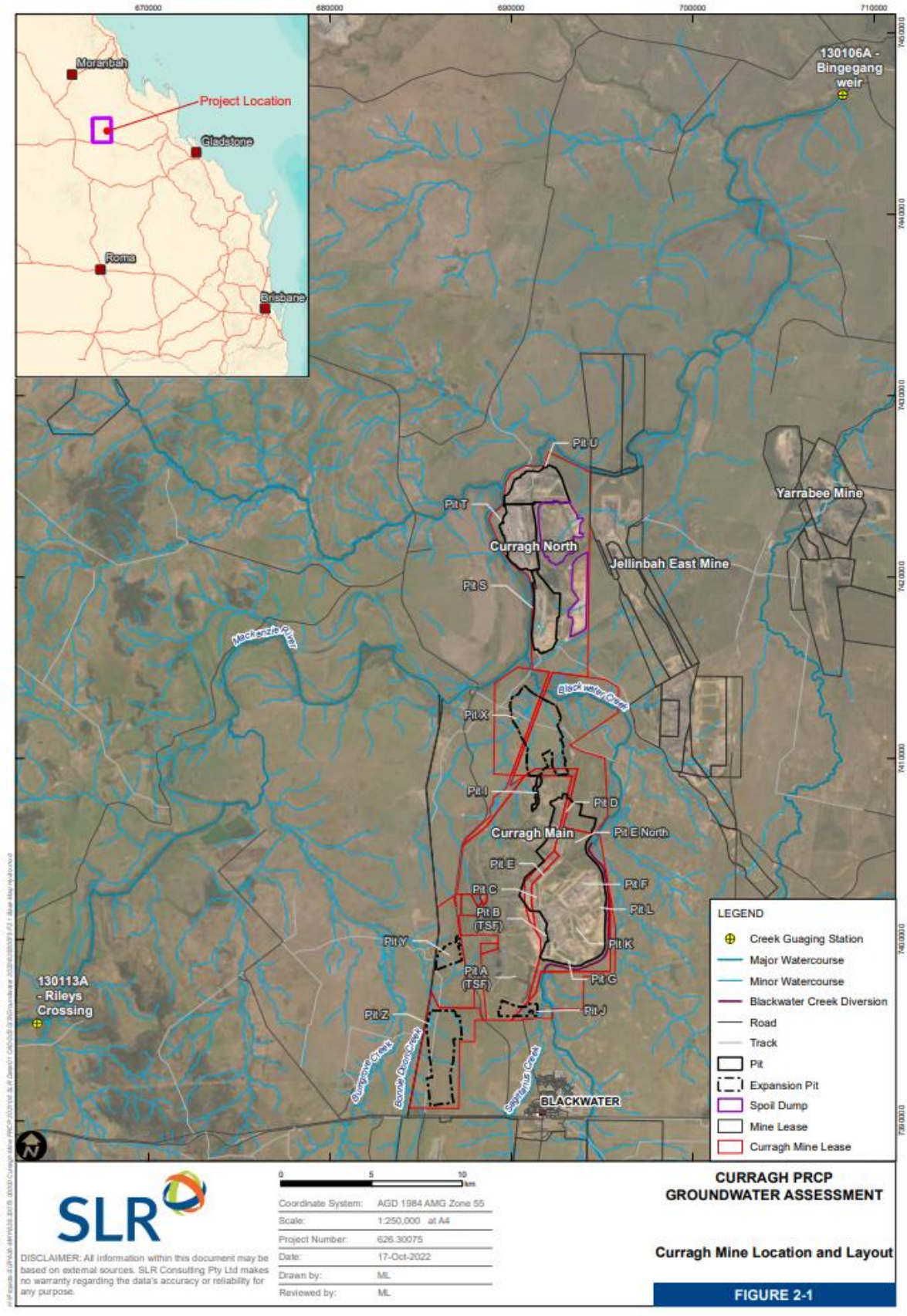



**Figure 2-1 Site Setting**

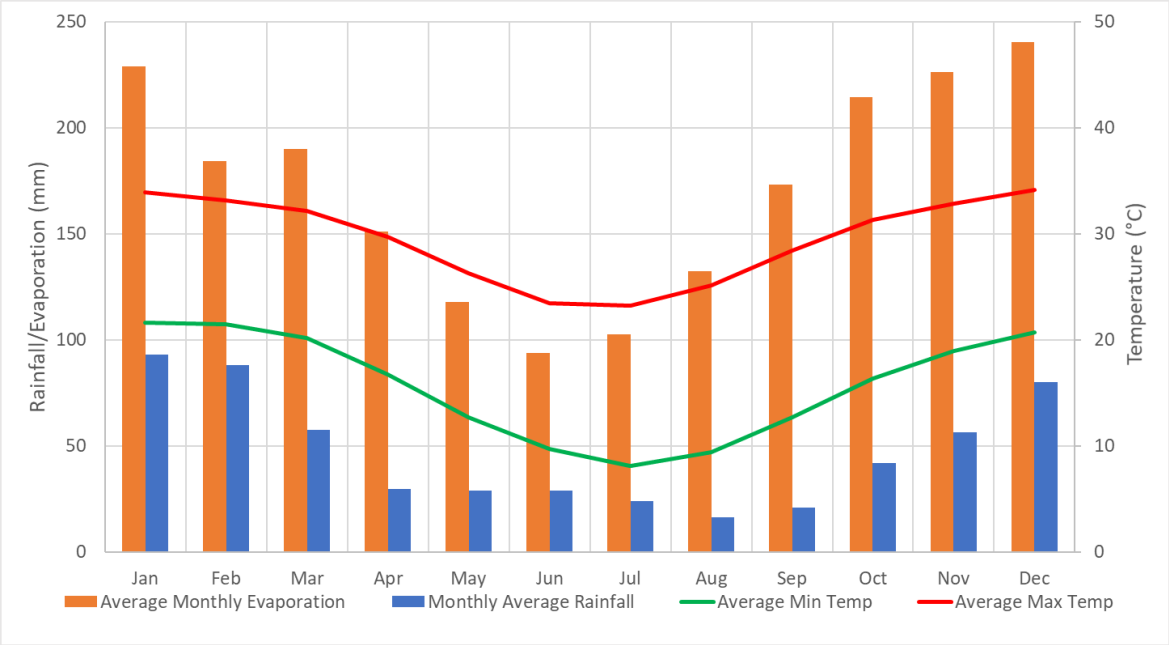



**Figure 2-2 Average Monthly Evaporation, Rainfall and Temperature (January 1900 to August 2021)**

In order to assess rainfall over recent years within a longer term context, the cumulative rainfall departure (CRD) was calculated for the data period 1900 to 2021 (**Figure 2-3**). The CRD is a summation of difference between the actual monthly rainfall compared to the average monthly for the same period. A rising slope in the CRD indicates periods of rainfall above the long term average (e.g., 2010 to 2012), and a falling slope indicates periods when rainfall is below the long term average (e.g., 1999 to 2007). Rainfall volumes over more recent years of the record (2017 to 2021) have been lower than average, as is indicated by the falling slope in the CRD.

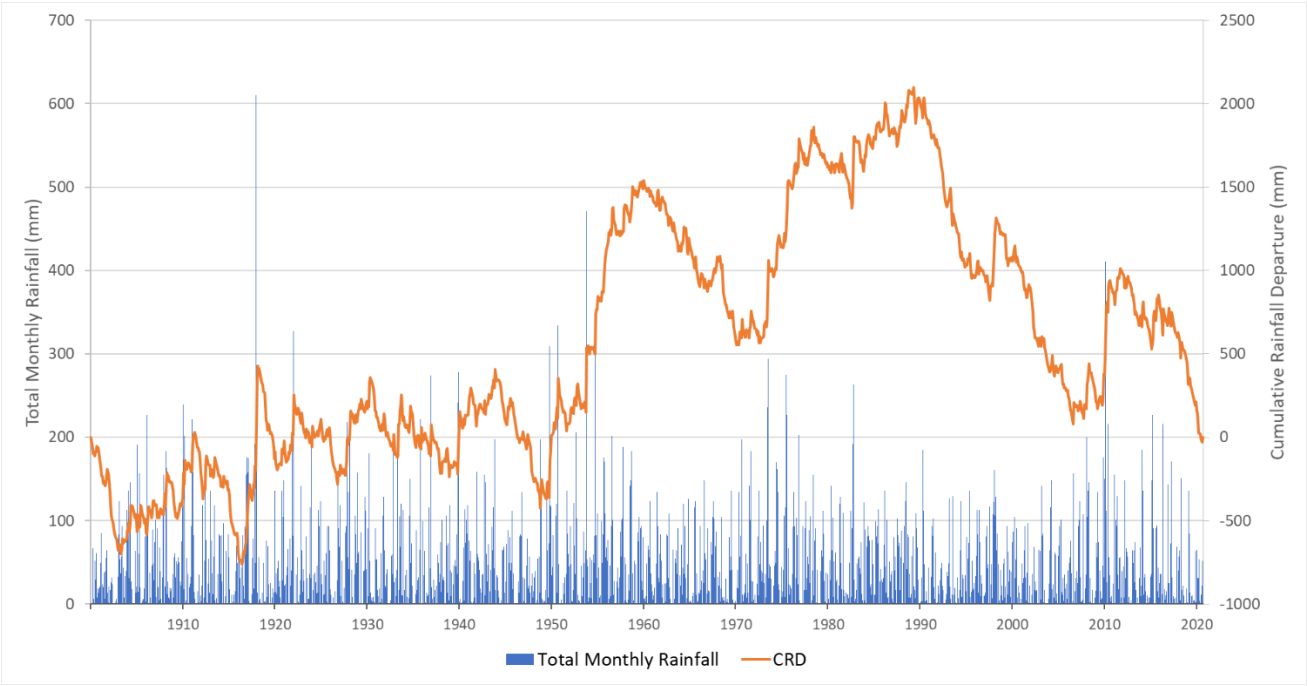



**Figure 2-3 Cumulative Rainfall Departure and Total Monthly Rainfall (1900-2021)**

Since the start of mining in 1983 the area has generally seen lower than average rainfall except for the remainder of the 1980s and significant wet seasons in late 1998 and 2010/11.

### 2.1.3 Hydrology

#### 2.1.3.1 Mackenzie River

The mine extends across the floodplain of the Mackenzie River and its tributaries. The Mackenzie River forms at the confluence of the Nogoa and Comet rivers, 30km west of Blackwater and is the main watercourse in the area and a major tributary of the Fitzroy River. The total catchment area of Mackenzie River to Bingegang Weir (25km downstream of the mine), is approximately 51,000 square km. To the northwest of the mine the Mackenzie River floodplain is a relatively flat, with the current course of the river meandering through a tract of alluvium approximately 3 to 8 km wide.

Fairbairn Dam located upstream on the Nogoa River approximately 80km WSW of Blackwater stores 1,300 gigalitres (GL) when full. Releases from the dam maintain levels downstream so that various towns, mines and irrigators can be supplied. This regulation of the Mackenzie River has altered the natural flow regime.

**Figure 2-4** presents flow duration curves for the gauge at Riley's Crossing (130113A) 25km west of Blackwater, and for Bingegang weir (130106A) 25km north-west (downstream) of the northern extent of the mine. The data indicates that higher flows mostly driven by rainfall over the catchment naturally result in increasing flows downstream with Bingegang recording higher flows than Riley's Crossing upstream when flows at both gauges are above ~200 ML/d. Below ~200 ML/d the effects of river regulation by releases from Fairburn Dam and downstream extraction / losses appear to be apparent with perennial flow recorded at Riley's Crossing whilst downstream at Bingegang there appears to be no flow over the weir 70% of the time.

The main tributaries of Mackenzie River in the study area include Blackwater Creek, Burngrove Creek, Cooroora Creek and Scrub Creek.

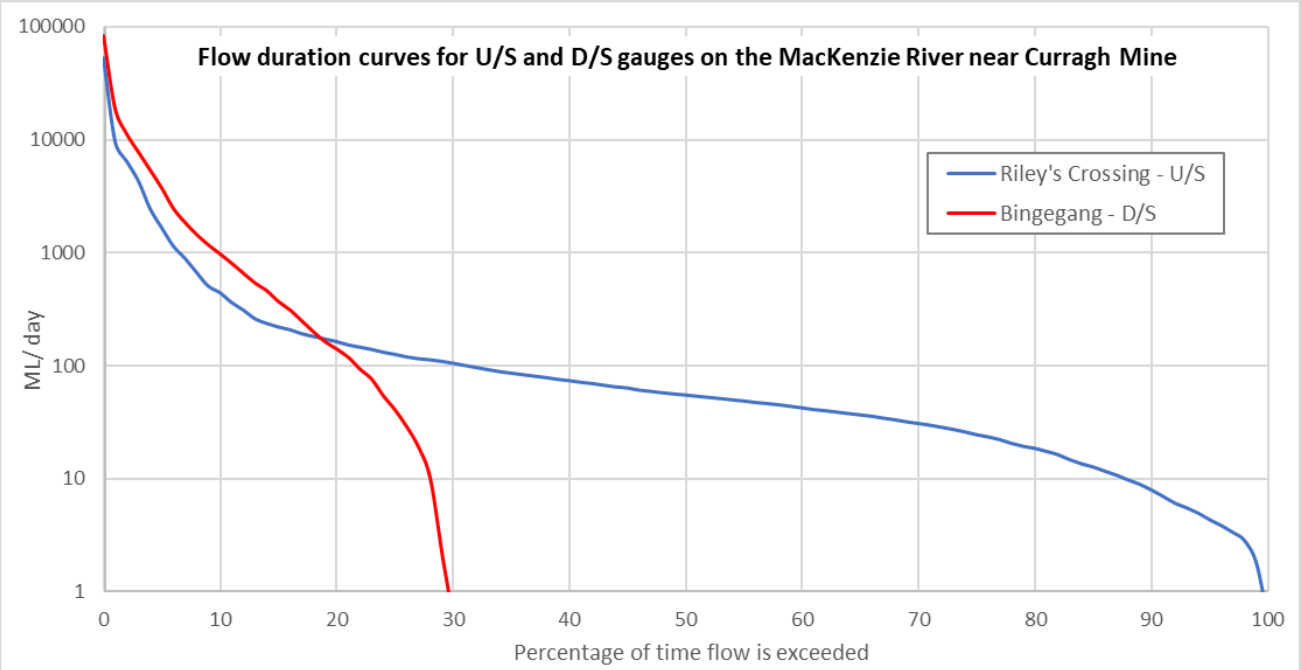



**Figure 2-4 Flow Duration Curves for Gauging Stations on the Mackenzie River in the Vicinity of Curragh Mine (Nov 2013 – Oct 2021)**

#### 2.1.3.2 Blackwater Creek and tributaries

The main tributary of Mackenzie River in the study area is Blackwater Creek, which flows in a northerly direction to the east of Curragh Main via a major diversion around Pits J, K, L, F, and E. Blackwater Creek is naturally ephemeral although at its upstream end, it constantly flows due to discharge of treated effluent from Blackwater Wastewater Treatment Plant into Sagittarius Creek between Blackwater and the mine (PB 2016).

Blackwater Creek is highly modified having been diverted several times to accommodate mining at Curragh. The current Blackwater Creek diversion is a 9 km long engineered drainage structure made of compacted earth vegetated with grasses and shrubs. The discharge from Blackwater WTP is observed along the extent of the diversion although not north of the diversion (PB 2016).

Just downstream of the diversion around Curragh Main and to the east of the proposed Pit X Blackwater Creek becomes an ephemeral braided channel system.

Tributaries of Blackwater Creek include Taurus Creek, Sagittarius Creek, Minnie Creek and Bullock Creek, all of which are ephemeral. Minnie Creek flows through the proposed Pit X area and will be subject to a 5.3 km diversion near its confluence with Blackwater Creek plus a 2.9 km diversion of one of its unnamed tributaries around the western side of the pit prior to the commencement of mining in this area (PB 2016).

#### 2.1.3.3 Burngrove Creek and tributaries

Other tributaries of Mackenzie River in the Project area include Burngrove Creek. A tributary of Burngrove Creek is Bonnie Doon Creek, which flows in a northerly direction to the west of proposed Pit Z and will be subject to a diversion. Both Burngrove Creek and Bonnie Doon Creek are ephemeral.

### 2.1.4 Geology

presented in

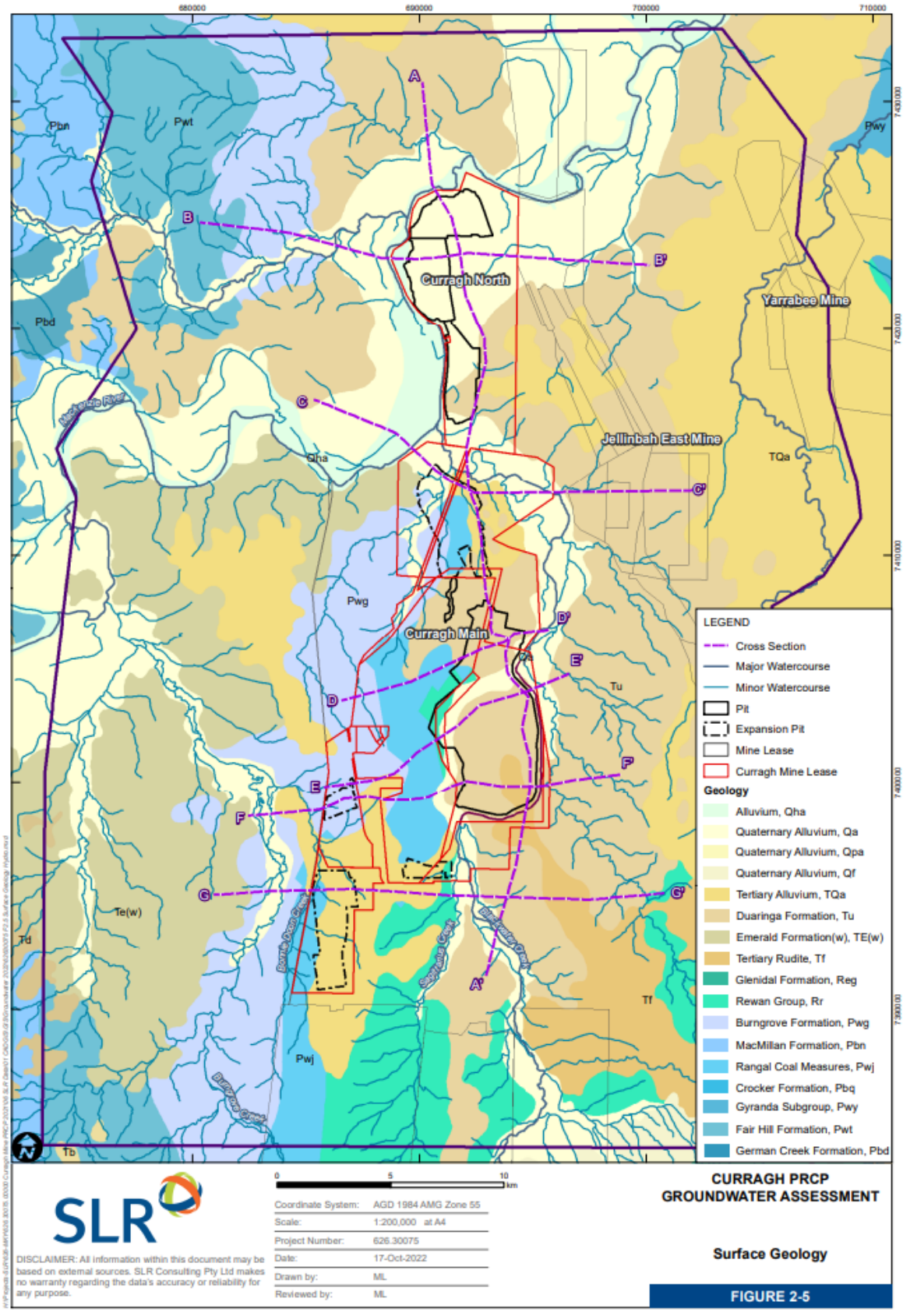


**Figure** 2-5 and the regional (solid) geology is presented in **Figure 2-6**

The study area is underlain by gently folded Permo-Triassic strata within the Bowen Basin overlain by Tertiary and Quaternary sediments. The Permo-Triassic strata, which are heavily faulted in places, dip eastward and include the Triassic Rewan Formation and the underlying Permian Blackwater Group, which includes the Rangal Coal Measures, Burngrove Formation and Fair Hill Formation. The overlying sediments comprise unconsolidated Quaternary alluvium associated with creeks, rivers and floodplains and the poorly consolidated Tertiary sediments of the Duaringa and Emerald formations. The Back Creek Group underlies the Blackwater Group and forms the basement of the area.

The stratigraphic sequence underlying the area is presented in **Table 2-2** and summarised below.

#### 2.1.4.1 Quaternary and Tertiary alluvium

Alluvium associated with the main watercourses of the Mackenzie River and Blackwater Creek (and their tributaries) is present across much of Curragh North and parts of Curragh Main and the proposed expansion pits.

In the proposed Pit X area, exploration drilling indicates the alluvium is typically less than 12m thick and predominantly comprised of clay with occasional sand and gravel lenses / channels at depth. Alluvium in the vicinity of proposed Pit J and Pit Z is generally thin (typically 2m but up to 4m) and comprised of clay and silt. Alluvium occurs in the southeast corner of proposed Pit D extension and is typically less than 2m (and up to 10m) and comprised of clay and sand (WSP 2016).

Floodplain alluvium associated with the Mackenzie River occurs extensively at Curragh North and exhibits an overall fining upwards sequence and significant lateral variability with an average thickness of 18 - 20m. Drilling data indicates the alluvium may be up to 35 m thick and the base of the alluvium is deepest close to the Mackenzie River (WSP 2016).

**Table 2-2 Regional Stratigraphy**

| Age | Group | Stratigraphic Unit | Description |
|---|---|---|---|
| Quaternary | | Alluvium | Soils, unconsolidated silts, sands, gravels and clays, |
| Cenozoic (Tertiary) | | Duaringa Formation/ Emerald Formation | Claystone, siltstone, sandstone, conglomerate (often poorly consolidated), lignite, basalt |
| Triassic | Mimosa | Rewan Formation | Mudstone, interbeds of lithic sandstone. |
| Upper Permian | Blackwater Group | Rangal Coal Measures | Coal seams calcareous sandstone, calcareous shale, mudstone, calcareous tuff in places. Main coal seams include Aries, Castor, Pollux, Orion, Pisces. |
| | | Burngrove Formation | Siltstone, carbonaceous shales and mudstone, fine lithic sandstone, calcareous lithic and feldspathic sandstone, tuffaceous shales and thin coal seams. |
| | | Fair Hill Formation | Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal |
| Permian | Back Creek Group | Macmillan Formation | Interbedded mudstone and sandstone, prominent dark grey basal unit. |

#### 2.1.4.2 Cenozoic sediments

The Duaringa Formation is present in the proposed Pit X and Pit D extension areas and outcrops extensively in the north, east and south of the study area. In the north of the study area the Cenozoic sediments have been eroded by the Mackenzie River. The Emerald Formation is present in the western section of the proposed Pit X area and outcrop in the west of the study area (WSP 2016).

The Cenozoic sediments consist of interbedded stiff to hard clayey sands, gravels and thick beds of ferruginous clays of medium to high plasticity. They are fluvial and colluvial in origin and partially consolidated. The sequence unconformably overlies Permian coal measures with an indistinct boundary due to the clay rich and ferruginous composition of both horizons caused by in-situ weathering (WSP 2016).

#### 2.1.4.3 Triassic sediments

The Rewan Formation overlies the Rangal Coal Measures and outcrops / subcrops directly east of the mined areas. It typically comprises thinly interbedded mudstones, lithic sandstones and siltstones. Drilling in the Minyango mine area recorded Rewan Formation up to 350m thick with a depth of weathering between 30 and 70 m (WSP 2016).

#### 2.1.4.4 Permian sediments

The Permian Rangal Coal Measures (RCM) is the uppermost sequence in the Blackwater Group and comprises predominantly fine grained to occasionally medium grained lithic sandstone, siltstone, mudstone, carbonaceous mudstone and coal.

The RCM contain seams of high quality PCI coal, high quality medium-to-low ash coals suitable for prime coking coal, anthracite, semi-anthracite, and high energy thermal coals. The Cancer, Aries, Castor, Pollux, Orion and Pisces seams within the RCM are mined at Curragh. The strata generally dip to the east at less than 3°, with dips increasing locally in fault zones. The Rangal Coal Measures outcrop / subcrop in Curragh North and Curragh Main areas. The Rangal Coal Measures also subcrop east (the upthrow side) of the Jellinbah Fault where they are extracted at Jellinbah Mine (WSP 2016).

The boundary between the Burngrove Formation and the overlying RCM is the Yarrabee Tuff Bed, a distinctive marker horizon. The tuff lies between the target Pisces seam in the RCM and the Pisces Lower seam. The upper part of the Burngrove Formation (below the Yarrabee Tuff Bed and Pisces Lower seam), comprise dark grey to grey mudstones grading to siltstones. The Burngrove Formation outcrops/subcrops in the proposed Pit X, Y and Z locations and to the west of Curragh Mine (WSP 2016).

The Fair Hill Formation underlies the Burngrove Formation and outcrops/subcrops to the west of the mine. The formation comprises lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff and tuffaceous mudstone and includes the Fort Cooper Coal Measures.

The upper Permian sediments are weathered. The depth of weathering in the study area is approximately 14 metres below ground level (mbgl), except where Quaternary erosion and deposition has resulted in the replacement of Permian sediments by Quaternary alluvium. Where this occurs deeper weathering up to 35 mbgl is observed (WSP 2016).

### 2.1.5 Structural geology

The mine is located within an area of the Bowen Basin subject to faulting and gentle folding. The study area lies on the eastern limb of the Comet Ridge, adjacent to the Folded Zone within the Bowen Basin. This ridge was formed over an existing basement platform, creating a regional anticlinal structure with low amplitude and gentle folds (WSP 2016).

The NNW-SSE trending Jellinbah Fault is located directly east of Curragh North and approximately 5 km east of Curragh Main. It is the major fault structure in the Curragh Mine region. The fault has an approximate vertical displacement of 120 m brining the RCM back up to depths that allows the Jellinbah Mine to target the associated coal seams.

The RCM in the vicinity of the mine have been affected by low angle thrust faulting from the north-east and results in seam displacements up to 20 m vertically. Fault deformation has resulted in seam thinning, seam repetitions and absenting occurring throughout the Curragh Mine (PB 2016).

#### 2.1.5.1 Geological Cross-sections

Cross-sections showing the geology of the study area have been developed using the geological model for the site together with LiDAR (current and pre mining). The sections also show and final landforms / voids, approximate pre-mining and post-mining groundwater levels / void lake levels, tailings storages and the locations of other potentially sources of groundwater contamination (landfills and infrastructure areas).

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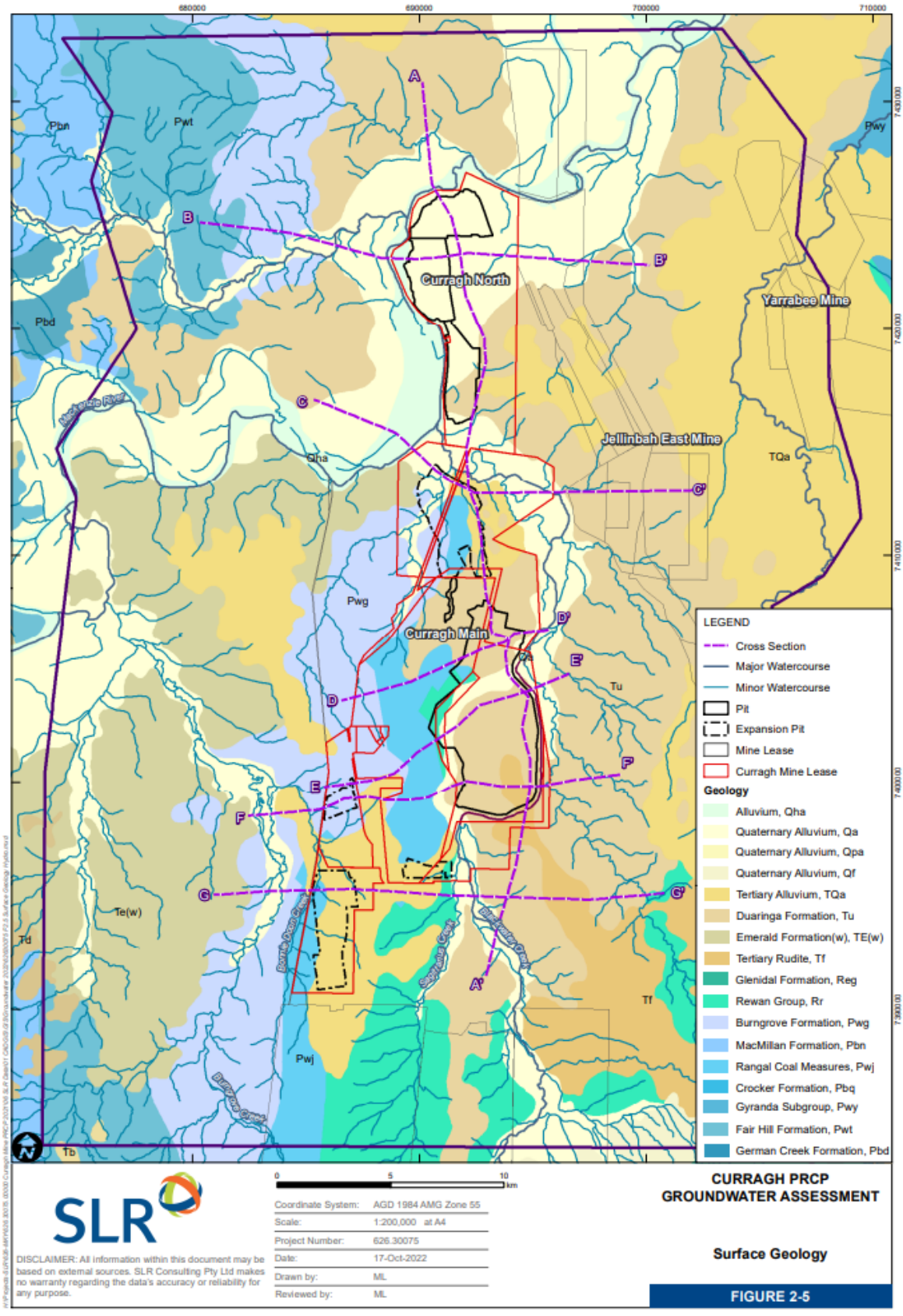

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Curragh Main
Yarrabee Mine
Jellinbah East Mine
Pbn
Pwt
Pwy
Pbd
Qha
TQa
Pwg
Qa
Tu
Te(w)
Td
Tf
Pwj
Tb
LEGEND
Cross Section
Major Watercourse
Minor Watercourse
Pit
Expansion Pit
Mine Lease
Curragh Mine Lease
Geology
Alluvium, Qha
Quaternary Alluvium, Qa
Quaternary Alluvium, Qpa
Quaternary Alluvium, Qf
Tertiary Alluvium, TQa
Duaringa Formation, Tu
Emerald Formation(w), TE(w)
Tertiary Rudite, Tf
Glenidal Formation, Reg
Rewan Group, Rr
Burngrove Formation, Pwg
MacMillan Formation, Pbn
Rangal Coal Measures, Pwj
Crocker Formation, Pbq
Gyranda Subgroup, Pwy
Fair Hill Formation, Pwt
German Creek Formation, Pbd
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Coordinate System: AGD 1984 AMG Zone 55
Scale: 1:200,000 at A4
Project Number: 626.30075
Date: 17-Oct-2022
Drawn by: ML
Reviewed by: ML
DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.
CURRAGH PRCP
GROUNDWATER ASSESSMENT
Surface Geology
FIGURE 2-5

**Figure** 2-5, and comprise a north-south long section (A-A' **Figure 2-7**), and several east-west sections (B-B' **Figure 2-8**, C-C' **Figure 2-9**, and D-D' **Figure 2-10,** E-E' **Figure 2-11,** F-F' **Figure 2-12,** G-G' **Figure 2-13**)

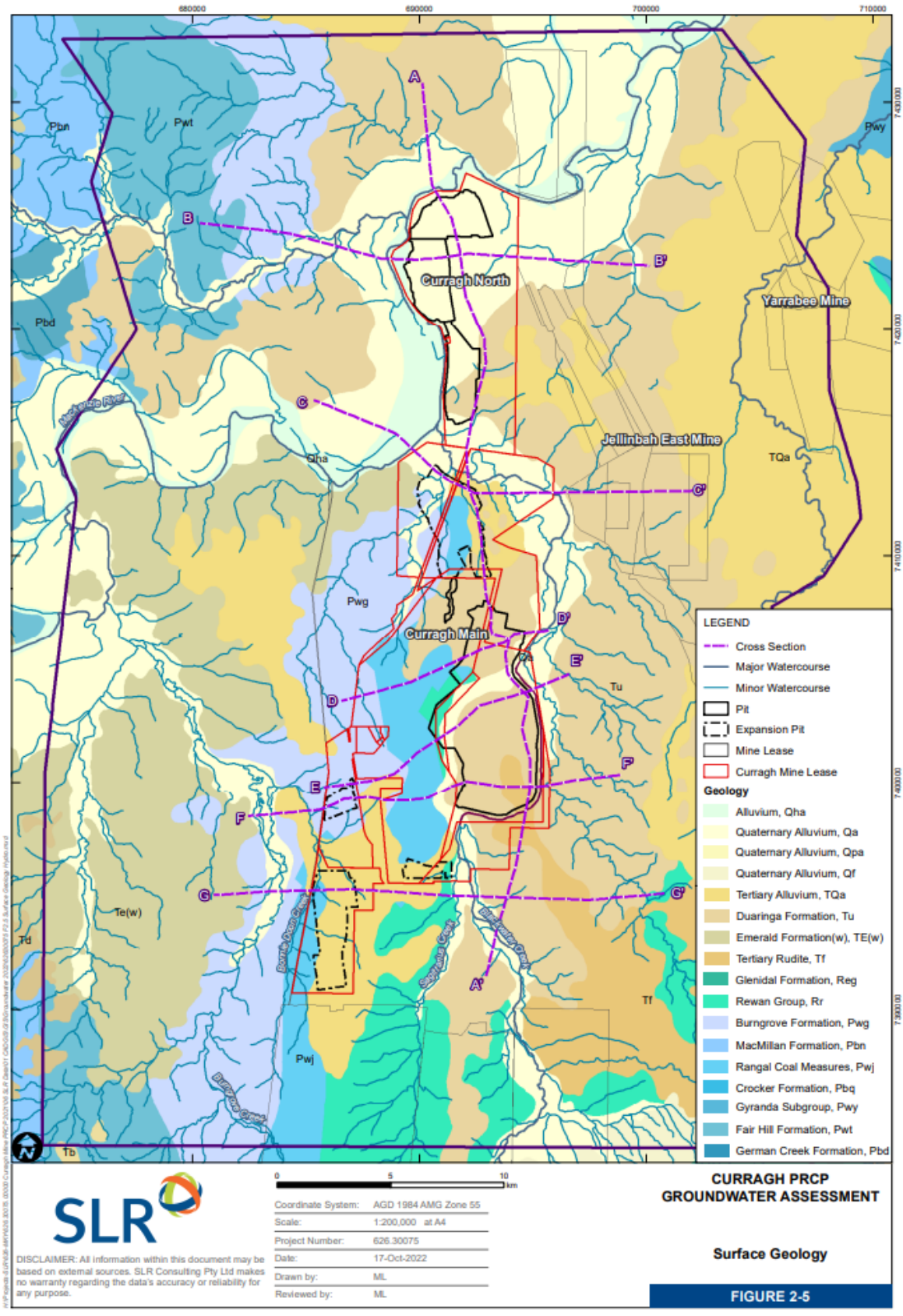



**Figure 2-5 Surface Geology**

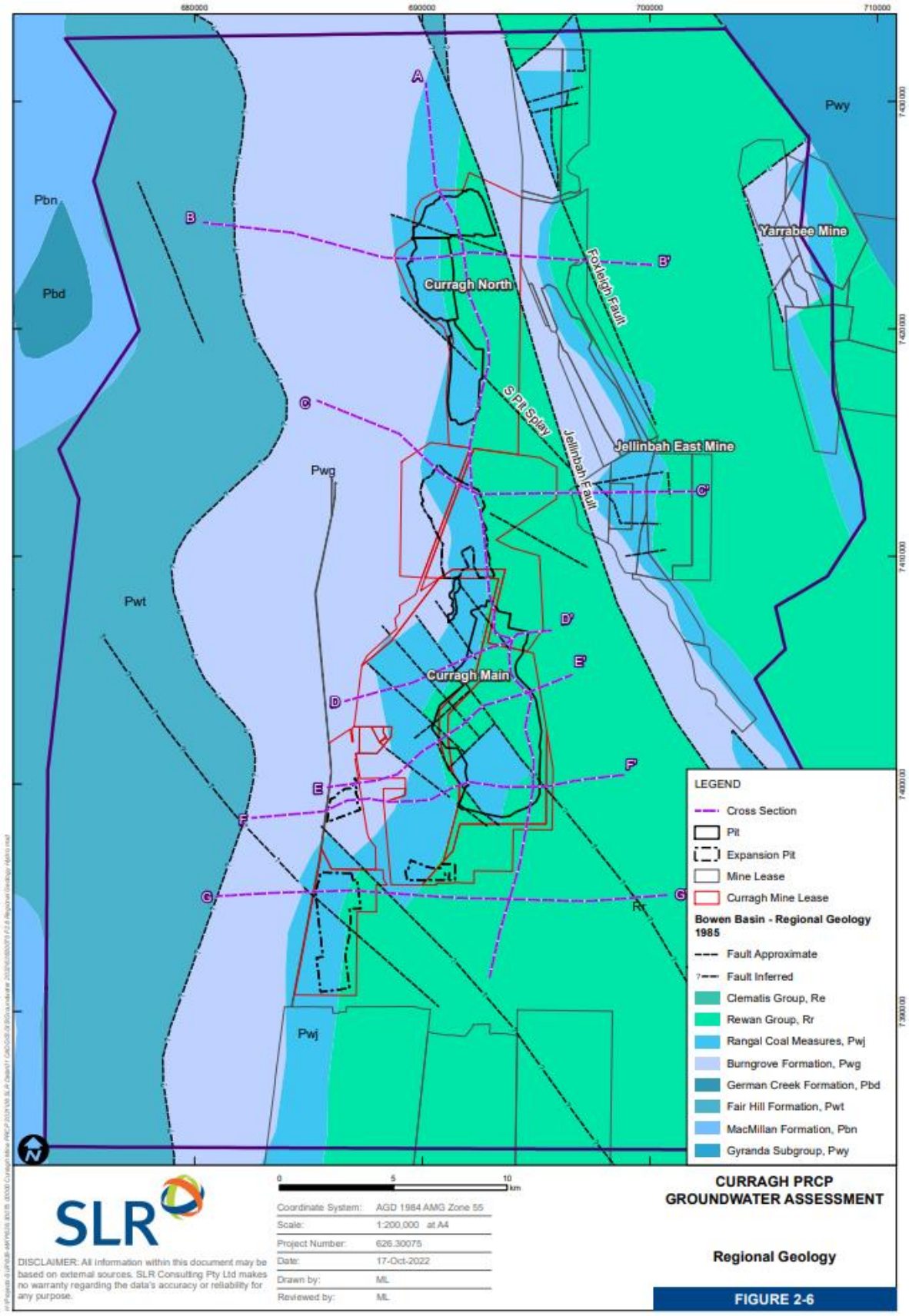



**Figure 2-6 Regional Geology**

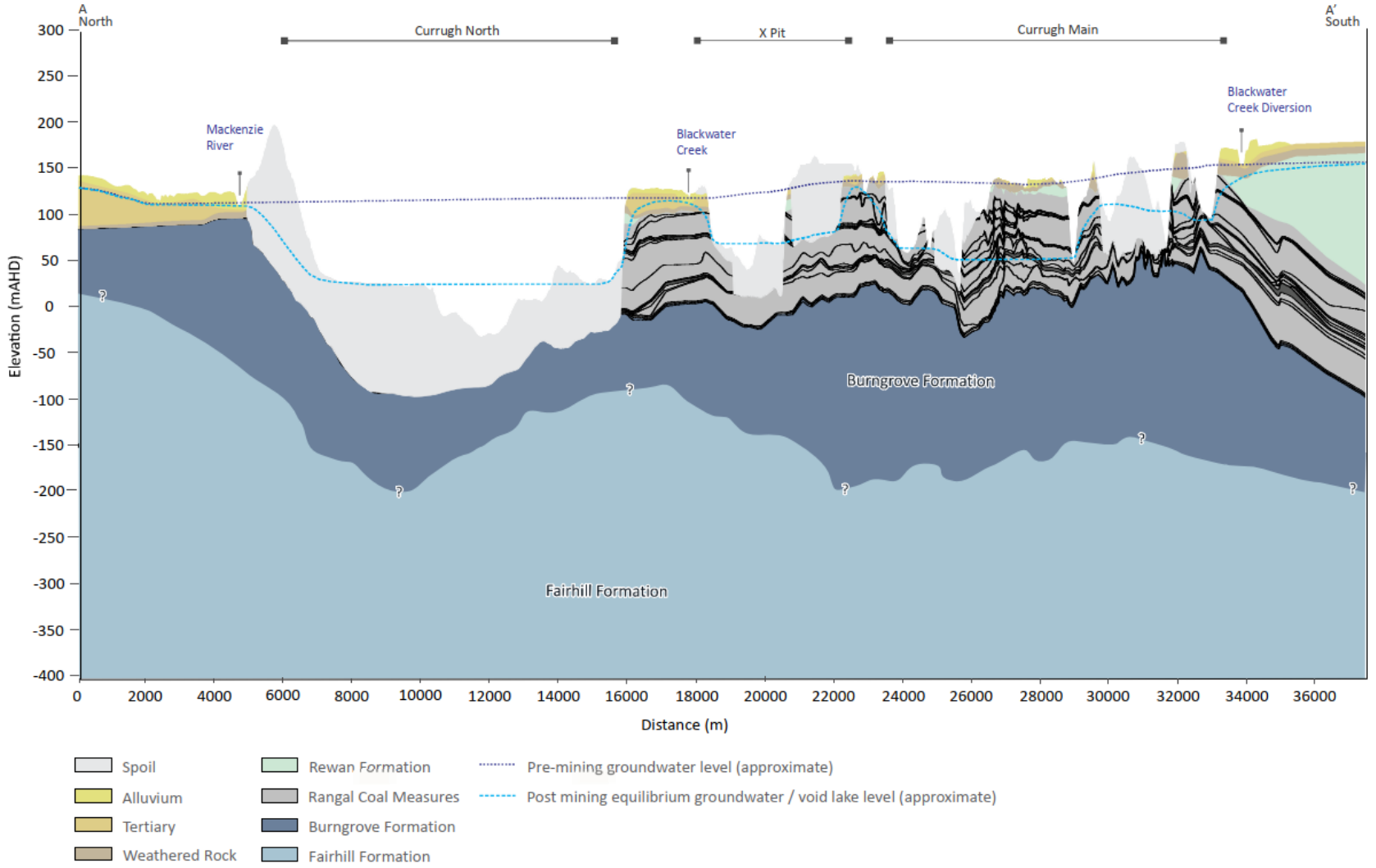



**Figure 2-7 Geological cross-section A-A' of Curragh Mine Complex showing final landform and pre- and post- mining water table**

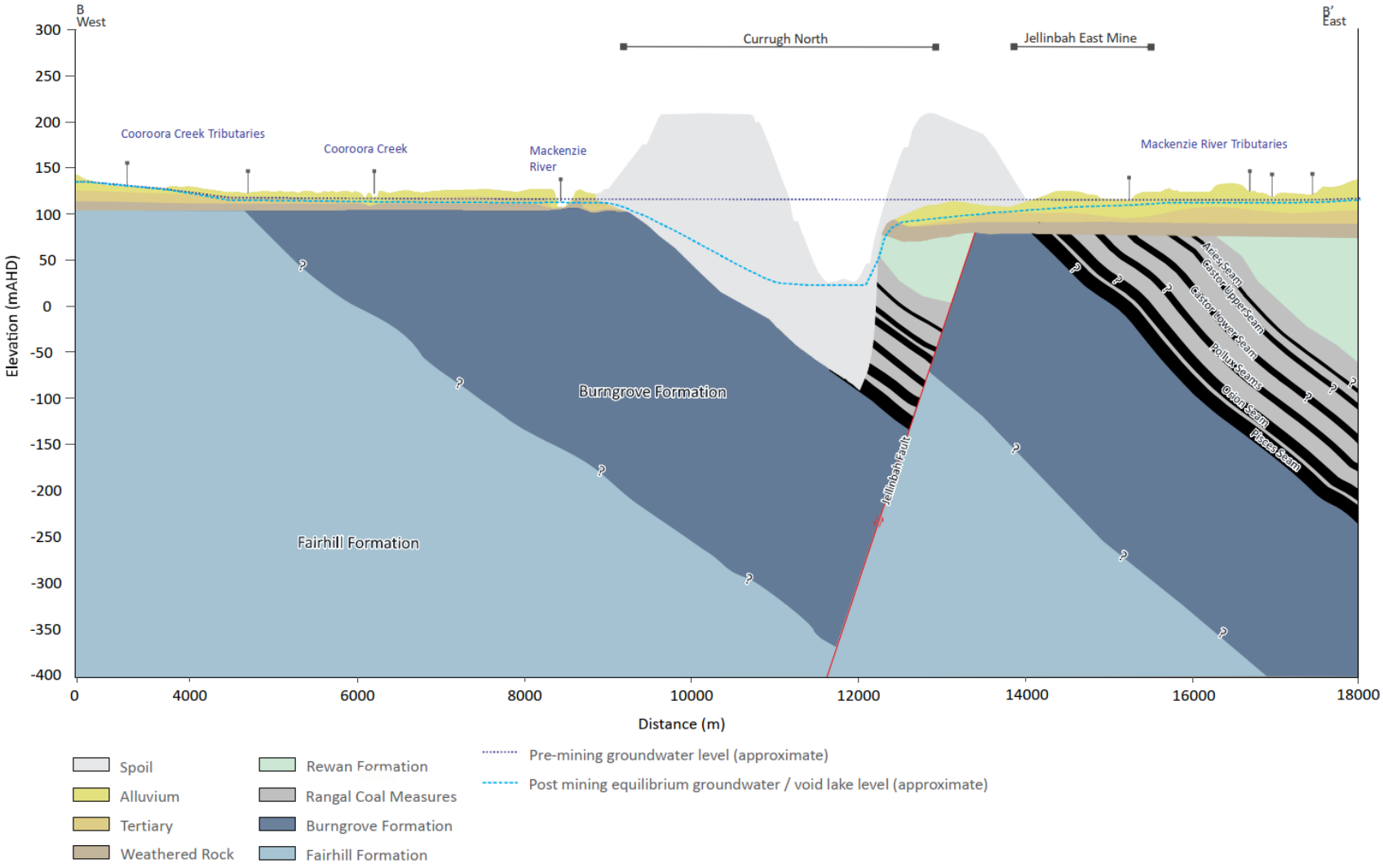



**Figure 2-8 Geological cross-section B-B' of Curragh Mine Complex showing final landform and pre- and post- mining water table**

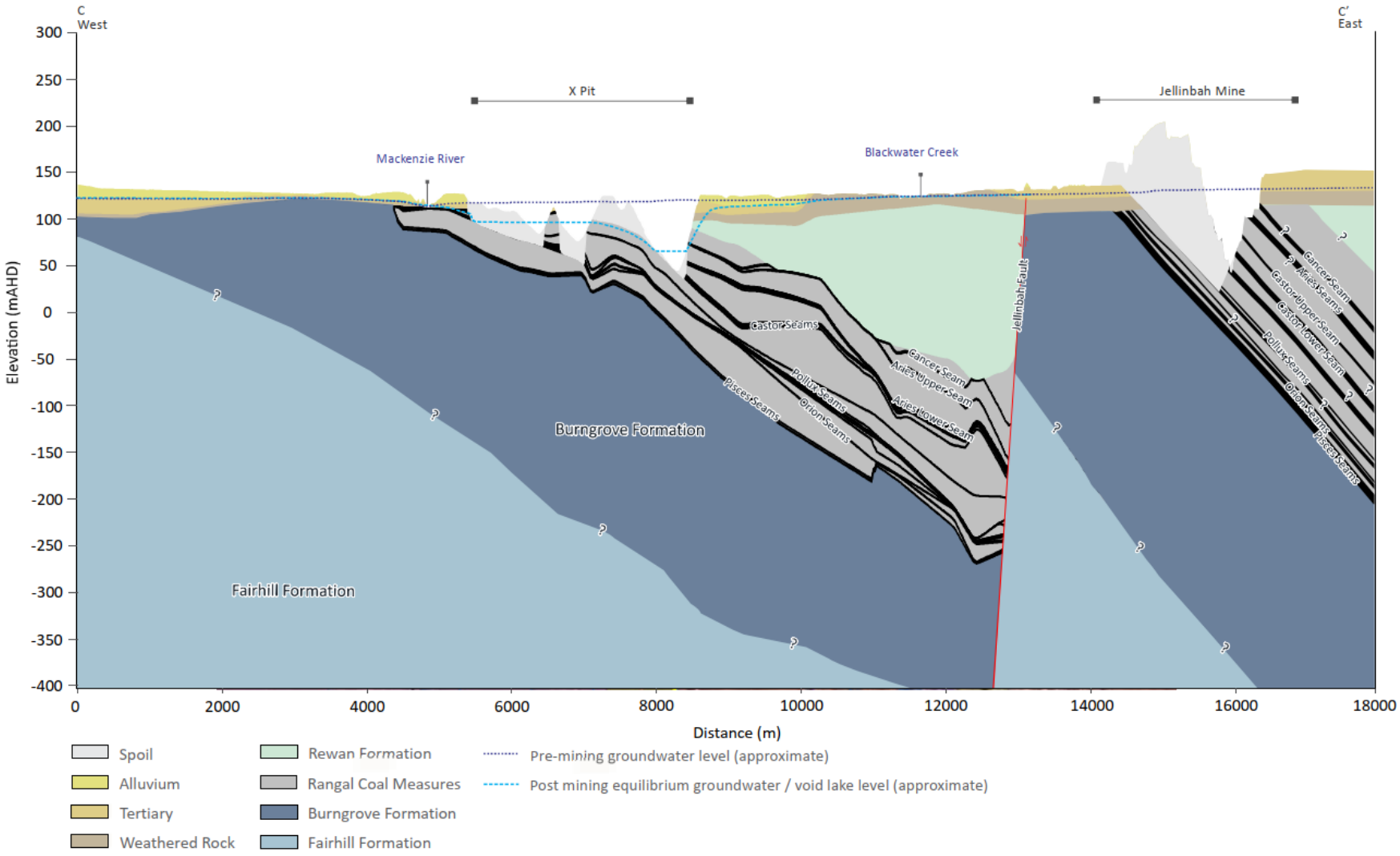



**Figure 2-9 Geological cross-section C-C' of Curragh Mine Complex showing final landform and pre- and post- mining water table**

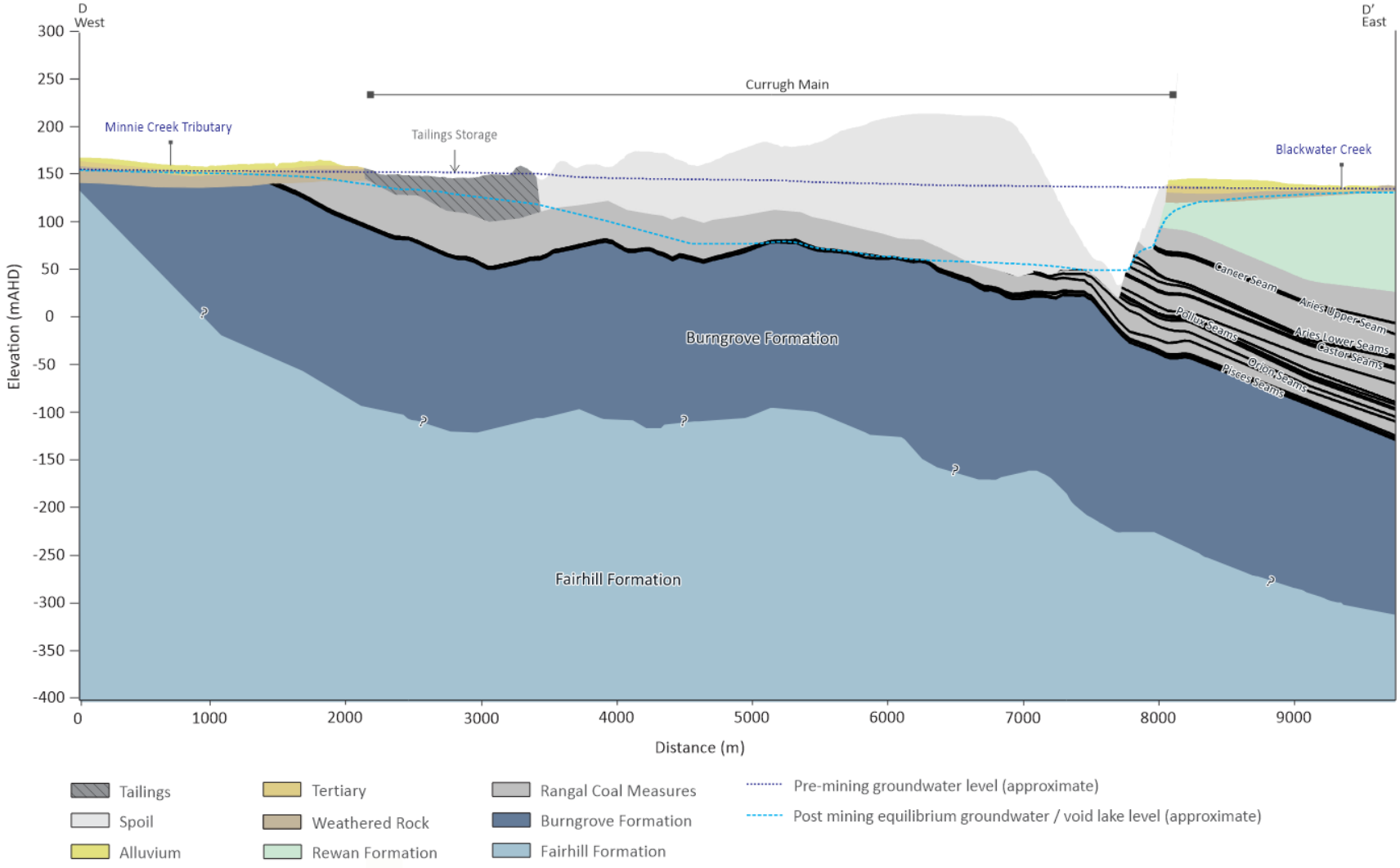



**Figure 2-10 Geological cross-section D-D' of Curragh Mine Complex showing final landform and pre- and post- mining water table**

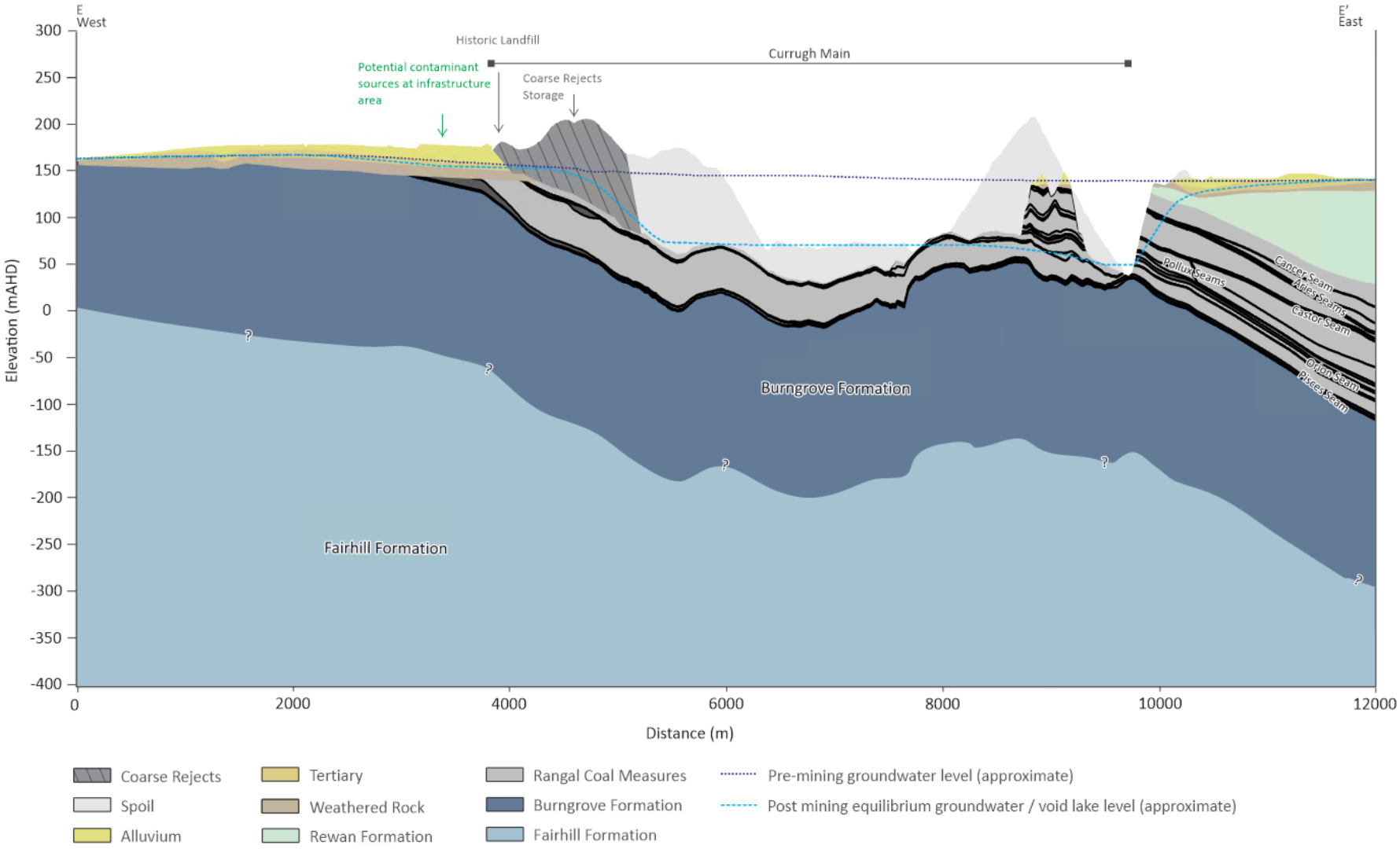



**Figure 2-11 Geological cross-section E-E' of Curragh Mine Complex showing final landform and pre- and post- mining water table**

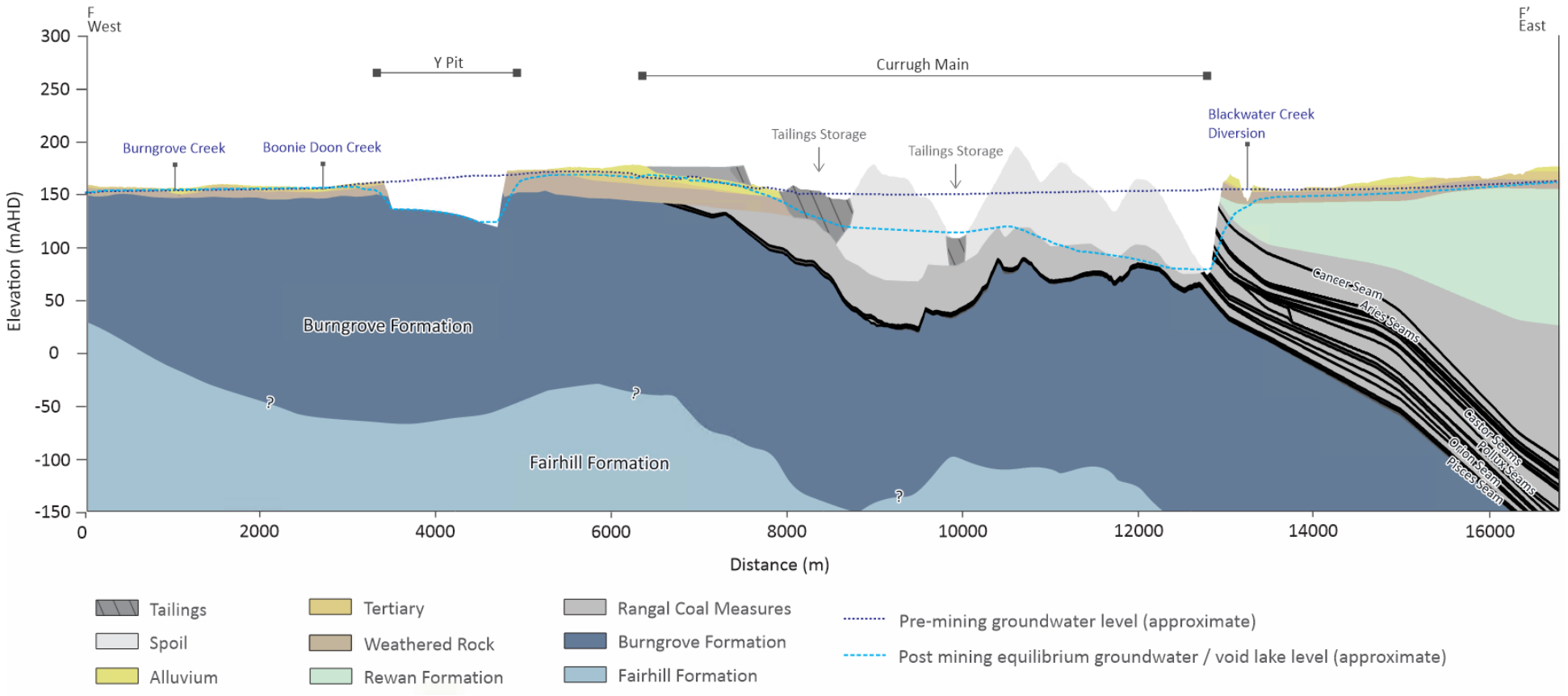



**Figure 2-12 Geological cross-section F-F' of Curragh Mine Complex showing final landform and pre- and post- mining water table**

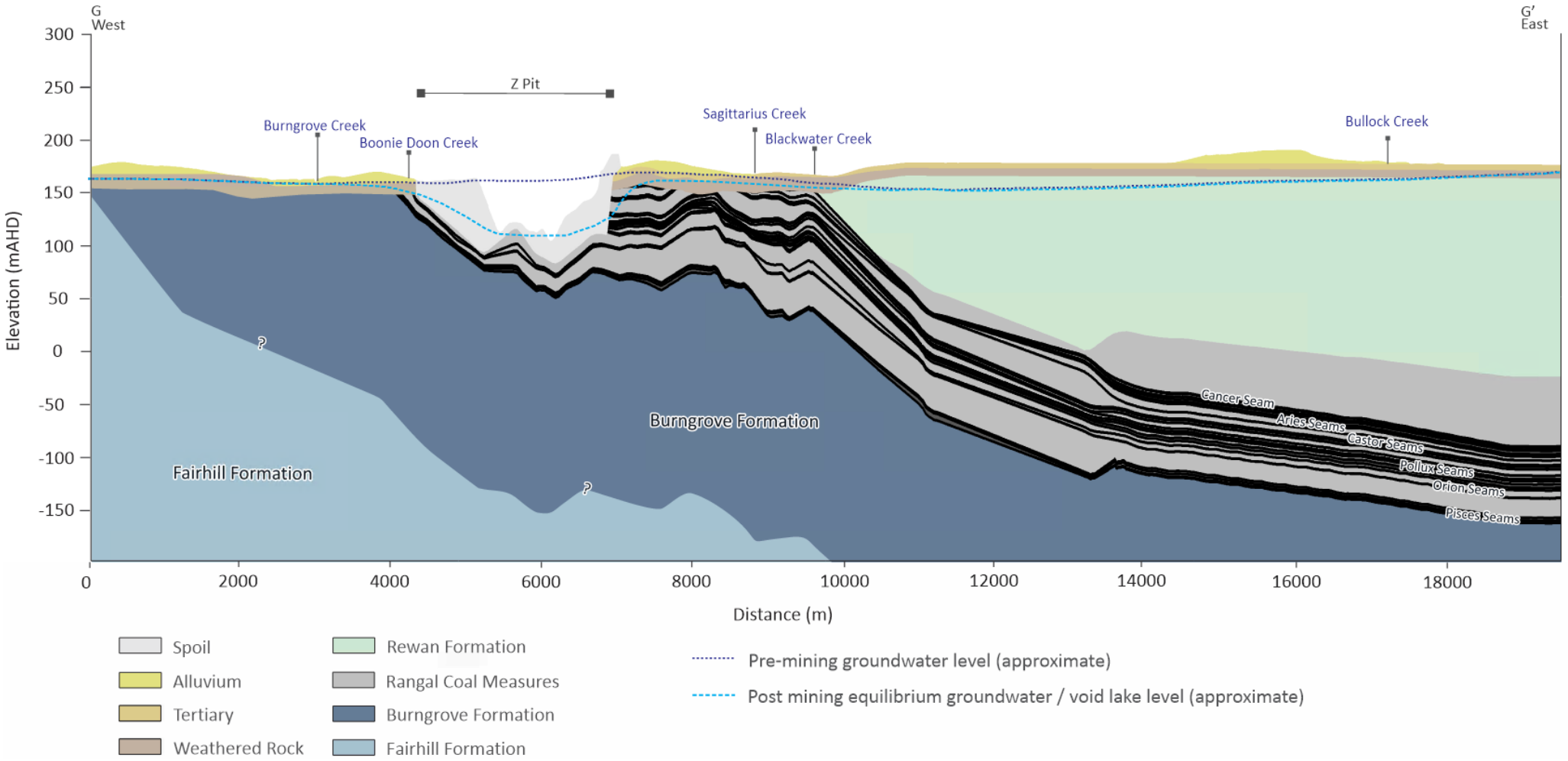



**Figure 2-13 Geological cross-section G-G' of Curragh Mine Complex showing final landform and pre- and post- mining water table**

## 2.2 Groundwater Monitoring Data

### 2.2.1 Groundwater Monitoring Network

The groundwater monitoring network at Curragh Mine has progressively developed since the 1990s. The available monitoring data indicates that there are 36 bores from which data is currently collected with 22 used for groundwater quality monitoring and 23 used for groundwater level monitoring. The monitoring bore network for the mine is shown in **Figure 2-14**. Details of the monitoring bores, including bore construction, target formation and date of installation, are provided in **Table 2-3**.

Groundwater monitoring bores across the mine have been installed in the alluvium, Duaringa Formation, Rewan Formation, Rangal Coal Measures and the Burngrove Formation, with emphasis on water bearing units. The network has been designed to improve the understanding of the hydrogeological conditions in the area surrounding the mine and identify impacts associated within mining operations. Monitoring bore locations have been chosen to:

- provide spatial coverage across the mine area
- provide hydrogeological data on the range of formations and hydrogeological environments
- identify potential impacts to sensitive features such as groundwater dependent ecosystems (GDEs) and areas of potential surface water-groundwater interaction
- detect changes in groundwater conditions due to seepage from site infrastructure, including tailings storage facilities (TSFs), landfills, fuel farms and water storage dams
- establish a baseline of undisturbed groundwater conditions so that trigger levels can be developed to detect impacts associated with mining.

The Groundwater Monitoring Plan for the site identifies three categories of monitoring bore:

- compliance bores - monitored to assess potential impacts from mining activity on sensitive receptors
- reference bores - monitored to establish baseline groundwater conditions so that appropriate trigger levels for the detection of impacts associated with mining can be developed
- observation bores - monitored to improve the understanding of the hydrogeological conditions in the area surrounding the mine.

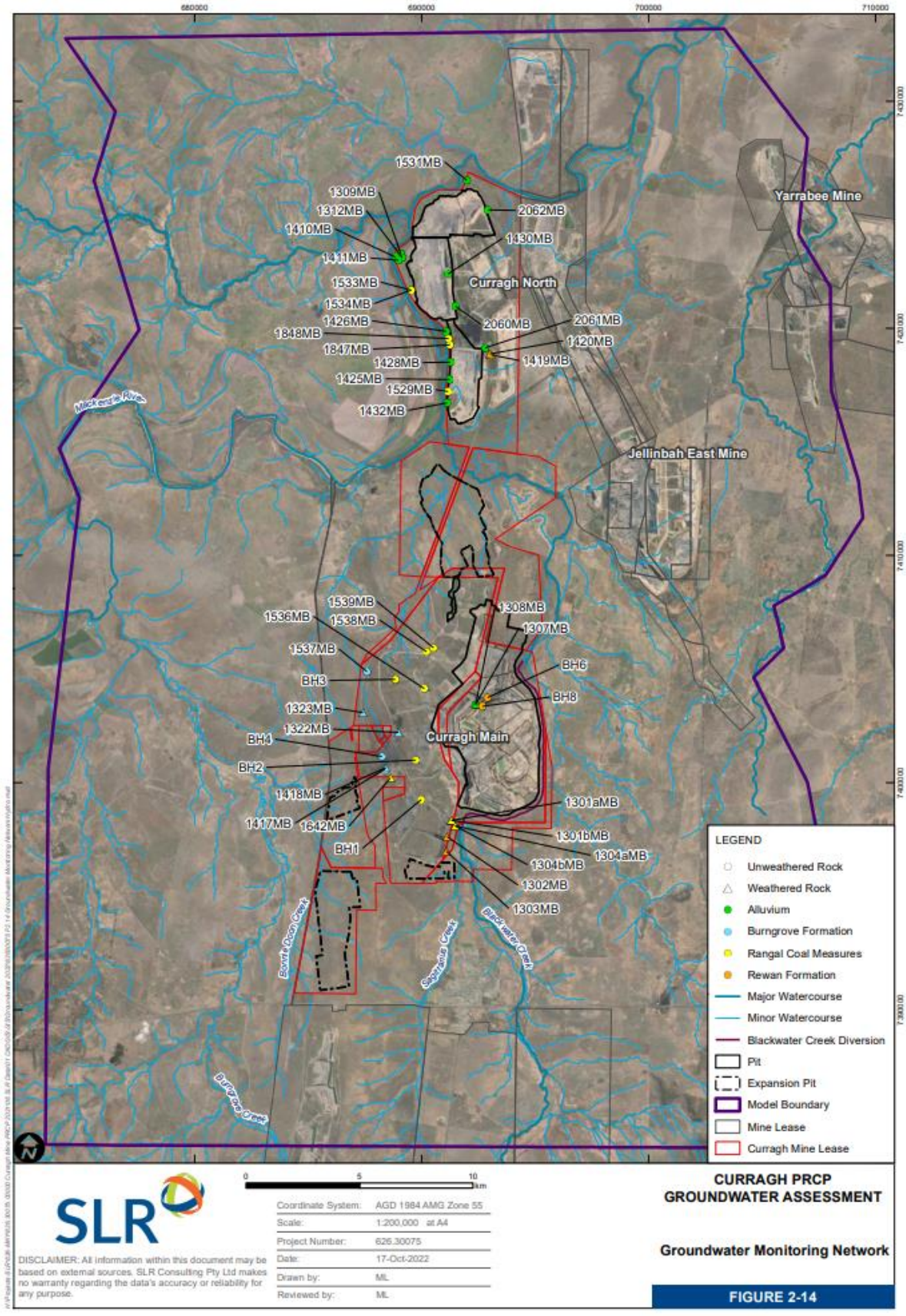



**Figure 2-14 Monitoring bore network**

## Table 2-3 Groundwater Monitoring Bores

| Bore | Easting | Northing | Ground RL (mAHD) | Screen Depth (mbgl) | Formation description | Date installed | Location | Available data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Water Quality | Water Level |
| **Alluvium** | | | | | | | | | |
| 1307MB* | 692378 | 7403433 | 143.16 | 4 – 7 | Alluvium | 08-07-2013 | Dam A | no | yes |
| 1308MB* | 692387 | 7403452 | 143.30 | 10 – 14 | Alluvium / weathered Tertiary (Duaringa Fm.) | 09-07-2013 | Dam A | no | no |
| 1309MB” | 689082 | 7423302 | 124.43 | 12 – 18 | Alluvium | 10-07-2013 | CN3 (between pit and Mackenzie R) | yes | yes |
| 1312MB* | 689148 | 7423118 | 125.93 | 11 – 17 | Alluvium | 11-07-2013 | CN3 (between pit and Mackenzie R) | yes | yes |
| 1426MB” | 691085 | 7419864 | 128.79 | 12 – 26 | Alluvium | 25-11-2014 | S Pit West - below levee north | yes | yes |
| 1428MB* | 691266 | 7418518 | 127.9 | 13 – 26 | Alluvium | 26-11-2014 | S Pit West - below levee central | no | no |
| 1531MB* | 691987 | 7426518 | 125.53 | 21 – 27 | Alluvium | 16-07-2015 | U Pit extension - north near levee | yes | yes |
| 1533MB” | 689529 | 7421689 | 132.36 | 21 – 27 | Alluvium | 15-07-2015 | T Pit - West levee | no | no |
| 1410MB” | 688842 | 7423144 | 126.05 | 10 – 18 | Alluvium | 27-11-2014 | CN3 | yes | yes |
| 1430MB* | 691169 | 7422399 | 127.56 | 22 – 27 | Alluvium | 21-11-2014 | T Pit - East (palaeochannel) | no | no |
| 1432MB* | 691123 | 7416724 | 134.75 | 2 – 5 | Alluvium | 25-11-2014 | S Pit Tertiary Ridge | no | no |
| 1411MB” | 688974 | 7423011 | 128.23 | 9 – 20 | Alluvium | 21-11-2014 | CN3 | yes | yes |
| 1425MB | 691229 | 7417747 | 125.12 | 16 – 19 | Alluvium | 24-11-2014 | S Pit West - below levee south | no | yes |
| 2060MB | 691488.4 | 7420977 | 123.88 | 18 – 24 | Alluvium | - | Dam A | no | yes |
| 2061MB | 692800.1 | 7419144 | 129.75 | 26.5 – 32.5 | Alluvium | - | Dam A | no | yes |
| 2062MB | 692921.8 | 7425213 | 123.77 | 13 – 19 | Alluvium | - | Dam A | no | yes |
| **Tertiary** | | | | | | | | | |
| 1301aMB* | 691313 | 7398339 | 151.83 | 4 – 11 | Tertiary (weathered) | 06-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1302MB* | 691118 | 7397611 | 153.64 | 3 – 6 | Tertiary (weathered) | 05-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1303MB* | 691086 | 7396966 | 156.9 | 3 – 6 | Tertiary (weathered) | 05-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1304aMB* | 691481 | 7398090 | 153.35 | 6 – 9 | Tertiary (weathered) | 04-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1419MB^ | 693083 | 7418830 | 137.96 | 1.2 – 15 | Tertiary (weathered Duaringa Fm.) | 19-11-2014 | Curragh North Fuel Farm | yes | no |
| 1420MB” | 693004 | 7418881 | 138.43 | 1.2 - 15 | Tertiary (weathered Duaringa Fm.) | 20-11-2014 | Curragh North Fuel Farm | yes | no |
| **Rewan Formation** | | | | | | | | | |

| Bore | Easting | Northing | Ground RL (mAHD) | Screen Depth (mbgl) | Formation description | Date installed | Location | Available data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Water Quality | Water Level |
| BH6* | 692902 | 7403743 | 141.98 | n/a | Rewan Fm | n/a | Dam A and B | no | no |
| BH8* | 692678 | 7403357 | 142.90 | n/a | Rewan Fm | n/a | Dam A | no | no |
| **Rangal Coal Measures** | | | | | | | | | |
| BH1" | 689978 | 7399250 | 157.70 | n/a | RCM | n/a | Crib hut 3 | yes | no |
| BH2" | 689746 | 7400993 | 169.8 | n/a | RCM | n/a | R5 landfill | yes | no |
| BH3" | 688846 | 7404539 | 176.52 | n/a | RCM | n/a | R8 landfill | yes | no |
| 1301bMB* | 691308 | 7398335 | 151.69 | 14 – 18 | RCM (weathered) | 06-07-2013 | New TSF (formerly Pit A R2) | yes | no |
| 1304bMB* | 691481 | 7398084 | 153.33 | 14 – 17 | RCM (weathered) | 02-07-2013 | New TSF (formerly Pit A R2) | yes | yes |
| 1529MB" | 691161 | 7417212 | 123.81 | 33 – 39 | RCM | 17-07-2015 | S Pit West - below levee south | yes | yes |
| 1534MB^ | 689540 | 7421687 | 132.52 | 27 – 33 | RCM | 13-07-2015 | T Pit - West levee | yes | yes |
| 1536MB" | 690116 | 7404141 | 148.504 | 35.5 – 41.5 | RCM | 02-07-2015 | Landfill - east | yes | yes |
| 1538MB^ | 690217 | 7405768 | 153.18 | 73 – 79 | RCM | 29-06-2015 | Ramp 10/11 | yes | yes |
| 1539MB* | 690523 | 7405931 | 152.2 | 53 – 59 | RCM | 03-07-2015 | Ramp 10/11 - second site | yes | yes |
| 1642MB | 688631 | 7400213 | 174.587 | 1.4 – 18.5 | RCM (weathered) | n/a | | no | yes |
| 1847MB | 691245.7 | 7419276 | 129.169 | 76.5 – 85.5 | RCM (Pisces) | n/a | | no | yes |
| 1848MB | 691184.3 | 7419553 | 128.902 | 85 – 94.5 | RCM (Pisces) | n/a | | no | yes |
| **Burngrove Formation** | | | | | | | | | |
| BH4" | 688260 | 7401147 | 170.19 | n/a | Burngrove Fm. | n/a | CHPP landfill | yes | no |
| 1322MB* | 688976 | 7402204 | 162.69 | 2 – 25 | Burngrove Fm. (weathered) | 26-07-2013 | Down gradient of industrial process area | no | yes |
| 1323MB^ | 687417 | 7403078 | 164.44 | 11 – 25 | Burngrove Fm. (weathered) | 25-07-2013 | Up gradient of mining ops | yes | yes |
| 1417MB^ | 688376 | 7400592 | 175.56 | 1.2 – 15 | Burngrove Fm. (weathered) | 18-11-2014 | Curragh Fuel Farm | yes | no |
| 1418MB" | 688428 | 7400647 | 175.56 | 1.2 – 16 | Burngrove Fm. (weathered) | 18-11-2014 | Curragh Fuel Farm | yes | no |
| 1537MB^ | 687589 | 7404885 | 157.71 | 30.5 – 36.5 | Burngrove Fm. (coal seam) | 27-06-2015 | SAR | yes | yes |

*Observation bore, ^Reference bore, "Compliance bore

## 2.3 Hydrogeology

### 2.3.1 Hydrostratigraphy

The main hydrostratigraphic units in the vicinity of the mine are described below, from the shallowest to the deepest/oldest:

- **Alluvium** – up to 30m thick in the north associated with the floodplain / channel deposits of the Mackenzie River. Thinner (up to 12 m), near extension Pit X and comprises clay, sand and gravel. At Curragh Main and the southern extension pits, up to 10 m thick but generally much thinner and predominantly clay and silt. The alluvium is dry in many areas. Unconfined water bearing sand and gravel may occur at the base of the alluvial sequence around Curragh North and near the proposed Pit X, but it is considered unlikely to be significantly water bearing where present across the south of the mine.
- **Regolith** - unconsolidated surface layer of weathered rock which may provide a preferential shallow flow pathway for groundwater. Occurs across the Project area at thicknesses between 5 and 15 m. Includes weathered residual rocks of the Duaringa and Emerald formations, Rewan Formation, Rangal Coal Measures and Burngrove Formation in areas of outcrop and below the alluvium. Variable permeability.
- **Cenozoic** (Tertiary Duaringa and Emerald formations) - Occurs around Curragh Main extension Pits X and D. Comprises cemented sands and gravels and sandstones, siltstones and mudstones. Water bearing zones may occur in more permeable layers, unconfined to semi-confined.
- **Rewan Group** - is a regional aquitard comprising mudstones interbedded with siltstone and fine to medium grained labile sandstone.
- **Rangal Coal Measures** - Occurs along the strike of the mine and is overlain to the east by the Rewan. Groundwater flow is primarily within the coal seams (via interconnected cleats and fractures), which are confined by low permeability overburden and interburden. The coal measures are highly faulted resulting in “compartmentalisation” with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of flow. Faults themselves may form barriers to flow or provide conduits.
- **Burngrove Formation** – outcrops/subcrops to the west of the mine dipping east below the Rangal Coal Measures. Groundwater flow occurs primarily via coal seams and fractured sandstone units with low permeability siltstone and claystone forming aquitards. As with the RCM sequence it is considered to be highly faulted with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of groundwater flow. This Formation is considered “basement” for the purposes of this assessment.

#### 2.3.1.1 Alluvium

The alluvium comprises coarse sands, gravels, silt, and clay. Groundwater present within the sand and gravel units is generally regarded as unconfined. Floodplain alluvium associated with the Mackenzie River and Blackwater Creek occurs extensively across Curragh North and the northern part of the extension Pit X.

For the 2016 expansion project hydrogeological assessment PB undertook a review of bore logs from the exploration drilling program which identified that Curragh North is underlain by a paleochannel system of significant thickness (12 - 30 m), predominantly comprising sand and gravel. The Pit X extension area is underlain by a thinner alluvial sequence (typically less than 12 m) predominantly comprising clay with sand and gravel lenses, generally occurring at depth. The alluvium in the southern areas of the mine is generally thin (<10m but typically much thinner) and comprised predominantly of clay and silt (PB 2016).

The Mackenzie River channel has migrated across the floodplain over time resulting in coarse sediments (sands and gravels) being deposited as point bar/channel deposits and lenses with overlying finer floodplain sediments. There is significant lateral variability and discontinuity in the coarser alluvial deposits which is likely to control/limit connectivity to the Mackenzie River (PB 2016). The permeability of the sands and gravels horizons within the alluvium will be variable and depend on the fines content (silt and clay).

Groundwater studies undertaken at Curragh North prior to the commencement of mining found the majority of monitoring bores installed in alluvium were dry. Where intersected, groundwater occurred within coarse basal sands and gravels (PB 2016).

Potential impacts from mining activities will depend on intersection of the alluvium by mining and connectivity between pits and watercourses via the alluvium with the main receptors being landholder bores and GDEs.

#### 2.3.1.2 Rangal Coal Measures

Coal seams are typically the most permeable horizons within the Rangal Coal Measures and are considered fractured rock aquifers with groundwater flow occurring via joints and cleats. The coal measures have also been extensively faulted which is likely to restrict flow through the coal seams due to the lateral discontinuity. The faults themselves may present barriers to flow or provide pathways for groundwater flow.

To the east of the mining activity the coal seam aquifers are confined by the interburden layers of low permeability shale, siltstone and mudstone.

#### 2.3.1.3 Burngrove Formation

The Burngrove Formation comprises an interbedded fractured rock aquifer system with water bearing units comprising fractured or weathered sandstone and coal seams. These fractured rock aquifer units are confined by low permeability sequences of siltstone, mudstone and tuff. The fractured rock aquifers are heterogeneous in properties and distribution over their spatial extent.

### 2.3.2 Groundwater Levels and Flow Direction

Groundwater level data was provided by the mine for late 2015 onward and is presented in hydrographs below for the alluvium, RCM and Burngrove Formation. Earlier groundwater level data presented in the 2016 PB groundwater assessment for the mine expansion is also described below.

#### 2.3.2.1 Alluvium

The alluvium associated with Mackenzie River is dry in many areas and where water is present it generally occurs in coarse channel deposits at the base of the alluvium. Perched groundwater in sand and gravel lenses within low permeability fines (silt and clay) has also been recorded in previous investigations (PB, 2016).

Pre-mining groundwater levels in the alluvium at Curragh North were generally 18 to 22 mbgl with groundwater levels recorded since commencement of mining ranging from approximately 16 to 26 mbgl (PB, 2016). The alluvium associated with Blackwater Creek in the southern area of the mine is dry in many areas.

More recent groundwater level data for the alluvium is presented in **Figure 2-15**. The data appears to show clear responses to rainfall variations through 2016 and 2017 and a slight declining trend apparent in some bores (in line with low rainfall since early 2018).

Most of the current alluvial monitoring is focused on the Mackenzie River alluvial deposits directly west of Curragh North. The only current alluvial monitoring south of this is at 1307MB within Curragh Main with the alluvial groundwater level reflecting the higher elevation of this area.

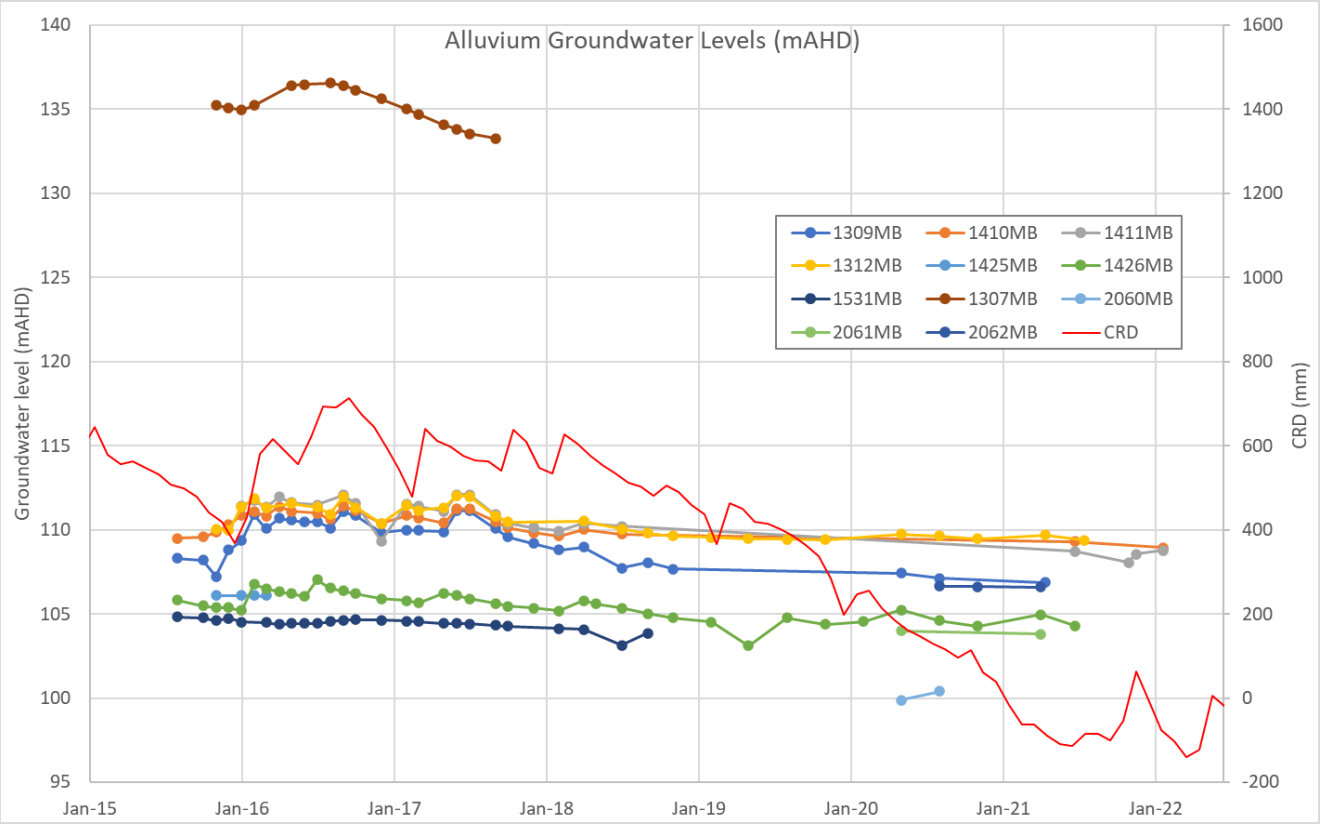



**Figure 2-15 Alluvium Groundwater Levels and Cumulative Rainfall Departure**

Overall, the alluvial groundwater levels clearly reflect a northerly flow direction along the Mackenzie River west of Curragh North. The 2016 PB assessment numerical modelling indicated that groundwater flow in the alluvium followed topography and drainage lines to the north and northeast. Data for 1309MB and 1312MB for July 2013 to the end of 2015 is consistent with subsequent data obtained from these bores.

Approximate contours for the alluvium (April 2018) are presented in **Figure 2-16** based on limited monitoring data. Alluvial monitoring bores are generally limited to the west and north of Curragh North and any alluvium in mined areas has obviously been removed. Contours have been generated through the northern part of the Blackwater Creek Alluvium although details on the nature of this alluvium (thickness and saturation) are very limited. The contours reflect a decline in alluvium groundwater levels to the north. Water levels in the adjacent McKenzie River (taken from LiDAR) appear to be slightly above the available water levels for the alluvium adjacent to the river indicating that the McKenzie River is a losing river. This aligns with the available data which indicates that at lower flows the McKenzie is regulated with releases from Fairbairn Dam and loses flow between Riley's Crossing (upstream weir) and Bingegang weir (downstream)

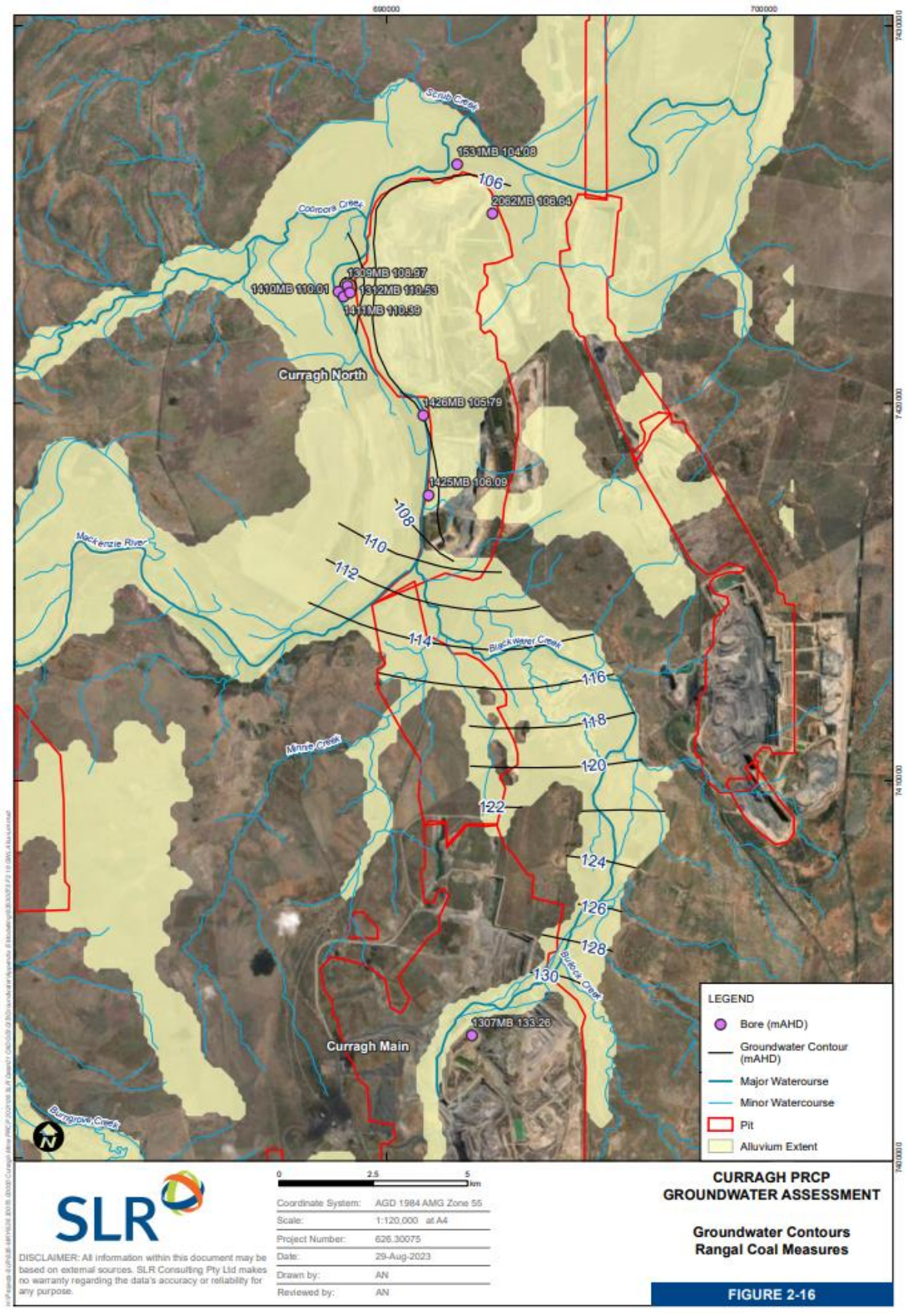



**Figure 2-16 Alluvium Groundwater Contours**

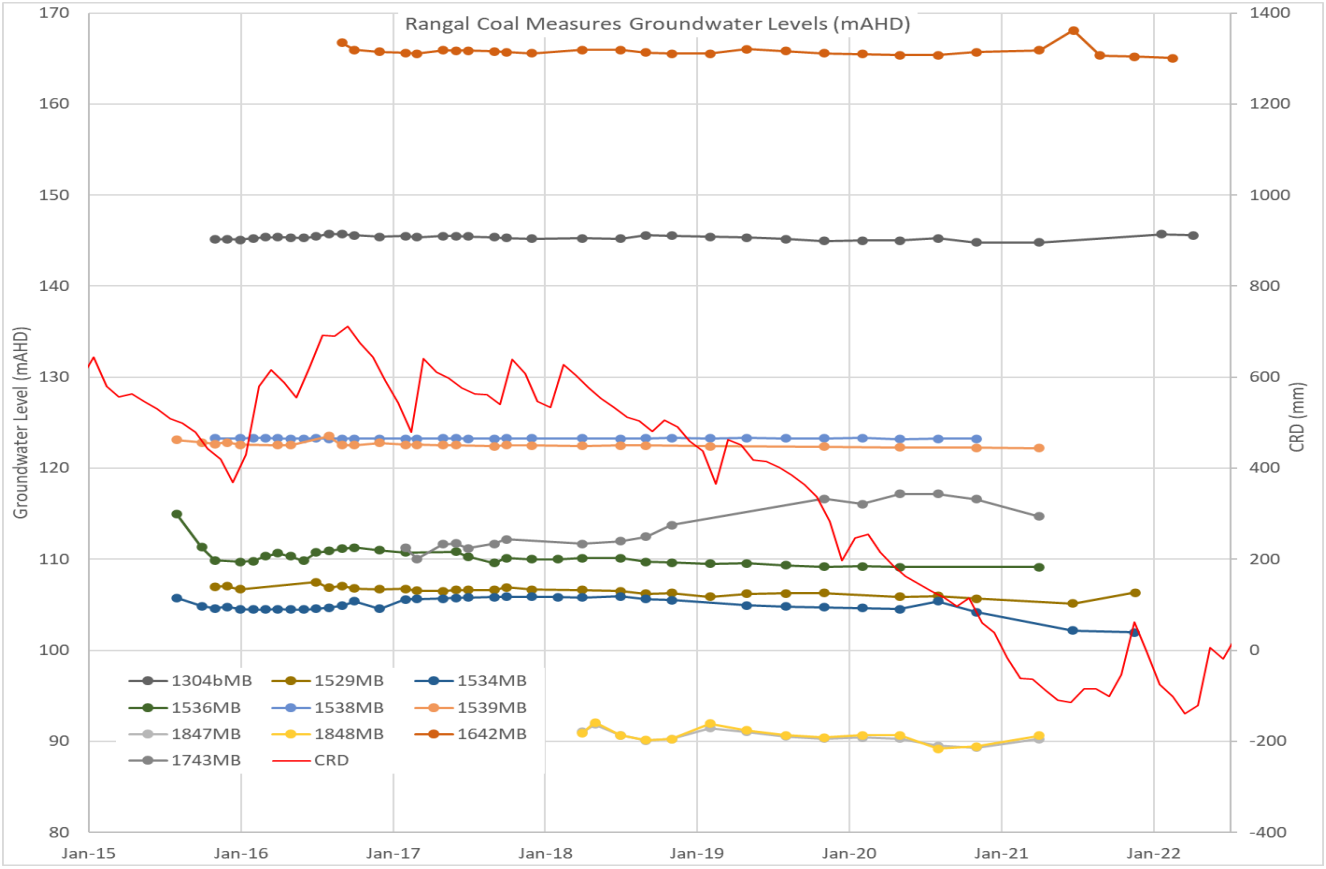



**Figure 2-17 RCM Groundwater Levels and Cumulative Rainfall Departure**

### 2.3.2.1 Rangal Coal Measures

Monitoring of the Pisces seam at Curragh North prior to the commencement of mining indicated pressure heads of 0 to 78 m above the seam. Groundwater levels in RCM outcrop areas were observed to respond to rainfall variations seen in the CRD and groundwater level recovery was also observed at some locations where mining progression had moved away from certain bores (PB, 2016). Prior to mining, the groundwater flow direction in the Permian strata was to the north-east at a very gentle gradient of 1 in 400 (Douglas Partners 2014). Since commencement of mining, the groundwater flow direction in the Permian strata has been influenced by dewatering in the active pit areas of Curragh and Jellinbah mines.

Recent groundwater level monitoring data for RCM bores is presented in **Figure 2-17** and generally shows very steady levels with little or no response to the CRD although several bores show slight declining trends from 2017 onward in line with lower than average rainfall although this may also be due to the influence of mining. Bore 1743MB shows a rising trend from 2017 onward, contrary to the CRD. This bore is located to the east of the Pit A TSF and south of Pit B TSF and screened at shallow depth (14-17 m bgl). It is possible that the rising groundwater level trend in this bore relates to the filling of the adjacent TSFs.

Very approximate contours for the RCM (July 2018) are presented in **Figure 2-18** based on limited monitoring locations. RCM monitoring bores are generally limited to the west of the mine pits in the area of sub-crop. Obviously much of the RCM has been mined out (at least the upper and middle seams) across the pits at Curragh North and Curragh Main and so the contours are somewhat interpretive given the limited monitoring data, the bore locations and the removal of much of the RCM in the vicinity of the monitoring bores. The contours reflect a general decline in RCM groundwater levels to the north and gradients eastwards into the mined areas.

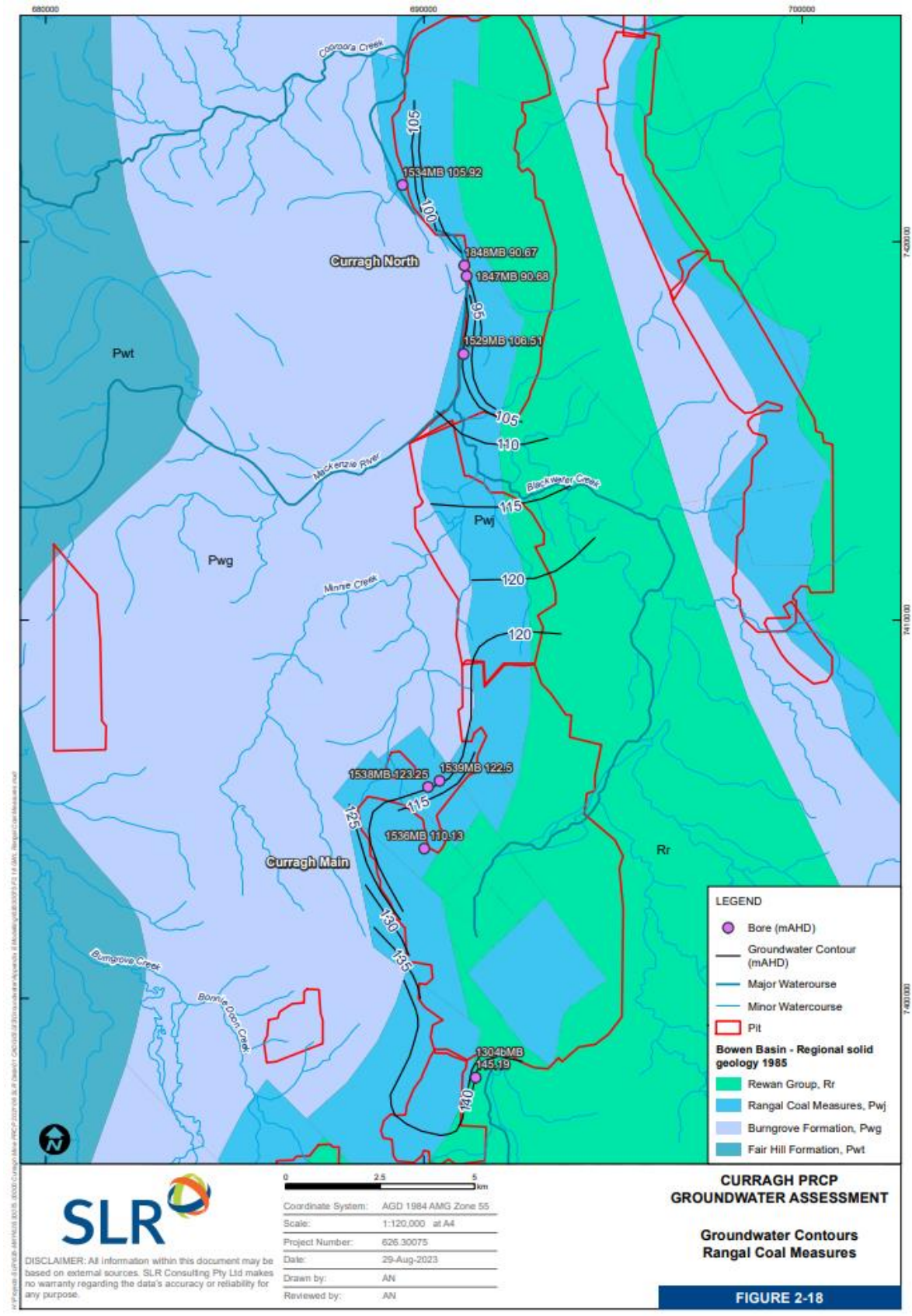



**Figure 2-18 Rangal Coal Measures Groundwater Contours**

#### 2.3.2.2 Burngrove Formation

Groundwater levels recorded in the Burngrove Formation since commencement of mining have ranged from approximately 6 to 29 mbgl with shallow bores in unconfined outcrop areas showing levels that correspond to long term rainfall trends. (PB, 2016).

Recent groundwater level monitoring data for the four bores installed in the Burngrove Formation are presented in **Figure 2-19** All four bores are installed on the west side of Curragh Main to depths of less than 35m bgl. 1417MB shows a slight declining trend over time and possibly some response to the CRD over this period. 1537MB and to a lesser extent 1322MB show a slight rising trend over the monitoring period, possibly due to the progression of mining activity away from these locations. Recovery responses may also be somewhat masked by lower than average rainfall over the monitoring period.

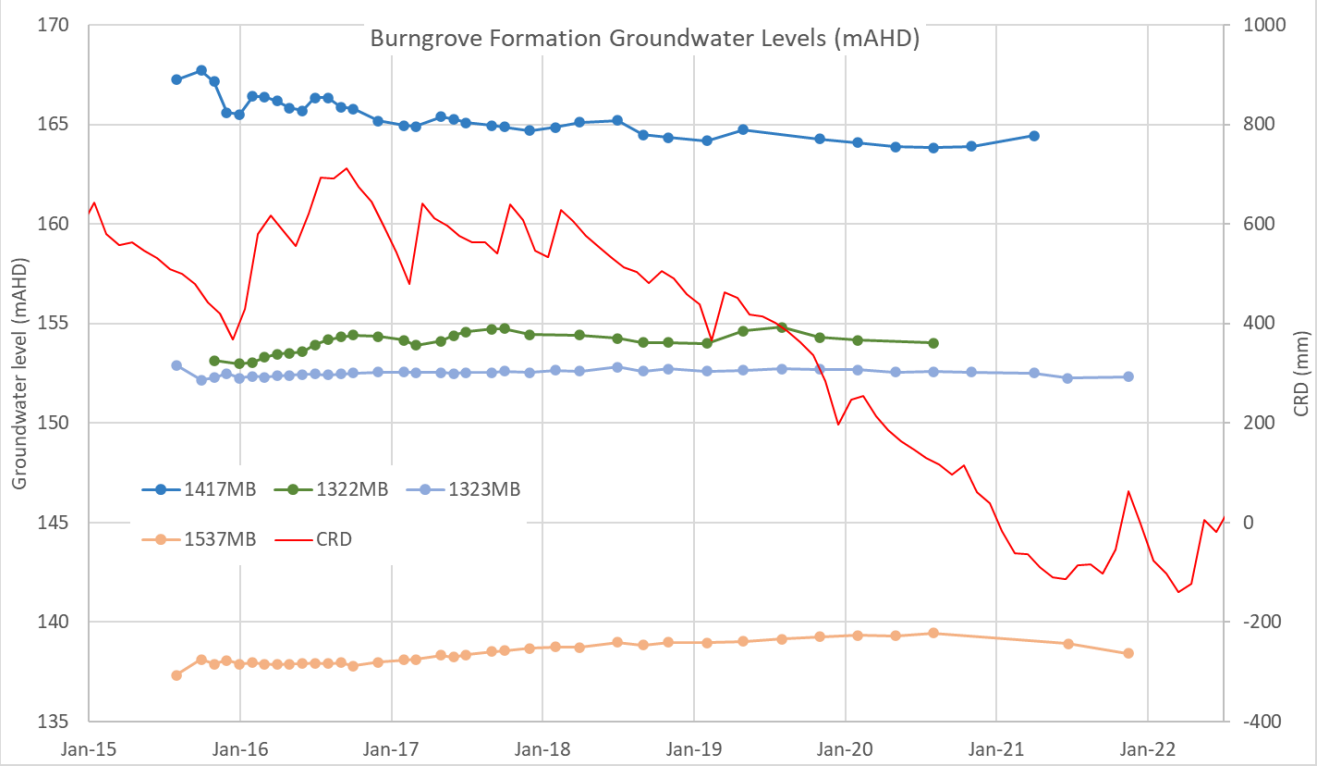



**Figure 2-19 Burngrove Formation Groundwater Levels and Cumulative Rainfall Departure**

### 2.3.3 Pre-mining groundwater flow

Modelled pre-mining groundwater levels (water table) simulated in the numerical model are presented in **Figure 3-5** and show a generally northerly flow of groundwater across the southern area of the model domain, turning more towards the north-east in the northern part of the model domain, essentially aligned with the Mackenzie River which flows in the same direction.

### 2.3.4 Effects of faulting on groundwater flow

As well as the larger mapped faults referred to in **Section 2.1.5**, the many minor faults will be present throughout the Permian strata.

A seismic survey across an area approximately 4x4km directly south of Blackwater was completed for the Minyango Project in 2011 (Velseis, 2012). The aim was to map the roof of the Aries and Pollux seams, mapping structures / faulting including characterisation of displacement, orientation and fault type. A total of 709 structural features were interpreted within the 16 sq km survey area for all seams.

Most structures (faults) interpreted from the survey were high angle with two main faulting trends identified striking either NNW-SSE or approximately E-W. No dominant fault type was identified with a similar number of faults characterised as reverse, normal and undefined. Many of the structures classified as undefined appear as if they may have been reactivated as they display both normal and reverse characteristics. The largest vertical displacements interpreted across the Aries and Pollux seams were 53.5m and 38m respectively. However, most faults interpreted across both horizons had displacements of less than 15m.

The high degree of faulting within the Rangal Coal Measures identified locally by the Velseis survey will have will have resulted in “compartmentalisation” with the faulting juxtaposing the more permeable coal seams against interburden along fault planes. This will limit the coal seams exposed in the pit highwalls from acting as continuous pathways for potential seepage migration with abrupt discontinuation of seams where they are displaced by faulting against lower permeability interburden.

Whilst faulting around Curragh is considered likely to have resulted in strong compartmentalisation within the coal measures, some faults may act as conduits for groundwater flow.

### 2.3.5 Hydraulic Properties

Hydraulic property data obtained from the Curragh site and surrounding mines and other relevant sources for the key formations of interest was collated by PB for the 2016 Curragh expansion project and has been reproduced in **Table 2-4**.

The parameter ranges presented in **Table 2-4** indicates the highly variable hydraulic conductivity in the alluvium depending on the silt / clay content. The coal seams within the Rangal Coal Measures exhibit variably moderate permeability, and typically significantly higher than the interburden strata.

## Table 2-4 Hydraulic Parameter Estimates (reproduced from PB, 2016)

| Age / Formation | Lithology | Kh (m/d) | Kv (m/d) | Ss ($m^{-1}$) | Sy | Source | Project | Source |
|---|---|---|---|---|---|---|---|---|
| Quaternary Alluvium | Mackenzie River alluvium - silty clay | 0.0009 – 0.001 | | | | Falling head test | Curragh North | 1 |
| | Mackenzie River alluvium - sand | 0.09 – 9 | | | | Falling head test | Curragh North | 1 |
| | Mackenzie River alluvium - sand/gravel | 0.9 – 9 | | | | Falling head test | Curragh North | 1 |
| | Mackenzie River alluvium - gravel | 10 | | | | Constand rate test | Mackenzie South | 2 |
| | Blackwater Creek alluvium | 0.4 | | | | Rising head test | Minyango | 3 |
| | Blackwater Creek alluvium | 0.6 | 0.018 | | | Calibrated model parameters | Minyango | 3 |
| | Floodplain/ river alluvium | 1 – 40 | 0.1 – 2 | 0.0005 | 0.05 – 0.18 | Calibrated model parameters | Arrow Energy | 7 |
| | Not specified0.00 | 100 | 10 | 0.001 | 0.25 | Unknown | Ensham Central | 6 |
| | Not specified | 0.7 – 1.5 | | 0.0001 | | Unknown | Barabala North | 13 |
| | Not specified | 10 | 1 | | 0.2 | | Millenium expansion | 8 |
| | Not specified | 0.088 – 0.38 | | 0.00001 | | Unknown | Caval Ridge | 9 |
| | Not specified | 10 | 1 | 0.00005 | 0.1 | Unknown | Springsure Creek | 11 |
| Tertiary | Duaringa Fm. - unspecified | 0.05 | 0.005 | 0.00005 | 0.12 | Calibrated model parameters | Arrow Energy | 7 |
| | | 0.6 | 0.018 | | | | Minyango | 3 |
| | Weathered – sandy gravels | 0.9 | | | | Unknown | Curragh North | 1 |
| | Weathered – claystone / cemented strata | 0.43 | | | | Unknown | Curragh North | 1 |
| Triassic Rewan Fm. | Sedimentary strata | 0.00075 | 0.0000001 | 0.00005 | 0.05 | Calibrated model parameters | Arrow Energy | 7 |
| | | 0.00015 – 0.055 | | | | Falling head tests | Minyango | 3 |
| | | 0.0009 | 0.000054 | | | Calibrated model parameters | Minyango | 3 |
| | | 0.00001 – 0.0001 | 0.000001 – 0.00001 | 0.000001 | 0.005 | Unknown | Ensham Central | 6 |
| | | 0.1 | 0.00001 | 0.000005 | 0.05 | Unknown | Daunia | 10 |
| | | 0.0001 | 0.0000007 | 0.00001 | 0.01 | Unknown | Springsure Creek | 11 |

| Age / Formation | Lithology | Kh (m/d) | Kv (m/d) | Ss ($m^{-1}$) | Sy | Source | Project | Source |
|---|---|---|---|---|---|---|---|---|
| | | 0.000007 | | | | Calibrated model parameters | Carmichael | 12 |
| Permian Rangal Coal Measures | Overlying units | 0.04 | 0.001 | | | Packer tests | Curragh North | 1 |
| | Fractured coal | 0.009 – 0.09 | | | | Packer tests | Curragh North | 1 |
| | Intact coal | 0.017 | | | | Packer tests | Curragh North | 1 |
| | Aries coal seam | 0.003 | | | | Falling head test | Minyango | 3 |
| | | 0.14 | | | | Drill stem test | Minyango | 4 |
| | Aries / Castor coal seam | 0.00014 | | | | Packer leak-off test | Cook Colliery | 5 |
| | Castor coal seam | 0.06 | | | | Drill stem test | Minyango | 4 |
| | Pollux coal seam | 0.017 | | | | Drill stem test | Minyango | 4 |
| | | 0.9 | | | | Constant rate test | Mackenzie South | 2 |
| | Pisces coal seam | 0.003 | | | | Drill stem test | Minyango | 4 |
| | Interburden | 0.0001 | $1 \times 10^{-8}$ | $8.5 \times 10^{-6}$ | 0.05 | Calibrated model parameters | Arrow Energy | 7 |
| | | 0.00009 | $1.8 \times 10^{-6}$ | | | Calibrated model parameters | Minyango | 3 |
| | | 0.1 | | $5 \times 10^{-6}$ | 0.05 | Unknown | Daunia | 10 |
| | | 0.001 | 0.00001 | 0.00001 | 0.01 | Unknown | Springsure Creek | 11 |
| Permian Burngrove | Coal and interburden | 0.00044 | $8.8 \times 10^{-6}$ | 0.00005 | 0.12 | Calibrated model parameters | Minyango | 3 |
| | | 0.000009 | $9.9 \times 10^{-7}$ | | | Calibrated model parameters | | |
| Permian Fair Hill Fm. | Fort Cooper coal seams (Virgo/ Leo/ Aquarius) | 0.000017 | | | | Packer leak-off test | Cook Colliery | 5 |

**1** Minserve (1998), cited in Parsons Brinckerhoff (2003), **2** ERM (2002), cited in AGE (2006), **3** AGE (2013a), **4** Polymetra (2009), cited in AGE (2013a), **5** North Queensland Energy (1993), cited in AGE (2013a), **6** AGE (2006), cited in HydroSimulations (2014), **7** Ausenco-Norwest (2012), **8** Matrix Plus (2010), **9** URS (2009), cited in HydroSimulations (2014), **10** BHP Billiton Mitsubishi Alliance, cited in HydroSimulations (2014), **11** CDM Smith (2013), cited in HydroSimulations (2014), **12** GHD (2013), **13** JBT (2012), cited in HydroSimulations (2014)

### 2.3.6 Groundwater Quality

Groundwater quality data has been provided for the bores listed in **Table 2-5** and which are shown on **Figure 2-14**. Data is generally available from late 2015 onward with limited data provided from before this time. Historically, groundwater quality monitoring was infrequent between 1997 to 2012 with the frequency increasing thereafter. Samples were analysed for electrical conductivity (EC), pH, major ions, nutrients, dissolved metals and hydrocarbons. Water quality statistics for selected analytes are shown in **Table 2-6**.

**Table 2-6** also includes data for three water samples taken in 2022 from the Pit B tailings storage facility. As there are no monitoring bores installed in the tailings these samples have been taken as providing indicative water quality for water within the tailings.

**Table 2-5 Currently available groundwater quality data**

| Screened Formation | Bore ID | Data availability | |
|---|---|---|---|
| | | From | To |
| Alluvium | 1309MB | 28-10-2015 | 01-04-2020 |
| Alluvium | 1312MB | 03-10-2019 | 03-10-2019 |
| Alluvium | 1426MB | 30-10-2015 | 10-11-2020 |
| Alluvium | 1531MB | 28-10-2015 | 13-05-2020 |
| Alluvium | 1410MB | 03-03-2016 | 29-06-2018 |
| Alluvium | 1411MB | 28-04-2016 | 11-06-2019 |
| Tertiary (weathered) | 1301aMB | 30-01-2020 | 06-01-2021 |
| Tertiary (weathered) | 1302MB | 03-10-2019 | 07-01-2021 |
| Tertiary (weathered) | 1303MB | 03-10-2019 | 07-01-2021 |
| Tertiary (weathered) | 1304aMB | 18-09-2013 | 13-06-2016 |
| Tertiary (weathered Duaringa Fm.) | 1419MB | 06-08-2015 | 28-06-2018 |
| Tertiary (weathered Duaringa Fm.) | 1420MB | 30-12-2016 | 20-06-2017 |
| RCM | BH1 | 26-06-2000 | 09-11-2020 |
| RCM | BH2 | 09-02-2000 | 16-11-2020 |
| RCM | BH3 | 09-02-2000 | 11-11-2020 |
| RCM (weathered) | 1301bMB | 03-10-2019 | 06-01-2021 |
| RCM (weathered) | 1304bMB | 04-09-2013 | 06-01-2021 |
| RCM | 1529MB | 06-08-2015 | 10-11-2020 |
| RCM | 1534MB | 06-08-2015 | 09-12-2020 |
| RCM | 1536MB | 16-04-2018 | 14-05-2020 |
| RCM | 1538MB | 19-08-2015 | 11-11-2020 |
| RCM | 1539MB | 29-10-2015 | 20-08-2018 |
| Burngrove Fm. | BH4 | 09-02-2000 | 09-12-2020 |
| Burngrove Fm. (weathered) | 1323MB | 07-01-2014 | 09-11-2020 |
| Burngrove Fm. (weathered) | 1417MB | 05-08-2015 | 09-11-2020 |
| Burngrove Fm. (weathered) | 1418MB | 22-06-2015 | 11-11-2020 |
| Burngrove Fm. (coal seam) | 1537MB | 30-10-2015 | 10-11-2020 |

## Table 2-6 Groundwater quality statistics

**Table 2-7 Total dissolved solids (mg/L) - livestock water quality guidelines and groundwater quality**

| Livestock | Low range | Medium range | High range |
|---|---|---|---|
| Beef Cattle | 0 – 4,000 | 4,000 – 5,000 | 5,000 – 10,000 |
| Dairy Cattle | 0 – 2,400 | 2,400 – 4,000 | 4,000 – 7,000 |
| Sheep | 0 – 4,000 | 4,000 – 10,000 | 10,000 – 13,000 |
| Horses | 0 – 4,000 | 4,000 – 6,000 | 6,000 – 7,000 |
| Pigs | 0 – 4,000 | 4,000 – 6,000 | 6,000 – 8,000 |
| Poultry | 0 – 2,000 | 2000 – 3,000 | 3,000 – 4,000 |
| **Formation** | **20th %ile** | **50th %ile** | **80th %ile** |
| Mackenzie Alluvium | 334 | 378 | 640 |
| Tertiary | 1,132 | 2,350 | 9,596 |
| Rangal Coal Measures | 1,090 | 8,434 | 9,674 |
| Burngrove Fm. | 2,242 | 4,710 | 8,366 |
| Tailings Water Samples (3 samples from Pit B TSF 2022)) | 4,480 (min) | 6,717 (mean) | 8,260 (max) |

**Low range** - No adverse effects expected
**Medium Range** - Animals may have initial reluctance to drink, but stock should adapt without loss of production.
**High range** - Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually.

To provide a broad picture of groundwater quality in the vicinity of the mine **Table 2-6** and **Table 2-7** presents water quality statistics (20th, 50th and 80th percentiles) for each of the main formations monitored together with the following relevant water quality guidelines:

- **Livestock drinking water guidelines (ANZECC, 2000) –** given the rural agricultural setting of the mine the stock watering guidelines are considered relevant to assessing local groundwater values.
- **Australian Drinking Water Guidelines (ANZECC, NRMMC 2011)** – given the rural setting of the mine and the potential presence of local stock and domestic bores the drinking water guidelines are considered relevant to assessing local groundwater values.
- **Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) –** these guidelines, originating from the ANZECC & ARMCANZ (2000) water quality guidelines, provide guideline values for the protection of fresh and marine water habitats. The values selected from this guidance relates to slightly-moderately disturbed freshwater systems for 95% species protection. These guidelines are considered relevant for protection of the Mackenzie River and its tributaries.
- **Groundwater Quality Objectives for the Fitzroy River Basin** (Zone 13 & 34) (DEHP 2011) - These guidelines are intended to be protective of surface waters where there is the potential for groundwater surface water interaction i.e., groundwater quality should not compromise identified EVs and WQOs for those waters. This guidance groundwater quality objectives i.e., background groundwater quality statistics that should be maintained for groundwaters, for 44 zones and depths (shallow and deep) across the Fitzroy Basin. The mine lies within Zone 13 which is categorised as Low-Moderate salinity alluvial groundwater – reflective of the Mackenzie River Alluvium. In addition, guideline values for Zone 34 (deep) have been included which is regarded as saline groundwater and considered more representative of deeper groundwater within the RCM and Burngrove Formation.

A summary of general groundwater quality compared these to guideline values is presented below.

- **Livestock drinking water guidelines (ANZECC, 2000)** – except for sulphate in Tertiary strata at the 50th and 80th percentile none of the guideline values for stock watering in Table 2-6 are exceeded in any lithology even at the 20$^{th}$ percentile. TDS is considered separately in **Table 2-7**:
    - **Mackenzie River Alluvium** – Salinity/TDS is suitably low for stock watering.
    - **Tertiary** – salinity is generally low and suitable for most stock although higher salinities/TDS are observed around the 80$^{th}$ percentile rendering it suitable for beef cattle and sheep only.
    - **RCM** – salinity/TDS is elevated with concentrations around the 50$^{th}$ percentile becoming unsuitable for more sensitive livestock. 80$^{th}$ percentile TDS exceeds the high range guidelines for most livestock except sheep and beef cattle.
    - **Burngrove Formation** – salinities/TDS around the 50$^{th}$ percentile concentration are generally still suitable for all but the most sensitive livestock (poultry and dairy cattle) but increase to similar concentrations seen in the Tertiary and RCM at the 80$^{th}$ percentile. 80$^{th}$ percentile TDS exceeds the high range guidelines for most livestock except sheep and beef cattle.
    - **Pit B tailings water** – the three samples collected show mean and maximum salinities similar to but lower than the RCM with the mean TDS being generally unsuitable for more sensitive livestock. Maximum TDS exceeds the high range guidelines for most livestock except sheep and beef cattle.
- **Australian Drinking Water Guidelines (ANZECC, NRMMC 2011) –** groundwater quality in the Mackenzie River Alluvium to the west of Curragh North is considered generally suitable for drinking water based on chemical quality noting the exceedances below. The composition of groundwater in the Tertiary, RCM, and Burngrove Fm. Is considered unsuitable for drinking water, primarily due to its generally high salinity. The following exceedances of guideline values are noted:
    - **Mackenzie River Alluvium -** The (aesthetic) guidelines for TDS, Na and total hardness are exceeded at the 80th percentile and the (aesthetic) guideline for Fe is exceeded at all percentiles. In addition, the guideline for As is fractionally exceeded at the 80th percentile.
    - **Tertiary -** The (aesthetic) guidelines for TDS, Cl, Na, SO4 and hardness are exceeded at the 20th percentile. In addition, the guidelines for Al, As and Fe are exceeded at the 80th percentile and one analysis for Mn also exceeds the guideline.
    - **RCM -** The (aesthetic) guidelines for TDS, Cl, Na and hardness are exceeded at the 20th percentile, and SO4 at the 50th percentile. In addition, the guidelines for As, Fe and Mn are exceeded at the 80th percentile.
    - **Burngrove Formation** - The (aesthetic) guidelines for TDS, Cl, Na and hardness are exceeded at the 20$^{th}$ percentile, and SO4 at the 80$^{th}$ percentile.
    - **Pit B tailings water** – The (aesthetic) guidelines for TDS, Cl, Na, hardness and SO4 are exceeded. and SO4 at the 50th percentile. In addition, the maximum concentration of Sb exceeds guideline value.
- **Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) –** 95% species protection. With regard to the potential impacts on surface water ecosystems local groundwater the following exceedances identified:
    - **Mackenzie River Alluvium** – none of the guideline values are exceeded at the 20th percentile.
    - **Tertiary** – The guideline for B and Zn is exceeded although the sample count for these analytes is just 1.

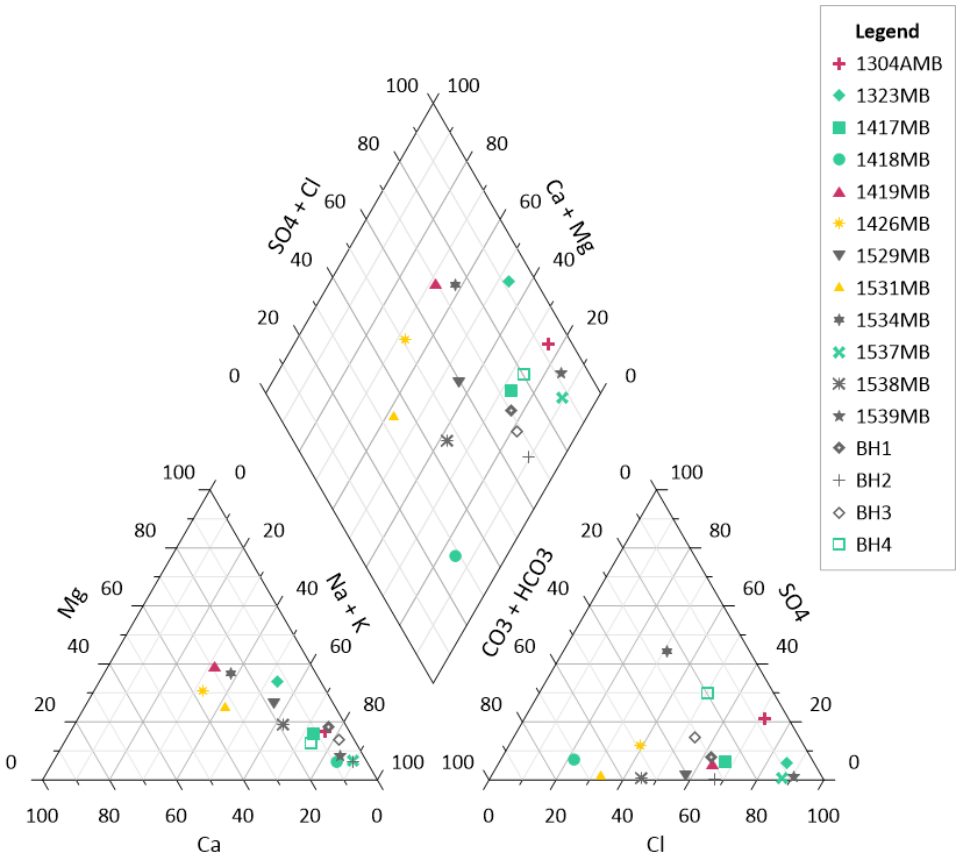
- **RCM** - The guideline for B is exceeded at the 20th percentile; Cr, Cu and Zn at the 50th percentile and, Co, K and Ag at the 80th percentile.
- **Burngrove Formation** - The guideline for B is exceeded at the 20$^{th}$ percentile; Cu and Zn at the 50$^{th}$ percentile and, Cr at the 80$^{th}$ percentile.
- **Pit B tailings water** - The guideline for B, Co and Se is exceeded by the maximum concentration; and the guideline for Zn by all three samples.

- **Groundwater Quality Objectives for the Fitzroy River Basin (Zone 13 & 34) (DEHP 2011)** - These guidelines are intended to be protective of surface waters where there is the potential for groundwater - surface water interaction. The Mackenzie River Alluvium has been compared to Zone 13 (shallow) guidelines which are intended for low salinity alluvial groundwater. The Tertiary, RCM and Burngrove Formation groundwater has been compared to guidelines for Zone 34 (deep) which are considered more appropriate for the deeper geology across the mine:
  - **Mackenzie River Alluvium** – pH (slightly lower than the 20th %ile guideline); and exceedances for EC (80th %ile), Ca (20th and 50th %iles), Fe (20th, 50th and 80th %iles), Na (80th %ile), and SO4 (50th and 80th %iles).
  - **Tertiary** – pH (slightly lower than the 20th %ile guideline); and exceedances for Ca (20th and 50th %iles), Mg (20th and 50th %iles), Mn (20th, 50th and 80th %iles), Na and SO4 (20th, 50th and 80th %iles).
  - **RCM** - pH (slightly lower than the 20th and 50th %ile guideline); and exceedances for Fe (50th and 80th %iles), Mg (20th %ile), Mn, Na and SO4 (20th, 50th and 80th %iles).
  - **Burngrove Formation** - pH (slightly lower than the 20$^{th}$ %ile guideline); and exceedances for EC (20$^{th}$ and 50$^{th}$ %iles), Fe (80$^{th}$ %ile), Mg (20$^{th}$ %iles), Mn (20$^{th}$, 50$^{th}$ and 80$^{th}$ %iles), Na and SO4 (50$^{th}$ and 80$^{th}$ %iles).
  - **Pit B tailings water** –
    - exceedances of the “shallow” guideline values for pH (slightly higher) and EC, Ca, Cl, Mg, Mn, Na, SO4 and total hardness (20th, 50th and 80th %iles); Zn (20$^{th}$ and 50th %iles);
    - exceedances of the “deep” guideline values for pH (slightly higher) and SO4 (20th, 50th and 80th %iles); EC, Cl, Mg, Na, and total hardness (20th, 50th %iles); Ca, Mn, Zn (20$^{th}$ %ile).

The quality of tailings water obtained from the Pit B TSF is considered to be broadly very similar to the groundwater samples obtained from the RCM. The tailings water has trace concentrations of As and Sb and a significantly higher SO4 concentrations compared to the RCM groundwater. Whereas RCM groundwater contains trace concentrations of Cu and Cr which the tailings water samples do not.

For bores with sufficient data on major ion chemistry, the mean major ion concentrations have been plotted on a Piper Diagram (**Figure 2-20**), to determine key differences in the hydrochemical facies of groundwater sampled from different strata. The Piper Plot displays individual bores colour coded for the different formations: Mackenzie River Alluvium (yellow), Tertiary (red), RCM (grey) and Burngrove Formation (green).

The fresher groundwater of the Mackenzie River Alluvium (yellow), fall within the Mg-HCO3 field while the RCM bores plot mostly within the Na-Cl field as does groundwater sampled from the Burngrove Formation. The two bores screened in the Tertiary plot separately in the Na-Cl field and the adjacent mixed Ca-Mg-Cl field.




*Mackenzie River Alluvium (yellow), Tertiary (red), RCM (grey) and Burngrove Formation (green)

**Figure 2-20 Piper plot of groundwater major ion chemistry**

### 2.3.7 Groundwater Recharge and Discharge

#### 2.3.7.1 Recharge

Recharge of the alluvial aquifers occurs via stream flow, particularly during periods of high flow and flooding, as well as via rainfall infiltration. Most creeks in the region are ephemeral, although flow in the Mackenzie River is controlled by releases from Fairbairn Dam and the upper reach of Blackwater Creek flows due to discharge from the Blackwater Wastewater Treatment Plant. These streams may provide a constant source of recharge to the underlying alluvial and weathered rock groundwater systems. Groundwater studies undertaken at Curragh North prior to the commencement of mining found the alluvium was dry in many areas which may be related to clays and silts in the upper part of the alluvial profile restricting direct recharge and streamflow infiltration (PB 2003).

In the initial phases of mining at Pit S at Curragh North in late 2014, conceptual understanding was that Mackenzie River may provide recharge to the alluvium with a hydraulic gradient in the alluvium towards Pit S (Douglas and Partners, 2014). However, the 2016 PB assessment indicates that very minor inflow from the alluvium in the wall buttress on the Mackenzie River side of the pit has been observed and no change in water levels in Mackenzie River during mining (PB 2016). This may be due to the disconnected nature of the permeable channel deposits and the presence of clay and silt layers limiting the connectivity between the alluvium and mining operations directly east of the Mackenzie River at Curragh North (PB 2016).

From a review of available monitoring data Parsons Brinckerhoff (2003) identified a limited response in alluvial groundwater levels to rainfall events and subsequent river level rises and suggest this was due to the monitored alluvial groundwater being perched, and the high fines content of the alluvial sand and gravel lenses.

Following a review of alluvial bore logs between the Mackenzie River and proposed Pit X, and Blackwater Creek and proposed extension Pits D and J which identified a relatively high proportion of clay, PB (2016) again suggest that recharge to alluvium in these areas may be limited.

Recharge to the aquifer units within the RCM and Burngrove Formation is likely to occur predominantly through rainfall infiltration in outcrop areas, and via vertical leakage, particularly where coal seams subcrop permeable alluvium. Some recharge may also occur via stream flow where formations outcrop / subcrop along creek lines, for example where the RCM outcrops Bonnie Doon Creek.

#### 2.3.7.2 Discharge

The major discharge from the RCM in the vicinity of the mine is direct inflow to the mine pits. Regional groundwater flow is also a discharge mechanism with the general direction of groundwater flow being toward the north-east.

Evapotranspiration from the water table is also a significant discharge mechanism in areas where the water table is shallow and within the rooting depth of vegetation.

The BOM GDE Atlas indicates that Mackenzie River, Blackwater Creek and Cooroora Creek have a moderate potential for groundwater interaction. There is potential that groundwater in alluvium may discharge to Mackenzie River at times, particularly during the wet season when groundwater levels may rise. This is discussed further below.

Local extraction of groundwater by landholders is also a discharge mechanism although this appears to be limited in the vicinity of the mine (**Section 2.4.2**).

Other streams in the study area, including Blackwater Creek, Minnie Creek, Sagittarius Creek and Bonnie Doon Creek, are considered unlikely to receive baseflow from groundwater. This is consistent with site observations which indicate these streams are dry during the dry season and only flow following rainfall runoff during the wet season (PB 2016).

### 2.3.8 Surface Water Groundwater Interaction

#### 2.3.8.1 Mackenzie River (including Cooroora Creek)

The Mackenzie River is the main watercourse in the vicinity of the mine with regulation and releases from Fairburn Dam having altered the natural flow regime. Cooroora Creek is a tributary of Mackenzie River to the west of Curragh North.

##### 2.3.8.1.1 Occurrence of groundwater

Groundwater studies undertaken by Parsons Brinckerhoff (2003) at Curragh North prior to the commencement of mining found that most monitoring bores installed in alluvium were dry. Where water was present in monitoring bores, it occurred within the basal palaeochannel deposits of gravel and coarse sands.

#### 2.3.8.1.2 Pre-mining groundwater levels

Groundwater studies undertaken by Parsons Brinckerhoff (2003) at Curragh North prior to the commencement of mining included installation of a groundwater monitoring network in the Mackenzie River alluvium and monitoring levels in the Mackenzie River.

Monitoring was undertaken from November 2001 to May 2003 at three alluvial bores located immediately adjacent to Mackenzie River (near current Pit U and Pit T). Hydrographs for these bores and levels in the Mackenzie River are presented in **Figure 2-21** and show that groundwater levels in the alluvium were 3-5 m below the Mackenzie River stage. The monitoring also shows that high flow events captured in the monitoring data with river stage increases of over 1m had little or no impact on groundwater levels in the neighbouring alluvial groundwater bores. The data was interpreted as an indication that prior to mining at Curragh North, there was limited leakage from the river to the alluvium, and no discharge of groundwater from the alluvium to the river.

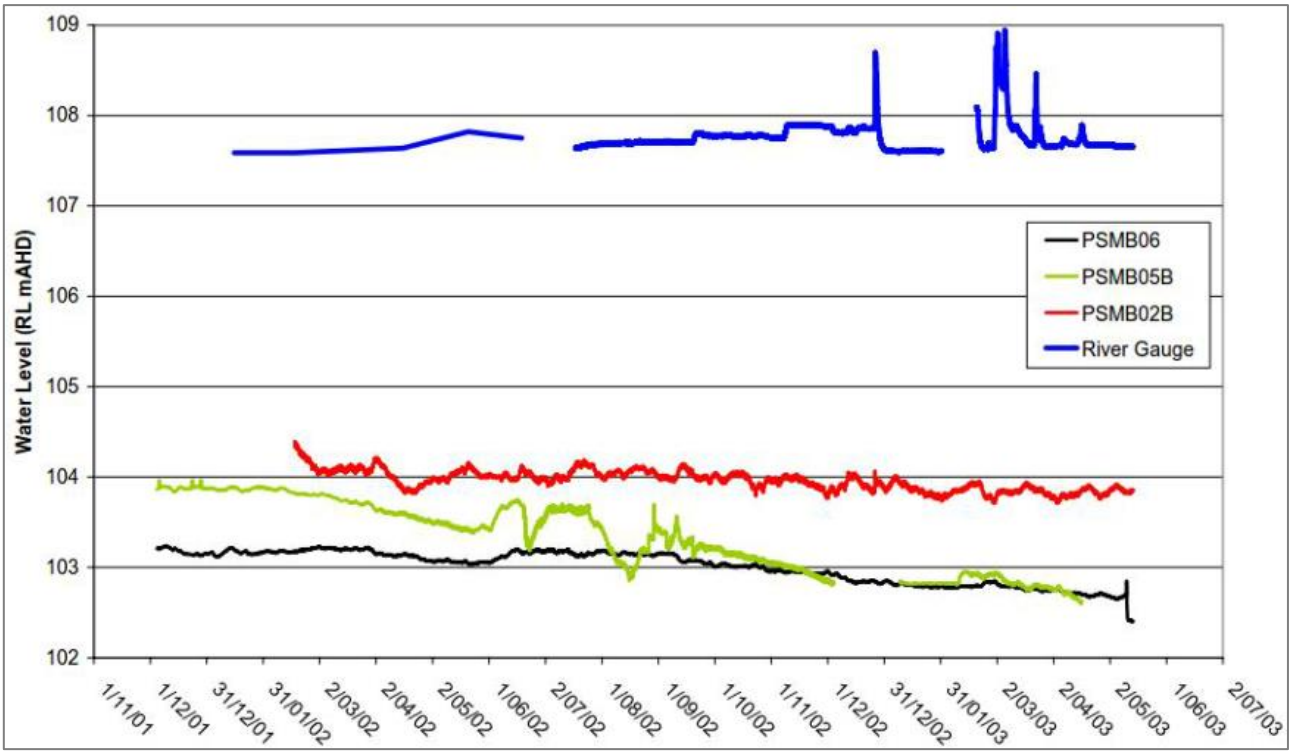



**Figure 2-21 Mackenzie River stage and Mackenzie alluvium groundwater levels (reproduced from AGE, 2006)**

Groundwater monitoring undertaken for the Mackenzie South Project observed a similar relationship with groundwater levels in an alluvial bore (MSP0203), immediately adjacent to the Mackenzie River 4.2 m below the river stage prior to the commencement of mining (AGE, 2006). It is noted that the monitoring undertaken for the Curragh North and Mackenzie South projects was undertaken during a period of low rainfall.

#### 2.3.8.1.3 Observations of mining adjacent to the river

Curragh North pits (S, T and U) experience inflows from the alluvium, which, in this area is relatively thick and comprised of sand and gravel. Average daily inflow from the alluvium to these pits is estimated to be 3.5 Ml/d (40 l/s), with the bulk of this inflow occurring at Pit U (3 Ml/d) (PB 2016).

A review of inflows to Pit S by Douglas Partners (2014) indicated that at the start of mining in late 2014, inflows were observed from sand and gravel at the base of the alluvium. Curragh Mine also reported that saturated alluvium was encountered in Pit S at approximately 5 to 10 mbgl with initial inflow/dewatering rates of approximately 6.5 Ml/day (PB 2016).

Two months after mining started in Pit S, the alluvium on the western pit face adjacent to Mackenzie River was dewatered and the majority of inflow was observed from the east pit face and monitoring bores screened to the base of the alluvium between the Mackenzie River and Pit S were dry or recorded water levels near the base (PB 2016).

Site observations of limited seepage from west buttress wall of Pit S suggest there is limited hydraulic connection between the Mackenzie River and the alluvium intersected in Pit S. This may be due to low permeability alluvial silt and clay between the river and pit, combined with low permeability riverbed material. Curragh Mine personnel have observed that pit inflows have not changed in relation to changing water levels in the Mackenzie River or wet season rainfall conditions (PB 2016).

#### 2.3.8.1.4 Riverbed materials

Inspection of the Mackenzie River by AGE (2006) immediately downstream of Curragh North, found the material exposed in the banks to be clay bound gravels suggesting the Mackenzie River stream bed is of relatively low permeability, limiting seepage of water from the river to the alluvium. Similar stream bed materials were observed in the Nogoa River upstream, where a detailed study of connectivity between the river and underlying alluvium was undertaken for Ensham Mine (AGE, 2006). The study involved installation of 23 monitoring bores in alluvium along both sides of the Nogoa River and excavation of pits in the stream bed and showed that there was no connection between the alluvium and river (AGE, 2006). The findings of this study were supported by investigations undertaken by the Queensland government on the Nogoa River floodplain which concluded 'it is unlikely that there is any connection between the river system and groundwater. Groundwater is restricted to the deeper section of the alluvium and there are large tracts of dry alluvium' (cited in AGE 2006).

### 2.3.8.2 Blackwater Creek

Blackwater Creek is a tributary of Mackenzie River. It is a highly modified system having undergone three previous channel alterations due to Curragh Mine workings including a 9.4 km diversion in 2010.

The field investigation program for the Minyango project found the Blackwater Creek alluvium was only saturated in areas where there is a significant thickness of deeper alluvial sediment (AGE 2013). Within the study area, the Blackwater Creek alluvium forms a relatively thin heterogeneous system, with lenses of poorly connected clean sand separated by lower permeability clayey facies and bedrock highs (PB 2016). The constant flow in the upstream section of Blackwater Creek is understood to be from the Blackwater Wastewater Treatment Plant (WTP) which discharges effluent via Sagittarius Creek.

Depth to groundwater (based the PB 2016 calibrated numerical groundwater model) indicates that Blackwater Creek is unlikely to receive baseflow from groundwater, with groundwater levels more than three metres below the stream bed. This is supported by observation of the downstream end of Blackwater Creek being dry except following rainfall.

Blackwater Creek was conceptualised by PB in 2016 to be a losing stream that is disconnected from the water table.

## 2.4 Groundwater Related Values

### 2.4.1 Groundwater dependent ecosystems (GDEs)

A Groundwater Dependent Ecosystem (GDE) is one in which the plant and/ or animal community is dependent on the availability of groundwater to maintain its structure and function. The BoM Groundwater Atlas (BoM, 2021) indicates areas of primarily low potential terrestrial GDEs / IDEs (inflow dependent ecosystems associated with the riparian corridor of the Mackenzie River and, to a lesser extent, Blackwater Creek (**Figure 2-22**). These terrestrial GDEs are vegetation ecosystems that rely on the subsurface presence of groundwater.

The 2016 PB assessment (due to its objective of assessing impacts associated with expansion), considered the potential for impacts on GDEs in considerable detail. The area of potential subsurface GDEs was assumed to be restricted to areas of saturated alluvium based on the results from the numerical groundwater modelling. It was also assumed that within the areas of saturated alluvium that groundwater dependence was related to the depth to the water table and vegetation rooting depth. The following criteria were used to refine the areas of likely and potential subsurface GDEs in the vicinity of the site:

- Where field verified and Queensland Herbarium mapped regional ecosystems associated with likely and potential GDEs intersected with modelled areas of saturated alluvium
- The likelihood or potential for groundwater dependence of a terrestrial GDE was based on the depth to groundwater within the area of saturated alluvium as follows:
    - High likelihood of groundwater dependence – depth to groundwater <10 m
    - Possible groundwater dependence – depth to groundwater between 10 and 20 m
    - Groundwater dependence unlikely – depth to groundwater >20 m.

The assessment (PB, 2016) identified that much of the reach of the Mackenzie River and Cooroora Creek (tributary of the Mackenzie), within the model domain, and the northern reaches of Blackwater Creek, had a high potential to host terrestrial GDEs along the riparian corridor with a likely depth to groundwater of <10 m.

### 2.4.2 Local groundwater use

There are four registered bores within 3km of Curragh mining operations (existing or proposed); details are presented in **Table 2-8** and their locations are shown on **Figure 2-22**.

**Table 2-8 Registered bores within 3km of Curragh mining operations**

| RN | | Depth (m) | SWL (mbgl) | Water quality | Yield (L/s) | Installed |
|---|---|---|---|---|---|---|
| 43459 | - | - | - | - | - | - |
| 84221 | Burngrove Formation | 31 | 30 | salty | 0.12 | 1988 |
| 97709 | - | 57 | 13 | Fresh | 3.2 | 1998 |
| 111877 | Mackenzie River Alluvium | 23 | 15 | | | 2002 |

RN111877 is owned by Central Highlands Regional Council and located at the campground approximately 150 m south of Bedford Weir on the Mackenzie River. The Council have indicated the bore is used to irrigate grass near and in the toilet block at the campground and that the groundwater is relatively saline. The bore is used to fill a 45,000 L tank 2 to 3 times each week (PB, 2016).

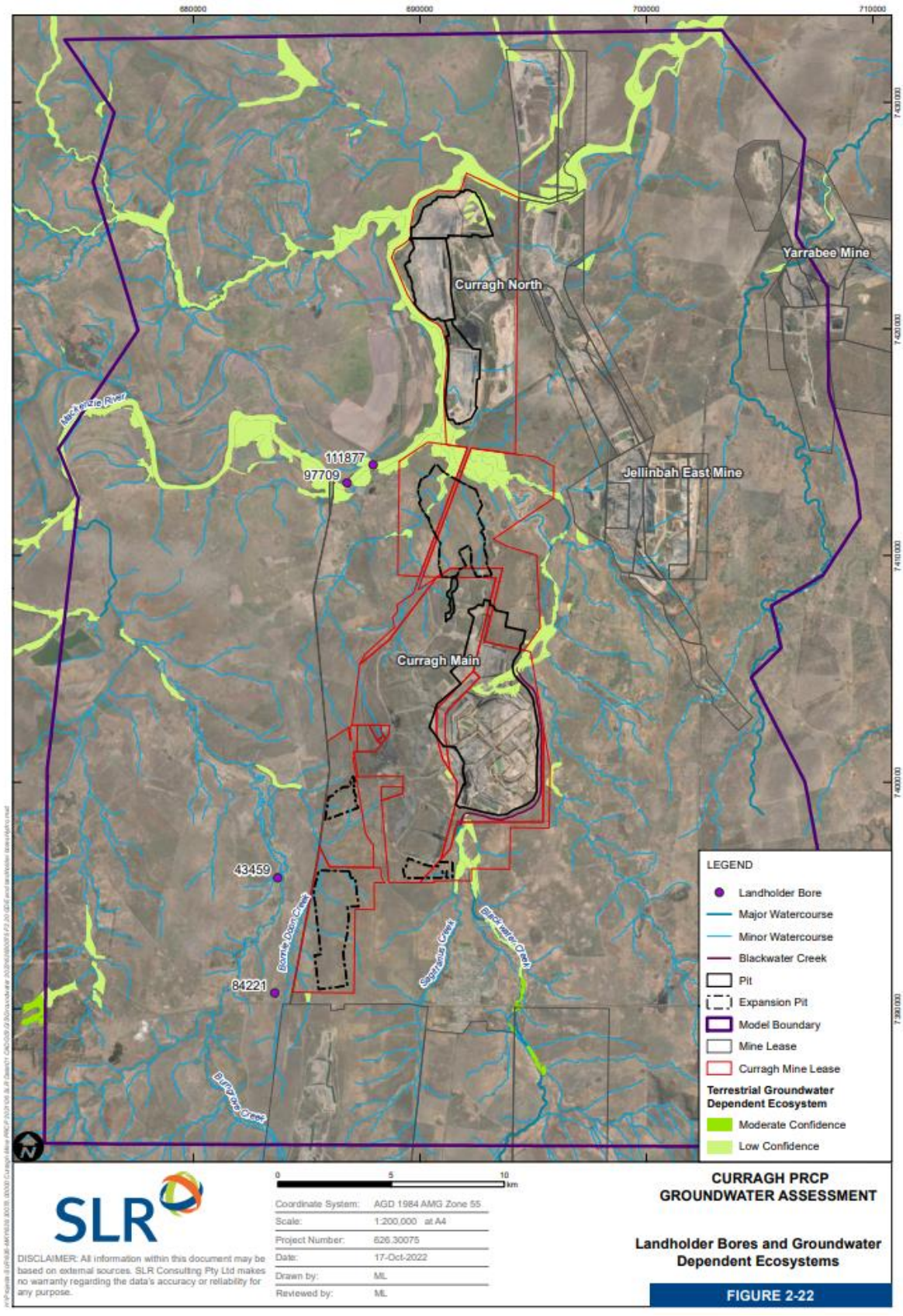



**Figure 2-22 GDEs and Registered Bores**

## 2.5 Potential Sources of Groundwater Contamination

A number of sources of potential contamination to groundwater have been identified at Curragh. These sources include:

- tailings and coarse reject storages
- on site landfills (historic and current)
- Locations identified by Curragh staff – mostly focussed around infrastructure areas (workshop areas, vehicle washdown areas, bulk fuel storage / fuelling points, historic diesel spill site)

The locations of these potential sources are shown on **Figure 2-23**. Detailed evaluation of these locations, the presence of actual contamination and the likelihood or potential of these sites to contaminate groundwater is beyond the scope of this study. However, they have been identified at this stage to understand the local post mining groundwater flow regime and whether shallow groundwater at these locations is likely to be moving off site or continually towards the final voids if the final voids are generally acting as groundwater sinks. This has been evaluated through the use of "particle tracking" modelling and the post-mining shallow groundwater surface determined by numerical modelling (Section 4.3).

The tailings storage facilities (TSFs) are large volumes of material extending below the water table which have the potential to locally affect groundwater quality. However, limited sampling of water from the Pit B TSF suggests that the water quality is similar to that of the Rangal Coal Measures (Section 2.3.6). However, the destination of groundwater at or around the TSFs has also been evaluated using particle tracking and the post-mining groundwater levels (Section 4.3).

Shallow groundwater in the vicinity of the TSFs and the sources of potential groundwater contamination would migrate towards the final voids (which act as groundwater sinks), rather than migrate off site (Section 4.3)

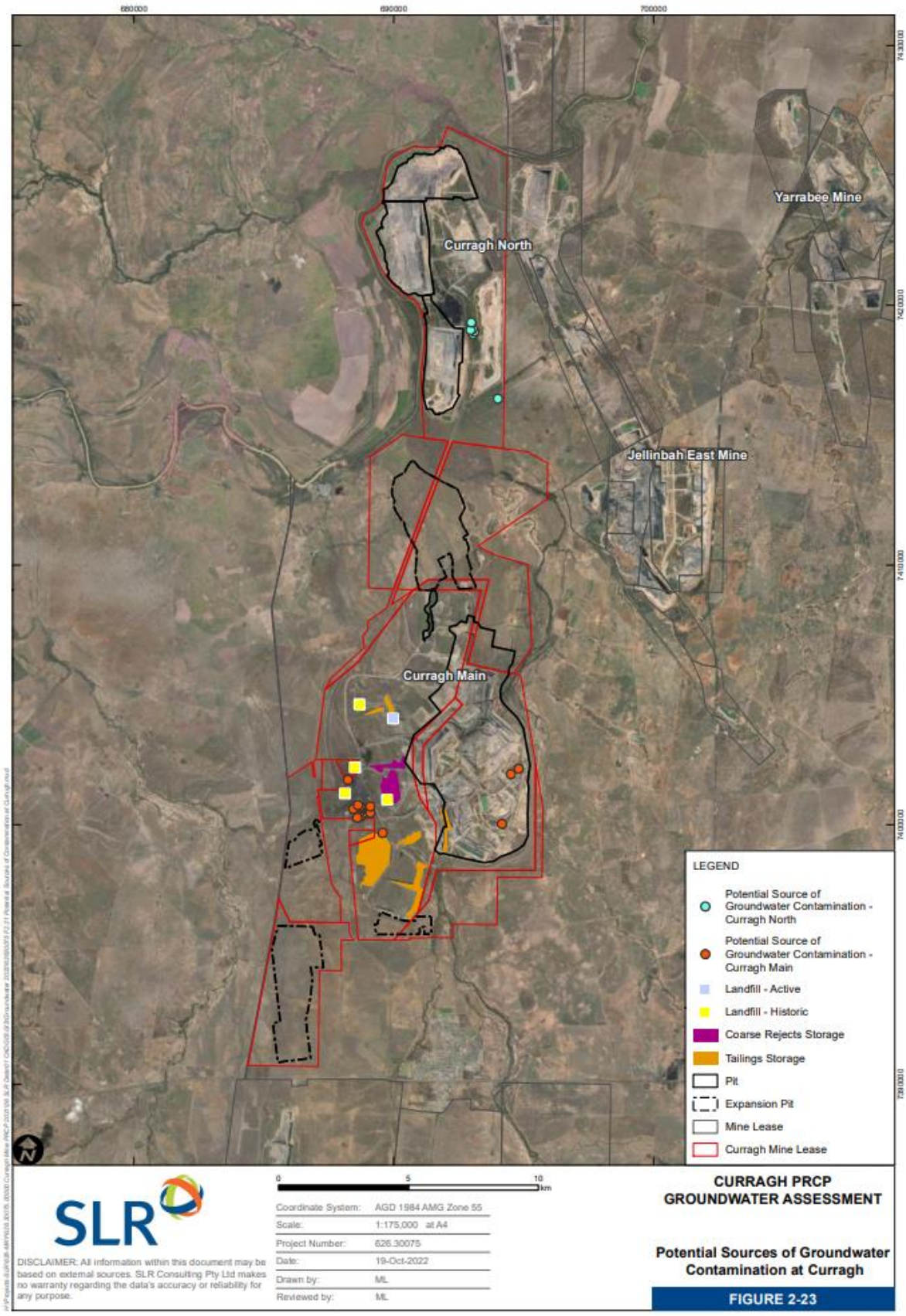



**Figure 2-23 Potential Groundwater Contamination Sources**

# 3 Numerical Groundwater Modelling

## 3.1 Model History and Current Objectives

A numerical groundwater model for Curragh Mine was developed in 2016 by Parsons Brinckerhoff for Wesfarmers Resources Pty Ltd. The model was constructed and calibrated with the primary objective of quantifying the potential impacts of the Curragh Extension Project (X, Y and Z Pits) on groundwater resources and associated environmental values. The model was independently peer reviewed and audited by HydroSimulations in 2016. The peer review found the modelling design, model calibration and predictions to be fit for the purpose of quantifying impacts from proposed mining for the Curragh Extension Project.

The 2016 model was provided to SLR Consulting by CCPL in 2021 and was updated for use in a preliminary assessment of post-closure groundwater related issues for the Curragh Concept Residual Void Assessment (CRVA) (SLR, 2021). For the CRVA, the 2016 model temporal datasets were extended. Post-mining recovery simulation with detailed final void modelling was added to facilitate estimation of the effect of mine closure on the local groundwater regime. There were however some limitations with the 2021 model and a number of key updates were considered necessary to accurately simulate mine closure and groundwater level recovery including updating the model grid to add refinement where needed, incorporation of the most recent geological model including the extension pit areas; and representation of the final voids and tailings storages.

The key changes to the model design from that reported for the 2021 CRVA model (SLR, 2021) include:

- Model extent and grid – extended model domain, unstructured Voronoi grid with refinement in key areas;
- Model layers – constructed layers to capture significant displacement faults within Curragh Mine area and incorporate the most recent geological model for the Curragh Mine Complex;
- Boundary conditions – set model boundary conditions with revised grid and regional flows;
- Stresses – model inputs updated with recent and site-specific data;
- Calibration – the new model has been calibrated with an updated calibration data set.

The primary objective of this work is to develop an understanding of the post closure hydrogeological regime at Curragh as part of the closure planning process. The key objectives of this modelling exercise have been to:

- Develop a calibrated model with mine progression, final voids, tailings storages in line with the current closure landform design developed by Coronado;
- Simulate the post-mining groundwater level recovery to assess whether the final voids will generally act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post-mining landform on local groundwater levels by comparing the long-term post closure case to a null case (no mining scenario).

**Section 3** of this report sets out the design and construction of the new model and calibration. **Section 4** presents the model set up for post closure recovery and the results.

## 3.2 Model Design Summary

### 3.2.1 Model Code

MODFLOW-USG Transport was used as the model code (Panday *et al.* 2013). MODFLOW-USG is a recent version of industry standard MODFLOW code and was considered the most suitable modelling code for accomplishing the model objectives. MODFLOW-USG optimises the model grid and increases numerical stability by using unstructured, variably sized cells. These cells take any polygonal shape, with variable size constraints allowing for refinement in areas of interest (i.e., geological or mining features).

Where previous MODFLOW versions restricted interlayer flow to vertical connectivity, MODFLOW-USG offers lateral connectivity between model layers. Lateral connectivity enables more accurate representations of hydrostratigraphic units, particularly those that pinch out, outcrop, or cross geological faults. MODFLOW-USG is also able to simulate unsaturated conditions, allowing progressive mine dewatering and post closure rewetting to be represented by the model.

Fortran code and a MODFLOW-USG edition of the Groundwater Data Utilities (Watermark Numerical Computing) were used to construct the MODFLOW-USG input files.

### 3.2.2 Model Extent and Mesh Design

The model geometry including the grid and layering have been changed from the 2021 groundwater model update by SLR. The model domain is presented in **Figure 3-1**. The horizontal and vertical extent of the numerical model was set up to cover all historical and future mining operations at Curragh Mine (approximately 49.3 km N-S and 34.8 km W-E).

The model domain is intended to place boundary conditions sufficiently distant from Curragh Complex to allow the extent of potential impacts from mining activities on the groundwater system to be assessed without being impacted by model boundary conditions, on the basis of the predicted extent of residual drawdown for Curragh Complex reported by the SLR (2021) model. The western boundary follows the sub-crop line at the base of the Fairhill Formation and the eastern boundary has been set along a combination of major faults and the geological boundary between the RCM and the Rewan Formation.

To optimise model run times by reducing the total cell count, an unstructured grid with varying Voronoi cell sizes was designed using AlgoMesh (HydroAlgorithmics, 2014). Varying Voronoi cell sizes allow areas of interest to be refined, while a coarser resolution elsewhere reduces the total cell count and model run times. The model domain was vertically discretised into 23 layers, each layer comprising a cell count of up to 41,111. The total number of cells in the model is 395,021 after pinching out layers across those parts of the model domain where these geological units are not present.

The following features have been included in the grid design:

- The McKenzie River is represented in the model with a 200 m cell size constraint;
- Open cut mining at Curragh is represented with a 100 m cell size constraint;
- Other open cut mine areas included in the model have a 100 m cell size constraint;
- Final voids at Curragh are represented with a 50 m cell size constraint; and
- Tailings storage facilities at Curragh are represented with a 50 m or 100 m cell size constraint;

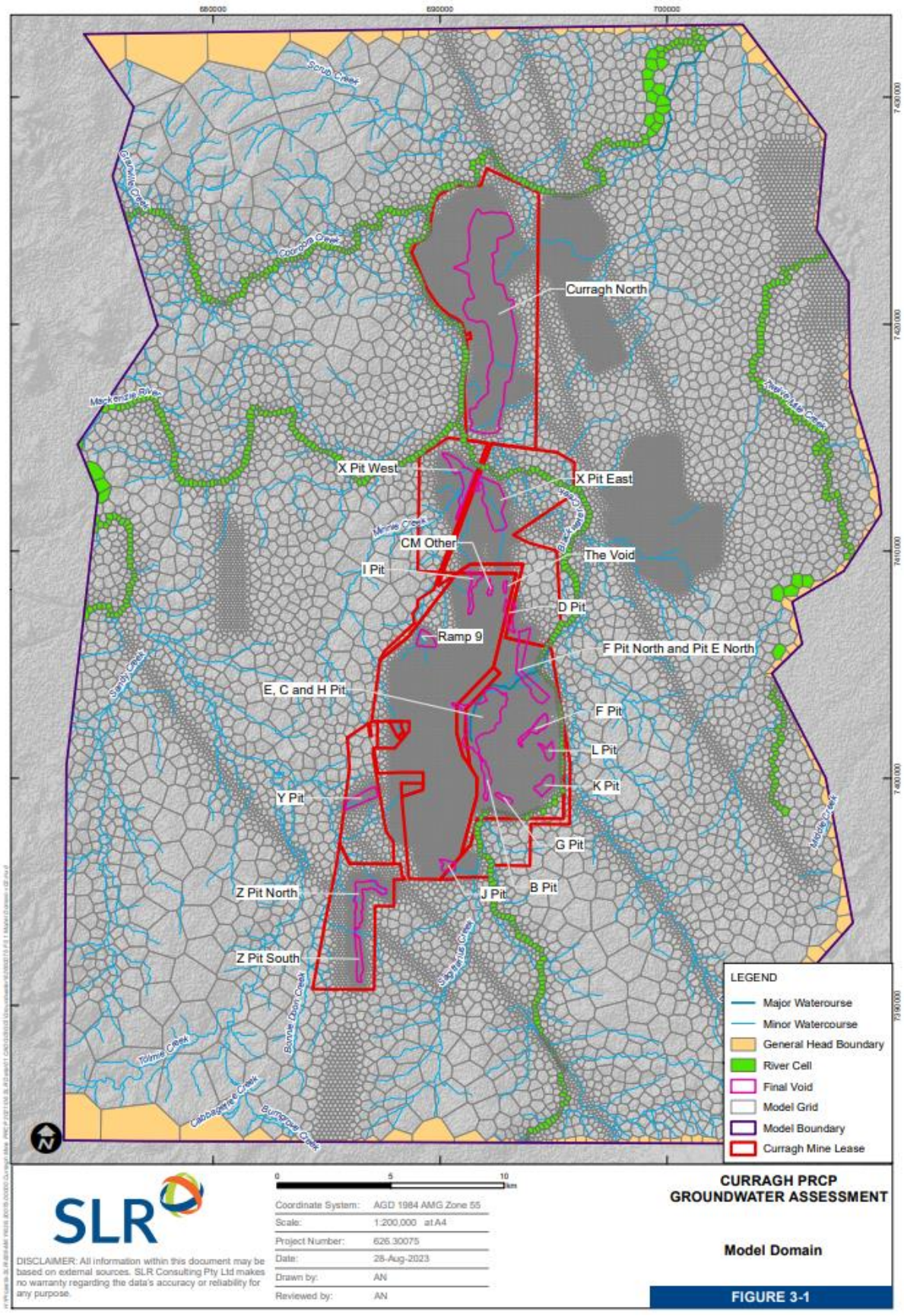



**Figure 3-1 Model Domain**

The model was developed with 23 layers to represent the regional stratigraphy and capture key coal seams mined at site and surrounding operations. The model layers are presented in **Table 3-1**, detailing the average thickness and maximum thickness for each relevant unit included in the model. Model layer extents (lateral and vertical) have been defined using the Curragh Mine geological model with the support of exploration data from Queensland Globe for geological data beyond the extent of the Curragh Mine geological model.

Consistent with the 2021 model, the RCM are represented over three model layers, upper, middle and lower RCM, with coal seams aggregated into a total thickness at the base of each of these layers.

Major regional faults are included in the model together with a number of smaller scale local faults. The Jellinbah Fault, a regional thrust fault running in a north-westerly direction to the east of the Project resulting in up to 400 m of displacement, has been incorporated into the model by representing separate model layers (the repeated geological sequence) on either side of the fault, with lateral connection simulated between adjacent units along the fault line. Layers 3 to 11 represent geological units to the west of the Jellinbah Fault with the equivalent geological units represent by layers 12 to 23 on the eastern side of the fault. Other faults within the model domain have been represented only through model layer elevations.

To represent the geological structure pinched out layers were used from Layer 3 to Layer 23.

### Table 3-1 Model Layers and Thicknesses

| Model Layer | Formation | Unit | Average Thickness (m) | Maximum Thickness (m) |
|---|---|---|---|---|
| 1 | Alluvium/Gravel | Surface cover | 15.5 | 42.4 |
| 1 | Alluvium (Sand-Clay) | | 9.2 | 18.0 |
| 1 | Alluvium-Clay | | 9.2 | 18.0 |
| 1 | Weathered Rock /Rewan | | 6.6 | 15.1 |
| 1 | Weathered Rock-RCM | | 13.0 | 38.3 |
| 1 | Weathered Rock | | 9.3 | 31.0 |
| 2 | Weathered | Tertiary and minor Triassic Clematis, weathered Permian | 13.0 | 64.2 |
| 3 | Rewan WEST | Triassic sandstone, siltstone, mudstone | 46.3 | 515.9 |
| 4 | RCM Overburden West | | 29.5 | 316.3 |
| 5 | RCM Upper Seams West | Cancer, Aries, Castor seams | 15.2 | 428.0 |
| 6 | RCM Interburden West | Sandstone, siltstone | 36.7 | 131.4 |
| 7 | RCM Middle Seams West | | 2.5 | 5.0 |
| 8 | RCM Interburden West | Sandstone, siltstone | 18.5 | 57.0 |
| 9 | RCM Lower Seams West | Pisces seam | 3.4 | 4.0 |
| 10 | Burngrove West | Sandstone, siltstone, mudstone, coal seams | 159.2 | 277.6 |
| 11 | Fairhill Formation West | Sandstone, mudstone, coal seams | 50.0 | 57.2 |
| 12 | Rewan EAST | Triassic sandstone, siltstone, mudstone | 169.6 | 641.2 |
| 13 | RCM Overburden East | | 4.6 | 20.2 |

| Model Layer | Formation | Unit | Average Thickness (m) | Maximum Thickness (m) |
|---|---|---|---|---|
| 14 | RCM Upper Seams East | Cancer, Aries, Castor seams | 1.0 | 2.2 |
| 15 | RCM Interburden East | Sandstone, siltstone | 33.8 | 54.6 |
| 16 | RCM Middle Seams East | | 3.2 | 3.3 |
| 17 | RCM Interburden East | Sandstone, siltstone | 10.0 | 33.4 |
| 18 | RCM Lower Seams East | Pisces seam | 2.8 | 2.8 |
| 19 | Burngrove East | Sandstone, siltstone, mudstone, coal seams | 203.9 | 647.7 |
| 20 | Fairhill Formation East | Sandstone, mudstone, coal seams | 125.0 | 125.0 |
| 21 | Fairhill Formation East | Sandstone, mudstone, coal seams | 125.0 | 125.0 |
| 22 | Fairhill Formation East | Sandstone, mudstone, coal seams | 125.0 | 125.0 |
| 23 | Fairhill Formation East | Sandstone, mudstone, coal seams | 125.0 | 125.0 |

### 3.2.3 Temporal discretisation

Consistent with the simulated time periods in the 2021 model (SLR), the model uses a steady-state stress period to represent the pre-mining conditions. The calibration period comprised 11 time slices (i.e., stress periods) of 3 years followed by 6 annual stress periods representing historical mining between January 1983 and January 2022. Together, the initial steady-state and transient calibration was split into 18 stress periods. The predictive period comprised 23 transient annual stress periods, representing future mining at Curragh Complex between January 2022 and January 2045. The predictive period was followed by a recovery period from January 2045 to January 2132, discretised into 3 annual, 14 biennial and 7 eight-year transient stress periods.

The temporal discretisation of the model has been updated from that previously used in the Curragh Model (SLR, 2021), to allow for the active mining simulation to extend to 2045. **Table 3-2** and **Table 3-3** summarise the calibration and predictive model stress periods respectively, alongside simulated timing of active mining. Mining simulated at Curragh has been summarised into the following areas:

- Curragh North - U, T and S Pits;
- Curragh Main – A, B, C, D, E, F, G, H, I, J, K and L Pits; and
- Curragh Expansion Areas - X Pit (East and West), Y Pit, Z Pit, and Ramp 9.

### Table 3-2 Calibration Model Stress Period Setup

| Calibration Period | Interval | Stress Period | Date (from) | Date (to) | Mackenzie (North & South) (OC) | Curragh North (OC) | Jellinbah (Plains & Central) (OC) | Washpool Coal (OC) | Curragh Main (OC) | Curragh Expansion Areas (OC) | Blackwater (OC) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Steady-state | | 1 | Steady-state | | | | | | | | |
| Transient | 3-yearly | 2 | 01/01/1983 | 31/12/1985 | | | | | x | | |
| | 3-yearly | 3 | 01/01/1986 | 31/12/1988 | | | | | x | | |
| | 3-yearly | 4 | 01/01/1989 | 31/12/1991 | | | | | x | | |
| | 3-yearly | 5 | 01/01/1992 | 31/12/1994 | | | x | | x | | |
| | 3-yearly | 6 | 01/01/1995 | 31/12/1997 | | | x | | x | | |
| | 3-yearly | 7 | 01/01/1998 | 31/12/2000 | | | x | | x | | x |
| | biennial | 8 | 01/01/2001 | 31/12/2003 | x | x | x | | x | | x |
| | 3-yearly | 9 | 01/01/2004 | 31/12/2006 | x | x | x | | x | | x |
| | 3-yearly | 10 | 01/01/2007 | 31/12/2009 | x | x | x | | x | | x |
| | 3-yearly | 11 | 01/01/2010 | 31/12/2012 | x | x | x | | x | | |
| | 3-yearly | 12 | 01/01/2013 | 31/12/2015 | x | x | x | | x | | x |
| | Annual | 13 | 01/01/2016 | 31/12/2016 | x | x | x | x | x | | x |
| | Annual | 14 | 01/01/2017 | 31/12/2017 | x | x | x | x | x | | |
| | Annual | 15 | 01/01/2018 | 31/12/2018 | x | x | x | x | x | | |
| | Annual | 16 | 01/01/2019 | 31/12/2019 | | x | x | x | x | | |
| | Annual | 17 | 01/01/2020 | 31/12/2020 | | x | x | x | x | | |
| | Annual | 18 | 01/01/2021 | 31/12/2021 | | x | x | x | x | | |

## Table 3-3 Predictive Model Stress Period Setup

| Predictive Interval | Stress Period | Date (from) | Date (to) | Mackenzie (North & South) (OC) | Curragh North (OC) | Jellinbah (Plains & Central) (OC) | Curragh Main (OC) | Expansion Areas (OC) |
|---|---|---|---|---|---|---|---|---|
| Annual | 19 | 01/01/2022 | 31/12/2022 | x | x | x | x | x |
| Annual | 20 | 01/01/2023 | 31/12/2023 | x | x | x | x | x |
| Annual | 21 | 01/01/2024 | 31/12/2024 | x | x | x | x | x |
| Annual | 22 | 01/01/2025 | 31/12/2025 | x | x | x | x | x |
| Annual | 23 | 01/01/2026 | 31/12/2026 | x | x | x | x | x |
| Annual | 24 | 01/01/2027 | 31/12/2027 | x | x | x | x | x |
| Annual | 25 | 01/01/2028 | 31/12/2028 | x | x | x | x | x |
| Annual | 26 | 01/01/2029 | 31/12/2029 | x | | x | x | x |
| Annual | 27 | 01/01/2030 | 31/12/2030 | x | | x | x | x |
| Annual | 28 | 01/01/2031 | 31/12/2031 | x | | x | x | x |
| Annual | 29 | 01/01/2032 | 31/12/2032 | x | | x | x | x |
| Annual | 30 | 01/01/2033 | 31/12/2033 | x | | x | x | x |
| Annual | 31 | 01/01/2034 | 31/12/2034 | x | | x | x | x |
| Annual | 32 | 01/01/2035 | 31/12/2035 | x | | x | x | x |
| Annual | 33 | 01/01/2036 | 31/12/2036 | x | | x | x | x |
| Annual | 34 | 01/01/2037 | 31/12/2037 | x | | x | x | x |
| Annual | 35 | 01/01/2038 | 31/12/2038 | x | | x | x | x |
| Annual | 36 | 01/01/2039 | 31/12/2039 | x | | x | | x |
| Annual | 37 | 01/01/2040 | 31/12/2040 | x | | | | x |
| Annual | 38 | 01/01/2041 | 31/12/2041 | x | | | | x |
| Annual | 39 | 01/01/2042 | 31/12/2042 | | | | | x |
| Annual | 40 | 01/01/2043 | 31/12/2043 | | | | | x |
| Annual | 41 | 01/01/2044 | 30/12/2044 | | | | | |

### 3.2.4 Model Stresses and Boundary Conditions

Stresses and boundary conditions used in the model have been adopted from the 2021 CRVA model (SLR, 2021) as follows.

#### 3.2.4.1 Rainfall Recharge

The dominant mechanism for recharge to the groundwater system is through diffuse infiltration of rainfall through the soil profile and subsequent deep drainage to underlying groundwater systems. Diffuse rainfall recharge to the model was represented using the MODFLOW-USG Recharge package (RCH).

The recharge rates were established through the calibration process, with bounds based on the conceptual understanding of the system and comparing them with other groundwater models prepared for the region. The starting values adopted in the calibration process were from the Curragh Mine model (SLR, 2021). Rainfall recharge was imposed as a percentage of actual rainfall, calculated from the SILO Grid Point observations.

The model included 9 recharge zones, based on surface geology, as listed below:

- Quaternary Alluvium (Northern);
- Quaternary Alluvium (Central);
- Quaternary Alluvium (Southern);
- Weathered Permian units;
- Weathered Triassic units;
- Emerald Formation;
- Duaringa Formation;
- Weathered Tertiary and Quaternary units; and
- Basalt.

#### 3.2.4.2 Evapotranspiration

MODFLOW evapotranspiration package (EVT) was used to simulate evapotranspiration in the model. The 9 recharge zones were used for construction of the EVT package to simulate varied evapotranspiration rates across the model domain.

The evapotranspiration rates were established through the calibration process, with starting values adopted based on the long-term average, annual, actual evapotranspiration for the Curragh Mine area. Evapotranspiration rates were adopted for the 9 zones as a calibrated factor applied to an approximate annual rate of 800 mm/year, set to an extinction depth of 2 m.

#### 3.2.4.1 Fixed head boundaries

General Head Boundary (GHB) conditions have been specified along the northern, southern and the eastern model boundaries. The GHB boundary condition is used to represent the regional flow into and out of the model area and has been assigned using GHB cells in all layers using pre-mining head elevations. Groundwater will enter the model where the head set in the GHB is higher than the modelled water levels in the adjacent cell and will leave the model when the water level is lower in the GHB. GHB conductance is calculated using the hydraulic conductivity and the dimensions of each GHB cell and is therefore variable in this model due to variable cell-size.

A no flow boundary was applied to the western boundary of the model that represents the outcrop of the Fair Hill Formation.

#### 3.2.4.2 Rivers

MODFLOW river package (RIV) was used to simulate significant watercourses in the model domain. The model includes the Mackenzie River and some tributaries of Mackenzie River, including Blackwater Creek. The Mackenzie River was represented at a constant level using the RIV package. The smaller tributaries to the Mackenzie River were represented using the RIV package, with stage elevations set equal to the minimum surface elevation in each cell, making these RIV cells act as drains.

#### 3.2.4.3 Mining

MODFLOW drain package (DRN) was used to simulate historical and future open pit mining within the model domain. The simulated future mine progression in the model was primarily based on the 2016 study with updates to reflect historical mining that occurred after 2016, and more recent updates to future mine progression plans.

#### 3.2.4.4 Variation in Hydraulic Properties - Open Cut Mining

Hydraulic properties were varied with time using the Time-variant materials (TVM) package of MODFLOW-USG Transport.

For open cut mining, Hawkins (1998) and Mackie (2009) indicate that spoil and waste rock are more permeable than the undisturbed strata. Completed open cut mining areas will be backfilled with waste overburden as the extraction proceeds. Backfilling of open cut mine areas with spoil was also modelled using TVM package. The model cell properties were updated to spoil properties guided by operational mine plans, and satellite imagery. Horizontal hydraulic conductivity of 0.3 m/day and vertical hydraulic conductivity of 0.1 m/day is applied to the spoil. The storage parameters used for the spoil were a specific yield of 0.1 and a specific storage of $1.0 \times 10^{-5}$ m-1.

## 3.3 Model Calibration

Transient calibration was previously undertaken on the existing Curragh Model (SLR, 2021) and the calibrated parameters have been used as a starting point for calibration of the updated model. Automated calibration utility PEST ++ (Doherty 2019) and manual calibration were used to match the available transient water level data.

The calibration dataset groundwater level measurements recorded from August 1997 until June 2021. Most of this calibration dataset was derived from the original PB model (PB, 2016). The calibration consists of 980 target heads established for 65 bores from the following sites:

- Jellinbah Coal Mine: 19 groundwater level observations sites;
- Curragh Mine: 45 groundwater monitoring bores located across the Curragh, Curragh East and Curragh North mining areas; and
- Other bores: 1 water resource investigation bore.

Groundwater bores used for the calibration were weighted as 1 each in the calibration where data was considered reliable. Curragh monitoring bores BH3 and BH4 were weighted as 0.5, BH5 was weighted as 0.1, and BH2 was weighted as 0, reflective of data reliability. Consistent with the SLR (2021) recalibration data set, bore 1314MB was excluded from the calibration as the observed data indicated significant measurements errors. The observation points and their average residuals are presented in **Appendix B**.

The hydraulic properties (horizontal and vertical conductivity, specific yield and specific storage), and recharge rates were adjusted during the transient recalibration to provide best match between the measurements and model simulated heads. Manual parameter adjustment was undertaken to ensure the calibrated parameters were consistent with the conceptual understanding of the hydrogeological system. Vertical hydraulic conductivity was calibrated as a factor of horizontal conductivity ($K_z/K_x$). Reduced vertical hydraulic conductivity is typically observed due to sedimentary layering throughout the sequence, and by aggregation of strata in a numerical model.

### 3.3.1 Calibration Statistics

One of the industry standard methods to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. This is done by assessing the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). A root mean square (RMS) is expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2\right]^{0.5}$$

Where:

- n = number of measurements
- $h_o$ = observed water level
- $h_m$ = simulated water level

RMS is considered to be the best measure of error, if errors are normally distributed. The weighted RMS error for the calibrated model is 6.09 m.

The acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head change in the system is small, the errors are only a small part of the overall model response. Scaled RMS (SRMS) error is the RMS divided by the range of measured heads. The weighted SRMS is 7.68% which indicates a good calibration well within the Australian guideline indicator of 10% SRMS error (MDBC, 2001; Barnett *et al*., 2012). **Figure 3-2** shows the observed and simulated groundwater levels graphically for all bores used in the calibration. The current model shows a consistent match to the observations when compared to the SLR (2021) model calibration.

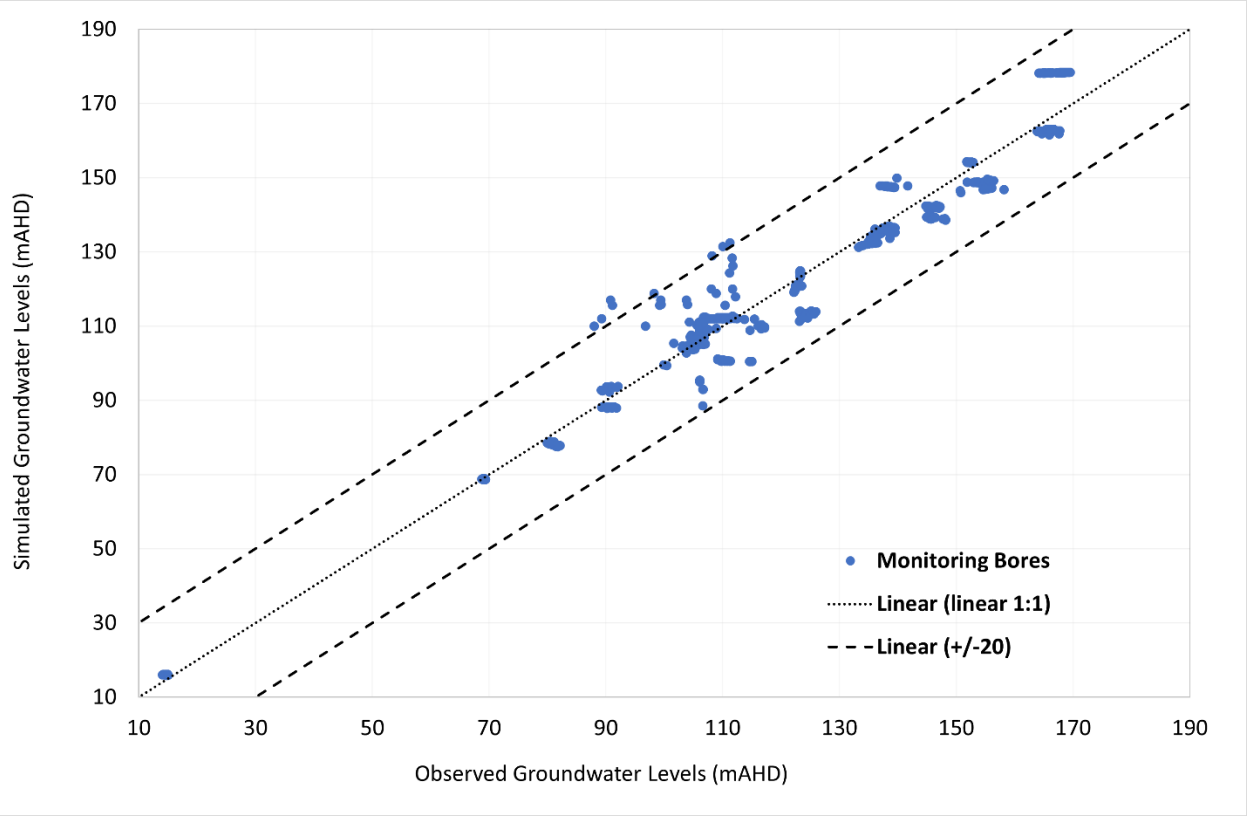



**Figure 3-2 Calibration Scattergram – Modelled vs Observed Groundwater Levels (all bores)**

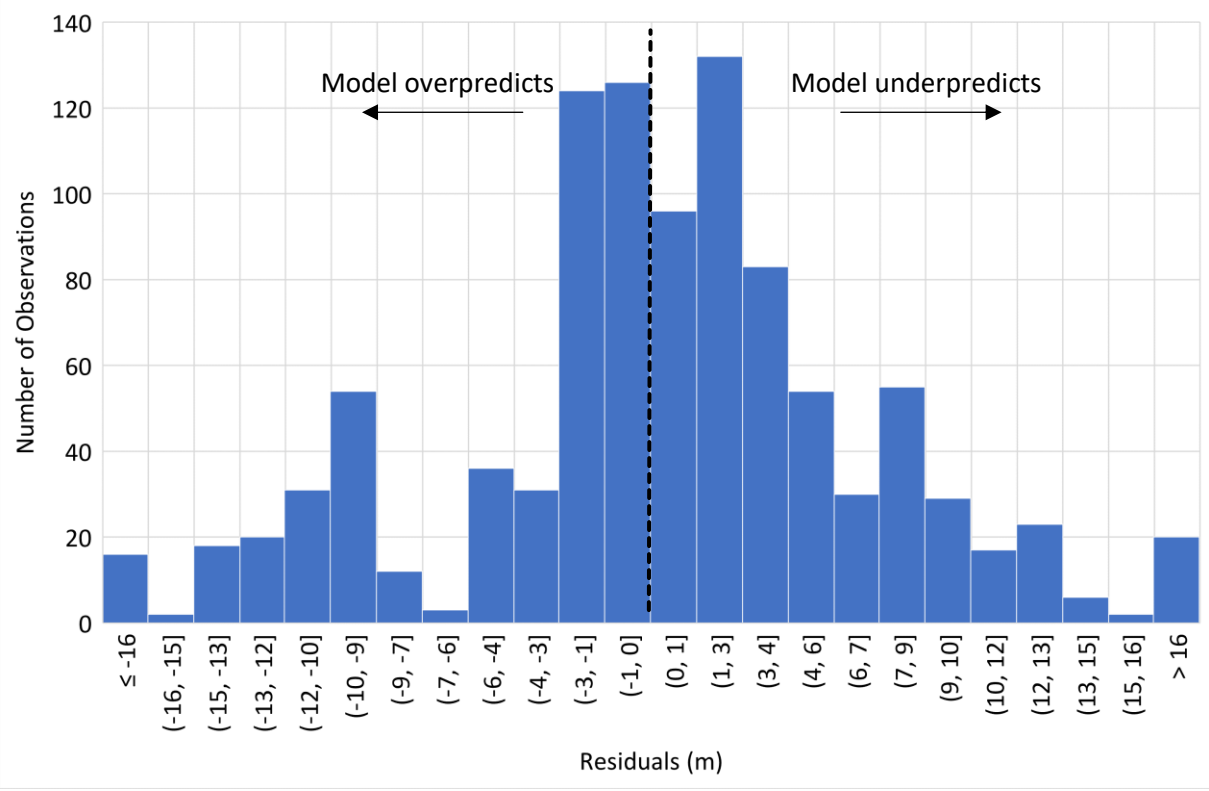



**Figure 3-3 Calibration Residual Histogram**

**Figure 3-3** shows the distribution of calibration residuals. As shown in the figure, all calibration residuals for calibration data points are within ± 20 m. A negative residual represents an over estimation of water levels, while a positive residual represents an underestimate. The calibration residual distribution indicates that overall, the model tends to under-predict groundwater levels. The model slightly under-predicts groundwater levels within the model domain.

The overall transient calibration statistics are presented in **Table 3-4.** As shown in the table, all calibration targets are calibrated within ±20 m of the observed measurements. This provides an indication of sufficient fit for the regional dataset; however, further discussion on the fit between modelled and observed trends is included in **Section 3.3.2**.

**Table 3-5** and **Figure 3-4** show the average calibration residual and absolute average residual per model layer and the spatial distribution of residuals, respectively. The residual is the difference between the measured and the modelled water level at each bore. **Table 3-5** shows an overall under-estimation of water levels in the model layers across the model domain. The table shows Layer 6 has the largest average residual, and Layer 15 has the largest absolute average residual. **Appendix B** contains a table of average, maximum and minimum residuals for each bore in the transient calibration.

### Table 3-4 Calibration Statistics

| Statistic | Value |
|---|---|
| Sum of Squares (m2) | 35,838 |
| Mean of Squares (m) | 39,2 |
| Square Root of Mean of Squares (RMS) (m) | 6.3 |
| Scaled Root Mean Square (SRMS) (%) | 7.7% |
| Root Mean Fraction Square (RMFS) (%)* | 4.7% |
| Scaled Root Mean Fraction Square (SRMFS) (%) ** | 7.7% |
| Sum of Residuals (m) | 4,241 |
| Mean Residual (m) | 4.2 |
| Scaled Mean Residual (%) | 5.10 |
| Coefficient of Determination (tend to unity) | 1.0 |
| Targets within ±2m | 428 |
| Targets within ±5m | 716 |
| Targets within ±20m | 1,012 |

*RMFS represents the sample standard deviation of the differences between predicted values and observed values as a fraction of the observed value expressed as a percentage.

** SRMFS scales the RMFS error by the ratio of the mean observed value to the range of the observed values expressed as a percentage.

### Table 3-5 Average Residual by Model Layer

| Model Layer | Formation | Unit | Average Residual (m) | Average Absolute Residual (m) | Number of Observation Targets | Number of bores |
|---|---|---|---|---|---|---|
| 1 | Alluvium, Weathered Rock | Surface cover | 1.18 | 3.72 | 412 | 37 |
| 2 | Regolith | Tertiary and minor Triassic Clematis, weathered Permian | 1.34 | 4.10 | 117 | 10 |
| 3 | Rewan Formation (West of Fault) | Triassic sandstone, siltstone, mudstone | 2.08 | 2.08 | 29 | 2 |
| 4 | RCM Overburden (West of Fault) | Sandstone, siltstone | - | - | - | - |
| 5 | RCM Upper Seams (West of Fault) | Cancer, Aries, Castor seams | - | - | - | - |
| 6 | RCM Interburden (West of Fault) | Sandstone, siltstone | 5.33 | 6.51 | 62 | 3 |
| 7 | RCM Middle Seams (West of Fault) | Pollux (Upper and Lower), Orion (Upper and Lower) | - | - | - | - |
| 8 | RCM Interburden (West of Fault) | Sandstone, siltstone Pisces seam | 4.66 | 4.67 | 65 | 2 |
| 9 | RCM Lower Seams (West of Fault) | Pisces seam | - | - | - | - |
| 10 | Burngrove (West of Fault) | Sandstone, siltstone, mudstone, coal seams | -4.42 | 6.44 | 292 | 8 |
| 11 | Fairhill Formation (West of Fault) | Sandstone, mudstone, coal seams | - | - | - | - |
| 12 | Rewan Formation (East of Fault) | Triassic sandstone, siltstone, mudstone | - | - | - | - |
| 13 | RCM Overburden (East of Fault) | Sandstone, siltstone | - | - | - | - |
| 14 | RCM Upper Seams (East of Fault) | Cancer, Aries, Castor seams | - | - | - | - |
| 15 | RCM Interburden (East of Fault) | Sandstone, siltstone | -20.80 | 20.80 | 1 | 1 |
| 16 | RCM Middle Seams (East of Fault) | Pollux (Upper and Lower), Orion (Upper and Lower) | - | - | - | - |
| 17 | RCM Interburden (East of Fault) | Sandstone, siltstone | - | - | - | - |
| 18 | RCM Lower Seams (East of Fault) | Pisces seam | - | - | - | - |
| 19 | Burngrove (East of Fault) | Sandstone, siltstone, mudstone, coal seams | -4.21 | 7.76 | 2 | 2 |
| 20 to 23 | Fairhill Formation (East of Fault) | Sandstone, mudstone, coal seams | - | - | - | - |

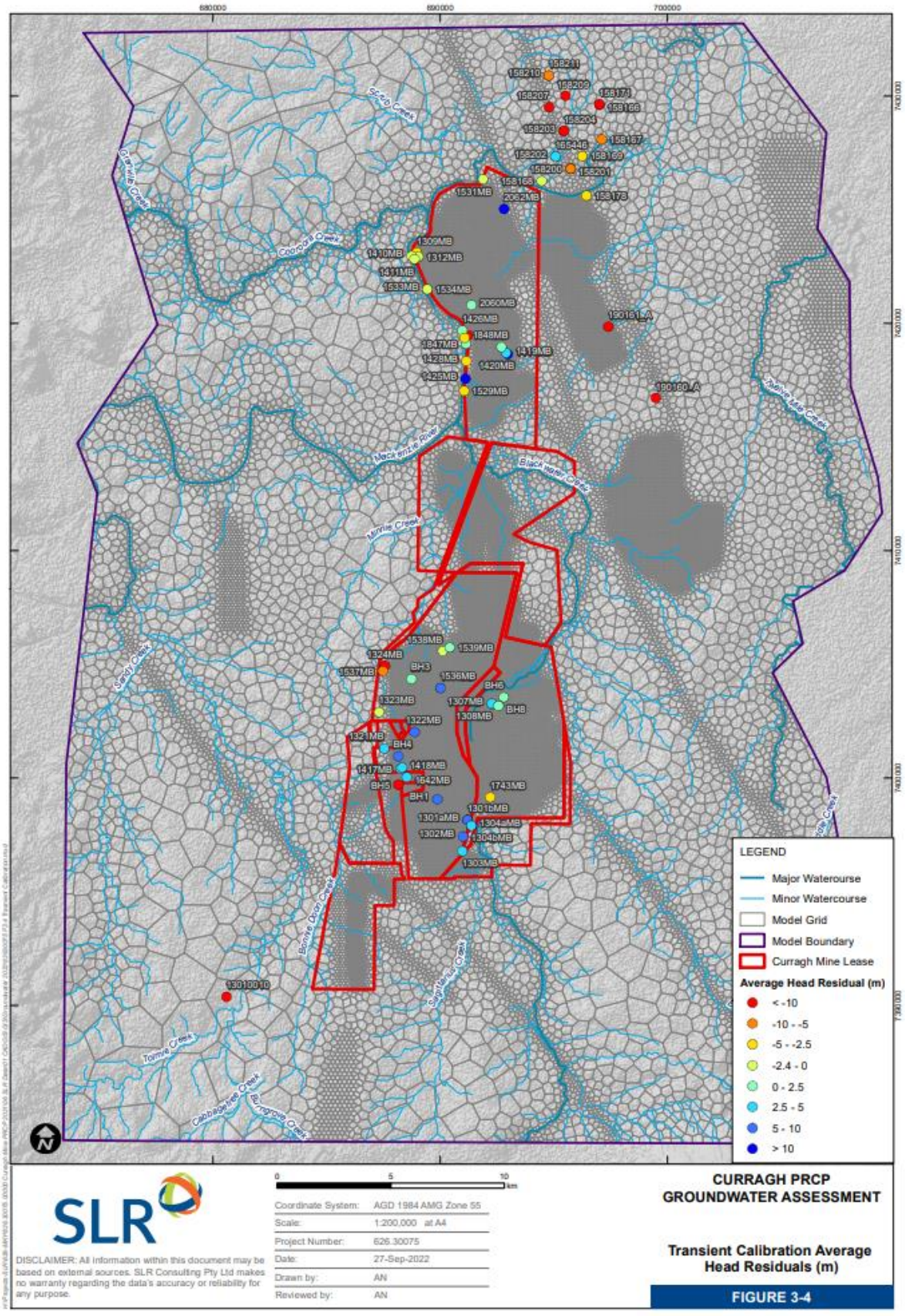



**Figure 3-4 Transient Calibration Average Head Residuals (m)**

### 3.3.2 Calibration Fit

#### 3.3.2.1 Groundwater levels

This section provides discussion on the match between modelled and observed groundwater level trends (calibration hydrographs) for key bores across the Curragh Mine Complex. Calibration hydrographs, showing modelled and observed groundwater levels are presented in **Appendix C**. The hydrographs show that generally the model has replicated the groundwater transient trends in the bores.

Reproducing historical changes in groundwater levels at Curragh Complex requires accurate data for mining progression (spatial extent and depth), backfilling and void water levels as well as the screening depth interval (or targeted geological unit) for each bore. In many cases, this information was incomplete or not available. Considering these limitations, the response to the historical mining at Curragh Complex were reasonably well simulated at most locations around the historical mining areas. This includes close matches to mining response in bores in Layer 1 (1307MB, 1425MB, 1426MB), Layer 3 (BH6, BH8). Layer 6 (1848MB) and Layer 10 (1534MB).

Within the mine area, the model overpredicts groundwater levels for bores in the Burngrove Formation (Layer 10) such as seen in the calibration hydrographs for bores 1537MB and BH5. Underprediction can be seen in the hydrographs for bores screened in the regolith (Layer 2) in the calibration hydrographs for 1301MB, 1302MB, 1303MB and 1304MB.

Water levels in the alluvium and shallow regolith in the vicinity of the mine are generally well simulated and are within 5m of the measured water level (1308MB, 1309MB, 1312MB, 1322MB, 1410MB, 1411MB and 1531MB).

Groundwater levels in regional bores to the far north and south of the model domain are overestimated by 10 to 15 m. Only one measurement is available for each bore located to the north. These bores target the alluvium (158166 and 158209) and the RCM (158171, 158207, 158208, 158210). The difference in groundwater level between observed and simulated likely relate to the simplification of the geological units into discrete model layers away from the project area, where limited data is available.

#### 3.3.2.2 Mine Pit Inflows

Measured average groundwater inflows to Curragh North and Curragh Main pits (derived for the PB 2016 work), were available for 2015 and were used to assess the performance of the model in simulating mine pit inflows. Manual calibration was undertaken to match the magnitude of groundwater inflow.

**Table 3-6** summarises the average observed and simulated inflows to the mine workings over different periods. Overall, the model provides a reasonable fit to measured pit inflows for 2015. The modelled pit inflows are underpredicted at Curragh Main, Curragh pit U & T, and overpredicted at Curragh North pit S. It should be noted however that that there will be inaccuracies in the measured inflows and that the magnitude of the modelled inflows for 2015 will be heavily influenced by the accuracy of mine progression built into the model. Choosing a slightly longer period (3 years from 2014-2016) and averaging the inflow rates generally provides a better match to the observed 2015 inflow rates for individual pits / mine areas and a closer match to the total measured inflow for the four areas in **Table 3-6**.

The average inflows for the full calibration period (2002-2016) are much higher for Pit T and Pit S and reflect higher initial inflows to these pits in the early phases of mining.

**Table 3-6 Mine Pit Inflows**

| | Curragh Main (C, D, E, F, H Pits) | Curragh North (U Pit) | Curragh North (T Pit) | Curragh North (S Pit) | Total |
|---|---|---|---|---|---|
| **2015 Measured Inflow (ML/d)** | 2.3 | 5.60 | 1.00 | 0.60 | 9.5 |
| **2015 Modelled Inflow (ML/d)** | 0.79 | 3.61 | 0.62 | 0.84 | 5.86 |
| **2014-2016 Modelled Inflow (ML/d)** | 1.45 | 3.7 | 0.85 | 1.34 | 7.34 |
| **Model calibration period (2002-2016), average inflow (ML/d)** | 2.36 | 6.38 | 3.59 | 1.32 | 13.64 |

### 3.3.3 Water Balance

The water balance for the steady-state and transient calibration simulations are presented in **Table 3-7** and **Table 3-8**, respectively. The water balance for the steady-state model indicates that regional groundwater flow (GHB) was the largest inflow contributor to the model (48.4 ML/d). In the transient simulation, the largest net contribution to the model was also regional groundwater flow (GHB) (48.4 ML/d). Regional net groundwater inflows were 39.7 and 39.9 ML/day for the steady state and transient runs respectively, indicating that more than half the total groundwater inflow enters the model domain through this boundary.

Net outflows of 10.6 ML/d (steady state) and 7.3 ML/d (transient) from the model occur due to seepage from the Mackenzie River (i.e., surface water and groundwater interaction in the Mackenzie River). Also contributing to outflow from the groundwater system is evapotranspiration (43.8 and 42.8 ML/d outflow for the steady state and transient simulations, respectively). The mass balance error for the steady state and transient calibrations are 0.00 %, within the error threshold recommended by the Australian Groundwater Modelling Guidelines (Barnett et al., 2012), and indicating the model is stable and achieves an accurate numerical solution.

**Table 3-7 Steady State Model Mass Balance**

| Component | Inflow (ML/day) | Percent of Total Inflow (%) | Outflow (ML/day) | Percent of Total Outflow (%) |
|---|---|---|---|---|
| Recharge (RCH) | 14.76 | 23.13 | - | - |
| ET (from GW) (EVT) | - | - | 43.80 | 68.66 |
| SW-GW Interaction (RIV) * | 0.65 | 1.02 | 11.26 | 17.65 |
| Regional GW Flow (GHB) | 48.39 | 75.85 | 8.73 | 13.69 |
| Mines (DRN) | - | - | - | - |
| Storage | - | - | - | - |
| Total | 63.80 | 100.00 | 63.79 | 100.00 |

### Table 3-8 Transient Model Water Balance

| Component | Inflow (ML/day) | Percent of Total Inflow (%) | Outflow (ML/day) | Percent of Total Outflow (%) |
|---|---|---|---|---|
| Recharge (RCH) | 14.11 | 18.05 | - | - |
| ET (from GW) (EVT) | - | - | 42.82 | 54.79 |
| SW-GW Interaction (RIV) * | 2.11 | 2.69 | 9.42 | 12.05 |
| Regional GW Flow (GHB) | 48.44 | 61.96 | 8.56 | 10.95 |
| Mines (DRN) | - | - | 11.99 | 15.34 |
| Storage | 13.52 | 17.30 | 5.37 | 6.87 |
| Total | 78.17 | 100.00 | 78.16 | 100.00 |

### 3.3.4 Calibrated Hydraulic Parameters

**Table 3-9** summarises the calibrated values for horizontal and vertical hydraulic conductivity used in the model.

**Table 3-9 Calibrated Hydraulic Parameters**

| Model Layer | Formation | Unit | Horizontal Hydraulic Conductivity (m/day)* | Anisotropy Kz/Kx |
|---|---|---|---|---|
| 1 | Alluvium (Gravel) | Surface cover | $4.1 \times 10^{01}$ | $4.43 \times 10^{-03}$ |
| 1 | Alluvium (Sand-Clay) | | $1.11 \times 10^{-01}$ | $1.63 \times 10^{-02}$ |
| 1 | Alluvium (Clay) | | 5.00 | $4.67 \times 10^{-03}$ |
| 1 | Weathered Rock (Rewan) | | $5.47 \times 10^{-02}$ | $1.84 \times 10^{-02}$ |
| 1 | Weathered Rock (RCM) | | 1.40 | $2.65 \times 10^{-01}$ |
| 1 | Weathered Rock (Fairhill/Burngrove) | | 1.47 | $1.53 \times 10^{-01}$ |
| 2 | Weathered Rock (Other) | Tertiary and minor Triassic Clematis, weathered Permian | $1.46 \times 10^{-01}$ | $2.30 \times 10^{-01}$ |
| 3 | Rewan Formation (West of Fault) | Triassic sandstone, siltstone, mudstone | $1.62 \times 10^{-02}$ | $1.22 \times 10^{-02}$ |
| 4 | RCM Overburden (West of Fault) | Sandstone, siltstone | $8.63 \times 10^{-04}$ | $3.04 \times 10^{-02}$ |
| 5 | RCM Upper Seams (West of Fault) | Cancer, Aries, Castor seams | $5.72 \times 10^{-02}$ | $1.69 \times 10^{-01}$ |
| 6 | RCM Interburden (West of Fault) | Sandstone, siltstone | $7.87 \times 10^{-04}$ | $9.69 \times 10^{-03}$ |
| 7 | RCM Middle Seams (West of Fault) | Pollux (upper and lower), Orion (upper and lower) | 5.52 | $1.14 \times 10^{-02}$ |
| 8 | RCM Interburden (West of Fault) | Sandstone, siltstone | $5.48 \times 10^{-01}$ | $5.0 \times 10^{-03}$ |
| 9 | RCM Lower Seams (West of Fault) | Pisces seam | $9.30 \times 10^{-03}$ | $3.27 \times 10^{-02}$ |
| 10 | Burngrove (West of Fault) | Sandstone, siltstone, mudstone, coal seams | $1.22 \times 10^{-04}$ | $1.62 \times 10^{-02}$ |
| 11 | Fairhill Formation (West of Fault) | Sandstone, mudstone, coal seams | $1.26 \times 10^{-04}$ | $1.19 \times 10^{-01}$ |
| 12 | Rewan Formation (East of Fault) | Triassic sandstone, siltstone, mudstone | $3.73 \times 10^{-02}$ | $2.24 \times 10^{-02}$ |
| 13 | RCM Overburden (East of Fault) | Sandstone, siltstone | $2.04 \times 10^{-03}$ | $2.50 \times 10^{-02}$ |
| 14 | RCM Upper Seams (East of Fault) | Cancer, Aries, Castor seams | 1.39 | $3.41 \times 10^{-01}$ |
| 15 | RCM Interburden (East of Fault) | Sandstone, siltstone | $6.36 \times 10^{-03}$ | $8.34 \times 10^{-02}$ |
| 16 | RCM Middle Seams (East of Fault) | Pollux (upper and lower), Orion (upper and lower) | 2.51 | $2.94 \times 10^{-02}$ |
| 17 | RCM Interburden (East of Fault) | Sandstone, siltstone | $3.99 \times 10^{-01}$ | $1.47 \times 10^{-02}$ |
| 18 | RCM Lower Seams (East of Fault) | Pisces seam | 2.20 | $4.66 \times 10^{-01}$ |
| 19 | Burngrove (East of Fault) | Sandstone, siltstone, mudstone, coal seams | $2.05 \times 10^{-04}$ | $1.04 \times 10^{-01}$ |
| 20 | Fairhill Formation (East of Fault) | Sandstone, mudstone, coal seams | $8.32 \times 10^{-05}$ | $4.26 \times 10^{-01}$ |
| 21 | Fairhill Formation (East of Fault) | | $1.45 \times 10^{-04}$ | $2.70 \times 10^{-01}$ |
| 22 | Fairhill Formation (East of Fault) | | $8.09 \times 10^{-04}$ | $1.57 \times 10^{-01}$ |
| 23 | Fairhill Formation (East of Fault) | | $1.78 \times 10^{-03}$ | $4.77 \times 10^{-01}$ |

Note: * upper hydraulic conductivity derived from depth of 20 m below surface and using depth formula

The hydraulic conductivity of the Permian interburden material and coal seams in the model reduces with depth. This relationship of depth and permeability has been based on data SLR have analysed from other Bowen Basin coal mines. The hydraulic conductivity of the interburden/overburden and coal seam layers decreases with depth according to the following equation (exponential):

Coal/Interburden: $$\mathbf{HC = HC_0 \times e^{(-0.012 \times depth)}}$$

Where:

- HC is horizontal hydraulic conductivity at specific depth;
- $HC_0$ is horizontal hydraulic conductivity at depth of 0 m (intercept of the curve);
- depth is depth of the floor of the layer (thickness of the cover material);
- slope is a term representing slope of the formula (steepness of the curve).

$HC_0$ was estimated in the calibration. It varies for the coal seams and for the interburden and overburden units in the model. The final calibrated parameters used in the revised model are consistent with the range of field and literature derived hydraulic parameters compiled for the conceptual model in the Groundwater Technical Report for the Curragh Extension Project (SLR, 2021).

### 3.3.5 Calibrated Storage Properties

**Table 3-10** summarises the calibrated values for specific storage and specific yield.

**Table 3-10 Calibrated Storage Parameters**

| Model Layer | Formation | Unit | Specific Yield | Specific Storage SS ($m^{-1}$) |
|---|---|---|---|---|
| 1 | Alluvium (Gravel) | Surface cover | $4.49 \times 10^{-02}$ | $1.44 \times 10^{-06}$ |
| 1 | Alluvium (Sand-Clay) | | $2.92 \times 10^{-02}$ | $4.02 \times 10^{-06}$ |
| 1 | Alluvium (Clay) | | $2.10 \times 10^{-03}$ | $9.98 \times 10^{-06}$ |
| 1 | Weathered Rock (Rewan) | | $5.32 \times 10^{-03}$ | $4.42 \times 10^{-06}$ |
| 1 | Weathered Rock (RCM) | | $4.69 \times 10^{-02}$ | $3.14 \times 10^{-06}$ |
| 1 | Weathered Rock (Fairhill/Burngrove) | | $1.71 \times 10^{-03}$ | $7.19 \times 10^{-06}$ |
| 2 | Weathered Rock (Other) | Tertiary and minor Triassic Clematis, weathered Permian | $4.69 \times 10^{-02}$ | $2.93 \times 10^{-06}$ |
| 3 | Rewan Formation (West of Fault) | Triassic sandstone, siltstone, mudstone | $7.91 \times 10^{-03}$ | $1.59 \times 10^{-06}$ |
| 4 | RCM Overburden (West of Fault) | Sandstone, siltstone | $6.96 \times 10^{-03}$ | $2.39 \times 10^{-06}$ |
| 5 | RCM Upper Seams (West of Fault) | Cancer, Aries, Castor seams | $4.51 \times 10^{-03}$ | $5.51 \times 10^{-07}$ |
| 6 | RCM Interburden (West of Fault) | Sandstone, siltstone | $7.07 \times 10^{-03}$ | $4.80 \times 10^{-06}$ |
| 7 | RCM Middle Seams (West of Fault) | Pollux (upper and lower), Orion (upper and lower) | $3.28 \times 10^{-03}$ | $1.03 \times 10^{-07}$ |
| 8 | RCM Interburden (West of Fault) | Sandstone, siltstone | $1.98 \times 10^{-03}$ | $4.44 \times 10^{-07}$ |
| 9 | RCM Lower Seams (West of Fault) | Pisces seam | $7.23 \times 10^{-03}$ | $2.65 \times 10^{-06}$ |
| 10 | Burngrove (West of Fault) | Sandstone, siltstone, mudstone, coal seams | $5.05 \times 10^{-03}$ | $8.43 \times 10^{-07}$ |

| Model Layer | Formation | Unit | Specific Yield | Specific Storage SS ($m^{-1}$) |
|---|---|---|---|---|
| 11 | Fairhill Formation (West of Fault) | Sandstone, mudstone, coal seams | $2.57 \times 10^{-03}$ | $7.15 \times 10^{-07}$ |
| 12 | Rewan Formation (East of Fault) | Triassic sandstone, siltstone, mudstone | $8.37 \times 10^{-03}$ | $2.15 \times 10^{-06}$ |
| 13 | RCM Overburden (East of Fault) | Sandstone, siltstone | $7.29 \times 10^{-03}$ | $6.95 \times 10^{-07}$ |
| 14 | RCM Upper Seams (East of Fault) | Cancer, Aries, Castor seams | $6.55 \times 10^{-03}$ | $2.35 \times 10^{-07}$ |
| 15 | RCM Interburden (East of Fault) | Sandstone, siltstone | $6.13 \times 10^{-03}$ | $5.00 \times 10^{-06}$ |
| 16 | RCM Middle Seams (East of Fault) | Pollux (upper and lower), Orion (upper and lower) | $7.75 \times 10^{-03}$ | $3.86 \times 10^{-07}$ |
| 17 | RCM Interburden (East of Fault) | Sandstone, siltstone | $1.60 \times 10^{-03}$ | $2.43 \times 10^{-07}$ |
| 18 | RCM Lower Seams (East of Fault) | Pisces seam | $1.00 \times 10^{-02}$ | $3.02 \times 10^{-06}$ |
| 19 | Burngrove (East of Fault) | Sandstone, siltstone, mudstone, coal seams | $1.58 \times 10^{-03}$ | $2.94 \times 10^{-07}$ |
| 20 | Fairhill Formation (East of Fault) | Sandstone, mudstone, coal seams | $1.73 \times 10^{-03}$ | $1.07 \times 10^{-07}$ |
| 21 | Fairhill Formation (East of Fault) | | $1.61 \times 10^{-03}$ | $1.23 \times 10^{-07}$ |
| 22 | Fairhill Formation (East of Fault) | | $2.68 \times 10^{-03}$ | $1.35 \times 10^{-07}$ |
| 23 | Fairhill Formation (East of Fault) | | $1.08 \times 10^{-03}$ | $1.97 \times 10^{-07}$ |

### 3.3.6 Calibrated Recharge

Recharge is predominantly through direct rainfall infiltration through the soil profile, and along the ephemeral drainage lines. The rate of recharge infiltration depends on the location, topography and geology at each model cell. Initial estimates of recharge were adopted from the previous Curragh Model (SLR, 2021). As discussed in **Section 3.2.4**, the MODFLOW-USG recharge package simulated diffuse rainfall recharge across the model domain. For the steady state simulation, the model calculated the recharge rate as a percentage of long-term annual rainfall (565.4 mm/year) for each geological unit outcropping at the surface and for the transient simulation, the model calculated the recharge rate as a percentage of actual annual rainfall. The model then adjusted these initial percentages through the calibration process. **Table 3-11** presents the calibrated recharge rate for each geological unit in the model as well as the recharge rate applied to spoil.

**Table 3-11 Calibrated Rainfall Recharge**

| Model Surface Geology Zone | Long-term Average Recharge (mm/year) | % Annual Rainfall |
|---|---|---|
| Quaternary Alluvium (Northern) | 3.61 | 0.64 |
| Quaternary Alluvium (Central) | 10.65 | 1.88 |
| Quaternary Alluvium (Southern) | 9.11 | 1.61 |
| Weathered Permian | 0.94 | 0.17 |
| Weathered Triassic | 0.29 | 0.05 |
| Emerald Formation | 0.16 | 0.03 |
| Duaringa Formation | 0.12 | 0.02 |
| Weathered Tertiary/Quaternary | 10.92 | 1.93 |
| Basalt | 0.21 | 0.04 |

| Model Surface Geology Zone | Long-term Average Recharge (mm/year) | % Annual Rainfall |
|---|---|---|
| Spoil | 5.65 | 1.0 |

### 3.3.7 Calibrated Pre-Mining Groundwater Levels

**Figure 3-5** shows the calibrated pre-mining water table (defined as the shallowest groundwater level below surface, regardless of the geological unit / model layer). As shown in **Figure 3-5**, the simulated water levels reflect the flow regime prior to commencement of any mining within the model domain and indicate a general flow of groundwater towards the north to north-west discharging through the RIV boundary condition in the north of the model (Mackenzie River). The simulated water table broadly reflects topography across the model domain.

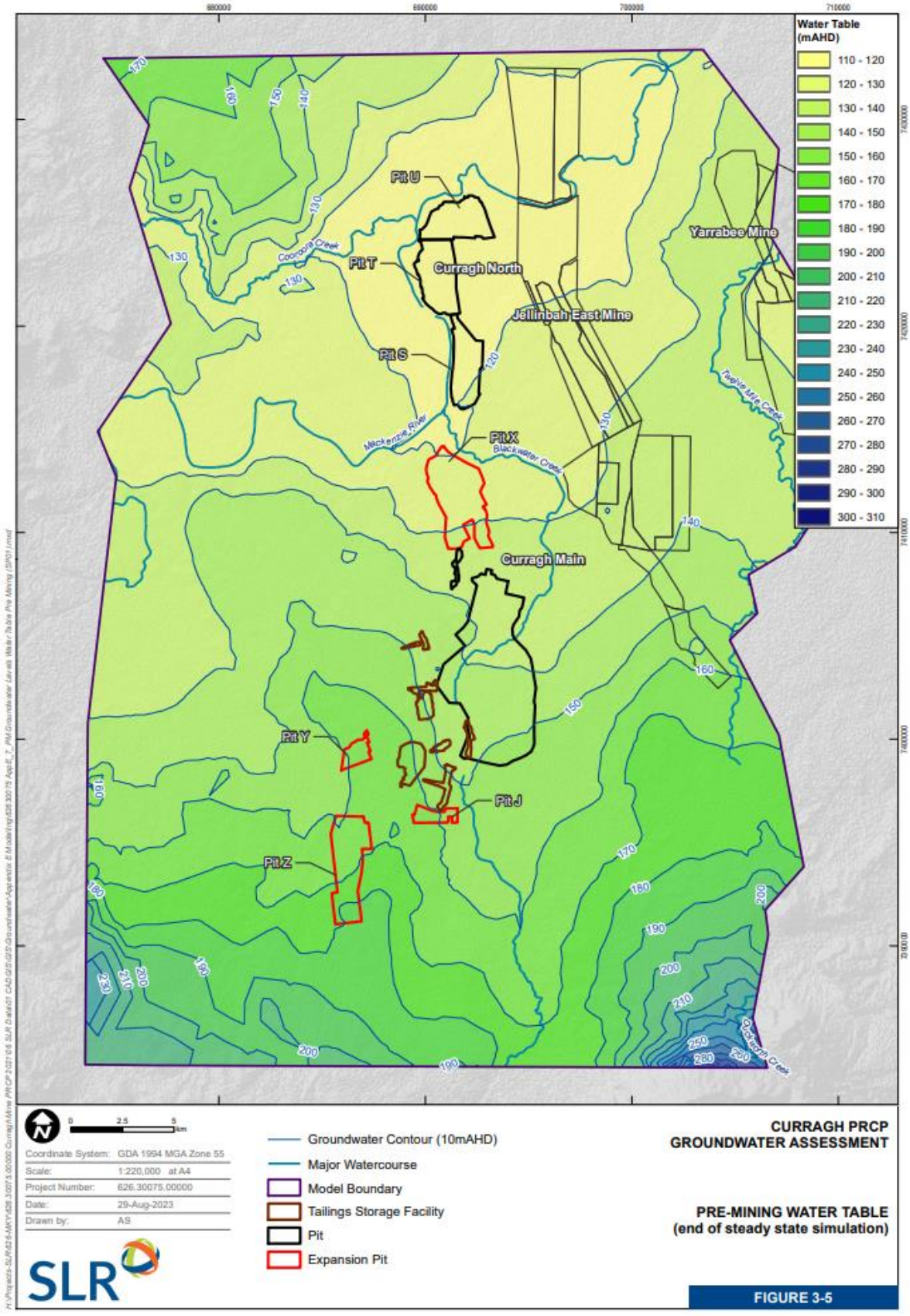



**Figure 3-5 Simulated Pre-Mining Water Table**

## 3.4 Predictive Model

Transient predictive modelling was used to simulate the proposed future mining at Curragh (Curragh North, Curragh Main, expansion pits X, Y, Z, and Ramp 9), as well as mining at other approved and foreseeable mines within the model domain. The predictive model stress period setup is detailed in **Section 3.2.3**, and the mine progression simulated in the model is presented in **Figure 3-6.**

All mining areas included in the model were simulated using the MODFLOW Drain (DRN) package. A nominally high drain conductance of 100 square metres per day ($m^2$/day) was applied to drain cells to simulate rapid removal of water from the system. Drain cells simulating mining were projected down to the base of the target coal seams. A two-year operational window was assumed for open-cut mine cells, after which time the drains were removed and the MODFLOW Time Varying Materials (TVM) package was used to assign spoil or void properties to the cells.

As discussed in **Section 3.2.4.4**, the properties of model cells representing the backfilled pits were updated to spoil properties guided by the backfill elevations in the final landform. Horizontal hydraulic conductivity of 0.3 m/day and vertical hydraulic conductivity of 0.1 m/day is applied to the spoil. The storage parameters used for the spoil were a specific yield of 0.05 and a storage coefficient of $1.0 \times 10^{-5}$ m.

The model cells representing residual voids as informed by the final landform were assigned void properties upon removal of the drains representing active mining at those cells. High horizontal and vertical hydraulic conductivities (1000 m/day) and storage parameters based on the compressibility of water (specific yield of 1.0, storage coefficient of $5.0 \times 10^{-6}$ $m^{-1}$) were applied to void cells, to simulate free water movement within the void.

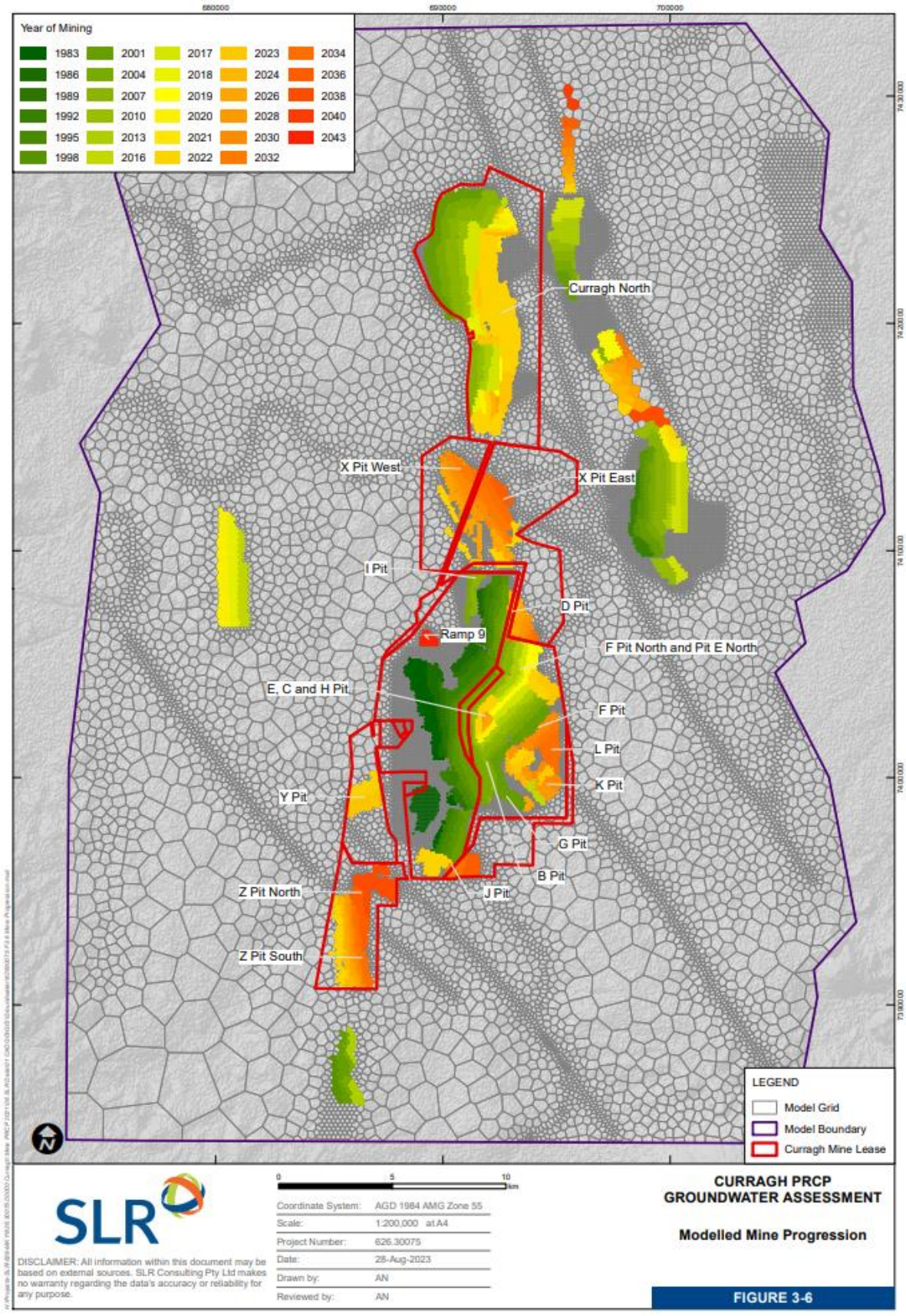



**Figure 3-6 Mine Progression**

### 3.4.1 Predictive Water Balance

The water balance for the predictive simulation is presented in **Table 3-12**. The water balance for the predictive model indicates that Regional GW Flow (GHB) was the largest net inflow contributor to the model (48.46 ML/d). Regional groundwater inflow and outflow are 48.46 ML/day and 8.61 ML/day respectively, indicating that groundwater enters the model domain through this boundary.

The largest net contributor to outflow from the model during the predictive simulation beside evapotranspiration (41.70 ML/d outflow) were the drain cells, used to simulate mining activity (9.67 ML/d). A net outflow of 3.16 ML/d from the model occurs due to baseflow to the Mackenzie River. The mass balance error for the predictive calibration is 0.00%.

**Table 3-12 Predictive Model Water Balance**

| Component | Inflow (ML/day) | Percent of Total Inflow (%) | Outflow (ML/day) | Percent of Total Outflow (%) |
|---|---|---|---|---|
| Recharge (RCH) | 15.32 | 18.91 | - | - |
| ET (from GW) (EVT) | - | - | 41.70 | 51.47 |
| SW-GW Interaction * | 3.63 | 4.48 | 6.79 | 8.38 |
| Regional GW Flow (GHB) | 48.46 | 59.81 | 8.61 | 10.63 |
| Mines (DRN) | - | - | 9.67 | 11.94 |
| Storage | 13.61 | 16.80 | 14.25 | 17.58 |
| Total | 81.02 | 100.00 | 81.02 | 100.00 |

* The other tributaries or drainage lines in the model are set as drains to the groundwater system and do not result in any recharge.

### 3.4.2 Predicted Mine Inflows

Simulated mine pit inflows were extracted using MODFLOW-USG ZONBUD utility and calculated as time weighted averages for model Drain cells, for the predictive simulation period (January 2022 to January 2045). The total inflow rate predicted for the Curragh Complex averaged 8.19 ML/day over the predictive model simulation.

# 4 Recovery Model

## 4.1 Recovery Model Setup

Post mining impacts were investigated with a recovery model, commencing at the end of active mining. A preliminary transient recovery model consisting of 24 stress periods of varying length (annual, biennial, 8-yearly and an extended final stress period of 500 years) was developed initially to assess the relationship between the final voids' lake elevations and groundwater inflow. At the start of the recovery model, all remaining model drain cells (representing pit dewatering in areas of active mining) were removed from pits and the properties of the final void cells were converted to values representative of a void as described in **Section 3.4**.

The relationship between groundwater inflows to the voids and void lake level was extracted from the preliminary recovery model and incorporated into the site water balance model (WBM) developed for the Curragh PRCP (SLR, 2022). The WBM predicts the equilibrium lake levels that will be reached in each void and these final void lake levels are used in the final groundwater recovery model. Further information relating to the Curragh Complex WBM can be found in Section 3 of the Curragh Mine Complex Surface Water Residual Void Modelling (SLR, 2022).

The final recovery model uses the MODFLOW river package (RIV) to simulate increasing void lake elevations in each of the final voids over the recovery period, with stage elevations vs time applied according to the WBM predictions for each void, up to the final equilibrium lake levels predicted by the WBM. The WBM predicted water levels in the final voids to reach equilibrium conditions after approximately 50 to 80 years, dependent on void structure and interaction with the regional groundwater system.

Tailings Storage Facilities (TSFs) and Coarse Reject Storage areas (CRSs) were represented in the recovery model based on the available mapping of storage areas. An isotropic hydraulic conductivity of $1 \times 10^{-5}$ m/day, specific yield of 0.01 and storage coefficient of $5 \times 10^{-6}$ m were assigned to the model cells representing TSF and CRS, using the MODFLOW Time Varying Materials (TVM) package.

The RIV package was used to represent increasing sediment levels of tailings and course reject material, with final fill levels defined by final landform elevation. The sediment levels in TSF and CRS were increased from the mined layer to the final fill level at a constant rate over a 10-year period, to represent the gradual filling of sediment storage facilities during mine operation. Sediments were assigned a vertical conductivity of $5 \times 10^{-2}$ m/day. The water levels in TSF and CRS were increased at a corresponding rate, at 1 m above the sediment level.

The layout of the final voids across the Curragh Mine Complex is presented in **Figure 4-1**.

Void recovery graphs in each of the voids over the recovery period are presented in **Appendix D**.

A summary of predictions from the recovery model, including final void water levels and groundwater flux (at equilibrium) are presented in **Section 4.2**.

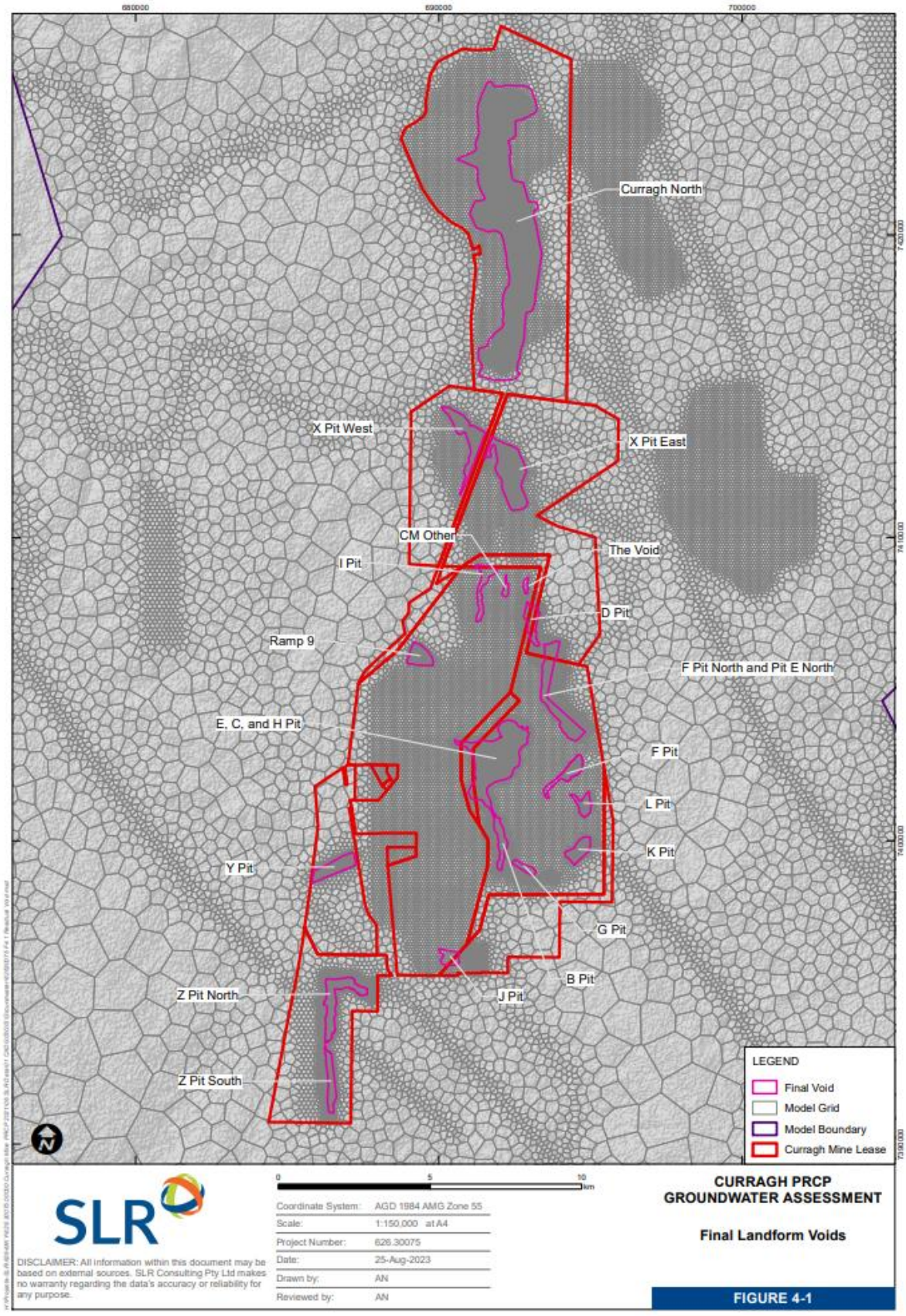



**Figure 4-1 Residual Void Locations**

## 4.2 Post-mining Equilibrium

Simulated post-mining groundwater fluxes to the final voids at equilibrium conditions were extracted using MODFLOW-USG ZONBUD utility. The net groundwater flux has been calculated as a cumulative void flux for each area at Curragh Complex (Curragh North, X Pit, Curragh Main, Ramp 9, Y Pit and Z Pit) to account for interaction between the adjacent voids within each area, where spoil connects the voids. The simulated average groundwater takes at the end of recovery (December 2132) at each of the site areas are presented in **Table 4-1**.

The groundwater fluxes to the final voids presented in **Table 4-1** are total fluxes, including throughflow from spoil (higher recharge over the spoil and drainage into the final void), and groundwater inflow from the Rangal Coal Measures (RCM). An equilibrium groundwater flux of 6.14 ML/day was predicted at Curragh North, where the minimum elevation of the final landform is significantly lower than the other voids. The relative depth of the residual void at Curragh North, and it's size, is likely to account for the higher predicted groundwater flux to this void. Equilibrium total groundwater flux to the voids in X Pit, Curragh Main, Ramp 9, Y Pit and Z Pit are predicted to be 0.57, 1.44, 0.02, 0.08 and 0.64 ML/day respectively, indicating all simulated voids are predicted to be groundwater sinks with net groundwater inflow to the voids. The simulated fluxes to the voids in the groundwater model are consistent with groundwater fluxes in the surface WBM developed for simulating final landforms for Curragh Mine (SLR, 2022).

Based on the geological data reviewed for this assessment it appears that equilibrium void lake levels are generally below the minimum level of base of weathering (**Table 4-1**). The predicted equilibrium void lake levels in Pit I, Ramp 9 and Main Other exceed the approximate minimum base of weathering by about 5 to 9 m. Where the base of weathering levels are exceeded by the void lake level, the alluvium and weathered rock profile could potentially present preferential pathways for outward seepage of water from the void lakes. However, this will depend on the groundwater levels in the surrounding geological formations relative to the void lake levels. In most cases the final voids are not adjacent to the pit shell edge and the in situ geology but sit within the spoil backfill landform within the mined areas. The minimum base of weathering elevation presented in **Table 4-1** therefore represents the base of weathering elevation on pit shell perimeter near that void estimated from site geological model base of weathering surface.

The predicted water salinity results presented in **Table 4-1** have been derived from the surface water balance modelling (SLR,2022). The predicted salinities indicate that all voids are expected to exceed hypersaline EC levels (>50,000 µS/cm) within approximately 200 years of closure.

## Table 4-1 Post-Mining Equilibrium Residual Void Summary

| Curragh Area: | | Curragh N | X Pit | | Curragh Main | | | | | | | | | | | Ramp 9 | Y Pit | Z Pit | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Void[1]: | | UTS | X West | X East | I Pit | Main Other | The Void | D Pit | F Pit | F Pit North & E Pit | E,C,H Pits | B Pit | K Pit | L Pit | G Pit | J Pit | | | Z Pit North | Z Pit South |
| Final landform minimum elevation (mAHD) | | -48 | 78.4 | 33.5 | 133.1 | 120 | 93 | 29.1 | 91.6 | 26.6 | 40.6 | 108 | 63.1 | 64.6 | 130.1 | 92.6 | 77.1 | 116 | 78.1 | 87.1 |
| Post-mining equilibrium void lake level (mAHD)* | | 23 | 98 | 67 | 135 | 135 | 100 | 62 | 111 | 49 | 70 | 112 | 77 | 103 | 137 | 111 | 132 | 123 | 108 | 105 |
| Final landform crest elevation (mAHD) | | 132.5 | 123.5 | 123.5 | 146 | 147 | 135 | 103.5 | 149 | 103.5 | 129 | 129 | 163 | 149 | 150 | 153 | 156 | 162 | 136 | 136 |
| Approximate base of weathering (mAHD)** | | 45 | 105 | 99 | 130 | 126 | 126 | 120 | 120 | 117 | 130 | 136 | 137 | 133 | 137 | 131 | 123 | 148 | 153 | 160 |
| Void lake salinity (uS/cm), predicted by the water balance model.[2] | ~10 years | 13,900 | 19,200 | 15,600 | >50,000 | 11,700 | 10,200 | 16,500 | 18,200 | 27,500 | 15,700 | >50,000 | 28,400 | 13,800 | 40,700 | 23,300 | 17,300 | 40,600 | 19,800 | 23,400 |
| | ~30 years | 20,100 | 39,600 | 27,500 | >50,000 | 25,700 | 15,600 | 28,800 | 38,600 | >50,000 | 33,700 | >50,000 | >50,000 | 24,200 | >50,000 | 49,300 | 25,600 | >50,000 | 37,600 | 48,500 |
| | ~200 years | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 | >50,000 |
| Net groundwater flux to void at equilibrium (ML/day)*** | | 6.14 | 0.57 | | 1.44 | | | | | | | | | | | | 0.02 | 0.08 | 0.64 | |

Notes:
1 The residual voids have been grouped where a void may act as a source of water to an adjacent void, but where collectively they act as a groundwater sink.
2 532,836 µS/cm is the maximum salinity limit set in the surface water balance model (SLR 2022)
* 50th percentile final void lake levels derived from the surface water model.
** Approximate elevation of base of weathering on pit shell perimeter near the void estimated from site geological model base of weathering surface.
*** Total flux, including drainage from the spoil and groundwater inflow from the RCM.

## 4.3 Recovered Groundwater Levels

**Appendix E** presents simulated pre-mining (PM), end of mining (EoM), and equilibrium end of recovery (EoR), groundwater levels for the water table and the following geological units:

- Alluvium
- Regolith
- RCM overburden
- RCM Upper Coal Seams
- RCM Middle Coal Seams
- RCM Lower Coal Seams

Reviewing the PM, EoM and EoR contour plots for the water table, the regional groundwater flow directions and hydraulic gradients are largely preserved from PM to EoR with significant EoR drawdown being restricted to the pit areas and extending a limited distance from the pits.

The contour plots for simulated alluvium groundwater levels clearly show a significant drying of the alluvium in the vicinity of the pit shells from PM to EoM although outside these areas there is limited impact comparing the PM to EoR plots. The EoR simulated levels shows limited differences compared to the EoM levels and extent of saturation in the alluvium. It should be noted that accurate information on the extent, nature and degree of saturation of the alluvium across the model domain is very limited.

The PM contour plot for the regolith shows almost full saturation indicating that, together with the alluvium, this layer is mostly where the water table resides across the model domain. The EoM plot obviously shows complete removal of this layer from the mined areas with desaturation and drawdown in the immediate vicinity of the pits. There appears to be a slight increase in drawdown from the EoM to the EoR, probably due to the time taken for maximum drawdown to propagate from the mined areas and the fact that the final lake levels generally do not recover above the base of weathering.

The RCM overburden (above the upper aggregated RCM coal seams) obviously shows significant drawdown between the PM and EoM plots, particularly east of Curragh North. This increased drawdown east of Curragh North is due to a combination of the depth of working in Curragh North and the barrier effect of the Jellinbah Fault immediately to the east. Significant drawdown effects in the RCM do not propagate east of this fault. Some recovery is seen in the EoR plot, particularly east of Curragh North with decreasing recovery seen further south. A very similar drawdown and recovery pattern is seen in the contour plots for the upper RCM coal seams, with very similar, but slightly lower, groundwater levels.

The contour plots for the middle and lower RCM seams are very similar and show greater drawdown at the EoM and EoR compared to the upper seams. There is some post mining recovery but the levels in these layers are generally much lower at the EoR close to the voids by the low final void lake levels, particularly at Curragh North. Even with the greater drawdown in these layers at the EoM there is no significant drawdown to the east of the major Jellinbah Fault.

**Appendix F** presents the geological cross sections included in Section 2, with the addition of the EoR groundwater levels for :

- Alluvium and regolith
- RCM Upper Coal Seams
- RCM Lower Coal Seams

These cross sections also show the final landform and EoR void lake levels where they pass through final voids. The upper RCM seams have obviously been mined out through the pit shells but the lower RCM seams are mostly still in situ. The difference between EoR groundwater levels in the upper seams and the lower seams is clear in these sections with groundwater levels in the upper RCM seams significantly exceeding those in the lower RCM seams. It is also clear that the residual voids act as groundwater sinks at the EoR with hydraulic gradients from the surrounding in-situ geology clearly towards the voids. Some void lakes sitting at higher elevations are likely to be filled mostly by infiltration to the spoil draining directly to the void. These higher voids (e.g. Pit F, Pit L on Section A-A') will seep to adjacent voids at lower elevations with the local group of voids as a whole acting as a groundwater sink.

## 4.4 Post-mining Gradients and Residual Drawdown

The predicted post-mining water table at equilibrium (end of recovery) is shown in **Figure 4-2**. Hydraulic gradients at equilibrium indicate an overall flow direction toward residual voids at Curragh Main and Curragh North. All residual voids show hydraulic heads decreasing with proximity to the void, indicating all voids are predicted to act as local groundwater sinks.

Residual drawdown refers to the remaining drawdown after full post-mining recovery compared to pre-mining groundwater levels and is obtained by subtracting the predicted equilibrium post-closure groundwater levels from a 'null-mining' model scenario. The 'null-mining' model run does not include any historical or future mining at Curragh Complex, but all other stresses (including surrounding mine activity) and boundary conditions remain unchanged from the model simulating mining at Curragh Complex. The residual drawdown is therefore a comparison of groundwater levels between a 'mining and closure' scenario, and a 'no mining' scenario.

Predicted drawdown figures (**Figure 4-3** and **Figure 4-4**) show where residual drawdown impacts are predicted to exceed 1 m. **Figure 4-3** presents the residual drawdown within the alluvium only, at post-mining equilibrium. Predicted recovered heads in the alluvium west of Curragh North show residual drawdowns of 1 to 2 m extending up to 4 km from mined pits at Curragh North although drawdowns at the very edge of the voids are higher (10-20 m). **Figure 4-4** presents the residual drawdown of the water table at post-mining equilibrium.

## 4.5 Particle Tracking

To investigate groundwater movement within and around the mine from the end of mining through to post-mining equilibrium particle tracking has been used. Mod-PATH3DU code (S.S. Papadopulos & Associates, Inc., 2021) was used to track the flow paths and destination of groundwater during and after recovery. Particle starting locations were selected within and around the mining areas and particles are released in the uppermost saturated layer at the start of the post-mining simulation (end of mining). The particle starting locations and their movement through the groundwater recovery simulation and in the post mining equilibrium setting are shown in **Figure 4-5** and **Figure 4-6**. Particle pathways are colour coded by the geological formation through which they are traveling. Particle tracking runs for 500 years from the end of mining.

The particle flow paths indicate that in all cases groundwater flow is ultimately toward the residual voids i.e., none of the voids act as seepage sources to the wider groundwater system (although some voids may act as sources to adjacent voids with lower final landform elevations or predicted equilibrium water levels). Particle tracking also indicates that indicates that there is no off-site migration of groundwater and that groundwater in the vicinity of the TSFs and sources of potential groundwater contamination (infrastructure area, landfills) will migrate towards the final voids rather than migrate off site.

In some cases it can be seen that particle traces initially show movement of particles is away from the voids. This occurs during the initial recovery phase where higher recharge over the spoil may result in more rapid recovery within the pit shells than the surrounding geology and some initial outward movement of groundwater from the mined areas. As recovery progresses groundwater levels in the in the surrounding geological formations exceed the recovery levels within the pit shells and final voids and any initial outward hydraulic gradients reverse and groundwater movement is towards the final voids.

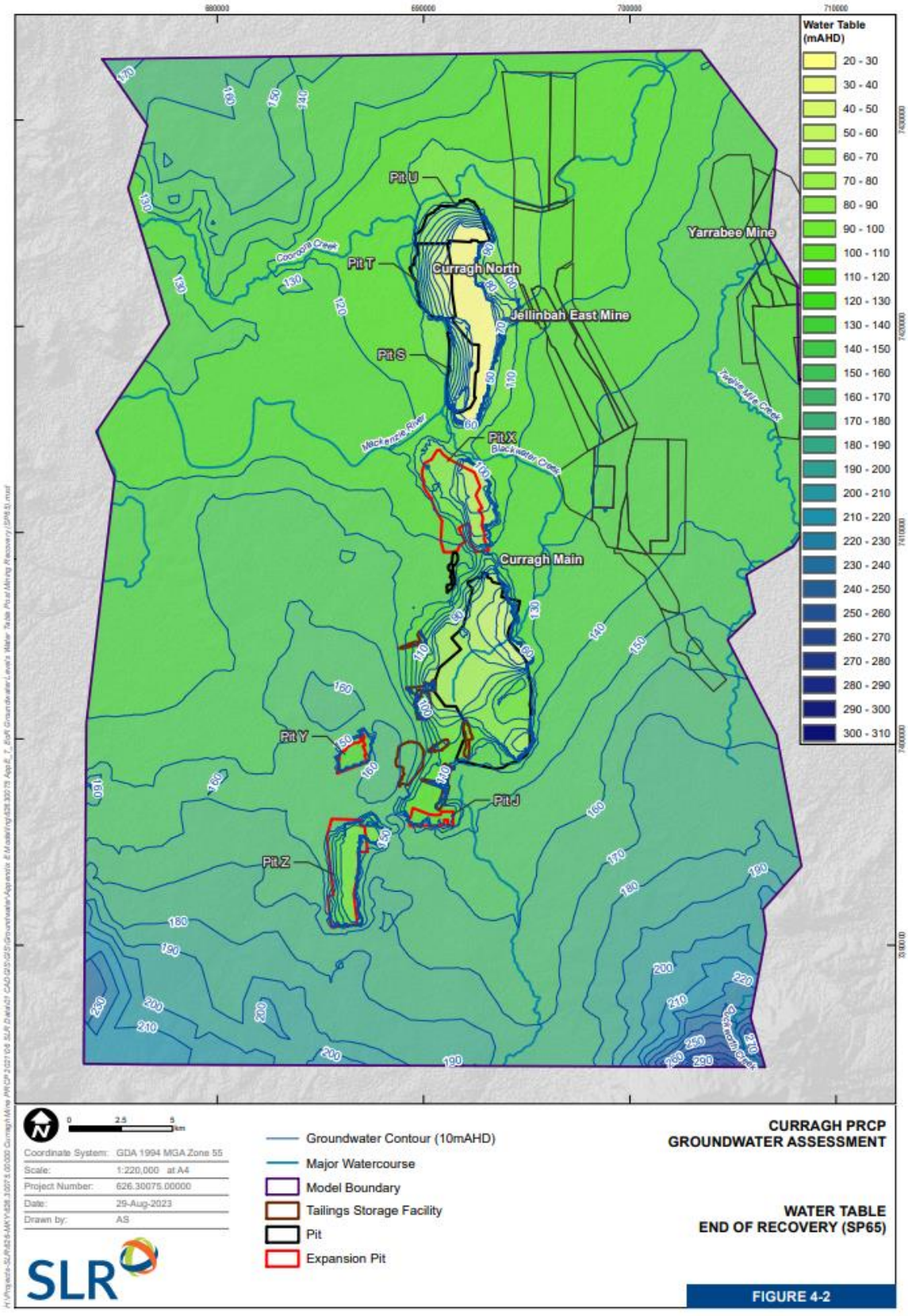



**Figure 4-2 Predicted Water Table (End of Recovery)**

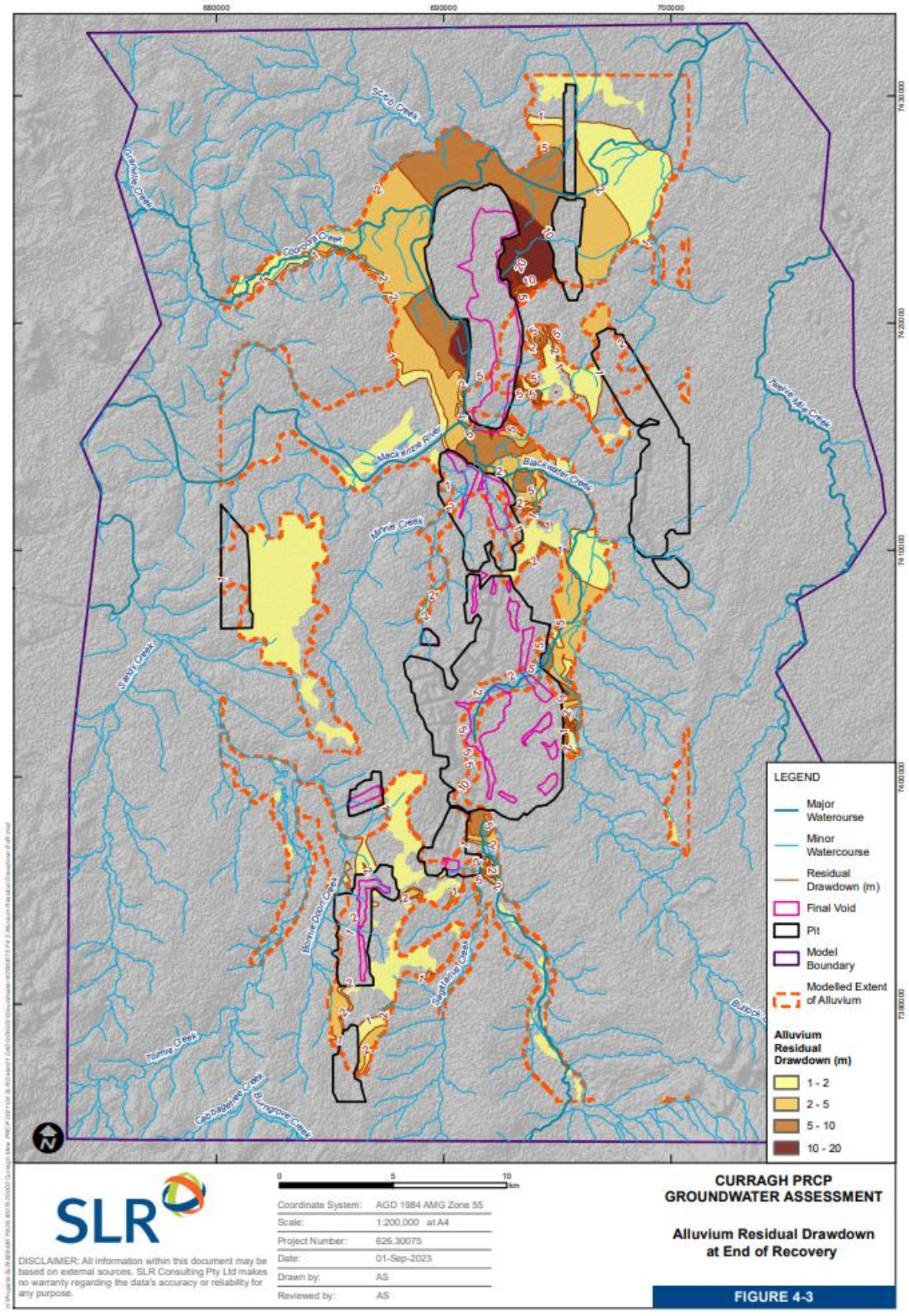



**Figure 4-3 Predicted Residual Drawdown in Alluvium (End of Recovery)**

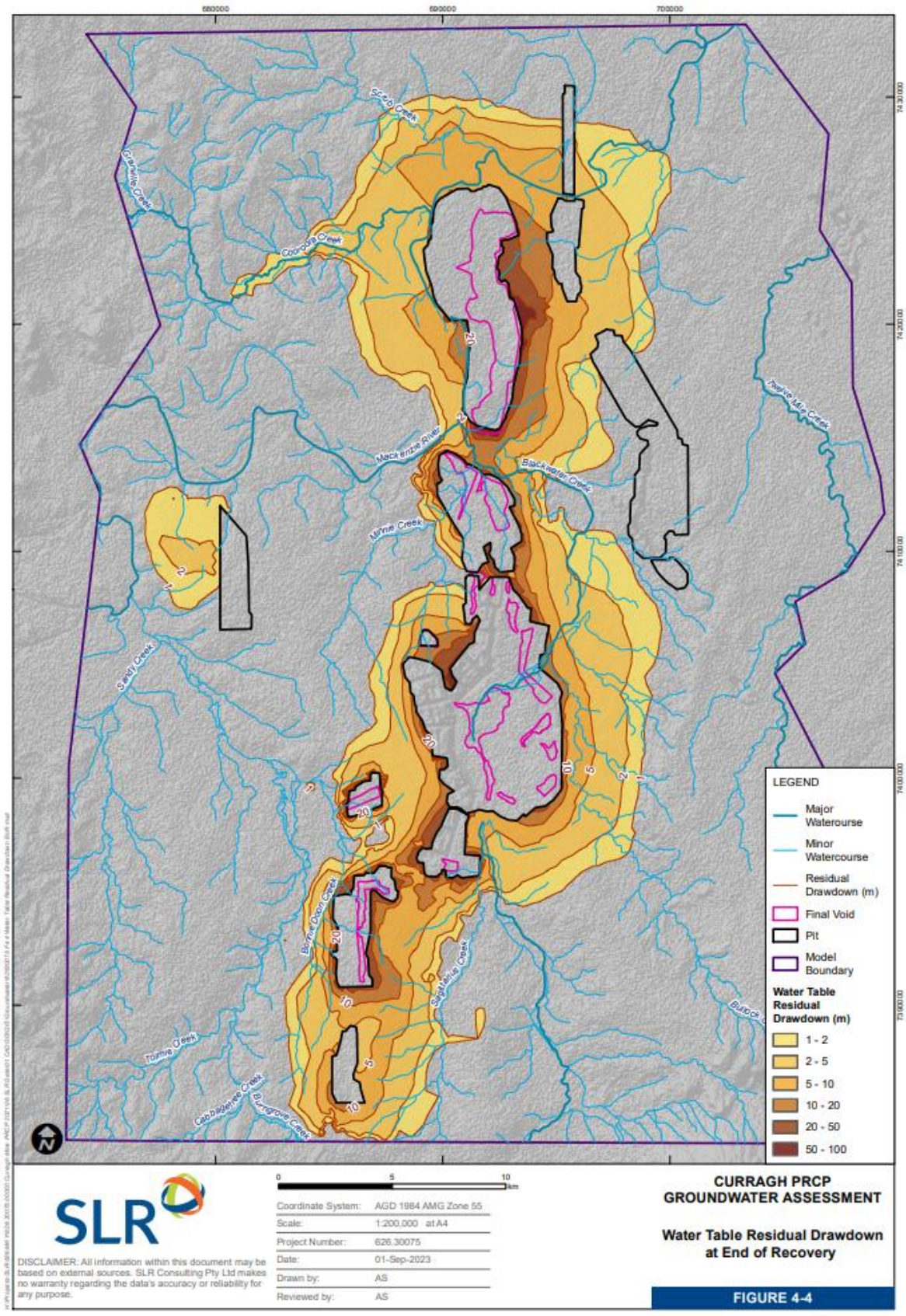



**Figure 4-4 Predicted Residual Water Table Drawdown (End of Recovery)**

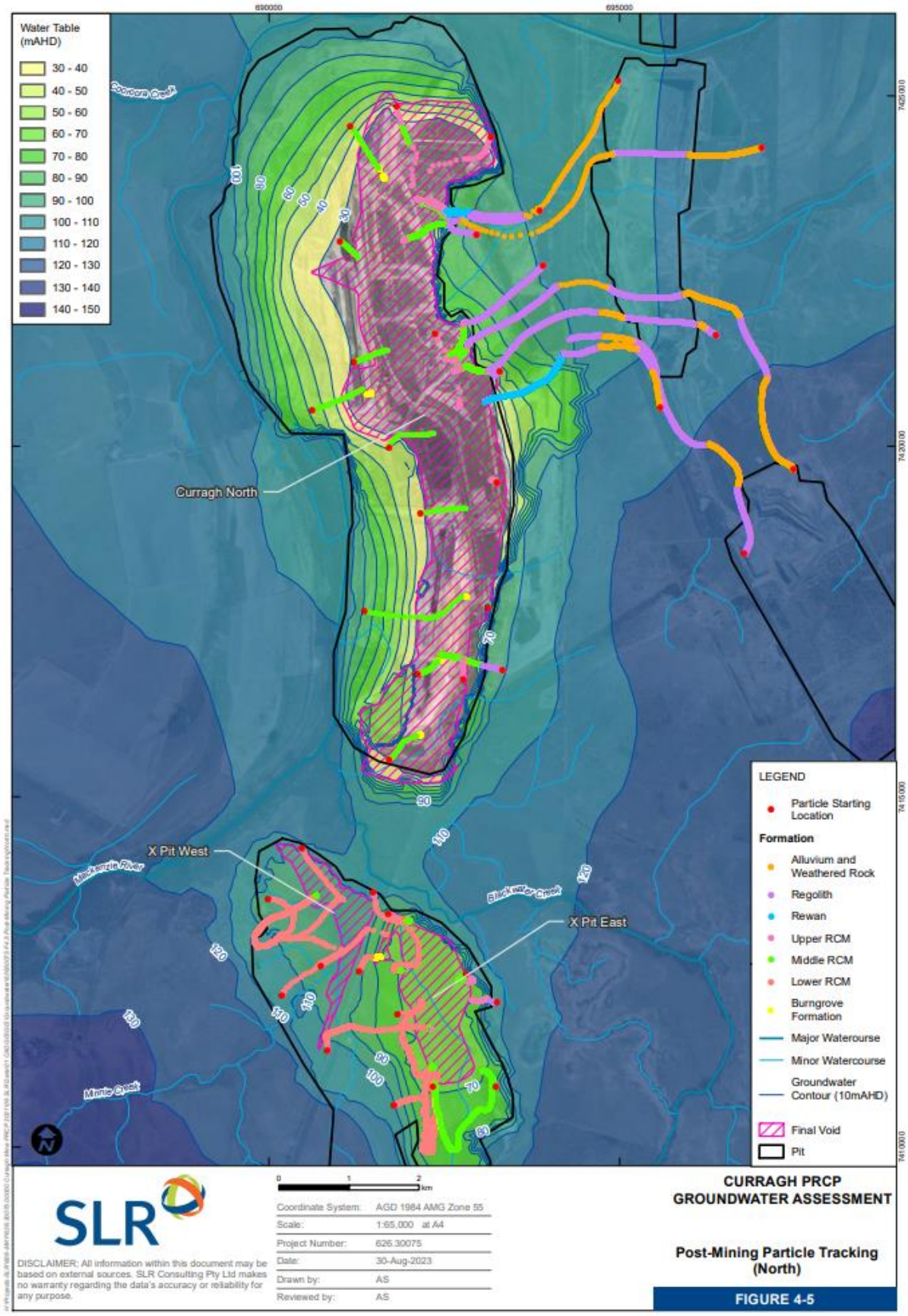



**Figure 4-5 Particle Tracking – Groundwater recovery and Post-Mining Equilibrium (North)**

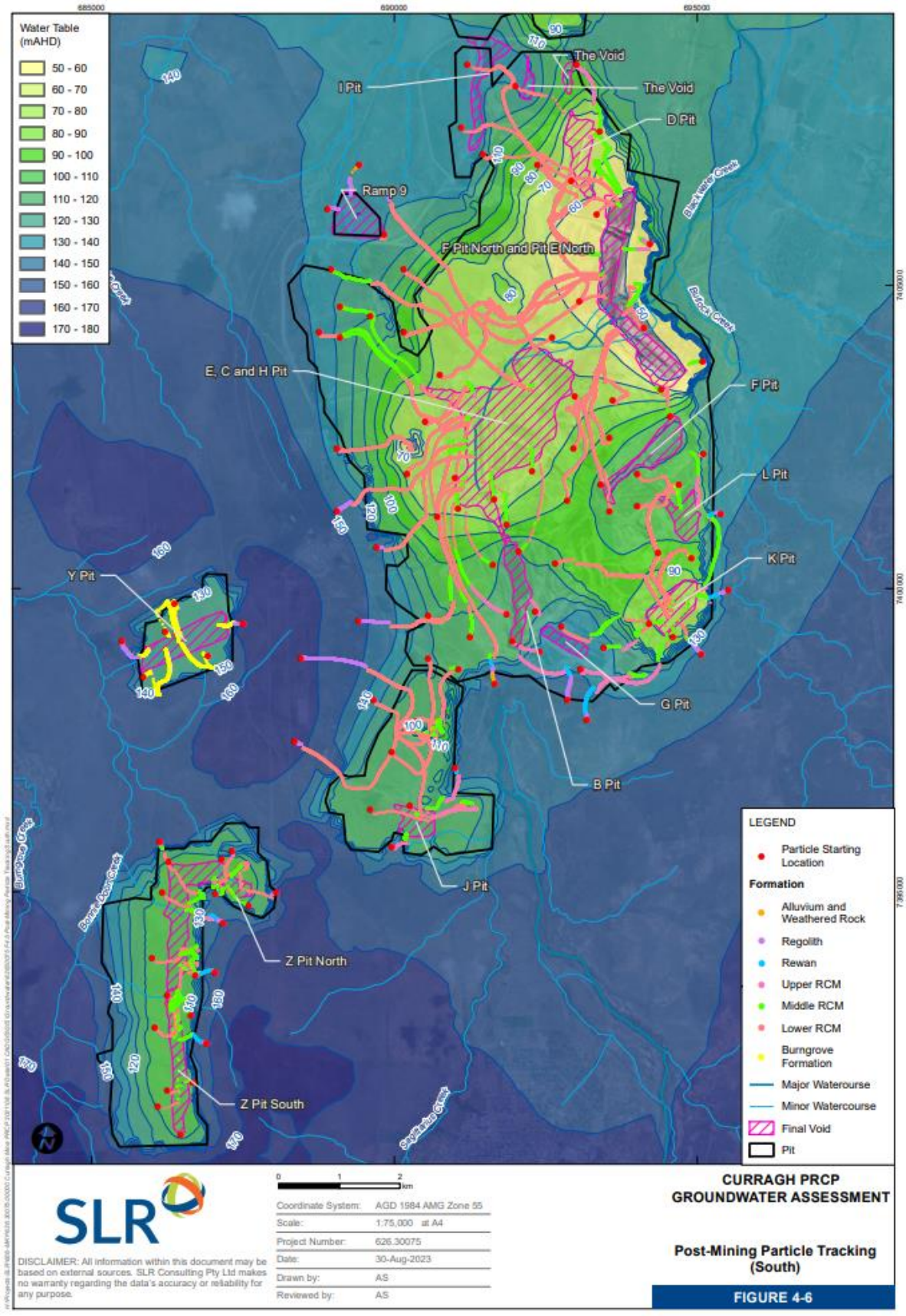



**Figure 4-6 Particle Tracking – Groundwater recovery and Post-Mining Equilibrium (South)**

# 5 Conclusions

## 5.1 Conclusions

The Curragh Complex numerical groundwater model achieved the modelling objectives, as outlined in **Section 3.1**. Model calibration statistics are within suggested guidelines (MDBC, 2001) and mass balance errors were 0%, through the model calibration and predictive modelling. The model considers all available data relevant to calibration, including the updated geological model, pit shells, tailings storage facilities, groundwater level database, and the final landforms. The following key conclusions are drawn from the numerical modelling assessment of the post-mining groundwater environment at the Curragh Complex:

- The modelling indicates that lakes will form within the final voids of the proposed post-mining landform. These lakes will act as groundwater 'sinks' with groundwater within mining disturbed areas (including the TSFs, CRS and shallow groundwater at the location of potential sources of contamination) migrating towards these sinks. This is clearly demonstrated by the particle tracking (Figure 4-5 and Figure 4-6), post mining (end of recovery) groundwater contours for key formations (Appendix E) and the geological cross sections showing post-mining (end of recovery) groundwater levels (Appendix F)
- Post-mining residual drawdown in the Mackenzie River Alluvium to the west of Curragh North will generally be in the order of 1-2m (but up to 20m near the mine voids), noting that the Mackenzie River is regarded as a "losing" watercourse with pre-mining groundwater levels in the alluvium 3-5m below the river stage in the vicinity of the mine (**Section 2.3.8.1**). This is consistent with conclusions drawn from the preliminary numerical modelling (SLR, 2021).
- Based on the geological data reviewed for this assessment, it appears that equilibrium void lake levels are generally below the base of the alluvium and the base of weathering (potential preferential pathways for outward seepage of water from the void lakes). Where the minimum base of weathering elevation is potentially exceeded by the predicted equilibrium void lake levels at Ramp 9 and Pit G, particle tracking shows that any seepage from these voids will migrate to adjacent voids with lower void lake levels.
- Post-mining, the total estimated "groundwater" inflow to all voids is approximately 8.89 ML/d although the majority of this is water derived from infiltration to the spoil and drainage into the void lake rather than inflow from the Rangal Coal Measures or Alluvium.

## 5.2 Model Limitations

It is important to note that groundwater models have inherent uncertainties which should be quantified and reduced where required and possible. The limitations and uncertainty associated with the model are discussed below. The IESC *Uncertainty analysis – Guidance for groundwater modelling within a risk management framework* (2018) identifies four key sources of scientific uncertainty affecting groundwater model simulations:

- Structural/conceptual.
- Parameterisation.
- Measurement error.
- Scenario uncertainties.

These four sources of uncertainty have been qualitatively assessed with regards key aspects of the Curragh Mine groundwater model, as presented in **Table 5-1**.

Overall, the model is considered fit for purpose to achieve the objectives of the PRCP groundwater assessment outlined in **Section 1** based on the data provided and the project timeframe. The table includes a detailed summary of the model setup and capabilities, demonstrating that the model is fit for purpose, as well as some recommendations if future updates to the model should be required.

**Table 5-1 Groundwater Model and Data Limitations and Recommended updates for more Detailed Assessment of Closure**

| Type | Part | Status | Comment |
|---|---|---|---|
| Structural/ Conceptual | Grid and Model Extent | Fit for purpose. | The model has an unstructured Voronoi grid that includes detailed cell refinement around the final voids, the tailings at the site, neighbouring mines and along drainage features such as Mackenzie River<br>The model extent encompasses Curragh Complex with boundaries set to subcrop and outcrop lines in the solid geology. |
| | Layers | Fit for purpose | Top of layer 1 incorporates site LiDAR data<br>Representation of alluvium and regolith refined based on CSIRO (2015) regolith mapping and available geology.<br>Extent of modelled alluvium consistent with mapped extent of alluvium near pits and along Mackenzie River.<br>Model vertical resolution sufficient to represent relevant geological units and unstructured grid allows layer pinch out where units not present.<br>Model structure refined based on the most up to date site geology model. |
| | Conceptualisation – Geological Structure | Fit for purpose | The structure of the geology is based on site geology model.<br>Major fault (Jellinbah thrust) has been included in the model through duplicate layers representing disconnected sections of each unit to either side of the fault.<br>Minor faults have been included through layer displacements from site geological model. |
| | Conceptualisation – GDEs | Fit for purpose. Potential for further assessment. | The risk to potential GDE's was assessed in 2016 for approval of the mining expansion. Closure and the associated partial recovery of the groundwater system will represent an improved groundwater level condition for potential GDEs compared to the approved maximum extent of mining. Post closure risks to potential GDEs has not been explicitly evaluated. |
| | Conceptualisation – Surface Water Groundwater Interactions | Fit for purpose. | Key groundwater–surface water interaction is related to drainage features and associated alluvium and the main drainage feature within the model of the Mackenzie River and the associated alluvial deposits. Investigations and monitoring undertaken by PB indicate the alluvium is largely dry and creeks are ephemeral / losing. Monitoring of the Mackenzie River Alluvium found that groundwater levels were 3-5 m below the Mackenzie River stage. |

| Type | Part | Status | Comment |
|---|---|---|---|
| | Conceptualisation – Saturated Extent of Alluvium and Regolith | Fit for purpose. Future improvements could be made. | The model provides a close fit to groundwater levels in alluvium, generally within 2 m of observed levels.<br>Additional monitoring would verify the presence/absence of groundwater in the Alluvium at key locations i.e., west of Curragh North. |
| Parameterisation | Hydraulic Conductivity – Depth Dependence | Fit for purpose. Future improvements could be made. | Limited site specific hydraulic conductivity data (horizontal and to a lesser extent vertical) obtained in 1998. The data shows a general decline in hydraulic conductivity with depth that is replicated in the model.<br>Additional data (if available) should be utilised to verify and update the modelled change with depth, and to refine model calibration and predictions. |
| | Spoil and Tailings Properties | Fit for purpose. Future improvements possible. | No site-specific data is available for the spoil and tailings. Spoil properties were adopted from existing studies.<br>Measurements of spoil and tailings hydraulic properties could be utilised to verify and refine the model calibration and predictions in updates of the model. |
| | Rivers | Fit for purpose.<br><br>Improvements possible. | Mackenzie River stage height is assigned a long term annual average level assumed in the previous version of the model. Monitoring of the Mackenzie River Alluvium found that groundwater levels were 3-5 m below the Mackenzie River stage so variable stage height at times might increase leakage to the alluvium temporarily. Major flood events may have a significant impact on alluvial groundwater recharge but are difficult to replicate within the model. Future modelling could attempt to represent significant flood events as periods of enhanced recharge to the alluvium.<br>No site-specific information on surface water discharge, flow monitoring or water storage has been included in the model but could be considered in future model updates.<br>Blackwater Creek and other minor tributaries within the vicinity of Curragh Complex are ephemeral and only flow briefly after rainfall. Therefore, river stage height of zero was assigned to these watercourses in the model. |
| | Recharge | Fit for purpose | Recharge zonation is based on mapped surface geology and calibrated recharge rates. Soil mapping and site water quality data could be further utilised to base recharge rates. |

| Type | Part | Status | Comment |
|---|---|---|---|
| Measurement Error | Observation Data Quality | Fit for purpose Future improvements possible. | Further review of bore construction details and screening of groundwater level data / formations monitored could be undertaken as well as incorporation of any new groundwater level monitoring to refine the groundwater model in future. |
| | Landholder Bore Data Quality | Fit for purpose | Further detailed review of impacts at the locations of landholder bores should be undertaken with the updated model for PRCP |
| | Temporal spread | Fit for purpose. Future improvements possible. | Timeseries water level data with varying resolution has been used in the calibration from the site as well as the neighbouring mine Jellinbah Coal Mine.<br>Model temporal discretisation of annual stress periods temporal behaviour of the groundwater system to be simulated in the model. Temporal resolution could be increased to quarterly stress periods to allow climate seasonality to be included. |
| Scenario Uncertainties Future stresses/ conditions | Calibration | Fit for purpose | A transient calibration model was run and calibrated to observed groundwater levels (1983-June 2021) using PEST and observed mine inflows (2015) with manual calibration.<br>Using shorter time slices in the model would allow climate seasonality to be better represented in the model.<br>The model calibration could be further refined if additional monitoring bores are installed. |
| | Predictive | Fit for purpose Future improvements possible. | Model captures open cut mining progression and timing at Curragh Complex, based on the 2016 groundwater study with minor updates made to reflect recent changes in mine progression.<br>The model includes some future mining at surrounding mines based on publicly available data and the information from the previous version of the model.<br>The simulated mining progression and the timing for the pits could be improved if an updated mine progression plan is provided. This may require changes to the predictive model temporal discretisation. |
| | Sensitivity and uncertainty | Fit for purpose. Future improvements may be required. | Predictive uncertainty analysis was not considered necessary for the purpose of this assessment.<br>Additional work to test the uncertainty of the model parameters may be required. This includes differences in the properties spoil properties and hydraulic properties of the in-situ strata. As well the influence of streamflow and recharge on model predictions and recovery. |

# 6 References

Ausenco-Norwest, 2012. Groundwater Model, Northern Bowen Basin Regional Model Impact Predictions, Queensland, Australia. Prepared for Arrow Energy Pty Ltd. Available at: http://www.arrowenergy.com.au/__data/assets/pdf_file/0018/3870/Appendix- Model-Technical-Report.pdf.

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A., 2012. Australian Groundwater Modelling Guidelines. Waterlines Report Series No. 82, June 2012.

AGE 2006. Ensham Central Project EIA - Groundwater Impact Assessment. Prepared for Hansen Consulting, cited in HydroSimulations, Baralaba North Continued Operations (BNCOP) for Cockatoo Coal Ltd, April 2014.

AGE, 2013. Minyango Project Groundwater. Proj G1562. Report for Hansen Bailey. April 2013.

Bureau of Meteorology (BOM). (2021). Map of Climate Zones Australia. Retrieved August 20, 2021, from http://www.bom.gov.au/climate/how/newproducts/images/zones.shtml

Doherty, J., 2010. PEST - Model Independent Parameter Estimation. User Manual 5th Edition. Watermark Numerical Computing.

Douglas Partners 2014. Report on S Pit Groundwater Study Review, Curragh Coal Mine via Blackwater, Central Queensland, Project 80724.00, November 2014.

HydroAlgorithmics 2014. AlgoMesh 2. Released 1 September 2020, from http://www. hydroalgorithmics.com /algomesh-version-2-released.

HydroSimulations, 2016. Curragh Extension Project Groundwater Model: Final Review (Ref: HC2016/26).

MDBC (Middlemis, H., Merrick, N., and Ross, J.), 2001. Murray-Darling Basin Commission – Groundwater Flow Modelling Guideline. Report for MDBC. January 2001.

Parsons Brinckerhoff 2003. Curragh North Coal Mine – Hydrology, flooding and groundwater report, Project No. 2132105A-PR001Ebt (Appendix G of Curragh North Mine Environmental Impact Statement). August 2003.

Parsons Brinkerhoff (PB), 2016. Curragh Extension Project – Groundwater Technical Report (2172652H-WAT-REP-002 RevB)

Queensland Government. (2021). *Scientific Land Owners (SILO) database – Australian climate data from 1889 to yesterday*. Retrieved August, 23, 2021, from https://www.longpaddock.qld.gov.au/silo/point-data/

Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., and Hughes, J.D., 2013., MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: USGS Techniques and Methods 6-A45.

SLR, 2021a. Curragh Mine Complex, Concept Residual Void Assessment Groundwater Technical Appendix, November 2021.

SLR, 2021b. Curragh Mine Complex, Concept Residual Void Assessment (626.30075.00000), November 2021.

Velseis Processing Pty Ltd (2012). 2011 Minyango 3D Seismic Survey, Minyango Project Area, Qld. Final Report, Interpretation and Data Processing.

# APPENDIX A

Groundwater Quality Charts

Appendix A contents here

# APPENDIX B

Calibration Average Residuals

| Bore ID | Model Layer | Easting (GDA94 Z55) | Northing (GDA94 Z55) | Average Residual | Min | Max |
|---|---|---|---|---|---|---|
| 158166 | 1 | 697110 | 7429801 | -11.83 | -11.83 | -11.83 |
| 158167 | 1 | 697216 | 7428270 | -6.75 | -6.75 | -6.75 |
| 158168 | 1 | 694575 | 7426440 | -0.10 | -0.10 | -0.10 |
| 158169 | 1 | 696360 | 7427541 | -4.67 | -4.67 | -4.67 |
| 158171 | 1 | 697111 | 7429825 | -16.39 | -16.39 | -16.39 |
| 158178 | 1 | 696548 | 7425796 | -2.82 | -2.82 | -2.82 |
| 158200 | 1 | 695844 | 7426992 | -11.81 | -22.02 | -1.60 |
| 158201 | 1 | 695844 | 7426991 | -7.57 | -13.22 | -1.92 |
| 158202 | 1 | 695173 | 7427519 | -0.44 | -0.44 | -0.44 |
| 158203 | 1 | 695553 | 7428644 | -5.08 | -5.08 | -5.08 |
| 158204 | 2 | 695553 | 7428644 | -13.67 | -22.73 | -4.60 |
| 158207 | 2 | 694898 | 7429684 | -20.44 | -24.50 | -16.38 |
| 158208 | 1 | 695619 | 7430189 | -21.91 | -26.21 | -17.61 |
| 158209 | 1 | 695619 | 7430189 | -13.23 | -13.23 | -13.23 |
| 158210 | 2 | 694883 | 7431081 | -20.56 | -20.56 | -20.56 |
| 158211 | 1 | 694883 | 7431081 | -9.93 | -9.93 | -9.93 |
| 165446 | 19 | 695184 | 7427524 | 3.56 | 3.56 | 3.56 |
| 13010010 | 10 | 680703 | 7390562 | -11.05 | -13.97 | -8.84 |
| 1301aMB | 2 | 691308 | 7398335 | 6.26 | 5.69 | 7.03 |
| 1301bMB | 2 | 691308 | 7398335 | 6.33 | 5.61 | 7.14 |
| 1302MB | 2 | 691118 | 7397611 | 9.27 | 8.89 | 9.55 |
| 1303MB | 2 | 691086 | 7396966 | 4.49 | 4.23 | 4.74 |
| 1304aMB | 2 | 691481 | 7398090 | 4.69 | 4.20 | 5.10 |
| 1304bMB | 2 | 691481 | 7398084 | 3.71 | 2.42 | 5.25 |
| 1307MB | 1 | 692378 | 7403433 | 2.74 | 1.91 | 4.07 |
| 1308MB | 1 | 692387 | 7403452 | 2.64 | 1.62 | 4.92 |
| 1309MB | 1 | 689082 | 7423302 | -2.76 | -4.86 | -0.86 |
| 1312MB | 1 | 689148 | 7423118 | -1.51 | -2.68 | -0.05 |
| 1321MB | 1 | 687647 | 7401486 | 4.38 | 4.38 | 4.38 |
| 1322MB | 1 | 688976 | 7402204 | 5.26 | 3.10 | 6.27 |
| 1323MB | 2 | 687417 | 7403078 | -1.66 | -2.47 | -1.23 |
| 1324MB | 1 | 687673 | 7405113 | -10.08 | -10.08 | -10.08 |
| 1410MB | 1 | 688842 | 7423144 | -1.87 | -3.06 | -0.85 |
| 1411MB | 1 | 688974 | 7423011 | -1.14 | -2.94 | -0.17 |
| 1417MB | 1 | 688376 | 7400592 | 2.86 | 1.34 | 5.12 |

| Bore ID | Model Layer | Easting (GDA94 Z55) | Northing (GDA94 Z55) | Average Residual | Min | Max |
|---|---|---|---|---|---|---|
| 1418MB | 1 | 688428 | 7400647 | 4.28 | 2.83 | 5.74 |
| 1419MB | 1 | 693083 | 7418830 | 11.59 | 9.22 | 12.44 |
| 1420MB | 1 | 693004 | 7418881 | 3.15 | -5.14 | 11.44 |
| 1425MB | 1 | 691229 | 7417747 | 10.87 | 10.65 | 11.16 |
| 1426MB | 1 | 691085 | 7419864 | 0.59 | -0.95 | 1.88 |
| 1428MB | 1 | 691266 | 7418518 | -3.81 | -3.81 | -3.81 |
| 1529MB | 9 | 691161 | 7417212 | -5.66 | -7.03 | -4.40 |
| 1531MB | 1 | 691987 | 7426518 | -0.10 | -1.51 | 0.48 |
| 1533MB | 1 | 689529 | 7421689 | -5.11 | -5.12 | -5.11 |
| 1534MB | 10 | 689540 | 7421687 | -1.18 | -2.93 | 1.03 |
| 1536MB | 6 | 690116 | 7404141 | 9.81 | 8.03 | 14.50 |
| 1537MB | 10 | 687589 | 7404885 | -9.19 | -10.77 | -6.05 |
| 1538MB | 9 | 690217 | 7405768 | -0.96 | -1.62 | -0.01 |
| 1539MB | 9 | 690523 | 7405931 | 0.59 | 1.43 | 0.38 |
| 1642MB | 1 | 688631 | 7400213 | 2.76 | 2.45 | 3.68 |
| 1743MB | 1 | 692314 | 7399333 | -3.49 | -21.35 | 7.70 |
| 1847MB | 6 | 691246 | 7419276 | 2.41 | 1.22 | 3.95 |
| 1848MB | 6 | 691184 | 7419553 | -2.60 | -3.54 | -1.59 |
| 190160_A | 15 | 699601 | 7416892 | -20.80 | -20.80 | -20.80 |
| 190161_A | 19 | 697507 | 7420034 | -11.97 | -11.97 | -11.97 |
| 2060MB | 1 | 691488 | 7420977 | 0.69 | 0.33 | 1.05 |
| 2061MB | 1 | 692800 | 7419144 | 0.84 | 0.61 | 1.08 |
| 2062MB | 1 | 692922 | 7425213 | 15.14 | 13.68 | 18.06 |
| BH1 | 8 | 689979 | 7399250 | 7.84 | 5.74 | 11.39 |
| BH3 | 8 | 688847 | 7404539 | 0.47 | -0.01 | 1.46 |
| BH4 | 10 | 688261 | 7401147 | 6.24 | 2.87 | 8.65 |
| BH5 | 10 | 688269 | 7399885 | -12.18 | -19.66 | -9.05 |
| BH6 | 3 | 692902 | 7403743 | 1.67 | 1.20 | 2.43 |
| BH8 | 3 | 692678 | 7403357 | 2.45 | -0.04 | 4.26 |
| BH8A | 1 | 692678 | 7403356 | 2.24 | 1.05 | 3.74 |

# APPENDIX C

Calibration Hydrographs

Appendix C contents here

# APPENDIX D

Post Mining Recovery Hydrographs – Final Voids

# APPENDIX E

Simulated Groundwater Level Contours

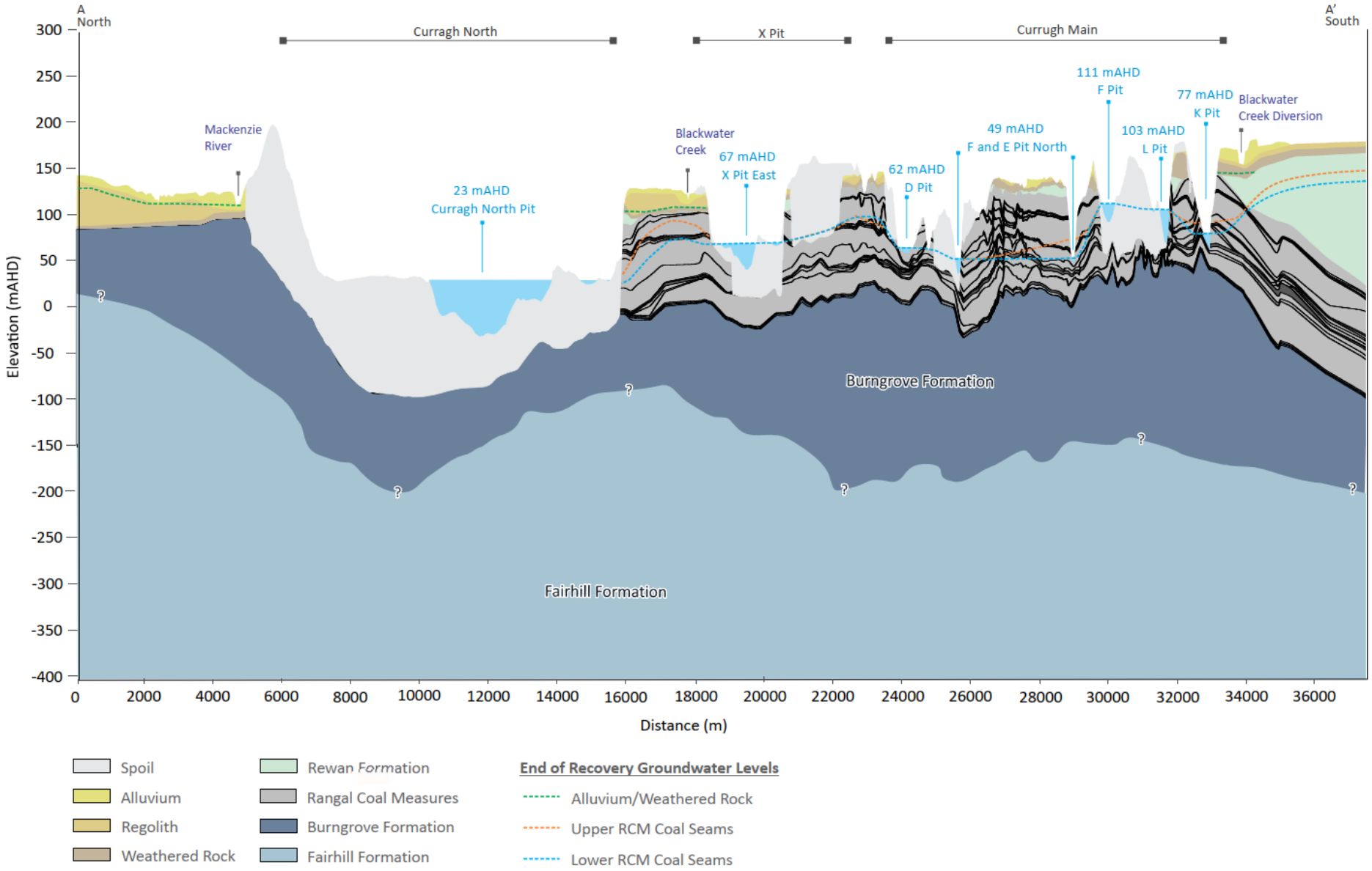
Pre-mining, end of mining, and end of recovery contours for:

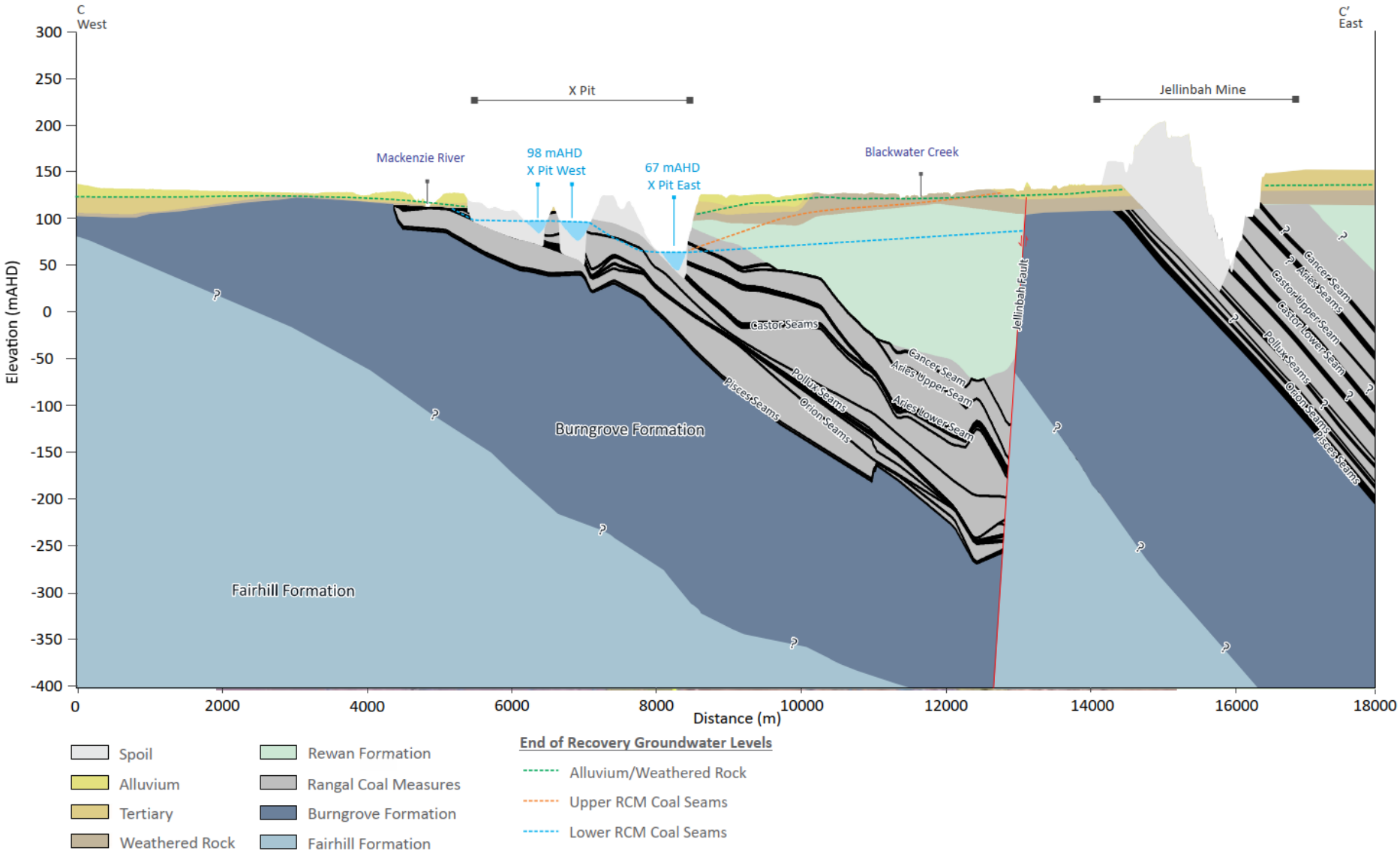
- Water Table
- Alluvium
- Regolith
- RCM overburden
- RCM Upper Coal Seams
- RCM Middle Coal Seams
- RCM Lower Coal Seams

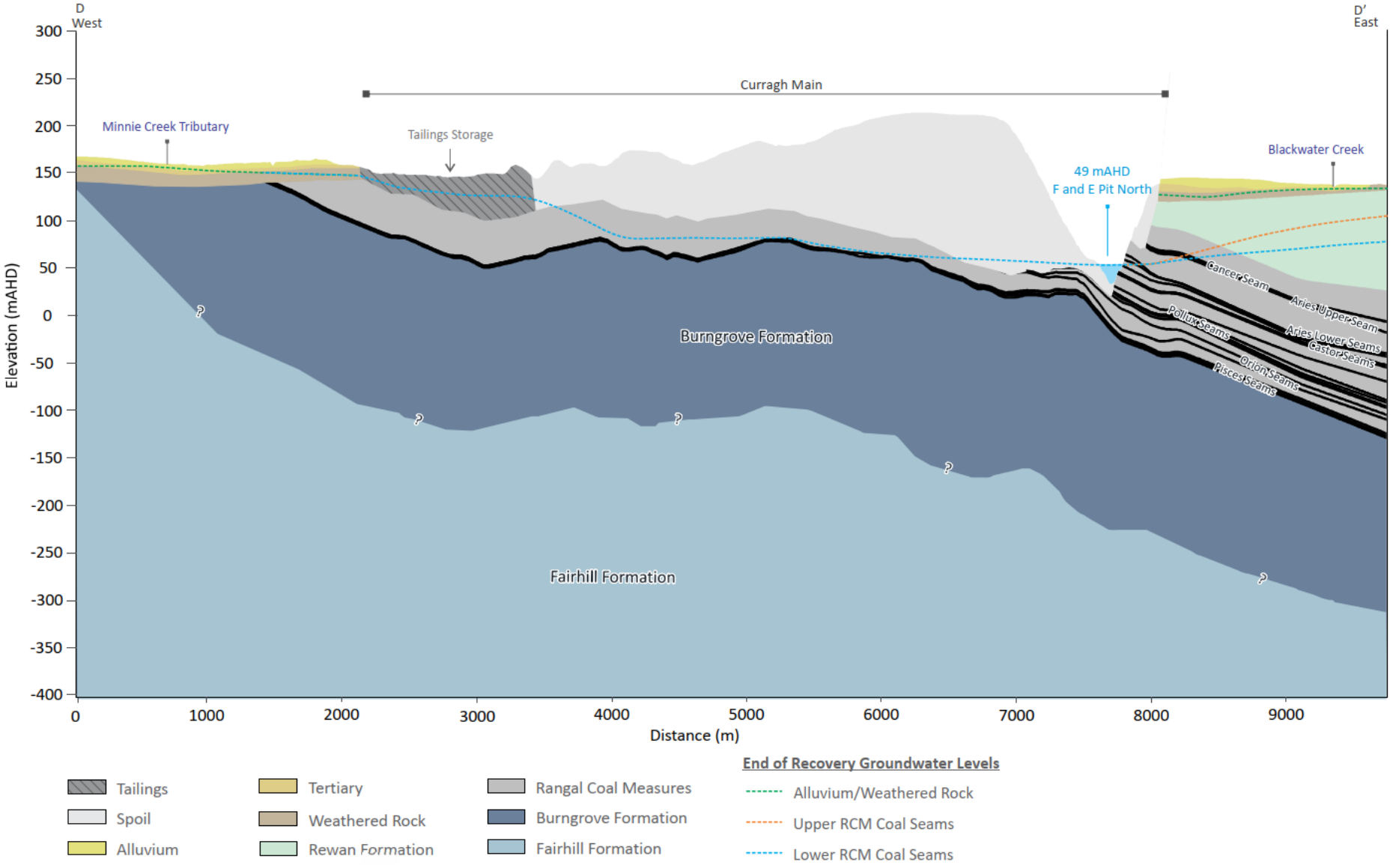
# APPENDIX F

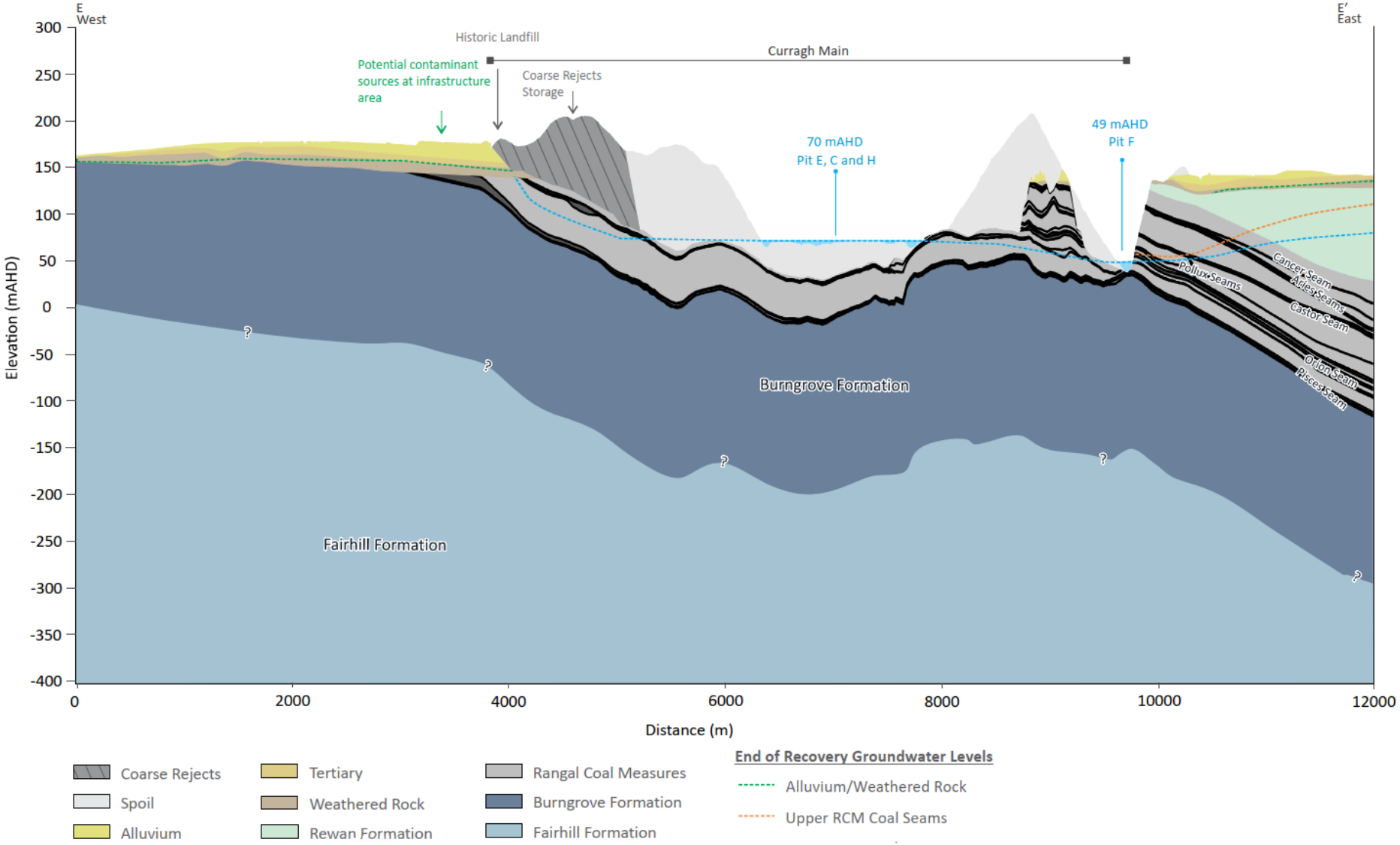
Geological Cross Sections Showing Post-Mining Groundwater Levels and Final Void Lake Levels

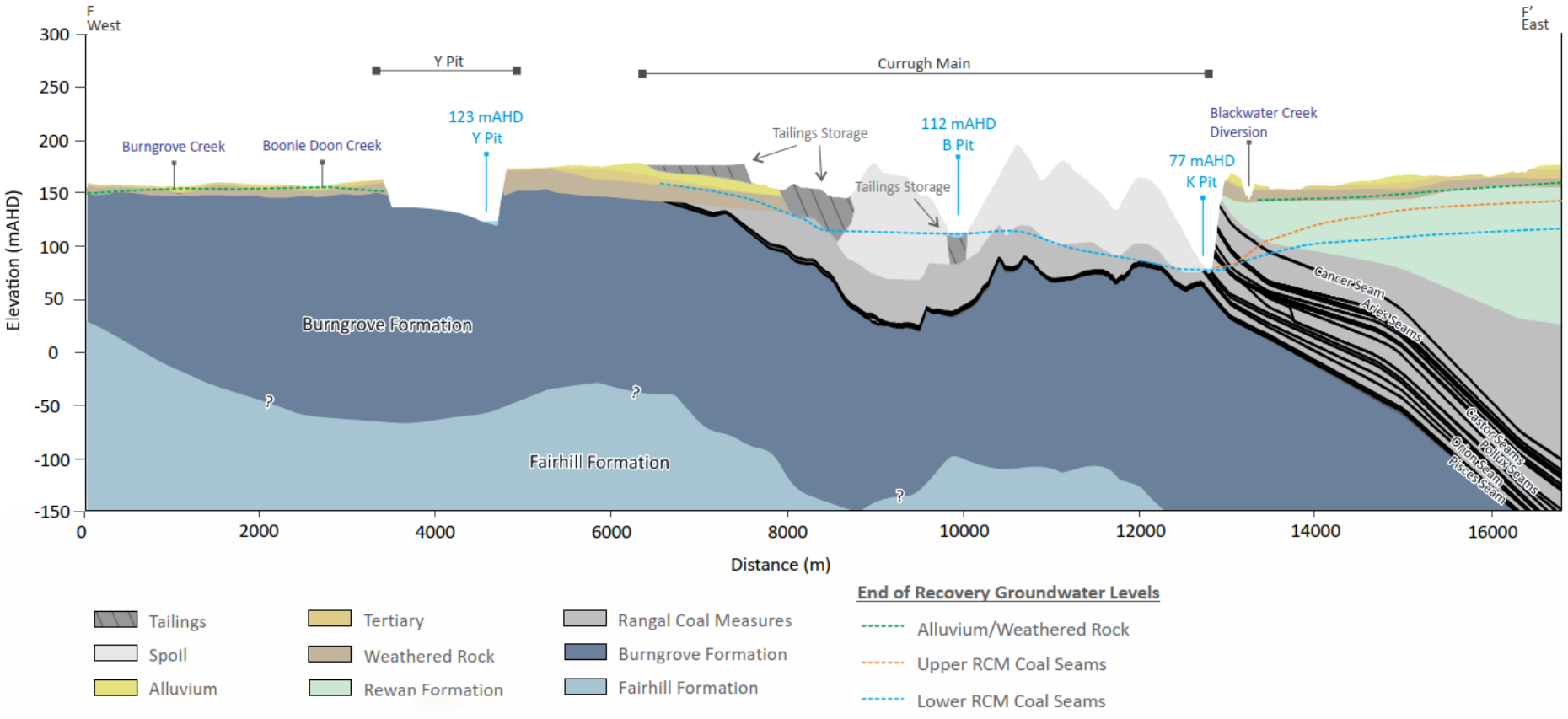
(Refer to Figures 2.5 and 2.6 for section lines)

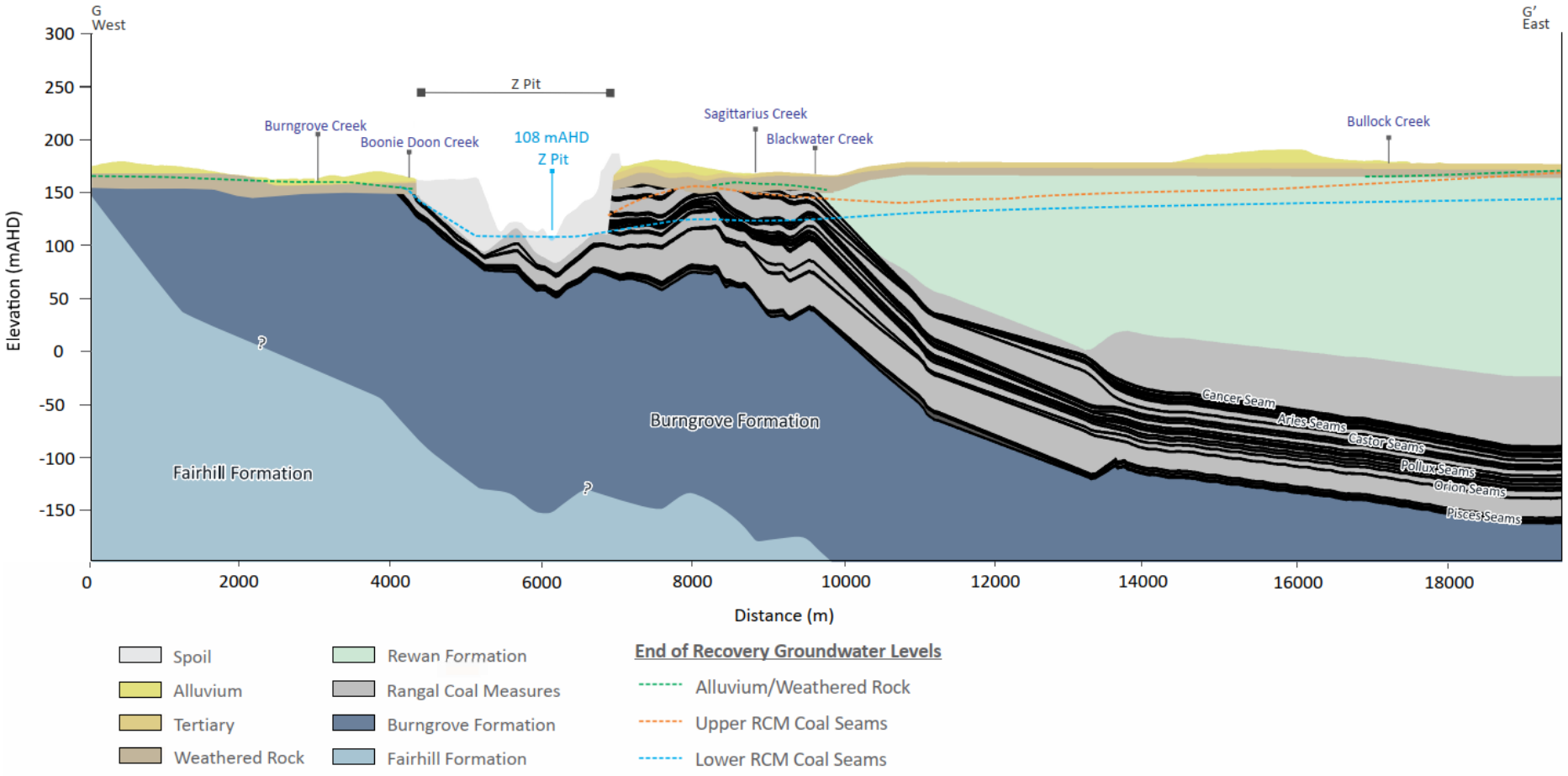

A
North
A'
South
Curragh North
X Pit
Currugh Main
Mackenzie River
Blackwater Creek
23 mAHD
Curragh North Pit
67 mAHD
X Pit East
62 mAHD
D Pit
49 mAHD
F and E Pit North
111 mAHD
F Pit
103 mAHD
L Pit
77 mAHD
K Pit
Blackwater Creek Diversion
Burngrove Formation
Fairhill Formation
Elevation (mAHD)
Distance (m)
Spoil
Alluvium
Regolith
Weathered Rock
Rewan Formation
Rangal Coal Measures
Burngrove Formation
Fairhill Formation
End of Recovery Groundwater Levels
Alluvium/Weathered Rock
Upper RCM Coal Seams
Lower RCM Coal Seams


C
West
C'
East
X Pit
Jellinbah Mine
Mackenzie River
98 mAHD
X Pit West
67 mAHD
X Pit East
Blackwater Creek
Jellinbah Fault
Gastor Seams
Cancer Seam
Aries Upper Seam
Aries Lower Seam
Pollux Seams
Orion Seams
Pisces Seams
Gastor Upper Seam
Gastor Lower Seam
Burngrove Formation
Fairhill Formation
Elevation (mAHD)
Distance (m)
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Spoil
Alluvium
Tertiary
Weathered Rock
Rewan Formation
Rangal Coal Measures
Burngrove Formation
Fairhill Formation
End of Recovery Groundwater Levels
Alluvium/Weathered Rock
Upper RCM Coal Seams
Lower RCM Coal Seams


D
West
D'
East
Curragh Main
Minnie Creek Tributary
Tailings Storage
Blackwater Creek
49 mAHD
F and E Pit North
Cancer Seam
Aries Upper Seam
Pollux Seams
Aries Lower Seams
Castor Seams
Orion Seams
Pisces Seams
Burngrove Formation
Fairhill Formation
Elevation (mAHD)
Distance (m)
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Tailings
Spoil
Alluvium
Tertiary
Weathered Rock
Rewan Formation
Rangal Coal Measures
Burngrove Formation
Fairhill Formation
End of Recovery Groundwater Levels
Alluvium/Weathered Rock
Upper RCM Coal Seams
Lower RCM Coal Seams


E
West
E'
East
Historic Landfill
Curragh Main
Potential contaminant sources at infrastructure area
Coarse Rejects Storage
70 mAHD
Pit E, C and H
49 mAHD
Pit F
Pollux Seams
Cancer Seam
Alpes Seams
Castor Seam
Orion Seam
Pisces Seam
Burngrove Formation
Fairhill Formation
Elevation (mAHD)
Distance (m)
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
0
2000
4000
6000
8000
10000
12000
Coarse Rejects
Spoil
Alluvium
Tertiary
Weathered Rock
Rewan Formation
Rangal Coal Measures
Burngrove Formation
Fairhill Formation
End of Recovery Groundwater Levels
Alluvium/Weathered Rock
Upper RCM Coal Seams


F
West
F'
East
Y Pit
Currugh Main
123 mAHD
Y Pit
112 mAHD
B Pit
77 mAHD
K Pit
Blackwater Creek
Diversion
Burngrove Creek
Boonie Doon Creek
Tailings Storage
Tailings Storage
Burngrove Formation
Fairhill Formation
Cancer Seam
Aries Seams
Castor Seams
Pollux Seams
Orion Seam
Pisces Seam
Elevation (mAHD)
Distance (m)
300
250
200
150
100
50
0
-50
-100
-150
0
2000
4000
6000
8000
10000
12000
14000
16000
Tailings
Spoil
Alluvium
Tertiary
Weathered Rock
Rewan Formation
Rangal Coal Measures
Burngrove Formation
Fairhill Formation
End of Recovery Groundwater Levels
Alluvium/Weathered Rock
Upper RCM Coal Seams
Lower RCM Coal Seams


G
West
G'
East
Z Pit
Burngrove Creek
Boonie Doon Creek
108 mAHD
Z Pit
Sagittarius Creek
Blackwater Creek
Bullock Creek
Elevation (mAHD)
300
250
200
150
100
50
0
-50
-100
-150
?
?
Fairhill Formation
Burngrove Formation
Cancer Seam
Aries Seams
Castor Seams
Pollux Seams
Orion Seams
Pisces Seams
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Distance (m)
Spoil
Alluvium
Tertiary
Weathered Rock
Rewan Formation
Rangal Coal Measures
Burngrove Formation
Fairhill Formation
End of Recovery Groundwater Levels
Alluvium/Weathered Rock
Upper RCM Coal Seams
Lower RCM Coal Seams

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# Topsoil Quality Assessment Report

Coronado Curragh Pty Ltd

20 July 2022

## Version Control

Please update this version control with updates when applicable:

| Version Number | Date | Name | Update Details |
|---|---|---|---|
| 1 | 25/Aug/2020 | C Merlow | |
| 2 | 20/Jul/2022 | M Bourke | Update to reflect 2022 stockpile location and volume data |

| Review Status | |
|---|---|
| ☐ | Review by Click here to enter a date. |
| ■ | Review not required |

| Prepared | |
|---|---|
| ■ | By Curragh |
| ☐ | For Curragh Under PO/Contract Number: |

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# 1.0 Introduction

This soil assessment report details information including spatial distribution, volumes and quality of topsoil stockpiles within the Curragh Mine. Coronado Curragh Pty Ltd (Curragh) has conducted this assessment study to determine topsoil availability and quality to assist in the management of topsoil in progressive rehabilitation activities.

# 2.0 Objective

The objective of this report is to assess the suitability of the currently stockpiled topsoil at Curragh Mine for rehabilitation purposes, and to determine what portion of the stockpiled topsoil, if any, may require amelioration for planned rehabilitation. There have been several baseline land suitability and soil type assessments conducted on Curragh mining leases since its inception. These reports have focused on in situ topsoil classification and land suitability of both pre and post mining activities. Excerpts from these reports are provided in Appendix A and indicate up to six soil types across the mining leases, with varying soil chemistry (GT Environmental, AARC, LRS EHSS).

In 2019 Curragh commissioned GT Environmental to engage with the Environmental Team and provide in depth, onsite practical training on topsoil assessment techniques and interpretation of field and laboratory results. During this training the *Coronado/GT Environment Topsoil Training, Assessment and Sampling Guideline* was developed, along with *EMS Work Instruction (WI) 20 Topsoil Stockpiles Quality Assessment* and *EMS FORM 1.14 Topsoil Quality Assessment*. *EMS PROC 1.3 Topsoil Management Procedure* was updated later as a result of the training.

Topsoil is currently stripped in advance of mining activities and stockpiled for utilisation in planned rehabilitation activities as per Environmental Authority (EA) conditions and in accordance with *EMS PLAN 1.0 Land Management Plan* and *EMS PROC 1.3 Topsoil Management Procedure*. As each new topsoil stockpile is created it is included into the topsoil inventory in its specific zone and allocated the next numerical number available. Therefore, the lower the stockpile ID number the older the topsoil stockpile is. However, as mining progresses some of the old topsoil stockpiles are required to be relocated. As this occurs comments are made in the topsoil inventory to indicate that a topsoil stockpile has been relocated to a new location, and whether it has kept its original number or had a new number allocated.

Topsoil stockpile zones are allocated as a new active mining pit or overburden dump location are created. Topsoil stockpiles are surveyed by the Curragh Survey Team for topsoil volume as they are generated, or at the end of each month with the aerial LIDAR process. Topsoil stockpile volume and location reconciliations are conducted by the Curragh Survey and Environmental Teams regularly and are saved in both a mapping layer for visual representation and an inventory list for volumetric analysis.

Topsoil stockpile locations and topsoil zones for Curragh Main and Curragh North are shown in Figure 1 and Figure 2 respectively, with current stockpiled topsoil volumes, by topsoil zone, provided in Table 1.




**Figure 1 - Curragh Main Topsoil Stockpile Locations by Zone**

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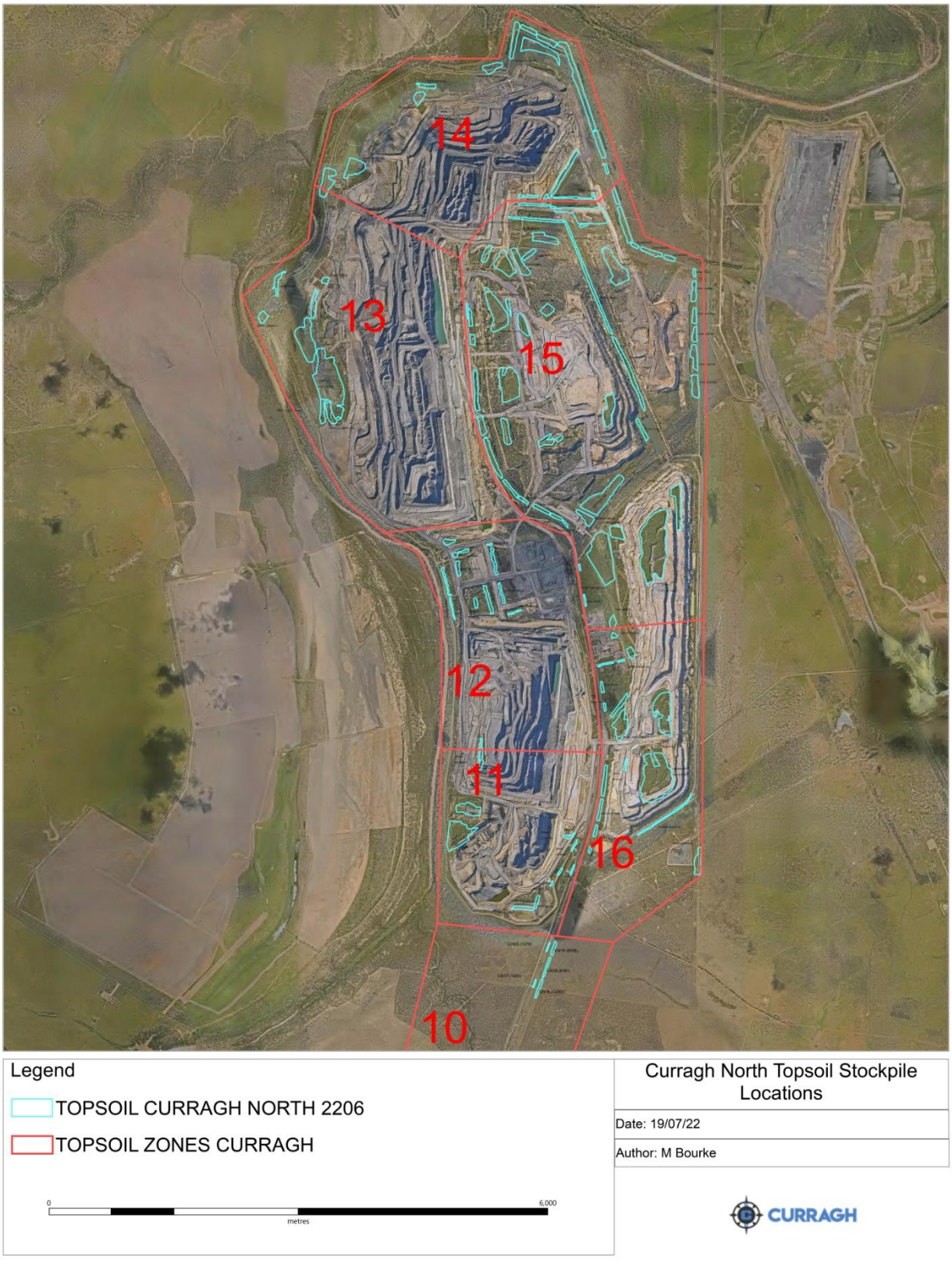



**Figure 2 - Curragh North Topsoil Stockpile Locations by Zone**

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**Table 1 - Topsoil Inventory June 2022**

| Location Description | | Volume $m^3$ | Total $m^3$ |
|---|---|---|---|
| Curragh | Zone 1 | 893,942 | |
| | Zone 2 | 70,284 | |
| | Zone 3 | 533,081 | |
| | Zone 4 | 255,829 | |
| | Zone 5 | 626,809 | |
| | Zone 6 | 433,939 | |
| | Zone 7 | 955,893 | |
| | Zone 8 | 785,359 | |
| | Zone 9 | 1,065,168 | **5,620,304** |
| Curragh North | Zone 10 | 56,461 | |
| | Zone 11 | 119,893 | |
| | Zone 12 | 134,156 | |
| | Zone 13 | 856,792 | |
| | Zone 14 | 849,045 | |
| | Zone 15 | 4,180,573 | |
| | Zone 16 | 1,097,372 | **7,294,292** |
| **TOTAL** | | | **12,914,596** |

# 3.0 Methodology

## 3.1 Sampling Strategy

To undertake the assessment of all stockpiled topsoil on site, a sampling strategy was adopted. The Topsoil zones had previously been developed by the Curragh Survey Team to assist the process of mapping and accounting for stockpiled topsoil. Sampling was conducted in 2020 and a minimum of one stockpile from each zone was included in the sampling program*.

Zones with a collective volume of greater than 650,000$m^3$ of topsoil, were required to have two stockpiles from each zone sampled. Zones with a collective volume of less than 650,000$m^3$ were required to have only one stockpile from each zone sampled. Stockpile locations within each zone were chosen after a spatial assessment of all stockpile locations, taking into consideration adjacent zones.

Two composite samples, consisting of four grab samples each, were taken within every assessed stockpile. Each composite sample was collected in a north / south or east / west cross section dependent on the form and location of the stockpile.

The sampling strategy resulted in 23 stockpiles being sampled and a total of 45 individual samples being collected. The samples were taken by the Curragh environment personnel and sent to an Australian Laboratory Services (ALS) Laboratory for analysis of physical and chemical properties.

* - Zone 10 was omitted from the assessment as it is the area between Curragh and Curragh North. All topsoil in this location was stripped to form the access road between Curagh and Curragh Main and forms the smallest zone by volume

.

## 3.2 Field Observations

A range of field observations were captured using *EMS FORM 1.14 Topsoil Quality Assessment* during sampling. Parameters assessed in the field observations included, but were not limited to, vegetation cover, soil surface, erosion impacts present, soil colour and inclusion of waste or foreign objects.

Additional dispersion behaviour and slaking assessments were conducted in accordance with *EMS WI 20 Topsoil Stockpile Quality Assessment*. Using the techniques and skills obtained during the 2019 detailed onsite training provided by GT Environmental, such methods as the field texture bolus, including ribboning was utilised to determine the field texture attributes and clay percentage as referenced in *Gunn, R.H, et. al (1988), Australian Soil and Land Survey: Guidelines for conducting surveys*. Slaking and dispersion behaviour of peds placed in deionised water over a ten minute period were observed and recorded. This information was used to provide a complete assessment of the topsoil quality. A summary of results from the field observations can be found in Section 4.0 of this report.

## 3.3 Laboratory Analysis

All samples were sent to an ALS Laboratory for analysis of the below parameters:

- ADMC at 40ºC
- pH plus EC 1:5
- Total N, Nitrate, Nitrite, Ammonia
- Bicarbonate Ext P (Oslen - Alkaline Soils)
- Organic Matter Content
- Exchangeable Cations (Ca, Mg, K, Na), CEC, Ca/Mg ratio, ESP
- Metals (Mn, Cu, Fe, Zn, B, Al)
- Sulphur (Total as S)
- Chloride

# 4.0 Results

## 4.1 Field Results

***Vegetation cover*** was measured during the sample collection process by capturing the type of vegetation cover (Grass, weeds, native and non-native trees and shrubs), the percent of vegetation cover and the condition of the vegetation present (established, immature, green, dry, dead) on the topsoil. The type, condition and percentage of vegetation cover can indicate good soil and can also indicate the age of the stockpile. Percent and type of vegetation coverage was also noticed to be dependent on the stockpile shape and surface conditions. In paddock dumped topsoil stockpiles much of the grass cover was in the depressions and the shrubs were growing on the crests. In scraper produced stockpiles a more uniform coverage of vegetation was observed across the whole stockpile.

Some vegetation types can also provide other indications of soil type, for instance the presence of sandalwood or black tea-tree can indicate sodic or saline conditions. A full suite of general vegetation type was captured on EMS FORM 1.14 and are recorded in the field data entry spreadsheet on G Drive.

It was also observed that as the paddock dumped topsoil stockpiles aged the spread of the vegetation coverage increased over the slopes and crests. The age of the topsoil stockpile is identified by the topsoil stockpile ID number. The smaller the ID number the older the stockpile. Of the remaining topsoil stockpiles on site, that have not been consumed in the progressive rehabilitation to date, topsoil age can range from one month old to up to twenty-five years old.

Of the stockpiles sampled during the study, 89% were identified to have established vegetation, with the remaining 11% showing immature vegetation.

***Erosion impacts*** were observed at 12 sample locations. Two locations (17%) at Curragh and ten locations (83%) at Curragh North. Rill erosion was evident at all locations where percent vegetation cover was less than 85%. At two sample locations where the percent vegetation cover was 95%, gully erosion was evident on the extremities of a paddock dump stockpile.

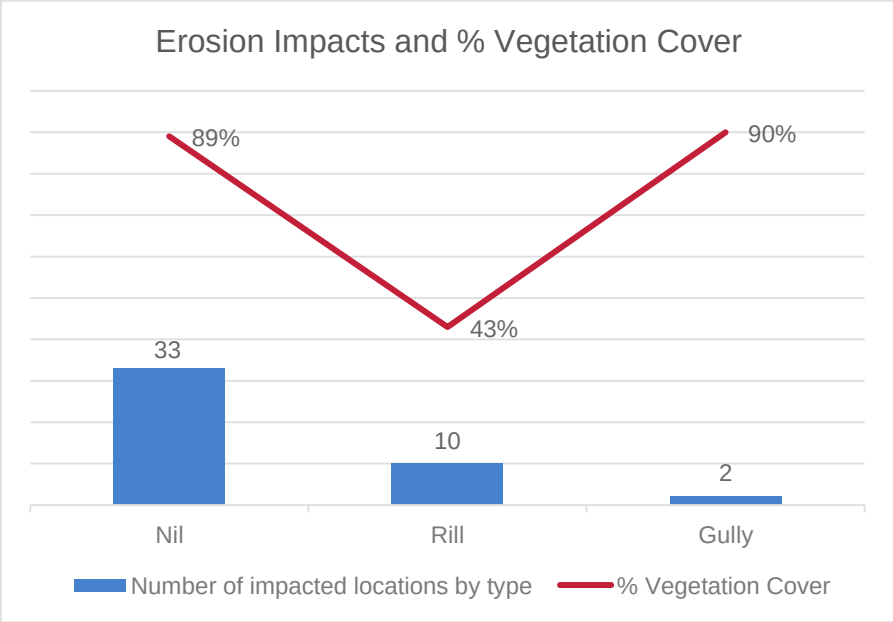



**Figure 3 Erosion Impacts and Percent Vegetation Cover**

During the topsoil stockpile assessment study ***Soil texture, Colour, Dispersion and Slaking behaviour*** were assessed in the field by the Curragh Environmental team. Soil texture and clay content as well as the dispersive nature of topsoil is vital to understand prior to use in rehabilitation activities, to ensure success.

Soils with distinctive 'bright' colours are usually of better quality than those soils with pale 'washed out' colours. Soils with pale colours are often an indication of 'base depletion', or soils that have been subject to many cycles of erosion and redeposition which has stripped and removed most of the referred cations and replaced them with sodium and chloride. These chemical constituents generally indicate poor fertility and other physical problems (McCann, R, 2019). A full suite of soil colours were captured on EMS FORM 1.14 and also recorded in the field data entry spreadsheet on G Drive.

The physical aspects of the soil such as field dispersion, slaking and dispersive behaviours provide indications as to the ability for use of the topsoil in rehabilitation applications. Most textures from sand to heavy clay can be used in rehabilitation when factors such as slope and location are planned for accordingly. Soils with approximately equal proportions of sand, silt and clay may form physical bonds and set hard, resulting in poor structure and infiltration potential. This is typical in brigalow and eucalypt subsoils (McCann, R, 2019).

The below tables from *EMS WI 20 Topsoil Stockpile Quality Assessment* were used as the basis for the infield assessment of all soil samples.

Table 2 - Field dispersion analysis

| Score | Field analysis |
|---|---|
| 0 | Very stable soil |
| 1 | Stable soil, will resist dispersion after tillage |
| 2 / 3 | Soil is prone to compaction and hard setting |
| 4 /5 | Soil will disperse if cultivated wet |
| 6 | Soil disperses strongly if cultivated wet |
| 7 / 8 | May benefit from stubble retention.<br>If complete dispersion is observed within both initial wetting and remoulded aggregate tests, it is likely that dispersive attributes of the soil may require soil amelioration and provide a poor environmental for plant growth. Laboratory analysis will assist with further analysis. |

Table 3 - Field Slaking Scores

| Score | Slaking Behaviour | Field analysis |
|---|---|---|
| 0 | If the aggregate remains intact | This soil is stable to wetting. This is typical of pasture soils. No action is needed |
| 1 | if the aggregate collapses around the edges but remains mainly intact | |
| 2 | If the aggregate collapses into angular pieces | This is typical of self-mulching clays. If the soil does not disperse no action is necessary. |
| 3 | If the aggregate collapses into small (less than 2 mm diameter) rounded pieces, forming a cone | Surface may form a crust.<br>However, this is only a problem in non-swelling |
| 4 | If the aggregate collapses into single grains (you can see sand grains). | This soil is very likely to crust and hard-set (sands and loams).<br>Reduced cultivation, stubble retention and more frequent irrigations may be necessary on these soils. |

Table 4 - Dispersive behaviour

| Score | Dispersive Behaviour |
|---|---|
| 0 | Nil dispersion |
| 1 | Slight dispersion, recognised by slight milkiness of water adjacent to the aggregate |
| 2 | Moderate dispersion with obvious milkiness |
| 3 | Strong dispersion with considerable milkiness and about half of the original volume of the aggregate dispersed outwards |
| 4 | Complete dispersion, leaving only sand grains in a cloud of clay |

The results of the infield assessments are presented in Table 5 and indicate that of the 45 samples taken across 23 stockpiles on site, 32 samples or 71% place within the suitable range for field dispersion, 32 or 71% place within the suitable range for slaking behaviour and 45 or 100% of the samples place within the suitable range for dispersive behaviour.

Table 6 - Curragh North Field Dispersion and Slaking Behaviour

| Topsoil Stockpile # | Zone # | Volume ($m^3$) | Dominant Texture | Field Dispersion Score | Field Slaking Score | Dispersive Behaviour |
|---|---|---|---|---|---|---|
| CN364_1 | 11 | 305,894 | Clay, loam sandy | 2 - 3 | 3 | 0 |
| CN364_2 | 11 | 305,894 | Clayey sand | 2 - 3 | 1 | 0 |
| CN385_1 | 11 | 26,135 | Clayey sand | 4 - 5 | 1 | 1 |
| CN385_2 | 11 | 26,135 | Clayey sand | 4 - 5 | 3 | 2 |
| CN387_1 | 11 | 51,624 | Clayey sand | 4 - 5 | 3 | 2 |
| CN387_2 | 11 | 51,624 | Sandy loam | 4 - 5 | 3 | 0 |
| CN212_1 | 12 | 22,240 | Clay loam | 1 | 2 | 0 |
| CN212_2 | 12 | 22,240 | Clay loam | 1 | 2 | 0 |
| CN413_1 | 13 | 420,158 | Sandy clay loam | 1 | 1 | 1 |
| CN413_2 | 13 | 420,158 | Sandy clay loam | 4 - 5 | 3 | 0 |
| CN55_1 | 13 | 38,570 | Clay loam | 1 | 1 | 1 |
| CN55_2 | 13 | 38,570 | Clay loam | 1 | 1 | 2 |
| CN326_1 | 14 | 46,764 | Light medium clay | 1 | 1 | 1 |
| CN326_2 | 14 | 46,764 | Light clay | 2 - 3 | 1 | 0 |
| CN400_1 | 14 | 66,387 | Clay loam | 1 | 4 | 0 |
| CN400_2 | 14 | 66,387 | Clay loam | 1 | 4 | 0 |
| CN93_1 | 15 | 328,172 | | 2 - 3 | 1 | 0 |
| CN93_2 | 15 | 328,172 | Medium Clay | 2 - 3 | 1 | 2 |
| CN225_1 | 16 | 17,600 | Medium heavy clay | 4 - 5 | 3 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| CN225_2 | 16 | 17,600 | Medium clay | 4 - 5 | 1 | 0 |
| CN414_1 | 16 | 28,087 | Sand | 4 - 5 | 0 | 1 |
| CN414_2 | 16 | 28,087 | Sand | 4 - 5 | 4 | 1 |

General topsoil stockpile categorisation values can be assigned to each stockpile based on the overall presence of vegetation and percentage of uncontaminated material observed as per the categories defined in Table 7.

**Table 7 - Stockpile Quality Category**

| Topsoil Stockpile Category | Value Description |
|---|---|
| A | High value. Low levels of contaminated material. Uncontaminated soil content at least 70% of the stockpile. Quality topsoil. |
| B | Moderate value. Soil purity 50-70%. Higher levels of contamination and variable quality. Useable topsoil value but preferable in lower sloping areas or as 'subsoil' material or capping. |
| C | Marginal. Significant levels of contamination present (>50%). Quality better than most spoil present but only useful a capping / subsoil material in rehabilitation. |
| D | Unsuitable. No better that spoil material present. |

In total 23 Stockpiles were sampled during the study and the categories assigned to the stockpiles show a 50:50 split of Category A and Category B stockpiles, with 48% and 52% respectively. At Curragh Main the results split was 58%:42% for Category A and Category B stockpile qualities. With Curragh North stockpiles almost identically opposite with 41% assigned a stockpile quality Category A and 59% assigned a Category B.

## 4.2 Laboratory Results

Soil **pH** is important as it affects the ability of nutrients in soil. Ensuring the pH of the soil is as close as possible to the neutral range as indicated below in Table 8 will ensure satisfactory results when the topsoil is used for planned rehabilitation activities.

**Table 8 - pH Rating**

| Rating | pH |
|---|---|
| Acidic | 5.6–6.5 |
| Neutral | 6.6–7.5 |
| Mild Alkalinity | 7.6–8.5 |
| Alkaline | >8.5 |

The laboratory results of all pH (1:5 soil/water) samples show soil pH within the 7.3 – 9.2 range. Topsoil at Curragh Main ranges from 7.6 – 8.4 with the average value of 8.13. Topsoil at Curragh North ranges from 8.4 – 9.2 with the average of 8.71. Overall pH of the topsoil

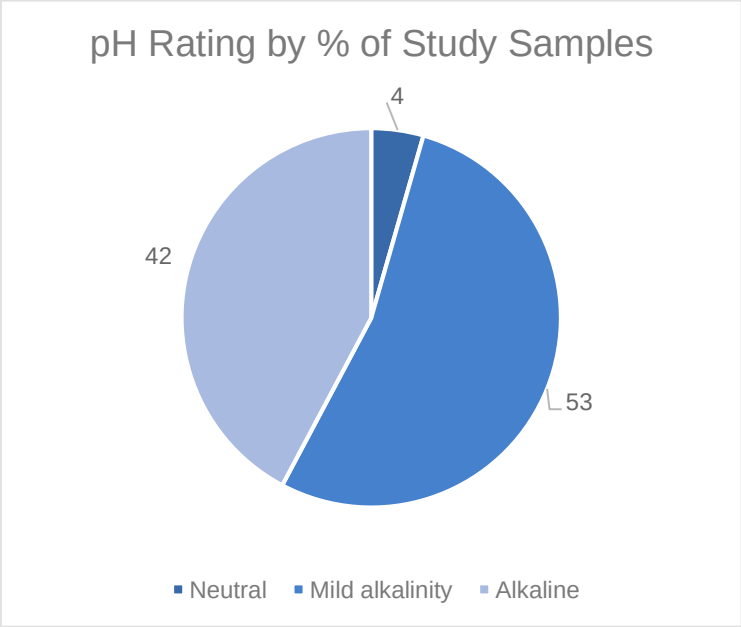



**Figure 4 pH Rating by % of Study Samples**

***Cation Exchange Capacity (CEC)*** is the measurement used to assess the overall fertility status in surface soil. The stockpiled topsoil is surface soil stripped and placed into stockpiles. The samples taken and sent for laboratory analysis were all taken from within a depth of 300mm of the stockpile surfaces, the laboratory results indicated the overall fertility status of the samples collected and provide guidance to the fertility status of topsoil in general across site in accordance with Table 9.

**Table 9 - Cation Exchange Capacity Rating and Results**

| Rating | CEC/ECEC (meq/100 g of soil) | # of samples | % of study area |
|---|---|---|---|
| very low | <5 | 3 | 7 |
| low | 5–15 | 11 | 24 |
| moderate | 15–25 | 25 | 56 |
| high | 25–40 | 6 | 13 |
| very high | >40 | 0 | 0 |

The results of all CEC samples indicate a moderate rate of overall fertility within the sample suite, with 13% of samples in the high fertility range and 31% within the low or very low range. Curragh Main CEC results indicate more fertile soil overall than that of the Curragh North samples. Average CEC score for Curragh Main is 20.26meg/100g soil and Curragh North is 13.96meg/100g soil.

***Exchangeable sodium percentage*** (ESP) is used to assess the relative abundance of exchangeable sodium. Where high levels of exchangeable sodium are present relative to other cations the soil material

physical property is deemed to be of a sodic nature. Table 10 provides the rating table used for analysis of the sample results. Soils with a low exchangeable sodium percentage disperse readily.

**Table 10 – Exchangeable Sodium Percentage Rating**

| Rating | Exchangeable Sodium Percentage (%) |
|---|---|
| non-sodic (low) | <6 |
| sodic (moderate) | 6–15 |
| strongly sodic (high) | 15–20 |
| extremely sodic (very high) | >20 |

***Calcium Magnesium ratio*** provides a guide to the relative abundance of the two major cations (Calcium and Magnesium) and is useful when used in conjunction with Exchangeable Sodium Percentage to predict soil physical behaviour. Soils with a high Calcium dominance, as described by the rating in Table 11, will counteract the dispersive nature of the ESP.

**Table 11 - Calcium Magnesium Ratio Rating**

| Rating | Ca/Mg ratio | Comments |
|---|---|---|
| very low | <0.10 | Mg is >10 times more dominant than Ca |
| low | 0.10–0.50 | Mg is 5–10 times more dominant than Ca |
| moderate | 0.51–1.0 | Ca and Mg becoming co-dominant |
| high | 1.1–2 | Ca more dominant than Mg |
| very high | >2 | Ca >2 times more dominant than Mg |

The laboratory results of both the ESP and calcium/magnesium ratio indicate majority of soils across site (80%) rated as non-sodic with 18% being sodic and 2% (one sampled stockpile) with a strongly sodic rating. The strongly sodic stockpile is located at Curragh North. Correspondingly, of the soils sampled across site, 88% and 12% identify as having a very high and high dominance of calcium resulting in majority (80-100%) of soils across site physical property being non dispersive.

***Bicarbonate Extractable Phosphorus*** is the current measurement for the assessment of relative differences in soil fertility.

Table 12 – Bicarbonate Extractable Phosphorus Rating

| Rating | Bicarb. extr. P (ppm) |
|---|---|
| very low | <5 |
| low | 6-9 |
| moderate | 10-15 |
| high | 16-40 |
| very high | >40 |

Using the rating table adapted from Ahern provided in McCann, R (2019), 46.7% of the samples taken during the assessment returned a moderate or higher soil fertility rating.
37.8% returned a low fertility rating and 15.6% returned a very low soil fertility rating. On average Curragh North samples indicated almost two times greater soil fertility than Curragh Main with the reading being 15.8ppm and 8.31ppm respectively. Curragh North samples ranged from 1ppm to 48.2ppm, whilst Curragh Main samples ranged for 1ppm to 26.7ppm.

***Total Organic Carbon*** is generally used to assess surface soil fertility. All topsoil stockpiles on the mine site are surface topsoil stripped and placed in stockpiles. Therefore the assessment of total organic carbon is relevant to each stockpile in its entirety.

Table 13 - Organic Carbon Rating

| Rating | Organic Carbon (%)[1] |
|---|---|
| Very Low | <0.5 |
| Low | 0.5-1.5 |
| Moderate | 1.6-2.5 |
| High | 2.6-5.0 |
| Very High | >5.0 |

1 – Categories from Bruce and Rayment (1982)

Using the rating table from Bruce and Rayment (1982) the Laboratory results for ***Total Organic Carbon*** indicate that 44% of the samples taken during the assessment returned a moderate or higher soil fertility. 53% returned a low fertility rating and 2% a very low rating. Curragh Main samples were on average higher than Curragh North samples, with average values of 1.9% and 1.1% respectively. Curragh Main results ranged from 1% to 4.2%, whilst Curragh North results ranged from 0.5% to 2.4%.

The full suite of laboratory results is provided in Appendix B.

## 5.0 Conclusion and Recommendations

This topsoil quality assessment study conducted in 2020 has shown most of the stockpiled topsoil at both Curragh Main and Curragh North is of acceptable physical and chemical quality and will not require amelioration during planned rehabilitation activities. With selective placement of topsoil depending on its quality and proposed location, any potential negative effects from poorer soil quality can be further mitigated.

The overall stockpiled topsoil quality is rated as an A or B, based of field observations, indicating high purity and relatively uncontaminated high value topsoil.

The results from the topsoil quality assessment indicate a similar quality to that which has historically been found within Brigalow and Eucalypt Scrub plains at Curragh and Curragh Main (McCann, R, 2019).

It is recommended that all EMS Documents capturing the management of topsoil be updated to incorporate a routine sampling regime that may include aspects such as; sampling of topsoil once stripped and stockpiled, sampling of stockpiles during storage, as well as sampling the topsoil stockpiles identified for use in planned rehabilitation activities prior to the rehabilitation campaign commencement.

The site could also benefit from undertaking seeding of stockpiles to ensure the percent cover is greater than 85% to prevent erosion impacts and dilution of nutrients during the period of stockpiling until vegetation establishes naturally.

Amelioration could be considered if rehabilitation of an area is required to be established prior to an upcoming unfavourable weather event such as drought or a severe wet season. Inclusion of amelioration would improve the speed in which the vegetative cover establishes and provide protection from environmental impacts. Similarly, the use of a hydromulch or other materials could be considered in such circumstances.

## 6.0 References

AustralAsian Resource Consultants Pty Ltd (2004) Supplementary Topsoil Survey for the Curragh North Mining Lease. AARC

Bruce, R.C. and Rayment, G.F. (1982) Analytical Methods and interpretations used by the Agricultural Chemical Branch, QDPI, for soil and land use surveys. QDPI Bulletin QB82004.
Brisbane

EMS PLAN 1.0 Land Management Plan

EMS PLAN 1.1 Topsoil Management Plan

EMS PROC 1.3 Topsoil Management Procedure

EMS FORM 1.14 Topsoil Quality Assessment

Gunn, R.H, et. al (1988), Australian Soil and Land Survey: Guidelines for conducting surveys

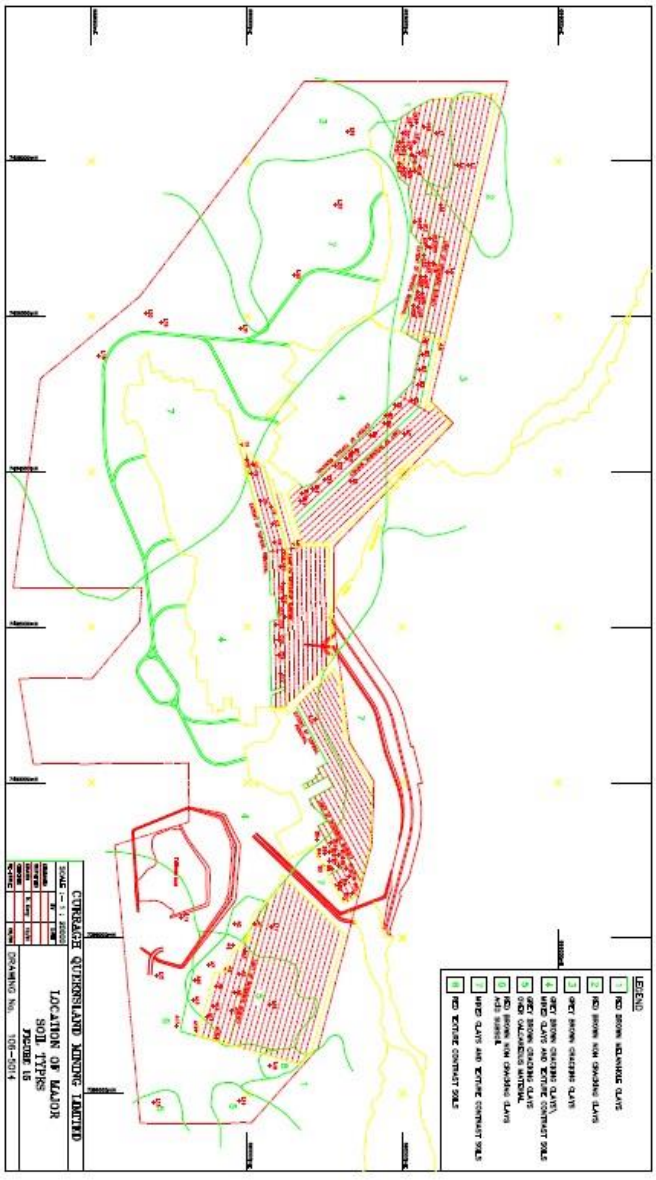
McCann, R (2019) Topsoil Training, Assessment and Sampling Coronado Global Resources Inc. v2. GT Environmental Pty Ltd.

# 7.0 Appendixes

## Appendix A – Historical Soil Assessments

***Curragh***

During an insitu topsoil study, Land Reclamation Services (LRS) identified 7 soil mapping units in the Curragh mine area in 1990. The summary of soil types is shown in the below mapping with detailed summary provided in the table below.



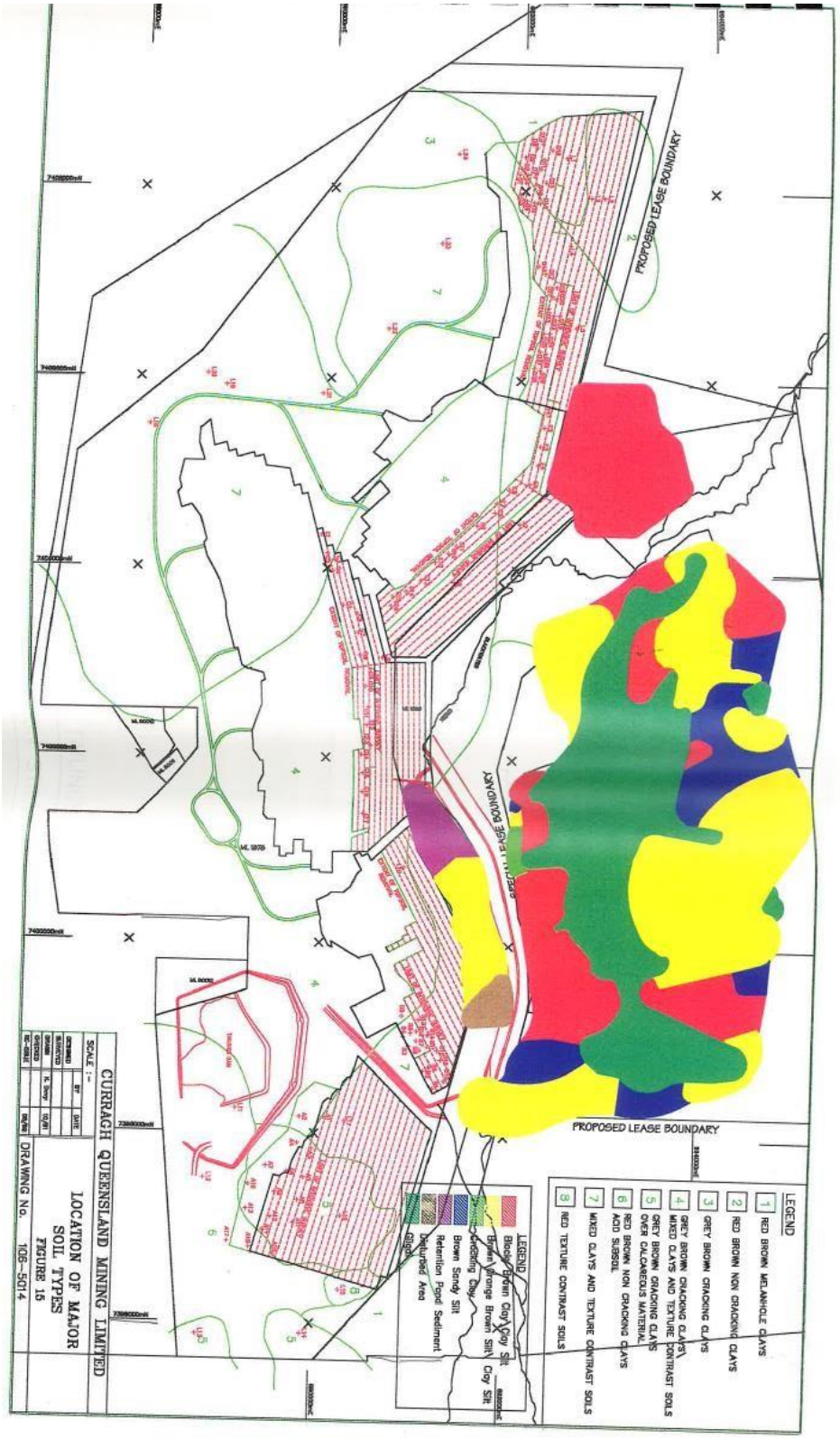
14 LRS 1990 Insitu soil study summary

| Soil Description | Suitability for Rehabilitation |
|---|---|
| Red brown melonhole clays | • Top 10 cm chemically suitable for rehabilitation.<br>• Lower horizons are dispersive and have high chloride concentration.<br>• Melon hole relief makes striping top layer without contamination from lower horizons impossible.<br>• Therefore this soil is not suitable for rehabilitation. |
| Red brown non-cracking clays | • Top 20cm are suitable for rehabilitation.<br>• Lower horizons are dispersive and have moderate chloride concentrations.<br>• Topsoil should be carefully stripped to 20 cm. |
| Grey brown cracking clays | • High chloride concentrations throughout the profile.<br>• All horizons are potentially dispersive.<br>• Recommended that this soil is not used in rehabilitation. |
| Grey brown cracking clays over calcareous material | • Well-structured cracking clay with low chlorides and dispersivity to at least 60 cm.<br>• Soil should be stripped to 60 cm depth.<br>• 0–30 cm should be stockpiled separately to 30-60 cm. |
| Red brown cracking clays – acid subsoil | • Only the top 20 cm is chemically suitable for rehabilitation.<br>• Subsoils are not recommended for rehabilitation. |
| Mixed clays and texture contrast soils | • Only the top 15 cm is suitable for rehabilitation.<br>• Lower horizons consist of impervious clays which are dispersive. |
| Red texture contrast soils | • Only the A horizon should be used for rehabilitation as the lower clays are impervious and dispersive.<br>• Therefore only the top 15 cm should be stripped and stockpiled for rehabilitation. |

### *Curragh East*

In 1998, Environment Health and Safety Systems (EHSS) conducted soil samples from 17 sites and soils were described in detail to classify additional mapping area at Curragh East. The report indicates that:

- Analyses shows that some soils are poorly to moderately fertile;
- Soils are potassium and nitrogen deficient;
- Soils are calcium and magnesium moderately deficient; and
- Sodicity of soils is low although deeper layers may prove more problematic.


PROPOSED LEASE BOUNDARY
PROPOSED LEASE BOUNDARY
LEGEND
1 RED BROWN MELANHOLE CLAYS
2 RED BROWN NON CRACKING CLAYS
3 GREY BROWN CRACKING CLAYS
4 GREY BROWN CRACKING CLAYS\ MIXED CLAYS AND TEXTURE CONTRAST SOILS
5 GREY BROWN CRACKING CLAYS OVER CALCAREOUS MATERIAL
6 RED BROWN NON CRACKING CLAYS ACID SUBSOIL
7 MIXED CLAYS AND TEXTURE CONTRAST SOILS
8 RED TEXTURE CONTRAST SOILS
LEGEND
Bleached Brown Clay Clay Silt
Brown Orange Brown Silty Clay Silt
Cracking Clay
Brown Sandy Silt
Retention Pond Sediment
Disturbed Area
Slope
CURRAGH QUEENSLAND MINING LIMITED
LOCATION OF MAJOR SOIL TYPES
FIGURE 15
DRAWING No. 105-5014

15 Curragh East Soils and Additional Mapping

| Soil Description | Description of Soils |
|---|---|
| Variable Texture Contrast Soils | • Occur on the eastern and north-eastern part of the Curragh East area and are characterised by coarse textured sandy clay loams to sandy clay over-lying coarsely structured alkaline clay subsoil.<br>• The soils are associated with the ridge running north/south over the Curragh East area and support a range of vegetation from tall Poplar Box forest to short mixed forest. |
| Cracking Clays over Alluvial Parent Material | • This mapping unit is associated with the undisturbed section of the Blackwater Creek streambed. This cracking heavy clay forms a deep layer over an alluvial parent material, the dark brown to grey soil has a coarse blocky structure and ranges from acid to neutral in the upper 0.5 metres to strongly alkaline below this depth. |

### *Curragh North*

In 2003, a soil survey of the Curragh North Project (ML80110 and ML 80123) site was conducted by Australasian Resource Consultants Pty Ltd as part of a study of the existing environment for the Curragh North project. The results of this survey included the results of soil sampling undertaken in 1996, 1998 and 2003. In total, 61 samples were collected in these previous sampling episodes.

Based on field and laboratory assessment, the 6 soil types identified at Curragh North have been mapped into 4 different mapping units and described in the Map and Table below

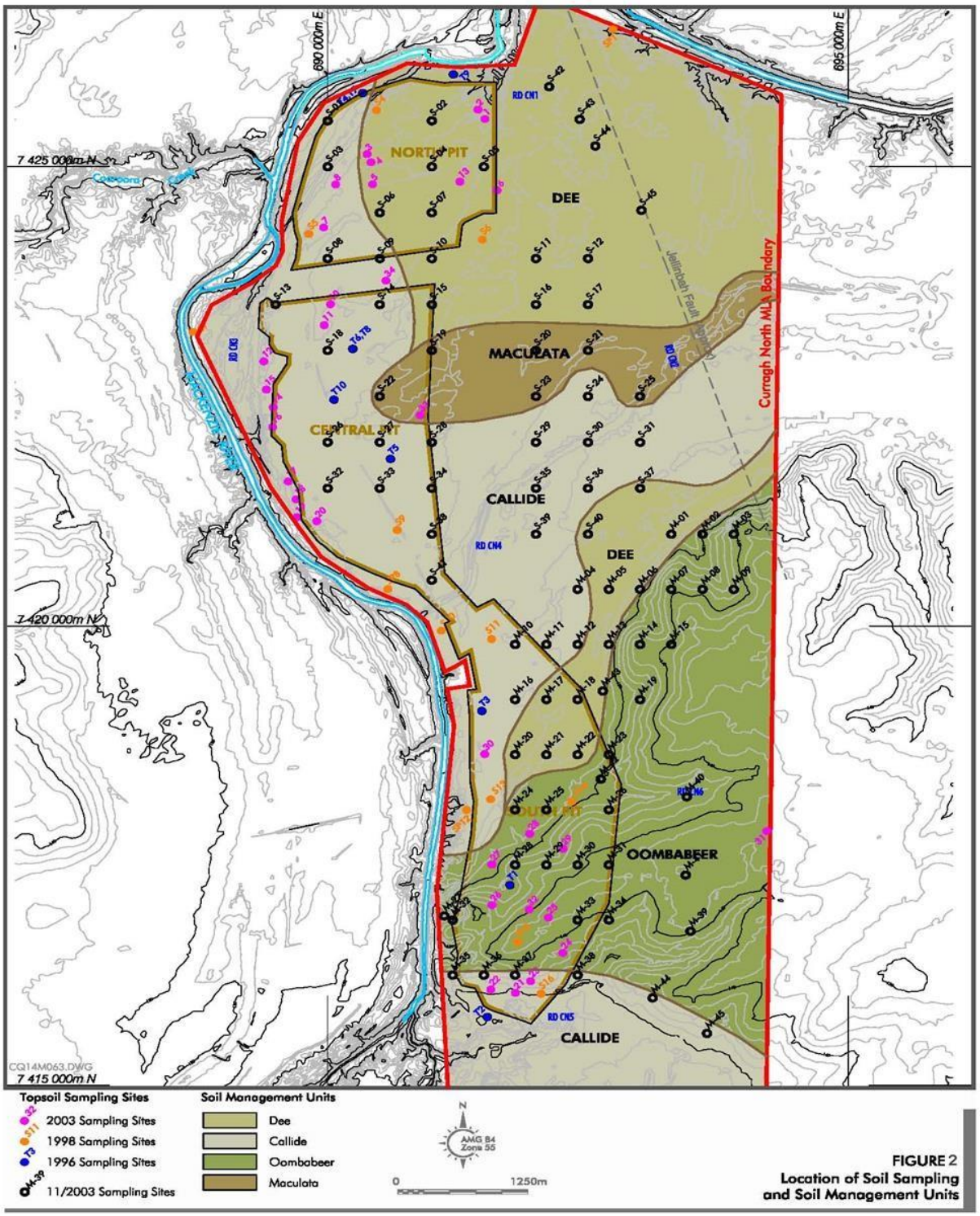



**FIGURE 2**
**Location of Soil Sampling and Soil Management Units**

| Soil Type | Description |
|---|---|
| Soil Type 1 | • Grey to reddish brown self-mulching clays with a moderate to strong pedal structure with some calcareous inclusions.<br>• The majority of this area has been cleared for low intensity grazing on improved pastures. The topography is of low relief with slopes tending to be less than 2%. This soil type constitutes the Dee soil management unit.<br>• Structure changes with depth to become massive typically at a depth of approximately 30cm. The soil is alkaline to strongly alkaline, nonsaline, of low sodicity and a high cation exchange capacity.<br>Calcareous inclusions occur at depths below approximately 30cm. |
| Soil Type 2 | • Light clay to clay loam A horizon (grey to dark reddish brown) graduating to medium to heavy clay subsoil. Moderately pedal structure is typical throughout the profile.<br>• The area has previously been cleared for low intensity grazing. The topography is generally of low relief with slopes tending to be less than 2%.<br>• The area is characterised by grey to dark reddish brown clay loam to light clay with occasional cracking. The surface is firm and is typically moderately pedal. Peds are less than 20 mm in size. The A horizon is approximately 30 cm in depth, below which a sharp texture and colour change of the lower horizon can be found. Colour becomes darker and texture increases to medium to heavy clays.<br>• The soil is typically slightly acid to neutral with pH increasing with depth. The soils are non-sodic and are of moderate to high cation exchange capacity. This soil constitutes the Callide soil management unit. |
| Soil Type 3 | • Loamy sand to clay loam A horizon (dark reddish grey to black) underlain by sandy loam to silty clay loam horizons. Structure is typically moderate to strongly pedal and polyhedral in nature.<br>• Native vegetation has been cleared from this soil type for low intensity cattle grazing. The topography is of low relief with slopes of less than 2% common.<br>• This soil is typified by loamy sand to clay loam a horizon of approximately 20 cm in depth. The A horizon is dark reddish grey to black in colour. Underlying the A horizon is a sandy loam to silty clay loam horizon which is darker in colour than the A horizon. The boundary between horizons is clear in nature. A polyhedral structure of moderate to strong pedality occurs throughout the profile.<br>• pH of the A horizon is neutral to slightly alkaline, with the pH becoming more alkaline with depth. These soils are non-saline in nature and are of moderate fertility (CEC). This soil constitutes the Maculata soil management unit. |

| Soil Type | Description |
|---|---|
| Soil Type 4 | • Light yellowish brown to reddish black loamy sand to sandy loam A horizon of weak to moderate pedality overlying loamy sand to silty loam horizons.<br>• Soil type 4 has been cleared of native vegetation for low intensity cattle grazing. Occurring on the upper ridges and steeper slopes of the proposed mining lease area, this soil type is found on gently to moderately inclined relief.<br>• A loamy sand to sandy loam A horizon typifies this soil type. This horizon is generally light yellowish brown to reddish black in colour. The A horizon is of weak to moderate pedality. Underlying the A horizon is a horizon of slightly higher clay content (loamy sand to silty loam). The underlying horizon is also darker in colour and is only weakly pedal or a pedal (granular) in structure. The boundary between these horizons is abrupt.<br>• These soils are slightly acid to slightly alkaline in the A horizon, with alkalinity increasing with depth. These soils are slightly to moderately sodic in the surface horizon with exchangeable sodium percent generally increasing with depth. Excessive salinity does not occur in these soils. This soil is one of the three soil types which constitute the Oombabeer soil management unit. |
| Soil Type 5 | • Brown/dark brown A horizon of light clay with strong polyhedral pedality overlying a pale yellow massive B horizon.<br>• This soil type occurs in a portion of the mining lease adjacent to the Mackenzie River on which native woodland is established. Cattle frequently graze this area. This soil type occurs on slopes with a slope of less than 2%.<br>• The A horizon of this soil consists of a brown/dark brown light clay with strong polyhedral (< 20mm) pedality. A pale yellow massive B horizon underlies the A horizon. The boundary between horizons is gradual.<br>• These soils are moderately alkaline in the A horizon, with alkalinity increasing with depth. This soil type is also non-sodic in nature and is of moderate fertility. Salinity is not a limitation to plant growth on this soil. This soil is one of the three soil types which constitutes the Oombabeer soil management unit. |

| Soil Type | Description |
|---|---|
| Soil Type 6 | • Weak red to dark reddish grey A horizon of loamy sand to clayey sand texture overlying a weak red to pinkish grey B horizon with a single grain apedal structure. Each of these soil types is described below.<br>• This soil type has been cleared for low intensity cattle grazing. Improved pastures are found on this soil type. This soil type occurs on low relief with slopes tending to less than 2%.<br>• A weak red to dark reddish grey loamy sand to clayey sand constitutes the A horizon of this soil. This horizon is characterised by a weak pedal structure with peds less than 10 mm. The underlying horizon is a weak red to pinkish grey loamy sand with granular apedal structure. A gradual boundary separates the horizons.<br>• This soil is neutral to moderately alkaline with pH increasing with depth. The soil is also non-sodic, non-saline and of low cation exchange capacity (fertility). This soil is one of the three soil types which constitute the Oombabeer soil management unit. |

***Curragh West***

Existing soils data for Curragh West (ML 80171) is limited to broad-scale mapping based on aerial photo interpretation and limited regional scale fieldwork. A soil investigation was conducted to determine soil types and a summary included in the 2011 Environmental Management Plan prepared by Parsons Brinckerhoff. Selected soil samples were tested to assess their acidity, salinity, dispersion potential, and nutrient content. The results were used to aid classification of individual soil types and to assess reuse potential of soils for future rehabilitation purposes.

Based on the investigation, three soil units were identified within Curragh West. The distribution of soil units is closely related to the topography and geomorphology of Curragh West. Abrupt boundaries between soil types generally do not occur. The three soils types are Grey duplex soils, Grey-brown uniform clays, and Red-brown uniform clays.

# Appendix B – Laboratory Results

ALS Environmental

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **EB2020245** | Page | : 1 of 20 |
| Client | : **CORONADO CURRAGH PTY LTD** | Laboratory | : Environmental Division Brisbane |
| Contact | : KIM TUART | Contact | : Anna Riddell |
| Address | : CURRAGH MINE<br>BLACKWATER QLD, AUSTRALIA 4717 | Address | : 2 Byth Street Stafford QLD Australia 4053 |
| Telephone | : 07 4986 9338 | Telephone | : +61 7 4952 5795 |
| Project | : General Soil | Date Samples Received | : 31-Jul-2020 12:20 |
| Order number | : ---- | Date Analysis Commenced | : 04-Aug-2020 |
| C-O-C number | : ---- | Issue Date | : 19-Aug-2020 12:41 |
| Sampler | : CRYSTAL MERLOW, KELLY SMITH | | |
| Site | : ---- | | |
| Quote number | : TV/028/19 v5 | | |
| No. of samples received | : 45 | | |
| No. of samples analysed | : 45 | | |

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Ben Felgendrejeris | Senior Acid Sulfate Soil Chemist | Brisbane Acid Sulphate Soils, Stafford, QLD |
| Ben Felgendrejeris | Senior Acid Sulfate Soil Chemist | Brisbane Inorganics, Stafford, QLD |
| Dave Gitsham | Metals Instrument Chemist | Brisbane Inorganics, Stafford, QLD |
| Kim McCabe | Senior Inorganic Chemist | Brisbane Acid Sulphate Soils, Stafford, QLD |
| Kim McCabe | Senior Inorganic Chemist | Brisbane Inorganics, Stafford, QLD |
| Mark Hallas | Senior Inorganic Chemist | Brisbane Acid Sulphate Soils, Stafford, QLD |
| Mark Hallas | Senior Inorganic Chemist | Brisbane Inorganics, Stafford, QLD |
| Santusha Pandra | Senior Chemist | Brisbane Inorganics, Stafford, QLD |

## General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020-T (Total Metals by ICP-MS): Sample C125_2 (EB2020245-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Calcium/Magnesium Ratio for some samples as the required results for Calcium/Magnesium are below limit of reporting.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio for CN387_1 (EB2020245-037) as the required results for Magnesium/Potassium are below limit of reporting.
- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2020245_002 (C125_1) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG020-T (Total Metals): Manganese Method Blank is above the limit of reporting but are not considered significant compared to analyte levels in the samples.
- EG020-T (Total Metals by ICP-MS): Sample C142_1 (EB2020245-031) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): Sample CN413_1 (EB2020245-011) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2020245_042 (C07_1) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).
- Test comment

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C125_2 | C125_1 | C122_1 | C81_1 | C81_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 02-Jul-2020 13:10 | 02-Jul-2020 12:15 | 21-Jul-2020 16:00 | 21-Jul-2020 14:00 | 21-Jul-2020 14:30 |
| Compound | CAS Number | LOR | Unit | EB2020245-001 | EB2020245-002 | EB2020245-003 | EB2020245-004 | EB2020245-005 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.9 | 8.9 | 8.4 | 8.3 | 7.9 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 220 | 335 | 986 | 180 | 176 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 5.5 | 5.9 | 4.1 | 12.7 | 15.0 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 12.2 | 8.4 | 10.6 | 10.7 | 13.7 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 4.0 | 2.8 | 4.9 | 4.2 | 5.8 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.3 | 0.2 | 0.5 | 1.8 | 2.6 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | 1.8 | 1.5 | 2.2 | <0.2 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 18.3 | 13.0 | 18.2 | 16.8 | 22.1 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | 9.8 | 11.7 | 12.0 | <0.2 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 3.1 | 3.0 | 2.2 | 2.5 | 2.3 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 11.8 | 10.8 | 9.2 | 2.3 | 2.2 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.02 | 0.02 | 0.04 | 0.03 | 0.03 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 80 | 230 | 1100 | 70 | 30 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 8450 | 9690 | 9880 | 12300 | 14100 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 24100 | 27500 | 20600 | 26300 | 27900 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 18.3 | 20.2 | 19.6 | 25.1 | 26.4 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 1300 | 739 | 800 | 955 | 1360 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 18.0 | 22.3 | 32.8 | 29.7 | 32.6 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.3 | 0.4 | 0.6 | 0.7 | 0.9 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 17.5 | 23.5 | 18.8 | 28.7 | 55.6 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C125_2 | C125_1 | C122_1 | C81_1 | C81_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 02-Jul-2020 13:10 | 02-Jul-2020 12:15 | 21-Jul-2020 16:00 | 21-Jul-2020 14:00 | 21-Jul-2020 14:30 |
| Compound | CAS Number | LOR | Unit | | EB2020245-001 | EB2020245-002 | EB2020245-003 | EB2020245-004 | EB2020245-005 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 17.8 | 23.9 | 19.4 | 29.4 | 56.5 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 800 | 990 | 640 | 1420 | 2230 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 820 | 1010 | 660 | 1450 | 2290 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 215 | 252 | 319 | 408 | 443 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 1.7 | 1.5 | 10.7 | 8.3 | 14.1 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 2.2 | 2.4 | 1.5 | 3.5 | 5.3 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.2 | 1.4 | 0.9 | 2.0 | 3.1 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C31_1 | C71_1 | C71_2 | C122_2 | CN413_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 09-Jul-2020 15:30 | 21-Jul-2020 13:00 | 21-Jul-2020 13:30 | 21-Jul-2020 16:35 | 23-Jul-2020 16:00 |
| Compound | CAS Number | LOR | Unit | EB2020245-006 | EB2020245-007 | EB2020245-008 | EB2020245-009 | EB2020245-010 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 7.4 | 8.3 | 8.2 | 8.2 | 9.0 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 137 | 142 | 158 | 294 | 290 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 2.0 | 9.7 | 10.3 | 4.1 | 9.5 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 2.4 | 16.9 | 19.9 | 14.7 | 9.1 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 1.1 | 4.7 | 6.8 | 4.4 | 4.9 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.8 | 1.4 | 2.7 | 0.7 | 0.6 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | <0.2 | <0.2 | 1.1 | 1.8 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 4.2 | 23.0 | 29.5 | 21.0 | 16.5 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | <0.2 | <0.2 | 5.3 | 11.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.2 | 3.6 | 2.9 | 3.3 | 1.8 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 1.4 | 3.4 | 2.5 | 5.9 | 8.6 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.01 | 0.03 | 0.03 | 0.01 | 0.02 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 20 | 30 | 30 | 220 | 170 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 2640 | 11700 | 13000 | 8640 | 6840 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 7790 | 22800 | 26600 | 18600 | 13900 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 6.0 | 22.0 | 22.6 | 17.4 | 10.6 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 431 | 827 | 827 | 663 | 400 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 6.8 | 31.7 | 31.1 | 29.8 | 22.9 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.5 | 0.9 | 0.9 | 0.4 | 0.2 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 23.2 | 11.0 | 21.6 | 44.7 | 26.4 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C31_1 | C71_1 | C71_2 | C122_2 | CN413_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Jul-2020 15:30 | 21-Jul-2020 13:00 | 21-Jul-2020 13:30 | 21-Jul-2020 16:35 | 23-Jul-2020 16:00 |
| Compound | CAS Number | LOR | Unit | | EB2020245-006 | EB2020245-007 | EB2020245-008 | EB2020245-009 | EB2020245-010 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 23.7 | 11.9 | 22.5 | 45.1 | 26.6 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 920 | 2450 | 2080 | 640 | 450 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 940 | 2460 | 2100 | 680 | 480 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 190 | 371 | 360 | 305 | 351 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 8.8 | 3.3 | 4.0 | 16.4 | 16.2 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 2.6 | 3.7 | 4.8 | 1.8 | 1.6 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.5 | 2.1 | 2.8 | 1.0 | 0.9 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | CN413_1 | C17_1 | C17_2 | C46_1 | C46_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 23-Jul-2020 16:00 | 22-Jul-2020 11:00 | 22-Jul-2020 11:00 | 22-Jul-2020 12:30 | 22-Jul-2020 12:30 |
| Compound | CAS Number | LOR | Unit | EB2020245-011 | EB2020245-012 | EB2020245-013 | EB2020245-014 | EB2020245-015 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.7 | 8.5 | 8.5 | 8.2 | 7.6 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 311 | 121 | 106 | 189 | 73 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 6.8 | 7.3 | 10.0 | 4.4 | 3.5 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 7.9 | 13.5 | 14.0 | 6.4 | 13.4 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 2.9 | 4.5 | 3.7 | 2.6 | 3.8 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.5 | 0.9 | 0.8 | 0.7 | 1.1 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | 0.8 | <0.2 | <0.2 | 0.4 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 12.1 | 19.0 | 18.5 | 10.1 | 18.3 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | 7.0 | <0.2 | <0.2 | 3.8 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.8 | 3.0 | 3.7 | 2.5 | 3.6 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 5.9 | 4.8 | 4.9 | 3.6 | 3.4 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.01 | 0.04 | 0.01 | 0.01 | 0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 170 | 20 | 20 | 60 | <10 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 7660 | 12200 | 14100 | 5370 | 3680 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 11000 | 27600 | 31200 | 11800 | 9480 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 11.8 | 26.2 | 29.0 | 11.6 | 9.4 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 599 | 1080 | 922 | 1290 | 796 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 18.6 | 36.7 | 35.6 | 12.3 | 10.9 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.3 | 0.7 | 0.4 | 0.3 | 0.2 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 41.2 | 10.2 | 6.7 | 34.4 | 11.5 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | CN413_1 | C17_1 | C17_2 | C46_1 | C46_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 23-Jul-2020 16:00 | 22-Jul-2020 11:00 | 22-Jul-2020 11:00 | 22-Jul-2020 12:30 | 22-Jul-2020 12:30 |
| Compound | CAS Number | LOR | Unit | | EB2020245-011 | EB2020245-012 | EB2020245-013 | EB2020245-014 | EB2020245-015 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 41.5 | 10.9 | 7.1 | 34.7 | 11.7 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 700 | 1460 | 1520 | 970 | 840 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 740 | 1470 | 1530 | 1000 | 850 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 254 | 386 | 354 | 231 | 222 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 17.7 | 5.8 | 1.3 | 11.4 | 21.9 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 2.7 | 4.8 | 4.1 | 2.6 | 2.1 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.6 | 2.8 | 2.4 | 1.5 | 1.2 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C60_2 | CN364_1 | CN364_2 | CN326_1 | CN326_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 24-Jul-2020 11:15 | 27-Jul-2020 14:30 | 27-Jul-2020 14:30 | 28-Jul-2020 09:45 | 28-Jul-2020 09:45 |
| Compound | CAS Number | LOR | Unit | EB2020245-016 | EB2020245-017 | EB2020245-018 | EB2020245-019 | EB2020245-020 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.5 | 9.1 | 8.8 | 8.6 | 9.0 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 160 | 118 | 87 | 84 | 94 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 11.4 | 6.6 | 3.6 | 16.5 | 13.6 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 3.5 | 5.0 | 3.4 | 13.5 | 13.9 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 1.5 | 2.6 | 1.4 | 8.2 | 8.4 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 1.1 | 0.4 | 0.5 | 0.7 | 0.5 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | 0.7 | <0.2 | 0.8 | 1.1 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 6.1 | 8.8 | 5.3 | 23.2 | 23.9 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | 8.5 | <0.2 | 3.6 | 4.8 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.4 | 1.9 | 2.3 | 1.6 | 1.6 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 1.4 | 5.9 | 3.1 | 12.3 | 15.9 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.02 | <0.01 | <0.01 | <0.01 | 0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 20 | 30 | 20 | 10 | <10 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 11000 | 5350 | 3050 | 9400 | 12200 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 30900 | 10500 | 6290 | 17300 | 23000 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 24.5 | 8.3 | 5.9 | 14.2 | 18.4 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 1020 | 282 | 184 | 472 | 908 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 36.4 | 11.5 | 6.4 | 28.0 | 35.9 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 32.9 | 4.7 | 9.5 | 1.9 | 1.4 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C60_2 | CN364_1 | CN364_2 | CN326_1 | CN326_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 24-Jul-2020 11:15 | 27-Jul-2020 14:30 | 27-Jul-2020 14:30 | 28-Jul-2020 09:45 | 28-Jul-2020 09:45 |
| Compound | CAS Number | LOR | Unit | | EB2020245-016 | EB2020245-017 | EB2020245-018 | EB2020245-019 | EB2020245-020 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 33.1 | 4.7 | 9.5 | 1.9 | 1.4 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 1400 | 390 | 310 | 620 | 560 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 1430 | 390 | 320 | 620 | 560 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 508 | 161 | 132 | 538 | 498 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 12.7 | 4.6 | 6.5 | 15.5 | 10.0 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 3.3 | 1.3 | 1.2 | 1.8 | 1.6 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.9 | 0.8 | 0.7 | 1.0 | 0.9 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | CN93_1 | CN93_2 | C51_1 | C51_2 | CN212_1 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 28-Jul-2020 12:45 | 28-Jul-2020 12:45 | 28-Jul-2020 16:30 | 28-Jul-2020 16:30 | 27-Jul-2020 12:15 |
| Compound | CAS Number | LOR | Unit | EB2020245-021 | EB2020245-022 | EB2020245-023 | EB2020245-024 | EB2020245-025 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.0 | 7.8 | 8.5 | 8.0 | 8.5 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 137 | 98 | 136 | 248 | 113 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 13.7 | 18.2 | 12.0 | 16.4 | 12.0 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 11.0 | 14.2 | 17.4 | 15.7 | 11.5 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 4.4 | 6.2 | 5.8 | 3.9 | 4.9 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 1.0 | 1.7 | 1.6 | 1.6 | 1.2 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | <0.2 | 0.3 | <0.2 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 16.4 | 22.2 | 25.1 | 21.2 | 17.6 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | <0.2 | 1.1 | <0.2 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.5 | 2.3 | 3.0 | 4.0 | 2.3 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 4.3 | 3.6 | 3.5 | 2.4 | 4.0 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.02 | 0.02 | 0.02 | 0.04 | <0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 30 | 20 | 30 | 30 | 30 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 12900 | 13600 | 12400 | 10400 | 10000 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 19700 | 19900 | 26500 | 28000 | 16700 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 18.3 | 17.8 | 26.9 | 23.0 | 13.3 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 854 | 665 | 913 | 874 | 438 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 30.4 | 31.5 | 34.5 | 31.0 | 24.0 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.2 | <0.1 | 0.2 | 0.2 | 0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 24.5 | 13.9 | 21.2 | 78.4 | 5.3 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | CN93_1 | CN93_2 | C51_1 | C51_2 | CN212_1 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 28-Jul-2020 12:45 | 28-Jul-2020 12:45 | 28-Jul-2020 16:30 | 28-Jul-2020 16:30 | 27-Jul-2020 12:15 |
| Compound | CAS Number | LOR | Unit | | EB2020245-021 | EB2020245-022 | EB2020245-023 | EB2020245-024 | EB2020245-025 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 24.7 | 13.9 | 21.4 | 78.6 | 5.4 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 1040 | 1340 | 1460 | 2710 | 900 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 1060 | 1350 | 1480 | 2790 | 900 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 369 | 530 | 336 | 347 | 377 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 24.0 | 23.2 | 4.0 | 4.2 | 26.1 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 3.7 | 3.3 | 3.3 | 7.2 | 2.9 |
| Total Organic Carbon | ---- | 0.5 | % | | 2.2 | 1.9 | 1.9 | 4.2 | 1.7 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | CN212_2 | CN400_1 | CN400_2 | CN225_1 | CN225_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 27-Jul-2020 12:15 | 27-Jul-2020 13:30 | 27-Jul-2020 13:30 | 23-Jul-2020 12:00 | 23-Jul-2020 12:00 |
| Compound | CAS Number | LOR | Unit | EB2020245-026 | EB2020245-027 | EB2020245-028 | EB2020245-029 | EB2020245-030 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 7.8 | 8.0 | 8.0 | 8.6 | 8.8 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 74 | 205 | 92 | 905 | 664 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 11.9 | 8.6 | 8.6 | 11.1 | 18.8 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 8.6 | 11.0 | 12.0 | 15.6 | 12.0 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 2.5 | 4.8 | 4.8 | 6.3 | 5.7 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 1.3 | 0.6 | 1.2 | 0.5 | 0.4 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | 0.8 | 0.6 | 3.3 | 3.3 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 12.4 | 17.2 | 18.7 | 25.6 | 21.5 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | 4.6 | 3.5 | 12.8 | 15.4 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 3.4 | 2.3 | 2.5 | 2.5 | 2.1 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 1.9 | 8.6 | 4.0 | 12.8 | 13.0 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.01 | 0.01 | 0.01 | 0.03 | 0.04 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 20 | 140 | 50 | 710 | 310 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 6850 | 8510 | 8830 | 11100 | 10400 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 12500 | 14400 | 13900 | 15100 | 13600 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 10.2 | 12.5 | 12.4 | 15.2 | 13.9 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 333 | 522 | 420 | 880 | 1480 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 20.8 | 24.6 | 24.0 | 23.9 | 20.6 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | <0.1 | 0.2 | 0.1 | 0.9 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 14.8 | 36.5 | 9.6 | 47.9 | 43.3 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | CN212_2 | CN400_1 | CN400_2 | CN225_1 | CN225_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 27-Jul-2020 12:15 | 27-Jul-2020 13:30 | 27-Jul-2020 13:30 | 23-Jul-2020 12:00 | 23-Jul-2020 12:00 |
| Compound | CAS Number | LOR | Unit | | EB2020245-026 | EB2020245-027 | EB2020245-028 | EB2020245-029 | EB2020245-030 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 14.8 | 36.7 | 9.7 | 48.8 | 43.3 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 930 | 650 | 830 | 650 | 680 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 940 | 690 | 840 | 700 | 720 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 432 | 376 | 399 | 164 | 153 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 35.8 | 18.0 | 30.2 | 4.4 | 4.6 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 2.9 | 1.9 | 2.1 | 1.6 | 1.8 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.7 | 1.1 | 1.2 | 1.0 | 1.1 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C142_1 | C142_2 | CN385_1 | CN385_2 | CN414_1 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 23-Jul-2020 10:30 | 23-Jul-2020 10:30 | 23-Jul-2020 11:30 | 23-Jul-2020 11:30 | 23-Jul-2020 12:45 |
| Compound | CAS Number | LOR | Unit | EB2020245-031 | EB2020245-032 | EB2020245-033 | EB2020245-034 | EB2020245-035 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.5 | 8.4 | 8.7 | 8.2 | 7.8 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 77 | 70 | 73 | 48 | 63 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 15.2 | 17.3 | 9.3 | 10.4 | 6.0 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 15.3 | 20.9 | 4.0 | 3.8 | 2.2 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 3.0 | 5.3 | 1.7 | 2.0 | <0.2 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.5 | 0.5 | 0.3 | 0.7 | 0.3 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | 0.2 | <0.2 | <0.2 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 18.9 | 27.0 | 6.0 | 6.5 | 2.5 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | 0.9 | <0.2 | <0.2 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 5.1 | 3.9 | 2.3 | 1.9 | ---- |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 6.1 | 10.5 | 4.9 | 2.8 | <0.2 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 10 | 10 | 20 | 20 | <10 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 15400 | 14100 | 4160 | 3460 | 1260 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 29800 | 26700 | 9240 | 9450 | 3360 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 25.9 | 23.1 | 4.7 | 4.6 | 2.8 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 940 | 2490 | 112 | 102 | 242 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 40.5 | 23.9 | 4.1 | 5.0 | 3.3 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 5.7 | 3.3 | 2.1 | 5.4 | 21.4 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C142_1 | C142_2 | CN385_1 | CN385_2 | CN414_1 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 23-Jul-2020 10:30 | 23-Jul-2020 10:30 | 23-Jul-2020 11:30 | 23-Jul-2020 11:30 | 23-Jul-2020 12:45 |
| Compound | CAS Number | LOR | Unit | | EB2020245-031 | EB2020245-032 | EB2020245-033 | EB2020245-034 | EB2020245-035 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 5.7 | 3.3 | 2.1 | 5.4 | 21.4 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 1000 | 1550 | 290 | 350 | 340 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 1000 | 1550 | 290 | 360 | 360 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 478 | 309 | 98 | 88 | 107 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 2.4 | <1.0 | <1.0 | 2.9 | 6.4 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 1.8 | 3.5 | 1.0 | 1.1 | 1.3 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.0 | 2.0 | 0.6 | 0.6 | 0.8 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | CN414_2 | CN387_1 | CN387_2 | CN55_1 | CN55_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 23-Jul-2020 12:45 | 23-Jul-2020 13:30 | 23-Jul-2020 13:30 | 23-Jul-2020 14:45 | 23-Jul-2020 14:45 |
| Compound | CAS Number | LOR | Unit | EB2020245-036 | EB2020245-037 | EB2020245-038 | EB2020245-039 | EB2020245-040 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.3 | 9.2 | 8.4 | 7.3 | 8.3 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 34 | 126 | 50 | 61 | 94 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 5.8 | 9.6 | 6.8 | 15.6 | 14.2 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 2.1 | 3.1 | 5.6 | ---- | 10.3 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | <0.2 | 1.2 | 1.2 | ---- | 3.1 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.3 | <0.2 | 0.5 | ---- | 1.3 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | 0.6 | <0.2 | ---- | 0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 2.4 | 5.0 | 7.4 | ---- | 15.0 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | 11.4 | <0.2 | ---- | 1.6 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | ---- | 2.5 | 4.7 | ---- | 3.4 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | <0.2 | ---- | 2.2 | ---- | 2.3 |
| **ED007: Exchangeable Cations** | | | | | | | | |
| Exchangeable Calcium | ---- | 0.1 | meq/100g | ---- | ---- | ---- | 14.0 | ---- |
| Exchangeable Magnesium | ---- | 0.1 | meq/100g | ---- | ---- | ---- | 4.9 | ---- |
| Exchangeable Potassium | ---- | 0.1 | meq/100g | ---- | ---- | ---- | 2.0 | ---- |
| Exchangeable Sodium | ---- | 0.1 | meq/100g | ---- | ---- | ---- | <0.1 | ---- |
| Cation Exchange Capacity | ---- | 0.1 | meq/100g | ---- | ---- | ---- | 21.0 | ---- |
| Exchangeable Sodium Percent | ---- | 0.1 | % | ---- | ---- | ---- | 0.4 | ---- |
| Calcium/Magnesium Ratio | ---- | 0.1 | - | ---- | ---- | ---- | 2.8 | ---- |
| Magnesium/Potassium Ratio | ---- | 0.1 | - | ---- | ---- | ---- | 2.5 | ---- |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | <10 | <10 | <10 | <10 | 10 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 1360 | 2740 | 3280 | 7850 | 8600 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 3390 | 8180 | 5420 | 14000 | 15100 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 3.3 | 2.4 | 5.3 | 12.2 | 13.2 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 266 | 168 | 206 | 497 | 626 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | CN414_2 | CN387_1 | CN387_2 | CN55_1 | CN55_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 23-Jul-2020 12:45 | 23-Jul-2020 13:30 | 23-Jul-2020 13:30 | 23-Jul-2020 14:45 | 23-Jul-2020 14:45 |
| Compound | CAS Number | LOR | Unit | | EB2020245-036 | EB2020245-037 | EB2020245-038 | EB2020245-039 | EB2020245-040 |
| | | | | | Result | Result | Result | Result | Result |
| **EG020T: Total Metals by ICP-MS - Continued** | | | | | | | | | |
| Zinc | 7440-66-6 | 0.5 | mg/kg | | 3.5 | 3.2 | 4.4 | 25.6 | 27.0 |
| **EK055: Ammonia as N** | | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | | 3.6 | 6.5 | 6.6 | 11.6 | 19.4 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 3.6 | 6.5 | 6.6 | 11.6 | 19.4 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 360 | 200 | 510 | 1410 | 990 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 360 | 210 | 520 | 1420 | 1010 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 111 | 136 | 134 | 488 | 455 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 5.4 | 1.8 | 6.4 | 48.2 | 38.7 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 1.4 | 0.7 | 1.4 | 4.2 | 3.2 |
| Total Organic Carbon | ---- | 0.5 | % | | 0.8 | <0.5 | 0.8 | 2.4 | 1.8 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C07_2 | C07_1 | C149_1 | C149_2 | C60_1 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 24-Jul-2020 09:00 | 24-Jul-2020 09:00 | 24-Jul-2020 10:15 | 24-Jul-2020 10:15 | 24-Jul-2020 11:15 |
| Compound | CAS Number | LOR | Unit | EB2020245-041 | EB2020245-042 | EB2020245-043 | EB2020245-044 | EB2020245-045 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.4 | 8.4 | 8.5 | 8.4 | 8.2 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 105 | 108 | 147 | 178 | 140 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 16.0 | 13.4 | 12.2 | 10.4 | 16.4 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 15.4 | 25.9 | 14.6 | 13.6 | 23.6 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 5.7 | 8.5 | 5.7 | 5.6 | 7.2 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 1.7 | 1.3 | 1.6 | 1.6 | 2.5 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | 0.3 | 0.4 | 0.3 | <0.2 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 23.2 | 36.1 | 22.2 | 20.9 | 33.3 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | 1.5 | 1.0 | 1.3 | <0.2 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.7 | 3.0 | 2.6 | 2.4 | 3.3 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 3.3 | 6.4 | 3.6 | 3.4 | 2.8 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.02 | <0.01 | 0.01 | 0.01 | 0.02 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 20 | 20 | 40 | 20 | 20 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 15000 | 14600 | 6940 | 6060 | 15500 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 30800 | 31100 | 9540 | 13000 | 32400 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 28.8 | 28.2 | 13.9 | 11.9 | 26.6 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 1100 | 2400 | 1040 | 909 | 1820 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 32.0 | 32.6 | 14.3 | 14.3 | 38.5 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.1 | 0.2 | 0.1 | 0.2 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 11.9 | 8.6 | 16.7 | 42.2 | 29.7 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C07_2 | C07_1 | C149_1 | C149_2 | C60_1 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 24-Jul-2020 09:00 | 24-Jul-2020 09:00 | 24-Jul-2020 10:15 | 24-Jul-2020 10:15 | 24-Jul-2020 11:15 |
| Compound | CAS Number | LOR | Unit | | EB2020245-041 | EB2020245-042 | EB2020245-043 | EB2020245-044 | EB2020245-045 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 12.0 | 8.8 | 16.8 | 42.4 | 29.7 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 1020 | 1330 | 960 | 970 | 1470 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 1030 | 1340 | 980 | 1010 | 1500 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 182 | 228 | 185 | 366 | 538 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 2.6 | 1.7 | 14.8 | 11.8 | 26.7 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 3.2 | 2.9 | 2.3 | 2.5 | 3.7 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.9 | 1.7 | 1.3 | 1.4 | 2.1 |

ALS Environmental

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **EB2020245** | Page | : 1 of 20 |
| **Amendment** | : **1** | | |
| Client | : **CORONADO CURRAGH PTY LTD** | Laboratory | : Environmental Division Brisbane |
| Contact | : KIM TUART | Contact | : Anna Riddell |
| Address | : CURRAGH MINE<br>BLACKWATER QLD, AUSTRALIA 4717 | Address | : 2 Byth Street Stafford QLD Australia 4053 |
| Telephone | : 07 4986 9338 | Telephone | : +61 7 4952 5795 |
| Project | : General Soil | Date Samples Received | : 31-Jul-2020 12:20 |
| Order number | : ---- | Date Analysis Commenced | : 04-Aug-2020 |
| C-O-C number | : ---- | Issue Date | : 26-Aug-2020 16:46 |
| Sampler | : CRYSTAL MERLOW, KELLY SMITH | | |
| Site | : ---- | | |
| Quote number | : TV/028/19 v5 | | |
| No. of samples received | : 45 | | |
| No. of samples analysed | : 45 | | |

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Ben Felgendrejeris | Senior Acid Sulfate Soil Chemist | Brisbane Acid Sulphate Soils, Stafford, QLD |
| Ben Felgendrejeris | Senior Acid Sulfate Soil Chemist | Brisbane Inorganics, Stafford, QLD |
| Dave Gitsham | Metals Instrument Chemist | Brisbane Inorganics, Stafford, QLD |
| Kim McCabe | Senior Inorganic Chemist | Brisbane Acid Sulphate Soils, Stafford, QLD |
| Kim McCabe | Senior Inorganic Chemist | Brisbane Inorganics, Stafford, QLD |
| Mark Hallas | Senior Inorganic Chemist | Brisbane Acid Sulphate Soils, Stafford, QLD |
| Mark Hallas | Senior Inorganic Chemist | Brisbane Inorganics, Stafford, QLD |
| Santusha Pandra | Senior Chemist | Brisbane Inorganics, Stafford, QLD |

## General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020-T (Total Metals by ICP-MS): Sample C125_2 (EB2020245-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Calcium/Magnesium Ratio for some samples as the required results for Calcium/Magnesium are below limit of reporting.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio for CN387_1 (EB2020245-037) as the required results for Magnesium/Potassium are below limit of reporting.
- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- Amendment (26/08/2020): This report has been amended to allow the distribution to additional recipients. All analysis results are as per the previous report.
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2020245_002 (C125_1) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG020-T (Total Metals): Manganese Method Blank is above the limit of reporting but are not considered significant compared to analyte levels in the samples.
- EG020-T (Total Metals by ICP-MS): Sample C142_1 (EB2020245-031) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): Sample CN413_1 (EB2020245-011) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2020245_042 (C07_1) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).
- Test comment

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C125_2 | C125_1 | C122_1 | C81_1 | C81_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 02-Jul-2020 13:10 | 02-Jul-2020 12:15 | 21-Jul-2020 16:00 | 21-Jul-2020 14:00 | 21-Jul-2020 14:30 |
| Compound | CAS Number | LOR | Unit | EB2020245-001 | EB2020245-002 | EB2020245-003 | EB2020245-004 | EB2020245-005 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.9 | 8.9 | 8.4 | 8.3 | 7.9 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 220 | 335 | 986 | 180 | 176 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 5.5 | 5.9 | 4.1 | 12.7 | 15.0 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 12.2 | 8.4 | 10.6 | 10.7 | 13.7 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 4.0 | 2.8 | 4.9 | 4.2 | 5.8 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.3 | 0.2 | 0.5 | 1.8 | 2.6 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | 1.8 | 1.5 | 2.2 | <0.2 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 18.3 | 13.0 | 18.2 | 16.8 | 22.1 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | 9.8 | 11.7 | 12.0 | <0.2 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 3.1 | 3.0 | 2.2 | 2.5 | 2.3 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 11.8 | 10.8 | 9.2 | 2.3 | 2.2 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.02 | 0.02 | 0.04 | 0.03 | 0.03 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 80 | 230 | 1100 | 70 | 30 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 8450 | 9690 | 9880 | 12300 | 14100 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 24100 | 27500 | 20600 | 26300 | 27900 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 18.3 | 20.2 | 19.6 | 25.1 | 26.4 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 1300 | 739 | 800 | 955 | 1360 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 18.0 | 22.3 | 32.8 | 29.7 | 32.6 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.3 | 0.4 | 0.6 | 0.7 | 0.9 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 17.5 | 23.5 | 18.8 | 28.7 | 55.6 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C125_2 | C125_1 | C122_1 | C81_1 | C81_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 02-Jul-2020 13:10 | 02-Jul-2020 12:15 | 21-Jul-2020 16:00 | 21-Jul-2020 14:00 | 21-Jul-2020 14:30 |
| Compound | CAS Number | LOR | Unit | | EB2020245-001 | EB2020245-002 | EB2020245-003 | EB2020245-004 | EB2020245-005 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 17.8 | 23.9 | 19.4 | 29.4 | 56.5 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 800 | 990 | 640 | 1420 | 2230 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 820 | 1010 | 660 | 1450 | 2290 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 215 | 252 | 319 | 408 | 443 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 1.7 | 1.5 | 10.7 | 8.3 | 14.1 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 2.2 | 2.4 | 1.5 | 3.5 | 5.3 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.2 | 1.4 | 0.9 | 2.0 | 3.1 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C31_1 | C71_1 | C71_2 | C122_2 | CN413_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 09-Jul-2020 15:30 | 21-Jul-2020 13:00 | 21-Jul-2020 13:30 | 21-Jul-2020 16:35 | 23-Jul-2020 16:00 |
| Compound | CAS Number | LOR | Unit | EB2020245-006 | EB2020245-007 | EB2020245-008 | EB2020245-009 | EB2020245-010 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 7.4 | 8.3 | 8.2 | 8.2 | 9.0 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 137 | 142 | 158 | 294 | 290 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 2.0 | 9.7 | 10.3 | 4.1 | 9.5 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 2.4 | 16.9 | 19.9 | 14.7 | 9.1 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 1.1 | 4.7 | 6.8 | 4.4 | 4.9 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.8 | 1.4 | 2.7 | 0.7 | 0.6 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | <0.2 | <0.2 | 1.1 | 1.8 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 4.2 | 23.0 | 29.5 | 21.0 | 16.5 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | <0.2 | <0.2 | 5.3 | 11.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.2 | 3.6 | 2.9 | 3.3 | 1.8 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 1.4 | 3.4 | 2.5 | 5.9 | 8.6 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.01 | 0.03 | 0.03 | 0.01 | 0.02 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 20 | 30 | 30 | 220 | 170 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 2640 | 11700 | 13000 | 8640 | 6840 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 7790 | 22800 | 26600 | 18600 | 13900 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 6.0 | 22.0 | 22.6 | 17.4 | 10.6 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 431 | 827 | 827 | 663 | 400 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 6.8 | 31.7 | 31.1 | 29.8 | 22.9 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.5 | 0.9 | 0.9 | 0.4 | 0.2 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 23.2 | 11.0 | 21.6 | 44.7 | 26.4 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C31_1 | C71_1 | C71_2 | C122_2 | CN413_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Jul-2020 15:30 | 21-Jul-2020 13:00 | 21-Jul-2020 13:30 | 21-Jul-2020 16:35 | 23-Jul-2020 16:00 |
| Compound | CAS Number | LOR | Unit | | EB2020245-006 | EB2020245-007 | EB2020245-008 | EB2020245-009 | EB2020245-010 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 23.7 | 11.9 | 22.5 | 45.1 | 26.6 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 920 | 2450 | 2080 | 640 | 450 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 940 | 2460 | 2100 | 680 | 480 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 190 | 371 | 360 | 305 | 351 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 8.8 | 3.3 | 4.0 | 16.4 | 16.2 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 2.6 | 3.7 | 4.8 | 1.8 | 1.6 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.5 | 2.1 | 2.8 | 1.0 | 0.9 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | CN413_1 | C17_1 | C17_2 | C46_1 | C46_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 23-Jul-2020 16:00 | 22-Jul-2020 11:00 | 22-Jul-2020 11:00 | 22-Jul-2020 12:30 | 22-Jul-2020 12:30 |
| Compound | CAS Number | LOR | Unit | EB2020245-011 | EB2020245-012 | EB2020245-013 | EB2020245-014 | EB2020245-015 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.7 | 8.5 | 8.5 | 8.2 | 7.6 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 311 | 121 | 106 | 189 | 73 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 6.8 | 7.3 | 10.0 | 4.4 | 3.5 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 7.9 | 13.5 | 14.0 | 6.4 | 13.4 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 2.9 | 4.5 | 3.7 | 2.6 | 3.8 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.5 | 0.9 | 0.8 | 0.7 | 1.1 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | 0.8 | <0.2 | <0.2 | 0.4 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 12.1 | 19.0 | 18.5 | 10.1 | 18.3 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | 7.0 | <0.2 | <0.2 | 3.8 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.8 | 3.0 | 3.7 | 2.5 | 3.6 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 5.9 | 4.8 | 4.9 | 3.6 | 3.4 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.01 | 0.04 | 0.01 | 0.01 | 0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 170 | 20 | 20 | 60 | <10 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 7660 | 12200 | 14100 | 5370 | 3680 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 11000 | 27600 | 31200 | 11800 | 9480 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 11.8 | 26.2 | 29.0 | 11.6 | 9.4 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 599 | 1080 | 922 | 1290 | 796 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 18.6 | 36.7 | 35.6 | 12.3 | 10.9 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.3 | 0.7 | 0.4 | 0.3 | 0.2 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 41.2 | 10.2 | 6.7 | 34.4 | 11.5 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | CN413_1 | C17_1 | C17_2 | C46_1 | C46_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 23-Jul-2020 16:00 | 22-Jul-2020 11:00 | 22-Jul-2020 11:00 | 22-Jul-2020 12:30 | 22-Jul-2020 12:30 |
| Compound | CAS Number | LOR | Unit | | EB2020245-011 | EB2020245-012 | EB2020245-013 | EB2020245-014 | EB2020245-015 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 41.5 | 10.9 | 7.1 | 34.7 | 11.7 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 700 | 1460 | 1520 | 970 | 840 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 740 | 1470 | 1530 | 1000 | 850 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 254 | 386 | 354 | 231 | 222 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 17.7 | 5.8 | 1.3 | 11.4 | 21.9 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 2.7 | 4.8 | 4.1 | 2.6 | 2.1 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.6 | 2.8 | 2.4 | 1.5 | 1.2 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C60_2 | CN364_1 | CN364_2 | CN326_1 | CN326_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 24-Jul-2020 11:15 | 27-Jul-2020 14:30 | 27-Jul-2020 14:30 | 28-Jul-2020 09:45 | 28-Jul-2020 09:45 |
| Compound | CAS Number | LOR | Unit | EB2020245-016 | EB2020245-017 | EB2020245-018 | EB2020245-019 | EB2020245-020 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.5 | 9.1 | 8.8 | 8.6 | 9.0 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 160 | 118 | 87 | 84 | 94 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 11.4 | 6.6 | 3.6 | 16.5 | 13.6 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 3.5 | 5.0 | 3.4 | 13.5 | 13.9 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 1.5 | 2.6 | 1.4 | 8.2 | 8.4 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 1.1 | 0.4 | 0.5 | 0.7 | 0.5 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | 0.7 | <0.2 | 0.8 | 1.1 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 6.1 | 8.8 | 5.3 | 23.2 | 23.9 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | 8.5 | <0.2 | 3.6 | 4.8 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.4 | 1.9 | 2.3 | 1.6 | 1.6 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 1.4 | 5.9 | 3.1 | 12.3 | 15.9 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.02 | <0.01 | <0.01 | <0.01 | 0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 20 | 30 | 20 | 10 | <10 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 11000 | 5350 | 3050 | 9400 | 12200 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 30900 | 10500 | 6290 | 17300 | 23000 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 24.5 | 8.3 | 5.9 | 14.2 | 18.4 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 1020 | 282 | 184 | 472 | 908 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 36.4 | 11.5 | 6.4 | 28.0 | 35.9 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 32.9 | 4.7 | 9.5 | 1.9 | 1.4 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C60_2 | CN364_1 | CN364_2 | CN326_1 | CN326_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 24-Jul-2020 11:15 | 27-Jul-2020 14:30 | 27-Jul-2020 14:30 | 28-Jul-2020 09:45 | 28-Jul-2020 09:45 |
| Compound | CAS Number | LOR | Unit | | EB2020245-016 | EB2020245-017 | EB2020245-018 | EB2020245-019 | EB2020245-020 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 33.1 | 4.7 | 9.5 | 1.9 | 1.4 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 1400 | 390 | 310 | 620 | 560 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 1430 | 390 | 320 | 620 | 560 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 508 | 161 | 132 | 538 | 498 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 12.7 | 4.6 | 6.5 | 15.5 | 10.0 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 3.3 | 1.3 | 1.2 | 1.8 | 1.6 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.9 | 0.8 | 0.7 | 1.0 | 0.9 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | CN93_1 | CN93_2 | C51_1 | C51_2 | CN212_1 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 28-Jul-2020 12:45 | 28-Jul-2020 12:45 | 28-Jul-2020 16:30 | 28-Jul-2020 16:30 | 27-Jul-2020 12:15 |
| Compound | CAS Number | LOR | Unit | EB2020245-021 | EB2020245-022 | EB2020245-023 | EB2020245-024 | EB2020245-025 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.0 | 7.8 | 8.5 | 8.0 | 8.5 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 137 | 98 | 136 | 248 | 113 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 13.7 | 18.2 | 12.0 | 16.4 | 12.0 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 11.0 | 14.2 | 17.4 | 15.7 | 11.5 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 4.4 | 6.2 | 5.8 | 3.9 | 4.9 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 1.0 | 1.7 | 1.6 | 1.6 | 1.2 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | <0.2 | 0.3 | <0.2 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 16.4 | 22.2 | 25.1 | 21.2 | 17.6 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | <0.2 | 1.1 | <0.2 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.5 | 2.3 | 3.0 | 4.0 | 2.3 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 4.3 | 3.6 | 3.5 | 2.4 | 4.0 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.02 | 0.02 | 0.02 | 0.04 | <0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 30 | 20 | 30 | 30 | 30 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 12900 | 13600 | 12400 | 10400 | 10000 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 19700 | 19900 | 26500 | 28000 | 16700 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 18.3 | 17.8 | 26.9 | 23.0 | 13.3 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 854 | 665 | 913 | 874 | 438 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 30.4 | 31.5 | 34.5 | 31.0 | 24.0 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.2 | <0.1 | 0.2 | 0.2 | 0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 24.5 | 13.9 | 21.2 | 78.4 | 5.3 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | CN93_1 | CN93_2 | C51_1 | C51_2 | CN212_1 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 28-Jul-2020 12:45 | 28-Jul-2020 12:45 | 28-Jul-2020 16:30 | 28-Jul-2020 16:30 | 27-Jul-2020 12:15 |
| Compound | CAS Number | LOR | Unit | | EB2020245-021 | EB2020245-022 | EB2020245-023 | EB2020245-024 | EB2020245-025 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 24.7 | 13.9 | 21.4 | 78.6 | 5.4 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 1040 | 1340 | 1460 | 2710 | 900 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 1060 | 1350 | 1480 | 2790 | 900 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 369 | 530 | 336 | 347 | 377 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 24.0 | 23.2 | 4.0 | 4.2 | 26.1 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 3.7 | 3.3 | 3.3 | 7.2 | 2.9 |
| Total Organic Carbon | ---- | 0.5 | % | | 2.2 | 1.9 | 1.9 | 4.2 | 1.7 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | CN212_2 | CN400_1 | CN400_2 | CN225_1 | CN225_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 27-Jul-2020 12:15 | 27-Jul-2020 13:30 | 27-Jul-2020 13:30 | 23-Jul-2020 12:00 | 23-Jul-2020 12:00 |
| Compound | CAS Number | LOR | Unit | EB2020245-026 | EB2020245-027 | EB2020245-028 | EB2020245-029 | EB2020245-030 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 7.8 | 8.0 | 8.0 | 8.6 | 8.8 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 74 | 205 | 92 | 905 | 664 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 11.9 | 8.6 | 8.6 | 11.1 | 18.8 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 8.6 | 11.0 | 12.0 | 15.6 | 12.0 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 2.5 | 4.8 | 4.8 | 6.3 | 5.7 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 1.3 | 0.6 | 1.2 | 0.5 | 0.4 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | 0.8 | 0.6 | 3.3 | 3.3 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 12.4 | 17.2 | 18.7 | 25.6 | 21.5 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | 4.6 | 3.5 | 12.8 | 15.4 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 3.4 | 2.3 | 2.5 | 2.5 | 2.1 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 1.9 | 8.6 | 4.0 | 12.8 | 13.0 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.01 | 0.01 | 0.01 | 0.03 | 0.04 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 20 | 140 | 50 | 710 | 310 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 6850 | 8510 | 8830 | 11100 | 10400 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 12500 | 14400 | 13900 | 15100 | 13600 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 10.2 | 12.5 | 12.4 | 15.2 | 13.9 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 333 | 522 | 420 | 880 | 1480 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 20.8 | 24.6 | 24.0 | 23.9 | 20.6 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | <0.1 | 0.2 | 0.1 | 0.9 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 14.8 | 36.5 | 9.6 | 47.9 | 43.3 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | CN212_2 | CN400_1 | CN400_2 | CN225_1 | CN225_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 27-Jul-2020 12:15 | 27-Jul-2020 13:30 | 27-Jul-2020 13:30 | 23-Jul-2020 12:00 | 23-Jul-2020 12:00 |
| Compound | CAS Number | LOR | Unit | | EB2020245-026 | EB2020245-027 | EB2020245-028 | EB2020245-029 | EB2020245-030 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 14.8 | 36.7 | 9.7 | 48.8 | 43.3 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 930 | 650 | 830 | 650 | 680 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 940 | 690 | 840 | 700 | 720 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 432 | 376 | 399 | 164 | 153 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 35.8 | 18.0 | 30.2 | 4.4 | 4.6 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 2.9 | 1.9 | 2.1 | 1.6 | 1.8 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.7 | 1.1 | 1.2 | 1.0 | 1.1 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C142_1 | C142_2 | CN385_1 | CN385_2 | CN414_1 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 23-Jul-2020 10:30 | 23-Jul-2020 10:30 | 23-Jul-2020 11:30 | 23-Jul-2020 11:30 | 23-Jul-2020 12:45 |
| Compound | CAS Number | LOR | Unit | EB2020245-031 | EB2020245-032 | EB2020245-033 | EB2020245-034 | EB2020245-035 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.5 | 8.4 | 8.7 | 8.2 | 7.8 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 77 | 70 | 73 | 48 | 63 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 15.2 | 17.3 | 9.3 | 10.4 | 6.0 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 15.3 | 20.9 | 4.0 | 3.8 | 2.2 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 3.0 | 5.3 | 1.7 | 2.0 | <0.2 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.5 | 0.5 | 0.3 | 0.7 | 0.3 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | 0.2 | <0.2 | <0.2 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 18.9 | 27.0 | 6.0 | 6.5 | 2.5 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | 0.9 | <0.2 | <0.2 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 5.1 | 3.9 | 2.3 | 1.9 | ---- |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 6.1 | 10.5 | 4.9 | 2.8 | <0.2 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 10 | 10 | 20 | 20 | <10 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 15400 | 14100 | 4160 | 3460 | 1260 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 29800 | 26700 | 9240 | 9450 | 3360 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 25.9 | 23.1 | 4.7 | 4.6 | 2.8 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 940 | 2490 | 112 | 102 | 242 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 40.5 | 23.9 | 4.1 | 5.0 | 3.3 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 5.7 | 3.3 | 2.1 | 5.4 | 21.4 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C142_1 | C142_2 | CN385_1 | CN385_2 | CN414_1 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 23-Jul-2020 10:30 | 23-Jul-2020 10:30 | 23-Jul-2020 11:30 | 23-Jul-2020 11:30 | 23-Jul-2020 12:45 |
| Compound | CAS Number | LOR | Unit | | EB2020245-031 | EB2020245-032 | EB2020245-033 | EB2020245-034 | EB2020245-035 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 5.7 | 3.3 | 2.1 | 5.4 | 21.4 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 1000 | 1550 | 290 | 350 | 340 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 1000 | 1550 | 290 | 360 | 360 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 478 | 309 | 98 | 88 | 107 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 2.4 | <1.0 | <1.0 | 2.9 | 6.4 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 1.8 | 3.5 | 1.0 | 1.1 | 1.3 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.0 | 2.0 | 0.6 | 0.6 | 0.8 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | CN414_2 | CN387_1 | CN387_2 | CN55_1 | CN55_2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 23-Jul-2020 12:45 | 23-Jul-2020 13:30 | 23-Jul-2020 13:30 | 23-Jul-2020 14:45 | 23-Jul-2020 14:45 |
| Compound | CAS Number | LOR | Unit | EB2020245-036 | EB2020245-037 | EB2020245-038 | EB2020245-039 | EB2020245-040 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.3 | 9.2 | 8.4 | 7.3 | 8.3 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 34 | 126 | 50 | 61 | 94 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 5.8 | 9.6 | 6.8 | 15.6 | 14.2 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 2.1 | 3.1 | 5.6 | ---- | 10.3 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | <0.2 | 1.2 | 1.2 | ---- | 3.1 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 0.3 | <0.2 | 0.5 | ---- | 1.3 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | <0.2 | 0.6 | <0.2 | ---- | 0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 2.4 | 5.0 | 7.4 | ---- | 15.0 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | <0.2 | 11.4 | <0.2 | ---- | 1.6 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | ---- | 2.5 | 4.7 | ---- | 3.4 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | <0.2 | ---- | 2.2 | ---- | 2.3 |
| **ED007: Exchangeable Cations** | | | | | | | | |
| Exchangeable Calcium | ---- | 0.1 | meq/100g | ---- | ---- | ---- | 14.0 | ---- |
| Exchangeable Magnesium | ---- | 0.1 | meq/100g | ---- | ---- | ---- | 4.9 | ---- |
| Exchangeable Potassium | ---- | 0.1 | meq/100g | ---- | ---- | ---- | 2.0 | ---- |
| Exchangeable Sodium | ---- | 0.1 | meq/100g | ---- | ---- | ---- | <0.1 | ---- |
| Cation Exchange Capacity | ---- | 0.1 | meq/100g | ---- | ---- | ---- | 21.0 | ---- |
| Exchangeable Sodium Percent | ---- | 0.1 | % | ---- | ---- | ---- | 0.4 | ---- |
| Calcium/Magnesium Ratio | ---- | 0.1 | - | ---- | ---- | ---- | 2.8 | ---- |
| Magnesium/Potassium Ratio | ---- | 0.1 | - | ---- | ---- | ---- | 2.5 | ---- |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | <10 | <10 | <10 | <10 | 10 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 1360 | 2740 | 3280 | 7850 | 8600 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 3390 | 8180 | 5420 | 14000 | 15100 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 3.3 | 2.4 | 5.3 | 12.2 | 13.2 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 266 | 168 | 206 | 497 | 626 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | CN414_2 | CN387_1 | CN387_2 | CN55_1 | CN55_2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 23-Jul-2020 12:45 | 23-Jul-2020 13:30 | 23-Jul-2020 13:30 | 23-Jul-2020 14:45 | 23-Jul-2020 14:45 |
| Compound | CAS Number | LOR | Unit | | EB2020245-036 | EB2020245-037 | EB2020245-038 | EB2020245-039 | EB2020245-040 |
| | | | | | Result | Result | Result | Result | Result |
| **EG020T: Total Metals by ICP-MS - Continued** | | | | | | | | | |
| Zinc | 7440-66-6 | 0.5 | mg/kg | | 3.5 | 3.2 | 4.4 | 25.6 | 27.0 |
| **EK055: Ammonia as N** | | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | | 3.6 | 6.5 | 6.6 | 11.6 | 19.4 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 3.6 | 6.5 | 6.6 | 11.6 | 19.4 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 360 | 200 | 510 | 1410 | 990 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 360 | 210 | 520 | 1420 | 1010 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 111 | 136 | 134 | 488 | 455 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 5.4 | 1.8 | 6.4 | 48.2 | 38.7 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 1.4 | 0.7 | 1.4 | 4.2 | 3.2 |
| Total Organic Carbon | ---- | 0.5 | % | | 0.8 | <0.5 | 0.8 | 2.4 | 1.8 |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | C07_2 | C07_1 | C149_1 | C149_2 | C60_1 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 24-Jul-2020 09:00 | 24-Jul-2020 09:00 | 24-Jul-2020 10:15 | 24-Jul-2020 10:15 | 24-Jul-2020 11:15 |
| Compound | CAS Number | LOR | Unit | EB2020245-041 | EB2020245-042 | EB2020245-043 | EB2020245-044 | EB2020245-045 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 8.4 | 8.4 | 8.5 | 8.4 | 8.2 |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 105 | 108 | 147 | 178 | 140 |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | 16.0 | 13.4 | 12.2 | 10.4 | 16.4 |
| **ED006: Exchangeable Cations on Alkaline Soils** | | | | | | | | |
| ø Exchangeable Calcium | ---- | 0.2 | meq/100g | 15.4 | 25.9 | 14.6 | 13.6 | 23.6 |
| ø Exchangeable Magnesium | ---- | 0.2 | meq/100g | 5.7 | 8.5 | 5.7 | 5.6 | 7.2 |
| ø Exchangeable Potassium | ---- | 0.2 | meq/100g | 1.7 | 1.3 | 1.6 | 1.6 | 2.5 |
| ø Exchangeable Sodium | ---- | 0.2 | meq/100g | 0.3 | 0.4 | 0.3 | <0.2 | <0.2 |
| ø Cation Exchange Capacity | ---- | 0.2 | meq/100g | 23.2 | 36.1 | 22.2 | 20.9 | 33.3 |
| ø Exchangeable Sodium Percent | ---- | 0.2 | % | 1.5 | 1.0 | 1.3 | <0.2 | <0.2 |
| ø Calcium/Magnesium Ratio | ---- | 0.2 | - | 2.7 | 3.0 | 2.6 | 2.4 | 3.3 |
| ø Magnesium/Potassium Ratio | ---- | 0.2 | - | 3.3 | 6.4 | 3.6 | 3.4 | 2.8 |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | 0.02 | <0.01 | 0.01 | 0.01 | 0.02 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 10 | mg/kg | 20 | 20 | 40 | 20 | 20 |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 15000 | 14600 | 6940 | 6060 | 15500 |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| Iron | 7439-89-6 | 50 | mg/kg | 30800 | 31100 | 9540 | 13000 | 32400 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Copper | 7440-50-8 | 0.1 | mg/kg | 28.8 | 28.2 | 13.9 | 11.9 | 26.6 |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 1100 | 2400 | 1040 | 909 | 1820 |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 32.0 | 32.6 | 14.3 | 14.3 | 38.5 |
| **EK055: Ammonia as N** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 20 | mg/kg | <20 | <20 | <20 | <20 | <20 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N (Sol.) | 14797-65-0 | 0.1 | mg/kg | 0.1 | 0.2 | 0.1 | 0.2 | <0.1 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N (Sol.) | 14797-55-8 | 0.1 | mg/kg | 11.9 | 8.6 | 16.7 | 42.2 | 29.7 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | | Client sample ID | C07_2 | C07_1 | C149_1 | C149_2 | C60_1 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 24-Jul-2020 09:00 | 24-Jul-2020 09:00 | 24-Jul-2020 10:15 | 24-Jul-2020 10:15 | 24-Jul-2020 11:15 |
| Compound | CAS Number | LOR | Unit | | EB2020245-041 | EB2020245-042 | EB2020245-043 | EB2020245-044 | EB2020245-045 |
| | | | | | Result | Result | Result | Result | Result |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued** | | | | | | | | | |
| Nitrite + Nitrate as N (Sol.) | ---- | 0.1 | mg/kg | | 12.0 | 8.8 | 16.8 | 42.4 | 29.7 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 20 | mg/kg | | 1020 | 1330 | 960 | 970 | 1470 |
| **EK062: Total Nitrogen as N (TKN + NOx)** | | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 20 | mg/kg | | 1030 | 1340 | 980 | 1010 | 1500 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| Total Phosphorus as P | ---- | 2 | mg/kg | | 182 | 228 | 185 | 366 | 538 |
| **EK081: Bicarbonate Extractable Phosphorus (Olsen)** | | | | | | | | | |
| Bicarbonate Extractable P (Olsen) | ---- | 1.0 | mg/kg | | 2.6 | 1.7 | 14.8 | 11.8 | 26.7 |
| **EP004: Organic Matter** | | | | | | | | | |
| Organic Matter | ---- | 0.5 | % | | 3.2 | 2.9 | 2.3 | 2.5 | 3.7 |
| Total Organic Carbon | ---- | 0.5 | % | | 1.9 | 1.7 | 1.3 | 1.4 | 2.1 |

# Memorandum

| | | | |
|---|---|---|---|
| **To:** | Margaret Stewart | **At:** | Coronado Curragh Pty Ltd |
| **From:** | Luke Rettke | **At:** | SLR Consulting Australia Pty Ltd |
| **Date:** | 12 October 2022 | **Ref:** | 620.30075.0000-M01-v0.1-20221012.docx |
| **Subject:** | Waste Rock Characterisation Report | | |

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## 1 Waste Rock Characterisation

### 1.1 Sampling Frequency

A total of 20 waste rock samples were collected from the Curragh WRD. Based on the minor volumes of waste rock to be generated by the Curragh Mine the waste rock characterisation frequency is believed to comply with the frequency suggested in MEND (2009) (**Table 1**).

**Table 1 Sampling frequency based on waste rock tonnage (MEND 2009)**

| Tonnage of Unit (metric tonnes) | Minimum Number of Samples |
|---|---|
| <10,000 | 3 |
| <100,000 | 8 |
| <1,000,000 | 26 |
| <10,000,000 | 80 |

### 1.2 Acid Producing Potential

The characterisation of 20 waste rock samples from the Curragh WRD (**Figure 1** and **Table 2**) suggests that 17 of 20 samples are non-acid forming (NAF). Two sample are classified as Uncertain and one sample was classified as potentially acid generating (PAF). The net acid producing potential (NAPP) of all 20 samples ranges from positive 6.7 to negative 88.8 kg/$H_2SO_4$/tonne. Combined with the mostly alkaline NAG pH (16 of 20 samples) the overwhelming negative NAPP indicates a strong and available alkaline buffering capacity. Given this strong and available buffering capacity, the bulk waste rock is very unlikely to develop acid generating characteristics.

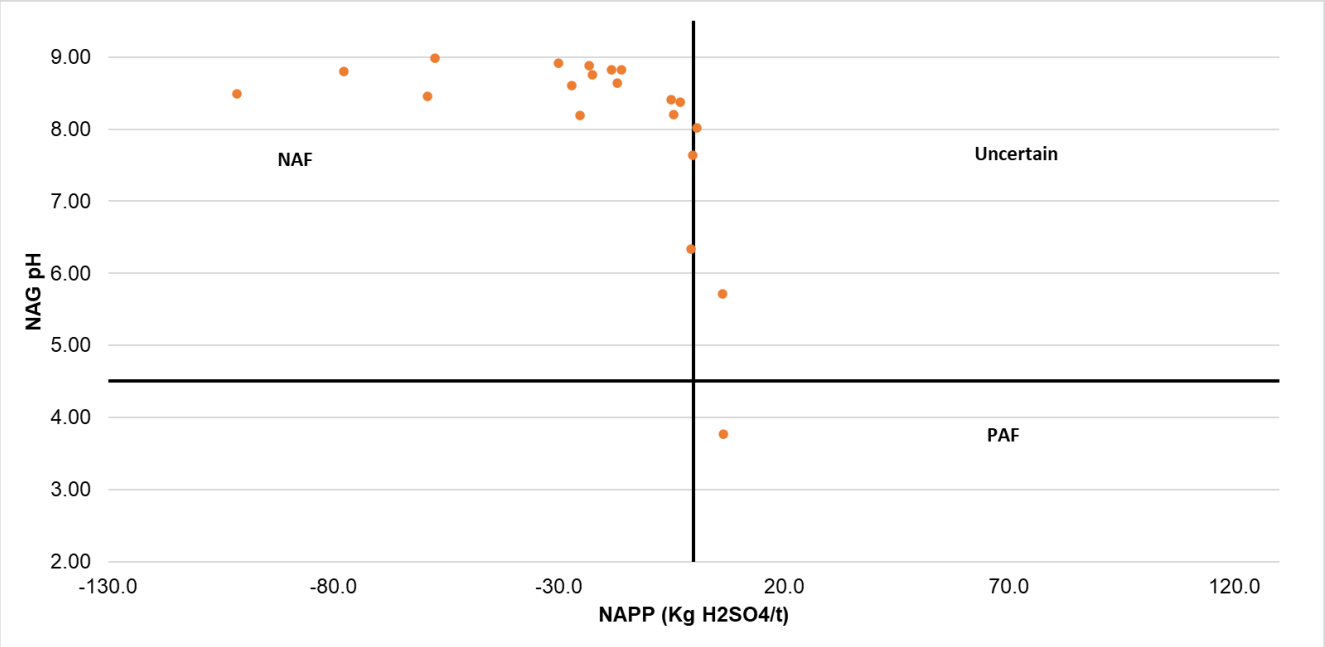



**Figure 1 AMD characteristics of total 20 samples collected**

**Table 2 Summary of test results for 20 Curragh waste rock samples collected**

| Sample | NAG pH | MPA kg $H_2SO_4$/t based on total S | ANC kg $H_2SO_4$/t | NAPP kg $H_2SO_4$/t based on total S |
|---|---|---|---|---|
| SP-CN-C418 | 8.64 | 1.348 | 18.3 | -23.8 |
| SP-CN-C16 | 7.64 | 0.980 | 1.1 | -0.1 |
| SP-CM-C07 | 8.91 | 0.980 | 31.0 | -30.1 |
| SP-CM-C10 | 8.49 | 0.858 | 102.4 | -88.8 |
| SP-CM-C126 | 8.02 | 3.461 | 2.9 | -6.5 |
| SP-CM-C042 | 8.98 | 1.041 | 58.4 | -61.1 |
| SP-CM-C152 | 8.82 | 1.776 | 17.9 | -30.7 |
| SP-CM-C100 | 8.41 | 1.807 | 6.8 | -10.7 |
| SP-CM-C38/38 | 8.75 | 2.266 | 24.7 | -54.8 |
| SP-CM-C077 | 8.82 | 1.960 | 20.3 | -38.6 |
| SP-CN-C369/370 | 5.72 | 7.656 | 1.2 | -1.8 |
| SP-CN-CN93 | 8.20 | 1.378 | 5.9 | -6.9 |
| SP-CN-CN320 | 6.34 | 1.011 | 1.7 | -0.7 |
| SP-CN-CN342 | 3.77 | 6.584 | 0.0 | 6.7 |
| SP-CN-CN413 | 8.19 | 1.439 | 26.7 | -37.7 |

| Sample | NAG pH | MPA kg $H_2SO_4$/t based on total S | ANC kg $H_2SO_4$/t | NAPP kg $H_2SO_4$/t based on total S |
|---|---|---|---|---|
| SP-CN-CN334 | 8.37 | 5.114 | 8.0 | -36.8 |
| SP-CN-CN364 | 8.88 | 1.807 | 25.0 | -44.4 |
| SP-CM-C051 | 8.60 | 1.348 | 28.5 | -37.9 |
| SP-CN-CN223 | 8.46 | 1.256 | 60.4 | -76.3 |
| SP-CM-C142 | 8.80 | 0.858 | 78.5 | -67.9 |

## 1.1 Geochemical Abundance Index (GAI)

The geochemical abundance index (GAI) can be used to estimate the enrichment of metals in the samples relative to median crustal concentration. The GAI is expressed on a log 2 scale. The GAI was developed by Förstner et al., (1993) and is defined as follows:

$$GAI = log_2 \left( {}^{C}/_{(1.5 * B)} \right)$$

$$C = measured\ concentration\ in\ sample$$
$$B = average\ crustal\ abundance$$

The enrichment ranges of a metal based on the GAI values are interpreted as follow:

- GAI=0 indicates <3 times median crustal abundance
- GAI=1 indicates 3 to 6 times median crustal abundance
- GAI=2 indicates 6 to 12 times median crustal abundance
- GAI=3 indicates 12 to 24 times median crustal abundance
- GAI=4 indicates 24 to 48 times median crustal abundance
- GAI=5 indicates 48 to 96 times median crustal abundance
- GAI=6 indicates more than 96 times median crustal abundance

GAI value of 3 is taken as the threshold for predicting potential metalliferous drainage from samples. The median crustal abundances used to compare results against in the GAI are provided in **Table 3**.

**Table 3 Median crustal abundance for trace metals (Berkman and Ryall, 1976; Bowen, 1979)**

| Name | Symbol | Median Crustal Abundance (mg/kg) |
|---|---|---|
| Aluminium | Al | 71000 |
| Arsenic | As | 6 |
| Beryllium | Be | 6 |
| Boron | B | 8.6 |
| Cadmium | Cd | 0.35 |
| Cobalt | Co | 8 |
| Chromium | Cr | 70 |
| Copper | Cu | 30 |

| Name | Symbol | Median Crustal Abundance (mg/kg) |
|---|---|---|
| Iron | Fe | 40000 |
| Manganese | Mn | 1000 |
| Molybdenum | Mo | 2 |
| Nickel | Ni | 50 |
| Lead | Pb | 35 |
| Zinc | Zn | 90 |
| Selenium | Se | 0.4 |
| Vanadium | V | 90 |

The GAI assessment of the 20 waste rock samples (**Table 4**) shows that the waste rock is depleted with regards to most metals. A slight enrichment only exists in four samples with regards to arsenic and cobalt.

## Table 4 GAI summary of 20 drill core waste rock samples the Curragh WRD

| Sample | Al | As | Be | B | Cd | Co | Cr | Cu | Fe | Pb | Mn | Mo | Ni | Zn | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SP-CN-C418 | -2 | -1 | -3 | -2 | -3 | 0 | -2 | 0 | 0 | -1 | 0 | -4 | 0 | 0 | -1 |
| SP-CN-C16 | -4 | -2 | -4 | -1 | -8 | -1 | -2 | -2 | -2 | -4 | -4 | -4 | -3 | -4 | -2 |
| SP-CM-C07 | -2 | 0 | -2 | 0 | -2 | 0 | -1 | 0 | 0 | -1 | 0 | -2 | -1 | 0 | 0 |
| SP-CM-C10 | -3 | 0 | -3 | 0 | -2 | 0 | -3 | 0 | -1 | -1 | -1 | -2 | -1 | 0 | -2 |
| SP-CM-C126 | -3 | 0 | -3 | -1 | -1 | 0 | -3 | 0 | -1 | -1 | -3 | -1 | -1 | 0 | -2 |
| SP-CM-C042 | -3 | 0 | -3 | -1 | -2 | 0 | -3 | 0 | -1 | -2 | 0 | -1 | -1 | 0 | -2 |
| SP-CM-C152 | -3 | 0 | -3 | 0 | -3 | 0 | -2 | 0 | 0 | -2 | -1 | -3 | -1 | -1 | -1 |
| SP-CM-C100 | -3 | 0 | -4 | -1 | -4 | 0 | -2 | -1 | -1 | -2 | -1 | -5 | -1 | -1 | -2 |
| SP-CM-C38/38 | -3 | 0 | -3 | -1 | -2 | 0 | -3 | 0 | 0 | -2 | 0 | -1 | -1 | 0 | -2 |
| SP-CM-C077 | -3 | 1 | -2 | 0 | -1 | 0 | -3 | 0 | 0 | -1 | 0 | -1 | -1 | 0 | -1 |
| SP-CN-C369/370 | -3 | 1 | -3 | -2 | -2 | 0 | -3 | 0 | 0 | -1 | 0 | 0 | -1 | 0 | -2 |
| SP-CN-CN93 | -3 | -1 | -3 | -1 | -4 | 0 | -1 | -1 | -1 | -3 | -1 | -3 | -1 | -1 | -1 |
| SP-CN-CN320 | -5 | -3 | -5 | -3 | -8 | -1 | -3 | -3 | -3 | -4 | -3 | 0 | -3 | -3 | -3 |
| SP-CN-CN342 | -4 | 0 | -4 | -2 | -4 | 0 | -2 | -1 | -1 | -3 | -3 | -3 | -1 | -1 | -2 |
| SP-CN-CN413 | -3 | 0 | -3 | -2 | -2 | 0 | -2 | 0 | -1 | -1 | -1 | -3 | -1 | 0 | -1 |
| SP-CN-CN334 | -4 | 0 | -3 | -2 | -2 | 0 | -3 | 0 | 0 | -1 | 0 | -1 | -1 | -1 | -2 |
| SP-CN-CN364 | -3 | 0 | -3 | -2 | -2 | 0 | -2 | 0 | -1 | -2 | -1 | -1 | -1 | 0 | -2 |
| SP-CM-C051 | -3 | 1 | -3 | -1 | -2 | 0 | -3 | 0 | 0 | -1 | 0 | -1 | -1 | 0 | -2 |
| SP-CN-CN223 | -3 | 0 | -3 | -2 | -3 | 0 | -2 | 0 | -1 | -2 | -1 | -1 | -1 | -1 | -2 |
| SP-CM-C142 | -1 | 0 | -2 | -2 | -2 | 1 | 0 | 0 | 0 | -2 | 0 | -2 | 0 | 0 | 0 |

## 1.2 Waste Rock Leachate Characteristics

The Australian Standard Leaching procedure (ASLP) subjects the waste rock samples to a 1:5 deionised (DI) water leach. The leachate is then tested for dissolved metal concentrations. ASLP results for the 20 samples from the Curragh WRD are shown in **Table 5** and exceeding water quality parameters with regards to the toxicant default guideline values for water quality in aquatic ecosystems (95% protection level) of the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (Australian Government, 2022) are discussed below.

Limit exceedances in the 1:5 DI leachate occurred mainly for dissolved aluminium, copper, chromium, zinc and vanadium, with less exceedances for manganese, cadmium, cobalt and nickel . At the pH values measured (pH 8.4 – 9.8) most of these metals should not be mobile. Hence, the exceedances of these metal are likely due to the presence of natural clays (Brookins; 1988, Meunier; 1994), which will disperse and potentially pass through the standard (0.45 µm) filtration as particles. The NATA accredited laboratory assisting with the analysis noted that all samples were filtered at 0.45µm prior to analysis, however while “some samples were quite clear, others still had fine particulate suspended in the solution which was biasing the results high” (Matt Pocock, pers com 2022).

## Table 5 ASLP results of the 20 core waste rock samples compared to the ANZECC95% protection Level (Australian Government 2022)

| | pH | EC | Al | As | Cd | Cu | Pb | Mo | Zn | B | Cr | Co | Mn | Ni | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mS/cm | mg/L >pH6.5 | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L |
| ANZECC 95% | | | **0.055** | **0.024** | **0.0002** | **0.0014** | **0.0034** | **0.034** | **0.008** | **0.94** | **0.0033** | **0.0014** | **1.9** | **0.011** | **0.006** |
| SP-CN-C418 | 9.52 | 140 | **0.41** | 0.002 | 0.000 | 0.000 | 0.001 | 0.004 | 0.003 | 0.028 | 0.000 | 0.000 | 0.002 | 0.000 | 0.002 |
| SP-CN-C16 | 8.92 | 180 | **22.9** | 0.001 | 0.000 | 0.001 | 0.001 | 0.002 | **0.010** | 0.099 | **0.019** | 0.001 | 0.005 | 0.005 | **0.007** |
| SP-CM-C07 | 8.67 | 1980 | 0.02 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.181 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 |
| SP-CM-C10 | 9.46 | 500 | **0.90** | 0.002 | 0.000 | **0.003** | 0.001 | 0.004 | 0.005 | 0.132 | 0.001 | 0.000 | 0.011 | 0.001 | 0.01 |
| SP-CM-C126 | 8.27 | 2670 | 0.00 | 0.004 | 0.000 | 0.001 | 0.000 | 0.023 | 0.001 | 0.086 | 0.000 | 0.000 | 0.005 | 0.000 | 0.001 |
| SP-CM-C042 | 9.82 | 220 | **0.11** | 0.003 | 0.000 | 0.001 | 0.000 | 0.012 | 0.003 | 0.059 | 0.000 | 0.000 | 0.002 | 0.000 | 0.002 |
| SP-CM-C152 | 8.83 | 3220 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.157 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 |
| SP-CM-C100 | 9.43 | 120 | **7.36** | 0.002 | 0.000 | **0.003** | 0.002 | 0.002 | **0.009** | 0.075 | **0.006** | 0.001 | 0.038 | 0.003 | **0.014** |
| SP-CM-C38/38 | 10.02 | 420 | **0.15** | 0.001 | 0.000 | 0.000 | 0.000 | 0.004 | 0.003 | 0.047 | 0.000 | 0.000 | 0.000 | 0.000 | 0.00 |
| SP-CM-C077 | 9.18 | 740 | **0.18** | 0.002 | 0.000 | **0.003** | 0.001 | 0.005 | 0.004 | 0.089 | 0.000 | 0.000 | 0.006 | 0.001 | 0.002 |
| SP-CN-C369/370 | 5.70 | 120 | 0.01 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 | 0.014 | 0.000 | **0.002** | 0.620 | 0.009 | 0.000 |
| SP-CN-CN93 | 9.15 | 180 | **5.15** | 0.006 | 0.000 | **0.004** | 0.002 | 0.004 | **0.013** | 0.056 | **0.008** | 0.001 | 0.103 | 0.007 | **0.044** |
| SP-CN-CN320 | 9.23 | 40 | **3.23** | 0.002 | 0.000 | 0.001 | 0.001 | 0.001 | 0.007 | 0.005 | **0.008** | 0.001 | 0.012 | 0.003 | **0.011** |
| SP-CN-CN342 | 3.39 | 1340 | **3.17** | 0.001 | **0.002** | **0.021** | 0.001 | 0.000 | **0.734** | 0.006 | **0.002** | **0.891** | **8.26** | **1.14** | 0.000 |
| SP-CN-CN413 | 9.33 | 120 | **0.09** | 0.001 | 0.000 | **0.002** | 0.000 | 0.001 | **0.094** | 0.011 | 0.000 | **0.145** | 1.53 | **0.173** | 0.001 |
| SP-CN-CN334 | 9.54 | 270 | 0.03 | 0.007 | 0.000 | 0.000 | 0.000 | 0.024 | 0.006 | 0.020 | 0.000 | 0.001 | 0.016 | 0.002 | 0.001 |
| SP-CN-CN364 | 9.69 | 430 | **0.11** | 0.005 | 0.000 | 0.001 | 0.000 | 0.010 | 0.005 | 0.039 | 0.000 | 0.000 | 0.003 | 0.000 | 0.00 |
| SP-CM-C051 | 9.12 | 700 | **0.06** | 0.001 | 0.000 | 0.001 | 0.000 | 0.005 | 0.000 | 0.080 | 0.000 | 0.000 | 0.004 | 0.000 | 0.002 |

| | pH | EC | Al | As | Cd | Cu | Pb | Mo | Zn | B | Cr | Co | Mn | Ni | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SP-CN-CN223 | 9.47 | 190 | **0.24** | 0.008 | 0.000 | 0.001 | 0.000 | 0.015 | 0.006 | 0.037 | 0.000 | 0.000 | 0.004 | 0.000 | 0.003 |
| SP-CM-C142 | 9.05 | 110 | 0.01 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.011 | **0.002** | 0.000 | 0.001 | 0.000 | 0.004 |
| SP-CN-C418 | 9.52 | 140 | **0.41** | 0.002 | 0.000 | 0.000 | 0.001 | 0.004 | 0.003 | 0.028 | 0.000 | 0.000 | 0.002 | 0.000 | 0.002 |
| SP-CN-C16 | 8.92 | 180 | **22.9** | 0.001 | 0.000 | 0.001 | 0.001 | 0.002 | **0.010** | 0.099 | **0.019** | 0.001 | 0.005 | 0.005 | **0.007** |

# 2 Conclusion

The geochemical assessment of 20 additional wasterock samples from Curragh confirmed the results of previous waste rock assessments by URS in 2005 and 2015. The waste rock collected is in its entirety non-acid generating and has significant buffering capacity. Metal concentrations of the waste rock, represented through the GAI, are very low. Showing that the sedimentary sequences forming the waste rock are depleted with regards to most metals. As a result of the high buffering capacity and relatively low metal concentrations of the solid waste rock future metal leaching from the waste rock will be low. Compared to available guideline values for freshwater, several ASLP metal concentrations, particularly aluminium and vanadium, are in exceedance. Such exceedances are unlikely at the reported leachate pH and are thought to be the result of colloid transport through the 0.45µm filter membrane.

# 3 References

Australian Government, (2022). Toxicant default guideline values for water quality in aquatic ecosystems. https://www.waterquality.gov.au/anz-uidelines/guideline-values/default/water-quality-toxicants/search#tox-289. Accessed 07.02.2022.

Brookins D. G. (1988). Eh-pH Diagrams for Geochemistry. Springer-Verlag, Berlin.

Förstner, U., Ahlf, W., & Calmano, W., 1993, "Sediment Quality Objectives and Criteria Development in Germany", Water Science & Technology, 28:307-316.

MEND (2009). Prediction Manual for Drainage Chemistry from sulphidic Geologic Materials. MEND Report 1.20.1.

Matt Pocock (2022). Technical Team Leader (Waters and ICP), Environmental Analysis Laboratory. Southern Cross University.

Meunier, J.D. (1994). The Composition and Origin of Vanadium-Rich Clay Minerals in Colorado Plateau Jurassic Sandstones. Clays and Clay Minerals, Volume 42, pages391–401.

URS (2005). Geochemical Characterisation and Assessment of Overburden and Potential Coal Reject material at the Ensham Central Project. Prepared for Hansen Consulting. 24 October, 2005. 42625576/R001-Final.DOC.

URS (2015). Geochemical Characterisation of Overburden and Potential Rejects. Prepared for Ensham Resources Pty. Ltd., 19 March 2015. 42627460/R001/A

Checked/
Authorised by: MT

# CURRAGH MINE

## Progressive Rehabilitation and Closure Plan
## Flood Assessment

**Prepared for:**

Coronado Curragh Pty Ltd
Blackwater, QLD, 4717

SLR Ref: 626.30075-R02
Version No: -v0.2
September 2022

# PREPARED BY

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# BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

# DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
|---|---|---|---|---|
| 626.30075-R02-v0.2 | 8 September 2022 | TS | HD | EW |
| 626.30075-R02-v0.1 | 11 August 2022 | TS | HD | EW |
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## APPENDICES

APPENDIX A IFD Data
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# 1 Introduction

## 1.1 Scope of Work

SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to undertaken hydrologic and hydraulic modelling for the floodplain surrounding the Curragh Complex, as part of the Progressive Rehabilitation and Closure Plan. The modelling was undertaken to refine the previous hydraulic modelling undertaken in the *Conceptual Residual Void Assessment Preliminary Flood Impact Report* (SLR, 2021). The key tasks undertaken include:

- Development of a hydrologic model in WBNM of the Mackenzie River and Blackwater Creek catchments and calibration to two historical events;
- Refinement of previously conducted stream gauge Flood Frequency Analysis (FFA);
- Estimation of 0.1% AEP and PMF events in accordance with Australian Rainfall and Runoff (2019);
- Revision of the hydraulic model with updated LiDAR;
- Reporting of methods used and findings of the above assessments, including all relevant mapping of flood level and depths.

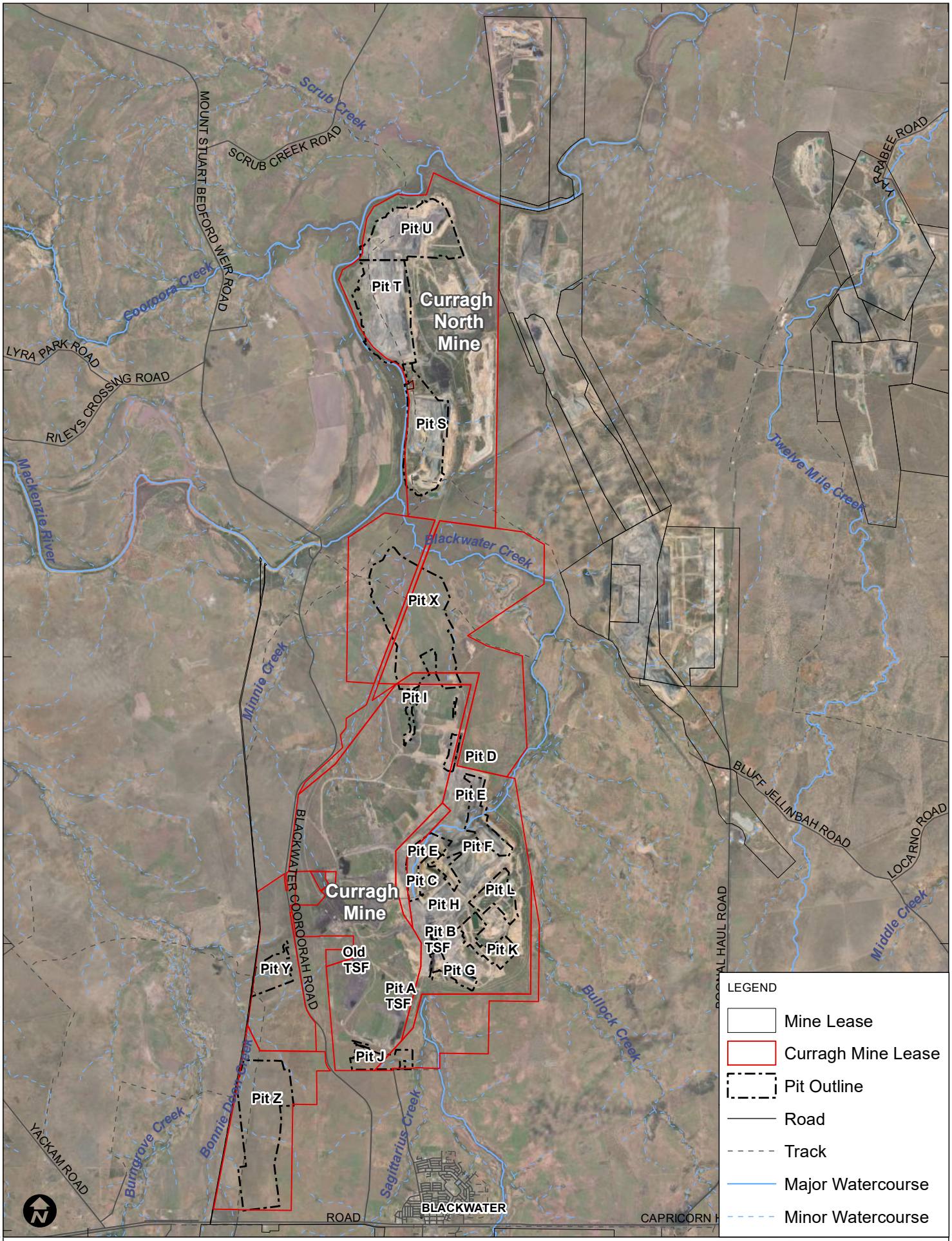
## 1.2 Project Information

The Curragh mine is an open cut coal mine located in the Bowen Basin, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton in Central Queensland. The Curragh Complex has been operating since 1983 and covers an area of approximately 19,650 ha. Mackenzie River and Blackwater Creek run adjacent to the mine. Blackwater Creek flows from the south, flows through a diversion and joins Mackenzie River north of Pit X. The project location is shown in **Figure 1**.

## 1.3 Relevant Documentation

This assessment was undertaken referring to the following guidelines and documentation:

- *Environmental Protection Act 1994;*
- *Environmental Protection Regulation 2019;*
- *'Guideline – Progressive Rehabilitation and Closure Plans'*, Department of Environment and Science, March 2021 (PRCP Guideline);
- *'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains'*, Department of Environment and Science, March 2020 (Voids in Flood Plains Information Sheet); and
- *'Australian Rainfall and Runoff: A guide to Flood estimation'*, Geoscience Australia, 2019 (AR&R).




SLR

DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.

0 2 4 km

| | |
|---|---|
| Coordinate System: | AGD 1984 AMG Zone 55 |
| Scale: | 1:170,000 at A4 |
| Project Number: | 626.30075 |
| Date: | 24-Nov-2021 |
| Drawn by: | ML |
| Reviewed by: | ML |

Data Source:

**CURRAGH PRCP**

**Current Mine Layout**

**FIGURE 1**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\GIS\626.630075 F01 Base Map.mxd

## 1.4 Assumptions and Limitations

This flood assessment has relied upon information which was received from the client and other sources. SLR has assumed that information provided is accurate and, except where noted, SLR has not verified the accuracy of the information provided.

This report has been prepared for the purposes of assessing the impacts of a PMF and 0.1% AEP flood event for the relevant watercourse which impacts on the Curragh Complex.

- The hydrological model has been developed using the *Jellinbah Mackenzie North Pit Flood Study* (WRM, 2018) (referred herein as the Jellinbah flood study) as a guide. A model in WBNM has been developed, using larger sub-catchments. Although there are differences between the model set up and parameters used, two calibration events have been run through the current WBNM model to verify that the model can achieve a similar level of calibration using reasonable model parameters.
- The FFA undertaken in the *Conceptual Residual Void Assessment Preliminary Flood Impact Report* (SLR, 2021) and the Jellinbah flood study report show large differences in magnitude. It was noted in the *Conceptual Residual Void Assessment Preliminary Flood Impact Report* that the various gauges assessed lacked any convergence, with the 0.1% AEP peak flow estimates differing by an order of magnitude. Potential reasons for this include the inability of this assessment to account for large floodplain storage, the presence of artificial features such as dams and weirs, the presence of mine pits which absorbed flow on at least one occasion, short gauge records and lack of accuracy of rating curves.
- Coincident flooding assessment between the Mackenzie River and the other tributaries within the hydraulic model has not been undertaken. The hydrological model output with the highest peak in the main Mackenzie River and Blackwater Creek inflows have been chosen as the critical event for assessment.
- The hydraulic modelling is based on 1m LiDAR information (dated Dec 2021). A terrain surface was developed combining the residual void landform and 1m LiDAR.
- No bathymetric data for Mackenzie River was available and hence assumptions were made regarding the bathymetry in the vicinity of the weirs.
- All roughness values adopted were as established in the *Conceptual Residual Void Assessment Preliminary Flood Impact Report* (SLR, 2021). These were determined by review of aerial photography with no site visits carried out.
- The proposed Mackenzie North Levee, Pit V levee, and Jellinbah levee are not included in this assessment as there was no information available. As data becomes available, re-running of the hydraulic model is recommended.

This report should be read in full, and no excerpts are to be taken as representative of the findings. This report has been prepared on behalf of CCPL and we accept no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

## 1.5 Definitions and Terminology

### Table 1 Report Definitions

| Term | Definition |
|---|---|
| Annual Exceedance Probability (AEP) | The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a flood level of 3.5 mAHD has an AEP of 1% or 1 in 100 (or 1:100), it means that there is a 1% chance (i.e., a 1 in 100 chance) of a flood level of 3.5 mAHD (or larger) occurring in any one year (See also average recurrence interval). |
| Australian Height Datum (AHD) | National survey datum corresponding approximately to mean sea level. |
| Average Recurrence Interval (ARI) | The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. ARI is another way of expressing the likelihood of occurrence of a flood event (see also annual exceedance probability). |
| Average Variability Method (AVM) | Technique for estimating design temporal pattern of average variability to ensure AEP neutrality in transition from PMP to PMPDF |
| Catchment | The catchment at a particular point is the area of land that drains to that point. |
| Design flood | A hypothetical flood representing a specific likelihood of occurrence (for example the 1% AEP probability flood). |
| Discharge | The rate of flow of water measured in terms of volume over time (i.e., the amount of water moving past a point). Discharge and flow are interchangeable. |
| DEM | Digital Elevation Model – a three-dimensional model of the ground surface. |
| Flood | Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences. |
| Flood Frequency Analysis | An analysis of historical flood records to determine estimates of design flood flows. |
| Floodplain | Land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood (PMF) event. |
| Flood Storage | Floodplain areas that are important for the temporary storage of floodwaters during a flood |
| Floodway | A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood. |
| Historical Flood | A flood which has occurred in the past. |
| Hydrograph | A graph showing how a river or creek's discharge or water level changes with time. |

| Term | Definition |
|---|---|
| Hydrology | The term given to the study of the rainfall-runoff process in catchments. |
| Levee | Operational mine protection device. |
| Long-term stable embankment | Landform feature which may protect residual voids from flood ingress, is not a regulated structure. |
| Peak flood level, flow, or velocity | The maximum flood level, flow or velocity occurring during a flood event at a particular location. |
| Pit | Operational open cut mine pit/void |
| Probable Maximum Flood (PMF) | The flood that results from the transformation of the PMP using conservatively high (but reasonable) values for design inputs such as losses, temporal pattern, etc. (BoM, 2005) |
| Probable Maximum Precipitation (PMP) | 'The greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends" (World Meteorological Organization, 1986) |
| Probability | A statistical measure of the likely frequency or occurrence of flooding |
| Residual void | Post closure landform design term. |
| Runoff | The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek. |
| Velocity | The speed at which floodwater are moving. |
| Water level | Same as flood level. |

## Table 2 Report Abbreviations

| Abbreviation | Term |
|---|---|
| 1D/2D | One dimensional / two dimensional |
| AEP | Annual Exceedance Probability |
| AHD | Australian Height Datum |
| ARI | Average Recurrence Interval |
| ARR2019 | Australian Rainfall and Runoff 2019 |
| BoM | Bureau of Meteorology |
| CCPL | Coronado Curragh Pty Ltd |
| CRVA | Concept Residual Void Assessment |
| Curragh Complex | Curragh Mine Complex "the mine" |
| DEM | Digital Elevation Model |
| km | Kilometres |
| $m^3/s$ | Cubic Metres per second |

| Abbreviation | Term |
|---|---|
| mAHD | Elevation in metres relative to the Australian Height Datum |
| RFFE | Regional Flood Frequency Estimation |

# 2 Legislation and Guidelines

## 2.1 Relevant Legislation and Guidelines

The relevant documentation for this assessment is detailed in **Section 1.3**. Key details in the context of the assessment are provided below.

The Environmental Protection Act 1994 states:

*'In accordance with Section 126D(3) of the EP Act, if land the subject of the proposed PRCP schedule will contain a void situated wholly or partly in a flood plain, the schedule must provide for the rehabilitation of the land to a stable condition.'*

The Environmental Protection Regulation 2019 section 41C(3) also states:

*'The administering authority must treat the land as a flood plain to the extent the results of the flood plain modelling show that, when all relevant activities carried out on the land have ended, the land is the same height as, or lower than, the level modelled as the peak water level 0.1% AEP for a relevant watercourse under the ARR'*

Further guidance is provided in the PRCP Guideline and the Voids in Flood Plains Information Sheet.

Sections 3.4 and 3.6.1 of the PRCP Guideline both require a floodplain assessment to be carried out. Specifically, Section 3.4 requires a Void in Floodplain assessment for all unapproved Non-Use Management Area (NUMA) voids (i.e. floodplain assessment of the pre-mining landform), whilst Section 3.6.1 requires a post-mining landform assessment irrespective whether a post-mining land use (PMLU) or NUMA is proposed. This assessment was undertaken only to address the requirements of Section 3.6.1.

The hydrologic and hydraulic analyses were undertaken in accordance with AR&R (2019).

## 2.2 Applicability to the Project

Based on the review of the EP Act, EP Regulation, PRCP Guideline and the Voids in Floodplains information sheets, it is considered that the legislative requirements set out **Table 3** are applicable to the project.

**Table 3 Applicable Legislative Requirements**

| Requirement | Application to the Project | Source |
|---|---|---|
| For transitional sites, a floodplain assessment is required where:<br>- A void has been identified as a NUMA in a land outcome document, but the location has not been specified; or<br>- Where there are no land outcomes in the land outcome document. | A Voids in Floodplain was previously undertaken by SLR as detailed in<br>*Conceptual Residual Void Assessment Preliminary Flood Impact Report* (SLR, 2021) (ref 626.30075-R01-v0.1) | PRCP Guideline Section 3.4 |

| Requirement | Application to the Project | Source |
|---|---|---|
| The requirement for a flood assessment under Section 3.6.1 of the Guideline applies to the post mining landform across the whole site irrespective of whether a PMLU or a NUMA are proposed. Furthermore, Section 3.6.1 is not only required to indicate flood risk but also to demonstrate the final landform (including waste rock dumps and diversions) will remain in a stable condition in a range of flood flow conditions. | The final voids are all considered to be NUMAs and therefore will be retained in the post-mining landform where it can be shown the voids are in a stable condition.<br>Therefore, a flood assessment is required to show the proposed final voids will remain in a stable condition following closure of Curragh. | PRCP Guideline Section 3.6.1 |

# 3 Data Review and Gap Analysis

## 3.1 Available Data

The following data was provided or obtained for the assessment:

- Residual void landform (supplied as 0.5m contours);
- 1m LiDAR provided as x,y,z points;
- Shuttle Radar Topography Mission (SRTM) terrain data – sourced from Geoscience Australia for the hydraulic model extent where LiDAR wasn't available;
- Aerial photography sourced from Queensland Globe, used to determine roughness of land uses within the floodplain extent;
- Rainfall intensity-frequency-duration (IFD) data for the area (Bureau of Meteorology (BoM));
- Catchment specific hydrologic data (ARR Data Hub);
- Pluviograph rainfall data for various gauges in the catchment (Bureau of Meteorology (BoM));
- Stream gauge station records for creeks within the catchment (Department of Regional Development, Manufacturing and Water (RDMW));
- *'Bowen Basin River Diversions – Design and Rehabilitation Criteria'* (Australian Coal Association Research Program (ACARP), 2002); and
- *Jellinbah Mackenzie North Pit Flood Study* (WRM, 2018).

## 3.2 Watercourses

A review of the existing watercourses in the vicinity of Curragh Mine was undertaken to identify the watercourses that may affect flooding conditions at CVM. The following watercourses were included in the assessment in the hydraulic model (refer to **Figure 1** for location):

- Mackenzie River;
- Blackwater Creek;
- Sagittarius Creek;
- Bullock Creek;
- Burngrove Creek;
- Cooroora Creek; and
- Scrub Creek.

## 3.3 Landform

A model landform was developed for the assessment based on the available data as detailed in **Section 3.1.** The 2021 LiDAR DEM was used as the underlying base topography. The provided post-mining DEM was overlayed on the base topography to form the post-mining model landform, as shown in **Figure 6** and discussed further in **Section 5.2.**

## 3.4 Previous Studies

The following assessment has been undertaken for the Mackenzie River:

- *Jellinbah Mackenzie North Pit Flood Study* (WRM, 2018).

The Jellinbah Mackenzie North Pit Flood Study involved developing a calibrated hydrologic model of the Mackenzie River catchment. The results of the hydrological model were used to for the detailed design of the proposed Mackenzie North Levee.

# 4 Hydrologic Modelling

## 4.1 Overview

WBNM software was adopted for the hydrologic modelling of the catchment. WBNM software is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall. WBNM was used with the software Storm Injector (Version 1.3.2) to streamline the required model runs by Australian Rainfall and Runoff 2019 (ARR2019) and to develop the local and total inflow hydrograph boundaries for input to the hydraulic model.

The hydrological model catchment for the Mackenzie River is in excess of 50,000 km$^2$ and combines the Nogoa River, Theresa Creek, and Comet River catchments which discharge into the Mackenzie River catchment.

## 4.2 Previous Modelling

Previous modelling of the Mackenzie River catchment in the vicinity of the Curragh site has been conducted by WRM using URBS (WRM, 2018). This model was calibrated and amended over a number of projects. The model itself was not available however the reporting associated with the modelling was contained in *the Jellinbah Mackenzie North Pit Flood Study* (WRM, 2018). The information available within this report, particularly the catchment boundaries, was used to develop the WBNM model. A smaller number of catchment subareas was adopted for the WBNM model as the level of detail adopted for the previous hydrological modelling was not considered necessary or beneficial.

The URBS parameters adopted in the Jellinbah flood study hydrological model are noted as below in **Table 4**.

**Table 4 Adopted URBS model parameters (WRM, 2018)**

| Catchment | Alpha | Beta |
|---|---|---|
| Nogoa | 0.33 | 2.5 |
| Theresa | 0.27 | 3.0 |
| Mackenzie | 0.35 | 3.0 |
| Comet | 0.45 | 3.5 |

According to the URBS manual (Carroll, 2016), the typical range of Alpha is 0.1 to 0.3 and for Beta is 1 to 9. While the values of Beta are in the typical range, some values of Alpha are outside the typical range. As Alpha and Beta are related to catchment routing, this suggests that the calibration required some parameters to be outside the typical range.

## 4.3 Model set up

### 4.3.1 Catchments

The total catchment area for the Mackenzie River is 50,714 km$^2$. This can be separated into the Nogoa River (16,189 km$^2$), Theresa Creek (8,484 km$^2$), Comet River (16,133 km$^2$) and Mackenzie River (9,908 km$^2$) catchments. Sub-catchments for the WBNM model were delineated using SRTM topographic data and watercourse data from QSpatial, with the Jellinbah flood study URBS model as a guide. The WBNM model layout is shown in **Figure 2**. Details for the sub-catchments are listed in **Table 5**.

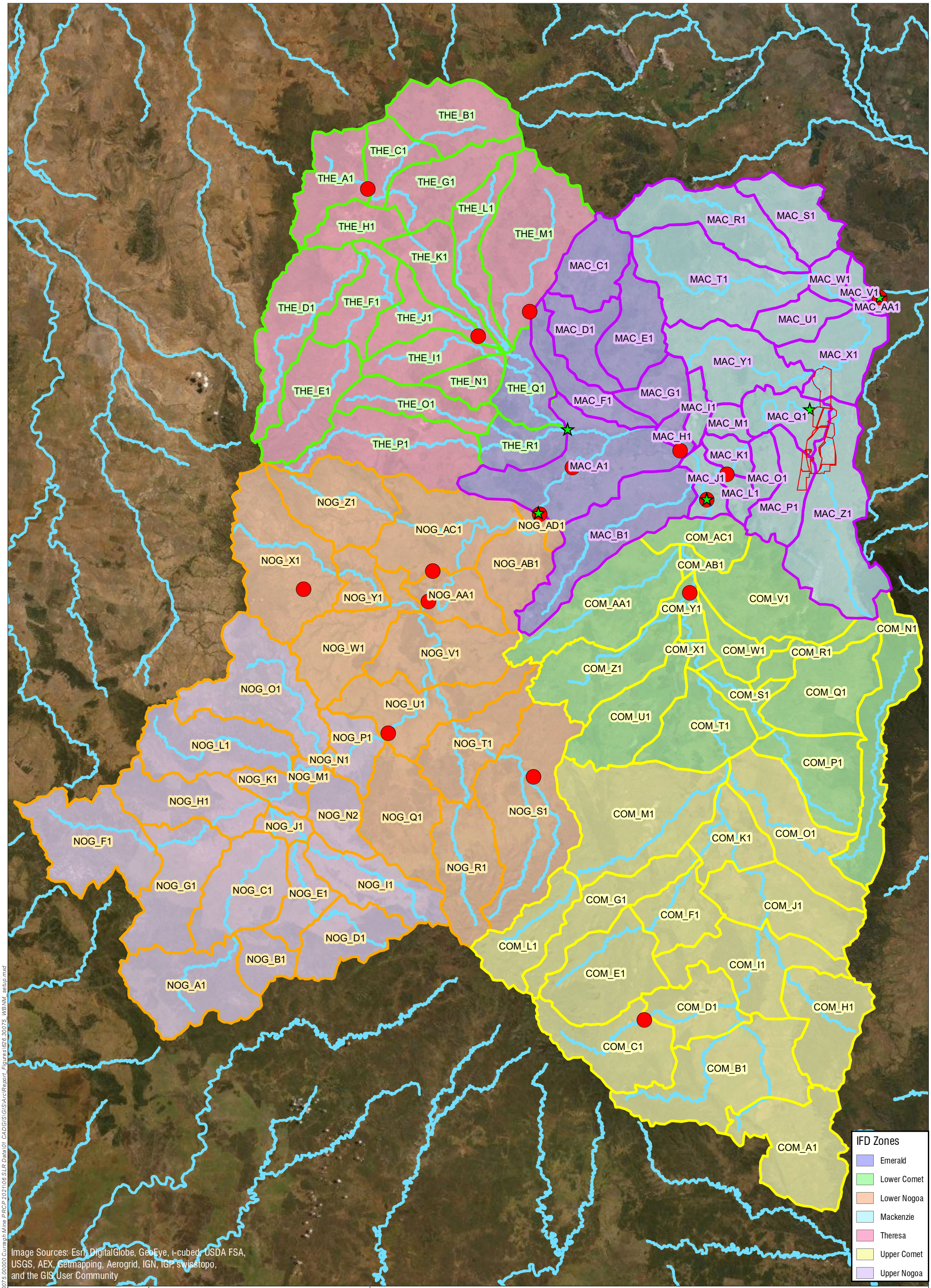
**Table 5 WBNM Model Sub-catchment Details**

| Sub-catchment ID | Downstream Sub-catchment ID | Area (km$^2$) | Fraction Impervious |
|---|---|---|---|
| COM_A1 | COM_B1 | 780.2 | 0.01 |
| COM_B1 | COM_D1 | 1067.9 | 0.03 |
| COM_C1 | COM_D1 | 646.6 | 0.00 |
| COM_D1 | COM_I1 | 434.5 | 0.03 |
| COM_E1 | COM_F1 | 738.3 | 0.00 |
| COM_F1 | COM_K1 | 378.6 | 0.03 |
| COM_G1 | COM_K1 | 524.8 | 0.00 |
| COM_H1 | COM_I1 | 619.6 | 0.00 |
| COM_I1 | COM_J1 | 740.1 | 0.00 |
| COM_J1 | COM_K1 | 703.8 | 0.01 |
| COM_K1 | COM_T1 | 385.0 | 0.02 |
| COM_L1 | COM_M1 | 459.8 | 0.00 |
| COM_M1 | COM_T1 | 1217.0 | 0.03 |
| COM_N1 | COM_O1 | 744.0 | 0.00 |
| COM_O1 | COM_T1 | 760.3 | 0.01 |
| COM_P1 | COM_S1 | 582.5 | 0.00 |
| COM_Q1 | COM_S1 | 650.1 | 0.00 |
| COM_R1 | COM_S1 | 213.5 | 0.03 |
| COM_S1 | COM_X1 | 194.5 | 0.01 |
| COM_T1 | COM_X1 | 577.3 | 0.00 |
| COM_U1 | COM_Y1 | 593.5 | 0.01 |
| COM_V1 | COM_AB1 | 773.6 | 0.02 |
| COM_W1 | COM_AB1 | 249.6 | 0.00 |
| COM_X1 | COM_Y1 | 62.1 | 0.03 |
| COM_Y1 | COM_AB1 | 143.2 | 0.01 |

| Sub-catchment ID | Downstream Sub-catchment ID | Area (km²) | Fraction Impervious |
|---|---|---|---|
| COM_Z1 | COM_Y1 | 663.0 | 0.01 |
| COM_AA1 | COM_AB1 | 875.6 | 0.01 |
| COM_AB1 | COM_AC1 | 51.2 | 0.06 |
| COM_AC1 | MAC_J1 | 303.3 | 0.01 |
| MAC_A1 | MAC_J1 | 1004.2 | 0.04 |
| MAC_B1 | MAC_J1 | 817.0 | 0.03 |
| MAC_C1 | MAC_D1 | 420.2 | 0.00 |
| MAC_D1 | MAC_G1 | 366.2 | 0.00 |
| MAC_E1 | MAC_G1 | 462.3 | 0.06 |
| MAC_F1 | MAC_H1 | 324.9 | 0.01 |
| MAC_G1 | MAC_H1 | 255.0 | 0.01 |
| MAC_H1 | MAC_J1 | 85.9 | 0.12 |
| MAC_I1 | MAC_J1 | 112.4 | 0.14 |
| MAC_J1 | MAC_K1 | 182.0 | 0.05 |
| MAC_K1 | MAC_O1 | 133.3 | 0.00 |
| MAC_L1 | MAC_K1 | 97.7 | 0.01 |
| MAC_M1 | MAC_Q1 | 101.6 | 0.00 |
| MAC_O1 | MAC_Q1 | 139.7 | 0.04 |
| MAC_P1 | MAC_Q1 | 353.3 | 0.07 |
| MAC_Q1 | MAC_X1 | 319.1 | 0.04 |
| MAC_R1 | MAC_W1 | 708.7 | 0.07 |
| MAC_S1 | MAC_W1 | 411.0 | 0.05 |
| MAC_T1 | MAC_W1 | 953.7 | 0.08 |
| MAC_U1 | MAC_AA1 | 259.4 | 0.00 |
| MAC_V1 | MAC_AA1 | 69.3 | 0.01 |
| MAC_W1 | MAC_AA1 | 143.3 | 0.00 |
| MAC_X1 | MAC_AA1 | 518.5 | 0.07 |
| MAC_Y1 | MAC_X1 | 619.5 | 0.00 |
| MAC_Z1 | MAC_X1 | 1024.8 | 0.10 |
| MAC_AA1 | SINK | 25.1 | 0.01 |
| NOG_A1 | NOG_C1 | 745.7 | 0.00 |
| NOG_B1 | NOG_C1 | 236.5 | 0.00 |
| NOG_C1 | NOG_J1 | 658.0 | 0.00 |

| Sub-catchment ID | Downstream Sub-catchment ID | Area (km²) | Fraction Impervious |
|---|---|---|---|
| NOG_D1 | NOG_E1 | 456.1 | 0.00 |
| NOG_E1 | NOG_J1 | 303.0 | 0.00 |
| NOG_F1 | NOG_G1 | 816.8 | 0.00 |
| NOG_G1 | NOG_H1 | 680.9 | 0.00 |
| NOG_H1 | NOG_K1 | 589.6 | 0.00 |
| NOG_I1 | NOG_J1 | 517.5 | 0.00 |
| NOG_J1 | NOG_K1 | 118.9 | 0.01 |
| NOG_K1 | NOG_M1 | 185.4 | 0.00 |
| NOG_L1 | NOG_M1 | 722.0 | 0.00 |
| NOG_M1 | NOG_N1 | 69.2 | 0.00 |
| NOG_N1 | NOG_P1 | 21.1 | 0.00 |
| NOG_N2 | NOG_N1 | 314.2 | 0.00 |
| NOG_O1 | NOG_N1 | 874.9 | 0.00 |
| NOG_P1 | NOG_U1 | 270.8 | 0.00 |
| NOG_Q1 | NOG_U1 | 654.2 | 0.00 |
| NOG_R1 | NOG_T1 | 618.6 | 0.00 |
| NOG_S1 | NOG_T1 | 1231.8 | 0.00 |
| NOG_T1 | NOG_U1 | 565.5 | 0.00 |
| NOG_U1 | NOG_V1 | 678.2 | 0.00 |
| NOG_V1 | NOG_AA1 | 690.4 | 0.00 |
| NOG_W1 | NOG_AA1 | 632.0 | 0.00 |
| NOG_X1 | NOG_Y1 | 1000.5 | 0.00 |
| NOG_Y1 | NOG_W1 | 225.0 | 0.01 |
| NOG_Z1 | NOG_AC1 | 655.4 | 0.00 |
| NOG_AA1 | NOG_AC1 | 331.8 | 0.00 |
| NOG_AB1 | NOG_AD1 | 430.0 | 0.14 |
| NOG_AC1 | NOG_AD1 | 823.3 | 0.07 |
| NOG_AD1 | MAC_A1 | 71.9 | 0.36 |
| THE_A1 | THE_C1 | 446.4 | 0.03 |
| THE_B1 | THE_C1 | 590.9 | 0.01 |
| THE_C1 | THE_G1 | 295.8 | 0.06 |
| THE_D1 | THE_F1 | 744.0 | 0.01 |
| THE_E1 | THE_F1 | 589.9 | 0.00 |

| Sub-catchment ID | Downstream Sub-catchment ID | Area (km²) | Fraction Impervious |
|---|---|---|---|
| THE_F1 | THE_J1 | 425.5 | 0.00 |
| THE_G1 | THE_K1 | 515.8 | 0.01 |
| THE_H1 | THE_K1 | 273.8 | 0.00 |
| THE_I1 | THE_Q1 | 363.9 | 0.00 |
| THE_J1 | THE_K1 | 330.1 | 0.00 |
| THE_K1 | THE_Q1 | 405.2 | 0.00 |
| THE_L1 | THE_Q1 | 425.3 | 0.01 |
| THE_M1 | THE_Q1 | 1020.5 | 0.01 |
| THE_N1 | THE_Q1 | 202.8 | 0.00 |
| THE_O1 | THE_R1 | 387.4 | 0.00 |
| THE_P1 | THE_R1 | 823.6 | 0.02 |
| THE_Q1 | MAC_A1 | 342.1 | 0.00 |
| THE_R1 | MAC_A1 | 301.0 | 0.03 |


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COM_A1
IFD Zones
Emerald
Lower Comet
Lower Nogoa
Mackenzie
Theresa
Upper Comet
Upper Nogoa
Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
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Mackenzie River Subcatchments
Comet Creek Subcatchments
Nogoa River Subcatchments
Theresa Creek Subcatchments
Curragh Mine Lease
Streamflow Gauges
Sub-daily Rainfall Gauges
Major Watercourses
Curragh Mine PRCP
Flood Assessment
WBNM Model Layout
Figure 2

## 4.4 Model Calibration

A number of flood events have occurred within the Mackenzie River catchment in the last 10 years. Gauge data was examined to determine appropriate events for use in the calibration of the modelling. The following events were considered to be of sufficient size to be adopted for further assessment:

- January 2008;
- January 2011; and
- May 2022

After detailed assessment of these events, the 2011 event and the 2022 event were chosen for hydrologic model calibration. Although the 2008 event was larger than the 2011 event, there were several BoM gauges where 2008 rainfall data was not available and therefore the 2011 was chosen over the 2008 event. The 2008 event also had the added complication of the flooding of the Ensham open cut pits, as outlined in Section A5.2 of the Jellinbah flood study (WRM, 2018) and was therefore not considered further.

The streamflow gauges used are listed in **Table 6**. These gauges are located at the most downstream end of the Theresa Creek, Nogoa River, and Comet River catchments, and two gauges in the Mackenzie River catchment. They are also shown in **Figure 2**.

**Table 6 Streamflow Gauges**

| Stream Gauge No. | Station Name | Catchment | 2011 | 2022 |
|---|---|---|---|---|
| 130206A | Gregory Highway | Theresa | ✓ | ✓ |
| 130504B | Comet Weir | Comet | ✓ | ✓ |
| 130216A | Fairbairn Dam | Nogoa | ✓ | x |
| 130111A | Bedford Weir TW | Mackenzie | ✓ | x |
| 130106A | Bingegang Weir HW | Mackenzie | x | ✓ |

The sub-daily rainfall gauges used in calibration are listed in **Table 7**. Thiessen polygons were used to initially allocate which rainfall gauge was attributed to each subarea. The gauges are also shown in **Figure 2**.

**Table 7 Sub-daily rainfall gauges**

| Gauge No. | Station Name | Catchment | 2011 | 2022 |
|---|---|---|---|---|
| 35187 | Valeria Alert | Theresa | ✓ | ✓ |
| 35185 | Capella (Rowe's Hill) Alert | Theresa | ✓ | ✓ |
| 130207 | Sandy Creek at Clermont | Theresa | ✓ | ✓ |
| 535101 | Fairbairn Dam Alert | Nogoa | ✓ | ✓ |
| 535099 | Raymond Alert | Nogoa | ✓ | ✓ |
| 35251 | Craigmore Alert | Nogoa | ✓ | ✓ |

| Gauge No. | Station Name | Catchment | 2011 | 2022 |
|---|---|---|---|---|
| 35292 | Ducabrook Alert | Nogoa | ✓ | ✓ |
| 35293 | Heathwood Alert | Nogoa | ✓ | ✓ |
| 35294 | Kulumur Range Alert | Nogoa | ✓ | ✓ |
| 535076 | Emerald Alert | Mackenzie | ✓ | ✓ |
| 130504 | Comet River at Comet Weir | Mackenzie | ✓ | ✓ |
| 130219 | Nogoa River at Duck Ponds | Mackenzie | ✓ | ✓ |
| 130113 | Riley's Crossing TM | Mackenzie | ✓ | ✓ |
| 130106 | Bingegang Weir HW Alert | Mackenzie | x | ✓ |
| 130509 | Carnarvon Creek at Rewan | Comet | ✓ | ✓ |
| 35276 | Springsure Creek Junction | Comet | ✓ | ✓ |

The results were compared at Bedford Weir for the 2011 event and at Bingegang for the 2022 event, as the data for the 2011 event at Bingegang Weir was not available The calibration results are shown in **Figure 3** for the 2011 event and **Figure 4** for the 2022 event. The model parameters adopted are listed in **Table 8**.

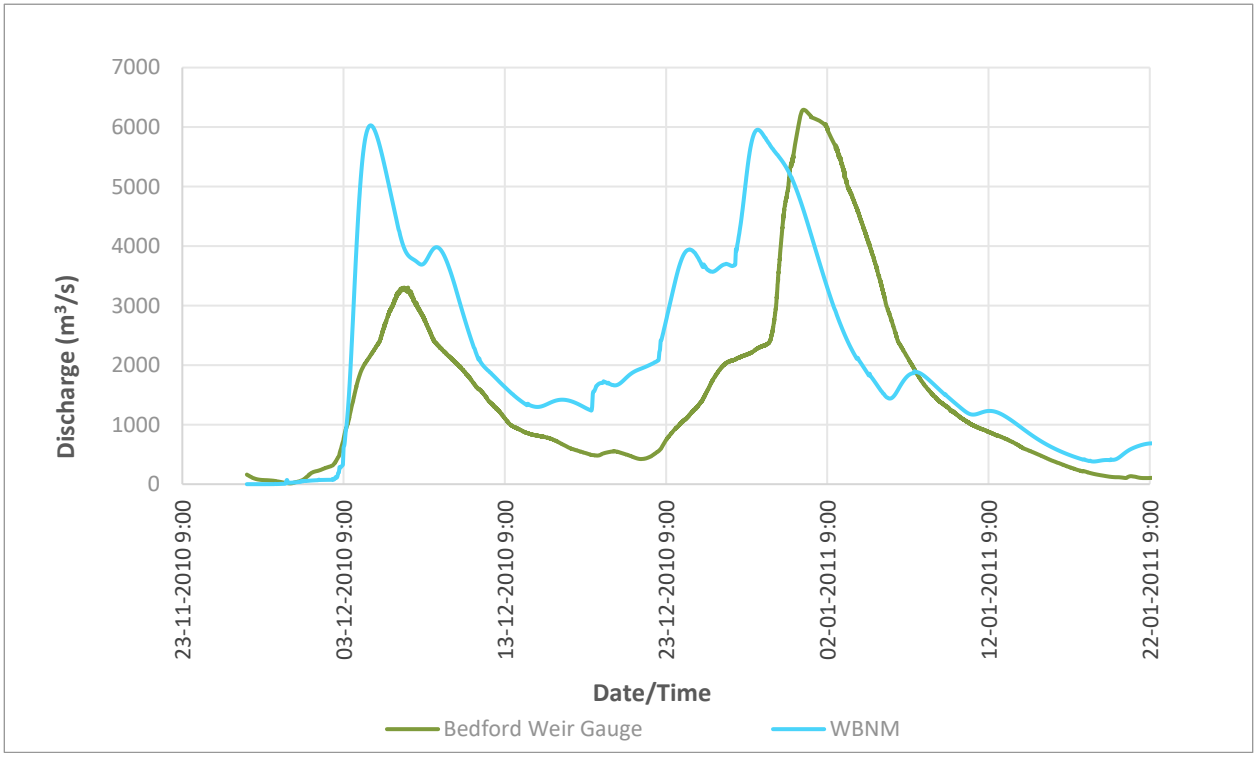



**Figure 3 Comparison of Flows for 2011 event at Bedford Weir**

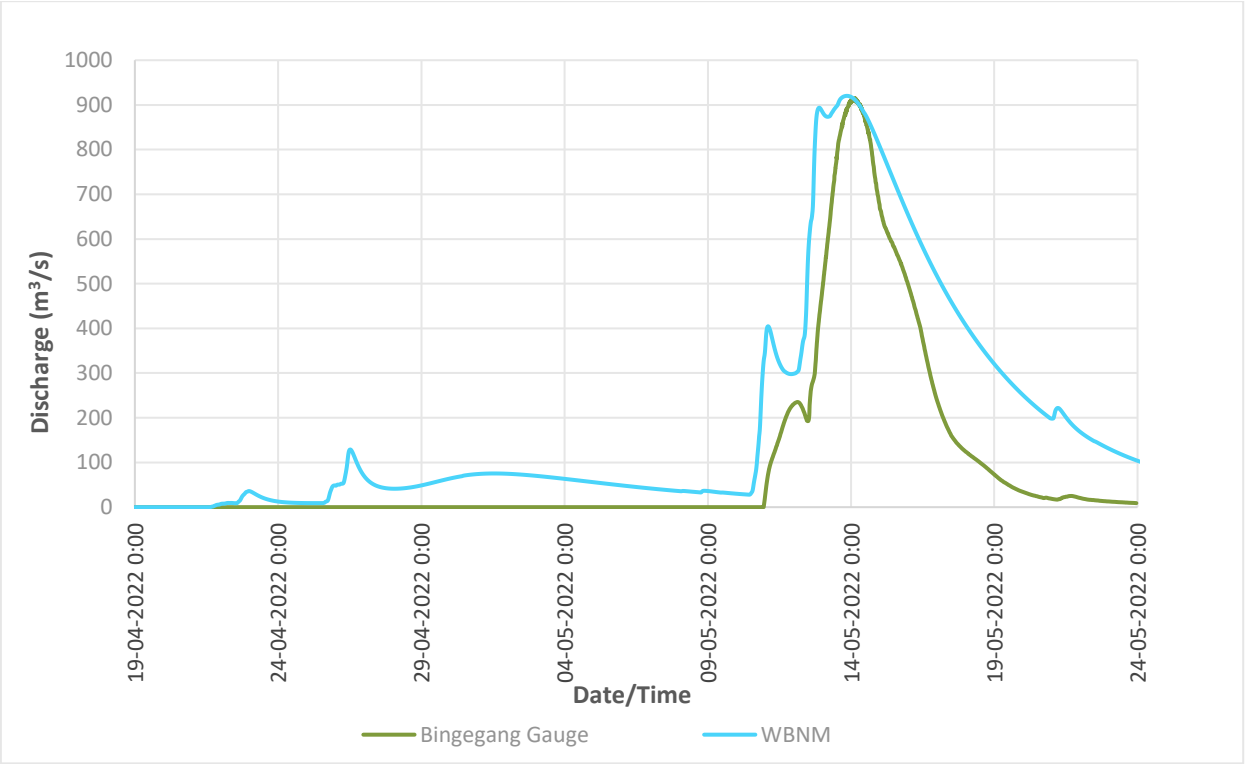



**Figure 4 Comparison of Flows for 2022 event at Bingegang Weir**

For the 2011 event, while the magnitude of the second peak is similar to the measured peak discharge at the gauge, the timing is different by approximately half a day. The first peak is over-predicted while the shape of the peak is similar to the recorded peak. As the catchment which contributes to the flow to the Bedford Weir is of a significant size and as there is large variability across the subareas, the number of sub-daily rainfall gauges may have been insufficient. The results show that there is more variability across the catchment than the WBNM model is predicting, which was also the case for the Jellinbah flood study URBS model, despite having used more gauge information.

For the 2022 event, the timing and magnitude of the peak of the modelled discharge was matched to the recorded gauge peak discharge. However, the volume of the WBNM hydrograph is much higher than the recorded data. It should be noted that, as the event was very recent, there is no quality rating for the rainfall gauge information.

**Table 8 Adopted WBNM model parameters for calibration events**

| Catchment | Lag Parameter | 2011 | | 2022 | |
|---|---|---|---|---|---|
| | | IL (mm) | CL (mm/h) | IL (mm) | CL (mm/h) |
| Nogoa | 2.6 | 20 | 3.0 | 20 | 4.0 |
| Theresa | 2.6 | 30 | 3.0 | 80 | 10.0 |
| Mackenzie | 2.6 | 60 | 1.5 | 80 | 5.0 |
| Comet | 2.6 | 60 | 2.0 | 40 | 4.0 |

The purpose of this calibration exercise was to verify that the WBNM model was able to replicate similar peak flows to historical gauge data. Calibration of a large catchment is very difficult, as demonstrated in the Jellinbah flood study (WRM, 2018), with the added complication of inaccurate rating curves to convert recorded levels to discharge. Rating curves were also investigated at Bingegang Weir and Bedford Weir using TUFLOW, and both rating curves used by Department of Regional Development, Manufacturing and Water (RDMW) were deemed to be sufficient for the purposes of this project.

## 4.5 Rating Curves

The Jellinbah flood study (WRM, 2018) discussed the inconsistencies of rating curves at length. Rating curves at three locations were checked to verify the recommended changes from the Jellinbah flood study at the following locations –Theresa Creek at Gregory Highway, Bedford Weir and Bingegang Weir. TUFLOW was used to create rating curves which modelled flows from 0 to 8000 $m^3/s$.

The gauge information at Theresa Creek showed good agreement with both the TUFLOW model rating curve and the latest rating curve information from RDMW. The Bedford Weir gauge data also showed good agreement with the TUFLOW model rating curve and rating curve from RDMW. The Bingegang Weir rating curve generated by TUFLOW differed from the RDMW rating curve and the recommended rating curve by the Jellinbah flood study, due to the TUFLOW model being based on SRTM data for model terrain. The rating curve generated by TUFLOW was more similar to the RDMW rating curve for higher flows, and therefore it was deemed appropriate for use in the FFA.

## 4.6 Flood Frequency Analysis

The size of the catchment necessitates a flood frequency analysis for the determination of peak flow rates for design events. A number of flood frequency analyses have been conducted for the gauges in this area, with varying results. In the Jellinbah flood study (WRM, 2018), two stream gauges were analysed for the FFA – Mackenzie River at Carnangarra (1974-1999), and Mackenzie River at Bingegang Weir HW (1974-2002). Mackenzie River at Carnangarra is approximately 37km upstream from Bedford Weir, and approximately 100km upstream from Bingegang Weir. The Carnangarra flows were taken as representative of flows at Bedford Weir in the Jellinbah flood study (WRM, 2018). These gauges were analysed for the period since the Fairbairn Dam was constructed.

In the Voids in Floodplain modelling report (SLR, 2021), the same gauge at Bingegang (1972-2021) was used for analysis. All analyses used a LP3 flood frequency distribution. The peak discharges predicted from these analyses are listed in **Table 9.**

**Table 9 Comparison of previously analysed FFA results**

| Event (% AEP) | Peak Discharge ($m^3/s$) | | |
|---|---|---|---|
| | **Mackenzie River at Bedford** (WRM, 2018) | **Mackenzie River at Bingegang** (WRM, 2018) | **Mackenzie River at Bingegang** (SLR, 2021) |
| 1% | 9,300 | 9,300 | 12,777 |
| 0.1% | 17,200 | - | 54,393 |
| PMF | 49,900 | - | - |

As there was a significant difference between the flow rates, further analyses were undertaken using TUFLOW FLIKE and comparing different rating curves to convert the peak water level to peak discharge.

Analysis of the data sets used for each FFA shows that different rating curves were used for each. All gauges record the water level, which is later converted to a flow rate based on a rating curve for the gauge. Whilst many gauges include recorded information to assist in the development of the rating curve, these recordings are typically for small events, with the higher flow rates determined based on theoretical equations (e.g., the weir equation if the gauge is at a weir) or hydraulic models. Calibration of hydrologic models is dependent on flow hydrographs and therefore on the rating curve for the gauge. The Jellinbah flood study FFA (WRM, 2018) noted that the rating curve may not be reliable for larger events and adjusted the rating curve based on the results of the URBS model, surmising that the URBS model predicted the more frequent events well and therefore should also predict the larger events well. This resulted in the 1978 event flow rate at Bingegang (the largest recorded event) being adjusted from approximately 8000 $m^3/s$ to 5500 $m^3/s$. This, in turn, resulted in a significant reduction in the flow rates determined using the FFA for the 1%, 0.1% and PMF events.

It should be noted that information from 2003 to 2013 is missing from the Bingegang gauge. It is known that two large flood events occurred in this time – in 2008 and 2011. The Bingegang FFA results are shown in **Figure 5**.

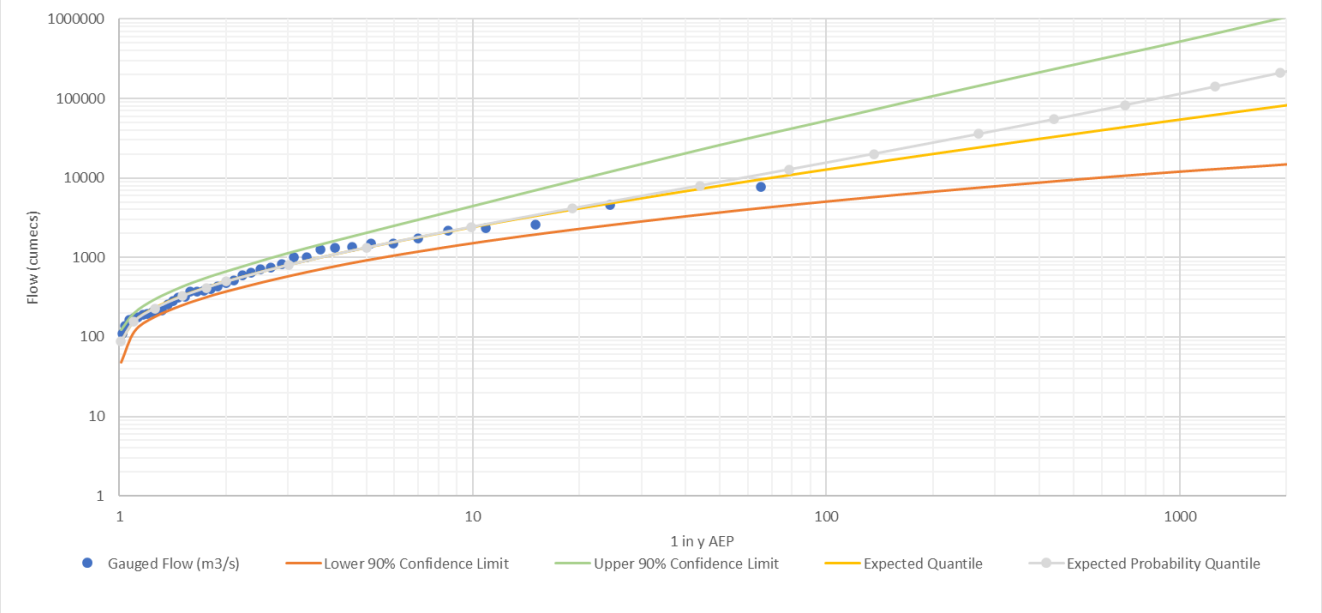



**Figure 5 Flood Frequency Analysis at Bingegang Weir**

Based on the results of this assessment, it was considered that there is insufficient recorded data available to determine the peak flow rate for rare events. As shown above, the error bands for the 0.1% AEP event are more than an order of magnitude. It was considered appropriate to adopt the 1% AEP peak flow rate based on the FFA. However, beyond this, it was considered that the WBNM model, which resulted in a 1% AEP peak flow rate within an acceptable range of the flow determined using the FFA, was the most appropriate method for determining the peak flow rates for rarer events.

## 4.7 Regional Flood Frequency Estimation

Regional Flood Frequency Estimation (RFFE) is not suitable for this catchment due to the significant catchment size. RFFE is recommended for catchments between 0.5km$^2$ and 1000km$^2$. Additionally, catchments with multiple dams and weirs are not suitable for RFEE. In the Mackenzie River catchment, there are multiple weirs and Fairbairn Dam is located downstream of the Nogoa River catchment.

## 4.8 Design Events

### 4.8.1 Intensity-Frequency-Duration Rainfall Data

Rainfall Intensity-Frequency-Duration (IFD) data for the model was obtained from the Bureau of Meteorology (BoM) for a range of AEP events. The catchment was split into 7 zones – Mackenzie, Upper Nogoa, Theresa, Lower Nogoa, Upper Comet, Lower Comet, and Emerald. The adopted design rainfalls for Mackenzie are listed as an example in **Table 10**. All IFD data are listed in **Appendix A**. Refer to **Figure 2** to show the split of the catchments to IFD zones.

**Table 10 IFD Rainfall Data**

| Mackenzie Storm Duration | Rainfall depth (mm) | |
|---|---|---|
| | 1% | 0.1% |
| 6 hour | 144 | 220 |
| 9 hour | 163 | 279 |
| 12 hour | 178 | 305 |
| 18 hour | 203 | 346 |
| 24 hour | 223 | 380 |
| 30 hour | 240 | 413 |
| 36 hour | 255 | 439 |
| 48 hour | 280 | 476 |
| 72 hour | 315 | 521 |
| 96 hour | 335 | 548 |
| 120 hour | 347 | 565 |
| 144 hour | 352 | 577 |

### 4.8.2 Losses

Initial and continuing losses were obtained from ARR Data Hub. The global initial loss adopted was 65mm and continuing loss was 1.1 mm/h. For the 0.1% AEP and PMP events, initial loss of 0mm was adopted. The initial loss for each storm duration is calculated by subtracting the median pre-burst rainfall depth from the global catchment initial loss, as outlined by ARR2019.

### 4.8.3 Lag Parameter

The WBNM manual recommends a lag parameter of between 1.3 and 1.8 for most catchments. As mentioned in **Section 4.2**, some of the adopted model parameters in URBS were outside the recommended values, which suggested that this model required atypical model parameters in order to produce realistic peak flows. This proved to be correct when the peak flows with default losses were producing significantly higher flows compared to the peak flows predicted from the Flood Frequency Analysis (FFA) (refer to **Section 4.5**) when using a lag parameter of 1.8. The lag parameter of 2.6 was chosen to produce a 1% AEP design peak flow that matched the peak flow from the FFA. The FFA is discussed in **Section 4.5.** Historical event calibration was also undertaken with the same lag parameter of 2.6, with acceptable results.

### 4.8.4 Areal Reduction Factor

Areal reduction factors (ARF) are required under ARR2019 as design rainfall IFDs are based on specific points in a catchment rather than the whole catchment, and these point rainfall intensities are not representative of the areal average rainfall intensity across the catchment. The ARFs represent the ratio between the areal average rainfall and point rainfall for the same AEP and storm duration. ARFs are calculated based on the catchment area, AEP, and storm duration. As there are two main inflows for the project site, Mackenzie River and Blackwater Creek, the ARFs needed to be calculated separately due to the difference in magnitude of the contributing catchments (i.e., the larger Mackenzie River catchment is less likely to have high intensity storms across the whole catchment than the smaller Blackwater Creek catchment).

According to ARR2019, for catchments larger than 30,000 $km^2$, the generalised equations for areal reduction factor (ARF) in ARR2019 do not apply. ARR2019 recommends that a flood frequency analysis for catchment rainfall data be undertaken.

The following approach was taken:

- The ARFs using 30,000$km^2$ was adopted for Mackenzie River inflow, checking that the values aligned with the FFA peak flows; and
- The ARFs using 1024$km^2$ were adopted for the MAC_Z1 subarea (which contains Blackwater, Bullock, and Sagittarius Creeks). The adopted ARFs are listed in **Table 11**.

**Table 11 WBNM Areal Reduction Factor**

| Storm Duration | ARF 1% AEP | | ARF 0.1% AEP | |
|---|---|---|---|---|
| | Mackenzie River | Blackwater Creek | Mackenzie River | Blackwater Creek |
| 18 hour | 0.597 | 0.877 | 0.558 | 0.876 |
| 24 hour | 0.633 | 0.891 | 0.593 | 0.889 |
| 30 hour | 0.652 | 0.898 | 0.612 | 0.897 |
| 36 hour | 0.667 | 0.904 | 0.627 | 0.903 |
| 48 hour | 0.689 | 0.912 | 0.648 | 0.911 |
| 72 hour | 0.717 | 0.923 | 0.676 | 0.921 |
| 96 hour | 0.735 | 0.929 | 0.693 | 0.928 |
| 120 hour | 0.747 | 0.934 | 0.705 | 0.933 |
| 144 hour | 0.757 | 0.938 | 0.714 | 0.936 |

### 4.8.5 Temporal Patterns

In accordance with ARR 2019, areal temporal patterns were used for the 1% AEP event, for the 40,000km$^2$ catchment area for the Mackenzie River inflow. It should be noted that 40,000km$^2$ catchment area is the largest available in ARR2019 for areal temporal patterns. For the events for the Blackwater Creek catchment, the areal temporal pattern for 1000km$^2$ was adopted. For the 0.1% AEP event, the GTSMR temporal patterns were applied; AVM60000 for Mackenzie River and AVM1000 for Blackwater Creek.

### 4.8.6 Storm Events

The WBNM model was run for the 1%, 0.1% AEP and PMP events. A range of storm durations between 6 and 144 hours were analysed for the 1% AEP and between 24 and 120 hours for the 0.1% AEP and PMP events.

### 4.8.7 Probable Maximum Flood Analysis

As the Mackenzie River catchment is larger than 1000km$^2$, short duration PMP estimates cannot be calculated. The Generalised Tropical Storm Method Revised (GTSMR) was used to estimate PMP depths for the 24 hour, 36 hour, 48 hour, 72 hour and 96 hour and 120 hour storm durations.

Analyses were done for both Mackenzie River and Blackwater Creek. They are located in the GTSMR Coastal Zone. The adopted parameters are provided in **Table 12** and the PMP rainfall depth estimates are listed in **Table 13.**

**Table 12 GTSMR Parameters**

| Parameter | Mackenzie River | Blackwater Creek |
|---|---|---|
| Moisture Adjustment Factor (MAF) | 0.727 | 0.735 |
| Topographical Adjustment Factor (TAF) | 1.03 | 1.0 |
| Decay Amplitude Factor (DAF) | 0.967 | 0.998 |
| Standard Area (km$^2$) | 60000 | 1000 |

**Table 13 PMP Rainfall Estimates**

| Storm Duration (h) | PMP Rainfall Depth (mm) | |
|---|---|---|
| | Mackenzie River | Blackwater Creek |
| 24 | 410 | 910 |
| 36 | 510 | 1080 |
| 48 | 620 | 1240 |
| 72 | 760 | 1510 |
| 96 | 840 | 1710 |
| 120 | 870 | 1800 |

## 4.9 Adopted Peak Flows

The adopted design flows for the 1% AEP, 0.1% AEP, and PMF events for Mackenzie River are listed in **Table 14**.

**Table 14 Adopted Peak Design Flows**

| Event | Peak flow at MAC_AA1 ($m^3/s$) [Equivalent to Bingegang Weir location] | Peak flow into TUFLOW model ($m^3/s$) [MAC_Q1] |
|---|---|---|
| 1% AEP | 12,816 | 11,997 |
| 0.1% AEP | 28,412 | 26,742 |
| PMF | 95,080 | 87,338 |

# 5 Hydraulic Assessment

## 5.1 Software

A hydraulic model was developed for the purpose of assessing the post-mining flood extent. The industry standard hydrodynamic modelling software TUFLOW (Build 2020-10-AD) was utilised for the 2D hydraulic modelling. The TUFLOW Heavily Parallelised Compute (HPC) solution scheme was adopted in this project to minimise the model simulation time. Details of the model setup, methodology and results are provided in the following sections.

## 5.2 Model Setup

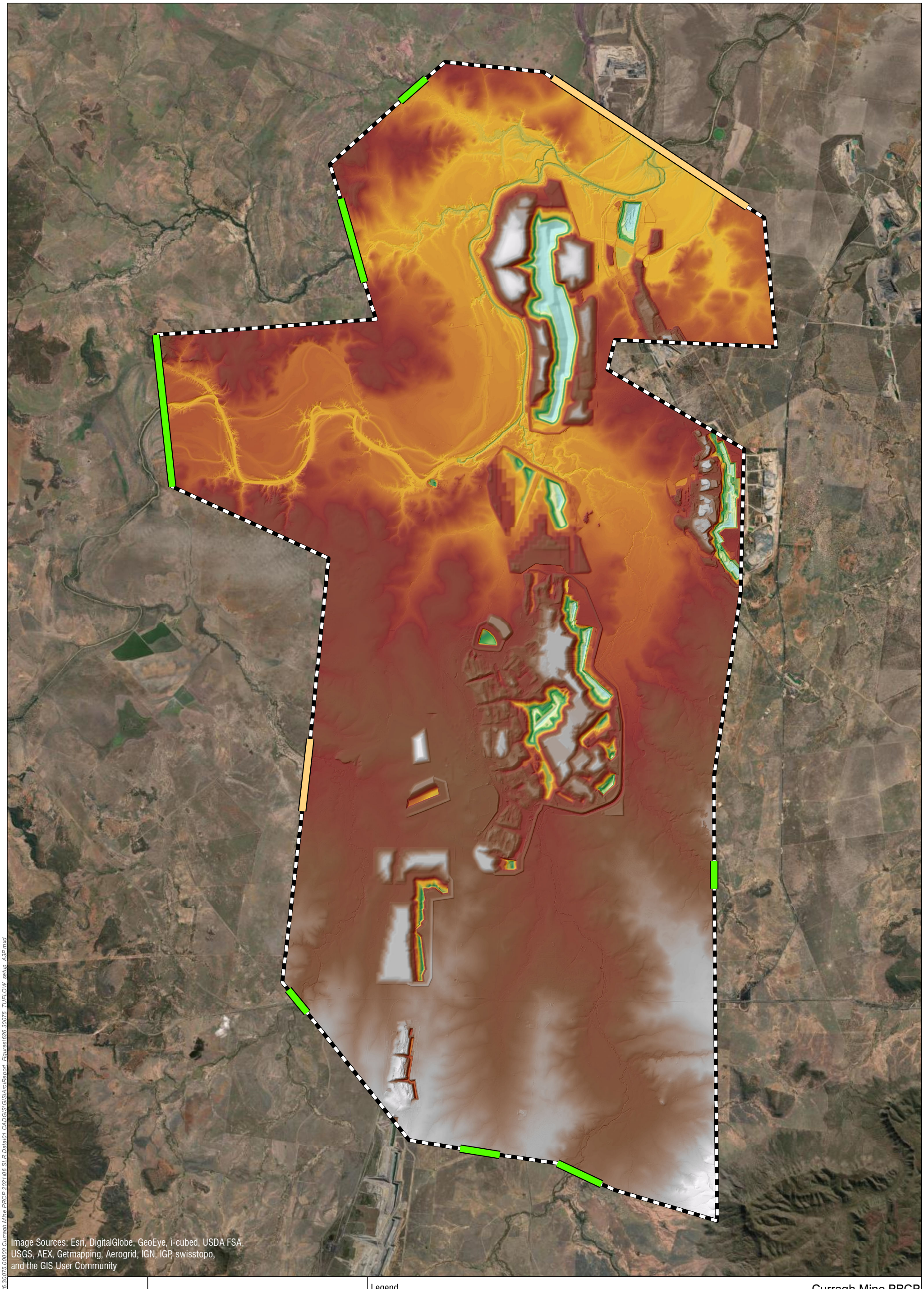
### 5.2.1 Topography

The residual void DEM (as supplied Nov 2021 and provided Sept 2022 for Curragh North and X Pit) was utilised as the topography for the hydraulic modelling. A grid cell size of 20 metres was adopted for the model. The model domain and DEM data are shown in **Figure 6**.

Post-mining contour data was processed into a 5-metre spaced Digital Elevation Model (DEM). To create the residual void landform used in the floodplain modelling, the processed residual void DEM (which incorporated available 1m LiDAR) was overlaid on 1m LiDAR from CCPL. A long-term stable embankment has been incorporated into the residual void landform to provide flood immunity to the residual voids up to the 0.1% AEP event.

### 5.2.2 Hydraulic Roughness

The hydraulic roughness for the model was adopted based on available Queensland Globe aerial imagery and the model landform. The adopted land use types are consistent with the current catchment characteristics. The Manning's roughness values adopted for the various land use types in the assessment are shown in **Table 15**. The model hydraulic roughness is shown in **Figure 7**.




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- Downstream Boundaries
- Inflow Boundaries
- TUFLOW Model Extent

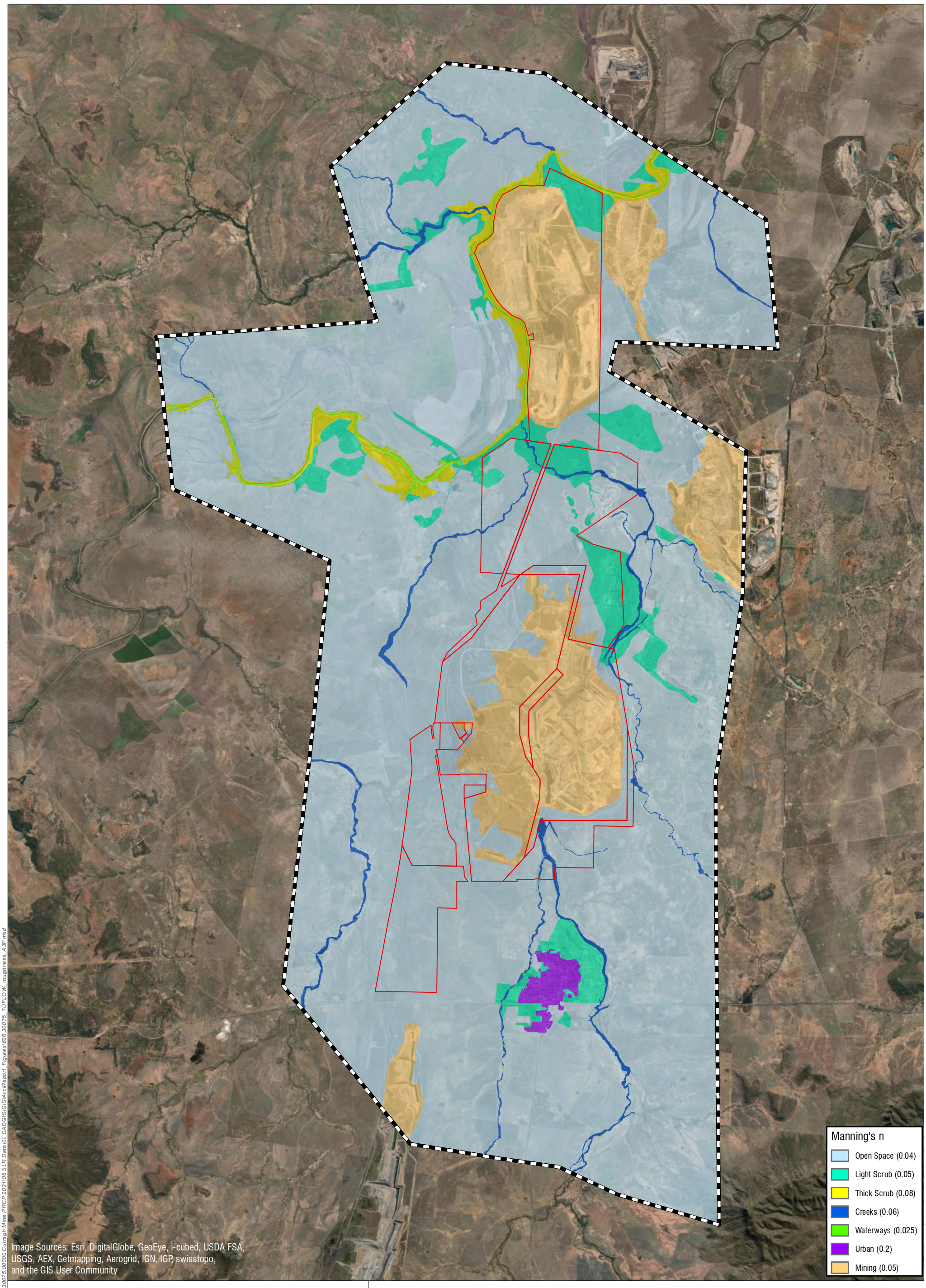
Topography (mAHD)
High : 230
Low : 40

Curragh Mine PRCP
Flood Assessment

**TUFLOW Model Layout**

**Figure 6**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\GIS\ArcReport Figures\626.30075 TUFLOW setup A3P.mxd




H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\GIS\ArcIReport_Figures\626.30075_TUFLOW_roughness_A3P.mxd

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Curragh Mine Lease

TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

**TUFLOW Model Hydraulic Roughness**

**Figure** 7

**Table 15 TUFLOW Manning's n Values**

| Land use | Manning's n |
|---|---|
| Creek | 0.06 |
| Waterways | 0.025 |
| Grassland | 0.04 |
| Light Scrub | 0.05 |
| Thick Scrub | 0.08 |
| Mining and rehabilitated area | 0.05 |
| Urban | 0.2 |

### 5.2.3 Inflows

Inflows were adopted from the WBNM model outputs. The hydrographs were applied as inflow boundaries as 2D boundary condition lines for the Mackenzie River, Blackwater Creek, Burngrove Creek, and Sagittarius Creek on the model domain as shown in **Figure 6**. The smaller inflows were split according to catchment area.

### 5.2.4 Downstream Boundaries

The downstream boundaries adopted for the Conceptual Residual Void Assessment TUFLOW model were maintained. The location was chosen to ensure that the boundary condition would not impact flood behaviour in the areas of interest. Boundaries were positioned on Burngrove Creek on the western side and Mackenzie River on the northern boundary of the site. A stage-discharge relationship was applied as the tailwater condition for the 2D model domain, with the water surface gradient equivalent to the ground surface slope in the vicinity of the boundaries. Based on the post-mining landform data, slopes of 0.004% and 0.2% were used for the boundary locations for Burngrove Creek and Mackenzie River respectively. Downstream boundaries are shown in **Figure 6**. A sensitivity test was also undertaken for the downstream slope for the Mackenzie River, testing 0.1% and 0.4% slope, and this showed no significant changes in water level for the areas of interest.

### 5.2.5 Critical Duration Assessment

As recommended by ARR2019, several design storm events per AEP event were simulated in the hydraulic models (one duration either side of the hydrological critical duration, where possible). The critical durations for Mackenzie River and Blackwater Creek are listed in **Table 16**.

**Table 16 Critical Storm Durations**

| | AEP Events | | |
|---|---|---|---|
| Watercourse | 1% | 0.1% | PMF |
| Mackenzie River | 120h | 48h | 72h |
| Blackwater Creek | 96h | 24h | 24h |

# 6 Results

Peak water surface levels, depths, velocities, and bed shear stress for each AEP are mapped in **Appendix B**.

## 6.1 Flood Ingress to voids

The results show that all voids are not subject to inundation in the AEP events assessed for events up to and including the 0.1% AEP, as required by PRCP guidelines. Inundation of Curragh North, X Pit West, X Pit East, E Pit, C Pit, B Pit, H Pit, and J Pit occurs in the PMF. Refer to Figures B1-3, B2-3 for the peak flood level and depths respectively.

A summary of the modelled 0.1% AEP flood levels and velocities for each of the points is provided in **Table 17**. The location of the points is shown in **Figure 8.**

**Table 17 Maximum Surface Water Elevations and Velocities**

| Void Name | 0.1% AEP Indicative Water Level (mAHD) | PMF Indicative Water Level (mAHD) | 0.1% AEP Average Velocity (m/s) |
|---|---|---|---|
| D Pit | 140.34 | 142.06 | 0.5-1.8 |
| F Pit | 148.03 | 149.18 | 1.0-3.1 |
| F Pit N/ E Pit N* | 144.83 | 145.49 | 3.0-4.7 |
| J Pit* | 158.16 | 163.71 | 0.5-1.7 |
| K Pit | 153.39 | 158.22 | 2.2-5.6 |
| L Pit* | 149.98 | 152.54 | 2.0-3.3 |
| S Pit (Curragh North) | 134.93 | 140.68 | 0.5-0.9 |
| U Pit (Curragh North) | 127.78 | 131.69 | 0.5-1.6 |
| X Pit East | 134.93 | 140.68 | 0.5-3.3 |
| X Pit West | 134.93 | 140.68 | 0.5-2.0 |
| X Pit SE* | 134.93 | 140.68 | 0.5-1.0 |
| Y Pit* | 157.53 | 158.61 | 0.5-1.5 |
| Z Pit North | 164.37 | 165.64 | 0.5-1.7 |
| Z Pit South | 169.08 | 170.49 | 0.5-1.4 |

* Note that these points have been moved from their previous position in the Voids in Floodplain Modelling assessment (SLR, 2021) as they were no longer inundated in the current assessment

It should be noted that the proposed modifications to the floodplain due to progression of mining on adjacent mining leases is outside the control of CCPL and it may have impacts to the Curragh site. It is recommended that further assessment be undertaken as the information becomes available to determine whether any impacts are exacerbated.

Based on the results of the model, flooding in Mackenzie River and Blackwater Creek will not result in inundation of the final voids which could impact their structural integrity for events up to the 0.1% AEP.

## 6.2 Scour and Erosion Potential

The ACARP 2002 Guidelines provide indicative parameter thresholds for scour potential in diversions in the Bowen Basin. The criteria, which is provided in **Table 18**, is directed towards diversion design, which is not the purpose of this assessment, however also provides general indication of scour and erosion potential in all waterways in the Bowen Basin and was therefore utilised in the analysis of the hydraulic model results.

The stability of the proposed landform was assessed by considering the bed shear stress and velocities in the vicinity of the landforms. There is no guideline relating to bed shear stress for events larger than 2% AEP in the ACARP guidelines.

**Table 18 Guideline values for average shear stress and velocity for streams within the Bowen Basin (ACARP C8030 – Maintenance of Geomorphic Processes in Bowen Basin River Diversions)**

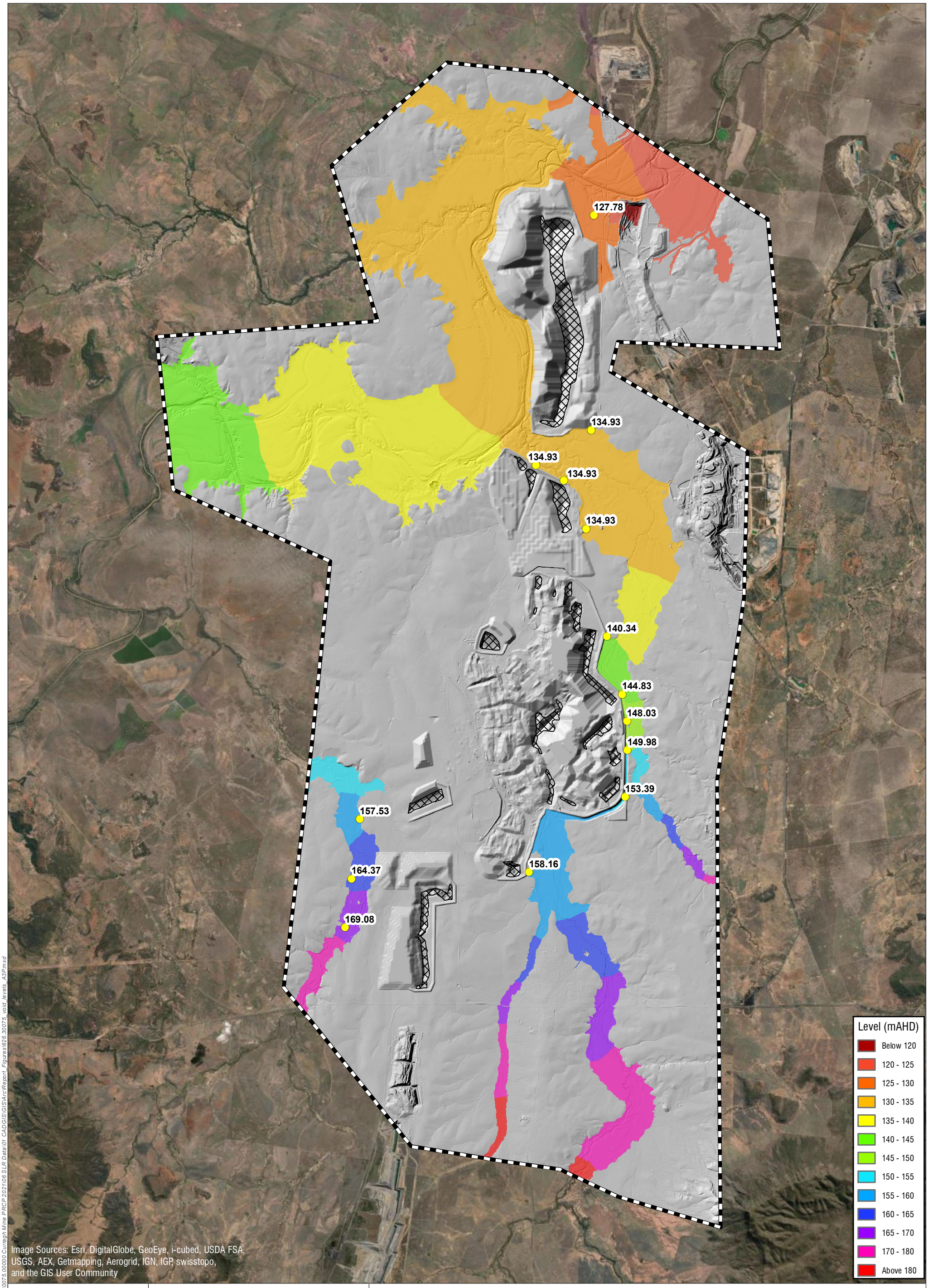
| Parameter | 2% AEP |
|---|---|
| Shear Stress ($N/m^2$) | < 80 |
| Velocity (m/s) | < 2.5 |

The shear stresses predicted for the 1% AEP in this assessment are generally below the values in the ACARP guidelines. The high shear stress values are localised and located within the waterways. The same can be said for velocities in the 1% AEP event, where the velocities are generally lower than 2.5m/s apart from in the waterways. The shear stress and velocities are high in the Blackwater Creek diversion (velocities up to 2.8m/s and bed shear stress of up to 400 $N/m^2$), however the diversion is considered stable in its current form. Ongoing monitoring of the diversion may be required in accordance with legislative requirements.

For the larger events (0.1% AEP and PMF), more breakouts from the waterways are evident and higher velocities and bed shear stress are predicted, especially north of Curragh North, where the Blackwater Creek flow has joined Mackenzie River. However, high velocity values are not near the landforms in the 0.1% AEP in this area and therefore are unlikely to affect the erosion susceptibility of the landforms. Velocities of up to 3m/s are predicted for the Blackwater Creek diversion adjacent to landforms for the 0.1% AEP. It should be noted however that erosion potential of creek diversions is assessed based on 2% AEP and 50% AEP events, and there is no guideline relating to 0.1% AEP velocity values.

Based on the results of the flood modelling undertaken, the main outcomes are:

- All pits are not inundated in events up to and including the 0.1% AEP, as required by PRCP guidelines;
- Scour and erosion potential of landforms is low for the 1% AEP, as high shear stresses and velocities occur in localised areas within the watercourses;
- Inundation of Curragh North, X Pit West, X Pit East, E Pit, C Pit, B Pit, H Pit, and J Pit occurs in the PMF event (Note there are no requirements that pits be flood free in a PMF event);
- High velocities and bed shear stress are predicted within the Blackwater Creek diversion, which may require ongoing monitoring in accordance with legislative requirements;
- High velocities and bed shear stress are predicted in the 0.1% AEP and PMF events north of Curragh North.




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Legend

- Extraction Points
- Residual Void Extent
- TUFLOW Model Extent

# Curragh Mine PRCP Flood Assessment

## 0.1% AEP Peak Flood Levels

Figure 8

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# 7 Conclusions

SLR was contracted by CCPL to support the preparation of the Curragh Mine Progressive Rehabilitation and Closure Plan (PRCP). The assessment detailed in this report was undertaken specifically to address Section 3.6.1 of the PRCP Guideline, which relates to the analysis of flooding as part of the PRCP.

A model landform was developed for the project, which was based on the post-mining surface provided by CCPL and included the proposed final voids.

A hydrological model was developed using SRTM topographical data for the Mackenzie River catchment. The model was calibrated using recorded stream flow data for Mackenzie River for two historical events. A range of hydrological analyses including FFA and rating curve generation utilising TUFLOW were undertaken to evaluate the peak flows for the Mackenzie River catchment.

A hydraulic model was updated from the modelling previously developed in the Voids in Floodplain Modelling assessment (SLR, 2021) with updated LiDAR dated 2021 provided by CCPL. The hydraulic model covers Mackenzie River and Blackwater Creek and was based on the model landform for the purpose of assessing the post-mining flooding conditions in accordance with Section 3.6.1 of the PRCP Guideline.

The results of the hydraulic modelling showed that inundation of the pits does not occur for the 0.1% AEP event as required by the PRCP Guideline. Inundation of Curragh North, X Pit West, X Pit East, E Pit, C Pit, B Pit, H Pit, and J Pit occurs for the PMF event, with the remainder of the pits not inundated for this event. The hydraulic results also suggest that the landforms are not likely to be prone to erosion for up to the 0.1% AEP event.

# APPENDIX A IFD DATA

| Mackenzie (Lat -23.260, Long 148.72) | Rainfall depth (mm) | |
|---|---|---|
| Storm Duration | 1% | 0.1% |
| 6 hour | 144 | 220 |
| 9 hour | 163 | 279 |
| 12 hour | 178 | 305 |
| 18 hour | 203 | 346 |
| 24 hour | 223 | 380 |
| 30 hour | 240 | 413 |
| 36 hour | 255 | 439 |
| 48 hour | 280 | 476 |
| 72 hour | 315 | 521 |
| 96 hour | 335 | 548 |
| 120 hour | 347 | 565 |
| 144 hour | 352 | 577 |

| Upper Nogoa (Lat -24.52, Long 147.22) | Rainfall depth (mm) | |
|---|---|---|
| Storm Duration | 1% | 0.1% |
| 6 hour | 140 | 201 |
| 9 hour | 158 | 227 |
| 12 hour | 173 | 248 |
| 18 hour | 197 | 283 |
| 24 hour | 216 | 311 |
| 30 hour | 232 | 341 |
| 36 hour | 246 | 365 |
| 48 hour | 269 | 401 |
| 72 hour | 301 | 445 |
| 96 hour | 322 | 470 |
| 120 hour | 335 | 486 |
| 144 hour | 344 | 495 |

| Lower Nogoa (Lat -24.06, Long 147.74) | Rainfall depth (mm) | |
|---|---|---|
| Storm Duration | 1% | 0.1% |
| 6 hour | 152 | 221 |
| 9 hour | 171 | 247 |
| 12 hour | 185 | 269 |
| 18 hour | 209 | 304 |
| 24 hour | 229 | 334 |
| 30 hour | 246 | 368 |
| 36 hour | 261 | 394 |
| 48 hour | 285 | 432 |
| 72 hour | 320 | 475 |
| 96 hour | 343 | 500 |
| 120 hour | 357 | 516 |
| 144 hour | 364 | 528 |

| Upper Comet (Lat -24.81, Long 148.55) | Rainfall depth (mm) | |
|---|---|---|
| Storm Duration | 1% | 0.1% |
| 6 hour | 164 | 236 |
| 9 hour | 186 | 267 |
| 12 hour | 203 | 292 |
| 18 hour | 228 | 328 |
| 24 hour | 247 | 356 |
| 30 hour | 262 | 388 |
| 36 hour | 274 | 410 |
| 48 hour | 294 | 437 |
| 72 hour | 322 | 464 |
| 96 hour | 342 | 482 |
| 120 hour | 357 | 498 |
| 144 hour | 370 | 515 |

| Lower Comet (Lat -24.06, Long 148.62) | Rainfall depth (mm) | |
|---|---|---|
| Storm Duration | 1% | 0.1% |
| 6 hour | 156 | 224 |
| 9 hour | 175 | 251 |
| 12 hour | 190 | 273 |
| 18 hour | 214 | 307 |
| 24 hour | 231 | 332 |
| 30 hour | 246 | 355 |
| 36 hour | 258 | 372 |
| 48 hour | 277 | 398 |
| 72 hour | 303 | 431 |
| 96 hour | 321 | 453 |
| 120 hour | 333 | 470 |
| 144 hour | 342 | 484 |

| Emerald (Lat -24.39, Long 148.22) | Rainfall depth (mm) | |
|---|---|---|
| Storm Duration | 1% | 0.1% |
| 6 hour | 154 | 222 |
| 9 hour | 173 | 250 |
| 12 hour | 188 | 271 |
| 18 hour | 210 | 304 |
| 24 hour | 228 | 329 |
| 30 hour | 242 | 358 |
| 36 hour | 254 | 378 |
| 48 hour | 273 | 405 |
| 72 hour | 301 | 436 |
| 96 hour | 320 | 456 |
| 120 hour | 335 | 473 |
| 144 hour | 346 | 489 |

| Theresa (Lat -23.06, Long 147.70) | Rainfall depth (mm) | |
|---|---|---|
| Storm Duration | 1% | 0.1% |
| 6 hour | 153 | 226 |
| 9 hour | 174 | 256 |
| 12 hour | 190 | 280 |
| 18 hour | 217 | 320 |
| 24 hour | 239 | 353 |
| 30 hour | 257 | 384 |
| 36 hour | 273 | 409 |
| 48 hour | 300 | 449 |
| 72 hour | 338 | 503 |
| 96 hour | 363 | 537 |
| 120 hour | 379 | 558 |
| 144 hour | 389 | 572 |

# APPENDIX B FLOOD MODELLING RESULTS

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Level (m AHD)
- Below 120
- 120 - 125
- 125 - 130
- 130 - 135
- 135 - 140
- 140 - 145
- 145 - 150
- 150 - 155
- 155 - 160
- 160 - 165
- 165 - 170
- 170 - 180
- Above 180

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07-Sep-2022 Scale: 1:150,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

# Curragh Mine PRCP Flood Assessment

## PRCP Conditions (E11) Peak Flood Levels - 1% AEP

APPENDIX B1-1

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Level (m AHD)
- Below 120
- 120 - 125
- 125 - 130
- 130 - 135
- 135 - 140
- 140 - 145
- 145 - 150
- 150 - 155
- 155 - 160
- 160 - 165
- 165 - 170
- 170 - 180
- Above 180

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E12)**
**Peak Flood Levels - 0.1% AEP**

**APPENDIX B1-2**

Level (m AHD)
- Below 120
- 120 - 125
- 125 - 130
- 130 - 135
- 135 - 140
- 140 - 145
- 145 - 150
- 150 - 155
- 155 - 160
- 160 - 165
- 165 - 170
- 170 - 180
- Above 180

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Sheet Size : A3 AGD 1966 AMG Zone 55

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E12)**
**Peak Flood Levels - PMP**

**APPENDIX B1-3**

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Depth (m)
- Below 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 8
- 8 - 10
- Above 10

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Sheet Size : A3 AGD 1966 AMG Zone 55

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E11)**
**Peak Flood Depths - 1% AEP**

**APPENDIX B2-1**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Arc\AutoMapping\v02\Output\MXDs\626.30075_APPENDIX B2-1_E11_01p_d.mxd

Depth (m)
- Below 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 8
- 8 - 10
- Above 10

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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07-Sep-2022 Scale: 1:150,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E12)**
**Peak Flood Depths - 0.1% AEP**

**APPENDIX B2-2**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Arc\AutoMapping\v02\Output\MXDs\626.30075_APPENDIX B2-2_E12_1in1000_d.mxd

Depth (m)
- Below 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 8
- 8 - 10
- Above 10

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

SLR
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0 2,000 4,000 6,000 8,000 Metres

07-Sep-2022 Scale:1:150,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E12)**
**Peak Flood Depths - PMP**

**APPENDIX B2-3**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Arc\AutoMapping\v02\Output\MXDs\626.30075 APPENDIX B2-3 E12 PMP d.mxd

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Velocity (m/s)
- Below 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- Above 3.5

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07-Sep-2022 Scale: 1:150,000

Sheet Size : A3 AGD 1966 AMG Zone 55

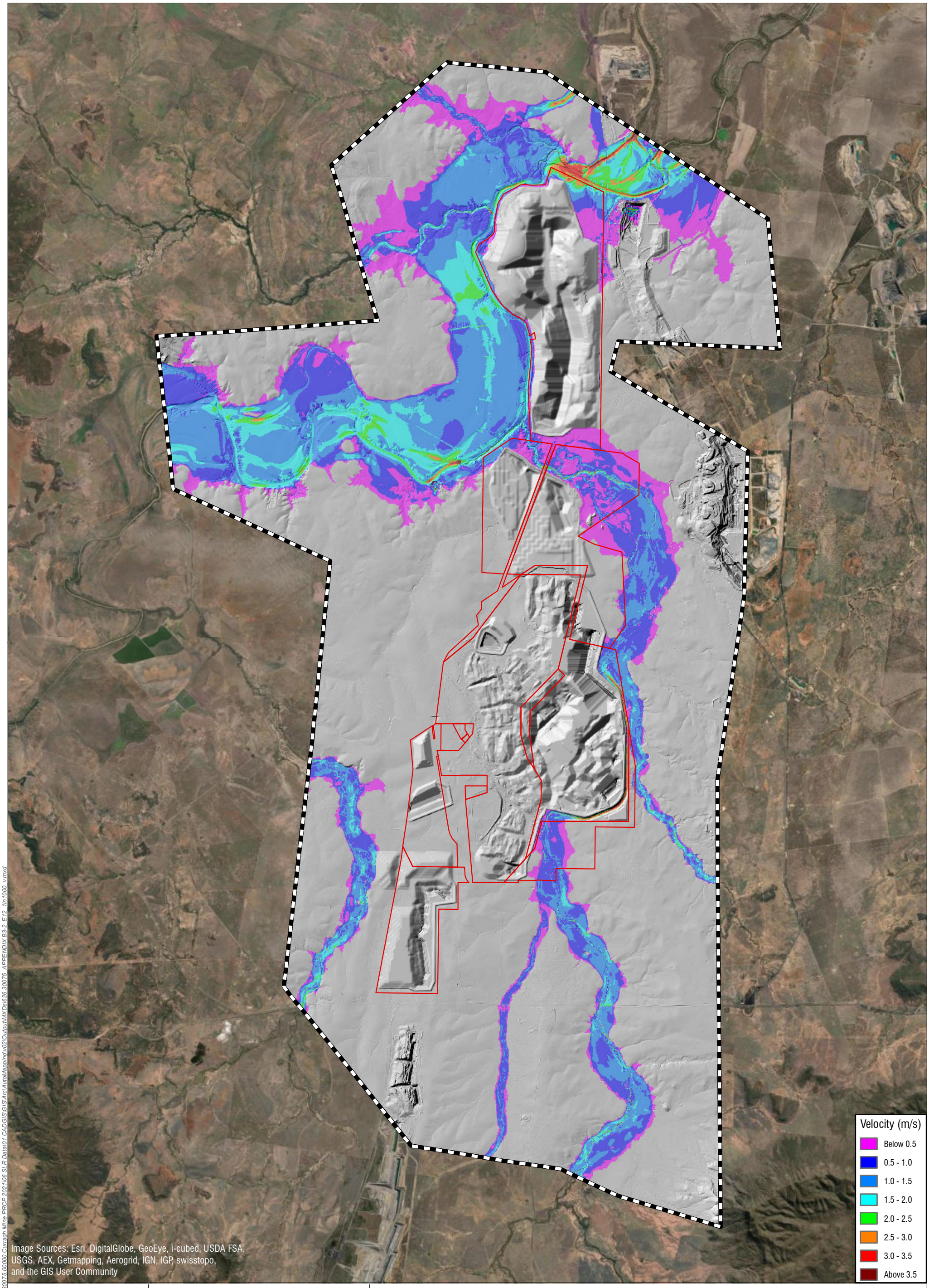
Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E11)**
**Peak Flood Velocities - 1% AEP**

**APPENDIX B3-1**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\ArcIAutoMapping\v02\Output\MXDs\626.30075_APPENDIX B3-1_E11_01p_v.mxd




H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v02\OutputMXDs\626.30075_APPENDIX B3-2_E12_1in1000_v.mxd

SLR

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0 2,000 4,000 6,000 8,000 Metres

07-Sep-2022 Scale: 1:150,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E12)**
**Peak Flood Velocities - 0.1% AEP**

**APPENDIX B3-2**

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Velocity (m/s)
- Below 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- Above 3.5

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

0 2,000 4,000 6,000 8,000 Metres

07-Sep-2022 Scale: 1:150,000

Sheet Size : A3 AGD 1966 AMG Zone 55

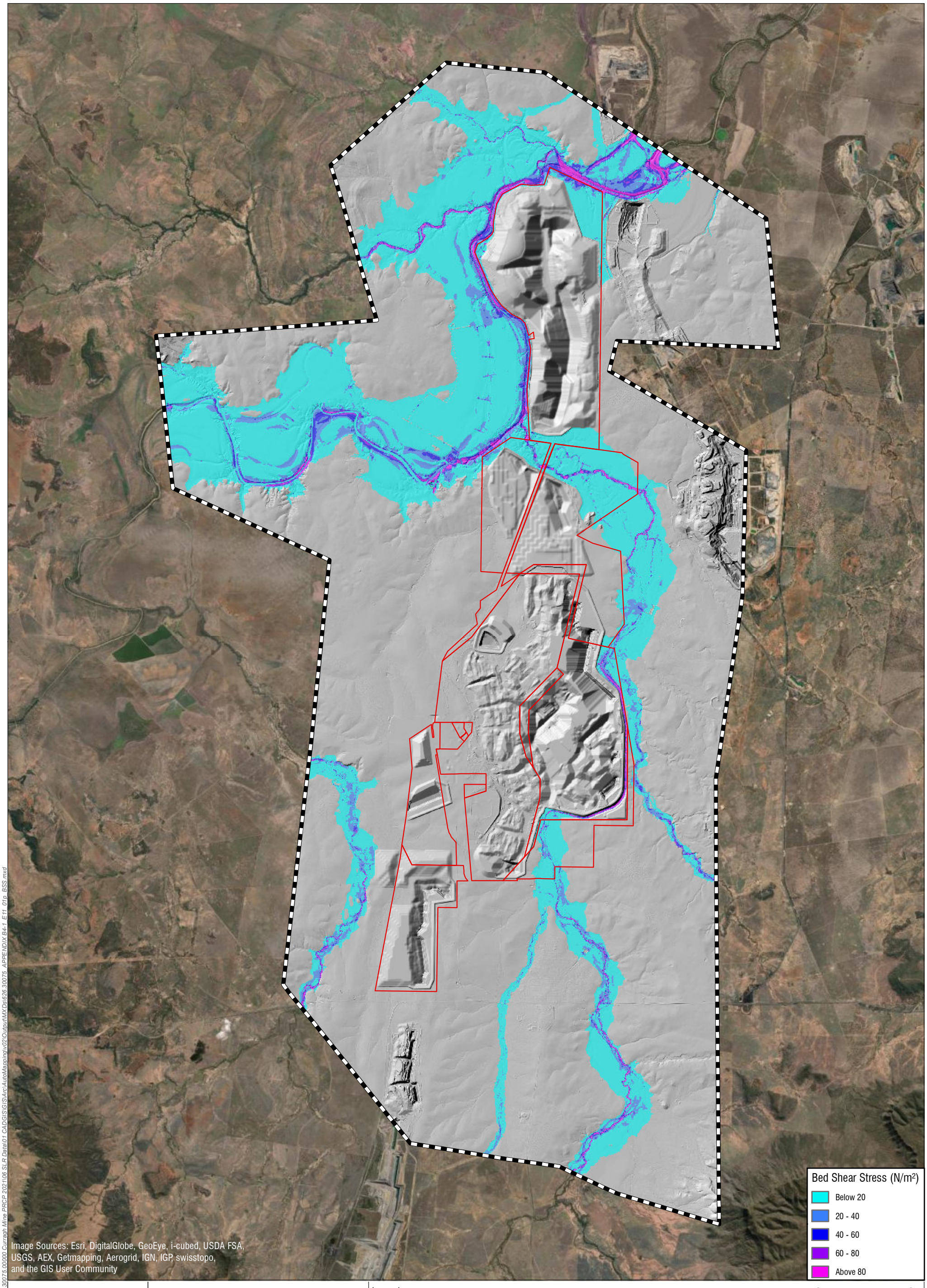
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Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E12)**
**Peak Flood Velocities - PMP**

**APPENDIX B3-3**

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0 2,000 4,000 6,000 8,000 Metres

07-Sep-2022 Scale:1:150,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E11)**
**Peak Flood Bed Shear Stress - 1% AEP**

**APPENDIX B4-1**

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

0 2,000 4,000 6,000 8,000 Metres

07-Sep-2022 Scale: 1:150,000

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Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E12)**
**Peak Flood Bed Shear Stress - 0.1% AEP**

**APPENDIX B4-2**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211\06 SLR Data\01 CADGIS\GIS\ArcAutoMappingIv02\OutputMXDs\626.30075_APPENDIX B4-2_E12_1in1000_BSS.mxd

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

0 2,000 4,000 6,000 8,000 Metres

07-Sep-2022 Scale: 1:150,000

Sheet Size : A3 AGD 1966 AMG Zone 55

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Curragh Mine PRCP
Flood Assessment

**PRCP Conditions (E12)**
**Peak Flood Bed Shear Stress - PMP**

**APPENDIX B4-3**

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CADGIS\GIS\ArcAutoMapping\v02\OutputMXDs\626.30075_APPENDIX B4-3_E12_PMP_BSS.mxd

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# CURRAGH MINE COMPLEX

## Residual Void Modelling

**Prepared for:**

Coronado Curragh Pty Ltd
Blackwater,
QLD, 4717



**SLR Ref: 626.30075-R01**
**Version No: -v3.0**
**September 2022**

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# BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

# DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
|---|---|---|---|---|
| 626.30075-R01-v3.0 | 9 September 2022 | Emily Curtis | Fiona Stark | Fiona Stark |
| 626.30075-R01-v2.0 | 29 November 2021 | Emily Curtis | Nicole Bichel | Nicole Bichel |
| 626.30075-R01-v1.0 | 26 November 2021 | Emily Curtis | Nicole Bichel | Nicole Bichel |

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Appendix A Stage Storage Curves
Appendix B Residual Void Water Levels
Appendix C Residual Void Water Quality

# 1 Introduction

SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to provide a Concept Residual Void Assessment (CRVA) for the Curragh Mine Complex (the mine). In support of the CRVA a Residual Void Water Balance Model (WBM) for the mine and has been developed to determine the final water level and quality of the residual voids.

## 1.1 Scope of works

The scope of work includes the development of a surface water final void model which accounts for the modelled groundwater inflows derived from the recovery groundwater model.

An iterative modelling process is required between the groundwater numerical model and the WBM to develop a groundwater inflow relationship for the final void. The final void model then provides long-term estimate of water level and salt concentration for the void stored water while the groundwater recovery model allows estimating post-closure (equilibrium) groundwater levels, potential areas of seepage and discharge to creeks.

This report covers the WBM development. For further information regarding the groundwater numerical model can be found in the Curragh Mine Complex Progressive Rehabilitation and Closure Plan Groundwater Technical Appendix (SLR, 2022).

## 1.2 Residual Voids

Following closure of the mine, 19 residual void areas are expected to remain. The arrangement of these voids for the purpose of the WBM are listed below with multiple pits grouped where hydrologically linked.

- Curragh North;
- Curragh Main: Pit I; Main Other; The Void; D Pit; F Pit North and Pit E North; E, C and H Pit; B Pit; F Pit; L Pit; K Pit; G Pit; J Pit; and
- Expansion Areas: Ramp 9; X Pit (East and West); Y Pit; Z Pit (North and South).

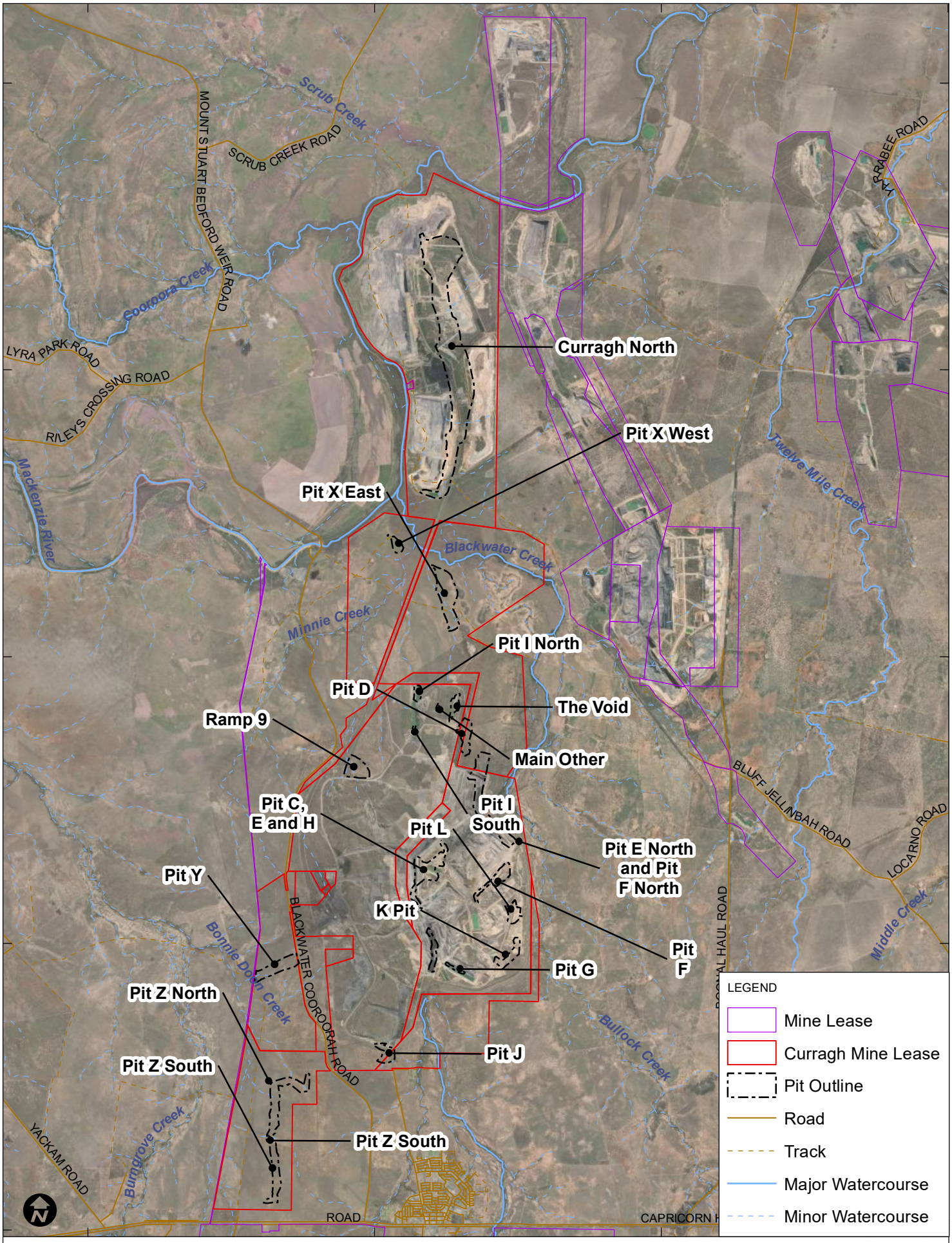
The assessed voids are shown in **Figure 1-1**.

## 1.3 Supplied Data

The following data was provided by CCPL to SLR to complete the assessment

- A final landform as separate designs for Curragh main, Curragh North, and Pits X, Y and Z. The final void designs were provided in dxf format as 0.5 m contours.
- 1 m Lidar data for the existing site (dated 2021).

Anticipated groundwater inflow volumes and associated water quality was derived from the numerical groundwater report.




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SLR

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0 2 4 km

| | |
|---|---|
| Coordinate System: | AGD 1984 AMG Zone 55 |
| Scale: | 1:170,000 at A4 |
| Project Number: | 626.30075 |
| Date: | 16-Sep-2022 |
| Drawn by: | SM |
| Reviewed by: | FS |

Data Source:

**CURRAGH PRCP**

**Proposed Void Locations**

**FIGURE 1-1**

# 2 Water Balance Modelling

A Water Balance Model (WBM) was developed using Goldsim software package to assess the long-term water level and water quality was of the residual voids following closure of CCPL.

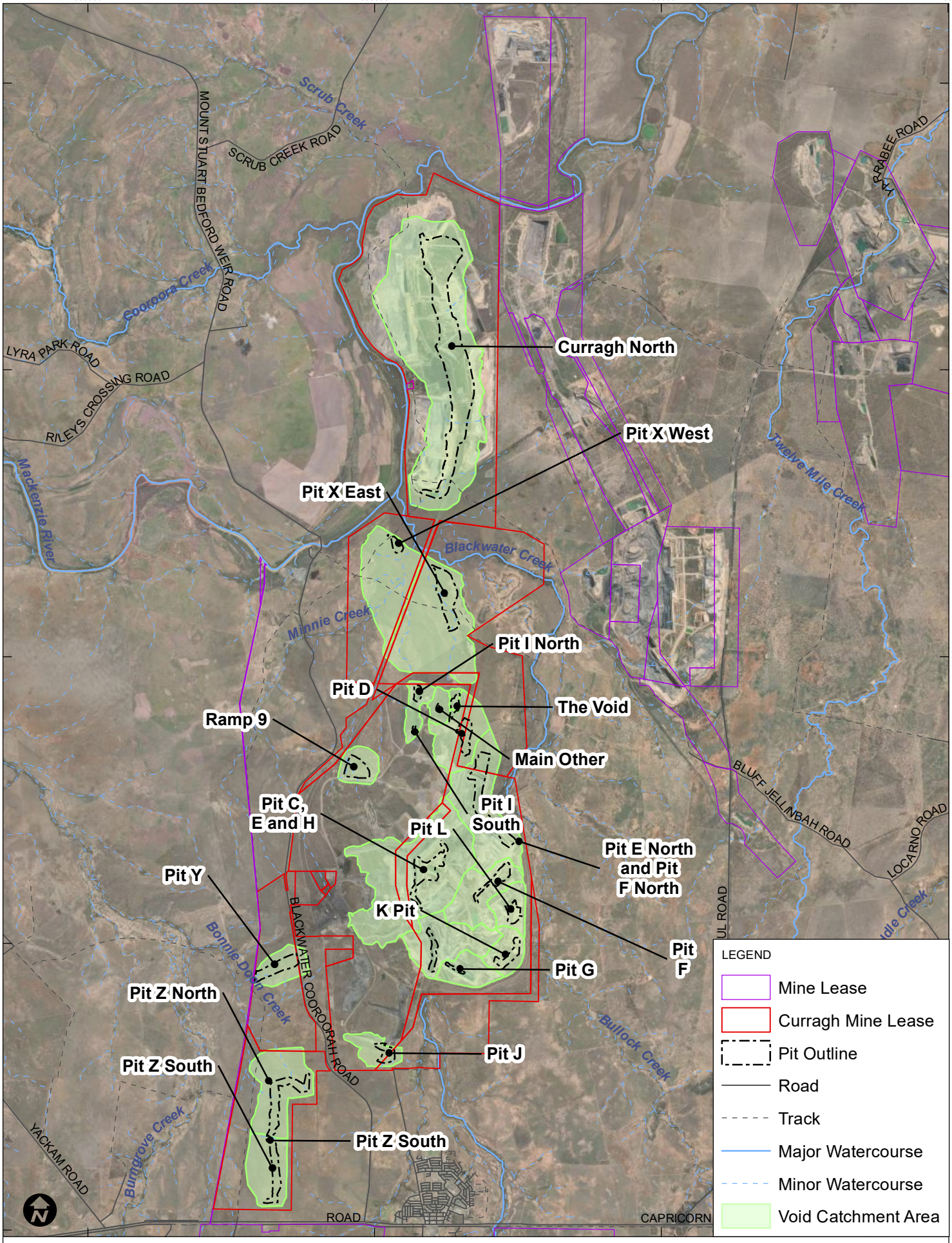
The model simulates daily changes in the volumes of stored water in response to inflows (rainfall, groundwater) and outflows (evaporation and controlled releases/overflows). The WBM was run for daily time step over 200-year simulation period, represented by 500 climate sequences, allowing the model to assess long term water levels, quality and risk of overflow for each void.

## 2.1 Catchment Areas

The catchment configurations for the residual voids at the mine were determined based on the final landform contours provided by CCPL. The residual void catchments consist primarily of rehabilitated spoil dumps, with an elevated stable landform constructed around the perimeter prevent external catchment and flood ingress into the voids. A summary of the catchment breakdown is provided in **Table 1.** The catchments are shown in **Figure 2-1**.

**Table 1 Catchment Summary**

| Curragh Area | Residual Void | Residual Void Footprint (ha) | Catchment Area (ha) |
|---|---|---|---|
| Curragh North | Curragh North | 637.3 | 2404.3 |
| Curragh Main | I Pit | 31.8 | 122.0 |
| | Main Other | 2.1 | 77.4 |
| | The Void | 7.1 | 26.6 |
| | D Pit | 28.4 | 342.8 |
| | F Pit North and Pit E North | 127.3 | 625.7 |
| | E, C and H Pit | 170.1 | 1257.5 |
| | B Pit | 41.0 | 406.6 |
| | F Pit | 39.4 | 350.3 |
| | L Pit | 18.6 | 164.6 |
| | K Pit | 13.0 | 163.5 |
| | G Pit | 14.6 | 179.8 |
| | J Pit | 27.9 | 146.2 |
| Ramp 9 | Ramp 9 | 40.3 | 149.8 |
| X Pit | X Pit East | 100.0 | 905.9 |
| | X Pit West | 26.4 | 542.0 |
| Y Pit | Y Pit | 47.8 | 181.9 |
| Z Pit | Z Pit North | 92.6 | 469.9 |
| | Z Pit South | 35.7 | 315.6 |




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| | |
|---|---|
| Coordinate System: | AGD 1984 AMG Zone 55 |
| Scale: | 1:170,000 at A4 |
| Project Number: | 626.30075 |
| Date: | 16-Sep-2022 |
| Drawn by: | SM |
| Reviewed by: | FS |

Data Source:

**CURRAGH PRCP**

**Catchment Plan**

**FIGURE 2-1**

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## 2.2 Stage Storage Relationship

The stage storage surface area curves were derived from the final landform contours, provided by CCPL. Void depths range from 13 m to 180 m with inverts from -48 mAHD to 133 mAHD. Residual void stage storage surface area relationship for each residual void is provided in **Appendix A**.

## 2.3 Climate

Long term historical climate data has been collected by the Bureau of Meteorology (BoM) for the New Caledonia station (035132) at -23.429, 148.927 for 1900 to 2020 and was sourced from the Scientific Information for Land Owners (SILO) data drill as a Patch Point Data set. The Patch Point Data provides infilling of any missing data from nearby gauges based on relationships developed between the overlapping records of each gauge.

A summary of the annual average climate data is given in **Figure 2-2**.

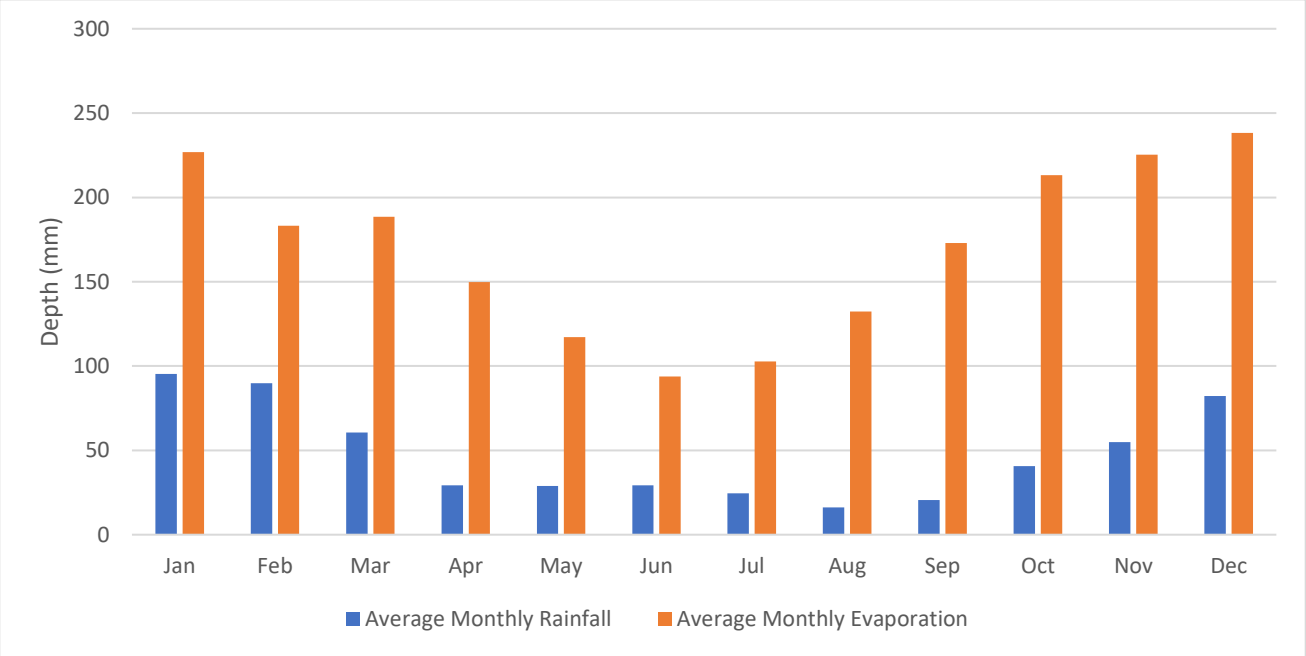



**Figure 2-2 Long Term Average Rainfall and Evaporation**

The average annual rainfall in the region (BoM Station 035132) is approximately 572mm, with the distribution of monthly rainfall shown in **Figure 2-2**. Rainfall is greatest during the summer months December to February, with 47% of annual rainfall occurring over these months. The highest monthly average rainfall total is 95mm in January, and the driest month is August with an average rainfall of 16mm.

The site experiences large water loss year-round, with an average annual evaporation for the site of 2,044mm. On a monthly basis, maximum evaporation occurs later in the year (October to December). During the dryer months evaporation is significantly lower, with the lowest total typically occurring in June. **Figure 2-2** summaries the average evaporation for all moths of the year for the site.

### 2.3.1 Probabilistic Rainfall

Probabilistic rainfall was generated for the WBM. The purpose of the probabilistic rainfall generation is to develop a wide range of climate sequences based on the recorded rainfall data of the area. These sequences have the same statistical characteristics of the historical data set for a range of parameters including mean, variance, skew, and the number of wet days or dry days. The 500 sequences of probabilistic data are summarised as exceedance probabilities. Some sequences may be wetter or dryer than others in order to account for the variability of the climate which may occur following establishment of the residual voids. The probabilistic rainfall data replicated the seasonality of the rainfall data.

The probabilistic rainfall data was generated from the historical data using the eWater CRC Stochastic Climate Library (SCL). Data was generated from 500 replicates of 120 years (from 1900 to 2020 as consistent with the available historical data record) of daily rainfall data for in accordance with the SCL Manual. Probabilistic rainfall at 200 years length were generated. The generated data was found to be representative of the historical record within acceptable tolerances for key statistics.

Comparison of the probabilistic data and the historical rainfall record for the annual rainfall totals is shown in **Figure 2-3**. Review of **Figure 2-3** shows the model simulates a range greater than that of the recorded historical rainfall data but the median (50$^{th}$ percentile) of the results are aligned.

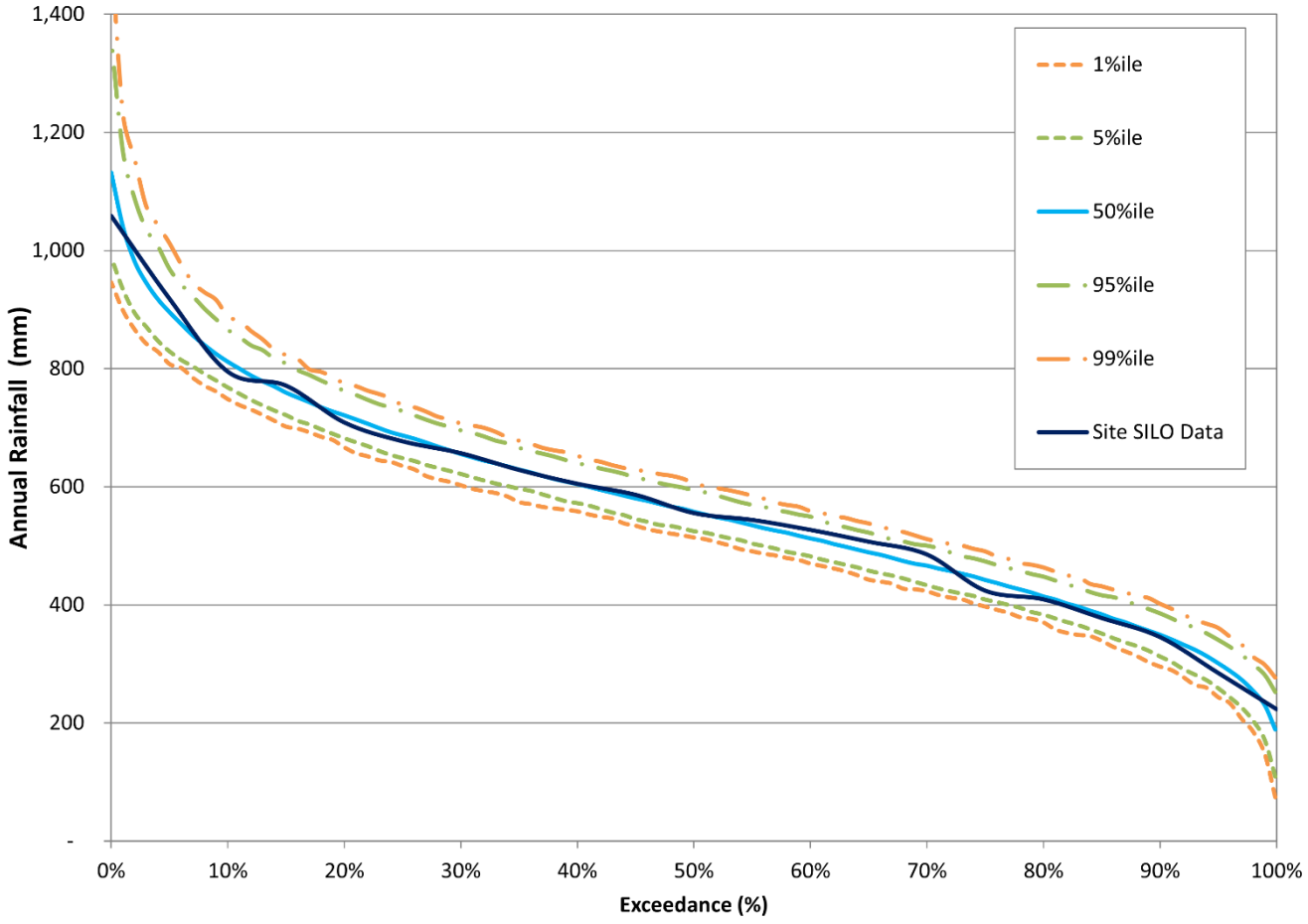



**Figure 2-3 Comparison of Historical and Probabilistic Data**

### 2.3.2 Evaporation

The evaporation values in the model were sourced from SILO, which provides Class A rates. For the WBM, monthly averages were used as the evaporation data for the area is limited. The extended evaporation records available in SILO consisted of infilled data from monthly averages (rather than daily records from other gauges) for the period prior to gauge readings. This is most likely due to the limited available data for infilling. **Table 2** outlines the adopted lake evaporation rates and pan factor. Pan factors have been determined using the Morton Lake Evaporation.

**Table 2 Adopted Monthly Evaporation Rates**

| Month | Evaporation (mm/d) | Pan Factor |
|---|---|---|
| January | 7.3 | 0.90 |
| February | 6.5 | 0.93 |
| March | 6.1 | 0.90 |
| April | 5.0 | 0.89 |
| May | 3.8 | 0.86 |
| June | 3.1 | 0.84 |
| July | 3.3 | 0.87 |
| August | 4.3 | 0.88 |
| September | 5.8 | 0.87 |
| October | 6.9 | 0.88 |
| November | 7.5 | 0.89 |
| December | 7.7 | 0.89 |

Note: Class A Pan Evaporation and the above Pan Factors were applied to the model, resulting in evaporation rates similar to Morton evaporation over shallow lakes.

## 2.4 Runoff Modelling

The WBM utilises the Australian Water Balance Model (AWBM) rainfall runoff module to calculate the rainfall and runoff inflows in each catchment. There are two AWBM modules in the WBM representing the runoff response for the following land use types:

- Void; and
- Rehabilitation.

The rainfall is converted to runoff using the Australian Water Balance Model (AWBM), illustrated in **Figure 2-4**. This runoff can be split into two forms:

1. Surface runoff which travels overland to the destination; or
2. Sub-surface which travels through the ground to reach the destination.

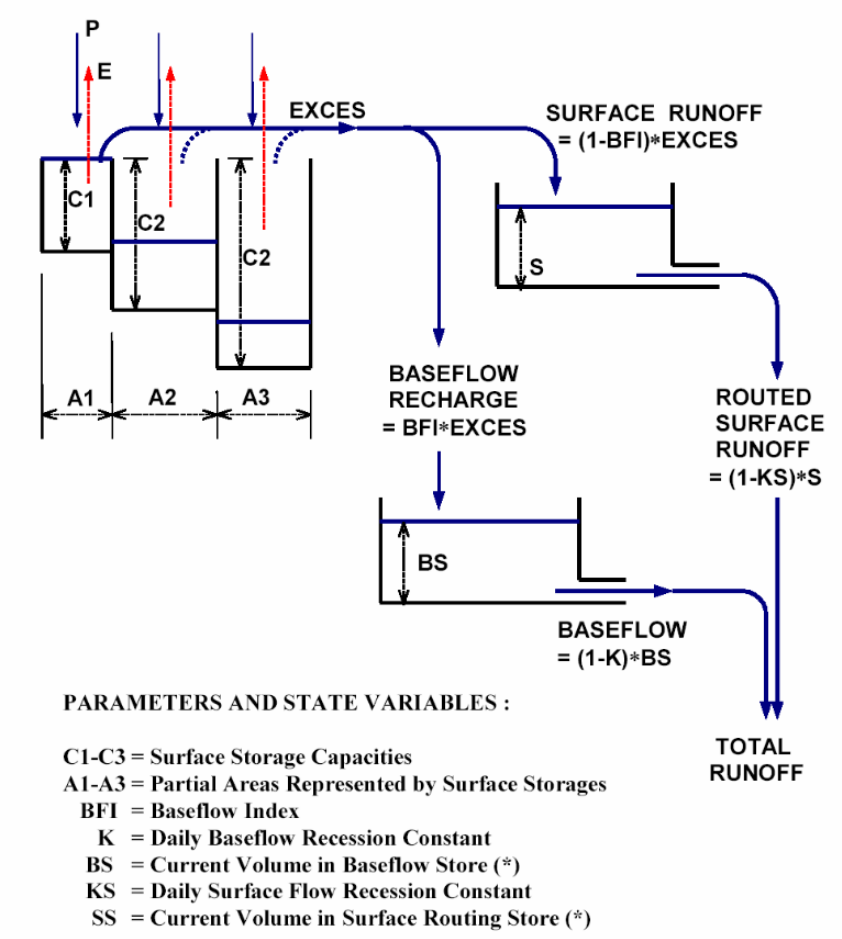



**Figure 2-4 AWBM Rainfall Runoff Model**

AWBM parameters were adopted based on values derived in the area for similar projects and are considered suitable for use in this assessment. A summary of the AWBM parameters used for different catchment types are presented in **Table 3**.

**Table 3 Adopted AWBM Parameters**

| Parameter | Abb | Landuse | |
|---|---|---|---|
| | | Void | Rehabilitation |
| Small storage capacity (mm) | C1 | 10 | 11 |
| Medium storage capacity (mm) | C2 | 25 | 60 |
| Large storage capacity (mm) | C3 | 50 | 130 |
| Small partial area portion | A1 | 0.134 | 0.134 |
| Medium partial area portion | A2 | 0.433 | 0.433 |
| Large partial area portion | A3 | 0.433 | 0.433 |
| Baseflow Index | BFI | 0.1 | 0.35 |
| Baseflow recession | K | 0.6 | 0.6 |
| Daily streamflow recession | KS | 0.1 | 0.1 |

## 2.5 Groundwater Interaction

Groundwater interactions with the WBM were derived from the groundwater model developed for the PRCP and provided as a relationship between water level and inflow (SLR, 2022). The relationships adopted in the WBM were calculated at a daily timestep based on this relationship using the water level in the voids as predicted by the WBM.

Further information relating to derived groundwater inflows can be found in Section 4 of the Curragh Mine Complex Progressive Rehabilitation and Closure Plan Groundwater Technical Appendix (SLR, 2022).

## 2.6 Water Quality

The water balance model was developed to include a high-level salt balance to track both the quantity and quality of water on-site. The salt balance tracks the water quality in all of the inflows into the voids and subsequent effects from evaporation and releases on the storage water quality. The water quality values are presented in . These adopted values are consistent with those adopted for other Queensland mine sites.

Based on groundwater monitoring data at the mine, an EC of 12,500 µS/cm was adopted as the average salinity concentration of groundwater inflows. Salinity parameters for surface runoff were determined based on prior experience in the area.

Adopted water quality parameters are summarised in **Table 4**.

**Table 4 Adopted Salinity Generation Parameters**

| Inflow | Salinity (EC) (µS/cm) |
|---|---|
| Void | 3,000 |
| Rehabilitation | 250 |
| Groundwater Inflow | 12,500 |

The above salinity values are converted to a concentration in milligrams per litre using an average multiplication factor of 0.67 (Measuring Salinity DERM, June 2007) to quantify the mass of salt transferred in the model.

# 3 Results

The WBM was run for a range of rainfall conditions to allow for the calculation of percentiles of the final void levels. These percentiles represent the results range due to variability in climate. The results of the WBM focus on the 5th, 50th and 99th percentile. This represents the dry, median and very wet climatic condition. The 99th percentile result is used to assess the risk of overflow of the voids.

## 3.1 Residual Void Water Levels

The WBM was predicted to stabilise after approximately 100 years to the approximate levels for the median condition shown in **Table 5**. It is noted that some individual voids within the WBM reached equilibrium level in less than 20 years. Graphical representations of the results for each residual void are provided in **Appendix B.**

**Table 5 Residual Void Water Level Summary**

| Void | Residual Void Level (50%ile) (mAHD) | Depth (m) | Surface Area (ha) |
|---|---|---|---|
| Curragh North | 23 | 71 | 197 |
| I Pit | 135 | 1 | 5 |
| Main Other | 135 | 15 | 2 |
| The Void | 100 | 7 | 1 |
| D Pit | 62 | 33 | 12 |
| F Pit North and Pit E North | 49 | 23 | 24 |
| E, C and H Pit | 70 | 30 | 45 |
| B Pit | 112 | 4 | 13 |
| F Pit | 111 | 19 | 12 |
| L Pit | 103 | 38 | 6 |
| K Pit | 77 | 14 | 8 |
| G Pit | 137 | 7 | 6 |
| Ramp 9 | 132 | 54 | 39 |
| J Pit | 111 | 18 | 8 |
| X Pit East | 67 | 33 | 39 |
| X Pit West | 98 | 20 | 19 |
| Y Pit | 123 | 8 | 8 |
| Z Pit North | 108 | 30 | 27 |
| Z Pit South | 105 | 17 | 13 |

The relative size of external catchment to the void footprint results in water levels that stabilise well below the indicative spill level with evaporative losses balancing inflows into the voids. A similar trend in water level is seen across all the residual voids. Water depths range from 1 m to 71 m within the voids for median conditions (50$^{th}$ percentile). During dry climatic conditions (5$^{th}$ percentile) water levels are approximately 0.1 m to 6 m lower. During very wet (99$^{th}$ percentile) climatic conditions the water level increases by 0.4 m to 9 m depending on the void and generally causes greater fluctuation in the equilibrium water level. Median final water levels range from 11 m to 109 m below the indicative spill levels and are not expected to overtop.

The surface area of the final void water level ranges in size from 1 ha to ~200 ha. There is one main final void at Curragh North with all other voids having a footprint less than 50 ha. Of the 19 voids 73 % have a footprint less than 24 ha and 42% less than 10 ha.

## 3.2 Water Quality

Water within the residual voids becomes highly saline throughout the simulation. This was not unexpected due to the high salinity of groundwater in the region and the assumption that the only loss from the system is evaporation (through which no salt is lost). Within the WBM salinity is capped at a maximum EC of 532,836 µS/cm which is equivalent to the point where the concentration of salt becomes high enough that the solution is saturated and any additional salt will precipitate out of solution. All voids are expected to exceed hypersaline EC levels (>50,000 µS/cm) within approximately 120 years of closure, with some exceeding this value within 30 years.

The average salinity of the voids throughout the simulation period are provided in **Table 6**. Graphical representations of the results for each residual void are provided in **Appendix C.**

**Table 6 Average Stage Salinity (EC µS/cm)**

| Void | Year 10 | Year 30 | Year 200 |
|---|---|---|---|
| Curragh North | 13,900 | 20,100 | >50,000 |
| I Pit | >50,000 | >50,000 | >50,000 |
| Main Other | 11,700 | 25,700 | >50,000 |
| The Void | 10,200 | 15,600 | >50,000 |
| D Pit | 16,500 | 28,800 | >50,000 |
| F Pit North and Pit E North | 27,500 | >50,000 | >50,000 |
| E, C and H Pit | 15,700 | 33,700 | >50,000 |
| B Pit | >50,000 | >50,000 | >50,000 |
| F Pit | 18,200 | 38,600 | >50,000 |
| L Pit | 13,800 | 24,200 | >50,000 |
| K Pit | 28,400 | >50,000 | >50,000 |
| G Pit | 40,700 | >50,000 | >50,000 |
| Ramp 9 | 17,300 | 25,600 | >50,000 |
| J Pit | 23,300 | 49,300 | >50,000 |
| X Pit East | 15,600 | 27,500 | >50,000 |
| X Pit West | 19,200 | 39,600 | >50,000 |

| Void | Year 10 | Year 30 | Year 200 |
|---|---|---|---|
| Y Pit | 40,600 | >50,000 | >50,000 |
| Z Pit North | 19,800 | 37,600 | >50,000 |
| Z Pit South | 23,400 | 48,500 | >50,000 |

# 4 Conclusions

At Curragh Complex the median residual void water levels are expected to range from 23 mAHD to 137 mAHD with water depths of 1 m to 71 m . The results indicate that the mine is not a net accumulator of water after approximately 100 years when the equilibrium water levels are reached. The final water levels remain below the spill level and the voids are unlikely to overtop in the 99$^{th}$ percentile climate scenario.

A significantly high concentration of salt is expected to accumulate within the residual voids. The elevated salinity of the groundwater inflows input a high level of salt into the voids which is not lost from the system via evaporation. The salinity of the voids is expected to exceed that of the groundwater and form highly concentrated solution. Although poor quality, water within the voids is not expected to interact with surrounding surface water given the final water levels.

# APPENDIX A

Stage Storage Curves

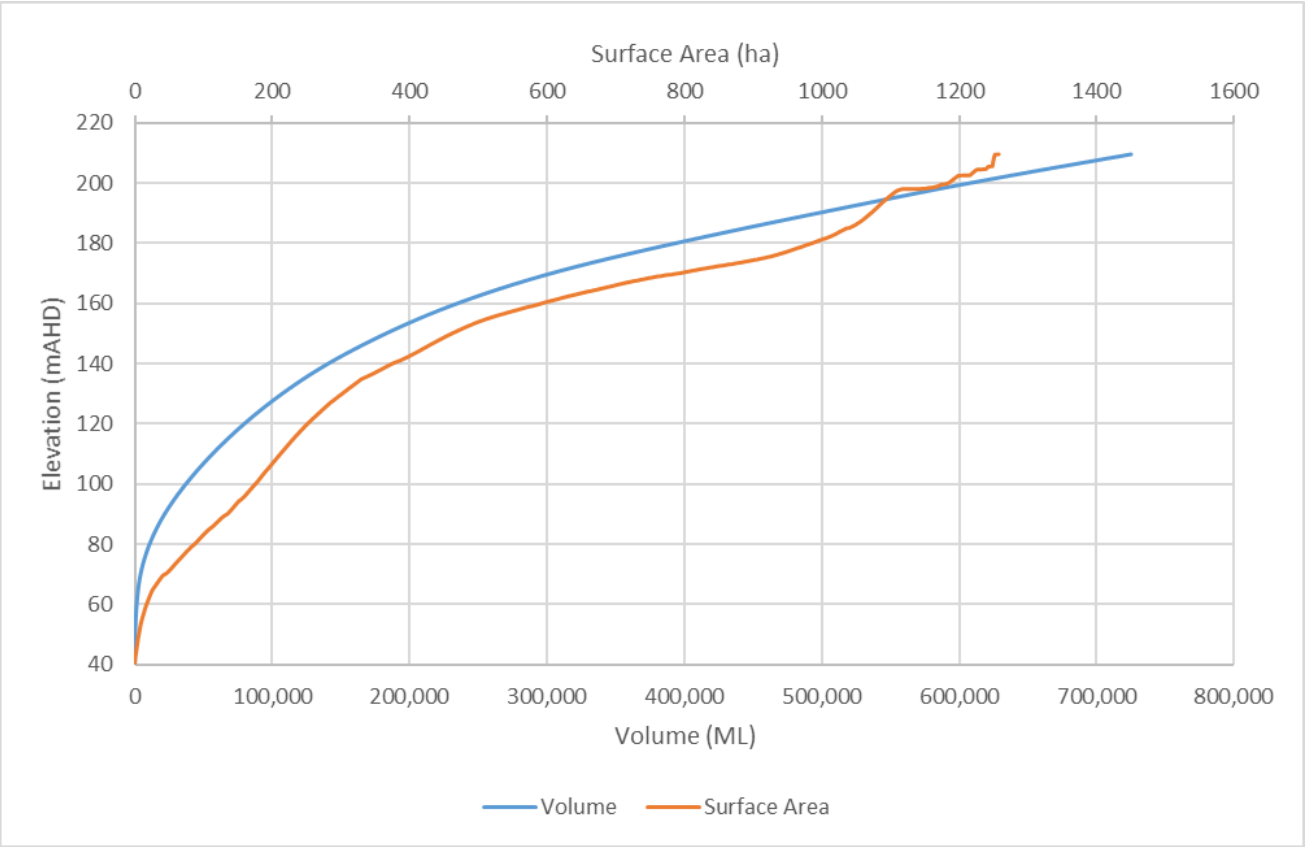



**Figure 1A** – E, C and H Pit Stage Storage

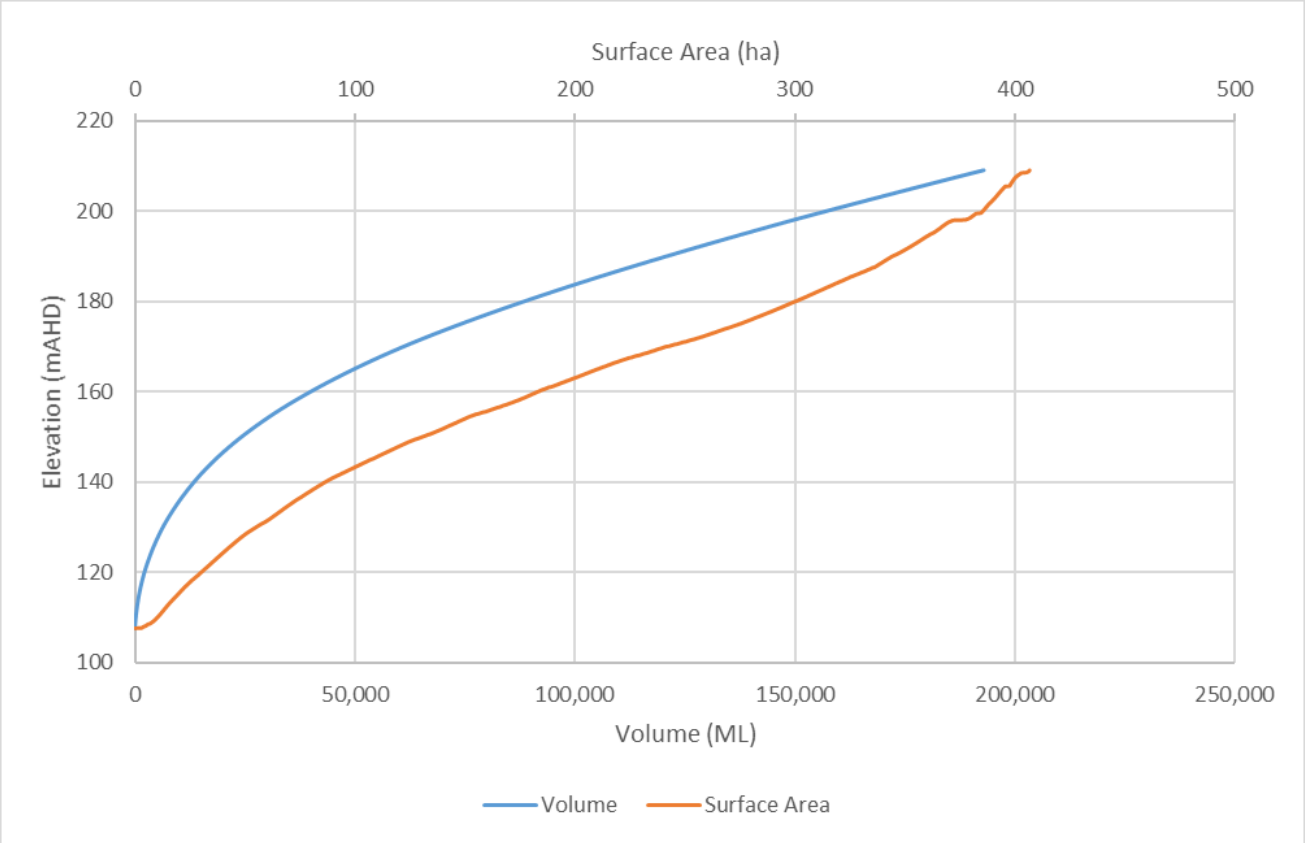



**Figure 2A** – B Pit Stage Storage

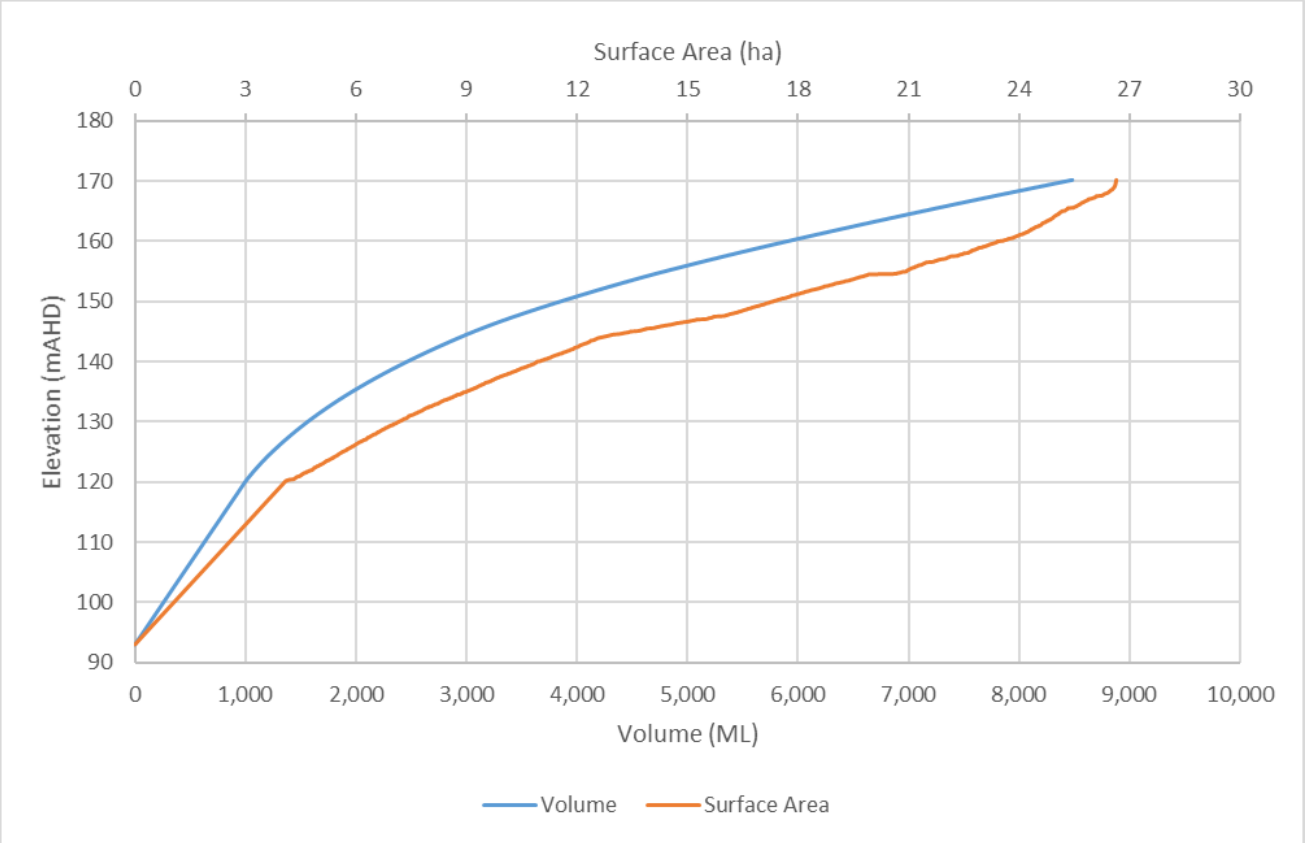



**Figure 3A** – The Void Stage Storage

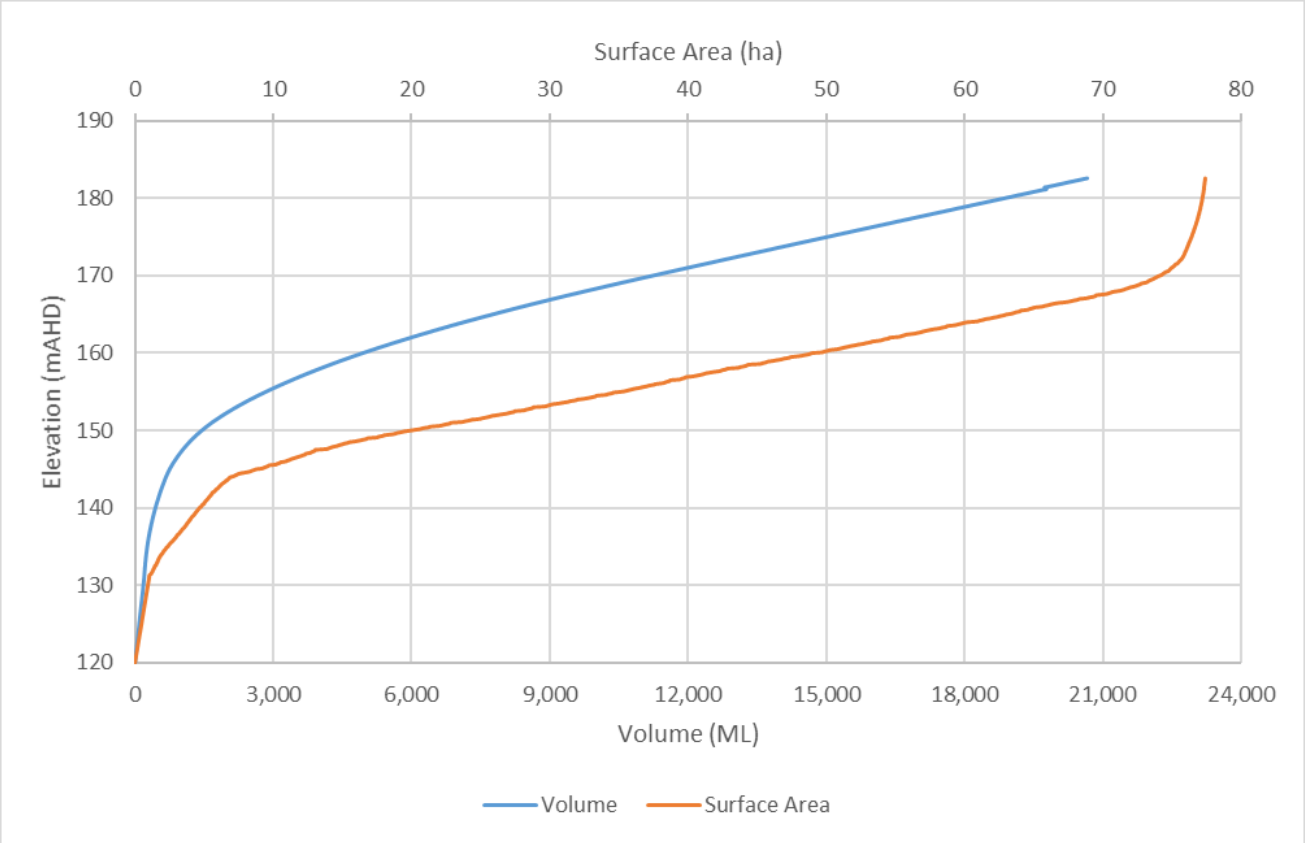



**Figure 4A** – Main Other Stage Storage

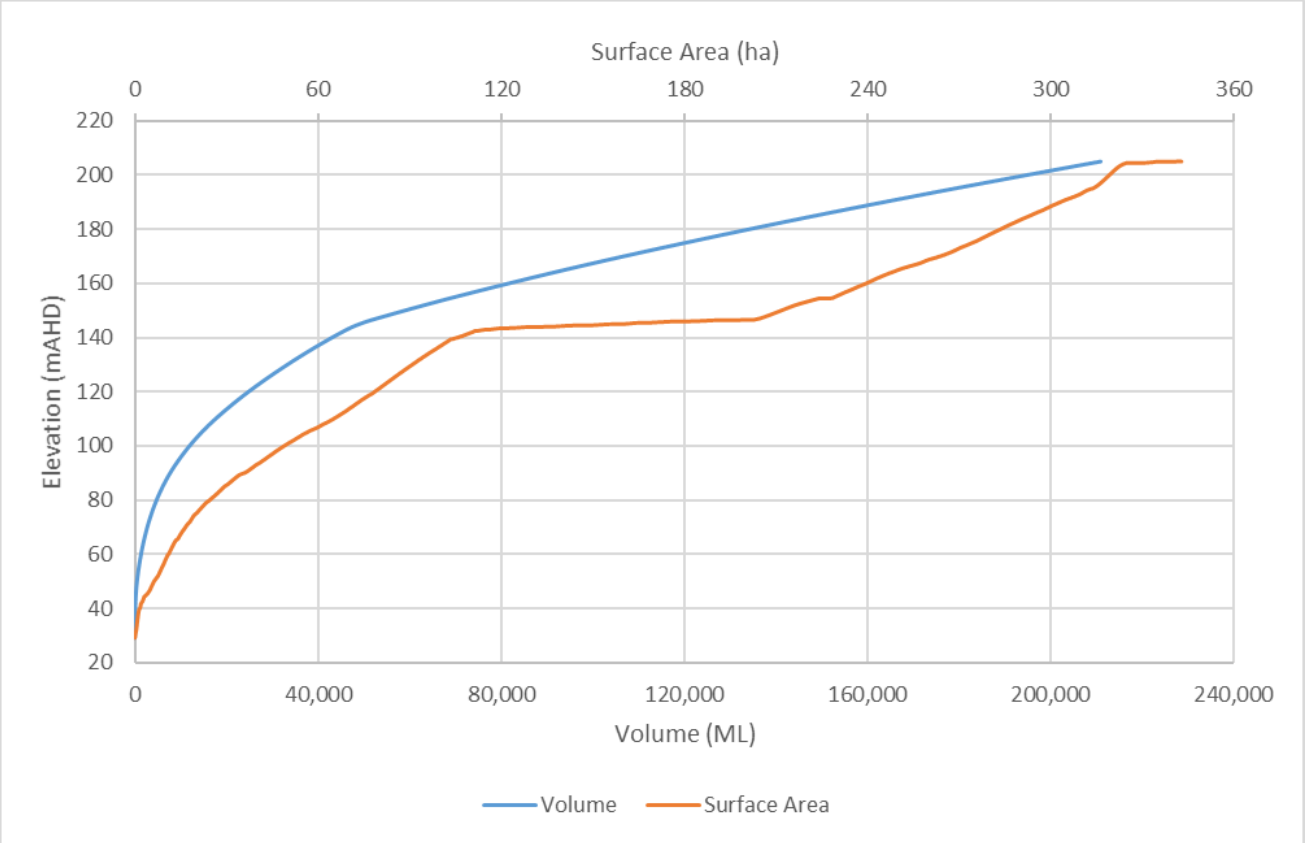



**Figure 5A** – D Pit Stage Storage

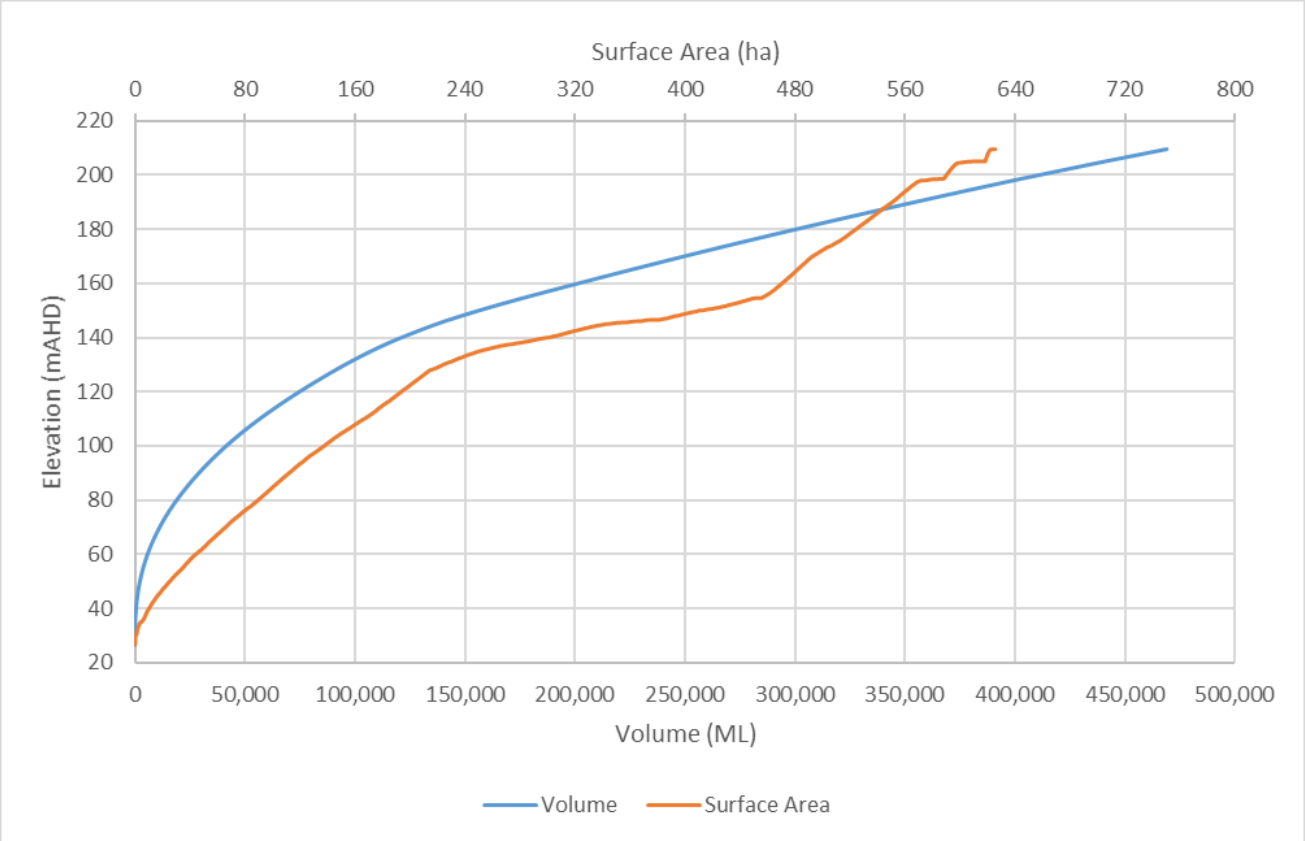



**Figure 6A** – F Pit North and Pit E North Stage Storage

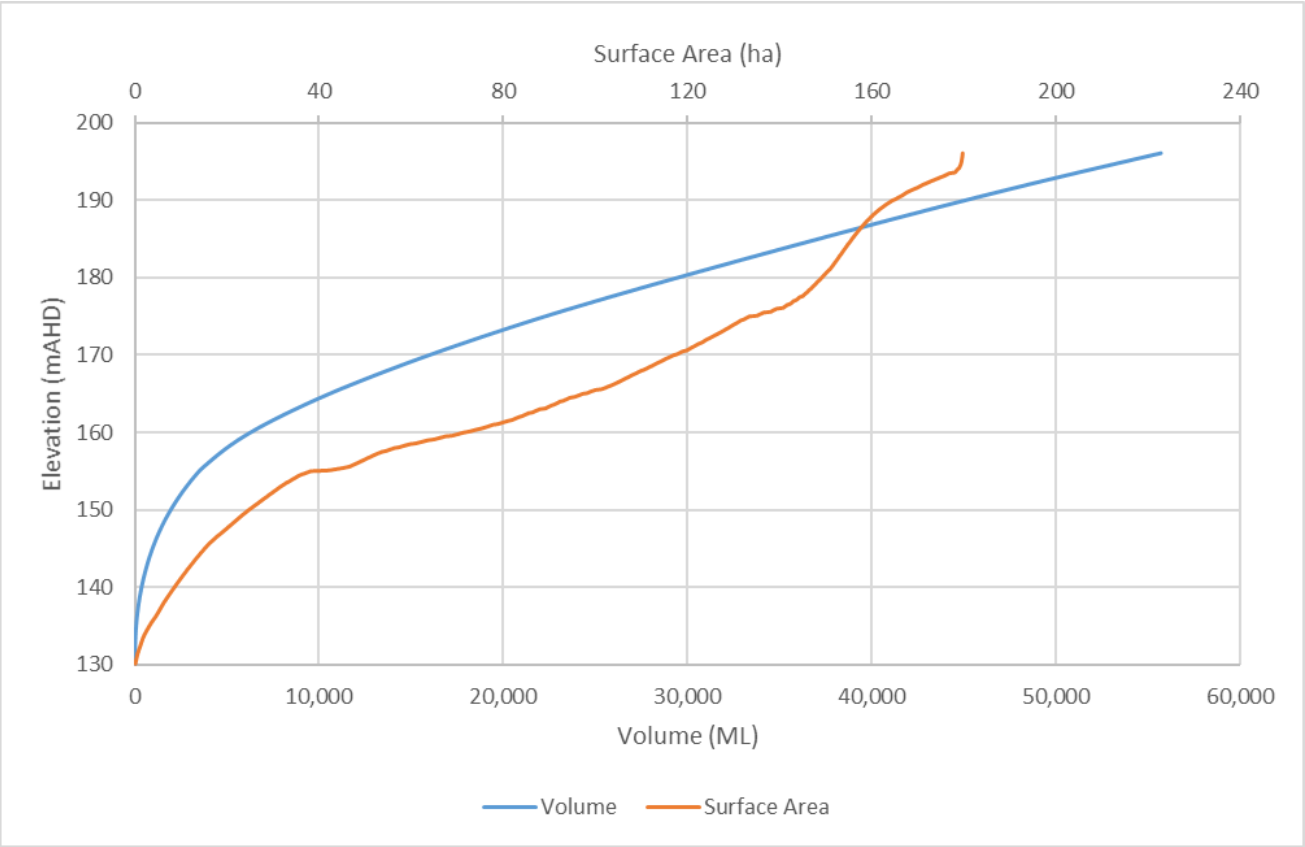



**Figure 7A** – G Pit Stage Storage

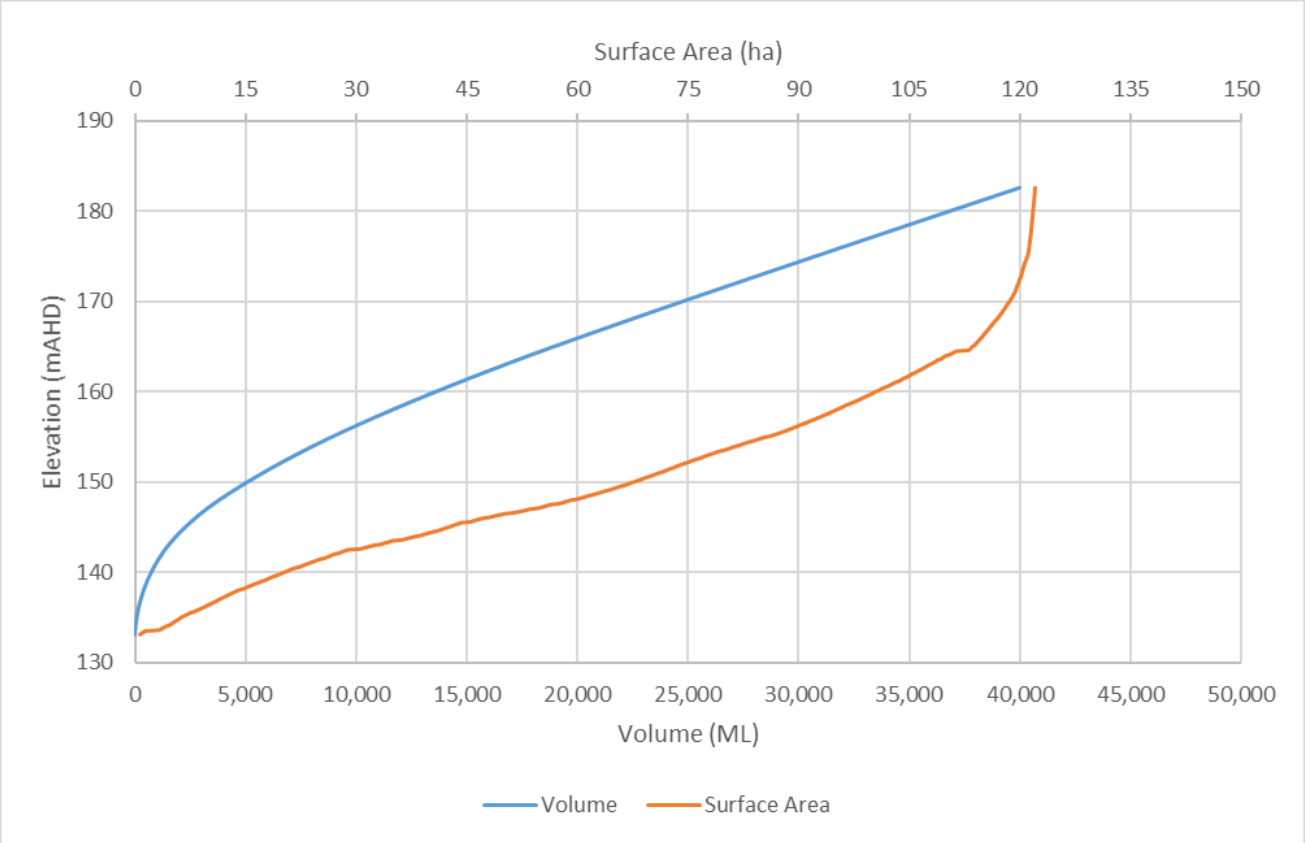



**Figure 8A** – I Pit Stage Storage

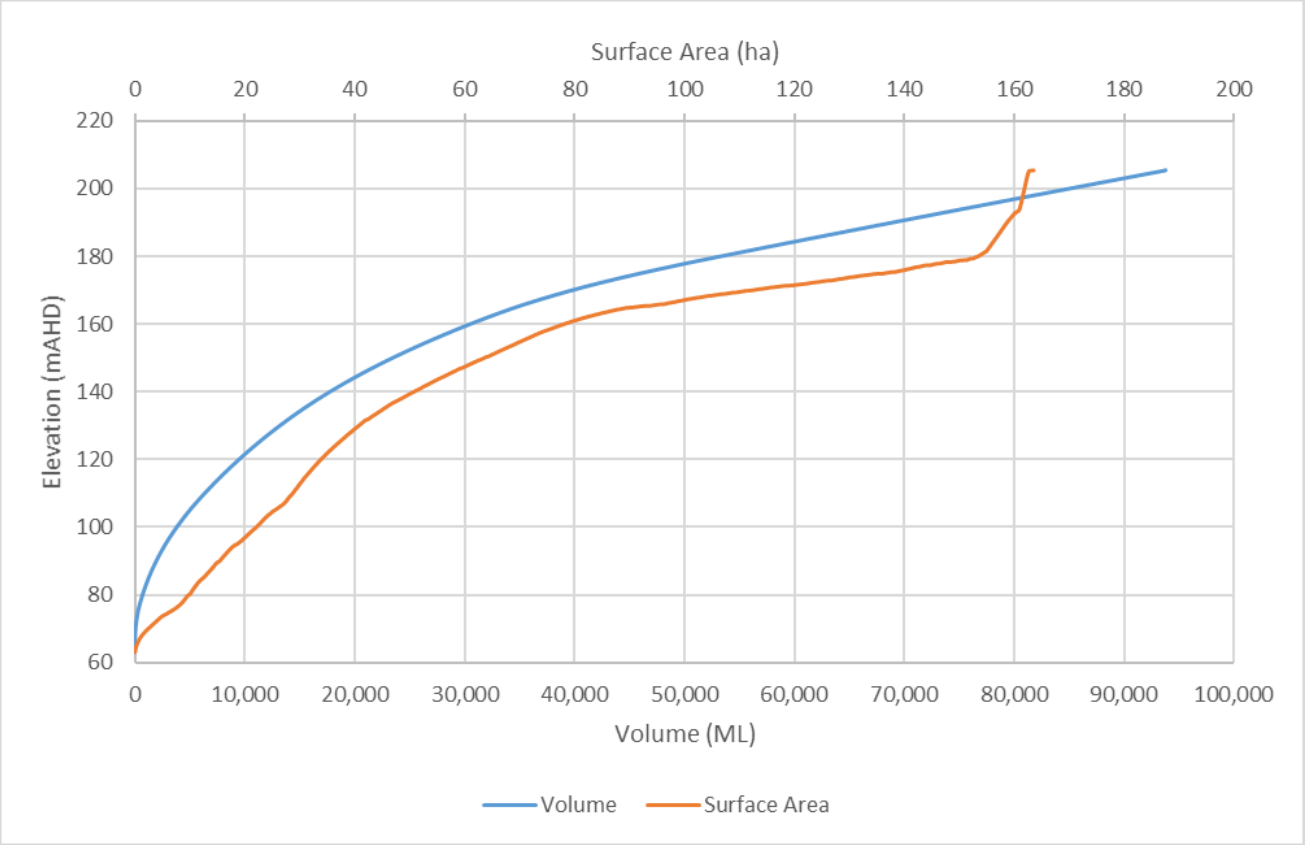



**Figure 9A** – K Pit Stage Storage

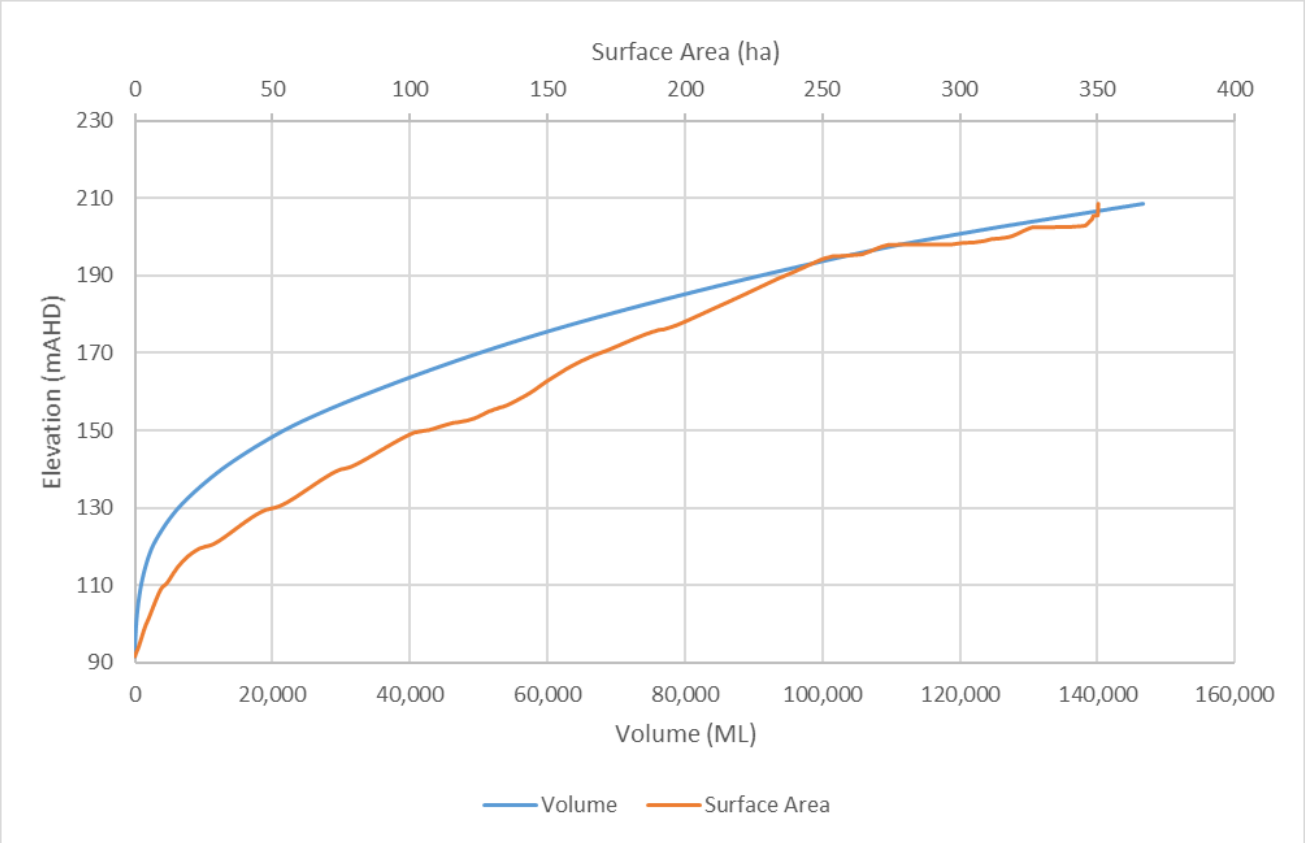



**Figure 10A** – F Pit Stage Storage

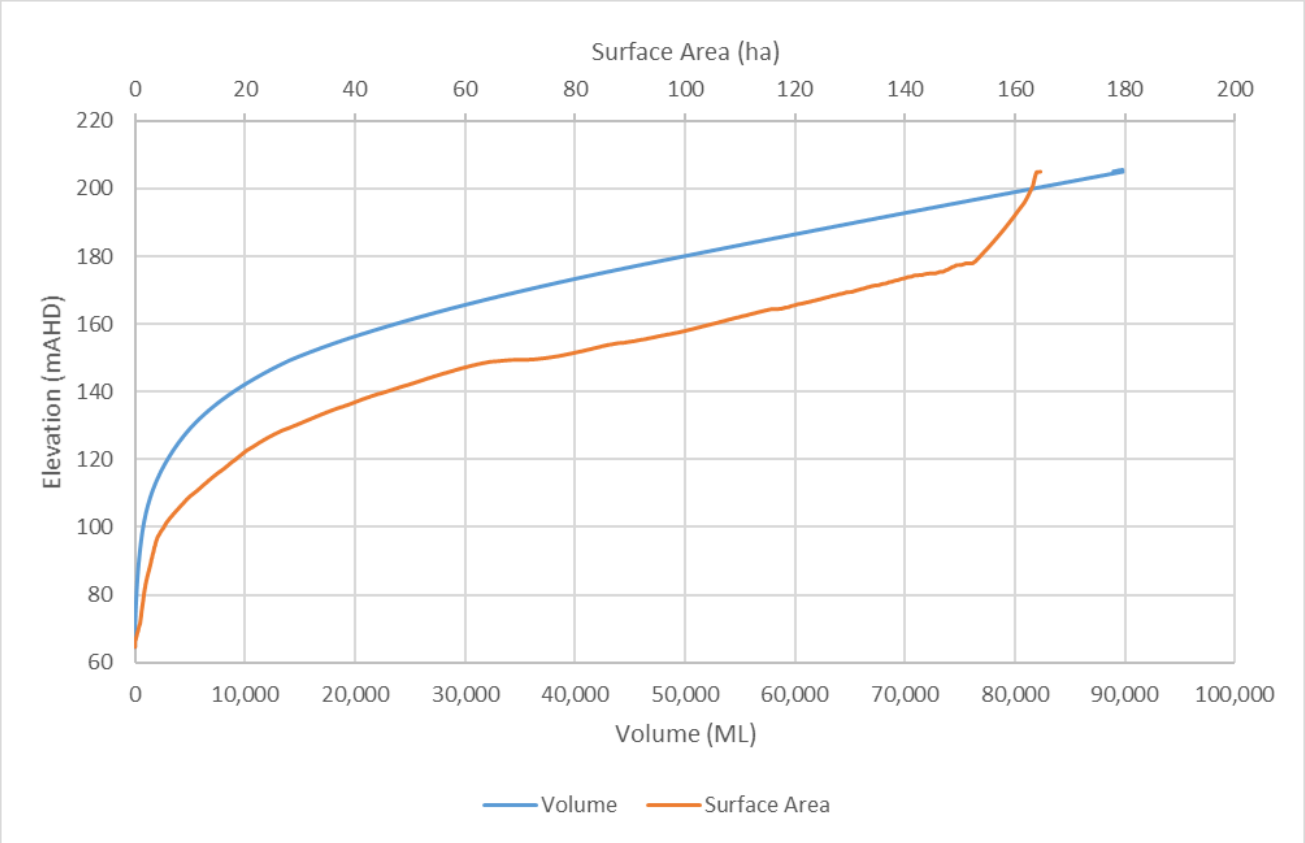



**Figure 11A** – L Pit Stage Storage

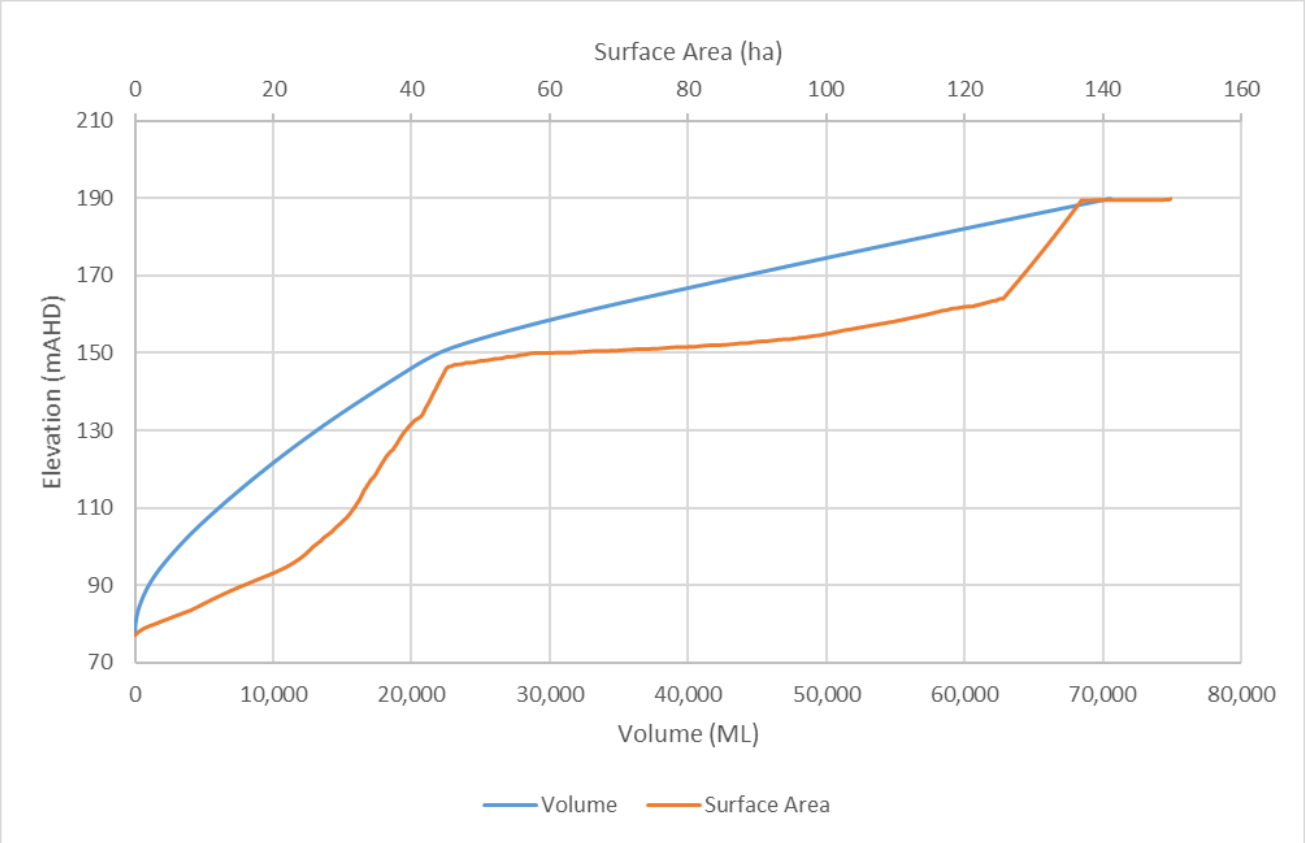



**Figure 12A** – Ramp 9 Stage Storage

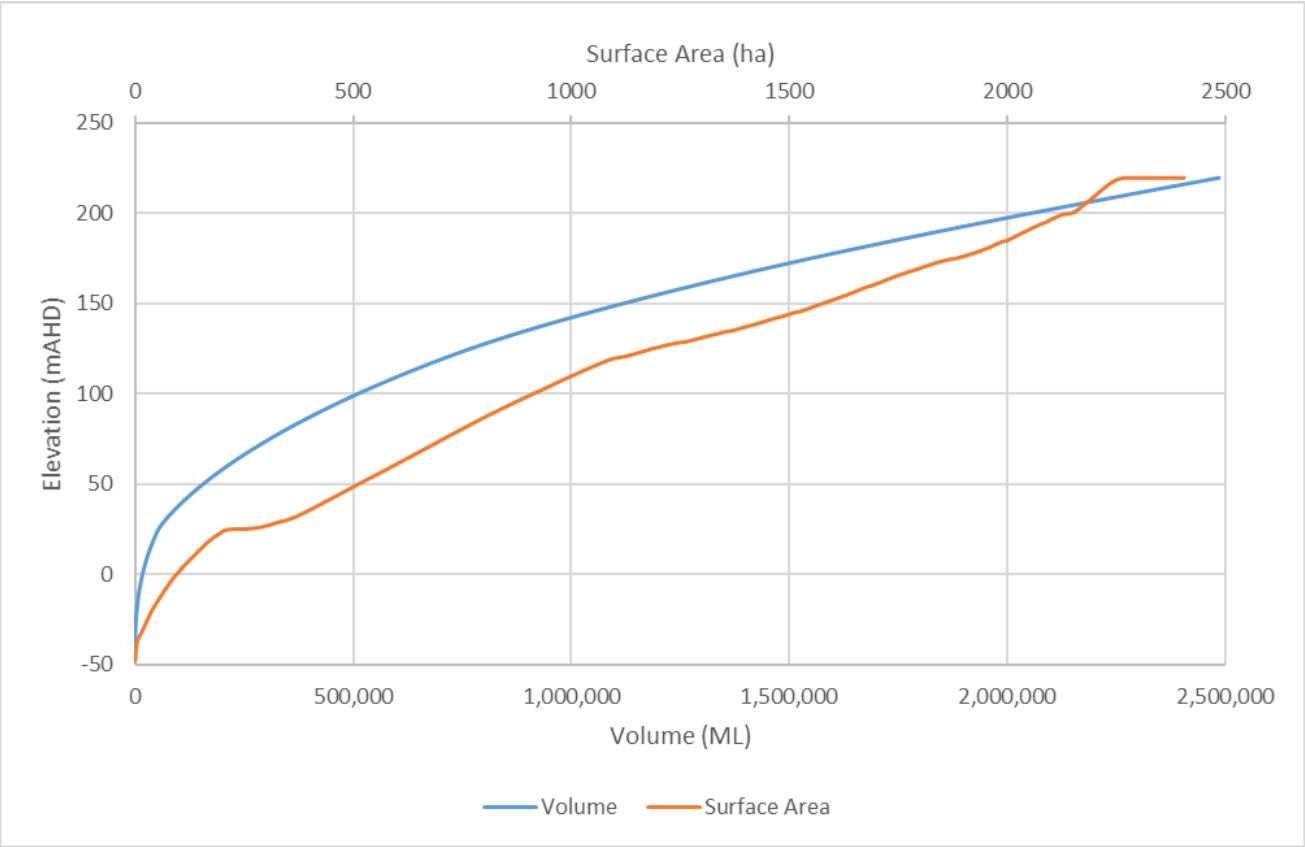



**Figure 13A** – Curragh North Stage Storage

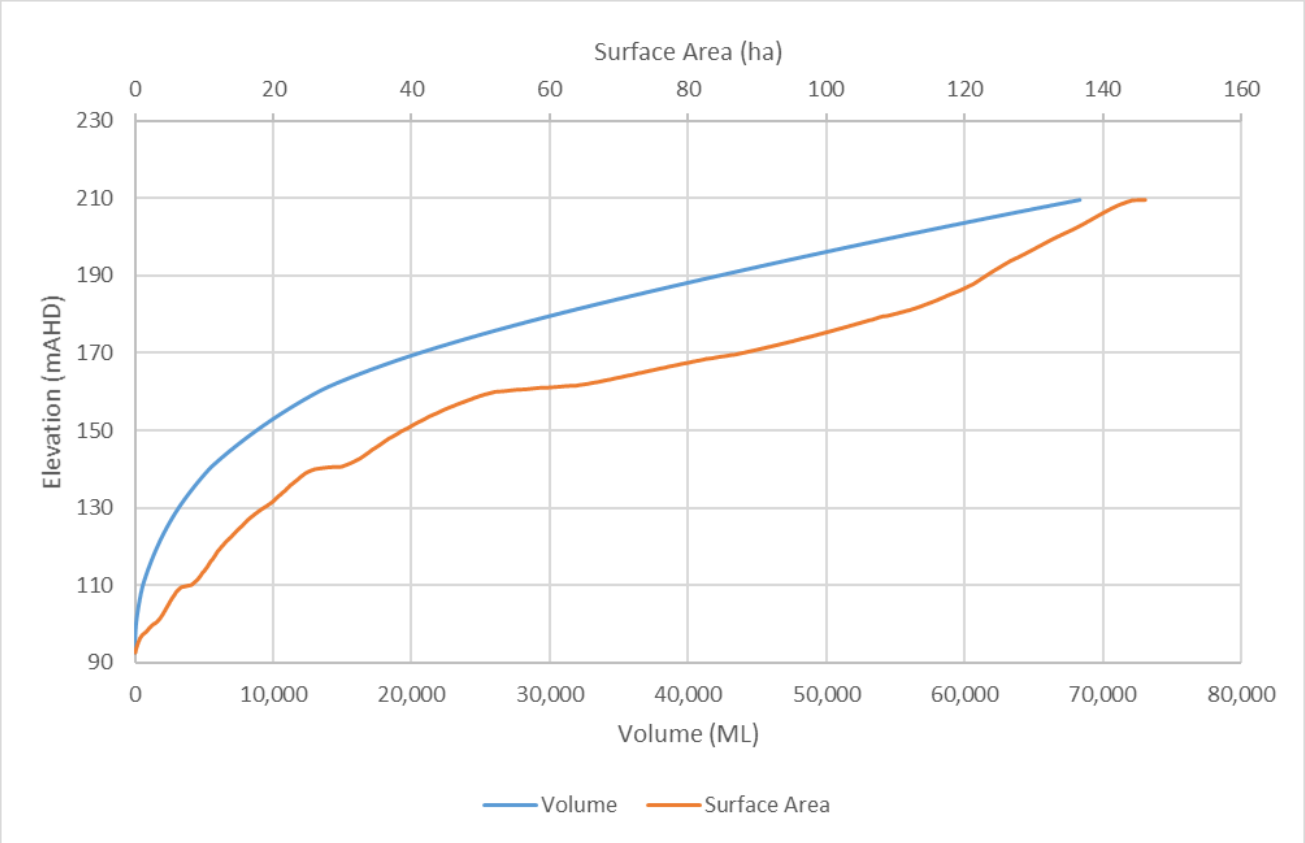



**Figure 14A** – J Pit Stage Storage

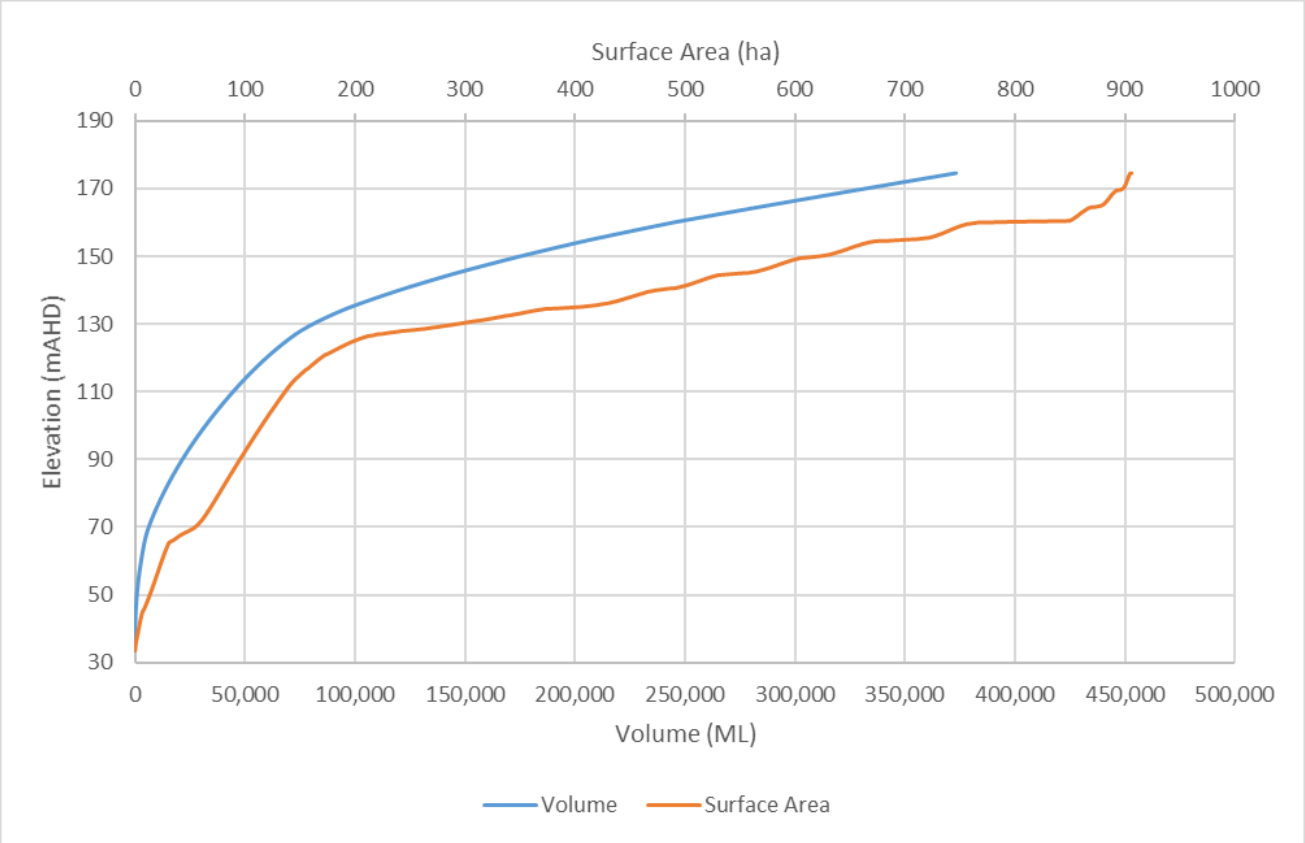



**Figure 15A** – X Pit East Stage Storage

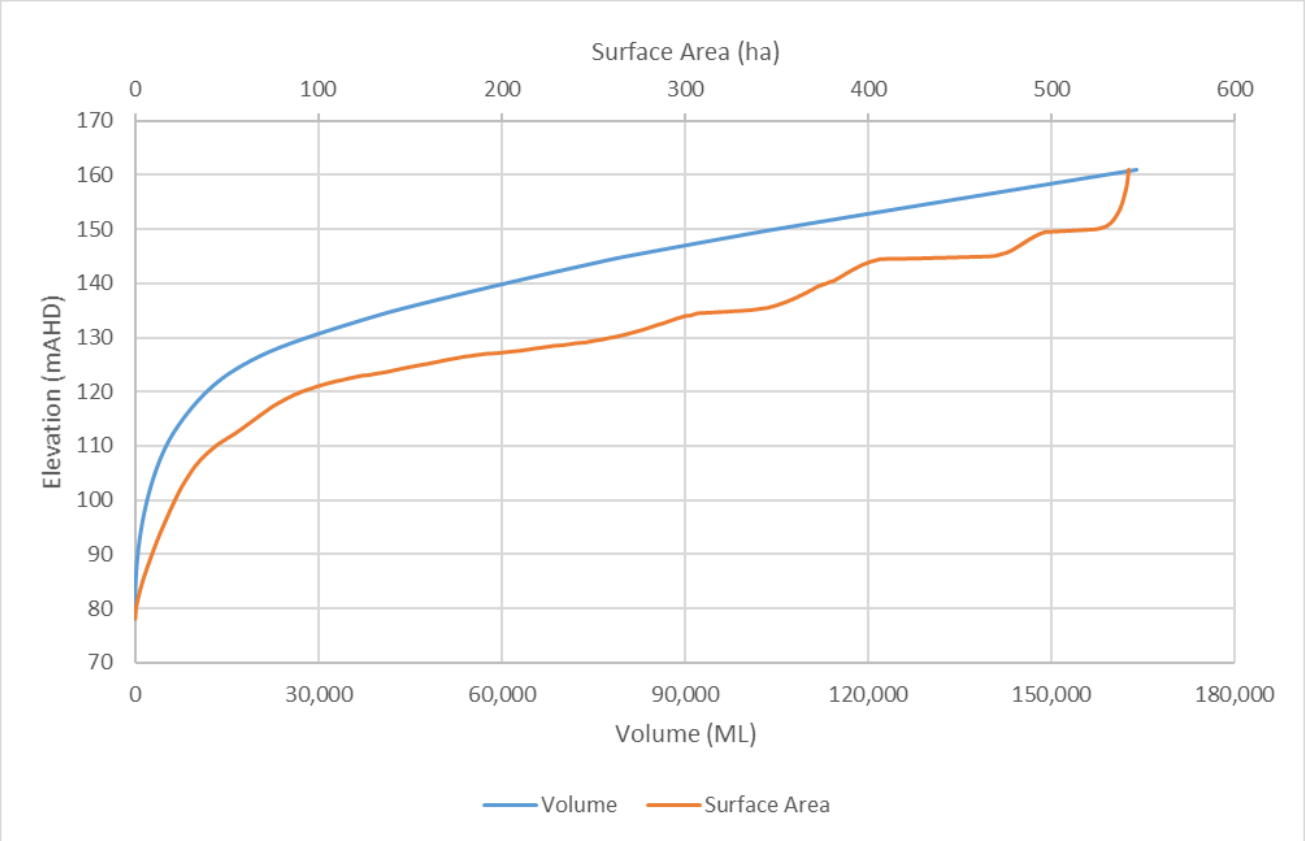



**Figure 16A** – X Pit West Stage Storage

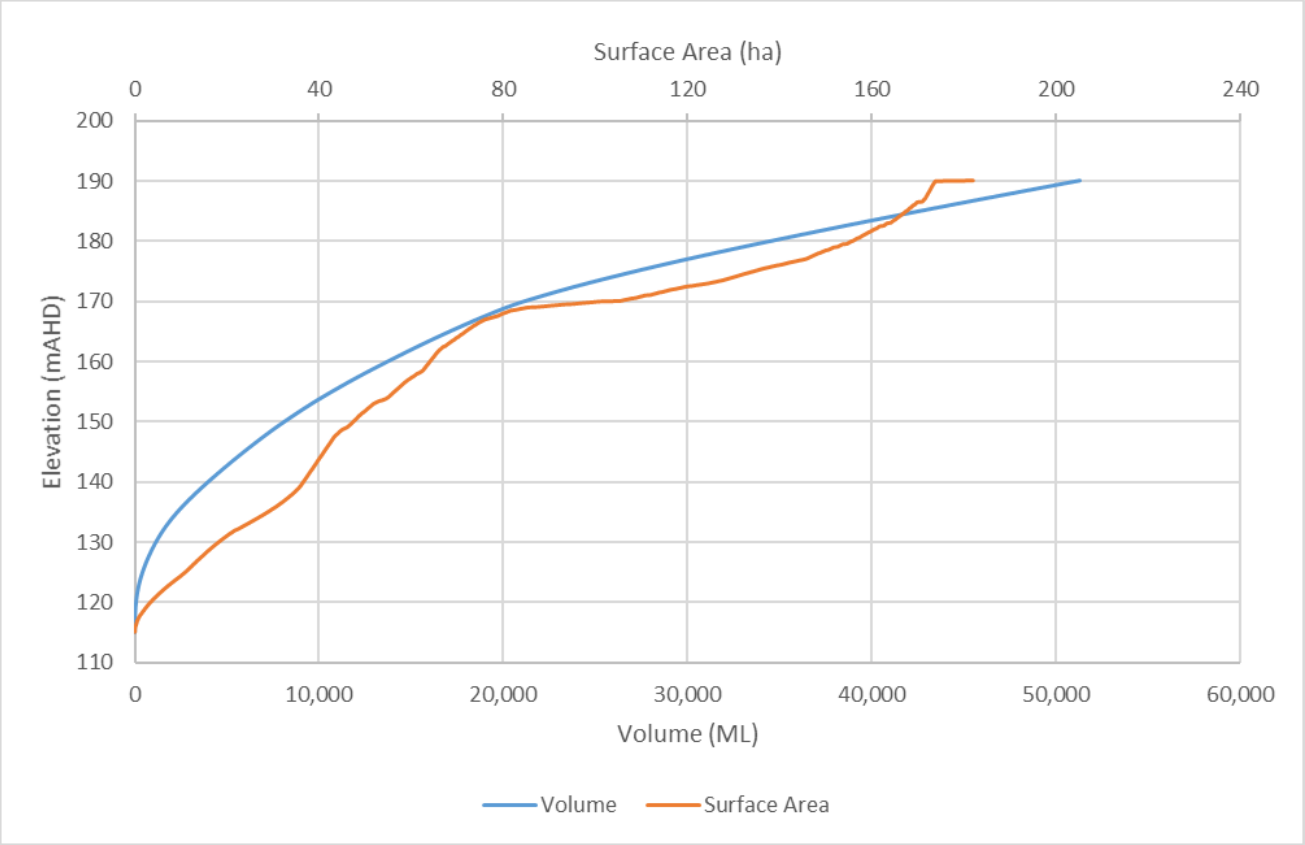



**Figure 17A** – Y Pit Stage Storage

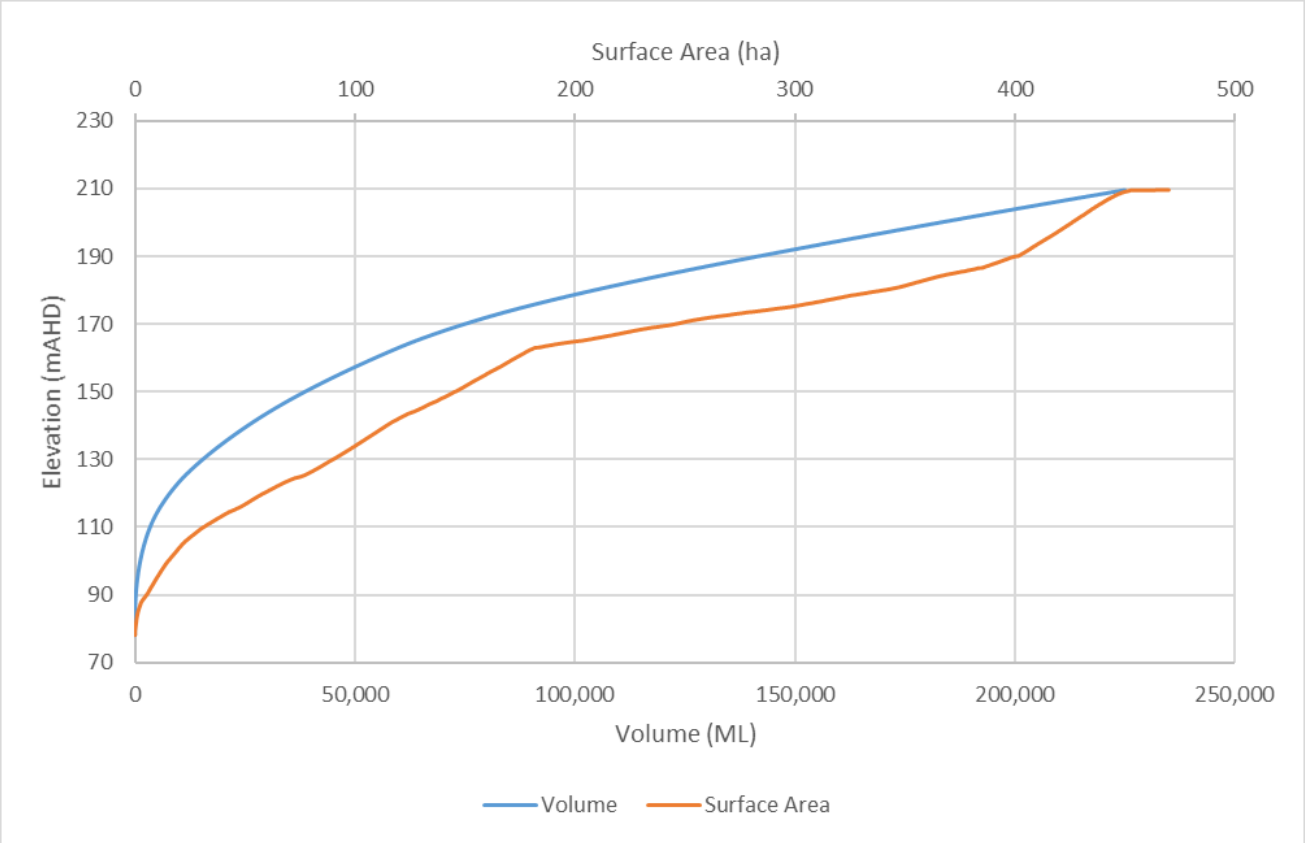



**Figure 18A** – Z Pit North Stage Storage

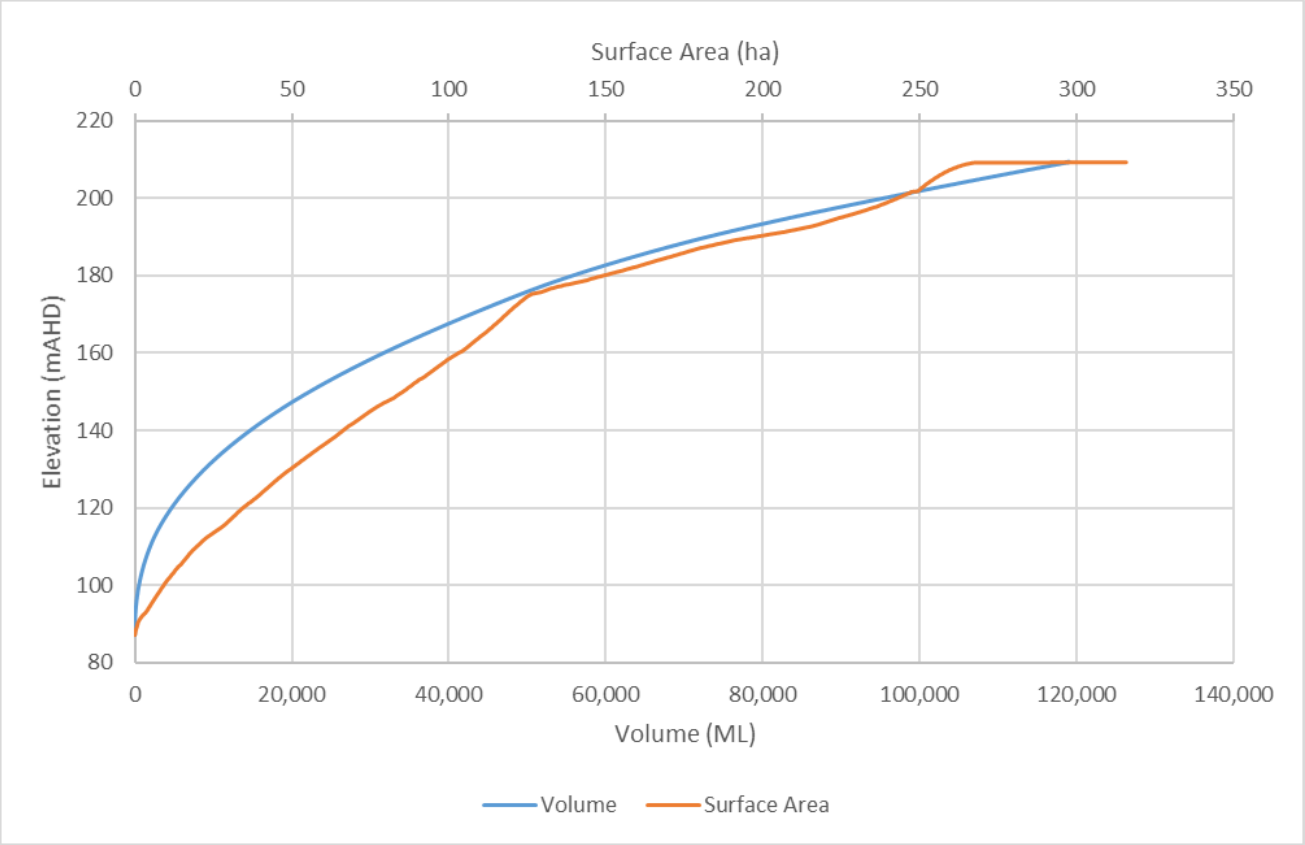



**Figure 19A** – Z Pit South Stage Storage

# APPENDIX B

Residual Void Water Levels

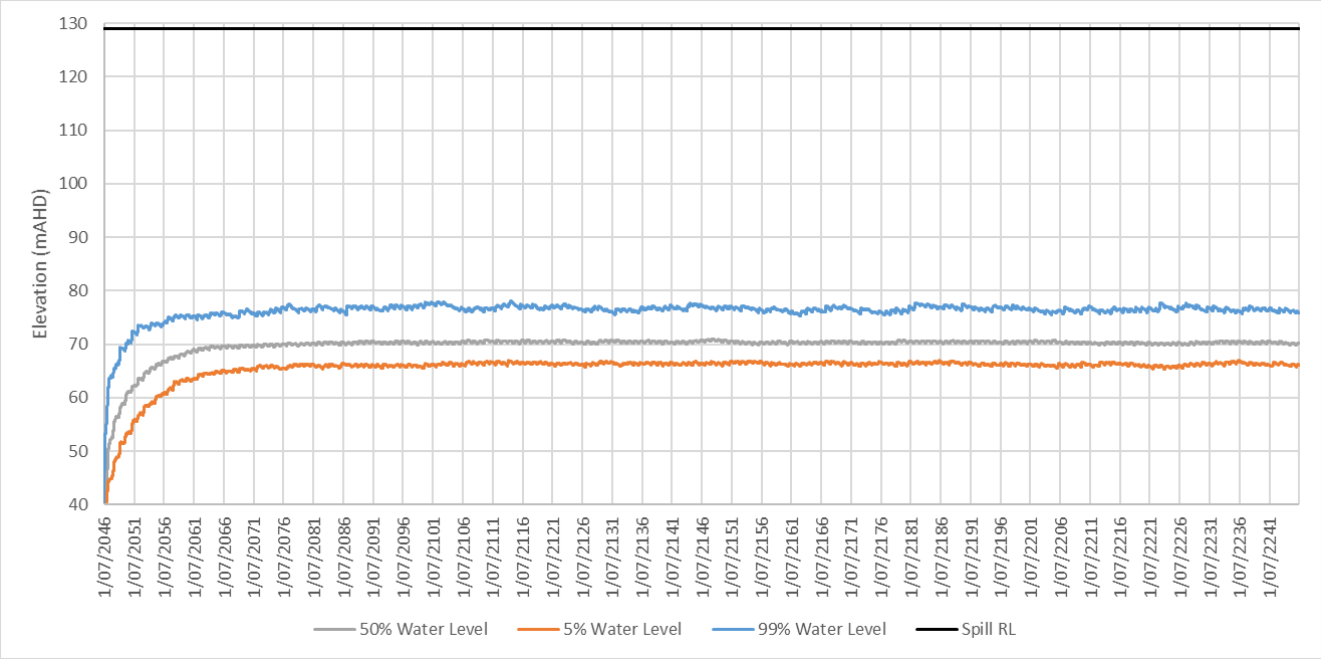



**Figure 1B** – E, C and H Pit Final Water Level

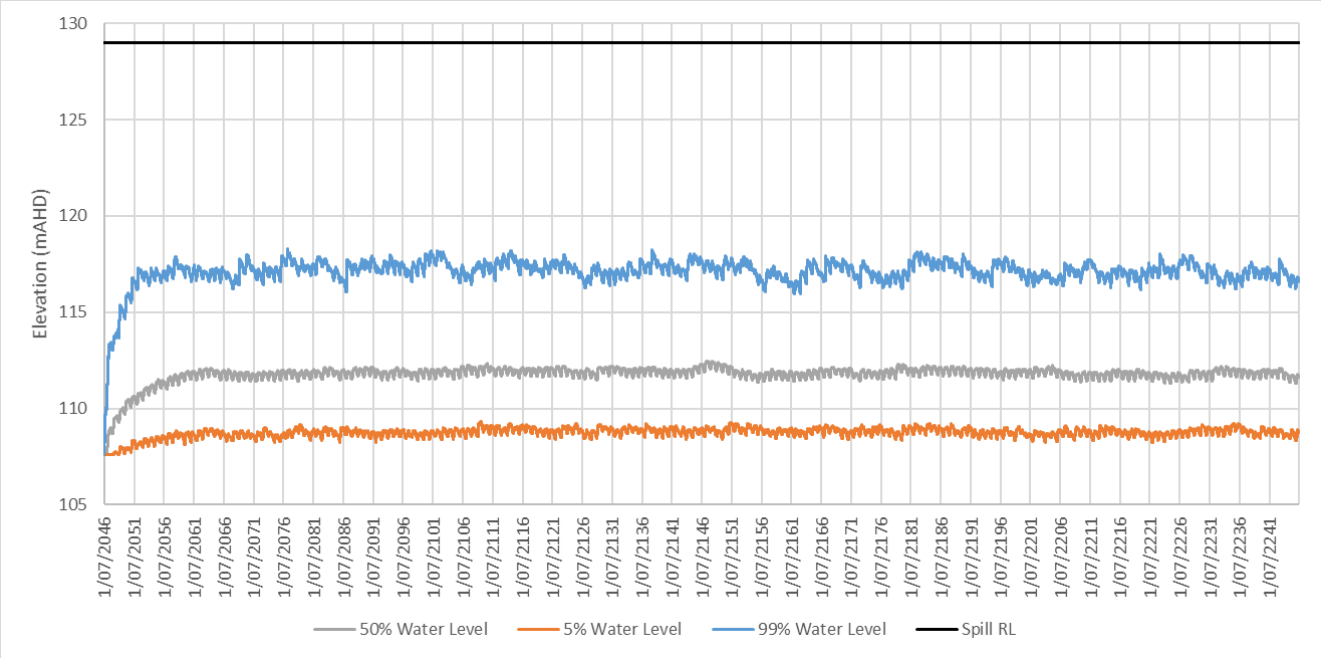



**Figure 2B** – B Pit Final Water Level

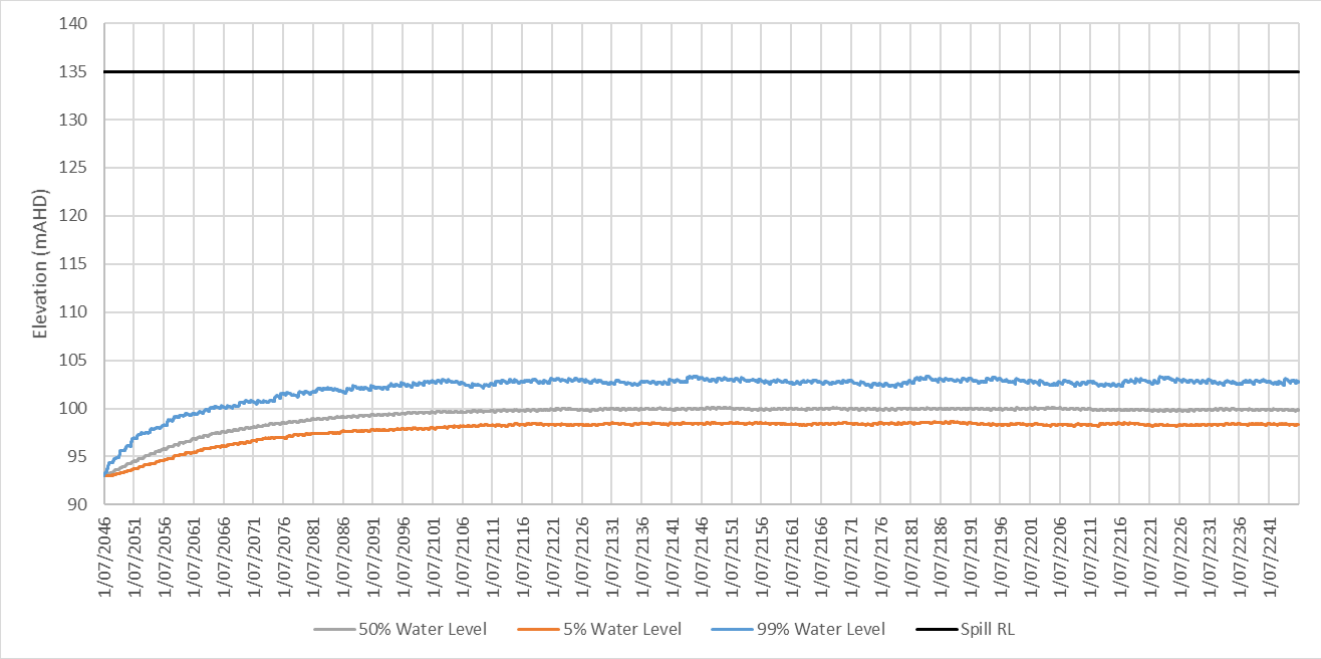



**Figure 3B** – The Void Final Water Level

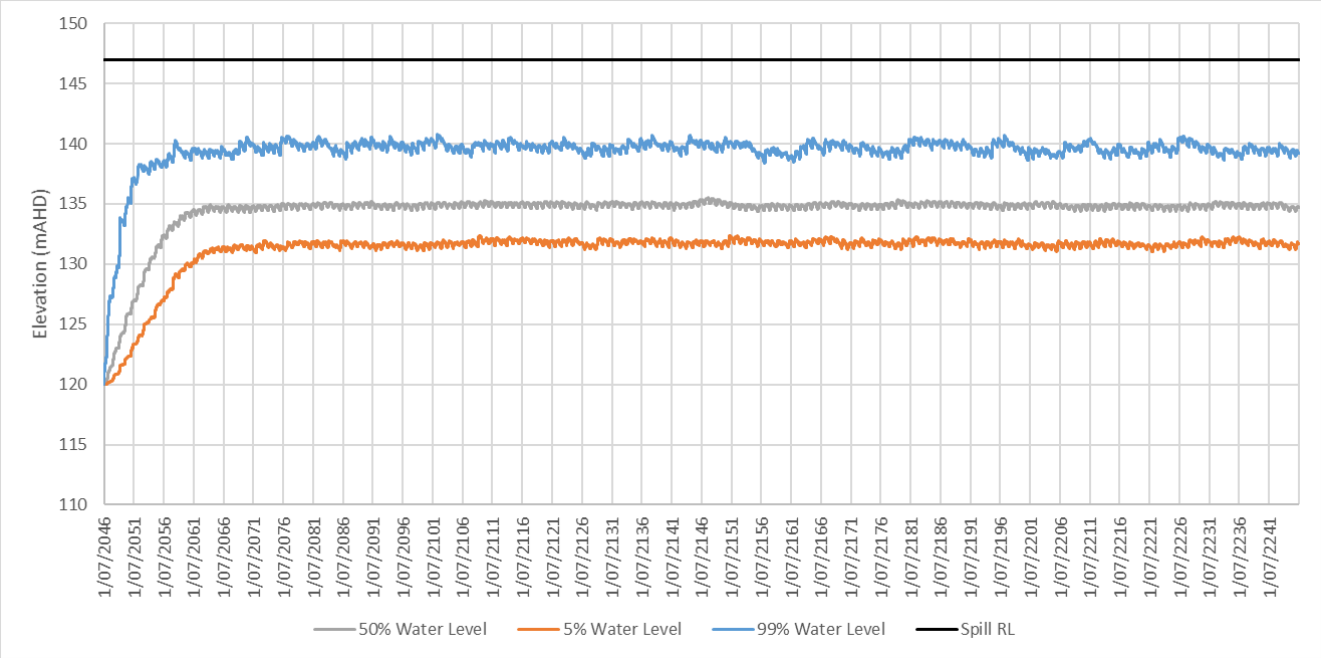



**Figure 4B** – Main Other Final Water Level

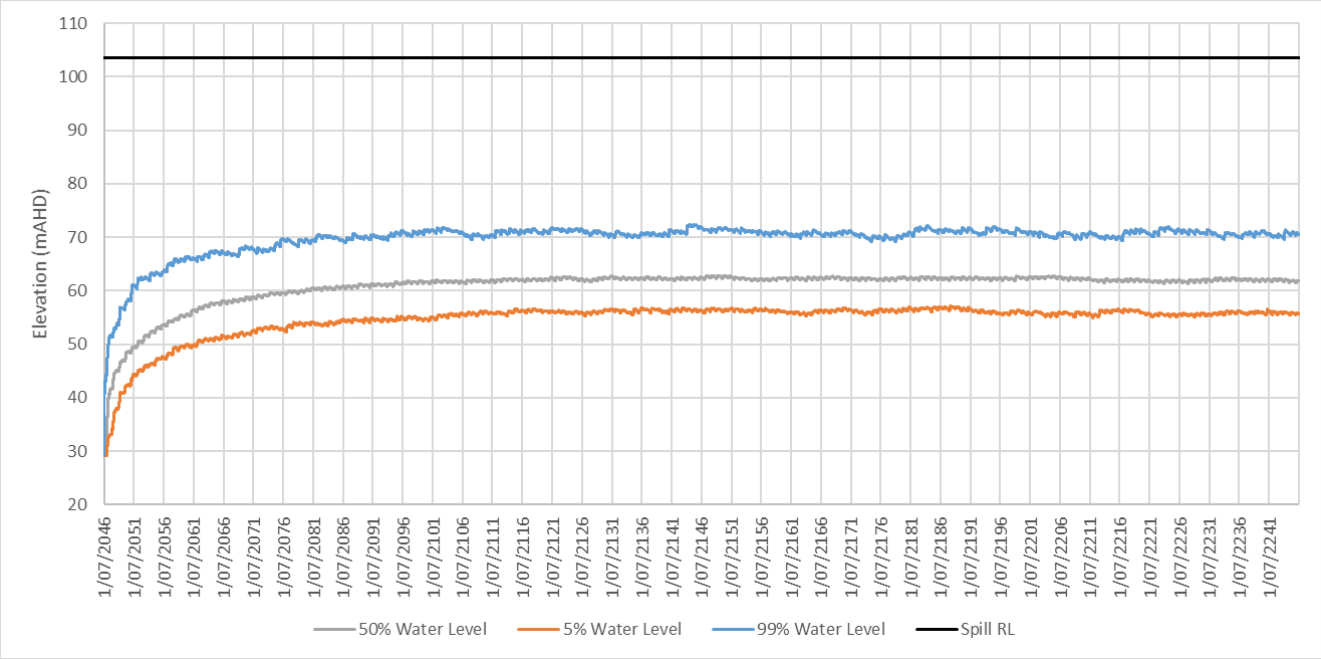



**Figure 5B** – D Pit Final Water Level

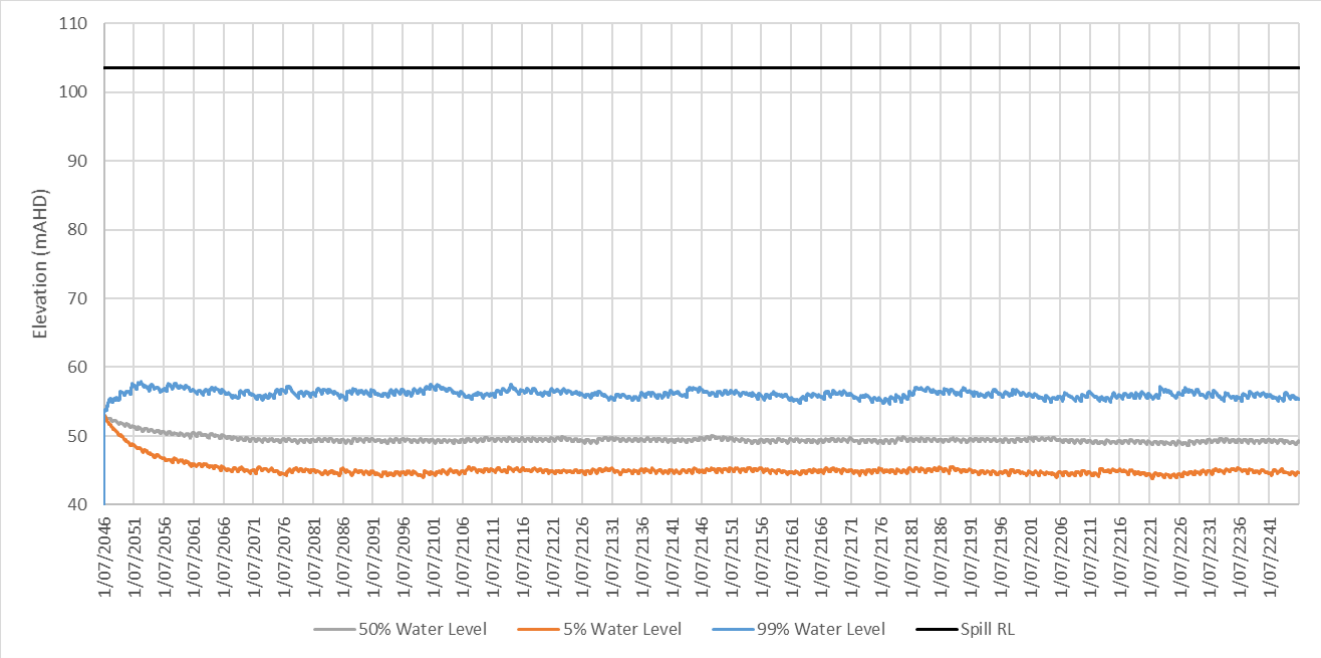



**Figure 6B** – F Pit North and Pit E North Final Water Level

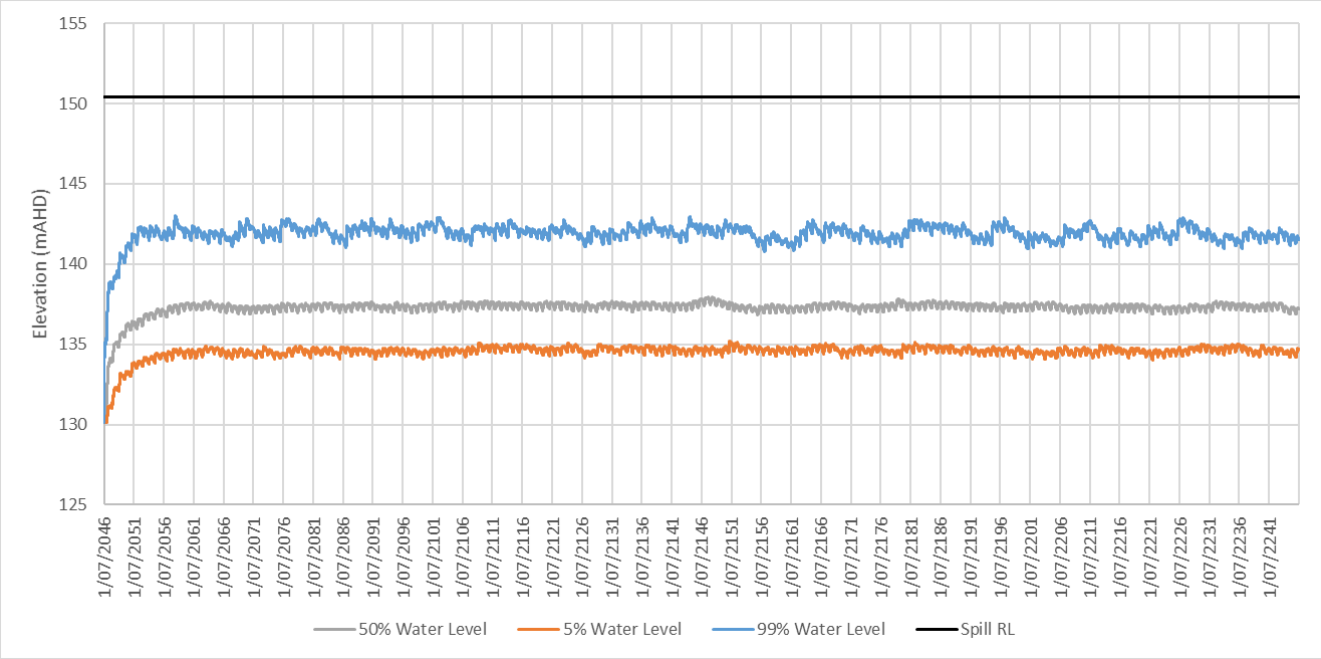



**Figure 7B** – G Pit Final Water Level

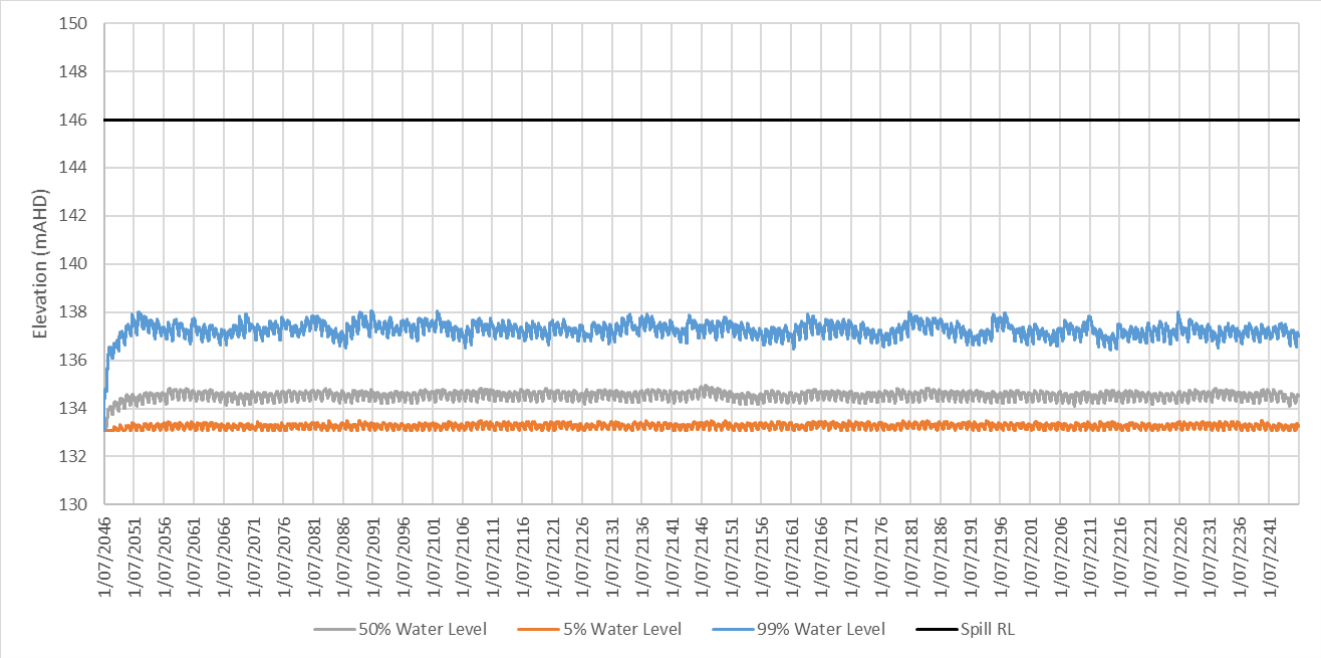



**Figure 8B** – I Pit Final Water Level

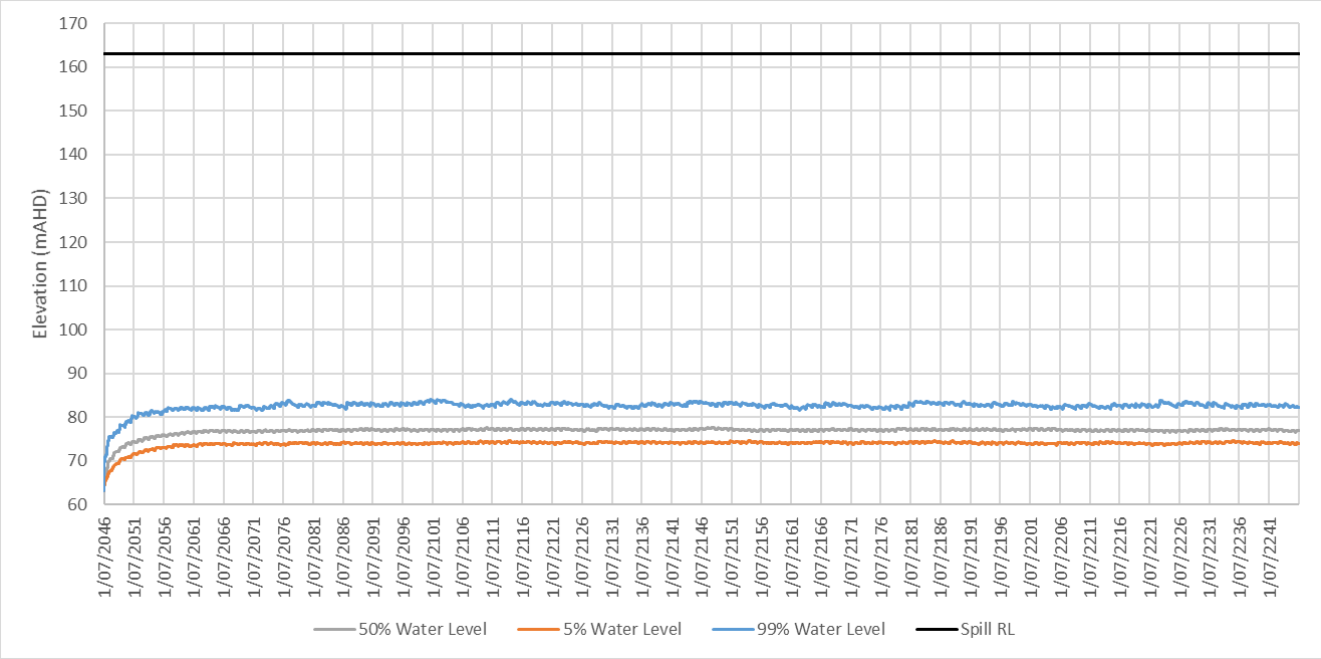



**Figure 9B** – K Pit Final Water Level

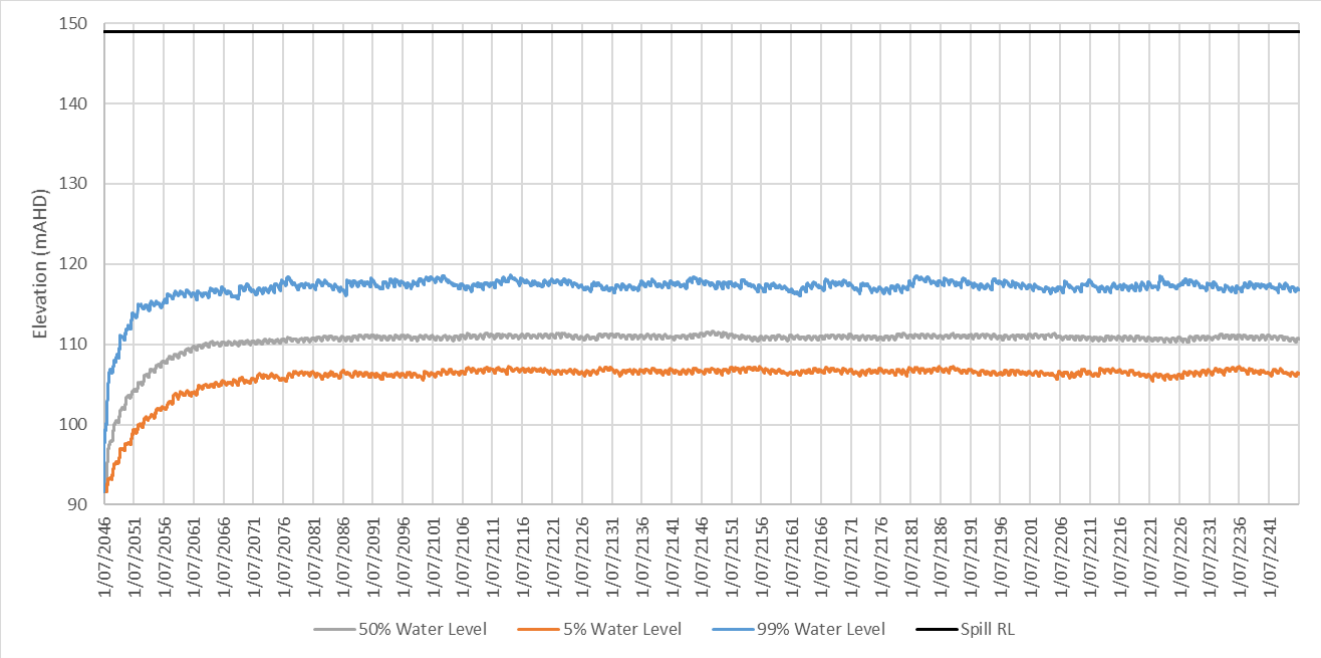



**Figure 10B** – F Pit Final Water Level

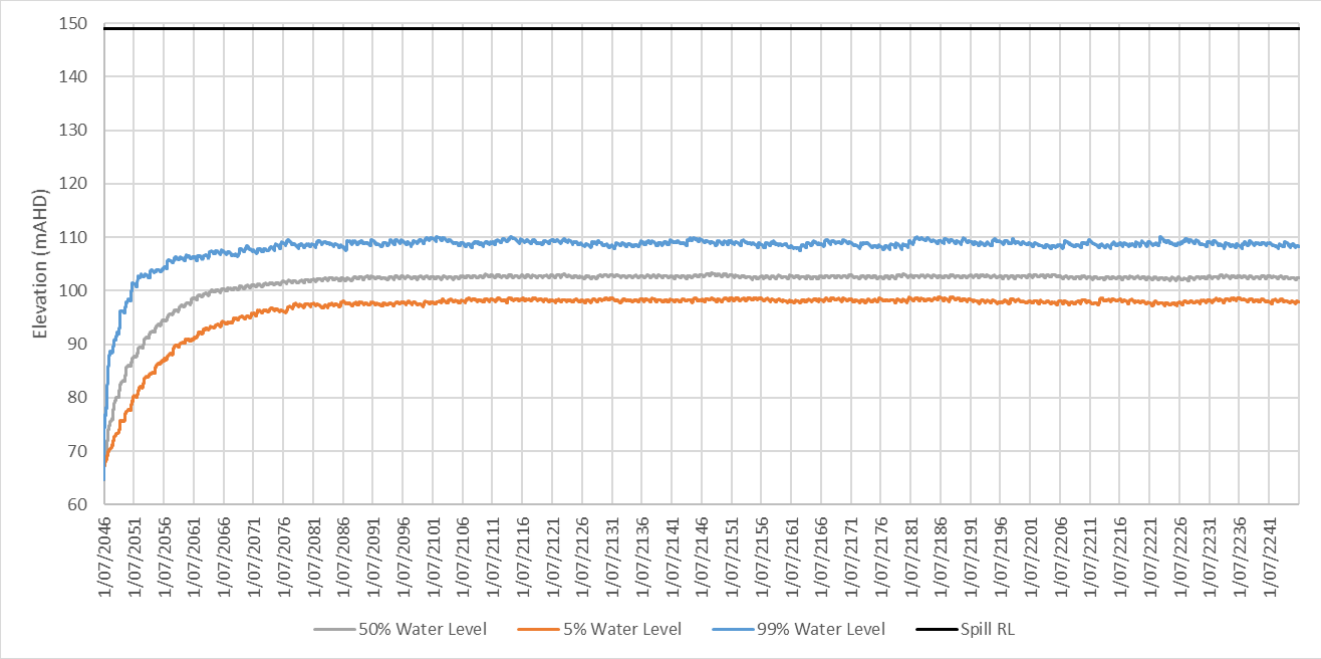



**Figure 11B** – L Pit Final Water Level

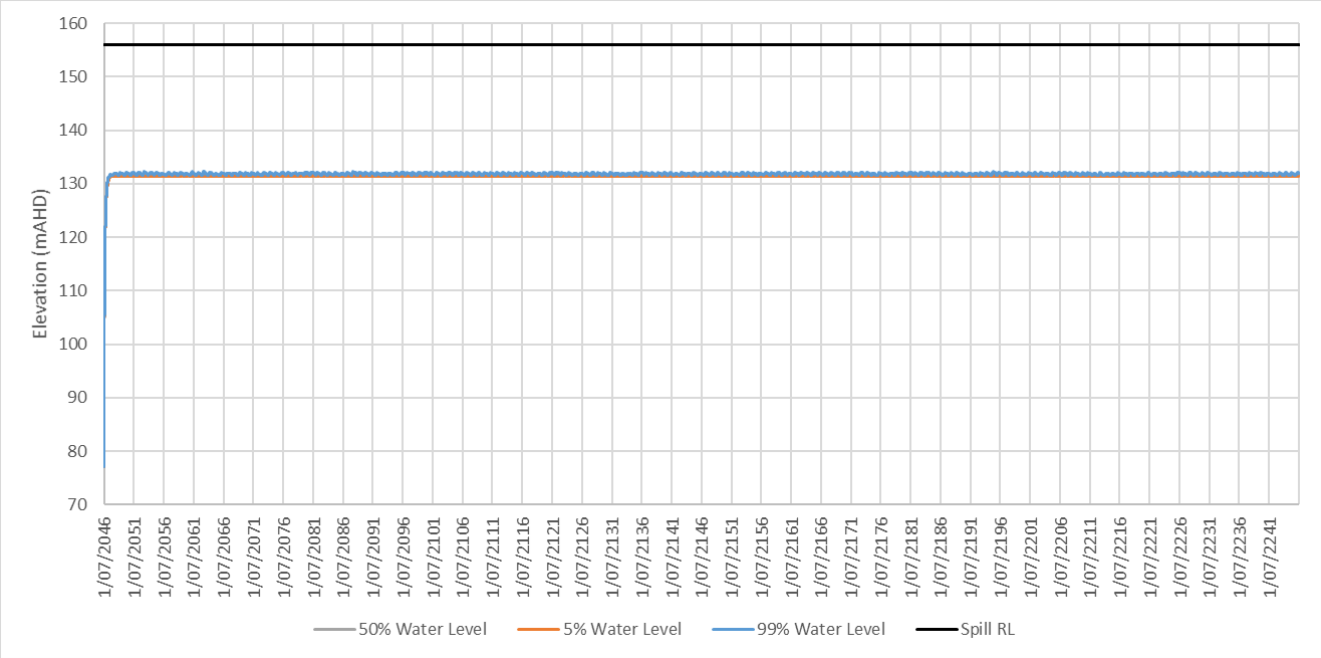



**Figure 12B** – Ramp 9 Final Water Level

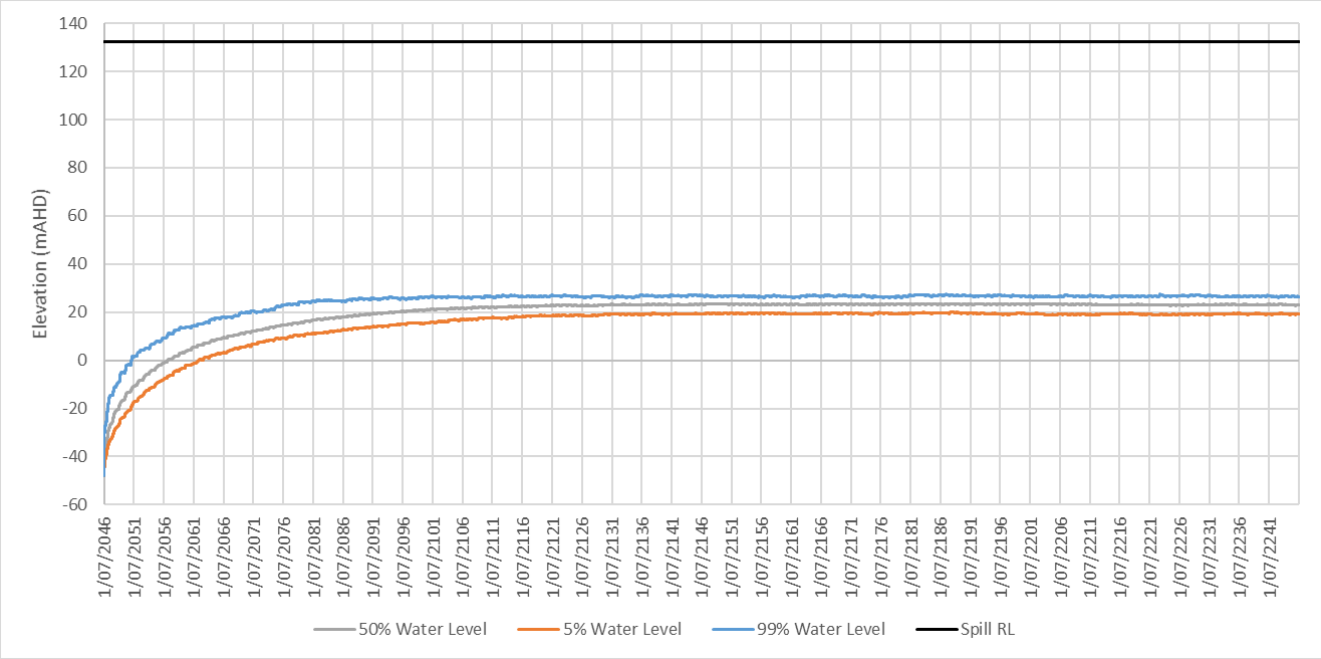



**Figure 13B** – Curragh North Final Water Level

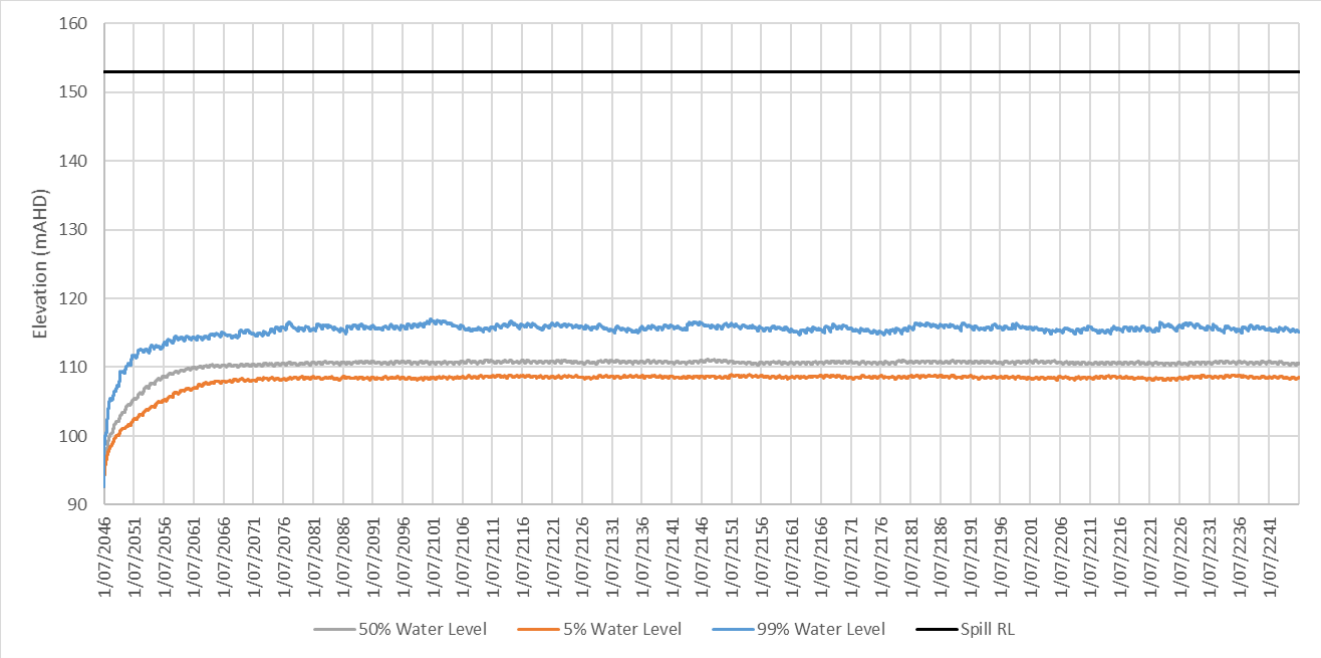



**Figure 14B** – J Pit Final Water Level

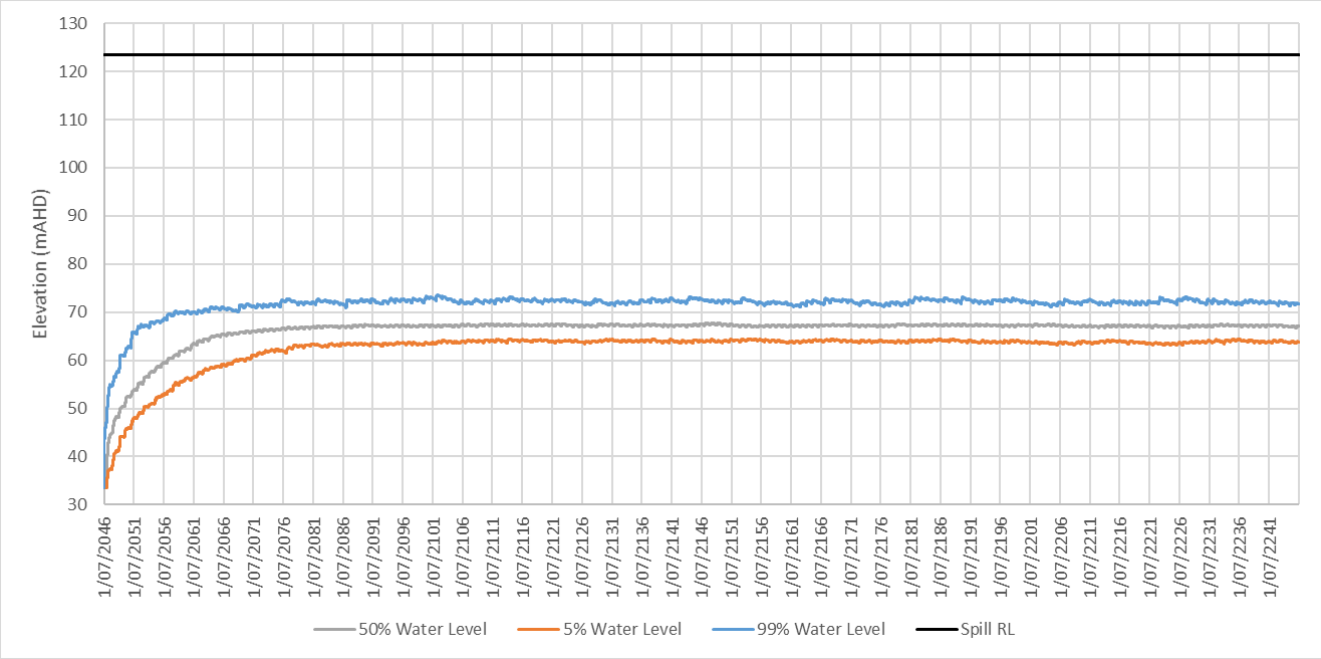



**Figure 15B** – X Pit East Final Water Level

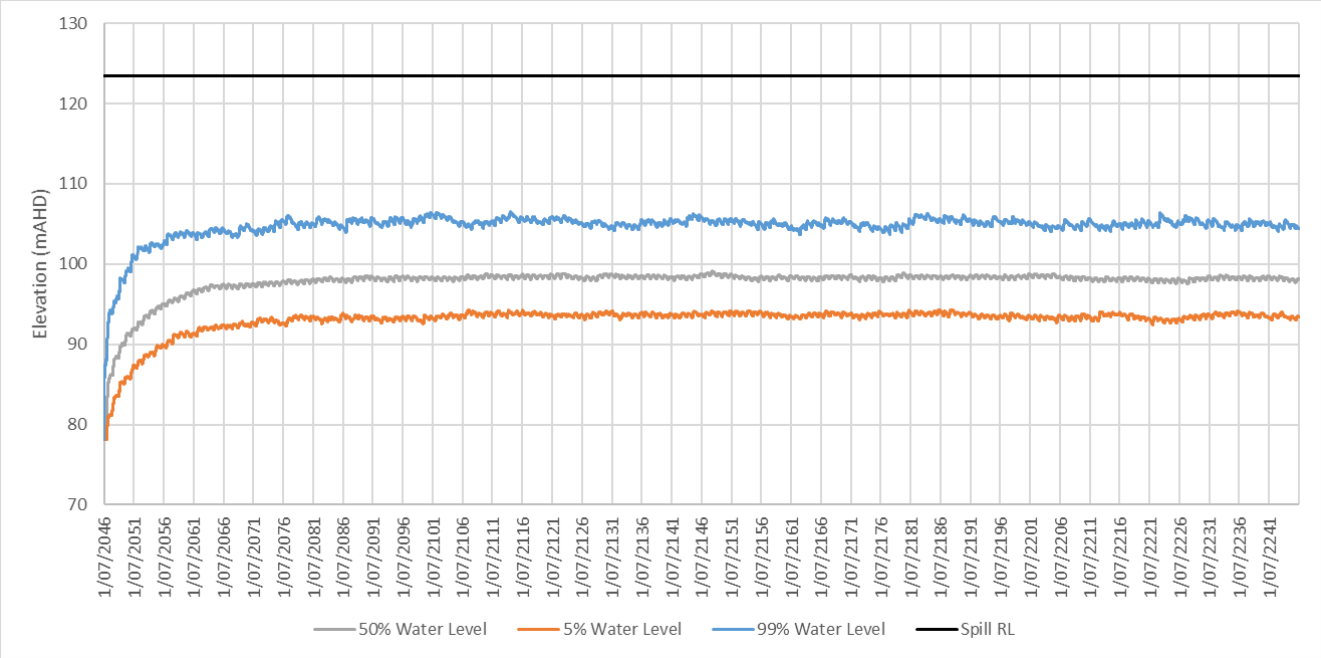



**Figure 16B** – X Pit West Final Water Level

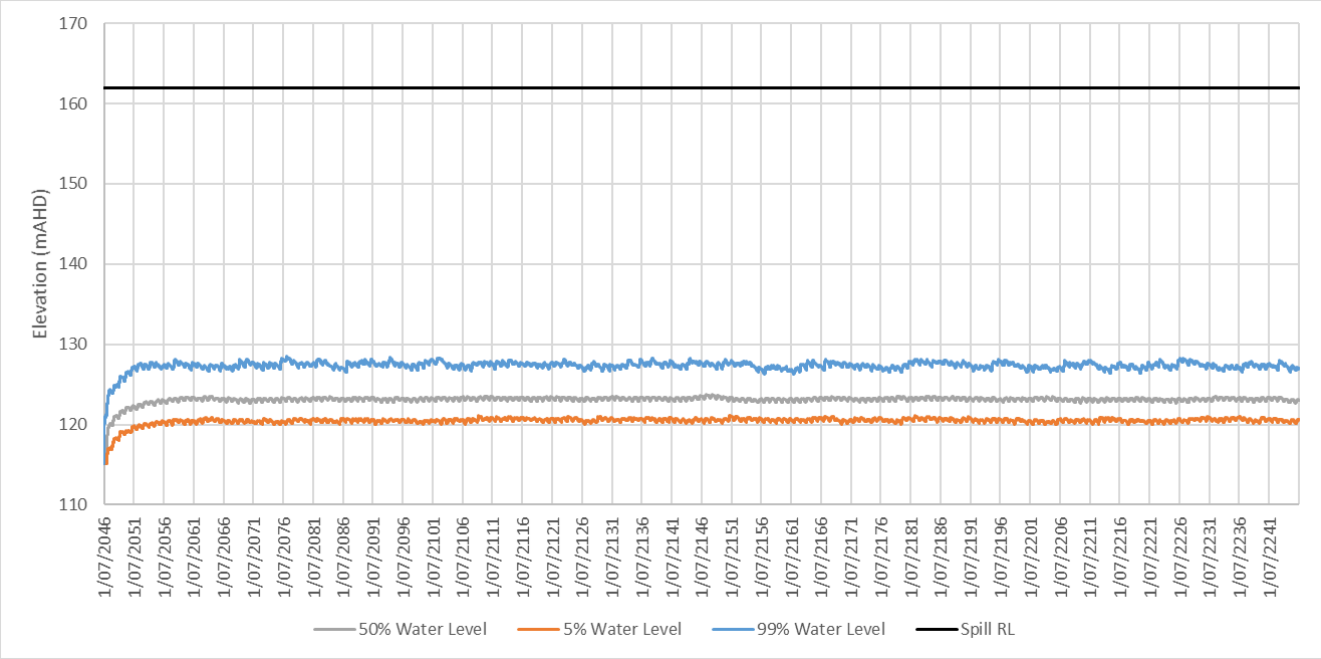



**Figure 17B** – Y Pit Final Water Level

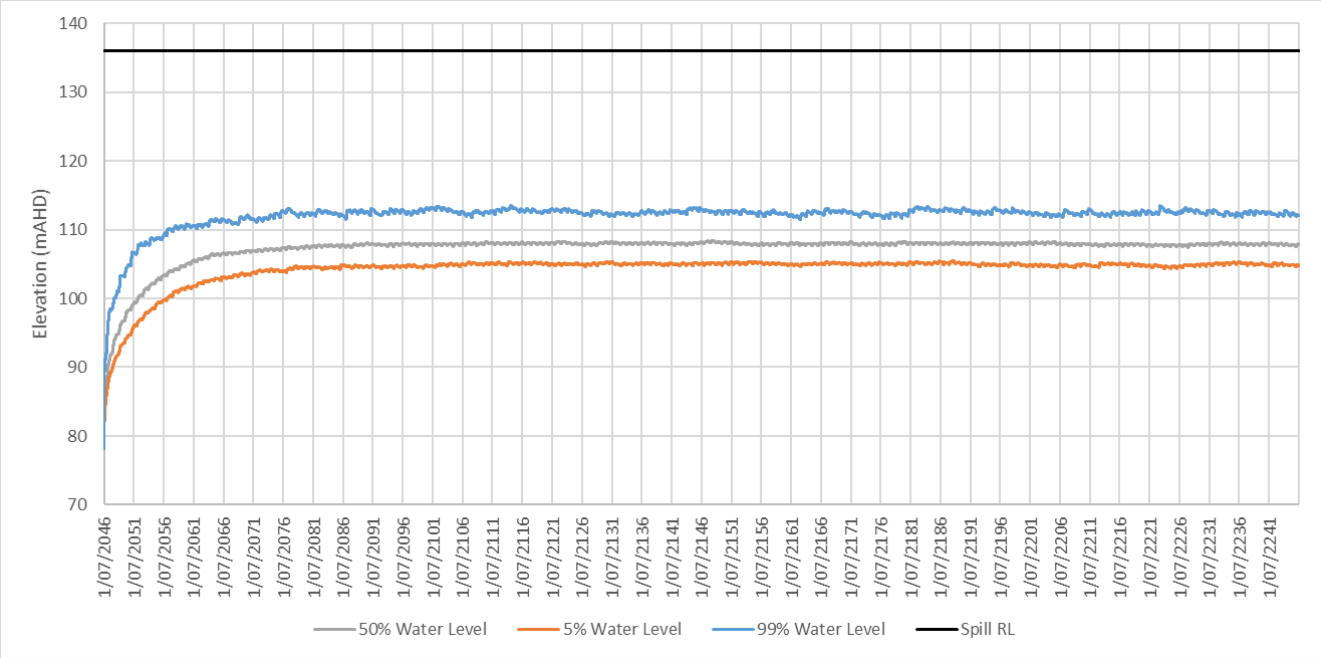



**Figure 18B** – Z Pit North Final Water Level

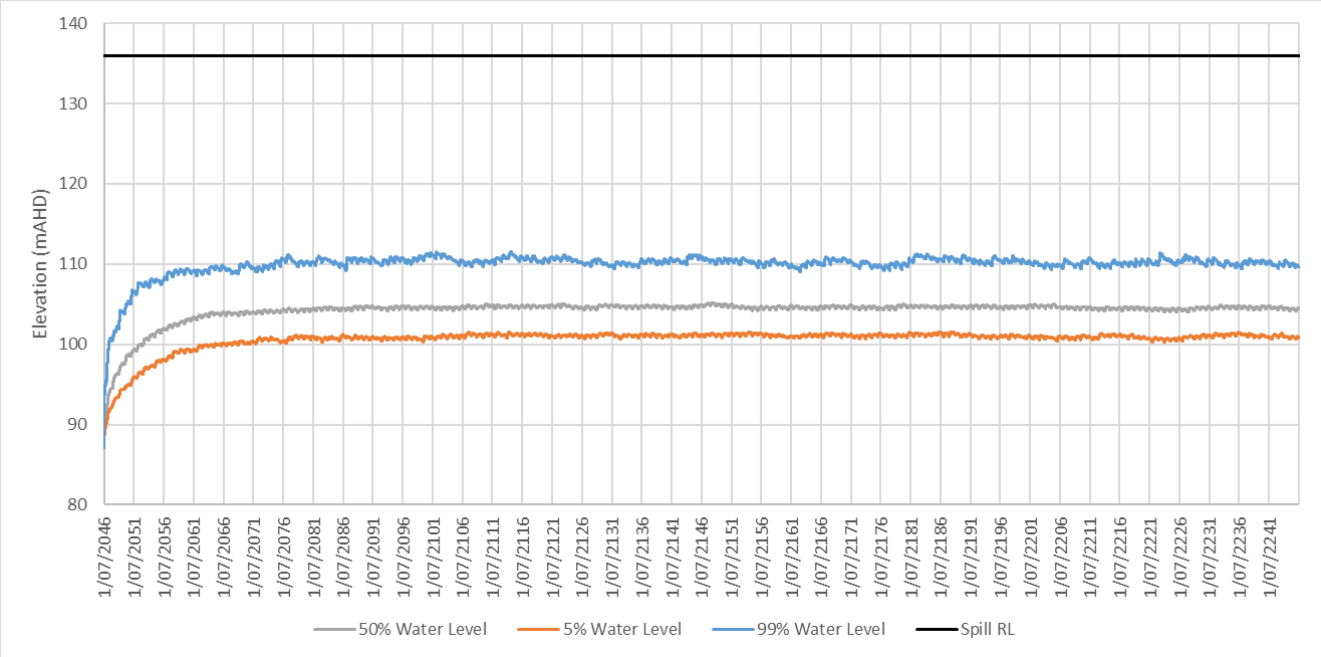



**Figure 19B** – Z Pit South Final Water Level

# APPENDIX C

Residual Void Water Quality

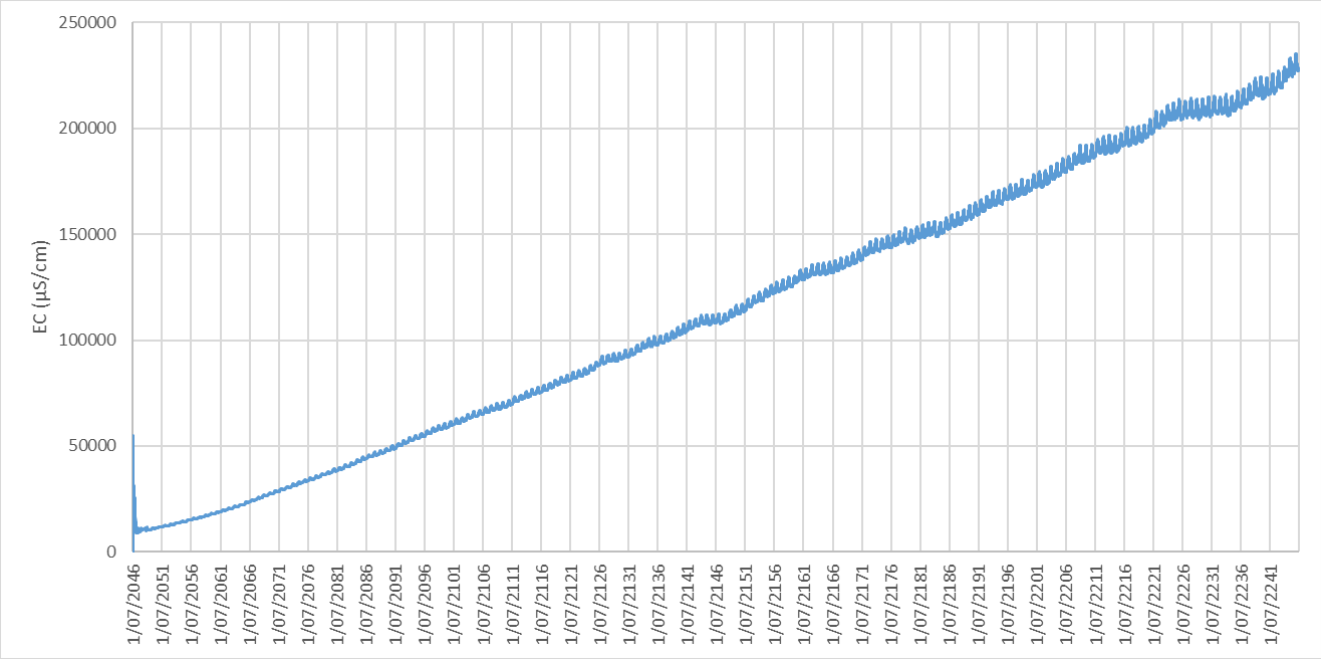



**Figure 1C** – E, C and H Pit Water Quality

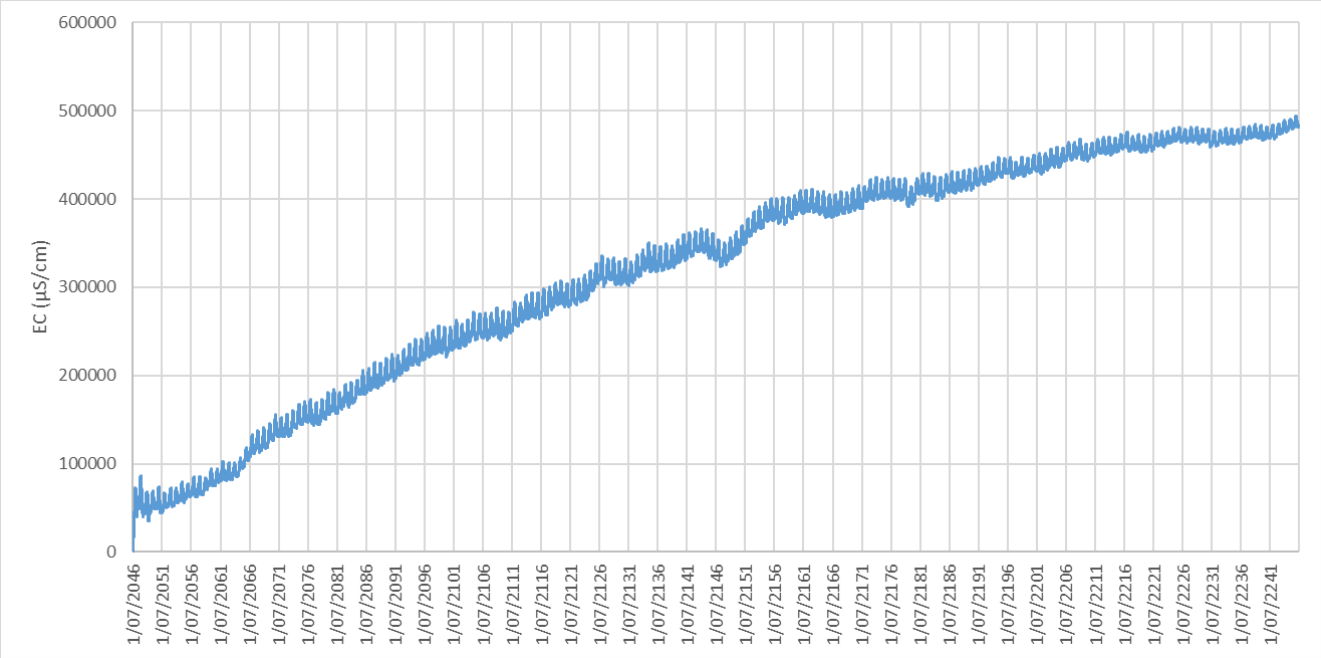



**Figure 2C** – B Pit Water Quality

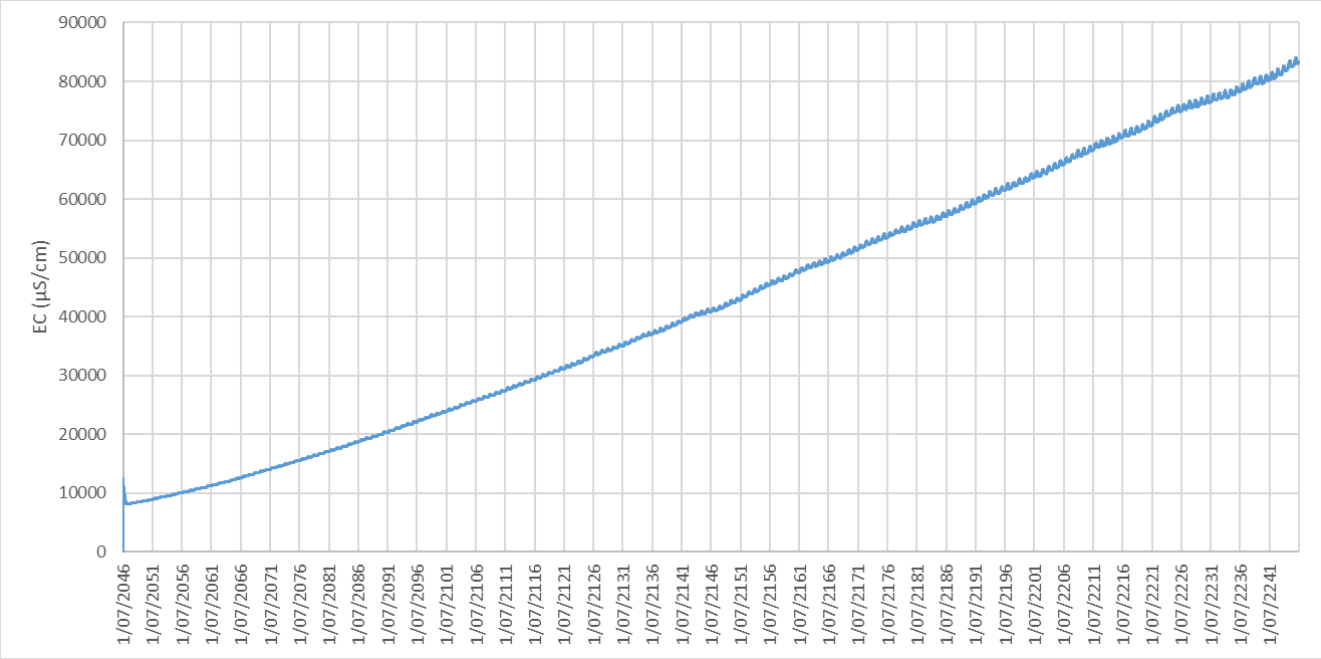



**Figure 3C** – The Void Water Quality

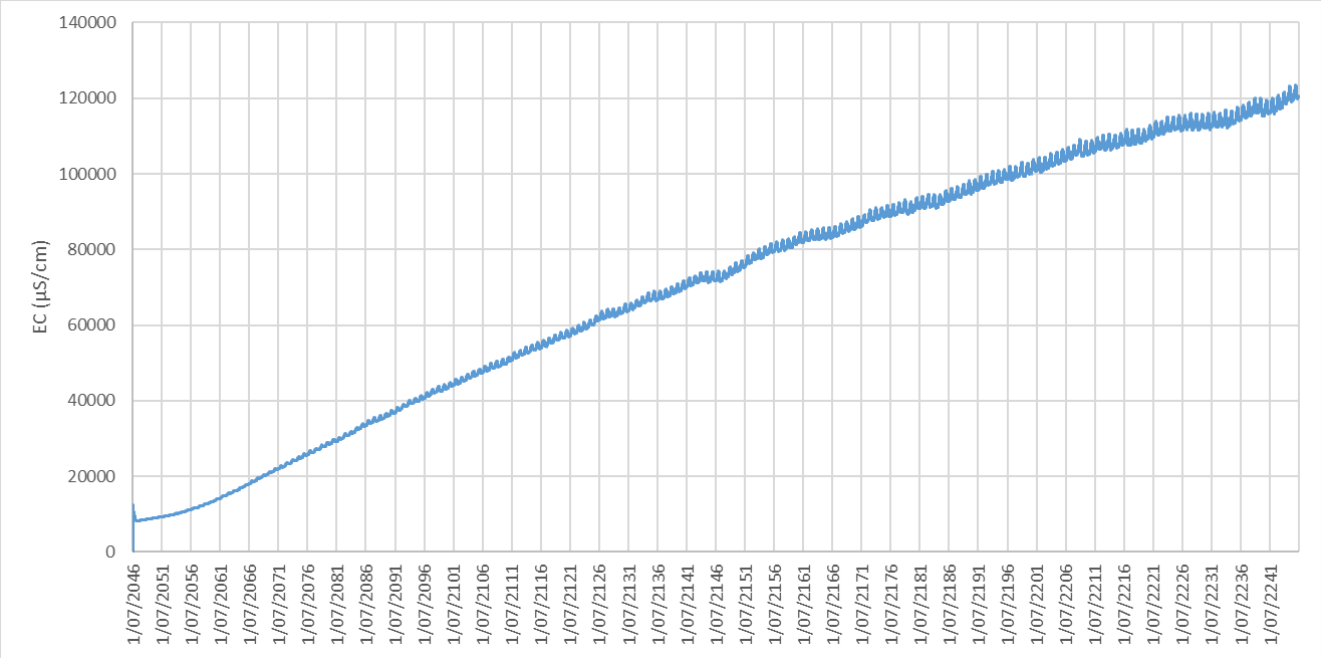



**Figure 4C** – Main Other Water Quality

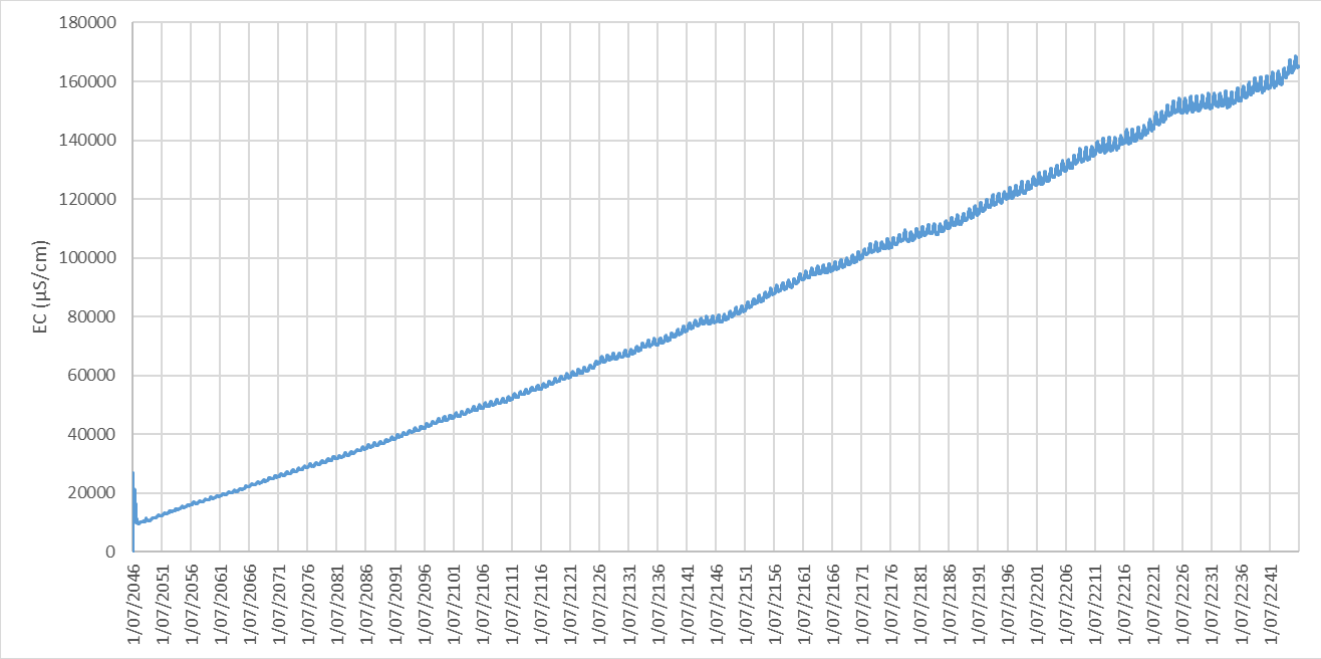



**Figure 5C** – D Pit Water Quality

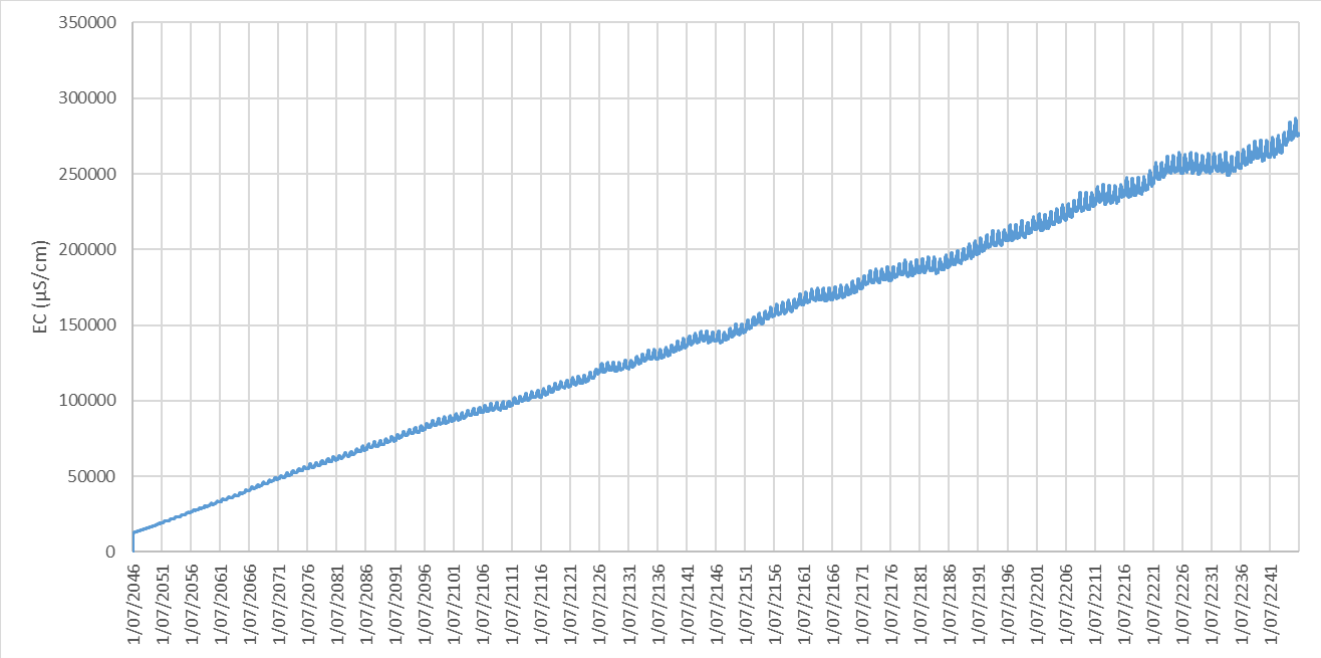



**Figure 6C** – F Pit North and Pit E North Water Quality

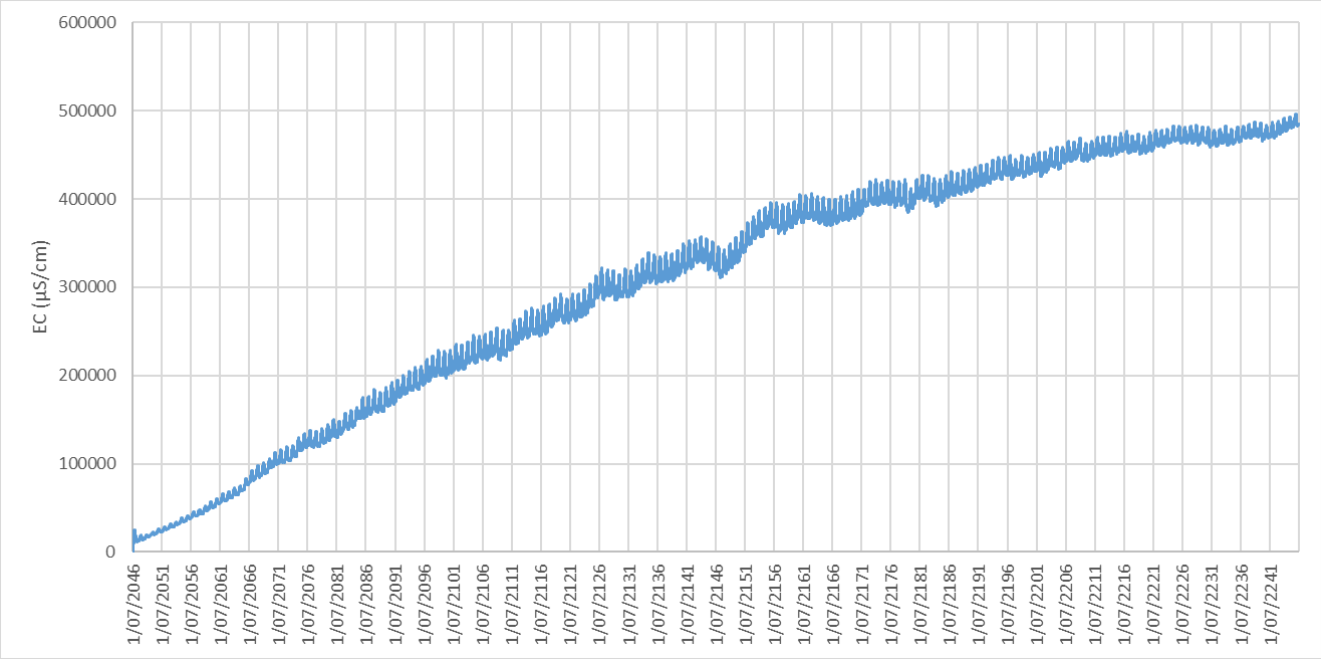



**Figure 7C** – G Pit Water Quality

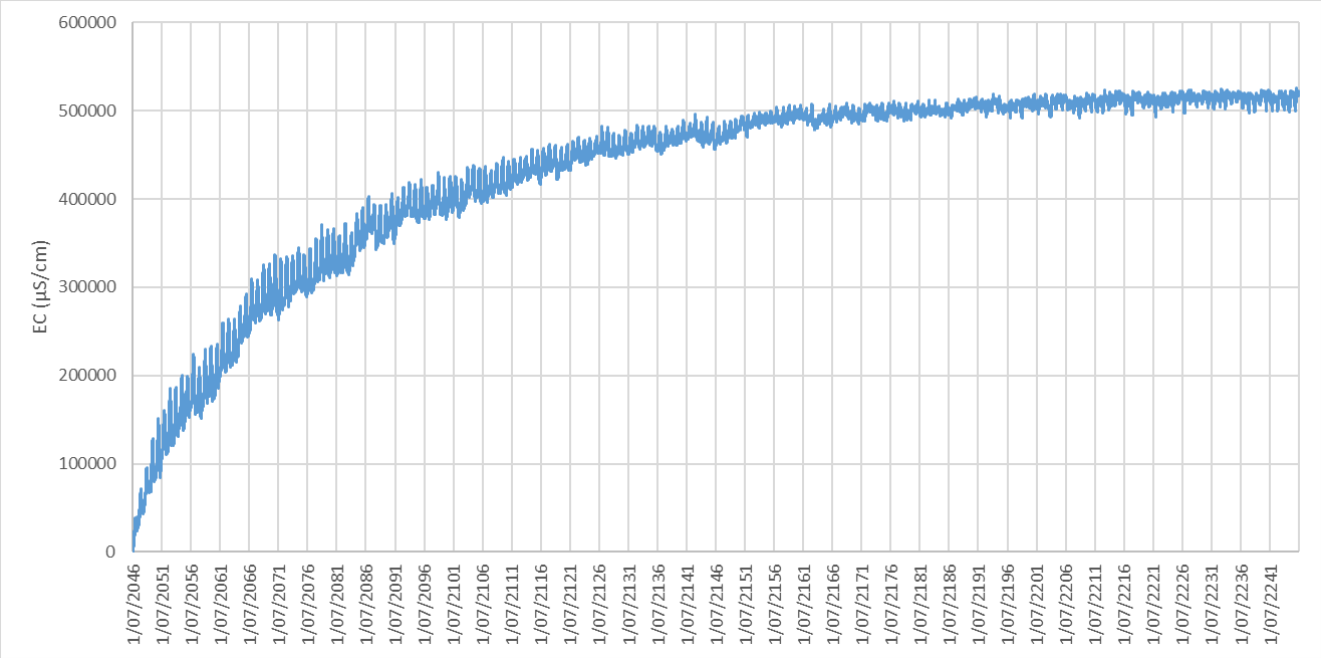



**Figure 8C** – I Pit Water Quality

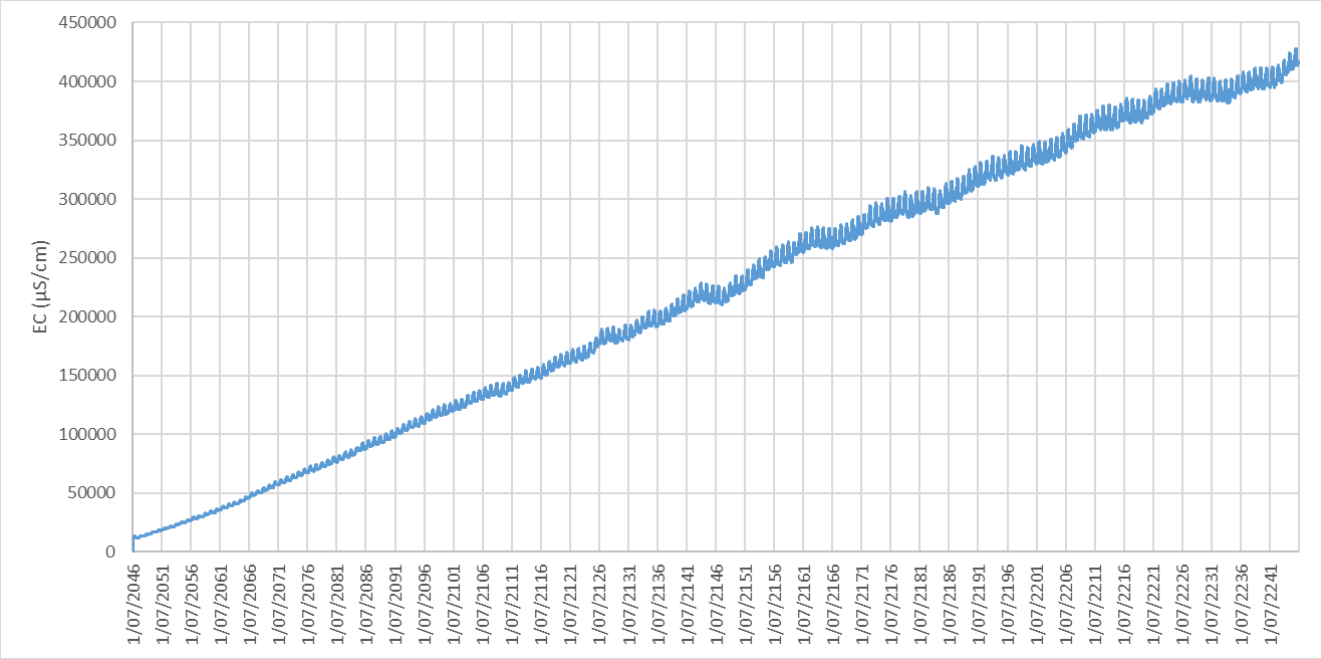



**Figure 9C** – K Pit Water Quality

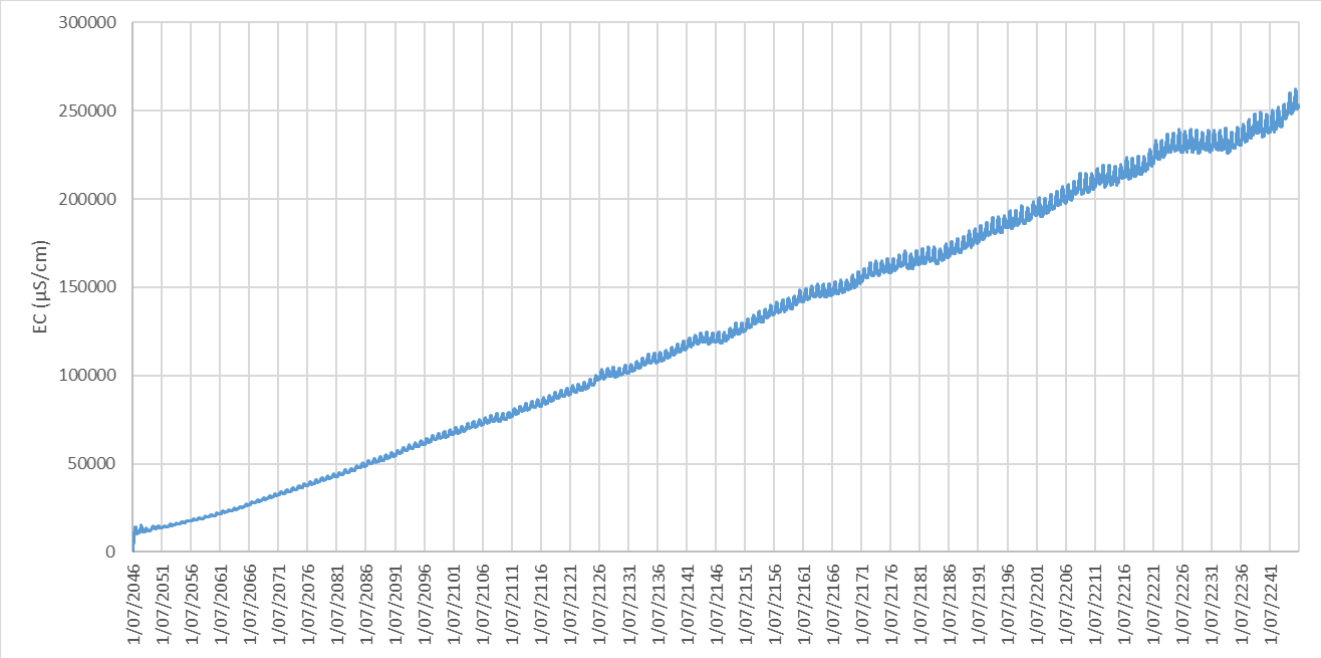



**Figure 10C** – F Pit Water Quality

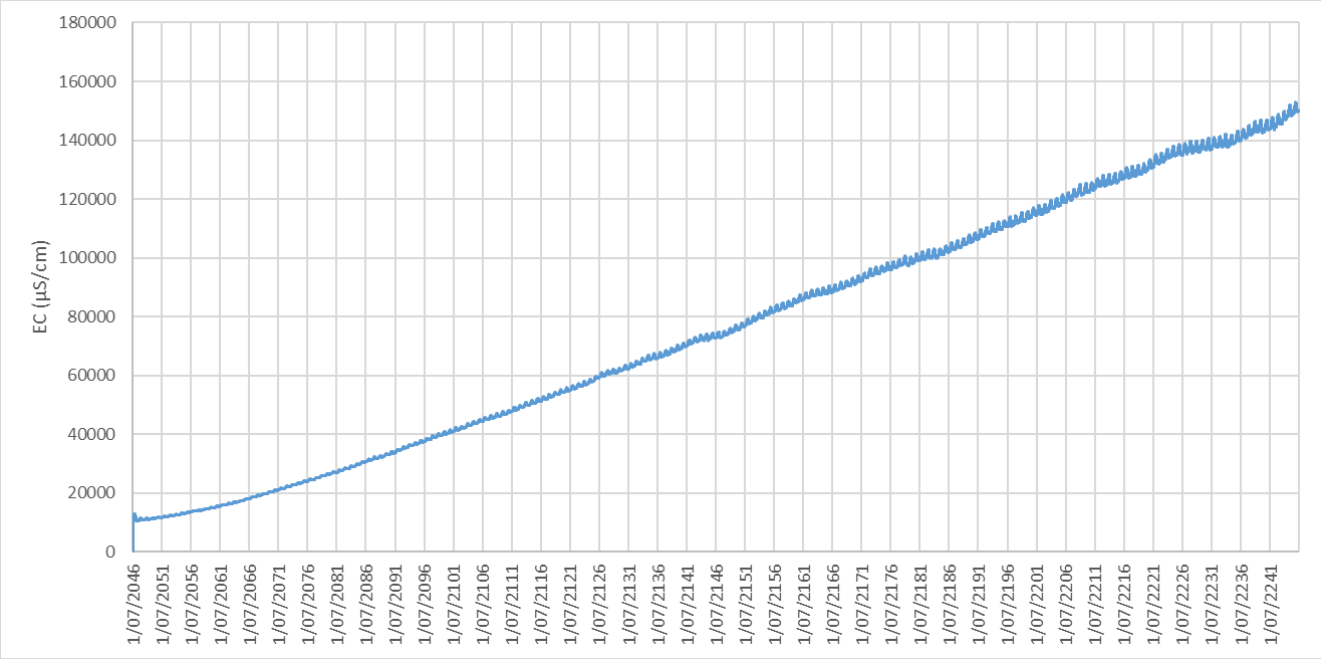



**Figure 11C** – L Pit Water Quality

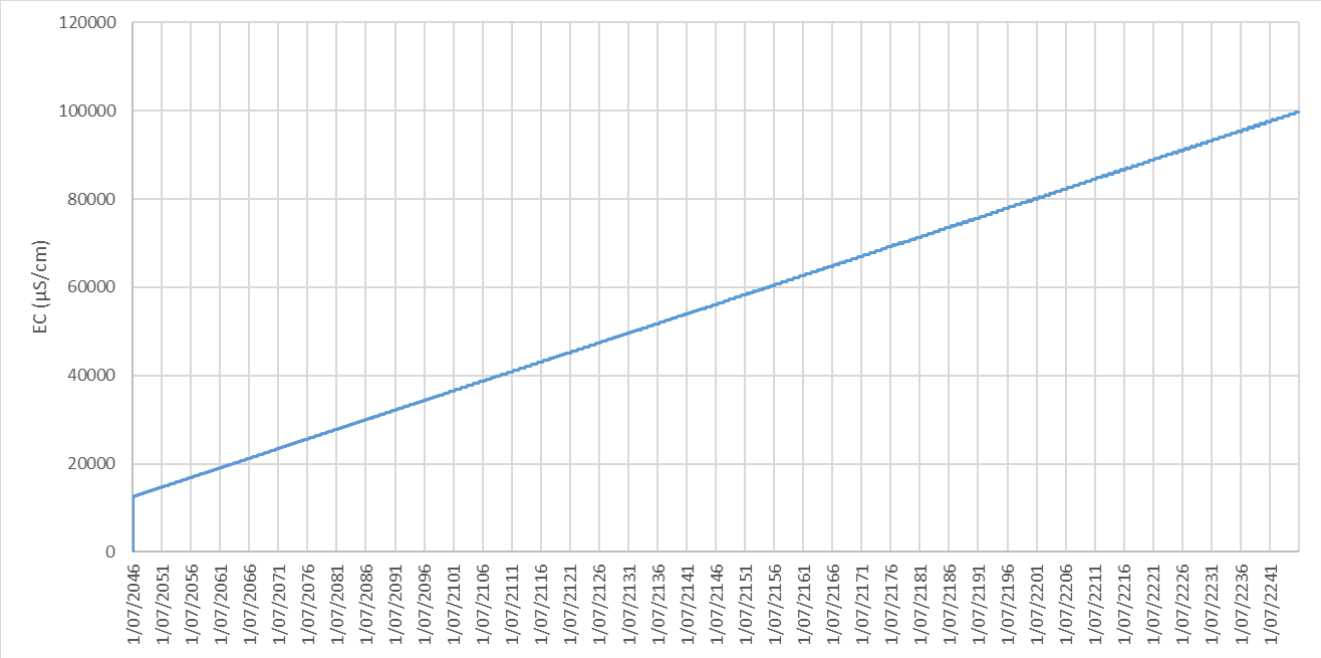



**Figure 12C** – Ramp 9 Water Quality

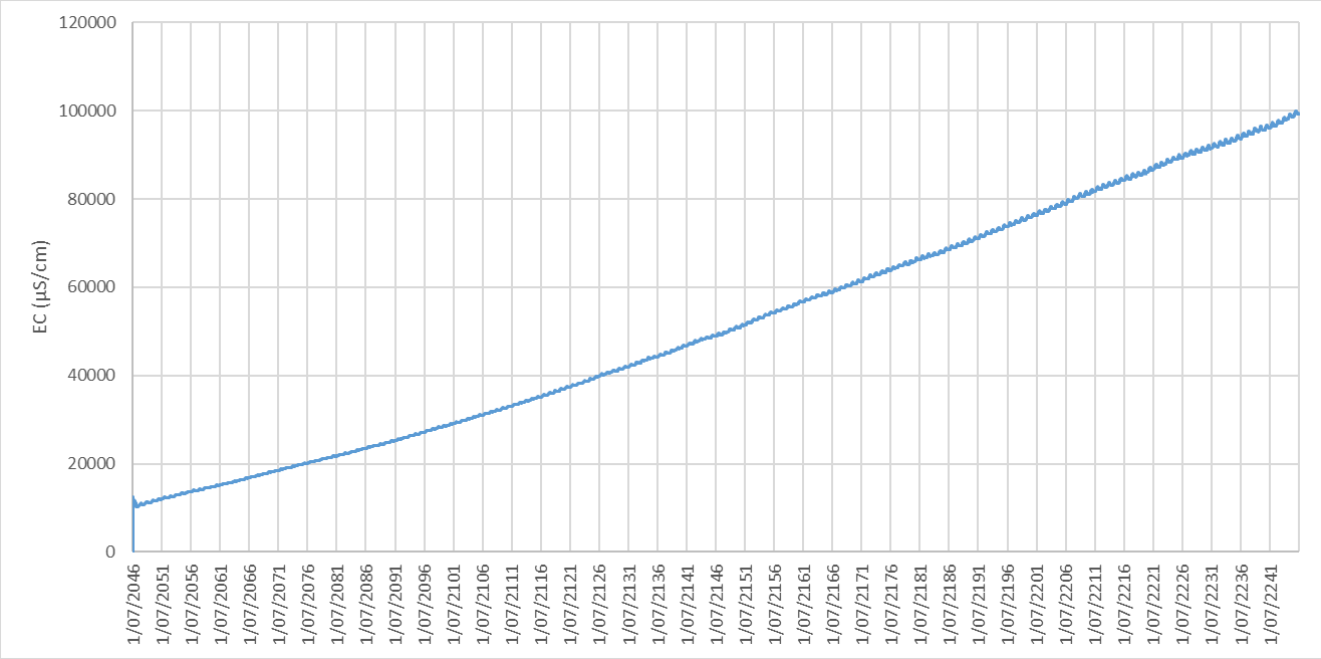



**Figure 13C** – Curragh North Water Quality

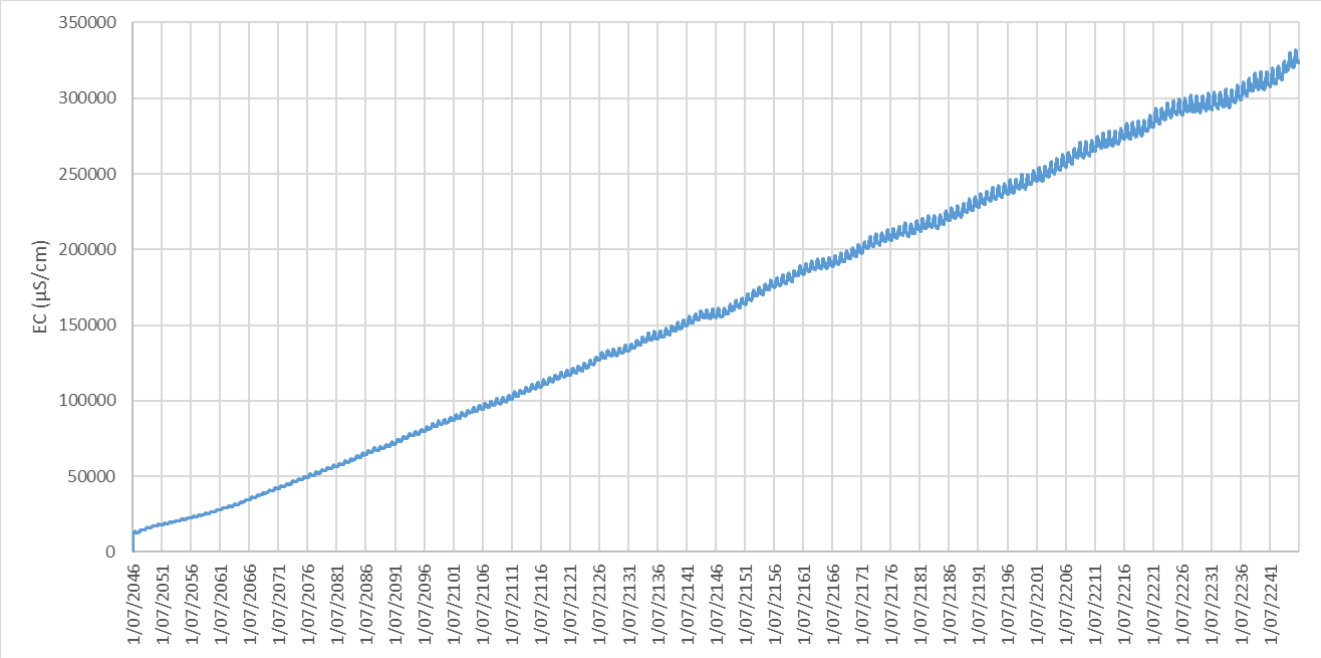



**Figure 14C** – J Pit Water Quality

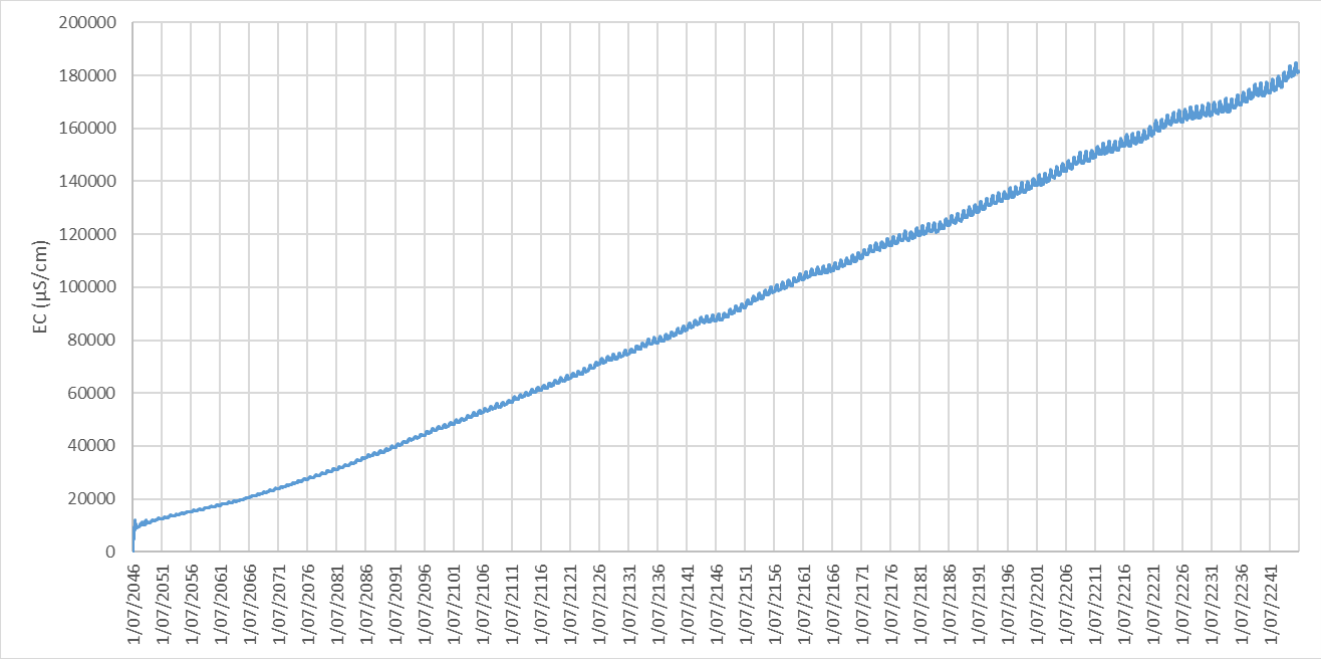



**Figure 15C** – X Pit East Water Quality

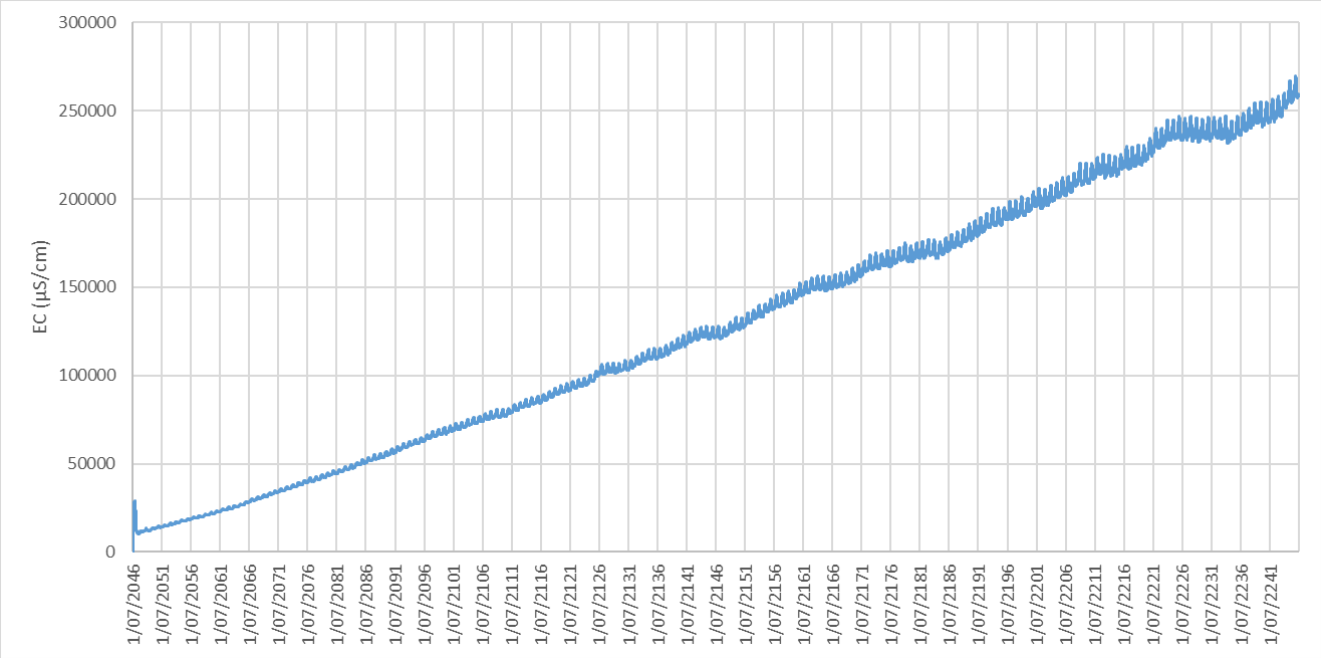



**Figure 16C** – X Pit West Water Quality

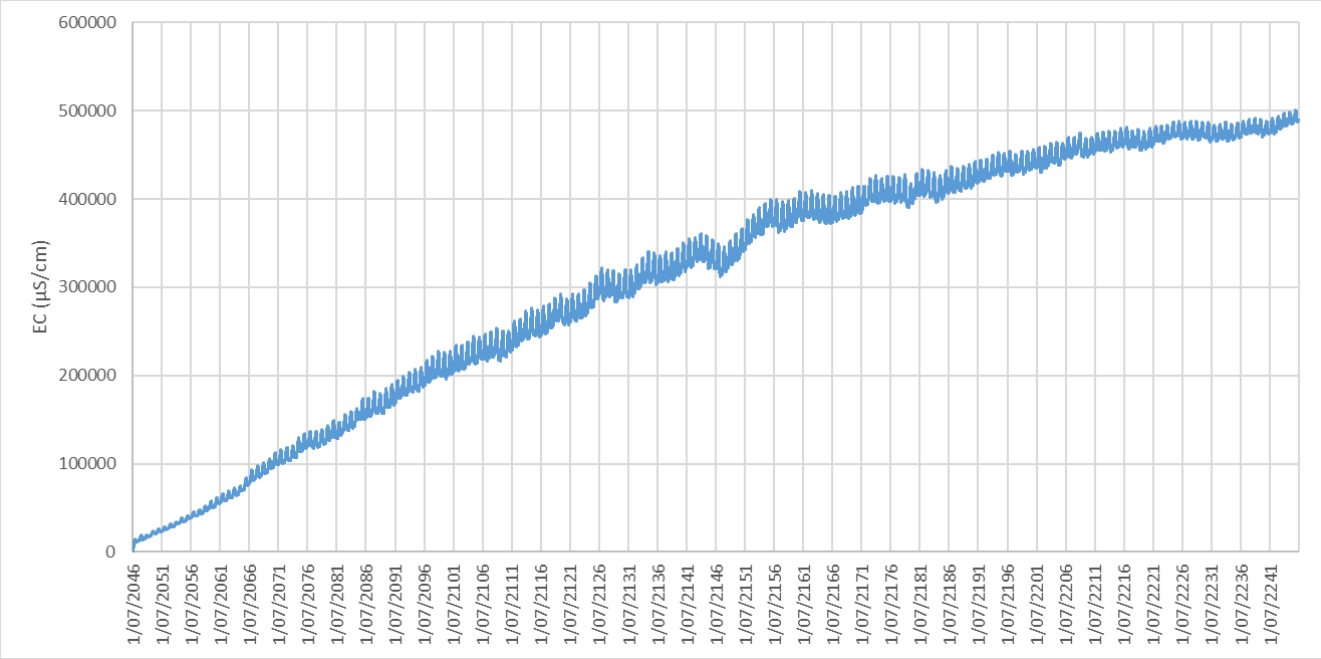



**Figure 17C** – Y Pit Water Quality

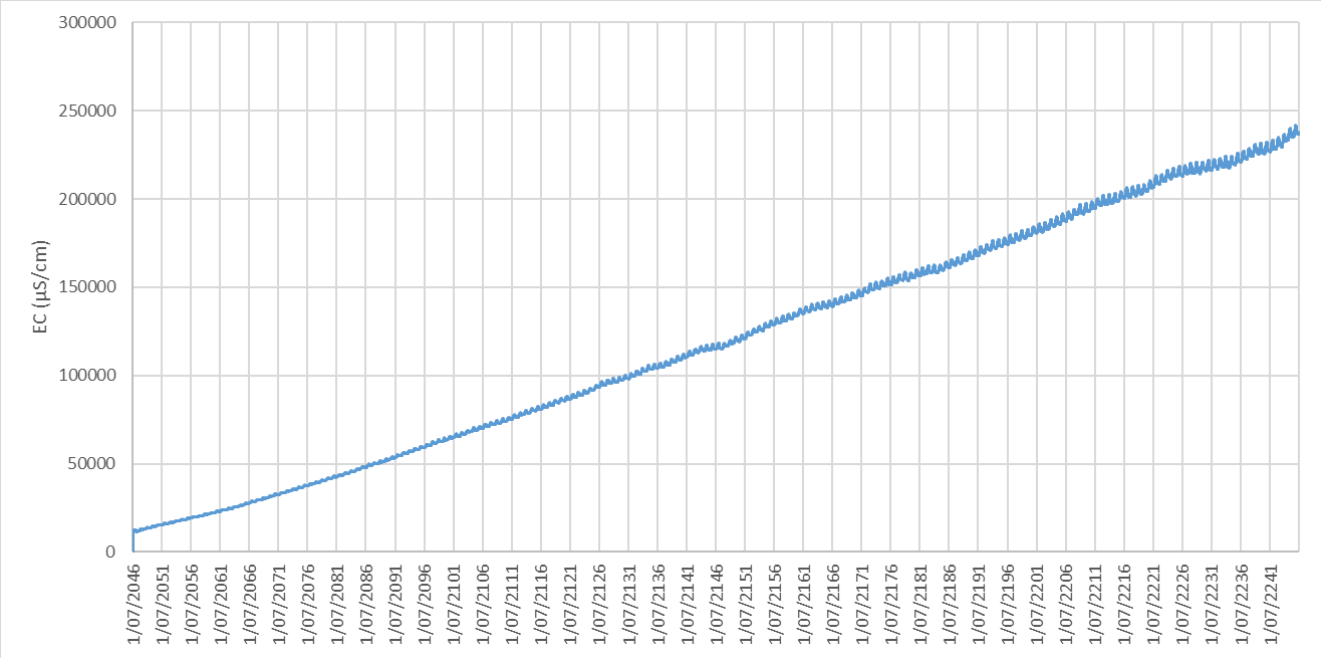



**Figure 18C** – Z Pit North Water Quality

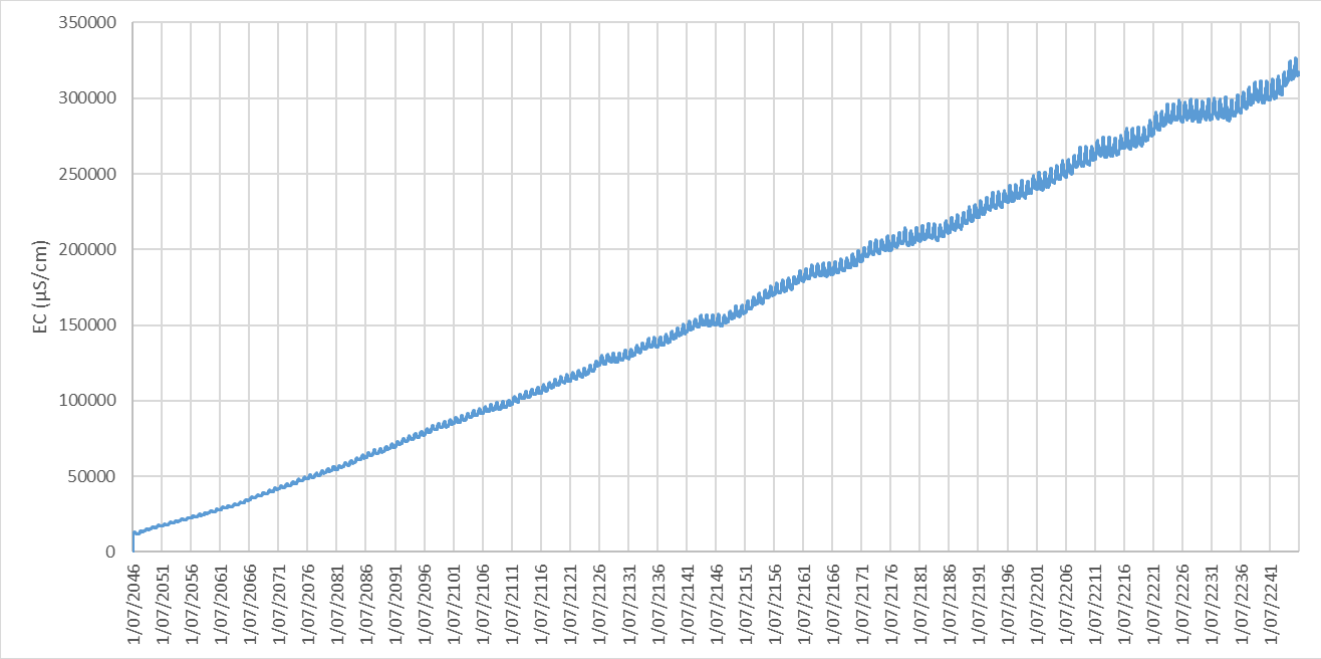



**Figure 19C** – Z Pit South Water Quality

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Wesfarmers Curragh

# Old Tailings Dam Rehabilitation

# Geotechnical Investigation and Assessment for Capping

5 May 2016



PARSONS BRINCKERHOFF

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# 1. Introduction

Deposition of tailings in the Curragh Mine Tailings Dam, referred to as Old Tailings Dam, has ceased and regulatory requirements (Condition H11) dictate that rehabilitation commences. Curragh are currently in the planning process of decommissioning Old Tailings Dam such that a stable and relatively maintenance free final landform is achieved to satisfy regulatory requirements.

The Old Tailings Dam has a surface area of around 195ha, approximately 114ha of which has been covered with tailings. For the most part, the Old Tailings Dam does not hold water, however, the southern area of the dam (near the spillway) had approximately 1 m of water (at time of preparation of the scope of works). Any capping strategy is to incorporate dewatering of this area as well as consideration for placing material over these wet tailings.

Tailings are retained by an earth embankment constructed from mine spoil. A mine haul road is located at the downstream toe of the embankment to the east, with an explosive magazine and hard stand located to the north and power lines to the west.

The final landform of the rehabilitated tailings dam is to support self-sustaining vegetation and graded so that all surface waters flows are redirected to the spillway at the south of the dam. Permian spoil from the adjacent mining operations has been proposed to be utilised in the capping layers.

This report presents the results of the site investigation and stability analysis for the initial placement of a capping layer over the tailings and provides comments and recommendations to allow a construction process to be developed while working over tailings. Separate documentation is to be provided which will address the requirements of a self-sustaining vegetation cover.

## 1.1 Background

Principal characteristics of the Stage 3 embankment are summarised in Table 1. Key dates on the dams operation to provide background and support to the condition of the tailings are below:

- Stage 1 of the tailings dam was designed by Longworth and Mackenzie in 1987/1988 and licenced in 1989
- The decant structure in the northern cell was buried in 1998 (PB inspection report 2005)
- Deposition in the northern cell ceased in 1999 (PPK report 2001)
- Placement of the tailings in the southern cell was from two discharge points
- Seepage through the embankment (PPK report 2001)
- Following an inspection of the tailings dam completed by Golder Associates in October 2013, GHD completed a stability review of the north east corner of the embankment (GHD, 2014). GHD completed a number of stability analyses and recommended that the embankment batter face be trimmed to a slope of 2.5H in 1V or construction of a 6 m wide buttress at the base of the embankment.

**Table 1 Dam details**

| | |
|---|---|
| Total length | 3350 m |
| Crest height | RL 176 m<br>RL 177m (top of safety berm) |
| Crest width | 13 m |
| Maximum height | 24 m |
| Batter slopes | 2 horizontal (H) in 1 vertical (V) – upstream<br>= 2.5 H in 1 V - downstream |
| Spillway crest level | RL 174.6 m |

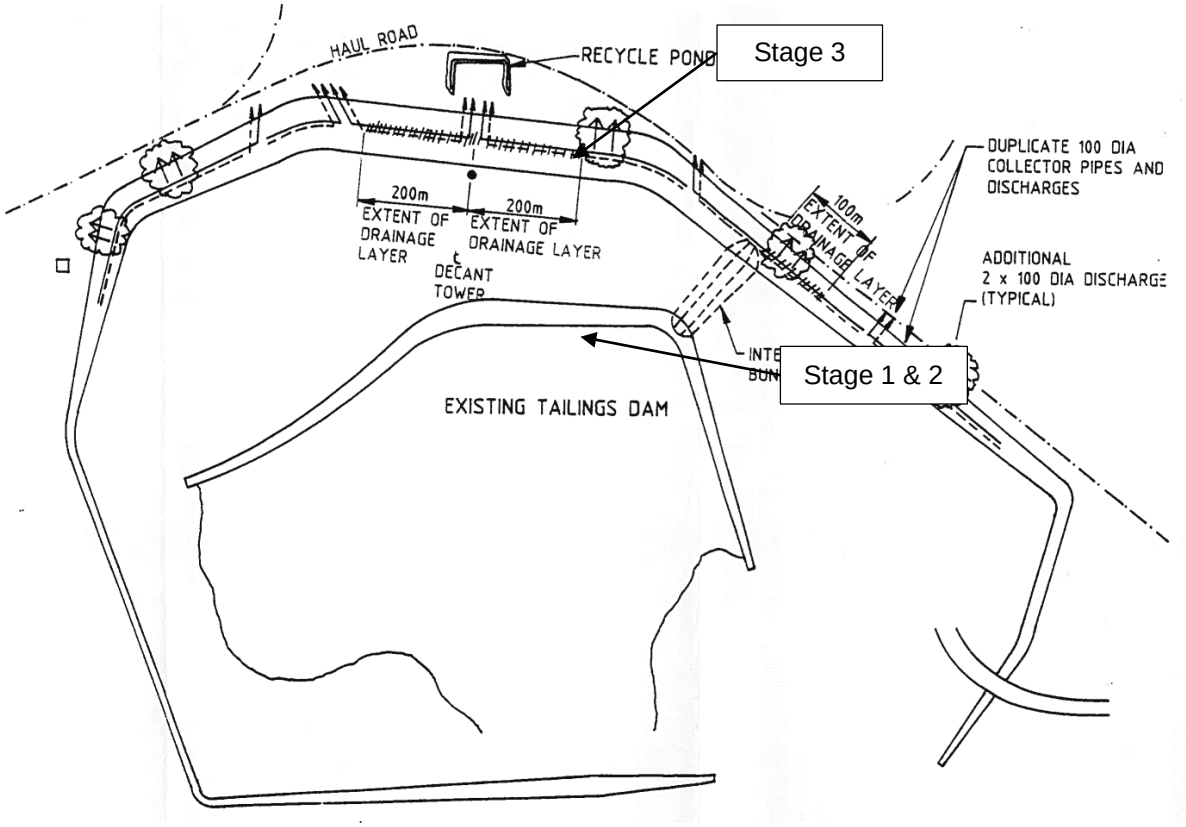



**Figure 1-1: Old Tailings Dam layout**

# 2. Method of investigation

The objective of the investigation was to characterise the near surface strength profile of the tailings material to assess whether the tailings surface could support a capping layer. This was achieved through a field investigation comprising in-situ testing, sub-surface sampling and a laboratory testing regime

Fieldwork for the investigation was carried out on the 3rd and 4th of December 2015 and comprised:

- 10 x test pits excavated with a long reach excavator
- 5 x dynamic cone penetrometer (DCP) tests
- 3 x vane shear tests

Test locations were recorded on site using a hand held GPS, which has an accuracy of ± 5 m, and are shown on Figure 1, attached in Appendix B. Pocket penetrometer (PP) tests were also completed on material excavated from the test pits as noted on the logs.

Fieldwork was carried out by a senior engineering geologist from Parson Brinckerhoff who was responsible for recording subsurface conditions encountered, preparing engineering logs and nominating sampling and testing locations. Test pit logs and explanatory notes that describe the terms and symbols used are included in Appendix C.

Disturbed samples of the tailings were collected from the test pits which were sent to a NATA accredited laboratory for the following testing:

- Moisture content
- Atterberg limits
- Particles size distribution with hydrometer.

# 3. Results of investigation

## 3.1 Site description

At the time of the investigation and site inspection, the surface of the Old Tailings Dam was in a relatively dry state. The tailings surface was concave, indicating either settlement of the tailings or beaching as a result of the deposition. Alligator cracking (which occurs as the tailings shrinks) was not readily evident on the surface, however previous inspections of the tailings has noted cracking (PPK E&I, 2001). Some grass and trees have established in the tailings deposit.



**Figure 3-1: Tailings surface from northern cell**

## 3.2 Subsurface conditions

Based on the results of the site investigation, the tailings appears to be in a relatively dry state. Previous annual inspections noted that there was seepage (readily) observed through the Stage 3 embankment which is likely to have helped promote drainage and consolidation of the tailings. The moisture content profile of the tailings measured from the samples collected during the investigation, is shown in Figure 3.1. Moisture contents are generally less than the liquid limits.

The undrained shear strength was directly (vane shear) and indirectly (DCP and PP) measured in situ, as shown in Figure 3.2. Results from the vane shear test show that the undrained shear strength is generally

greater 30 kPa. Remoulded undrained shear strengths are generally above 20 kPa (with the exception of one point in SH3). DCP blow counts are generally between 1 and 3 to depths of 1.5 m, followed by a gradual increase. PP results (excluding TP08 and TP07, either side of the ponded water) suggest values greater than 100 kPa to a depth around 1.5 m.

The observations from the test pit investigation also indicate that the vertical faces of the excavation remained stable to the depths investigated (max 5.0m).

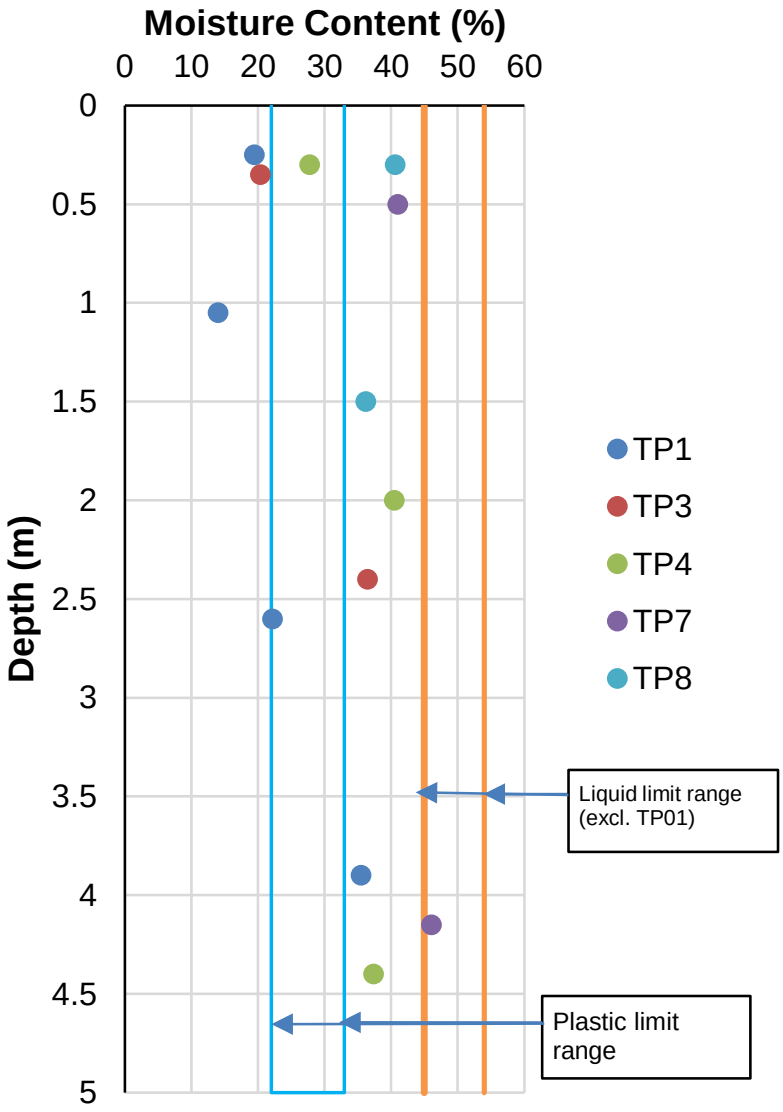



**Figure 3-2: Moisture content profile with depth**

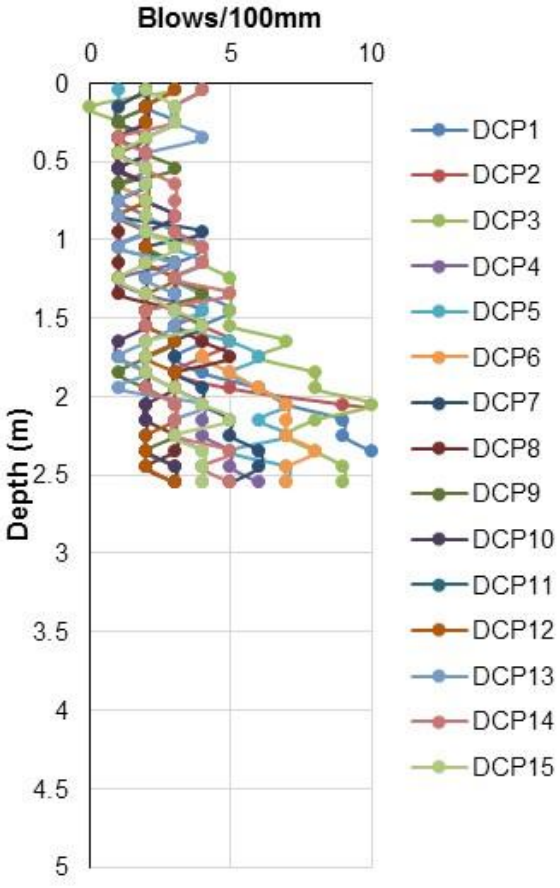



**Figure 3-3: In situ testing results- Dynamic Cone Penetrometer Results**

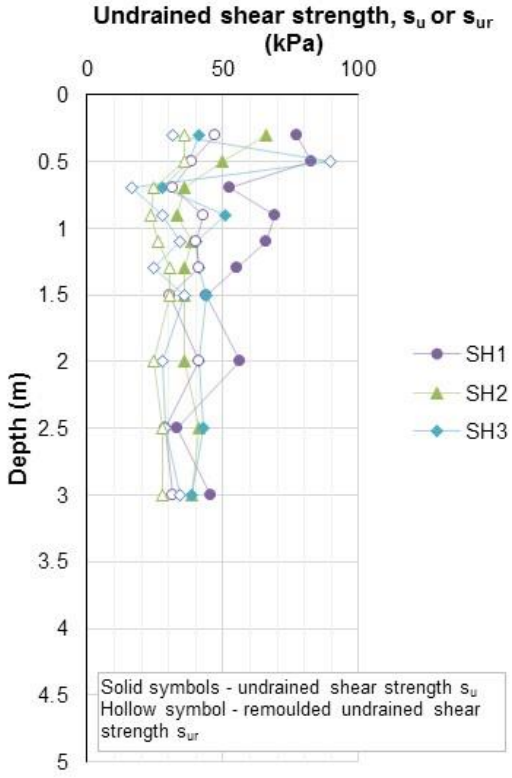



**Figure 3-4: In situ testing results - Undrained shear strength**

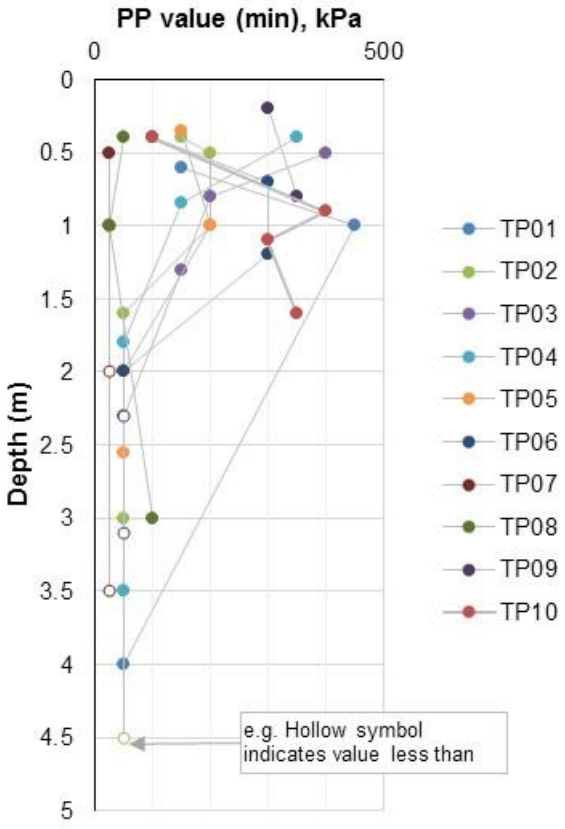



**Figure 3-5: In situ testing results - Pocket Penetrometer results**

## 3.3 Laboratory results

Laboratory test certificates are included in Appendix D and summarised below in Table 3-1.

Laboratory results indicate that the tailings is of medium to high plasticity and is predominantly silt sized. Moisture contents generally increase with depth.

**Table 3-1 Atterberg limits, moisture content and particle size distribution test results**

| Location | Depth (m) | Moisture content (%) | LL[(1)] (%) | PL[(2)] (%) | PI[(3)] (%) | LS[(4)] (%) | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|---|---|---|---|---|
| TP01 | 0.10-0.40 | 19.5 | - | - | - | - | - | - | - |
| TP01 | 1.00-1.10 | 14.0 | 35 | 22 | 13 | 3.5 | 42 | 46 | 12 |
| TP01 | 2.50-2.70 | 22.2 | - | - | - | - | - | - | - |
| TP01 | 3.80-4.00 | 35.5 | - | - | - | - | - | - | - |
| TP03 | 0.20-0.50 | 20.4 | - | - | - | - | - | - | - |
| TP03 | 2.30-2.50 | 36.5 | 45 | 29 | 16 | 5.0 | 15 | 62 | 23 |
| TP04 | 0.20-0.40 | 27.8 | - | - | - | - | - | - | - |
| TP04 | 1.90-2.10 | 40.5 | 47 | 31 | 16 | 5.0 | 7 | 72 | 21 |
| TP07 | 0.40-0.60 | 41.0 | 54 | 33 | 21 | 6.0 | 1 | 66 | 33 |
| TP07 | 4.00-4.30 | 46.1 | - | - | - | - | - | - | - |
| TP08 | 0.20-0.40 | 40.6 | 53 | 33 | 20 | 5.5 | 6 | 69 | 25 |
| TP08 | 1.40-1.60 | 36.2 | - | - | - | - | - | - | - |

(1) Liquid limit
(2) Plastic limit
(3) Plasticity index
(4) Linear shrinkage

# 4. Capping design

## 4.1 Capping and rehabilitation criteria

A number of performance criteria were initially set out in the design brief which are summarised below:

1. Produce a “stable” final landform. From a geotechnical perspective this suggests that the final landform should maintain a suitable factor of safety (generally > 1.5 for long term) against bearing capacity failure for normal land use practices. A stable landform is also taken to include the stability of the capping during construction.
2. Develop a final landform that is free draining to the spillway at the south of the dam. This serviceability requirement will necessitate consideration of the settlement of the tailings as a result of the placement of the capping layers.
3. Provide a finished surface with self-sustaining vegetation cover that requires minimum (if any) maintenance in the long term.

Based on the current conditions of the tailings, it is considered that controlled capping of Old Tailings Dam is feasible.

## 4.2 Capping design approaches

The conventional approach for capping coal tailings dams is to allow sufficient time following the cessation of tailings placement for desiccation (drying) of near surface tailings to form a crust of sufficient strength and depth to support the placement of the first layer of capping fill. The desiccation can be assisted by promoting surface drainage during and following last tailings deposition. The desiccation process can typically take 3 to 8 years to achieve the required strength profile.

As the Old Tailings Dam is currently no longer in use, it is possible that development of the crust is well underway. The scope of works proposed by Parsons Brinckerhoff is based on this assumption.

## 4.3 Methodology

To assess the global stability and bearing capacity of tailings under the proposed capping, the computer programme GEOSTUDIO Slope/W was used. Slope/W is based on limit equilibrium analysis for assessing the stability of earth structures using the Morgenstern-Price method.

A number of stability models were run to assess what mine spoil layer lift thickness could be recommended; i.e. the maximum layer thickness that could be placed without triggering an unacceptable factor of safety against failure. The Slope/W analysis output data is presented in Appendix E.

## 4.4 Geotechnical model

Based on the results of the investigation, the material properties shown in Table 4.1 have been adopted in analysis of the capping thickness.

**Table 4.1 Material properties adopted for the analysis**

| Material | Unit weight ($kN/m^3$) | Undrained shear strength (kPa) | Effective cohesion, c' (kPa) | Effective friction angle, $\phi$' (°) |
|---|---|---|---|---|
| Capping | 17 | - | 1 | 30 |
| Tailings | 15 | 30 | - | - |

## 4.5 Failure mechanisms

The failure mechanisms which are modelled to assess the capping thickness comprise:

1. Punching shear failure due to the load of the construction equipment and the capping
2. Bearing capacity failure at the leading edge of the capping cover due to capping thickness
3. Squeezing failure where tailings are forced into a 'bow wave' due to the weight of the advancing capping

The failure mechanisms and the corresponding factors of safety (FoS) considered for each model are summarised in Table 4-2.

**Table 4-2 Failure mechanisms**

| Failure mechanism | Adopted FoS | Reference |
|---|---|---|
| **Punching shear failure to assess the minimum thickness of capping material required over very soft tailings to support a dozer** | 2.0 | Bowles, 1996 |
| **Bearing capacity/stability failure to assess the stability of the capping layer over tailings with a dozer** | 1.5 | Kingsland and Burton, 2009 |
| **Squeezing (bow wave) failure where the very low strength tailings extrude from under the edge of the stiff capping material** | 1.3 | Bowles, 1996 |

## 4.6 Plant selection

Reject material is proposed to be delivered to the dam using CAT 785 mining trucks. Spreading of the capping is anticipated to be completed with either a D6 or D9 dozer. The static ground pressures estimated for each design vehicle are shown in Table 4.3.

These design ground pressures do not allow for dynamic loads (e.g. during tipping material from the CAT785 or pushing with the dozer). In particular, use of the CAT 785 trucks during initial placement of the first capping layer is not recommended.

**Table 4.3 Design vehicles**

| Material | CAT 785 | D9T | D6N XL |
|---|---|---|---|
| Gross machine weight (kg) | 249,433<br>Distribution loaded<br>- Front 33%<br>- Rear 67% | 47,900 | 21,783 |
| Ground pressure (kPa) | 410 | 110 | 52 |

## 4.7 Analysis

The bearing capacity and stability of the tailings was analysed with varying capping thickness.

The allowable bearing capacity ( $q_{all}$ ) of the tailings can first be assessed based on the following equation

$$q_{all} = \frac{5.14 s_u}{FoS} \qquad \text{Eq. 1}$$

where *FoS* is the factor of safety, taken as 1.5. By assuming a density for the capping layer (loosely placed coarse reject $\gamma$=17 kN/m$^3$), an initial thickness of the cap can be trialled.

Adopting a uniform tailings profile with an undrained shear strength of 30 kPa, up to 6 m of coarse rejects could be placed. This thickness of capping is considered excessive and thinner layers are proposed as outlined below.

Given the uniform undrained shear strength profile, squeezing of soft tailings is considered unlikely.

Punching shear, assuming a 0.81m wide x 3.28m long area (representative of D9 dozer tracks), has been assessed and was found to achieve a suitable FoS (i.e. >2.0).

Global stability of the capping was analysed using Geostudio Slope/W, with a similar tailings profile as above. An initial 1 m thick layer of capping has been adopted along with a 110 kPa surcharge loading (4m wide) and 52 kPa to simulate construction equipment (D9 and D6, respectively). An offset of 1 m from the leading edge has been adopted and should be applied during construction.

The loading applied by the construction equipment is short-term, and a minimum FoS of 1.3 is considered appropriate for this case. As shown in **Error! Reference source not found.**, an unacceptable FoS is obtained for the D9, while an acceptable value is obtained for the D6 dozer in **Error! Reference source not found.**.

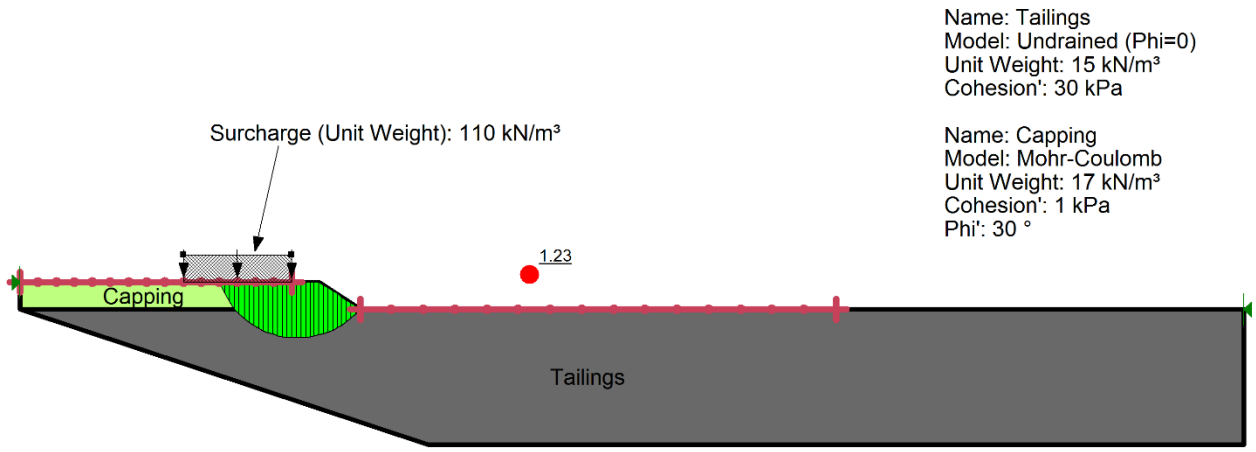



**Figure 4-1: Slip circle analysis of tailing capping – D9 dozer**

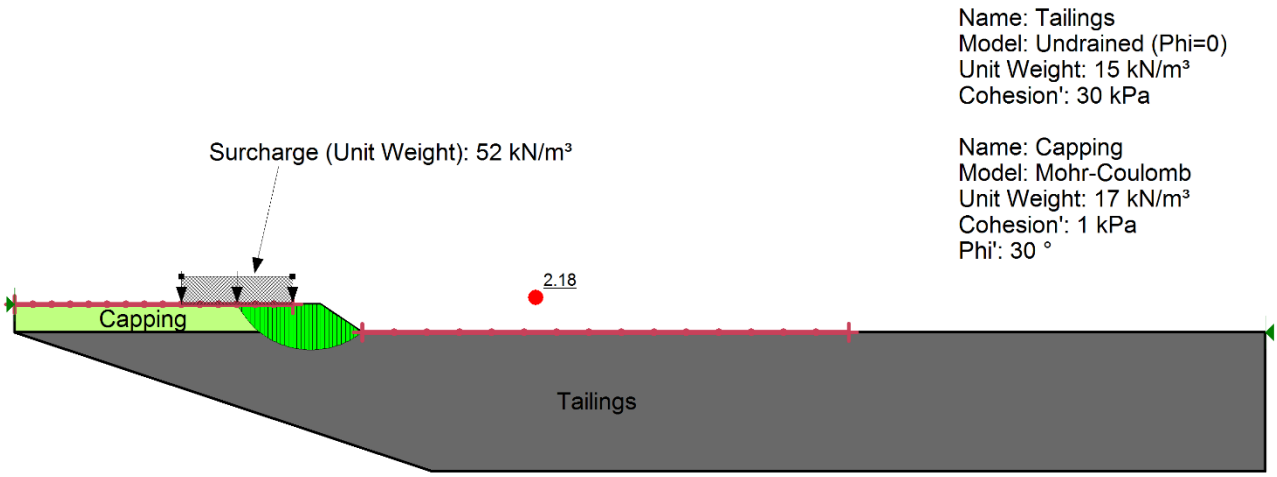



**Figure 4-2: Slip circle analysis of tailing capping – D6 dozer**

It is envisaged that the CAT 785s could be used to block tip from the embankment and spreading of the capping layer be completed with a dozer push. During this operation it is suggested that the stockpile height be limited to a maximum of 2m (above the 1m capping thickness).

A proximity limit of 5 m is recommended for vehicle movements where there the minimum capping thickness to support vehicles is achieved.

# 5. Capping strategy

## 5.1 Capping material and layer thickness

Capping material is to comprise coarse reject material or inert well-graded granular mine spoil with boulders greater than 500 mm removed to reduce the likelihood of a punching failure. The capping material will need to have a low moisture content (i.e. not saturated) prior to placement and will need to be placed in accordance with approval requirements regarding minimum cover.

Capping material should be dumped short of the leading edge of the advancing cap and pushed into position by a dozer. Dumping of the capping material directly onto the tailings surface should be avoided until additional geotechnical testing is carried out across the tailings surface.

## 5.2 Rate of construction

The geotechnical analysis indicates that the tailings profile tested was of sufficient shear strength to support a capping thickness up to 1.0 m and dozer. Some additional strength gain might also be expected with time following capping placement. Block tipping may be possible over the capping layer as it progresses, but will require a minimum offset to be maintained from the leading edge. Larger vehicles and increased block tipping limits may be possible after some measured strength gain within the tailings.

## 5.3 Water management

The existing tailings surface should be kept free of water until such time as the entire tailings surface is capped.

The placed capping layer should generally be graded in a south direction towards the spillway.

## 5.4 Testing

As construction of the capping layer progresses, testing of the tailings should be carried out in front of the advancing layer. Geotechnical investigation including test pitting by mini excavator and shear vane testing at to assess the tailings profile within capped areas to verify the shear strength for access by larger dump trucks

## 5.5 Capping construction

Given the size of Old Tailings Dam works area may be defined for placement of capping material in a single shift which will allow working on multiple fronts. Placement of capping in these areas would then be on a round-robin basis.

Equipment sizes should be kept to a minimum. In the above analysis, a ground pressure applied by the equipment has been limited to 100 kPa. Where dump trucks are used for the placement of material over tailings consideration should be given to offset distances (e.g. 50/30m rules). These should be maintained while working on the capping to limit the interaction of dynamic loads.

Further investigation of the underlying tailings shear strength is required following the placement of the initial cap prior to placement of subsequent layers or accessing by larger construction vehicles than analysed.

## 5.6 Construction control measures

Visual inspection of the capping and tailings surface should be undertaken at the commencement of capping placement each day. Additionally, an experienced tailings dam/geotechnical engineer should undertake routine visual inspection at weekly intervals. All personnel working on the dam should be trained to recognise warning signs of dam failure.

The best indication of the stability of the capping layer will come from detailed observation and recording of the performance of the capping as material is placed and shortly thereafter. Items to particularly take note of are outlined below and shown in Figure 5-1:

- Cracks forming within the capping layer – cracks may take a period of time after placement to be observed on the surface. Mapping the extent and time after material placement will provide information which can be used to update the capping strategy as the works progress.
- Deformation of the tailings surface at the toe of the capping. Settlement monitoring markers (0.5m x 0.5m base plate and 2m long vertical bar) are recommended to be installed at a number of locations to allow survey monitoring of the settlement of the tailings with time and provide a rough visual guide for capping layer thickness during placement. The measured settlements can be used to provide an indication of the likely long-term settlement of the tailings and any requirements for over placement of the capping layer to allow for a final free draining landform.
- Pore pressure generation (and dissipation with time). Placement of the capping layer generates an excess pore-water pressure in the tailings which will dissipate over time (a function of material state and permeability). The rate with which this excess pore-water pressure dissipates will govern the time intervals required between placement of the capping and subsequent loading.

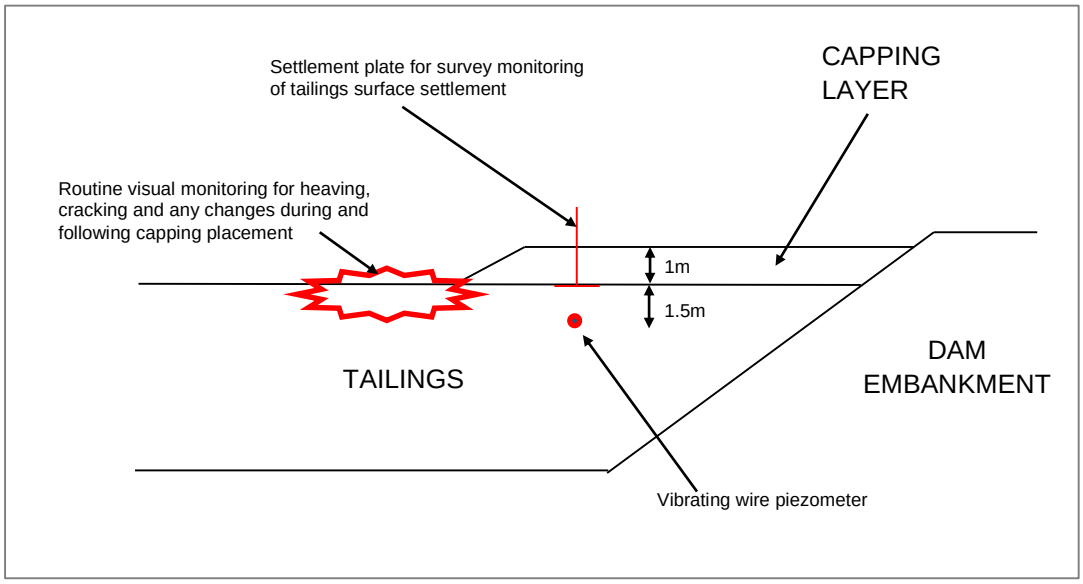



**Figure 5-1: Typical monitoring arrangement**

Should any of the following warning signs be observed at any time, work should be suspended and inspected by an experienced tailings dam/geotechnical engineer prior to recommencement of capping:

- Significant settlement of capping material (i.e. >300 mm in 24 hours) where there has been no trafficking
- Formation of wheel ruts greater than 200 mm deep. This could be avoided by vehicles not driving in the same path
- Settlement of a machine (punching failure) greater than 200 mm
- cracking of capping layer with cracks 200 mm deep

- cracking of tailings crust greater than 50 mm
- bulging of tailings
- formation of scarps (steps in surface where one side moves vertically relative to another)
- generation of a ‘bow wave’ during dozer push greater than 300 mm high at the leading edge.

Due to the dynamic nature of the capping construction, survey monitoring and trigger action response plans (TARPs) should be developed. The survey monitoring and TARPs should be referenced for the monitoring of settlement of the capping and safe work practices that are to be adhered to for the duration of the capping construction.

# 6. Final landform earthworks

As part of mine rehabilitation, additional earthworks are required to tie the capping layers in to the surrounding landform.

Future capping layers should be placed from the north of the storage towards the south to promote the drainage of surface water runoff and prevent areas of ponding. The final capped surface should tie in with the surrounding landform in accordance with mine approvals.

Further geotechnical advice is required prior to the placement of subsequent capping layers to confirm the strength of the underlying tailings to support the additional capping material and advise on allowable construction load limits for future rehabilitation.

# 7. References

GHD (2014). Tailings Dam Stability Analysis. Job No. 41/21979. Dated 14 February 2014.

PPK Environment & Infrastructure (2000). Tailings dam annual report October 2000. Report No: 86M064A-PR0001Abpw. Dated October 2000.

PPK Environment & Infrastructure (2001). Tailings dam annual report November 2001. Report No: 86P194A-PR0001Abpw. Dated November 2001.

Rust PPK (1996) Tailings dam annual report. Report No: 82H116A-PR001Bbw. Dated December 1996.

# Appendix A

Limitations



# Limitations of Geotechnical Site Investigation

***Scope of services***

This geotechnical site assessment report (the report) has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the client and PB (scope of services). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

***Reliance on data***

In preparing the report, PB has relied upon data, surveys, analyses, designs, plans and other information provided by the client and other individuals and organisations, most of which are referred to in the report (the data). Except as otherwise stated in the report, PB has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report (conclusions) are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. PB will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to PB.

***Geotechnical investigation***

Geotechnical engineering is based extensively on judgment and opinion. It is far less exact than other engineering disciplines. Geotechnical engineering reports are prepared to meet the specific needs of individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor or even some other consulting civil engineer. This report was prepared expressly for the client and expressly for purposes indicated by the client or his representative. Use by any other persons for any purpose, or by the client for a different purpose, might result in problems. The client should not use this report for other than its intended purpose without seeking additional geotechnical advice.

***This geotechnical report is based on project-specific factors***

This geotechnical engineering report is based on a subsurface investigation which was designed for project-specification factors, including the nature of any development, its size and configuration, the location of any development on the site and its orientation, and the location of access roads and parking areas. Unless further geotechnical advice is obtained this geotechnical engineering report cannot be used:

- when the nature of any proposed development is changed
- when the size, configuration location or orientation of any proposed development is modified.

This geotechnical engineering report cannot be applied to an adjacent site.

# Limitations of Geotechnical Site Investigation

***The limitations of site investigation***

In making an assessment of a site from a limited number of boreholes or test pits there is the possibility that variations may occur between test locations. Site exploration identifies specific subsurface conditions only at those points from which samples have been taken. The risk that variations will not be detected can be reduced by increasing the frequency of test locations; however this often does not result in any overall cost savings for the project. The investigation program undertaken is a professional estimate of the scope of investigation required to provide a general profile of the subsurface conditions. The data derived from the site investigation program and subsequent laboratory testing are extrapolated across the site to form an inferred geological model and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite investigation the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

The borehole logs are the subjective interpretation of subsurface conditions at a particular location, made by trained personnel. The interpretation may be limited by the method of investigation, and can not always be definitive. For example, inspection of an excavation or test pit allows a greater area of the subsurface profile to be inspected than borehole investigation, however, such methods are limited by depth and site disturbance restrictions. In borehole investigation, the actual interface between materials may be more gradual or abrupt than a report indicates.

***Subsurface conditions are time dependent***

Subsurface conditions may be modified by changing natural forces or man-made influences. A geotechnical engineering report is based on conditions which existed at the time of subsurface exploration.

Construction operations at or adjacent to the site, and natural events such as floods, or groundwater fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. The geotechnical engineer should be kept appraised of any such events, and should be consulted to determine if additional tests are necessary.

***Avoid misinterpretation***

A geotechnical engineer should be retained to work with other appropriate design professionals explaining relevant geotechnical findings and in reviewing the adequacy of their plans and specifications relative to geotechnical issues.

***Bore/profile logs should not be separated from the engineering report***

Final bore/profile logs are developed by geotechnical engineers based upon their interpretation of field logs and laboratory evaluation of field samples. Customarily, only the final bore/profile logs are included in geotechnical engineering reports. These logs should not under any circumstances be redrawn for inclusion in architectural or other design drawings. To minimise the likelihood of bore/profile log misinterpretation, contractors should be given access to the complete geotechnical engineering report prepared or authorised for their use. Providing the best available information to contractors helps prevent costly construction problems. For further information on this matter reference should be made to ‘Guidelines for the Provision of Geotechnical Information in Construction Contracts’ published by the Institution of Engineers Australia, National Headquarters, Canberra 1987.

***Geotechnical involvement during construction***

During construction, excavation is frequently undertaken which exposes the actual subsurface conditions. For this reason geotechnical consultants should be retained through the construction stage, to identify variations if they are exposed and to conduct additional tests which may be required and to deal quickly with geotechnical problems if they arise.

# Limitations of Geotechnical Site Investigation

***Report for benefit of client***

The report has been prepared for the benefit of the client and no other party. PB assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of PB or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

***Other limitations***

PB will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

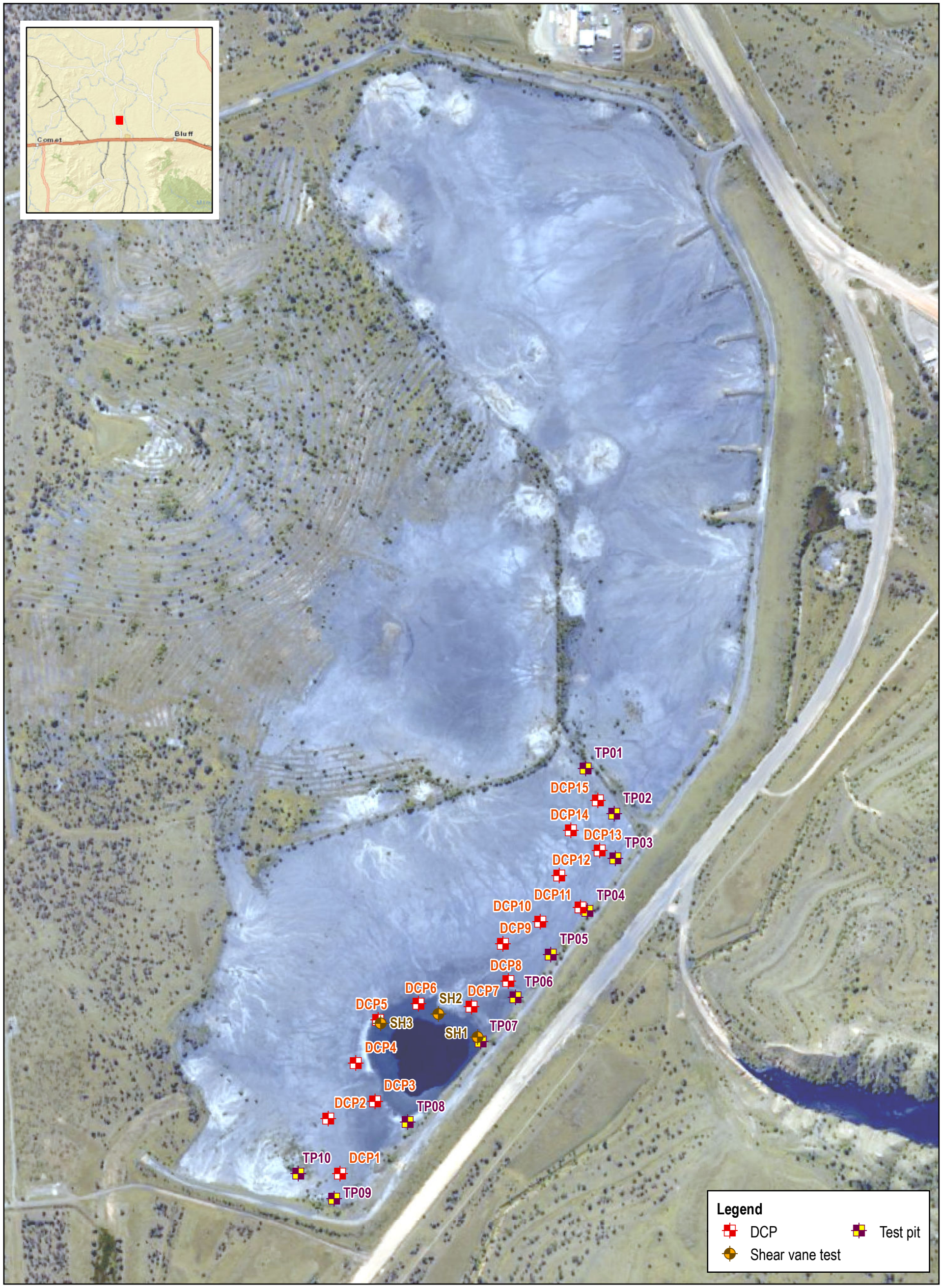
## Amendment details

| Revision | Details | Date | By |
|---|---|---|---|
| A | Original | 18/07/08 | M Jenkins |

# Appendix B

Site plan






Data source:

Aerial provided by Wesfarmers Curragh (9/12/2015)

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Map no: 2172961A_GIS_F001_A1

Author: - SuansriR

Last edited by: - SuansriR

Last edited date: 11/12/2015

0 0.055 0.11

km

1:6,500

N

Scale ratio correct when printed at A3

Coord sys: GCS GDA 1994

**Old Tailings Dam Rehabilitation**

**Figure X**

Test locations

Wesfarmers Curragh

# Appendix C

Engineering logs



PARSONS BRINCKERHOFF

# Explanatory Notes — Soil Description

In engineering terms soil includes every type of uncemented or partially cemented inorganic material found in the ground. In practice, if the material can be remoulded by hand in its field condition or in water it is described as a soil. The dominant soil constituent is given in capital letters, with secondary textures in lower case. The dominant feature is assessed from the Unified Soil Classification system and a soil symbol is used to define a soil layer as follows:

**SUPPORT**

C Casing
M Drill mud
Nil No support

**FIELD TEST**

DM Dilatometer test
HB Hammer bounce
OT Other test (eg. plate load test)
PE Permeability test
PM Pressuremeter test
PP Pocket penetrometer
SPT Standard penetration test
SV Shear vane test

**SAMPLE**

B Bulk disturbed sample
D Disturbed sample
PT Push tube
SPT SPT sample
U50 Undisturbed sample in 50mm diameter tube
U75 Undisturbed sample in 75mm diameter tube

**UNIFIED SOIL CLASSIFICATION**

The appropriate symbols are selected on the result of visual examination, field tests and available laboratory tests, such as, sieve analysis, liquid limit and plasticity index.

| USC Symbol | Description |
|---|---|
| GW | Well graded gravel |
| GP | Poorly graded gravel |
| GM | Silty gravel |
| GC | Clayey gravel |
| SW | Well graded sand |
| SP | Poorly graded sand |
| SM | Silty sand |
| SC | Clayey sand |
| ML | Silt of low plasticity |
| CL | Clay of low plasticity |
| OL | Organic soil of low plasticity |
| MH | Silt of high plasticity |
| CH | Clay of high plasticity |
| OH | Organic soil of high plasticity |
| Pt | Peaty Soil |

**MOISTURE CONDITION**

Dry - Cohesive soils are friable or powdery
Cohesionless soil grains are free-running

Moist - Soil feels cool, darkened in colour
Cohesive soils can be moulded
Cohesionless soil grains tend to adhere

Wet - Cohesive soils usually weakened
Free water forms on hands when handling

For cohesive soils the following codes may also be used:

MC>PL Moisture Content greater than the Plastic Limit.
MC~PL Moisture Content near the Plastic Limit.
MC<PL Moisture Content less than the Plastic Limit.

**WATER SYMBOLS AND DEFINITIONS**

**Partial water loss** **Water inflow**

**Complete water loss**

**Water level at date shown**

**COHESIVE SOILS - CONSISTENCY**

The consistency of a cohesive soil is defined by descriptive terminology such as very soft, soft, firm, stiff, very stiff and hard. These terms are assessed by the shear strength of the soil as observed visually, by the pocket penetrometer values and by resistance to deformation to hand moulding.

A Pocket Penetrometer may be used in the field or the laboratory to provide approximate assessment of unconfined compressive strength of cohesive soils. The values are recorded in kPa, as follows:

| Strength | Symbol | Pocket Penetrometer Reading (kPa) |
|---|---|---|
| Very Soft | VS | < 25 |
| Soft | S | 25 to 50 |
| Firm | F | 50 to 100 |
| Stiff | St | 100 to 200 |
| Very Stiff | VSt | 200 to 400 |
| Hard | H | > 400 |

**COHESIONLESS SOILS - RELATIVE DENSITY**

Relative density terms such as very loose, loose, medium, dense and very dense are used to describe silty and sandy material, and these are usually based on resistance to drilling penetration or the Standard Penetration Test (SPT) 'N' values. Other condition terms, such as friable, powdery or crumbly may also be used.

The Standard Penetration Test (SPT) is carried out in accordance with AS 1289, 6.3.1. For completed tests the number of blows required to drive the split spoon sampler 300 mm is recorded as the N value. For incomplete tests the number of blows and the penetration beyond the seating depth of 150 mm are recorded. If the 150 mm seating penetration is not achieved the number of blows to achieve the measured penetration is recorded. SPT correlations may be subject to corrections for overburden pressure and equipment type.

| Term | Symbol | Density Index | N Value (blows /0.3 m) | DCP (blows /100m |
|---|---|---|---|---|
| Very Loose | VL | 0 to 15 | 0 to 4 | 0 to 1 |
| Loose | L | 15 to 35 | 4 to 10 | 1 to 2 |
| Medium Dense | MD | 35 to 65 | 10 to 30 | 2 to 5 |
| Dense | D | 65 to 85 | 30 to 50 | 5 to 10 |
| Very Dense | VD | >85 | >50 | >10 |

**COHESIONLESS SOILS - PARTICLE SIZE TERMS**

| Name | Subdivision | Size |
|---|---|---|
| Boulders | | >200mm |
| Cobbles | | 63mm to 200mm |
| Gravel | coarse | 20mm to 63mm |
| | medium | 6mm to 20mm |
| | fine | 2.36mm to 6mm |
| Sand | coarse | 0.6mm to 2.36mm |
| | medium | 0.2mm to 0.6mm |
| | fine | 0.075mm to 0.2mm |

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# Explanatory Notes — Rock Description

The rock is described with strength and weathering symbols as shown below. Other features such as bedding and dip angle are given.

***NFGWO*** **No Free Groundwater Observed**

The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

***NFGWE*** **No Free Groundwater Encountered**

The borehole/test pit was dry soon after excavation. Inflow may have been observed had the borehole/test pit been left open for a longer period.

## DRILLING/EXCAVATION METHODS

| Symbol | Term |
|---|---|
| AS | Auger Screwing |
| HA | Hand Auger |
| NMLC | Diamond Core –triple tube |
| NQ/HQ/PQ | Diamond Core – wireline |
| PCB | Poly Carbonised Diamond Bit |
| PC | Percussion |
| PT | Push Tube |
| RAB | Rotary Air Blast |
| RC | Reverse Circulation |
| S | Sonic drill |
| VB | Vibrocoring |
| WB | Washbore with blade |
| WR | Washbore with roller (tricone) |

## ROCK MATERIAL WEATHERING

Rock weathering is described mainly using the following abbreviations and definitions used in AS1726.

| Term | Symbol | Definition |
|---|---|---|
| Residual soil | RS | Soil developed on extremely weathered rock, the mass structure & substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported. |
| Extremely weathered | XW | Rock is weathered to such an extent that it has 'soil' properties, ie: it either disintegrates or can be remoulded in water, but the texture of original rock is evident. |
| Highly weathered | HW | Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original rock substance |
| Distinctly weathered | DW | Rock strength usually changed by weathering. The rock may be highly discoloured, usually iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores. |
| Moderately weathered | MW | Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable |
| Slightly weathered | SW | Rock is slightly discoloured but shows little or no change of strength from fresh rock. |
| Fresh | FR | Rock shows no sign of decomposition or staining. |

If differentiation between highly and moderately weathered rock cannot be determined, then distinctly weathered is used which complies to terms described in Australian Standard AS1726.

## ROCK QUALITY

The fracture spacing is shown where applicable and the Rock Quality Designation (RQD) where:

$$RQD\ (\%) = \frac{\text{Sum of Axial lengths of core > 100mm long}}{\text{length of core run}}$$

## ROCK STRENGTH

Rock strength is described using AS1726 & ISRM - Commission on Standardisation of Laboratory & Field Tests, "Suggested method of determining the Uniaxial Compressive Strength of Rock materials & the Point Load Index", as follows:

| Term | Symbol | Point Load Index $Is_{(50)}$ (MPa) |
|---|---|---|
| Extremely Low | EL | <0.03 |
| Very Low | VL | 0.03 to 0.1 |
| Low | L | 0.1 to 0.3 |
| Medium | M | 0.3 to 1 |
| High | H | 1 to 3 |
| Very High | VH | 3 to 10 |
| Extremely High | EH | >10 |

● Diametral Point Load Index test

■ Axial Point Load Index test

## DEFECT SPACING/BEDDING THICKNESS

Measured at right angles to defects of same set or bedding.

The method of measurement shall be reported.

| Term | Defect Spacing | Bedding |
|---|---|---|
| Extremely closely spaced | <6 mm<br>6 to 20 mm | Thinly Laminated<br>Laminated |
| Very closely spaced | 20 to 60 mm | Very Thin |
| Closely spaced | 0.06 to 0.2 m | Thin |
| Moderately widely spaced | 0.2 to 0.6 m | Medium |
| Widely spaced | 0.6 to 2 m | Thick |
| Very widely spaced | >2 m | Very Thick |

## DEFECT DESCRIPTION

| Symbol | Term | Symbol | Term |
|---|---|---|---|
| Bg | Bedding | DB | Drill Break |
| Pt | Parting | Se | Seam |
| Cn | Contact | SZ | Sheared Zone |
| Bd | Boundary | CZ | Crushed Zone |
| Jt | Joint | F | Fault |
| Fo | Foliation | Vn | Vein |
| C | Cleavage | | |

## PLANARITY/ROUGHNESS

| Planarity | Description | Planarity | Description |
|---|---|---|---|
| Pl | Planar | Cu | Curved |
| Un | Undulating | Vu | Vuggy |
| Ir | Irregular | Wv | Wavy |
| St | Stepped | | |

| Roughness | Description | Roughness | Description |
|---|---|---|---|
| Sm | Smooth | Po | Polished |
| Ro | Rough | Sl | Slickensided |

The inclination if defects are measured from the perpendicular to the core axis.

## COATING OR INFILLING

| Abbreviation | Description | Abbreviation | Description |
|---|---|---|---|
| Cl | Clay | Py | Pyrite |
| Qz | Quartz | Fl | Feldspar |
| Ca | Calcite | Co | Coal |
| Ch | Chlorite | Gp | Gypsum |
| Fe | Limonite/ironstone | Cr | Crushed rock |
| Mn | Manganese | | |

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# TEST PIT ENGINEERING LOG

TEST PIT NO.

# TP01

SHEET : 1 OF 1

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **3/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **3/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689648 N 7398594 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) | DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD) | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | | 0.00 | | D | | ML | FILL: Clayey SILT, brown / black. | MC<PL | | 150 - 250 | |
| | | | | 0.90 | | | | CI | FILL: Silty CLAY, black | | | 450 | |
| | | | | 1 | | D | | | | | | | |
| | | | | 2 | | | | | | | | | |
| | | | | 2.50 | | D | | CI | As above, but with fine grained sand. | MC=PL | | | |
| | | | | 3 | | | | | | | | | |
| | | | | | | D | | | | | | 50 | |
| | | | | 4 | | | | | | | | | |
| | | | | 4.30 | | | | CI | FILL: Gravelly Sandy CLAY, medium plasticity, fine to coarse gravel, fine grained sand. | | | | FILL |
| | | | | | | | | | END OF TEST PIT AT 4.60 m<br>Target depth | | | | |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

Parsons Brinckerhoff Australia Pty Ltd. V00 8.30.002 PB_LIB_7.4_GJB.GLB Log PB NON-CORED LOG CURRAGH 2172961A.GPJ <<DrawingFile>> 14/12/2015 09:42 Developed by Datgel Pty Ltd



PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP01

| | |
|---|---|
| DRAWN | DATE 14/12/2015 |
| CHECKED | DATE 14/12/2015 |
| SCALE Not To Scale | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 |

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PARSONS BRINCKERHOFF

# TEST PIT ENGINEERING LOG

**TEST PIT NO.**

# TP02

**SHEET : 1 OF 1**

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **3/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **3/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689693 N 7398514 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) / DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | 0.00 | | D | | ML | FILL: Clayey SILT, black, low plasticity | MC<PL | | 150 - 200 | |
| | | | 0.50 | | | | ML-MH | As above, but brown / black, low to medium plasticity | | | 200 - 300 | |
| | | | 1.00 1 | | | | CI | FILL: Silty CLAY, black, medium plasticity | | | 200 - 250 | |
| | | | | | D | | | | | | 50 | |
| | | | 2 | | | | | | | | | |
| | | | 3.00 3 | | D | | CI-CH | As above, but medium to high plasticity | MC=PL | | 50 - 100 | |
| | | | 4 | | | | | | | | <50 | |
| | | | | | | | | END OF TEST PIT AT 4.80 m<br>Target depth | | | | |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP02

| | | |
|---|---|---|
| DRAWN | DATE 14/12/2015 | |
| CHECKED | DATE 14/12/2015 | |
| SCALE Not To Scale | | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 | |

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PARSONS BRINCKERHOFF

# TEST PIT ENGINEERING LOG

TEST PIT NO.

# TP03

SHEET : 1 OF 1

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **3/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **3/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689694 N 7398437 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) / DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD) | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | 0.00 | | D | | ML | FILL: Clayey SILT, low plasticity, black, dark / grey | MC<PL | | 400 - 450 | |
| | | | 0.70 | | | | CL-CI | FILL: Silty CLAY, low to medium plasticity, black | | | 200 - 250 | |
| | | | 1 | | | | | | | | 150 - 200 | |
| | | | 2.00 2 | | | | CI | As above, but medium plasticity | MC=PL | | | |
| | | | | | D | | | | | | 50 | |
| | | | 3 | | | | | | | | | |
| | | | 4 | | | | | END OF TEST PIT AT 4.60 m<br>Target depth | | | | |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP03

| | | |
|---|---|---|
| DRAWN | DATE 14/12/2015 | |
| CHECKED | DATE 14/12/2015 | |
| SCALE Not To Scale | | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 | |

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

# TEST PIT ENGINEERING LOG

**TEST PIT NO.**

# TP04

**SHEET : 1 OF 1**

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **3/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **3/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689648 N 7398346 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) | DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | | 0 | | D | | | FILL: Clayey SILT, low plasticity, black / brown | MC<PL | | 350 - 400 | |
| | | | | 0.75 | | | | | FILL: Silty CLAY, medium plasticity, black | | | 150 - 200 | |
| | | | | 1 | | | | | | MC=PL | | | |
| | | | | 2 | | D | | | | | | 50 | |
| | | | | 3 | | | | | | | | 50 | |
| | | | | 4 | | D | | | | MC=PL - MC>PL | | | |
| | | | | 4.90 | | | | | FILL: Clayey GRAVEL, fine to coarse grained, brown, medium plasticity clay | D | | | FILL |
| | | | | 5 | | | | | END OF TEST PIT AT 5.00 m<br>Target depth | | | | |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP04

| | |
|---|---|
| DRAWN | DATE 14/12/2015 |
| CHECKED | DATE 14/12/2015 |
| SCALE Not To Scale | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 |

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

# TEST PIT ENGINEERING LOG

**TEST PIT NO.**

# TP05

**SHEET : 1 OF 1**

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **3/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **3/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689588 N 7398270 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) / DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY (FB VL L MD D VD / VS S F ST VST H) | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | 0.00 | | D | | ML | FILL: Clayey SILT, low plasticity, black / brown | MC<PL | | 150 - 200 | |
| | | | 0.50 | | | | CL-CI | FILL: Silty CLAY, low to medium plasticity, black | | | 200 | |
| | | | 1.50 | | | | CI-CH | As above, but medium to high plasticity | MC=PL | | 50 - 100 | |
| | | | 2.00 | | D | | | | | | 50 | |
| | | | 4.60 | | | | GC | FILL: Clayey Sandy GRAVEL, fine to coarse grained, fine to medium grained sand, low plasticity clay, brown / grey | D | | | FILL |
| | | | 5.00 | | | | | END OF TEST PIT AT 5.00 m<br>Target depth | | | | |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP05

| | | |
|---|---|---|
| DRAWN | DATE 14/12/2015 | |
| CHECKED | DATE 14/12/2015 | |
| SCALE Not To Scale | | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 | |

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

# TEST PIT ENGINEERING LOG

**TEST PIT NO.**

# TP06

**SHEET : 1 OF 1**

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **3/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **3/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689530 N 7398197 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) | DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY (FB VL L MD D VD / VS S F ST VST H) | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | | 0 | | | | ML | FILL: Clayey SILT, low plasticity, black | MC<PL | | 100 - 200 | |
| | | | | | | D | | | | | | 300 | |
| | | | | 1 | | | | | | | | | |
| | | | | 1.20 | | | | CI | FILL: Silty CLAY, medium plasticity, black / dark grey | MC<PL - MC<=PL | | 300 - 400 | |
| | | | | 2.00 | | | | SM | FILL: Silty SAND, fine to medium grained, light brown, traces of clay | D | | 50 - 100 | |
| | | | | 2.20 | | | | CH | FILL: Silty CLAY, high plasticity, black / dark grey | MC=PL | | <50 | |
| | | | | | | D | | | | | | | |
| | | | | 3 | | | | | Visible moisture | MC>PL | | <50 | |
| | | | | 4 | | | | | | | | | |
| | | | | | | | | | END OF TEST PIT AT 4.50 m<br>Collapse | | | | Pipe exposed with water coming out |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP06

| | |
|---|---|
| DRAWN | DATE 14/12/2015 |
| CHECKED | DATE 14/12/2015 |
| SCALE Not To Scale | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 |

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

# TEST PIT ENGINEERING LOG

**TEST PIT NO.**

# TP07

**SHEET : 1 OF 1**

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **3/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **3/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689473 N 7398120 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) / DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD) | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | 0.30 | | | | ML | FILL: Clayey SILT, low to medium plasticity, black | MC<PL | | | |
| | | | | | D | | CI-CH | FILL: Silty CLAY, medium to high plasticity, black / dark grey | MC=PL | | 25 - 50 | |
| | | | 1 | | | | | | | | <25 | |
| | | | 2 | | | | | | | | <25 | |
| | | | 3 | | | | | | | | <25 | |
| | | | 4 | | D | | | END OF TEST PIT AT 4.30 m<br>Collapse | | | | |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP07

| | |
|---|---|
| DRAWN | DATE 14/12/2015 |
| CHECKED | DATE 14/12/2015 |
| SCALE Not To Scale | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 |

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

# TEST PIT ENGINEERING LOG

**TEST PIT NO.**

# TP08

**SHEET : 1 OF 1**

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **3/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **3/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689354 N 7397981 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) / DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD) | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | | | D | | ML | FILL: Clayey SILT, low to medium plasticity, black | MC<PL | | | |
| | | | 0.40 | | D | | CI-CH | FILL: Silty CLAY, medium to high plasticity, black | MC=PL | | 50 - 100 | |
| | | | 1 | | | | | | | | <25 | |
| | | | 2 | | | | | | | | | |
| | | | 2.90 | | | | CI | Silty CLAY, medium plasticity, brown to grey / brown, trace fine sand | | | 100 - 150 | RESIDUAL SOIL |
| | | | 3 | | | | | | | | | |
| | | | 3.40 | | | | | SANDSTONE, fine to medium grained, orange, low to medium strength, highly weathered | | | | WEATHERED ROCK |
| | | | | | | | | END OF TEST PIT AT 3.70 m<br>Refusal | | | | |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP08

| | | |
|---|---|---|
| DRAWN | DATE 14/12/2015 | |
| CHECKED | DATE 14/12/2015 | |
| SCALE Not To Scale | | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 | |

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

# TEST PIT ENGINEERING LOG

**TEST PIT NO.**

# TP09

**SHEET : 1 OF 1**

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **4/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **4/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689234 N 7397849 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) / DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD) | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | | | D | | ML | FILL: Clayey SILT, low plasticity, dark grey / black | MC<PL | | 300 - 350 | |
| | | | 0.70 | | | | CL-CI | Silty CLAY, low to medium plasticity, orange / brown | | | 350 - 450 | RESIDUAL SOIL |
| | | | 1 | | | | | | | | | |
| | | | 2 | | | | | END OF TEST PIT AT 2.20 m<br>Target depth | | | | |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP09

| | |
|---|---|
| DRAWN | DATE 14/12/2015 |
| CHECKED | DATE 14/12/2015 |
| SCALE Not To Scale | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 |

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

# TEST PIT ENGINEERING LOG

TEST PIT NO.

# TP10

SHEET : 1 OF 1

| | | | |
|---|---|---|---|
| Client: | **Wesfarmers Curragh** | Date Commenced: | **4/12/15** |
| Project: | **Geotechnical investigation for old tailings dam** | Date Completed: | **4/12/15** |
| Test Pit Location: | **Old Tailings Dam- Southern Cell** | Recorded By: | **AH** |
| Project Number: | **2172961A** | Log Checked By: | **JB** |

| | | | | | |
|---|---|---|---|---|---|
| Excavation Method: | **Long reach excavator** | Hole Angle: | **-90°** | Surface RL: | |
| Dimensions: | **4.00 m x 1.50 m** | Bearing: | **---** | Co-ords: | **E 689177 N 7397893 MGA94 55 K** |

| Test Pit Information | | | | | | | Field Material Description | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | SUPPORT | WATER | RL (m AHD) / DEPTH (m) | FIELD TEST | SAMPLE | GRAPHIC LOG | USCS SYMBOL | SOIL/ROCK MATERIAL FIELD DESCRIPTION | MOISTURE | RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD) | POCKET PENETROMETER (kPa) | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| EX | Nil | NFGWO | | | D | | ML | FILL: Clayey SILT, low plasticity, dark grey, orange / brown | MC<PL | | 100 - 200<br>400 - 450 | TAILINGS |
| | | | 1.00 1 | | | | CL-CI | Silty CLAY, low to medium plasticity, orange / brown, trace sandstone cobbles | | | 300 - 350<br>350 - 400 | RESIDUAL SOIL |
| | | | 2 | | | | | END OF TEST PIT AT 2.20 m<br>Target depth | | | | |

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP10

| | | |
|---|---|---|
| DRAWN | DATE 14/12/2015 | |
| CHECKED | DATE 14/12/2015 | |
| SCALE Not To Scale | | A4 |
| PROJECT No 2172961A | FIGURE No 1/1 | |

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

# Dynamic Cone Penetrometer Test Results

Sheet 1

| | | | |
|---|---|---|---|
| **CLIENT** | Wesfarmers Curragh | **OFFICE** | Singleton |
| **PROJECT** | Old Tailings Dam | **TEST DATE** | 4/12/2015 |
| **LOCATION** | Sourthen Cell | **TESTED BY** | AH |
| **PROJECT NO.** | 2172961A | **CHECKED** | JB |
| **TEST METHOD** | AS 1289 6.3.2 - Cone Penetrometer | **TEST EQUIPMENT** | |

| Depth | Test Location (Blows per 100mm) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DCP1 | DCP2 | DCP3 | DCP4 | DCP5 | DCP6 | DCP7 | DCP8 | DCP9 | DCP10 | DCP11 | DCP12 | DCP13 | DCP14 | DCP15 | | |
| 0.0-0.1 | 3 | 2 | 3 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 4 | 4 | 2 | | |
| 0.1-0.2 | 2 | 1 | 0 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | | |
| 0.2-0.3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 3 | 3 | 3 | | |
| 0.3-0.4 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 4 | 1 | 2 | | |
| 0.4-0.5 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | | |
| 0.5-0.6 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 2 | 2 | 2 | | |
| 0.6-0.7 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 3 | 2 | | |
| 0.7-0.8 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 2 | | |
| 0.8-0.9 | 3 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 3 | 2 | | |
| 0.9-1.0 | 2 | 2 | 2 | 3 | 3 | 2 | 4 | 1 | 2 | 2 | 1 | 2 | 2 | 3 | 2 | | |
| 1.0-1.1 | 1 | 2 | 4 | 4 | 3 | 2 | 2 | 1 | 2 | 2 | 3 | 2 | 1 | 4 | 3 | | |
| 1.1-1.2 | 3 | 2 | 4 | 3 | 4 | 3 | 3 | 1 | 3 | 2 | 3 | 2 | 3 | 4 | 2 | | |
| 1.2-1.3 | 3 | 3 | 5 | 1 | 3 | 3 | 3 | 1 | 3 | 2 | 3 | 3 | 2 | 3 | 1 | | |
| 1.3-1.4 | 4 | 3 | 5 | 2 | 4 | 4 | 3 | 1 | 4 | 2 | 3 | 2 | 3 | 5 | 2 | | |
| 1.4-1.5 | 5 | 3 | 5 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | | |
| 1.5-1.6 | 4 | 4 | 5 | 3 | 3 | 4 | 4 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 4 | | |
| 1.6-1.7 | 4 | 5 | 7 | 3 | 5 | 4 | 3 | 4 | 3 | 1 | 4 | 3 | 2 | 2 | 2 | | |
| 1.7-1.8 | 3 | 4 | 6 | 2 | 6 | 4 | 3 | 5 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | | |
| 1.8-1.9 | 4 | 3 | 8 | 2 | 5 | 5 | 3 | 3 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | | |
| 1.9-2.0 | 6 | 5 | 8 | 3 | 6 | 6 | 4 | 3 | 2 | 2 | 2 | 3 | 1 | 2 | 3 | | |
| 2.0-2.1 | 7 | 9 | 10 | 4 | 7 | 7 | 4 | 2 | 3 | 2 | 3 | 3 | 4 | 3 | 4 | | |
| 2.1-2.2 | 9 | 13 | 8 | 4 | 6 | 7 | 5 | 2 | 3 | 2 | 2 | 3 | 3 | 3 | 5 | | |
| 2.2-2.3 | 9 | 14 | 7 | 4 | 7 | 7 | 5 | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 3 | | |
| 2.3-2.4 | 10 | 12 | 8 | 5 | 5 | 8 | 6 | 3 | 2 | 2 | 3 | 2 | 4 | 5 | 4 | | |
| 2.4-2.5 | 11 | 12 | 9 | 5 | 7 | 7 | 6 | 2 | 3 | 3 | 4 | 2 | 4 | 4 | 4 | | |
| 2.5-2.6 | 13 | 15 | 9 | 6 | 7 | 7 | 5 | 3 | 3 | 3 | 4 | 3 | 4 | 5 | 4 | | |
| 2.6-2.7 | | | | | | | | | | | | | | | | | |
| 2.7-2.8 | | | | | | | | | | | | | | | | | |
| 2.8-2.9 | | | | | | | | | | | | | | | | | |
| 2.9-3.0 | | | | | | | | | | | | | | | | | |

# Appendix D

Laboratory test certificates



Trilab
Soil Rock Calibration

**Brisbane**
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

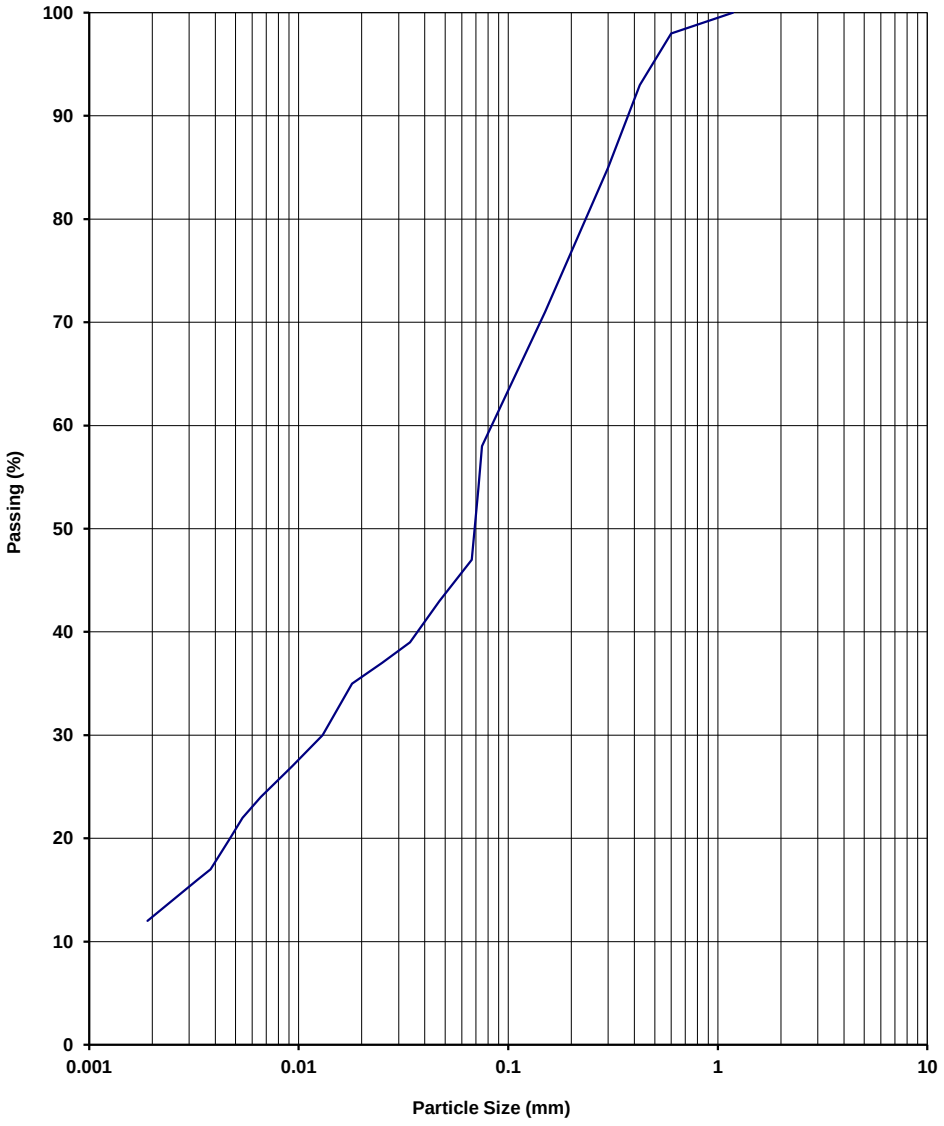
**Perth**
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

# PARTICLE SIZE DISTRIBUTION TEST REPORT

**Test Method: AS 1289 3.6.3, 3.5.1**

| | | | |
|---|---|---|---|
| **Client** | Parsons Brinckerhoff Pty Ltd | **Report No.** | 15120412-G |
| **Project** | 2172961A | **Test Date** | 11/12/15-22/12/15 |
| | | **Report Date** | 22/12/2015 |
| **Client ID** | TP01 | **Depth (m)** | 1.00-1.10 |

| Sieve Size (mm) | Passing % |
|---|---|
| 150.0 | |
| 75.0 | |
| 63.0 | |
| 53.0 | |
| 37.5 | |
| 26.5 | |
| 19.0 | |
| 9.5 | |
| 4.75 | |
| 2.36 | |
| 1.18 | 100 |
| 0.600 | 98 |
| 0.425 | 93 |
| 0.300 | 85 |
| 0.150 | 71 |
| 0.075 | 58 |
| 0.072 | 54 |
| 0.067 | 47 |
| 0.047 | 43 |
| 0.034 | 39 |
| 0.025 | 37 |
| 0.018 | 35 |
| 0.013 | 30 |
| 0.0093 | 27 |
| 0.0066 | 24 |
| 0.0054 | 22 |
| 0.0047 | 20 |
| 0.0038 | 17 |
| 0.0033 | 16 |
| 0.0019 | 12 |




NOTES/REMARKS: -

Moisture Content 14% -2.36mm Soil Particle Density(t/m$^3$) 1.92

Sample/s supplied by the client



Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

**Authorised Signatory**

C. Channon

NATA ACCREDITED FOR TECHNICAL COMPETENCE

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*ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING*

Trilab
Soil Rock Calibration

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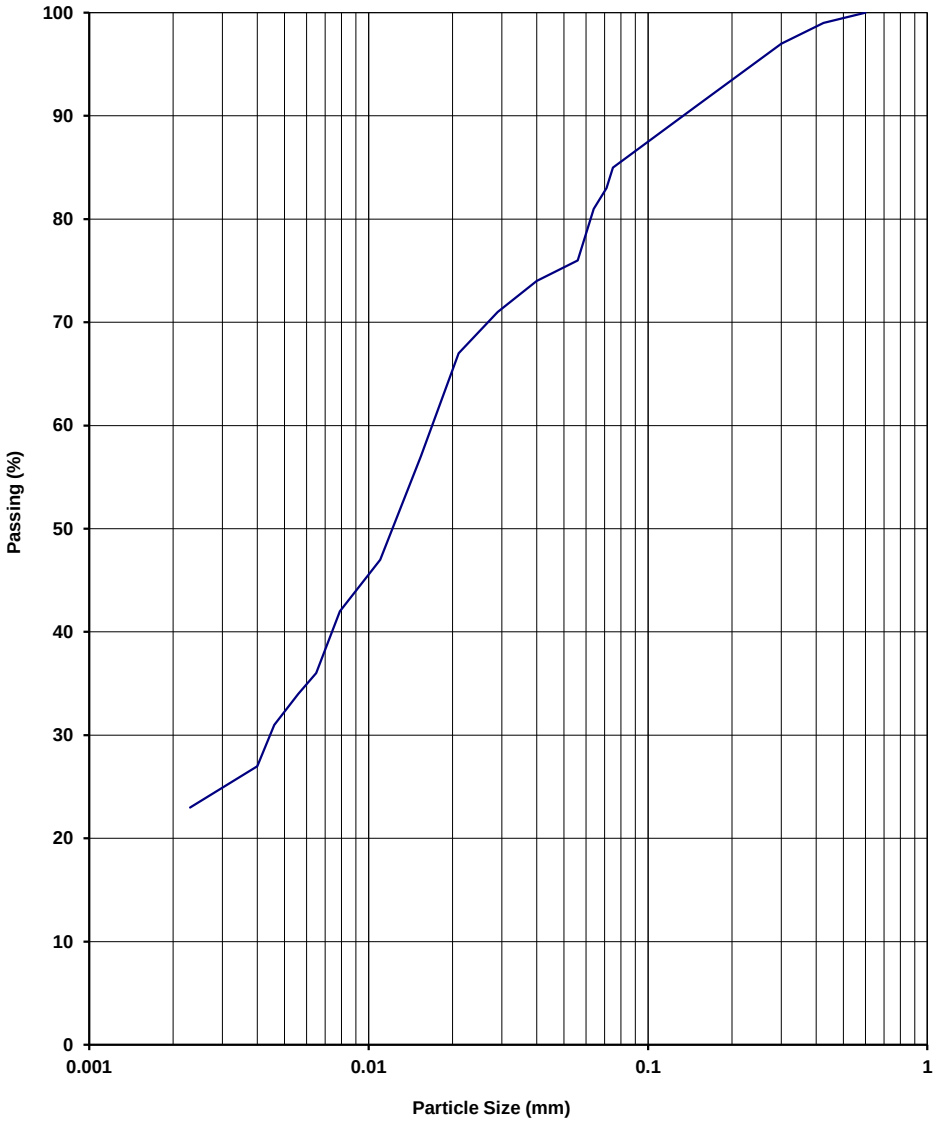
**Perth**
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

# PARTICLE SIZE DISTRIBUTION TEST REPORT

**Test Method: AS 1289 3.6.3, 3.5.1**

| | | | |
|---|---|---|---|
| **Client** | Parsons Brinckerhoff Pty Ltd | **Report No.** | 15120416-G |
| **Project** | 2172961A | **Test Date** | 17/12/15-22/12/15 |
| | | **Report Date** | 22/12/2015 |
| **Client ID** | TP03 | **Depth (m)** | 2.30-2.50 |

| Sieve Size (mm) | Passing % |
|---|---|
| 150.0 | |
| 75.0 | |
| 63.0 | |
| 53.0 | |
| 37.5 | |
| 26.5 | |
| 19.0 | |
| 9.5 | |
| 4.75 | |
| 2.36 | |
| 1.18 | |
| 0.600 | 100 |
| 0.425 | 99 |
| 0.300 | 97 |
| 0.150 | 91 |
| 0.075 | 85 |
| 0.071 | 83 |
| 0.064 | 81 |
| 0.056 | 76 |
| 0.04 | 74 |
| 0.029 | 71 |
| 0.021 | 67 |
| 0.0154 | 57 |
| 0.011 | 47 |
| 0.0079 | 42 |
| 0.0065 | 36 |
| 0.0056 | 34 |
| 0.0046 | 31 |
| 0.004 | 27 |
| 0.0023 | 23 |




NOTES/REMARKS: -

Moisture Content 36.5% -2.36mm Soil Particle Density(t/m$^3$) 1.61

Sample/s supplied by the client



Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

**Authorised Signatory**

C. Channon

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Trilab
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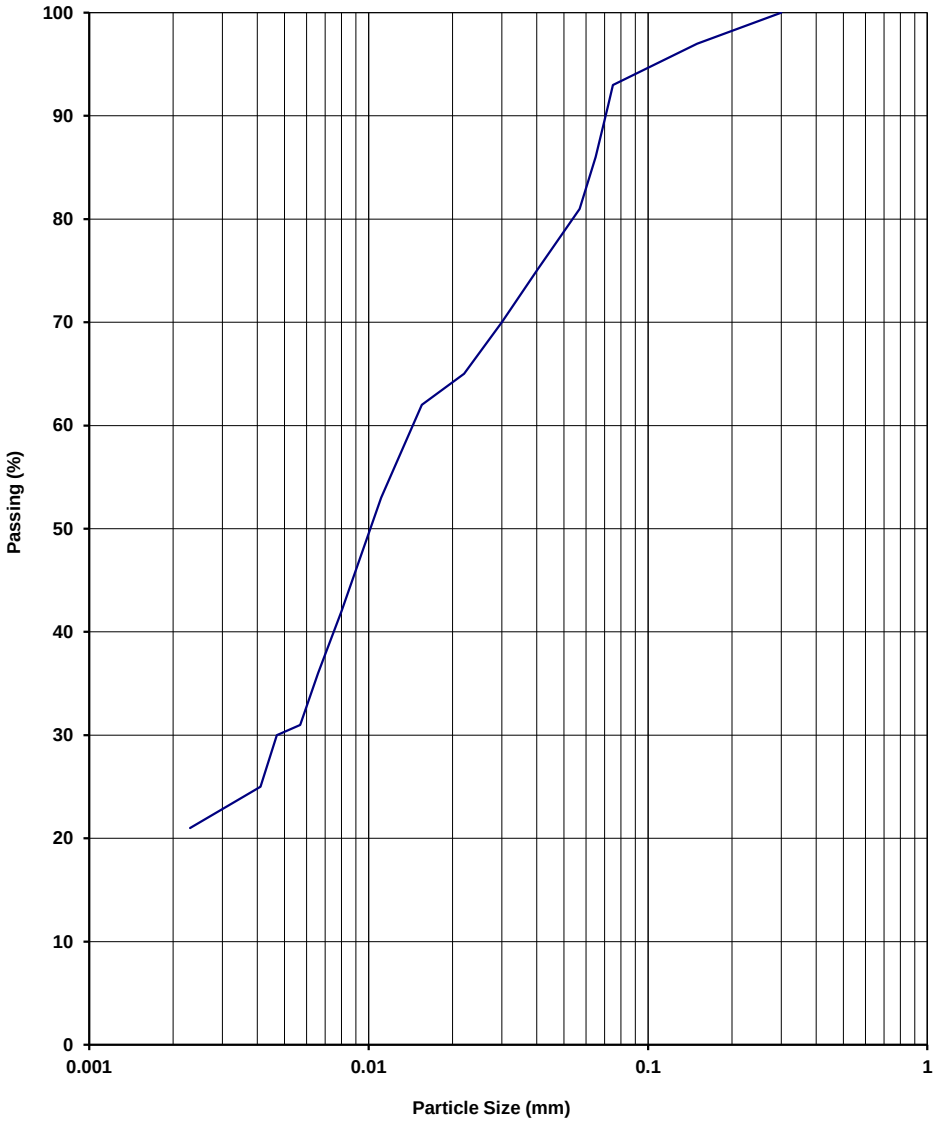
**Perth**
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

# PARTICLE SIZE DISTRIBUTION TEST REPORT

**Test Method: AS 1289 3.6.3, 3.5.1**

| | | | |
|---|---|---|---|
| **Client** | Parsons Brinckerhoff Pty Ltd | **Report No.** | 15120418-G |
| **Project** | 2172961A | **Test Date** | 17/12/15-22/12/15 |
| | | **Report Date** | 22/12/2015 |
| **Client ID** | TP04 | **Depth (m)** | 1.90-2.10 |

| Sieve Size (mm) | Passing % |
|---|---|
| 150.0 | |
| 75.0 | |
| 63.0 | |
| 53.0 | |
| 37.5 | |
| 26.5 | |
| 19.0 | |
| 9.5 | |
| 4.75 | |
| 2.36 | |
| 1.18 | |
| 0.600 | |
| 0.425 | |
| 0.300 | 100 |
| 0.150 | 97 |
| 0.075 | 93 |
| 0.072 | 91 |
| 0.065 | 86 |
| 0.057 | 81 |
| 0.04 | 75 |
| 0.03 | 70 |
| 0.022 | 65 |
| 0.0155 | 62 |
| 0.0111 | 53 |
| 0.008 | 42 |
| 0.0066 | 36 |
| 0.0057 | 31 |
| 0.0047 | 30 |
| 0.0041 | 25 |
| 0.0023 | 21 |




NOTES/REMARKS: -

Moisture Content 40.5% -2.36mm Soil Particle Density(t/m$^3$) 1.60

Sample/s supplied by the client



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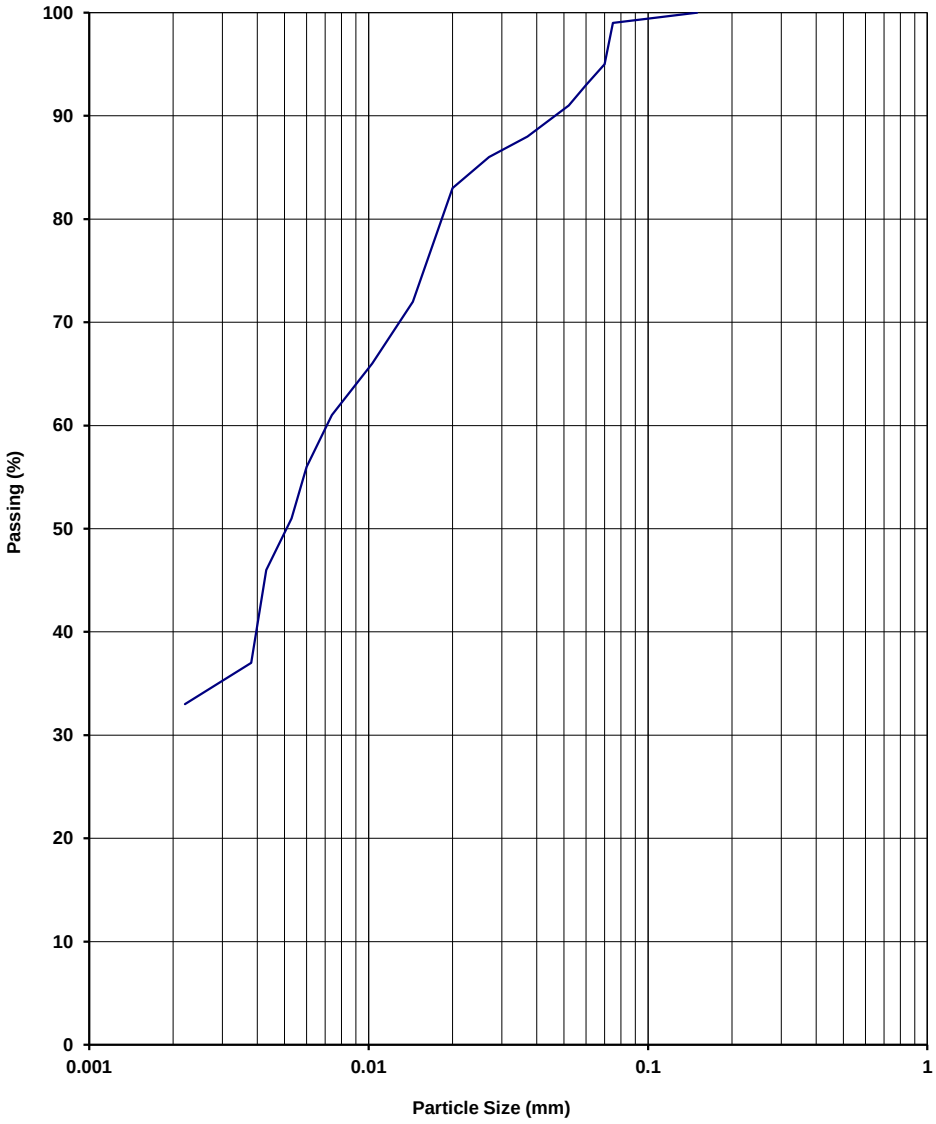
**Perth**
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

# PARTICLE SIZE DISTRIBUTION TEST REPORT

**Test Method: AS 1289 3.6.3, 3.5.1**

| | | | |
|---|---|---|---|
| **Client** | Parsons Brinckerhoff Pty Ltd | **Report No.** | 15120420-G |
| **Project** | 2172961A | **Test Date** | 17/12/15-22/12/15 |
| | | **Report Date** | 22/12/2015 |
| **Client ID** | TP07 | **Depth (m)** | 0.40-0.60 |

| Sieve Size (mm) | Passing % |
|---|---|
| 150.0 | |
| 75.0 | |
| 63.0 | |
| 53.0 | |
| 37.5 | |
| 26.5 | |
| 19.0 | |
| 9.5 | |
| 4.75 | |
| 2.36 | |
| 1.18 | |
| 0.600 | |
| 0.425 | |
| 0.300 | |
| 0.150 | 100 |
| 0.075 | 99 |
| 0.07 | 95 |
| 0.06 | 93 |
| 0.052 | 91 |
| 0.037 | 88 |
| 0.027 | 86 |
| 0.02 | 83 |
| 0.0144 | 72 |
| 0.0103 | 66 |
| 0.0074 | 61 |
| 0.006 | 56 |
| 0.0053 | 51 |
| 0.0043 | 46 |
| 0.0038 | 37 |
| 0.0022 | 33 |




NOTES/REMARKS: -

Moisture Content 41% -2.36mm Soil Particle Density(t/m$^3$) 1.68

Sample/s supplied by the client



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Tested at Trilab Brisbane Laboratory.

**Authorised Signatory**

C. Channon

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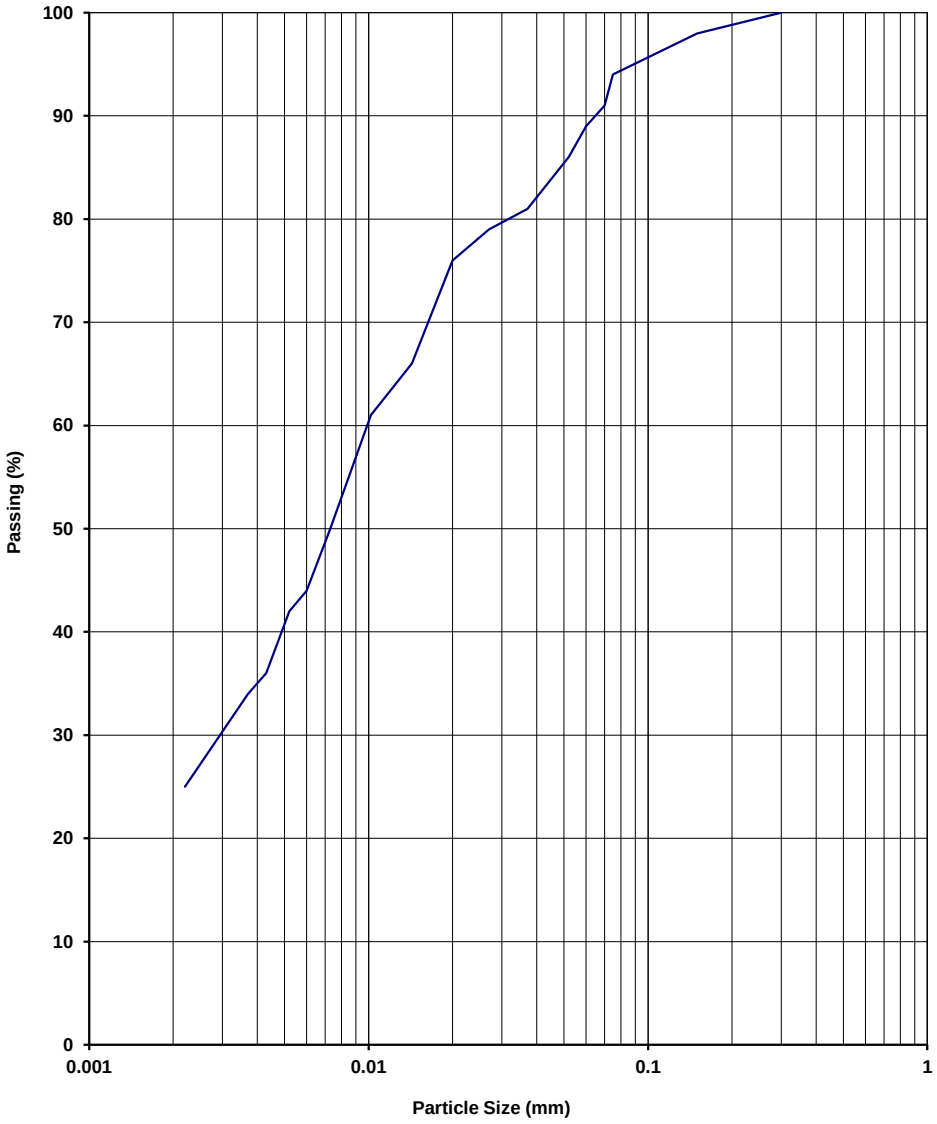
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# PARTICLE SIZE DISTRIBUTION TEST REPORT

**Test Method: AS 1289 3.6.3, 3.5.1**

| | | | |
|---|---|---|---|
| **Client** | Parsons Brinckerhoff Pty Ltd | **Report No.** | 15120422-G |
| **Project** | 2172961A | **Test Date** | 17/12/15-22/12/15 |
| | | **Report Date** | 22/12/2015 |
| **Client ID** | TP08 | **Depth (m)** | 0.20-0.40 |

| Sieve Size (mm) | Passing % |
|---|---|
| 150.0 | |
| 75.0 | |
| 63.0 | |
| 53.0 | |
| 37.5 | |
| 26.5 | |
| 19.0 | |
| 9.5 | |
| 4.75 | |
| 2.36 | |
| 1.18 | |
| 0.600 | |
| 0.425 | |
| 0.300 | 100 |
| 0.150 | 98 |
| 0.075 | 94 |
| 0.07 | 91 |
| 0.06 | 89 |
| 0.052 | 86 |
| 0.037 | 81 |
| 0.027 | 79 |
| 0.02 | 76 |
| 0.0143 | 66 |
| 0.0102 | 61 |
| 0.0073 | 50 |
| 0.006 | 44 |
| 0.0052 | 42 |
| 0.0043 | 36 |
| 0.0037 | 34 |
| 0.0022 | 25 |




NOTES/REMARKS: -

Moisture Content 40.6% -2.36mm Soil Particle Density(t/m$^3$) 1.70

Sample/s supplied by the client



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C. Channon

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Trilab
Soil Rock Calibration

**Brisbane**
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Ph: +61 7 3265 5656

**Perth**
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

# ATTERBERG LIMITS TEST REPORT

**Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1**

| | | | |
|---|---|---|---|
| **Client** | Parsons Brinckerhoff Pty Ltd | **Report No.** | 15120412-AL |
| **Project** | 2172961A | **Test Date** | 17/12/15-22/12/15 |
| | | **Report Date** | 22/12/2015 |

| **Sample No.** | 15120412 | 15120416 | 15120418 | 15120420 | 15120422 | - |
|---|---|---|---|---|---|---|
| **Client ID** | TP01 | TP03 | TP04 | TP07 | TP08 | - |
| **Depth (m)** | 1.00-1.10 | 2.30-2.50 | 1.90-2.10 | 0.40-0.60 | 0.20-0.40 | - |
| **Liquid Limit (%)** | 35 | 45 | 47 | 54 | 53 | - |
| **Plastic Limit (%)** | 22 | 29 | 31 | 33 | 33 | - |
| **Plasticity Index (%)** | 13 | 16 | 16 | 21 | 20 | - |
| **Linear Shrinkage (%)** | 3.5 | 5.0 | 5.0 | 6.0 | 5.5 | - |
| **Moisture Content (%)** | 14.0 | 36.5 | 40.5 | 41.0 | 40.6 | - |

| **Sample No.** | - | - | - | - | - | - |
|---|---|---|---|---|---|---|
| **Client ID** | - | - | - | - | - | - |
| **Depth (m)** | - | - | - | - | - | - |
| **Liquid Limit (%)** | - | - | - | - | - | - |
| **Plastic Limit (%)** | - | - | - | - | - | - |
| **Plasticity Index (%)** | - | - | - | - | - | - |
| **Linear Shrinkage (%)** | - | - | - | - | - | - |
| **Moisture Content (%)** | - | - | - | - | - | - |

NOTES/REMARKS: The samples were tested in a natural state, wet sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred



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Tested at Trilab Brisbane Laboratory.

Authorised Signatory

T. Ferguson

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**Laboratory No. 9926**

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***ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING***

Trilab
Soil Rock Calibration

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Geebung
QLD 4034
Ph: +61 7 3265 5656

**Perth**
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

# MOISTURE CONTENT TEST REPORT

**Test Method: AS 1289 2.1.1**

| | | | |
|---|---|---|---|
| **Client** | Parsons Brinckerhoff Pty Ltd | **Report No.** | 15120411-MC |
| **Project** | 2172961A | **Test Date** | 17/12/2015 |
| | | **Report Date** | 22/12/2015 |

| **Sample No.** | 15120411 | 15120412 | 15120413 | 15120414 | 15120415 | 15120416 | 15120417 |
|---|---|---|---|---|---|---|---|
| **Client ID** | TP01 | TP01 | TP01 | TP01 | TP03 | TP03 | TP04 |
| **Depth (m)** | 0.10-0.40 | 1.00-1.10 | 2.50-2.70 | 3.80-4.00 | 0.20-0.50 | 2.30-2.50 | 0.20-0.40 |
| **Moisture Content (%)** | 19.5 | 14.0 | 22.2 | 35.5 | 20.4 | 36.5 | 27.8 |

| **Sample No.** | 15120418 | 15120419 | 15120420 | 15120421 | 15120422 | 15120423 | - |
|---|---|---|---|---|---|---|---|
| **Client ID** | TP04 | TP04 | TP07 | TP07 | TP08 | TP08 | - |
| **Depth (m)** | 1.90-2.10 | 4.30-4.50 | 0.40-0.60 | 4.00-4.30 | 0.20-0.40 | 1.40-1.60 | - |
| **Moisture Content (%)** | 40.5 | 37.4 | 41.0 | 46.1 | 40.6 | 36.2 | - |

| **Sample No.** | - | - | - | - | - | - | - |
|---|---|---|---|---|---|---|---|
| **Client ID** | - | - | - | - | - | - | - |
| **Depth (m)** | - | - | - | - | - | - | - |
| **Moisture Content (%)** | - | - | - | - | - | - | - |

NOTES/REMARKS:

Sample/s supplied by the client



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Tested at Trilab Brisbane Laboratory.

Authorised Signatory

T. Ferguson

NATA
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**Laboratory No. 9926**

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***ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING***

# Appendix E

Slope/W outputs



10 November 2017

## WESFARMERS CURRAGH PTY LTD

# B PIT TAILINGS STORAGE FACILITY DESIGN PLAN

**Submitted to:**
Howard Lief
Wesfarmers Curragh Pty Ltd

REPORT

**Report Number.** 1532295-052-R-Rev3

Golder Associates

# Form of certification (Design plan)

**Name of Registered Professional Engineer providing certification:**

David Smallhorn

**Address of Registered Professional Engineer providing certification:**

Golder Associates
147 Coronation Drive
Milton QLD 4064

**Statement of relevant experience**

I hereby state that I am a Registered Professional Engineer of Queensland (Number 11332) and meet the requirements of the definition of 'suitably qualified and experienced person'.

**Statement of certification**

All relevant material relied upon by me, including subsidiary certifications of specialist components, where required by the environmental authority, is provided in the attached design plan "Wesfarmers Curragh Pty Ltd B Pit Tailings Storage Facility Design Plan", Reference 1532295-052-R-Rev3, dated 10 November 2017.

I hereby certify that the B Pit tailings storage facility as detailed in the design plan "Wesfarmers Curragh Pty Ltd B Pit Tailings Storage Facility Design Plan", Reference 1532295-052-R-Rev3, dated 10 November 2017:

(i) Has been prepared in accordance with good engineering practice and the design is also consistent with the standards required for structures of the assessed consequence category as set out in the *Manual for assessing consequence categories and hydraulic performance of structures* published by the administering authority

(ii) Is capable of delivering the performance stated in the attached design plan so as to be compliant with the relevant aspects of the EA, provided the structure is constructed or modified in consultation with the designer in the manner specified and the facility is operated and maintained as recommended.

I David Smallhorn, declare that the information provided as part of this certification is true to the best of my knowledge. I acknowledge that it is an offence under section 480 of the Environmental Protection Act 1994 to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

Signed:



David Smallhorn BE CPEng RPEQ 11332
Date: 10th November 2017

# Record of Issue

| VERSION | DESCRIPTION | CLIENT CONTACT | COMPANY | METHOD OF DELIVERY | DATE |
|---|---|---|---|---|---|
| Rev 0 | For review | Howard Lief | Wesfarmers Curragh | email | 04-May-17 |
| Rev 1 | Final | Howard Lief | Wesfarmers Curragh | email | 18-May-17 |
| Rev 2 | Updated of EA references | Howard Lief | Wesfarmers Curragh | email | 14-Sept-17 |
| Rev 3 | Additional comments incorporated | Howard Lief | Wesfarmers Curragh | email | 10-Nov-17 |

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# Record of Review

| VERSION | AUTHORS | AUTHORS | REVIEWER | APPROVED BY | DATE |
|---|---|---|---|---|---|
| Rev 0 | David Smallhorn | Scott Creighton | Mike Gowan | Scott Creighton | 04-May-17 |
| Rev 1 | David Smallhorn | Scott Creighton | Mike Gowan | Scott Creighton | 18-May-17 |
| Rev 2 | David Smallhorn | Scott Creighton | Mike Gowan | Scott Creighton | 18-May-17 |
| Rev 3 | David Smallhorn | Scott Creighton | Mike Gowan | Scott Creighton | 10-Nov-17 |
| **Title** | Principal Civil Engineer | | Principal | Principal Water Resources Engineer | |
| **Signatures** |  |  |  |  | |

# Important information

Your attention is drawn to the document titled - "Important Information Relating to this Report", which is included in APPENDIX J of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

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# Acronyms, Abbreviations and Terms

| Acronyms, Abbreviations and Definitions | |
|---|---|
| AEP | Annual Exceedance Probability |
| ANCOLD | Australian National Committee on Large Dams |
| CHPP | coal handling and preparation plant |
| DEHP | Department of Environment and Heritage Protection (Queensland) |
| DSA | Design Storage Allowance |
| EA | Environmental Authority EPML00643713 dated 31 August 2015 |
| ESS | Extreme Storm Storage |
| Golder | Golder Associates Pty. Ltd. |
| ha | hectares |
| km | kilometres |
| LOM | Life of Mine |
| m | metres |
| MIA | Mine infrastructure area |
| Ml | Mega litres |
| ML | Mining Lease |
| Mtpa | Million tonnes per annum |
| MRL | Mandatory Reporting Level |
| RE | regional ecosystem |
| RL | Reduced level in metres to mine level |
| WCPL | Wesfarmers Curragh Pty Ltd |

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**APPENDICES**

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**APPENDIX B**
Geotechnical site inspection documentation

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- Design storage allowance
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**APPENDIX J**
Important information relating to this report.

# 1.0 INTRODUCTION

Wesfarmers Curragh Pty Ltd (WCPL) operates the Curragh Mine Project (Curragh Mine) under Environmental Authority (EA) EPML00643713. WCPL has appointed Golder Associates Pty Ltd (Golder) to design a tailings storage facility (TSF) in B Pit. This report presents the design of the tailings storage facility (TSF) in B Pit, referred to as the B Pit TSF. The design proposes to repurpose an existing mine void to incorporate a containment embankment constructed within the pit using mine waste materials.

This report has generally been written in accordance with the design report format recommended by ANCOLD (2012b) and complies with the requirements of DEHP (2016).

# 2.0 BACKGROUND

The Curragh Mine commenced operation in 1983 and us an open cut coal mining operation located approximately 6 kilometres (km) north of the township of Blackwater in Central Queensland. The Curragh Mine produces a variety of coking, pulverized coal injected (PCI) and steaming coal products for both export and domestic markets. The Curragh Mine currently operates within 14 mining leases (MLs), ML1878, ML1990, ML80010, ML80011, ML80012, ML80086, ML80110, ML80112, ML80123, ML80171, ML700006, ML700007, ML700008 and ML700009. All tailings and coarse rejects are managed within the two Curragh Mine coal handling and process plants (CHPP). Curragh Mine produces tailings at an average rate around 1,300,000 cubic metres ($m^3$) per year. Tailings from the coal washing plants are stored in registered structures which are certified on an annual basis. As solids settle out the return water is pumped out of the tailings facility and into the Water Management System for recycling though the CHPPs or used for other industrial applications. Coase rejects are conveyed from the CHPPs into a rejects storage bin for transport via truck to in-pit spoil dumps. Coase rejects are also collected and buried with spoil as part of the rehabilitation process.

The Curragh Mine is currently using Pit A for tailings disposal and it is approaching full storage under the current configuration and deposition methodology. During 2014 Golder completed a Life of Mine tailings storage study, refer Golder (2014), which recommended developing B Pit as the next tailings storage area.

A general location plan for Curragh Mine is shown on Figure 2-1.




*Figure 2-1: Location plan*

# 3.0 SCOPE OF WORKS

The scope of works includes:

- A design report to address and satisfy relevant requirements of the Department of Environment and Heritage Protection (DEHP) as set out in the current Environmental Authority (EA) EPML00643713 including DEHP's '*Manual for assessing consequence categories and hydraulic performance of structures*' (2016);
- 'For Construction' drawings for the embankment and associated structures including pipeline access; and
- A construction specification to complement the For Construction drawings, as well as to establish the scope of construction works and the standards of works to be achieved.

# 4.0 REGULATORY CONTEXT

The B Pit TSF is subject to the regulated structure conditions in the EA No: EPML00643713 for the Curragh Mine. The relevant EA conditions and the Sections of the Design plan that meet and address the condition is summarised below in Table 1.

**Table 4-1: Design Plan Sections and related EA conditions**

| Condition number | EPML00643713 Condition | Document reference section |
|---|---|---|
| D1 | **Assessment of consequence category**<br><br>The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* at the following times:<br><br>a) prior to the design and construction of the structure, if it is not an existing structure; or<br>b) prior to any change in its purpose or the nature of its stored contents. | Section 9.3 |
| D2 | A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure. | Section 9.3;<br><br>Form of certification |
| D3 | Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*. | Form of certification |
| D4 | **Design and construction[1] of a regulated structure**<br><br>Conditions D5 to D9 inclusive do not apply to existing structures.<br><br>Note [1]: Construction of a dam includes modification of an existing dam-refer to the definitions. | Not applicable |
| D5 | All regulated structures must be designed by, and constructed[2] under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635).*<br><br>Note [2]: Certification of design and construction may be undertaken by different persons. | 'designed by': Form of certification<br><br>'constructed under': not applicable |
| D6 | Construction of a regulated structure is prohibited unless the holder has submitted a consequence category assessment report and certification to the administering authority has been certified by a | Section 9.3;<br><br>Form of certification; |

| | | |
|---|---|---|
| | suitably qualified and experienced person for the design and design plan and the associated operating procedures in compliance with the relevant condition of this authority. | Section 15.0 |
| D7 | Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635),* and must be recorded in the Regulated Dams/Levees register. | Form of certification; |
| D8 | **Regulated structures** must:<br>a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635);*<br>b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of:<br>i) floodwaters from entering the regulated dam from any watercourse or drainage line; and<br>ii) wall failure due to erosion by floodwaters arising from any watercourse or drainage line.<br>c) have the floor and sides of the dam designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam. | a) Section 9.0, Section 9.2, Section 9.3, Section 9.4<br>b) i) Section 5.2 (the B Pit TSF will not be impacted from floodwaters from any watercourse or drainage line due to diversion of Blackwater creek and the surrounding historic mining activities and spoil dumps).<br>ii) Section 5.2, Section 13.2<br>c) Section 12.3 |
| D9 | Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated<br>structure, and state that:<br>a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure;<br>b) construction of the regulated structure is in accordance with the design plan. | Not applicable – not yet constructed |
| D10 | Operation of a regulated structure, except for an existing structure, is prohibited unless:<br>a) the holder has submitted to the administering authority:<br>i) one paper copy and one electronic copy of the design plan and | a)<br>i) this design plan document to be submitted<br>ii) not applicable at this stage<br>iii) not applicable at this . stage |

| | | |
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| | certification of the 'design plan' in accordance with condition G6;<br>ii) a set of 'as constructed' drawings and specifications;<br>iii) certification of those 'as constructed drawings and specifications' in accordance with condition G9;<br>iv) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan;<br>v) the requirements of this authority relating to the construction of the regulated structure have been met;<br>vi) the holder has entered the details required under this authority, into a Register of Regulated Structures; and<br>vii) there is a current operational plan for the regulated structures. | iv) APPENDIX G<br>v) not applicable at this . stage<br>vi) Operational plan to be prepared prior to commissioning as detailed in Section 15.0. |
| D11 | For existing structures that are regulated structures:<br>a) where the existing structure that is a regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, the holder must submit to the administering authority within 12 months of the commencement of this condition a copy of the certified system design plan including that structure; and<br>b) there must be a current operational plan for the existing structures. | Not applicable – not an existing structure |
| D12 | Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings. | Not applicable – not yet constructed |
| D13 | Conditions D14 - D17 inclusive only apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain - overtopping'. | See D14 – D17 |
| D14 | The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable. | Not currently applicable – not yet constructed. The MRL is defined in Section 11.3. |
| D15 | The holder must, as soon as practical and within forty-eight (48) hours of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL. | Not currently applicable – not yet constructed |

| | | |
|---|---|---|
| D16 | The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam. | Not currently applicable – not yet constructed |
| D17 | The holder must record any changes to the MRL in the Register of Regulated Structures. | Not currently applicable |
| D18 | **Design storage allowance**<br><br>The holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to 1 July of each year. | Not currently applicable – not yet constructed |
| D19 | By 1 November of each year, storage capacity must be available m each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment systems). | Not currently applicable – not yet constructed |
| D20 | The holder must, as soon as possible and within forty-eight (48) hours of becoming aware that the regulated dam (or network of finked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, notify the administering authority. | Not currently applicable – not yet constructed |
| D21 | The holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems. | Not currently applicable – not yet constructed |
| D22 | Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person. | Not currently applicable – not yet constructed |
| D23 | At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure. | Not currently applicable – not yet constructed |
| D24 | The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*. | Not currently applicable – not yet constructed |

| | | |
|---|---|---|
| D25 | The holder must:<br><br>a) Within 20 business days of receipt of the annual inspection report, provide to the administering authority:<br>i) The recommendations section of the annual inspection report; and<br>ii) If applicable, any actions being taken in response to those recommendations; and<br>b) If, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this to the administering authority within 10 business days of receipt of the request. | Not currently applicable – not yet constructed |
| D26 | **Transfer arrangements**<br><br>The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority. | Not currently applicable |
| D27 | **Decommissioning and rehabilitation**<br><br>Dams must not be abandoned but be either:<br><br>a) decommissioned and rehabilitated to achieve compliance with condition D28; or<br>b) be left in-situ for a beneficial use(s) provided that:<br>i) it no longer contains contaminants that will migrate into the environment; and<br>ii) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and<br>iii) the administering authority, the holder of the environmental authority and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies). | Not currently applicable<br><br>Closure discussed in Section 13.0. |
| D28 | After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria:<br><br>a) the landform is safe for humans and fauna;<br>b) the landform is stable with no subsidence or erosion gullies for at least three (3) years;<br>c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated; not allowing for acid mine drainage; or there is no | Not currently applicable |

| | | |
|---|---|---|
| | ongoing contamination to waters (including groundwater);<br>d) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001);<br>e) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class;<br>f) for land that is not being cultivated by the landholder:<br>a. a. groundcover, that is not a declared pest species is established and self-sustaining<br>b. vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining, and<br>c. c. the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies).<br>i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of petroleum activities being completed. | |
| D29 | **Register of Regulated Structures**<br><br>A Register of Regulated Structures must be established and maintained by the **holder** for each **regulated structure**. | Curragh currently maintains Register of Regulated Structures. Pit B TSF will be added to the register upon commissioning. |
| D30 | The holder must provisionally enter the required information in the Register of Regulated Structures when a design plan for a regulated structure is submitted to the administering authority. | Submitted to DEHP as part of the Design plan submission |
| D31 | The holder must make a final entry of the required information in the Register of Regulated Structures once compliance with condition D10 and D11 has been achieved. | Not currently applicable – not yet constructed |
| D32 | The holder must ensure that the information contained in the Register of Regulated Structures is current and complete on any given day. | Curragh complies |
| D33 | All entries in the Register of Regulated Structures must be approved by the chief executive officer for the holder of this authority, or their delegate, as being accurate and correct. | Curragh complies |

| | | |
|---|---|---|
| D34 | The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Structures, in the electronic format required by the administering authority. | Curragh complies |
| D35 | **Transitional arrangements**<br><br>All existing structures that have not been assessed in accordance with either the Manual or the former Manual for Assessing Hazard Categories and Hydraulic Performance of Dams must be assessed and certified in accordance with the Manual within 6 months of amendment of the authority adopting this schedule. | Not applicable – not an existing structure |
| D36 | All existing structures must subsequently comply with the timetable for any further assessments in accordance with the Manual specified in **Table D1**, depending on the consequence category for each existing structure assessed in the most recent previous certification for that structure. | Not applicable – not an existing structure |
| D37 | **Table D1** ceases to apply for a structure once any of the following events has occurred:<br><br>a) It has been brought into compliance with the hydraulic performance criteria applicable to the structure under the Manual; or<br>b) It has been decommissioned; or<br>c) It has been certified as no longer being assessed as a regulated structure. | Not applicable – not an existing structure |
| D38 | Certification of the transitional assessment required by condition D35 and D36 (as applicable) must be provided to the administering authority within 6 months of amendment of the authority adopting this schedule. | Not applicable – not an existing structure |

# 5.0 SUMMARY OF BACKGROUND CONDITIONS

The following section outlines the background conditions for the proposed B Pit TSF. The background conditions documented in this section are also relevant inputs into Section 9.3 'DEHP Consequence Category'.

## 5.1 B Pit TSF description

Figure 5-1 shows the location of the Pit B TSF.

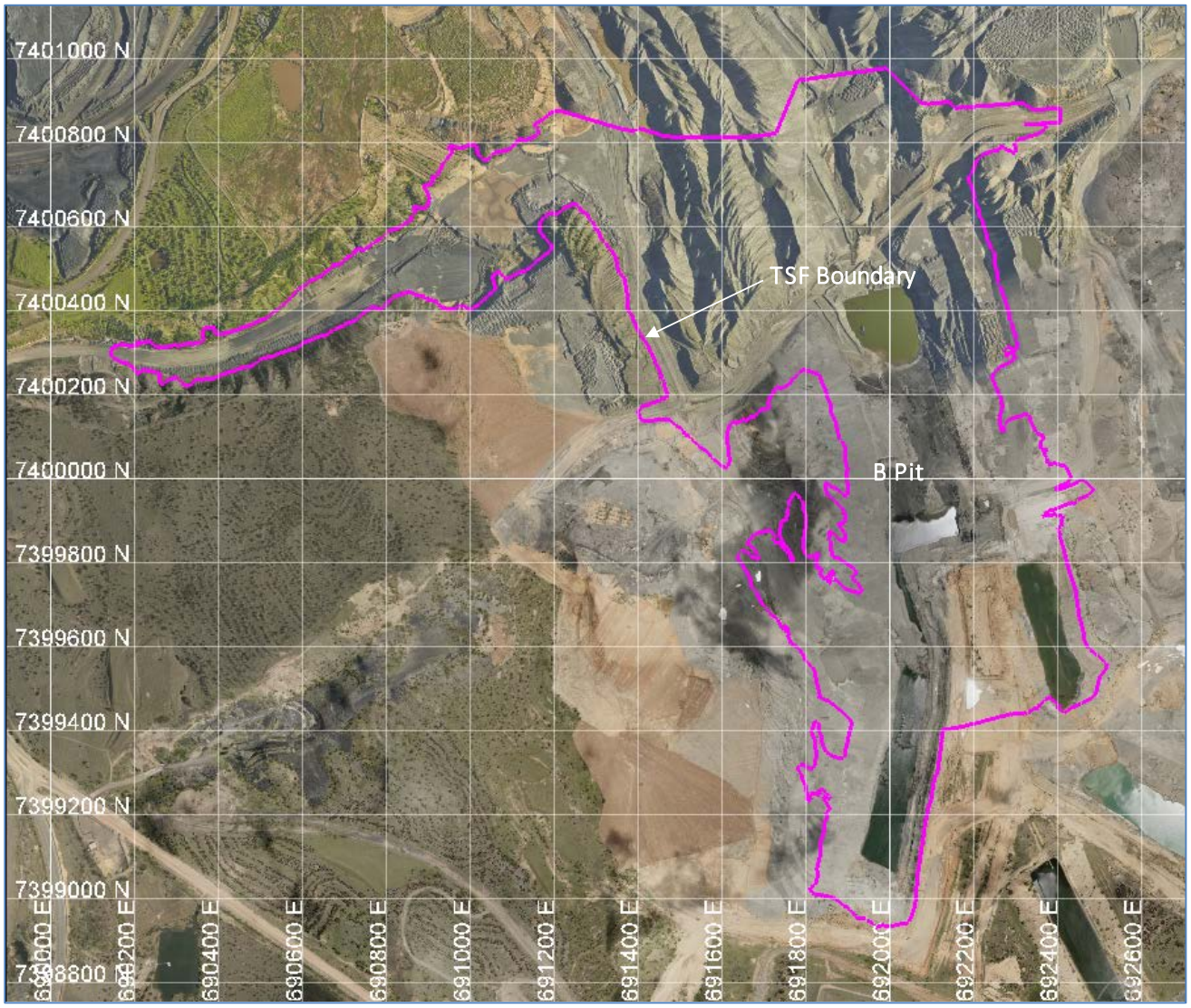



*Figure 5-1: B Pit TSF site plan*

The TSF can be described as having:

- An approximate footprint area of 144 ha
- To be constructed within an abandoned open cut mine void, previously operated as B Pit
- An available tailings storage volume of approximately 26.8 M $m^3$ under the Stage 2 design presented in this report

- Pit floor topography grading from north to south with an average slope of approximately 1%
- Variable pit depth varies approximately ranging between 45 and 75 m
- A low wall mine waste dump along the western side of the pit
- A high wall along the eastern side of the pit
- Disturbed undulating topography in the vicinity of the pit.

Figure 5-2 and Figure 5-3 show typical images of the site.



*Figure 5-2: B Pit looking south from northern end.*



*Figure 5-3: B Pit looking north from southern end.*

## 5.2 Water courses

### 5.2.1 Pre mining

The pre mining natural water courses in the vicinity of B Pit are shown on Figure 5-4 in light blue. Figure 5-5 shows the current water courses with the diversion works shown in dark blue and the natural drainage shown in light blue. Drainage flow would occur from south to north.

With reference to Figure 5-4 and Figure 5-5 any potential seepage from B Pit to outside the mining lease is unlikely to occur based on the diversion of the Blackwater Creek and the removal of existing drainage course through pit excavation to the north of B Pit.

The B Pit TSF will not be impacted from floodwaters entering from any watercourse or drainage line due to diversion of Blackwater creek and the surrounding historic mining activities and spoil dumps. Additionally, the embankment wall is within the open cut and would not be subject to erosion by floodwaters.

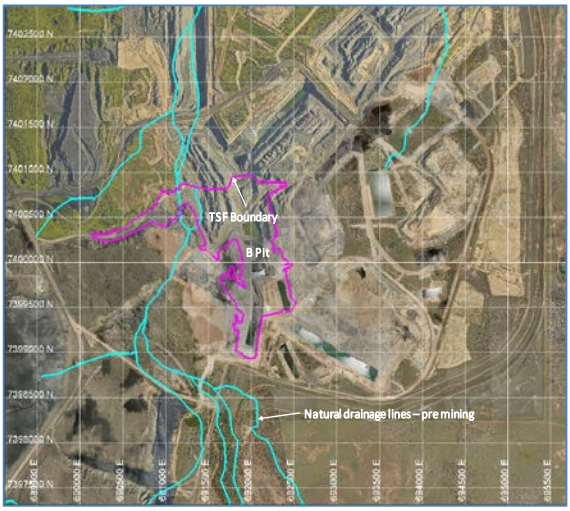



*Figure 5-4: Natural drainage lines in vicinity of B Pit.*




*Figure 5-5: Current drainage*

## 5.3 Site geology

The pre mined site surface geology, reproduced from Queensland Government 'Geoscientific Globe' 1:100 000 detailed geology mapping, is presented on Figure 5-6. Additional information has also been included on Figure 5-6 comprising:

- Faulting information observed during the Golder site inspection on 27 October 2016, refer APPENDIX B
- Near surface sand layers provided by Curragh.

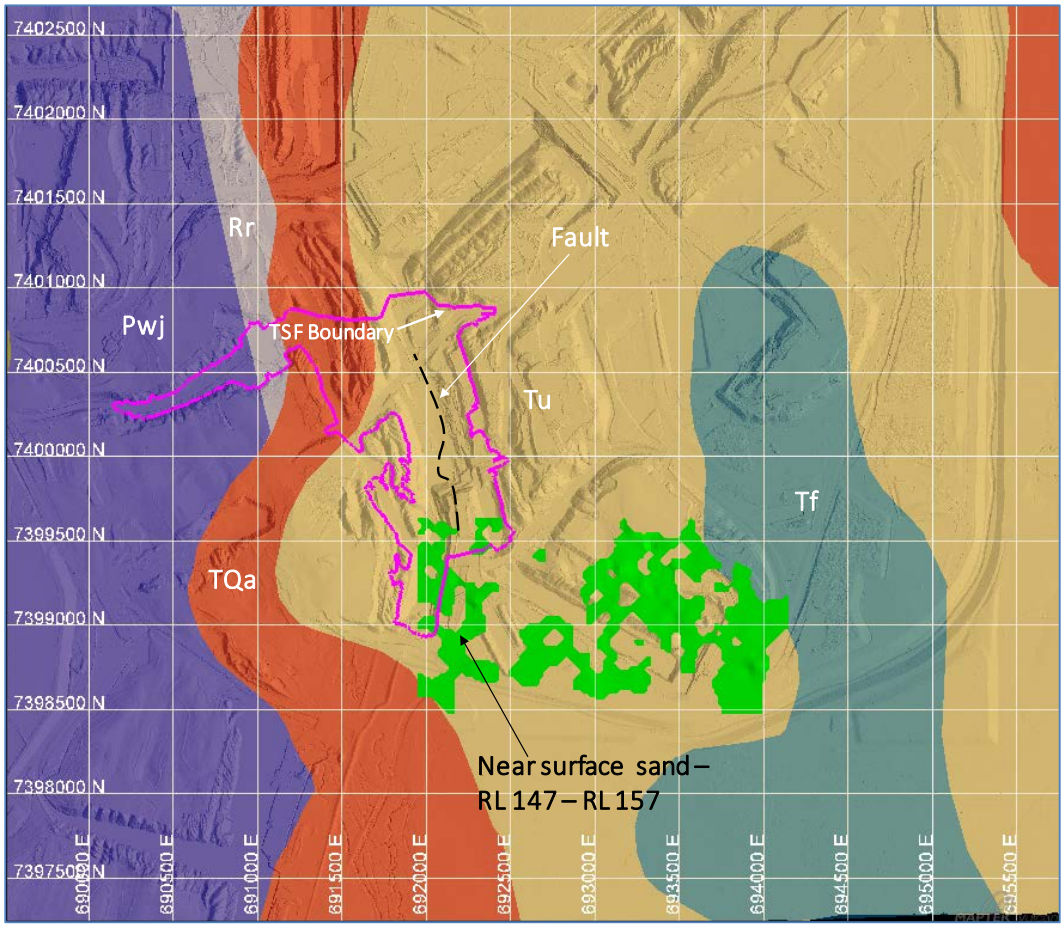



*Figure 5-6: Site surface geology*

The geological descriptions for the geology shown on Figure 5-6, as provided in the Queensland Government 'Geoscientific Globe, is described as:

- Duaringa formation (Tu) of early tertiary age – Mudstone, sandstone, conglomerate, siltstone, soil shale, lignite
- Late Tertiary – Quaternary aged Alluvium (TQa) – Red-brown mottled, poorly consolidated sand, silt, clay, minor gravel; high – level alluvial deposits (generally related to present stream valleys
- Rewan group of early Triassic age (Rr) - - Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone, and minor volcanilithic pebble conglomerate (at base)
- Rangal Coal Measures of Late Permian age (Pwj) – Calcareous sandstone, calcareous shale, mudstone, coal, concretionary limestone.

The fault line shown on Figure 5-6 is believed to dip to the west with a throw of around 15 to 20 m towards the west.

Information provided by Curragh (2016) and Curragh (2017) indicates:

- Faults around the Curragh mine can act as either aquitards or aquifers although generally any water being released from fault zones is at very low flow rates
- Hydraulic conductivity for the Tertiary sediments (TQa) between A pit and Blackwater creeks (immediately south of B pit) is estimated to be low
    - With almost no possibility of vertical leakage

- With likely seepage being horizontal and being limited by the lack of lateral continuity.

The geological stratigraphy at both A Pit and D-E-F Pits has been described in Curragh (2016) and Curragh (2017) as:

- Alluvium, up to 2 m thick overlying
- Tertiary aged rock (weathered sandstone, siltstone, gravels and sands) approximately 6 m to 10 m thick overlying
- Permian aged rock (sandstone, calcareous shale, mudstone and coal).

This stratigraphy is considered to be appropriate for the B Pit TSF area.

## 5.4 Regional Ecosystem

The regional ecosystem details, reproduced from Queensland Government 'Vegetation Management Globe', is presented on Figure 5-7.

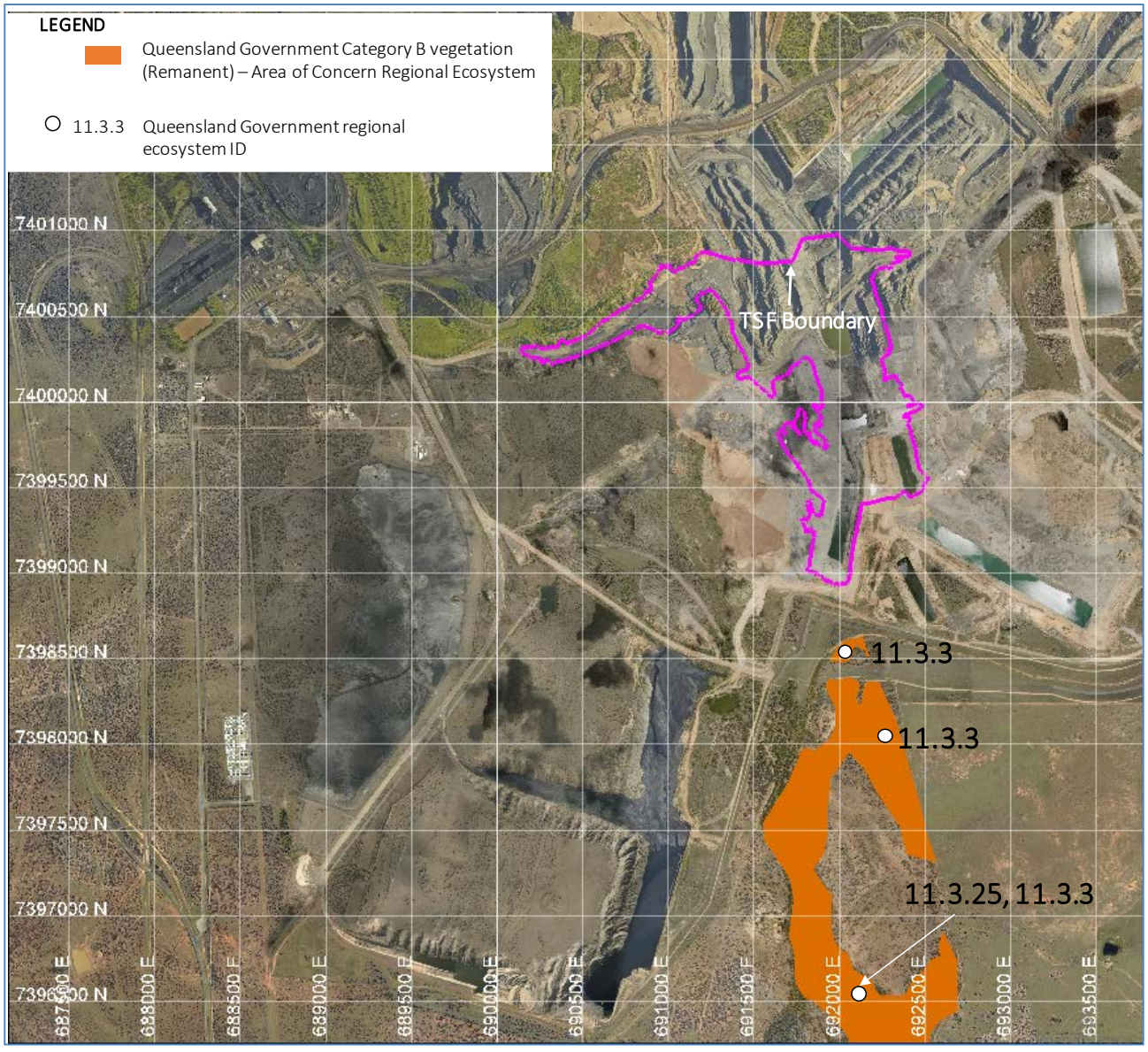



*Figure 5-7: B Pit area regional ecosystem plan.*

The Category B vegetation shown on Figure 5-7 is described by the Queensland Government as:

- 11.3.3 Corymbia terminalis low open woodland on basic metamorphics
- 11.3.25 Eucalyptus tereticornis or E. camaldulensis woodland fringing drainage lines.

## 5.5 Seismic risk

The earthquake hazard at Curragh is currently considered low by Australian Standards, when compared to other sites within Australia using hazard maps in Burbidge (2012). However, this low level of seismicity does not imply that large damaging earthquakes will not occur in the future. The low level of seismicity suggests that long recurrence intervals exist between events.

It has been observed that earthquakes larger than Magnitude 5.0 cause damage. The closet location to the TSF site that has experienced earthquakes of magnitude greater than 5.0 is Eidsvold, approximately 317 km south east of the Curragh. On 15th February 2015 the town of Eidsvold experienced a Richter local magnitude (ML) 5.2 earthquake Future seismic activity from this area is unlikely to pose a hazard to the TSF due to degradation of the ground motion over the large distance.

Historical earthquake records indicate that the past seismic events that have occurred in close proximity to TSF have earthquake magnitudes less than 5.0. Figure 5-8 shows all recorded earthquakes that have occurred within 200 km of Curragh since the year 1955 with ML magnitudes. The data has been sourced from the Geoscience Australia. :

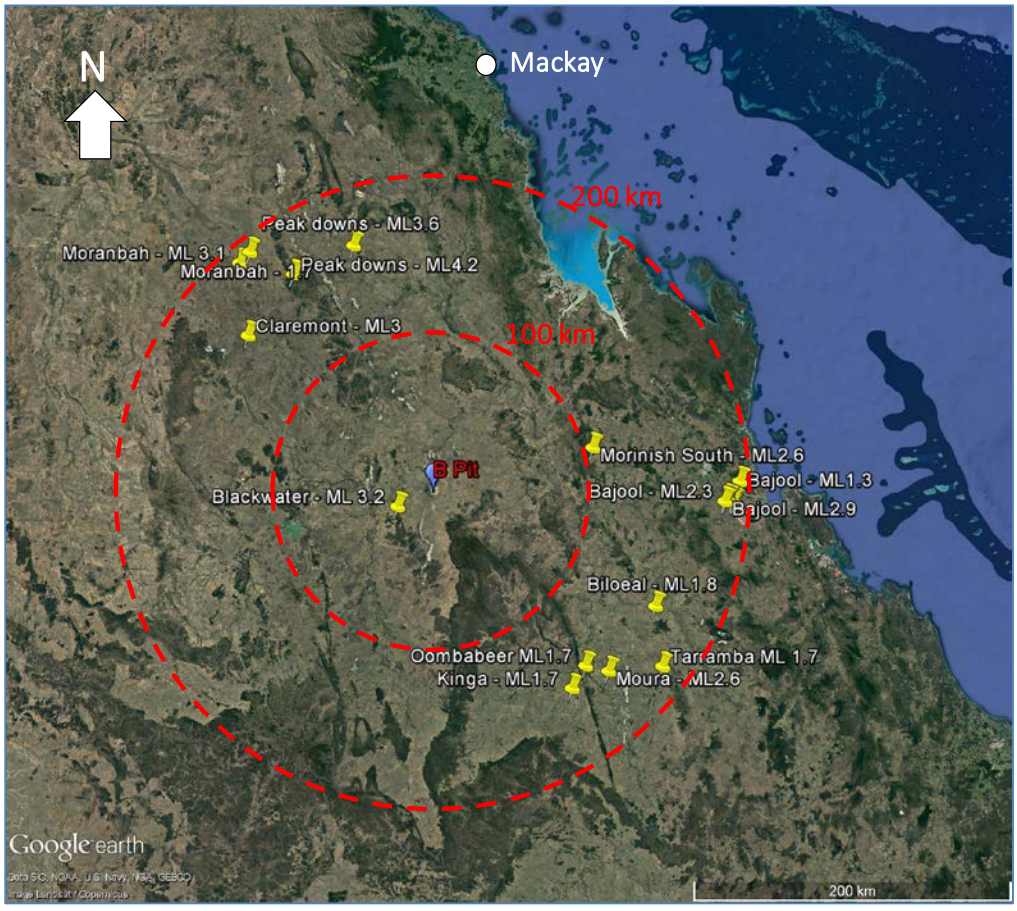



*Figure 5-8: Earthquake locations within 200 km of the B Pit TSF site.*

## 5.6 Baseline groundwater quality

Curragh (2015) documents groundwater quality information from monitoring bores located on the eastern edge of Pit A and founded in Tertiary material below the level of the Blackwater Creek, refer (Figure 5-9). The water quality results for May 2015 are shown in Table 2.

**Table 5-1: Pit A North and Blackwater Creek water quality - May 2015**

| BORE ID | SWL (mbgl) | SWL (m RL) | Flow rate (L/min) | Field pH | Field EC µS |
|---|---|---|---|---|---|
| 1301A MB (shallow) | 6.18 | 145.65 | <0.1 | 7.41 | 9 220 |
| 1301B MB (deep) | 5.96 | 145.74 | 0.3 | 6.6 | 16 410 |
| 1304B MB (deep) | 6.32 | 147.01 | <0.05 | 6.52 | 2 860 |

No groundwater quality information was available for monitoring bore RN 165387 located on the south eastern edge B Pit.

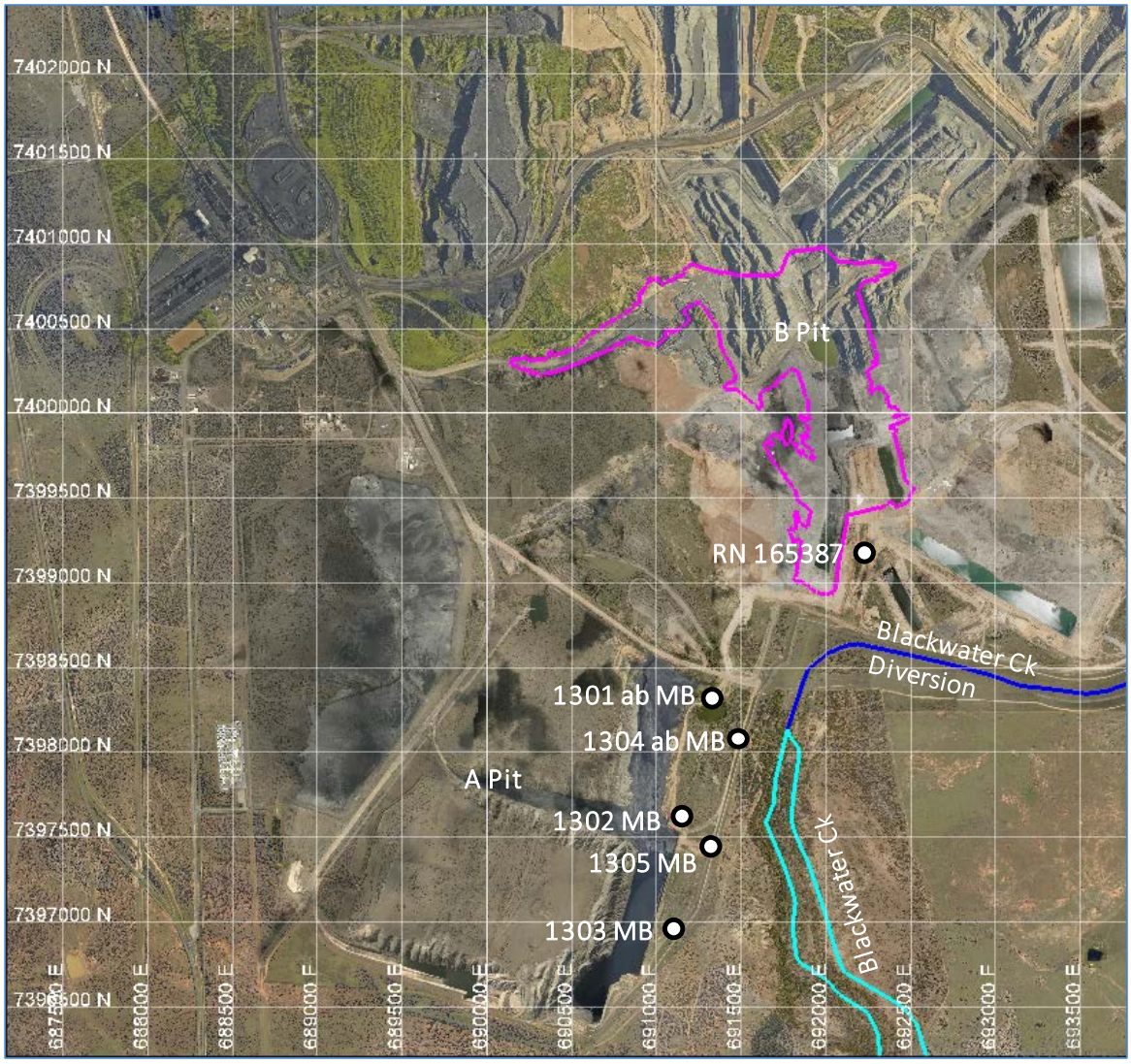



*Figure 5-9: Monitoring bore locations Pit A and Pit B.*

# 6.0 TAILINGS PROPERTIES

## 6.1 Physical properties

The physical properties of the tailings are shown in Table 6-1.

**Table 6-1: Tailings parameters**

| Parameter | Value | Unit | Source |
|---|---|---|---|
| Annual production rate | 1 040 000[1] | tpa | Curragh |
| Particle Size | ≤0.5 | mm | Sedgman |
| Particle density | 1.65 | | Curragh |
| Solids concentration – m/m | 37.4 | % | Curragh |
| Solids concentration – v/v | 26.5 | % | Curragh |
| Slurry density | 1.17 | $t/m^3$ | Curragh |
| Tailings initial settled dry density | 0.8 | $t/m^3$ | Golder |
| Tailings beaching angle[2] | | | |
| above water | 0.5 | % | Golder |
| below water | 3.0 | % | Golder |

## 6.2 Geochemical properties

The geochemical data for tailings liquor from the coal handling process plants has been provided for 2013 and is shown in Table 6-2.

**Table 6-2: Geochemical tailings properties.**

| Date | pH | | EC (µS) | |
|---|---|---|---|---|
| | CHPP1 | CHPP2 | CHPP1 | CHPP2 |
| 24/9/2013 | 8.22 | 8.25 | 4 630 | 756 |
| 27/9/2013 | 7.38 | 7.89 | 1 656 | 650 |
| 30/9/2013 | 8.49 | 8.08 | 3 950 | 2 050 |
| 14/10/2013 | 7.66 | 8.21 | 4 750 | 4 000 |

Curragh (2015) (Appendix I) documents the tailings chemistry as:

- pH (average) = 8.02
- EC (average) = 3 000 µS.

[1] This value is equivalent to 1,300,000 $m^3$/annum with a tailings settled dry density of 0.8 $t/m^3$

[2] Based on 2013 aerial and bathymetry survey for A Pit

# 7.0 TAILINGS STORAGE FACILITY DESIGN FEATURES

The Pit B TSF design requires the construction of a containment embankment at about the middle of the pit to prevent tailings from entering H Pit, which is still active and located to the north east of the embankment. Design drawings are presented in APPENDIX A. Other associated works comprise:

- The extension of slurry pipelines, from the existing slurry pipe lines to the Pit A TSF, to the Pit B TSF embankment
- The installation of decant return water pontoon pumps at the southern end of the Pit B TSF
- The construction of decant return water pipe lines.

The details of the TSF earthworks and piping design are provided in the following sections.

## 7.1 Site selection

The TSF site (Figure 2-1 and Figure 7-2) was selected following a TSF options study reported by Golder (2014). The advantages of the site include:

- A capacity providing up to 18 years of tailings storage based on
  - An annual deposition rate of 1 040 000 t
  - A maximum tailings elevation of RL 145 m
- Reduced potential for off-site spillage as the site is located within an existing mine void
- Low off-site seepage potential based on the surrounding geology (Duaringa formation) having a reported low horizontal hydraulic conductivity in the order of 0.05 to 0.6 m/day, refer Curragh (2016) (APPENDIX I)
- Within 3 km of the CHPP.

The containment embankment alignment is shown in Figure 7-2 and was selected on the basis of:

- Existing access from Ramp 4
- Minimising the embankment material volume
- Improved pit foundation conditions when compared to the Pit H area, north of the embankment alignment, based on a geotechnical site inspection by Golder, refer site notes APPENDIX B.

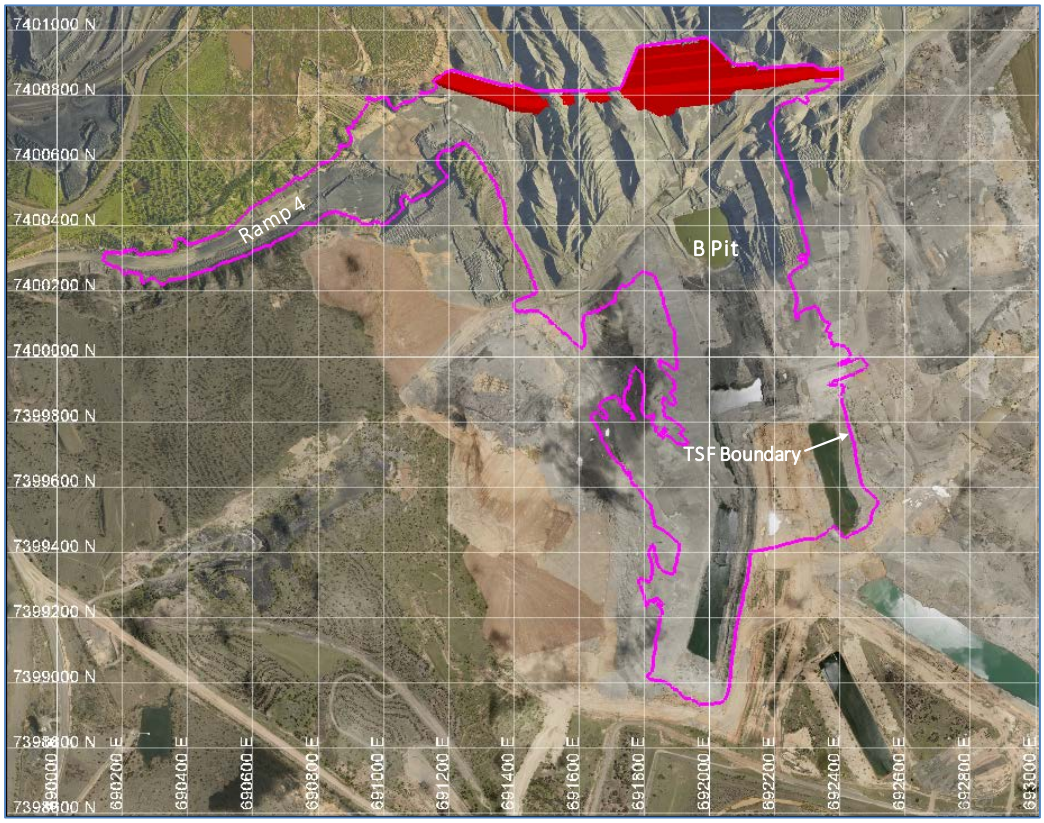



*Figure 7-1: B Pit TSF site with containment embankment at Stage 1 height.*

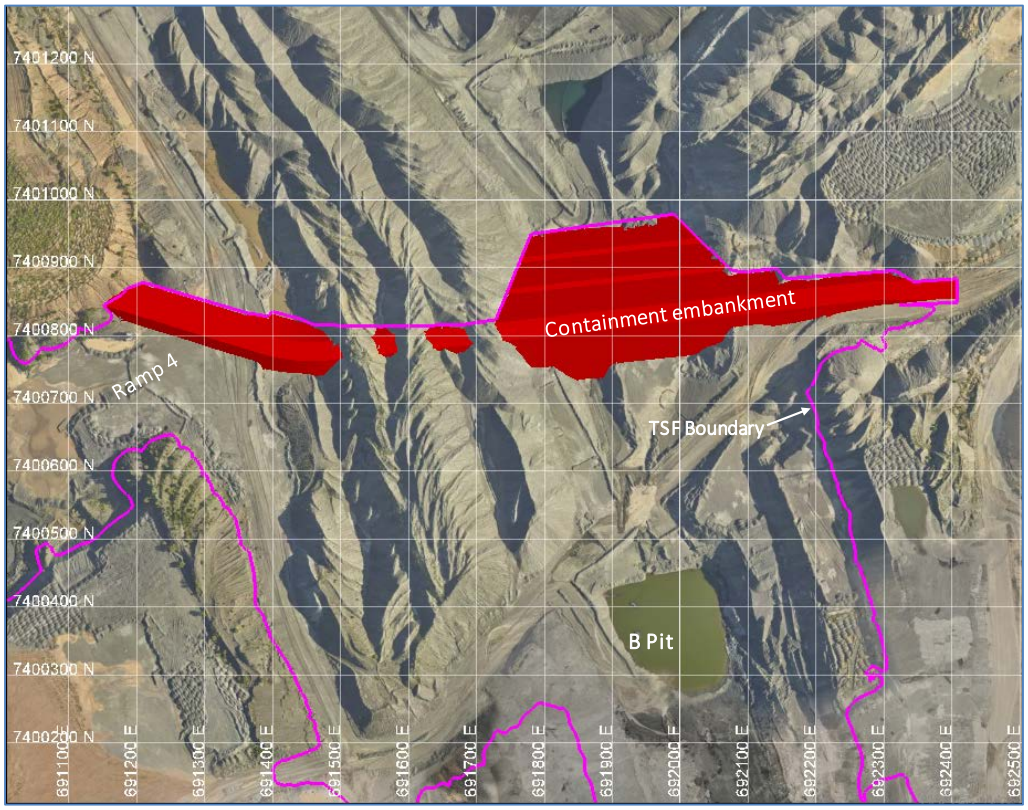



*Figure 7-2: B Pit TSF containment embankment at final height.*

## 7.2 TSF configuration

The TSF will occupy an approximate total area of 144 ha at final storage level with containment provided by the pit void and from a containment embankment at the northern end of Pit B. To defer capital expenditure the TSF development will be a staged construction with two raises.

The TSF will have a decant area located at the southern end of Pit B. There is one permanent floating pontoon pump to be used to abstract supernatant water. Temporary high wall pumps can be utilised when required.

The general TSF design configuration is summarised below.

**Table 7-1: TSF design configuration**

| Parameter | Stage 1 | Stage 2 | Units |
|---|---|---|---|
| Embankment construction Type | Valley embankment | Downstream raise | na |
| Construction material | Mine waste and coal rejects | Coal rejects | na |
| Embankment crest level | 125 | 147 | RLm (mine) |
| Embankment crest width | 33 | 33 | m |
| Internal embankment slope | 1V:1.3H | 1V:1.3H | na |
| External slope bench levels | 105 | 105, 125 | RLm (mine) |
| External bench width | 8 | 8 | m |
| External embankment slope between benches | 1V:1.8H | 1V:2H | na |
| Max embankment Height above 2017 pit surface | 19 | 57 | m |
| Embankment length | 290 m | 1 245 m | m |
| Maximum tailings level at final storage | 113.5 | 135 | RLm (mine) |
| Storage surface area at final stage storage elevation | 51.99 | 116.2 | ha |
| Calculated Storage volume | 9 705 440 | | $Mm^3$ |
| Calculated Storage | 3.8 | 20 | years |

The Pit B TSF will not have a spillway, as no external containment embankments, above the exiting ground surface, form part of the design.

### 7.2.1 Construction material features

The mine waste and CHPP rejects will be used to construct the embankment.

#### *7.2.1.1 Stage 1*

The Stage 1 embankment will be constructed using selected mine waste, with a layer of reject on the upstream slope to provide a filter against for tailings migration.

#### *7.2.1.2 Stage 2*

The Stage 2 raise will use only rejects, as the mine needs an area to dispose of the CHPP rejects.

## 7.3 Proposed operating conditions

The operational philosophy is based on the use of sub-aerial deposition i.e. deposition above water. This system:

- Maximises storage efficiency due to the development of a flatter beach slope than would occur below water
- Allows desiccation of the tailings beach, maximising settled density and thus storage efficiency
- Allows for the opportunity for rapid recovery of water for reuse and to minimise the potential for seepage.

Tailings deposition will be by one or more single point discharges, one at the eastern end of the embankment, in tailings pipe cut 2 (APPENDIX A Drawing 001) which will gradually retreat up Ramp 4 as the tailings level increases, and one off the embankment to prevent water ponding against the embankment. It should be noted that the Pit B TSF embankment has not been designed as a water retaining structure and hence ponding water is to be kept well away from it.

A decant pumping system will be operated to maintain freeboard within the TSF, with the decant water returned to the CHPP as a priority.

# 8.0 GEOTECHNICAL ASSESSMENT

This section provides the basis for the geotechnical material parameters adopted and used in the geotechnical analyses of the embankment, as well as an assessment of the existing foundation conditions.

## 8.1 Assessment of construction material geotechnical properties

As previously mentioned, the embankment is to be constructed using mine waste and rejects.

### 8.1.1 Laboratory testing

Laboratory testing was conducted on mine waste materials from H Pit, H Pit Pollux interburden and rejects with the test results provided in APPENDIX C. The tests conducted comprised:

- Classification tests (particle size distribution and Atterberg)
- Moisture density relationship
- Direct shear tests.

The laboratory results indicate the interburden and mine waste materials are predominantly sandy silty gravels with liquid limits varying from 31% to 33%.

**Table 8-1: Particle size distribution and liquid limit summary**

| Material description | Particle size distribution | | | Liquid Limit (%) |
|---|---|---|---|---|
| | Clay and Silt (%)[1] | Sand (%)[1] | Gravel (%)[1] | |
| H Pit mine waste | 35 | 30 | 35 | 33 |
| H Pit pollux Interburden | 27 | 33 | 40 | 31 |
| Rejects | 4 | 51 | 45 | non plastic |

1. Material descriptions based on particle size documented in AS1726

The direct shear strength results presented as cohesion (c), internal friction angle (ϕ) and density are shown in Table 8-2.

**Table 8-2: Direct shear strength and density results.**

| Material description | Wet density at Optimum Moisture Content, ɣ (kN/m$^3$) | Peak strength | | Residual strength | |
|---|---|---|---|---|---|
| | | c (kPa) | ϕ (degrees) | c (kPa) | ϕ (degrees) |
| H Pit mine waste | 21.5 | 99.9 | 19.1 | 98.8 | 18.9 |
| H Pit pollux Interburden | 21.7 | 116.1 | 26.0 | 115.6 | 25.8 |
| Rejects | 16.9 | 19.0 | 32.1 | 17.0 | 31.9 |

The cohesion values for the mine waste, interburden and rejects materials shown in Table 8-2 are much higher and the friction angle somewhat lower than historical effective shear strength assessments of mine waste materials from the Bowen Basin. We consider the direct shear test results to be representative of static total (undrained) shear strength rather than static effective shear strength.

The wet density values in Table 8-2 are also higher than historical assessments of mine waste material from the Bowen Basin. We consider the laboratory densities to be at the upper end of densities, rather than typical, based on historical information and the density testing occurring under optimum conditions.

Simmons & McManus (2004), APPENDIX D, present typical static effective shear strength and density parameters for mine waste based on back analysis of mine waste dump failures throughout the Bowen Basin, QLD.

### 8.1.2 Interpretation of geotechnical parameters

#### *8.1.2.1 Static geotechnical parameters*

Table 8-3 presents the adopted static shear strength and unit weighs for the construction materials. Table 8-4 documents the basis for these material parameters.

**Table 8-3: Selected geotechnical parameters for construction materials.**

| Material | Bulk density ɣ (kN/m$^3$) | Effective shear strength | | Undrained shear strength | | Permeability | |
|---|---|---|---|---|---|---|---|
| | | c' (kPa) | ϕ' (degrees) | c (kPa) | ϕ (degrees) | Hydraulic conductivity (m/s) | Ky/Kx |
| Mine waste - Saturated | 20 | 20 | 25 | 100 | 19 | 1 x 10$^{-4}$ | 0.5 |
| Mine waste - Unsaturated | 18 | 50 | 30 | 100 | 19 | 1 x 10$^{-6}$ | 0.5 |
| Rejects | 15 | 0 | 40 | 0 | 40 | 1 x 10$^{-2}$ | 1 |

**Table 8-4: Basis for selection of construction material parameters**

| Material | Basis |
|---|---|
| Mine waste - Saturated | ■ Unit weight - Simmons & McManus (2004), category 3 material<br>■ Effective strength - Simmons & McManus (2004), category 3 material<br>■ Undrained shear strength – direct shear testing, Section 8.1<br>■ Permeability – Sherwood (2013) |
| Mine waste - Unsaturated | ■ Unit weight - Simmons & McManus (2004), category 3 material<br>■ Effective strength - Simmons & McManus (2004), category 3 material<br>■ Undrained shear strength – direct shear testing, Section 8.1<br>■ Permeability – Sherwood (2013) |
| Rejects | ■ Unit weight based on Look (2007)<br>■ Effective and undrained shear strength – 300 mm x 300 mm direct shear testing on rejects from Lake Vermont at strain rate of 0.5 mm / minute (APPENDIX C).<br>■ Permeability – US Army Corps of Engineers (1993) |

#### *8.1.2.2 Seismic geotechnical parameters*

The material shear strength parameters under seismic loading conditions were obtained by reducing the undrained material parameters in Table 8-3 by 20%, in accordance with the US Army Corps (1984) method to allow for strain weakening following seismic loading.

**Table 8-5: Selected seismic geotechnical strength parameters.**

| Material | Bulk density ɣ (kN/m$^3$) | Seismic shear strength | |
|---|---|---|---|
| | | c (kPa) | ϕ (degrees) |
| Mine waste - Saturated | 20 | 80 | 15 |
| Mine waste - Unsaturated | 18 | 80 | 15 |
| Rejects | 14 | 0 | 32 |

## 8.2 Embankment foundation

Curragh has provided the following information on the B Pit foundation conditions;

- Survey information
  - Lidar surface topography data following completion of mining 'Lidar1602-CS-Running.00t'
  - Surface topography at 2017 'Current surface.dxf'
  - Pit bathymetry below stored water 'bpitbatho1610.dxf'
- Geological section along the embankment axis (developed by Raine and Associates).

Based on this information the subsurface material stratigraphy occurring beneath the embankment foundation can be summarized as:

- Non engineered mine waste backfill (silts, sands, gravels, cobbles) ranging in thickness from 5 m to 25 m overlying
- Siltstone with potential zones shearing / faulting up to 20 m.

The above materials are likely to exhibit the following characteristics:

- The mine waste and the siltstone is likely to be subject to differential movement over time
- Piping could occur through the mine waste under a hydraulic gradient from the TSF.

These foundation conditions are not considered ideal geotechnical conditions for an embankment foundation, but are considered to be manageable through embankment design engineering solutions which comprise:

- A wide embankment which can tolerate settlement
- A downstream batter slope which is intended to reduce hydraulic head and minimise the potential for foundation piping based on a Lanes creep ratio of between 2.5 and 3.0 for boulders, gravel and sand.

### 8.2.1 Assessment of foundation geotechnical properties

#### *8.2.1.1 Static geotechnical parameters*

Table 8-6 presents the geotechnical parameters adopted for the foundation materials.

**Table 8-6: Assessed foundation geotechnical parameters**

| Material | Bulk density ɣ (kN/m³) | Effective shear strength | | Undrained shear strength | | Permeability | |
|---|---|---|---|---|---|---|---|
| | | c' (kPa) | ϕ' (degrees) | c (kPa) | ϕ (degrees) | Hydraulic conductivity (m/s) | Ky/Kx |
| Mine waste - Saturated | 20 | 20 | 25 | 100 | 19 | $1 \times 10^{-4}$ | 0.5 |
| Mine waste - Unsaturated | 18 | 50 | 30 | 100 | 19 | $1 \times 10^{-6}$ | 0.5 |
| Permian aged rock -Siltstone | 20 | 500 | 28 | 500 | 28 | $1 \times 10^{-8}$ | 0.02 |

**Table 8-7: Basis for selection of foundation parameters**

| Material | Basis |
|---|---|
| Mine waste - Saturated | ■ Unit weight - Simmons & McManus (2004), category 3 material<br>■ Effective strength - Simmons & McManus (2004), category 3 material<br>■ Undrained shear strength – direct shear testing, Section 8.1<br>■ Permeability – Sherwood (2013) |
| Mine waste - Unsaturated | ■ Unit weight - Simmons & McManus (2004), category 3 material<br>■ Effective strength - Simmons & McManus (2004), category 3 material<br>■ Undrained shear strength – direct shear testing, Section 8.1<br>■ Permeability – Sherwood (2013) |
| Permian aged siltstone | ■ Unit weight - Look (2007)<br>■ Strength – Hoek and Brown (1997)<br>■ Permeability – Curragh (2016), Curragh (2017) |

### *8.2.1.2 Seismic geotechnical parameters*

The material shear strength parameters under seismic loading conditions were obtained by reducing the undrained material parameters in Table 8-3 by 20%, in accordance with the US Army Corps (1984) method to allow for strain weakening following seismic loading.

**Table 8-8: Selected shear strength and density for embankment fill and rejects.**

| Material | Bulk density ɣ (kN/m³) | Seismic shear strength | |
|---|---|---|---|
| | | c (kPa) | ϕ (degrees) |
| Mine waste - Saturated | 20 | 80 | 15 |
| Mine waste - Unsaturated | 18 | 80 | 15 |
| Permian aged Siltstone | 20 | 400 | 23 |

## 8.3 Tailings properties

The tailings characterisation is provided in Table 8-9.

**Table 8-9: Assessed tailings geotechnical parameters.**

| Parameter | Value | Basis |
|---|---|---|
| Undrained strength ratio (Su/σv') | 0.15 | Golder - Engineering experience |
| Settled density | 12 kN/m$^3$ | Curragh |
| Hydraulic conductivity | 1 x 10$^{-7}$ m/s | Golder, testing at Coppebella Coal Mine |
| Hydraulic conductivity ratio ($k_y/k_x$) | 0.5 | Golder |

## 8.4 In situ sub surface material permeability near B Pit

This section provides an assessment of the permeability of the sub surface materials near B Pit, as defined in Section 5.3, for the purpose of assessing potential out of pit seepage as documented in Section 12.3.

The permeability parameters and the basis for selection are shown in Table 8-9.

**Table 8-10: Permeability parameters for in situ materials.**

| Material | Hydraulic Conductivity (m/s) | $k_y/k_x$ ratio | Basis |
|---|---|---|---|
| Alluvium | 1.16 x 10$^{-5}$ | 0.1 | Curragh (2017), Flood plain alluvium |
| Tertiary aged rock (weathered) | 6.94 x 10$^{-6}$ | 0.1 | Curragh (2017), Duaringa formation |
| Permian rock | 1.00 x 10$^{-8}$ | 0.02 | Curragh (2016) |

## 8.5 Liquefaction potential of foundation and embankment materials

A liquefaction screening assessment was carried out on the mine waste (foundation and embankment materials) and rejects (embankment material) based on the methods outlined in Fell et. al. (2005). Figure 8-1 presents particle size distribution curves for the Pit H mine waste and interburden and rejects materials along with the approximate zone for liquefiable fill materials based on Hunter and Fell (2003) as referenced in Fell et. al. (2005).

The particle size distribution results shown in Figure 8-1 indicate that the Pit H materials and rejects may be liquefiable under certain conditions. However, additional screening criteria by Collins and Tjoumas (2003) below, as referenced in Fell et. al. (2005), indicates that the mine waste, interburden and rejects materials is unlikely to be liquefiable.

i) Liquefaction possible when water content ($w_c$) ≥ 0.9 liquid limit ($w_L$)

The water content of the mine waste and interburden materials were calculated at approximately 18% (assuming a specific gravity of 2.65 and a dry density of 1.8 t/m$^3$) and assuming fully saturated conditions. This was less than the liquid limit X 0.9 = 30%

The rejects could not be assessed for liquid limit as the material contains <5% fines

ii) Liquefaction possible when Liquidity Index ($I_L$) ≥ 0.75

The liquidity index of the mine waste and interburden materials were calculated at approximately 0.0625 which is less than 0.75.

iii) Liquefaction possible when Unconfined compressive strength (qu) ≤50 – 70 kN/m$^2$

The direct shear testing documented in Section 8.1.1 indicates that the rejects, mine waste and interburden materials are expected to have qu > 70 kN/m$^2$

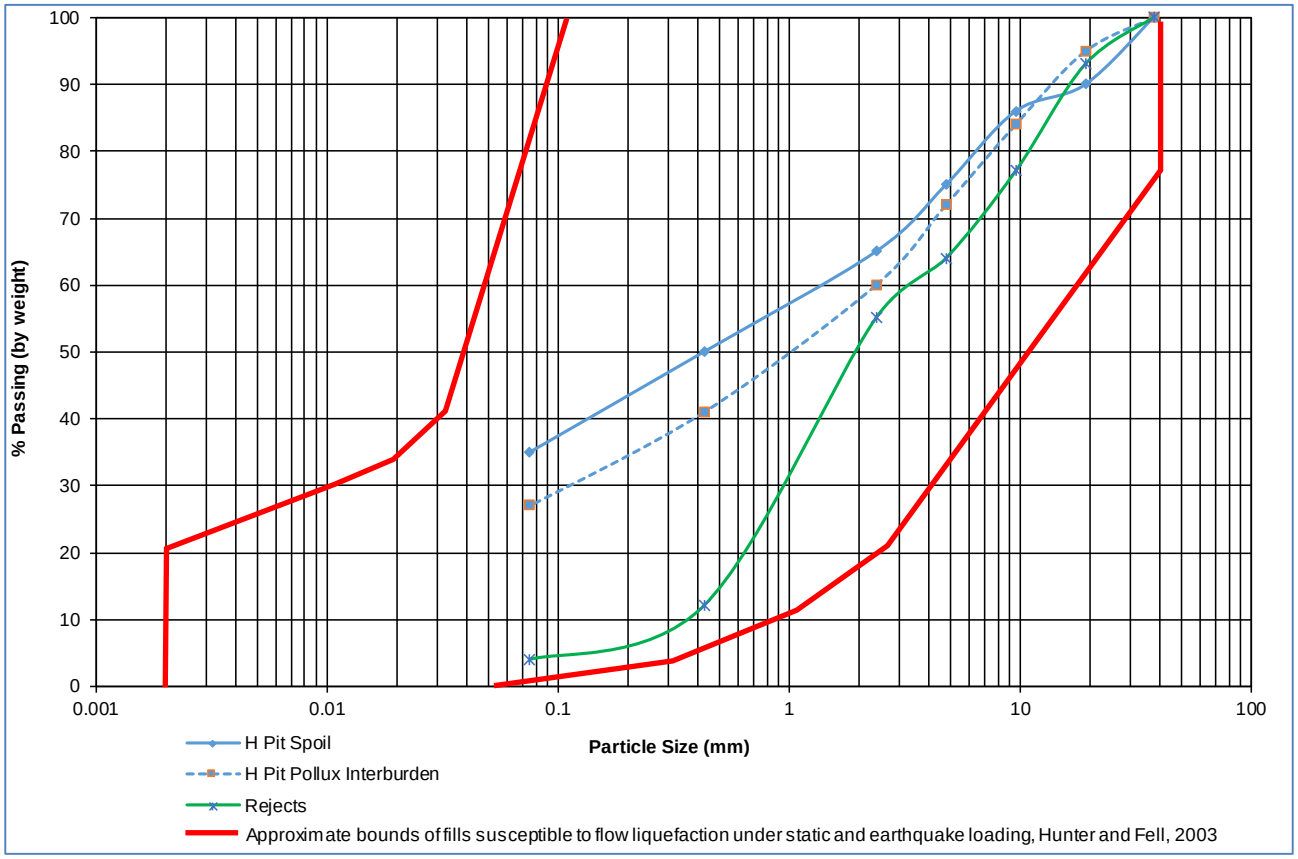



*Figure 8-1: Particle size distribution curves for Pit H mine waste, Pit H interburden and rejects with zone of liquefiable fills.*

## 8.6 Reject filter assessment

An assessment was undertaken on the coal rejects to confirm the suitability of the rejects as a filter for both the mine waste and the tailings. The assessment was undertaken in accordance with the Sherard and Dunnigan method as documented in USDA (1994).

The particle size distribution laboratory test results for Curragh mine waste and rejects (Section 8.1.1) was used for the assessment along with particle size distribution results for coal tailings from Coppabella coal mine. The Coppabella coal mine tailings are considered to have similar properties as the Curragh tailings have.

The results of the assessment are shown in Figure 8-2 (tailings filter) and Figure 8-3 (mine waste filter).

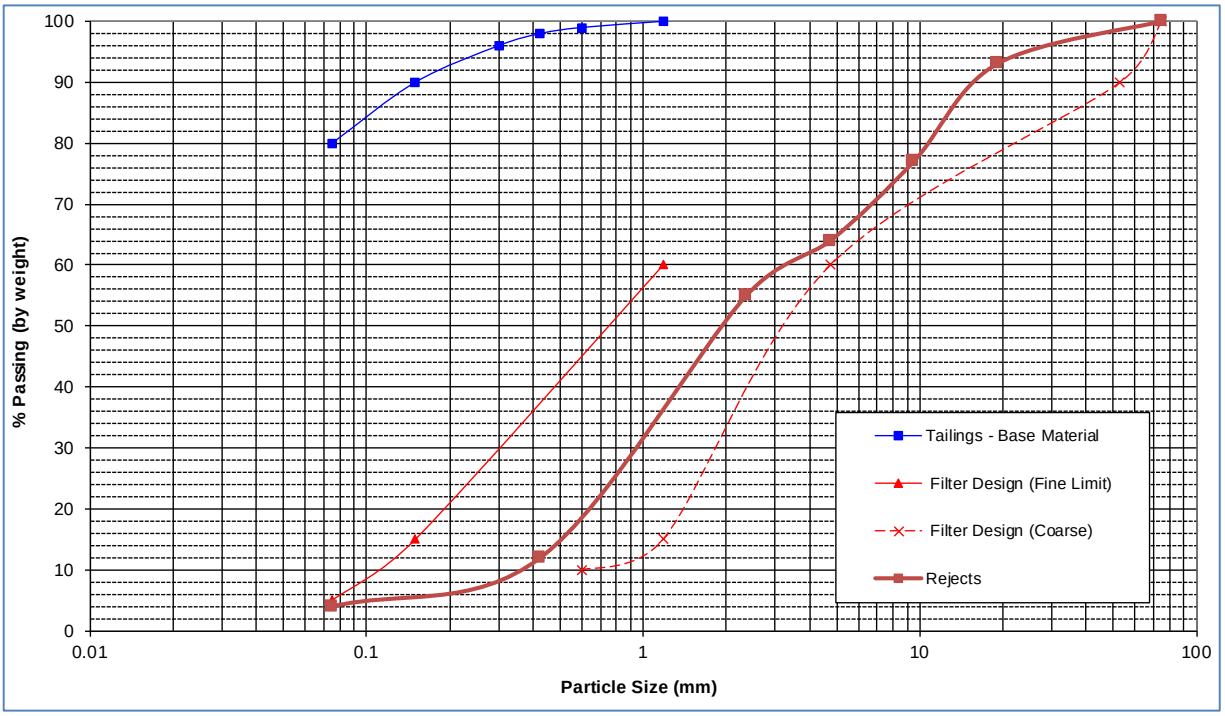



*Figure 8-2: Filter PSD design envelope for tailings with rejects PSD.*

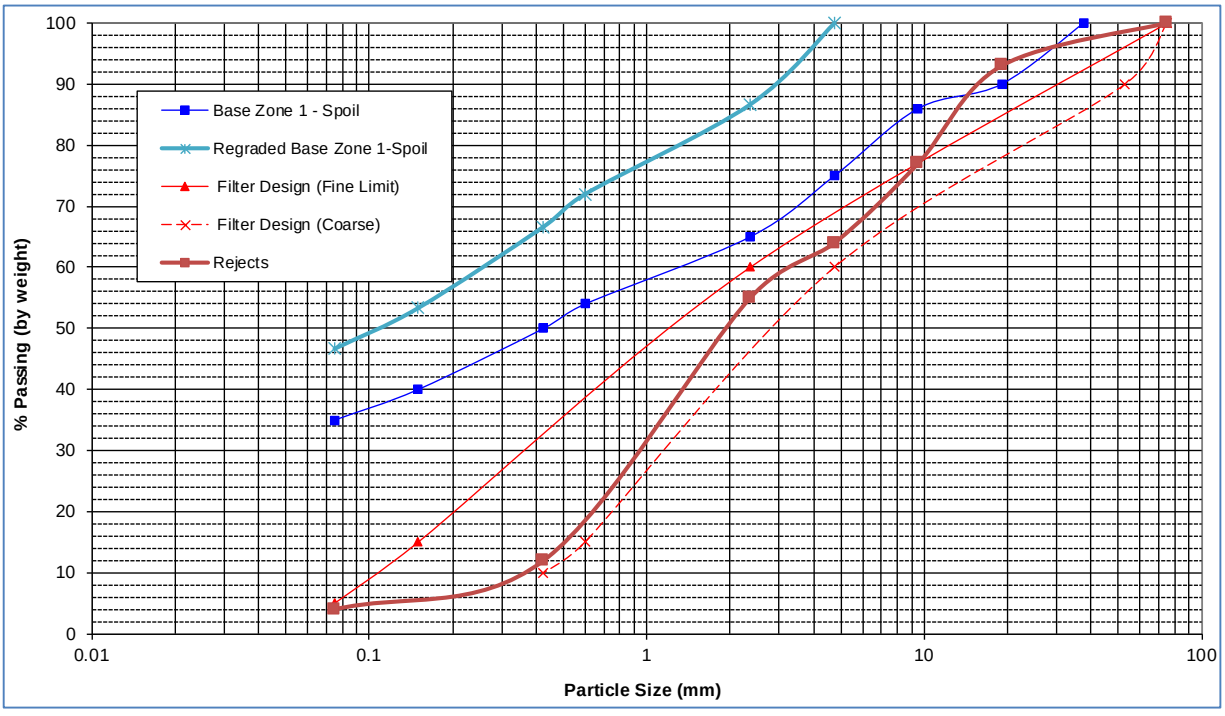



*Figure 8-3: Filter PSD design envelope for mine waste with rejects PSD.*

The assessment indicates that the rejects particle size distribution will be suitable as a filter for both tailings and mine waste.

# 9.0 DESIGN CRITERIA

The criteria adopted for the design of the TSF are based on the following key references:

- Guidelines in Tailings Dam Design, Construction and Operation (ANCOLD, 2012b).
- Manual for assessing consequence categories and hydraulic performance of structures (DEHP 2016)
- Operational data as provided by Curragh

Based on this list of references, the key aspects of design in relation to the TSF are as follows:

- Volumetric / Civil.
- ANCOLD Consequence Category
- DEHP Consequence Category
- Embankment Stability

These issues are addressed in the following sections.

## 9.1 Tailings and CPPs water requirements and volumetric / physical properties

The Tailings and CPPs water requirements and volumetric / physical design criteria for the TSF and decant pond is documented in Table 9-1 on the next page.

**Table 9-1: Tailings and CHPP Volumetric / physical properties.**

| Criteria | Value | Unit |
|---|---|---|
| ROM | 15.00 | Mt/yr |
| Product | 10.50 | Mt/yr |
| Annual tailings rate | 1.04 | Mt/yr |
| Thickener solids | 7% | |
| Slurry in water (thickener underflow) | 13.82 | $Mm^3/yr$ |
| Underflow Solids | 37% | |
| Tailings Specific gravity | 1.65 | |
| Initial dry density | 0.8 | $t/m^3$ |
| **Retained water within tailings** | 0.67 | $Mm^3/yr$ |
| Decant Supernatant Water | 62% | |
| **TSF water to decant pond for return (excluding rainfall and evaporation)** | 1.07 | $Mm^3/yr$ |
| Thickener overflow (clarifiers) recirculated back to CPPs | 12.08 | $Mm^3/yr$ |
| Total tailings water return (decant + clarifiers) | 13.15 | $Mm^3/yr$ |
| Rejects volume | 3.12 | Mt/yr |
| Rejects water content | 12% | |
| **Water bound with rejects** | 0.43 | $Mm^3/yr$ |
| Product water content | 9% | |
| **Water bound with product** | 1.04 | $Mm^3/yr$ |
| **Total CPPs water demand** | 3.21 | $Mm^3/yr$ |
| **Water demand for CPPs** (for product, rejects and due to water loss to TSF) | 2.14 | $Mm^3/yr$ |
| Operating embankment crest width | 28 | m |

## 9.2 ANCOLD consequence category and criteria

ANCOLD (2012c) provides Consequence Categories that are used to determine design and operational requirements, including freeboard and recommended design earthquake loading AEPs criteria.

### 9.2.1 Consequence category assessment

An assessment of TSF Consequence Category was undertaken based on ANCOLD (2012b) Guidelines considering embankment failure and uncontrolled release or seepage. The assessment, presented in Table 9-2 indicated a 'High C' rating based on the potential for one or more lives being lost.

The Consequence Category for the Decant pond was also assessed to be 'High C' based on the highest level of severity of damage and loss being 'minor' and the potential loss of life being ≥ 1.

**Table 9-2: ANCOLD Consequence Category TSF Assessment – Severity of Damages and Losses.**

| Damage and Loss | | Severity Level | | | |
|---|---|---|---|---|---|
| | | Minor | Medium | Major | Catastrophic |
| **Total Infrastructure Cost** | **COST ESTIMATE** | | | | |
| Residential | No effect | | | | |
| Commercial | <$10M | X | | | |
| Infrastructure | <$10M | X | | | |
| Dam replacement or repair cost | $10M to $100M | | X | | |
| **Total Estimated Cost** | $10M to $100M | | X | | |
| **Impact on dam owner's business** | | | | | |
| Importance to the business | Essential for tailings storage | | | X | |
| Effect on services provided by the owner | Severe restrictions on coal supply | | | X | |
| Effect on continuing credibility | Some reactions but short lived as no offsite discharge | X | | | |
| Community reaction and political implications | Some reactions but short lived as no offsite discharge | X | | | |
| Impact on financial viability | Some reactions but short lived as no offsite discharge | X | | | |
| Value of water in the storage | Can be absorbed from other storage sources | X | | | |
| **Health and social impacts** | | | | | |
| Public health | <100 people affected | X | | | |
| Loss of Services to the community | <100 people affected | X | | | |
| Cost of emergency management | <1000 person days | X | | | |
| Dislocation of people | No effect | X | | | |
| Dislocation of businesses | No effect | X | | | |
| Employment affected | No jobs lost | X | | | |
| Loss of heritage | Potential loss of scar tree on western border | | X | | |
| Loss of recreational facility | No effect | X | | | |
| **Environmental Impacts** | | | | | |
| Stock and fauna | Dam break contained in pit - would not contaminate water sources | X | | | |
| Ecosystems | Dam break contained in pit - Natural ecosystem would not be affected | X | | | |
| Rare and endangered species | No change to effect on species | X | | | |
| **Highest level of severity of damage and loss** | | | | **X** | |
| **Population at Risk (PAR)** | | 1 to 10 | | | |

### 9.2.2 ANCOLD freeboard and earthquake criteria

The following freeboard and earthquake design criteria have been adopted for the TSF from ANCOLD (2012b) based on the assessment documented in Section 9.2.1.

**Table 9-3: Earthquake return periods for High C ANCOLD Consequence category.**

| Criteria | Value |
|---|---|
| Embankment Contingency Freeboard | 1:10 AEP wind plus 0.5 m |
| Design Earthquake Loading (AEP) for OBE | 1:1 000 |
| Design Earthquake Loading (AEP) for MDE | 1:10 000 |

## 9.3 DEHP consequence category

The *Manual for assessing consequence categories and hydraulic performance of structures,* DEHP (2016), establishes hydraulic consequence categories which then establish mandatory criteria. An assessment of the consequence category for the B Pit TSF was carried out to establish the mandatory criteria comprising:

- DSA
- ESS
- MRL

The consequence categories provided in Table 1 of the Manual for assessing consequence categories and hydraulic performance of structures, DEHP (2016), was used to complete the Consequence Category Assessments below. For ease of reference, it has been reproduced in Table 9-4:

**Table 9-4: Consequence Category Assessment**

| Environmental Harm | High | Significant | Low |
|---|---|---|---|
| **Harm to humans** | Location such that people are routinely present in the failure path and if present loss of life to greater than 10 people is expected[7].<br><br>Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario | Location such that people are routinely present in the failure path and if present loss of life to 1 person or greater but less than 10 people is expected[7].<br><br>Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario | Location such that people are not routinely present in the failure path and loss of life is not expected[7].<br><br>Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario |
| | Location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of 20 or more people being affected[9]. | Location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of 10 or more people but less than 20 people being affected. | Location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of less than 10 people being affected. |
| **General environmental harm** | Location such that:<br><br>a) Contaminants may be released to areas of MNES, MSES or HEV waters that are not already authorised to be disturbed to at least the same extent under other conditions | Location such that contaminants may be released so that adverse effects (that are not already authorised to be disturbed to at least the same extent under other conditions of this authority | Location such that either:<br><br>a) Contaminants are unlikely to be released to areas of Significant Values or Moderate Values; or |

| Environmental Harm | High | Significant | Low |
|---|---|---|---|
| | of this authority subject to any applicable offset commitment (Significant Values); and<br><br>b) Adverse effects[10] on Significant Values are likely; and<br><br>c) The adverse effects are likely to cause at least one of the following:<br>i) Loss or damage or remedial costs greater than $50,000,000; or<br>ii) Remediation of damage<br>iii) permanent alteration to existing ecosystems; or<br>iv) The area of damage (including downstream effects) is likely to be at least 5 km². | subject to any applicable offset commitment) either:<br><br>a) Would be likely to be caused to Significant Values but those adverse effects would not be likely to meet the thresholds for the High Consequence category and instead would be likely to cause at least one of the following: i) Loss or damage or remedial costs greater than $10,000,000 but less than $50,000,000; or ii) Remediation of damage is likely to take more than 6 months but less than 3 years; or iii) Significant alteration to existing ecosystems; or iv) The area of damage (including downstream effects) is likely to be at least 1 km² but less than 5 km². or<br><br>b) Would be likely to be caused to environmental values classed as slightly or moderately disturbed waters[11], wetland of general ecological significance[12], riverine areas, springs or lakes and associated flora and fauna (Moderate Values), and the adverse effects are likely to cause at least one of the following :i) Loss or damage or remedial costs greater than $20,000,000; or ii) Remediation of damage is likely to take more than 1 year; or iii) Significant alteration to existing ecosystems; or iv) The area of damage (including downstream effects) is likely to be at least 2 km². | b) Contaminants are likely to be released to those areas, but would be unlikely to meet any of the minimum thresholds specified for the Significant Consequence Category for adverse effects. |
| **General economic loss or property damage** | Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require $10 million or greater in rehabilitation, compensation, repair or rectification costs[13]. | Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require $1 million and greater but less than $10 million in rehabilitation, compensation, repair or rectification costs[13]. | Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require less than $1million in rehabilitation, compensation, repair or rectification costs[13]. |

Notes:

7. People routinely present in the failure path' could be considered to be people who occupy buildings or other places of occupation that lie within the failure impact zone. For the purposes of this Manual, this should refer to people other than site personnel engaged by the resource operation and located on the tenements and tenure associated with the resource operation; for other ERAs, it would be the 'premises referred to in the authority'. It should be noted that while this is appropriate for the assessment of consequence categories in accordance with this Manual, adherence to the requirements of this Manual does

not limit, amend or change in any way, any other requirements to be complied with under relevant health and safety acts or legislation that requires the safety of site personnel to be considered.

8 When considering potential impacts on groundwater, it is not envisaged that a full hydrogeological assessment will be required in all cases. Any consideration of potential impacts on groundwater systems should consider the water quality of the potential receiving aquifer as well as the quality of fluid stored in the regulated dam. Existing groundwater drawdown in areas surrounding resource operations (e.g. drawdown as a result of mine pit or underground mine dewatering) can also be considered when assessing the consequence of dam seepage on groundwater systems.

9 'An adverse effect on human health means a physiological effect on human health and does not include an impact on the quality of downstream water that merely negatively affects taste and which is unlikely to cause persons to become physically ill.

10 Adverse effects includes chronic and acute effects where an acute effect is on living organism/s which results in severe symptoms that develop rapidly, and a chronic effect is an adverse effect on a living organism/s which develops slowly. In some instances, it may be necessary to carry out or reference existing ecological/toxicological studies to assess the impacts of contaminants on living organisms.

11 See Water EPP for definitions

12 Wetland of general ecological significance' means a wetland shown on a map of referable wetland as a 'general ecologically significant wetland' or 'wetland of other environmental value'. 13 This does not include the holder's own mine or gas production, on-site industrial or commercial assets, the holder's workers' accommodation, agricultural facilities on the holder's land such as a farm shed or farm dam or infrastructure solely for servicing the holder.

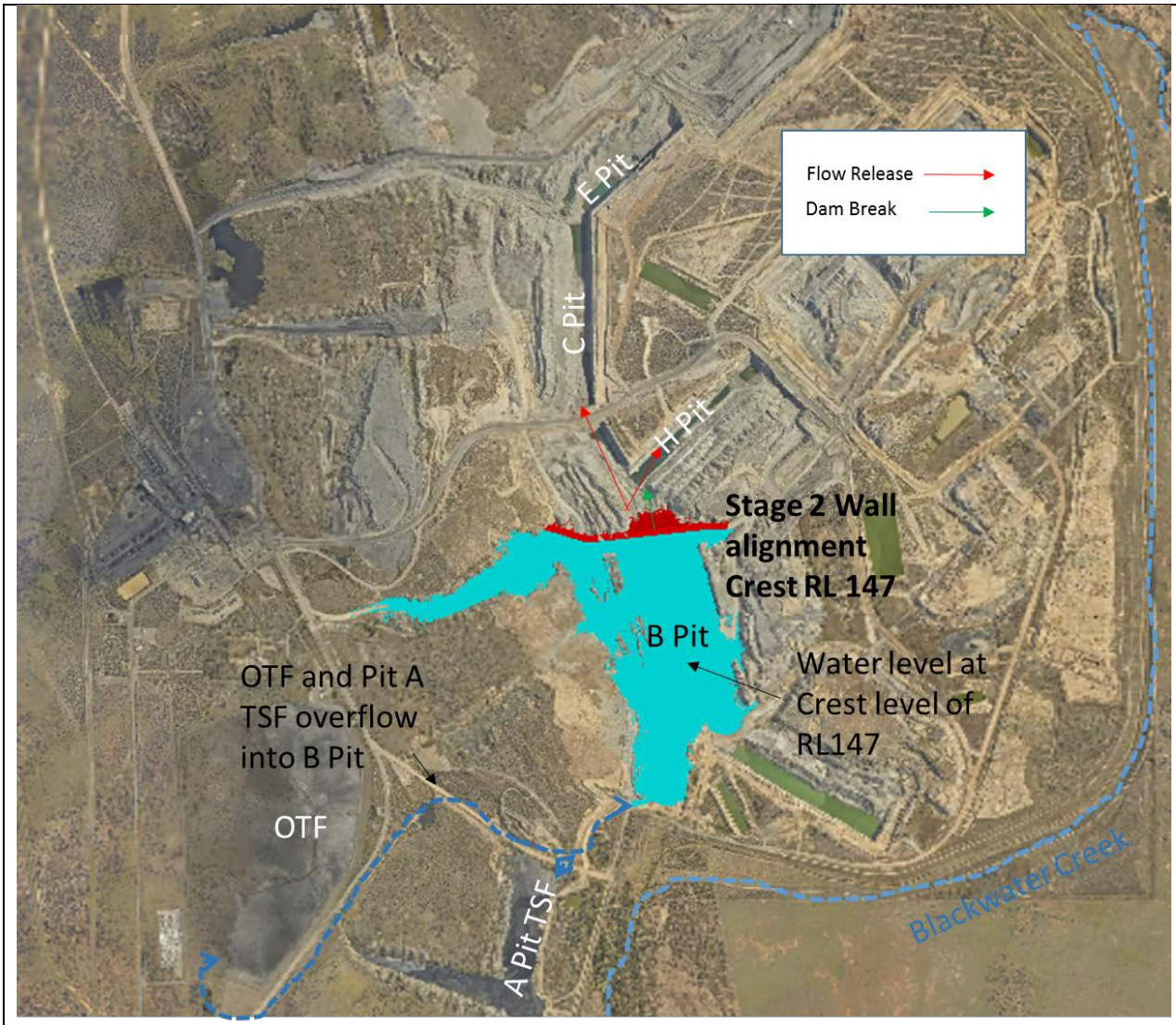
13 This does not include the holder's own mine or gas production, on-site industrial or commercial assets, the holder's workers' accommodation, agricultural facilities on the holder's land such as a farm shed or farm dam or infrastructure solely for servicing the holder.

### 9.3.1 Assessment

The consequence category assessment was completed in accordance with DEHP (2016) based on the following failure event scenarios:

- Failure to contain – seepage
- Failure to contain - overtopping
- Dam break.

Under this study the B Pit TSF was assessed to be 'SIGNIFICANT', based on the highest consequence category determined by the application of Section 2.1.2 of DEHP (2016). It is also the assessment that the structure should also be considered at a minimum as a Significant Category structure due to the intrinsic nature of it being an In-Pit TSF and its' size.




| | |
|---|---|
| Location | 691,763E 7401014 S Zone 55K |
| Function | Tailings disposal. Decant water pumped to RD30 and pumped to the CHPP's via RD1 and RD3. Pit B also contains the DSA of the Old Tailings Dam Facility (OTF) and Pit A Ramp 2 TSF. |
| Overflow Destination | Overflow will be contained within H Pit and C Pit |
| Dam Break Destination | It considered that the worst case scenario is that there is that there is a wall failure and that all water is release to adjoin pit resulting in a possible cascade failure. This location is depicted in the above figure. |
| Storage Volume | 7,913 ML (total volume of decant, DSA and Freeboard) |
| Possible Release Volume from Dam Break | 7,913 ML |
| Catchment Area | 1568.3 ha - Catchment area represents the relevant catchment of Pit B, Pit A, RD3, RD1, RD30, RD7 and OTF which drain to Pit B. |
| Water Quality | Curragh (2015) documents the tailings chemistry as pH (average) = 8.02, EC (average) = 3 000 µS. |

#### 9.3.1.1 Failure to contain – seepage

Failure to contain seepage is defined as spills or releases to ground and / or groundwater via seepage from the floor and / or sides of the structure. In the event of 'Failure to contain – seepage' the consequence has been assessed as being 'LOW', based on the highest consequence category determined by the application of Table 1 in DEHP(2016). The qualitative assessment is shown in Table 9-5.

**Table 9-5: B Pit TSF failure to contain - seepage scenario.**

| Environmental Harm | Assessment | Consequence Category |
|---|---|---|
| Harm to humans | Location such that there is no consumption of contaminated waters used for human consumption. | Low |
| General Environmental Harm | Adverse effects to areas of significant values are considered unlikely:<br><br>Potential seepage is not expected to reach the regional ecosystem of concern (Category B vegetation, refer Section 5.4) along Blackwater Creek. This is based on the likely low hydraulic conductivity and lack of continuity of the alluvial materials between B Pit and the Category B vegetation, refer Section 5.3.<br><br>Based on the Blackwater coalfield stratigraphic sequence, there is low vertical permeability of the bed material around B Pit. It was found that the coal seams are hydrologically isolated, which was confirmed by their significant different water chemistry (Curragh 2015).<br><br>Potential seepage is unlikely to reach the groundwater aquifers in the Tertiary materials based on the expected lack of vertical leakage in the Tertiary materials and the lack of transmissivity associated with faults, refer section 5.3.<br><br>Contamination of groundwater via seepage in the area of B Pit is therefore considered unlikely. | Low |
| General economic loss or property damage | The location of the TSF is such that harm to third party assets, excluding the mine's own commercial assets, is unlikely. | Low |

#### 9.3.1.2 Failure to contain – overtopping

'Failure to contain – overtopping' is defined as spills or releases from the structure that result from loss of containment due to overtopping of the structure and may be due to any cause other than a dam break. Overtopping could occur as a result of either poor management of tailings deposition resulting in increased beach angles, a failure of the decant water return system, or an extreme weather event that occurs in parallel with these.

In the event of 'Failure to contain – overtopping' the consequence has been assessed as being 'SIGNIFICANT', based on the highest consequence category determined by the application of Table 1 in DEHP(2016). The qualitative assessment is shown in Table 9-6

**Table 9-6: B Pit TSF Failure to contain – Overtopping scenario.**

| Environmental Harm | Assessment | Consequence Category |
|---|---|---|
| Harm to humans | Overtopping of the structure is unlikely to contaminate any water sources for human consumption. There are no drinking water sources at a lower elevation to a point of potential discharge. | Low |
| General Environmental Harm | Adverse effects to significant values, e.g. the regional ecosystem of concern along Blackwater Creek to the south and to the north, are considered possible in the event of a failure to contain overtopping scenario as it part of a DSA sharing system with other adjoining TSF facilities and mine water dams and is therefore consider within the significant category due to the proximity Category A and B endangered or of concern vegetation.<br><br>The adverse effects would not be likely to meet the thresholds for the HIGH consequence category as any spillage is expected to be minimal. | Significant |
| General economic loss or property damage | The location of the TSF is such that harm to third party assets, excluding the mine's own commercial assets, is unlikely. | Low |

### *9.3.1.3 Failure to contain – dam break*

'Failure to contain – dam break' is defined as collapse of the structure due to any possible cause. Possible causes may include:

- A failure of the containment embankment caused by an increase in the internal phreatic surface
- An overtopping of the containment wall leading to failure of the wall, following an extreme rainfall event.

In the event of 'Failure to contain –dam break' the consequence has been assessed as being 'SIGNIFICANT', based on the highest consequence category determined by the application of Table 1 in DEHP (2016). The qualitative assessment is shown in Table 9-7.

**Table 9-7: B Pit TSF failure to contain – dam break scenario.**

| Environmental Harm | Assessment | Consequence Category |
|---|---|---|
| Harm to humans | Location such that there is no consumption of contaminated waters used for human consumption. | Low |
| General Environmental Harm | Adverse effects to significant values, e.g. the regional ecosystem of concern along Blackwater Creek to the south and to the north, are considered possible in the event of a failure to contain overtopping scenario as it part of a DSA sharing system with other adjoining TSF facilities and mine water dams and is therefore considered within the significant category due to the proximity to Category A and B endangered and/or of concern vegetation. It is the assessment that the structure should also be considered at a minimum as a Significant Category structure due to the intrinsic nature of it being an In-Pit TSF and its size.<br>The volume of water or tailings has been estimated based on empirical equations. Although the majority would be | Significant |

| Environmental Harm | Assessment | Consequence Category |
|---|---|---|
| | contained within adjoin pits, it is not however impossible for a tailings breach of this magnitude to not have a cascade effect which could impact on the environment. | |
| General economic loss or property damage | The location of the Pit B TSF is such that harm to third party assets, excluding the mine's own commercial assets, is not possible. | Low |

A quantitative analysis was undertaken using the calculated maximum breach discharge (simplified breach equation) from the *Queensland Guidelines for Failure Impact Assessment of Water Dams* (DEWS, 2012).

The maximum depth of water in storage for Stage 1 and Stage 2 of B Pit TSF was taken as the depth of water from the pit crest to the tailings level.

The total volume of water release for Stage 1 and Stage 2 of B Pit TSF was taken as the capacity of water from the pit crest to the tailings level.

The maximum breach discharge is 2081.9 $m^3/s$ for Stage 1 and 3495.9 $m^3/s$ for Stage 2 B Pit TSF.

The reach length for Stage 1 and Stage 2 of B Pit TSF was estimated using the mathematical relationship between volume of released water and maximum downstream distance outlined in Table 2 of the *Queensland Guidelines for Failure Impact Assessment of Water Dams* (DEWS, 2012). As demonstrated in Figure 9-1, the reach length for Stage 1 is 20.18 Km, whereas the reach length for Stage 2 is 23.3 Km. The provided estimate is far greater then would be expected as the estimate is based on land based structures and most if not all of the failure would be contained below ground level within the adjoining pits.

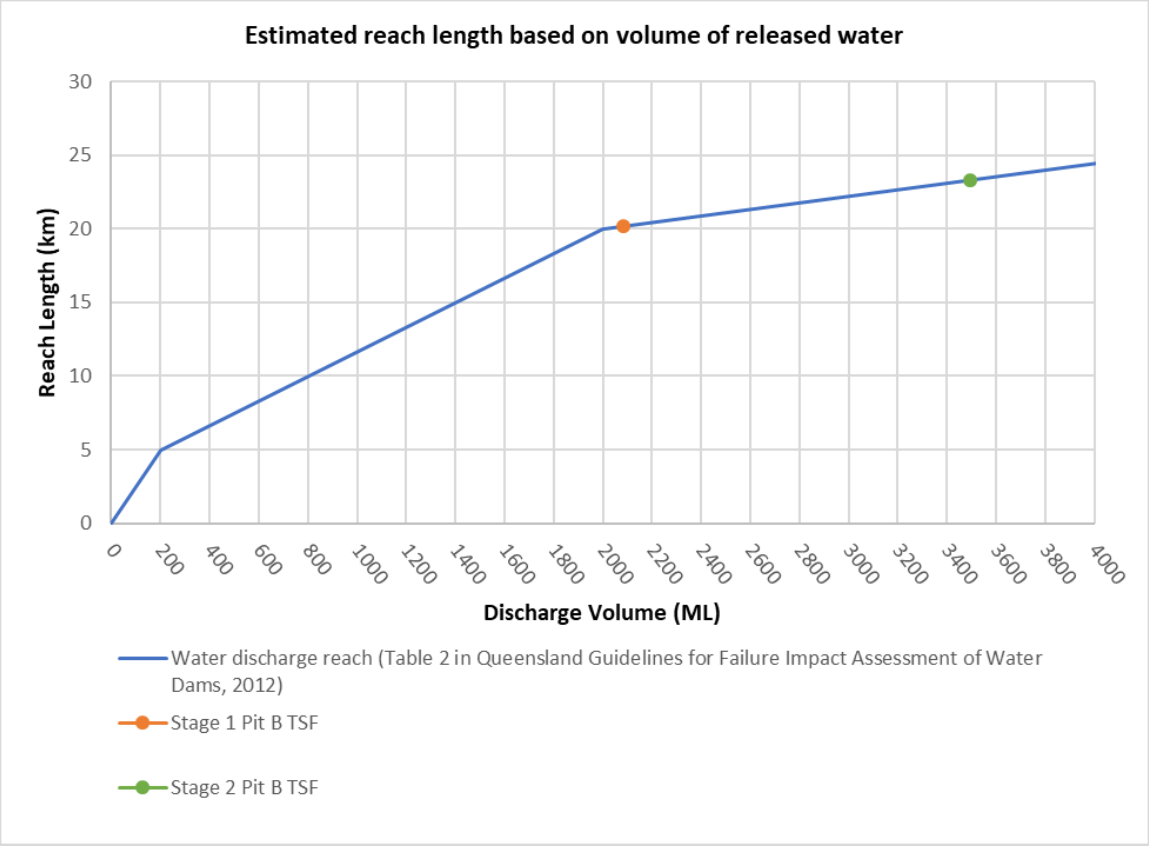



*Figure 9-1: Estimated reach length based on volume of released water during dam break*

### 9.3.2 Hydraulic performance criteria

The hydraulic performance criteria for the TSF will specify the capacity required to contain daily rainfall and safely pass flood waters. The hydraulic performance criteria, under the "Significant" consequence category, is summarised in Table 9-8.

**Table 9-8: Hydraulic performance criteria**

| Hydraulic Performance Element | Criteria |
|---|---|
| Design Storage Allowance (DSA) | 1:20 AEP |
| Extreme storm storage allowance (ESS) | 1:10 AEP 72 hr duration |
| Mandatory reporting level (MRL) | Level based on ESS |

It should be noted that no criteria for spillway hydraulic performance as the Pit B TSF design dose not incorporate a spillway. This is based on the design having no external containment embankments above the exiting ground surface.

The DSA, ESS and MRL requirements are shown in Figure 9-2.

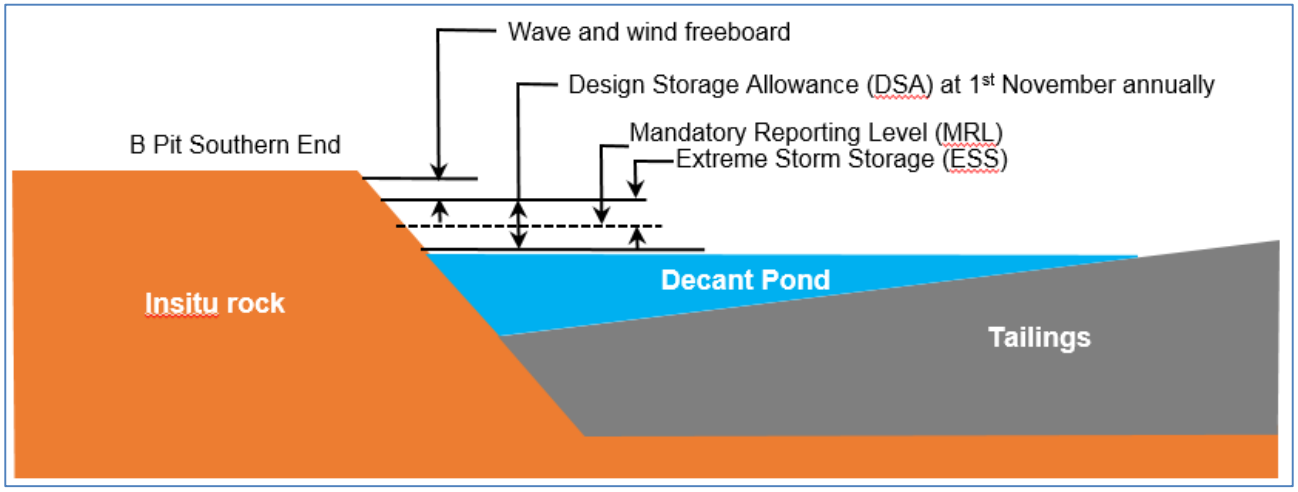



*Figure 9-2: Definitions of DSA, MRL and ESS.*

## 9.4 Embankment stability criteria

The TSF embankment is to be designed with regard to slope stability (i.e. to limit the risk of slope failure).

Detailed slope stability analysis in relation to the embankment section is to be undertaken on the basis of general limit equilibrium (GLE) conditions with the following minimum factors of safety adopted, based on ANCOLD (2012b), to withstand the most severe and unfavourable combination of static and dynamic loads.

The minimum factors of safety adopted for embankment stability are presented in Table 9-9 and are generally based on ANCOLD (2012a), for the expected range of stability conditions for the TSF embankment.

**Table 9-9: Stability criteria**

| Loading Condition | Minimum Factor of Safety |
|---|---|
| Short term - Construction | 1.3 |
| Long term – during operations | 1.5 |
| Post-Seismic | 1.0 – 1.2[3] |

[3] To be related to the confidence in selection of residual shear strength

# 10.0 TAILINGS DEPOSITION MODELLING

## 10.1 Data and parameters adopted

The tailings deposition modelling was carried out using the 'Goldtails' software. The software simulates deposition over a gridded surfaces using a parabolic deposition function. Table 10-1 shows the adopted modelling data and parameters.

**Table 10-1: Modelling data and parameters adopted.**

| Data | Description / value | Basis / Source |
|---|---|---|
| Survey data | | |
| Lidar1602-CS-Running.00t | 2016 pit surface | Wesfarmers |
| bpitbatho1610.dxf2016 | Bathymetry | Wesfarmers |
| g_bridge_post_mining_surface_161116.00t | 2016 mined peninsula | Wesfarmers |
| Containment embankment geometry | Refer Section 7.2 | Golder / Wesfarmers |
| Discharge Outlet locations | Tailings pipe cut 2, ramp 4 and containment embankment | Golder |
| Direction | South | |
| Tailings beach slope | 0.5% | Golder |
| Freeboard (minimum) | DSA volume plus wave allowance | Golder |
| Tailings output | 1.04 Mtpa | Wesfarmers |
| Average dry density | 0.8 t/m$^3$ | Wesfarmers |

## 10.2 Methodology and results

The existing topography survey data, provide by Wesfarmers around 2015, was amended to incorporate the 2016 bathymetry survey and the future mine floor surface of the peninsula area.

The southern end of B Pit was used as the control point for setting the minimum tailings full storage elevation based on the floor of the B Pit falling to the south and the maximum elevation for each stage being dependent on:

- Containment of the DSA volume above the tailings surface, refer Section 11.3.
- Establishing a steady state phreatic surface that would maintain an acceptable factor of safety for embankment stability, refer Section 12.4.

Figure 10-1 and Figure 10-2 presents the deposition surface at the maximum tailings storage for Stage 1 and Stage 2 respectively.

As shown in Figure 10-1, the maximum tailings deposition level is contained within B-Pit for Stage 1 and does not encroach onto Ramp 4. However, Ramp 4 does become inundated during Stage 2, as shown in Figure 10-2.

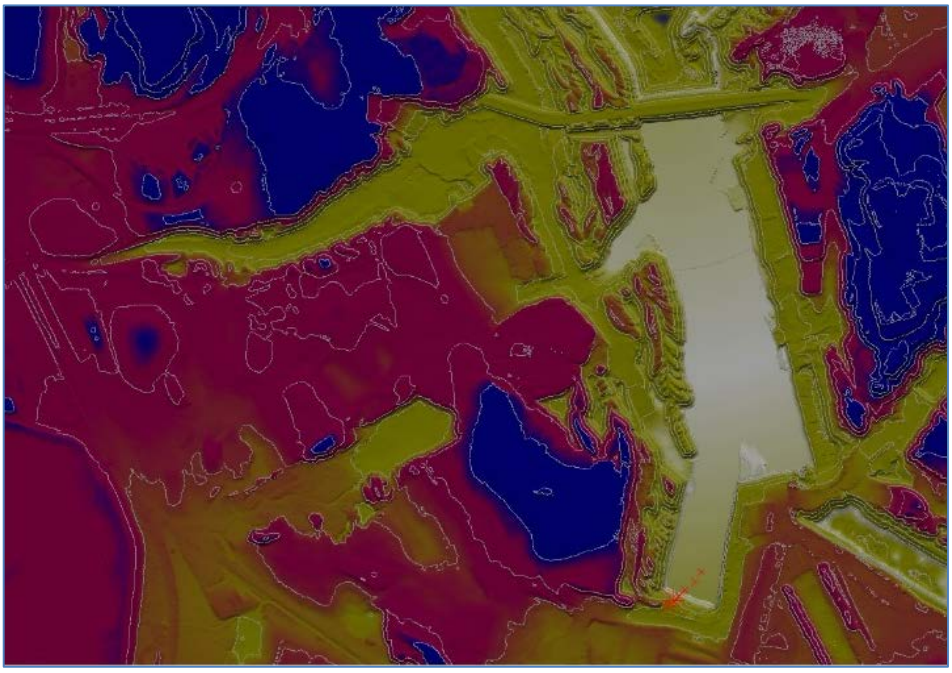


*Figure 10-1: Modelled Stage 1 deposition.*

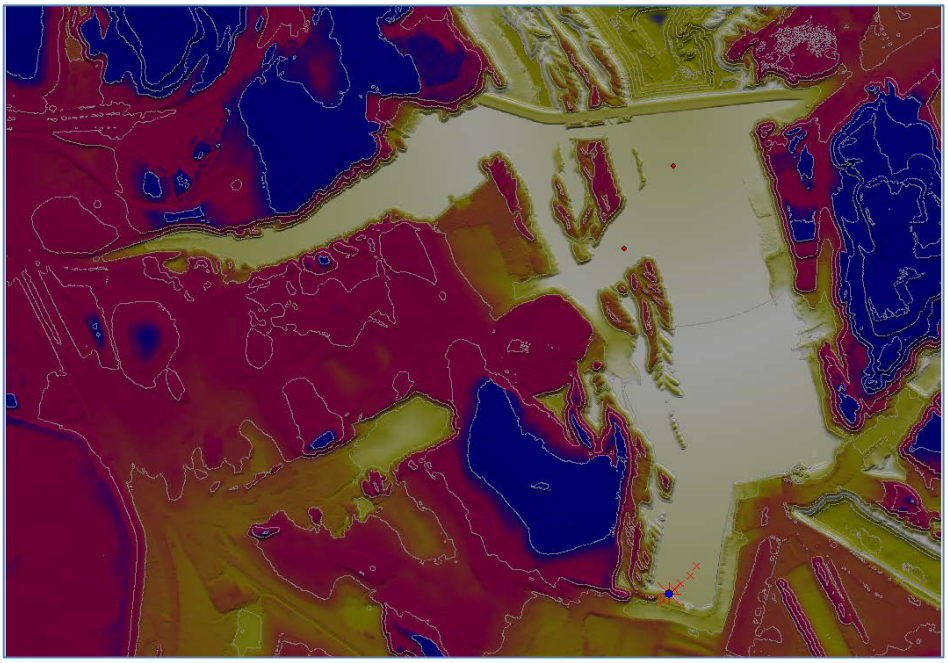


*Figure 10-2: Modelled Stage 2 deposition.*

## 10.3 Storage volume and life

The results of the tailings deposition modelling are shown in Table 10-2 with the storage life of the Pit B TSF presented in Figure 10-3 As can been seen in Figure 10-3, the Stage 1 estimated storage life is approximately 8 years. Once the TSF becomes stage 2, this has an estimated total life of 20-21 years, with the tailings beach level moving into Ramp 4 at around year 18.

**Table 10-2: B Pit tailings volumes and life**

| Minimum tailings elevation (RLm) | Maximum tailings elevation (RLm) | Cumulative volume (m³) | Cumulative storage (t) | Cumulative life (yrs) |
|---|---|---|---|---|
| 72 | 73.7 | 7 183 | 5 746 | 0.01 |
| 74 | 75.2 | 25 445 | 20 356 | 0.02 |
| 76 | 77.4 | 74 490 | 59 592 | 0.06 |
| 78 | 81.2 | 139 613 | 111 691 | 0.11 |
| 80 | 83.7 | 246 163 | 196 930 | 0.19 |
| 82 | 86.5 | 39 5610 | 316 488 | 0.30 |
| 84 | 89.7 | 563 869 | 451 095 | 0.43 |
| 86 | 89.8 | 796 509 | 637 207 | 0.61 |
| 88 | 89.9 | 1 133 238 | 906 590 | 0.87 |
| 90 | 90.1 | 1 515 804 | 1 212 643 | 1.17 |
| 92 | 98.9 | 1 998 696 | 1 598 957 | 1.54 |
| 94 | 101.5 | 2 488 475 | 1 990 780 | 1.91 |
| 96 | 103.6 | 3 013 728 | 2 410 983 | 2.32 |
| 98 | 105.6 | 3 594 482 | 2 875 586 | 2.76 |
| 100 | 107.8 | 4 263 392 | 3 410 713 | 3.28 |
| 102 | 110. | 5 006 537 | 4 005 229 | 3.85 |
| 104 | 112.1 | 5 806 148 | 4 644 918 | 4.47 |
| 106 | 114.3 | 6 651 140 | 5 320 912 | 5.12 |
| 108 | 116.5 | 7 545 747 | 6 036 597 | 5.80 |
| 110 | 118.6 | 8 487 629 | 6 790 103 | 6.53 |
| 112 | 120.8 | 9 479 912 | 7 583 930 | 7.29 |
| 114 | 122.8 | 10 535 794 | 8 428 636 | 8.10 |
| 116 | 124.8 | 11 654 262 | 9 323 410 | 8.96 |
| 118 | 126.8 | 12 845 176 | 10 276 141 | 9.88 |
| 120 | 128.9 | 14 099 680 | 11 279 744 | 10.85 |
| 122 | 130.9 | 15 412 107 | 12 329 686 | 11.86 |
| 124 | 132.9 | 16 780 164 | 13 24 131 | 12.91 |
| 126 | 134.9 | 18 204 644 | 14 563 715 | 14.00 |
| 128 | 137.0 | 19 748 837 | 15 799 069 | 15.19 |
| 130 | 139.0 | 21 453 020 | 17 162416 | 16.50 |

| Minimum tailings elevation (RLm) | Maximum tailings elevation (RLm) | Cumulative volume (m³) | Cumulative storage (t) | Cumulative life (yrs) |
|---|---|---|---|---|
| 132 | 141.0 | 23 575 268 | 18 860 214 | 18.13 |
| 134 | 143.0 | 25 748 931 | 20 599 145 | 19.81 |
| 135 | 144.0 | 26 890 209 | 21 512 167 | 20.68 |

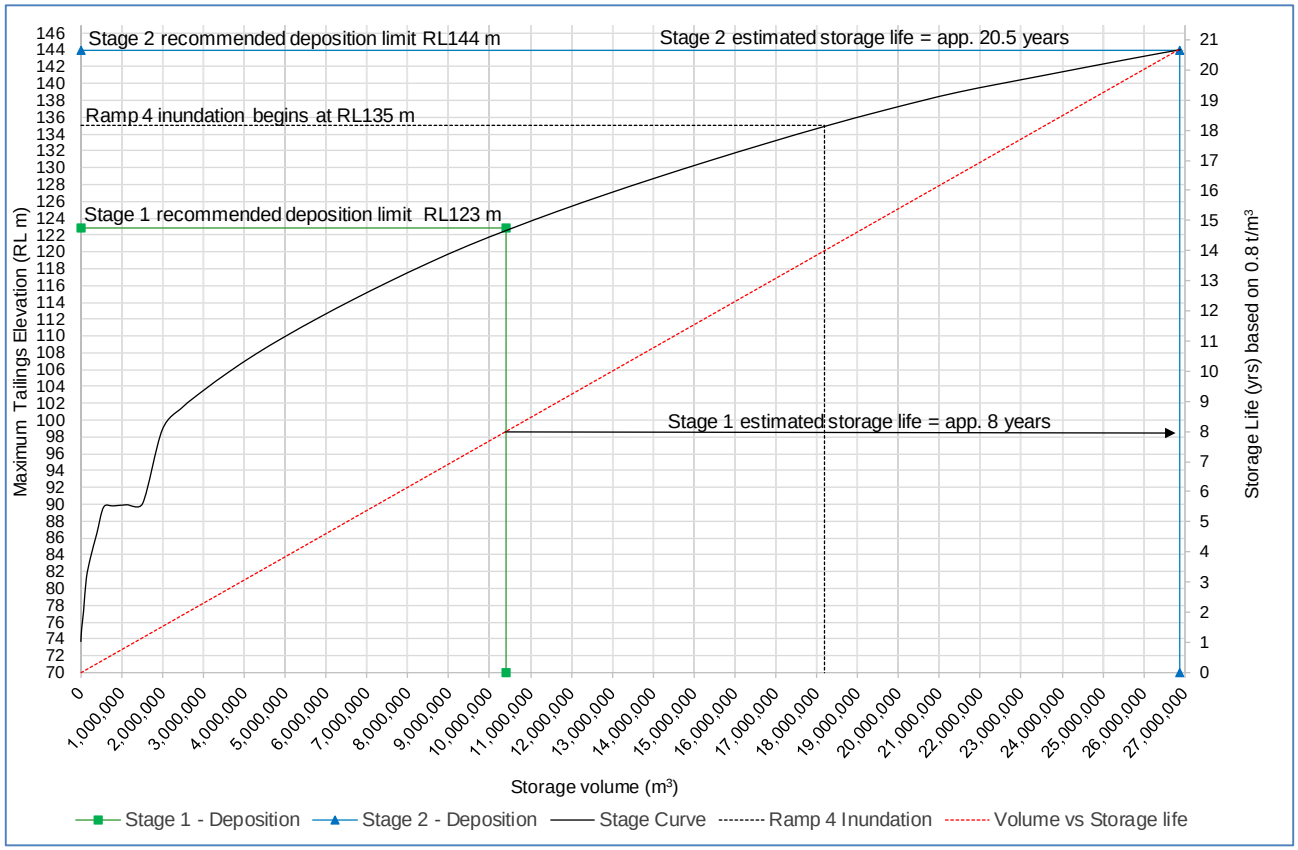



*Figure 10-3: Pit B TSF tailings deposition stage curve.*

The estimated storage life for each stage assumes a well distributed tailings surface across the TSF footprint and a decant pond in the order of 2 m to 3 m deep with an operating level of RL 117 and RL 141 for Stage 1 and Stage 2 embankments respectively.

# 11.0 HYDROLOGICAL ANALYSIS

This section documents the analyses undertaken for the DSA, MRL, ESS and wave run-up assessment

## 11.1 Design storage allowance

The design storage allowance (DSA) was estimated using the method of operational simulation for performance based containment. APPENDIX G provides details of the analysis.

The water balance model was based on the method and requirements outlined DEHP (2016).

The resultant DSA requirement using the method of operational simulation is 2 823 ML.

The model has been set up to run dynamically on a daily basis for the period 1 November to 30 March and for 100 model realisations. The water balance model has been developed in GoldSim[4], a graphical modelling environment which allows dynamic simulation of a particular system to represent and predict system behaviour. The model includes a sequence of 127 years of Data Drill climate data for predictive modelling. Each realisation randomly selects a new daily rainfall and the same year's corresponding daily evaporation record from the Data Drill data starting at 1 November. In this way 100 different summer climate scenarios for this location were simulated. All other variables, such as the rate of water inflow and outflows and the starting water level at 1 November; remain constant for each of the model simulations.

The model output, that is, the 100 records of resultant change in storage over the wet season; was then used to determine the DSA. The DSA is calculated from the statistical results of the plotting position analysis of operational simulation outcomes, to derive the design AEP, plus an additional volume equal to the Design Simulation Margin (DSM), applied to simulation outcomes to provide conservative compensation for model inaccuracy. The guideline recommends Pit B to maintain a DSA of the 1:20 year AEP wet season including process inputs subsequent to 1 November each year. Where there is a lack of calibration data for the model, the guideline recommends the use of a minimum DSM value of not less than 50% be applied. We have used the maximum DSM value of 100% in this case as we were not able to calibrate the model between modelled and measured site data.

## 11.2 Extreme storm storage

In accordance with Table 5 DEHP (2016), the extreme storm storage (ESS) for the TSF is the equivalent of the 1:10 AEP 72 hour storm event.

**Table 11-1: ESS summary parameters**

| Criteria | Value | Unit |
|---|---|---|
| 1:10 AEP 72 hour storm depth | 0.202 | m |
| Catchment Area | 1080.1 | ha |
| ESS | 2 185 258 | $m^3$ |

## 11.3 MRL and DSA levels

The MRL and DSA levels for stage 1 and stage 2 will need to be assessed each year by a suitably qualified person to confirm legislative compliance with DEHP (2016). The MRL and DSA levels for the modelled final tailings deposition levels for each stage are shown in Figure 11-1 and Figure 11-2 as a guide and for input into the seepage modelling in Section 12.3. Note that the final DSA levels shown allow for embankment configurations that have been assessed as having an adequate factor of safety for stability, refer Section 12.4.

The following TSF levels where applied to determine the associated DSA volume level and ESS level.

[4] GoldSim Technology Group www.goldsim.com

**Table 11-2: MRL and DSA Levels**

| Level | Stage 1 | Stage 2 |
|---|---|---|
| Embankment Crest | RL 125 | RL 147 |
| Freeboard | 0.5 m | 0.5m |
| Max level (FSL) | RL 124.5 | RL 146.5 |
| Decant Pond Operating Level | RL 117.0 | RL 141.0 |
| DSA Volume | 2823 ML | 2823 ML |
| DSA Level | RL 124.5 | RL 144.4 |
| ESS volume /MRL | 2190 ML | 2190 ML |
| MRL | RL 120.9 | RL 144.9 |

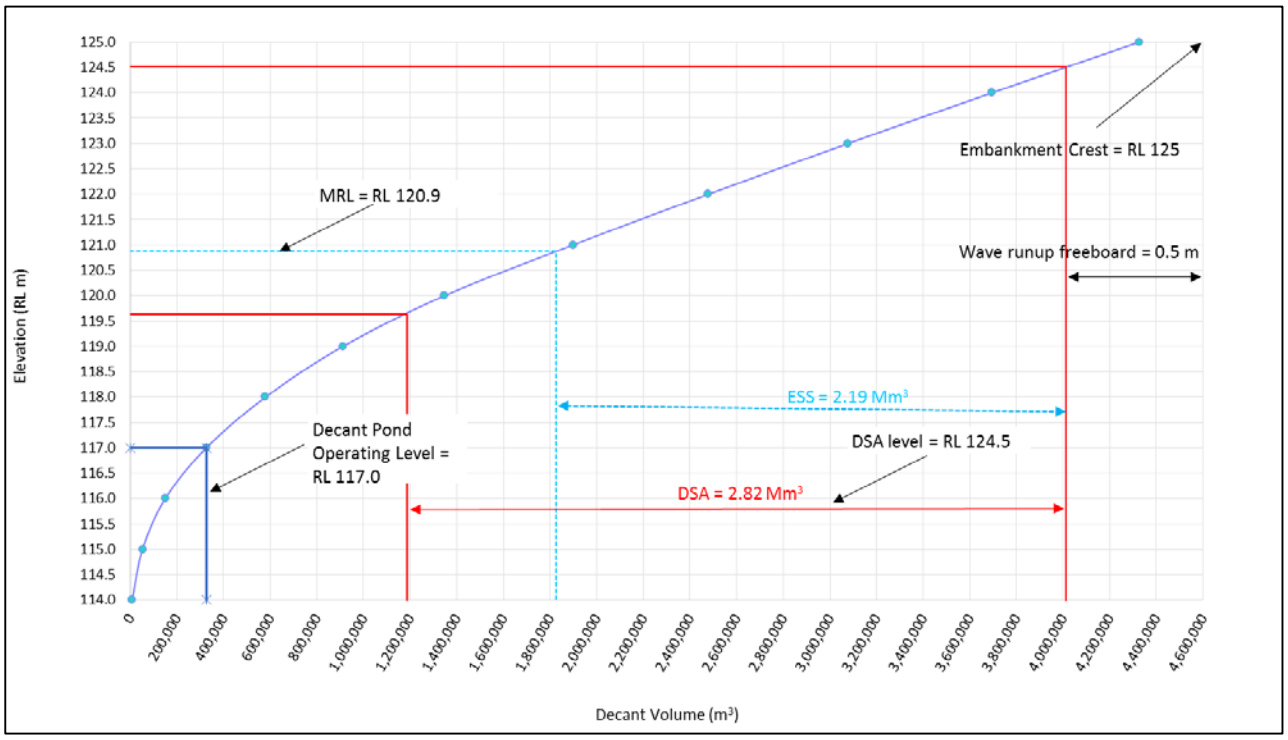



*Figure 11-1: Stage 1 Decant pond stage curve at final modelled tailings level*

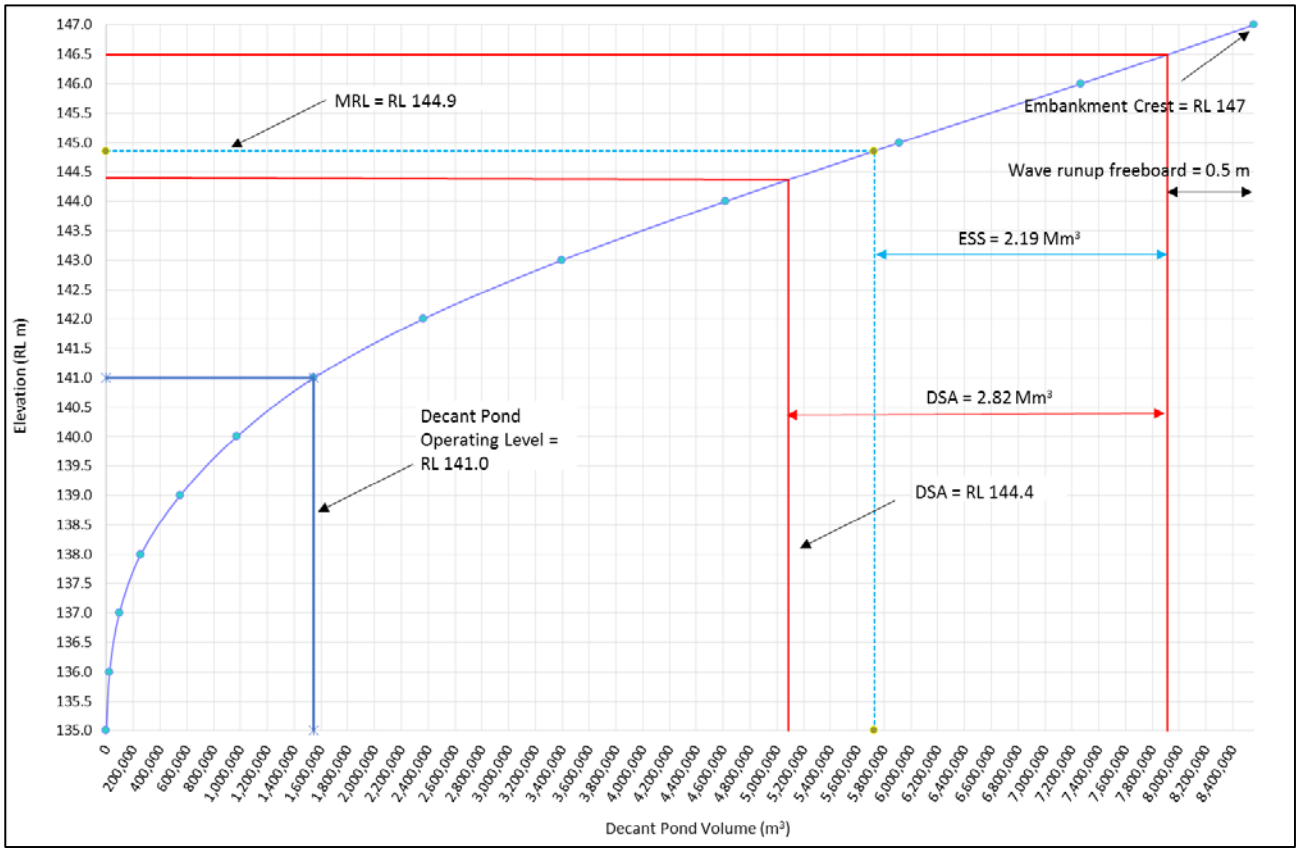



*Figure 11-2: Stage 2 Decant pond stage curve at final modelled tailings level.*

## 11.4 Wave run-up freeboard

The decant pond wave run-up assessment was undertaken in accordance with USBR (1981) and US Army Corps (1984b). APPENDIX G provides calculations for the wave run-up assessment.

The analysis indicates a wave run-up of 0.6 m based on a 1 in 10 year AEP. An additional 0.5 m should be included in accordance with ANCOLD (2012b).

## 11.5 Emergency Spillway

The B-Pit TSF has been designed without an emergency spillway. The reasons for this is as follows:

- The point of tailings deposition is at the embankment wall, thereby creating a beach sloping away from the embankment wall.
- It is expected that there would be sufficient capacity within the decant pond to adequately manage extreme rainfall events by mobilising additional pumping infrastructure.

This does not eliminate the risk of an overtopping failure of the B-Pit TSF, and it is up to WCPL to implement process and develop trigger action response plans (TARPs) to manage this risk.

# 12.0 GEOTECHNICAL ANALYSIS OF EMBANKMENT

## 12.1 Scope of geotechnical analysis

Geotechnical analysis has been carried out to confirm the configuration of the TSF embankment under Stage 1 (crest RL 125 m) and Stage 2 (crest RL 147 m) as described in Section 7.2.

The integrity of the analysed configuration is determined by the geotechnical characteristics of the embankment foundation and the proposed embankment fill materials, as well as the development of the phreatic surface within the embankment profile during operation. The geotechnical analyses have thus focused on coupled seepage and stability modelling to assess the suitability of the selected embankment configuration. Supplementary analyses have also been completed to assess the effects of seismicity on embankment stability.

The scope of geotechnical analyses carried out on the cross-section are summarised as follows.

**Table 12-1: Geotechnical analysis scope.**

| Analysis | Condition | Relevant Model Output/Purpose |
|---|---|---|
| Seepage | ■ TSF Wetting Front Assessment from Decant pond area under operating water level and DSA condition and steady state conditions | ■ Quantify seepage discharge to groundwater and/or surface discharge at operating decant pond levels at final stage tailings levels |
| | ■ Embankment Steady State/Equilibrium Conditions under operating water level and DSA condition | ■ Steady state phreatic surface within embankment based on a maximum storage level for each stage<br>■ Input to steady state stability analysis |
| Slope Stability | ■ Steady State/Equilibrium Conditions<br>■ Steady State/Equilibrium Conditions with Seismic Effects | ■ Factors of safety for embankment slope failure |

Details of the geotechnical analyses are provided in the following sections.

## 12.2 Modelled sections

Three sections were modelled comprising:

- Stage 1 Embankment section A-A' for stability and settlement assessment (Figure 12-1, Figure 12-3 and Figure 12-4)
- Stage 2 Embankment section B-B' for stability and settlement assessment (Figure 12-1, Figure 12-5 and Figure 12-6)
- Seepage section C-C' for the TSF wetting front assessment from the decant pond area (Figure 12-2 and Figure 12-7).

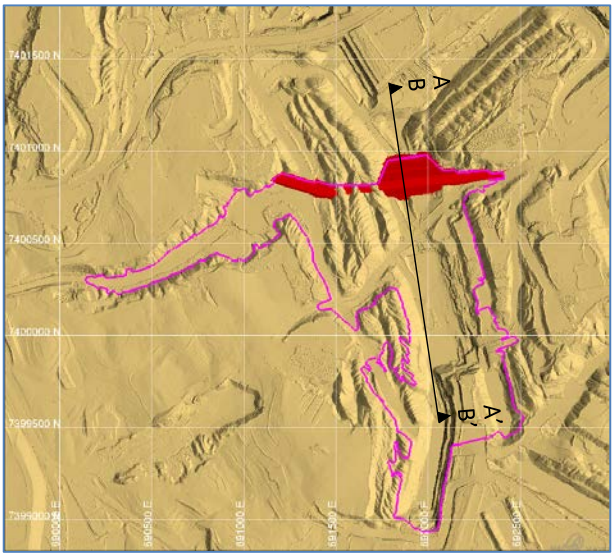



*Figure 12-1: Section A-A'/ B-B' embankment sections locations.*

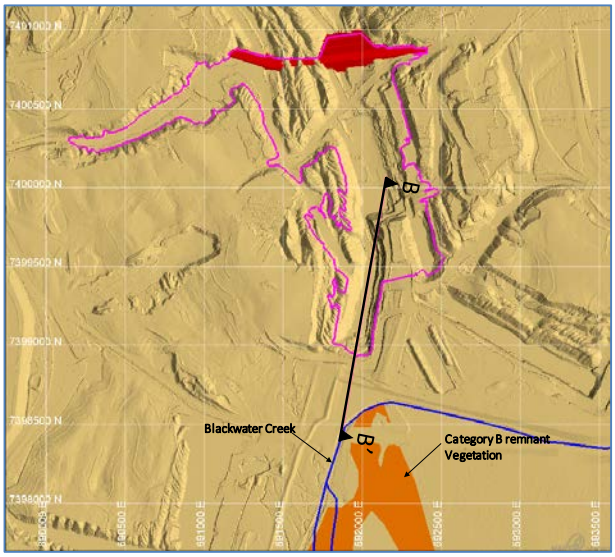



*Figure 12-2: Section C-C' seepage section location showing.*

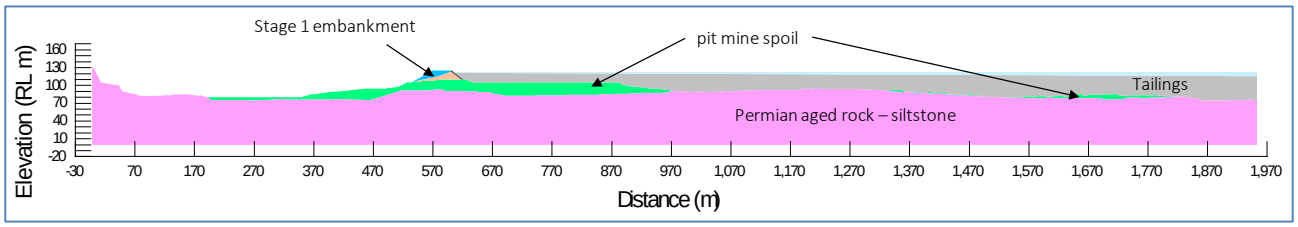



*Figure 12-3: Section A-A' Stage 1 Embankment.*

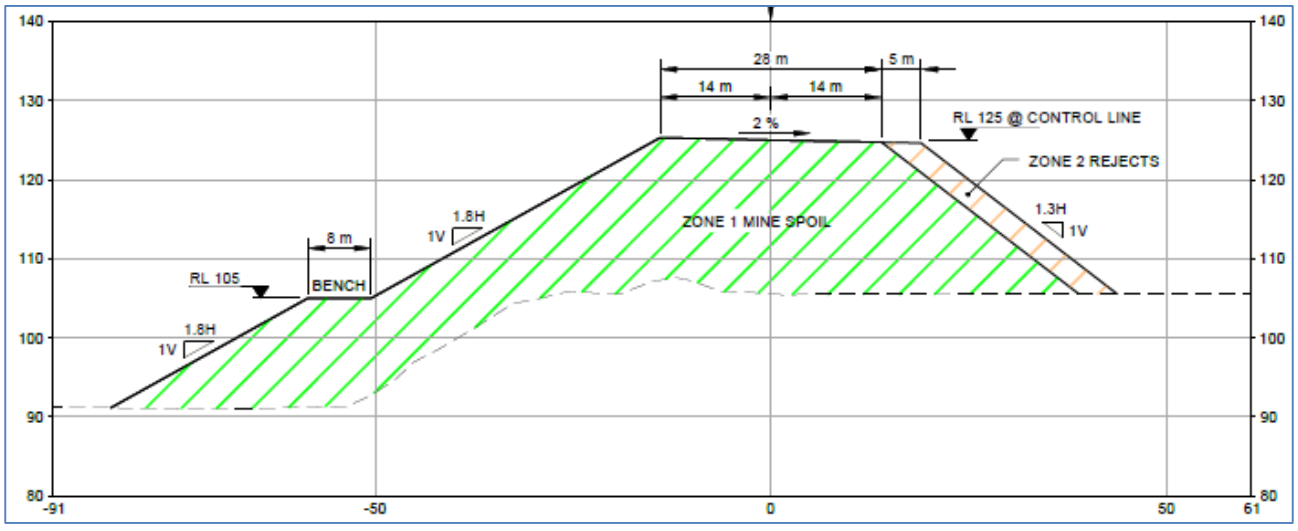



*Figure 12-4: Stage 1 embankment section details.*

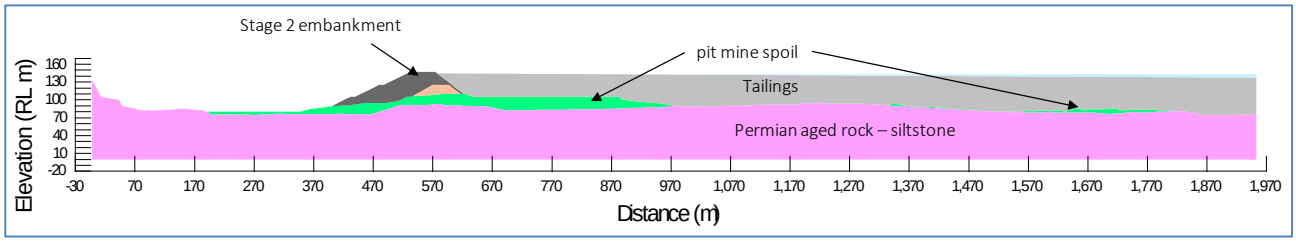



*Figure 12-5: Section B-B'' Stage 2 Embankment.*

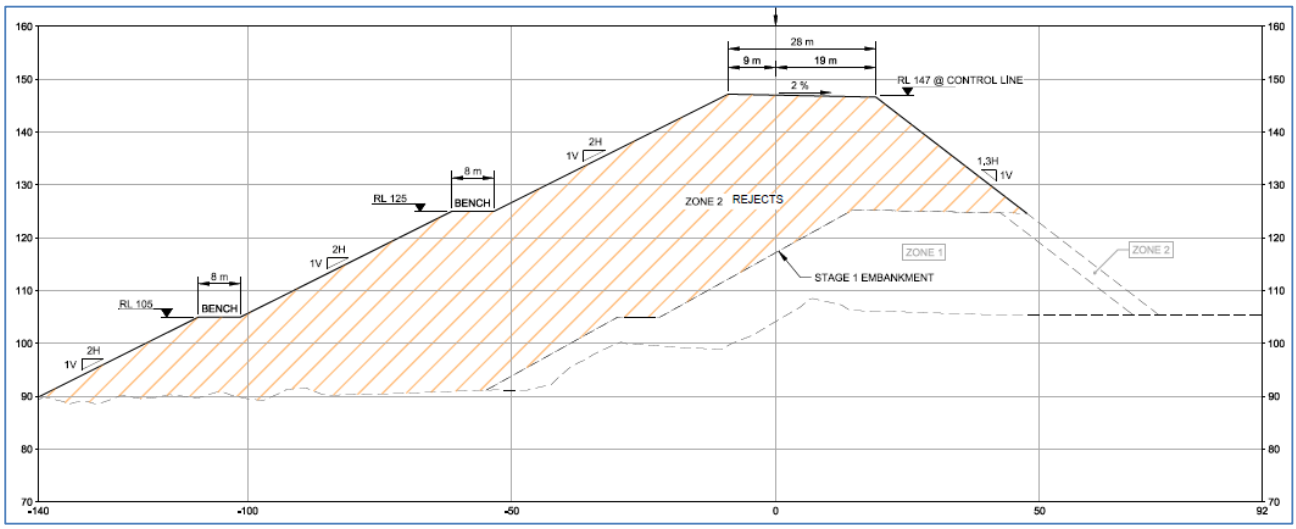



*Figure 12-6: Stage 2 embankment section details.*

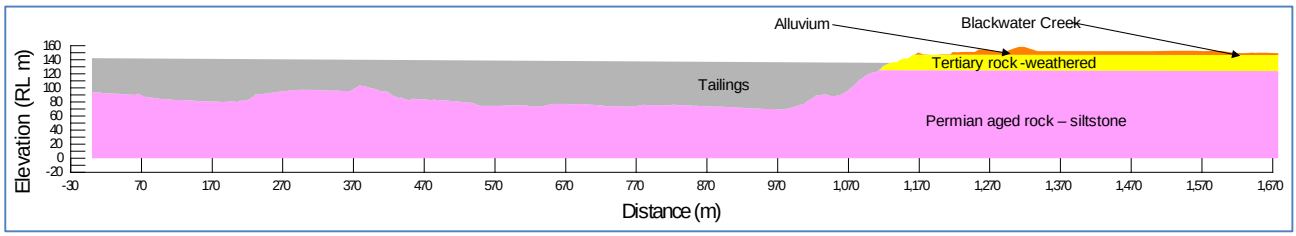



*Figure 12-7: Section C-C' wetting front seepage section.*

The sub-surface stratigraphy below the embankment was based on the surveys and geological mapping data provided by Curragh, refer Section 8.2.

## 12.3 Seepage

Seepage analysis has been carried out in relation to the model sections using the computer-based numerical (finite element) seepage modelling package, SEEP/W. SEEP/W is formulated on the basis of Darcy's Law for both saturated and unsaturated flow. The model iteratively solves mass balance differential equations for a grid of finite elements, based on appropriate boundary conditions. Modelling was carried out under steady state conditions on the basis that that rainfall infiltration and beach evaporation was ignored.

### 12.3.1 Seepage modelling parameters

The model inputs comprised material permeability values, decant pond water levels and groundwater levels. The adopted permeability values were based on the geotechnical assessment of materials presented in Section 8.0 and are summarised in Table 12-2.

**Table 12-2: Material permeability summary.**

| Material | Saturated Permeability $K_{sat}$ (m/s) | $k_y/k_x$ ratio[5] |
|---|---|---|
| Natural Sequences | | |
| Alluvium | $1.2 \times 10^{-5}$ | 0.1 |
| Tertiary aged rock -weathered | $6.9 \times 10^{-6}$ | 0.1 |
| Permian aged rock - siltstone | $1.0 \times 10^{-8}$ | 0.02 |
| Placed Materials | | |
| Mine waste | $1.0 \times 10^{-5}$ | 0.5 |
| Rejects | $1.0 \times 10^{-2}$ | 1 |
| Tailings | $1.0 \times 10^{-7}$ | 0.5 |

The decant pond water levels were based on:

- The operating water level at the final tailings level for each stage
- The water level at DSA at the final tailings level for each stage.

Tailings deposition modelling in Section 10.0 established the final tailings levels and the decant pond stage curves. The modelled water levels were obtained from the decant pond stage curves and are summarised in Table 12-3.

**Table 12-3: TSF water level summary.**

| Stage | Condition | Water level (RLm) |
|---|---|---|
| 1 | Operating water level | 116.7 |
| | DSA water level | 123.0 |
| 2 | Operating water level | 139.0 |
| | DSA water level | 143.0 |

The adopted groundwater level was RL 70 m on the basis that most of the A Pit monitoring bores are dry which may indicate a deep static phreatic surface.

### 12.3.2 Seepage modelling cases and results for the wetting front assessment

The modelled conditions are summarised below in Table 12-4 along with references to the SeepW output figures.

**Table 12-4: Wetting front seepage modelling cases**

| Case | Embankment Stage | Water level condition | Reference Figure APPENDIX E |
|---|---|---|---|
| 1A | 1 | Operating water level | E1 |
| 1B | 1 | DSA | E2 |
| 1C | 2 | Operating water level | E3 |
| 1D | 2 | DSA | E4 |

[5] Data represent horizontal permeabilities (x direction) with the vertical permeability (y direction)

The relevant hydraulic conductivity values obtained from the seepage assessment are shown in Table 12-5.

**Table 12-5: Summary of wetting front seepage results.**

| Case | Description | Flux location | Estimated steady state flow ($m^3/s$ per m) |
|---|---|---|---|
| 1A | Stage 1 Operating water level | Alluvium | 0 |
| | | Tertiary rock - 10 m thick (southern TSF area) | 0 |
| | | Tertiary rock - 10 m thick (Blackwater creek) | 0 |
| 1B | Stage 1 DSA level | Alluvium | 0 |
| | | Tertiary rock - 10 m thick (southern TSF area) | 0 |
| | | Tertiary rock - 10 m thick (Blackwater creek) | 0 |
| 1C | Stage 2 Operating water level | Alluvium | 0 |
| | | Tertiary rock - 10 m thick (southern TSF area) | $2.5 \times 10^{-7}$ |
| | | Tertiary rock - 10 m thick (Blackwater creek) | $2.0 \times 10^{-7}$ |
| 1D | Stage 2 DSA level | Alluvium | 0 |
| | | Tertiary rock - 10 m thick (southern TSF area) | $1.5 \times 10^{-6}$ |
| | | Tertiary rock - 10 m thick (Blackwater creek) | $1.2 \times 10^{-6}$ |

These seepage flows should be viewed in relative terms as a means of comparing likely seepage rates under differing TSF pond levels rather than absolute flows. Higher seepage flows than those predicted from this analysis could be expected as a result of unforeseen sub-surface structural features (fractures, joints) which have not been modelled due to difficulty in incorporating such features.

This comparison indicates that:

- Under stage 1 conditions there is unlikely to be any seepage through the alluvium and the tertiary rock material based on the TSF decant pond operating levels.
- Under stage 2 conditions the analysis show that there is minor seepage into the tertiary material, however based on the Blackwater coalfield stratigraphic sequence, there is low vertical permeability of the bed material around B Pit and the coal seams are considered hydrologically isolated, and therefore potential seepage is unlikely to reach the groundwater aquifers in the Tertiary materials based on the expected lack of vertical leakage in the Tertiary materials and the lack of transmissivity associated with faults. Seepage is not considered likely to intersect the alluvium layers as these are at a higher elevation to the operating water levels and also there is low hydraulic conductivity and lack of continuity in the alluvial materials.

### 12.3.3 Seepage modelling cases and results for stability

The modelled conditions are summarised below in along with references to the SeepW output figures.

**Table 12-6: Seepage modelling cases**

| Case | Relevant Model Output / Purpose | Embankment Stage | Water level condition | Reference Figure APPENDIX E |
|---|---|---|---|---|
| 2A | Stability modelling | 1 | Operating water level | E5 |
| 2B | | 1 | DSA | E6 |
| 2C | Stability modelling | 2 | Operating water level | E7 |
| 2D | | 2 | DSA | E8 |

The relevant hydraulic conductivity values obtained from the seepage assessment are shown in Table 31.

**Table 12-7: Summary of seepage results for embankment stability assessment.**

| Case | Description | Flux location | Estimated steady state flow ($m^3/s$ per m) |
|---|---|---|---|
| 2A | Stage 1 Operating water level | Downstream Embankment toe – mine waste foundation | $2.4 \times 10^{-5}$ |
| 2B | Stage 1 DSA level | Downstream Embankment toe – mine waste foundation | $3.5 \times 10^{-5}$ |
| 2C | Stage 2 Operating water level | Downstream Embankment toe – mine waste foundation | $1.4 \times 10^{-5}$ |
| 2D | Stage 2 DSA level | Downstream Embankment toe – mine waste foundation | $2.9 \times 10^{-5}$ |

As noted in Section 12.3.2 these seepage flows should be viewed in relative terms as a means of comparing likely seepage rates under differing TSF pond levels rather than absolute flows. This comparison indicates that:

- There is a marginal reduction in the seepage rate between Stage 1 and Stage 2
- There is a negligible increase in the seepage rate between the operating water level and the DSA

## 12.4 Stability modelling

Slope stability modelling of the TSF embankment has been completed using SLOPE/W which uses limit equilibrium theory to solve for the factor of safety of earth and rock slopes. The model calculates a factor of safety for a modelled two-dimensional section, satisfying both moment and force equilibrium.

Spencer's method of slices was adopted to analyse circular slip failure mechanisms. This method address inter-slice forces, which assumes a constant inter-slice force angle on all slices equivalent to the average base of slice angle.

The stability modelling was carried out under static and pseudo static (seismic) loading conditions. For seismic conditions the US Army Corps (1984a) method for assessing pseudo static seismic stability was adopted. This method assumes non liquefiable materials under seismic design loading, refer Section 8.5. Furthermore it recommends use of a seismic coefficient equal to one-half of peak ground acceleration (PGA) using undrained strength for cohesive materials and drained conditions for free draining granular materials, with a 20 percent strength reduction in all materials to allow for strain weakening during the earthquake loading.

The stability of the Stage 1 and Stage 2 embankment were assessed under the adopted minimum factors of safety noted in Section 9.4.

### 12.4.1 Stability cases

Three design cases were analysed to assess the critical stability condition for TSF. These cases are summarised in Table 12-8.

**Table 12-8: Stability modelling cases**

| | Design Case | Input Parameters |
|---|---|---|
| 3A | Stage 1 Embankment Downstream static stability under operating decant pond | ■ Effective stress parameters (c', ϕ') for embankment materials. Undrained strength ratio = 0.15 for tailings.<br>■ Phreatic surface represented as a piezometric line from seepage modelling for operating water level |
| 3B | Stage 1 Embankment Downstream static stability under DSA conditions | ■ Effective stress parameters (c', ϕ') for embankment materials. Undrained strength ratio = 0.15 for tailings.<br>■ Phreatic surface represented as a piezometric line from seepage modelling for DSA water level |
| 3C | Stage 1 Embankment under operating decant pond with seismic loading (Operational conditions) | ■ Seismic strengths for all material<br>■ Phreatic surface represented as a piezometric line from seepage modelling for operating water level<br>■ Dynamic loading from OBE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis) |
| 3D | Stage 1 Embankment under DSA with seismic loading (Operational conditions) | ■ Seismic strengths for all material<br>■ Phreatic surface represented as a piezometric line from seepage modelling for DSA water level<br>■ Dynamic loading from OBE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis) |
| 3E | Stage 1 Embankment under seismic loading (closure conditions) | ■ Seismic strengths for all material<br>■ Phreatic surface represented as a piezometric line under DSA water level<br>■ Dynamic loading from MDE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis) |
| 4A | Stage 1 Embankment Downstream static stability under operating decant pond | ■ Effective stress parameters (c', ϕ') for embankment materials. Undrained strength ratio = 0.15 for tailings.<br>■ Phreatic surface represented as a piezometric line from seepage modelling for operating water level |
| 4B | Stage 1 Embankment Downstream static stability under DSA conditions | ■ Effective stress parameters (c', ϕ') for embankment materials. Undrained strength ratio = 0.15 for tailings.<br>■ Phreatic surface represented as a piezometric line from seepage modelling for DSA water level |
| 4C | Stage 1 Embankment under operating decant pond with seismic loading (Operational conditions) | ■ Seismic strengths for all material<br>■ Phreatic surface represented as a piezometric line from seepage modelling for operating water level<br>■ Dynamic loading from OBE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis) |
| 4D | Stage 1 Embankment under DSA with seismic | ■ Seismic strengths for all material |

| | Design Case | Input Parameters |
|---|---|---|
| | loading (Operational conditions) | ■ Phreatic surface represented as a piezometric line from seepage modelling for DSA water level<br>■ Dynamic loading from OBE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis) |
| 4E | Stage 1 Embankment under seismic loading (closure conditions) | ■ Seismic strengths for all material<br>■ Phreatic surface represented as a piezometric line under a phreatic surface water level similar to operating to account for some water infiltration. It is assumed that under closure conditions there would be a capping surface which would be designed to shed water.<br>■ Dynamic loading from MDE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis) |

### 12.4.2 Seismic loading

The seismic loading condition is based on steady state design case, but with seismic loading also considered. In accordance with ANCOLD (2012b), the TSF has been assessed subject to an Operating Basis Earthquake (OBE) and Maximum Credible Earthquake (MCE).

- The OBE produces a level of ground motion which will cause only minor and repairable damage to the structure and may be used to assess the serviceability of the dam. OBE is generally expected to cause limited damage and deformation that can be repaired without significantly disrupting operations
- The MDE produces a level of ground motion which may badly damage the TSF but the facility should maintain its integrity and not allow the release of impounded tailings and/or water.

Table 12-9 presents the adopted seismic loadings for the analysis represented by Peak Horizontal Ground Acceleration (PGA)

**Table 12-9: Type table title here.**

| Design event | Average Recurrence Interval | PGA | Adopted Seismic Loading |
|---|---|---|---|
| OBE | 1 in 1000 years | 0.026 g | 0.013 g |
| MDE | 1 in 10 000 years | 0.150 g | 0.075 g |

The seismic return periods adopted were based on ANCOLD (2012b) using a 'High C' ANCOLD consequence category documented in Section 9.2.2.

The OBE PGA coefficient was derived by:

- Using the 1 in 500 Peak Horizontal Ground Acceleration coefficient obtained from the Geoscience Australia website (web link: http://www.ga.gov.au/interactive-maps/#/theme/hazards/map/earthquakehazards)
- Using probability factor ($k_p$) in AS 1170.4 to convert the 1 in 500 PGA coefficient to a 1 in 1 000 PGA.

The MDE PGA was obtained from Burbidge, D.R. (ed.) (2012).

The adopted seismic loadings are in accordance with the US Army Corps (1984a) method for assessing pseudo static seismic stability whereby they recommend a seismic loading equal to one-half of the PGA.

### 12.4.3 Stability modelling geotechnical parameters

The adopted stability parameters were based on the geotechnical assessment of materials presented in 8.0. Table 12-10 summarises the adopted parameters.

**Table 12-10: Stability modelling parameter summary.**

| Material | Unit weight (kM/m$^3$) | Static strength | Undrained Seismic Strength |
|---|---|---|---|
| Natural Sequences | | | |
| Permian aged rock - siltstone | 20 | c' = 500 kPa, ϕ' = 28 | c = 400 kPa, ϕ = 23 |
| Placed Materials | | | |
| Mine waste (unsaturated) | 18 | c' = 50 kPa, ϕ' = 30° | c = 80 kPa, ϕ = 16 |
| Mine waste (saturated) | 20 | c' = 20 kPa, ϕ' = 25° | c = 80 kPa, ϕ = 16 |
| Rejects | 15 | c' = 0 kPa, ϕ' = 40° | c = 0 kPa, ϕ = 34° |
| Tailings | 12 | 0.15 (Su/σv') | 0..12 (Su/σv') |

### 12.4.4 Stability results

The results are shown in Table 12-11 and Table 12-12 with the Slope/W output figures attached in APPENDIX F. Global embankment failure was taken as embankment failure from crest to toe that would cause loss of containment which was assumed to be at least half the embankment crest width. Local embankment failure was taken as any failure occurring between benches. Note that for Stage 1 the existing ground surface is near the stage 1 downstream bench level and for this reason local embankment stability has not been assessed.

**Table 12-11: Stage 1 stability results**

| Case | Global embankment | | |
|---|---|---|---|
| | Factor of Safety | Achieves assessment criteria | Figure APPENDIX F |
| 3A Static, operating pond | 1.5 | YES | F1 |
| 3B Static, DSA | 1.3 | NO | F2 |
| 3C Seismic OBE, operating pond | 1.5 | YES | F3 |
| 3D Seismic OBE, DSA | 1.2 | YES | F4 |
| 3E Seismic MDE | 1.3 | YES | F5 |

**Table 12-12: Stage 2 stability results**

| Case | Global embankment | | | Local embankment | | |
|---|---|---|---|---|---|---|
| | Factor of Safety | Achieves assessment criteria | Figure | Minimum Factor of Safety | Achieves assessment criteria | Figure |
| 4A Static, operating pond | 1.7 | YES | F6 | 1.6 | YES | F7 |
| 4B Static, DSA | 1.4 | NO | F8 | 1.3 | NO | F9 |
| 4C Seismic OBE, operating pond | 1.5 | YES | F10 | 1.7 | YES | F11 |
| 4D Seismic OBE, DSA | 1.3 | YES | F12 | 1.0 | YES | F13 |
| 4E Seismic MDE, | 1.2 | YES | F14 | 1.5 | YES | F15 |

The stability results under the modelled conditions indicate that:

- The stage 1 embankment meets the stability criteria for all conditions, except under static condition in combination with the DSA phreatic surface
- The stage 2 embankment meets the stability criteria for all conditions, except under static condition in combination with the DSA phreatic surface.

The DSA phreatic surface is considered a short term phenomena whereby removal of this water should be undertaken as part of mining operations as the embankment is not intended to act as a water storage structure. The Decant Ponds should be operated at a level of RL 117 and RL 141 for Stage 1 and Stage 2 embankments respectively.

On this basis a factor of safety between 1.3 and 1.5 is considered acceptable under short term conditions. However, a heightened level of dam safety inspections would need to be carried out under these conditions to look for signs of seepage and instability by measuring water levels within the monitoring piezometers.

# 13.0 EMBANKMENT EROSION PROTECTION

## 13.1 Internal batters

The internal batters are covered with a layer of rejects which is expected to assist in protecting the upstream batters from erosion. Over time tailings will gradually cover the internal batters eliminating the risk of erosion.

## 13.2 External batters

The crest has been graded to the upstream side to divert most of the crest drainage water which would potentially contribute to gully erosion on the downstream batters.

Under the Stage 1 embankment the cross sectional thickness of the embankment, with a minimum crest width of 28 m, is expected to tolerate a high level of erosion.

The Stage 2 embankment is to be constructed from coal rejects which is expected to be resilient to erosion.

# 14.0 DESIGN DRAWINGS AND SPECIFICATION

The design drawings and specification are attached in APPENDIX A.

# 15.0 OPERATIONAL GUIDELINES

DEHP requires the dam owner to prepare and submit an operational plan that is consistent with the requirements in the Environmental Authority. The information provided in this section does not constitute an operational plan but provides supporting information for the formation of such a plan.

The operational guidelines provided in this report are specific to the Stage 1 TSF are subject to periodic review and updating to reflect modifications to the conditions on which the document is based. The timing for such updates includes, but is not necessarily limited to the following:

- Alteration (either increase or decrease) of the capacity of the TSF by increased footprint or storage height.
- A significant incident with respect to the operation and/or performance of the facility is experienced.
- A significant change to the Environmental Authority for the Curragh Mine operation, or conditions contained therein, is made.

## 15.1 Tailings deposition

Tailings deposition into the Pit B TSF can occur from four tailings deposition lines (2 from each CHPP), however, it is understood that only one line from each CPP will be operational during normal operation. However it is noted that all four lines can function simultaneously.

General guidelines for tailings deposition into the TSF are provided as follows:

- Deposition is to comprise pumping through the single discharge line with deposition onto the rising tailings beach surface. No further control can be applied beyond the discharge pipeline, with the tailings beach development dependent on the deposition location.
- The overall tailings beach profile will be controlled by relocation of tailings discharge locations. The deposition sites will be from the end of the Stage 1 tailings pipe cut and from Ramp 4 (refer APPENDIX A), as required, to promote a tailings beach profile that slopes towards the centre of the TSF storage area. Slurry discharge from the containment embankment may also be required to develop the beach profile.
- Visual assessment of the decant pond location shall be made as part of the deposition process, to prompt the relocation of discharge sites. Decant water recovery is to be consistently maintained.
- The overall tailings beach profile should maintain an even level around the perimeter embankments, falling at approximately 0.5% towards the decant pond at the southern end of Pit B.

Further to the above general guidelines, on the ceasing of pumping through the delivery pipeline (i.e. at a plant shutdown or when transferring of deposition from site to site), the delivery pipeline shall be immediately flushed to assist in the prevention of settlement of tailings solids within and blockage of the pipe.

## 15.2 Decant pond operation

The operating objectives for the decant system are:

- To minimise the volume of water contained within the storage (thus contributing to maintenance of freeboard levels, and facilitating exposure of the deposited tailings beach to consolidation and air-drying, particularly as the capacity of the storage is approached)
- To minimise the transfer of suspended solids to the coal handling and process plant.

General guidelines for decant pond operation are as follows:

- Water will be recovered using a pontoon pump system to be designed by Curragh
- The decanting of water from the TSF is to be designed to meet the CHPP requirements

- The decant pond operating depth should be no greater than 2 to 3 m
- The decant ponds should be operated at a level of RL 117 and RL 141 for Stage 1 and Stage 2 embankments respectively.
- DEHP shall be notified if the decant pond level reaches the MRL, refer Section 11.3.
- On the 1st November each year there must be adequate storage above the decant pond to account for the DSA volume, refer Section 11.3.

## 15.3 Trigger levels

### 15.3.1 Definition

In general accordance with the US Federal Energy Regulatory Commission (Division of Dam Safety and Inspections) a trigger level can be defined as “an instrument reading that triggers increased surveillance or an emergency action”. The assigned trigger levels indicate that the stability factor of safety design criteria has been reached, Refer Section 15.4.

### 15.3.2 Actions under trigger levels

If the piezometric trigger levels are reached the following actions shall be undertaken:

- Review data for reliability
- Inform all responsible parties including the design engineer
- Inspect the site for signs of instability
- Design a remedial plan to increase the stability factor of safety back to the design or required value
- Carry out daily piezometer readings and provide these to the design engineer

If the piezometric levels rise above the trigger level the following shall be undertaken:

- Inform all parties working on the affected area to evacuate immediately
- Implement the emergency action plan

## 15.4 Inspection and monitoring

Regular site surveillance and monitoring of the TSF shall be undertaken based on the following.

### 15.4.1 Phreatic surface

Monitoring of the phreatic surface within the embankment and foundations – a minimum of two piezometers for each stage located on the crest and on the downstream embankment benches. Monitoring should be undertaken at a monthly frequency. Monitoring of the stored water levels should also be undertaken.

The recommended standpipe trigger levels are shown in Table 15-1:

**Table 15-1: Piezometer monitoring trigger levels**

| Piezometer Location | Stage 1 Piezometer Trigger Level (RLm) | Stage 2 Piezometer Trigger Level (RLm) |
|---|---|---|
| Upstream crest edge | 115 | 128 |
| External batter bench RL 125 m | not applicable | 100 |
| External batter bench RL 105 m | 104 | 96 |

### 15.4.2 Settlement

Settlement monitoring of the embankment – at least 2 monuments are required, located on the embankment crest. Monitoring should be undertaken at a frequency of not greater than 6 months during periods of high water levels.

Visual inspections (documented) of the TSF as follows:

Shift/daily and/or significant rainfall incident related inspections to inspect the physical conditions of the embankment, spillway, pipelines, seepage system and diversion system.

Annual and/or incident related dam safety inspections to review monitoring data (phreatic surface and settlement monitoring) and inspect conditions of embankment, spillway, pipelines, seepage system, diversion drains etc.

## 15.5 Emergency action plan

An emergency action plan for the TSF will be included in the operating manual that shall be prepared prior to commissioning the facility. This emergency action plan and routine checking procedures shall include, but not limited to the following details as provided below.

### 15.5.1 General overview

The plan shall provide a list of relevant steps to follow in the advent of a tailings dam pipe or embankment failure. Contact details of staff associated with the tailings dam, senior site staff responsible, safety officer and emergency services shall be provided.

It must be stressed however, that the safe operation of the tailings dam relies upon the implementation of operational procedures comprising tailings deposition, decant operation, and routine inspections and maintenance. These are to be set out in detail in related Standard Operating Procedures to minimise the potential for a catastrophic event such as a failed embankment.

### 15.5.2 Tailings lines and return water lines

The tailings line from the process plant to the tailings storage and the return water lines from the decant facility to the process water pond are bunded to contain any spillage of materials resulting from lines which develop leaks or burst during operation.

### 15.5.3 Pipeline failure

In the event of pipeline failure:

1) Shutdown the affected pipeline until repaired

2) Notify Process Supervisor

3) Collect and/or pump the spilled materials, as appropriate, and deposit in the tailings storage area.

4) Process Manager to notify the Site Senior Executive who will assess the spill and ascertain whether reporting to statutory bodies is required.

### 15.5.4 Tailings embankment

The embankment of the TSF has been designed with an adequate factor of safety against failure under normal operating conditions and under seismic load conditions appropriate for the location of the structure. Normal operating conditions refer to a relatively small decant water pond with no permanent free water ponding against the perimeter embankments.

Given the adoption of the tailings deposition philosophy, good decant operation, routine inspections and maintenance practices set out in other tailings dam procedures and, that the embankment construction has been or should be carried out in accordance with the design, the probability of embankment failure during normal operations is very low.

However, in the unlikely event of embankment failure, the flow of tailings from the storage will be controlled by the degree of saturation of the tailings at the time of failure.

#### 15.5.4.1 Small scale embankment failure

Small scale embankment failures can be defined as failures that are not likely to cause loss of containment

Action to control a small scale embankment failure and limit environmental damage would include:

1) Assess the requirement to shut down the process plant, or reduce process plant throughput

5) Contact Process Manager who will coordinate the following steps

6) Notify Site Senior Executive who will assess the failure and make contact with relevant statutory bodies

7) If necessary divert or build bunds to contain tailings by using earthmoving equipment

8) Contact a consultant suitably qualified in tailings dam design and operation for technical assistance

9) Deploy pumps to recover tailings water and return it either to the process water pond or to the storage if structurally sound.

10) Prior to the commencement of any repairs undertake a thorough inspection of the area with a consultant (as above)

11) Undertake remedial and repair work of the damaged embankment or affected area

12) Clean up of tailings as soon as practical after embankment repairs have been completed and the storage is considered to be in a safe condition.

13) Prepare an incident report, detailing all factors to the incident and the situation after clean –up. The report will identify causes of the problem and what actions will be taken to prevent a similar occurrence. This report will detail the ongoing monitoring programme to fully assess the impact of the incident.

14) Site Senior Executive to advise all appropriate government departments, as necessary, of the incident, review DEHP conditions of licence in respect to further reporting on the completion of remedial works.

Contact details of relevant personnel and emergency services will be maintained in the Crisis Management and Recovery Manual.

#### 15.5.4.2 Large scale embankment failures

Large scale embankment failures have the potential to cause loss of containment.

Action to control a large scale embankment failure and to limit environmental damage would include;

1) Shut down the process plant to eliminate escalating the failure.

2) Evacuate the area, if required, to the nearest muster point.

3) Contact Process Manager who will coordinate the following steps

4) Notify Site Senior Executive who will assess the failure and make contact with relevant statutory bodies

5) If necessary divert or build bunds to contain tailings by using earthmoving equipment

6) If tailings material has been discharged and enters possible stock water supplies the Site Senior Executive will organise a water sampling and analysis program.

7) Contact a consultant suitable qualified in tailings dam design and operation for technical assistance.

8) Site Senior Executive to advise relevant government departments of the incident as soon as possible and review the DEHP conditions on the licence in respect to further reporting on the completion of remedial works.

9) Deployment of pumps to recover tailings water and return it either to the process water pond or to the dam if structurally sound

10) Prior to the commencement of any repairs undertake a thorough inspection of the area with the assistance of a geotechnical specialist

11) Repair the damaged embankment

12) Clean up of tailings a soon a practical after the embankment repairs have been completed

13) Prepare an incident report, detailing all factors to the incident and the situation after clean-up. The report should identify causes of the problem and what actions will be taken to prevent a similar occurrence. This report should detail the ongoing monitoring programme to fully assess the impact of the incident

14) Site Senior Executive to submit report and advise all appropriate government departments, as necessary, of the incident.

Contact details of relevant personnel and emergency services will be maintained in the Crisis Management and Recovery Manual.

# 16.0 TECHNICAL RISK ASSESSMENT

A preliminary engineering risk assessment for the IPAC1 was undertaken utilizing a HAZOPS type risk approach. The components of the risk assessment are summarized in Appendix APPENDIX H Table 1 and the results are shown in Appendix APPENDIX H Table 2 and Table 3 for initial and residual risk under mitigation maesures.

The following risk assessment approach was undertaken:

- Identification of the risk assessment scope
- Identification of key hazards and impacts
- Assignment of probability
- Assignment of consequence
- Assignment of risk rating for each hazard
- Identification of risk reduction and mitigation measures.

The assessment approach is qualitative and is based on available information on the design and operation of the Pit B TSF. The likelihood of each hazard occurring has not been assessed on a statistical basis.

## 16.1 Risk categories

The impact, likelihood, consequence and overall risk of each hazard have been assessed in three general risk categories, described as follows:

- Safety and health of personnel and public
- Temporary or permanent impact on the environment, including regulatory impacts and remediation liabilities
- Cost to repair or replace damaged assets and cost of lost production / time.

## 16.2 Identified hazards and risk reduction measures

The major hazards identified along with the key risk reductions measures are presented in Table 16-1.

**Table 16-1: HAZOP risk assessment**

| Hazard | Key Risk Reduction Measure |
|---|---|
| Embankment stability failure | - Maintain the decant pond at or below the DSA level<br>- Conduct regular site visits and undertake embankment maintenance when necessary |
| Overtopping embankment from rainfall | - Implement additional decant pumping and divert water to external storage areas<br>- Stop pumping tailings into Pit B if necessary and divert to other storages if available |
| Seepage / piping | - Conduct regular visits to external embankment toe and downstream from the external toe to look for signs of seepage and piping<br>- If signs of seepage and / or piping are evident:<br>  - Minimise decant pond water depth by maximising pumping<br>  - Stop pumping tailings if necessary and divert to other storages if available<br>  - contact the design engineer to establish control measures |

| Hazard | Key Risk Reduction Measure |
|---|---|
| | - Control measures may include placing a buttress along the downstream batter with coarse rejects |
| Tailings pipeline failure | - Containment bunds to be installed along pipeline route. |

# 17.0 CLOSURE

The final surface cover of the TSF will be subject to investigation works and detailed assessment in the years prior to closure and would typically include an assessment of the geochemistry and leaching of the tailings material which would be used in conjunction with detailed cover analysis in determination of the preferred capping philosophy, whilst achieving the overall objectives as outlined below. Typical cover design options considered applicable at the Curragh Mine may include a barrier/low hydraulic conductivity cover or a store-and-release cover and would need to be consistent with the EA conditions. Notwithstanding the above, the following provides a conceptual strategy for the closure of the B Pit TSF, with the final cover system including all or a subset of the cover components as described below.

The typical objectives to be adopted for rehabilitation of the TSF would be to create a landform that is:

- Stable and sustainable;
- Compatible with the surrounding landform; and
- Of minimum long term environmental impact (i.e. non-polluting).

Based on these objectives, a concept for the TSF is as follows:

## 17.1 Landform development

It is envisaged that the final TSF landform would comprise long-term stable external batters with an upper surface formed such that ponding is substantially avoided. This would therefore necessitate a final campaign of tailings deposition at the southern end of the TSF to infill any significant depression. Final drainage formation towards a discharge channel may then be formed, as required.

## 17.2 Tailings surface capping

A tailings surface cap would serve the following purposes:

- Facilitate ongoing surface water drainage and prevent ponding;
- Stabilise the surface to mitigate against potential ongoing erosion; and
- Reduce potential rainfall infiltration into the tailings as recharge to seepage.

The cap would comprise the following components as described below to meet these performance standards. This configuration assumes that the tailings would remain geochemically benign.

### 17.2.1 Tailings surface stabilisation layer

To provide a geotechnical competent surface over the surface of the tailings, a stabilization layer may be necessary. The purpose of the stabilisation layer would be to provide a competent subgrade or bridging layer, which would evenly distribute the surcharge onto the tailings surface and thereby limit potential settlements. The area most likely to require stabilisation would be the decant pond surface, due to the likely extent of saturated slimes materials.

The stabilisation layer would typically comprise rock mattress (the rock comprising competent and durable material).

### 17.2.2 Sealing layer

A sealing layer may be required to reduce the downward infiltration of surface water, which would act as a recharge to seepage, as well as oxygen. The sealing layer would be constructed using a compacted clay fill material and would extend over the full surface area of the storage.

### 17.2.3 Surface protection layer

To protect the tailings surface from erosion and exposure deterioration (through wetting and drying), a surface protection layer would be required. This layer could also be utilized as a rooting zone for vegetation depending on the proposed end land use.

This layer would be formed typically using select mine waste rock from the existing waste rock spoil areas. Geochemically, the waste should be non-acid producing. From a geotechnical perspective, the material should be non-erosive/dispersive.

The thickness of this layer would be selected to not only maintain drainage, but also to compensate for settlement within the underlying tailings. A hummocky final land surface may also have some benefit with respect to maintaining moisture within the surface layers to support vegetation growth and to reduce erosion potential. The final surface landform would be subject to further, ongoing assessment through the life of the facility.

A more detailed assessment of a suitable capping configuration would need to be completed, subject to more data being available with respect to the physical and geochemical characteristics of the tailings. In particular, geochemical compatibility between the tailings and capping materials must be confirmed to ensure the integrity of the capping horizon is not compromised.

# 18.0 REFERENCES


1) ANCOLD (1998a). *Guidelines for Design of Dams for Earthquake,* August 1988, Australian National Committee on Large Dams

2) ANCOLD (2012b). Guidelines on Tailings Dams Planning, Design, Construction, Operation and Closure, May 2012, Australian National Committee on Large Dams

3) ANCOLD (2012c). *Guidelines on the Consequence Categories for Dams*, October 2012, Australian National Committee on Large Dams

4) Burbidge, D., R. (ed.) (2012). *The 2012 Australian Earthquake Hazard Map,* Record 2012/71, Geoscience Australia, Canberra

5) Curragh (2016). *D-E-F Pit Hydrology*, memorandum, 13 October 2016

6) Curragh (2015). *A Pit Geology / Groundwater Clarifications,* memorandum 14 August 2015

7) DEHP (2016). *Manual for assessing consequence categories and hydraulic performance of structures*, ESR/2016/1933, version 5, 29 March 2016, Department of Environment and Heritage Protection, Queensland Government

8) Department of of Environment and Heritage Protection, 2016. *Manual for assessing consequence categories and hydraulic performance of structures*, Version 5.0, March 2016.

9) Fell, R. (2004). Design of Embankment Dams to Withstand Earthquakes – Developments Since the ANCOLD Guidelines Were Published, ANCOLD conference

10) Golder (2014). *Curragh Coal Mine Life of Mine Tailings Storage Study,* report number 003-147635010, revision 3, Golder Associates, Brisbane

11) Hoek, E., Brown, E. T., (1997). *Practical estimates of rock mass strength,* Journal of Rock Mechanics and Mining Science, Vol 34, No 8 pp. 1165-1186

12) Sherwood (2013). *Kogan Creek Mine Ash Rehandling Geotechnical Assessment*, Report no. 34006-1-1, Sherwood Geotechnical and Research Services

13) Simmons, J., V., McMannus, D., A. (2004). *Shear Strength Framework for Design of Dumped Mine waste Slopes for Open Pit Coal Mines*, Proc. Advances in Geotechnical Engineering, The Skempton Conference, Vol. 2, 981-991, Thomas Telford

14) US Army Corps (1984a). *Rationalising the seismic coefficient method,* miscellaneous paper GL-84-13, July 1984, Vicksburg, Mississippi

15) US Army Corps (1984b). *Shore Protection Manual Volumes 1 and 2,* Coastal Engineering Research Centre, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi

16) US Army Corps (1993). *Seepage Analysis and Control for Dams,* Engineering Manual 1110-2-1901, 30 April 1993, Washington, DC

17) USBR (1981). *Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams,* Acer Technical Memorandum No. 2, U.S. Department of the Interior Bureau of Reclamation, Denver, Colorado

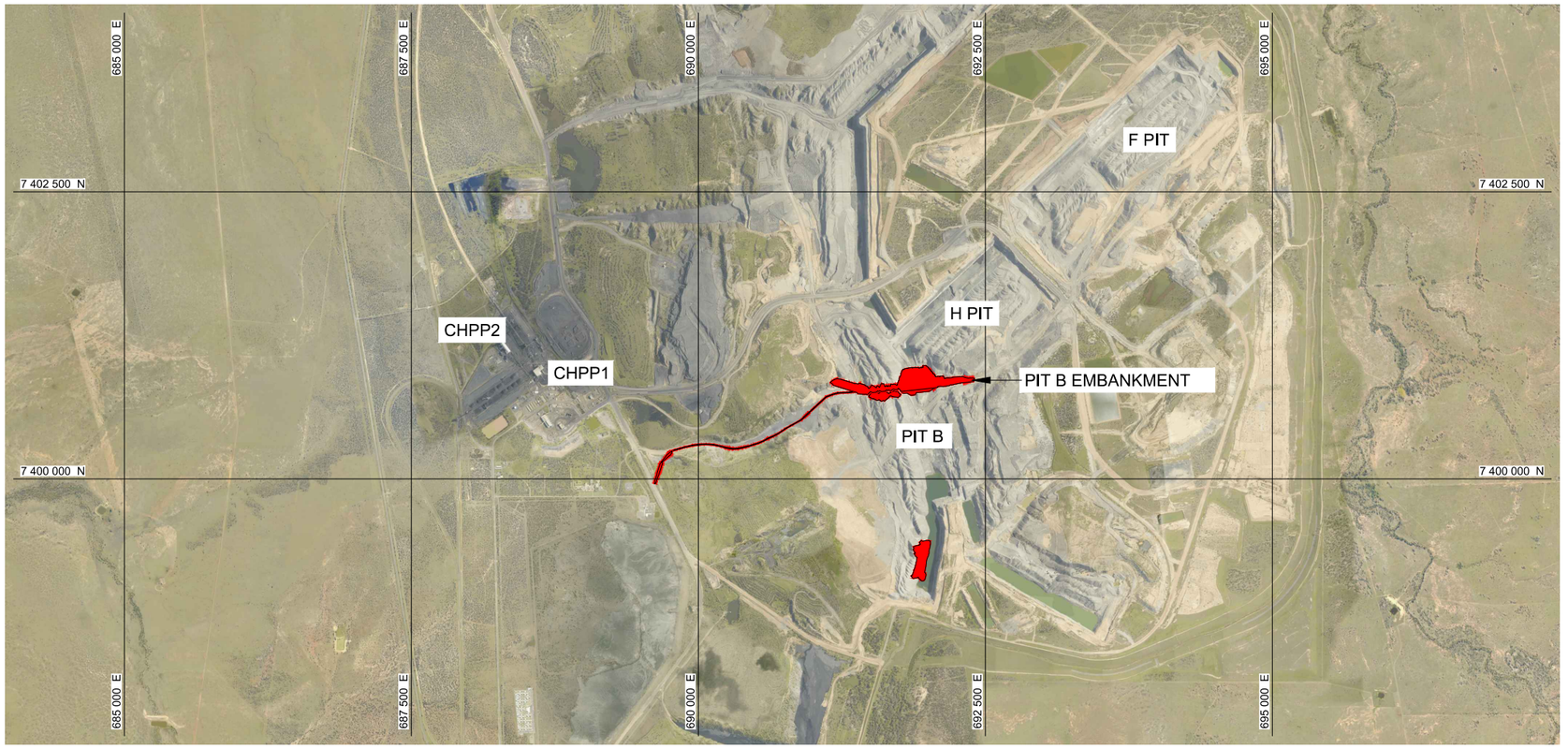
18) USDA (1994). *Part 633 National Engineering Handbook Chapter 26 Gradation Design of Sand and Gravel Filters*, , United States department of Agriculture, National Resources Conservation Services, Washington, DC

19) Wesfarmers Curragh Pty Ltd, 2016. *D-E-F Pit Hydrology*. 13 October 2016.

# APPENDIX A

## Technical specification and drawings

# PIT B TAILINGS STORAGE FACILITY EARTHWORKS - STAGES 1 AND 2




LOCALITY PLAN
SCALE 1:50,000 m

**DRAWING INDEX**

| DRG NO. | DESCRIPTION | REV. |
|---|---|---|
| 000 | LOCALITY PLAN AND DRAWING INDEX | 1 |
| 001 | GENERAL ARRANGEMENT PLAN | 1 |
| 002 | STAGE 1 - EMBANKMENT RL 125 - PLAN VIEW AND LONGITUDINAL SECTION | 1 |
| 003 | STAGE 1 - TAILINGS PIPE CUT 1 - PLAN VIEW AND LONGITUDINAL SECTION | 1 |
| 004 | STAGE 1 - TAILINGS PIPE CUT 2 - PLAN VIEW AND LONGITUDINAL SECTION | 1 |
| 005 | STAGE 1 - PROTECTION BUND - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 1 OF 3 | 1 |
| 006 | STAGE 1 - PROTECTION BUND - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 2 OF 3 | 1 |
| 007 | STAGE 1 - PROTECTION BUND - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 3 OF 3 | 1 |
| 008 | STAGE 1 - DECANT RAMP - PLAN VIEW AND LONGITUDINAL SECTION | 1 |
| 009 | STAGE 2 - EMBANKMENT RL 147 - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 1 OF 2 | 1 |
| 010 | STAGE 2 - EMBANKMENT RL 147 - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 2 OF 2 | 1 |
| 011 | TYPICAL CROSS SECTIONS - SHEET 1 OF 2 | 1 |
| 012 | TYPICAL CROSS SECTIONS - SHEET 2 OF 2 | 1 |
| 013 | SETOUT TABLES | 1 |
| 014 | ZONE 1 BORROW LOCATION | 1 |
| 015 | EMBANKMENT MONITORING BORES - TYPICAL DETAIL AND SETOUT TABLE | 1 |

**NOTE(S)**

1. ALL DIMENSIONS ARE IN METRES (m) UNLESS NOTED OTHERWISE. ALL ELEVATIONS ARE IN METRES (m). ALL CO-ORDINATES ARE IN METRES (m).
2. VERTICAL DATUM IS LOCAL.
3. HORIZONTAL DATUM IS IN CURRAGH SITE GRID.
4. REFER SPECIFICATION FOR COMPACTION REQUIREMENTS AND MATERIAL STANDARDS.
5. SETTING OUT DIMENSIONS SHOWN ON THE DRAWINGS SHALL BE VERIFIED BY THE SITE CONTRACTOR. REFER ANY DISCREPANCY TO THE COMPANY'S REPRESENTATIVE BEFORE PROCEEDING WITH WORK.
6. DESIGN IS BASED ON LIDAR SURVEY DATA. DUE TO POTENTIAL INACCURACIES IN THE SURVEY, THE CONTRACTOR SHALL VERIFY SURFACE LEVELS AND ADVISE THE CLIENT'S REPRESENTATIVE IMMEDIATELY IF THERE IS ANY DISCREPANCY WITH THE DESIGN LEVELS.
7. REFER ALL DISCREPANCIES TO THE COMPANY'S REPRESENTATIVE BEFORE PROCEEDING WITH THE WORKS.
8. DESIGN BASED ON FOLLOWING SURVEY FILES :
   - 1602-CS RUNNING.00t (DATED 16.09.2016)
   - bpibatho1610.dxf (DATED 29.11.2016)
   - g_bridge_161116.arch_d (DATED 18.11.2016)
9. ALL VOLUMES ARE IN CUBIC METRES (m³), AREAS ARE IN SQUARE METRES (m²) AND REDUCED LEVELS ARE IN METRES (m) UNLESS NOTED OTHERWISE.
10. THESE NOTES APPLY TO ALL DRAWING'S LISTED IN THE DRAWING INDEX.

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**CONSTRUCTION**

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1:50,000 METRES

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| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

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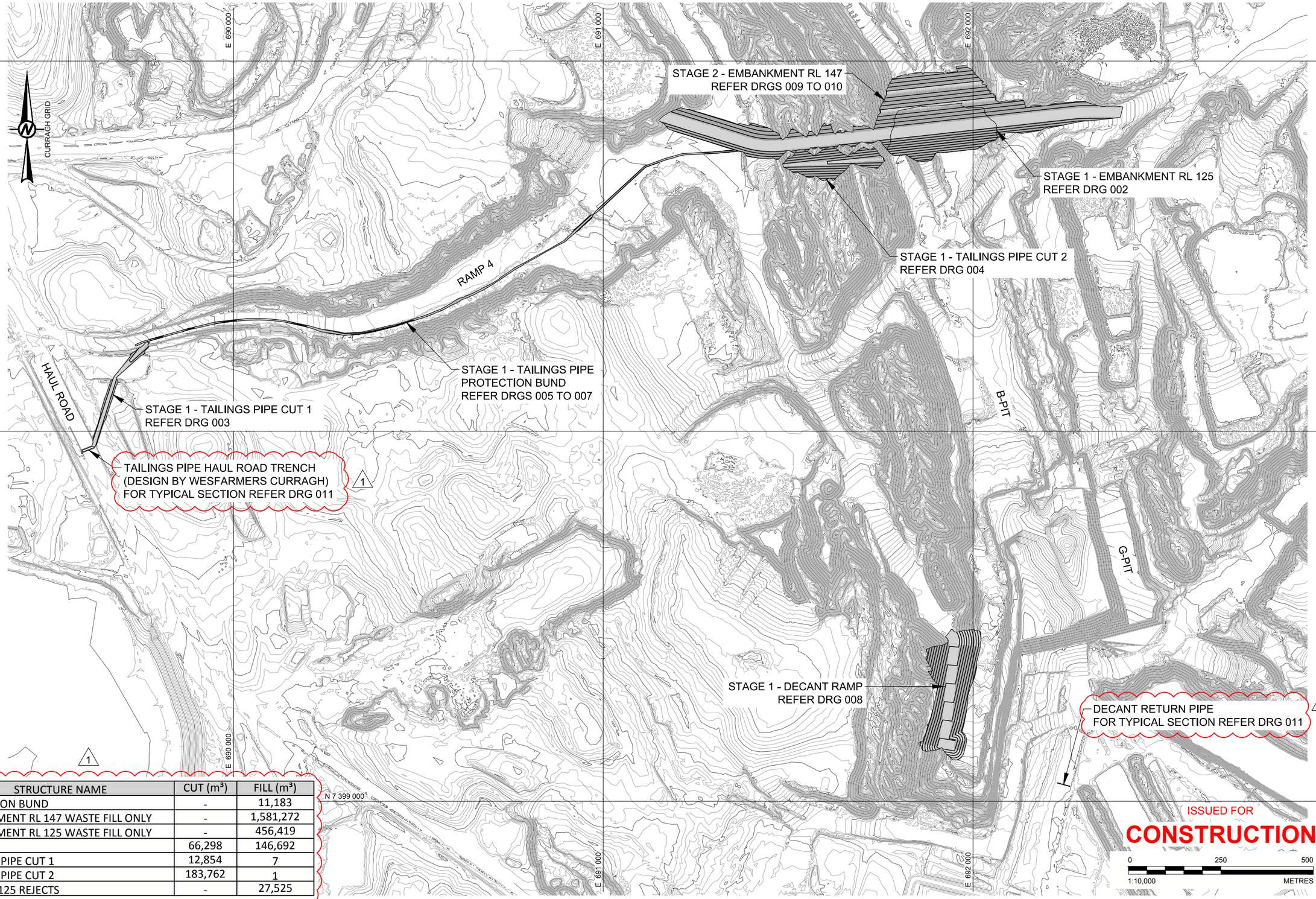
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WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**LOCALITY PLAN AND DRAWING INDEX**

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| STRUCTURE NAME | CUT (m³) | FILL (m³) |
|---|---|---|
| PROTECTION BUND | - | 11,183 |
| EMBANKMENT RL 147 WASTE FILL ONLY | - | 1,581,272 |
| EMBANKMENT RL 125 WASTE FILL ONLY | - | 456,419 |
| RAMP 2 | 66,298 | 146,692 |
| TAILINGS PIPE CUT 1 | 12,854 | 7 |
| TAILINGS PIPE CUT 2 | 183,762 | 1 |
| WALL RL 125 REJECTS | - | 27,525 |

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PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**GENERAL ARRANGEMENT PLAN**

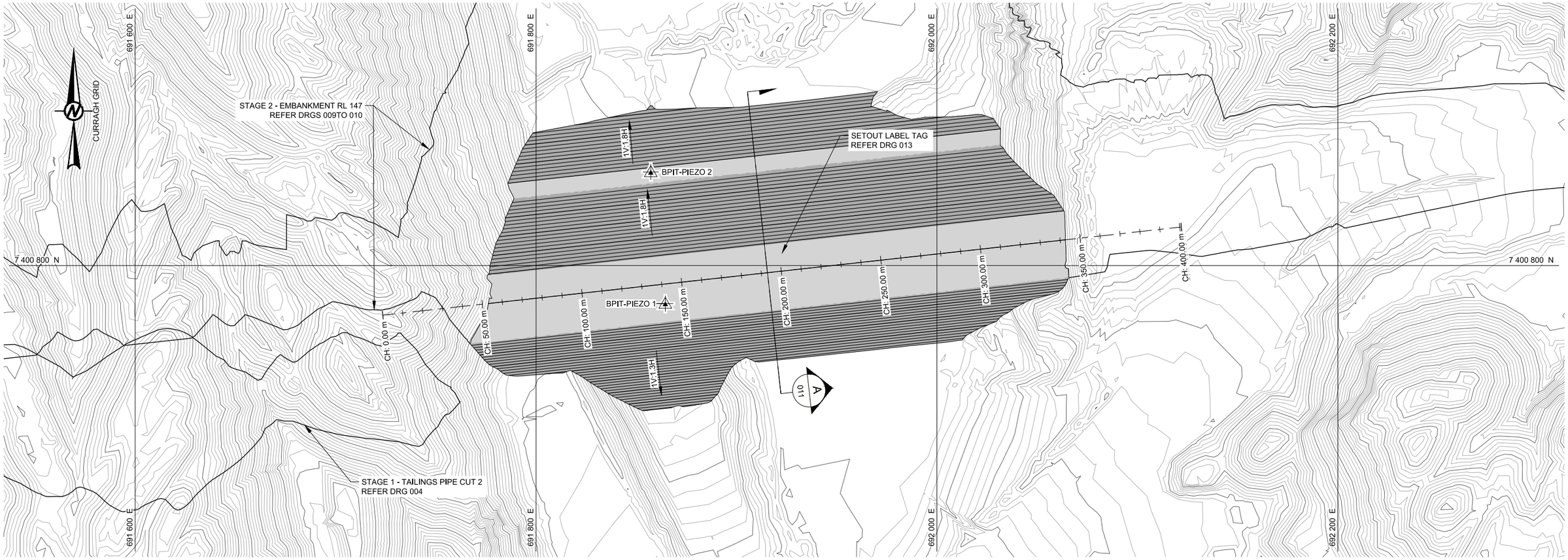
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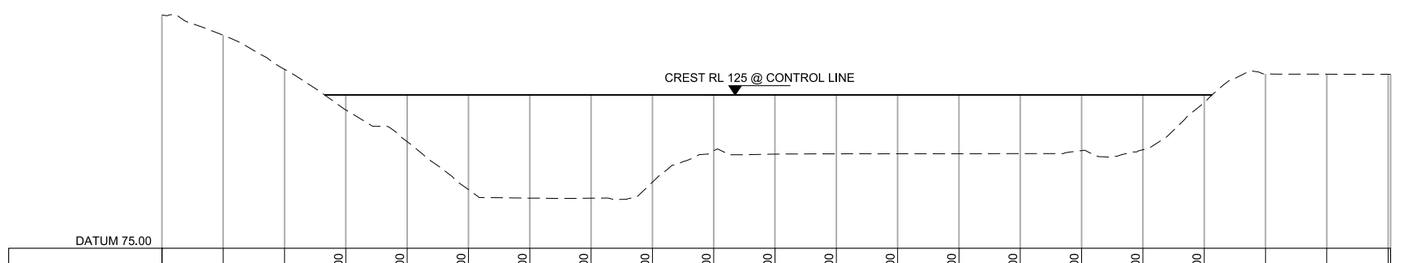
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PLAN VIEW
SCALE 1:2,000 m




| DATUM 75.00 | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROPOSED GROUND | | | | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | 125.00 | | | | |
| EXISTING GROUND | 150.96 | 144.45 | 133.33 | 120.07 | 109.75 | 94.10 | 91.35 | 91.32 | 96.54 | 106.78 | 105.68 | 105.78 | 105.82 | 105.82 | 105.84 | 106.82 | 107.11 | 122.46 | 131.82 | 131.74 | 131.70 |
| CUT AND FILL DEPTH (m) | | | | 4.93 | 15.25 | 30.90 | 33.65 | 33.68 | 28.46 | 18.22 | 19.32 | 19.22 | 19.18 | 19.18 | 19.16 | 18.18 | 17.89 | 2.54 | | | |
| CHAINAGE | 0.00 | 20.00 | 40.00 | 60.00 | 80.00 | 100.00 | 120.00 | 140.00 | 160.00 | 180.00 | 200.00 | 220.00 | 240.00 | 260.00 | 280.00 | 300.00 | 320.00 | 340.00 | 360.00 | 380.00 | 400.00 | 400.80 |

LONGITUDINAL SECTION
SCALE 1:2,000 m

| SETOUT TABLE FOR PIEZOMETER | | |
|---|---|---|
| PIEZOMETER No. | EASTING (m) | NORTHING (m) |
| BPIT-PIEZO 1 | 691864.50 | 7400781.02 |
| BPIT-PIEZO 2 | 691857.24 | 7400846.62 |

**NOTE**
1. REFER TO DRAWING 015 FOR TYPICAL DETAIL OF PIEZOMETER

ISSUED FOR
**CONSTRUCTION**

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1:2,000 METRES

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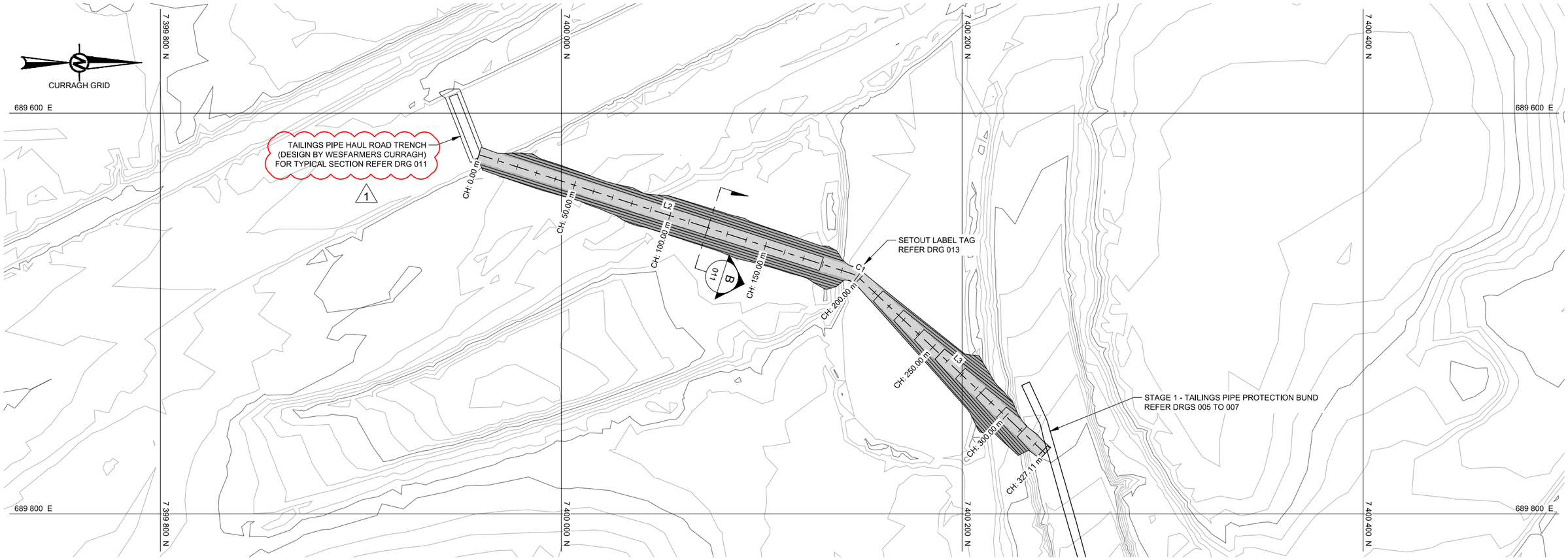
PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**STAGE 1 - EMBANKMENT RL 125 - PLAN VIEW AND LONGITUDINAL SECTION**

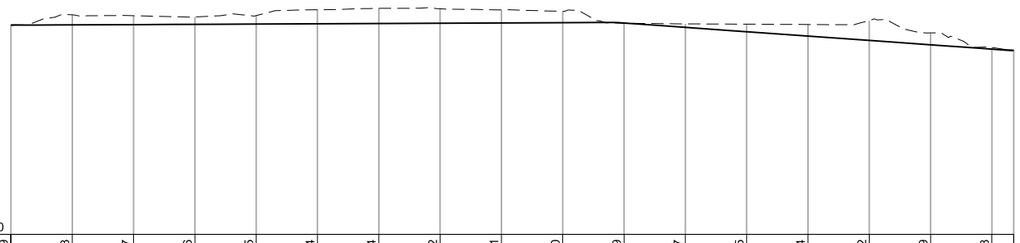
| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 3 of 16 | 002 |

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0

Path: \\golder.gds\gal\Brisbane\Cartomatics\WESFARMER_CURRAGH\CURRAGH199_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWGS | File Name: 1532295-052-R-002.dwg | Last Edited By: rfigueiredo Date: 2017-04-26 Time:11:01:33 AM | Printed By: dwillemse Date: 2017-11-08 Time:12:32:24 PM




PLAN VIEW
SCALE 1:2,000 m



DATUM 100.00

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROPOSED GROUND | 168.19 | 168.28 | 168.37 | 168.46 | 168.55 | 168.64 | 168.74 | 168.82 | 168.91 | 169.00 | 168.89 | 167.47 | 166.05 | 164.64 | 163.22 | 161.79 | 160.38 | |
| EXISTING GROUND | 168.34 | 171.57 | 171.29 | 170.87 | 171.33 | 173.22 | 173.70 | 173.55 | 173.20 | 172.73 | 168.85 | 168.62 | 168.52 | 168.40 | 169.63 | 165.68 | 160.91 | 160.14 |
| CUT AND FILL DEPTH (m) | -0.15 | -3.29 | -2.92 | -2.41 | -2.78 | -4.58 | -4.96 | -4.73 | -4.29 | -3.73 | 0.05 | -1.14 | -2.47 | -3.76 | -6.41 | -3.88 | -0.53 | |
| CHAINAGE | 0.00 | 20.00 | 40.00 | 60.00 | 80.00 | 100.00 | 120.00 | 140.00 | 160.00 | 180.00 | 200.00 | 220.00 | 240.00 | 260.00 | 280.00 | 300.00 | 320.00 | 327.11 |

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
**CONSTRUCTION**

0 50 100
1:2,000 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

CLIENT
CURRAGH Wesfarmers

CONSULTANT
Golder Associates

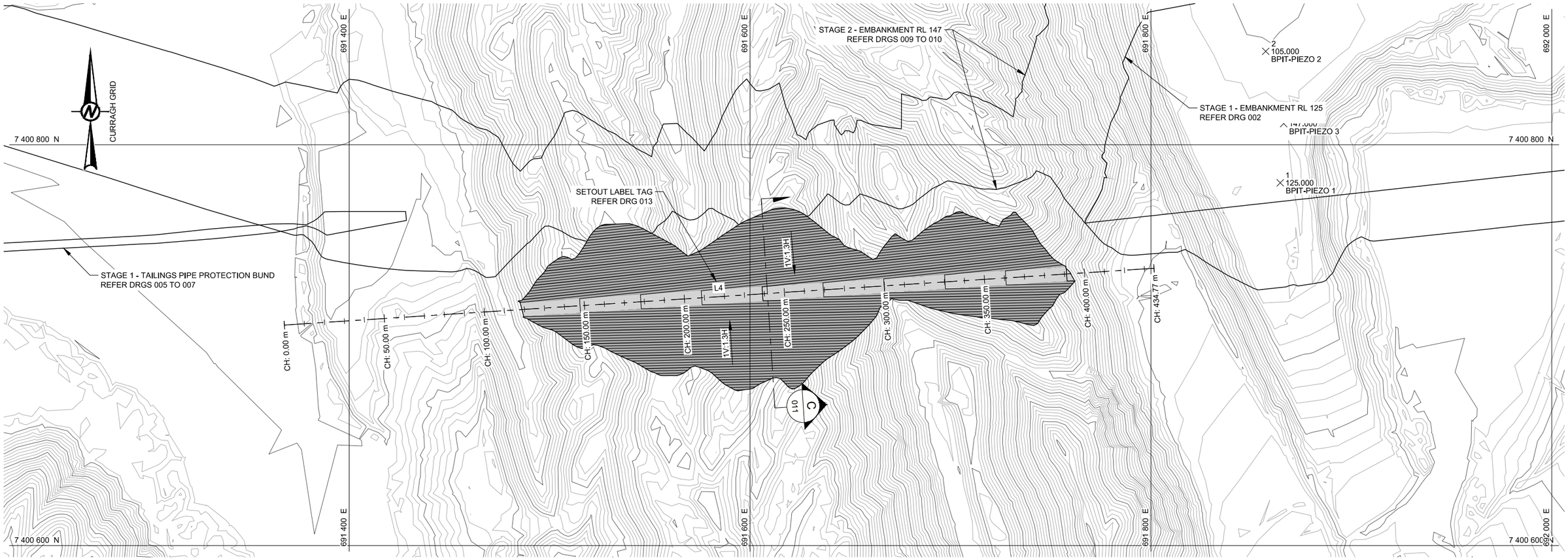
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

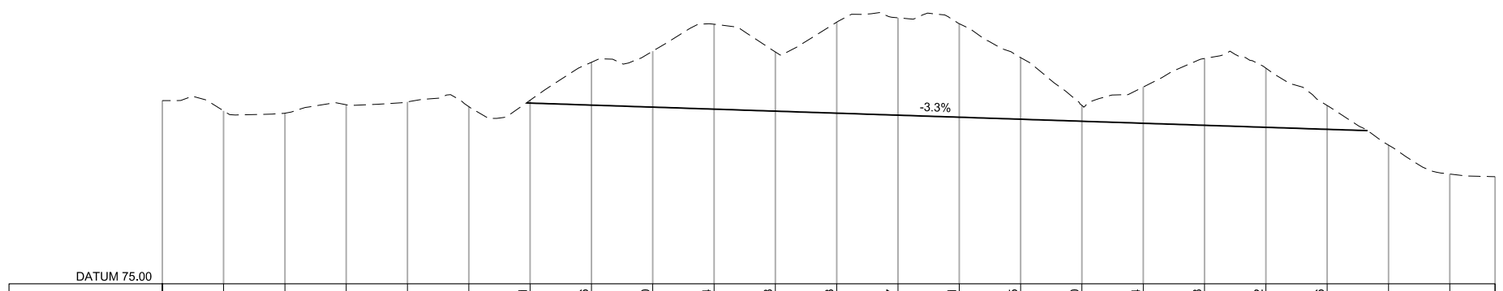
TITLE
**STAGE 1 - TAILINGS PIPE CUT 1 - PLAN VIEW AND LONGITUDINAL SECTION**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 4 of 16 | 003 |

Path: \\golder.gds\gal\Brisbane\Cartomatics\WESFARMER_CURRAGH\CURRAGH\99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWGS | File Name: 1532295-052-R-003.dwg | Last Edited By: vdisted Date: 2017-03-20 Time:10:28:24 AM | Printed By: dwillemse Date: 2017-11-08 Time:12:32:45 PM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0




PLAN VIEW
SCALE 1:2,000 m




| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATUM 75.00 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PROPOSED GROUND | | | | | | | 133.91 | 133.26 | 132.60 | 131.94 | 131.28 | 130.63 | 129.97 | 129.31 | 128.65 | 128.00 | 127.34 | 126.68 | 126.02 | 125.36 | | | |
| EXISTING GROUND | 134.71 | 131.39 | 130.64 | 133.37 | 134.31 | 132.74 | 134.85 | 147.21 | 150.85 | 159.62 | 150.58 | 160.28 | 161.70 | 159.78 | 148.73 | 133.16 | 139.15 | 148.47 | 145.31 | 133.15 | 120.23 | 110.80 | 109.92 |
| CUT AND FILL DEPTH (m) | | | | | | | -0.93 | -13.95 | -18.25 | -27.67 | -19.30 | -29.66 | -31.73 | -30.47 | -20.08 | -5.16 | -11.81 | -21.79 | -19.29 | -7.78 | | | |
| CHAINAGE | 0.00 | 20.00 | 40.00 | 60.00 | 80.00 | 100.00 | 120.00 | 140.00 | 160.00 | 180.00 | 200.00 | 220.00 | 240.00 | 260.00 | 280.00 | 300.00 | 320.00 | 340.00 | 360.00 | 380.00 | 400.00 | 420.00 | 434.77 |

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
**CONSTRUCTION**

0 50 100
1:2,000 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

CLIENT
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Golder Associates

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AUSTRALIA
[+61] (7) 3721 5400
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PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**STAGE 1 - TAILINGS PIPE CUT 2 - PLAN VIEW AND LONGITUDINAL SECTION**

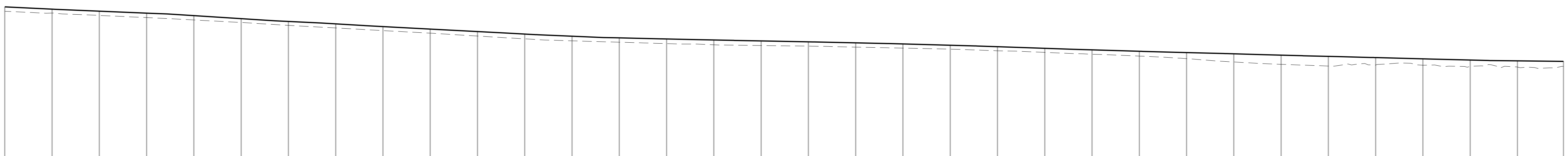
| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 5 of 16 | 004 |

Path: \\golder.gds\gal\Brisbane\Cartomatics\WESFARMER_CURRAGH\CURRAGH169_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWGS | File Name: 1532295-052-R-004.dwg | Last Edited By: dwillemse Date: 2017-03-14 Time:4:48:44 PM | Printed By: dwillemse Date: 2017-11-08 Time: 12:33:02 PM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0




CONTINUED ON DRG 006

PLAN VIEW
SCALE 1:2,000 m



DATUM 100.00

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROPOSED GROUND | 163.68 | 162.70 | 161.86 | 161.03 | 159.98 | 158.68 | 157.49 | 156.48 | 155.32 | 154.24 | 153.18 | 152.14 | 151.24 | 150.51 | 150.05 | 149.62 | 149.22 |
| EXISTING GROUND | 161.81 | 161.06 | 160.05 | 159.13 | 158.13 | 157.06 | 155.83 | 154.72 | 153.62 | 152.53 | 151.29 | 150.10 | 149.26 | 148.67 | 148.08 | 147.57 | 147.26 |
| CUT AND FILL DEPTH (m) | 1.87 | 1.64 | 1.82 | 1.90 | 1.85 | 1.62 | 1.66 | 1.75 | 1.71 | 1.72 | 1.89 | 2.04 | 1.97 | 1.84 | 1.96 | 2.05 | 1.96 |
| CHAINAGE | 0.00 | 20.00 | 40.00 | 60.00 | 80.00 | 100.00 | 120.00 | 140.00 | 160.00 | 180.00 | 200.00 | 220.00 | 240.00 | 260.00 | 280.00 | 300.00 | 320.00 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROPOSED GROUND | 148.83 | 148.41 | 147.94 | 147.38 | 146.76 | 146.08 | 145.42 | 144.82 | 144.28 | 143.74 | 143.18 | 142.65 | 142.14 | 141.62 | 141.10 | 140.76 | 140.55 |
| EXISTING GROUND | 147.01 | 146.57 | 146.17 | 145.72 | 145.02 | 144.35 | 143.56 | 142.78 | 141.70 | 140.27 | 139.28 | 138.55 | 138.99 | 138.90 | 138.42 | 138.09 | 138.40 |
| CUT AND FILL DEPTH (m) | 1.81 | 1.83 | 1.77 | 1.65 | 1.74 | 1.73 | 1.87 | 2.04 | 2.58 | 3.47 | 3.90 | 4.10 | 3.15 | 2.72 | 2.68 | 2.67 | 2.15 |
| CHAINAGE | 340.00 | 360.00 | 380.00 | 400.00 | 420.00 | 440.00 | 460.00 | 480.00 | 500.00 | 520.00 | 540.00 | 560.00 | 580.00 | 600.00 | 620.00 | 640.00 | 659.45 |

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
**CONSTRUCTION**

0 50 100
1:2,000 METRES

| Rev. | YYYY-MM-DD | DESCRIPTION | PREPARED | DESIGN | REVIEW | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DDW | DAS | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DDW | DAS | MJG | MJG | DA SMALLHORN |

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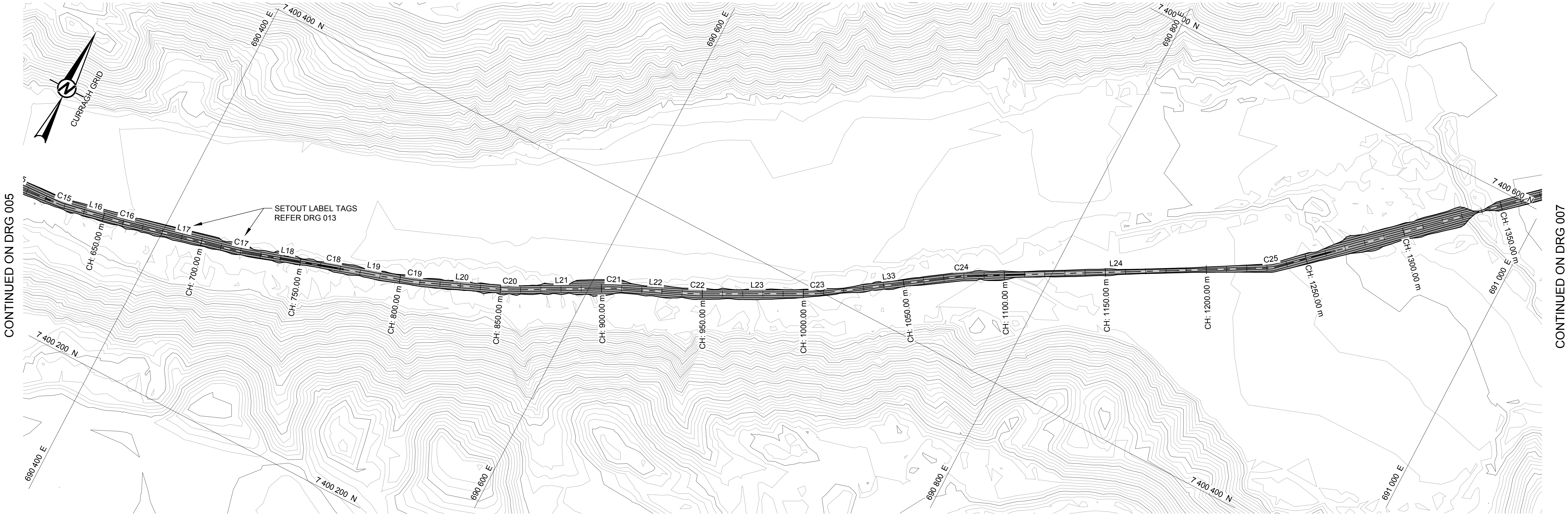
PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**STAGE 1 - PROTECTION BUND - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 1 OF 3**

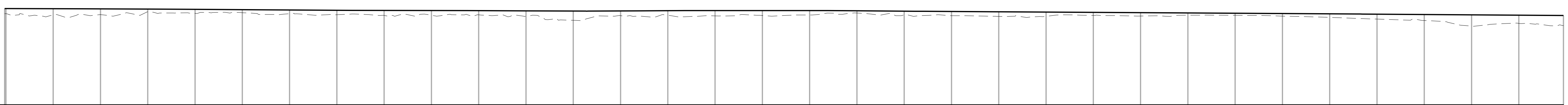
| PROJECT No. | CONTROL | Rev. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 6 of 16 | 005 |

Path: \\golder.gds\gap\Brisbane\Geomatics\WESFARMER_CURRAGH\CURRAGH\99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWG\ | File Name: 1532295-052-R-005 to 007.dwg

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3




PLAN VIEW
SCALE 1:2,000 m



DATUM 100.00

| CHAINAGE | PROPOSED GROUND | EXISTING GROUND | CUT AND FILL DEPTH (m) |
|---|---|---|---|
| 659.45 | 140.55 | 138.40 | 2.15 |
| 660.00 | 140.54 | 138.40 | 2.14 |
| 680.00 | 140.47 | 137.78 | 2.69 |
| 700.00 | 140.40 | 138.00 | 2.41 |
| 720.00 | 140.34 | 139.18 | 1.15 |
| 740.00 | 140.21 | 138.50 | 1.71 |
| 760.00 | 140.08 | 138.79 | 1.28 |
| 780.00 | 139.94 | 138.37 | 1.58 |
| 800.00 | 139.81 | 137.95 | 1.86 |
| 820.00 | 139.74 | 137.63 | 2.11 |
| 840.00 | 139.70 | 137.72 | 1.98 |
| 860.00 | 139.66 | 137.90 | 1.76 |
| 880.00 | 139.57 | 137.30 | 2.27 |
| 900.00 | 139.48 | 135.58 | 3.90 |
| 920.00 | 139.54 | 137.54 | 1.99 |
| 940.00 | 139.64 | 137.72 | 1.93 |
| 960.00 | 139.68 | 137.45 | 2.24 |
| 980.00 | 139.68 | 137.61 | 2.07 |
| 1000.00 | 139.68 | 137.82 | 1.87 |
| 1020.00 | 139.59 | 138.67 | 0.92 |
| 1040.00 | 139.44 | 137.88 | 1.56 |
| 1060.00 | 139.31 | 137.53 | 1.78 |
| 1080.00 | 139.19 | 137.24 | 1.95 |
| 1100.00 | 139.06 | 137.27 | 1.79 |
| 1120.00 | 138.94 | 137.67 | 1.27 |
| 1140.00 | 138.82 | 137.39 | 1.42 |
| 1160.00 | 138.69 | 137.73 | 0.96 |
| 1180.00 | 138.57 | 137.68 | 0.89 |
| 1200.00 | 138.44 | 137.35 | 1.10 |
| 1220.00 | 138.32 | 136.82 | 1.49 |
| 1240.00 | 138.18 | 136.10 | 2.09 |
| 1260.00 | 138.04 | 135.50 | 2.54 |
| 1280.00 | 137.89 | 133.17 | 4.72 |
| 1300.00 | 137.74 | 134.29 | 3.46 |
| 1318.90 | 137.60 | 133.37 | 4.23 |

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
**CONSTRUCTION**

0 50 100
1:2,000 METRES

| Rev. | YYYY-MM-DD | DESCRIPTION | PREPARED | DESIGN | REVIEW | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DDW | DAS | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DDW | DAS | MJG | MJG | DA SMALLHORN |

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CURRAGH Wesfarmers

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MILTON, QLD 4064
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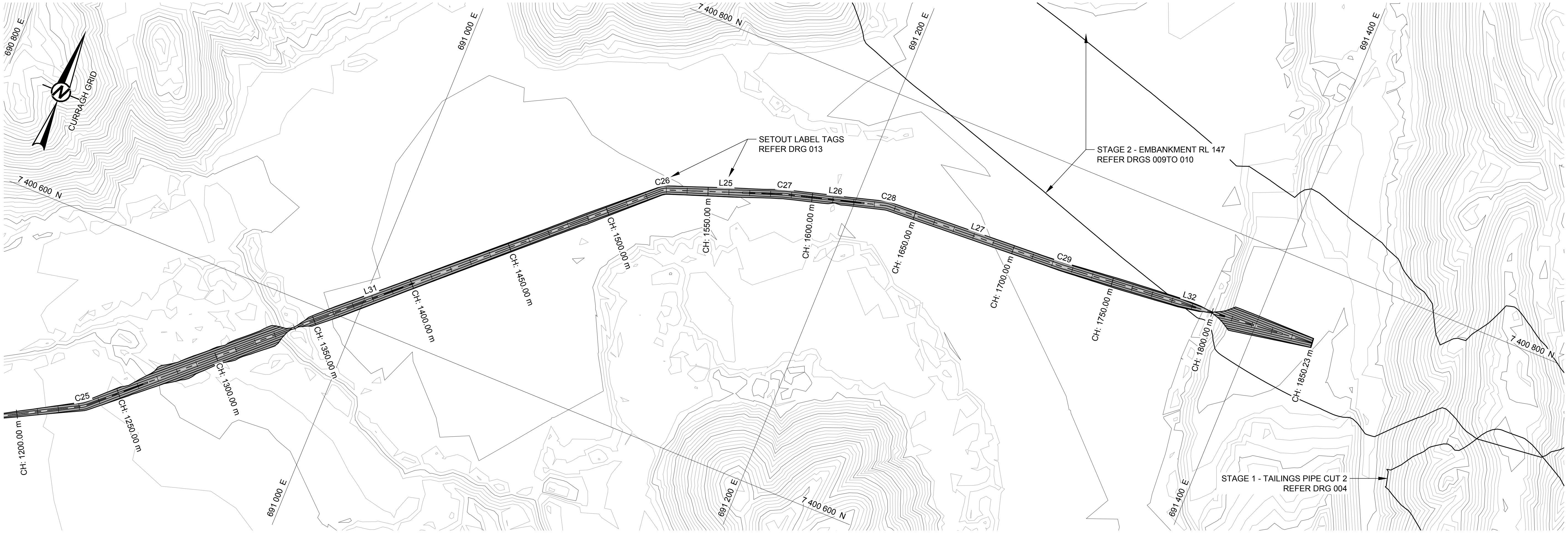

PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**STAGE 1 - PROTECTION BUND - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 2 OF 3**

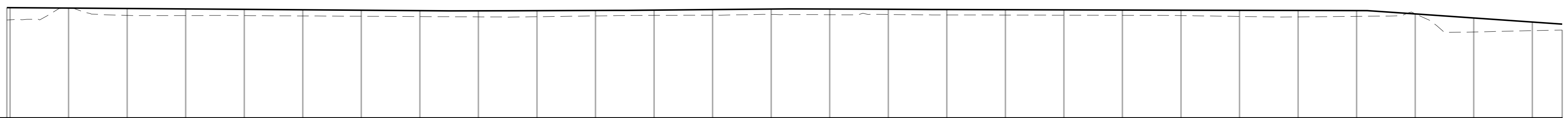
| PROJECT No. | CONTROL | Rev. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 7 of 16 | 006 |


Path: \\golder.gds\gap\Brisbane\Geomatics\WESFARMER_CURRAGH\CURRAGH\99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWG\ | File Name: 1532295-052-R-005 to 007.dwg
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0

CONTINUED ON DRG 006




PLAN VIEW
SCALE 1:2,000 m



DATUM 100.00

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PROPOSED GROUND | 137.60 | 137.59 | 137.45 | 137.30 | 137.15 | 137.01 | 136.86 | 136.71 | 136.56 | 136.52 |
| EXISTING GROUND | 133.37 | 133.44 | 137.59 | 134.95 | 134.90 | 134.87 | 134.77 | 134.66 | 134.55 | 134.43 |
| CUT AND FILL DEPTH (m) | 4.23 | 4.15 | -0.14 | 2.35 | 2.25 | 2.13 | 2.09 | 2.05 | 2.02 | 2.08 |
| CHAINAGE | 1318.90 | 1320.00 | 1340.00 | 1360.00 | 1380.00 | 1400.00 | 1420.00 | 1440.00 | 1460.00 | 1480.00 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PROPOSED GROUND | 136.57 | 136.63 | 136.76 | 136.94 | 137.12 | 137.12 | 137.02 | 136.94 | 136.88 | 136.82 |
| EXISTING GROUND | 134.49 | 134.76 | 134.97 | 135.02 | 135.27 | 135.18 | 135.25 | 135.11 | 135.07 | 135.02 |
| CUT AND FILL DEPTH (m) | 2.08 | 1.86 | 1.79 | 1.92 | 1.85 | 1.94 | 1.77 | 1.83 | 1.81 | 1.80 |
| CHAINAGE | 1500.00 | 1520.00 | 1540.00 | 1560.00 | 1580.00 | 1600.00 | 1620.00 | 1640.00 | 1660.00 | 1680.00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PROPOSED GROUND | 136.77 | 136.71 | 136.66 | 136.62 | 136.58 | 135.44 | 134.06 | 132.67 | |
| EXISTING GROUND | 134.98 | 134.88 | 134.59 | 134.43 | 134.61 | 135.50 | 129.28 | 129.72 | 129.95 |
| CUT AND FILL DEPTH (m) | 1.79 | 1.83 | 2.07 | 2.19 | 1.96 | -0.06 | 4.77 | 2.95 | |
| CHAINAGE | 1700.00 | 1720.00 | 1740.00 | 1760.00 | 1780.00 | 1800.00 | 1820.00 | 1840.00 | 1850.23 |

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
**CONSTRUCTION**

0 50 100
1:2,000 METRES

| Rev. | YYYY-MM-DD | DESCRIPTION | PREPARED | DESIGN | REVIEW | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DDW | DAS | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DDW | DAS | MJG | MJG | DA SMALLHORN |

CLIENT
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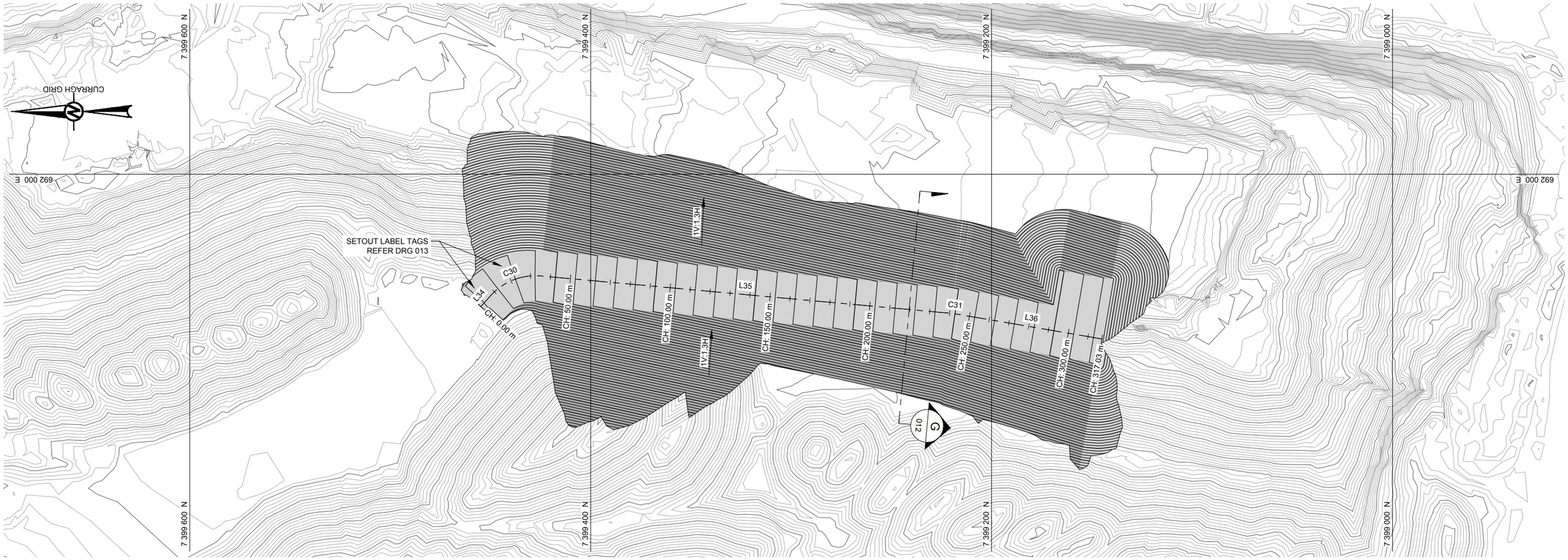
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AUSTRALIA
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PROJECT
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PIT B TSF EARTHWORKS

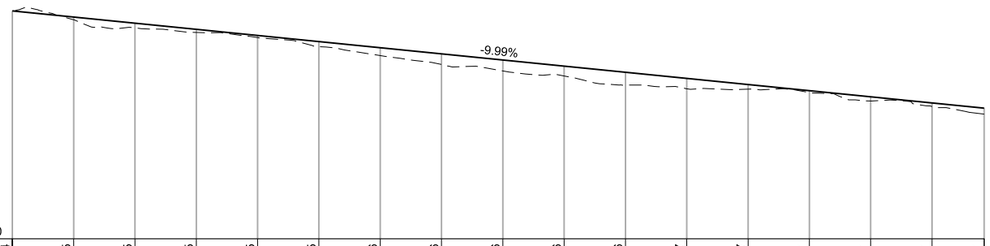
TITLE
**STAGE 1 - PROTECTION BUND - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 3 OF 3**

| PROJECT No. | CONTROL | Rev. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 8 of 16 | 007 |

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0
Path: \\golder.gds\gap\Brisbane\Geomatics\WESFARMER_CURRAGH\CURRAGH\99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWG\ | File Name: 1532295-052-R-005 to 007.dwg




PLAN VIEW
SCALE 1:2,000 m




| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATUM 50,00 | | | | | | | | | | | | | | | | | | | | | |
| PROPOSED GROUND | 124.24 | 122.25 | 120.25 | 118.25 | 116.25 | 114.25 | 112.26 | 110.26 | 108.26 | 106.26 | 104.26 | 102.27 | 100.27 | 98.27 | 96.27 | 94.27 | 92.57 | | | | |
| EXISTING GROUND | 124.24 | 121.38 | 118.72 | 117.25 | 115.58 | 112.61 | 109.69 | 106.81 | 104.70 | 103.06 | 100.07 | 98.89 | 98.75 | 97.66 | 94.91 | 93.06 | 90.62 | | | | |
| CUT AND FILL DEPTH (m) | 0.00 | 0.87 | 1.52 | 1.00 | 0.67 | 1.65 | 2.56 | 3.45 | 3.56 | 3.20 | 4.19 | 3.38 | 1.52 | 0.61 | 1.36 | 1.22 | 1.95 | | | | |
| CHAINAGE | 0.00 | 20.00 | 40.00 | 60.00 | 80.00 | 100.00 | 120.00 | 140.00 | 160.00 | 180.00 | 200.00 | 220.00 | 240.00 | 260.00 | 280.00 | 300.00 | 317.03 | | | | |

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
**CONSTRUCTION**

0 50 100
1:2,000 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

CLIENT
CURRAGH Wesfarmers

CONSULTANT
Golder Associates

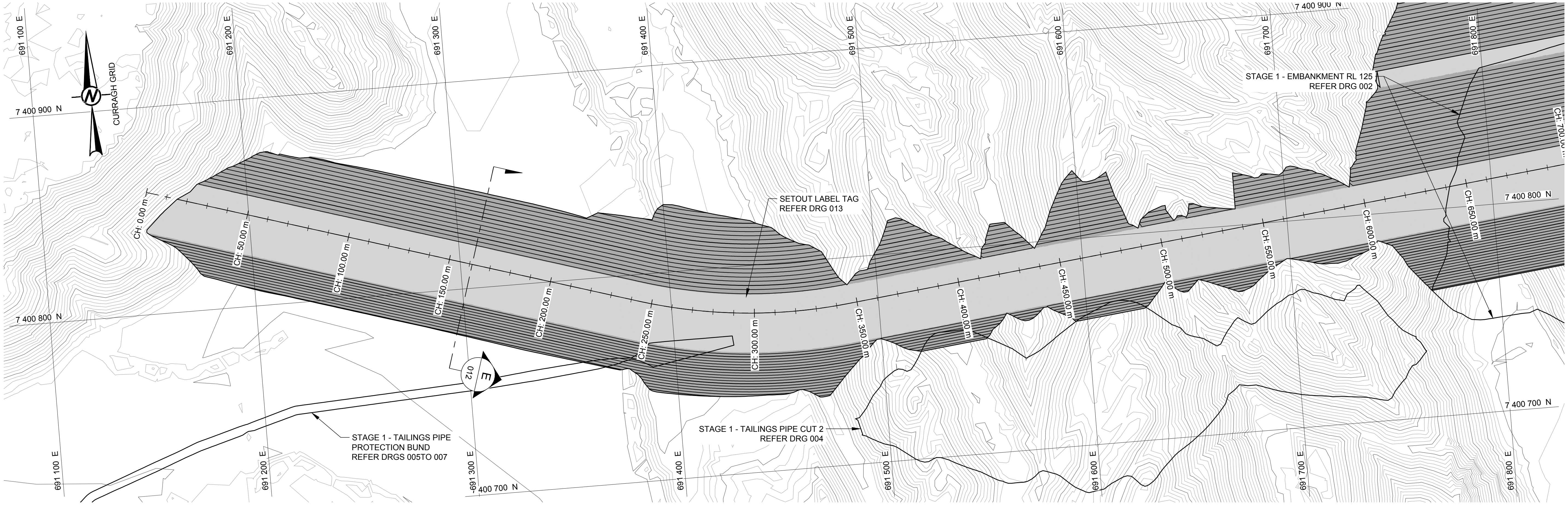
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147 CORONATION DRIVE
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AUSTRALIA
[+61] (7) 3721 5400
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PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**STAGE 1 - DECANT RAMP - PLAN VIEW AND LONGITUDINAL SECTION**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 9 of 16 | 008 |

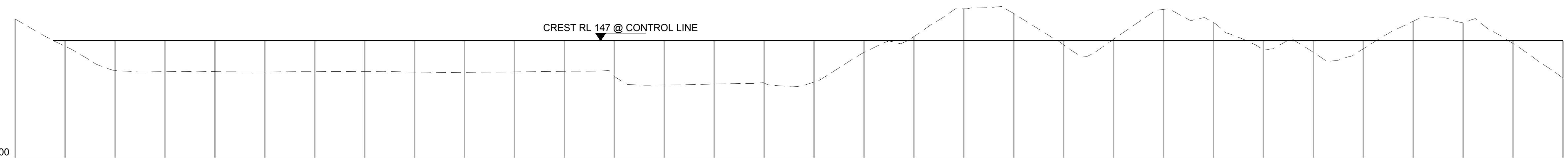
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0




CONTINUED ON DRG 010

PLAN VIEW

SCALE 1:2,000 m




DATUM 100.00

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROPOSED GROUND | | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 |
| EXISTING GROUND | 155.64 | 144.77 | 135.10 | 134.59 | 134.62 | 134.49 | 134.60 | 134.67 | 134.45 | 134.30 | 134.51 | 134.71 | 132.87 | 129.25 | 129.64 | 130.08 |
| CUT AND FILL DEPTH (m) | | 2.23 | 11.90 | 12.41 | 12.38 | 12.51 | 12.40 | 12.33 | 12.55 | 12.70 | 12.49 | 12.29 | 14.13 | 17.75 | 17.36 | 16.92 |
| CHAINAGE | 0.00 | 20.00 | 40.00 | 60.00 | 80.00 | 100.00 | 120.00 | 140.00 | 160.00 | 180.00 | 200.00 | 220.00 | 240.00 | 260.00 | 280.00 | 300.00 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROPOSED GROUND | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 | 147.00 |
| EXISTING GROUND | 130.44 | 142.31 | 148.65 | 159.76 | 157.87 | 145.32 | 147.60 | 159.54 | 154.21 | 143.39 | 142.35 | 143.75 | 154.77 | 154.16 | 145.85 | 131.99 |
| CUT AND FILL DEPTH (m) | 16.56 | 4.69 | -1.65 | -12.76 | -10.87 | 1.68 | -0.60 | -12.54 | -7.21 | 3.61 | 4.65 | 3.25 | -7.77 | -7.16 | 1.15 | 15.01 |
| CHAINAGE | 320.00 | 340.00 | 360.00 | 380.00 | 400.00 | 420.00 | 440.00 | 460.00 | 480.00 | 500.00 | 520.00 | 540.00 | 560.00 | 580.00 | 600.00 | 620.00 |

LONGITUDINAL SECTION

SCALE 1:2,000 m

ISSUED FOR

**CONSTRUCTION**

0 50 100

1:2,000 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

CLIENT

CURRAGH Wesfarmers

CONSULTANT

Golder Associates

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

PROJECT

WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE

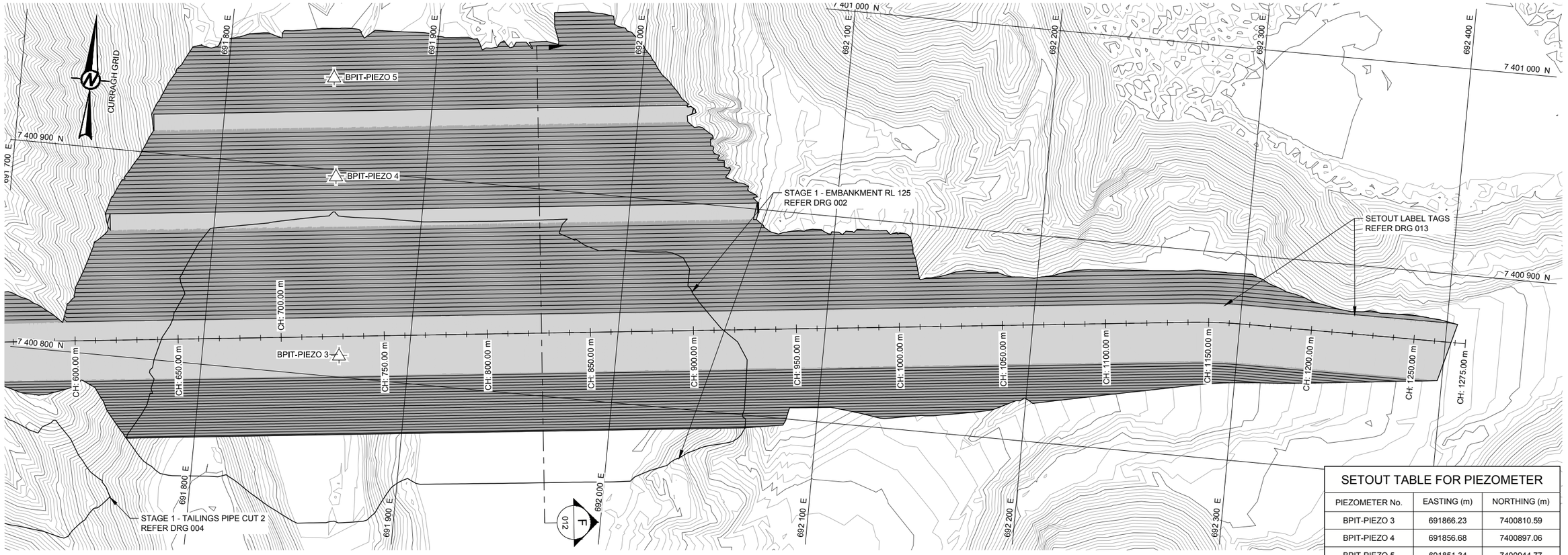
**STAGE 2 - EMBANKMENT RL 147 - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 1 OF 2**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 10 of 16 | 009 |

Path: \\golder.gds\gap\Brisbane\Geomatics\WESFARMER_CURRAGH\CURRAGH\99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWG\ | File Name: 1532295-052-R-009 to 010.dwg | Last Edited By: rfigueiredo Date: 2017-04-26 Time:10:59:10 AM | Printed By: dwillemse Date: 2017-11-08 Time:12:34:13 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0

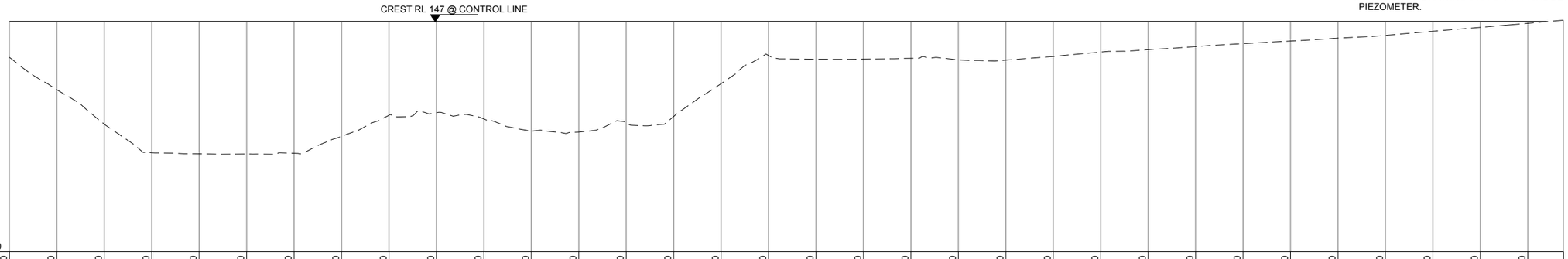
CONTINUED ON DRG 009




PLAN VIEW
SCALE 1:2,000 m

| SETOUT TABLE FOR PIEZOMETER | | |
|---|---|---|
| PIEZOMETER No. | EASTING (m) | NORTHING (m) |
| BPIT-PIEZO 3 | 691866.23 | 7400810.59 |
| BPIT-PIEZO 4 | 691856.68 | 7400897.06 |
| BPIT-PIEZO 5 | 691851.34 | 7400944.77 |

**NOTE(S)**
1. REFER TO DRAWING 015 FOR TYPICAL DETAIL OF PIEZOMETER.




DATUM 50.00

| CHAINAGE | PROPOSED GROUND | EXISTING GROUND | CUT AND FILL DEPTH (m) |
|---|---|---|---|
| 620.00 | 147.00 | 131.99 | 15.01 |
| 640.00 | 147.00 | 118.30 | 28.70 |
| 660.00 | 147.00 | 103.80 | 43.20 |
| 680.00 | 147.00 | 91.72 | 55.28 |
| 700.00 | 147.00 | 91.29 | 55.71 |
| 720.00 | 147.00 | 91.18 | 55.82 |
| 740.00 | 147.00 | 91.49 | 55.51 |
| 760.00 | 147.00 | 98.64 | 48.36 |
| 780.00 | 147.00 | 107.58 | 39.42 |
| 800.00 | 147.00 | 108.62 | 38.38 |
| 820.00 | 147.00 | 105.99 | 41.01 |
| 840.00 | 147.00 | 100.88 | 46.12 |
| 860.00 | 147.00 | 100.45 | 46.55 |
| 880.00 | 147.00 | 104.25 | 42.75 |
| 900.00 | 147.00 | 107.01 | 39.99 |
| 920.00 | 147.00 | 120.87 | 26.13 |
| 940.00 | 147.00 | 132.71 | 14.29 |
| 960.00 | 147.00 | 131.18 | 15.82 |
| 980.00 | 147.00 | 131.24 | 15.76 |
| 1000.00 | 147.00 | 131.56 | 15.44 |
| 1020.00 | 147.00 | 130.90 | 16.10 |
| 1040.00 | 147.00 | 130.80 | 16.20 |
| 1060.00 | 147.00 | 132.34 | 14.66 |
| 1080.00 | 147.00 | 134.18 | 12.82 |
| 00.00 | 147.00 | 135.19 | 11.81 |
| 20.00 | 147.00 | 136.49 | 10.51 |
| 1140.00 | 147.00 | 137.71 | 9.29 |
| 1160.00 | 147.00 | 138.82 | 8.18 |
| 1180.00 | 147.00 | 140.06 | 6.94 |
| 1200.00 | 147.00 | 141.22 | 5.78 |
| 1220.00 | 147.00 | 142.94 | 4.06 |
| 1240.00 | 147.00 | 144.61 | 2.39 |
| 1260.00 | 147.00 | 146.30 | 0.70 |
| 1275.00 | | 147.61 | |

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
# CONSTRUCTION

0 50 100
1:2,000 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

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CURRAGH Wesfarmers

CONSULTANT
Golder Associates

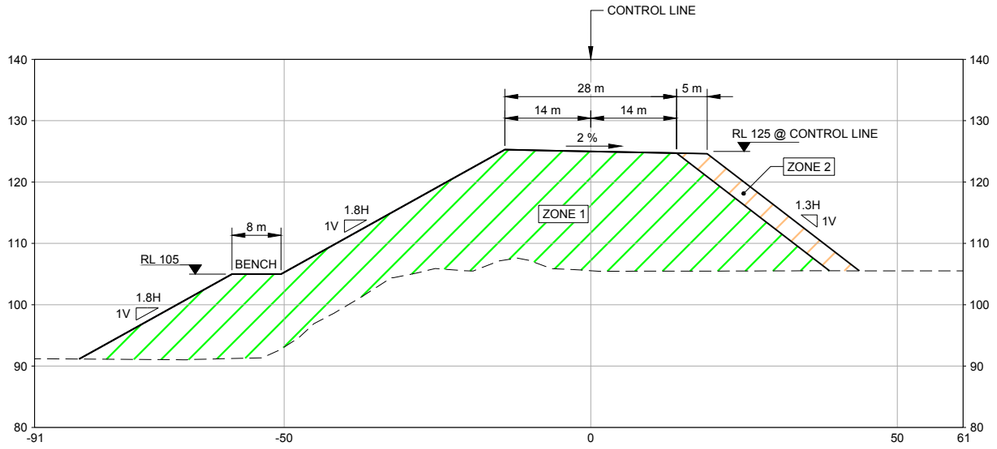
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
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PROJECT
WESFARMERS CURRAGH PTY LTD
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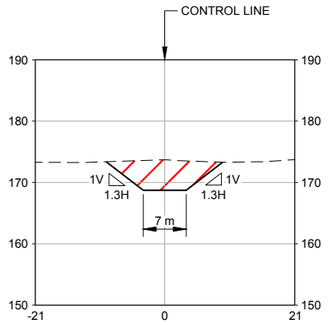
TITLE
**STAGE 2 - EMBANKMENT RL 147 - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 2 OF 2**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 11 of 16 | 010 |

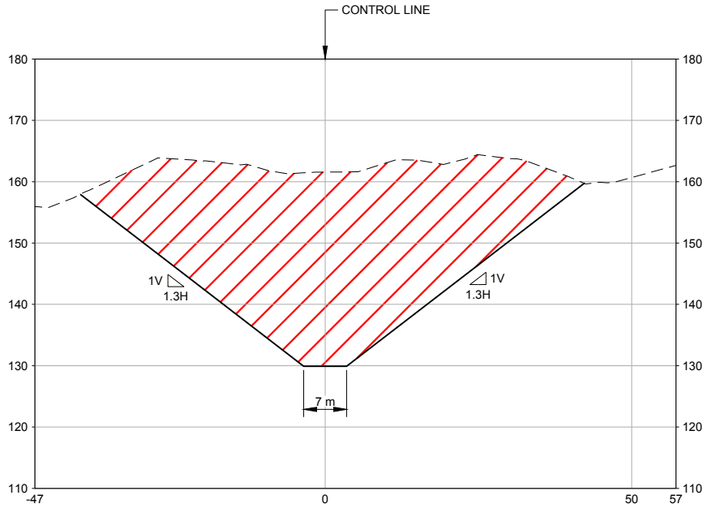
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0



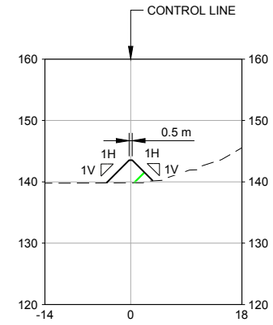

SCALE 1:1,000 m A 002 SECTION - STAGE 1 - WALL RL 125



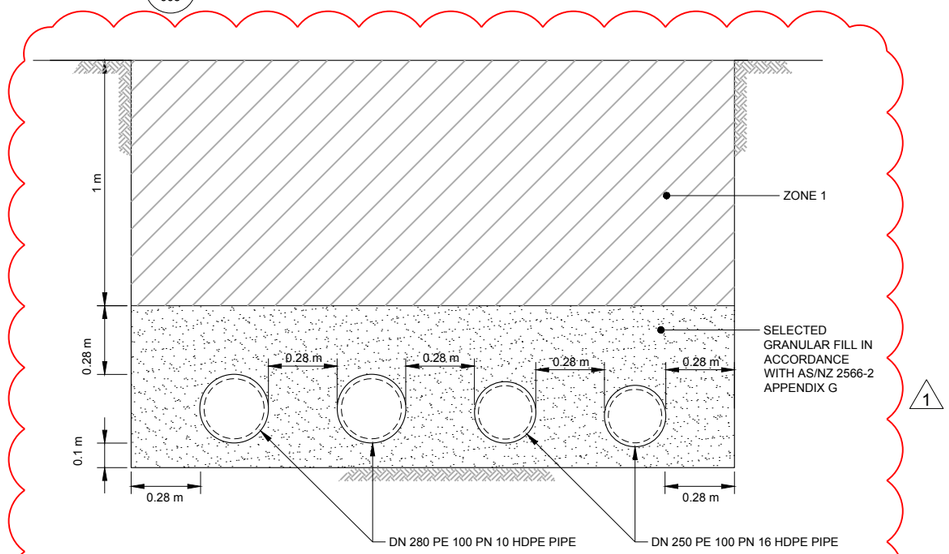

SCALE 1:1,000 m B 003 SECTION - STAGE 1 - TAILINGS PIPE CUT 1



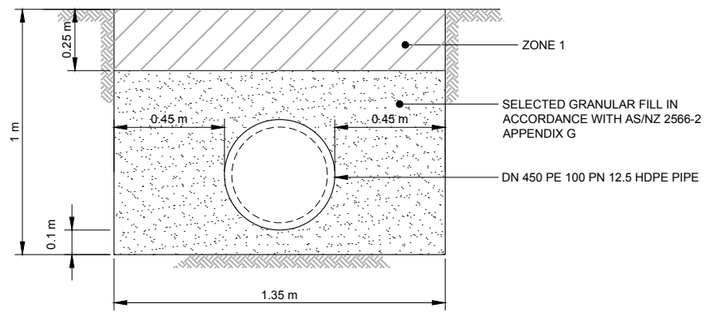

SCALE 1:1,000 m C 004 SECTION - STAGE 1 - TAILINGS PIPE CUT 2




SCALE 1:1,000 m D 005 SECTION - STAGE 1 - PROTECTION BUND




TYPICAL SECTION - TAILINGS PIPE HAUL ROAD TRENCH
SCALE 1:25 m




TYPICAL SECTION - DECANT RETURN PIPE LIGHT VEHICLE CROSSING
SCALE 1:25 m

**LEGEND**

- EXISTING GROUND SURFACE
- DESIGN SURFACE
- FILL - ZONE 1
- FILL - ZONE 2
- CUT

**NOTES**

1. ZONE 1 MATERIAL TO COMPRISE SELECTED INTERBURDEN SPOIL.
2. ZONE 1 MATERIAL TO BE PLACED IN 2 m LIFTS BY PADDOCK DUMPING AND DOZING, AND COMPACTED BY TRAFFICING HAUL PLANT.
3. ZONE 2 MATERIAL TO COMPRISE SELECTED REJECTS.
4. ZONE 2 MATERIAL TO BE TRACKED ROLLED.

ISSUED FOR
**CONSTRUCTION**

0 0.5 1
1:25 METRES

0 25 50
1:1,000 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

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147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
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PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**TYPICAL CROSS SECTIONS - SHEET 1 OF 2**

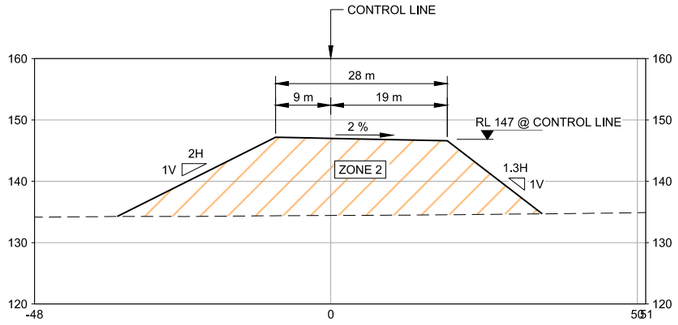
| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 12 of 16 | 011 |

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

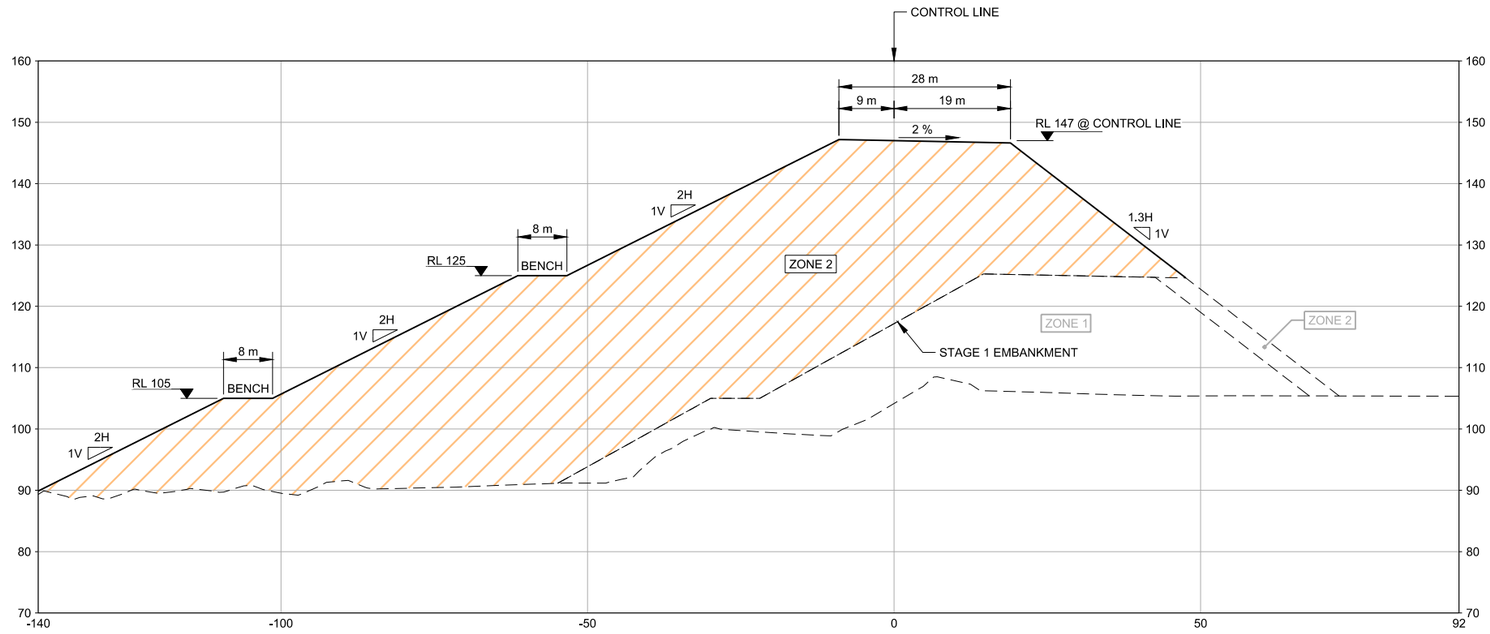
25 mm

0

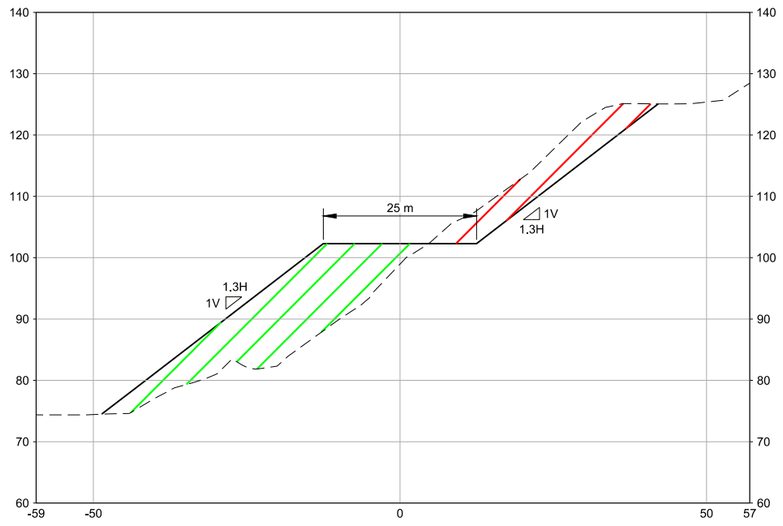
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SCALE 1:1,000 m E 009 SECTION - STAGE 2 - WALL RL 147




SCALE 1:1,000 m F 010 SECTION - STAGE 2 - WALL RL 147




SCALE 1:1,000 m G 008 SECTION - STAGE 1 - DECANT RAMP

**LEGEND**

- EXISTING GROUND SURFACE
- DESIGN SURFACE
- FILL - ZONE 1
- FILL - ZONE 2
- CUT

**NOTES**

1. ZONE 1 MATERIAL TO COMPRISE SELECTED INTERBURDEN SPOIL.
2. ZONE 1 MATERIAL TO BE PLACED IN 2 m LIFTS BY PADDOCK DUMPING AND DOZING, AND COMPACTED BY TRAFFICING HAUL PLANT.
3. ZONE 2 MATERIAL TO COMPRISE SELECTED REJECTS.
4. ZONE 2 MATERIAL TO BE TRACKED ROLLED.

ISSUED FOR

**CONSTRUCTION**

0 25 50

1:1,000 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

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PROJECT
WESFARMERS CURRAGH PTY LTD
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TITLE
**TYPICAL CROSS SECTIONS - SHEET 2 OF 2**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 13 of 16 | 012 |

Path: \\golder.gds\gap\Brisbane\Geomatics\WESFARMER_CURRAGH\CURRAGH99_PROJECTS\1532295_B-G PIT DETAIL_DESIGN\02_PRODUCTION\DWG\ | File Name: 1532295-052-R-011 to 012.dwg | Last Edited By: vkasted Date: 2017-03-20 Time:10:28:41 AM | Printed By: dwillemse Date: 2017-11-08 Time:12:34:38 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

0 25 mm

## EMBANKMENT STAGE 1 - RL125

| TAG NUMBER | START STATION<br>END STATION | START EASTING<br>START NORTHING | END EASTING<br>END NORTHING | RADIUS (m) | LENGTH (m) |
|---|---|---|---|---|---|
| L1 | 0.00<br>400.80 | 691723.53<br>7400775.23 | 692121.92<br>7400819.18 | | 400.80 |

## TAILINGS PIPE CUT 1

| TAG NUMBER | START STATION<br>END STATION | START EASTING<br>START NORTHING | END EASTING<br>END NORTHING | RADIUS (m) | LENGTH (m) |
|---|---|---|---|---|---|
| L2 | 0.00<br>195.11 | 689620.72<br>7399958.93 | 689680.07<br>7400144.80 | | 195.11 |
| C1 | 195.11<br>199.58 | 689680.07<br>7400144.80 | 689682.32<br>7400148.61 | 10 | 4.47 |
| L3 | 199.58<br>327.11 | 689682.32<br>7400148.61 | 689769.79<br>7400241.42 | | 127.53 |

## TAILINGS PIPE CUT 2

| TAG NUMBER | START STATION<br>END STATION | START EASTING<br>START NORTHING | END EASTING<br>END NORTHING | RADIUS (m) | LENGTH (m) |
|---|---|---|---|---|---|
| L4 | 0.00<br>434.77 | 691367.69<br>7400710.06 | 691801.54<br>7400738.37 | | 434.77 |

## DECANT RAMP

| TAG NUMBER | START STATION<br>END STATION | START EASTING<br>START NORTHING | END EASTING<br>END NORTHING | RADIUS (m) | LENGTH (m) |
|---|---|---|---|---|---|
| L34 | 0.00<br>7.27 | 691933.96<br>7399454.80 | 691939.38<br>7399449.95 | | 7.27 |
| C30 | 7.27<br>35.19 | 691939.38<br>7399449.95 | 691949.23<br>7399424.89 | 30 | 27.92 |
| L35 | 35.19<br>239.56 | 691949.23<br>7399424.89 | 691930.69<br>7399221.36 | | 204.37 |
| C31 | 239.56<br>244.31 | 691930.69<br>7399221.36 | 691930.08<br>7399216.66 | 60 | 4.74 |
| L36 | 244.31<br>317.03 | 691930.08<br>7399216.66 | 691917.78<br>7399144.98 | | 72.73 |

## EMBANKMENT STAGE 2 - RL147

| TAG NUMBER | START STATION<br>END STATION | START EASTING<br>START NORTHING | END EASTING<br>END NORTHING | RADIUS (m) | LENGTH (m) |
|---|---|---|---|---|---|
| L37 | 0.00<br>243.31 | 691151.59<br>7400858.94 | 691384.12<br>7400787.29 | | 243.31 |
| C32 | 243.31<br>345.51 | 691384.12<br>7400787.29 | 691485.15<br>7400777.71 | 250 | 102.20 |
| L38 | 345.51<br>1140.87 | 691485.15<br>7400777.71 | 692275.72<br>7400864.92 | | 795.36 |
| C33 | 1140.87<br>1167.03 | 692275.72<br>7400864.92 | 692301.82<br>7400866.42 | 250 | 26.16 |
| L39 | 1167.03<br>1275.00 | 692301.82<br>7400866.42 | 692409.79<br>7400866.98 | | 107.97 |

## PROTECTION BUND

| TAG NUMBER | START STATION<br>END STATION | START EASTING<br>START NORTHING | END EASTING<br>END NORTHING | RADIUS (m) | LENGTH (m) |
|---|---|---|---|---|---|
| L5 | 0.00<br>20.08 | 689735.01<br>7400231.67 | 689753.24<br>7400240.09 | | 20.08 |
| C2 | 20.08<br>21.65 | 689753.24<br>7400240.09 | 689754.70<br>7400240.63 | 10 | 1.56 |
| L28 | 21.65<br>151.70 | 689754.70<br>7400240.63 | 689879.83<br>7400276.10 | | 130.06 |
| C3 | 151.70<br>152.18 | 689879.83<br>7400276.10 | 689880.29<br>7400276.22 | 10 | 0.47 |
| L29 | 152.18<br>224.62 | 689880.29<br>7400276.22 | 689950.84<br>7400292.64 | | 72.44 |
| C4 | 224.62<br>225.68 | 689950.84<br>7400292.64 | 689951.89<br>7400292.83 | 10 | 1.06 |
| L30 | 225.68<br>277.48 | 689951.89<br>7400292.83 | 690003.30<br>7400299.15 | | 51.80 |
| C5 | 277.48<br>277.85 | 690003.30<br>7400299,15 | 690003.67<br>7400299.19 | 10 | 0.37 |
| L6 | 277.85<br>308.06 | 690003.67<br>7400299.19 | 690033.77<br>7400301.78 | | 30.22 |
| C6 | 308.06<br>308.66 | 690033.77<br>7400301.78 | 690034.37<br>7400301.81 | 10 | 0.60 |
| L7 | 308.66<br>341.81 | 690034.37<br>7400301.81 | 690067.51<br>7400302.67 | | 33.15 |
| C7 | 341.81<br>342.54 | 690067.51<br>7400302.67 | 690068.24<br>7400302.66 | 10 | 0.73 |
| L8 | 342.54<br>373.33 | 690068.24<br>7400302.66 | 690098.99<br>7400301.22 | | 30.79 |
| C8 | 373.33<br>373.86 | 690098.99<br>7400301.22 | 690099.53<br>7400301.18 | 10 | 0.54 |
| L9 | 373.86<br>410.26 | 690099.53<br>7400301.18 | 690135.74<br>7400297.53 | | 36.40 |
| C9 | 410.26<br>411.44 | 690135.74<br>7400297.53 | 690136.90<br>7400297.34 | 10 | 1.18 |
| L10 | 411.44<br>452.22 | 690136.90<br>7400297.34 | 690176.71<br>7400288.50 | | 40.78 |
| C10 | 452.22<br>452.26 | 690176.71<br>7400288.50 | 690176.75<br>7400288.49 | 10 | 0.04 |
| L11 | 452.26<br>480.58 | 690176.75<br>7400288.49 | 690204.37<br>7400282.23 | | 28.32 |
| C11 | 480.58<br>481.34 | 690204.37<br>7400282.23 | 690205.10<br>7400282.03 | 10 | 0.76 |
| L12 | 481.34<br>515.67 | 690205.10<br>7400282.03 | 690237.91<br>7400271.94 | | 34.33 |
| C12 | 515.67<br>517.06 | 690237.91<br>7400271.94 | 690239.26<br>7400271.62 | 10 | 1.39 |
| L13 | 517.06<br>548.94 | 690239.26<br>7400271.62 | 690270.74<br>7400266.55 | | 31.88 |
| C13 | 548.94<br>549.20 | 690270.74<br>7400266.55 | 690271.00<br>7400266.51 | 10 | 0.26 |
| L14 | 549.20<br>577.82 | 690271.00<br>7400266.51 | 690299.13<br>7400261.23 | | 28.62 |
| C14 | 577.82<br>580.42 | 690299.13<br>7400261.23 | 690301.72<br>7400261.09 | 10 | 2.60 |
| L15 | 580.42<br>627.71 | 690301.72<br>7400261.09 | 690348.88<br>7400264.62 | | 47.29 |
| C15 | 627.71<br>629.03 | 690348.88<br>7400264.62 | 690350.18<br>7400264.81 | 10 | 1.31 |
| L16 | 629.03<br>660.79 | 690350.18<br>7400264.81 | 690381.27<br>7400271.31 | | 31.76 |
| C16 | 660.79<br>661.10 | 690381.27<br>7400271.31 | 690381.57<br>7400271.38 | 10 | 0.31 |

## PROTECTION BUND

| TAG NUMBER | START STATION<br>END STATION | START EASTING<br>START NORTHING | END EASTING<br>END NORTHING | RADIUS (m) | LENGTH (m) |
|---|---|---|---|---|---|
| L17 | 661.10<br>719.13 | 690381.57<br>7400271.38 | 690437.97<br>7400285.02 | | 58.03 |
| C17 | 719.13<br>719.84 | 690437.97<br>7400285.02 | 690438.66<br>7400285.21 | 10 | 0.72 |
| L18 | 719.84<br>765.92 | 690438.66<br>7400285.21 | 690482.56<br>7400299.23 | | 46.08 |
| C18 | 765.92<br>765.97 | 690482.56<br>7400299.23 | 690482.60<br>7400299.24 | 10 | 0.05 |
| L19 | 765.97<br>806.40 | 690482.60<br>7400299,24 | 690521.17<br>7400311.36 | | 40.43 |
| C19 | 806.40<br>807.32 | 690521.17<br>7400311.36 | 690522.03<br>7400311.68 | 10 | 0.92 |
| L20 | 807.32<br>854.04 | 690522.03<br>7400311.68 | 690565.14<br>7400329.71 | | 46.72 |
| C20 | 854.04<br>855.05 | 690565.14<br>7400329.71 | 690566.05<br>7400330.15 | 10 | 1.01 |
| L21 | 855.05<br>905.27 | 690566.05<br>7400330.15 | 690610.19<br>7400354.10 | | 50.22 |
| C21 | 905.27<br>906.12 | 690610.19<br>7400354.10 | 690610.95<br>7400354.47 | 10 | 0.85 |
| L22 | 906.12<br>947.15 | 690610.95<br>7400354.47 | 690648.54<br>7400370.91 | | 41.03 |
| C22 | 947.15<br>947.84 | 690648.54<br>7400370.91 | 690649.16<br>7400371.21 | 10 | 0.69 |
| L23 | 947.84<br>1006.59 | 690649.16<br>7400371.21 | 690701.23<br>7400398.42 | | 58.75 |
| C23 | 1006.59<br>1007.78 | 690701.23<br>7400398.42 | 690702.25<br>7400399.04 | 10 | 1.19 |
| L33 | 1007.78<br>1078.59 | 690702.25<br>7400399.04 | 690760.65<br>7400439.07 | | 70.80 |
| C24 | 1078.59<br>1079.53 | 690760.65<br>7400439.07 | 690761.45<br>7400439.56 | 10 | 0.94 |
| L24 | 1079.53<br>1231.37 | 690761.45<br>7400439.56 | 690894.22<br>7400513.26 | | 151.84 |
| C25 | 1231.37<br>1233.76 | 690894.22<br>7400513.26 | 690896.15<br>7400514.65 | 10 | 2.39 |
| L31 | 1233.76<br>1526.84 | 690896.15<br>7400514.65 | 691111.53<br>7400713.41 | | 293.08 |
| C26 | 1526.84<br>1530.77 | 691111.53<br>7400713.41 | 691114.86<br>7400715.45 | 10 | 3.93 |
| L25 | 1530.77<br>1586.07 | 691114.86<br>7400715.45 | 691166.77<br>7400734.53 | | 55.30 |
| C27 | 1586.07<br>1586.83 | 691166.77<br>7400734.53 | 691167.49<br>7400734.76 | 10 | 0.76 |
| L26 | 1586.83<br>1634.84 | 691167.49<br>7400734.76 | 691213.68<br>7400747.85 | | 48.01 |
| C28 | 1634.84<br>1637.07 | 691213.68<br>7400747.85 | 691215.88<br>7400748.22 | 10 | 2.23 |
| L27 | 1637.07<br>1724.43 | 691215.88<br>7400748.22 | 691303.11<br>7400752.89 | | 87.36 |
| C29 | 1724.43<br>1724.82 | 691303.11<br>7400752.89 | 691303.50<br>7400752.92 | 10 | 0.39 |
| L32 | 1724.82<br>1850.23 | 691303.50<br>7400752.92 | 691428.38<br>7400764.46 | | 125.41 |

ISSUED FOR

**CONSTRUCTION**

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |
| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

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CURRAGH Wesfarmers

CONSULTANT

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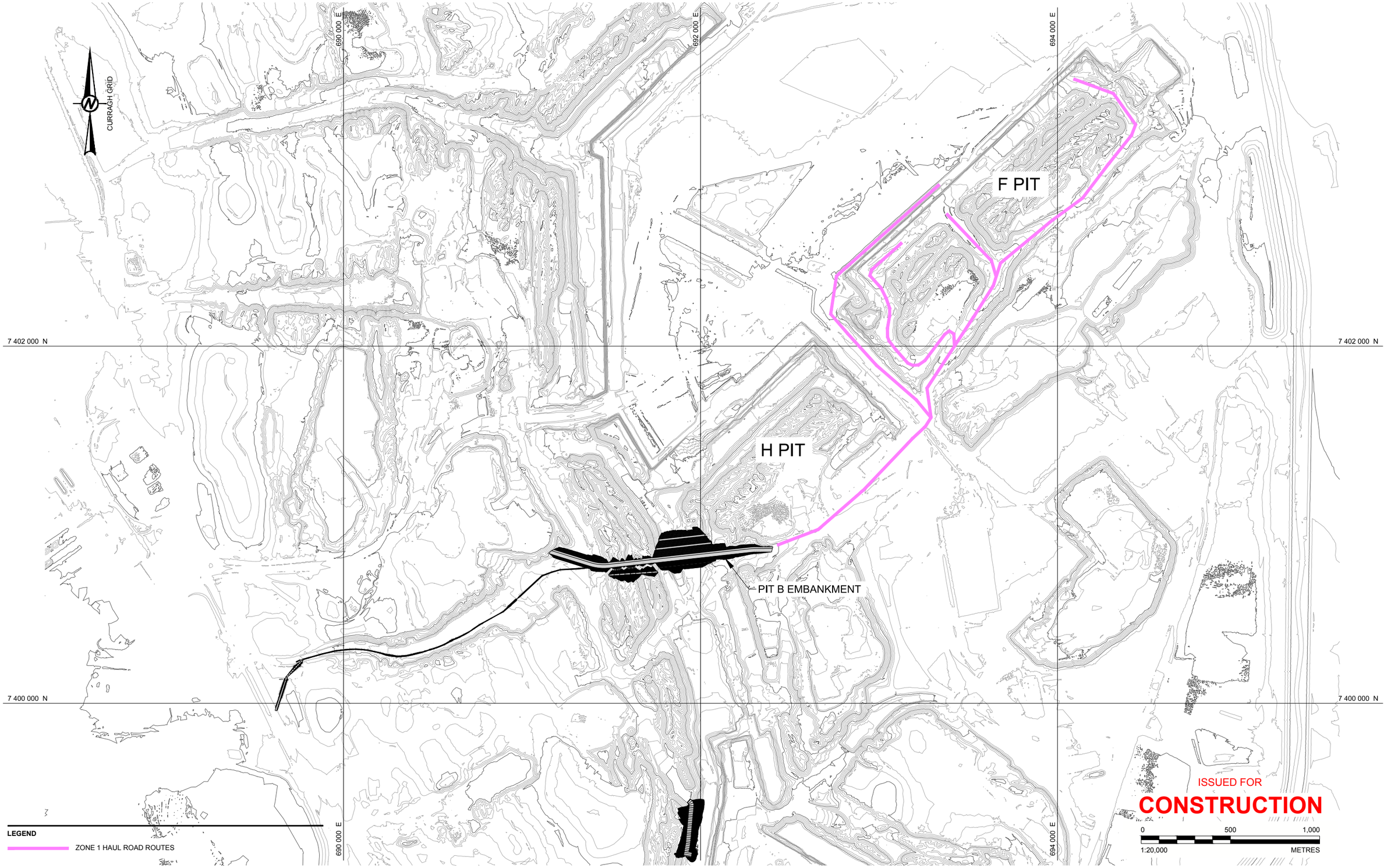
PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**SETOUT TABLES**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 1532295 | 052-R | 1 | 14 of 16 | 013 |

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
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| 0 | 2017-02-01 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |

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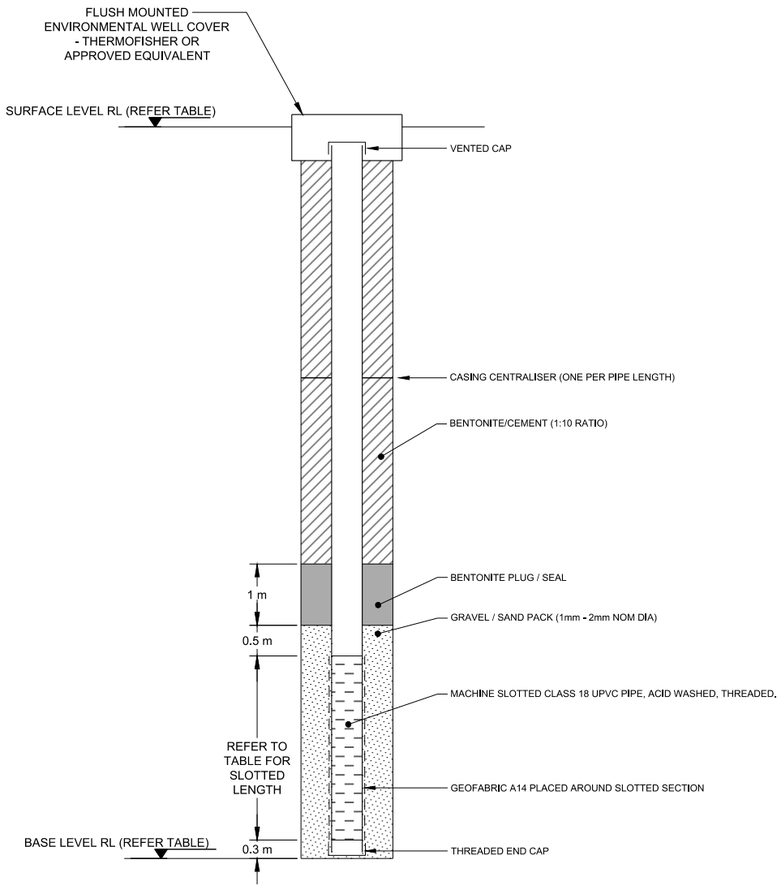
TITLE
**ZONE 1 BORROW LOCATION**

| PROJECT NO. | CONTROL | REV. | DRAWING |
|---|---|---|---|
| 1532295 | 052-R | 1 | 014 |

15 of 16

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

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TYPICAL MONITORING BORE
SCALE NTS

| PIEZOMETER No. | SURFACE LEVEL | BORE DEPTH BELOW SURFACE LEVEL (m) | SLOTTED PVC LENGTH (m) | BASE LEVEL RL |
|---|---|---|---|---|
| BPIT-PIEZO 1 | 125 | 25 | 16 | 100 |
| BPIT-PIEZO 2 | 105 | 10 | 16 | 95 |
| BPIT-PIEZO 3 | 147 | 49 | 16 | 98 |
| BPIT-PIEZO 4 | 125 | 40 | 16 | 85 |
| BPIT-PIEZO 5 | 105 | 24 | 16 | 81 |

ISSUED FOR
**CONSTRUCTION**

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED | RPEQ |
|---|---|---|---|---|---|---|---|
| 1 | 2017-05-04 | ISSUED FOR CONSTRUCTION | DAS | DDW | MJG | MJG | DA SMALLHORN |
| 0 | 2016-01-13 | NOT ISSUED | DAS | DDW | MJG | MJG | DA SMALLHORN |

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PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
**EMBANKMENT MONITORING BORES - TYPICAL DETAIL AND SETOUT TABLE**

| PROJECT NO. | CONTROL | REV. | DRAWING |
|---|---|---|---|
| 1532295 | 052-R | 1 | 015 |

16 of 16

Path: \\golder.gds\gal\Brisbane\Geomatics\WESFARMER_CURRAGH\CURRAGH99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWGS | Last Edited By: dwillemse Date: 2017-11-08 Time:12:30:28 PM | Printed By: dwillemse Date: 2017-11-08 Time:12:35:16 PM
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25 mm
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02 February 2017

TECHNICAL SPECIFICATION

A world of capabilities delivered locally

## CURRAGH COAL MINE

# B PIT TSF EARTHWORKS

**Submitted to:**
Howard Lief
Wesfarmers Curragh Pty Ltd

**Specification Number.** 1532295-051-S-Rev0

Golder Associates

# Record of Issue

| Company | Client Contact | Version | Date Issued | Method of Delivery |
|---|---|---|---|---|
| Wesfarmers Curragh | Howard Lief | A | 13 January 2017 | email |
| Wesfarmers Curragh | Howard Lief | B | 01 February 2017 | email |
| Wesfarmers Curragh | Howard Lief | 0 | 02 February 2017 | email |
| | | | | |
| | | | | |
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# 1.0 SPECIFICATION PRELIMINARIES

## 1.1 Extent of works

The B pit tailings construction works are required to provide ongoing tailings storage for Curragh Coal Mine. The construction works are to be staged and shall include, but shall not be limited to:

- Stage 1
  - Containment embankment – crest RL 125 m
  - Tailings pipeline cut through
  - Tailings pipeline protection bund
  - Tailings pipeline track through Ramp 4
- Stage 2 containment embankment – crest RL 147 m.

The Stage 2 works are not expected to be required for approximately 10 years after the completion of the Stage 1 works based on current tailings deposition rates. The timing for the Stage 2 works will need to be reviewed annually by Wesfarmers following the commissioning of the Stage 1 works.

## 1.2 Roles and responsibilities

The following roles and responsibilities apply to the work associated with this specification:

**Table 1: Roles and responsibilities.**

| Role | Responsibility |
|---|---|
| Owner | Wesfarmers Curragh |
| Superintendent | Owner's representative |
| Constructor | Engaged by the principal to complete the construction works subject to the requirements of the specification and drawings |
| Surveyor | Engaged by the principal to set out of the works and to conduct the final survey of constructed works |
| Golder Associates | Designer providing technical advice to the Principal constructor through the Owner and inspections of critical activities and general observations to assess compliance with the technical specification and IFC drawings |

## 1.3 Utilities

The Constructor shall take all necessary actions to identify underground services within the construction footprint. Where surface drainage works and / or underground pipes, conduits or cables exist in the vicinity of the works, the Constructor shall take care to protect such facilities from damage and, in the case of damage occurring to such facilities, the matter shall be reported to the Superintendent. The cost of the necessary repairs or renewals shall be borne entirely by the Constructor.

Should relocation of existing services be specified or directed by the Superintendent, the Constructor shall arrange for the work to be carried out under Day works charges.

## 1.4 Surplus spoil and rubbish disposal area

All rubbish, surplus spoil, cleared vegetation and other debris resulting from the construction of the Works shall be removed at weekly intervals as a minimum from the Site and shall be disposed of in the disposal areas approved by the Superintendent.

## 1.5 Survey

Reference points for the setting out of the works are shown on the drawings.

The Constructor shall arrange for a suitably qualified surveyor capable of exercising control of all survey requirements.

The surveyor shall establish survey control for all elements and associated site works as soon as practical and shall identify any conflicts or problems as soon as practical. Work shall be set out from cadastral boundaries and coordinates as shown on the drawings

All set-out coordinates shown on the plans shall be verified by the Constructor prior to the commencement of the work. Any discrepancies are to be reported to the Superintendent.

The Superintendent reserves the right to periodically check construction levels and setting out during and on completion of construction using a Wesfarmer appointed surveyor.

The following survey is a requirement:

- A monthly survey to establish the progress of the Works
- A survey of the completed works to be used by the Superintendent to prepare 'as built' drawings.

## 1.6 As Constructed information

### 1.6.1 General

As constructed information shall be acquired and prepared by a licensed surveyor. An engineering surveyor having extensive experience in the provision of 'As Constructed' information may, at the discretion of the Superintendent, be accepted in lieu of a licensed surveyor.

As constructed information shall, for acceptance, be signed by the appointed surveyor and shall be subject to endorsement by the Constructor on each form and drawing to indicate general compliance with the specified As Constructed information requirements. All work required for accurate survey and marking-up of As Constructed information shall be carried out by the Constructor.

Failure to comply with or to complete the specified As Constructed information requirements shall entitle the Principal to withhold payment in respect of all components of constructed or installed work for which As Constructed information is non-compliant or incomplete and to with-hold a Certificate of Practical Completion until As Constructed information requirements have been satisfactorily completed.

### 1.6.2 As Constructed information quality

As Constructed information shall be produced by the Surveyor and issued to the Superintendent in .dwg format at the end of the works. The Constructor shall annotate and capture As Constructed details including changes as the construction work proceeds in red pen on a hard cop set of drawings kept by the Constructor. The drafting of hand marked As Constructed information shall be of a quality acceptable for digitising and reproducing as determined by the Superintendent.

As Constructed drawings shall show the true position of the works in relation to known cadastral boundaries or Mine Coordinates.

## 1.7 Referenced standards

Except as otherwise specified in this Specification, all materials and workmanship are not required to comply with any standards.

## 1.8 Environmental control - dust

The Constructor shall take appropriate measures to control dust during construction work. Dust control measures shall include the use of water tankers or carts.

## 2.0 SCHEDULE OF DRAWINGS

The following Drawings are included in APPENDIX A and form part of the Technical Specification.

**Table 2: Drawing list**

| Drawing No. | Title | Revision |
|---|---|---|
| D000 | Locality Plan and Drawing Index | 0 |
| D001 | General Arrangement Plan | 0 |
| D002 | Stage 1 - Wall RL 125 - Plan View and Longitudinal Section | 0 |
| D003 | Stage 1 - Tailings Pipe Cut 1 - Plan and Longitudinal Section | 0 |
| D004 | Stage 1 - Tailings Pipe Cut 2 - Plan and Longitudinal Section | 0 |
| D005 | Stage 1 - Protection Bund - Plan and Longitudinal Section - Sheet 1 of 3 | 0 |
| D006 | Stage 1 - Protection Bund - Plan and Longitudinal Section - Sheet 2 of 3 | 0 |
| D007 | Stage 1 - Protection Bund - Plan and Longitudinal Section - Sheet 3 of 3 | 0 |
| D008 | Stage 1 - Ramp 2 - Plan View and Longitudinal Section | 0 |
| D009 | Stage 2 - Wall RL 147 - Plan View and Longitudinal Section - Sheet 1 of 2 | 0 |
| D010 | Stage 2 - Wall RL 147 - Plan View and Longitudinal Section - Sheet 2 of 2 | 0 |
| D011 | Typical Cross Sections - Sheet 1 of 2 | 0 |
| D012 | Typical Cross Sections - Sheet 2 of 2 | 0 |
| D013 | Setout Tables | 0 |
| D014 | Zone 1 Borrow Location | 0 |

## 3.0 SITE PREPARATION

No site preparation, stripping or grubbing is expected to be required. Where there is poor ground or vegetation that needs to be removed, the Designer will inform the Superintendent who will in turn instruct the Constructor to carry out the requirements.

## 4.0 EXCAVATIONS

The existing surfaces that require excavation include:

- Tailings pipe trench
- Tailings pipeline track through Ramp 4
- Tailings pipeline trench construction under main haul road

Excavations shall be excavated to the levels and dimensions shown on the drawings. The Constructor shall carry out the excavation of every type of material encountered.

All excavated material may be used as fill materials.

Roots and other organic material shall be removed from the excavated material prior to use as embankment construction or backfill.

### 4.1 Blasting

Blasting and the use of explosives shall not be allowed unless approved by the Superintendent.

If approved, blasting or the use of explosives, shall comply with AS 2187 Explosives - Storage, transport and use (SAA Explosive Code). Blasting work shall be carried out by a person having a current valid shot fire's permit, duly issued in Queensland.

The use of explosives shall be such as will not damage rock, pipelines or other structures beyond the prescribed limits of excavation.

## 4.2 Over excavation

Over excavation shall be backfilled using suitable excavated material as directed by the Superintendent and placed as specified in Section 5.0. Excavation shall only be within the lines and levels as shown on the Drawings unless such over excavation was carried out on the written instruction of the Superintendent.

## 4.3 Support of excavations

The Constructor shall ensure that all excavations are adequately supported as the works proceed and shall exercise every reasonable precaution by means of shoring, planking, props and progressive back-filling to ensure the safety of the works or surfaces over and adjacent to the works.

Any slips or falls of the sides of the excavations due to failure to adequately shore, brace and/or sheet such excavations shall be rectified and any materials, equipment or structures damaged by such slips or falls shall be repaired or replaced by the Constructor at his own expense.

Such shoring, bracing and/or sheeting shall be satisfactorily maintained during the whole life of the excavation and construction operations and shall be removed in a manner to prevent caving as excavations are backfilled.

Additional excavation and backfilling which results from over excavation shall be performed at the Constructors expense and to the satisfaction of the Superintendent.

## 4.4 Finished tolerances

All excavations and fill shall be completed to be within:

a) Horizontal alignment ±200 mm

b) Vertical level 0 to -100 mm

# 5.0 EMBANKMENT CONSTRUCTION

## 5.1 General

Detailed earthwork shall involve the construction of containment embankments and the tailings pipeline protection bund to the lines and grades shown on the drawings.

## 5.2 Earthworks materials

Zone 1 shall be selected spoil material used as bulk fill to construct the containment embankment and bunds. Zone 1 material shall be obtained from the Pit H interburden spoil dumps and from Pit F overburden and interburden spoil dumps.

The Zone 1 material maximum nominal particle size shall not be greater than 800 mm.

The borrow area shall not be extended without approval from the Superintendent.

Zone 2 shall be selected CHPP rejects and used as a filter material placed on the upstream face of the embankment. Zone 2 will be collected either directly from the CHPP or from the rejects dump.

## 5.3 Construction of Zone 1

Zone 1 used in embankment construction shall be placed by paddock dumping to form a maximum lift thickness of 4 m. The surface of the lift shall be dozed smooth to allow access and the lift compacted by using the haul plant. The thickness of each lift shall be such that a competent platform is achieved to the satisfaction of the Superintendent, containing minimal voids and not subject to significant deflection under the trafficking of the haul plant. Material used in this zone may be placed without moisture content adjustment.

## 5.4 Construction of Zone 2

Zone 2 shall be placed to achieve as near practical the geometry as shown on the design drawings or the geometry as agreed by the Superintendent. The material shall be compacted by a minimum of 2 passes using the spreading plant (minimum of D9 dozer or equivalent) or as directed by the Superintendent.

## 5.5 Protection of earthworks

### 5.5.1 General

The Constructor's responsibility for care of the Works shall include the protection of earthworks.

Adequate drainage of all working areas shall be maintained throughout the period of construction to ensure run-off of water without ponding, except where ponding forms part of a planned erosion and sedimentation control system.

When rain is likely or when work is not proposed to continue in a working area on the following day, precautions shall be taken to minimise ingress of any excess water into earthworks material. The material placed on embankments shall be sealed off by adequate compaction to provide a smooth tight surface.

Should in situ or stockpiled material become over wet as a result of the Constructor not providing adequate protection of earthworks, the Constructor shall be responsible for replacing and/or drying out the material and for any consequent delays to the operations.

On completion of the works all diversion and protective works shall be removed and disposed of and all temporary works shall be levelled in an approved manner to give a tidy appearance and not interfere with the operation of the works.

### 5.5.2 Ponded water

The B Pit area may pond runoff water during construction of the works. Such ponded water shall at all times be kept well away from earthwork construction, by pumping, or by a temporary ditches constructed in natural ground on one or both abutments.

## 5.6 Finished tolerances

All embankments, excluding spillway locations, shall be completed to be within:

a) Horizontal alignment along crest centreline ±200 mm

b) Vertical level 0 to +100 mm

Slopes shall not be steeper than those shown on the Drawings unless otherwise approved by the Superintendent.

# APPENDIX A

## Drawings

**Note:**
**Drawings provided elsewhere in document.**

At Golder Associates we strive to be the most respected global group of companies specialising in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organisational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.


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| Europe | + 356 21 42 30 20 |
| North America | + 1 800 275 3281 |
| South America | + 55 21 3095 9500 |

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**Australia**
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Golder Associates

# APPENDIX B

## Geotechnical site inspection documentation

# RECORD OF SITE VISIT

**1532295 | CURRAGH B PIT TAILINGS DAM | WESFARMERS RESOURCES**

GOLDER ASSOCIATES PTY LTD
ABN 64 006 107 857 | 147 Coronation Drive, MILTON, Qld 4064

**DOCUMENT NO:** 1532295-032-RSV-Rev 0

**DATE:** 27/10/16 **LOCATION:** B PIT/H PIT, CURRAGH **VISIT BY:** David Starr

**ACCOMPANIED BY:** Howard Leif, Maree Gaughan (Raine), Norman Javati, Michael Bailey

**ARRIVED SITE:** 07:00 **LEFT** 16:00 **VISIT REQUEST BY:** Howard Leif

**PURPOSE OF VISIT:**

- To advance the Detail Design of the B Pit tailings dam embankment by Golder.
- Discussions were held prior to site inspection with Howard Leif, Carl Heales, Mike Bailey, Maree Gaughan (for Raine & Associates), & Norman Javati (Pit Geologist).

**BACKGROUND:**

- The life of the current Pit A tailings storage facility has been extended by 12 to 18 months, but will end its useful life in early 2018.
- A significant amount of planning is required to convert Pit B into a tailings storage facility.
- The main objective of the discussions and site inspection is to make a judgement on the best location for the containment embankment.
- A location as far north as possible in Pit B will maximise the tailings storage volume.
- A location immediately downstream of Pit H has been suggested which would allow inter-burden to be used for construction, thus saving haulage costs.
- However, after considering the geotechnical constraints (particularly in light of advice provided by Raine & Associates) of the Pit H location, it was decided that there were too many adverse geological and geotechnical factors.
- Two other alignment options were then proposed in Pit B, named Pit B North and Pit B South which need coordinates to locate. *Action: Block plan to be provided with records from historical mining reports, being prepared by Norman.*
- Golder requested information on locations of the material sampled for the shear box testing – i.e. reject stockpile (see photo in body of report), inter-burden and overburden. *Action: Mike Bailey to provide marked-up plan with approximate locations.*
- Howard Leif referred to Mike Gowan's report dated 14 Sept 2016 – in relation to 5 year life up to 12 m above current level.



*Plate 1. Station 2 - View of overburden stockpiles, Pit H - note slumping & tension cracks*



*Plate 2. Station 2 - View towards south - Pit H in foreground, Pit B in distance*



*Plate 3. Station 2 - Zoom in of north end of Pit B*



*Plate 4. Station 2 - Low Point Pit H in foreground*



*Plate 5. Station 3 - Pit B Haul Rd viewed towards west*



*Plate 6. Station 3 - Northern end Pit B from Haul Rd view towards NW*



*Plate 7. Station 3 - View towards North, irregular mounds of overburden in Pit B north*



*Plate 8. Station 4 – North end flooded area Pit B (South of Haul Rd)*



*Plate 9. Station 4 - Flooded area of Pit B viewed towards south*



*Plate 10. Station 5 - View towards east along Haul Rd, Pit B*



*Plate 11. Station 6 - Previously mined area Pit B (just above level of mined seam)*



*Plate 12. Station 7 - Previously mined area south end Pit H (viewed towards north)*



*Plate 13. Station 8 - disturbed material in bench along fault line - Pit B*



*Plate 14. Station 9 - Pit B looking south*



*Plate 15. Station 9 - fault outcrop viewed towards north (down throw towards west)*



*Plate 16. Coarse rejects stockpile*

**COMMENT ON OBSERVATIONS: (REFER TO Plates 1 to 17)**

1. It was clear looking from Stations 1 and 2 that instability is occurring in the north and west faces of the Pit H overburden stockpile (Plates 1 and 2).
2. West facing overburden stockpiles along north of the Pit B haul road have irregular side slopes (as if material has spalled or been removed) and it is understood from Matt Raine that these irregularities may be due to seepage (Plates 4 and 8).
3. The low point in Pit H (Plate 5) is a source of water seepage and while this area was inspected (Station 7), it was not possible to examine the mine floor due to the presence of overburden.
4. It is understood that the level area in the northern end of Pit B has a veneer of overburden, so the previously mined surface could not be observed (Plate 7).
5. Side slope instability can be observed around the north and northeast side of the flooded area in Pit B (Plates 9 & 10), suggesting that the side slopes are probably close to or steeper than the unsaturated angle of repose.
6. The alignment originally proposed by Golder (along the haul road) is depicted in Plates 6 and 11.
7. A surface just above the previously mined lower seam in Pit B is depicted in Plate 12 in which no structure could be clearly observed.
8. The disturbed material shown in Plate 13 is believed to represent a major north-south fault line and the clayey nature of the gouge material suggests that the fault line may be relatively impermeable.
9. The fault shown in Plate 15 is believed to dip to the west with a throw of around 15 to 20 m towards the west.

**RECOMMENDATIONS:**

1. It was not possible to observe the previously mined floor in either Pit B or Pit H.
2. The information provided by Raine & Associates suggests that there are numerous fault structures associated with the mined seams. Instability of a tailings dam embankment is not expected to arise as a result of geological structures in the *in situ* material beneath the mined surfaces.
3. Heave is understood to have occurred within the pit floor during mining of the lower seam. The placement of a layer of overburden is presumed to have arrested uplift movements.
4. Nevertheless, a judgement on the condition of the pit floors will need to be based on historical records
5. Clear signs of instability in overburden stockpiles within Pit H have resulted in a joint decision to preclude potential tailings dam embankments in this area.
6. It is understood that there could be voids within and immediately above the previously mined surface of B Pit. Such features could give rise to zones of higher permeability, however, settlement due to placement of overburden fill to create the staged construction of a tailings dam embankment is likely to build-out potential settlements during construction.
7. Geotechnical investigations for the embankment dam have been considered. Our opinion is that unless particular benefit can be gained from such work, the time and cost associated is difficult to justify.
8. The impact of seepage along the highwall will need to be considered during detail design. Design considerations may include:
    a. Installation of vibrating wire piezometers at selected locations to monitor water pressures.
    b. Staggered steps to tie the embankment into the highwall.
    c. Test pit excavation near Station 7 to investigate seepage at the start of dam construction.
9. The materials available for construction of the embankment dam include Pit B overburden and coarse rejects. The inter-burden is understood to contain a range of particle sizes and rock types, and could weather after placement.

Geotechnical Engineer:

_____
David C Starr

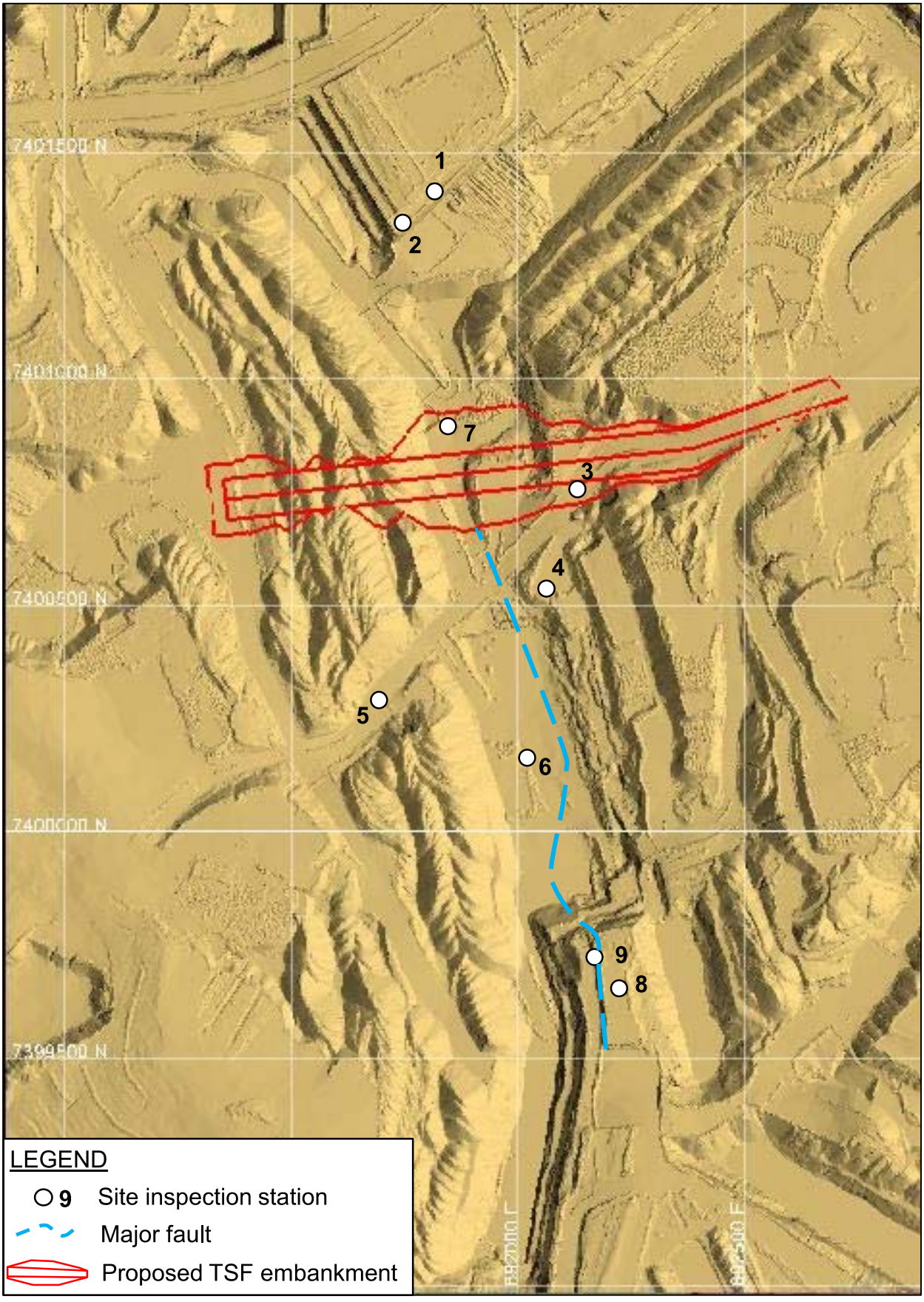
Reviewed by:



_____
Amanda Barrett

# ATTACHMENTS

VULCAN Plan and Air Photo overlay showing area of interest and site visit stations




| | | | |
|---|---|---|---|
| Golder Associates | CLIENT: Wesfarmers Resources | | PROJECT: Curragh B Pit Tailings Dam |
| | DRAWN: DS | DATE: 10-11-16 | TITLE: Key Plan Site Inspection 27th October 2016 |

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| | | | |
|---|---|---|---|
| Golder Associates | CLIENT Wesfarmers Resources | | PROJECT Curragh B Pit Tailings Dam |
| | DRAWN DS | DATE 10-11-16 | TITLE |

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# APPENDIX C

## Laboratory testing - construction materials

Cardno Construction Sciences
ABN: 74 128 806 735
Address:
13 Glasson, Street,
Emerald QLD 4720

Laboratory: Emerald Laboratory
Phone: 07 4982 0044 Fax: 07 4982 3102
Email: donna.marr@cardno.com.au

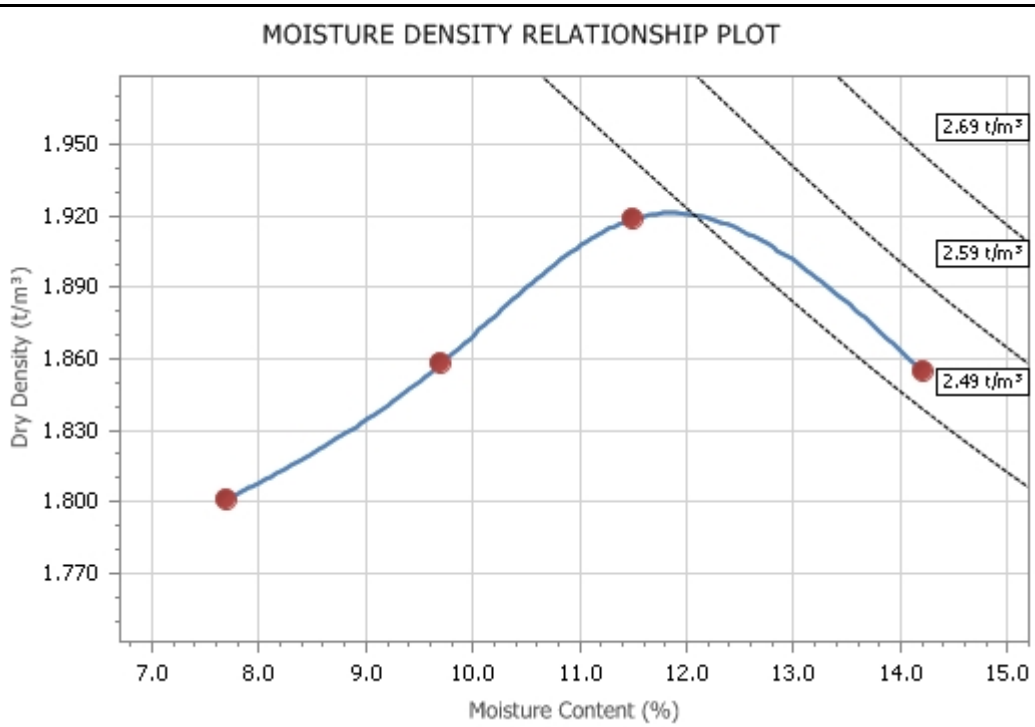
# MOISTURE DENSITY RELATIONSHIP REPORT

| | | | |
|---|---|---|---|
| Client: | Wesfarmers Curragh Pty Ltd | Report Number: | 1692/R/8748-1 |
| Client Address: | Private Mail Bag, Blackwater | Project Number: | 1692/P/271 |
| Project: | Pit B Tailings Dam Embankment Samples | Lot Number: | |
| Location: | Curragh Mine Via Blackwater | Internal Test Request: | 1692/T/3145 |
| Component: | | Client Reference/s: | 6/10/2016 |
| Area Description: | | Report Date / Page: | 10/10/2016 Page 1 of 3 |

| | | | |
|---|---|---|---|
| Test Procedures | AS1289.5.1.1, AS1289.2.1.1 | Sample Location | |
| Sample Number | 1692/S/18635 | Location | Curragh Pit H Spoil |
| Sampling Method | AS1289.1.2.1 Cl 6.2 | | |
| Date Sampled | 6/10/2016 | | |
| Sampled By | Andrea Fleming | | |
| Date Tested | 7/10/2016 | Compactive Effort | Standard |
| Material Source | Onsite | Fraction Tested (mm) | < 19.0mm |
| Material Type | Embankment | Percent Oversize (%) | 0.0 |
| Material Description | Grey clayey gravel | | |

Moisture / Density Relationship Data

| Moisture Content (%) | Dry Density (t/m³) |
|---|---|
| 7.7 | 1.801 |
| 9.7 | 1.858 |
| 11.5 | 1.919 |
| 14.2 | 1.855 |




| | | | |
|---|---|---|---|
| Maximum Dry Density (t/m³): | 1.92 | Optimum Moisture Content (%): | 12.0 |

Remarks

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
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Accreditation Number: 1986
Corporate Site Number: 1692

Approved Signatory: Donna Marr
Form ID: W4Rep Rev 1

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Email: donna.marr@cardno.com.au

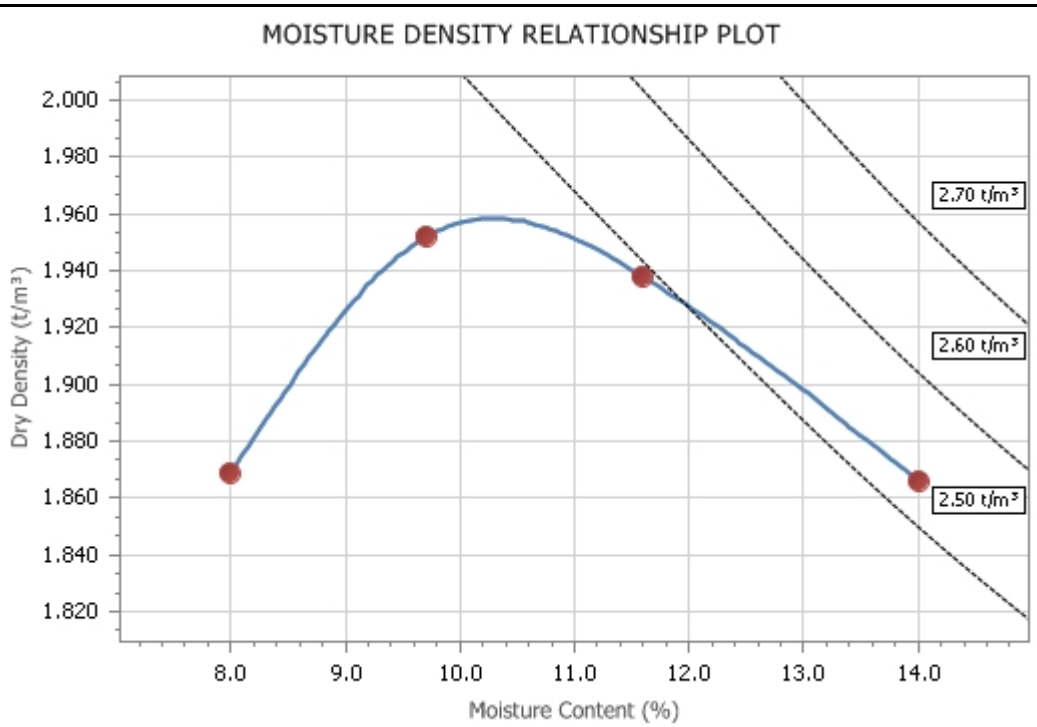
# MOISTURE DENSITY RELATIONSHIP REPORT

| | | | |
|---|---|---|---|
| Client: | Wesfarmers Curragh Pty Ltd | Report Number: | 1692/R/8748-1 |
| Client Address: | Private Mail Bag, Blackwater | Project Number: | 1692/P/271 |
| Project: | Pit B Tailings Dam Embankment Samples | Lot Number: | |
| Location: | Curragh Mine Via Blackwater | Internal Test Request: | 1692/T/3145 |
| Component: | | Client Reference/s: | 6/10/2016 |
| Area Description: | | Report Date / Page: | 10/10/2016 Page 2 of 3 |

| | | | |
|---|---|---|---|
| Test Procedures | AS1289.5.1.1, AS1289.2.1.1 | Sample Location | |
| Sample Number | 1692/S/18636 | Location | Pit H Pollux Interburden |
| Sampling Method | AS1289.1.2.1 Cl 6.2 | | |
| Date Sampled | 6/10/2016 | | |
| Sampled By | Andrea Fleming | | |
| Date Tested | 7/10/2016 | Compactive Effort | Standard |
| Material Source | Onsite | Fraction Tested (mm) | < 19.0mm |
| Material Type | Embankment | Percent Oversize (%) | 0.0 |
| Material Description | Grey clayey gravel | | |

Moisture / Density Relationship Data

| Moisture Content (%) | Dry Density (t/m³) |
|---|---|
| 8.0 | 1.869 |
| 9.7 | 1.952 |
| 11.6 | 1.938 |
| 14.0 | 1.866 |




| | | | |
|---|---|---|---|
| Maximum Dry Density (t/m³): | 1.96 | Optimum Moisture Content (%): | 10.5 |

Remarks

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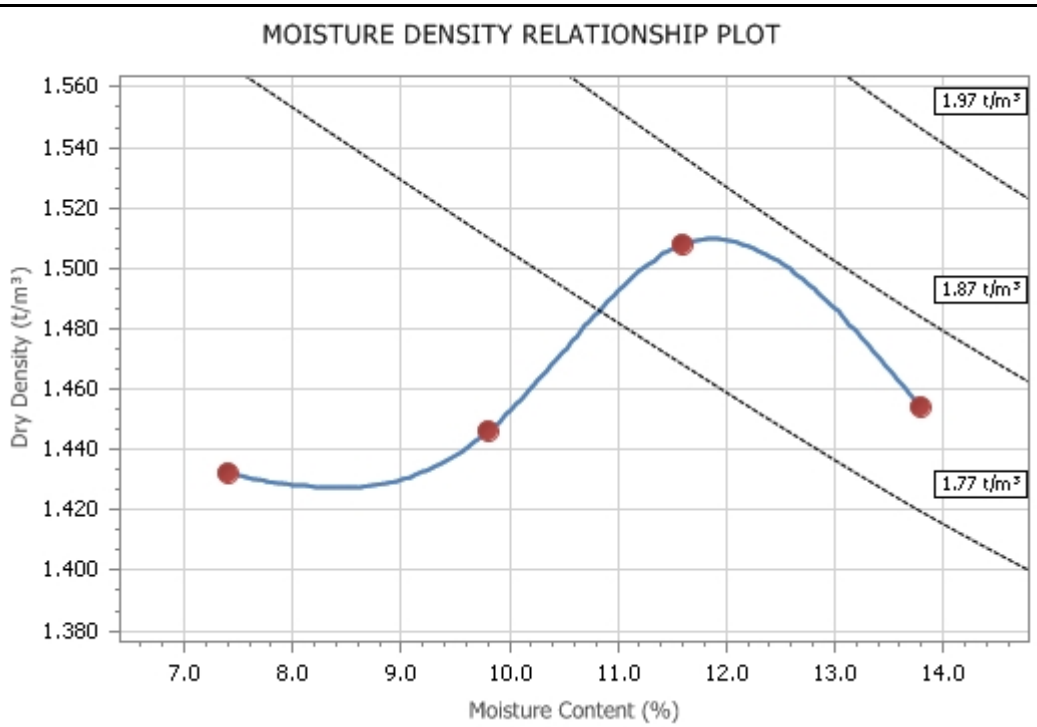
# MOISTURE DENSITY RELATIONSHIP REPORT

| | | | |
|---|---|---|---|
| Client: | Wesfarmers Curragh Pty Ltd | Report Number: | 1692/R/8748-1 |
| Client Address: | Private Mail Bag, Blackwater | Project Number: | 1692/P/271 |
| Project: | Pit B Tailings Dam Embankment Samples | Lot Number: | |
| Location: | Curragh Mine Via Blackwater | Internal Test Request: | 1692/T/3145 |
| Component: | | Client Reference/s: | 6/10/2016 |
| Area Description: | | Report Date / Page: | 10/10/2016 Page 3 of 3 |

| | | | |
|---|---|---|---|
| Test Procedures | AS1289.5.1.1, AS1289.2.1.1 | Sample Location | |
| Sample Number | 1692/S/18637 | Location | CPP#1 CPP#2 Coarse Rejects |
| Sampling Method | AS1289.1.2.1 Cl 6.2 | | |
| Date Sampled | 6/10/2016 | | |
| Sampled By | Andrea Fleming | | |
| Date Tested | 7/10/2016 | Compactive Effort | Standard |
| Material Source | Onsite | Fraction Tested (mm) | < 19.0mm |
| Material Type | Embankment | Percent Oversize (%) | 0.0 |
| Material Description | Black coal rejects | | |

Moisture / Density Relationship Data

| Moisture Content (%) | Dry Density (t/m³) |
|---|---|
| 7.4 | 1.432 |
| 9.8 | 1.446 |
| 11.6 | 1.508 |
| 13.8 | 1.454 |




| | | | |
|---|---|---|---|
| Maximum Dry Density (t/m³): | 1.51 | Optimum Moisture Content (%): | 12.0 |

Remarks

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Approved Signatory: Donna Marr
Form ID: W4Rep Rev 1

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# DIRECT SHEAR TEST REPORT

**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100158-DS |
| **Address** | 13 Glasson St, Emerald QLD 4720 | **Test Date** | 18/10/2016 |
| | | **Report Date** | 19/10/2016 |
| **Project** | 1692/P/271 - Pit B Tailings Dam Embankment Samples | | |
| **Client ID** | 1692/S/18636 - Pit H Pollux Interburden | **Depth (m)** | Not Supplied |
| **Description** | - | | |
| **Sample Type** | Three individual soil specimens - Remoulded. | | |

## SAMPLE DETAILS

| | Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|---|
| Maximum Dry Density (t/m$^3$) | 1.96 | 1.96 | 1.96 | |
| Optimum Moisture Content (%) | 10.5 | 10.5 | 10.5 | |
| Density Ratio Required (%) | 95 | 95 | 95 | |
| Specimen Condition | Saturated | Saturated | Saturated | |
| Specimen Dimensions (mm) | 305 x 305 | 305 x 305 | 305 x 305 | |
| Initial Sample Height (mm) | 172.3 | 172.3 | 172.3 | |
| Rate of Strain (mm/min) | 1.00 | 1.00 | 1.00 | |
| Initial Moisture Content (%) | 10.4 | 10.5 | 10.7 | |
| Initial Wet Density (t/m$^3$) | 2.06 | 2.06 | 2.06 | |
| Final Moisture Content (%) | 13.0 | 12.5 | 11.6 | |

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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Authorised Signatory
C. Purvis

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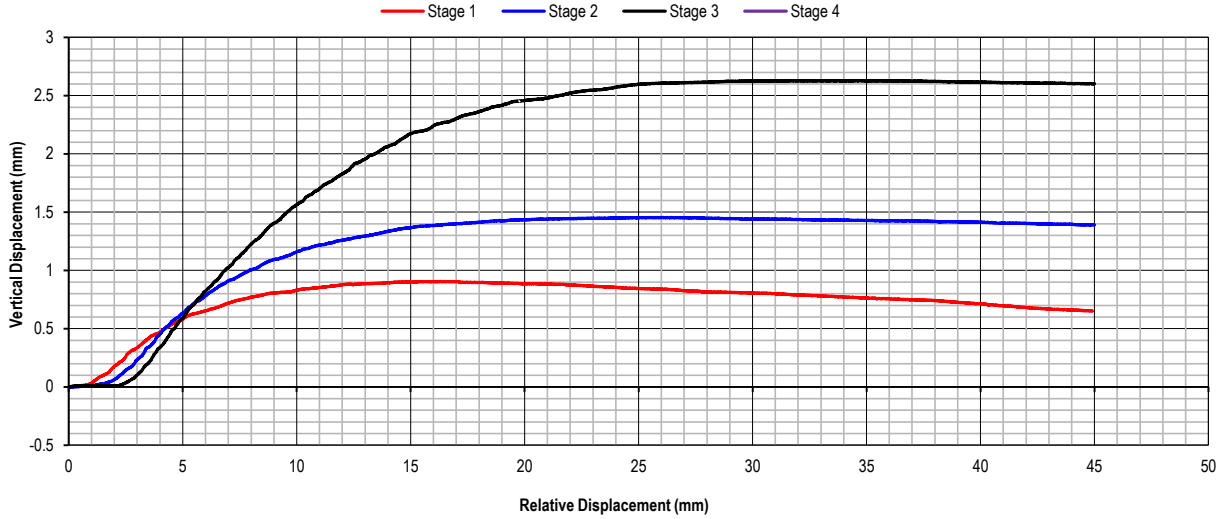
# DIRECT SHEAR TEST REPORT

**Test Method: ASTM D3080**

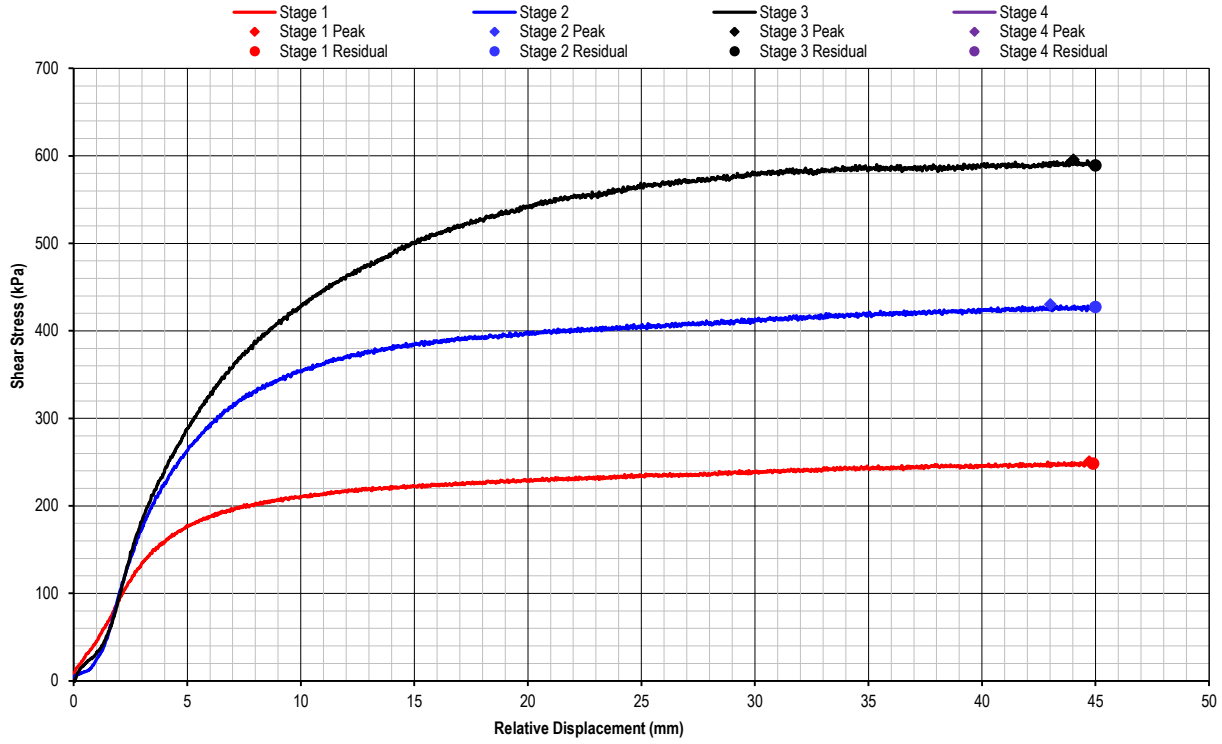
Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100158-DS |

## Vertical Displacement/Relative Displacement Plot




## Shear Stress/Displacement Plot




Notes/Remarks:

Graph not to scale

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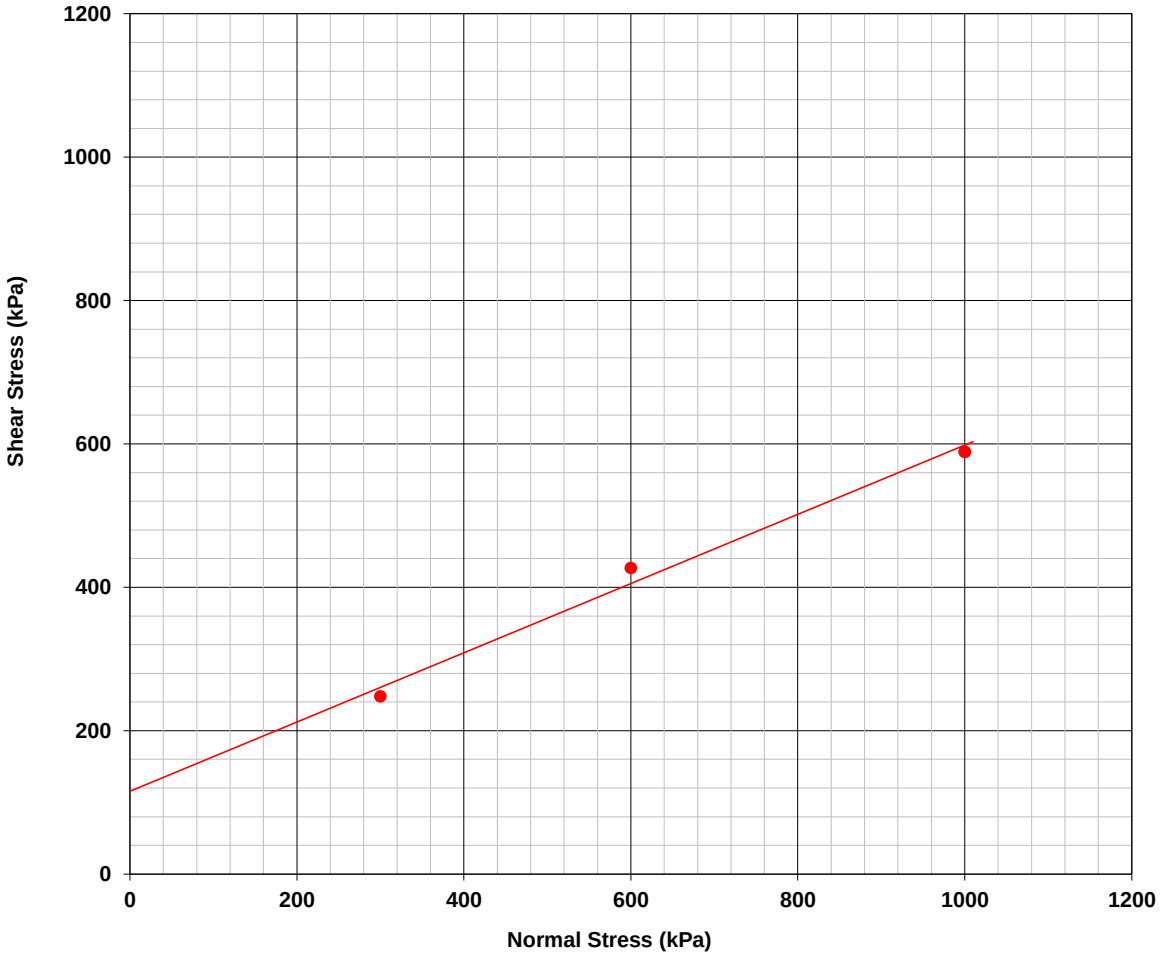
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100158-DS |

**Failure Criteria** **Residual**

## Residual - Normal Stress vs Shear Stress




| | | Stage | Residual Displacement | Normal Stress | Shear Stress |
|---|---|---|---|---|---|
| **Shear Angle (°)** | **25.8** | | (mm) | (kPa) | (kPa) |
| **Cohesion (kPa)** | **115.6** | 1 | 44.90 | 300.0 | 248.0 |
| | | 2 | 45.00 | 600.0 | 426.9 |
| **$R^2$** | **0.994** | 3 | 45.00 | 1000.0 | 588.9 |

Machine Description: Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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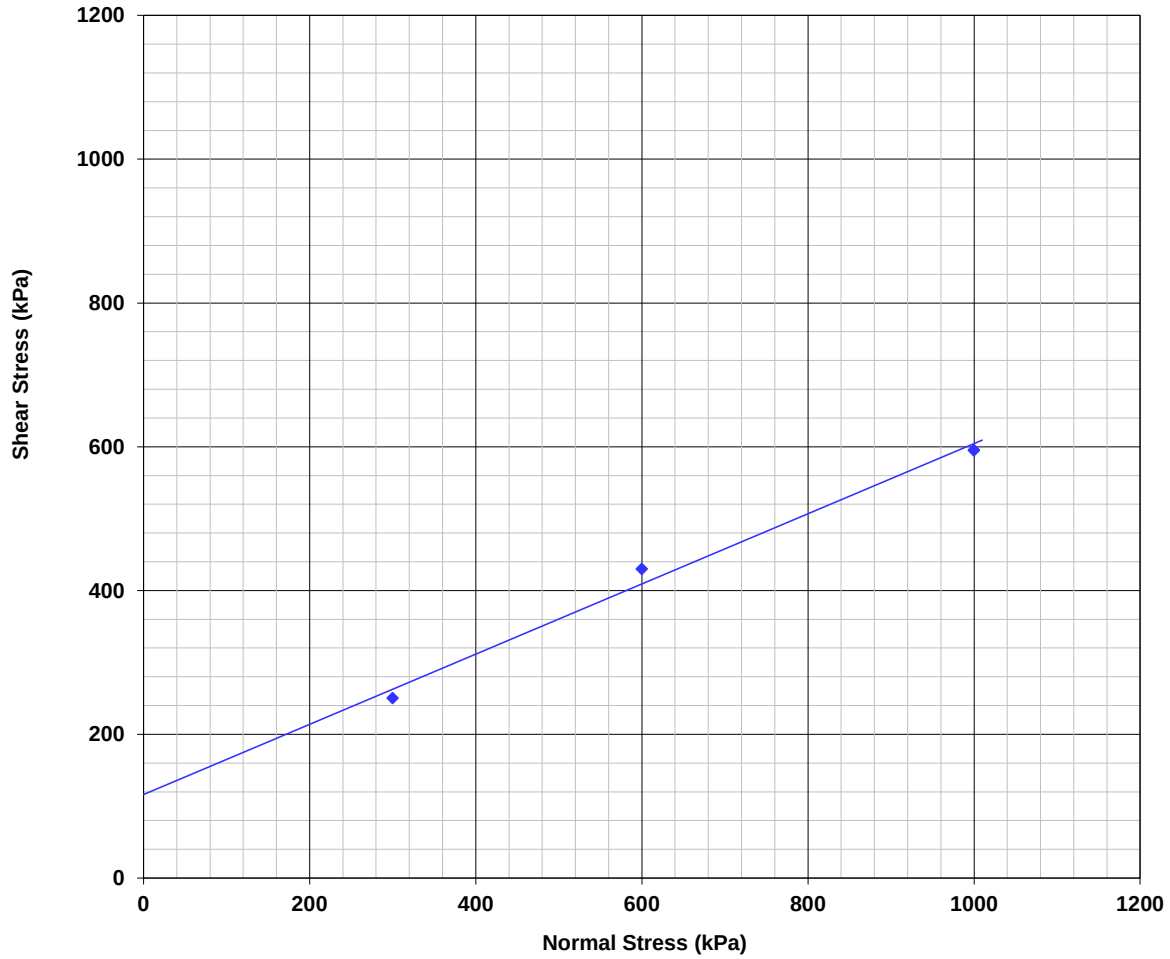
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100158-DS |

**Failure Criteria** **Peak**

## Peak - Normal Stress vs Shear Stress




| | | Stage | Displacement at Peak Stress | Normal Stress | Shear Stress |
|---|---|---|---|---|---|
| **Shear Angle (°)** | **26.0** | | (mm) | (kPa) | (kPa) |
| **Cohesion (kPa)** | **116.1** | 1 | 44.73 | 300.0 | 250.5 |
| **$R^2$** | **0.994** | 2 | 43.01 | 600.0 | 430.1 |
| | | 3 | 44.03 | 1000.0 | 595.2 |

Machine Description Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale Sample/s supplied by the client



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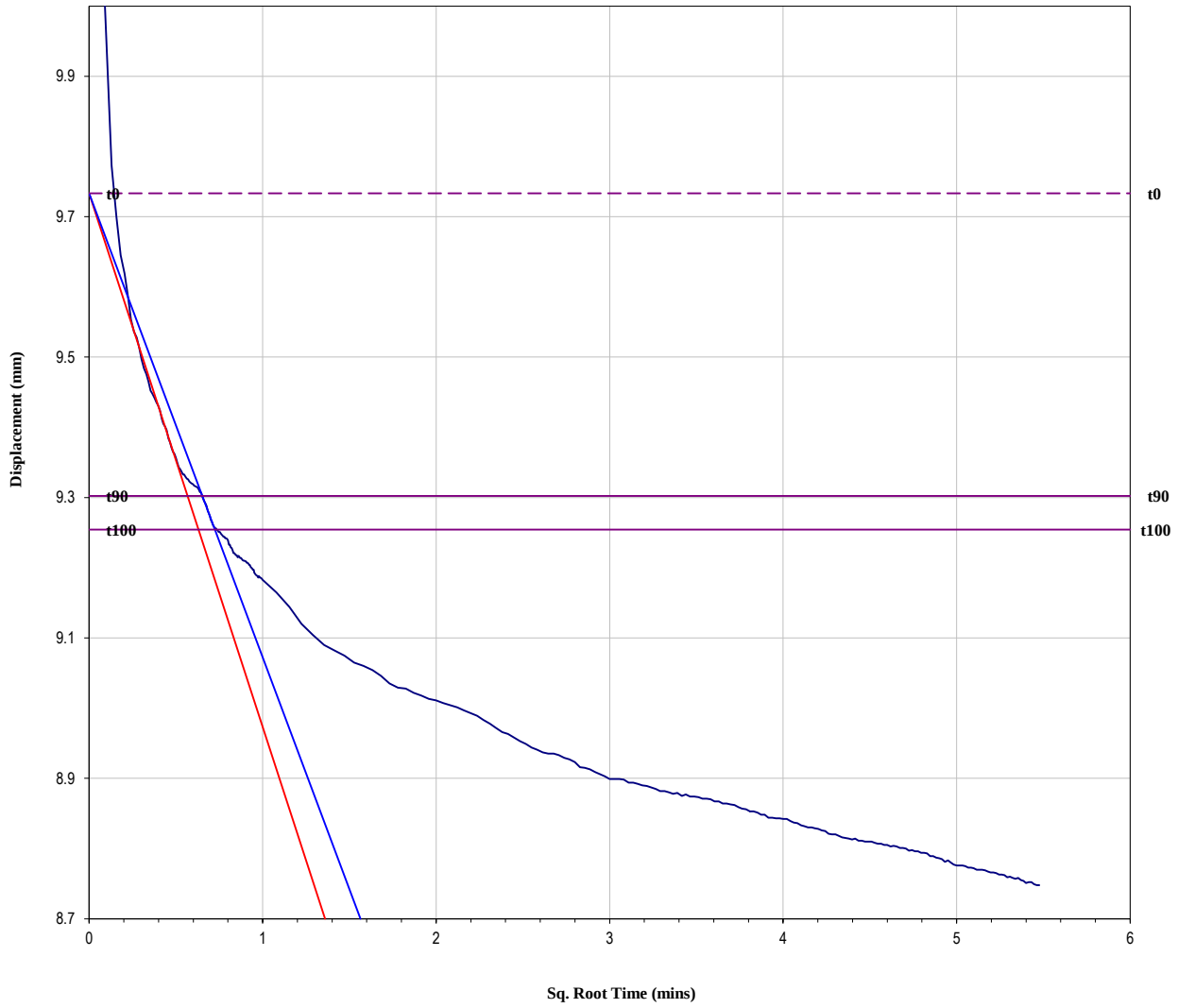
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100158-DS |

## Stage 1 Consolidation

**Displacement v's Time (Sq. Root Scale)**




| | | |
|---|---|---|
| $t_{90}$ | 0.43 | **mins** |
| **Time to Failure =** | 4.94 | **mins** |
| **Estimated Displacement to Failure =** | 5 | **mm** |
| **Displacement Rate =** | 1.01276 | **mm/min** |

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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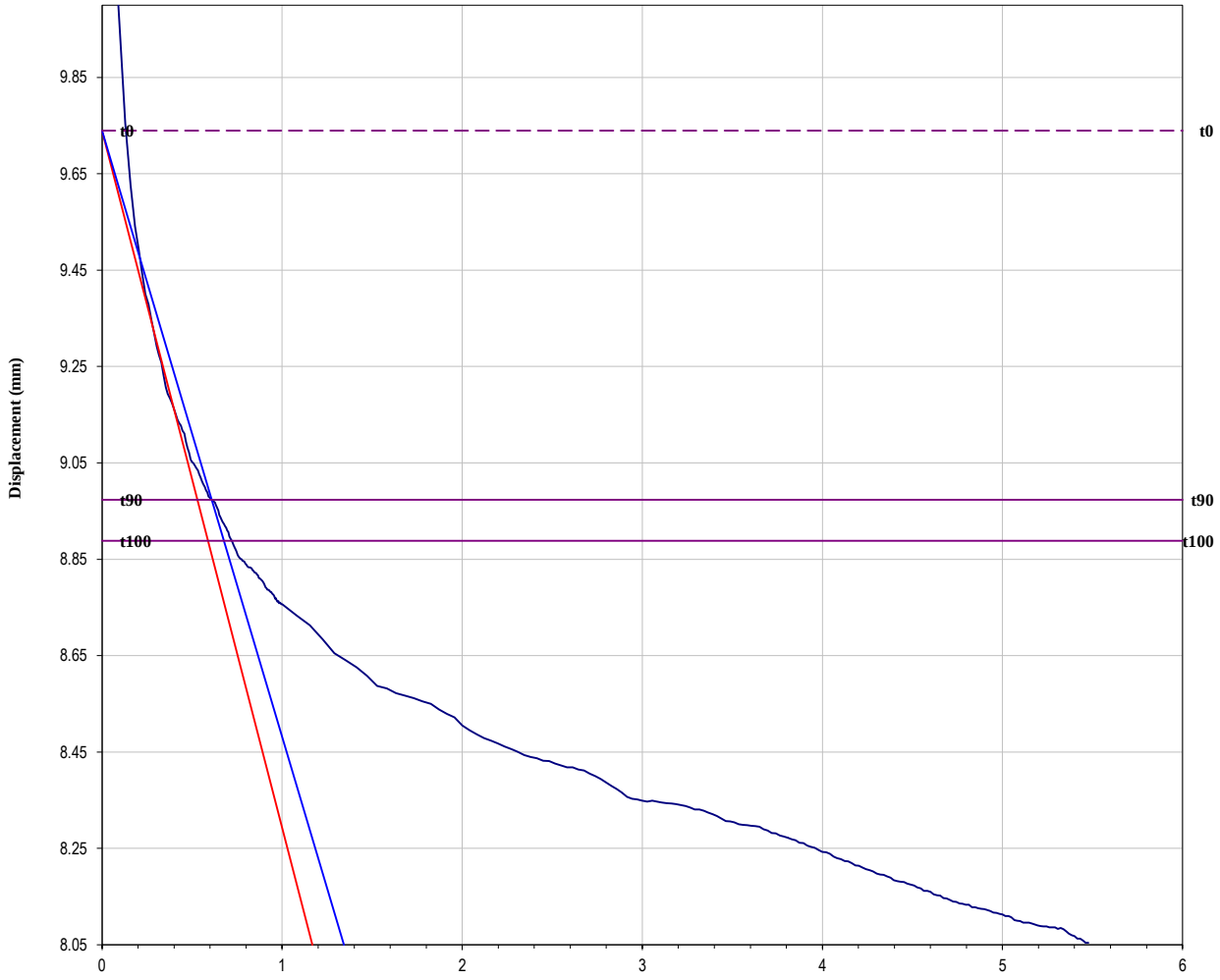
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100158-DS |

## Stage 2 Consolidation

**Displacement v's Time (Sq. Root Scale)**




| | | |
|---|---|---|
| $t_{90}$ | 0.37 | **mins** |
| **Time to Failure =** | 4.30 | **mins** |
| **Estimated Displacement to Failure =** | 5 | **mm** |
| **Displacement Rate =** | 1.16231 | **mm/min** |

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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Soil Rock Calibration

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QLD 4034
Ph: +61 7 3265 5656

**Perth**
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

# DIRECT SHEAR TEST REPORT

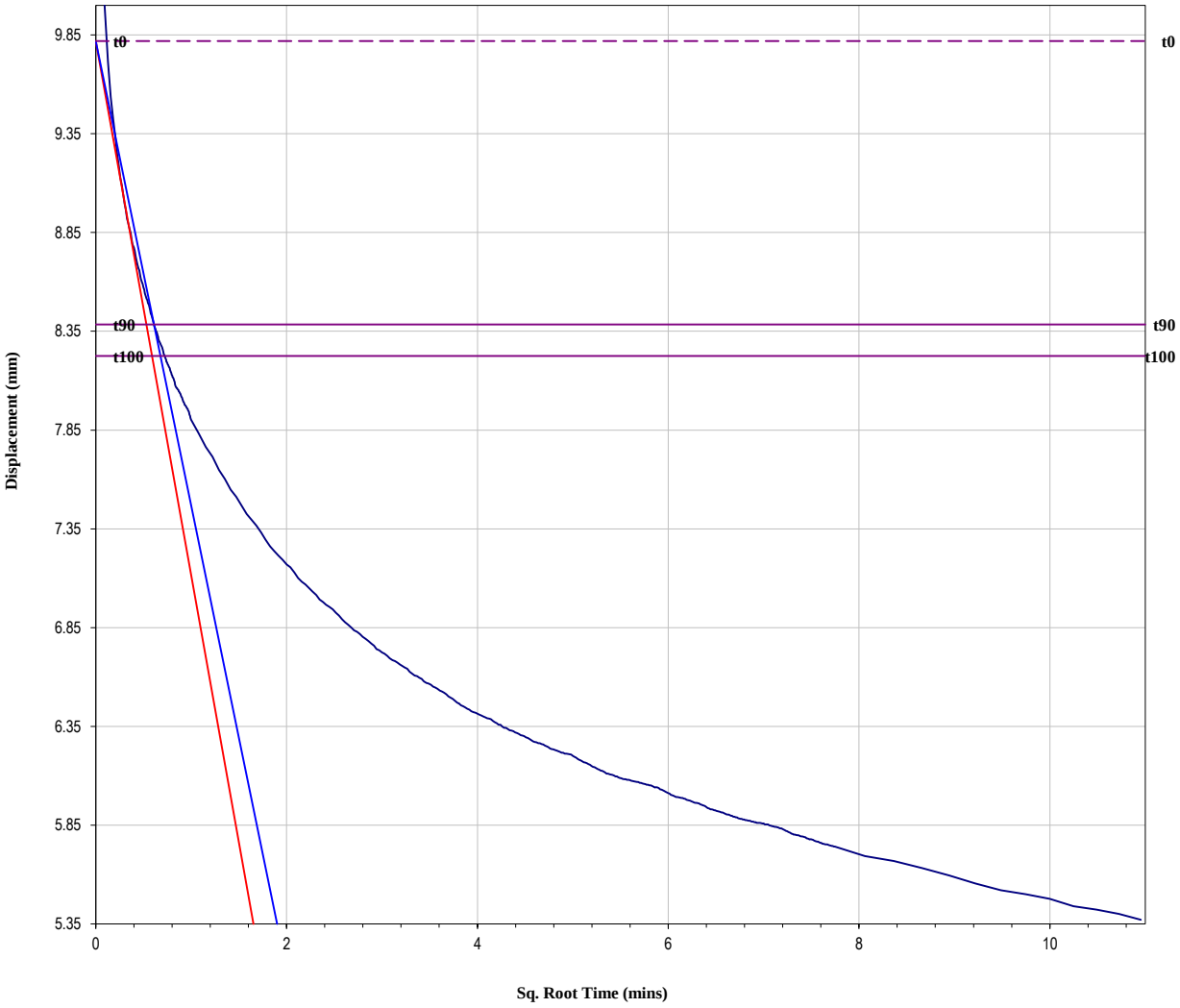
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100158-DS |

## Stage 3 Consolidation

**Displacement v's Time (Sq. Root Scale)**




| | | |
|---|---|---|
| $t_{90}$ | 0.37 | **mins** |
| **Time to Failure =** | 4.32 | **mins** |
| **Estimated Displacement to Failure =** | 5 | **mm** |
| **Displacement Rate =** | 1.15757 | **mm/min** |

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Authorised Signatory
C. Purvis

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Tested at Trilab Brisbane Laboratory

**Laboratory No. 9926**

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.
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*ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING*

Cardno Construction Sciences
ABN: 74 128 806 735
Address:
13 Glasson, Street,
Emerald QLD 4720

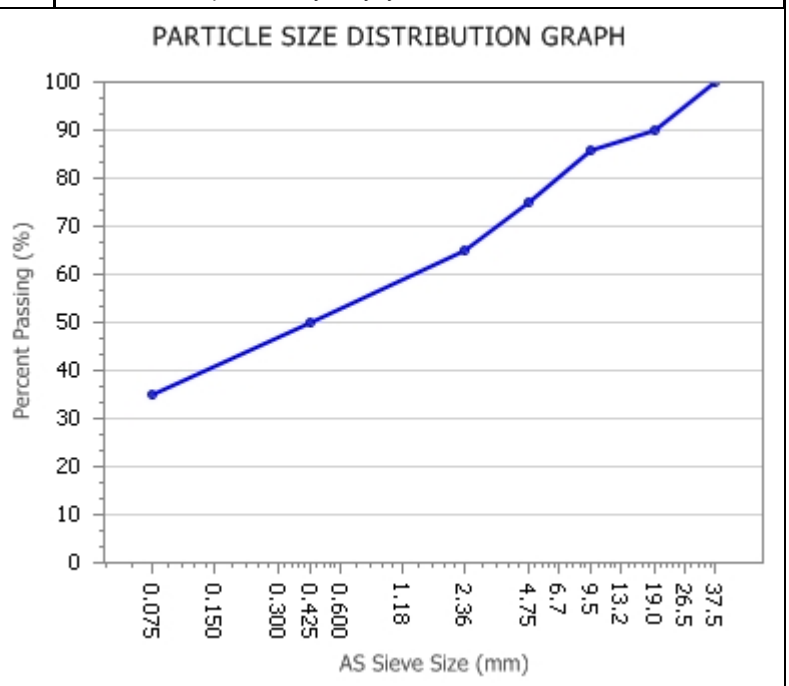
Laboratory: Emerald Laboratory
Phone: 07 4982 0044 Fax: 07 4982 3102
Email: donna.marr@cardno.com.au

# QUALITY OF MATERIALS REPORT

| | | | |
|---|---|---|---|
| Client: | Wesfarmers Curragh Pty Ltd | Report Number: | 1692/R/8747-1 |
| Client Address: | Private Mail Bag, Blackwater | Project Number: | 1692/P/271 |
| Project: | Pit B Tailings Dam Embankment Samples | Lot Number: | |
| Location: | Curragh Mine Via Blackwater | Internal Test Request: | 1692/T/3145 |
| Component: | | Client Reference/s: | 6/10/2016 |
| Area Description: | | Report Date / Page: | 10/10/2016 Page 1 of 3 |

| | | | |
|---|---|---|---|
| Test Procedures | AS1289.3.6.1, AS1289.3.1.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1 | | |
| Sample Number | 1692/S/18635 | Location | Curragh Pit H Spoil |
| Sampling Method | AS1289.1.2.1 Cl 6.2 | | |
| Date Sampled | 6/10/2016 | | |
| Sampled By | Andrea Fleming | | |
| Date Tested | 6/10/2016 | Material Source | Onsite |
| Att. Drying Method | Oven Dried | Material Type | Embankment |
| Atterberg Preparation | Dry Sieved | Material Description | Gray Clayey Gravel |

| AS Sieve (mm) | Specification Minimum | Percent Passing (%) | Specification Maximum |
|---|---|---|---|
| 37.5 | | **100** | |
| 19.0 | | **90** | |
| 9.5 | | **86** | |
| 4.75 | | **75** | |
| 2.36 | | **65** | |
| 0.425 | | **50** | |
| 0.075 | | **35** | |




| Test Result | Specification Minimum | Result | Specification Maximum | Test Result | Specification Minimum | Result | Specification Maximum |
|---|---|---|---|---|---|---|---|
| Liquid Limit (%) | | **33** | | 0.075/0.425 Fines Ratio | | **0.69** | |
| Plastic Limit (%) | | **17** | | PI x 0.425 Ratio (%) | | **808.0** | |
| Plastic Index (%) | | **16** | | LS x 0.425 Ratio (%) | | **404.0** | |
| Linear Shrinkage (%) | | **8.0** | | Linear Shrinkage Defects | - | | |

Remarks

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Accredited for compliance with ISO/IEC 17025

Accreditation Number: 1986
Corporate Site Number: 1692

Approved Signatory: Donna Marr
Form ID: W85Rep Rev 1

Cardno Construction Sciences
ABN: 74 128 806 735
Address:
13 Glasson, Street,
Emerald QLD 4720

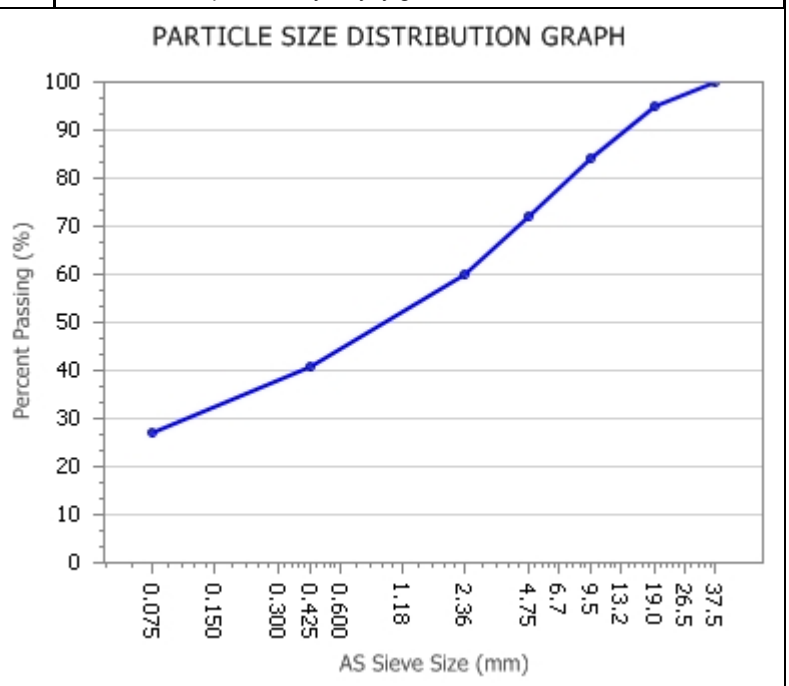
Laboratory: Emerald Laboratory
Phone: 07 4982 0044 Fax: 07 4982 3102
Email: donna.marr@cardno.com.au

# QUALITY OF MATERIALS REPORT

| | | | |
|---|---|---|---|
| Client: | Wesfarmers Curragh Pty Ltd | Report Number: | 1692/R/8747-1 |
| Client Address: | Private Mail Bag, Blackwater | Project Number: | 1692/P/271 |
| Project: | Pit B Tailings Dam Embankment Samples | Lot Number: | |
| Location: | Curragh Mine Via Blackwater | Internal Test Request: | 1692/T/3145 |
| Component: | | Client Reference/s: | 6/10/2016 |
| Area Description: | | Report Date / Page: | 10/10/2016 Page 2 of 3 |

| | | | |
|---|---|---|---|
| Test Procedures | AS1289.3.6.1, AS1289.3.1.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1 | | |
| Sample Number | 1692/S/18636 | Location | Pit H Pollux Interburden |
| Sampling Method | AS1289.1.2.1 Cl 6.2 | | |
| Date Sampled | 6/10/2016 | | |
| Sampled By | Andrea Fleming | | |
| Date Tested | 6/10/2016 | Material Source | Onsite |
| Att. Drying Method | Oven Dried | Material Type | Embankment |
| Atterberg Preparation | Dry Sieved | Material Description | Grey clayey gravel |

| AS Sieve (mm) | Specification Minimum | Percent Passing (%) | Specification Maximum |
|---|---|---|---|
| 37.5 | | **100** | |
| 19.0 | | **95** | |
| 9.5 | | **84** | |
| 4.75 | | **72** | |
| 2.36 | | **60** | |
| 0.425 | | **41** | |
| 0.075 | | **27** | |




| Test Result | Specification Minimum | Result | Specification Maximum | Test Result | Specification Minimum | Result | Specification Maximum |
|---|---|---|---|---|---|---|---|
| Liquid Limit (%) | | **31** | | 0.075/0.425 Fines Ratio | | **0.65** | |
| Plastic Limit (%) | | **18** | | PI x 0.425 Ratio (%) | | **534.3** | |
| Plastic Index (%) | | **13** | | LS x 0.425 Ratio (%) | | **308.2** | |
| Linear Shrinkage (%) | | **7.5** | | Linear Shrinkage Defects | - | | |

Remarks

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Corporate Site Number: 1692

Approved Signatory: Donna Marr
Form ID: W85Rep Rev 1

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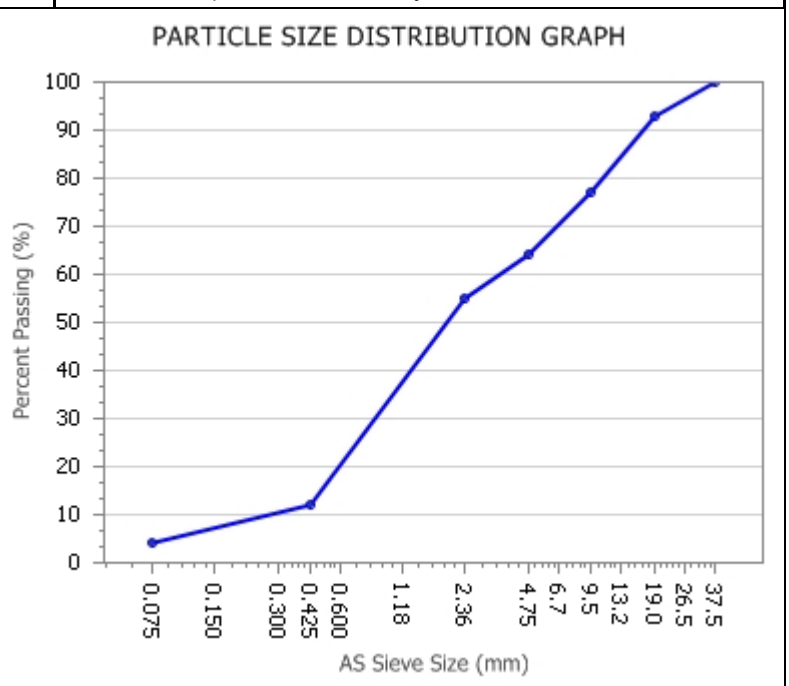
Laboratory: Emerald Laboratory
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Email: donna.marr@cardno.com.au

# QUALITY OF MATERIALS REPORT

| | | | |
|---|---|---|---|
| Client: | Wesfarmers Curragh Pty Ltd | Report Number: | 1692/R/8747-1 |
| Client Address: | Private Mail Bag, Blackwater | Project Number: | 1692/P/271 |
| Project: | Pit B Tailings Dam Embankment Samples | Lot Number: | |
| Location: | Curragh Mine Via Blackwater | Internal Test Request: | 1692/T/3145 |
| Component: | | Client Reference/s: | 6/10/2016 |
| Area Description: | | Report Date / Page: | 10/10/2016 Page 3 of 3 |

| | | | |
|---|---|---|---|
| Test Procedures | AS1289.3.6.1, AS1289.3.1.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1 | | |
| Sample Number | 1692/S/18637 | Location | CPP#1 CPP#2 Coarse Rejects |
| Sampling Method | AS1289.1.2.1 Cl 6.2 | | |
| Date Sampled | 6/10/2016 | | |
| Sampled By | Andrea Fleming | | |
| Date Tested | 6/10/2016 | Material Source | Onsite |
| Att. Drying Method | Oven Dried | Material Type | Embankment |
| Atterberg Preparation | Dry Sieved | Material Description | Black Coal Rejects |

| AS Sieve (mm) | Specification Minimum | Percent Passing (%) | Specification Maximum |
|---|---|---|---|
| 37.5 | | **100** | |
| 19.0 | | **93** | |
| 9.5 | | **77** | |
| 4.75 | | **64** | |
| 2.36 | | **55** | |
| 0.425 | | **12** | |
| 0.075 | | **4** | |




| Test Result | Specification Minimum | Result | Specification Maximum | Test Result | Specification Minimum | Result | Specification Maximum |
|---|---|---|---|---|---|---|---|
| Liquid Limit (%) | | **Not Obtainable** | | 0.075/0.425 Fines Ratio | | **0.29** | |
| Plastic Limit (%) | | **Not Obtainable** | | PI x 0.425 Ratio (%) | | **-** | |
| Plastic Index (%) | | **Non Plastic** | | LS x 0.425 Ratio (%) | | **0.0** | |
| Linear Shrinkage (%) | | **0.0** | | Linear Shrinkage Defects | - | | |

Remarks

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Accredited for compliance with ISO/IEC 17025

Accreditation Number: 1986
Corporate Site Number: 1692

Approved Signatory: Donna Marr
Form ID: W85Rep Rev 1

This report is prepared on behalf of
UNSW Global Pty Limited

# Large Shear Box Test Report - 1

# for

# Australian Soil Testing P/L

Author:
Professor Nasser Khalili

8 September 2010

Authorised Contact:
Rachel Brooks

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## Table of Contents

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2. Sample preparation and Testing Procedure ..... 1
3. Summary of Test Results ..... 1

**Annexes**

Annex 1 :Test Records of Shear Stress and Vertical Displacement

## 1. Sample identification

Sample number: Job 113-117

Sample location: Lake Vermont

Sample description: Disturbed samples of sandy gravel supplied by the client.

## 2. Sample preparation and Testing Procedure

The samples were placed in the shear box in three layers and compacted to the specified dry density at its natural moisture content. The samples were consolidated without flooding at the prescribed normal stress and sheared at a strain rate of 0.5mm/min until a constant volume was achieved.

## 3. Summary of Test Results

| Sample No | Normal Stress (kPa) | Peak Shear Stress (kPa) | Strength Parameters* |
|---|---|---|---|
| Job 113-117 | 50<br>100<br>200 | 54.41<br>101.51<br>194.32 | $\phi = 43.0^o$<br>c = 8.0 kPa |

* Note – The strength parameters were computed from three sets of test data.

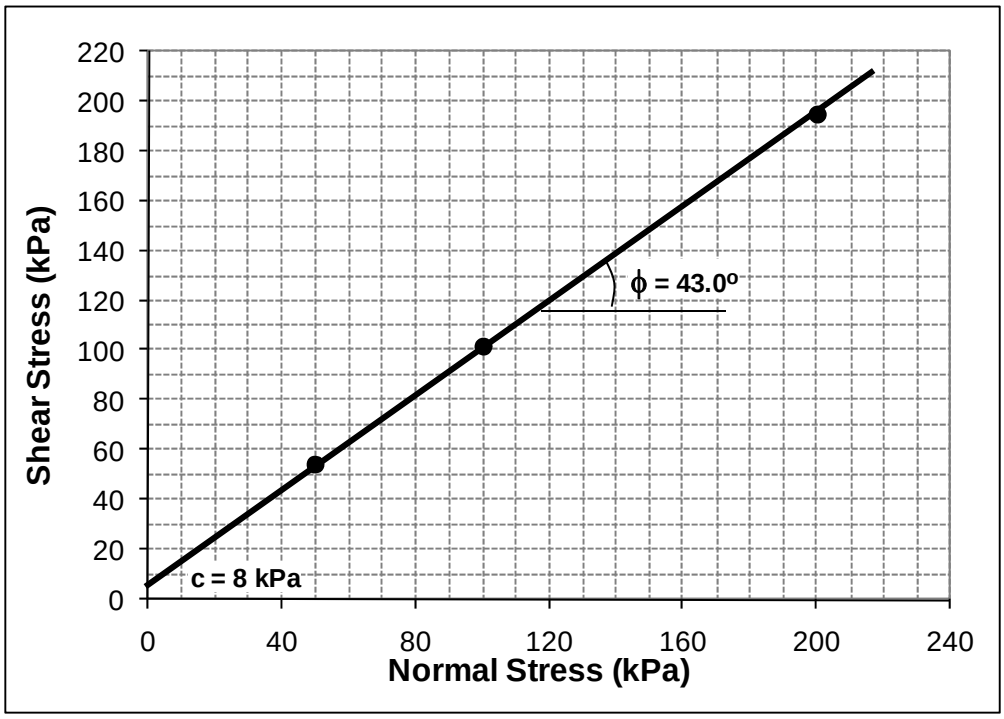



Fig 1 – Plot of shear strength versus normal stress for the test soil with dry unit weight of 1.1 t/m$^3$

**Professor Nasser Khalili**
BSc Teh., MSc Birm., PhD

for UNSW Global Pty Limited

# Annexes

# Annex 1

## Test Records of Shear Stress and Vertical Displacement

.

# Large Shear Box Test

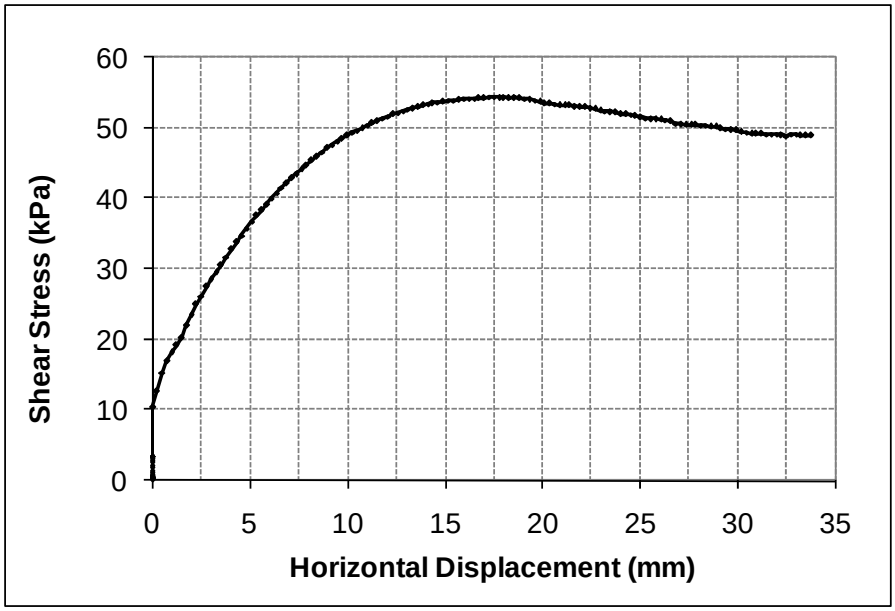
(AS 1289.6.2.2)

**Normal Stress = 50 kPa**

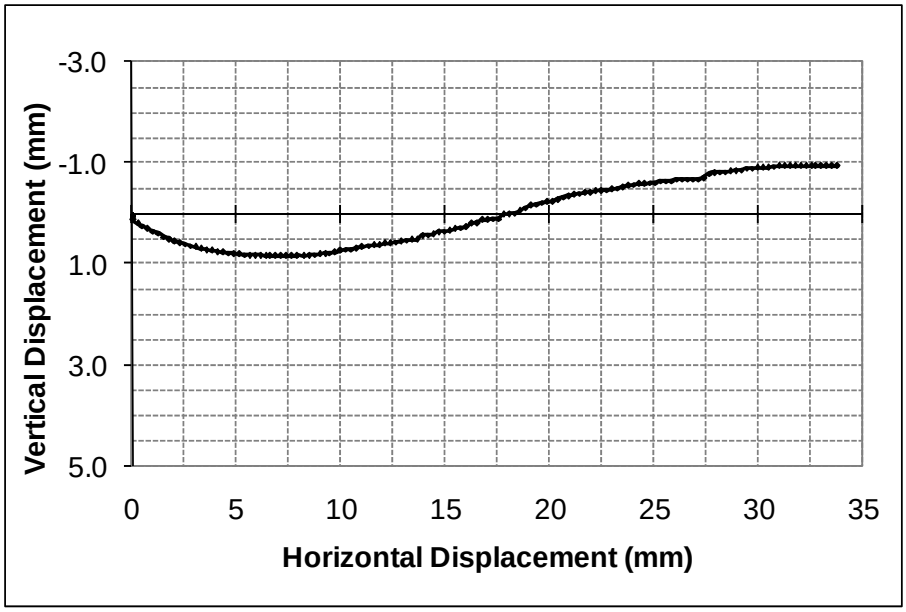
| | | | |
|---|---|---|---|
| Client: | *Golder Associates Pty. Ltd.* | Test Date: | *24 August, 2010* |
| Project: | | Dry Density: | *1.1 t/m$^3$* |
| Location: | Lake Vermont | Moisture Content: | *2.84%* |
| Sample ID: | Job 113-117 | Strain Rate: | *0.5 mm/min* |
| Test No: | *SGS-LST001* | Shear Box Size: | *304 mm×304 mm* |

**Sample Preparation:** Disturbed sample supplied by the client (initial moisture content ranging from 2.56 to 2.86%) compacted to the specified dry density.

## Plot of Shear Stress vs Horizontal Displacement



## Plot of Vertical Displacement vs Horizontal Displacement




Peak Shear Stress: **54.41 kPa**

**Note:** Tilting of the upper cap was observed during shearing; the volume changes measured may not be reliable.

## Large Shear Box Test

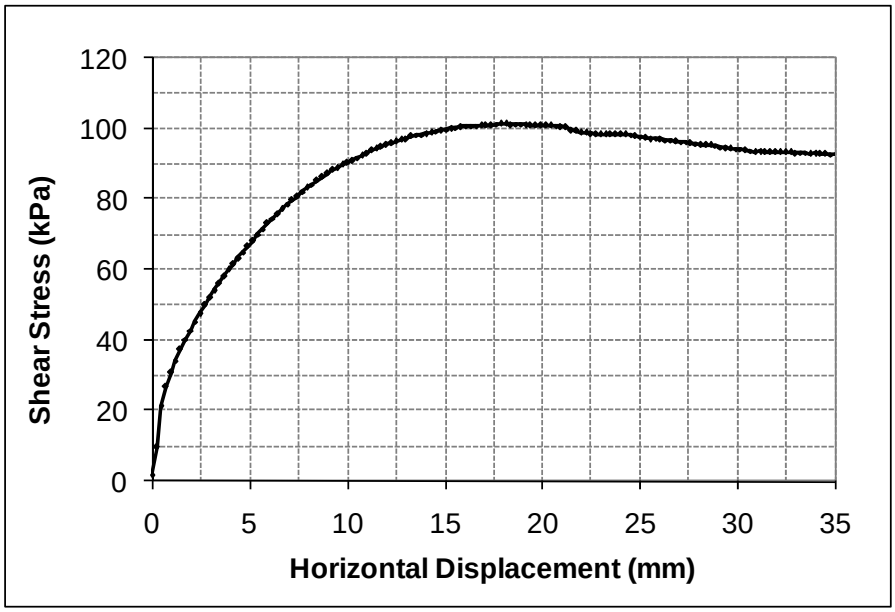
(AS 1289.6.2.2)

**Normal Stress = 100 kPa**

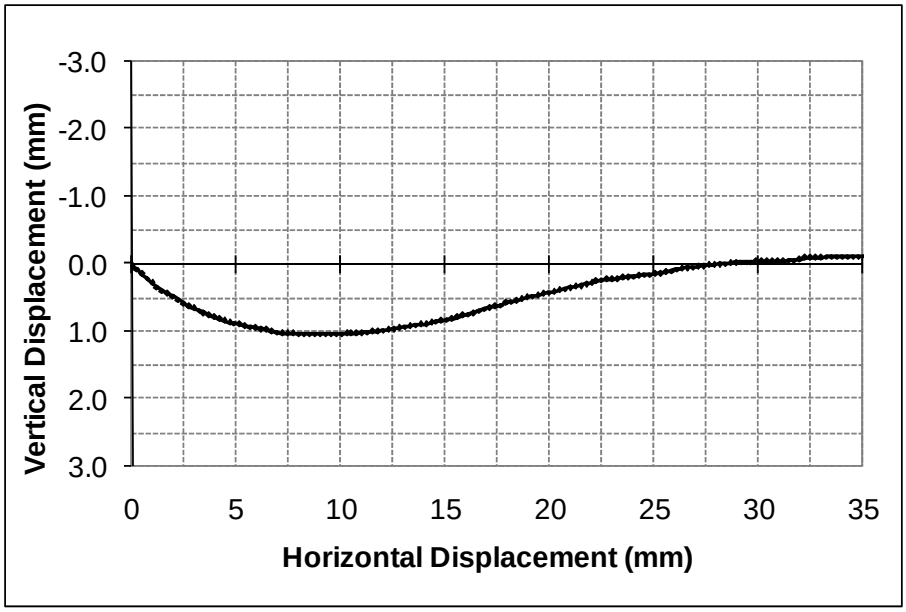
| | | | |
|---|---|---|---|
| Client: | *Golder Associates Pty. Ltd.* | Test Date: | *25 August, 2010* |
| Project: | | Dry Density: | *1.1 t/m³* |
| Location: | Lake Vermont | Moisture Content: | *2.84%* |
| Sample ID: | Job 113-117 | Strain Rate: | *0.5 mm/min* |
| Test No: | *SGS-LST002* | Shear Box Size: | *304 mm×304 mm* |

**Sample Preparation:** Disturbed sample supplied by the client (initial moisture content ranging from 2.56 to 2.86%) compacted to the specified dry density.

## Plot of Shear Stress vs Horizontal Displacement




## Plot of Vertical Displacement vs Horizontal Displacement




Peak Shear Stress: **101.52 kPa**

**Note:** Tilting of the upper cap was observed during shearing; the volume changes measured may not be reliable.

# Large Shear Box Test

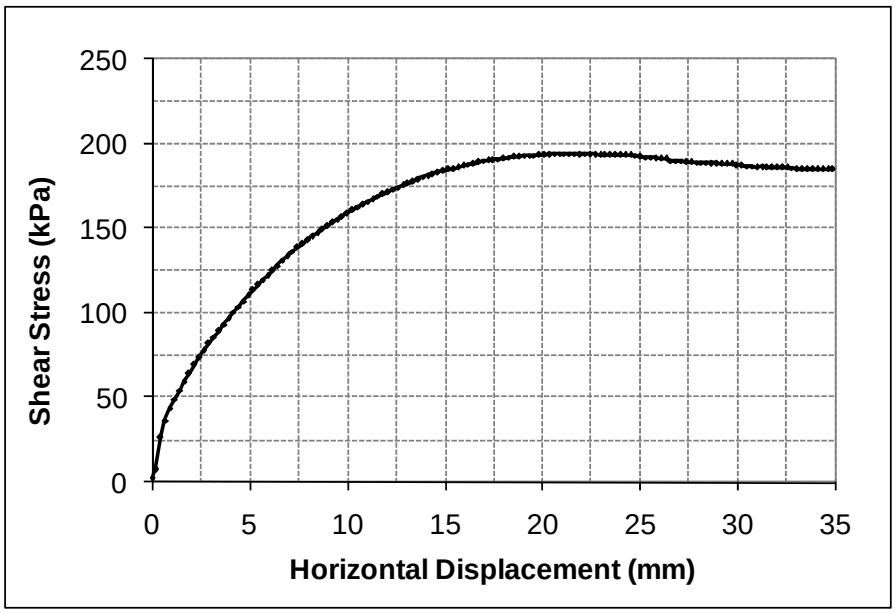
(AS 1289.6.2.2)

**Normal Stress = 200 kPa**

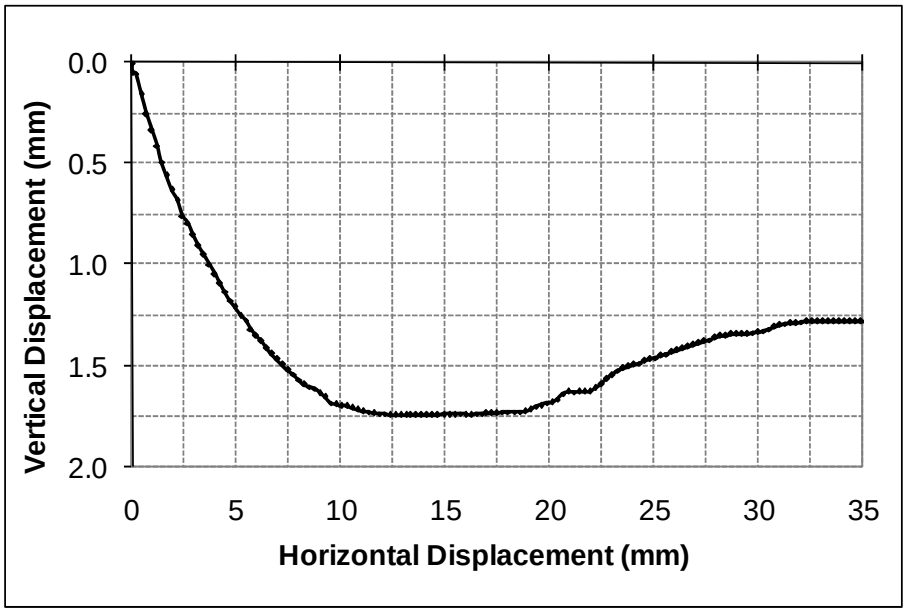
| | | | |
|---|---|---|---|
| Client: | *Golder Associates Pty. Ltd.* | Test Date: | *26 August, 2010* |
| Project: | | Dry Density: | *1.1 t/m$^3$* |
| Location: | Lake Vermont | Moisture Content: | *2.84%* |
| Sample ID: | Job 113-117 | Strain Rate: | *0.5 mm/min* |
| Test No: | *SGS-LST003* | Shear Box Size: | *304 mm×304 mm* |

**Sample Preparation:** Disturbed sample supplied by the client (initial moisture content ranging from 2.56 to 2.86%) compacted to the specified dry density.

## Plot of Shear Stress vs Horizontal Displacement



## Plot of Vertical Displacement vs Horizontal Displacement




Peak Shear Stress: **194.32 kPa**

**Note:** Tilting of the upper cap was observed during shearing; the volume changes measured may not be reliable.

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WA 6107
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# DIRECT SHEAR TEST REPORT

**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100157-DS |
| **Address** | 13 Glasson St, Emerald QLD 4720 | **Test Date** | 25/10/2016 |
| | | **Report Date** | 26/10/2016 |
| **Project** | 1692/P/271 - Pit B Tailings Dam Embankment Samples | | |
| **Client ID** | 1692/S/18635 - Curragh Pit H Spoil | **Depth (m)** | Not Supplied |
| **Description** | - | | |
| **Sample Type** | Three individual soil specimens - Remoulded. | | |

## SAMPLE DETAILS

| | Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|---|
| Maximum Dry Density (t/m$^3$) | 1.92 | 1.92 | 1.92 | |
| Optimum Moisture Content (%) | 12.0 | 12.0 | 12.0 | |
| Density Ratio Required (%) | 95 | 95 | 95 | |
| Specimen Condition | Saturated | Saturated | Saturated | |
| Specimen Dimensions (mm) | 305 x 305 | 305 x 305 | 305 x 305 | |
| Initial Sample Height (mm) | 172.3 | 172.3 | 172.3 | |
| Rate of Strain (mm/min) | 0.10 | 0.10 | 0.10 | |
| Initial Moisture Content (%) | 11.7 | 11.8 | 12.3 | |
| Initial Wet Density (t/m$^3$) | 2.04 | 2.04 | 2.04 | |
| Final Moisture Content (%) | 12.9 | 13.0 | 13.3 | |

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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Authorised Signatory
C. Purvis

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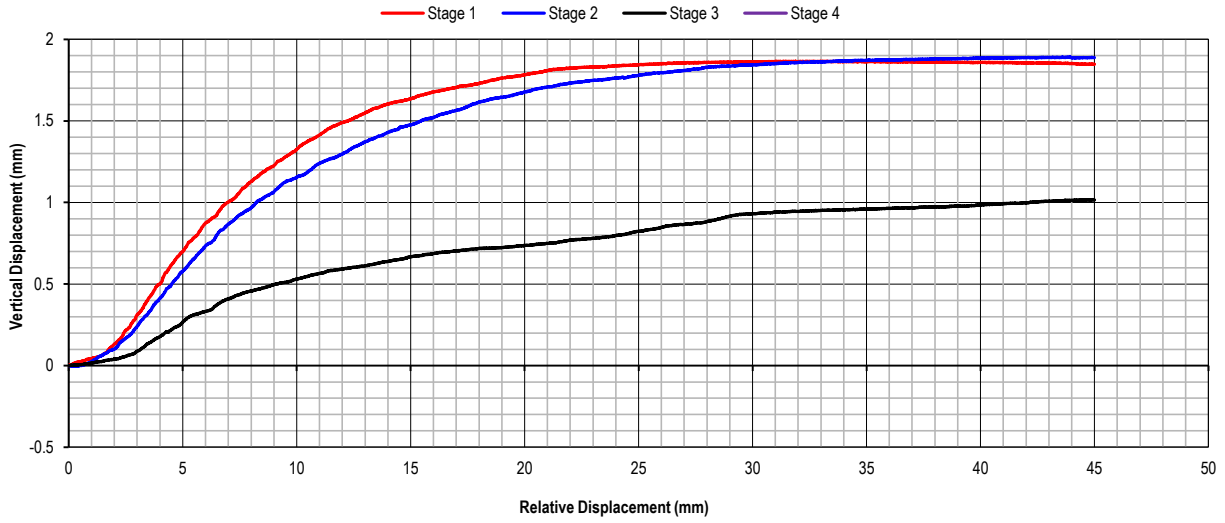
# DIRECT SHEAR TEST REPORT

**Test Method: ASTM D3080**

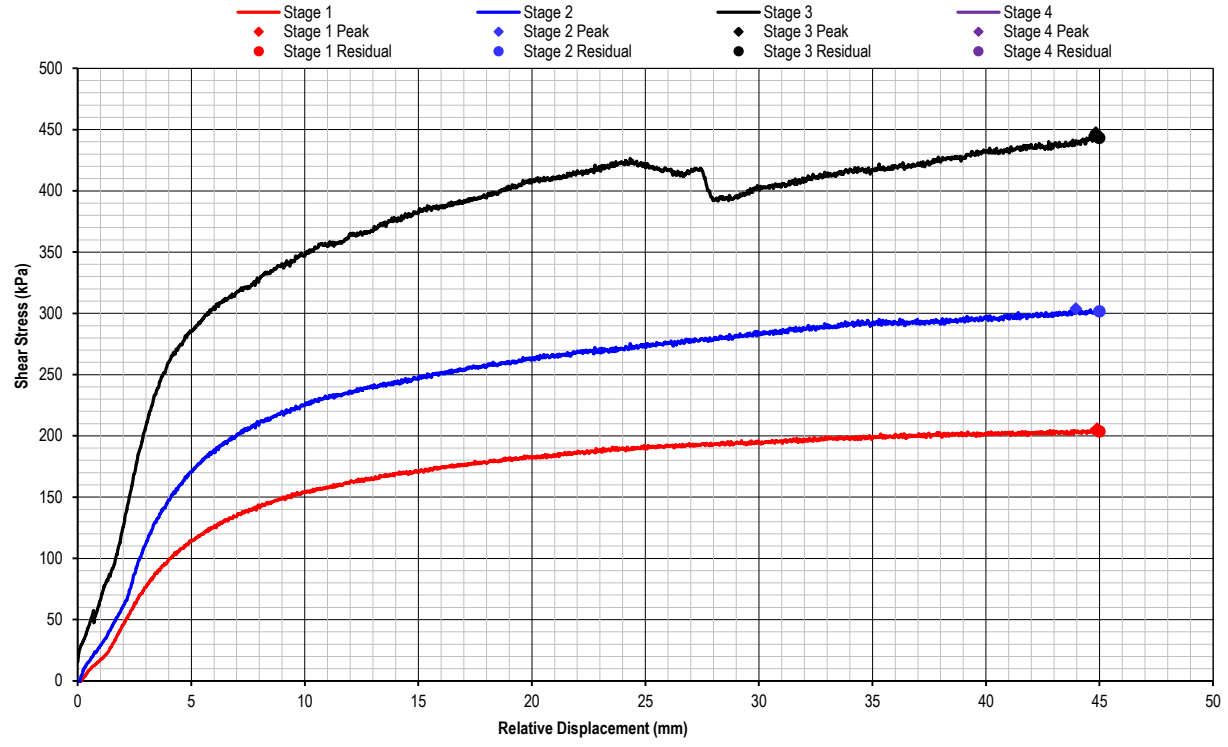
Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100157-DS |

## Vertical Displacement/Relative Displacement Plot




## Shear Stress/Displacement Plot




Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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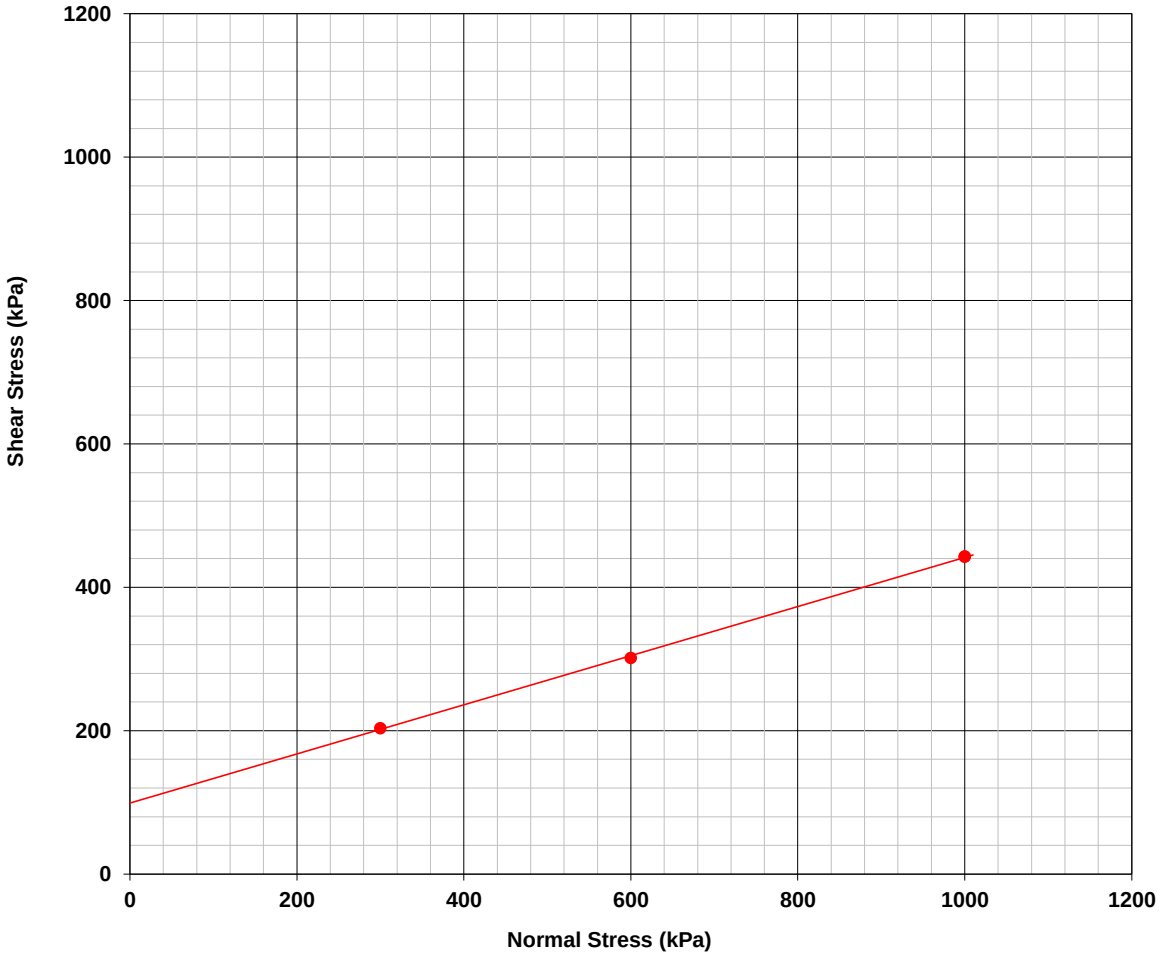
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100157-DS |

**Failure Criteria** **Residual**

## Residual - Normal Stress vs Shear Stress




| | | Stage | Residual Displacement | Normal Stress | Shear Stress |
|---|---|---|---|---|---|
| **Shear Angle (°)** | **18.9** | | (mm) | (kPa) | (kPa) |
| **Cohesion (kPa)** | **98.8** | 1 | 45.00 | 300.0 | 203.4 |
| | | 2 | 45.00 | 600.0 | 301.5 |
| **$R^2$** | **1.000** | 3 | 44.99 | 1000.0 | 443.0 |

Machine Description Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale Sample/s supplied by the client



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# DIRECT SHEAR TEST REPORT

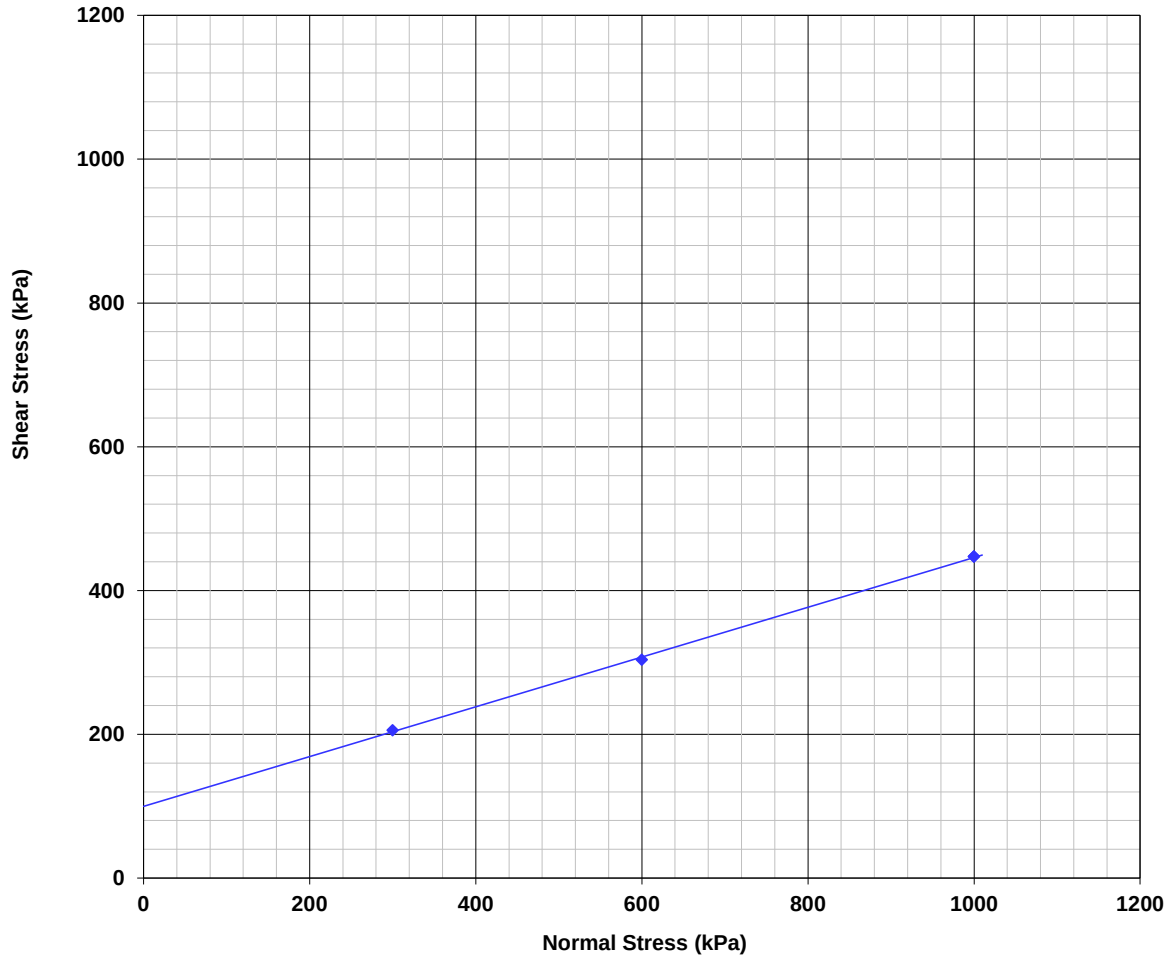
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100157-DS |

**Failure Criteria** **Peak**

## Peak - Normal Stress vs Shear Stress




| | | Stage | Displacement at Peak Stress | Normal Stress | Shear Stress |
|---|---|---|---|---|---|
| **Shear Angle (°)** | **19.1** | | (mm) | (kPa) | (kPa) |
| **Cohesion (kPa)** | **99.9** | 1 | 44.90 | 300.0 | 205.8 |
| | | 2 | 43.96 | 600.0 | 303.8 |
| **$R^2$** | **1.000** | 3 | 44.84 | 1000.0 | 447.4 |

Machine Description: Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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# DIRECT SHEAR TEST REPORT

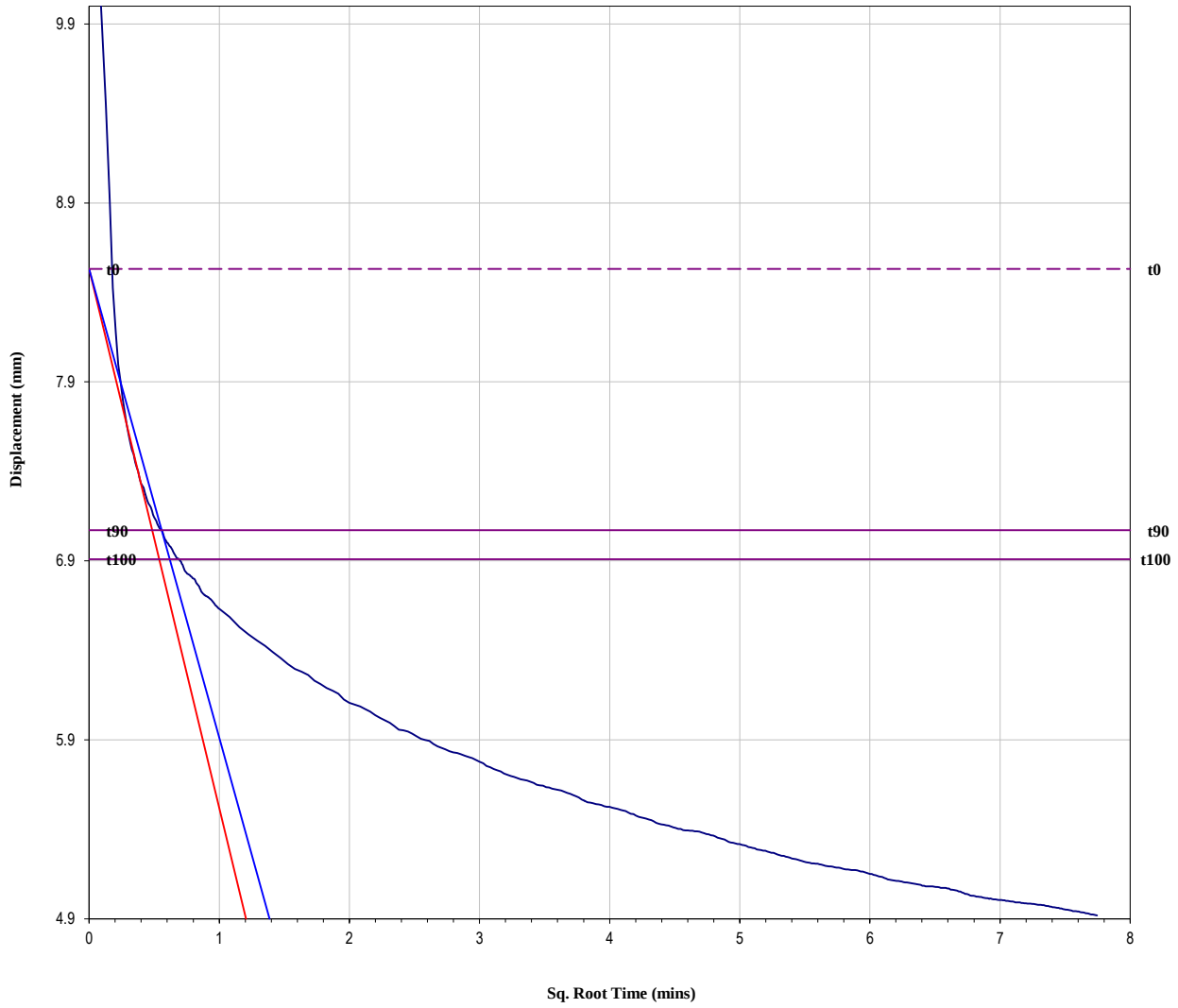
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
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## Stage 1 Consolidation

**Displacement v's Time (Sq. Root Scale)**




| | | |
|---|---|---|
| $t_{90}$ | 0.31 | **mins** |
| **Time to Failure =** | 3.60 | **mins** |
| **Estimated Displacement to Failure =** | 5 | **mm** |
| **Displacement Rate =** | 1.38717 | **mm/min** |

Notes/Remarks:

Graph not to scale

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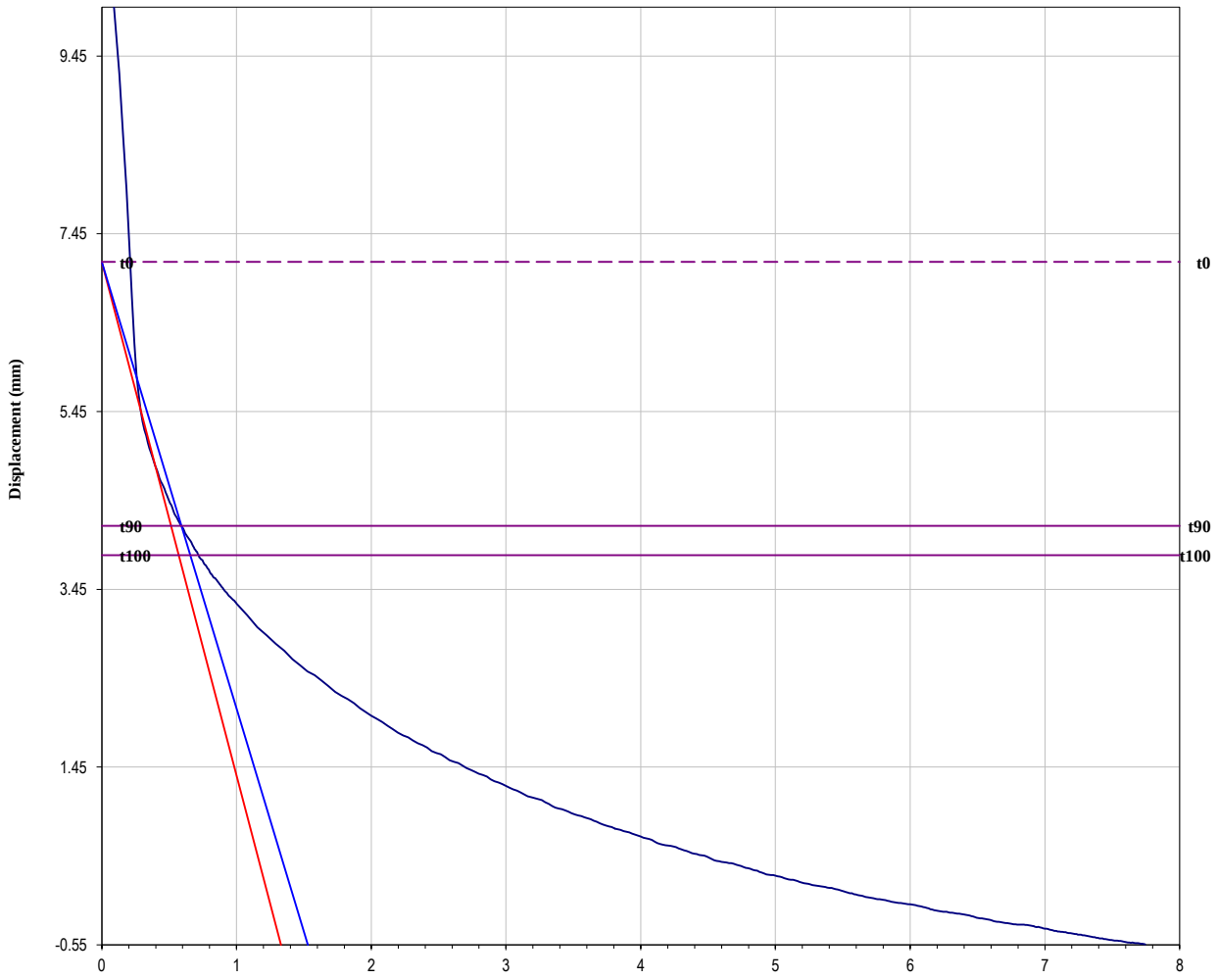
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100157-DS |

## Stage 2 Consolidation

**Displacement v's Time (Sq. Root Scale)**




| | | |
|---|---|---|
| $t_{90}$ | 0.35 | **mins** |
| **Time to Failure =** | 4.05 | **mins** |
| **Estimated Displacement to Failure =** | 5 | **mm** |
| **Displacement Rate =** | 1.23332 | **mm/min** |

Notes/Remarks:

Graph not to scale

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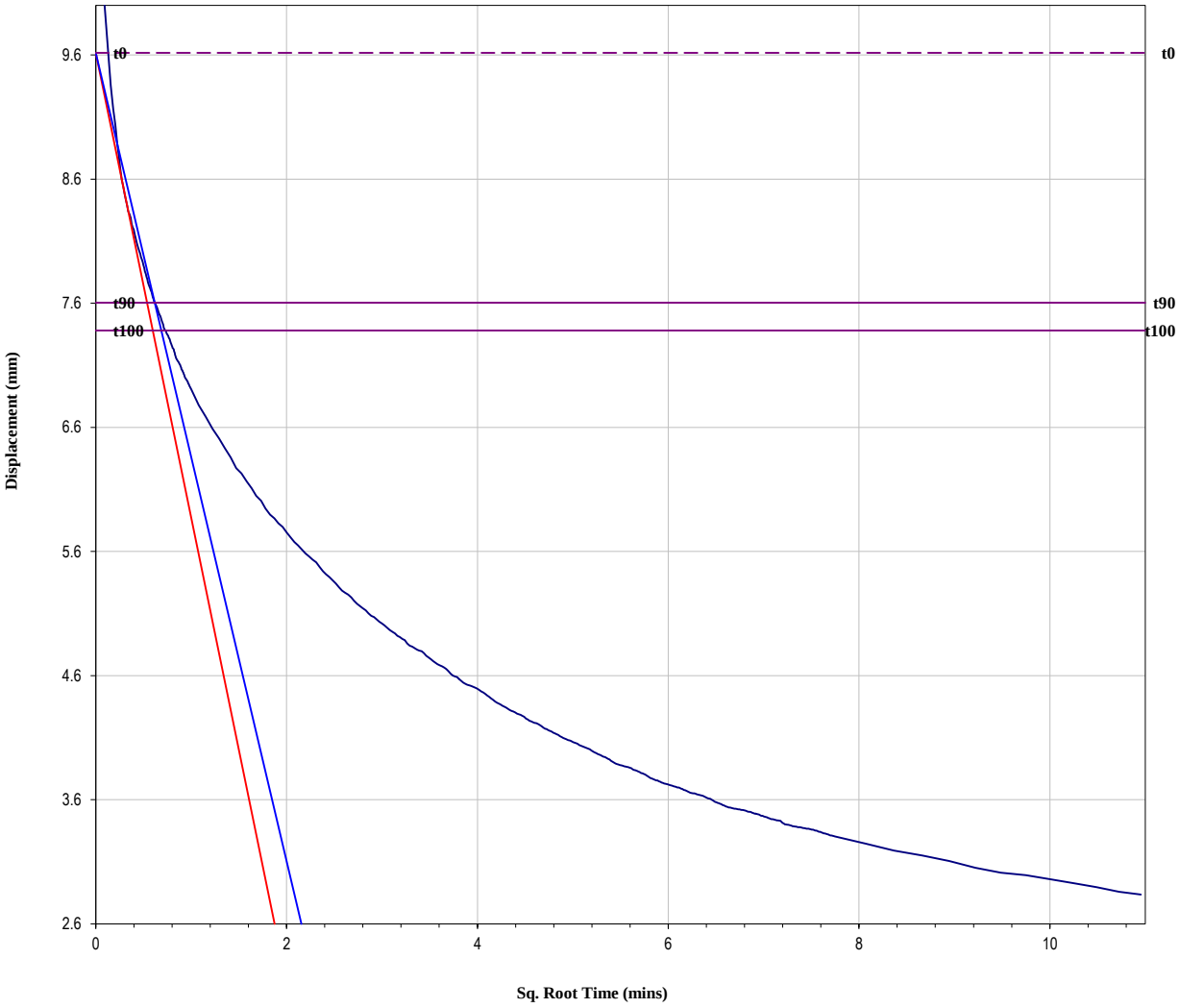
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100157-DS |

## Stage 3 Consolidation

**Displacement v's Time (Sq. Root Scale)**




| | | |
|---|---|---|
| $t_{90}$ | 0.38 | mins |
| **Time to Failure =** | 4.44 | mins |
| **Estimated Displacement to Failure =** | 5 | mm |
| **Displacement Rate =** | 1.12728 | mm/min |

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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# DIRECT SHEAR TEST REPORT

**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100159-DS |
| **Address** | 13 Glasson St, Emerald QLD 4720 | **Test Date** | 20/10/2016 |
| | | **Report Date** | 21/10/2016 |
| **Project** | 1692/P/271 - Pit B Tailings Dam Embankment Samples | | |
| **Client ID** | 1692/S/18637 - CPP#1 CPP#2 Coarse Rejects | **Depth (m)** | Not Supplied |
| **Description** | Tailings | | |
| **Sample Type** | Three individual soil specimens - Remoulded. | | |

## SAMPLE DETAILS

| | Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|---|
| Maximum Dry Density (t/m$^3$) | 1.51 | 1.51 | 1.51 | - |
| Optimum Moisture Content (%) | 12.0 | 12.0 | 12.0 | - |
| Density Ratio Required (%) | 95 | 95 | 95 | - |
| Specimen Condition | Saturated | Saturated | Saturated | - |
| Specimen Dimensions (mm) | 305 x 305 | 305 x 305 | 305 x 305 | - |
| Initial Sample Height (mm) | 172.3 | 172.3 | 172.3 | - |
| Rate of Strain (mm/min) | 1.00 | 1.00 | 1.00 | - |
| Initial Moisture Content (%) | 12.1 | 12.0 | 11.8 | - |
| Initial Wet Density (t/m$^3$) | 1.61 | 1.61 | 1.61 | - |
| Final Moisture Content (%) | 19.0 | 17.0 | 18.9 | - |

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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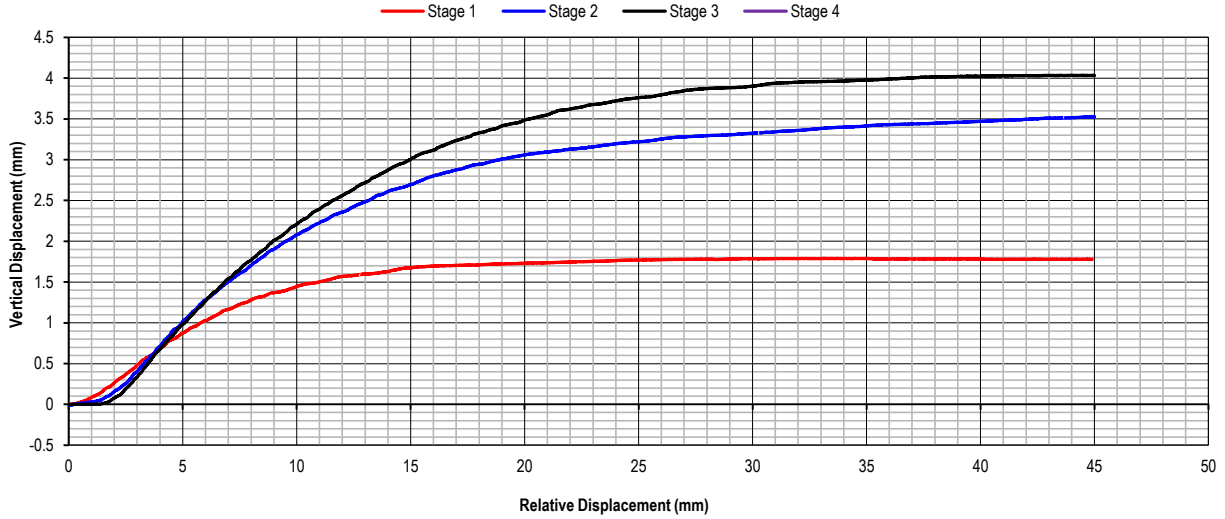
# DIRECT SHEAR TEST REPORT

**Test Method: ASTM D3080**

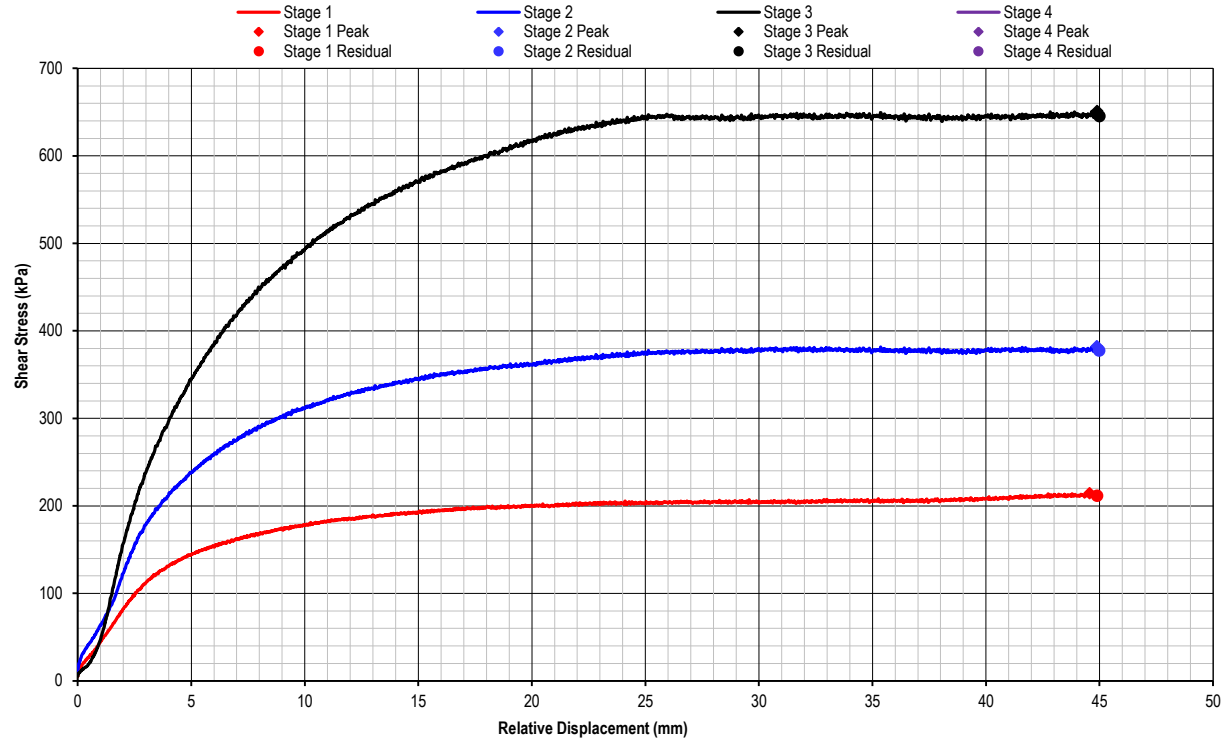
Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100159-DS |

## Vertical Displacement/Relative Displacement Plot




## Shear Stress/Displacement Plot




Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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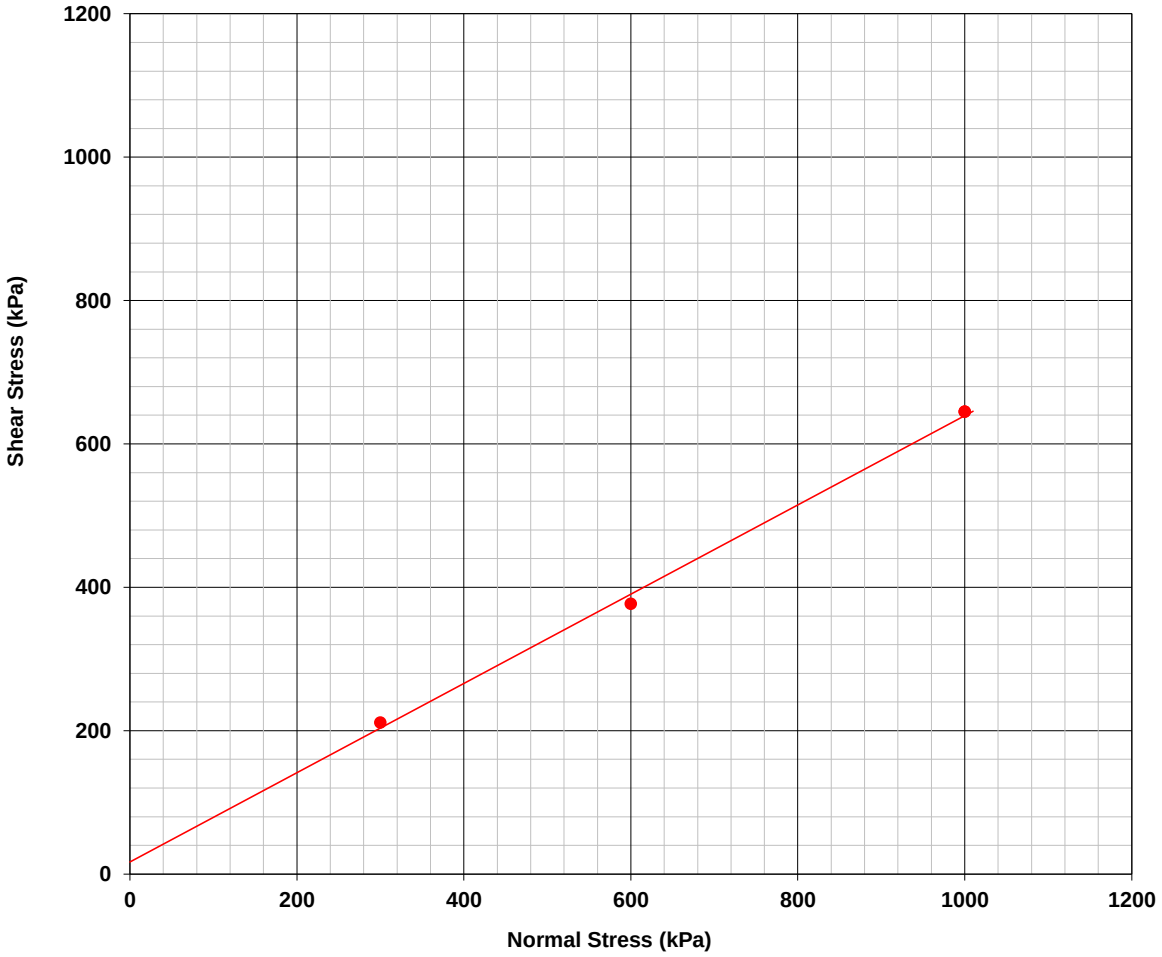
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100159-DS |

**Failure Criteria** **Residual**

## Residual - Normal Stress vs Shear Stress




| | | Stage | Residual Displacement | Normal Stress | Shear Stress |
|---|---|---|---|---|---|
| **Shear Angle (°)** | **31.9** | | (mm) | (kPa) | (kPa) |
| **Cohesion (kPa)** | **17.0** | 1 | 44.90 | 300.0 | 211.3 |
| | | 2 | 44.99 | 600.0 | 377.1 |
| **$R^2$** | **0.999** | 3 | 45.00 | 1000.0 | 645.1 |

Machine Description Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale Sample/s supplied by the client



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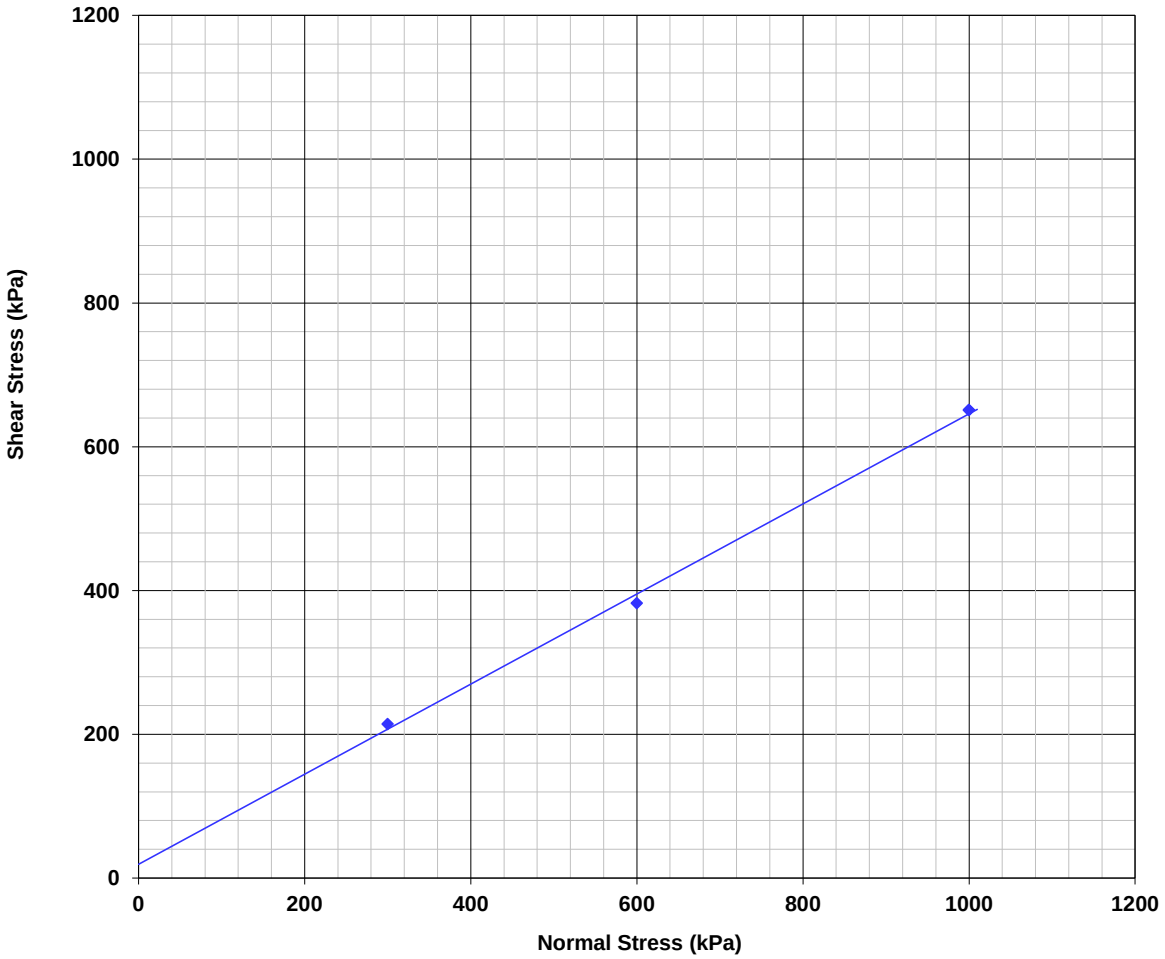
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100159-DS |

**Failure Criteria** **Peak**

## Peak - Normal Stress vs Shear Stress




| | | Stage | Displacement at Peak Stress | Normal Stress | Shear Stress |
|---|---|---|---|---|---|
| **Shear Angle (°)** | **32.1** | | (mm) | (kPa) | (kPa) |
| **Cohesion (kPa)** | **19.0** | 1 | 44.56 | 300.0 | 214.2 |
| **$R^2$** | **0.999** | 2 | 44.89 | 600.0 | 382.3 |
| | | 3 | 44.90 | 1000.0 | 651.0 |

Machine Description Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale Sample/s supplied by the client



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# DIRECT SHEAR TEST REPORT

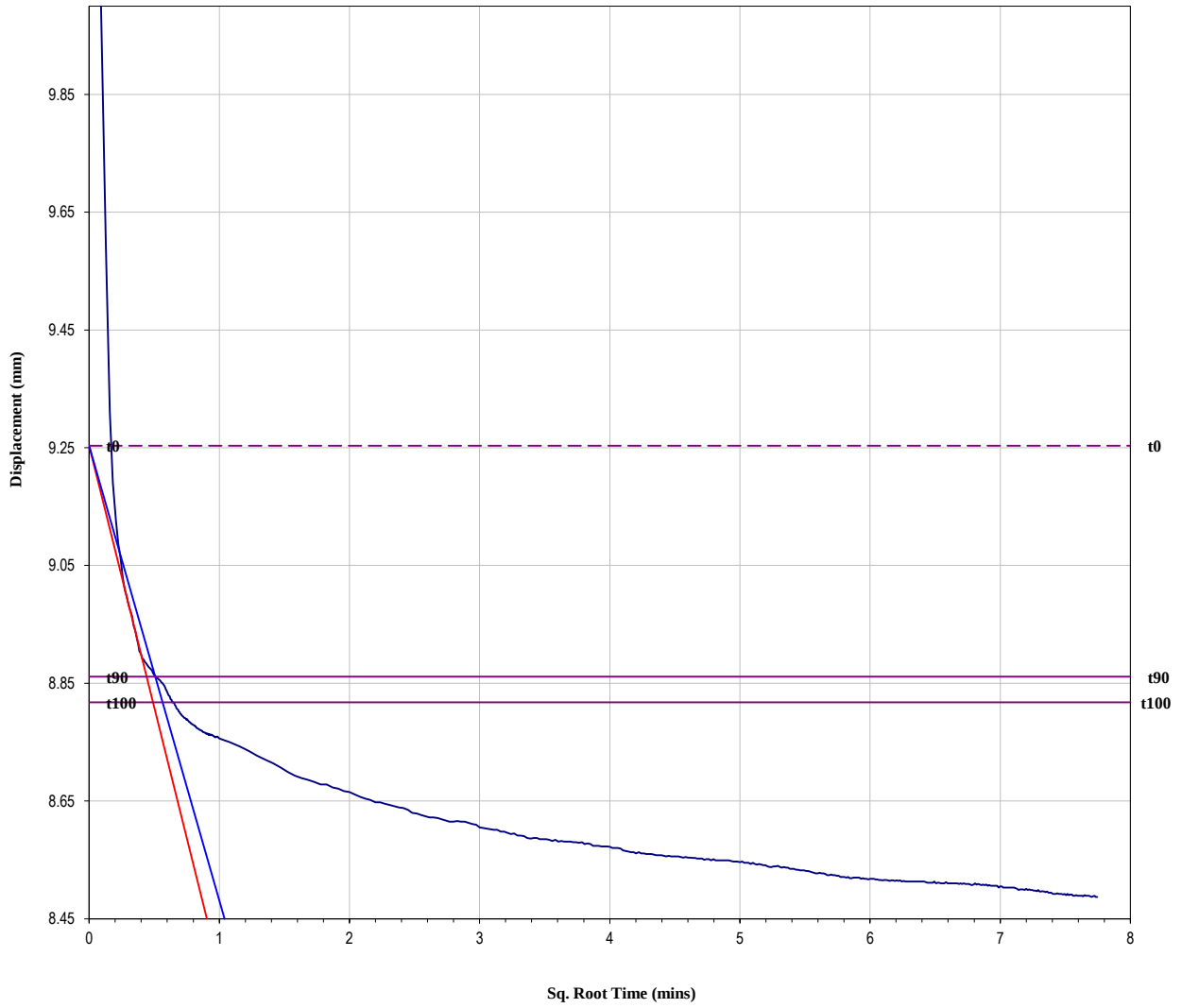
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Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100159-DS |

## Stage 1 Consolidation

**Displacement v's Time (Sq. Root Scale)**




| | | |
|---|---|---|
| $t_{90}$ | 0.26 | **mins** |
| **Time to Failure =** | 2.99 | **mins** |
| **Estimated Displacement to Failure =** | 5 | **mm** |
| **Displacement Rate =** | 1.67111 | **mm/min** |

Notes/Remarks:

Graph not to scale

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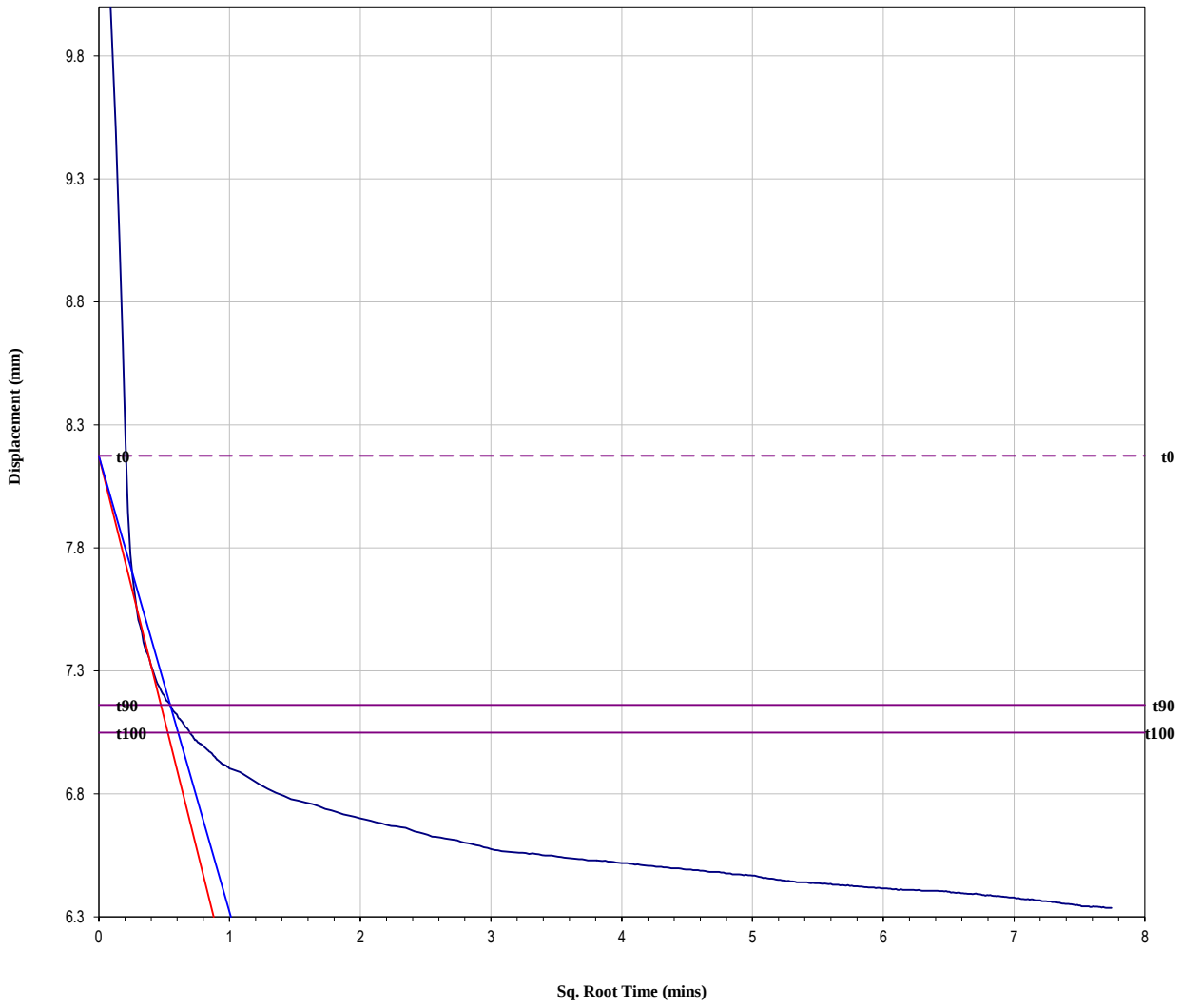
**Test Method: ASTM D3080**

Direct Shear Test of Soils Under Consolidated Drained Conditions.

| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100159-DS |

## Stage 2 Consolidation

**Displacement v's Time (Sq. Root Scale)**




| | | |
|---|---|---|
| $t_{90}$ | 0.30 | **mins** |
| **Time to Failure =** | 3.46 | **mins** |
| **Estimated Displacement to Failure =** | 5 | **mm** |
| **Displacement Rate =** | 1.44484 | **mm/min** |

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client



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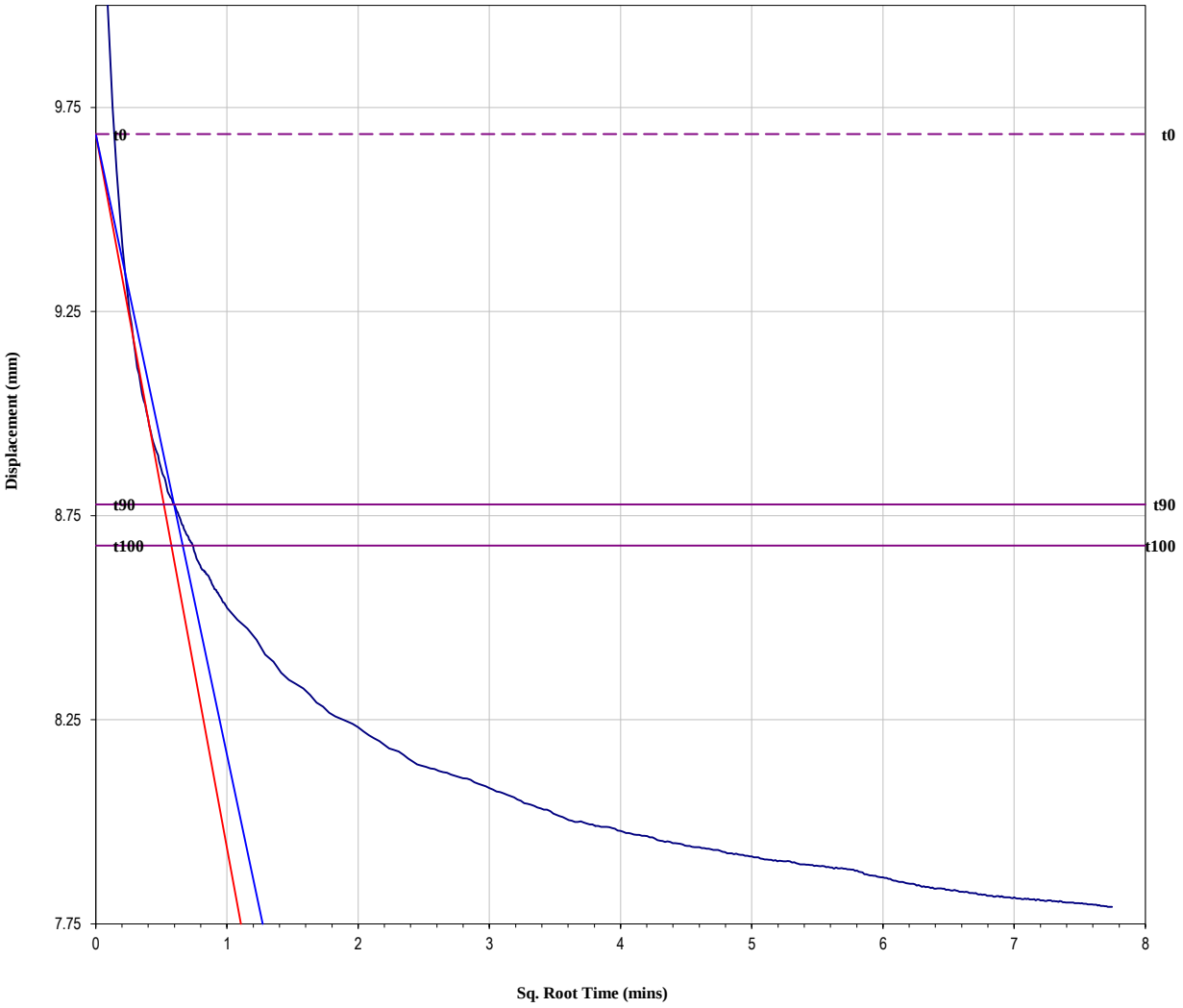
**Test Method: ASTM D3080**

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| | | | |
|---|---|---|---|
| **Client** | Cardno Construction Sciences Pty Ltd | **Report No.** | 16100159-DS |

## Stage 3 Consolidation

**Displacement v's Time (Sq. Root Scale)**




| | | |
|---|---|---|
| $t_{90}$ | 0.36 | **mins** |
| **Time to Failure =** | 4.13 | **mins** |
| **Estimated Displacement to Failure =** | 5 | **mm** |
| **Displacement Rate =** | 1.21115 | **mm/min** |

Notes/Remarks:

Graph not to scale

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# APPENDIX D

## Published documentation - mine waste geotechnical parameters

**Proc. Advances in Geotechnical Engineering: The Skempton Conference, R.J. Jardine, D.M. Potts and K.G. Higgins (eds). Vol 2, 981-991, Thomas Telford, 2004.**

# Shear Strength Framework for Design of Dumped Spoil Slopes for Open Pit Coal Mines

**John V Simmons** Principal, Sherwood Geotechniques, Brisbane, Australia
**Dennis A McManus** Principal Engineering Geologist, BMA Coal, Moranbah, Australia

## Abstract

Modern open pit coal mining results in dumped spoil slopes typically between 80m and 250m high. Stability can be compromised by weak geological conditions, seepage, slaking of clayey spoil materials, and dumping processes. The consequences of failure are expensive and may be catastrophic. Dump design is challenging because there is usually no opportunity for site-specific investigations and testing. A shear strength framework for open pit coal spoil dump materials has been developed for reliable assessment of shear strength parameters from visual-tactile observations. Although originally developed for the Permian Bowen Basin of eastern Australia, it is argued that the framework is applicable for coal measures materials generally. Vital to the framework are an understanding of geological conditions and a robust process for assessing relevant attributes of dumped material. The factors that must be taken into account for dump stability assessment are described. Verification of the strength parameters involved rigorous backanalysis, requiring the Sarma method for non-vertical slices in order to replicate observed characteristics of dump slope failures. The framework has limitations, and the most significant of these are discussed. Non-routine problems still require sound application of engineering judgement and risk management principles.

## Introduction

The Bowen Basin coking and thermal coal resource of central Queensland, Australia (Figure 1), has been the locus of large-scale open pit and underground mining since the mid-1970's. Relatively flat seam dips have resulted in open pit mining based on long strips with overburden removal using walking draglines and shovel/truck methods. Cast blasting and dozer-assistance have been widely adopted to improve cost efficiencies.

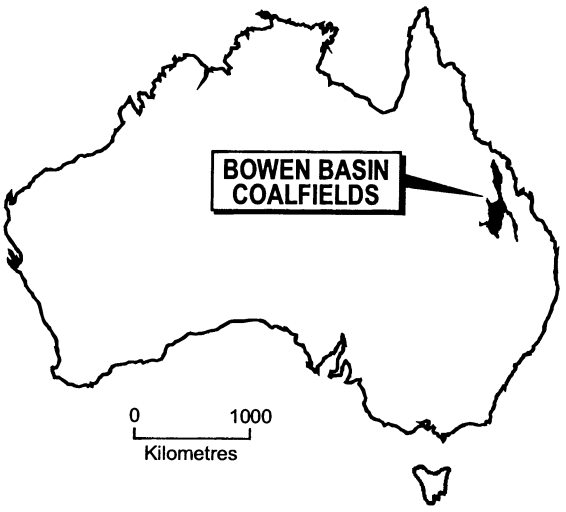



Figure 1 Location of Bowen Basin coalfields

Very large volumes of dumped spoil material are generated by strip mining. Dump slopes must be as

steep as possible while maintaining acceptable stability. Spoil material typically consists of boulders, cobbles, gravels, and fines. Particle size distribution is a function of initial lithology, blast fragmentation, comminution during handling, and post-depositional breakdown. Spoil material from near-surface is typically weathered and more fine-grained than spoil from deeper horizons. Differences between dragline and shovel/truck spoil materials are minor, and due only to the method of placement and to depositional fabric.

Spoil dump stability is controlled by shear strength, inclination and strength of the dump foundation, and influences of water. In most cases the foundation is the mined-out floor of the previous pit. Sub-floor strength is generally adequate, except where geological conditions include either weak clay seams or sheared surfaces of tectonic origin. While it is often simplest to dump the uppermost overburden onto the previous pit floor, this places the weakest material in the most highly stressed zone of the dump and is avoided where possible.

Geotechnical evaluation of Bowen Basin spoil materials commenced in the mid-1970's (Mallett et al, 1983), but was generally limited to characterisation as an extension of geological investigations. Because of the practical difficulty of sampling and testing spoil materials, emphasis was placed on observing and interpreting mechanisms of spoil dump failure, and on backanalysis to determine operational shear strength parameters.

BMA Coal operates a number of Bowen Basin mines spread over a distance of about 200km, in a variety of Permian coal measures lithologies, and with varying cover of Tertiary and Quaternary age. In-house geotechnical information, including laboratory tests and backanalysis results, indicated that certain geological conditions produced spoils of similar geotechnical properties irrespective of location. Routine slope design charts were developed (BHP Engineering, 1991), with spoil assigned to one of four categories based on the simplest possible geological descriptions. For each spoil category, design strength parameters were based on in-house information. This framework for categorising spoil was widely adopted within BMA Coal, and its use was extended generally to open pit mines in the Bowen Basin (Simmons and McManus, 1995).

## Generalisation of Framework

Coal measures rocks are sedimentary sequences formed within alluvial or estuarine depositional systems where peat mires developed and were buried. Sediments range from stream channel conglomerates and sandstones to alluvial floodplain sandstone-siltstone interbeds, siltstones, and claystones, and sometimes to shallow marine units. Products of volcanic ash falls or flows, or igneous intrusions, may also be present. Effects of burial, uplift, and tectonism are limited to certain ranges of pressure and temperature conditions coincident with the structures and ranks of commercially significant coals. Given the limited ranges of mineralogy, lithification, and structure of coal measures rocks, it is reasonable that spoil materials should have properties related more to geological attributes than to location.

Use of the BMA Coal spoil shear strength framework has been extended to the Permian, Triassic, and Jurassic coal basins of eastern Australia. This has involved confirmation through backanalysis of many spoil slope failures, as well as routine design of stable slopes where validity of strength is necessarily less precise. Confidence in the framework has now been established over a period of more than a decade and at more than 20 mine sites. Based on limited comparisons of unpublished data, the BMA Coal strength parameters appear to be applicable to the Cretaceous coal basins of western Canada. Within Miocene coal measures in Kalimantan, Indonesia, the BMA Coal strength parameters have been successfully used to

post-predict dump failures, and are very similar to results of subsequent site-specific field and laboratory testing (Simmons, 2003). Based on this experience, and considering the applicable range of geological conditions, the framework is believed to be applicable to spoil material from coal measures and geologically similar rocks generally.

Open pit coal spoil dump design is often carried out without formal checks of geotechnical stability, and with profile design based on mine planning considerations or on precedence. Site-specific investigation and strength testing is typically regarded as too difficult and costly, so shear strength parameters are assumed when stability analyses are undertaken. A reliable framework for estimating shear strength of dump materials is therefore critically important.

This paper describes factors to be considered in geotechnical design of dumped spoil slopes. Development of the BMA Coal strength framework, which involved observations, testing, and inferences about material behaviour based on backanalysis, is also described.

## Geotechnical Stability Design

### Geometric Constraints

Draglines work from operating benches at heights of 40m to 60m, limited by seam floor dips and the reaches and dig depths of the machines. Spoil is dumped at a typical rill angle of 37° to heights of 45m to 65m above operating bench level, by sequentially digging away below the bench to form an 'undercut' batter in the range of 37° to 45°. Greatest efficiency requires the dragline spoil dump profile to be as steep as possible, but overall stability may be improved by leaving a remnant bench that in practice must be 25m or less in width.

Trucked spoil dumps are more geometrically flexible than dragline dumps. In principle, truck dump slopes may be built to unlimited heights at the typical rill angle of 37°, but in practice dump face heights are limited to between 5m and 30m by dump-point stability and safety considerations. Where appropriate, the overall dump slope is terraced to achieve the desired slope for the rehabilitated landform.

Dragline spoil profiles are limited to between 80m and 120m total thickness, depending on machine specifications. As strips progress deeper, the dragline spoil has to be surcharged by prestrip spoil dumping using trucks or spreader systems. Surcharged dragline spoil profiles currently approach 200m in height, with final planned heights of 250m or greater. Overall truck dump heights up to 400m exist or are planned.

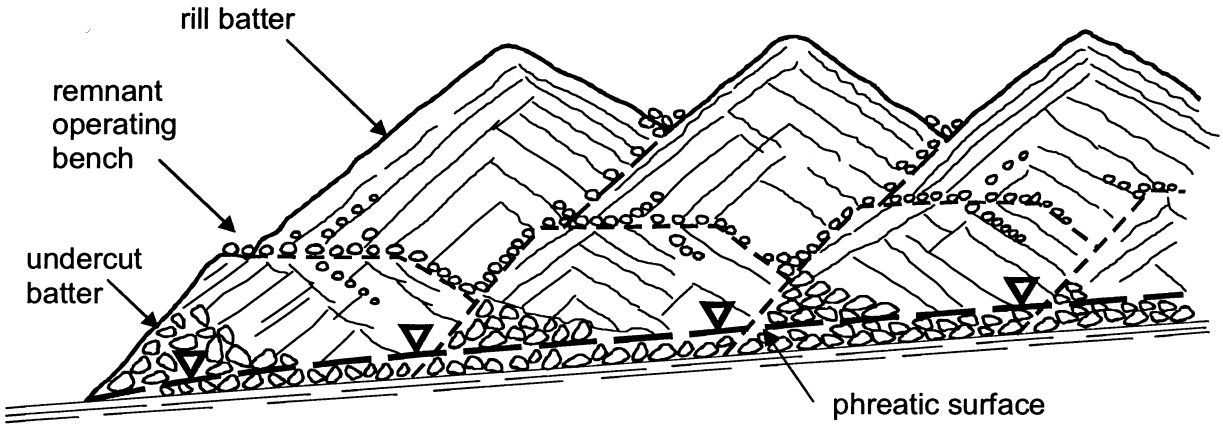



Figure 2 Schematic section of dragline spoil dump fabric and phreatic surface

## Depositional Fabric

The internal stratigraphy and depositional sequence of spoil dumps is complex. Spoil profiles are generally built by rilling, but may include a component of cast-blasted overburden. Rilling of both dragline and truck dumped spoil causes larger particles to roll preferentially towards the base of the rill profile but otherwise leaves a fabric of preferentially-aligned particles at the rill angle. Base and operating bench levels of dragline dumps become repositories for segregated coarse spoil that may be overlain by loose zones of relatively high permeability. Figure 2 is a schematic view of the fabric of a dragline dump profile.

The fabric of truck dumps varies depending on the adopted face heights, advancement procedures, and variability of materials. Dump running surfaces form compacted and sealed subhorizontal surfaces which are repositories for segregated coarse spoil and which become overlain by loose zones of relatively highly permeability. Figure 3 is a schematic view of the fabric of a truck dump profile.

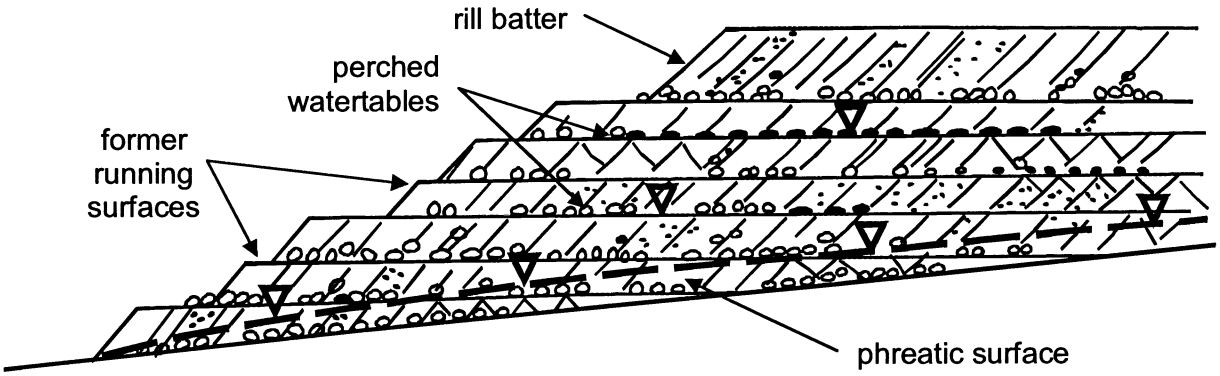



Figure 3 Schematic section of truck spoil dump fabric and phreatic surface

In surcharged dragline dumps, the lower part of the profile is typically formed in more blocky fresh rock spoil, while the upper part may be formed either wholly or partly of weaker and less permeable finer-grained material. This distribution of permeability strongly affects water infiltration and transmission.

## Dump Foundation Preparation

Foundation preparation is limited by economic factors, and inadequate preparation is the primary cause of dump failures. If weak floor conditions are known or suspected, floor disruption by blasting, formation of spoil-backfilled keys, cross-ripping, or terracing may be required to achieve stability. Even when floor strength is adequate, remnant pit water or mud must be removed, at least to designed limits. Instability usually results when spoil is dumped in an uncontrolled manner into pit water or mud.

## Seepage and Groundwater

Groundwater inflows may occur from the pit floor, pit walls, and older dump areas. The pit floor is usually an interface between relatively low permeability natural rock and relatively high permeability spoil. Because of complex internal dump stratigraphy, infiltrating water follows irregular flowpaths through zones of coarser spoil material. Internal flows percolate downwards towards the dump floor and then laterally in a generally downdip manner.

Measurement of groundwater conditions within dumps is rare, but direct observations from some BMA Coal Bowen Basin mines and from a mine in Indonesia show that a zone of saturated spoil builds up to form a phreatic surface to a thickness not exceeding 5m above the dump floor and tapering to the downslope toe. Local seepages suggest that groundwater

within truck dumps may also form thin and locally perched water tables developed on internal former running surfaces. Figures 2 and 3 also show typical dump phreatic surfaces.

BMA Coal data show that the internal phreatic surface adapts to the elevation of an externally ponded water surface. When an external pond is drawn down, the zone of effectively saturated spoil material zone remains but the phreatic surface is drawn down to the external control. As with any embankment, rapid drawdown may trigger instability.

Where dumps are built over initially horizontal surfaces, the compression of the foundation may induce ponding of external runoff water in the lowered ground surface against the dump toe. This situation has been observed to result in face instability caused by slaking and strength reduction at the base of the dump.

## Spoil Shear Strength Framework

### Guiding Principles

The framework is based upon assigning any given spoil material to one of four possible categories, each defined by attributes that are identifiable through field observation. For each category, laboratory triaxial and direct shear test results have been grouped in terms of three modes of strength mobilisation, as described below. Linear Mohr-Coulomb shear strength parameters for each mode and category were then determined for the effective normal stress range equivalent to a maximum dump height of about 90m. Prior to adoption, the strength parameters were verified by backanalysis using observed mechanisms of failure and the Sarma method as implemented in the computer code that is now called GALENA (Clover Technology, 1999). A field-based worksheet assists the identification of spoil categories. The framework is subject to review and development as new information becomes available and design demands change. Each of these aspects is discussed below.

### Strength Mobilisation Modes

Insitu coal measures rocks may be either saturated or unsaturated prior to excavation, but the resulting spoil masses normally have no free water in the void spaces between particles. Dumped material may compress to a limited extent degree due to particle crushing and rearrangement under the action of additional load. This is the normal "unsaturated" spoil condition, and corresponds to the strongest state that can be mobilised in the spoil mass. Due to the preferred orientations of particles and contacts, the unsaturated strength mode is believed to be anisotropic in character.

When significant quantities of water enter the void spaces within the spoil mass, the interparticle contacts and even the particles themselves are likely to slake, soften, and weaken. Test results show an accompanying significant reduction in mobilised shear strength, to what is termed the "saturated" strength mode, regardless of whether true saturation is achieved. Because there is still some preferred orientation of particles and contacts, the saturated strength is also anisotropic in character. Backanalyses have shown that the saturated strength mode is not reversible, even after free water is drained from the void space.

Saturation of a spoil mass with susceptible mineralogies can result in a third mode of strength development when sufficient shear distortion of the mass occurs by large deformation between softened particles. Backanalyses have shown this state to have, in practical terms, mobilised strength equivalent to the residual shear strength determined by direct shear tests on spoil fines. In the terminology of the framework, this is the "remoulded" mode. This mode has been recognised in relatively thin zones when spoil is dumped into water or wet mud,

when very loose and strongly slaking spoil is saturated, or as a consequence of shearing due to slope instability. Once developed, the remoulded strength mode is not reversible.

Relationships among the three strength mobilisation modes for spoil material are shown in conceptual form in Figure 4. Results from triaxial tests support the forms of the unsaturated and saturated modes, while results from direct shear tests support the form of the remoulded mode. Based on the authors' observations and understanding of the mobilisation characteristics, the saturated and remoulded modes may be considered as equivalent to the "fully softened" and "residual" strength states as understood in classical soil mechanics.

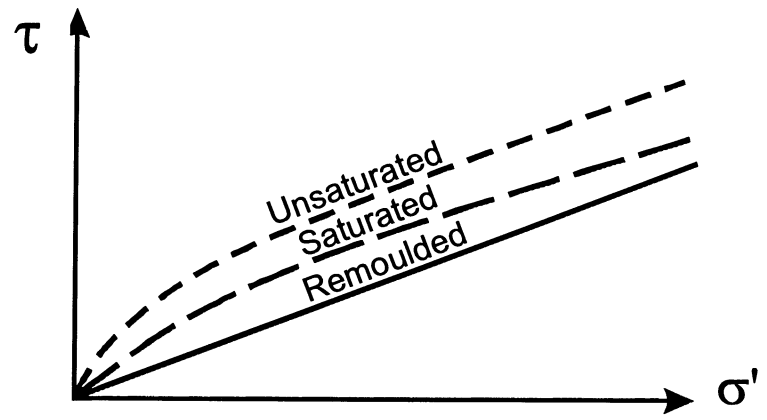



Figure 4 Three conceptual strength modes for spoil

Table 1 shows the Mohr-Coulomb shear strength parameters associated with the three strength mobilisation modes for each of the four spoil categories. These are the means and standard deviations from linear fits to more than 150 tests, assuming that c' and $\phi$' are independent variables. The tabulated unit weights were checked using both mass and volume reconciliation and by geophysical drillhole logging.

Table 1
**Shear Strength Parameters for Categories and Mobilisation Modes**
*(Parameter standard deviations in italicised parentheses)*

| Category | Unsaturated | | | Saturated | | | Remoulded |
|---|---|---|---|---|---|---|---|
| | $\gamma$ (kN/m$^3$) | c' (kPa) | $\phi$' (deg) | $\gamma$ (kN/m$^3$) | c' (kPa) | $\phi$' (deg) | c'=0 kPa, $\phi$' (deg) |
| 1 | 18 *(1)* | 20 *(10)* | 25 *(2.5)* | 20 *(1)* | 0 *(0)* | 18 *(3)* | 18 *(1.5)* |
| 2 | 18 *(1)* | 30 *(15)* | 28 *(3)* | 20 *(1)* | 15 *(7.5)* | 23 *(2.5)* | 18 *(1.5)* |
| 3 | 18 *(1)* | 50 *(15)* | 30 *(2)* | 20 *(1)* | 20 *(10)* | 25 *(2.5)* | 18 *(1.5)* |
| 4 | 18 *(1)* | 50 *(15)* | 35 *(2.5)* | 20 *(1)* | 0 *(0)* | 30 *(1.5)* | 28 *(2)* |

## Linkages to Instability Mechanisms

The forms of instability observed in spoil dumps, are indicated in Figure 5. Superficial planar-surface or shallow-arc mechanisms result primarily from undercutting of batters at angles steeper than the rill angle. Larger-scale deep-seated failure modes are observed to develop as multi-wedges, with well-developed bulging or heave at the toe of the passive wedge, steep backscarps, and characteristic graben structures with reverse mid-scarps. Intermediate forms of multi-wedge mechanisms are observed in high rilled slopes, involving

toe bulging, mass sliding along a rill surface, and an upper steep sliding surface or vertical tension crack. Multi-wedge mechanisms are a consequence of lower strength at the base of the dump profile (saturated zone) or within the immediate pit floor (weak clay bands or bedding-parallel shears).

Backanalysis of large-scale failure mechanisms requires multi-wedge geometries and appropriate methods of calculation. The Sarma method was used for all backanalyses during the original verification of the strength framework, with non-vertical slice boundaries as observed in actual failures. Methods based on vertical slice boundaries often give different results. This is inferred to be because anisotropic strength states exist in spoil dumps due to the depositional fabric. For design purposes it is recommended that the nominated strength parameters be used together with the Sarma method based on observed slice geometries.

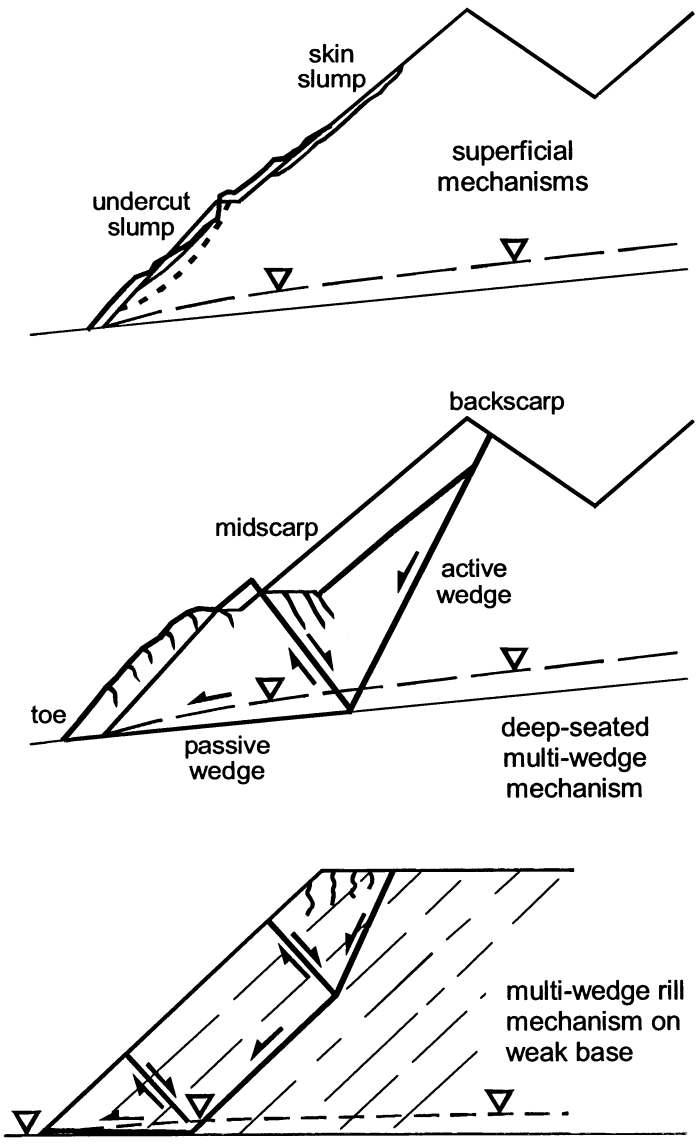



Figure 5 Failure mechanisms for spoil dumps

## Identification of Spoil Categories

BMA Coal experience has been that for reliable and consistent category identification, five attributes should be assessed. Each attribute within each category has a characteristic description. Weightings have been assigned to each attribute based on experience and judgement. Using visual and tactile methods and a worksheet, the best category description for each attribute is selected. Addition of the weightings by selected category gives the overall likelihood of that material being assigned to each of the four categories.

The need for reliable procedures for categorising spoil arose during a project on long-term stability of dump slopes (Rust PPK, 1996). An initial visual classification of 105 spoil bulk samples resulted in 45 samples that were categorised differently by personnel with different training and experience. The worksheet approach was developed and blind-tested using 13 bulk samples that had previously proven difficult to categorise, and involved two personnel again with different levels of experience. Agreement on categorisation using the worksheet was 100%.

Table 2 shows the category and attribute descriptions and the relative weightings attached to each attribute. Users are trained to observe attributes consistently. Recognised geological techniques are used to visually identify "Predominant Particle Size". "Consistency" is based on the material in the moist condition, and either cohesive or cohesionless attributes are described using familiar tactile procedures. "Plasticity" is based either on the Liquid Limit test, or on visual-tactile assessment according to site investigation standards. "Age" refers to the observed effects of weathering whereby the strength of freshly dumped spoil decreases until it reaches the strength of "old" spoil of similar provenance. Recent and therefore less weathered spoil is ranked less favourably than old spoil. Table 2 also shows the weightings of the attributes for operational purposes, where long-term stability considerations are not significant and the age attribute is ignored.

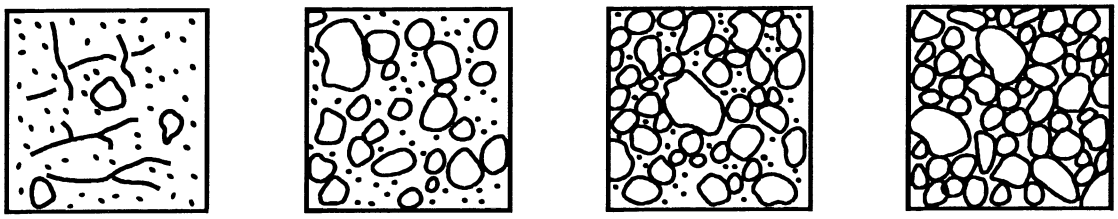
"Structural Control" is critical to interpreting spoil strength. This simplistic fabric-related parameter is illustrated in Figure 6. Spoil material is considered to consist of larger particles (the "framework") and finer particles (the "matrix"). The subdivision between framework and matrix depends on the overall particle size distribution. For training purposes, framework is described as the larger-sized fraction that, when in particle-to-particle contact, is relatively stiff and transmits most of the forces within the spoil mass. Correspondingly, matrix is described as the finer-sized component that fills the void spaces between framework particles. When there is a relative abundance of matrix, good framework particle contact cannot be mobilised and the spoil mass will be relatively more compressible and weaker.

Preferred particle orientation, as a result of fabric development by rilling and rolling, is not explicit in the categorisation process. However, strength anisotropy is believed to be implicit in the mechanisms and shear strengths verified by backanalysis, and this emphasises the requirement to use the Sarma method and appropriate mechanisms for design.

Table 2
**Spoil Categories and Attributes**

| CATEGORY | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| **Description Attributes** | **Weighting** *(excl. Age)* | Fine-grained clay-rich high plasticity | Fine-grained low plasticity with larger clasts | Larger clasts with fine matrix, low plasticity | Large blocks, minor fines, minor slaking |
| **Predominant Particle Size** | 3/31=**9.7%** *(11.6%)* | Clay | Sand | Gravel | Cobbles |
| **Consistency: cohesive cohesionless** | 7/31=**22.6%** *(26.9%)* | Soft to Firm Loose | Stiff Med. Dense | Hard Dense | XLS+ rock Very Dense |
| **Structure** | 7/31=**22.6%** *(26.9%)* | Matrix only | Matrix supported | Framework supported | Framework only |
| **Liquid Limit** | 9/31=**29.0%** *(34.6%)* | High (>50) | Intermediate (35 – 50) | Low (20 – 35) | Not Plastic (<20) |
| **Age** | 5/31=**16.1%** | 0 - 2y | 2 - 10y | 10 - 30y | >30y |

*( Note: XLS+ rock refers to rock of extremely low strength, or higher)*



Category 1 (matrix only) | Category 2 (matrix supported) | Category 3 (framework supported) | Category 4 (framework only)

Figure 6 Spoil structure control ranking (use with Table 2)

## Framework Extensions and Limitations

### Stress Ranges and Nonlinear Envelopes

Triaxial tests result in spoil shear strength envelopes that are distinctively nonlinear (Simmons, 2003). This is particularly so at lower effective normal stresses where contractant shear deformation is greatest. Such nonlinearity, as well as the effects of matrix suction in unsaturated material, helps explain why spoil slopes may be excavated to batters steeper than the angle of repose and why such batters are often stable only for limited timeframes.

The parameters in Table 1 were derived for typical dragline spoil dump heights of 60m to 90m. These parameters will significantly overestimate available shear strength for slopes less than 30m high, but underestimate the effective friction angle in the low stress range. The same parameters will also significantly overestimate available shear strength at the base of spoil slopes in excess of 130m high. In principle, nonlinear envelopes could be developed. The authors believe that there is merit to nonlinear envelopes, if determined thoughtfully.

### Refinement of Parameter Choices

Categories 1 and 4 spoils are relatively rare in comparison with Categories 2 and 3 spoils. The selection of a design category has in many cases been complicated either by variability of the spoil material, or by very similar likelihoods for Categories 2 and 3 from the identification procedure. On occasion, particularly where supported by backanalysis, the authors have selected design parameters mid-way between category values. Such choices are a matter of judgement, but when applied consistently have produced reliable outcomes.

This possibility of increasing the number of categories was considered as part of the identification procedures. Review of the triaxial test data could not identify an alternative sorting that was considered more reliable. The authors view use of the framework as a suitable starting-point for design, with more "refined" assumptions used only where justified.

### Verification by testing

In recent years the authors have encountered situations in weathered and/or clay-rich lithologies where additional strength testing was warranted. The resulting shear strength data were fitted with piecewise linear envelopes for design calculations. By comparison, use of the framework approach did not result in significant differences for slope designs. While reassuring in these cases, such outcomes should not be assumed generally. Testing of spoil

materials is neither simple not straightforward, but due consideration should be given to testing for clarification of matters considered important for reliability of design outcomes.

### Probabilistic Slope Stability Assessment

Probabilistic stability assessment, usually takes the form of a computed distribution of Factors of Safety (FOS) based on statistical properties of strength parameters and other variables. Table 1 lists means and standard deviations for the category strength parameters treated as independent variables. The authors have computed approximate FOS distributions using the point estimate technique. Expression of stability in terms of failure probabilities is often preferred by mining engineers, but the validity of this process requires further consideration. The authors have found it to be most helpful in sensitivity studies of stabilisation treatments.

### Possibly Inadequate Treatment of Strongly Slaking Spoil Materials

At Kaltim Prima Coal mine in Kalimantan, Indonesia, triaxial testing was carried out for Category 2 spoil derived from very low strength claystone or siltstone that showed strong slaking behaviour and dispersion (Simmons, 2003). From backanalysis, the spoil dumps were determined to develop only unsaturated or remoulded strength modes. Direct observations were limited, but it is believed that the strongly slaking spoil remained quite blocky when initially dumped. The dumps were characterised by corrected SPT blowcounts of close to zero in rilled material located within 1m above the pit floor and above former trafficked surfaces. The saturated basal zone of these dumps is believed to have become remoulded directly through the effects of slaking, dispersion, and interparticle void collapse.

There is no specific reference to slaking behaviour within the BMA Coal framework. Until such time as the framework can be justifiably extended to include slaking behaviour, it is recommended that tests be made of slaking behaviour. If judged to be necessary, design allowances may then be made for the likelihoods and consequences of basal remoulding.

## Stability Assessment Example for Surcharged Spoil Profile

Figure 7 shows a dragline dump profile on a floor dip of 6° and with a shovel/truck surcharge of 25m. The dragline spoil material is BMA Category 2 and the profile consists of a 40m bench with a 40° undercut batter, no remnant bench width, and a 40m rill batter at 37°. All spoil is assigned to Category 2. Shown on the figure is the critical mechanism corresponding to a minimum computed FOS of 1.19 using the Sarma method and GALENA. When the toeline of the shovel/truck spoil is located no closer than the second dragline spoil peak, the critical stability condition involves the immediate dragline spoil profile only. The mechanism including the shovel/truck spoil loading has a minimum computed FOS of 1.68.

To further illustrate the importance of the effects of inferred strength anisotropy, analyses using circular arc mechanisms with the Spencer method and GALENA resulted in a minimum computed FOS of 1.06 for the dragline spoil and 1.34 including the shovel/truck spoil loading. Circular arc mechanisms of this form have not been observed in practice. The use of circular arc methods with vertical slices for design is not considered to be credible, despite the lower FOS values obtained.

## Conclusions

The BMA Coal shear strength framework has been developed and applied over more than 12 years, to literally hundreds of design and backanalysis situations. It originated from confidential research and development activity, but spread widely with the training and movement of personnel between sites and between businesses. It is believed to be applicable

to open cut coal mine spoils generally, as a robust and reliable method for deriving strength parameters for routine applications. It also provides a rational basis for determining additional testing requirements for non-routine situations.

## Acknowledgements

The authors acknowledge permission from BHPBilliton Mitsubishi Alliance Coal Pty Ltd for publication of details of the framework. BMA Coal has applied vision and resources to develop the framework over the past 25 years. Also acknowledged is the permission of PT Kaltim Prima Coal Indonesia to refer to outcomes of spoil shear strength investigations. Alan Davies and Michael Dunbavan are acknowledged for their vital roles in the development of the spoil strength framework, particularly with the original data grouping and parameter selections. The assistance of Ross Stephens with graphics, and the helpful comments and suggestions from an anonymous reviewer, are greatly appreciated.

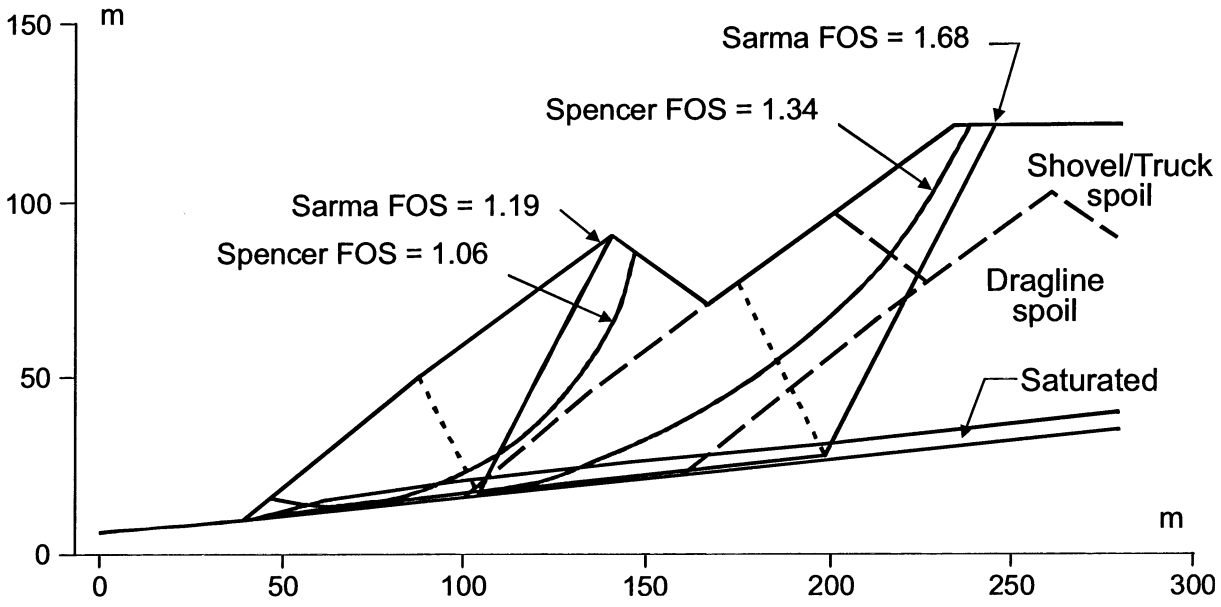



Figure 7 Example surcharged spoil profile stability analysis results

## References

BHP Engineering Pty Ltd (1991). Pit Slope Manual Project Report. Report No. G91/4 to BHP-Utah Coal Technical Services.

Clover Technology (1999). GALENA Slope Stability Analysis System Code and Users' Manual. www.GalenaSoftware.com.

Mallett, CW et al (1983). Stability of Spoil Piles and Highwalls in Deep Surface Mines. End of Grant Report Number 150, National Energy Research Development and Demonstration Program, Australian Government, Canberra.

Rust PPK Pty Ltd (1996). An Improved Geotechnical Categorisation Method For Bowen Basin Spoil. Spoil Hydrology Project Report to BHP Australia Coal Pty Ltd, Ref. 84H125A-PR0024cd.

Simmons, J V and D McManus (1995). Categorisation of Bowen Basin spoil materials for open pit mining. Proceedings, Bowen Basin Symposium 1995, Geological Society of Australia Coal Geology Group and Bowen Basin Geologists Group, pp 137-145.

Simmons, J V (2003). Spoil Shear Strength Testing and Usage. Report 22003-3 to PT Kaltim Prima Coal, Sherwood Geotechnical and Research Services, 45p.

# APPENDIX E

## Seepage modelling results

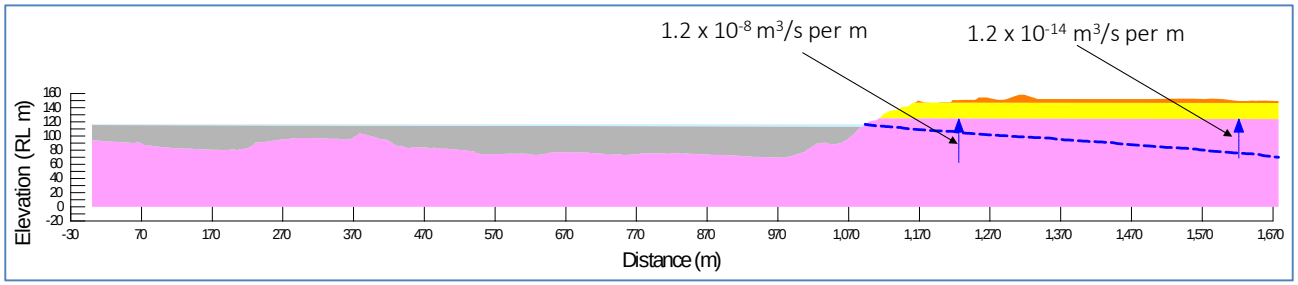



*Figure E1 – Wetting front assessment under stage 1 operating decant level*

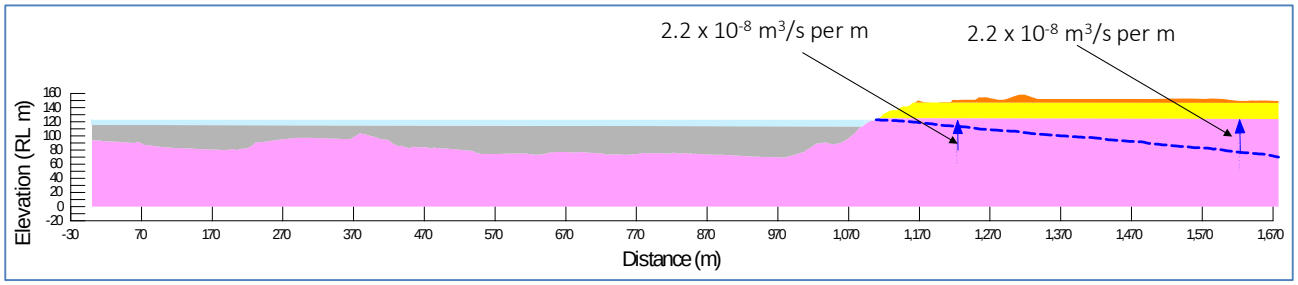



*Figure E2 – Wetting front assessment under stage 1 DSA level*

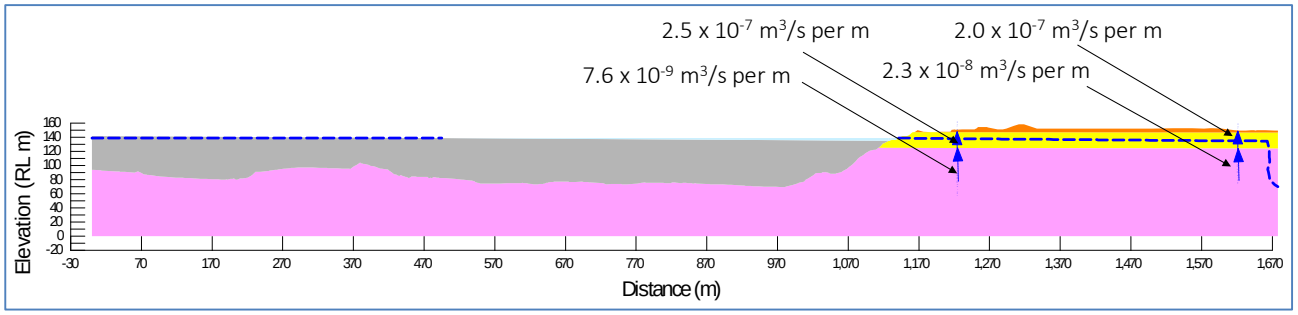



*Figure E3 – Wetting front assessment under stage 2 operating decant level*

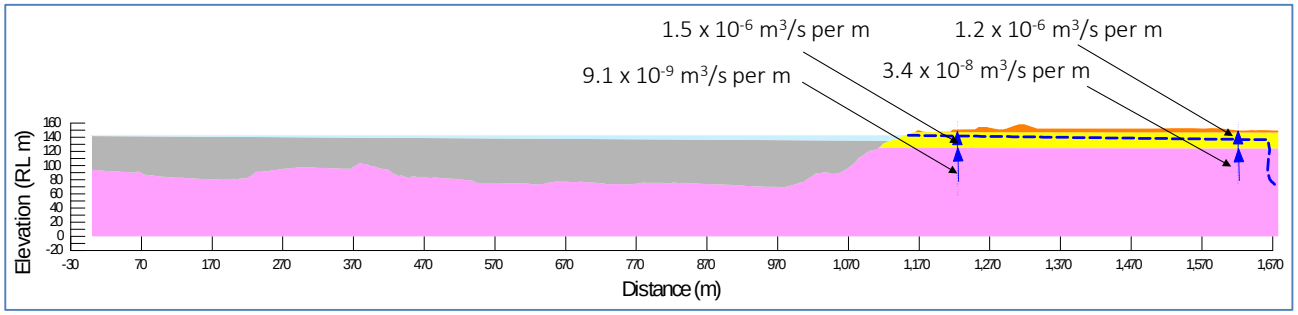



*Figure E4 – Wetting front assessment under stage 2 DSA level*

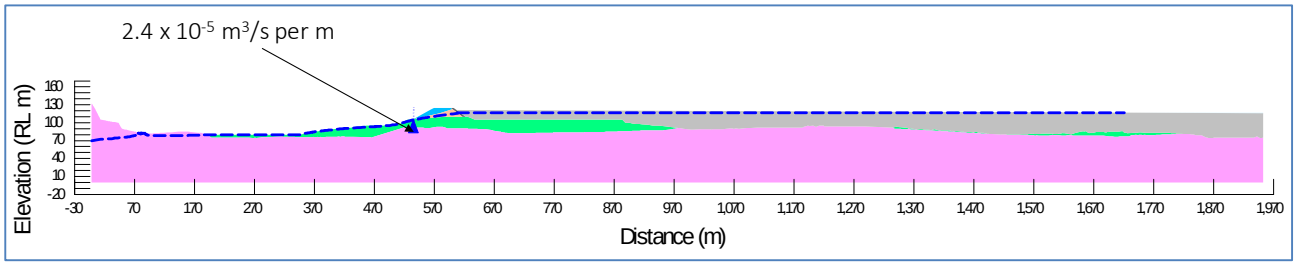



*Figure E5 –Seepage assessment for stability under stage 1 operating decant level*

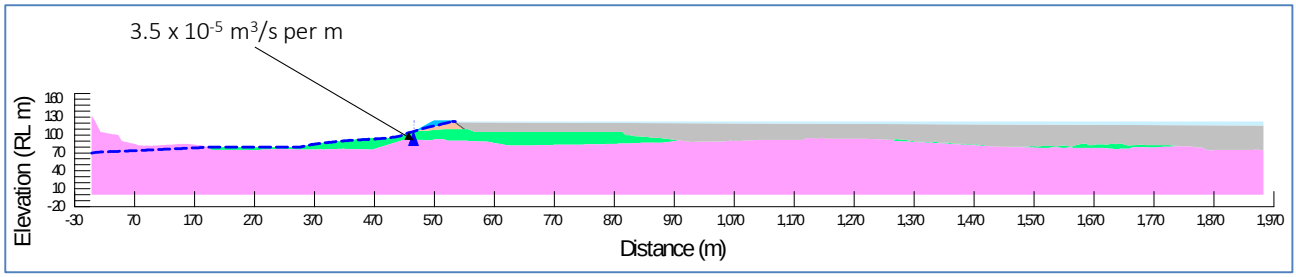



*Figure E6 –Seepage assessment for stability under stage 1 DSA*

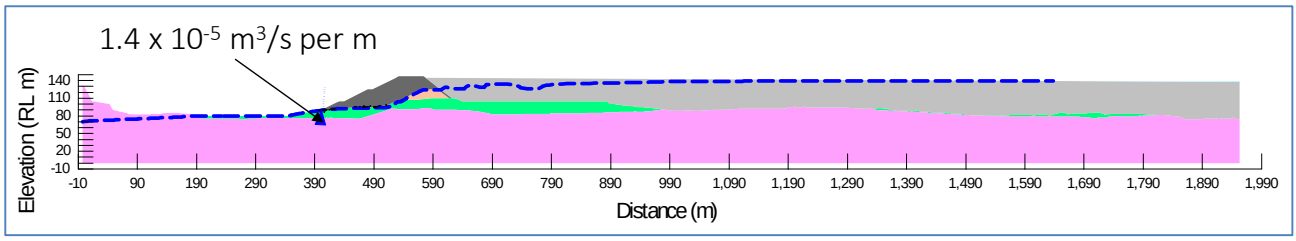



*Figure E7 –Seepage assessment for stability under stage 2 operating water level*

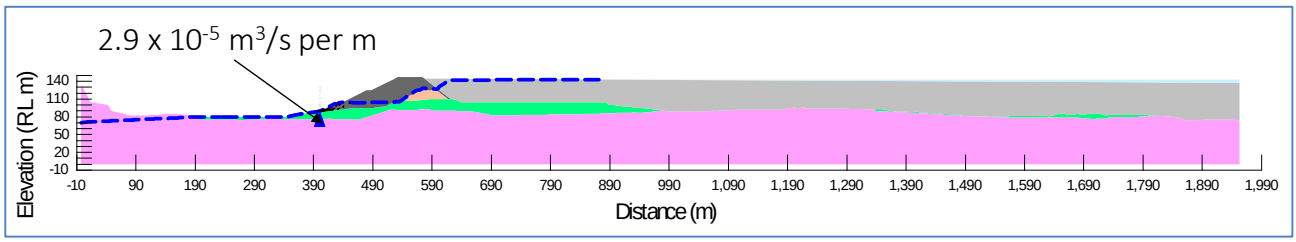



*Figure E8 –Seepage assessment for stability under stage 2 DSA*

# APPENDIX F

## Stability modelling results.

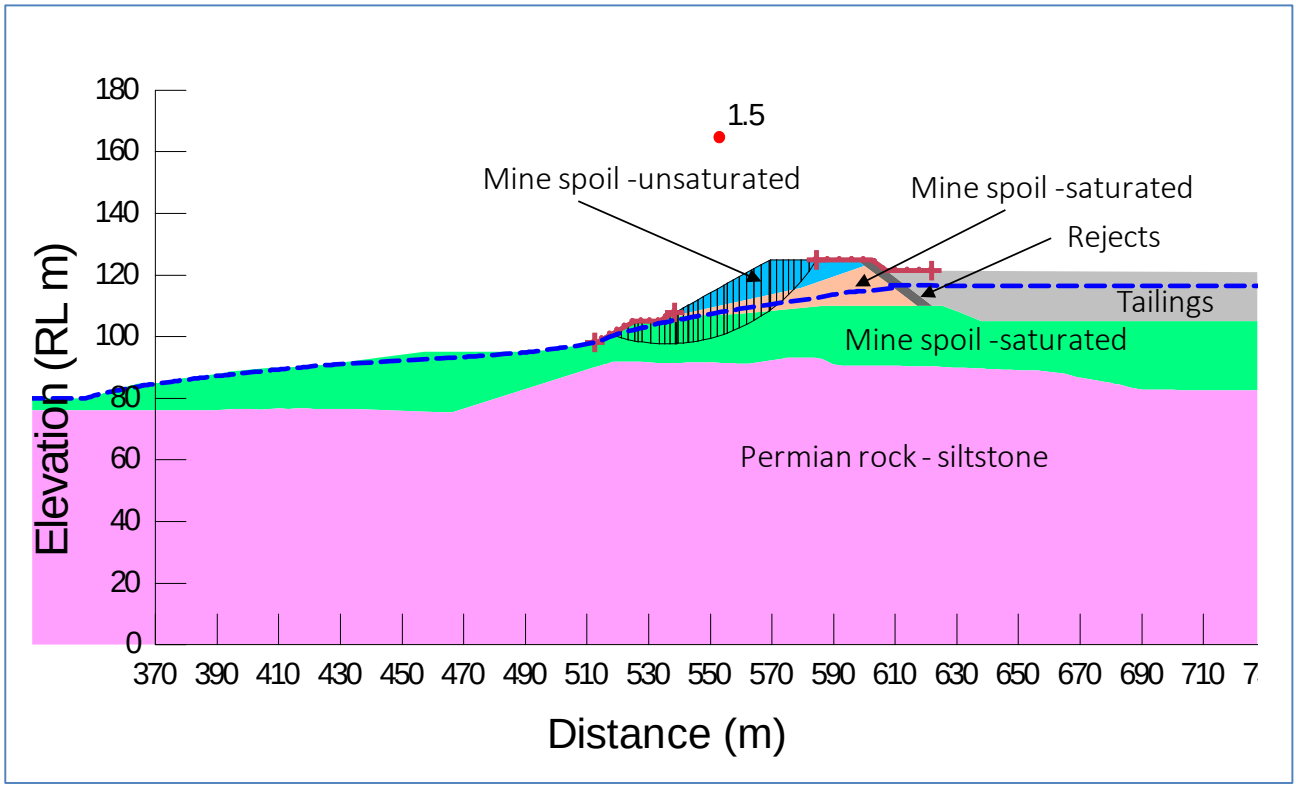



*Figure F1 – Stage 1 Static stability, global failure under operating water level RL 116.7 m*

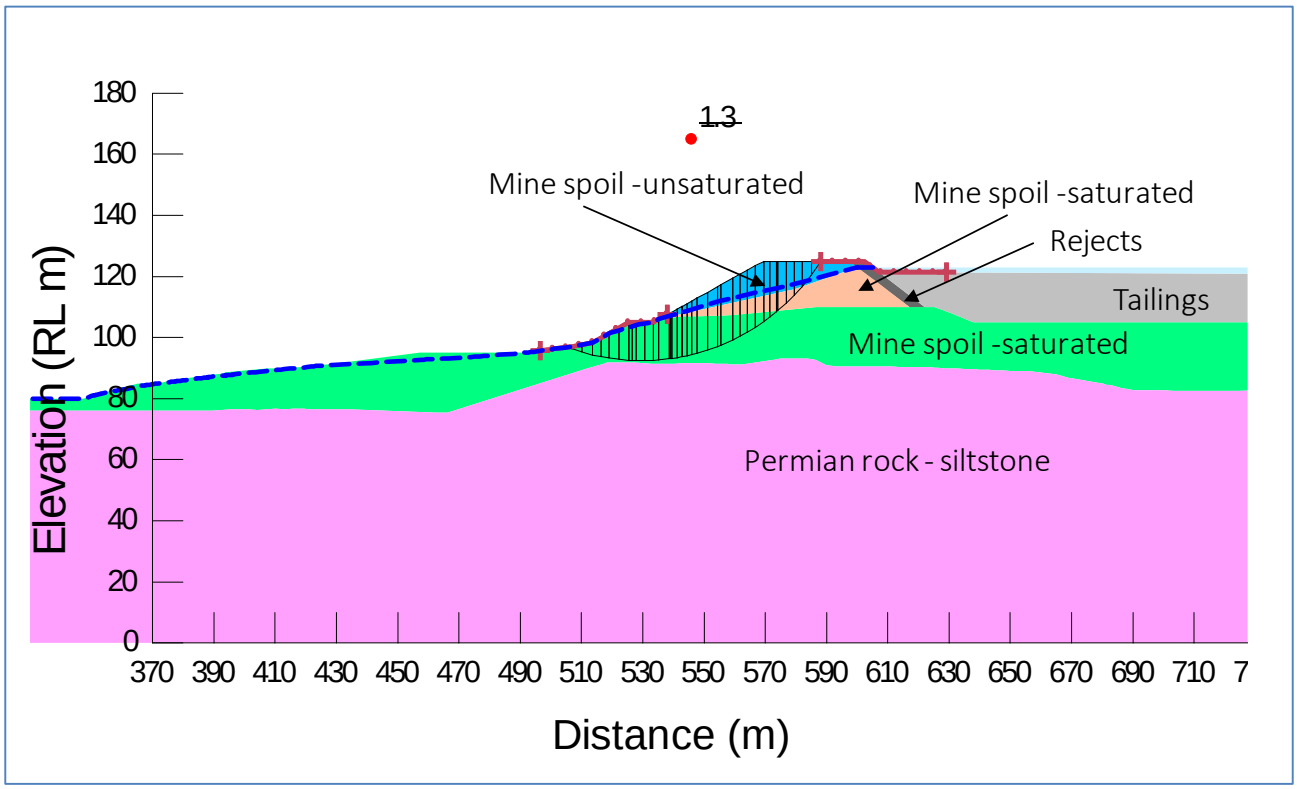



*Figure F2 – Stage 1 Static stability, global failure under DSA level RL 123 m*

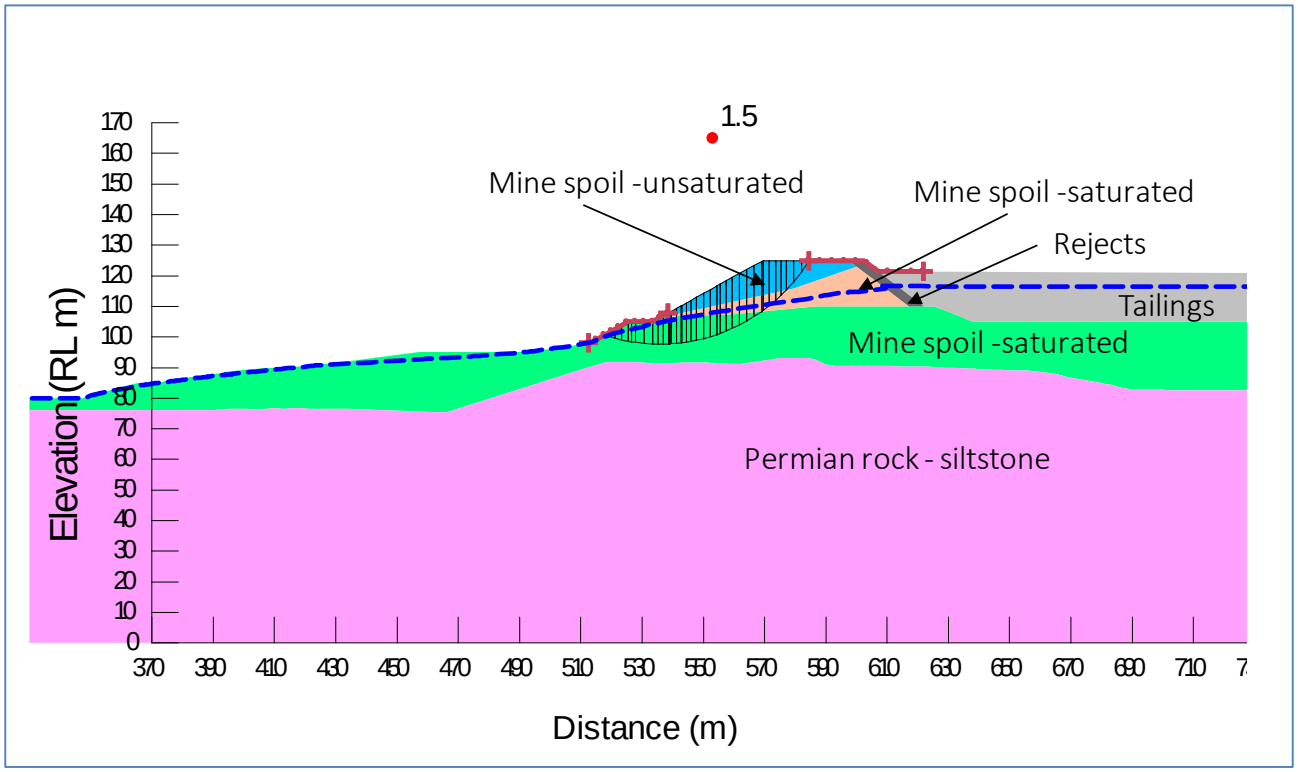



*Figure F3 – Stage 1 Seismic OBE stability, global failure under operating water level RL 116.7 m*

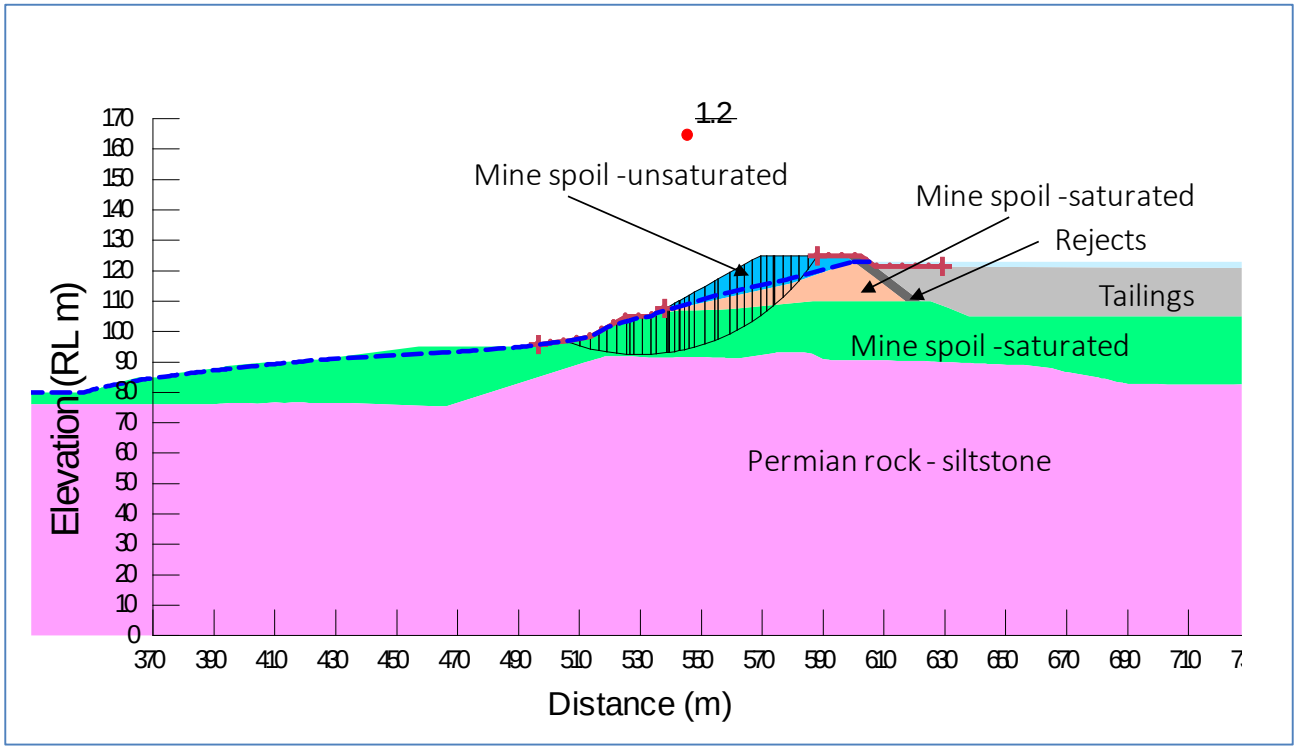



*Figure F4 – Stage 1 Seismic OBE stability, global failure under DSA level RL 123 m*

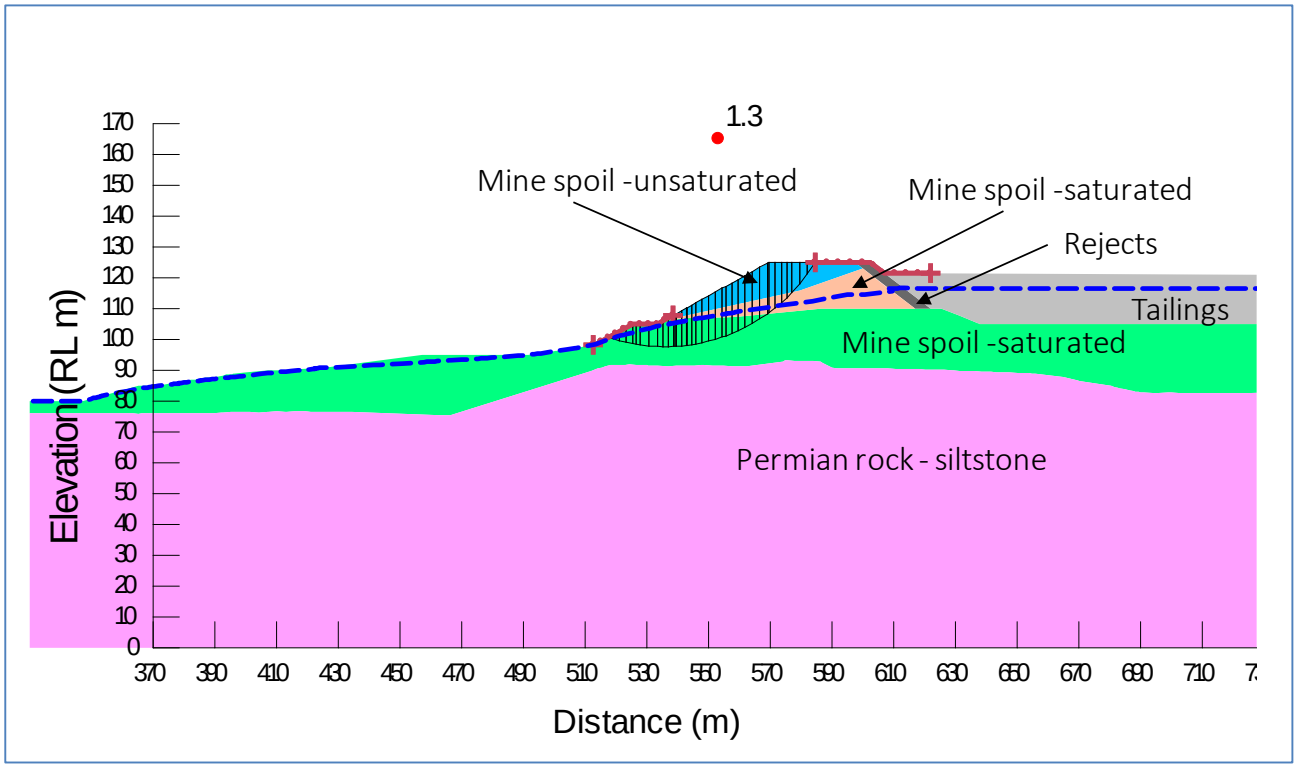



*Figure F5 – Stage 1 Seismic MDE stability, global failure under operating water level RL 116.7 m*

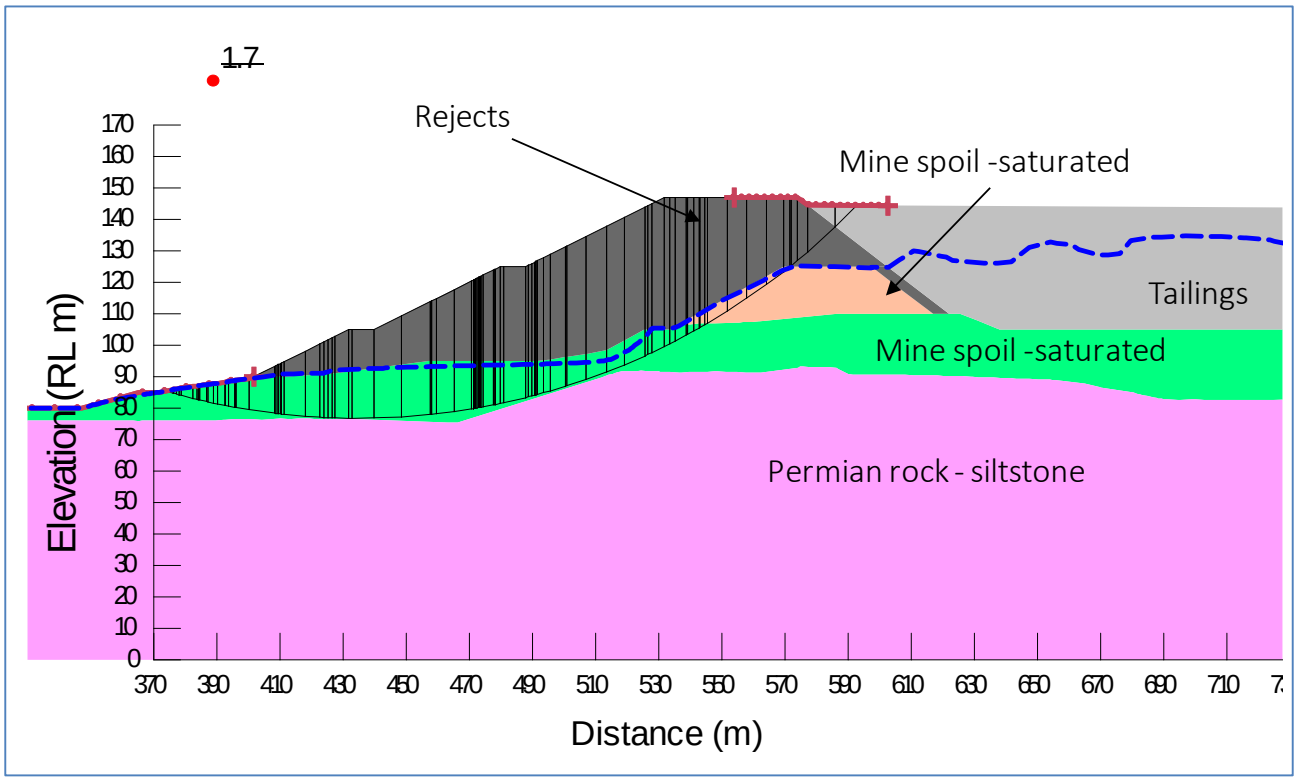



*Figure F6 – Stage 2 Static stability, global failure under operating water level RL 139 m*

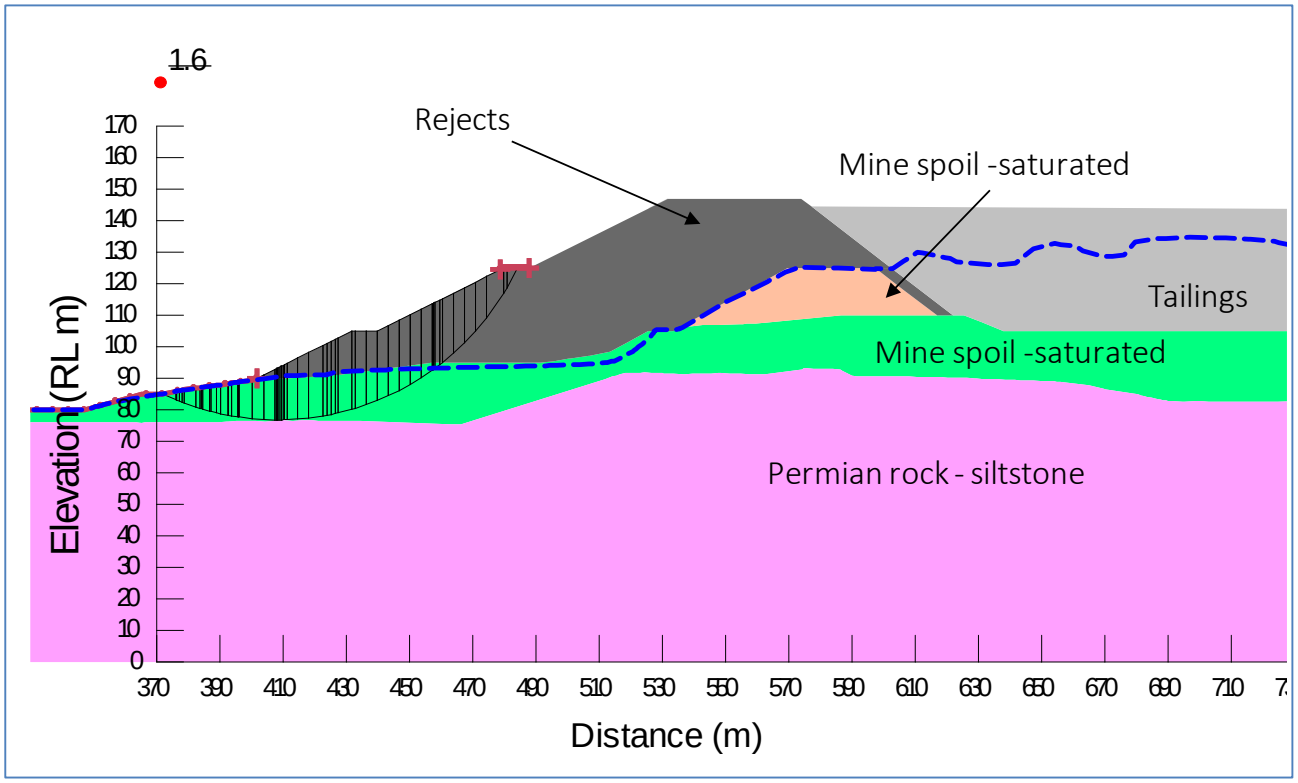



*Figure F7 – Stage 2 Static stability, local failure under operating water level RL 139 m*

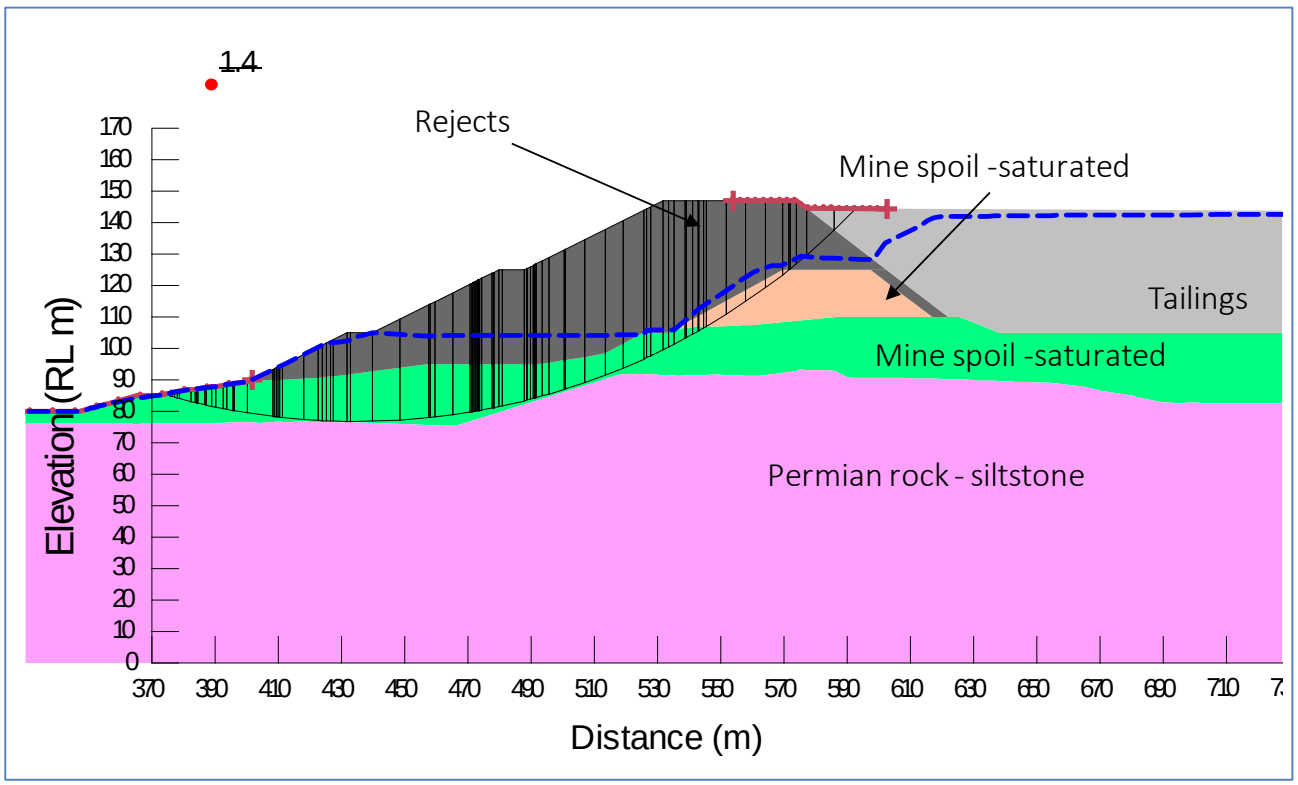



*Figure F8 – Stage 2 Static stability, global failure under DSA level RL 143 m*

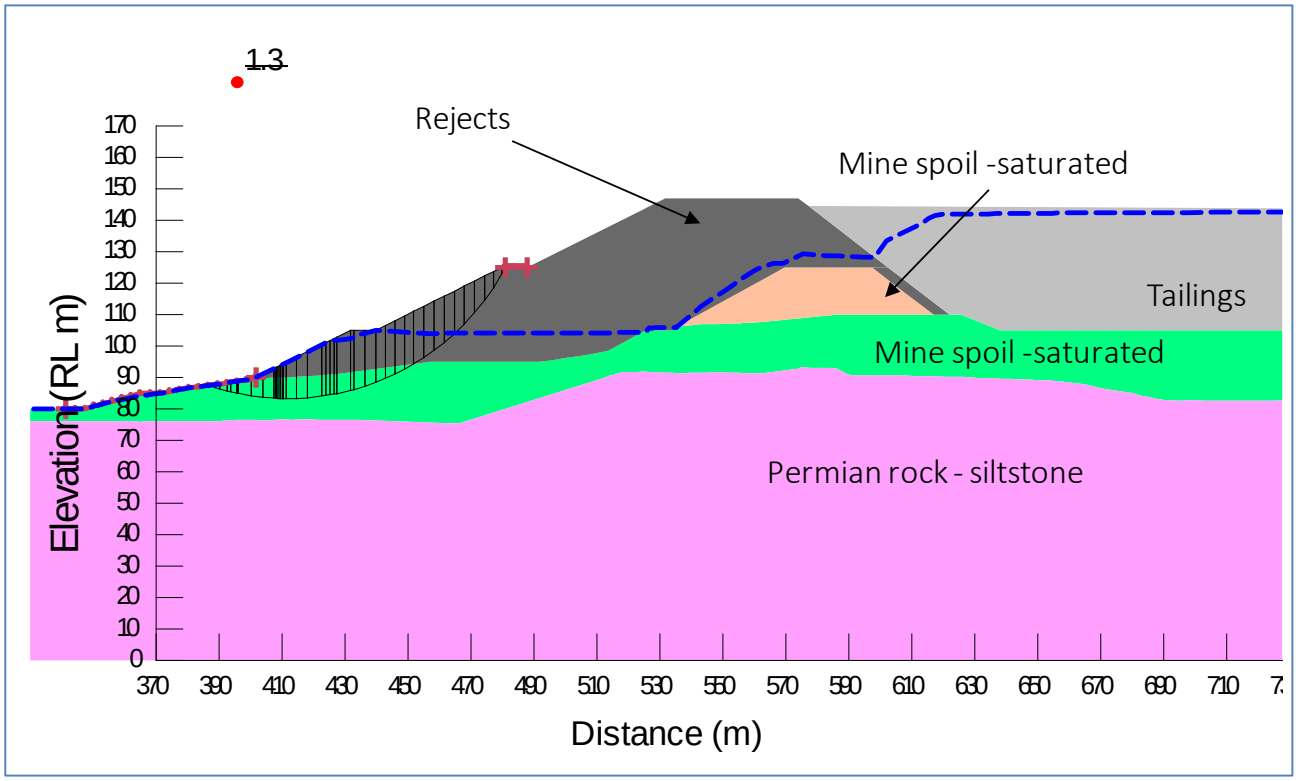



*Figure F9 – Stage 2 Static stability, local failure under DSA level RL 143 m*

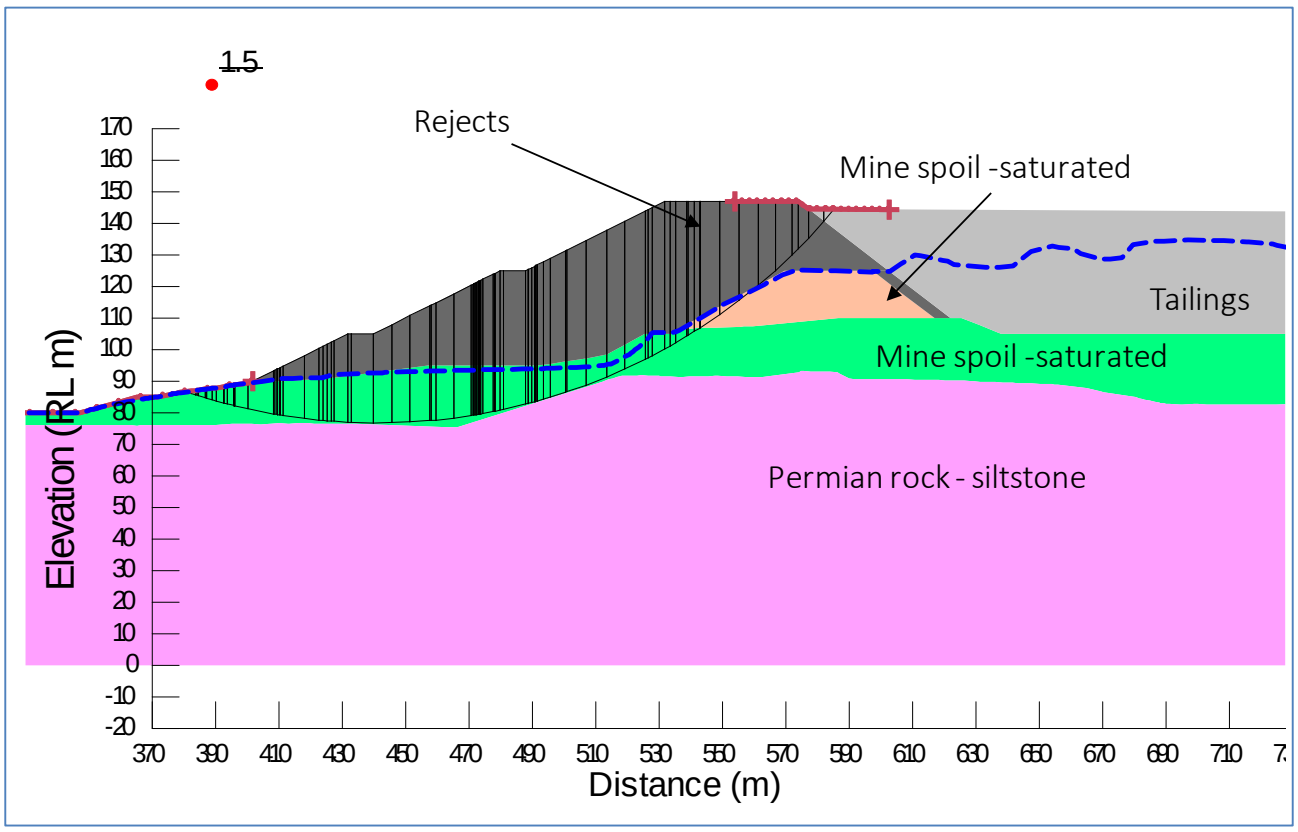



*Figure F10 – Stage 2 Seismic OBE stability, global failure under operating water level RL 139 m*

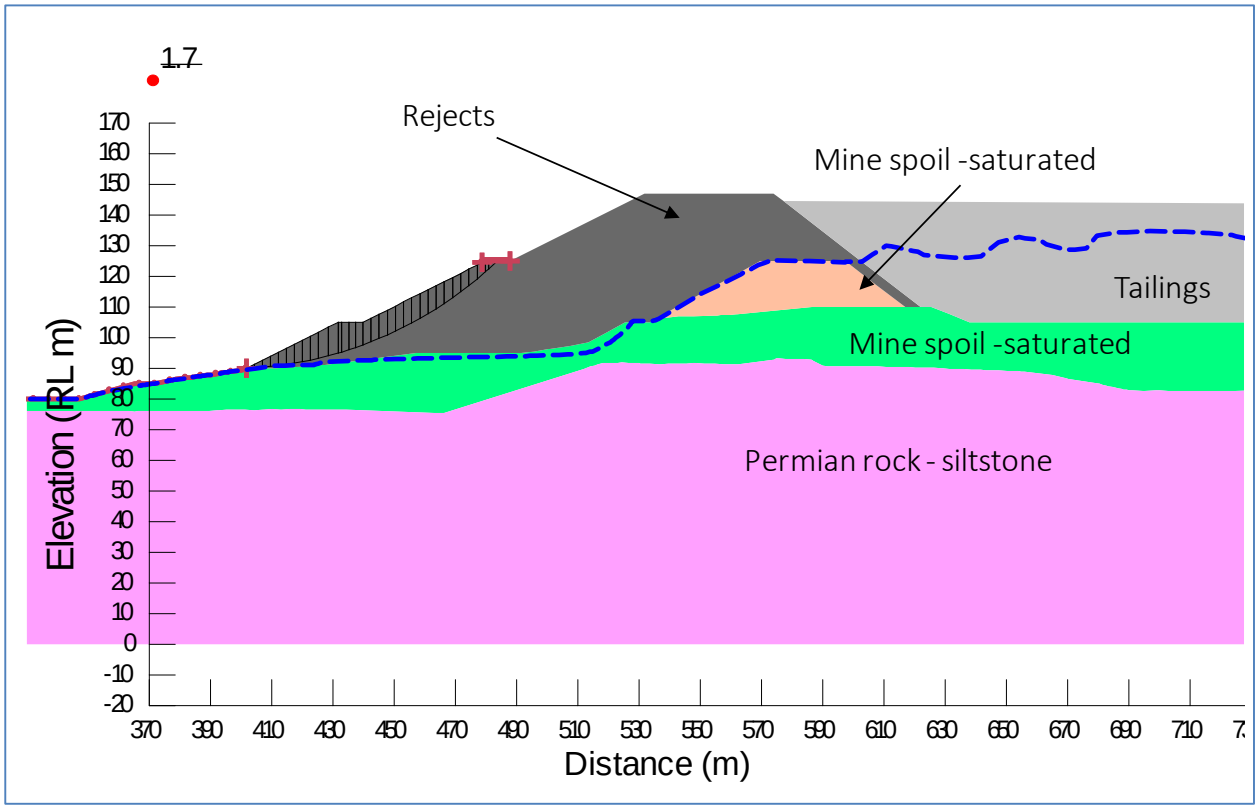



*Figure F11 – Stage 2 Seismic OBE stability, local failure under operating water level RL 139 m*

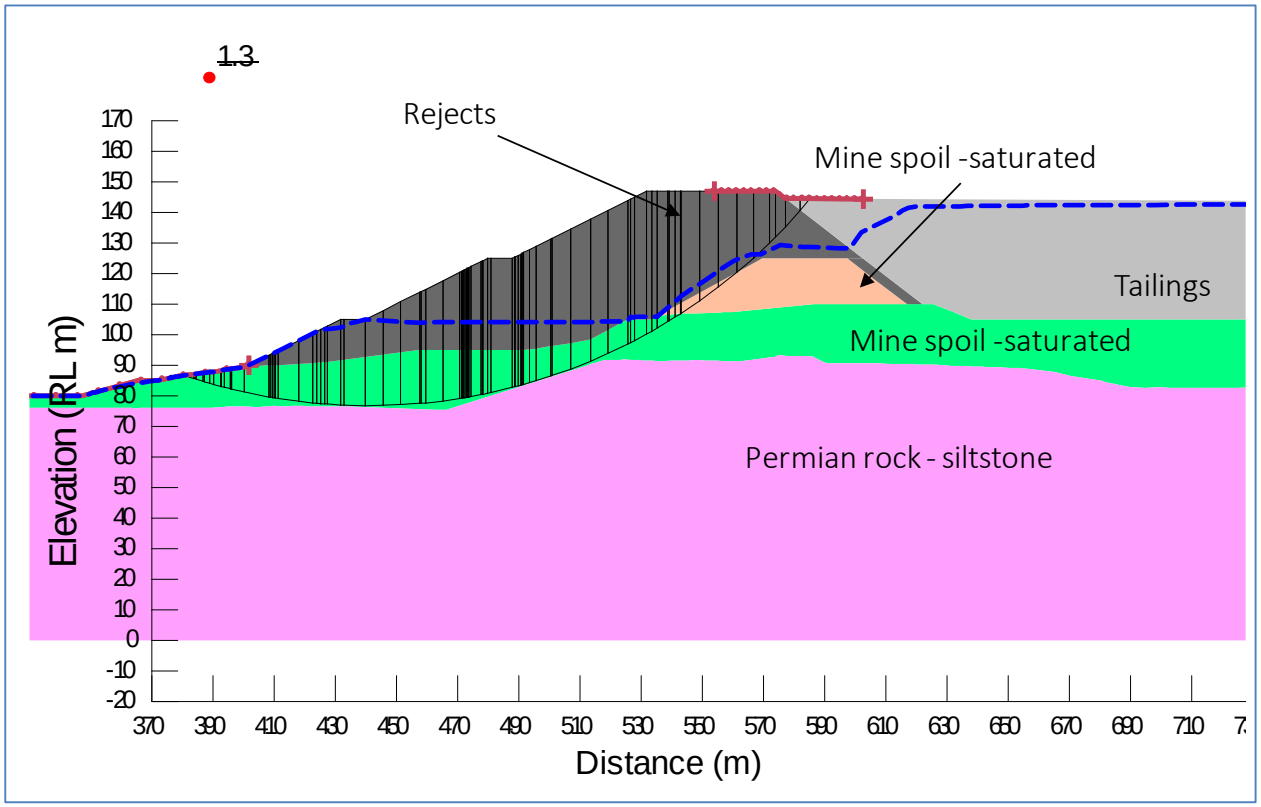



*Figure F12 – Stage 2 Seismic OBE stability, global failure under DSA level RL 143 m*

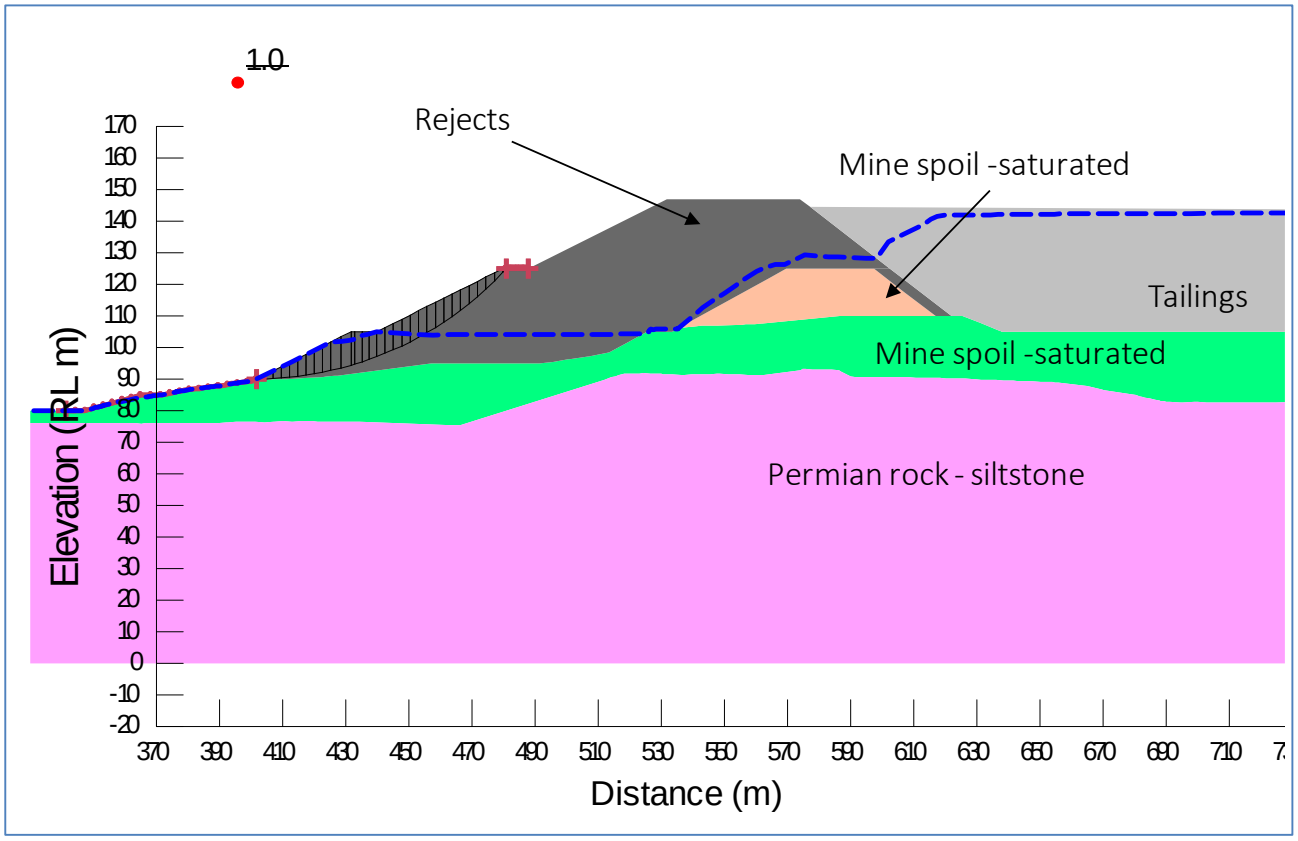



*Figure F13 – Stage 2 Seismic OBE stability, local failure under DSA level RL 143 m*

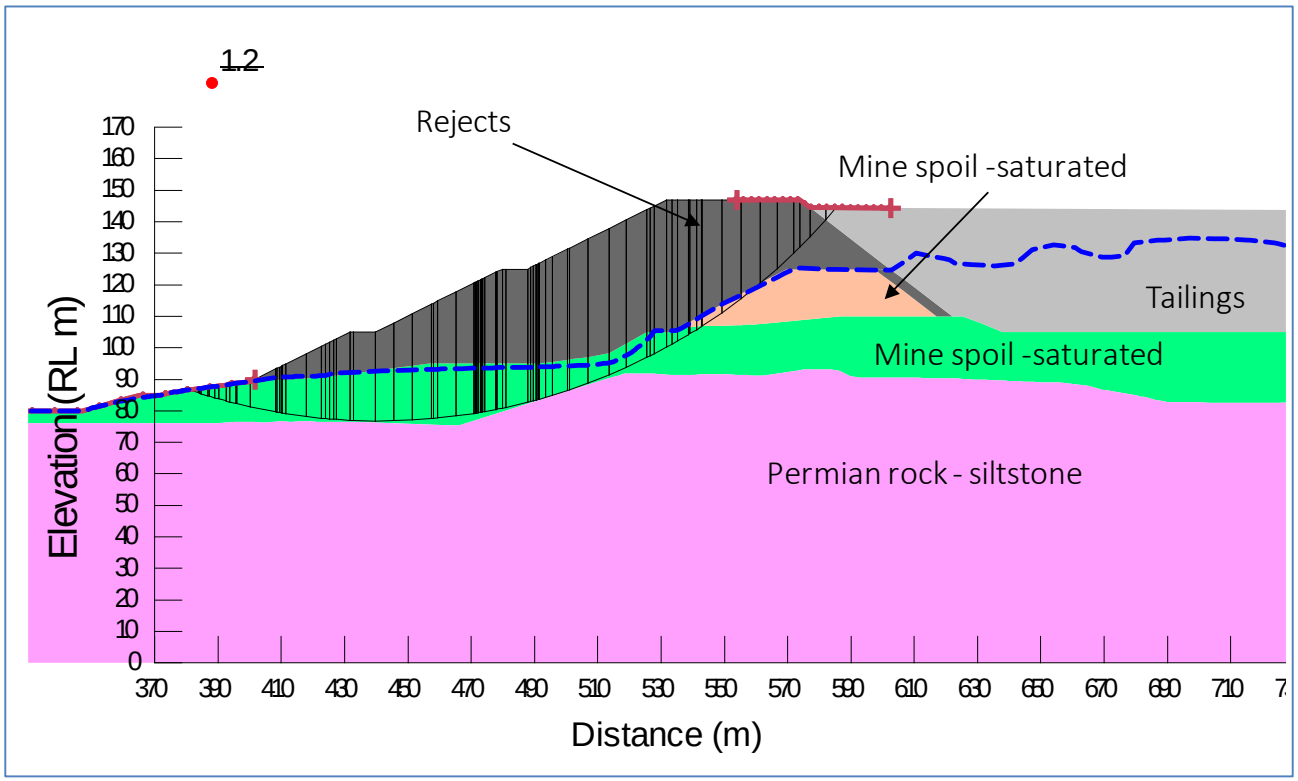



*Figure F14 – Stage 2 Seismic MDE stability, global failure under operating water level RL 139 m*

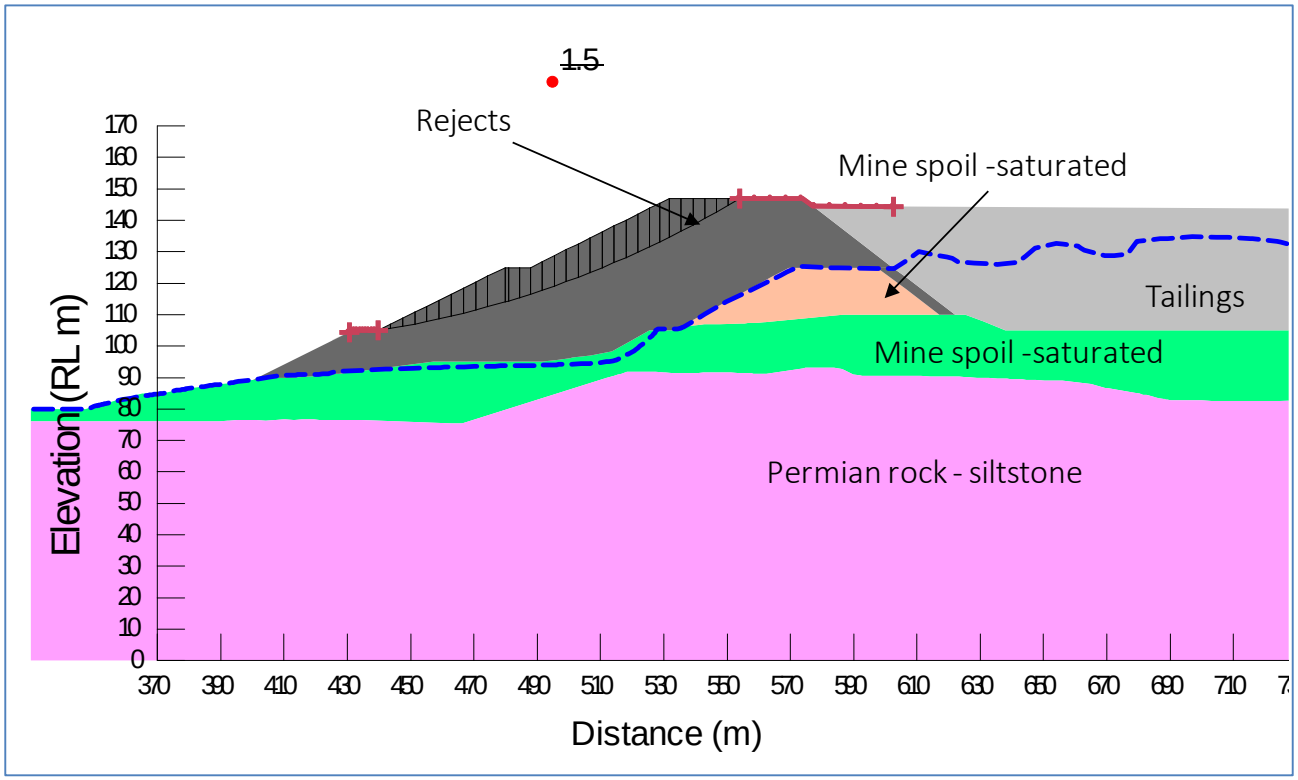



*Figure F15 – Stage 2 Seismic MDE stability, local failure under operating water level RL 139 m*

# APPENDIX G

## Hydrological analyses

- Design storage allowance
- Wave runup

# TECHNICAL MEMORANDUM

**DATE** 15 September 2017 **PROJECT No.** 1532295-040-TM-Rev2

**TO** Howard Lief
Wesfarmers Curragh Pty Ltd

**FROM** Scott Creighton **EMAIL** screighton@golder.com.au

**B PIT TSF - DSA ESTIMATION BY METHOD OF OPERATIONAL SIMULATION**

## 1.0 INTRODUCTION

Wesfarmers Curragh Pty Ltd (WCPL) commissioned Golder Associates Pty Ltd (Golder) to design the new in-pit Tailings Storage Facility (TSF) that is to be located within the existing void of B Pit. A requirement of the design is for the provision of a Design Storage Allowance (DSA). This memorandum outlines the methodology and results of the DSA analysis. The DSA was estimated based on the method of operational simulation for performance based containment. Golder has developed a water balance model based on the method and requirements outlined in *Version 5 the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (March 2016)* [1] (the guideline).

The resultant DSA requirement using the method of operational simulation is **2823 ML**.

This technical memorandum provides details of the model components and method sufficient to allow independent replication of the modelling by a suitably qualified and experienced person.

## 2.0 MODEL METHOD

The site water balance will vary significantly from year to year, due to climatic variability. To account for this variability, the performance of the water management system was assessed using a daily time step historical simulation water balance model developed in GoldSim[2]. GoldSim is a graphical modelling environment which allows dynamic simulation of a particular system to represent and predict system behaviour. Any system which can be described mathematically can be simulated.

GoldSim is particularly suitable to water balance modelling, and has specific elements to represent water reservoirs and their behaviour. It is also dimensionally aware having an internal database of units and conversion factors which means that data can be entered in any unit recognised by the software. The model components (detailed in Section 3.0) represent water storages including water inflows, outflows and retained water.

The model was configured to simulate the operation of all major components of the water management system including:

- rainfall and evaporation;
- catchment runoff and collection;
- pit dewatering;

[1] Department of of Environment and Heritage Protection, March 2016, *Manual for assessing consequence categories and hydraulic performance of structures*, Version 5.0

[2] GoldSim Technology Group www.goldsim.com


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- pump and gravity transfers;
- water storage filling and spilling; and
- water extraction, usage and transfers.

To assess a range of historical climate conditions that could be encountered by the project, the model includes a sequence of 127 years of available Data Drill climate data for predictive modelling. Data Drill climate data is supplied for a specific location from SILO enhanced meteorological data and is, as indicated in the guideline, an acceptable form of climate data to be used in operational simulation modelling. The Data Drill accesses grids of data derived either by splining or kriging the observational data from point observations from the Bureau of Meteorology recording stations around Australia.

The model has been set up to run dynamically on a daily basis for the period 1 November to 30 March and for 100 model realisations. Each realisation randomly selects a new daily rainfall and the same year's corresponding daily evapotranspiration record from the Data Drill data starting at 1 November. In this way 100 different summer climate scenarios for this location were simulated. All other variables, such as the rate of water inflow and outflows and the starting water level at 1 November; remain constant for each of the model simulations.

The model output, that is, the 100 records of resultant change in storage over the wet season; is then used to determine the DSA. The DSA is calculated from the statistical results of the plotting position analysis of operational simulation outcomes, to derive the design Annual Exceedance Probability (AEP), plus an additional volume equal to the Design Simulation Margin (DSM), applied to simulation outcomes to provide conservative compensation for model inaccuracy. The guideline recommends Pit B to maintain a DSA of the 1:20 year AEP wet season including process inputs subsequent to 1 November each year, consistent with a significant consequence rating. Where there is a lack of calibration data for the model, the guideline recommends the use of a minimum DSM value of not less than 50% be applied. Due to the absence of data for calibration, but applying input parameters consistent with other mine site in the area, we have applied a DSM value of 50% in this case as we were not able to calibrate the model between modelled and measured site data.

## 3.0 MODEL SETUP

The movement of water in the simulation is demonstrated in Figure 1. The water network was developed based on Golder's understanding of Curragh's water management system from previous work, site visits, and communications with Curragh representatives. The network has been updated to reflect the proposed project case of constructing an in-pit TSF within B Pit and holding deposition of tailings to Pit A. Components of the network was reviewed against a previous water balance completed by WRM in June 2016[3].

The water balance contains three independent circuits: B Pit, G Pit and I Pit circuits. B Pit circuit is relevant for the DSA operation simulation and thus will only be discussed in this memorandum. A separate memorandum will be issued by Golder focusing on the side-wide water balance model.

[3] WRM Water & Environment Pty Ltd, June 2016, *Curragh Extension Project – Submission to IESC, Surface water balance impact assessment report*, Document reference: 0990-04-D2

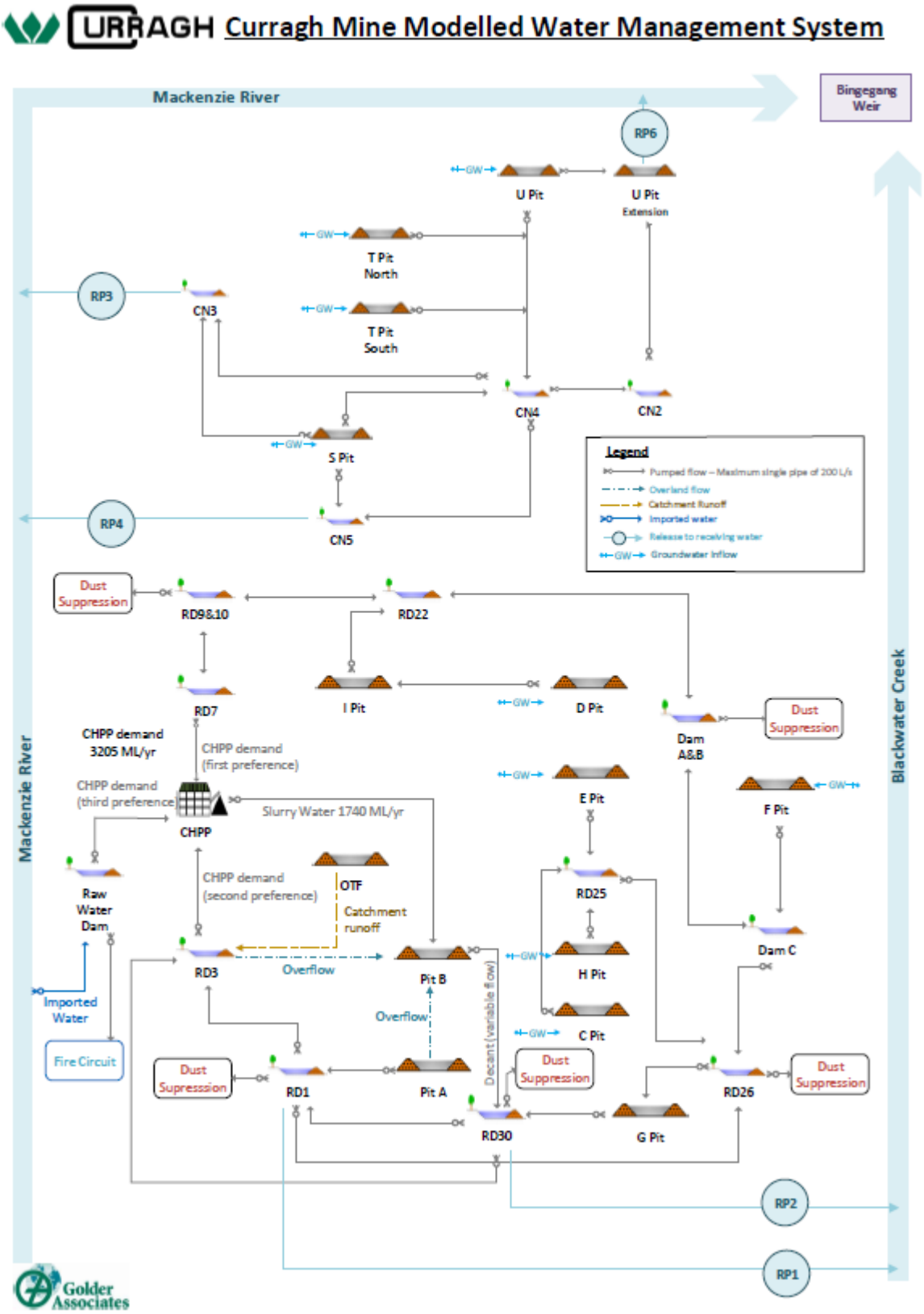



*Figure 1: Flow diagram of model setup, including B Pit TSF*

# 4.0 MODEL COMPONENTS

The model primary container view is shown in Figure 2, which provides the schematic representation of model components, including inflows, outflows, the decant water reservoir and relevant stage area storage curves for Pit B. Brief descriptions of the model components are provided below.

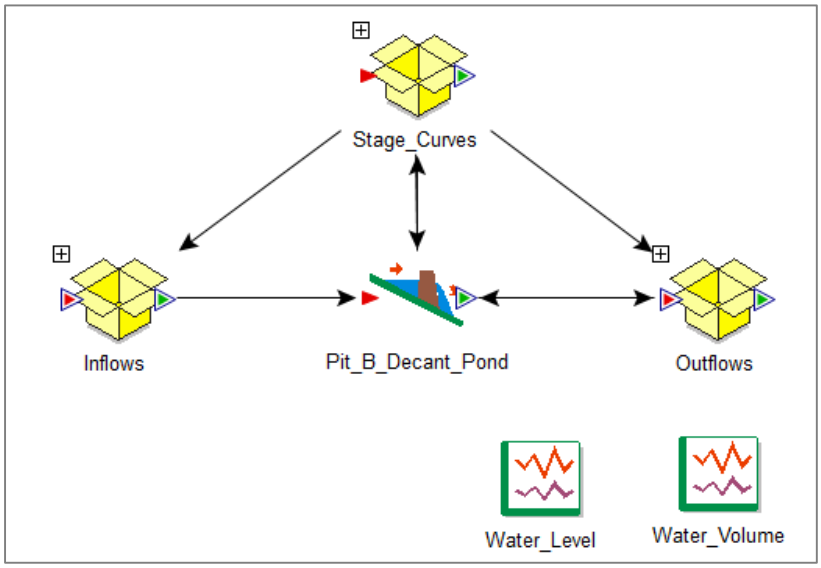



*Figure 2: Model Schematic.*

## 4.1 Stage-area-storage of the ponds

Relationships between stage (elevation) and associated surface area, and between stage and associated storage volume (Stage-Area-Storage) for water above the floor of the water storages were obtained from data 'Weekly Volumes – July 2016 to June 2017.xlsx) provided by Curragh (November 2016).

This Stage-Area-Storage data is directly referenced by the water storage element in GoldSim. The Stage-Area-Storage tables are provided in Attachment A.

## 4.2 Catchment areas

Catchment areas reporting to each modelled water storage was input into the model. Catchment areas from from WRM (2016) were referenced. The catchment area for Pit B and the surrounding catchments were revised to reflect the post diversion conditions for Pit A. The catchment areas for the mine have been determined from 2016 aerial photography, 2016 Lidar and previous water management reports for the operation.

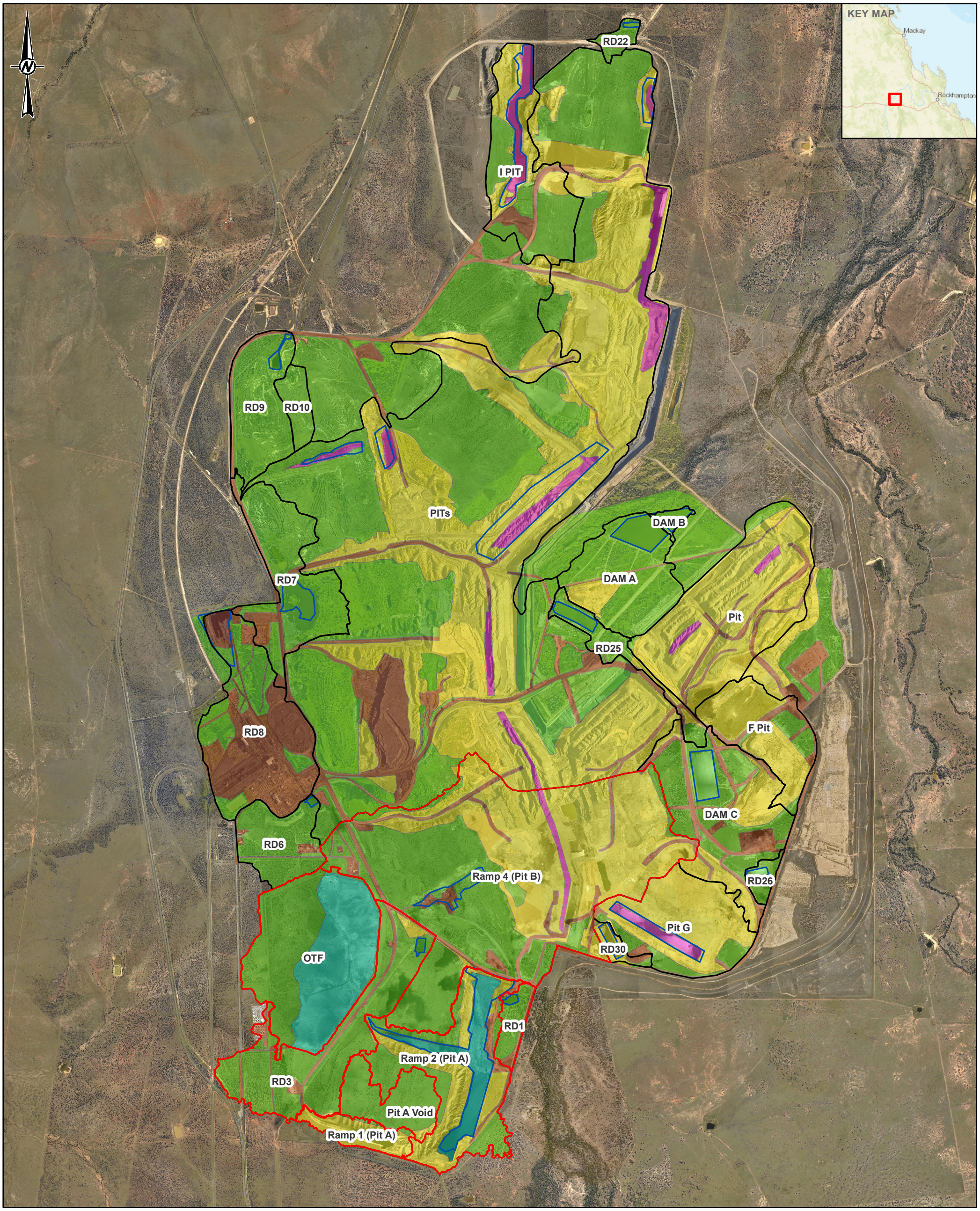
See Table 1 for the catchment area. The land use categories were developed by WRM (2016).

See Figure 3 for the updated adopted catchments. The catchments in red represent the revised catchments.

**Table 1: Relevant catchment areas**

| Storage | Natural (ha) | Spoil (ha) | Hardstand (ha) | Pit/Tailings (ha) | Total (ha) |
|---|---|---|---|---|---|
| Pit B | 287.2 | 320.3 | 57.0 | 9.8 | 674.2 |
| Pit A | 124.3 | 112.4 | 11.2 | 51.9 | 299.7 |
| RD3 | 154.7 | 5.9 | 19.2 | 0.5 | 180.2 |
| RD1 | 19.1 | 0 | 5.8 | 0 | 24.9 |
| RD30 | 1.7 | 9.6 | 2.0 | 0 | 13.4 |
| RD7 | 119.9 | 0 | 22.2 | 0 | 142.1 |
| OTF | 106.9 | 0 | 0.2 | 126.8 | 233.8 |

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LEGEND

**Landuse**

- Pit
- Spoil
- Natural
- Tailings
- Hardstand

- Revised Golder Catchment Area 2017
- Catchment Area (WRM 2016)
- Water storage

0 500 1,000 1,500

METRES

**REFERENCE(S)**

1. BASE IMAGE PROVIDED BY WESFARMERS CURRAGH AS AT 16 FEBRUARY 2016
2. INSET MAP SOURCES: ESRI, DELORME, NAVTEQ, USGS, INTERMAP, IPC, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI
3. LAND USE INFORMATION PROVIDED BY WRM (MARCH 2017)

CLIENT
WESFARMERS CURRAGH PTY LTD

CONSULTANT
Golder Associates

| | |
|---|---|
| YYYY-MM-DD | 2016-03-27 |
| DESIGNED | SL |
| PREPARED | SL |
| REVIEWED | SAC |
| APPROVED | SAC |

PROJECT
RPEQ MINE WATER SERVICES
CURRAGH MINE

TITLE
**CATCHMENT AREAS POST-DIVERSION**

| PROJECT NO. | CONTROL | REV. | FIGURE |
|---|---|---|---|
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0 25mm

## 4.3 Climate data

Data Drill data (127 years) for the approximate site location (latitude S 23.30°, longitude E 148.54°), was obtained for use in the predictive model simulation. Data Drill data is gridded synthetic data interpolated from point observations from the Bureau of Meteorology (BOM) records. Morton's evaporation over shallow lakes estimates were used to estimate evaporation loss from storages. Soil moisture evapotranspiration losses in the AWBM model were estimated using Morton's wet environment areal evapotranspiration over land.

Mean monthly rainfall is highest between November and March. This is illustrated in Figure 4, along with mean monthly evaporation and evapotranspiration, which is highest between October and March. Mean annual evapotranspiration is estimated to be 1,737 mm (with annual totals ranging between 1,487 mm and 1,866 mm). Mean annual open lake evaporation is estimated to be 1,814 mm (with annual totals ranging between 1,533 mm and 1,961 mm).

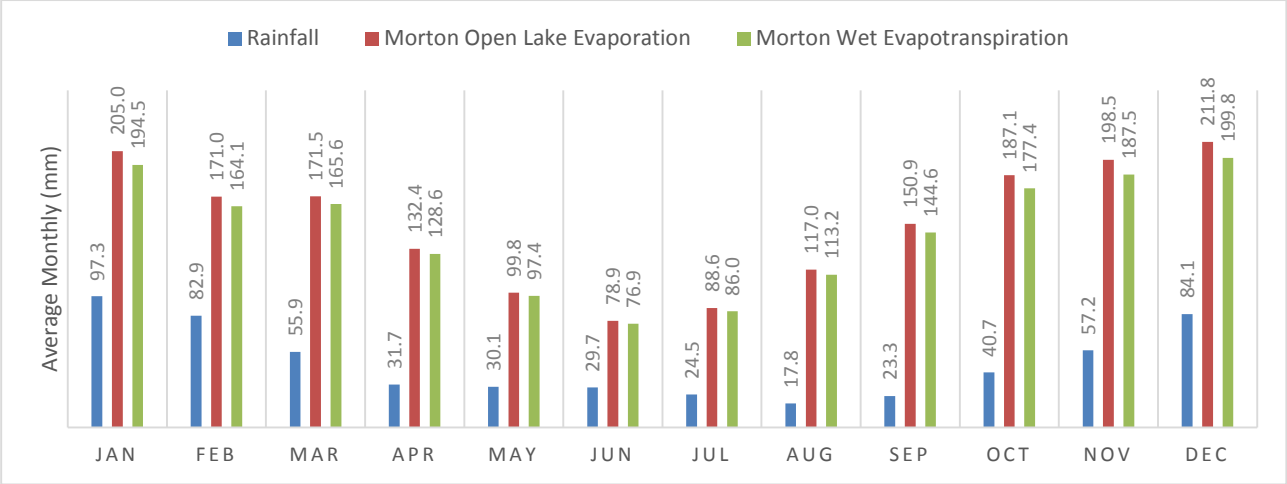



*Figure 4: Average monthly rainfall, Morton lake evaporation and Wet evapotranspiration – Data Drill data from 1889 to 2016*

## 4.4 Inflows

### 4.4.1 Rainfall (all catchments)

Direct rainfall to all water storages is calculated in the model on a daily basis from the rainfall record and the dynamic area of the pond surface.

### 4.4.2 Runoff (all catchments)

The Australian Water Balance Model (AWBM) was incorporated in the water balance model to simulate the catchment rainfall runoff. The AWBM is a catchment scale water balance model that relates runoff to rainfall. It is based on a conceptualised representation of a catchment's temporary surface and baseflow stores, rainfall loss to evaporation and gradual release of water from both stores to streamflow.

The AWBM separates surface runoff and baseflow, see Figure 5. The parameters $C_1$, $C_2$ and $C_3$ specify the surface storage capacities. The baseflow index (BFI) specify the amount of runoff that becomes baseflow. The baseflow recession constant ($K_b$) specify the rate of discharge of water from the baseflow store. The surface recession constant ($K_s$) specify the rate of discharge of water from the surface store.

Catchments across the site have been characterised into the following land use types:

- Natural/undisturbed;
- Open cut / mine pit;
- Spoil;
- Rehabilitated spoil;

- Tailings; and
- Hardstand.

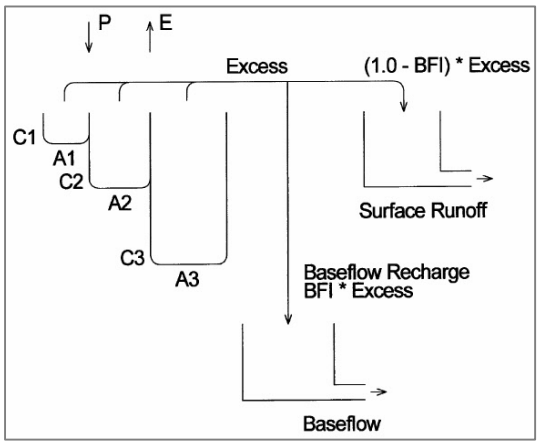



*Figure 5: AWBM conceptual model*

Table 2 shows adopted AWBM parameters, presented in WRM (2016), are based on past experience of similar mining projects. These parameters are within the expected range of values for the adopted land use types.

**Table 2: AWBM parameters**

| Parameter | Natural / Rehab | Spoil | Hardstand | Pit / Tailings |
|---|---|---|---|---|
| $A_1$ | 0.134 | 0.134 | 0.1 | 0.1 |
| $A_2$ | 0.433 | 0.433 | 0.9 | 0.9 |
| $A_3$ | 0.433 | 0.433 | 0 | 0 |
| $C_1$ | 11 | 14 | 38 | 12 |
| $C_2$ | 114 | 70 | 12 | 38 |
| $C_3$ | 229 | 168 | 38 | 0 |
| BFI | 0.17 | 0 | 0 | 0 |
| $K_s$ | 0.95 | 0 | 0 | 0 |
| $K_b$ | 0 | 0 | 0 | 0 |

Source: Table 6.1 from WRM (2016)

Catchment runoff to all water storages is calculated in the model on a daily basis using the rainfall record, evaporation, and AWBM parameters specified in Table 2.

### 4.4.3 Water in tailings slurry to Pit B TSF and decant

The tailings slurry water was modelled as an inflow to Pit B at 1,740,749 $m^3$/yr. The water retained within the tailings was estimated to be 669,697 $m^3$/yr, with 1,071,052 m3/yr reporting into the TSF decant pond for return to the CPP. See the process plant input parameters listed in Table 3.

**Table 3: Tailings and CHPP Volumetric / physical properties.**

| Criteria | Value | Unit |
|---|---|---|
| ROM | 15.00 | Mt/yr |
| Product | 10.50 | Mt/yr |
| Annual tailings rate | 1.04 | Mt/yr |
| Thickener solids | 7% | |
| Slurry in water (thickener underflow) | 13.82 | $Mm^3/yr$ |
| Slurry water (water in tailings pipeline to TSF) | 1.74 | $Mm^3/yr$ |
| Underflow Solids | 37% | |
| Tailings Specific gravity | 1.65 | |
| Initial dry density | 0.8 | $t/m^3$ |
| **Retained water within tailings** | 0.67 | $Mm^3/yr$ |
| Decant Supernatant Water | 62% | |
| **TSF water to decant pond for return (excluding rainfall and evaporation)** | 1.07 | $Mm^3/yr$ |
| Thickener overflow (clarifiers) recirculated back to CPPs | 12.08 | $Mm^3/yr$ |
| Total tailings water return (decant + clarifiers) | 13.15 | $Mm^3/yr$ |
| Rejects volume | 3.12 | Mt/yr |
| Rejects water content | 12% | |
| **Water bound with rejects** | 0.43 | $Mm^3/yr$ |
| Product water content | 9% | |
| **Water bound with product** | 1.04 | $Mm^3/yr$ |
| **Total CPPs water demand** | 3.21 | $Mm^3/yr$ |
| **Water demand for CPPs** (for product, rejects and due to water loss to TSF) | 2.14 | $Mm^3/yr$ |

### 4.4.4 Pumped water (various ponds)

Excess water from water storages is pumped to designated storages. See the pumped water section in Section 4.5.

### 4.4.5 Groundwater

The analysis and estimation of groundwater inflow are addressed in the groundwater impact assessment report (refer to Appendix B1 of the Supplementary Report) (WSP Parsons Brinckerhoff,2016). The following information is quoted from that report.

*"The Curragh North pits (S, T and U) experience inflows from the alluvium, which is thick and comprised of sand and gravel in this area, and the Rangal Coal Measures. At Curragh, alluvium is less than 2 m thick and comprised of clay, and inflows are predominantly from Rangal Coal Measures.*

The groundwater modelling (WSP Parsons Brinckerhoff, 2016) predicted groundwater inflows to operational pits over the proposed life of the approved operations. The inflows presented were cumulative inflows for Curragh Mine and do not include inflows to residual voids.

On this basis, it is assumed that there are no groundwater inflows to the mine voids within the contributing catchment of Pit B.

## 4.5 Outflows

### 4.5.1 Evaporation (all catchments and ponds)

Site evaporation records are not available and Morton's evaporation over shallow lakes estimates has been used in both the calibration and predictive simulations to estimate evaporation loss from storages. Soil moisture evapotranspiration losses in the AWBM model were estimated using Morton's wet environment areal evapotranspiration over land.

In the predictive model daily evaporation data is used from the corresponding 1 November start year to the Data Drill rainfall record. Evaporation from the water storages is calculated in the model on a daily basis from the Data Drill evaporation record and the dynamic area of the pond surface.

### 4.5.2 CHPP Clarifier and CHPP water demand (RD7 and RD3)

Water is extracted from RD3 and RD7 for make-up water which is the volume of water that is loss to water entrained in the product, rejects and Tailings. A total water supply to the CHPPs is 3.21 $Mm^3/yr$, which is the water required for the rejects (0.43 $Mm^3/yr$), water required for the product (1.04 $Mm^3/yr$), water retained in the tailings (0.67 $Mm^3/yr$ ), and water retuned from the TSF decant (1.07 $Mm^3/yr$ ). Water is preferentially taken from RD7 as RD7's catchment area is over two times larger than the catchment area for RD3 (i.e more catchment runoff reporting to the RD7). The remaining CHPP water demand is taken from RD3, and any shortfall is taken from the Raw water Dam (RWD).

A summary of the CHPP water requirements is presented in

Table 3.

### 4.5.3 Dust suppression (various ponds)

Haul road dust suppression requirements were applied to haul roads on dry days (with a depth of rainfall less than 5 mm) at an average width of 22 m, and at a rate to replace water lost to evaporation. The existing length of watered haul roads was estimated to be approximately 37 km (WRM 2016). Across the 100 model realisations, the dust suppression demand was equivalent to approximately 5.7 mm/day.

Haul road water demands were contributed evenly between four storages in the model: RD7, RD26, RD1 and Dam A & B (see Figure 1).

### 4.5.4 Pumped water (various ponds)

Excess water from water storages is pumped to designated storages when the water level is within 1 m below the spillway invert. Golder previously estimated the maximum potential pump rate within Curragh was approximately 200 L/s[4], therefore this simplified rate was assumed for the purpose of modelling.

An exception is the pumping from Pit B to RD30. A maximum decanting pump rate of 250 L/s was specified when the water level in Pit B is within 3 m below the spillway invert. The maximum pump rate was estimated for Pit B in a separate Golder memo (Golder ref: 1532295-057-TM-Rev1, February 2017).

The modelled pumping network is shown in Figure 1.

### 4.5.5 Seepage

As required by the method there was no allowance for seepage loss in the modelled system.

## 5.0 RESULTS

The model was used to predict the increase in stored water inventory over the wet season subsequent to 1 November each year. Stage-area-storage information provided by Curragh was used in the predictive model, along with the Data Drill rainfall data. The initial water volume in the predictive model (100 ML) is the pond volume in Pit B at 1 November 2015. All water transfers were assumed to be operational as defined in the water balance model development, in Section 3.0.

The model was simulated using daily time steps for the period 1 November to 30 March and 100 model realisations. The resultant water volume of the decant for each of the 100 realisations is shown in Figure 6.

[4] Golder Associates, November 2016, *Curragh Wet Weather Preparation 2016/2017*, Document reference: 1532295-028-TM-Rev0

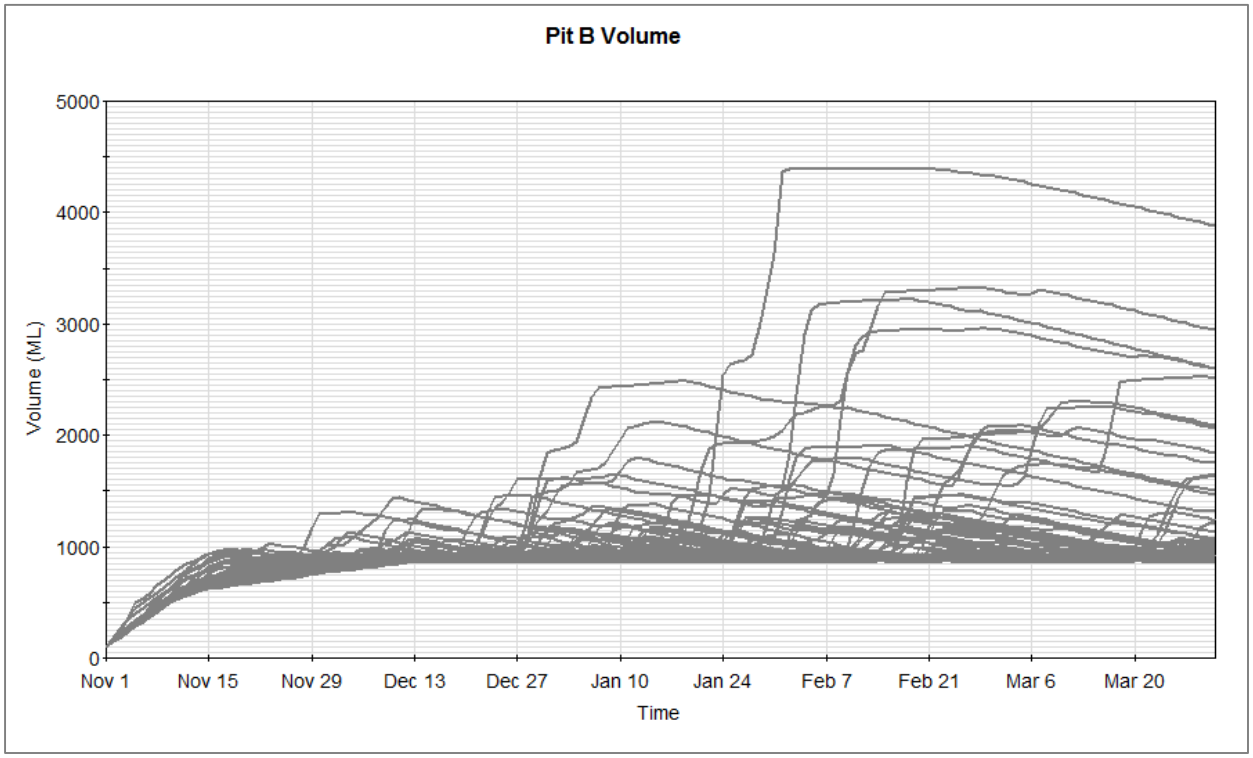



*Figure 6: Pit B decant water volume for each of 100 realisations.*

The maximum change in storage volume during the simulation for each of the 100 realisations was extracted from the model results. A Log-Pearson 3 (LP3) frequency analyses using the software TUFLOW FLIKE was then undertaken to determine the 1:20 AEP wet season water inventory increase. A DSM value of 50% has been applied due to insufficient data to calibrate the model (as described in Section 2.0).

The DSA is then calculated by:

DSA = (100% + DSM) x (1:20 AEP Increase in Water Inventory).

Based on the LP3 analysis, the 1:20 AEP wet season water inventory increase = 1882 ML (see figure below).

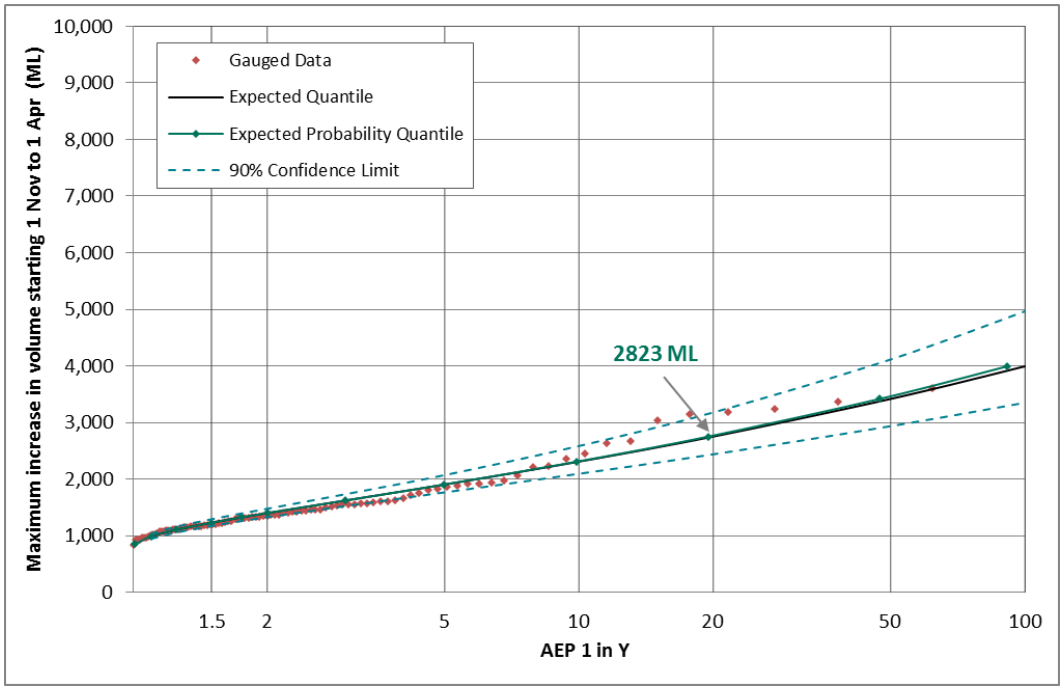



*Figure 7: Log-Pearson 3 analysis of the maximum increase in volume starting 1 November to 1 April*

Therefore the DSA of Pit B = 2823 ML.

Note the calculation of the DSA by the method of operational simulation applies to the wet season subsequent to the start water level and storage capacity at 1 November 2015. The DSA if using the method of operational simulation will need to be re-modelled and re-evaluated on an annual basis.

## 6.0 LIMITATIONS OF THE WATER BALANCE MODEL

The water balance model developed for the project is assumed to be representative of the proposed mine water management system. However, as the project is not yet operating there are several limitations of this model which must be understood when analysing the results:

1) There is no site-specific data available to calibrate the rainfall runoff behaviour for the mine site catchments. The Australian Water Balance Model (AWBM) parameters adopted for the model appear reasonable based in past experience and calibration to available stream flow data (calibrated model of Blackwater Creek) at Curragh (PB, 2004). However, mine site catchment runoff behaviour can vary from site to site and catchment to catchment.

2) The site water transfers developed in the model have been assumed to be accurate and a true representation of how the site may transfer water. It is however important to note that the sites pumping infrastructure and transfers are not static, and can be changed by the site operators at any time to suit operational requirements.

3) The water balance model does not include any allowance for seepage or transmission loss from dams and open channel drains. This assumption will tend to overestimate mine water volumes in the mine water management system and potential salt loads. This is conservative from the perspective of assessing containment performance and release compliance, and also risks of prolonged water accumulation in the open cut mine pits. This assumption is not conservative for assessing the availability of mine water to be reused in mine operations.

4) The mine water balance model simulations are undertaken for a static configuration of the mine representative of a given point in time, which for the purposes of the project mine water balance assessment and baseline is nominally 2016, in accordance with the 16 August 2016 Lidar and Aerials.

The simulation periods are performed with the complete 127 years of climate data (to test extremes of climate influence) and time series results are produced for water volumes (or flows in waterways).

## 7.0 CLOSURE

We trust that this technical memorandum meets your immediate requirements in relation to DSA calculation by the method of operational simulation. Please contact us if you have any questions regarding the modelling method or results.

## 8.0 REFERENCES


| | |
|---|---|
| Morton (1983) | Operational estimates of areal evapotranspiration and their significance to the science and practice of hydrology. Journal of Hydrology, Volume 66, 1-76. |
| PB (2004) | Curragh North Coal Mine – Hydrology, Flooding and Groundwater Report, Parsons Brinckerhoff, June 2004 |
| WSP Parsons Brinckerhoff (2016) | 'Curragh Extension Project, Groundwater Technical Report', Appendix B1 – supplementary advice. Parsons Brinckerhoff, June 2016. |
| WRM (2016) | Curragh Extension Project, Submission to IESC, Surface water balance impact assessment report, 16 June 2016. |


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Attachments: Stage Area Storage Tables

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## Attachment 1: Stage Area Storage Tables

**Table 4: RD7 Stage storage curve**

| Stage | Volume ($m^3$) | Area ($m^2$) |
|---|---|---|
| 145 | 0 | 0 |
| 146 | 3,458 | 4,286 |
| 147 | 7,310 | 5,160 |
| 148 | 12,730 | 5,520 |
| 149 | 18,460 | 5,760 |
| 150 | 24,400 | 6,000 |
| 151 | 30,540 | 6,200 |
| 152 | 36,890 | 6,400 |
| 153 | 43,440 | 6,600 |
| 154 | 50,180 | 6,780 |
| 155 | 57,150 | 7,020 |
| 156 | 73,650 | 24,480 |
| 157 | 139,800 | 78,420 |
| 158 | 260,000 | 133,400 |
| 159 | 408,132 | 166,038 |
| 160 | 592,682 | 202,652 |
| 160.4 | 678,221 | 220,733 |

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

**Table 5: RD3 Stage storage curve**

| Stage | Volume ($m^3$) | Area ($m^2$) |
|---|---|---|
| 138 | 0 | 0 |
| 139 | 2,820 | 3,686 |
| 140 | 6,328 | 10,014 |
| 141 | 8,280 | 18,294 |
| 142 | 9,277 | 27,571 |
| 143 | 9,567 | 37,138 |
| 144 | 1,251 | 38,389 |
| 145 | 1,251 | 39,640 |
| 146 | 1,251 | 40,891 |
| 147 | 1,251 | 42,142 |
| 148 | 1,251 | 43,393 |
| 149 | 1,251 | 44,644 |
| 150 | 1,251 | 45,895 |
| 151 | 1,251 | 47,146 |
| 152 | 1,251 | 48,397 |

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

**Table 6: Pit A Stage storage curve**

| Stage | Volume ($m^3$) | Area ($m^2$) |
|---|---|---|
| 139.1 | 0 | 0 |
| 140 | 12,700 | 23,000 |
| 141 | 42,900 | 36,000 |
| 142 | 85,900 | 52,000 |
| 143 | 157,300 | 92,000 |
| 144 | 276,100 | 141,000 |
| 145 | 440,700 | 175,000 |
| 146 | 620,900 | 185,000 |
| 147 | 838,300 | 272,000 |
| 148 | 1,179,100 | 389,000 |
| 149 | 1,617,100 | 473,000 |
| 150 | 2,136,900 | 560,000 |
| 151 | 2,701,700 | 565,000 |

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

**Table 7: Pit B Stage storage curve**

| Stage | Volume ($m^3$) | Area ($m^2$) |
|---|---|---|
| 141.86 | 0 | 0 |
| 142.86 | 40,870 | 94,417 |
| 143.86 | 225,368 | 306,202 |
| 144.86 | 693,635 | 641,273 |
| 145.86 | 1,496,893 | 975,547 |
| 146.86 | 2,627,771 | 1,275,361 |
| 147.14 | 3,001,417 | 1,340,991 |
| 148.14 | 4,389,305 | 1,414,988 |

Developed by Golder

**Table 8: RD1 Stage storage curve**

| Stage | Volume ($m^3$) | Area ($m^2$) |
|---|---|---|
| 140 | 900 | 9,000 |
| 141 | 3,280 | 2,380 |
| 142 | 9,313 | 6,033 |
| 143 | 12,954 | 3,641 |
| 144 | 16,595 | 3,641 |
| 145 | 20,236 | 3,641 |
| 146 | 23,877 | 3,641 |
| 147 | 27,518 | 3,641 |
| 148 | 31,159 | 3,641 |
| 149 | 34,800 | 3,641 |
| 150 | 38,441 | 3,641 |
| 151 | 42,082 | 3,641 |
| 151.4 | 43,538 | 3,641 |

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

**Table 9: RD30 Stage storage curve**

| Stage | Volume ($m^3$) | Area ($m^2$) |
|---|---|---|
| 148.5 | 0 | 0 |
| 149 | 6,725 | 13,450 |
| 150 | 20,175 | 13,450 |
| 151 | 33,625 | 13,450 |
| 152 | 47,075 | 13,450 |
| 153 | 60,525 | 13,450 |
| 154 | 73,975 | 13,450 |
| 155 | 87,425 | 13,450 |
| 156 | 100,875 | 13,450 |
| 157 | 114,325 | 13,450 |
| 158 | 127,775 | 13,450 |
| 158.5 | 134,500 | 13,450 |

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

| | | |
|---|---|---|
| Golder Associates | Project | B Pit TSF |
| | Description | Stage 1 Embankment Wave Runup |
| | Job No. | 1531363 |
| | Eng. | DS |
| | Date | 2-Mar-17 |

| WIND ASSESSMENT | | | |
|---|---|---|---|
| **Description** | **Symbol** | | **Unit** |
| Return Period | R | 10 | years |
| Wind Region (as per AS1170.2 Figure 3.1) | - | A (1 to 7) | m/s |
| 3-second wind gust speed | $V_R$ | 34 | m/s |
| Factor for Region C and D | $F_C$ , $F_D$ | 1 | - |
| Wind Direction Multiplier | $M_d$ | 1 | - |
| Terrain/Height Multiplier | $M_{z,cat}$ | 0.75 | - |
| Shielding Multiplier | $M_s$ | 1 | - |
| Topographic Multiplier | $M_t$ | 1 | - |
| Design Wind Speed | $V_{des,\theta}$ | 25.5 | m/s |
| Gust Factor | $G_{T,to}$ | 1.6 | - |
| **n-year wind speed** | **$V_n$** | **15.94** | **m/s** |
| required wind duratrion | t | **0.18** | hr |

| WAVE CLASSIFICATION | | | |
|---|---|---|---|
| **Description** | **Symbol** | | **Unit** |
| Effective Fetch Length | F | 0.47 | km |
| Average Reservoir Depth | d | 6.00 | m |
| Over-land wind speed | $U_L$ | 15.94 | m/s |
| Over-water wind speed | $U_W$ | 19.13 | m/s |
| **Wind Stress Factor** | **$U_A$** | **26.77** | **m/s** |
| Deep Water Significant Wave Length | $L_o$ | 3.28 | m |
| Required Wind Duration | t | 0.18 | hr |
| Depth/Wavelength | d/L | 1.83 | - |
| **Wave Classification** | **-** | **DEEP** | **-** |

| WAVE HEIGHT | | | |
|---|---|---|---|
| **Description** | **Symbol** | | **Unit** |
| Deep Water Significant Wave Height | $H_{mo}$ | 0.30 | m |
| Deep Water Significant Wave Period | $T_o$ | 1.45 | s |
| Deep Water Significant Wave Length | $L_o$ | 3.28 | m |
| Shallow Water Significant Wave Height | H | N/A | m |
| Shallow Water Significant Wave Period | T | N/A | s |
| Shallow Water Significant Wave Length | L | N/A | m |

| FREEBOARD REQUIREMENT | | | |
|---|---|---|---|
| **Description** | **Symbol** | | **Unit** |
| Significant Wave Height | $H_s$ | 0.30 | m |
| Significant Wave Period | T | 1.45 | s |
| Significant Wave Length | L | 3.28 | m |
| Embnakment Slope | α | 1.00 | m/m |
| Embankment Armor Material | - | wo or more layers of rock, (Hs/D=1.5 - 6.( | - |
| Influence angle of Incidence (direction of fetch relative to the dam axis) | β | 0.00 | ° |
| Surf Similarity Factor | $\xi_p$ | 3.33 | - |
| reduction factor for slope roughness | $\gamma_r$ | 0.50 | - |
| reduction factor for influence of a berm | $\gamma_b$ | 1.00 | - |
| reduction factor for shallow water conditions | $\gamma_h$ | 1.00 | - |
| reduction factor for angle of incidence | $\gamma_\beta$ | 1.00 | - |
| Coefficent dependant on ξp | A | -0.20 | - |
| Coefficent dependant on ξp | C | 4.50 | - |
| Set-up Fetch | $F_s$ | 0.94 | km |
| **Wave Runup** | **R** | **0.57** | **m** |
| **Wind Setup** | **S** | **0.01** | **m** |
| **Minimum Required Freeboard** | **(R+S)** | **0.58** | **m** |

| | | |
|---|---|---|
| Golder Associates | Project | B Pit TSF |
| | Description | Stage 2 Embankment Wave Runup |
| | Job No. | 1531363 |
| | Eng. | DS |
| | Date | 2-Mar-17 |

| WIND ASSESSMENT | | | |
|---|---|---|---|
| **Description** | **Symbol** | | **Unit** |
| Return Period | R | 10 | years |
| Wind Region (as per AS1170.2 Figure 3.1) | - | A (1 to 7) | m/s |
| 3-second wind gust speed | $V_R$ | 34 | m/s |
| Factor for Region C and D | $F_C$ , $F_D$ | 1 | - |
| Wind Direction Multiplier | $M_d$ | 1 | - |
| Terrain/Height Multiplier | $M_{z,cat}$ | 0.75 | - |
| Shielding Multiplier | $M_s$ | 1 | - |
| Topographic Multiplier | $M_t$ | 1 | - |
| Design Wind Speed | $V_{des,\theta}$ | 25.5 | m/s |
| Gust Factor | $G_{T,to}$ | 1.6 | - |
| **n-year wind speed** | **$V_n$** | **15.94** | **m/s** |
| required wind duratrion | t | **0.21** | hr |

| WAVE CLASSIFICATION | | | |
|---|---|---|---|
| **Description** | **Symbol** | | **Unit** |
| Effective Fetch Length | F | 0.59 | km |
| Average Reservoir Depth | d | 6.00 | m |
| Over-land wind speed | $U_L$ | 15.94 | m/s |
| Over-water wind speed | $U_W$ | 19.13 | m/s |
| **Wind Stress Factor** | **$U_A$** | **26.77** | **m/s** |
| Deep Water Significant Wave Length | $L_o$ | 3.82 | m |
| Required Wind Duration | t | 0.21 | hr |
| Depth/Wavelength | d/L | 1.57 | - |
| **Wave Classification** | **-** | **DEEP** | **-** |

| WAVE HEIGHT | | | |
|---|---|---|---|
| **Description** | **Symbol** | | **Unit** |
| Deep Water Significant Wave Height | $H_{mo}$ | 0.33 | m |
| Deep Water Significant Wave Period | $T_o$ | 1.57 | s |
| Deep Water Significant Wave Length | $L_o$ | 3.82 | m |
| Shallow Water Significant Wave Height | H | N/A | m |
| Shallow Water Significant Wave Period | T | N/A | s |
| Shallow Water Significant Wave Length | L | N/A | m |

| FREEBOARD REQUIREMENT | | | |
|---|---|---|---|
| **Description** | **Symbol** | | **Unit** |
| Significant Wave Height | $H_s$ | 0.33 | m |
| Significant Wave Period | T | 1.57 | s |
| Significant Wave Length | L | 3.82 | m |
| Embnakment Slope | α | 1.00 | m/m |
| Embankment Armor Material | - | Two or more layers of rock, (Hs/D=1.5 - 6.0) | - |
| Influence angle of Incidence (direction of fetch relative to the dam axis) | β | 0.00 | ° |
| Surf Similarity Factor | $\xi_p$ | 3.39 | - |
| reduction factor for slope roughness | $\gamma_r$ | 0.50 | - |
| reduction factor for influence of a berm | $\gamma_b$ | 1.00 | - |
| reduction factor for shallow water conditions | $\gamma_h$ | 1.00 | - |
| reduction factor for angle of incidence | $\gamma_\beta$ | 1.00 | - |
| Coefficent dependant on ξp | A | -0.20 | - |
| Coefficent dependant on ξp | C | 4.50 | - |
| Set-up Fetch | $F_s$ | 1.18 | km |
| **Wave Runup** | **R** | **0.63** | **m** |
| **Wind Setup** | **S** | **0.01** | **m** |
| **Minimum Required Freeboard** | **(R+S)** | **0.65** | **m** |

# APPENDIX H

## Risk Assessment

# HAZOP RISK ASSESSMENT – TABLE 1

| RISK CATEGORY | CONSEQUENCE | |
|---|---|---|
| **SAFETY**<br><br>Safety and health of personnel and public | 1 | loss of life or life threatening illness |
| | 2 | injury or illness causing maiming, loss of function or permanent disability |
| | 3 | recoverable injury or illness requiring immediate medical attention |
| | 4 | minor injury or illness requiring first aid or self treatment |
| | 5 | reportable incident, no injury |
| **ENVIRONMENTAL HARM / REGULATORY**<br><br>Temporary or permanent impact on the environment, including regulatory impacts and remediation liabilities | 1 | severe impact requiring costly remediation, effects may be long term or unrecoverable |
| | 2 | significant impact requiring significant remediation |
| | 3 | significant temporary impact or minor permanent impact requiring remediation |
| | 4 | temporary or minor impact requiring clean-up or minor remediation |
| | 5 | no measureable impact |
| **ENGINEERING / OPERATIONS / ASSETS**<br><br>Cost to repair or replace damaged assets and cost of lost production / time | 1 | >$10 million |
| | 2 | $1 million to $10 million |
| | 3 | $100,000 to $1 million |
| | 4 | $10,000 to $100,000 |
| | 5 | <$10,000 |

| PROBABILITY | |
|---|---|
| A | Almost certain, common (e.g. occurs weekly) |
| B | Likely (e.g. occurs several times a year) |
| C | Possible (e.g. occurs several times over the operational life) |
| D | Unlikely (e.g. occurs less than once in the operational life) |
| E | Rare (e.g. occurs less than once in 100 years) |

**OVERALL RISK MATRIX**

| PROBABILITY | CONSEQUENCE 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A | | | | | |
| B | | | | | |
| C | | | | | |
| D | | | | | |
| E | | | | | |

Legend:

| | |
|---|---|
| Extreme Risk | Senior management decision making |
| High Risk | Senior management attention and additional engineering, if required |
| Moderate Risk | Manage by specific monitoring, operation and response procedures |
| Low Risk | Manage by routine procedures |

**Table 2: Pit B TSF Hazard Table - Initial Risks**

| HAZARD NUMBER | DESCRIPTION | RISK CATEGORY | IMPACT | INITIAL RISK | | |
|---|---|---|---|---|---|---|
| | | | | PROBABILITY | CONSEQUENCE | OVERALL RISK |
| 1 | Failure of embankment | Safety | Failiure of embankment leading to personnel being inundated | D | 1 | High |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 1 | Moderate |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage | D | 1 | High |
| 2 | Overtopping of embankment due to extreme rainfall | Safety | Failiure of embankment leading to personnel being inundated | D | 1 | High |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 1 | Moderate |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure | E | 1 | Moderate |
| 3 | Significant leak through embankment or foundation (piping/internal erosion) | Safety | Failiure of embankment leading to personnel being inundated | D | 1 | High |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 1 | Moderate |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure | D | 1 | High |
| 4 | Significant leak from tailings pipeline | Safety | Potential impact on vehicle taffficability where pipelines are located near roads | E | 1 | Moderate |
| | | Environmental Harm / Regulatory | Possible flow into surface water drainage systems leading to Blackwater Creek ; damage to flora and fauna; land and water contamination | E | 1 | Moderate |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time | E | 1 | Moderate |

## Table 3: Pit B TSF Hazard Table - Residual Risks

| HAZARD NUMBER | DESCRIPTION | RISK CATEGORY | IMPACT | RESIDUAL RISK UNDER MITIGATION MEASURES | | | RISK REDUCTION AND MITIGATION MEASURES |
|---|---|---|---|---|---|---|---|
| | | | | PROBABILITY | CONSEQUENCE | OVERALL RISK | |
| 1 | Failure of embankment | Safety | Failiure of embankment leading to personnel being inundated | E | 1 | Moderate | - Monitor slope movement<br>- Monitor phreatic conditions in embankment and tailings and maintain decant pond at or below the maximum design operating water level which will be subject to tailings placement.<br>- Stop pumping tailings into the TSF, if necessary<br>- Implement water level reduction measures such as pumping from vertical spears/bores in tailings and pumping decant water to external storages<br>- Monitor embankment erosion<br>- Conduct regular visits maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD) and with Curragh Mine's Operation and Maintenance manuals<br>- Prepare and implement plans for operations, monitoring, and emergency response |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 5 | Low | |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in TSF storage | E | 1 | Moderate | |
| 2 | Overtopping of embankment due to extreme rainfall | Safety | Failiure of embankment leading to personnel being inundated | E | 1 | Moderate | - Reduce personnel exposure near TSF during wet weather<br>- Maintain freeboard in accordance with regulatory guidelines (DERM, ANCOLD)<br>- Monitor water level<br>- Stop pumping tailings into the TSF, if necessary and divert to other avaiable storages<br>- Implement water level reduction measures such as pumping decant water to external storages<br>- Conduct regular visits maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD)<br>- Prepare and implement plans for operations, monitoring, and emergency response |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 5 | Low | |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure | E | 5 | Low | |
| 3 | Significant leak through embankment or foundation (piping/internal erosion) | Safety | Failiure of embankment leading to personnel being inundated | D | 3 | Moderate | - Conduct regular visits and maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD)<br>- Monitor phreatic conditions in embankment<br>- Stop pumping tailings into the TSF, if necessary<br>- Implement water level reduction measures such as pumping decant water to external storages<br>- Monitor embankment erosion<br>- Prepare and implement plans for operations, monitoring, and emergency response<br>- If signs of piping / seepage are detected contact the design engineer to seek advice<br>- Piping / seepage control measures may include placing a butress of coarse rejects against the downstream emabnkment |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | D | 3 | Moderate | |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure | D | 3 | Moderate | |
| 4 | Significant leak from tailings pipeline | Safety | Potential impact on vehicle taffficability where pipelines are located near roads | E | 5 | Low | - Construct tailings pipeline to design specifications<br>- Maintain design slurry composition with low water content so as to restrict the flow distance of a spill<br>- Install automatic flow meters in pipes, with possible alarm and automatic shutdown<br>- Include engineering measures such as low pressure water line for clearing blockages, injection points and cross over stations to re-direct slurry in event of failure or blockage<br>- Construct a bund (catchment drain) the full length of the pipeline, with containment ponds<br>- Construct a containment pond as a facility for flushing of the line during maintenance<br>- Conduct regular visits and maintenance<br>- Prepare and implement plans for operations, monitoring, and emergency response |
| | | Environmental Harm / Regulatory | Possible flow into surface water drainage systems leading to Blackwater Creek ; damage to flora and fauna; land and water contamination | E | 4 | Low | |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time | E | 5 | Low | |

**Table 2: Pit B TSF Hazard Table - Initial Risks**

| HAZARD NUMBER | DESCRIPTION | RISK CATEGORY | IMPACT | INITIAL RISK | | |
|---|---|---|---|---|---|---|
| | | | | PROBABILITY | CONSEQUENCE | OVERALL RISK |
| 1 | Failure of embankment | Safety | Failiure of embankment leading to personnel being inundated | D | 1 | High |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 1 | Moderate |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage | D | 1 | High |
| 2 | Overtopping of embankment due to extreme rainfall | Safety | Failiure of embankment leading to personnel being inundated | D | 1 | High |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 1 | Moderate |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure | E | 1 | Moderate |
| 3 | Significant leak through embankment or foundation (piping/internal erosion) | Safety | Failiure of embankment leading to personnel being inundated | D | 1 | High |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 1 | Moderate |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure | D | 1 | High |
| 4 | Significant leak from tailings pipeline | Safety | Potential impact on vehicle taffficability where pipelines are located near roads | E | 1 | Moderate |
| | | Environmental Harm / Regulatory | Possible flow into surface water drainage systems leading to Blackwater Creek ; damage to flora and fauna; land and water contamination | E | 1 | Moderate |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time | E | 1 | Moderate |

## Table 3: Pit B TSF Hazard Table - Residual Risks

| HAZARD NUMBER | DESCRIPTION | RISK CATEGORY | IMPACT | RESIDUAL RISK UNDER MITIGATION MEASURES | | | RISK REDUCTION AND MITIGATION MEASURES |
|---|---|---|---|---|---|---|---|
| | | | | PROBABILITY | CONSEQUENCE | OVERALL RISK | |
| 1 | Failure of embankment | Safety | Failiure of embankment leading to personnel being inundated | E | 1 | Moderate | - Monitor slope movement<br>- Monitor phreatic conditions in embankment and tailings and maintain decant pond at or below the maximum design operating water level which will be subject to tailings placement.<br>- Stop pumping tailings into the TSF, if necessary<br>- Implement water level reduction measures such as pumping from vertical spears/bores in tailings and pumping decant water to external storages<br>- Monitor embankment erosion<br>- Conduct regular visits maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD) and with Curragh Mine's Operation and Maintenance manuals<br>- Prepare and implement plans for operations, monitoring, and emergency response |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 5 | Low | |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in TSF storage | E | 1 | Moderate | |
| 2 | Overtopping of embankment due to extreme rainfall | Safety | Failiure of embankment leading to personnel being inundated | E | 1 | Moderate | - Reduce personnel exposure near TSF during wet weather<br>- Maintain freeboard in accordance with regulatory guidelines (DERM, ANCOLD)<br>- Monitor water level<br>- Stop pumping tailings into the TSF, if necessary and divert to other avaiable storages<br>- Implement water level reduction measures such as pumping decant water to external storages<br>- Conduct regular visits maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD)<br>- Prepare and implement plans for operations, monitoring, and emergency response |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | E | 5 | Low | |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure | E | 5 | Low | |
| 3 | Significant leak through embankment or foundation (piping/internal erosion) | Safety | Failiure of embankment leading to personnel being inundated | D | 3 | Moderate | - Conduct regular visits and maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD)<br>- Monitor phreatic conditions in embankment<br>- Stop pumping tailings into the TSF, if necessary<br>- Implement water level reduction measures such as pumping decant water to external storages<br>- Monitor embankment erosion<br>- Prepare and implement plans for operations, monitoring, and emergency response<br>- If signs of piping / seepage are detected contact the design engineer to seek advice<br>- Piping / seepage control measures may include placing a butress of coarse rejects against the downstream emabnkment |
| | | Environmental Harm / Regulatory | Nil environmental harm, failure to meet regulatory conditions | D | 3 | Moderate | |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure | D | 3 | Moderate | |
| 4 | Significant leak from tailings pipeline | Safety | Potential impact on vehicle taffficability where pipelines are located near roads | E | 5 | Low | - Construct tailings pipeline to design specifications<br>- Maintain design slurry composition with low water content so as to restrict the flow distance of a spill<br>- Install automatic flow meters in pipes, with possible alarm and automatic shutdown<br>- Include engineering measures such as low pressure water line for clearing blockages, injection points and cross over stations to re-direct slurry in event of failure or blockage<br>- Construct a bund (catchment drain) the full length of the pipeline, with containment ponds<br>- Construct a containment pond as a facility for flushing of the line during maintenance<br>- Conduct regular visits and maintenance<br>- Prepare and implement plans for operations, monitoring, and emergency response |
| | | Environmental Harm / Regulatory | Possible flow into surface water drainage systems leading to Blackwater Creek ; damage to flora and fauna; land and water contamination | E | 4 | Low | |
| | | Engineering / Operations / Assets | Damage to assets; potential for lost production time | E | 5 | Low | |

# APPENDIX I

## Background Hydrogeology Reports

Curragh (2016). *D-E-F Pit Hydrology*, memorandum, 13 October 2016

Curragh (2015). *A Pit Geology / Groundwater Clarifications,* memorandum 14 August 2015

Wesfarmers Curragh Pty Ltd

MEMORANDUM

| | |
|---|---|
| **Date:** | 14 August 2015 |
| **To:** | A Dawson-Evenhuis, E Ballot, S Bourke, C Heales |
| **Copy:** | G Gribble |
| **From:** | Susan Dippel Forster |
| **Subject:** | A Pit Geology/Groundwater Clarifications |

**Background**

Two documents were produced in January 2013 regarding the hydrogeology of A Pit in view of plans to increase the volume of tails storage within that facility. The memos were written from a basis of a very conservative, 'worst case scenario' viewpoint in regard to the likelihood of tailings leakage into the adjacent Blackwater Creek. This document provides further information and clarification on the geology and likely groundwater interactions that were originally discussed in the 2013 memos.

**Geology**

The terminology of Recent sands/sediments was taken from and used in conjunction with information derived from the Parsons Brinckerhoff 2003 report (Tite and Grady, 2003) on Curragh North, which in turn was extracted from the Minserve Task No 10 and Task No 11 reports of 1998 (Boyd *et al.* 1998 and Hill *et al.* 1998). 'Recent' is the geological time scale terminology for the last 10,000 years and is also known as the Holocene Epoch. The sedimentary deposits which are included under this banner in the reference documents are referred to on site as Quaternary sands and Tertiary rocks.

The Quaternary Period dates from 2.58 million years ago to the present and at the Curragh mine sites refers exclusively to the thick, unconsolidated to semi-consolidated clay, sand and gravel alluvial deposits which overlie the Permian coal strata at Curragh North. Similar strata are rare to absent at Curragh (location of A Pit). The Tertiary (also known as the Cainozoic) Era covers a much broader range, beginning at 66 million years before present (b.p.) and stretches to the present day. At the mine sites the Tertiary is applied to those sediments which are older than the Quaternary sands but younger than the Permian (299-252 million years b.p.) coal strata. The Tertiary rocks are semi-consolidated to full cemented (former) gravels, sands and clays and are the dominant surface material around Curragh mine, including A Pit. Figure 1 shows the general distribution of surface rock types and is derived from the Geological Survey of Queensland QDEX data set.



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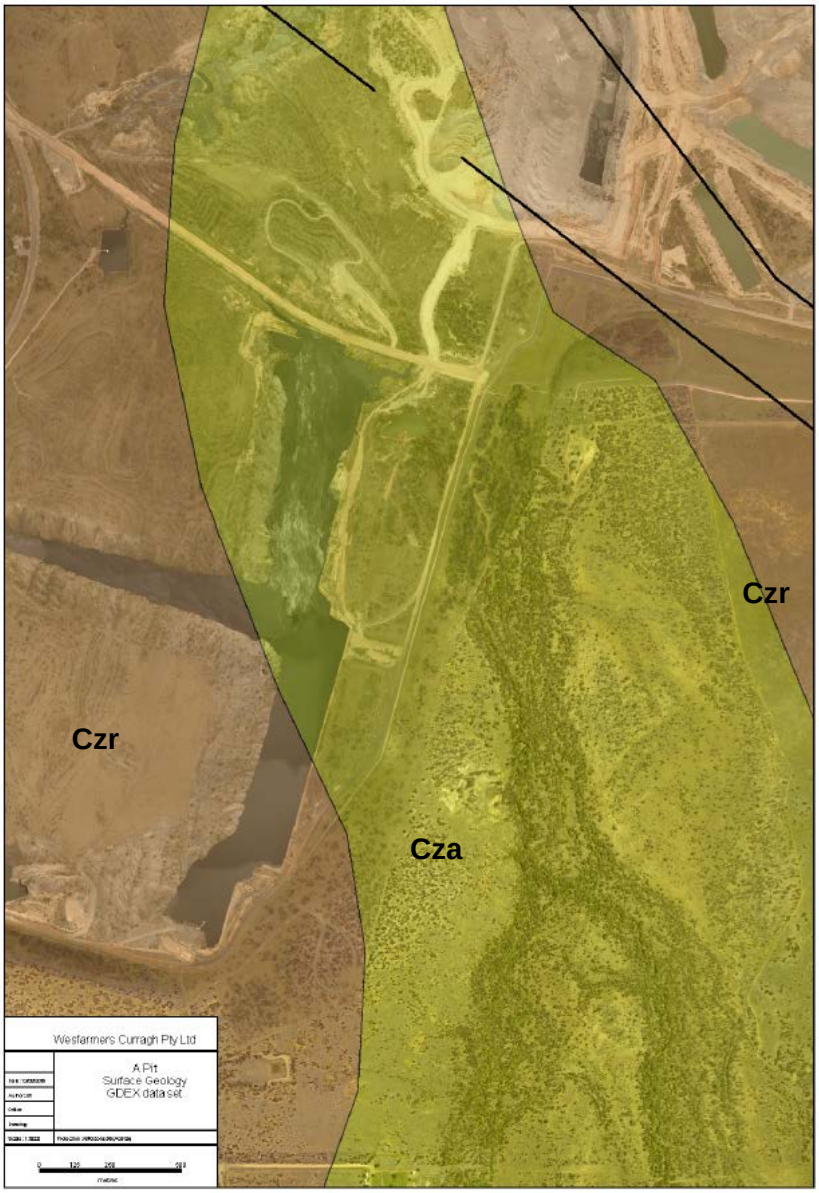



**Figure 1. Surface Geology of the A Pit area**

As shown on Figure 1, the QDEX datased identifies the two major rock types as follows:

| | |
|---|---|
| Cza (river sediments): | Cainozoic Alluvium consisting of mainly clay, silt, sand and gravel. |
| Czr (either side of the river sediments) | Cainozoic Miscellaneous Unconsolidated Sediments – soil, alluvium, gravel, scree, 'billy', sand, duricrust. |

Note that there is no further breakdown of the Cainozoic material into younger units.

At site, the Tertiary horizon is known to consist of closely interlayered, thin horizontal beds of lithified, fine-medium grained, quartzose clayey sandstone, siltstones and claystones with the occasional more friable, clayey-silty/sandy beds (poorly-consolidated sandstones) (Plate 1). The beds are generally of the scale of 5-10cm thick within an overall range of ~2.5-20cm and lie unconformably on the Permian Rangal Coal Measures. The major weathering profile generally extends to around two (2) metres below the contact. These sediments are lacustrine/fluviatile in origin, consisting of remnant channel or valley fill deposits that are 'somewhat re-cemented' (Boyd *et al.,* 1998; Malone *et al.*, 1969). The younger, unconsolidated to semi-consolidated Blackwater Creek sediments (mainly clays with occasional thin, sand/gravel lag beds) are thin and closely restricted to the path of the creek channels. These are identified as comprising mainly of reworked Tertiary sediments and laterites (Malone *et al.,* 1969).

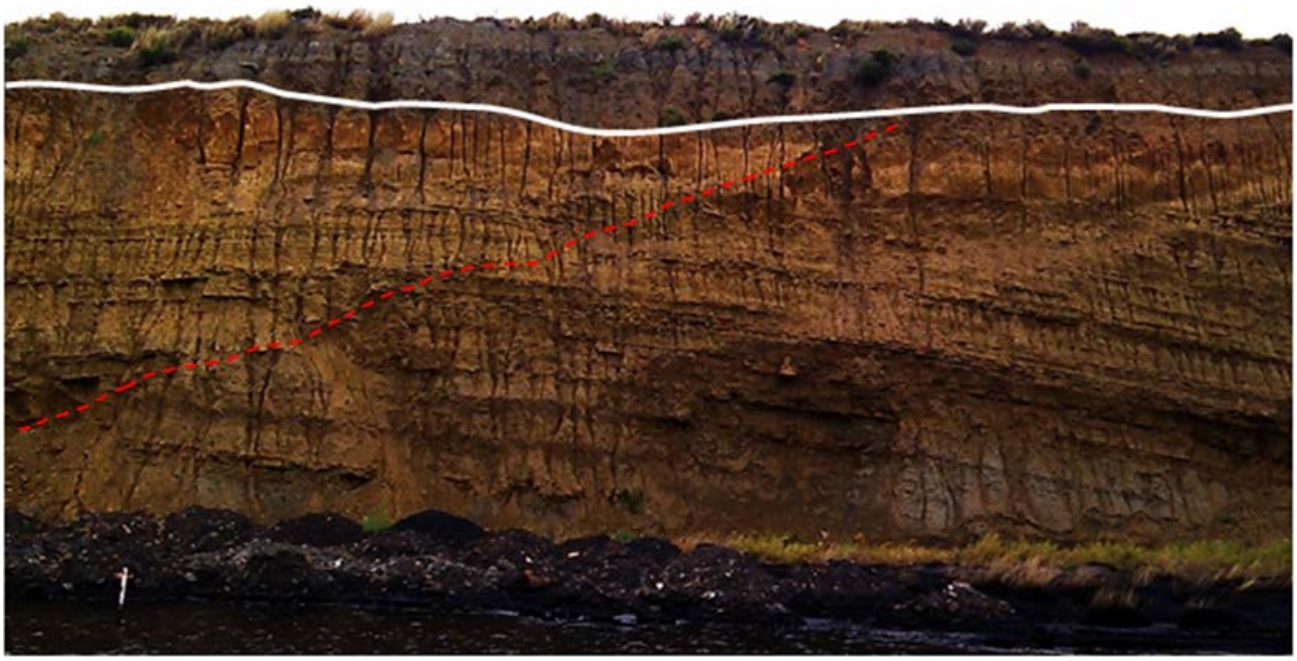


**Plate 1. Exposed section of Tertiary sediments, north-eastern wall of A Pit.** ~1m Quaternary alluvium (above white line) unconformaby overlies thinly interbedded Tertiary siltstone, claystone, sandstone and more friable sandy beds. The full profile is weathered and a fault (red dashed line) interrupts the bedding planes. Vertical extent is approximately 7m.

Overburden drilling consists of open holes which produce fines and small chips. As such it is almost impossible to accurately determine whether 'sand' horizons are from friable sands or from the consolidated sandstone beds. Samples are taken from metre down-hole intervals which, in the Tertiary

unit, will inevitably consist of a number of individual beds so the terms ‘sand’ or ‘sandy’ should be approached with caution when interpreting the bore logs for hydrogeological reasons and it should always be kept in mind that, unlike Curragh North, there are no thick (>0.5m) free sand beds and/or medium-coarse gravel lags at Curragh. Medium-coarse grained Tertiary sediments do occur at Curragh North but they are discontinuous and strongly cemented in the form of a conglomerate.

In line with their lacustrine/fluviatile deposition, the individual beds will be laterally discontinuous due to primary depositional onlap/offlap and interruption by palaeochannels and local structure as seen in Plate 1. The entirety of the Curragh leases is structurally complex, dominated by thrust faulting with subsidiary transcurrent faults. At the Curragh mine site thrust faulting is generally orientated around NNE-SSW with the transcurrent faults ENE-SSW. A Pit is slightly rotated to the east and has a major thrust fault mapped through the centre, offset at around Ramp 2 from the western side of the pit to the east by a transcurrent fault (Figure 2). Faults around the Curragh mine can act as either aquitards or aquifers although generally any water being released from fault zones is as seepage or at very low flow rates. It has not yet been identified whether there is any particularly consistent relationship between type and/or orientation of faulting and groundwater flow.




**Figure 2. Major structures at the Curragh Mine Site.**

## Hydrogeology

Historically, groundwater work at Curragh as a whole has focussed on the coal seams rather than the overburden. The information contained in the 2013 memos was taken from the Tite and Grady (2003) who in turn had summarised it from the Minserve Task 10 and 11 reports (Boyd *et al.* and Hill *et al.*, 1998). In these, the Tertiary deposits were reported as being "quartz rich" with a "clay matrix which was variably cemented", containing between 20-50% fines in all materials and were considered as a whole to be "very stiff to hard, clay-rich sand, gravels and thick beds of ferruginous clays of medium to high plasticity" (Boyd *et al.*, 1998).

Tite and Grady (2003) summarised aquifer hydraulic data obtained from field testing from the 1998 reports, these being the results shown in Table 1 in the original 2013 documents as well as below. Although the hydraulic conductivity *(K)* of the Tertiary Sandy Gravels appears to be high, it is orders of magnitude less than that of the Quaternary sands from Curragh North which is reflected in the adopted *K* values used for modelling the Tertiary being at the lower end of the range for the equivalent Quaternary unit.

**Table 1. Summary of hydraulic properties** (from Tite and Grady, 2003)

| | Measured hydraulic conductivity — K (cm/s) | Inferred hydraulic conductivity — K (cm/s) | Adopted K Values | |
|---|---|---|---|---|
| | | | cm/s | m/day |
| **Quaternary Strata** | | | | |
| Silty clay | N/A | $1 \times 10^{-7}$ to $1 \times 10^{-6}$ | $1 \times 10^{-6}$ | 0.0009 |
| Sand | $3 \times 10^{-4}$ | $4 \times 10^{-4}$ to $3 \times 10^{-2}$ | $1 \times 10^{-4}$ to $1 \times 10^{-2}$ | 0.09 to 9 |
| Sand/gravel | $7 \times 10^{-4}$ to $2 \times 10^{-2}$ | $1 \times 10^{-2}$ to $6 \times 10^{-2}$ | $1 \times 10^{-3}$ to $1 \times 10^{-2}$ | 0.9 to 9 |
| **Tertiary Strata** | | | | |
| Sandy gravels | N/A | $1 \times 10^{-4}$ to $1 \times 10^{-2}$ | $1 \times 10^{-3}$ | 0.9 |
| Claystone/other cemented strata | N/A | $1 \times 10^{-5}$ to $1 \times 10^{-4}$ | $5 \times 10^{-4}$ | 0.43 |
| **Permian Strata** | | | | |
| Sheared/fractured Coal | $1x\ 10^{-5}$ to $1x\ 10^{-4}$ | — | $1x\ 10^{-5}$ to $1x\ 10^{-4}$ | 0.009 to 0.09 |
| Intact Coals | $1x\ 10^{-5}$ to $2 \times 10^{-5}$ | — | $2x\ 10^{-5}$ | 0.02 |
| Overlying rocks (Intact) | | | | |
| K Horizontal | — | $1x\ 10^{-5}$ to $1 \times 10^{-6}$ | $5 \times 10^{-6}$ | 0.004 |
| K Vertical | | $1x\ 10^{-6}$ to $1x\ 10^{-7}$ | $1 \times 10^{-6}$ | 0.0009 |

Table 2 shows the adopted *K* values on a chart of average hydraulic properties. From this it can be seen that the Tertiary sandy gravels (orange) fall in the range of semi-pervious for Relative Permeability and would be classed towards the top end of a Poor aquifer while the claystone/cemented strata (pink) are lower down the Relative Permeability range and in the middle of the Poor aquifer classification.

**Table 2. Summary of average hydraulic properties**. (modified from Bear, 1972, downloaded from Wikipedia 13 Aug 2015)

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *K* (cm/s) | $10^{2}$ | $10^{1}$ | $10^{0}$=1 | $10^{-1}$ | $10^{-2}$ | $10^{-3}$ | $10^{-4}$ | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ | $10^{-8}$ | $10^{-9}$ | $10^{-10}$ |
| *K* (ft/day) | $10^{5}$ | 10,000 | 1,000 | 100 | 10 | 1 | 0.1 | 0.01 | 0.001 | 0.0001 | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ |
| Relative Permeability | Pervious | | | | Semi-Pervious | | | | | Impervious | | | |
| Aquifer | Good | | | | | Poor | | | | None | | | |
| Unconsolidated Sand & Gravel | Well Sorted Gravel | | Well Sorted Sand or Sand & Gravel | | | Very Fine Sand, Silt, Loess, Loam | | | | | | | |
| Unconsolidated Clay & Organic | | | | | Peat | | Layered Clay | | | Fat / Unweathered Clay | | | |
| Consolidated Rocks | Highly Fractured Rocks | | | | Oil Reservoir Rocks | | | Fresh Sandstone | | Fresh Limestone, Dolomite | | Fresh Granite | |

Due to the stratified nature of the deposit, if any fluid leaks from the A Pit tails it may be horizontal and via the semi-pervious, poor aquifer sandy layers. These are confined above and below by the cemented strata which are likely to be impermeable with similar vertical *K* values as shown in Tables 1 and 2 (shaded green) for the Permian rocks (sandstones and siltstones). These results, when considered in conjunction with the lack of horizontal continuity (depositional and structural) and high fines (clay/silt) content, suggest that the potential for leakage from A Pit is severely limited and would occur very slowly. The water quality of the tails is alkaline (average pH 8.02) which may also be expected to assist in slowing fluid progress by effectively chemically interacting with the individual grain particles to reduce existing pore throat sizes by precipitation of mineralisation onto the existing particles.

The regional topographic surface dips around east and plunges north-east, driving the regional drainage patterns generally towards the north-east. The base of weathering in the area of A Pit (modelled from drilling) follows the surface topography, with the low point being association with

Blackwater Creek. The three sections shown below (Figures 3 and 4) illustrate the relationship between the topography, interpreted sand-dominated unit, the modelled base of the Tertiary and base of weathering through the northern half of A Pit.

Material surrounding the 'sandy' unit within the Tertiary is clay. For the northern and central sections it should be noted that the 'sand' stops well short of the levee and major creek channels and that there is a dip in the base of the Tertiary between the 'sand' and the creek channels with the surface rising again to ~146m RL below the main creek channels east of the levee. The low point is at approximately 141m RL while the current surface of the creek beds (identified from Lidar) ranges from around 151m to 149m RL. There is currently some standing water in the main creek channel, with a surface (from Lidar) of around 149.8m RL, although the rest of the channels are dry. This water is believed to be effluent from the Blackwater town sewerage treatment and water treatment plants, located approximately two kilometres upstream. Note that the southern section modelling is severly constrained by lack of drilling data away from A Pit. Currently (July 2015 Lidar) the beach surface of the tails on the north-eastern side of A Pit is at around 149.5m RL and the pit water is at 145.6m RL.

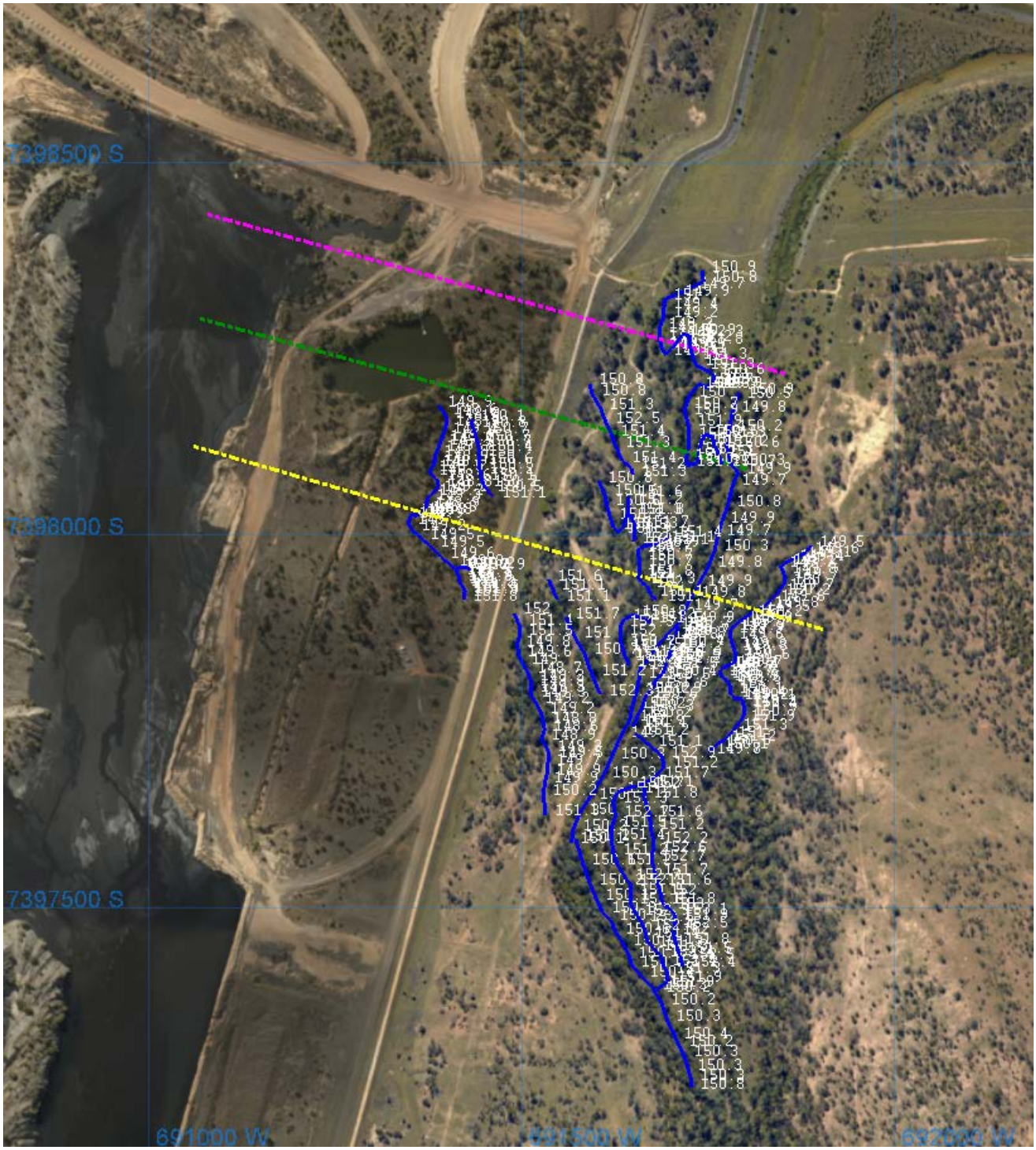



**Figure 3. Creek channel RLs (from Lidar) and section line locations as shown in Figure 4.**

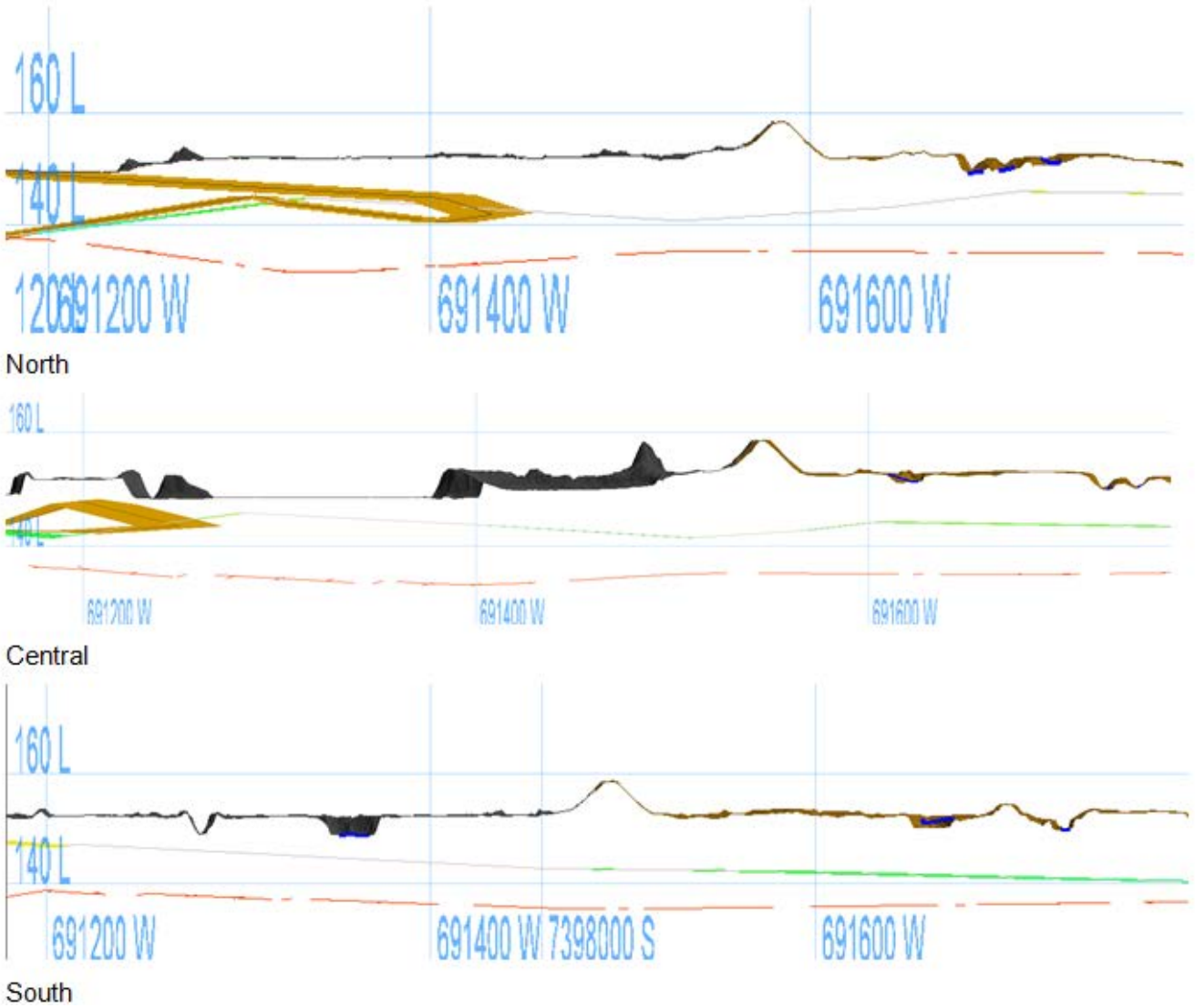



**Figure 4. Cross-sections, northern A Pit to Blackwater Creek.** 3x vertical exaggeration.

Seven water monitoring bores were drilled in 2013 to form two lines of monitoring points between A Pit and Blackwater Creek. 1301A/1301B are between the northern end of the pit and Retention Dam 1 (RD1), which is located within the nearest sub-channels of the creek while 1304A/1304B are south-east of RD1, still within the creek sub-channels. Both sites are west of the main creek channel and of the levee separating the mine area from the creek (Figure 5).

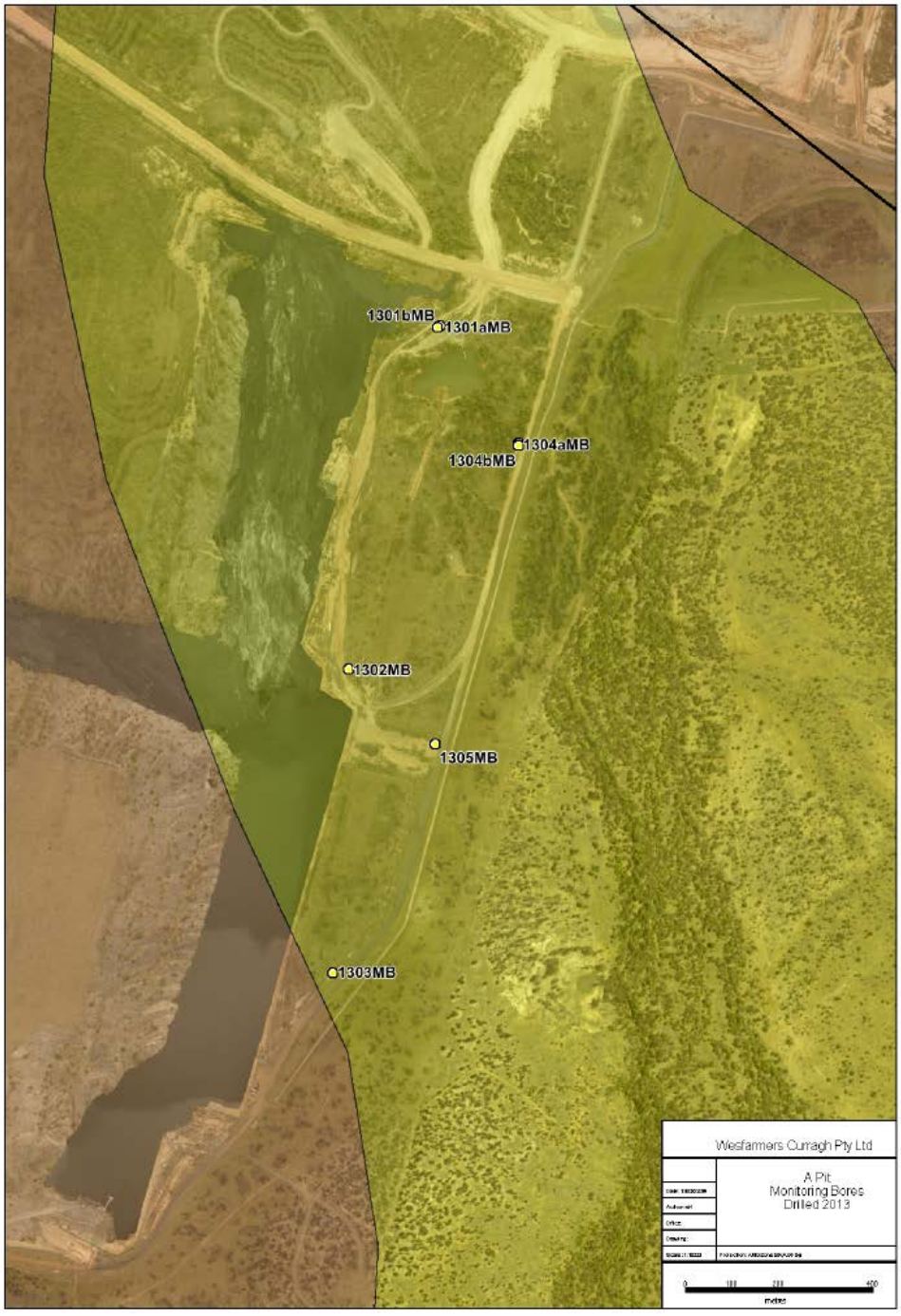



**Figure 5. Monitoring bore network, A Pit**

Bores 1302MB, 1303MB and 1305MB are dry, with 1301A/B and 1304A/B being regularly monitored and sampled. During drilling all bores were drilled to intersect the Tertiary and were logged as being dominated by clay, silty/sandy clay or mudstone/claystone, with few horizons identified as 'sand'. The two bores designated as A were shallower and designed to intersect the sandier horizons while those designated B were deeper and interstected the clay rich zones immediately above the contact with the

intact, although weathered, Permian sub-strata. At the last round of water monitoring (May 2015) the available standing water levels were:

**Table 3. Standing water levels and water quality in monitoring bores between A Pit north and Blackwater Creek**

| BORE ID | SWL (mbgl) | SWL (m RL) | Flow rate (L/min) | Field pH | Field EC µS |
|---|---|---|---|---|---|
| 1301A MB (shallow) | 6.18 | 145.65 | <0.1 | 7.41 | 9220 |
| 1301B MB (deep) | 5.96 | 145.74 | 0.3 | 6.6 | 16410 |
| 1304B MB (deep) | 6.32 | 147.01 | <0.05 | 6.52 | 2860 |

These are all below the surface of the dry creek beds and the water contained within the main creek channel east of the levee but similar to the SWL of the pit water. Flow rates were extremely low. The water quality in the bores is, however, notably different to that in the tails, where the average pH is 8.02 and the average EC is around 3000µs.

**Summary**

The Tertiary sediments of concern between A Pit and Blackwater creek and a thinly interlayered sequence of clay-rich, quartzose sandstone/siltstone/claystone with some beds of more friable sandy material which is also dominated by fine (silt/clay) particles. Individual beds are laterally discontinuous due to both depositional and structural factors and the friable beds are confined above and below by cemented units. The Tertiary 'sand' units to the west of the main creek tend to pinch out to the east while any younger (Quaternary) material at the topographical surface is thin (around 2m deep) and dominated by clays away from the immediate creek beds. The base of the Tertiary material drops to a low point 100-200m west of the main creek channel before rising again to a high beneath the current creek.

*K* is estimated to be low for all types of material with almost no possibility of vertical leakage. Any likely leakage will be horizontal and this will be limited by the lack of lateral continuity within the most permeable units as well as chemical interactions between the alkaline pit tails water and the rock particles. As such, it appears highly unlikely that anything other than very minor seepage would occur if the surface level of the tailing beach was raised and the seepage would concentrate in the low point of the stratigraphy and be at least partly self-sealing through chemical interactions along its flow path.

## References


Bear, M. 1972. *Dynamics of Fluids in Porous Media.* Dover Publications.

Boyd, G., Henderson, S., Gough, J. 1998. Task No. 10. Geotechnical Services. IN Minserve. 1998. *Report on the Feasibility Study for the Development of the Jellinbah Station Coal Deposit.* Stanwell Corporation Report

Hill, C., Henderson, S., Dixon, M., Isaacs, L. 1998. Task No. 11. Hydrogeology. IN Minserve. 1998. *Report on the Feasibility Study for the Development of the Jellinbah Station Coal Deposit.* Stanwell Corporation Report.

Malone, E.J., Olgers, F., Kirkegaard, A.G. 1969. *The Geology of the Duaringa and Saint Lawrence 1:250,000 Sheet Areas, Queensland.* Bureau of Mineral Resources Report No. 121.

Tite, B. and Gray, J. 2003. *Curragh North Coal Mine. Hydrology, Flooding and Groundwater Report.* Parsons Brinckerhoff report 2132105!-PR001Cbt.

Memorandum

| | |
|---|---|
| **Date:** | 13 October 2016 |
| **To:** | B McIntyre, M Stewart |
| **Copy:** | S O'Leary, P Wood |
| **From:** | S Dippel Forster |
| **Subject:** | D-E-F PIT HYDROLOGY |

A request was received on Friday 7 October last for information on the hydrology of D Pit. This memo summarises the currently available information for the entire area between D, E and F Pits.

## Physical Setting

The area of concern straddles the remnants of the original course of Blackwater Creek (Figure 1). Blackwater Creek is a tributary of the Mackenzie River and drains to the north-east. It is an ephemeral creek with deeply incised, braided channels which split and re-join each other through the central part of the proposed mining zone. In the immediate area the channels, although now detached from their headwaters by means of the creek diversion to the east of the current mine, still retain water for some time after major rain events. However, for the majority of the time the creek beds are dry, indicating no natural baseflow from groundwater (Rochford & Kwantes, 2016).

## Geology

The stratigraphy for the area is shown in Figure 2 and Table 1. Within the zone Quaternary alluvium (a fining upwards, laterally variable fluvial channel fill sequence of clay, silt, sand and gravel) is closely tied to the current river channels with older Tertiary material (soil, alluvium, gravel, screen, billy, sand and duricrust) found at surface further away on either side (Figure 3). These Cainozoic-age sequences overlie the Permian rocks containing the coal measures (Rewan Formation, Rangal Coal Measures and the Burngrove Formation).

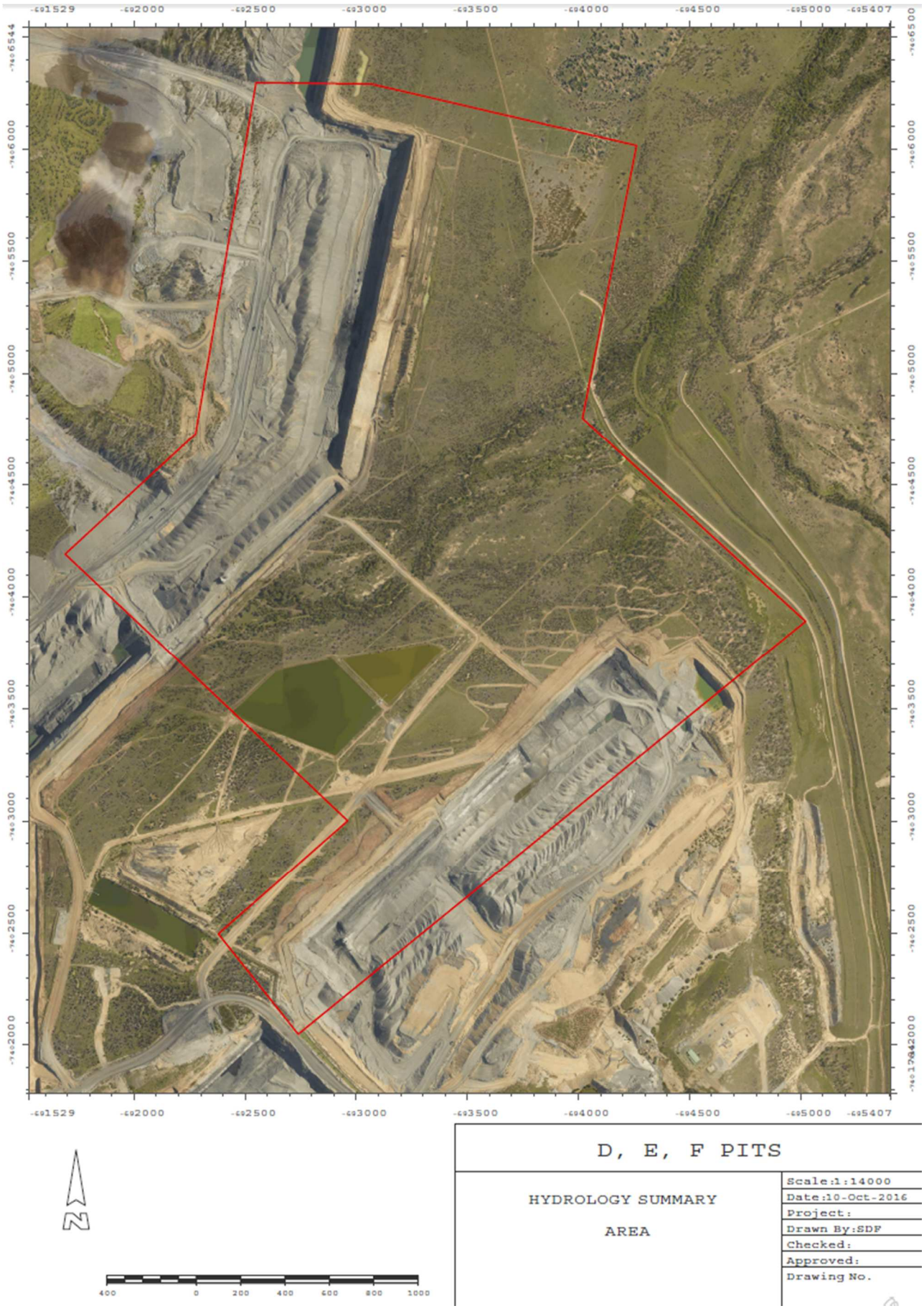



**Figure 1. Study Area**

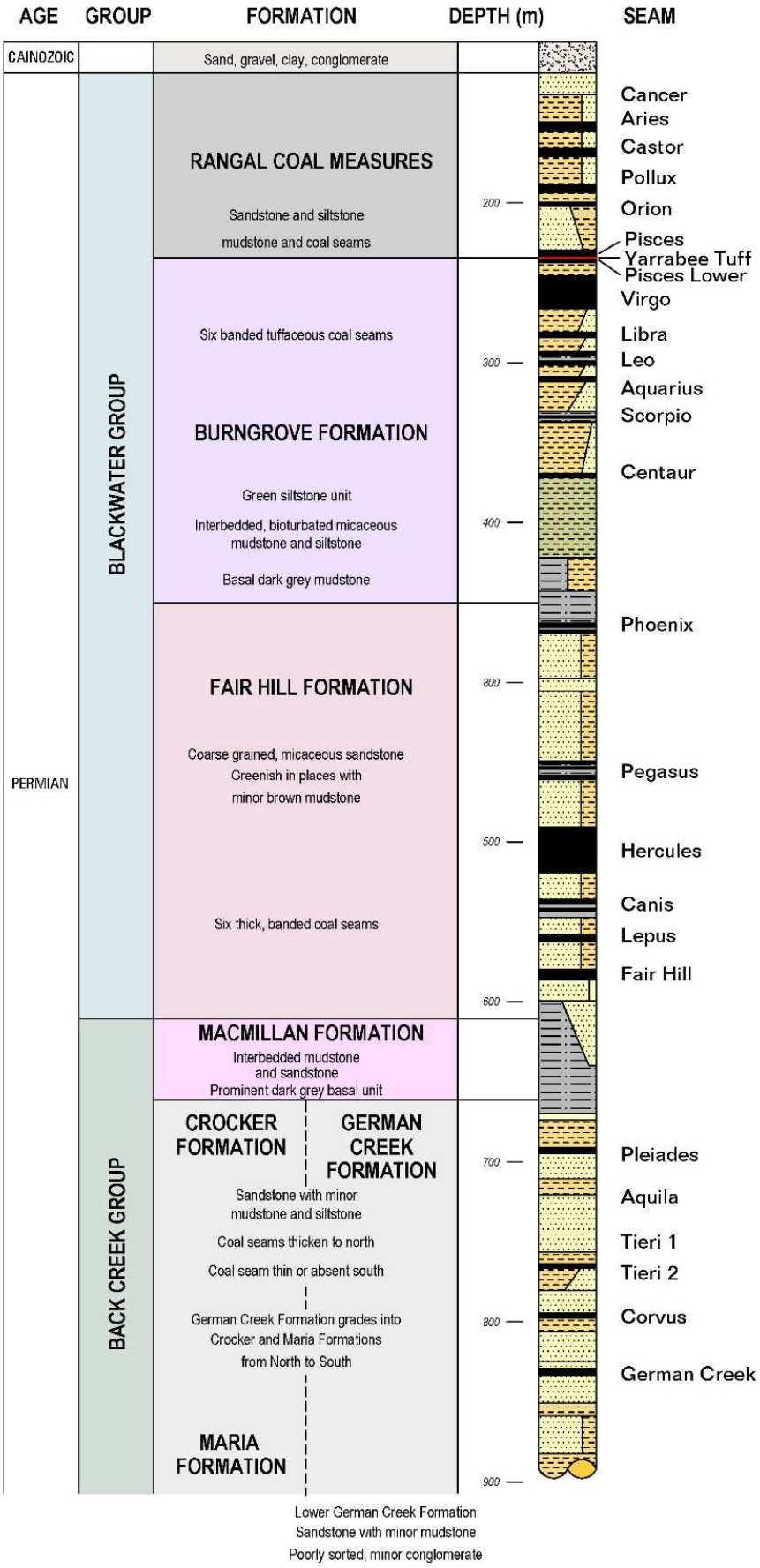



**Figure 2. Blackwater coalfield stratigraphic sequence.**

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| Age | Group | Stratigraphic unit | Lithology |
|---|---|---|---|
| Quaternary and Tertiary | | Alluvium | Alluvial sand, silt and gravel. |
| Tertiary | | Duaringa Formation/Emerald Formation | Mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt. Sediments are weakly consolidated in parts. |
| Triassic | Mimosa Group | Rewan Formation | Mudstone, interbeds of lithic sandstone. |
| Late Permian | Blackwater Group | Rangal Coal Measures (including the Bandanna Formation and Baralaba Coal Measures) | Carbonaceous mudstone, siltstone, coal, feldspathic and lithic sandstone, calcareous in places, tuff. |
| | | Burngrove Formation | Carbonaceous mudstone, thinly interbedded mudstone and fine lithic sandstone, siliceous siltstone, calcareous lithic and feldspathic sandstone. |
| | | Fair Hill Formation | Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal. |
| Permian | Back Creek Group | Macmillan Formation | Interbedded mudstone and sandstone, prominent dark grey basal unit. |

**Table 1**. **Stratigraphy** (from Rochford & Kwantes, 2016)

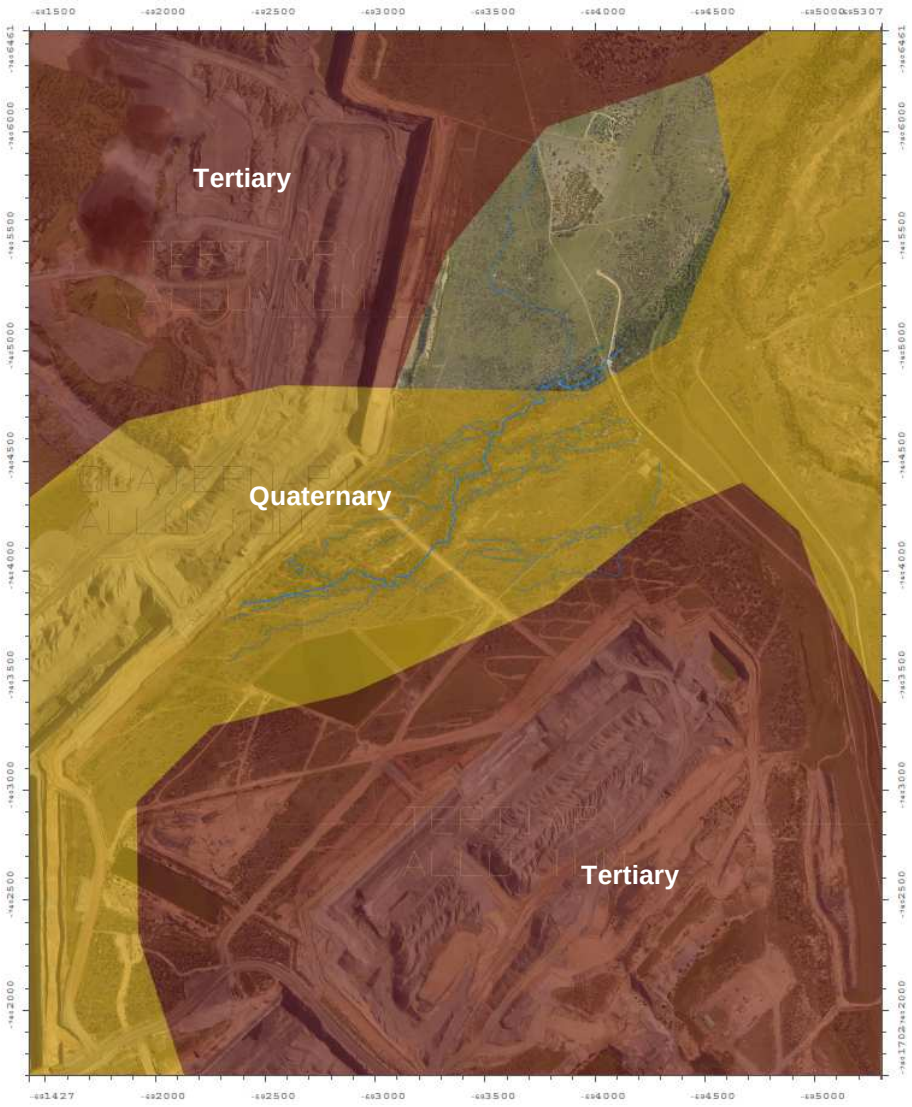



**Figure 3. Quaternary and Tertiary unit extents**

Quaternary sands are generally less than two metres thick with the major deposits (4-12m thick) constrained to the central parts of the current river system (Figure 4). These tend to occur as lenses with minimal to no interconnection that are in alignment with the creek directions and range in size from as little as 100m x 100m to 500m x 250m. The average thickness of the Quaternary sequence as a whole is 4-6m overall and around 10m in the deeper channel areas. The sand lenses are enclosed by silts and clays within the thickest and deepest parts of the Quaternary alluvium and are incised into the more consolidated, clay-rich Tertiary sediments and so are likely to only form discrete perched aquifers rather than one larger aquifer (Figure 5).

The Tertiary sediments have been identified as interbedded stiff to hard clay rich sands, gravels and thick beds of ferruginous clays of medium to high plasticity from the Duaringa Formation. They are remnant channel (fluvial) or valley (colluvial) fill and are partly cemented (Minserve, 1998).

The underlying Triassic and Permian sediments are the Rewan Formation and the Rangal Coal Measures respectively (Figure 6). The Rewan Formation consists of thinly interbedded mudstones, lithic standstones and siltstones and the Rangal Coal Measures are fine-medium grained lithic sandstone with siltstones and mudstones enclosing the coal seams and some carbonaceous mudstone. Overall the dip of this units is around 3° to the east but this can increase to grea ter than 10° in areas affected by structure. Due t o the predominance of very fine grains, silt and mud/clay in these units and from evidence visible in open pit highwall faces these rocks act as aquitards rather than aquifers, resulting in little or no filtration of groundwater through the rocks themselves although there is minor weeping from some structures or bedding planes.

The upper parts of these units are weathered where they come into contact with the overlying Tertiary/Quaternary sediments or structure. The average depth of the weathering profile in the Triassic/Permian sediments in the area is six to eight metres below the contact with the alluvium but can increase to over 12m in areas of faulting. The area is structurally complex with the deeper weathering profile occurring below the current river channels between major transcurrent faults (Figure 7). Taken from surface, the average depth to the base of weathering is 12-15m through the centre, extending to more than 20m to the north and south.

Dominant structures in the zone are closely spaced NNW-SSE trending thrust faults. These are off-set by a number of approximately east-west transcurrent faults. The latter tend to be very steeply dipping while the former are more flat-lying and comprise mostly fore-thrusts with some back-thrusts. All faults have a sinuous trace (Figure 8).

Conceptual geological cross-sections through D pit and E-F pits taken from Rochford & Kwantes (2016) are shown in Figures 9 to 11.

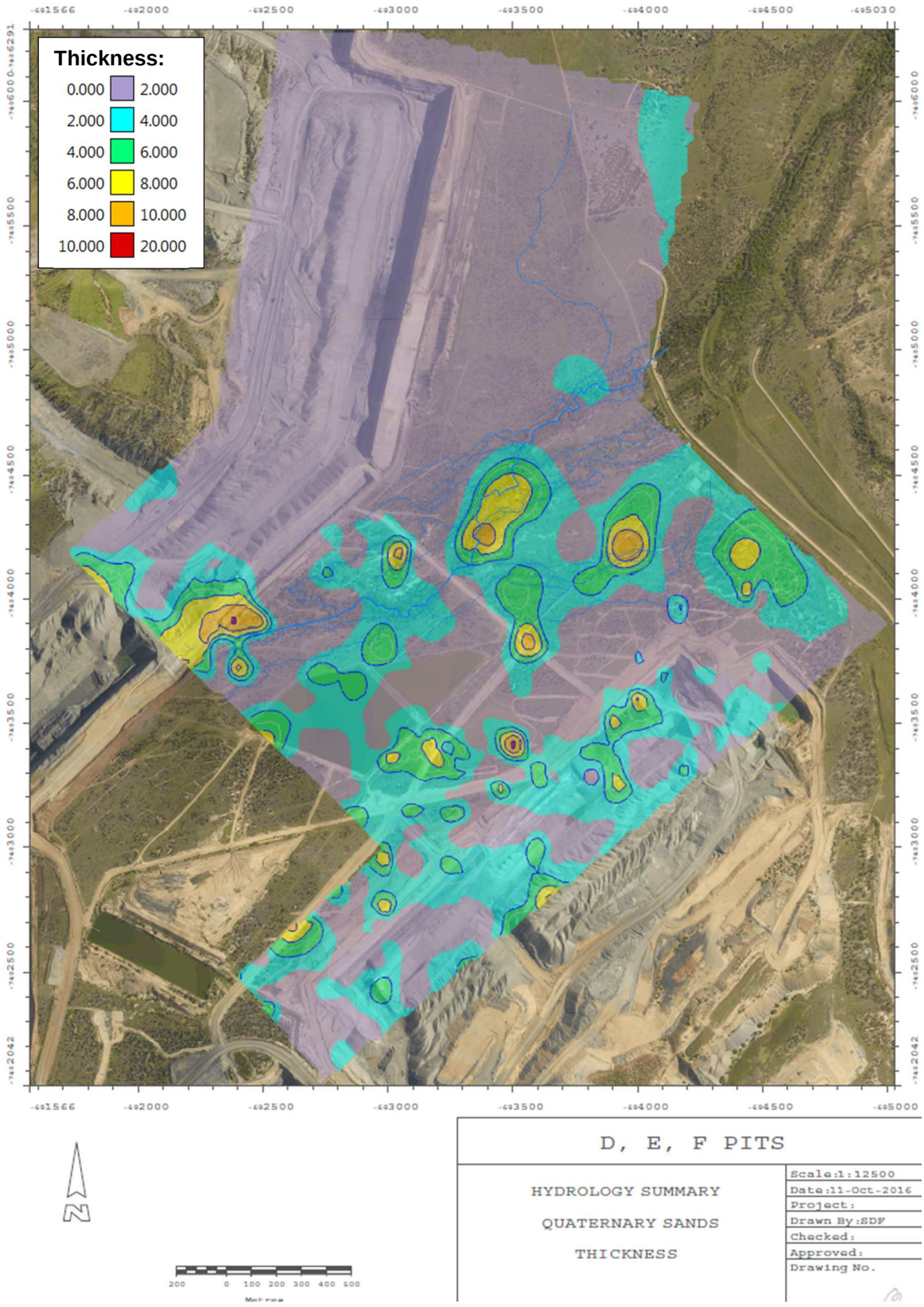



**Figure 4. Quaternary sand thickness plot**

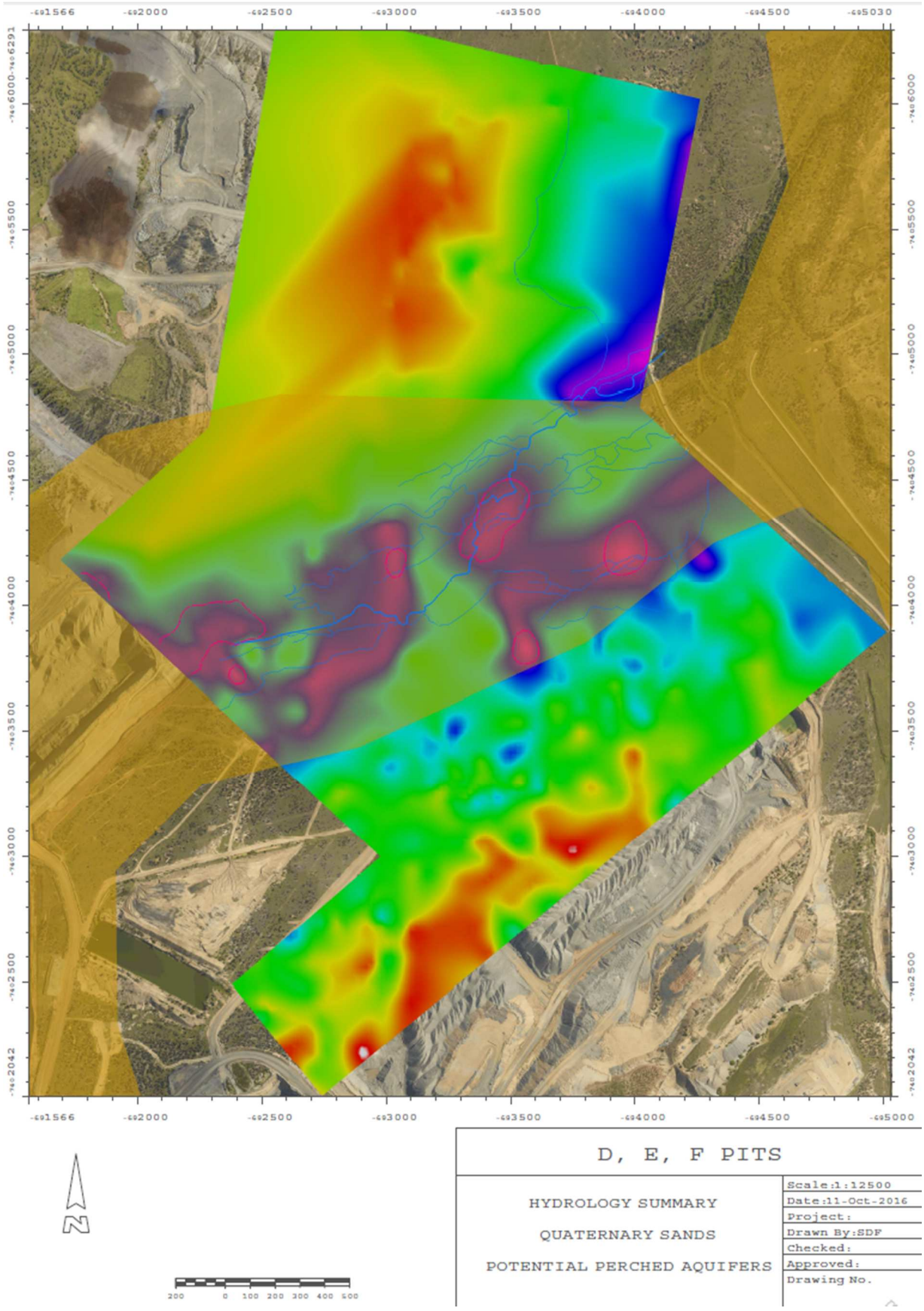



**Figure 5. Potential perched aquifers (outlined in pink) on modelled base of Quaternary**

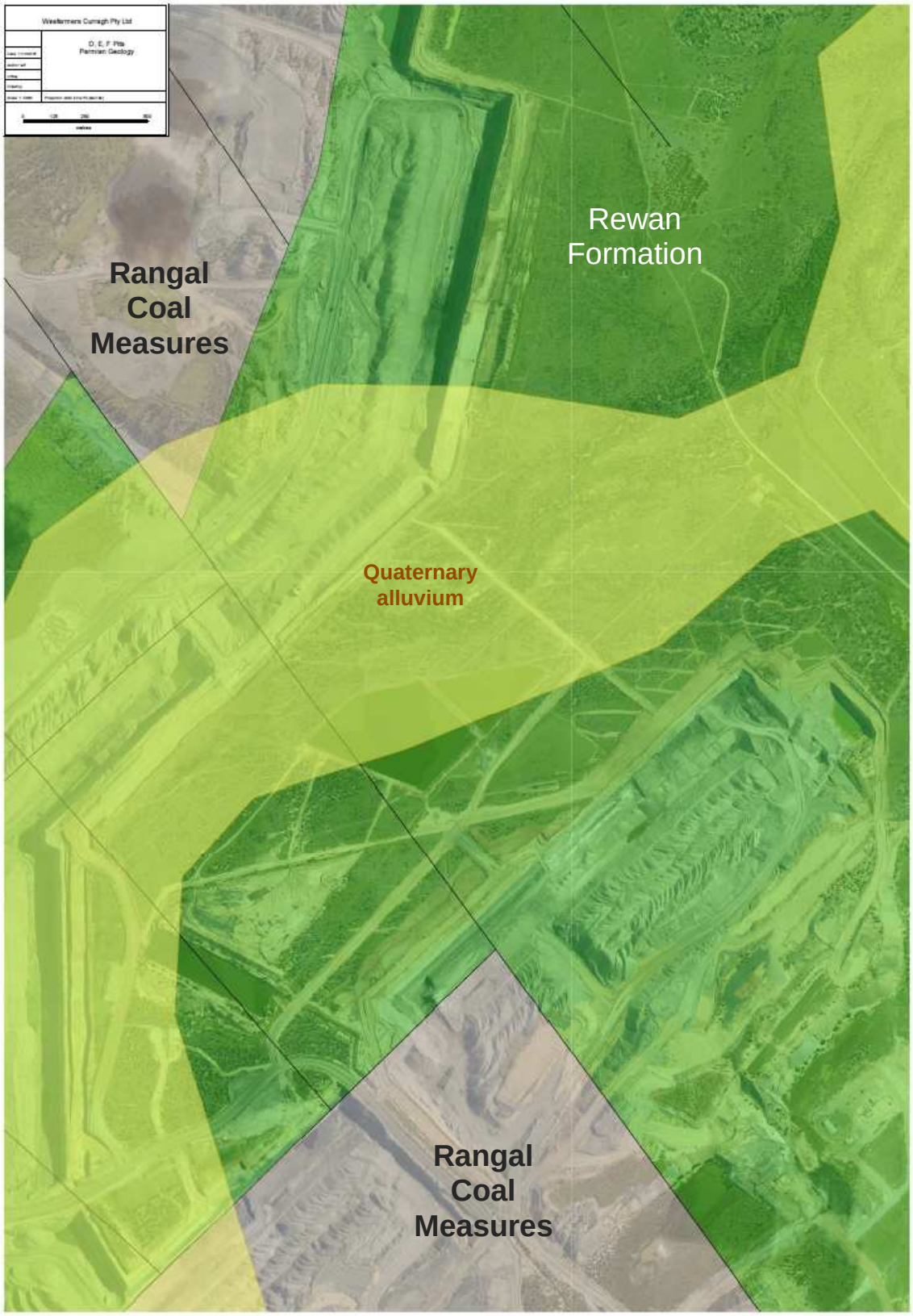



**Figure 6. Triassic and Permian Geology**

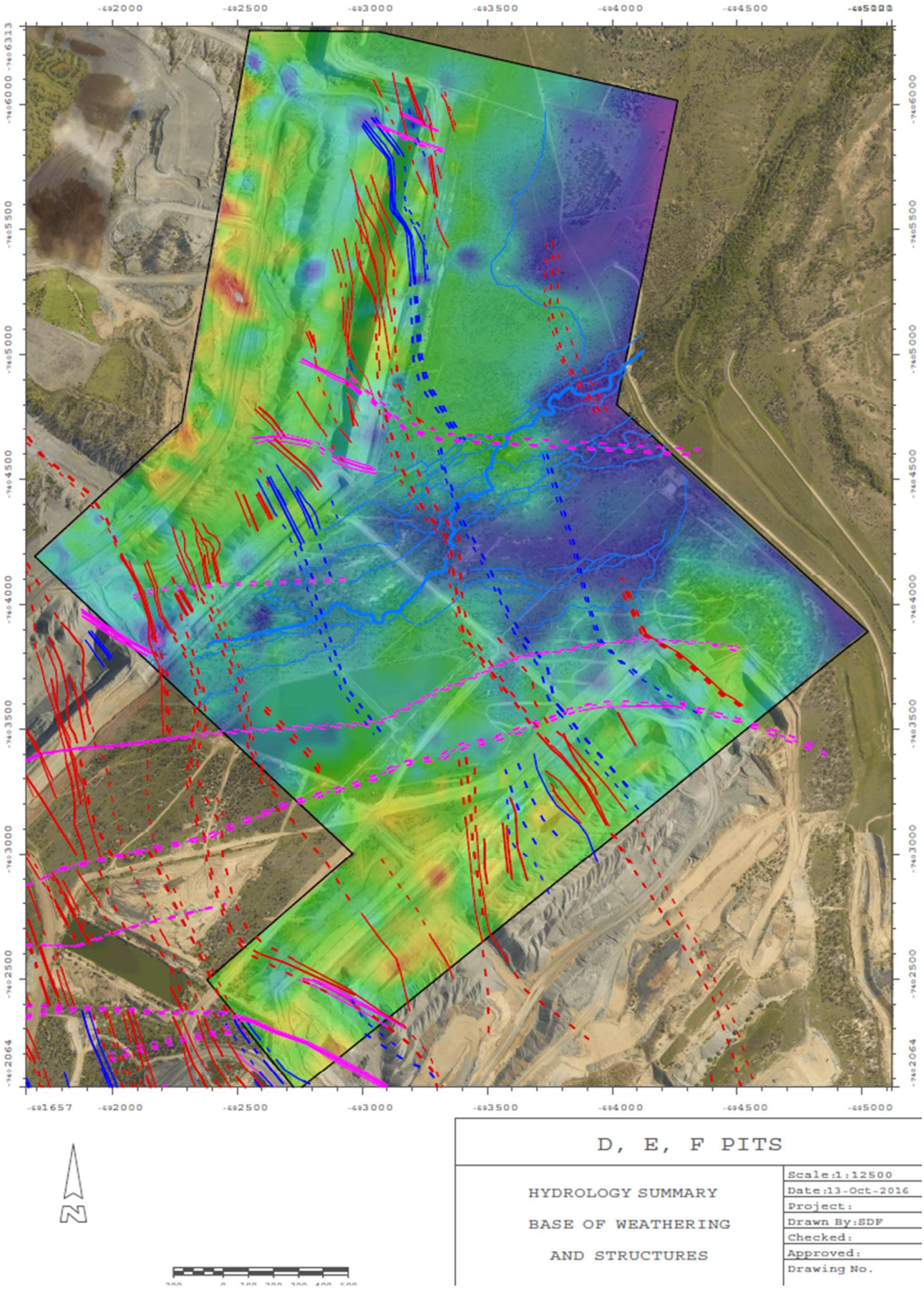



**Figure 7. Base of weathering and structures** (Red = shallow → Purple = deep)

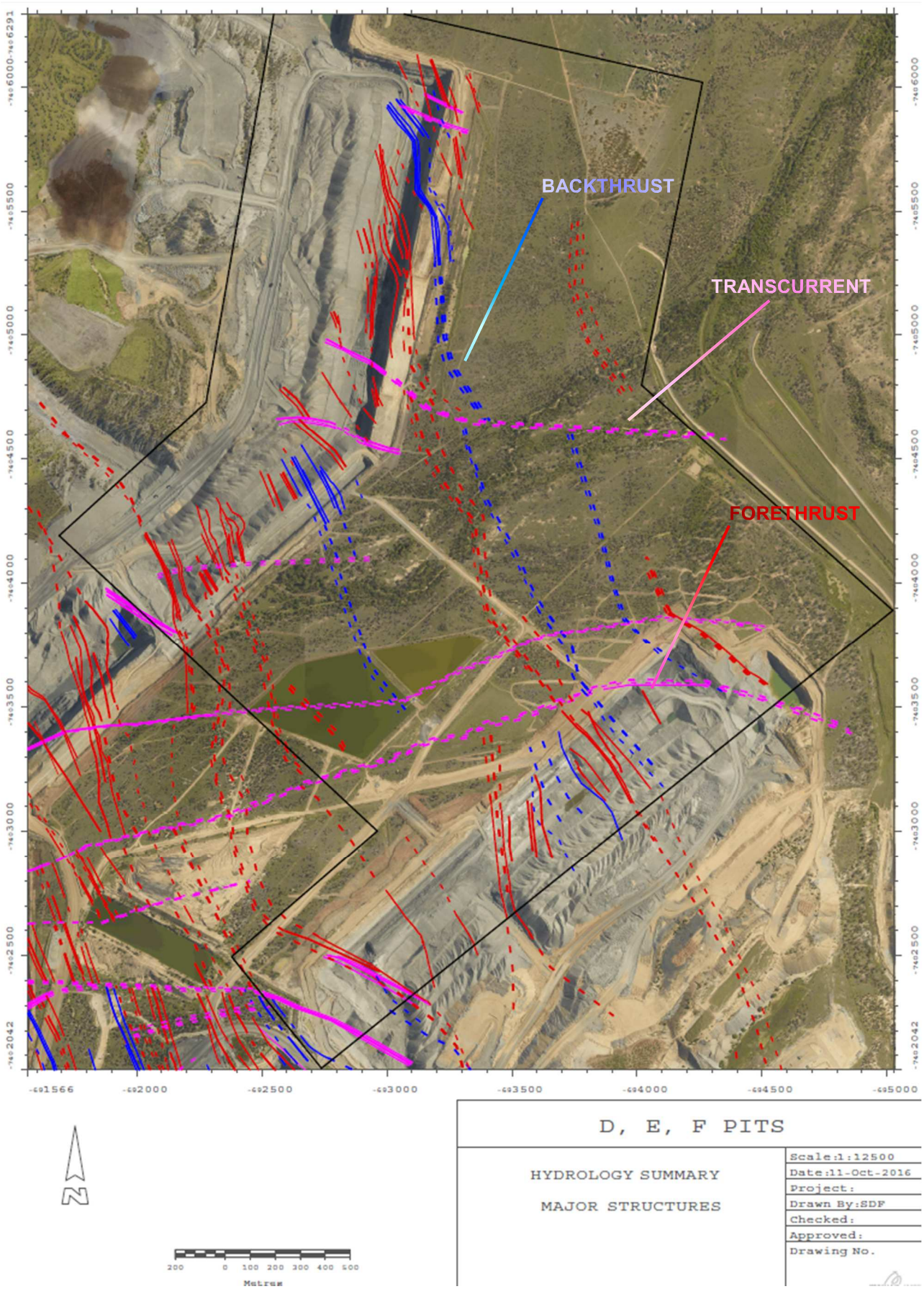



**Figure 8. Major structures**

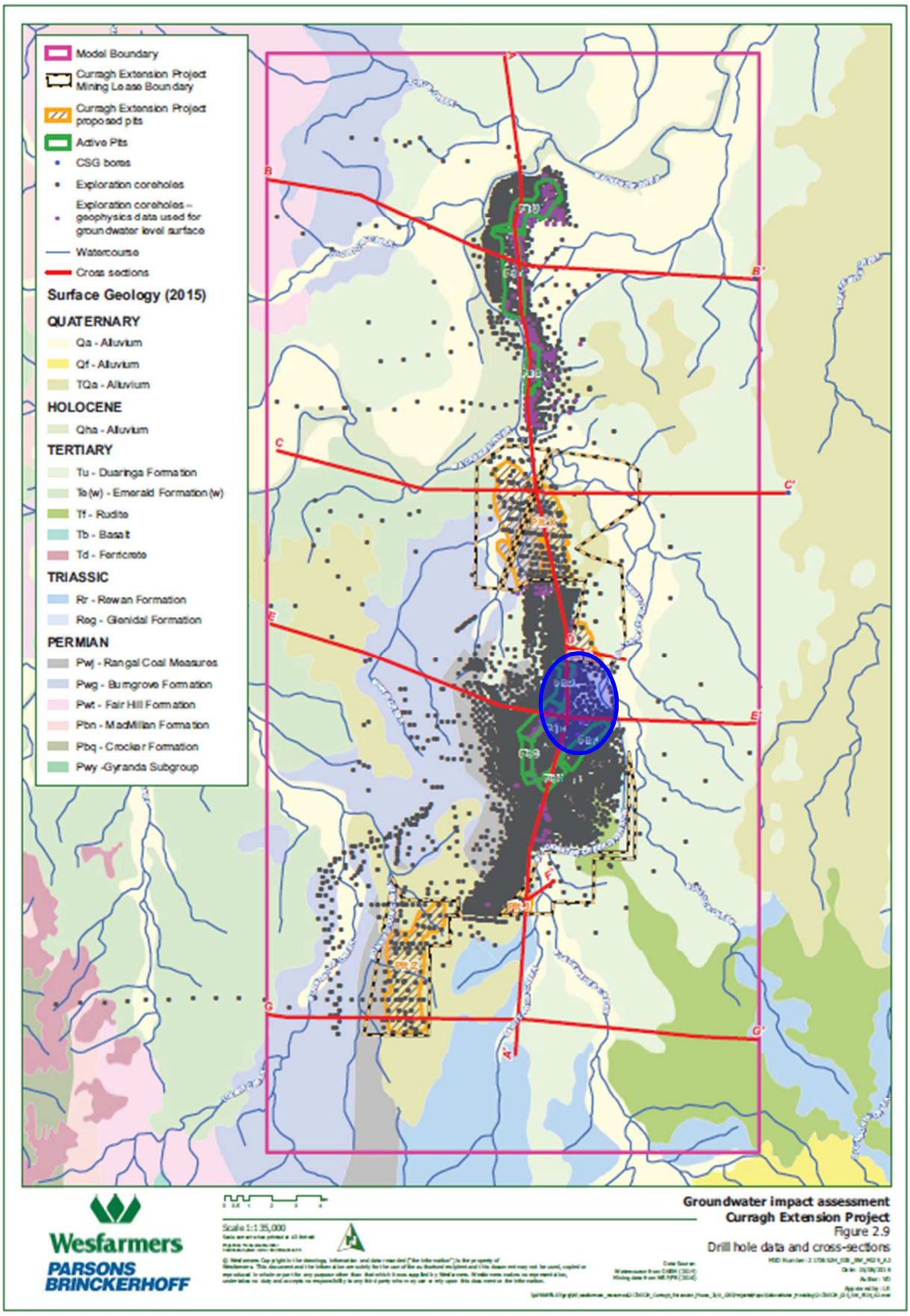



**Figure 9. Cross section D-D' and E-E' location** (from Rochford & Kwantes, 2016)

This study area circled in blue

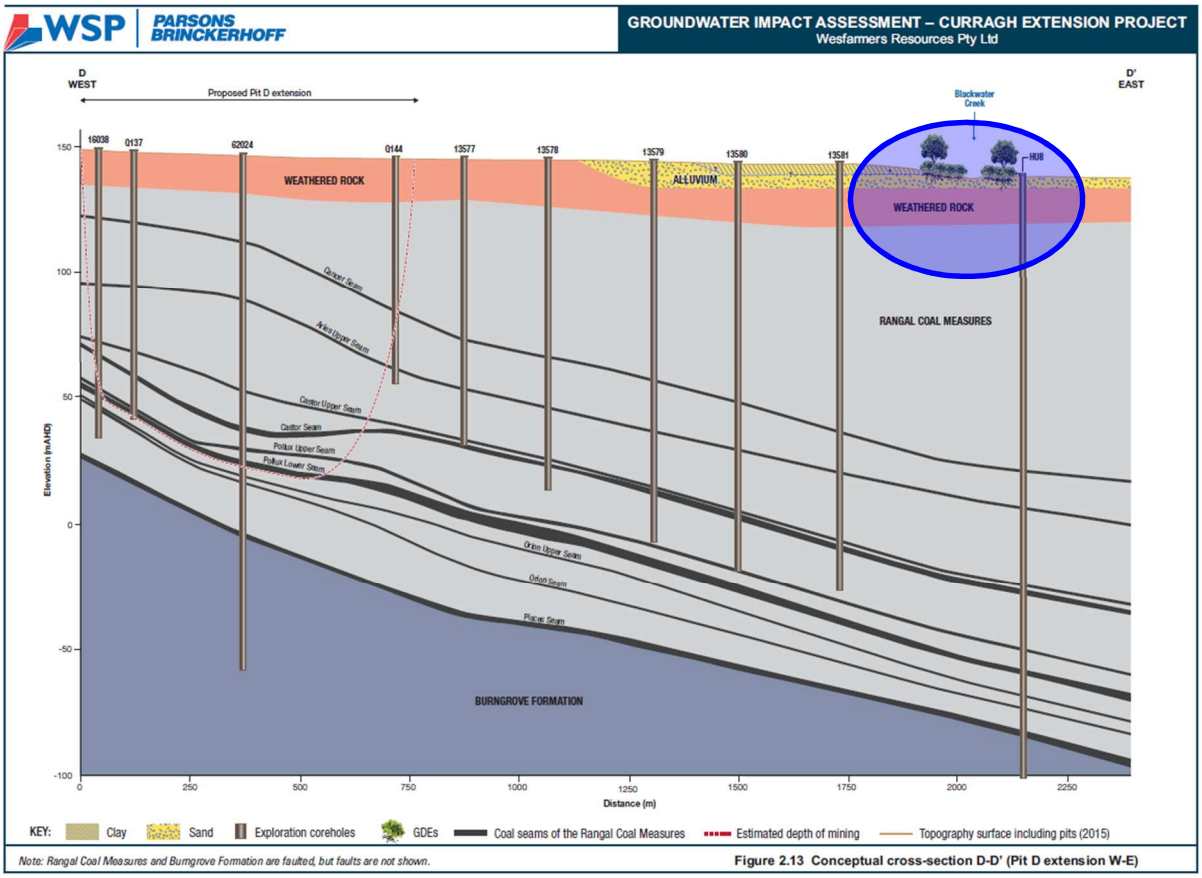



**Figure 10. Geology Cross-section D-D'** (from Rochford & Kwantes, 2016)

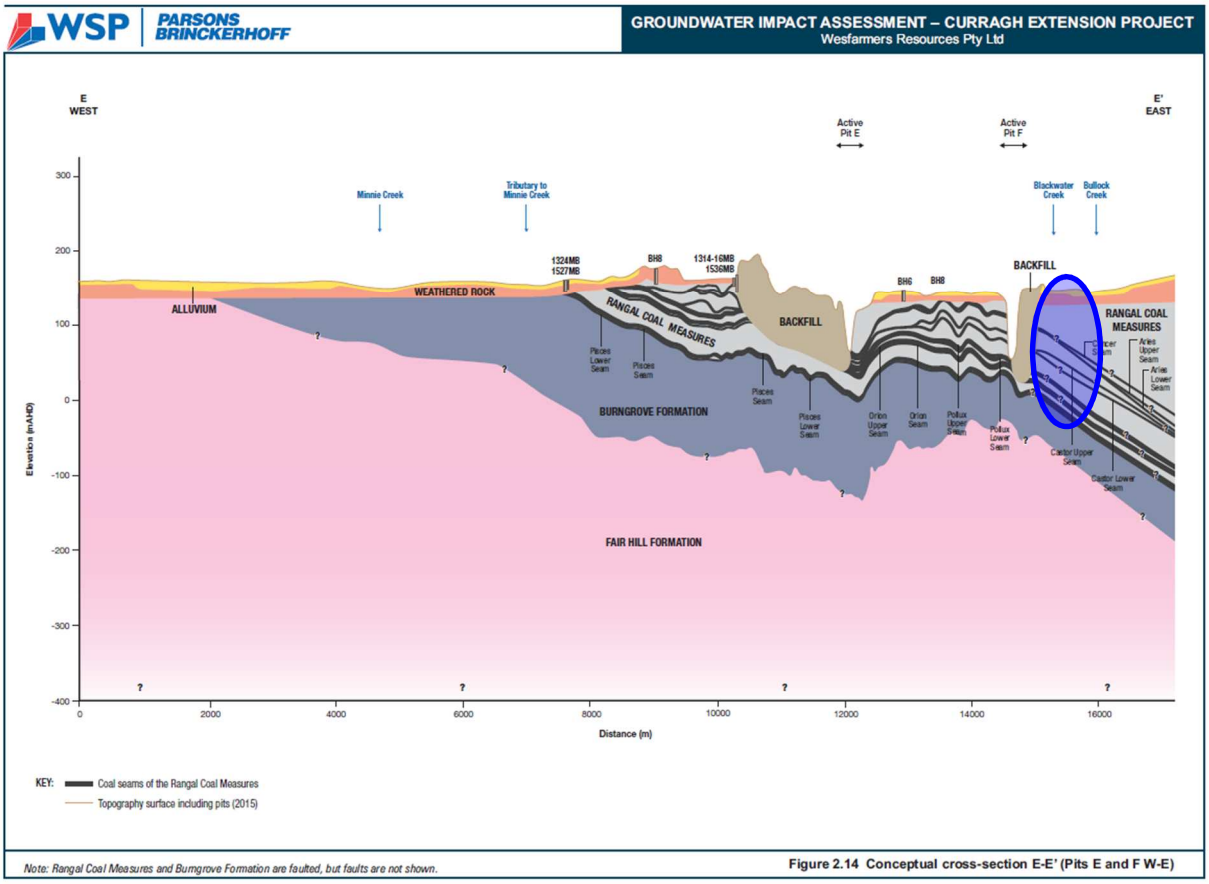



**Figure 11. Geology Cross-section E-E'** (from Rochford & Kwantes, 2016)

**Hydrogeology**

The hydrostratigraphy of the geological units is shown in Table 2. For the study area the most important unit is the alluvium. As noted above this material is generally dry apart from in the immediate vicinity of any rainwater held in the ephemeral remnant channels of Blackwater Creek with the latter also drying out reasonably quickly (depending on the size, duration and frequency of rain events), which is indicative of the SWL being below the base of the channels. From Lidar the bed of the main remnant channel drops from 138.9m RL at the south-west to 136.2m RL at the north-east while monitoring bore 1307MB, located at the western tip of Dam A (approximately 500m SSW of the head of the remnant channel) has recorded an SWL ranging from 134.93m RL to 136.53 (6.6-8.2m below ground level) over the past year (Figure 12). This bore may be affected by the presence of Dam A but, as it is constructed in the clay-rich Tertiary sequence, this is considered unlikely. The creek channels are deeply incised with near-vertical walls in the deeper channels and their absolute depth is unknown so it is possible that they are within the groundwater at their base but if so the area of creek bed exposed and/or the volume of groundwater intercepted is not sufficient to recharge the streams in any meaningful way.

| **Hydrostratigraphic Unit** | **Occurrence** | **Aquifer Characteristics** |
|---|---|---|
| Quaternary and Tertiary alluvium | Clay, silt, sand, gravel | Dry in many areas. Unconfined water bearing sand and gravel units may occur at the base of the alluvium but unlikely to be significant. |
| Weathered rock | Residual rock from Duaringa/Emerald/Rewan Formations and Rangal Coal Measures. | Variable permeability with water bearing zones in more permeable or fractured layers and low permeability zones where rock has weathered to clay. |
| Tertiary Duaringa/Emerald Formations | Cemented sands and gravels, sandstones, siltstones and mudstones. | Water bearing zones may occur in more permeable layers, unconfined to semi-confined. |
| Triassic Rewan Formation | Mudstone and interbeds of lithic sandstone. | Aquitard. |
| Permian Rangal Coal Measures | Sandstones, siltstones, coal. Affected by thrust faulting. Interburden has very low primary porosity and void spacing in sandstones typically cemented by clay providing poor interconnection of void space. | Water bearing cleated coal seams and faulted interburden, confined to unconfined fractured rock aquifer. Faulting restricts flow due to lateral discontinuity of water bearing coal seams. Interburden forms aquitards. |
| Permian Burngrove Formation | Fractured coal seams and sandstone units. | Water bearing cleated oal seams, confined to unconfined fractured rock aquifer. |

**Table 2. Hydrostratigraphy** (adapted from Rochford & Kwantes, 2016)

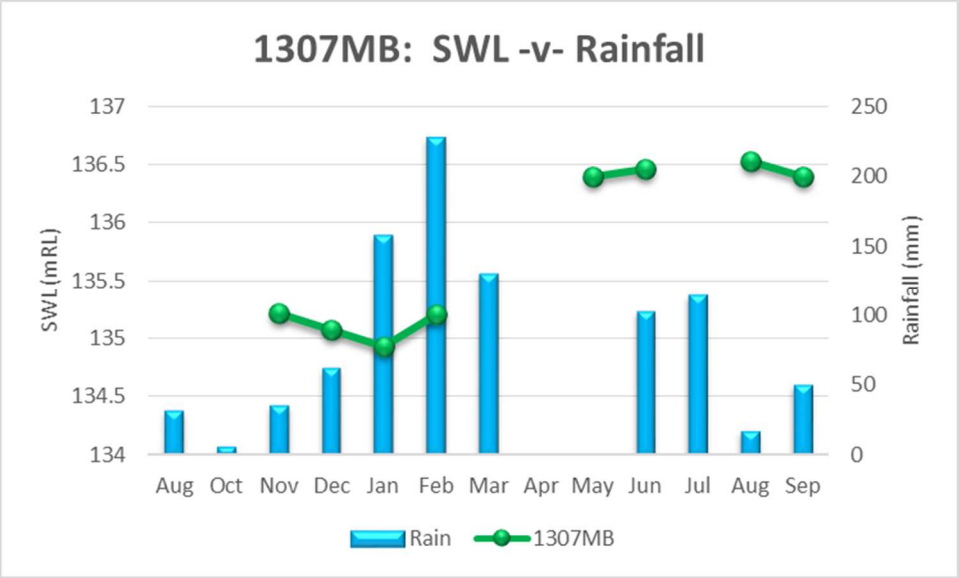



**Figure 12. SWL in 1307MB plotted against rainfall.**

Modelling of the base of the Quaternary (BQ) shows that the current Blackwater Creek channels occur above a zone where the BQ is significantly deeper than on either the northern or southern sides (Figure 13) in the same manner as the base of weathering (Figure 7). BQ is generally around 132-133m RL here, with the deepest parts (holding the thickest sand units) reaching depths below 130m RL. This zone may represent a palaeochannel possibly exploiting transcurrent faulting (Figure 14). The average natural surface RL across the area is around 142m RL and the average BQ outside of the deeper zone is 138-140m RL; taking the average SWL from 1307MB of 135.7 Figure 15 shows the areas that are most likely to contain any groundwater within the mining zone.

Parsons Brinckerhoff (2016) show that the groundwater flow direction in the alluvium follows the dip of the topography to the north and north-east apart from where it is intercepted by mining voids so any water contained within the identified zones will naturally drain to the north-east.

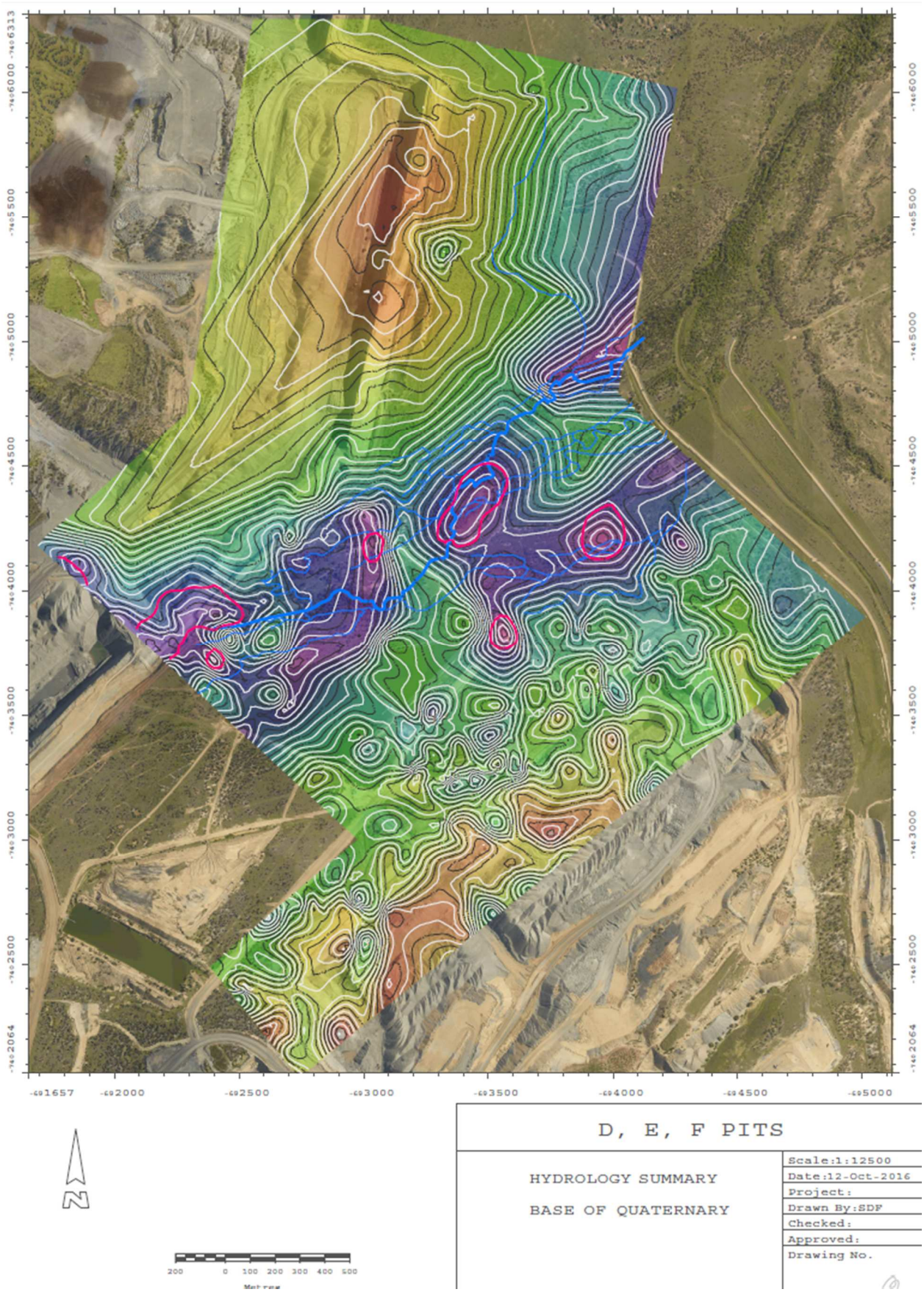



**Figure 13. Base of Quaternary with potential perched sand aquifers (**outlined in pink)

(Red = shallow → Purple = deep)

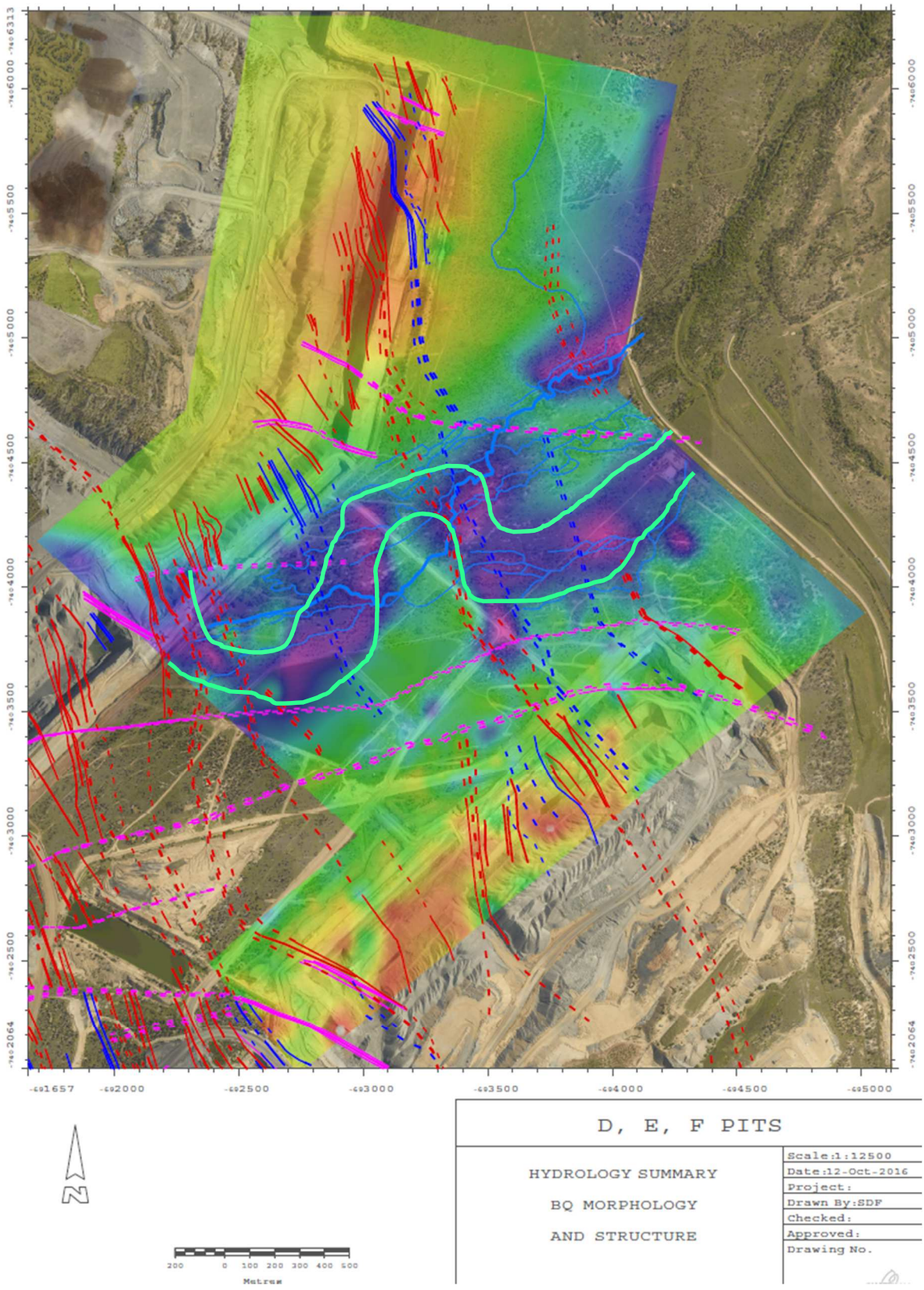



**Figure 14. BQ Morphology with possible palaeochannel, geological structure and current creek channels**

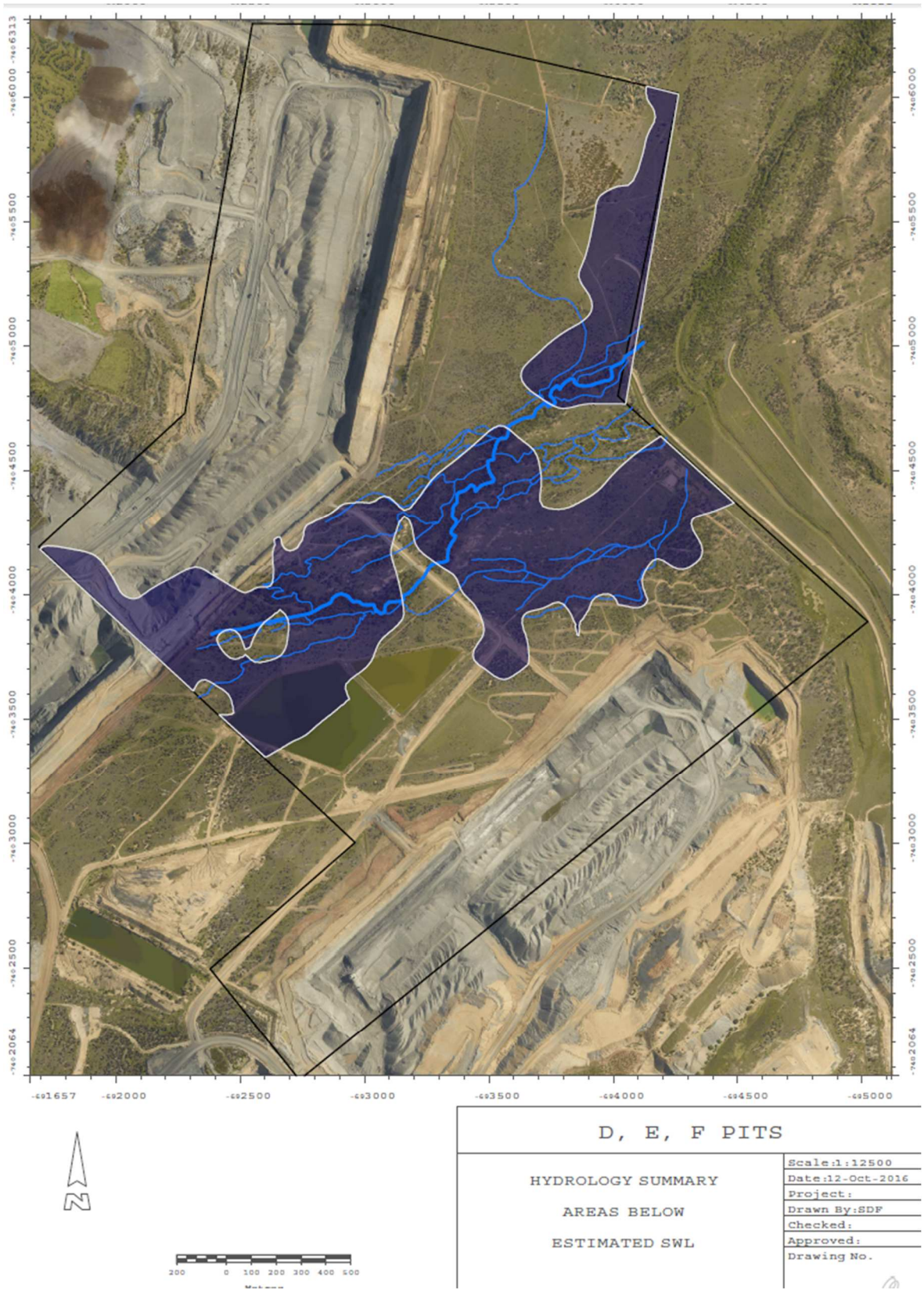



**Figure 15. Likely areas of alluvium containing groundwater**

Table 3 contains the known hydraulic properties for the alluvium. Because of the fluvial nature of the deposit permeability will be highly variable both vertically and laterally depending on the relative amounts of clay, silt, sand and gravels in any given area. With clay being the dominant secondary mineral identified with the sand units in the borehole logs and with clay being the dominant lithology identified generally in the alluvium it is expected that permeability will generally be low, resulting in low hydraulic conductivity (*K*), storage (*Ss*) and yield (*Sy*) throughout the area.

| **Geological Age** | **Formation** | **Lithology** | **Kh (m/d)** | **Kv (m/d)** | **Ss ($m^{-1}$)** | **Sy** |
|---|---|---|---|---|---|---|
| Quaternary | Alluvium | Blackwater Creek alluvium | 0.4-0.6 | 0.018 | | |
| | | Floodplain/river alluvium | 1-40 | 0.1-2 | 0.0005 | 0.05-0.18 |
| Tertiary | Duaringa Formation | Sedimentary Rocks | 0.05-0.6 | 0.005-0.018 | 0.00005 | 0.12 |
| | Weathered rock | Sandy gravels | 0.9 | | | |
| | | Claystone/other cemented strata | 0.43 | | | |

**Table 3. Hydraulic Properties (**adapted from Rochford & Kwantes, 2016

Kh: horizontal hydraulic conductivity. Kv: vertical hydraulic conductivity. Ss: specific storage. Sy: specific yield

Recharge of alluvium groundwater occurs by way of both rainwater infiltration and stream flow (Rochford & Kwantes, 2016). As noted above the zone of interest is no longer connected to a catchment basin due to mining activities so any groundwater currently remaining in the area can only be recharged by way of rain infiltration.

**Coal aquifers**

Both the Aries/Castor and Pollux coal seams at Curragh were investigated for their hydrogeology in the 1980s. Muller and Hair (1980) and Hair (1987) noted that both seams (testing was done in an area where there was no parting between Aries and Castor) are confined by low permeability strata of fine grained sandstone, siltstone, mudstone and shale. Groundwater is found in both seams and occurs within bedding fractures and joints (cleats) with testing indicating that both seams are highly fractured, producing a porous rock aquifer. Thrust faults act as probable impermeable boundaries. The Aries/Castor seam showed considerable lateral and vertical variation in permeability (Castor having significantly higher permeability) and is identified as a semi-confined aquifer with some possible leakage from its overlying shale/siltstones while the Pollux seam is considered to be a confined aquifer and has more consistent permeability (Table 4). Both show considerable anisotropy. Interseam sediments have significantly lower permeability (about two orders

of magnitude less) than the coal seams and thus the coal seam aquifers are hydrologically isolated which is confirmed by their significantly different water chemistry.

| Site | Aries-Castor seam | | Pollux seam | | Interseam sediments | |
|---|---|---|---|---|---|---|
| | Range | Average | Range | Average | Range | Average |
| A | $6.8 \times 10^{-3}$ to $5.6 \times 10^{-1}$ | $1.3 \times 10^{-1}$ (15 values) | $8.3 \times 10^{-4}$ to $5.3 \times 10^{-1}$ | $1.1 \times 10^{-1}$ (16 values) | $1.4 \times 10^{-4}$ to $3.1 \times 10^{-2}$ | $9.7 \times 10^{-3}$ (4 values) |
| B | $1.5 \times 10^{-1}$ to $5.0 \times 10^{-1}$ | $2.9 \times 10^{-1}$ (6 values) | | $2.6 \times 10^{-2}$ (1 value) | | |

**Table 4. Average permeability values for coal seams** (from Hair, 1987)

**Summary**

The D-E-F pit area consists of Quaternary and Tertiary alluvium overlying Triassic and Permian strata. The Quaternary consists of semi- to unconsolidated clays, silts, sands and gravels while the Tertiary are consolidated to semi-consolidated sands, gravels and ferruginous clays. The older rocks underlying the alluvium are the usual package of siltstones, fine-grained sandstones and coal seams. Groundwater occurs in the coal seams and can be expected to be found in the alluvium. In the latter it is likely to be in the form of hydrologically isolated perched aquifers associated with thicker, less silty sand lenses in the Quaternary material. Due to their isolated nature, poor permeability and consequent very low hydraulic properties it is not expected that groundwater will pose much of an issue in the alluvium while water from the coal seams can be managed in the usual manner.

**REFERENCES**

Hair, I.D. 1987. *Hydrogeology of Coal Seams at Curragh, Central Queensland.* Geological Survey of Queensland Record 1987/20.

Minserve. 1998. *Report on the Feasibility Study for the Development of the Jellinbah Station Coal Deposit.* Stanwell Corporation Report.

Muller, P.J. & Hair, I.D. 1980. *Curragh Coal Aquifer Testing. Report on Hydrogeological Investigations.* Geological Survey of Queensland Record 1980/39.

Rochford, L. & Kwantes, E. 2016. *Curragh Extension Project – Groundwater Technical Report.* Parsons Brinckerhoff Report produced for Wesfarmers Resources Pty Ltd, Document No. 2172652H-WAT-REP-002 RevB

# APPENDIX J

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# Curragh Mine
# Final Landform Design

## Geotechnical Slope Stability Analysis

**Prepared for:**

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Blackwater
QLD 4717
AUSTRALIA

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Appendix B – Design Risk & Opportunities Register

# 1. Introduction

This report has been prepared by Raine & Associates (R&A) for Coronado Curragh Pty Ltd (CCPL) in relation to their Curragh Coal Mine (Curragh). This report presents the results of two-dimensional limit equilibrium slope stability analyses undertaken by R&A in relation to the final landform designs developed by CCPL for Curragh.

## 1.1 Purpose

The purpose of this report is to assist CCPL, as part of the Curragh Planning System (CPS), identify, assess, manage, and document pre-emptively, potential geotechnical hazards associated with the 'long-term' global slope stability of the Curragh final landform designs.

Qualifications and Limitations associated with the work presented in this report are provided in Section 8.

## 1.2 Available Data

The following data was made available by CCPL (Table 1-1).

*Table 1-1 Supplied Data*

| Data Name and Format | Supplier | Comment |
|---|---|---|
| cnpitcontours.00t | CCPL | DXF contour model of the Curragh North final landforms |
| cupitcontours.00t | CCPL | DXF contour model of the X Pit final landform |
| X Pit 20211030.00t | CCPL | DXF contour model of the Y Pit final landform |
| Y_pit_final_CNT.00t | CPPL | DXF contour model of the Z Pit final landform |
| Z Pit 20211030.00t | CCPL | DXF contour model of the Curragh Main final landforms, using 2m contours |
| 2020Aug_LT_WOA_PublishedMOdel | CCPL | Life of Mine grids, inclusive of all coal seams and unconformable |
| finalvoids.dxf | CCPL | Digital NUMA outlines. |
| 1911.stat.blackwater.creek.arch_d | CCPL | Vulcan layer outlining Blackwater Creek |
| 1911.stat.levee.arch_d | CCPL | Vulcan layer outlining the current position of levees |
| 1911.stat.mackenzie.river.arch_d | CCPL | Vulcan layer outlining the Mackenzie River |
| FW_ Hydraulic conductivities (email) | SLR | Hydraulic Permeabilities |

## 1.3 References

The slope stability analyses presented in this report references the following documents:

- *Curragh Mine Progressive Rehabilitation and Closure Plan Flood Assessment* (SRL Ref: 626.30075-R02 Version No: -v0.2), dated September 2022;
- *Curragh Mine Complex Residual Void Modelling* (SLR Ref: 626.30075-R01 Version No: -v3.0), dated September 2022;
- R&A Report: *RA002_201706_02_Rev0 Slope Stability Analysis for Out of Pit Dumps_Rev0*, dated November 2017;
- Hawley, M. and Cunning, J. (2017), *Guidelines for Mine Waste Dump and Stockpile Design*, CSIRO;
- Martin, D. and Stacey, P., (2018) *Guidelines for Open Pit Slope Design* in Weak Rocks, CSIRO;
- Read, J. and Stacey, P., (2009) *Guidelines for Open Pit Slope Design*, CSIRO; and,
- Simmons, J. and McManus, D. (2004), *Shear Strength Framework for Design of Dumped Spoil Slopes for Open Pit Coal Mines*.

## 1.4 Safe Design

As noted in Section 1.1, the purpose of this report is to help CCPL, as part of the CPS, identify, assess, manage and document pre-emptively, potential geotechnical hazards associated with the 'long-term' global slope stability of the Curragh final landform designs.

It is noted that the term 'long-term' slope stability has not been defined or quantified.

'Global' or 'Overall Slope' stability considers the risks associated the overall slope which is measured from the from the toe of the slope to its the topmost crest. 'Global' stability does not consider bench scale failures, smaller localised failures within a bench, rockfalls etc. or instability that could arise as a result of erosional or other geomorphological processes.

To assist CCPL with this process, R&A have undertaken slope stability analysis for twenty-three (23) selected cross-sections through CCPL's final landform designs, the results of which are presented in this report. The slope stability analysis presented has been undertaken in line with industry standard practices, but does not constitute geotechnical 'certification' of the Curragh final landform designs. Qualifications and Limitations associated with the work presented in this report are provided in Section 8.

## 2. Geological Conditions, Structural Analysis and Interpretation

Curragh is located approximately 30 km north of the township of Blackwater in Central Queensland and is comprised of two active mining areas, referred to as Curragh Main and Curragh North.

Curragh is located on the western flank of the Bowen Basin and resides in the Upper Blackwater Group, which comprises of the Rangal Coal Measures, the Burngrove Formation and the Fair Hill Formation. In general, the Rangal Coal Measures are mined at Curragh. These deposits are comprised of grey mudstone and siltstone, light grey fine-grained sandstone and the productive coal seams of Cancer, Aries, Castor, Pollux, Orion and Pisces. The local basin coal seam stratigraphy is presented in Figure 2-2.

Locally, the Aries and Castor Coal Seams, and the Pollux, Orion, and Pisces Coal Seams are observed to coalesce. Where the Aries and Castor Coal Seams coalesce, they are named the Mammoth Seam (Figure 2-1). The Mammoth Coal Seam is observed in the vicinity of the current S-Pit Main and S-Pit South pits. Where the Pollux, Orion, and Pisces Coal Seams coalesce, they are named the Mackenzie Seam (Figure 2-1). The Mackenzie Seam (sometimes also referred locally as the Pisces Seam) is observed in the vicinity of all active pits at Curragh North, where it is directly underlain by the Yarrabee Tuff and Pisces Lower Coal Seam.

Curragh is located adjacent to the northwest trending Jellinbah Thrust Belt, which is believed to exhibit vertical stratigraphic throws in the order of 100's of metres. The dominant geological structures at Curragh are observed to be north-northwest to south-southeast trending thrusts faults crosscut by younger strike-slip and normal faults.

Zones of significant rock mass and coal seam shearing have been encountered in the vicinity of larger-scale faults. These zones are characterised by extensive shearing, repeating and/or stripping of stratigraphic units and represent areas of geological complexity. Pitwall design revisions are often implemented at Curragh to mitigate the risks associated with geological faults.

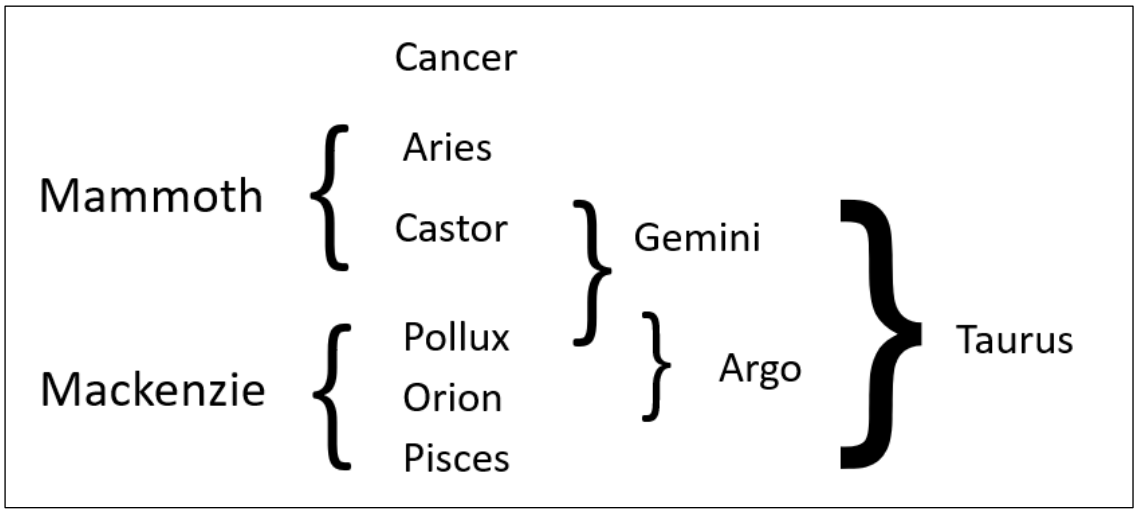



*Figure 2-1 Rangal Coal Measure coalesces naming convention (Curragh Geology Training Manual, CCPL)*

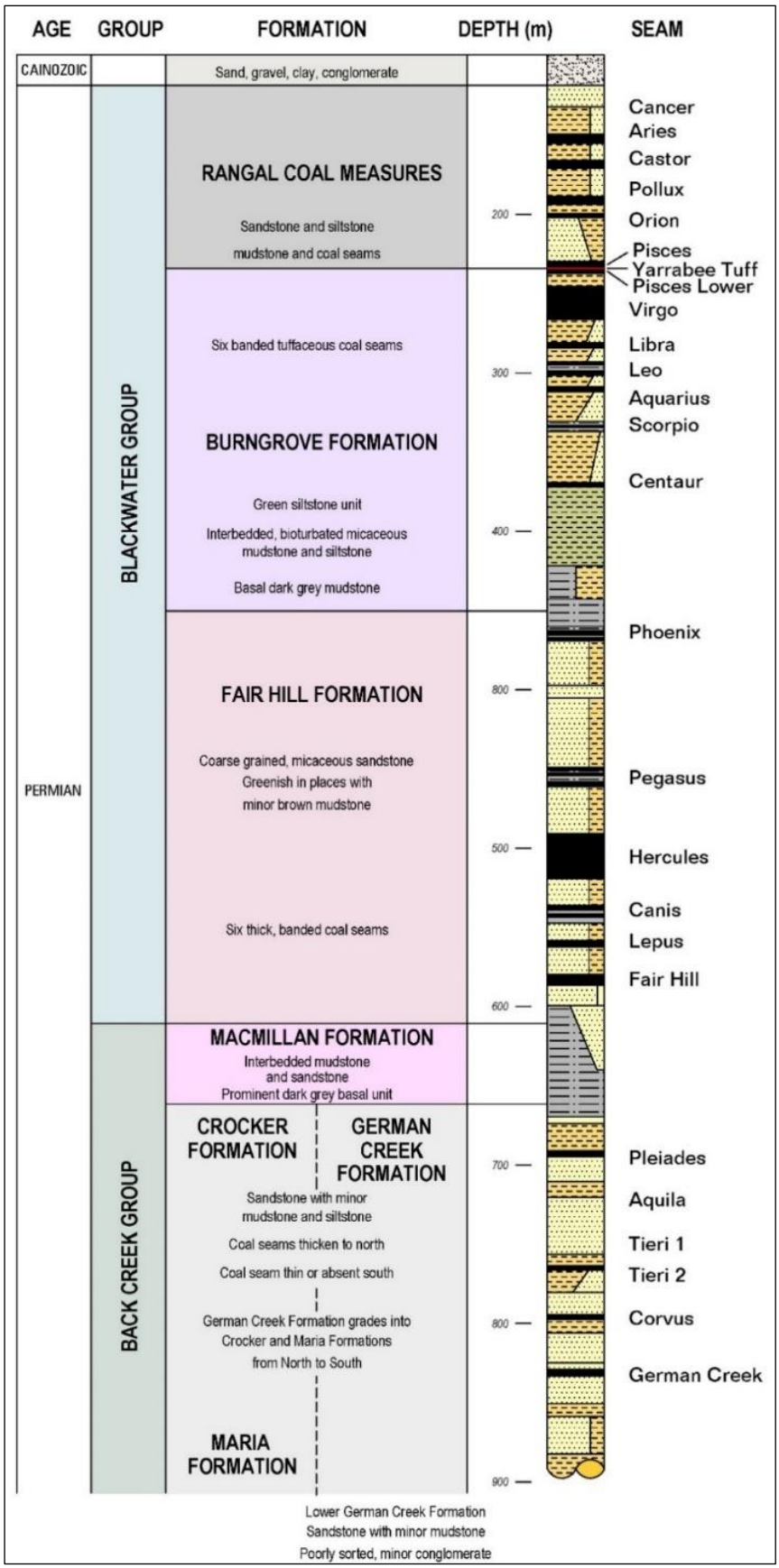



*Figure 2-2 Coal Seam Stratigraphy (Curragh Geology Training Manual, CCPL)*

## 2.1 Quaternary and Tertiary Materials

The alluvial soil materials observed at Curragh are comprised predominately of Quaternary Sands, Gravels and Clays, and Tertiary Clays and Sandy Clays.

## 2.2 Permian Interburden Lithologies

The Permian stratigraphy observed within the active mining areas at Curragh Main is comprised predominately of the Rangal Coal Measures, comprising coal, sandstone, siltstone, claystone, and carbonaceous units (refer to Table 2-1).

*Table 2-1 General Permian Material Classifications – Curragh Main*

| Material Name | Material Description |
|---|---|
| Siltstones, Sandstones, Claystones and Carbonaceous Units | Interlaminated and bedded siltstone and sandstones with occasional mudstone and / or carbonaceous units occurring in the Aries Overburden, Castor Interburden, Pollux Interburden, Orion Interburden and Pisces Interburden. |
| Coal | Black coal. |
| Burngrove Formation | Sandstone and siltstone occurring in the In the Virgo Interburden. |

The Permian stratigraphy observed within the active mining areas at Curragh North is also comprised predominately of the Rangal Coal Measures, comprising coal, sandstone, and siltstone, with occasional mudstone and carbonaceous units, and stratigraphically continuous tuffaceous layers (i.e. Yarrabee Tuff and Tuff Lower; refer to Table 2-2).

*Table 2-2 General Permian Material Classifications – Curragh North*

| Material Name | Material Description |
|---|---|
| Siltstones & Sandstones | Interlaminated and bedded siltstone and sandstone with occasional mudstone and/or carbonaceous units occurring in the Aries Overburden, Castor Interburden and Mackenzie Interburden. |
| Massive Sandstones | Massive to thickly bedded sandstone, typically medium to coarse grained occurring predominately in the Mackenzie Interburden. |
| Coal | Black coal. |
| Yarrabee Tuff | Stratigraphically continuous tuffaceous layer. |
| Tuff Lower | Stratigraphically continuous tuffaceous layer located approximately 1m to 2m below the Yarrabee Tuff. |
| Burngrove Formation | Sandstone and siltstone occurring in the In the Virgo Interburden. |

## 2.3 Seismic Risk

The Geoscience Australia Earthquake Hazard Maps (Earthquake Hazard Maps) present peak ground acceleration (response spectral period of 0.01 seconds) on rock expected for a 50 year return period, in units of *g*, evaluated for the geometric mean of the horizontal components.

For Curragh, the following have been obtained from the Earthquake Hazard Maps (Figure 2-3 and Figure 2-4):

- Exceedance probability of 10% in 50 years = 0.0-0.005g; and
- Exceedance probability of 2% in 50 years = 0.0-0.02g.

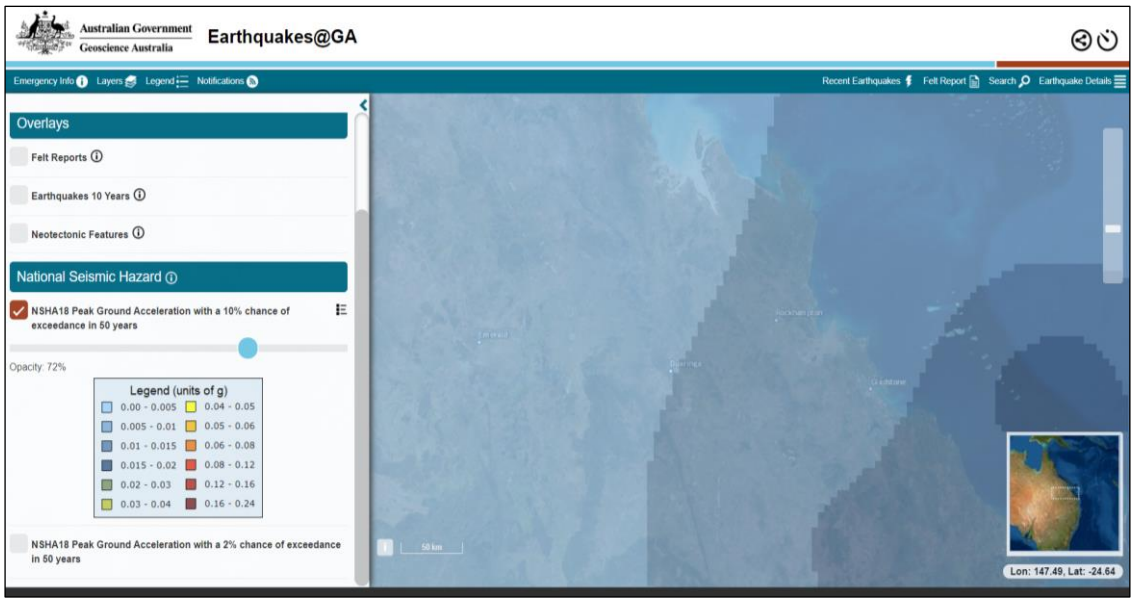



*Figure 2-3 Geoscience Australia Earthquake Hazard Map - 10% chance of exceedance in 50 years*

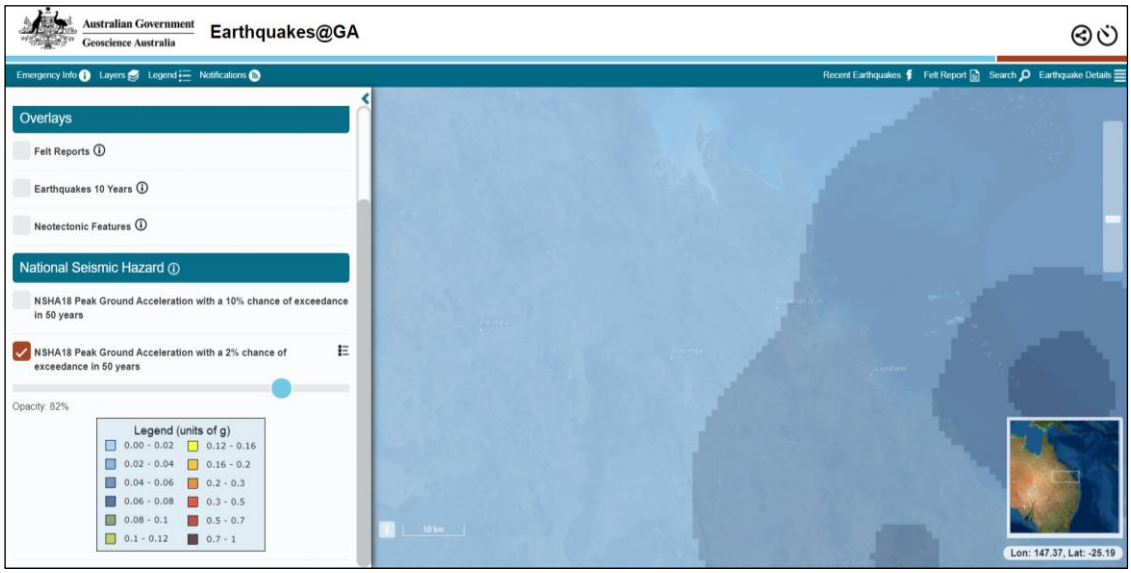



*Figure 2-4 Geoscience Australia Earthquake Hazard Map - 2% chance of exceedance in 50 years*

## 2.4 Predicted Flood Levels

Predicted flood levels for a 1:1000 AEP flood have been provided by SLR Consulting Australia Pty Ltd (SLR) (*Curragh Mine Progressive Rehabilitation and Closure Plan Flood Assessment* (SRL Ref: 626.30075-R02 Version No: -v0.2, Table 17), dated September 2022)) and are outlined in Table 2-3.

*Table 2-3 Maximum Surface Water Elevations*

| Void | Flood Level (AMG84) | Curragh Mine Grid |
|---|---|---|
| D Pit | 140.34 mAHD | 140.58 mAHD |
| F Pit | 148.03 mAHD | 148.27 mAHD |
| F Pit North / E Pit North | 144.83 mAHD | 145.07 mAHD |
| J Pit | 158.16 mAHD | 158.40 mAHD |

| Void | Flood Level (AMG84) | Curragh Mine Grid |
|---|---|---|
| K Pit | 153.39 mAHD | 153.63 mAHD |
| L Pit | 149.98 mAHD | 150.22 mAHD |
| S Pit (Curragh North) | 134.93 mAHD | 135.17 mAHD |
| U Pit (Curragh North) | 127.78 mAHD | 128.02 mAHD |
| X Pit East | 134.93 mAHD | 135.17 mAHD |
| X Pit West | 134.93 mAHD | 135.17 mAHD |
| X Pit South East | 134.93 mAHD | 135.17 mAHD |
| Y Pit | 157.53 mAHD | 157.88 mAHD |
| Z Pit North | 164.37 mAHD | 164.61 mAHD |
| Z Pit South | 169.08 mAHD | 169.32 mAHD |

## 2.5 Non-Use Management Area (NUMA)

The adopted NUMA void water levels, corresponding to a residual void water level 50$^{th}$ percentile, have been provided by SLR (*Curragh Mine Complex Residual Void Modelling* (SLR Ref: 626.30075-R01 Version No: -v3.0 Table 5, dated September 2022)) and are outlined in Table 2-4.

*Table 2-4 Supplied Residual Void Water Level Summary*

| Void | Residual Void Water Level (50%ile) (AMG84) | Residual Void Water Level (50%ile) (Curragh Mine Grid) |
|---|---|---|
| Curragh North | 23 mAHD | 23.24 mAHD |
| I Pit | 135 mAHD | 135.24 mAHD |
| Main Other | 135 mAHD | 135.24 mAHD |
| The Void | 100 mAHD | 100.24 mAHD |
| D Pit | 62 mAHD | 62.24 mAHD |
| F Pit North and E Pit North | 49 mAHD | 49.24 mAHD |
| E, C and H Pit | 70 mAHD | 70.24 mAHD |
| B Pit | 112 mAHD | 112.24 mAHD |
| F Pit | 111 mAHD | 111.24 mAHD |
| L Pit | 103 mAHD | 103.24 mAHD |
| K Pit | 77 mAHD | 77.24 mAHD |
| G Pit | 137 mAHD | 137.24 mAHD |
| Ramp 9 | 132 mAHD | 132.24 mAHD |
| J Pit | 111 mAHD | 111.24 mAHD |
| X Pit East | 67 mAHD | 67.24 mAHD |
| X Pit West | 98 mAHD | 98.24 mAHD |
| Y Pit | 123 mAHD | 123.24 mAHD |
| Z Pit North | 108 mAHD | 108.24 mAHD |
| Z Pit South | 105 mAHD | 105.24 mAHD |

# 3. Geotechnical Laboratory Data

## 3.1 Soil Materials – In-situ and Laboratory Test Results

Laboratory test results for soil and alluvial material samples utilised in these works were obtained from the following sources:

- The Minserve Group Pty Ltd (1998), Jellinbah Station Project (CN) Report. The following data were obtained from this report:
    - 4 Emerson Class Tests;
    - 21 Atterberg Limits Test Results; and,
    - 25 Particle Size Distribution Test Results.
- Golder Associates Pty Ltd (2012), Design Report Curragh U, S & T Pit Levee Raising Report. The following data were obtained from this report:
    - 44 CPT Profiles (located in the vicinity of the S-Pit and T-Pit South levee);
    - 26 Emerson Class Tests;
    - 38 Atterberg Limits Test Results; and,
    - 40 Particle Size Distribution Test Results.
- Drilling through alluvial soils and weathered rock in S-Pit South (2016):
    - 11 Atterberg Limits Test Results; and,
    - 6 Particle Size Distribution Test Results.
- Grab samples obtained from exposed alluvial materials in S-Pit and S-Pit South (2018 and 2019):
    - 10 Emerson Class Tests;
    - 17 Atterberg Limits Test Results; and,
    - 17 Particle Size Distribution Test Results.
- Grab samples obtained from exposed alluvial materials in F-Pit North (2022):
    - 5 Emerson Class Tests;
    - 2 Atterberg Limits Test Results; and,
    - 5 Particle Size Distribution Test Results.

Atterberg Limits, and Particle Size Distribution test data are presented in Figure 3-1, Figure 3-2 and Figure 3-3. Laboratory certificates and associated reports are provided on the CCPL systems.

## 3.2 Rock Core Samples - Laboratory Test Results

Uniaxial Compressive Strength data obtained from cored boreholes drilled at Curragh are provided in Table 3-1 and Table 3-2. Direct shear test results for the Yarrabee Tuff are provided in Figure 3-4. Laboratory certificates are provided on the CCPL system.

*Table 3-1 Summary of Uniaxial Compressive Strength Data Available for Curragh Main*

| Material Unit | Lithology | Mean Strength (UCS) | No of Samples |
|---|---|---|---|
| Weathered Permian | Siltstones, Sandstones, Mudstones & Carbonaceous Materials | 4.0 | 5 |
| Aries Overburden | Siltstones, Sandstones, Mudstones & Carbonaceous Materials | 13.5 | 77 |
| Castor Interburden | Siltstones, Sandstones, Mudstones & Carbonaceous Materials | 13.9 | 55 |
| Pollux Interburden | Siltstones, Sandstones, Mudstones & Carbonaceous Materials | 19.0 | 84 |
| Orion Interburden / Pisces Interburden / Virgo Interburden | Sandstones & Siltstones | 21.8 | 67 |
| Coal | Black Coals | 6.7 | 12 |
| Yarrabee Tuff | Tuff | 25 | 4 |

*Table 3-2 Summary of Uniaxial Compressive Strength Data Available for Curragh North*

| Material Unit | Lithology | Mean Strength (UCS) | No of Samples |
|---|---|---|---|
| Weathered Permian | Siltstones, Sandstones, Mudstones & Carbonaceous Materials | 1.8 | 13 |
| Aries Overburden | Siltstones, Sandstones, Mudstones, Claystones & Carbonaceous Materials | 22.0 | 157 |
| Castor Interburden | Siltstones, Sandstones & Carbonaceous Materials | 29.4 | 29 |
| Mackenzie Interburden | Siltstones, Sandstone, Carbonaceous Materials & Massive Sandstone | 26.6 | 281 |
| Aries, Castor & Mackenzie Seams | Black Coals | 6.7 | 20 |
| Yarrabee Tuff | Tuff | 11.4 | 9 |
| Virgo Interburden | Sandstone, Siltstone & Carbonaceous Materials | 34.7 | 60 |

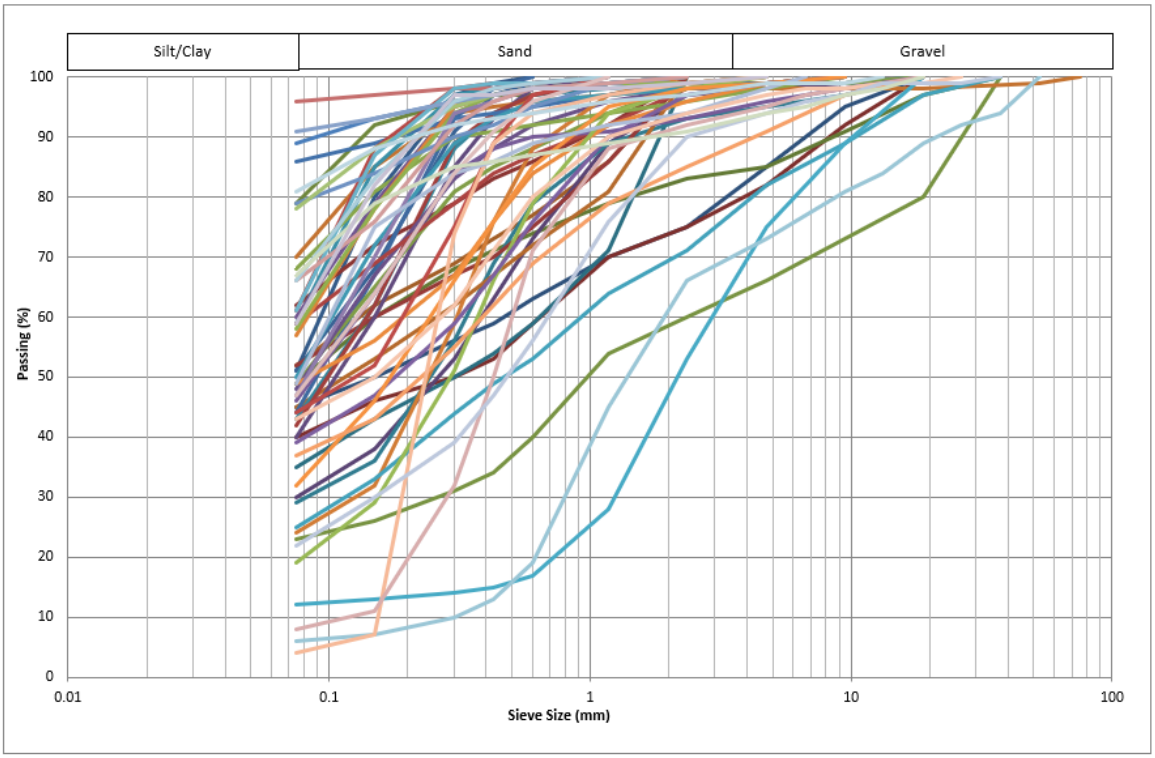



*Figure 3-1 Particle Size Distribution Chart – Quaternary Soil Materials*

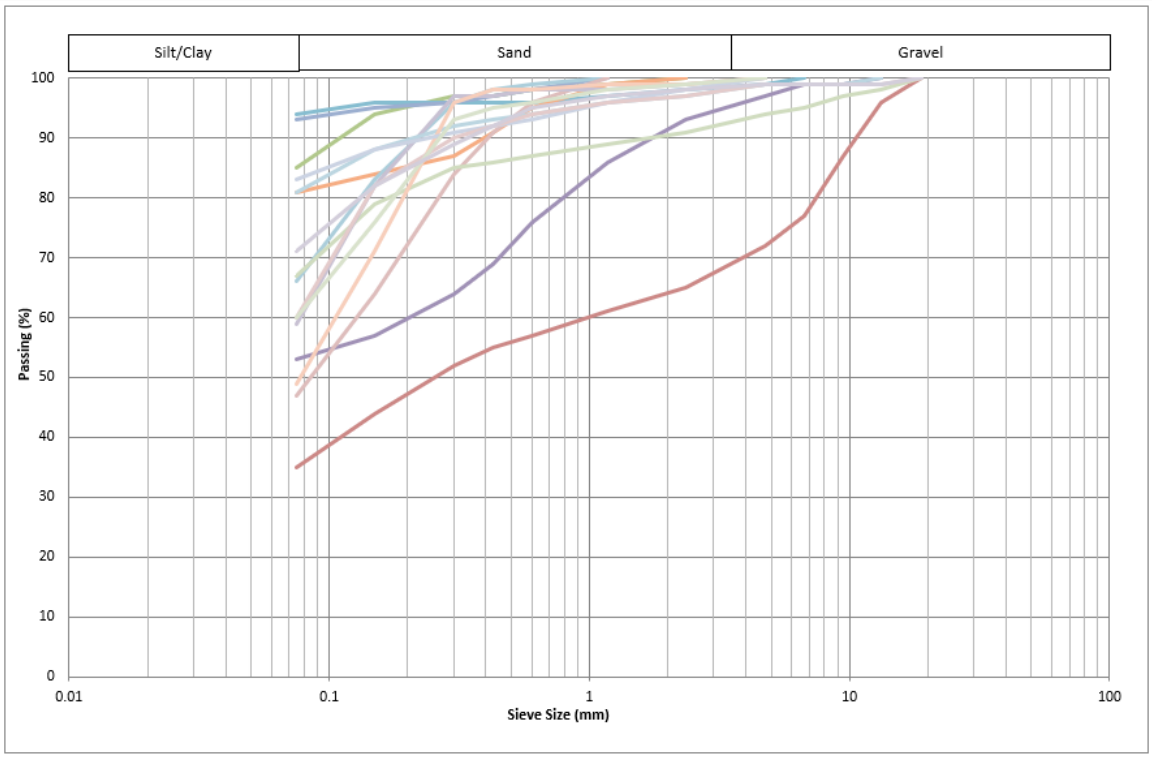



*Figure 3-2 Particle Size Distribution Chart – Tertiary Soil Materials*

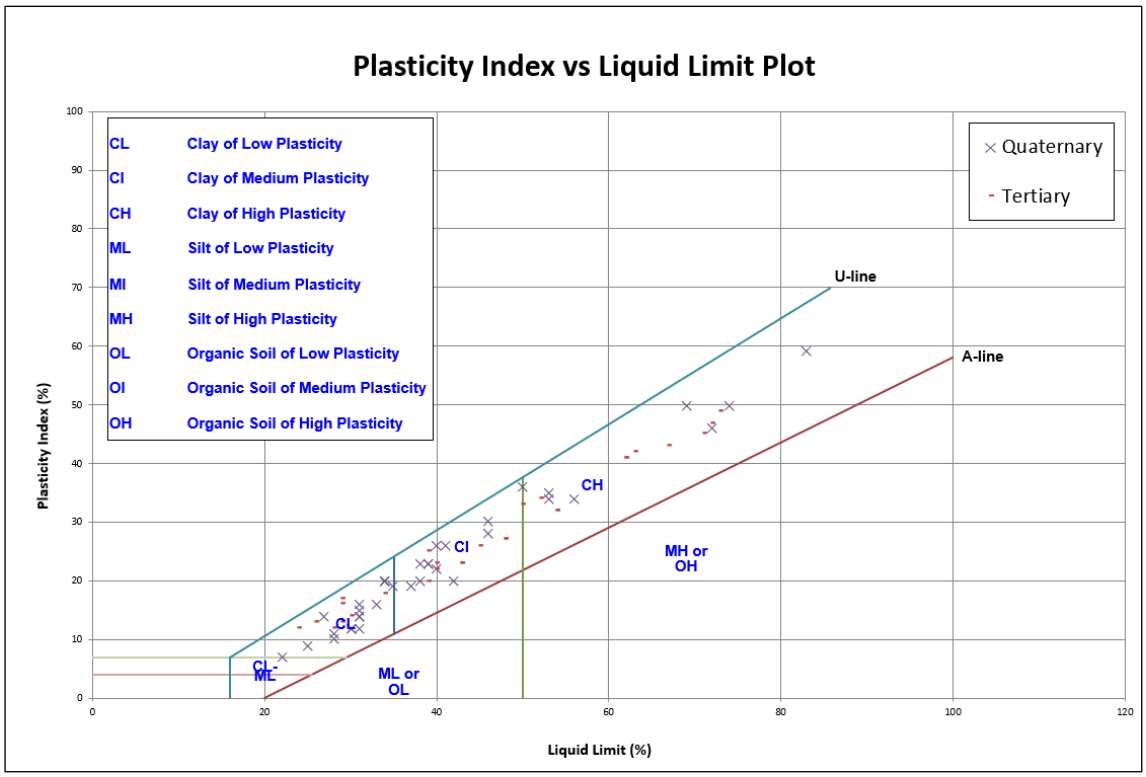



*Figure 3-3 Casagrande Chart – Quaternary & Tertiary Clays*

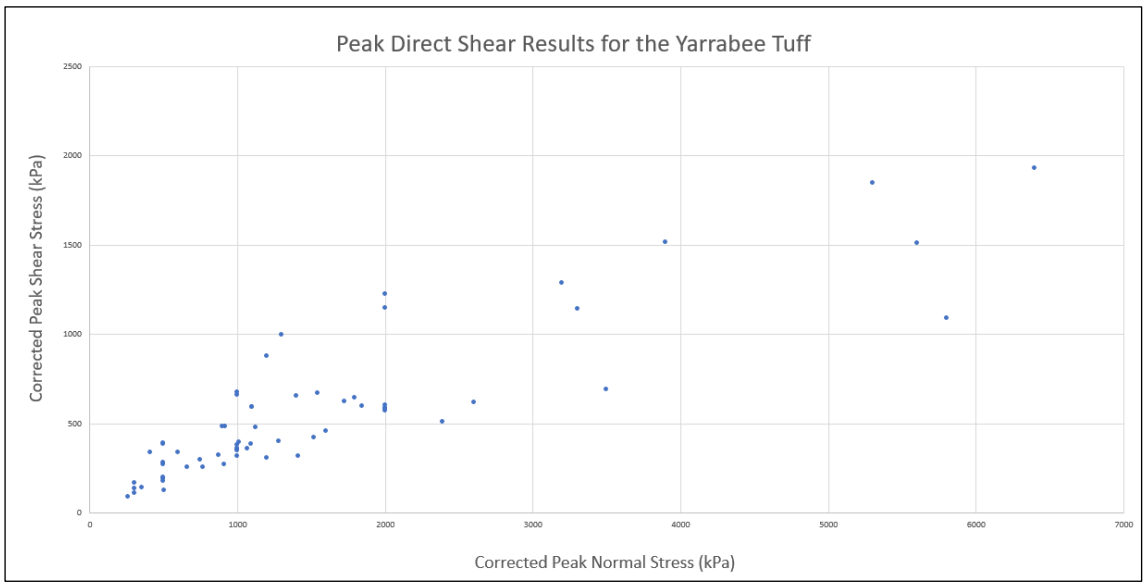



*Figure 3-4 Peak Direct Shear Data for the Yarrabee Tuff at Curragh*

# 4. Final Landform Designs

The final landform designs, which form the basis for this works, have been provided by CCPL (refer to Section 1.2).

As noted in Section 2, pitwall design revisions are often developed and implemented to mitigate the risks associated with pitwall stability and the anticipated and/or encountered ground conditions. At present there are varied levels of geological uncertainty across Curragh. This is quite normal in a mining environment where the geological uncertainty reduces as more data becomes available and designs are progressed through the CPS from planning to concept to detailed design to operations.

In considering these points, where the current final landform design comprises remnant pitwalls, alternative geometry options are provided to demonstrate that where pitwall design revisions are required to mitigate the risks associated with geological faults, design options that maintain the existing NUMA crest positions can be achieved.

The adopted geotechnical ground model scenarios and twenty-three (23) selected cross-section locations across the nineteen (19) final voids are provided in Figure 4-5 to Figure 4-49, and are listed in Table 4-1.

*Table 4-1 Cross Sections List*

| | | |
|---|---|---|
| U-Pit Cross Section 1 | F-Pit and E, C & H-Pit Void Cross Section 1 | J-Pit Cross Section 2 |
| S-Pit Cross Section 1 | L-Pit Cross Section 1 | Y-Pit Cross Section 1 |
| X-Pit East Cross Section 1 | K-Pit and E, C & H-Pit Void Cross Section 1 | Y-Pit Cross Section 2 |
| X-Pit West Cross Section 1 | K-Pit Cross Section 2 | Z-Pit North Cross Section 1 |
| I-Pit North, Main Other and The Void Cross Section 1 | G-Pit Section 1 | Z-Pit North Cross Section 2 |
| I-Pit South and D-Pit Cross Section 1 | Ramp 9 Cross Section 1 | Z-Pit South Cross Section 1 |
| E-Pit North Cross Section 1 | Ramp 9 Cross Section 2 | Z-Pit South Cross Section 2 |
| F-Pit North Cross Section 1 | J-Pit Cross Section 1 | |

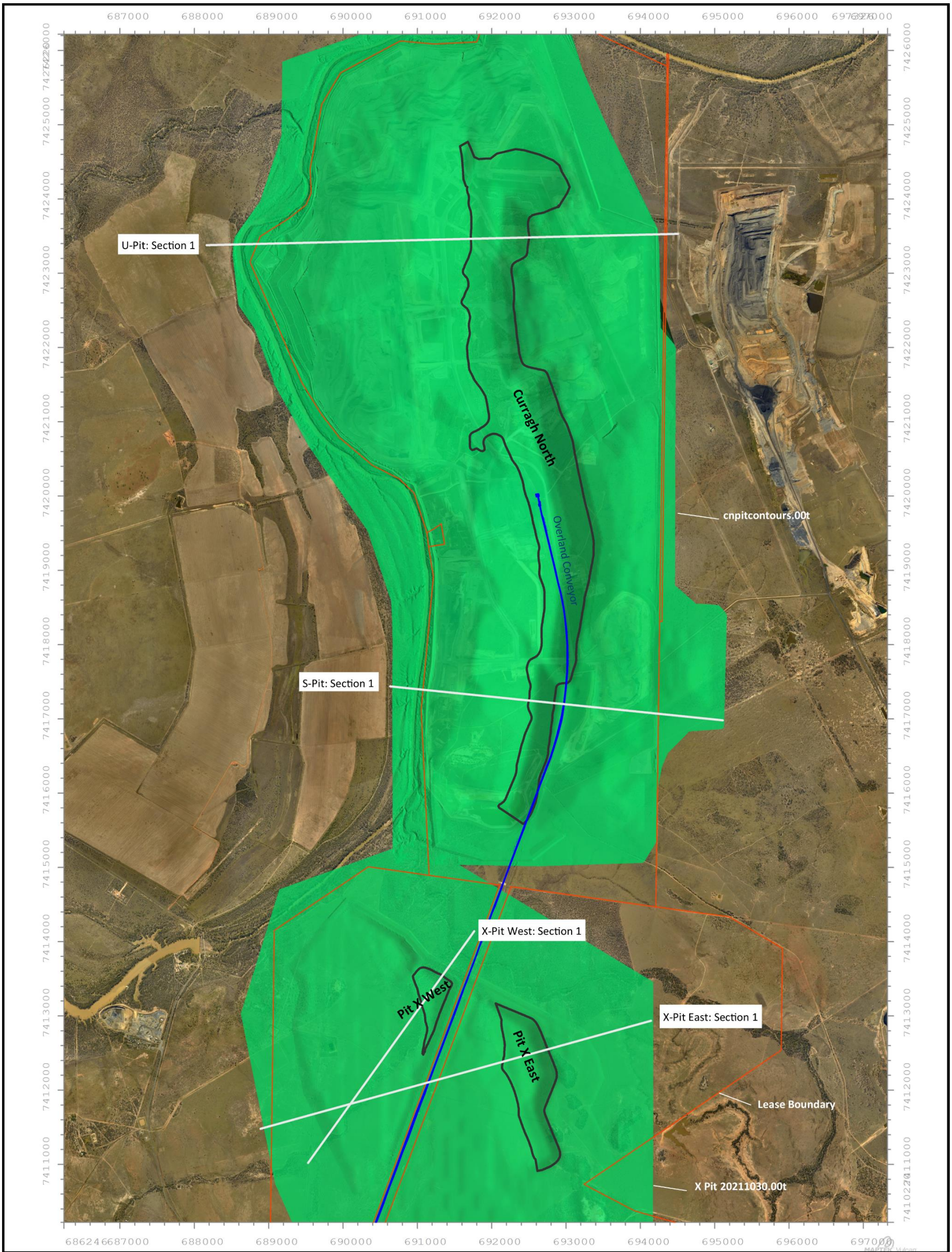



*Figure 4-1 Curragh North and X-Pit Final Landform & Cross Section Locations*

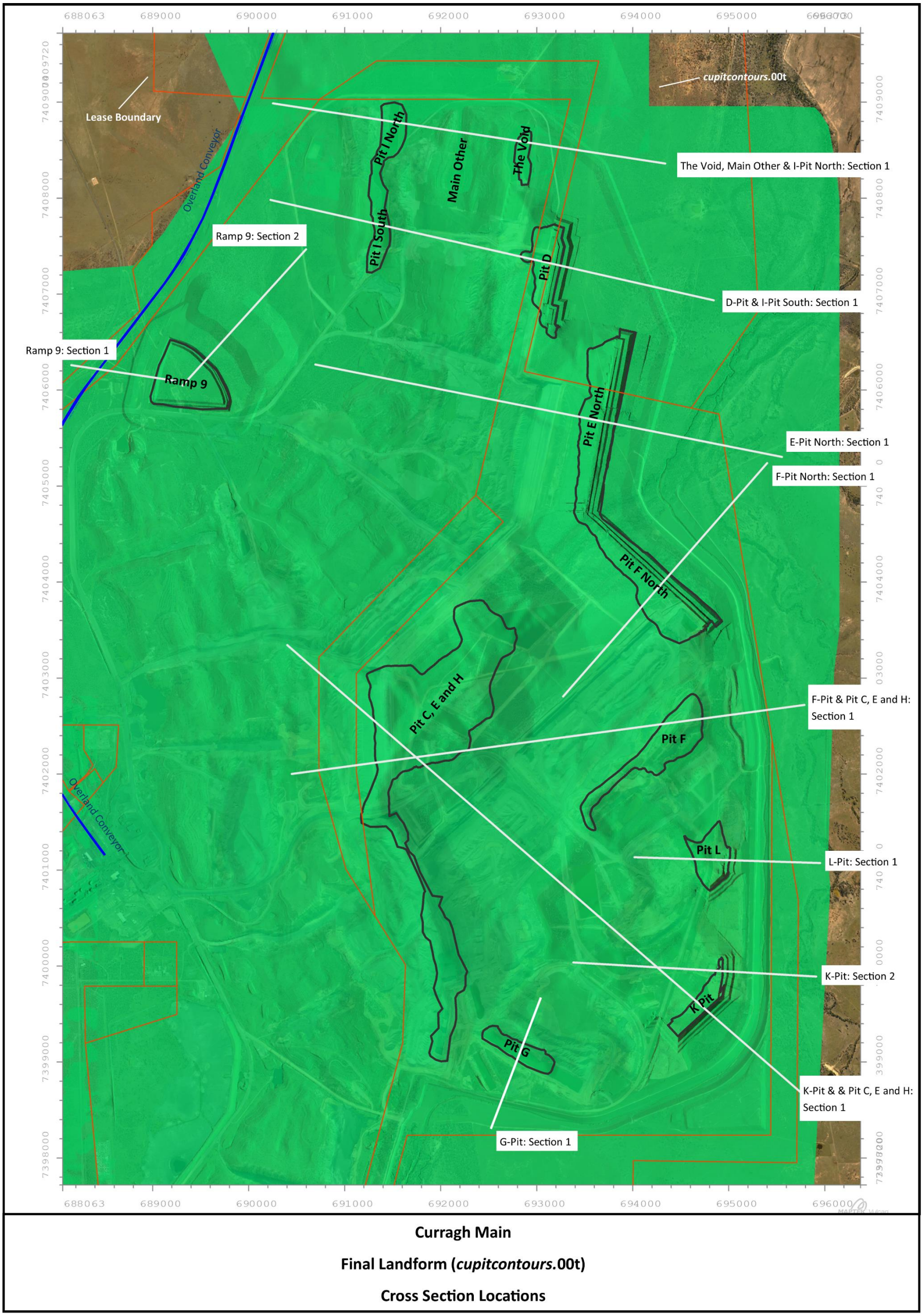
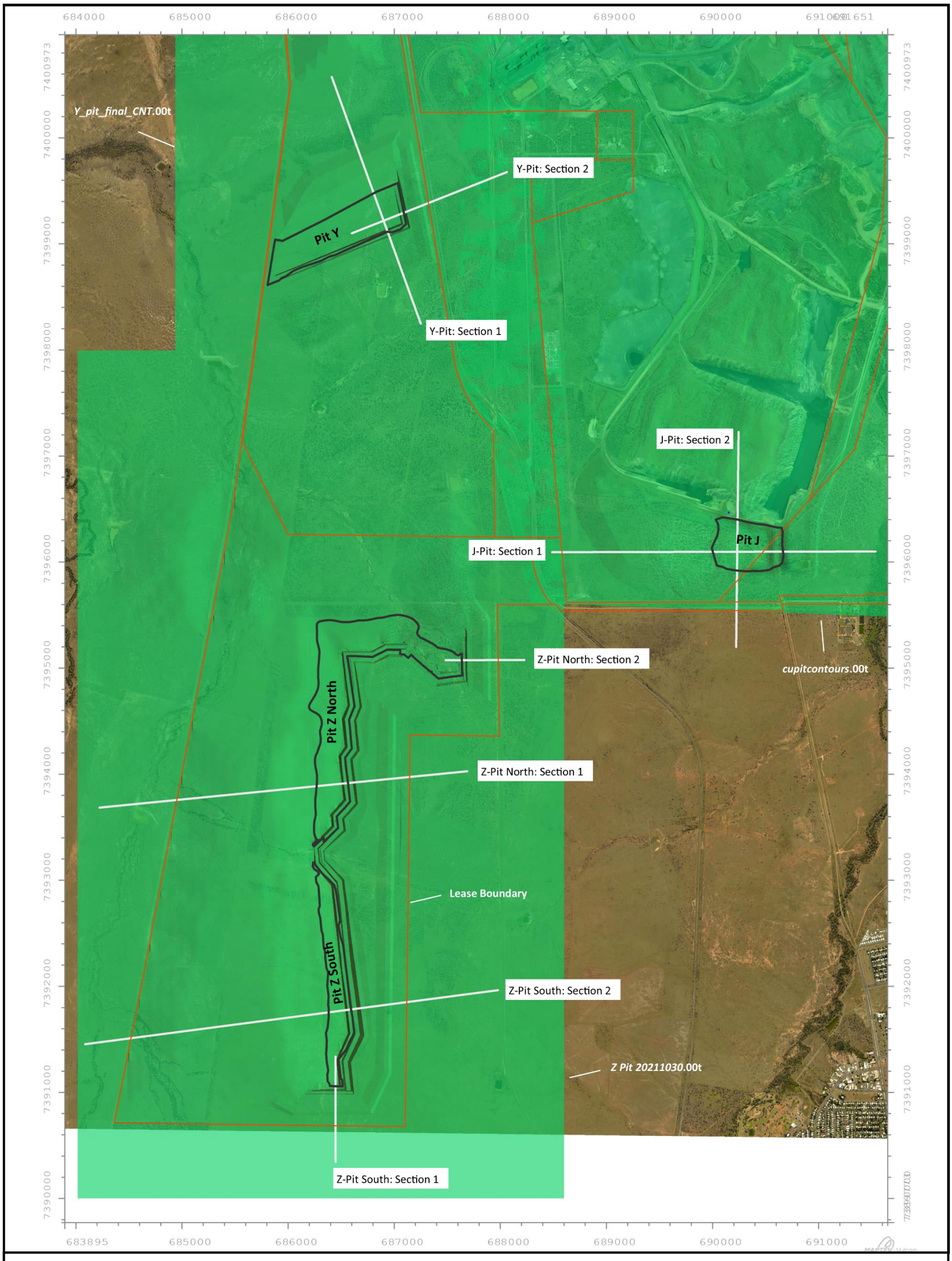



*Figure 4-2 Curragh Main Final Landform& Cross Section Locations*

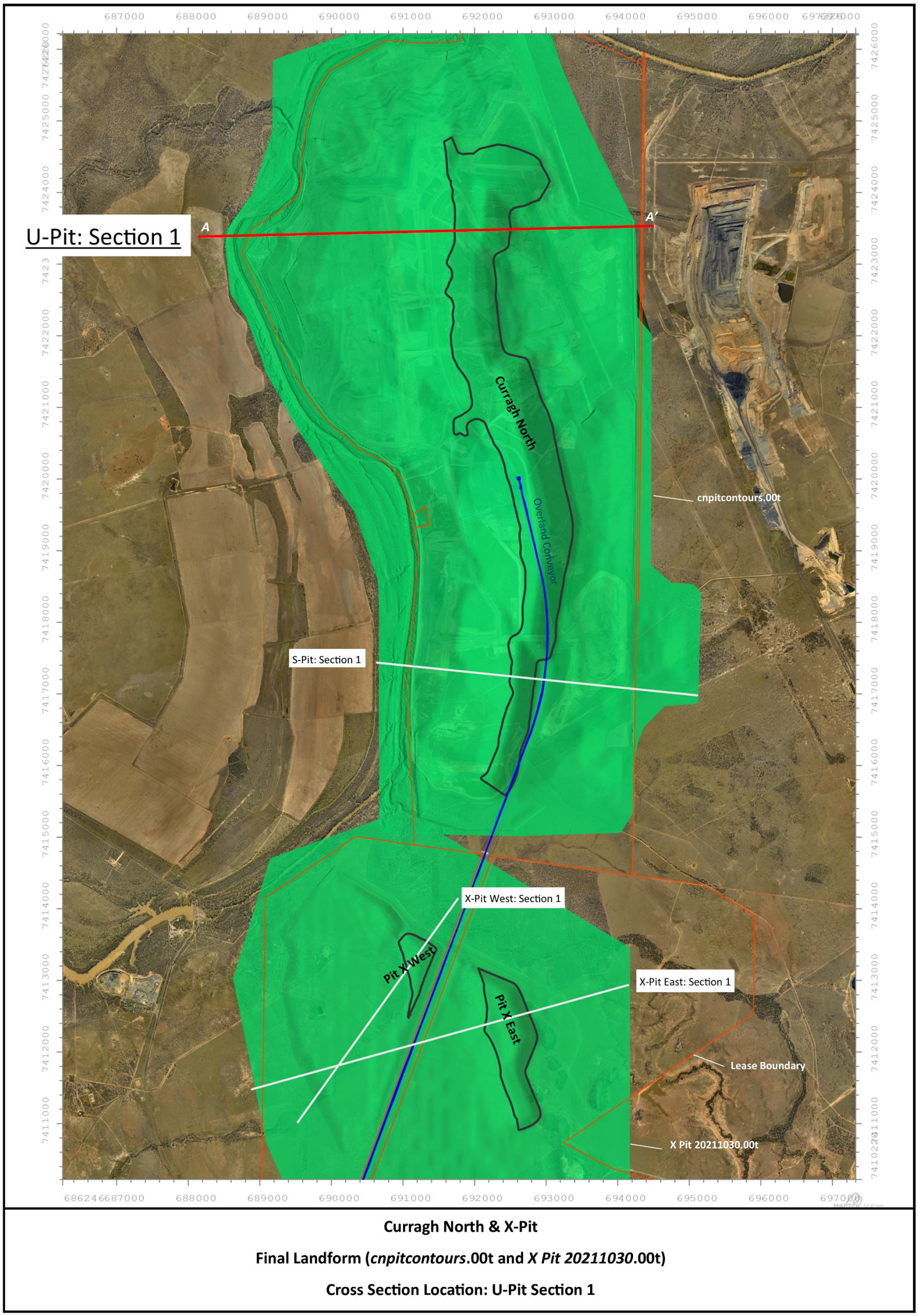



**Curragh West**

**Final Landform (*cupitcontours*.00t, *Y_pit_final_CNT*.00t and *Z Pit 20211030*.00t)**

**Cross Section Locations**

*Figure 4-3 Curragh West Final Landform& Cross Section Locations*




**Curragh North & X-Pit**

**Final Landform (*cnpitcontours*.00t and *X Pit 20211030*.00t)**

**Cross Section Location: U-Pit Section 1**

*Figure 4-4 U-Pit Cross Section 1 Location Plan*

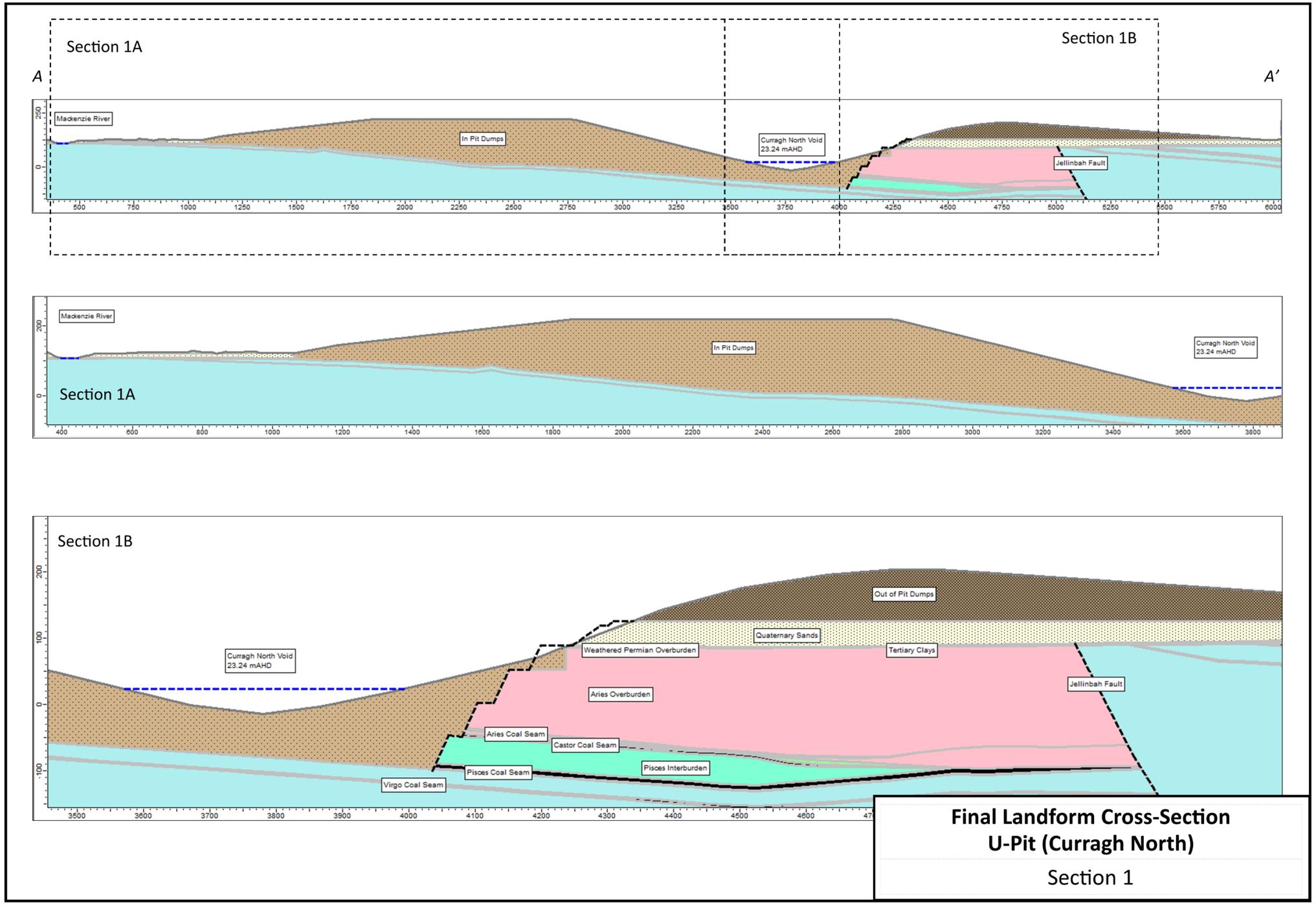



*Figure 4-5 U-Pit Cross Section 1*

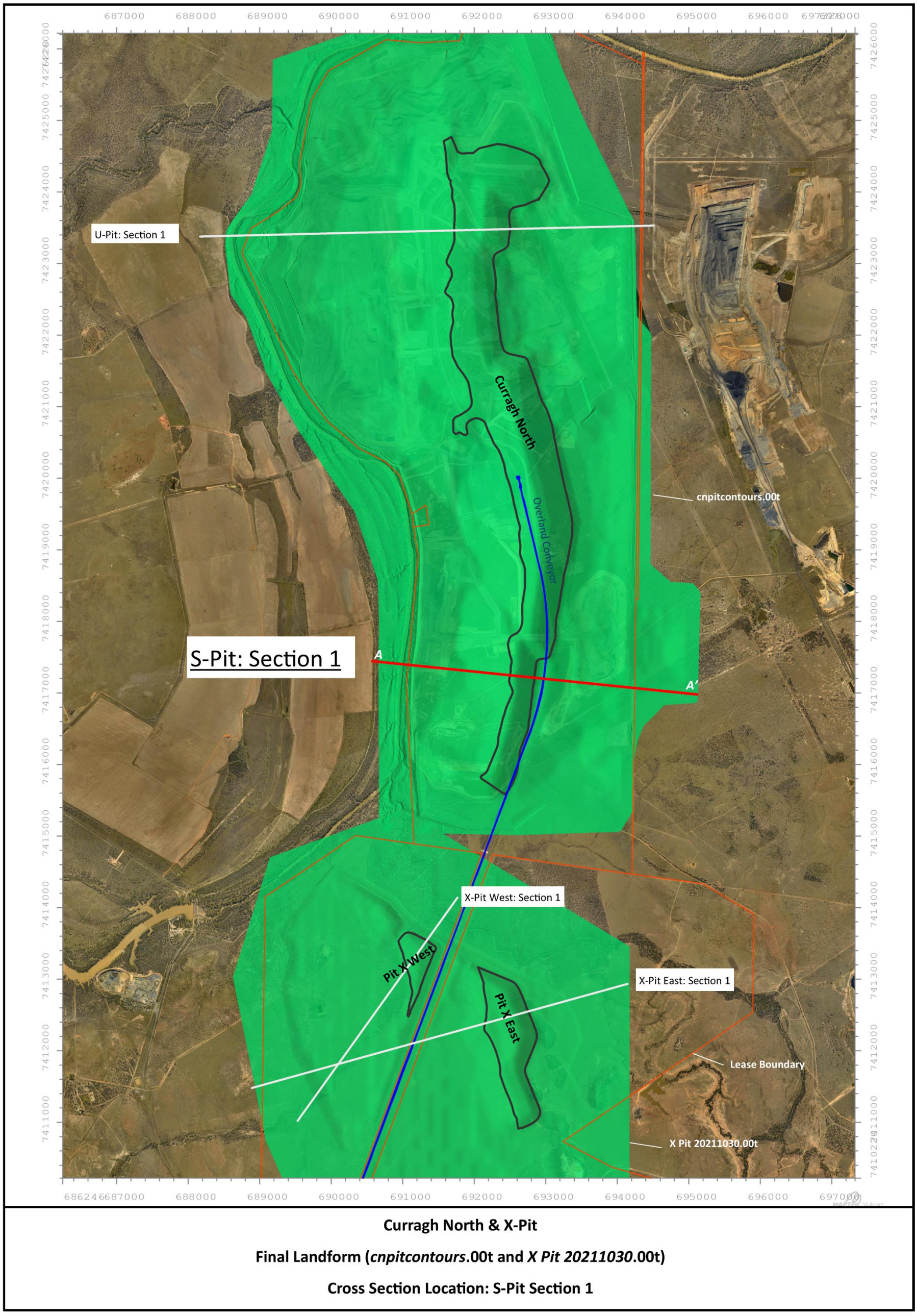



*Figure 4-6 S-Pit Cross Section 1 Location Plan*

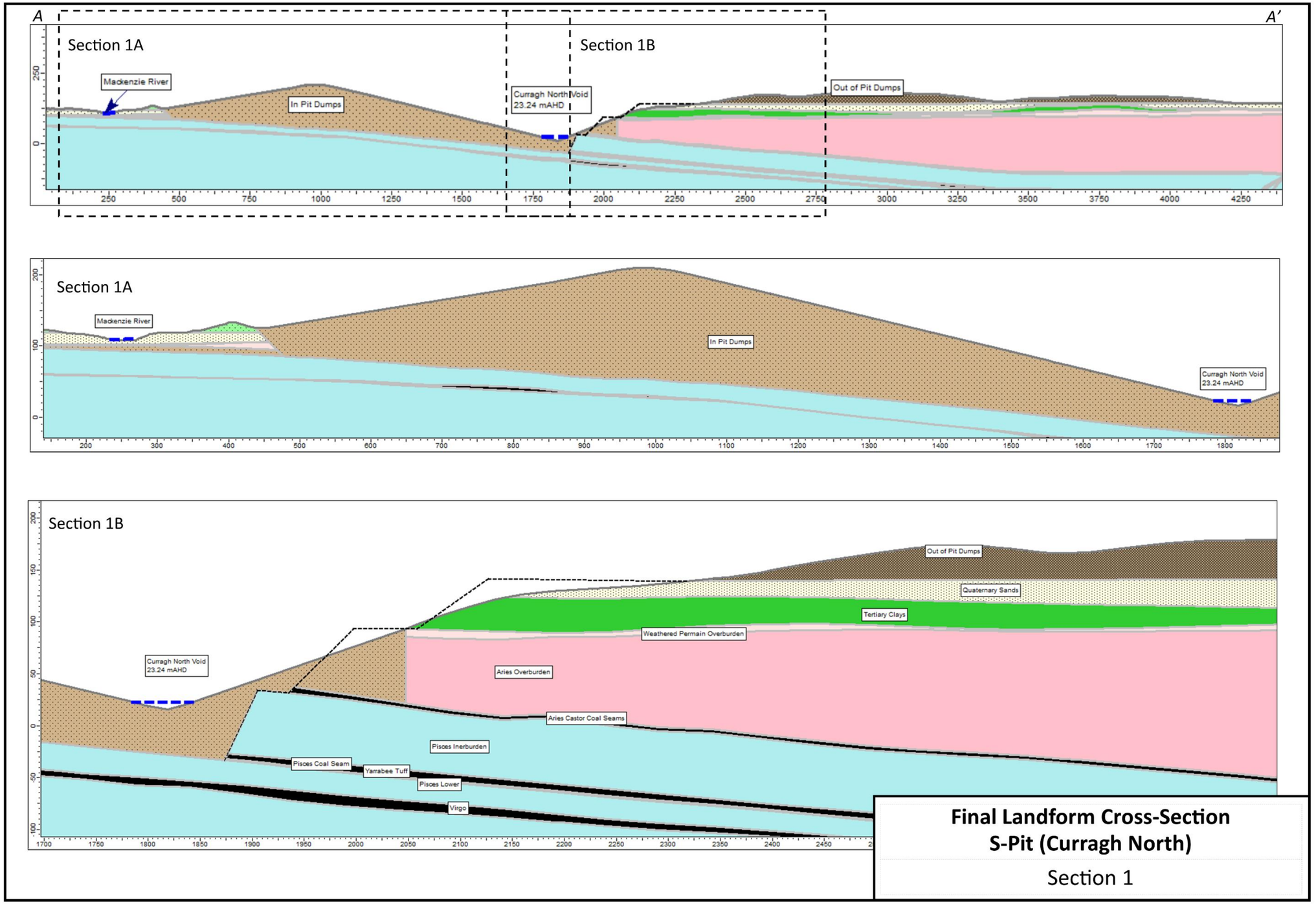
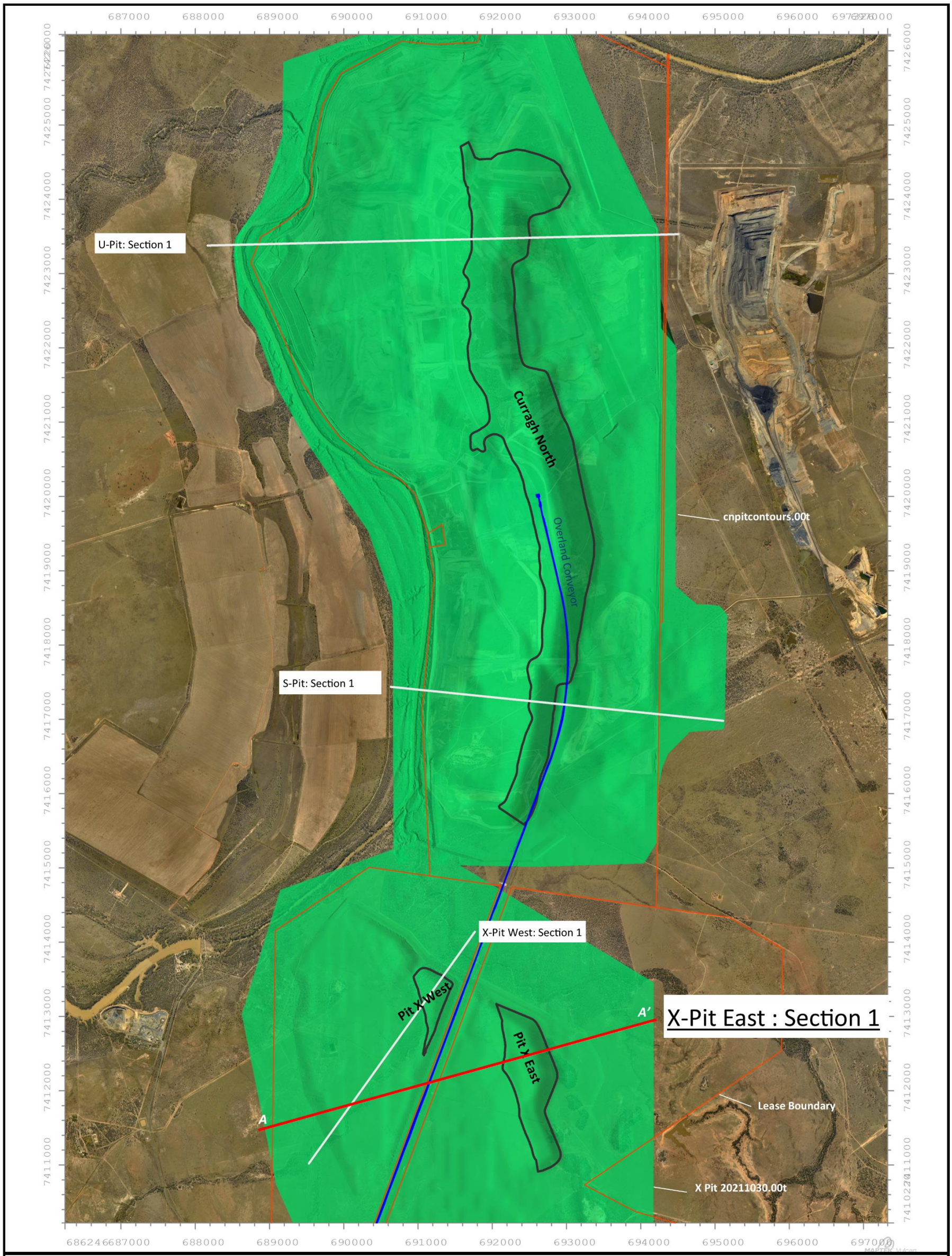



*Figure 4-7 S-Pit Cross Section 1*




**Curragh North & X-Pit**

**Final Landform (*cnpitcontours*.00t and *X Pit 20211030*.00t)**

**Cross Section Location: X-Pit East Section 1**

*Figure 4-8 X-Pit East Cross Section 1 Location Plan*

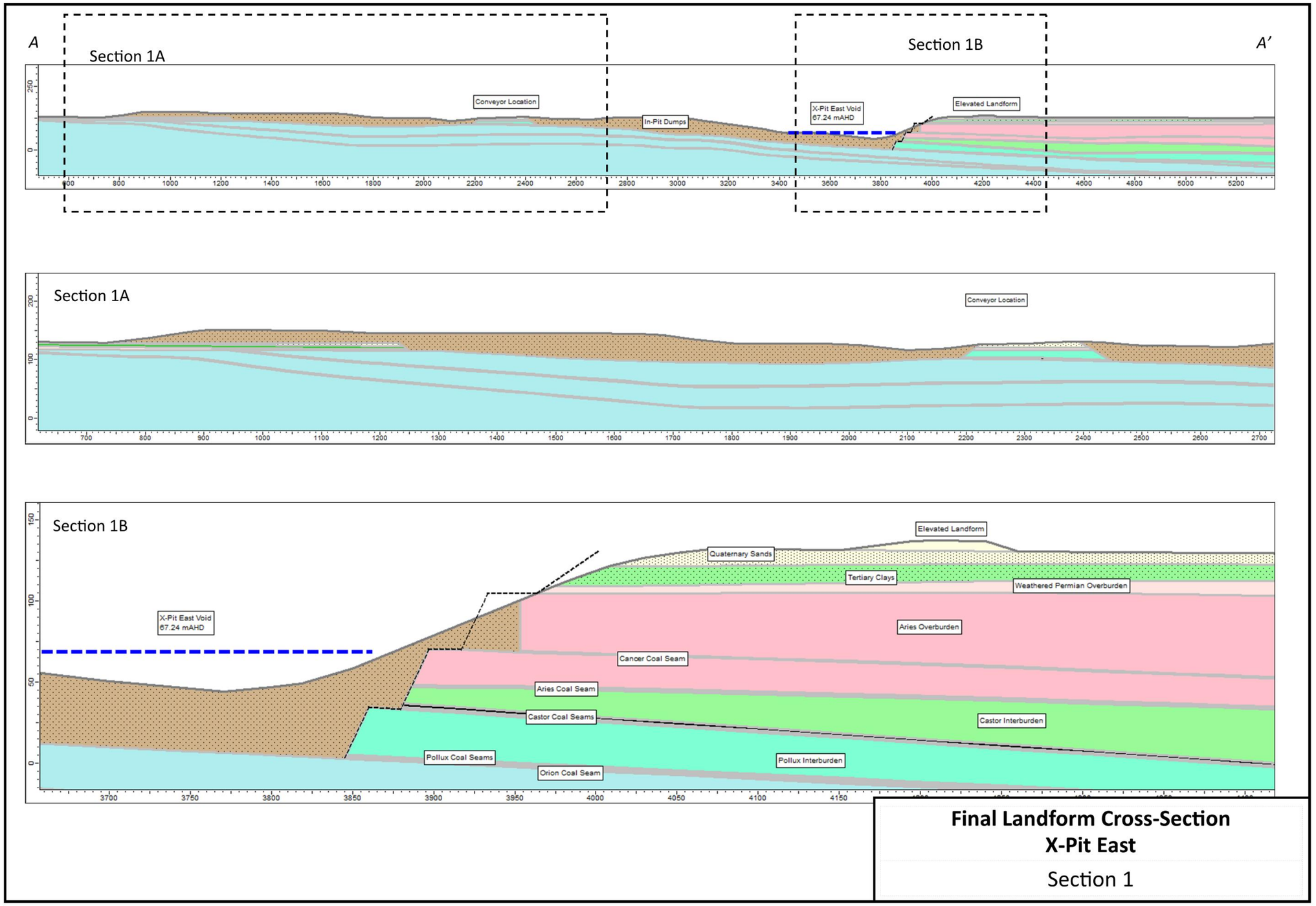



*Figure 4-9 X-Pit East Cross Section 1*

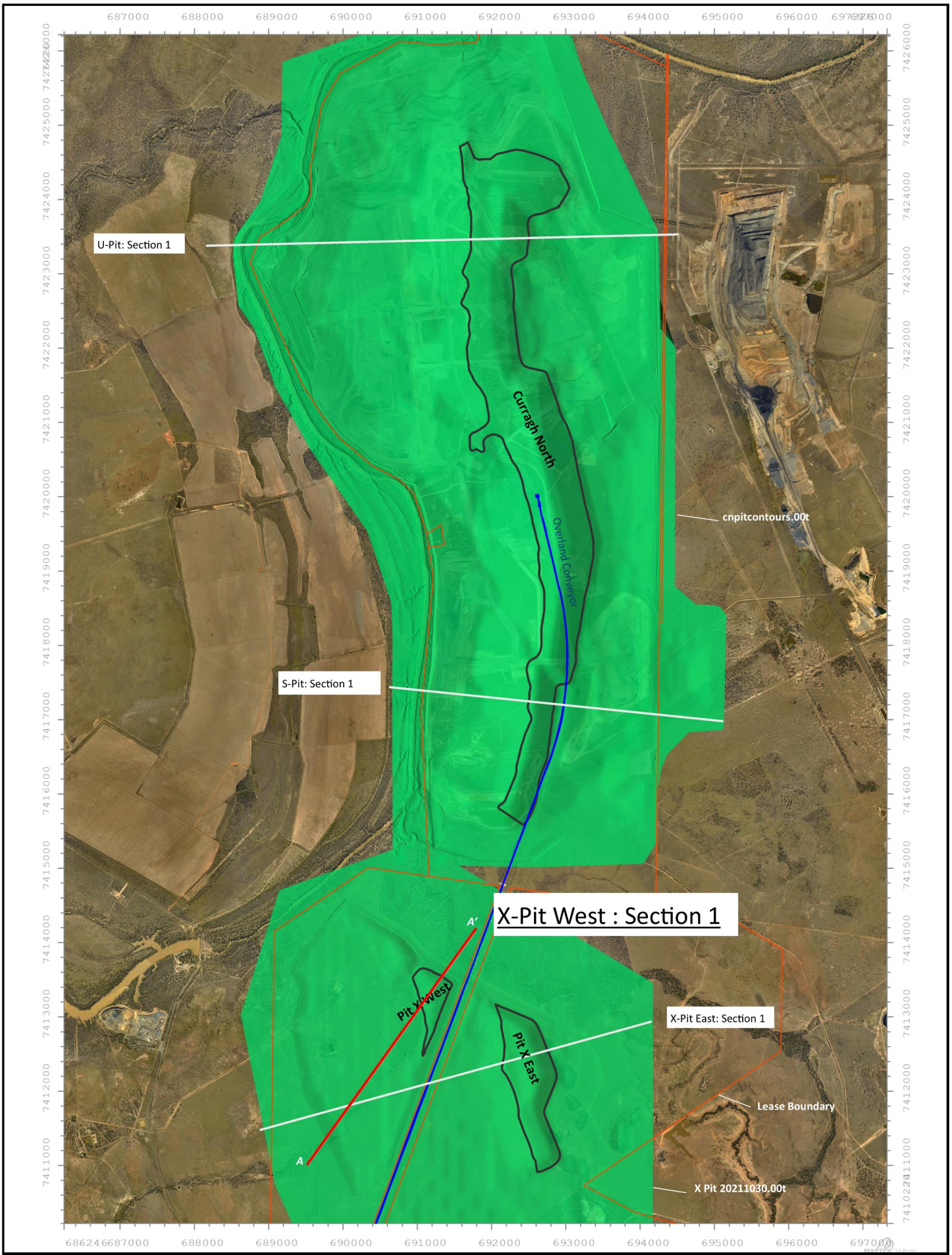



*Figure 4-10 X-Pit West Cross Section 1 Location Plan*

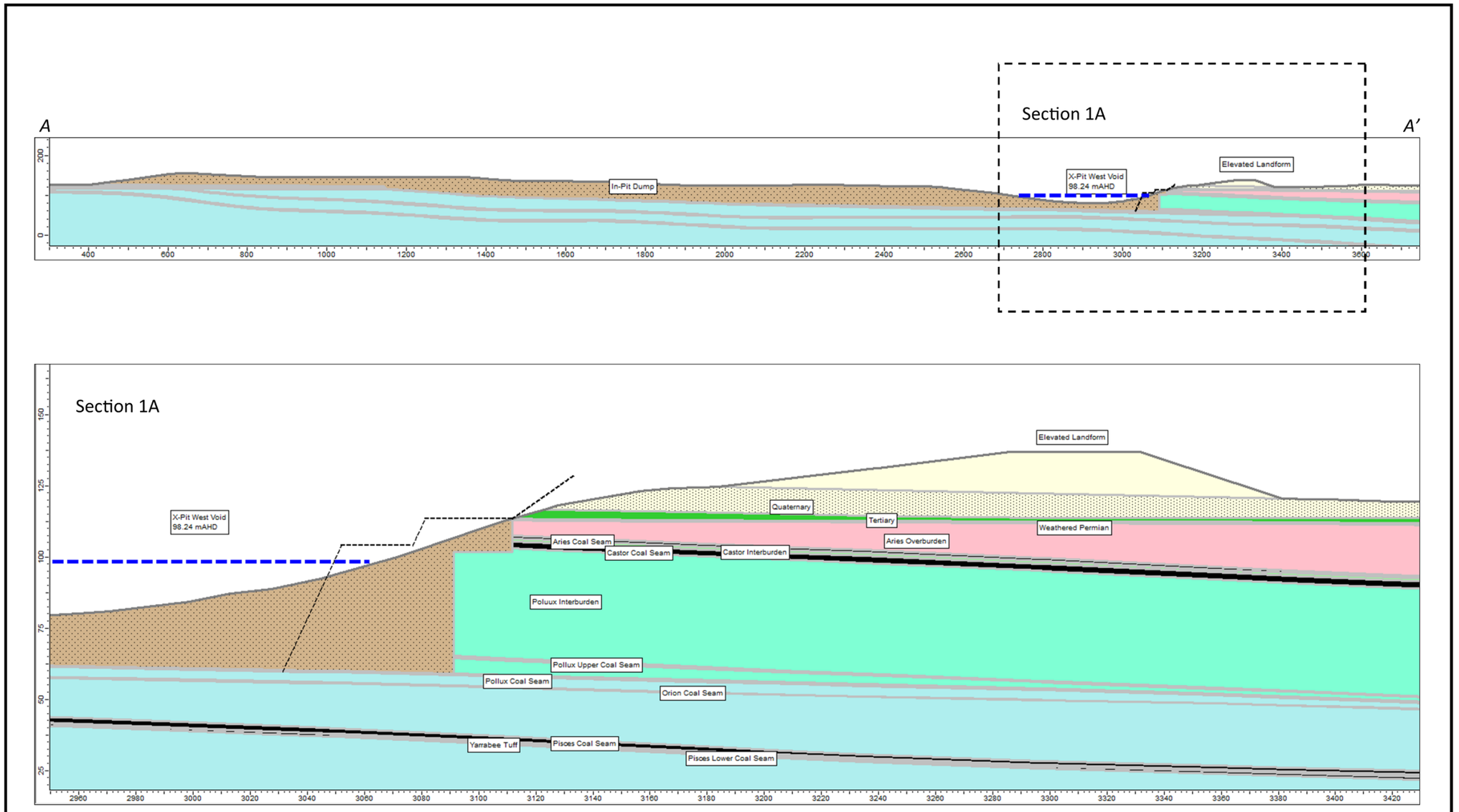



*Figure 4-11 X-Pit West Cross Section 1*

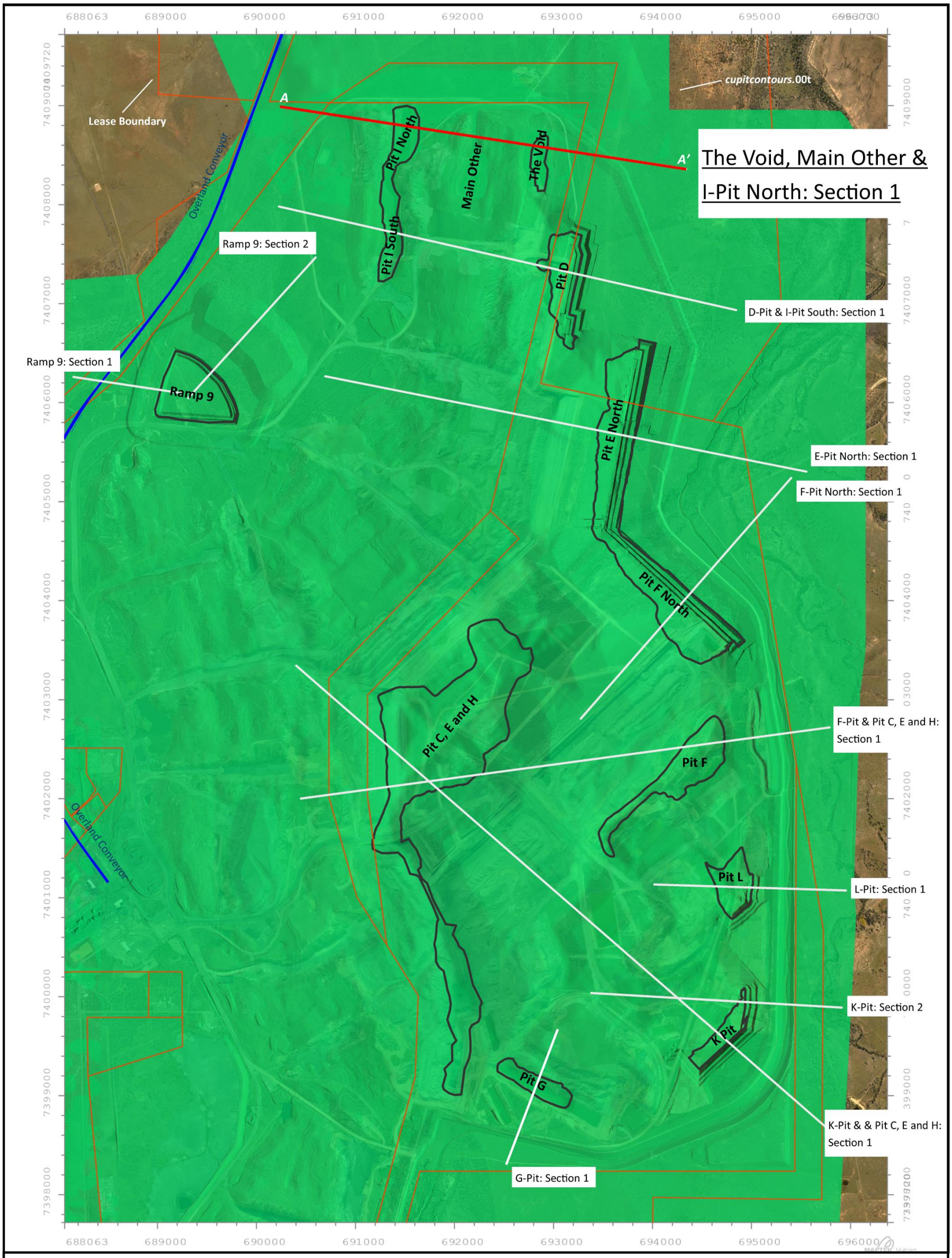



*Figure 4-12 I-Pit North, Main Other and The Void Section 1 Location Plan*

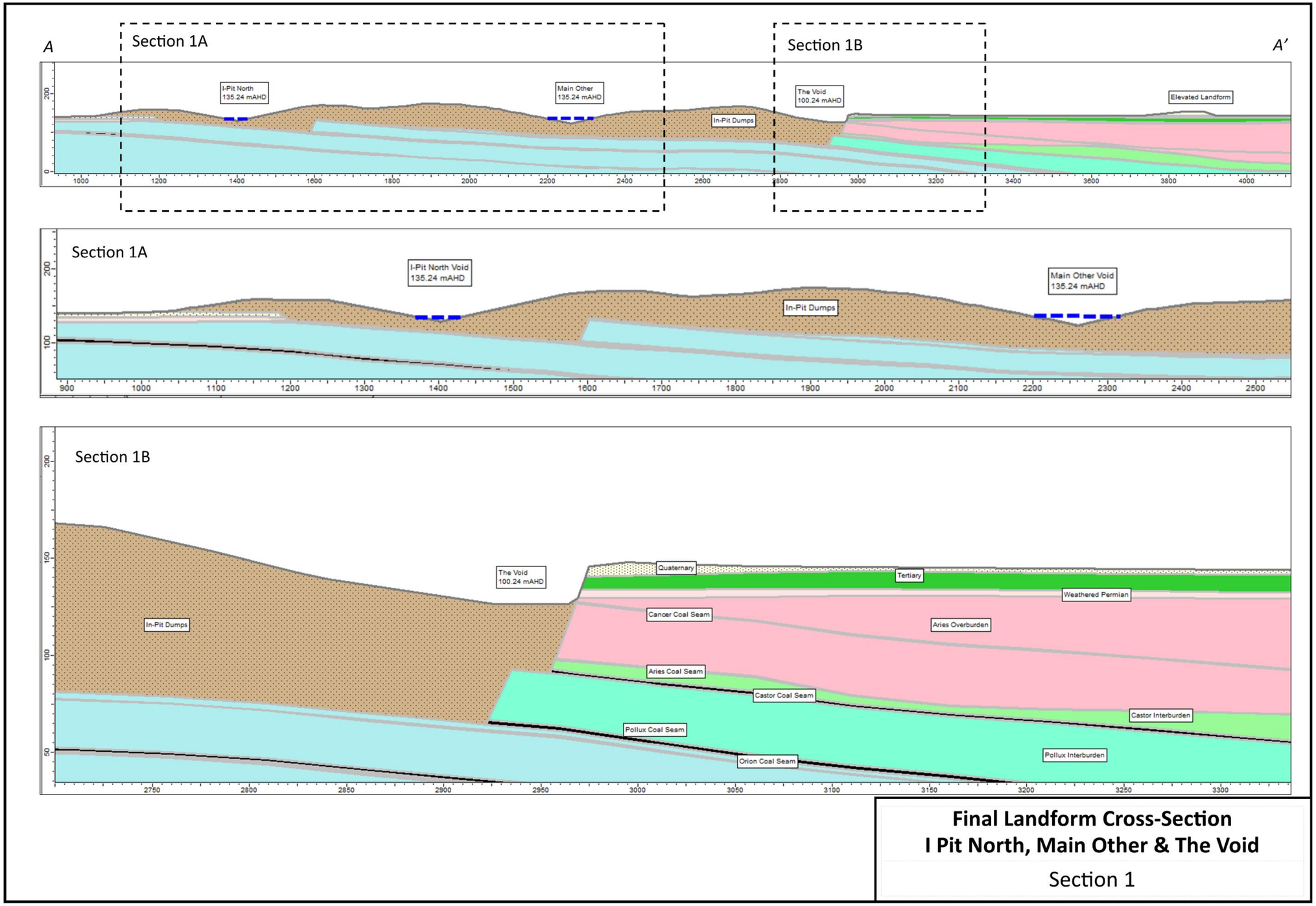
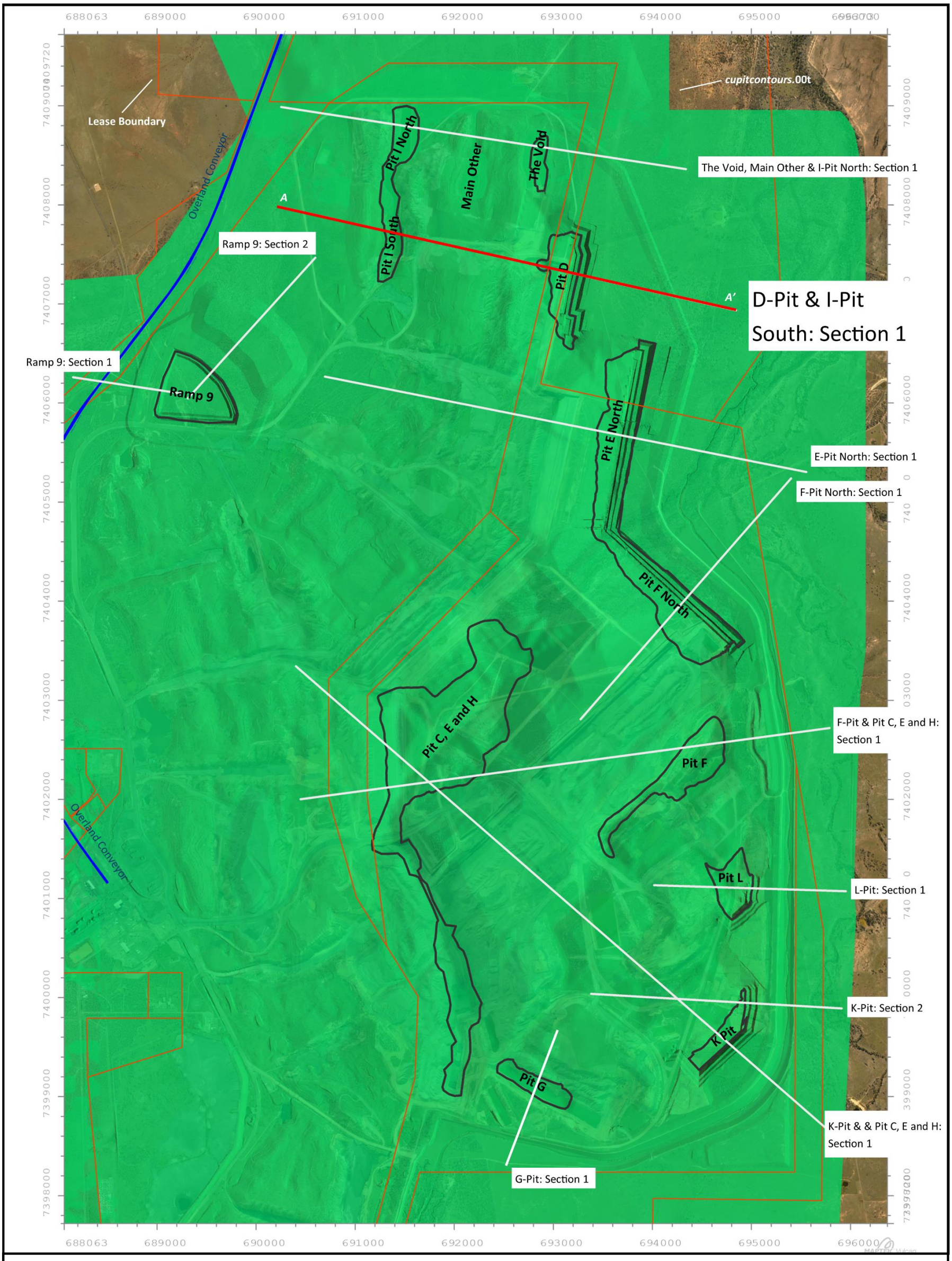



*Figure 4-13 I-Pit North, Main Other and The Void Section 1*




**Curragh Main**

**Final Landform (*cupitcontours*.00t)**

**Cross Section Locations: D-Pit & I-Pit South: Section 1**

*Figure 4-14 I-Pit South and D-Pit Section 1Location Plan*

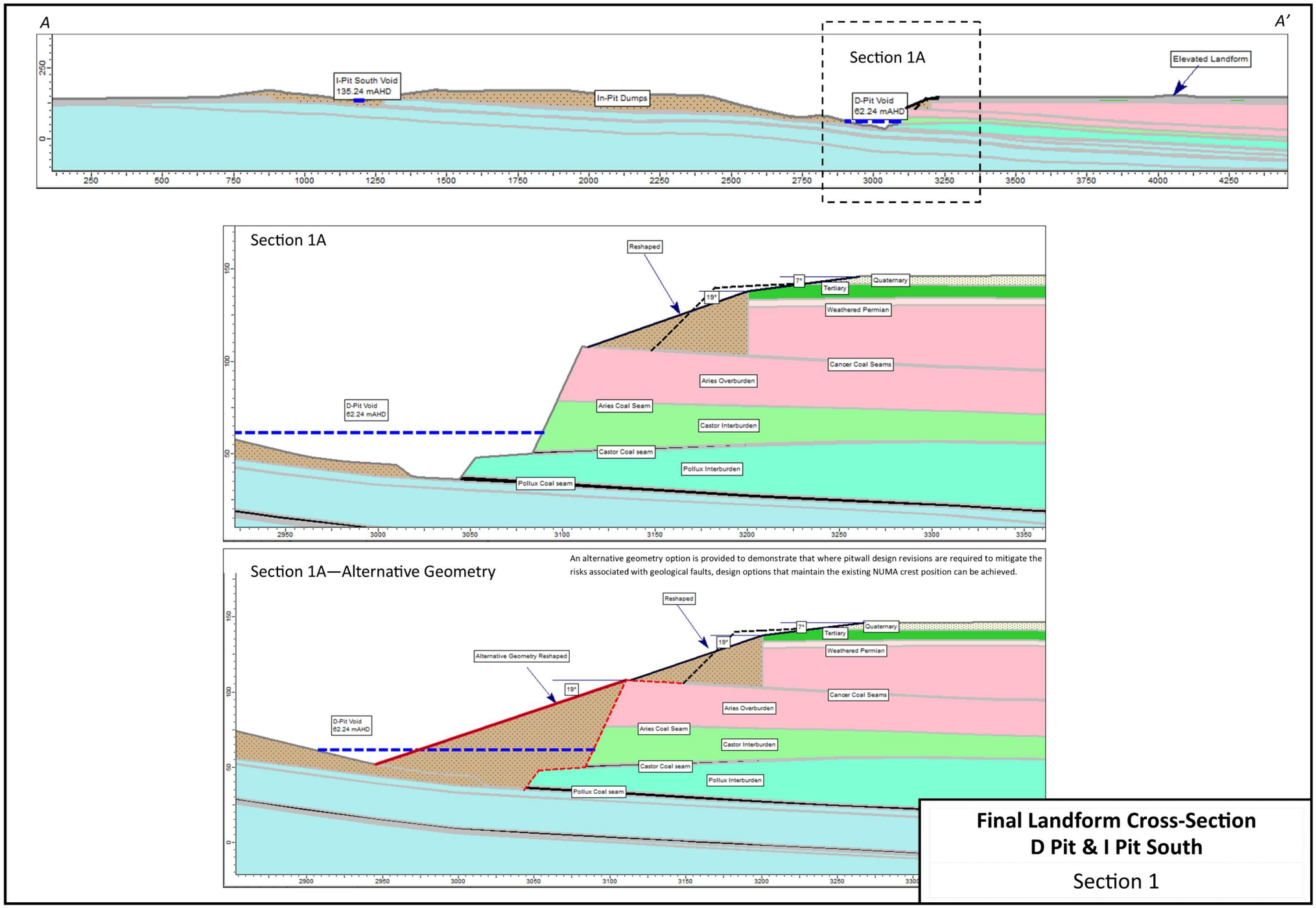
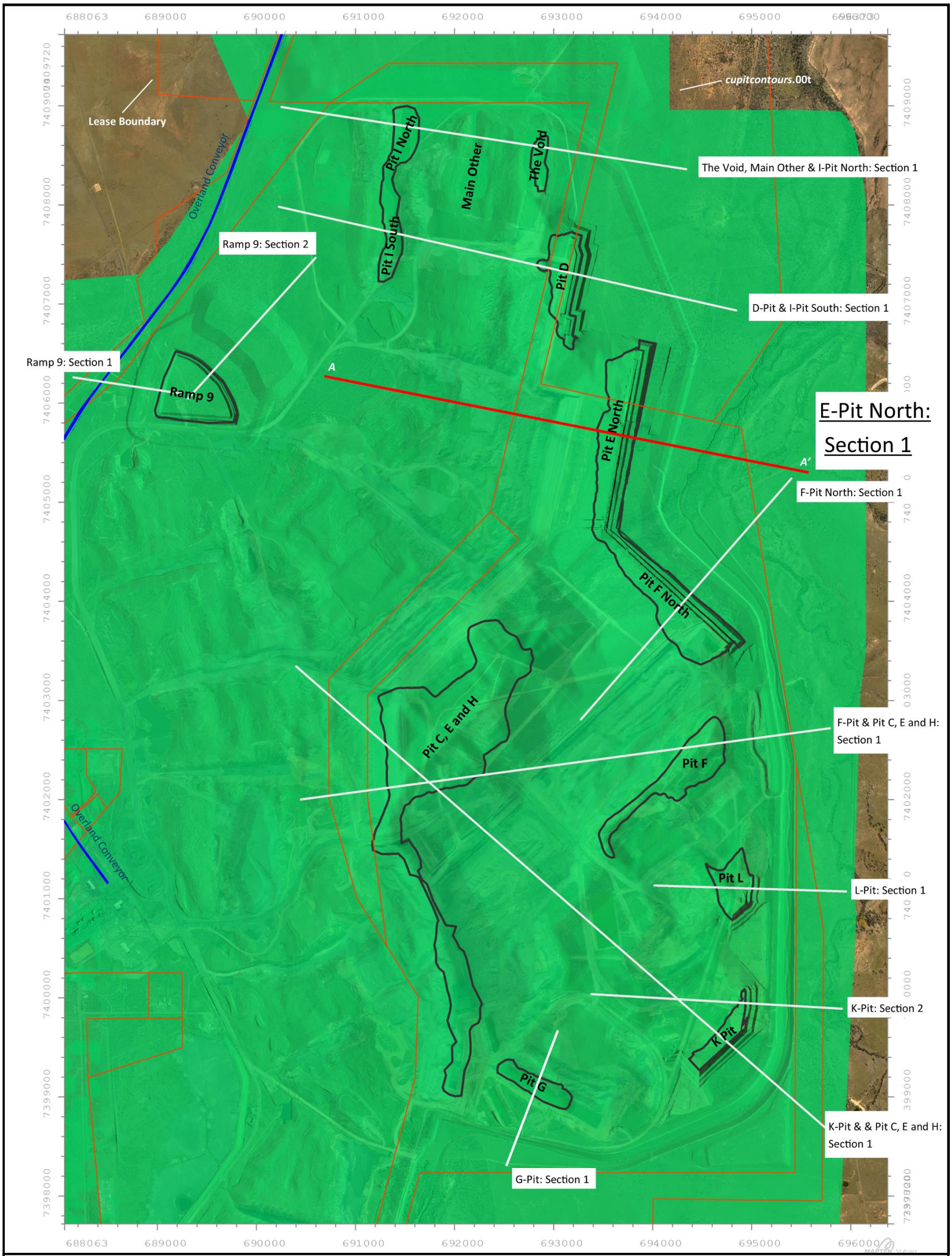



*Figure 4-15 I-Pit South and D-Pit Section 1*




**Curragh Main**

**Final Landform (*cupitcontours*.00t)**

**Cross Section Locations: E-Pit North: Section 1**

*Figure 4-16 E-Pit North Cross Section 1 Location Plan*

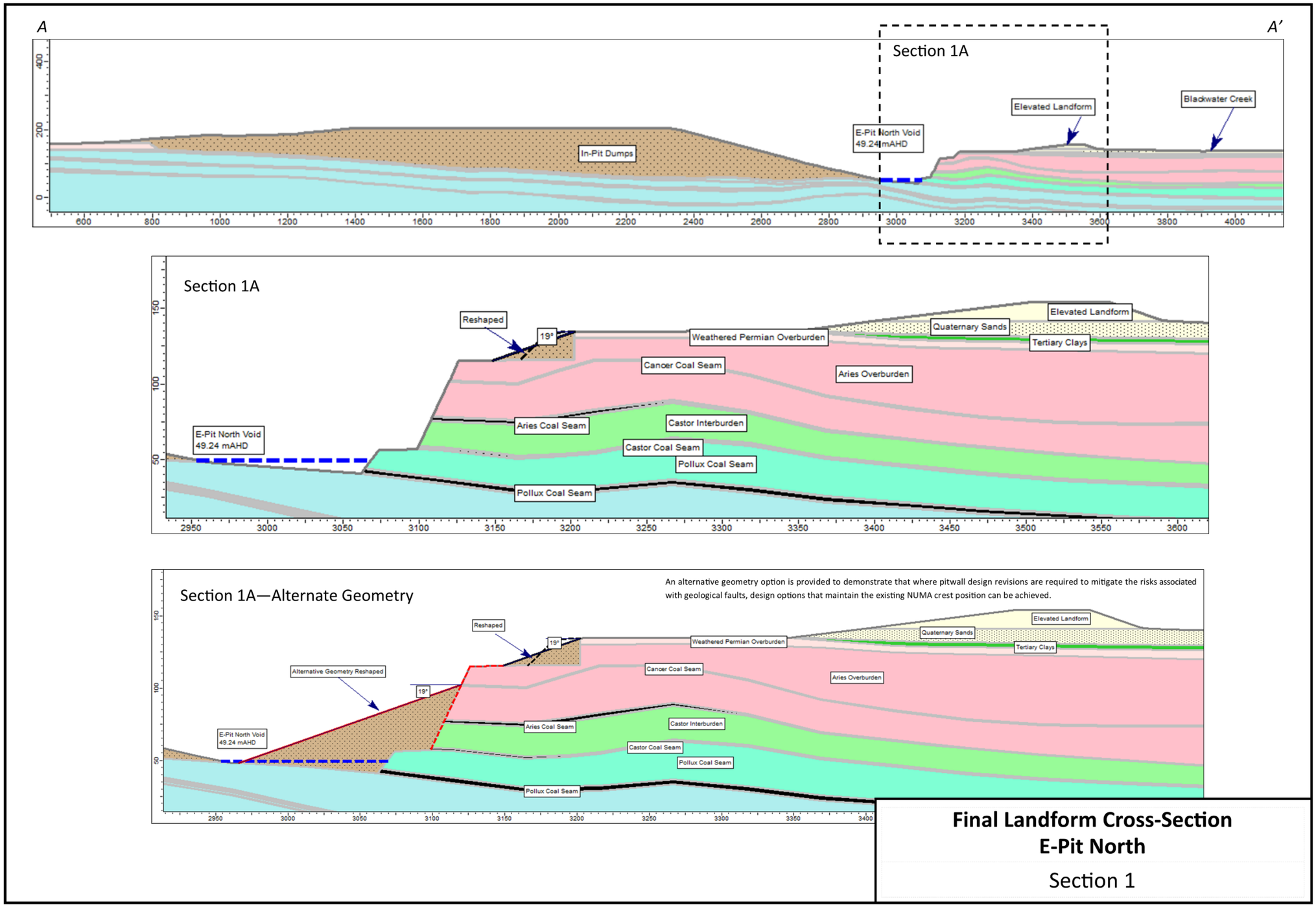



*Figure 4-17 E-Pit North Cross Section 1*

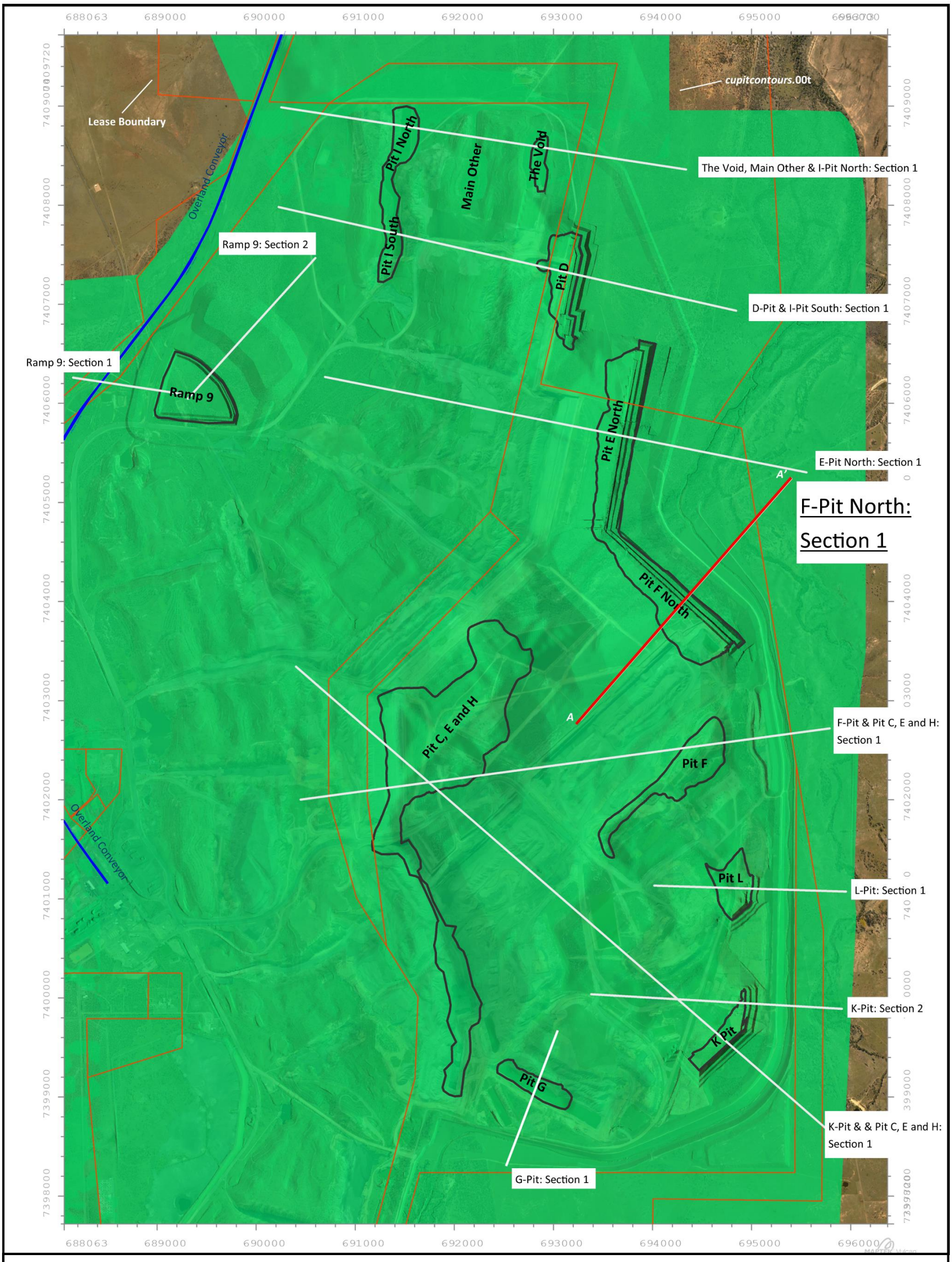



*Figure 4-18 F-Pit North Cross Section 1 Location Plan*

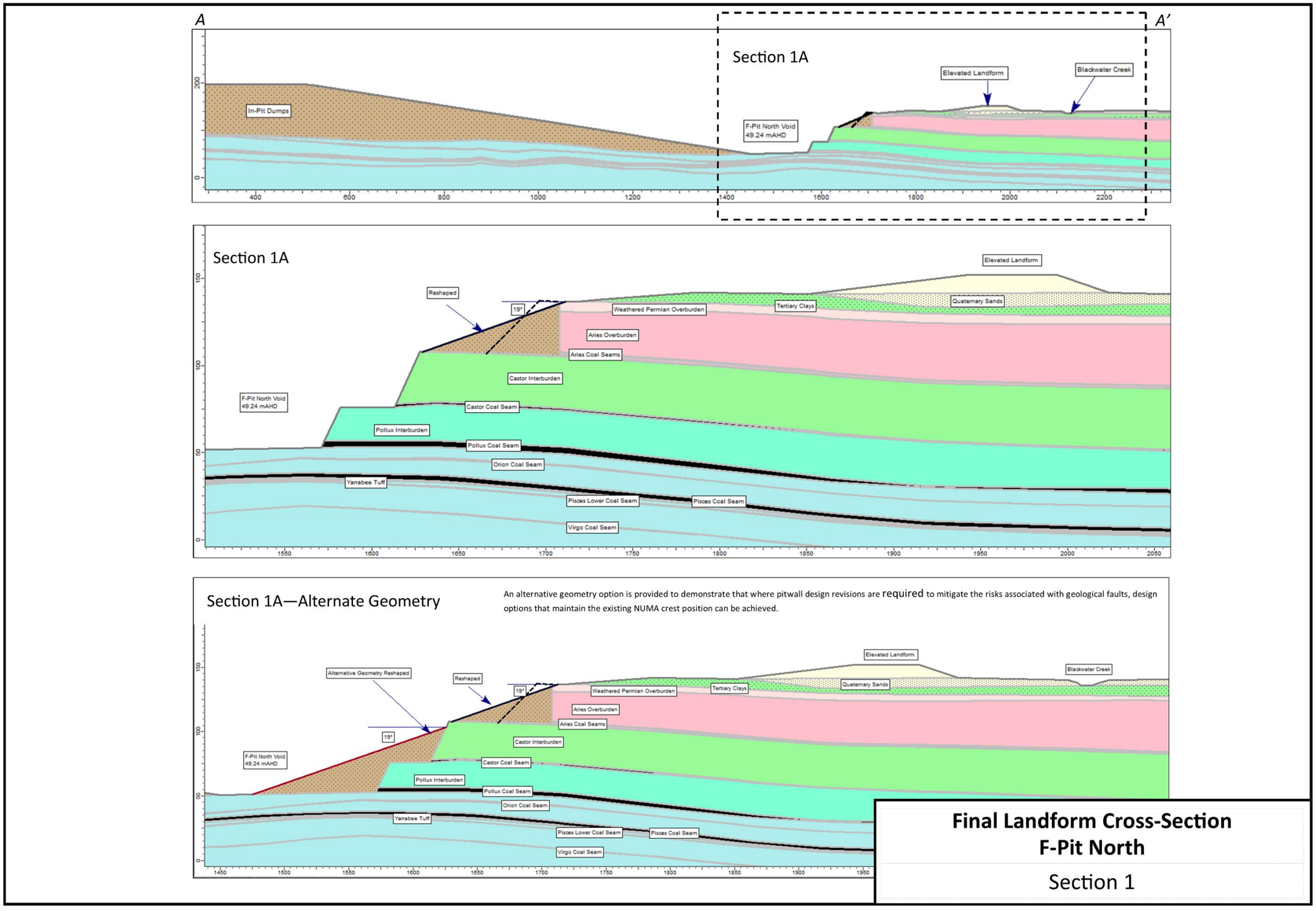
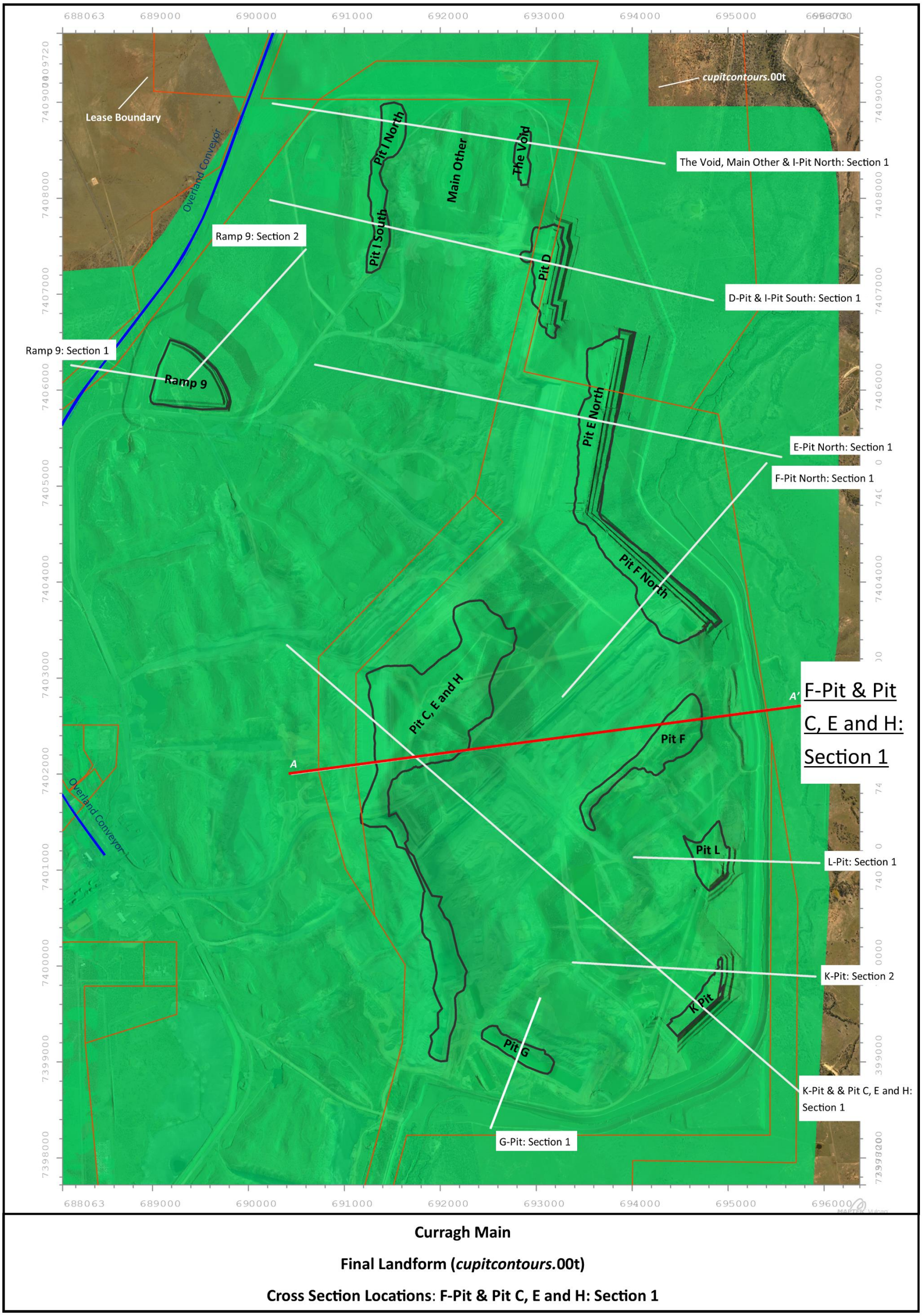



*Figure 4-19 F-Pit North Cross Section 1*




**Curragh Main**

**Final Landform (*cupitcontours*.00t)**

**Cross Section Locations: F-Pit & Pit C, E and H: Section 1**

*Figure 4-20 F-Pit and E, C & H-Pit Void Cross Section 1*

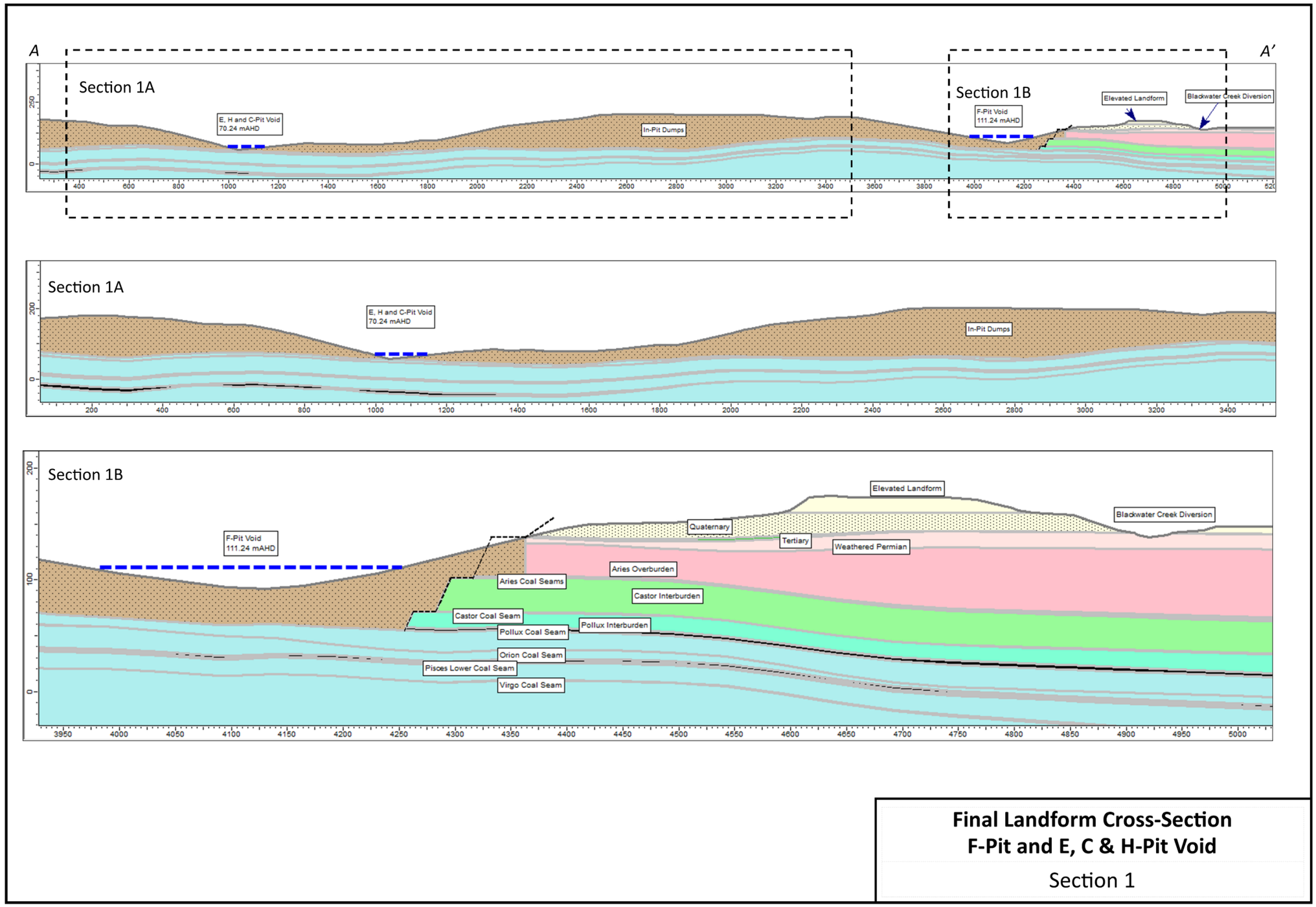
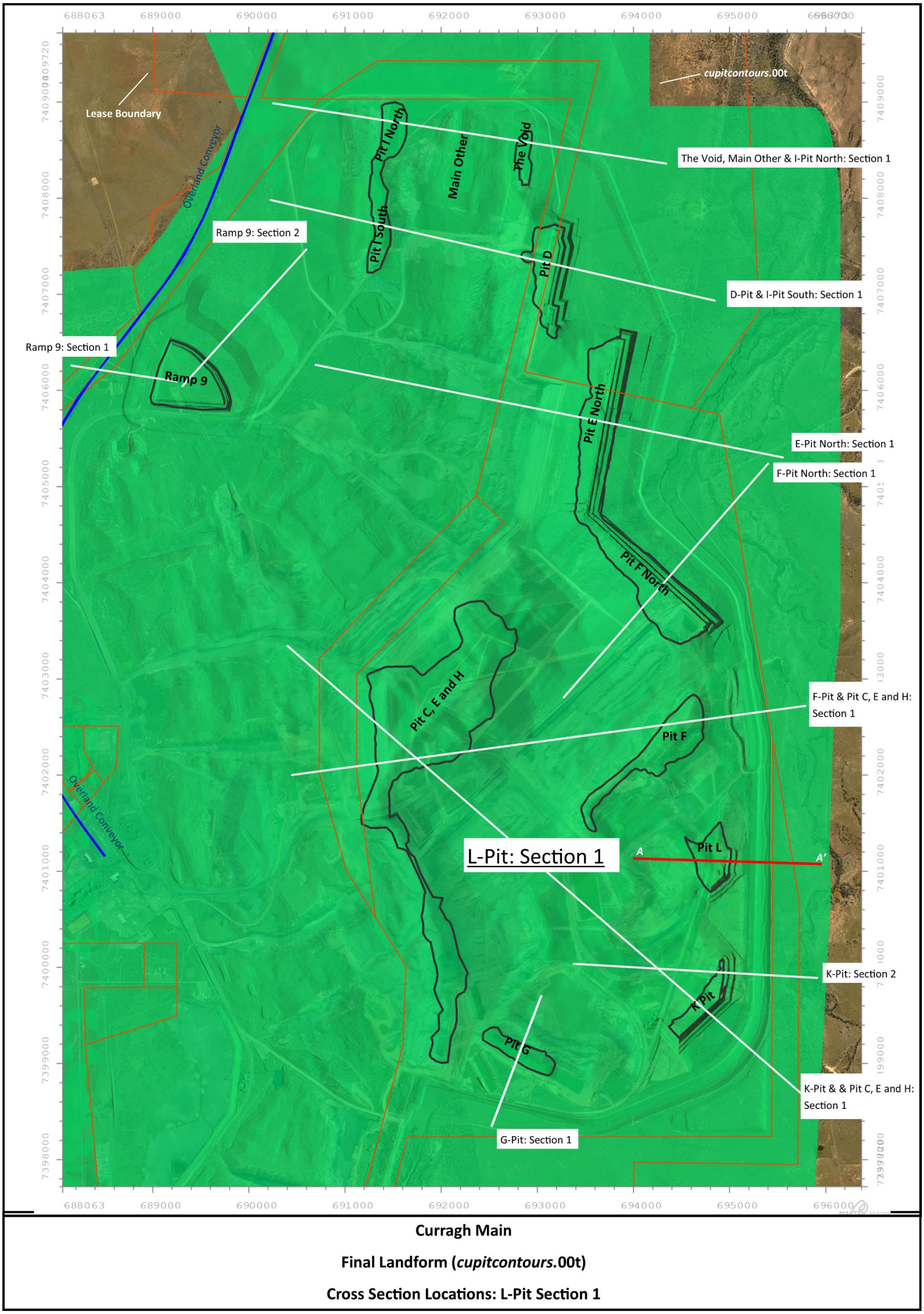



*Figure 4-21 F-Pit and E, C & H-Pit Void Cross Section 1*




**Curragh Main**

**Final Landform (*cupitcontours*.00t)**

**Cross Section Locations: L-Pit Section 1**

*Figure 4-22 L-Pit Cross Section Location Plan*

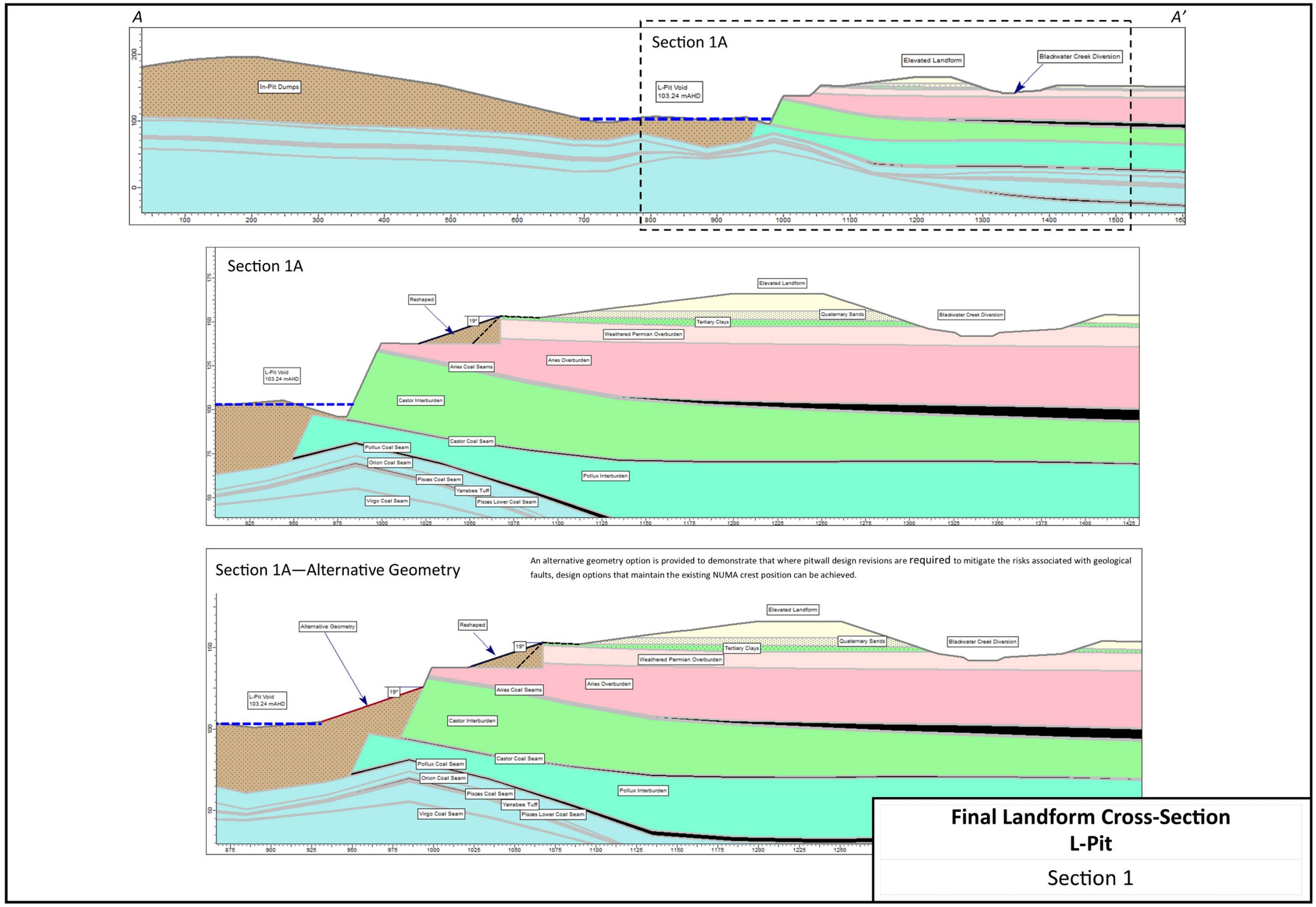
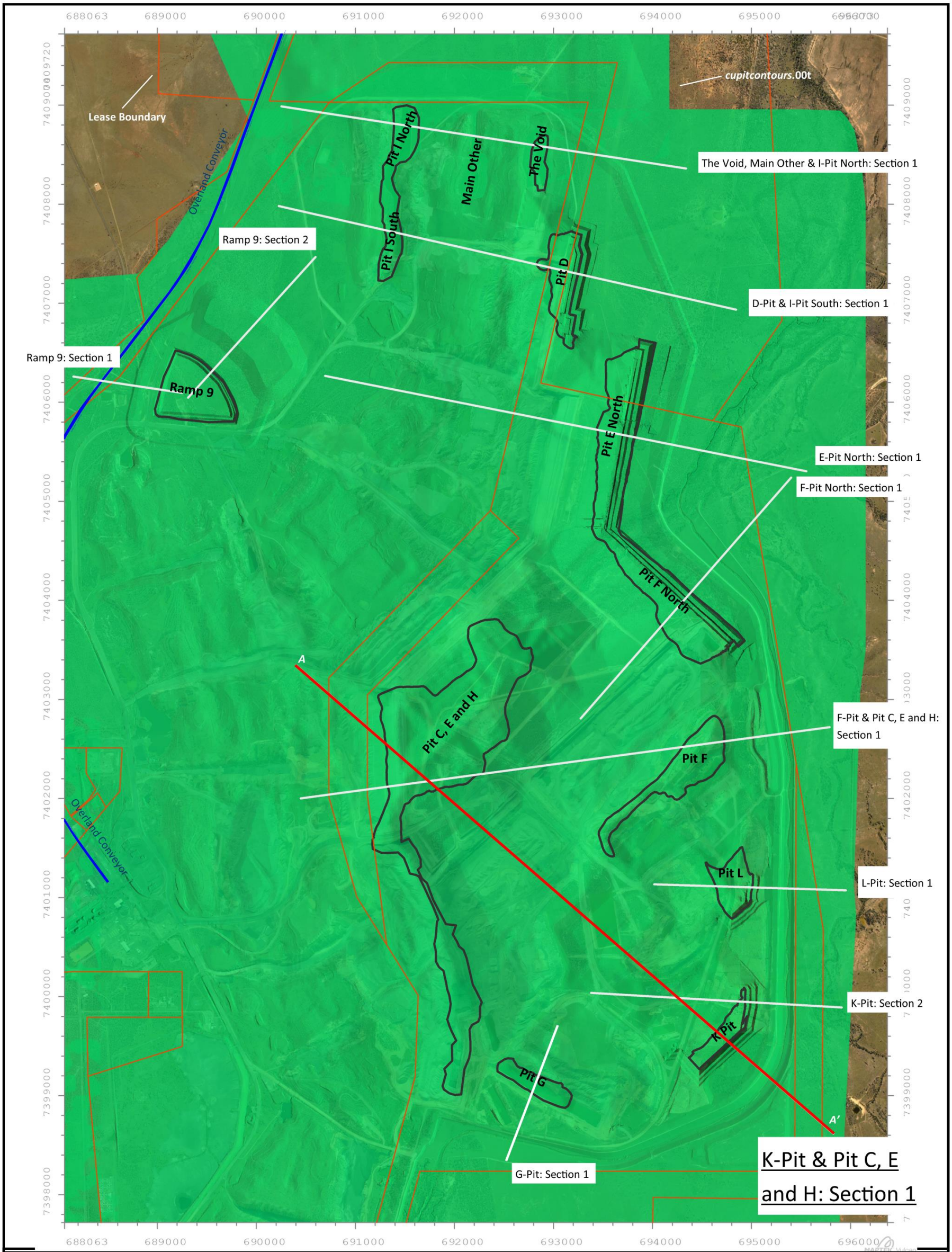



*Figure 4-23 L-Pit Cross Section 1*




**Curragh Main**

**Final Landform (*cupitcontours*.00t)**

**Cross Section Locations: K-Pit and Pit C, E and H: Section 1**

*Figure 4-24 K-Pit and E, C & H-Pit Void Cross Section 1 Location Plan*

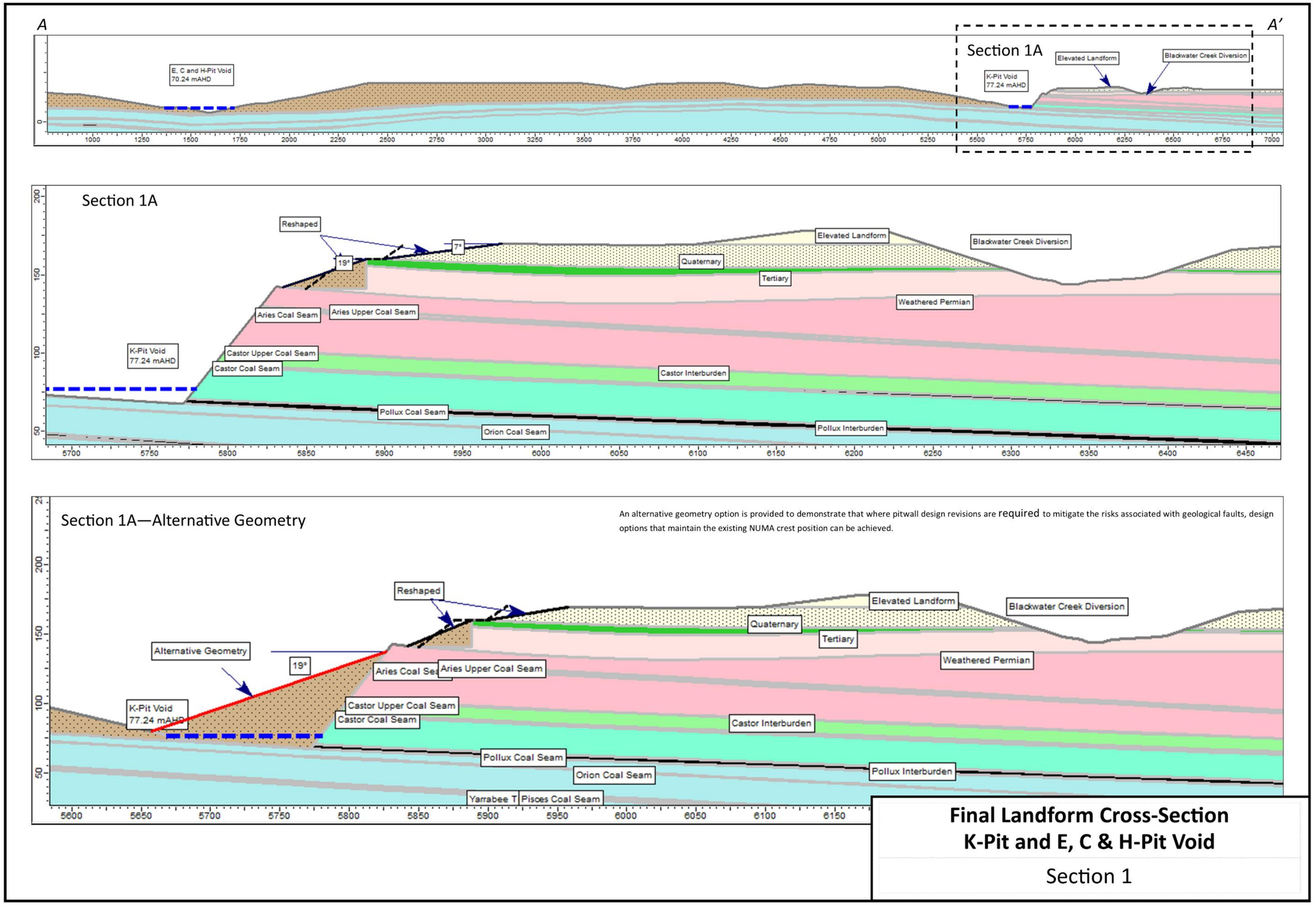



*Figure 4-25 K-Pit and E, C & H-Pit Void Cross Section 1*

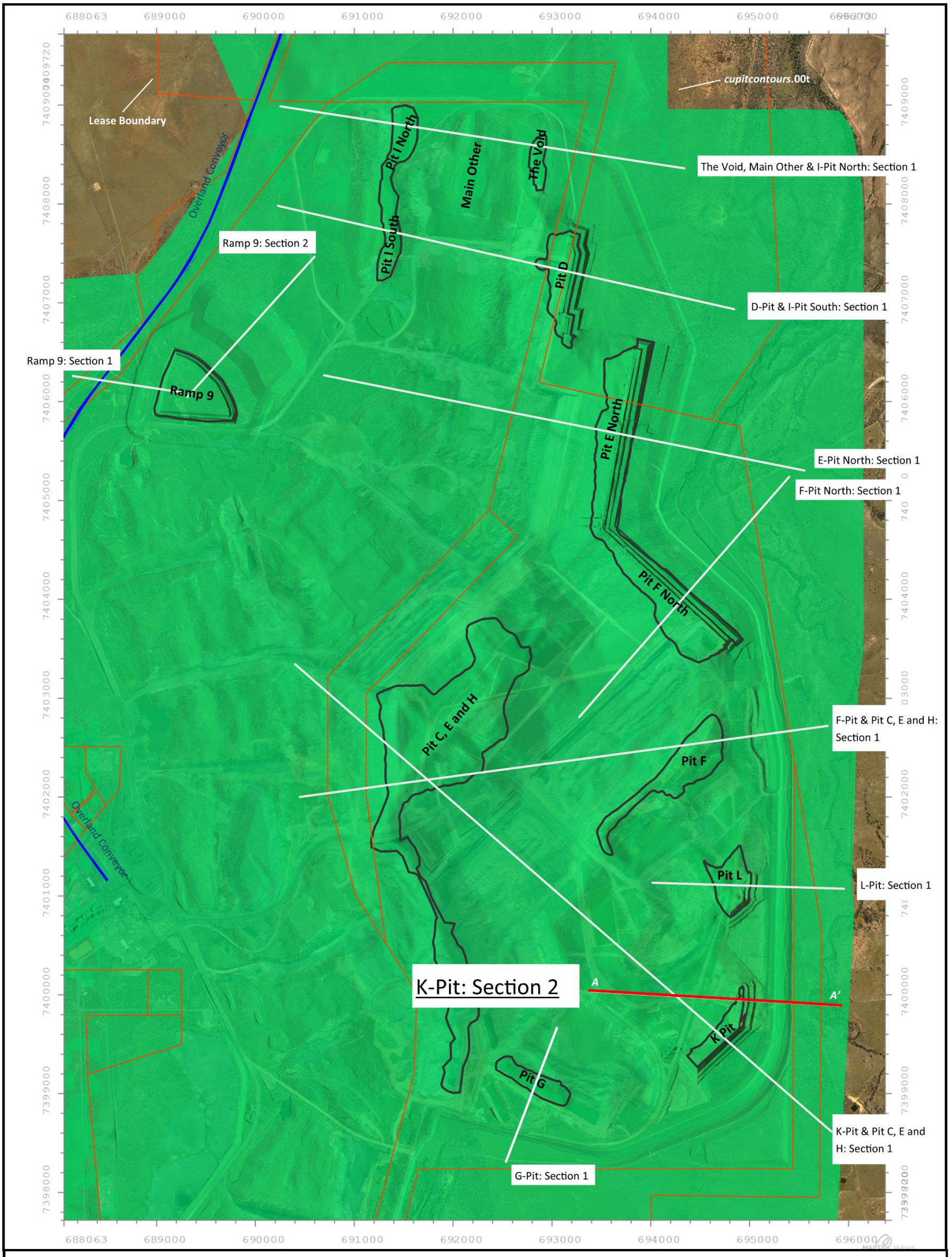



*Figure 4-26 K-Pit Cross Section 2 Location Plan*

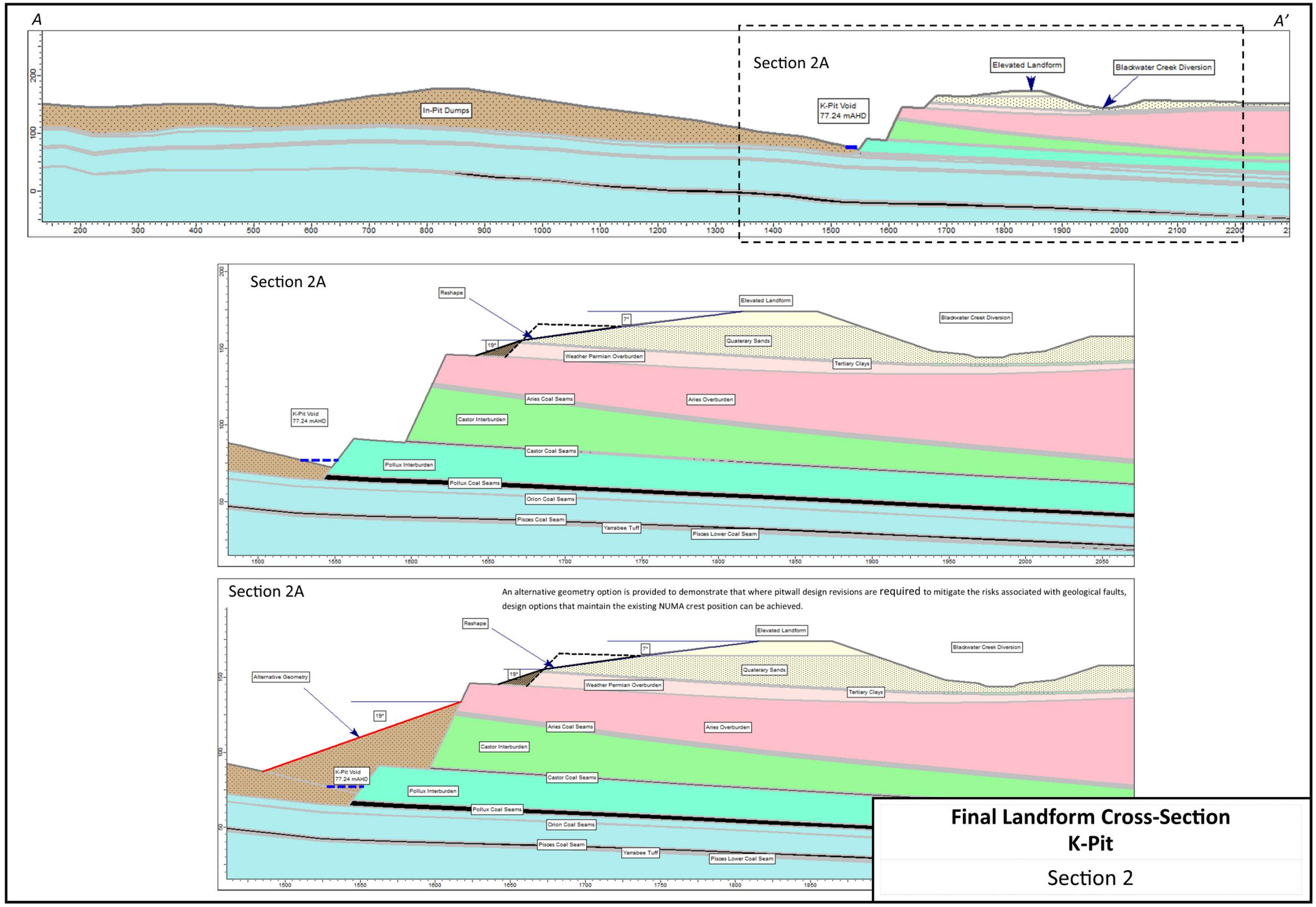
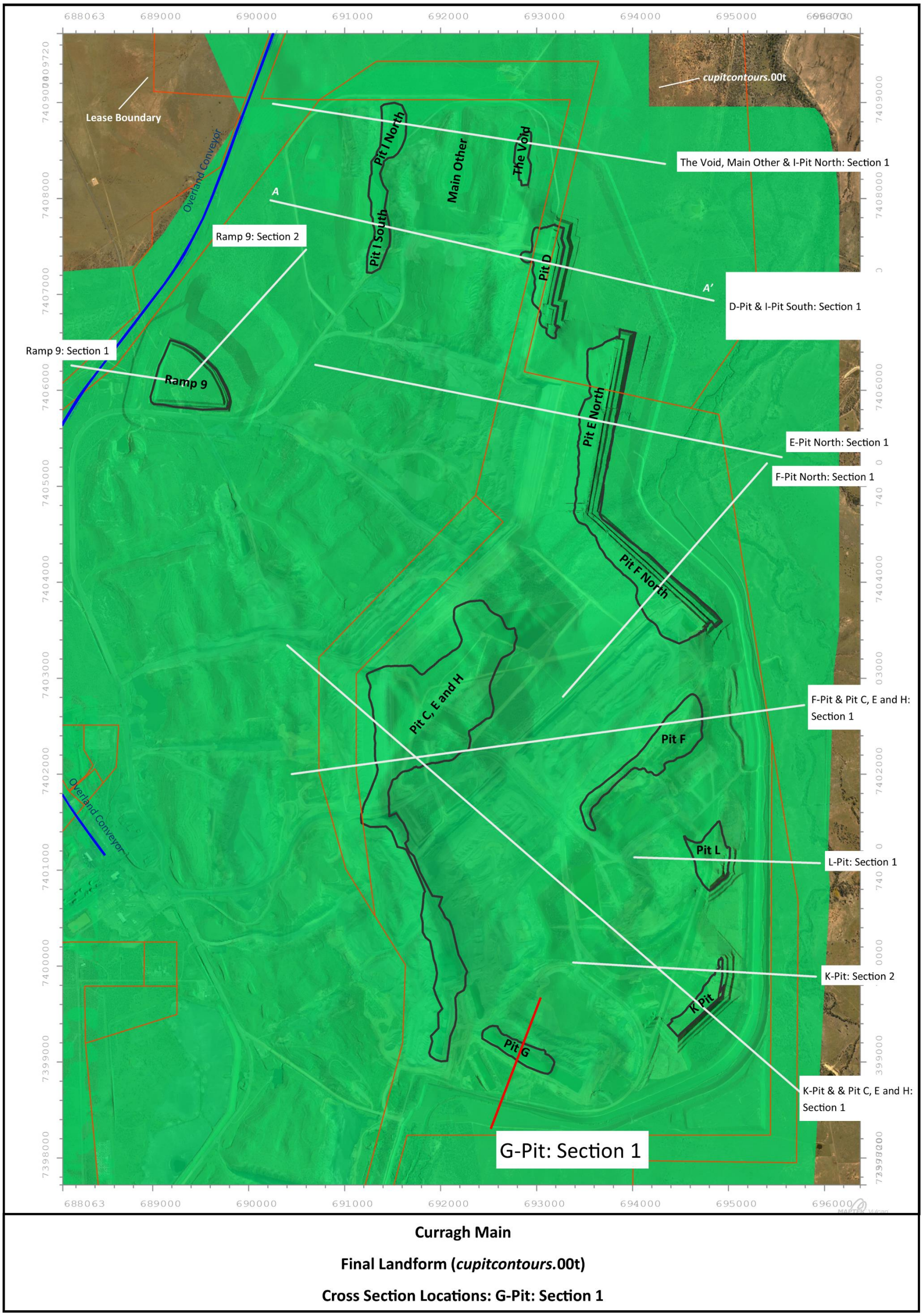



*Figure 4-27 K-Pit Cross Section 2*




**Curragh Main**

**Final Landform (*cupitcontours*.00t)**

**Cross Section Locations: G-Pit: Section 1**

*Figure 4-28 G-Pit Cross Section 1 Location Plan*

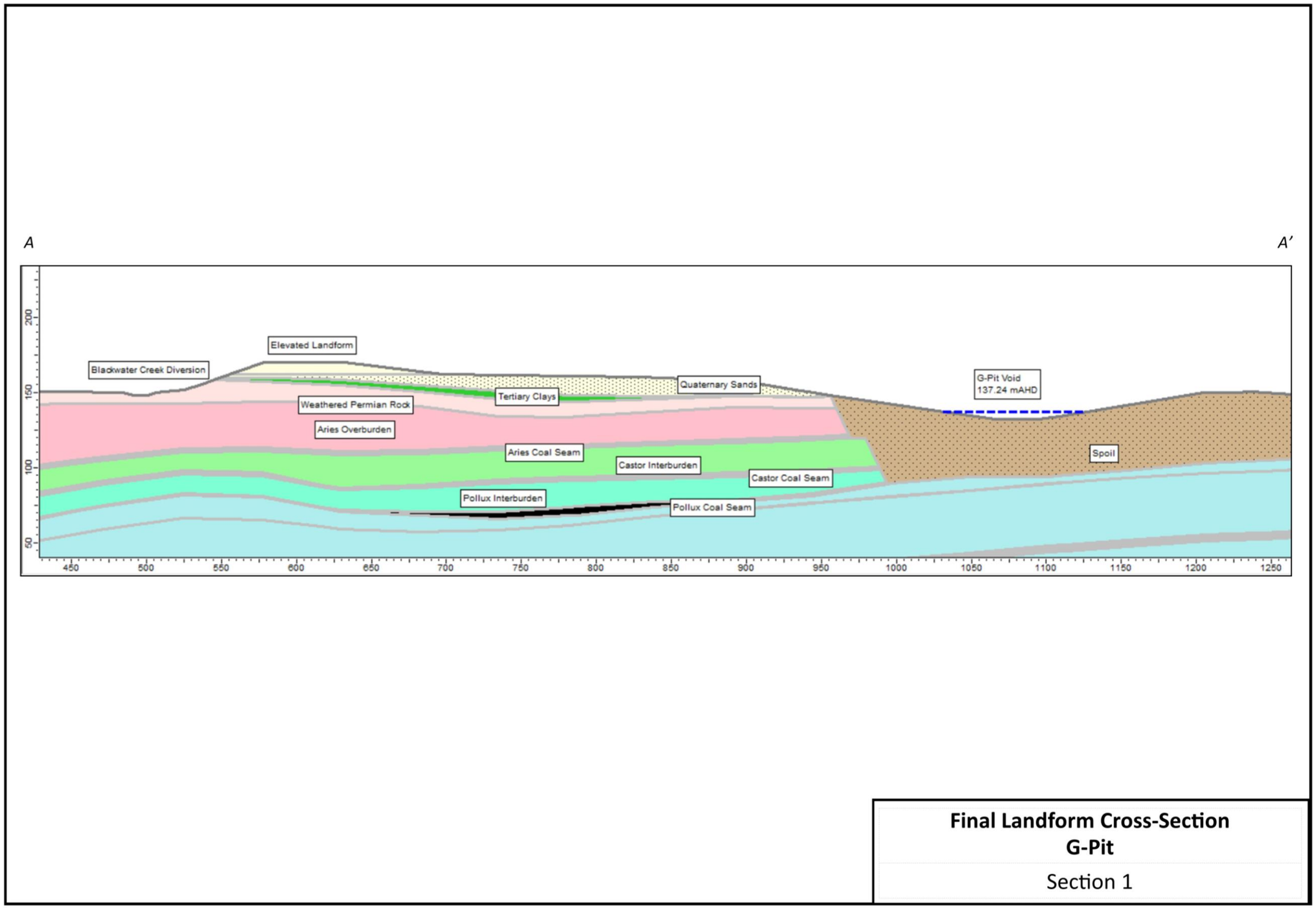



*Figure 4-29 G-Pit Cross Section 1*

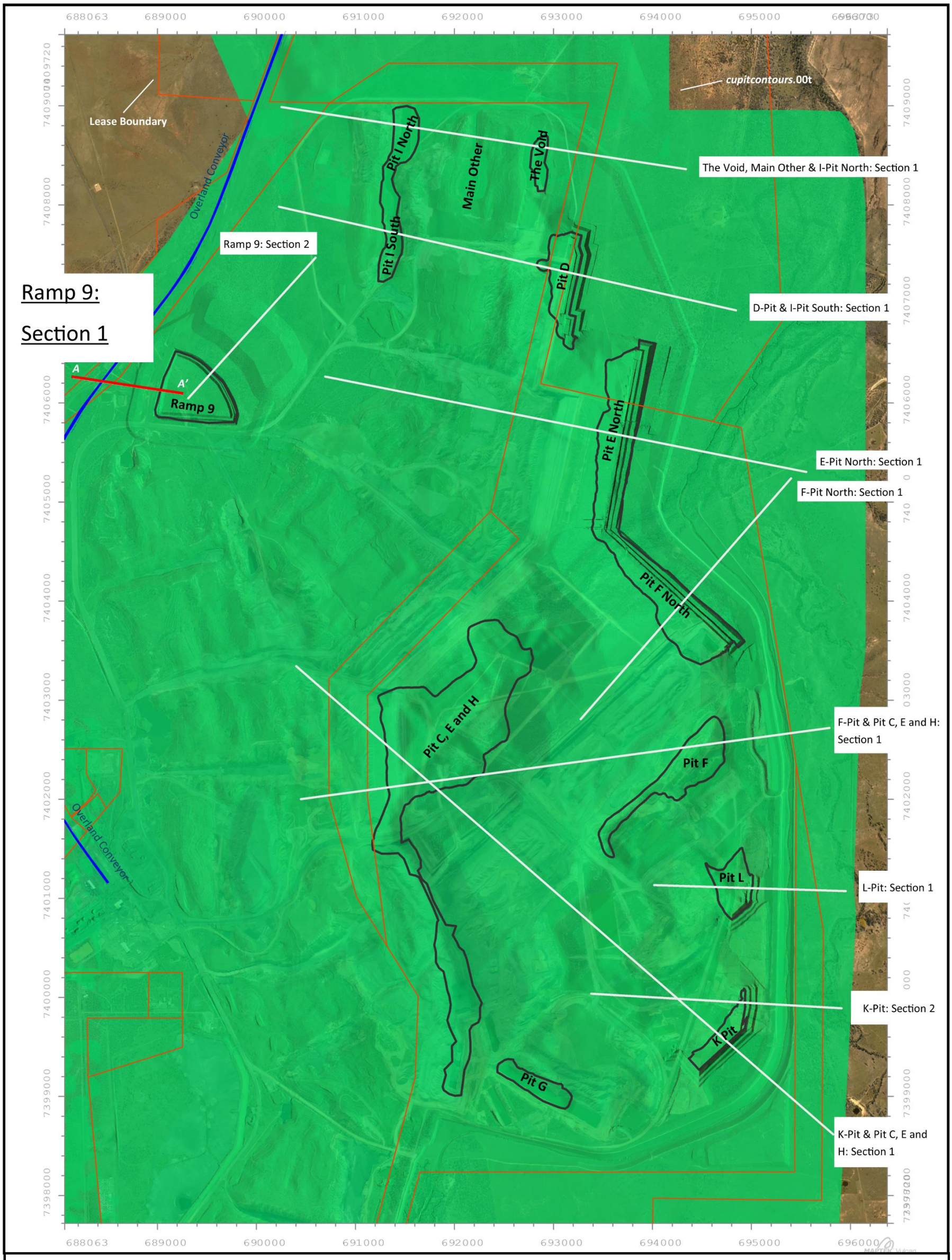



*Figure 4-30 Ramp 9 Cross Section 1 Location Plan*

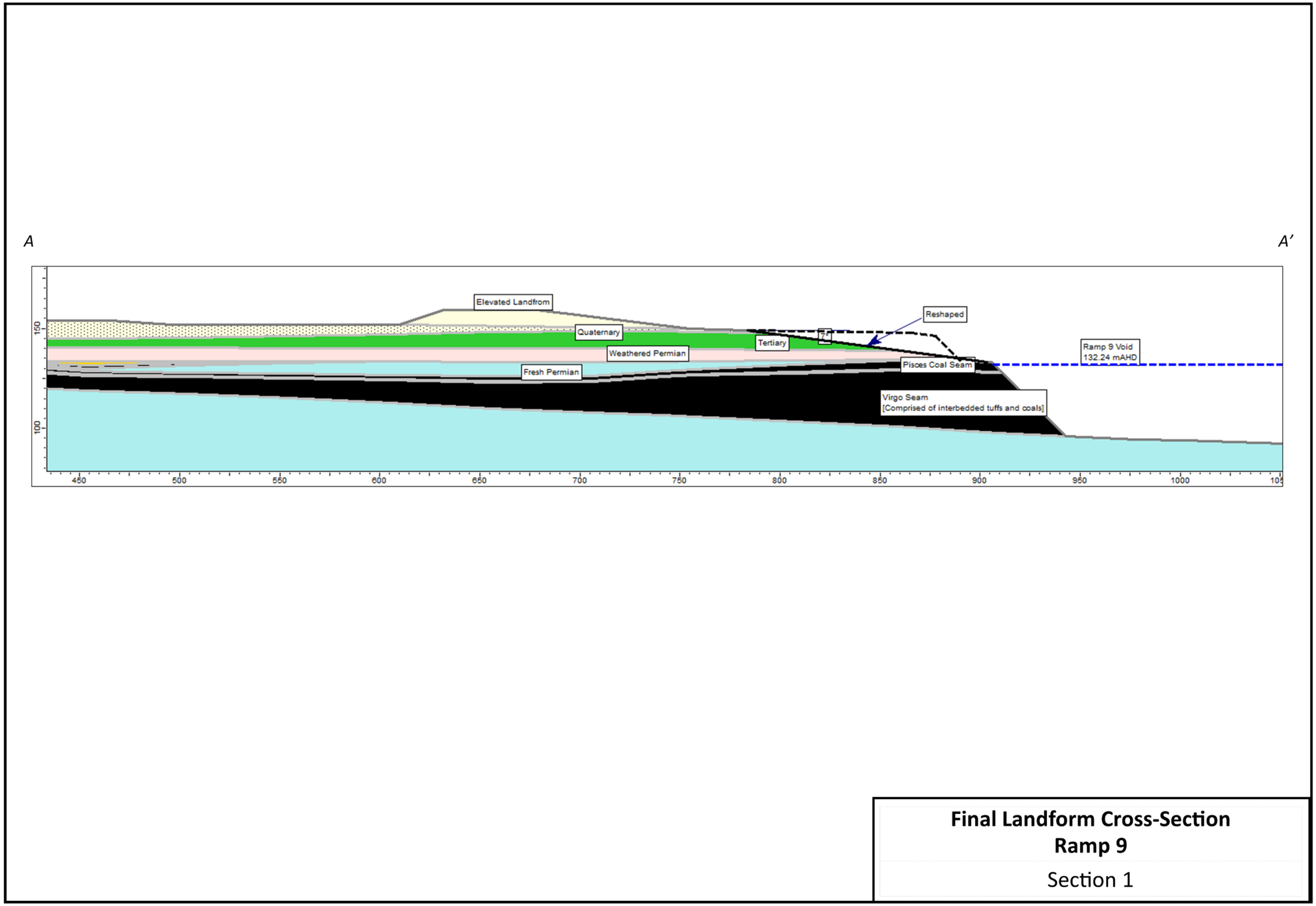



*Figure 4-31 Ramp 9 Cross Section 1*

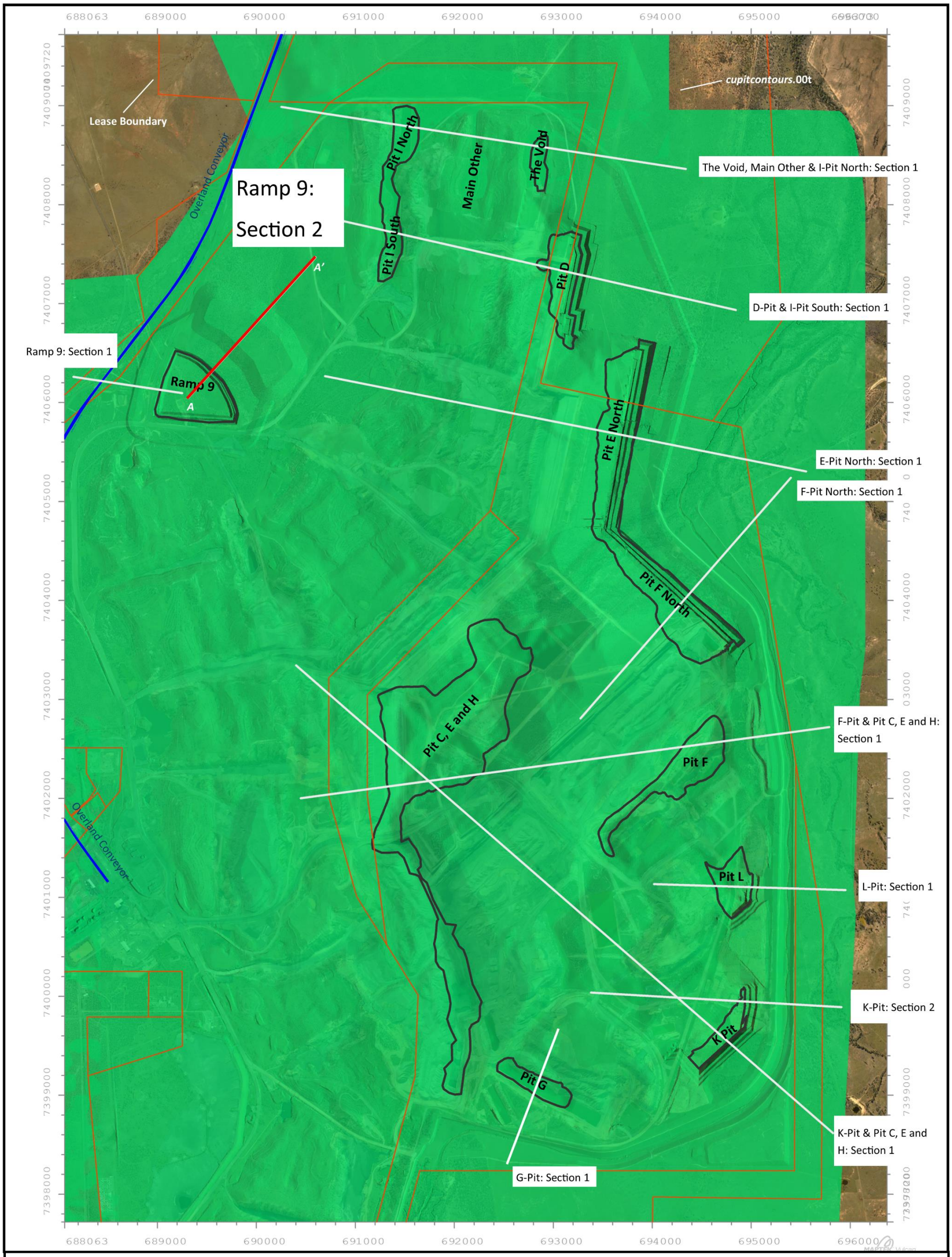
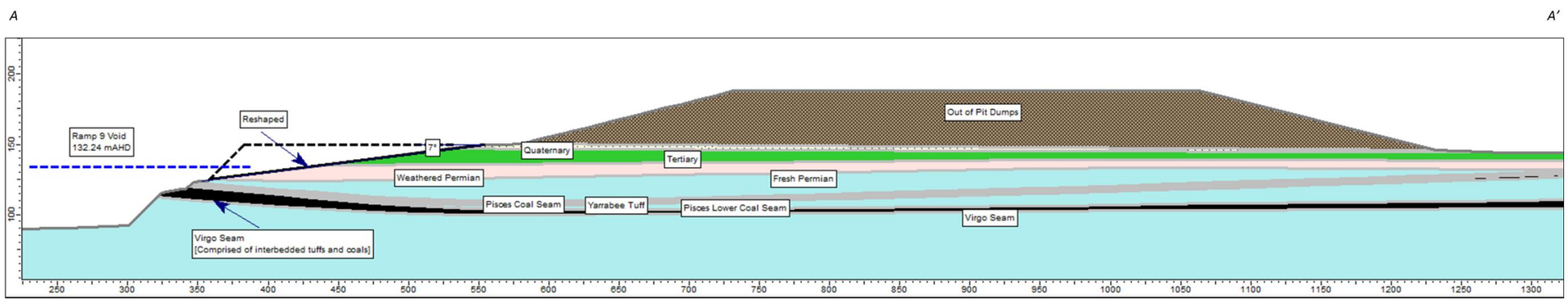


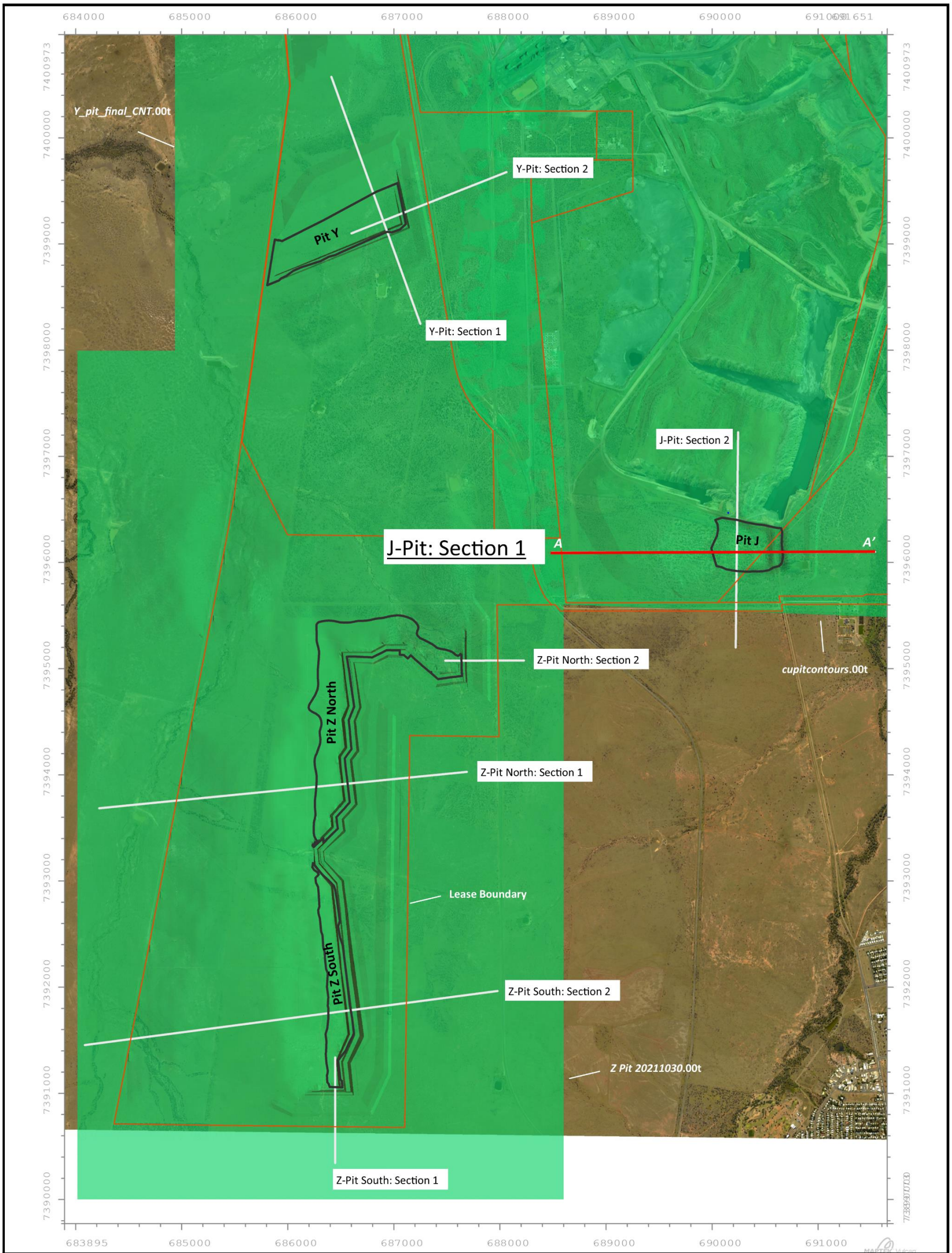

*Figure 4-32 Ramp 9 Cross Section 2 Location Plan*




**Final Landform Cross-Section**
**Ramp 9**

Section 2

*Figure 4-33 Ramp 9 Cross Section 2*




**Curragh West**

**Final Landform (*cupitcontours*.00t, *Y_pit_final_CNT*.00t and *Z Pit 20211030*.00t)**

**Cross Section Locations: J-Pit Section 1**

*Figure 4-34 J-Pit Cross Section 1 Location Plan*

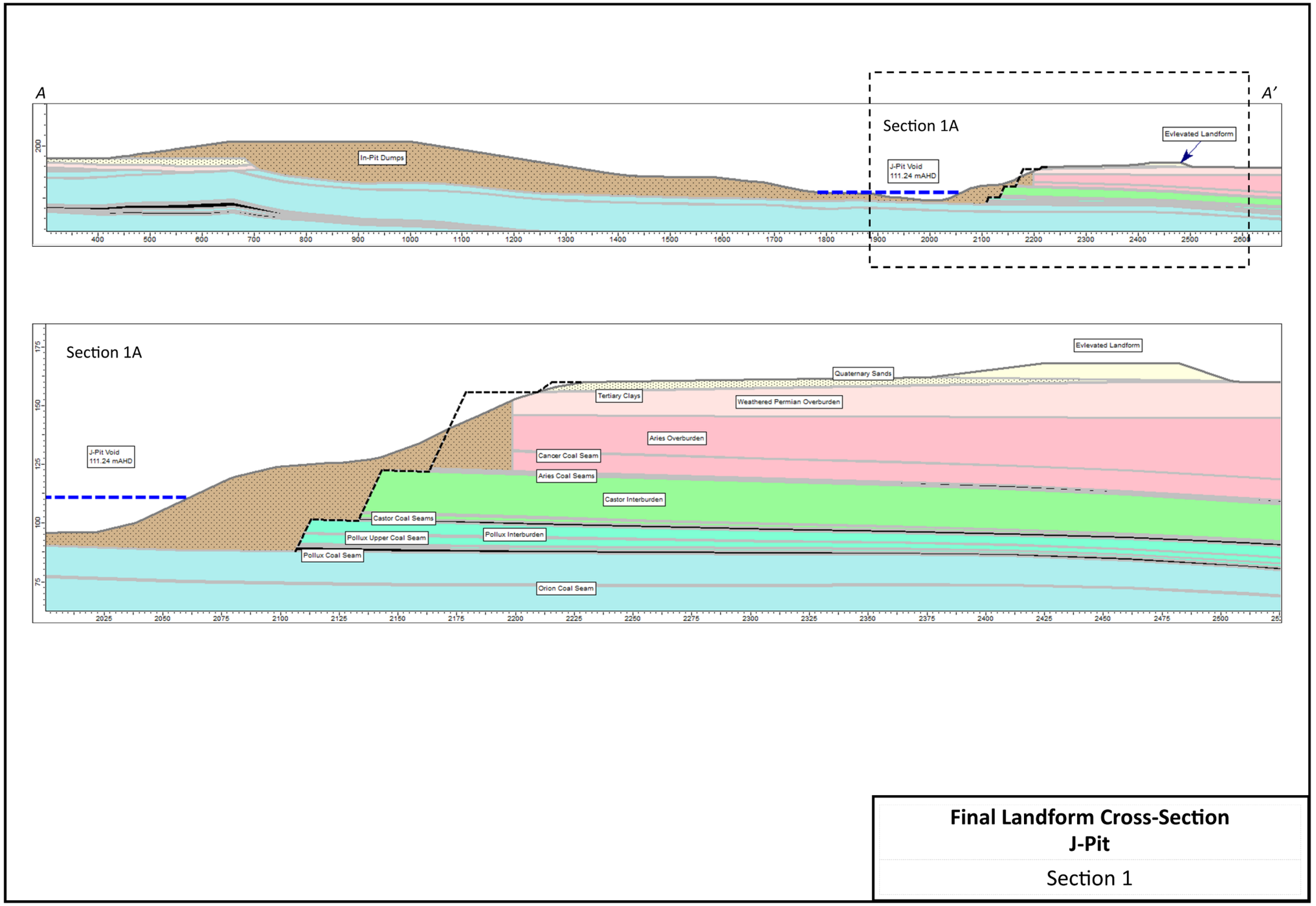
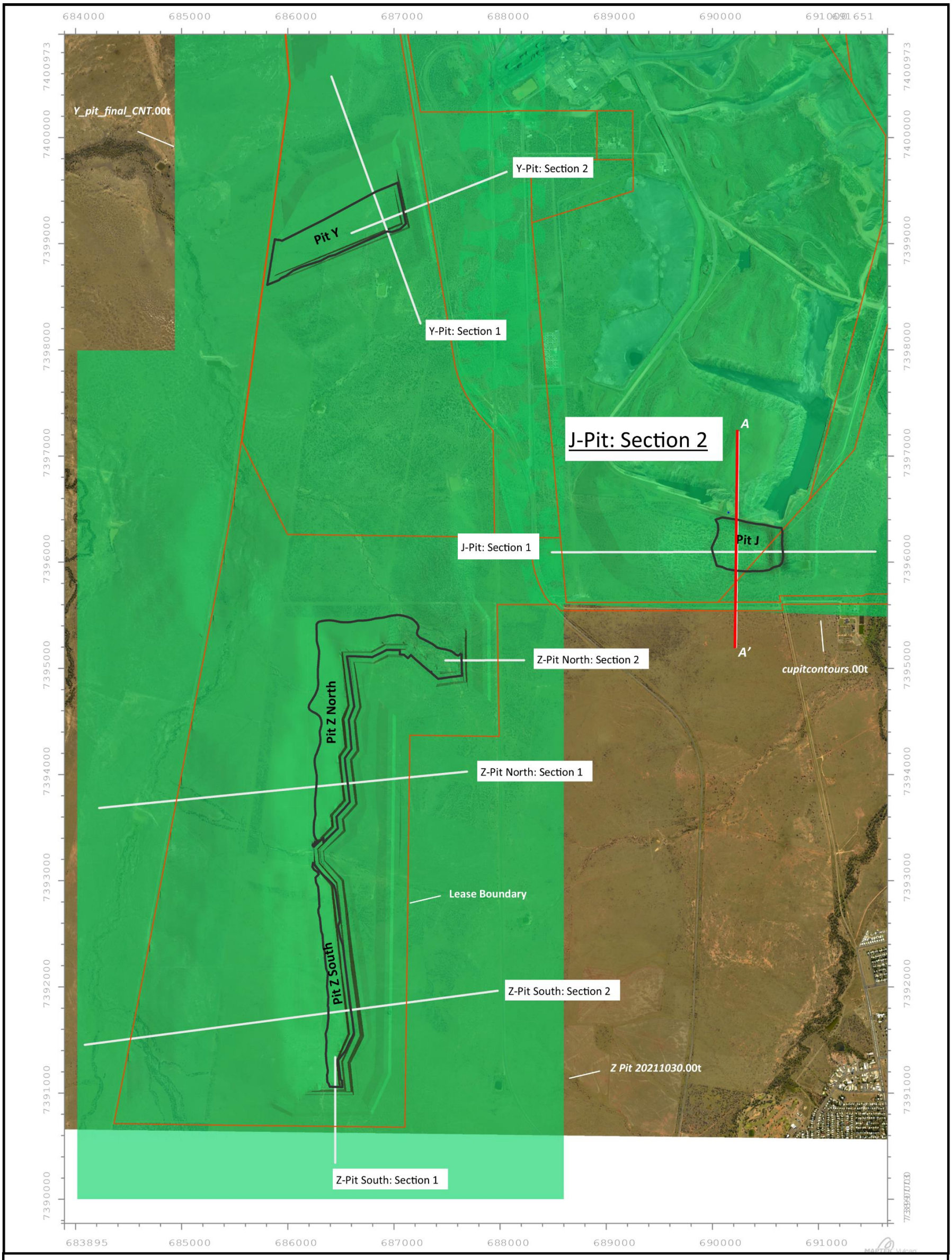



*Figure 4-35 J-Pit Cross Section 1*




**Curragh West**

**Final Landform (*cupitcontours*.00t, *Y_pit_final_CNT*.00t and *Z Pit 20211030*.00t)**

**Cross Section Locations: J-Pit Section 2**

*Figure 4-36 J-Pit Cross Section 2 Location Plan*

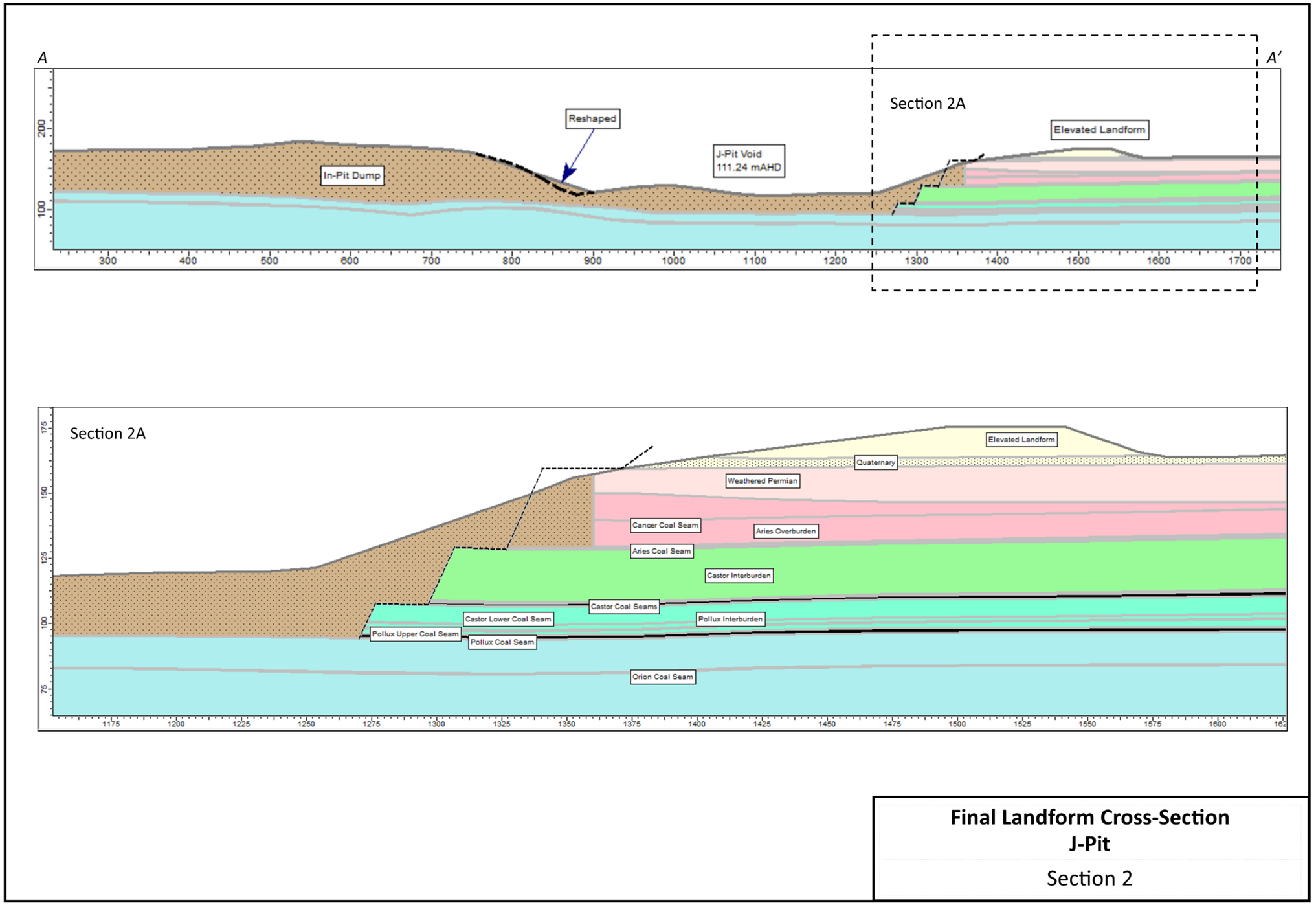
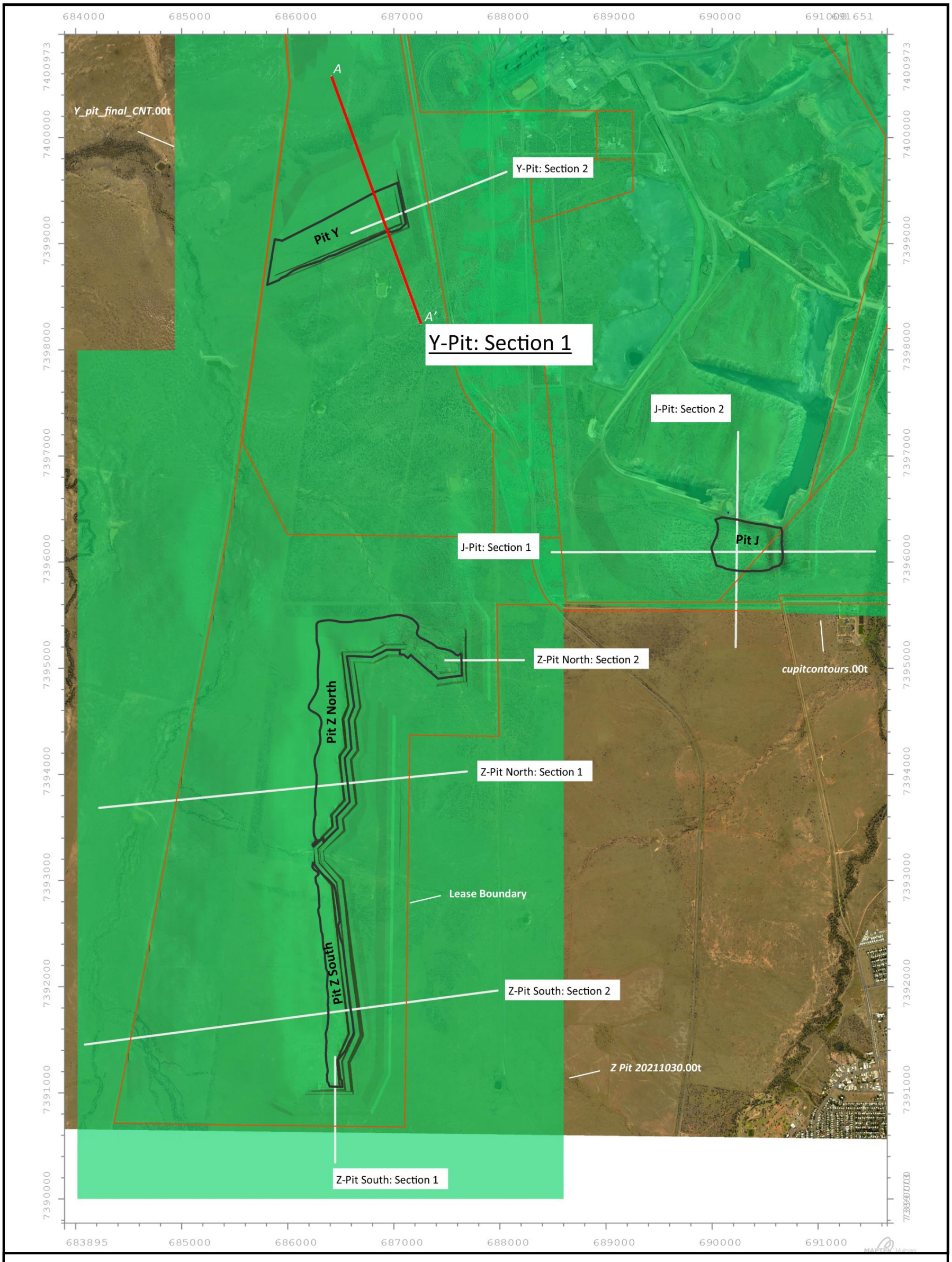



*Figure 4-37 J-Pit Cross Section 2*




**Curragh West**

**Final Landform (*cupitcontours*.00t, *Y_pit_final_CNT*.00t and *Z Pit 20211030*.00t)**

**Cross Section Locations: Y-Pit Section 1**

*Figure 4-38 Y-Pit Cross Section 1 Location Plan*

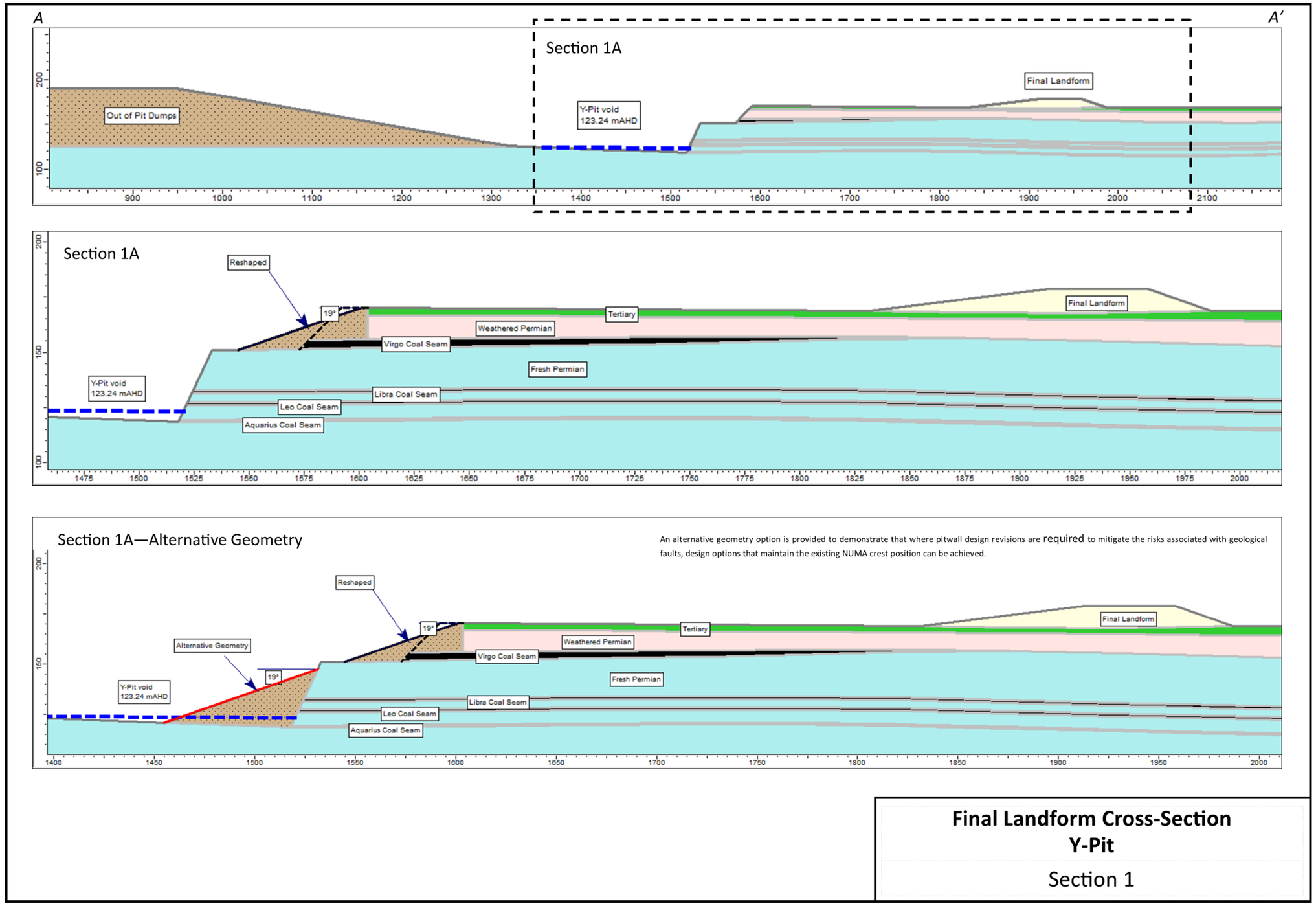
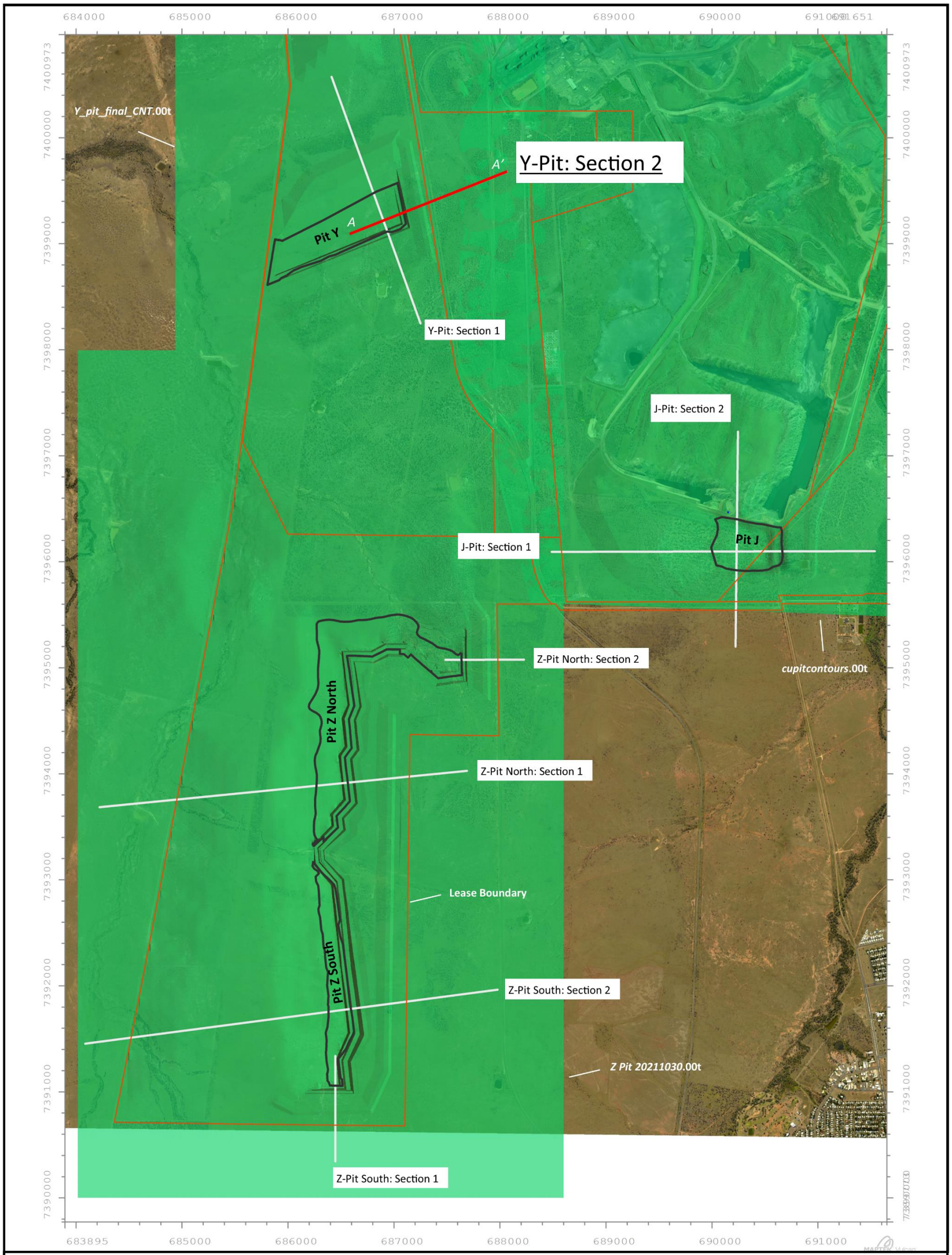



*Figure 4-39 Y-Pit Cross Section 1*




**Curragh West**

**Final Landform (*cupitcontours*.00t, *Y_pit_final_CNT*.00t and *Z Pit 20211030*.00t)**

**Cross Section Locations: Y-Pit Section 2**

*Figure 4-40 Y-Pit Cross Section 2*

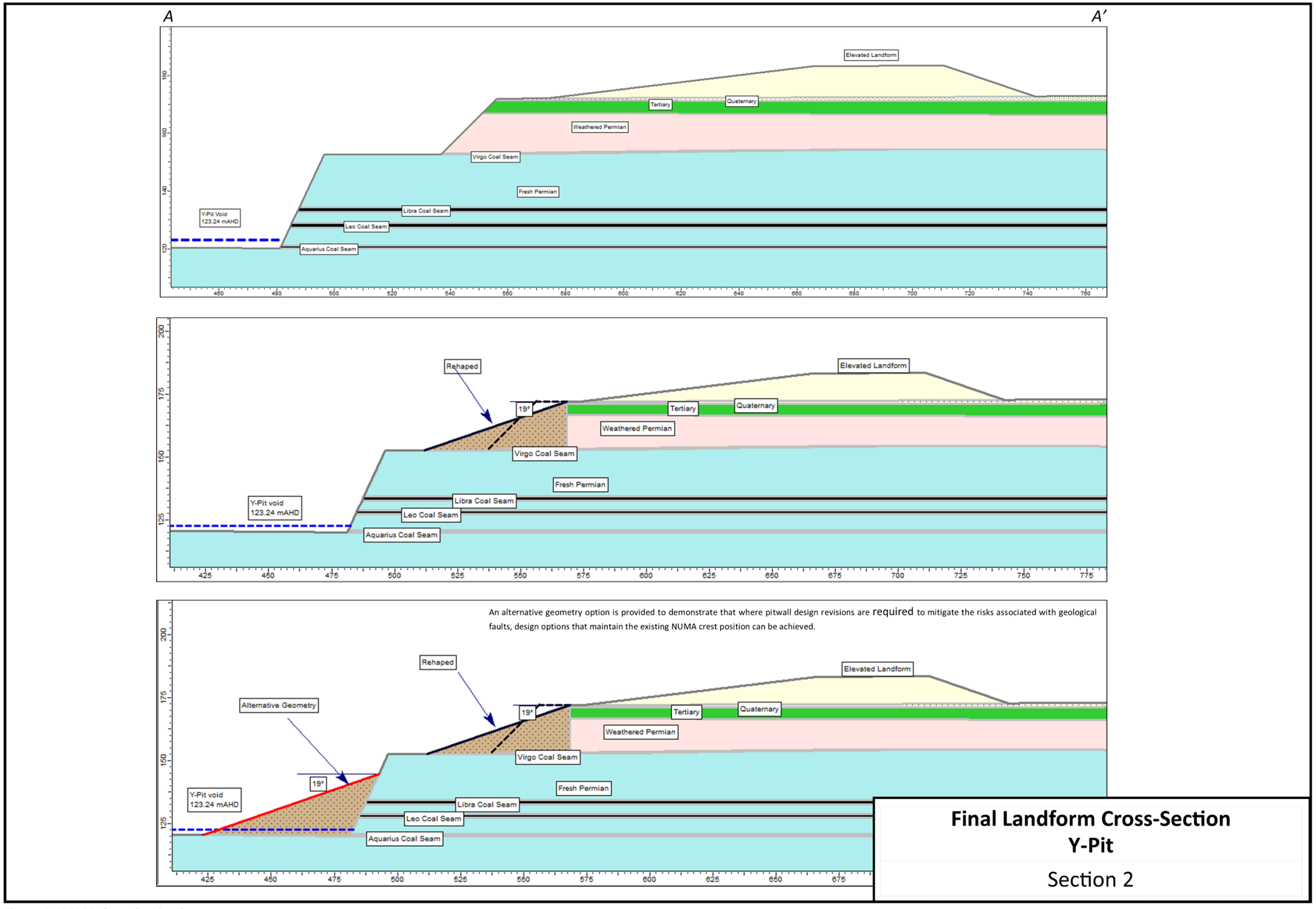
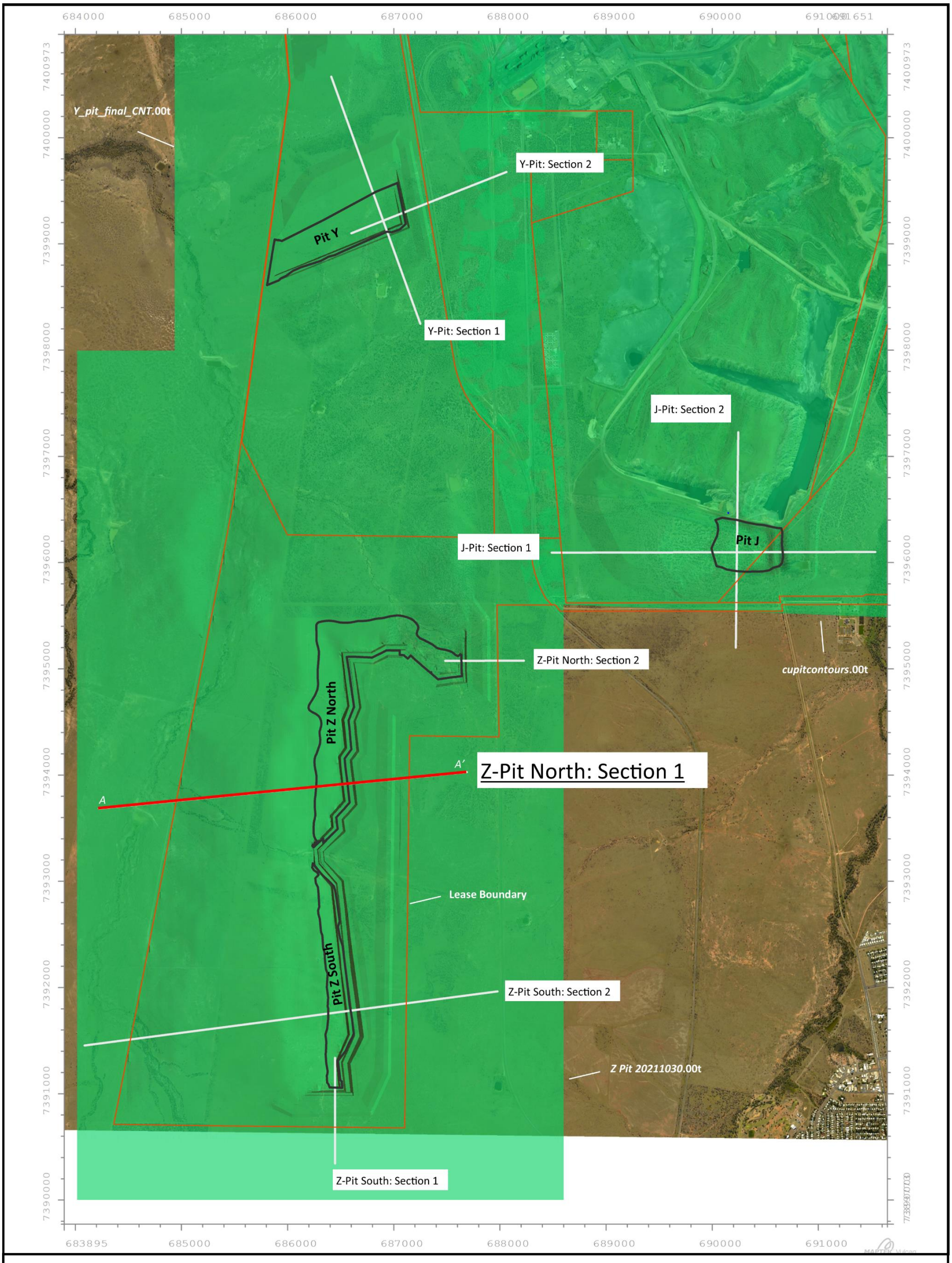



*Figure 4-41 Y-Pit Cross Section 2*




**Curragh West**

**Final Landform (*cupitcontours*.00t, *Y_pit_final_CNT*.00t and *Z Pit 20211030*.00t)**

**Cross Section Locations: Z-Pit North Section 1**

*Figure 4-42 Z-Pit North Cross Section 1 Location Plan*

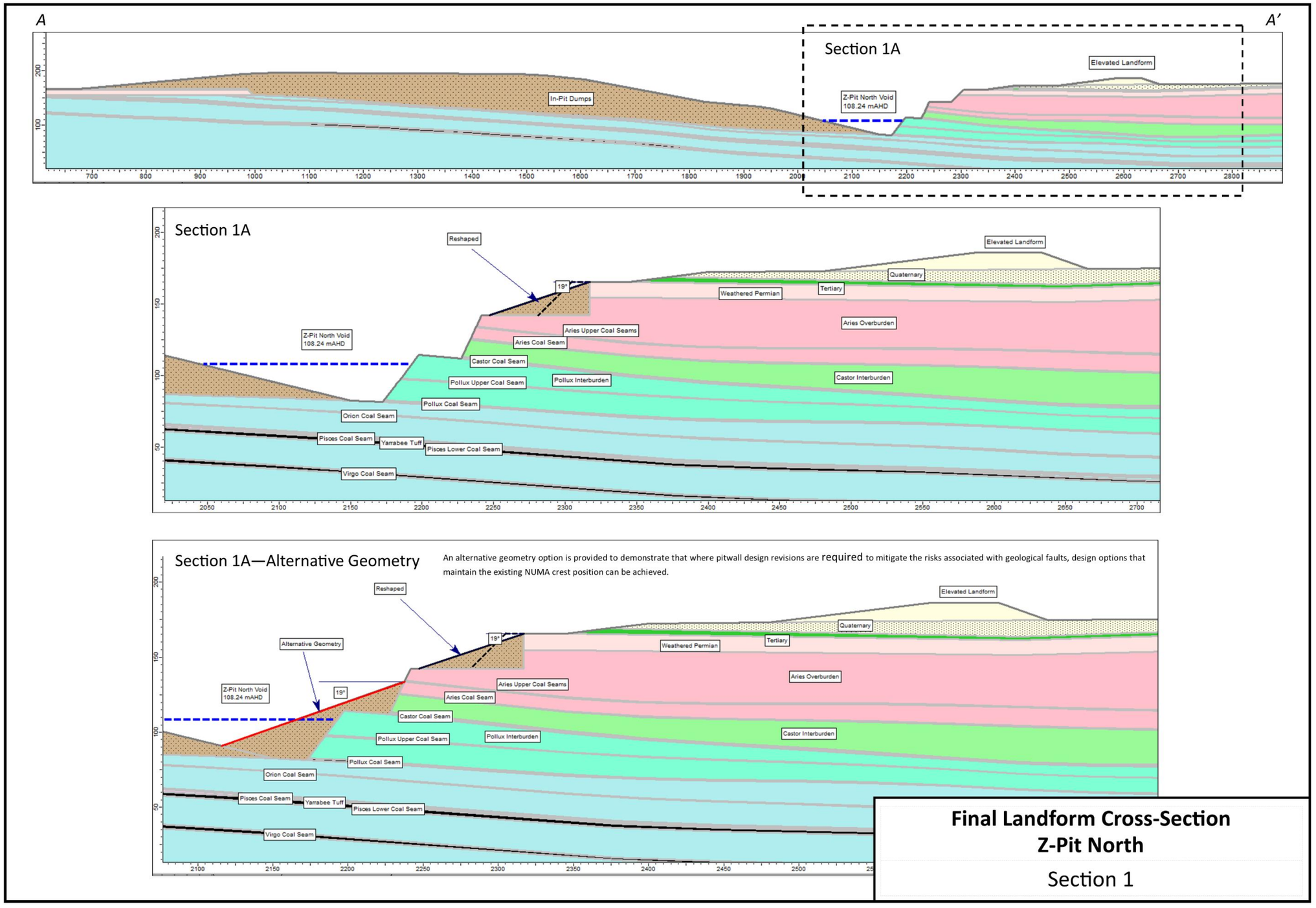
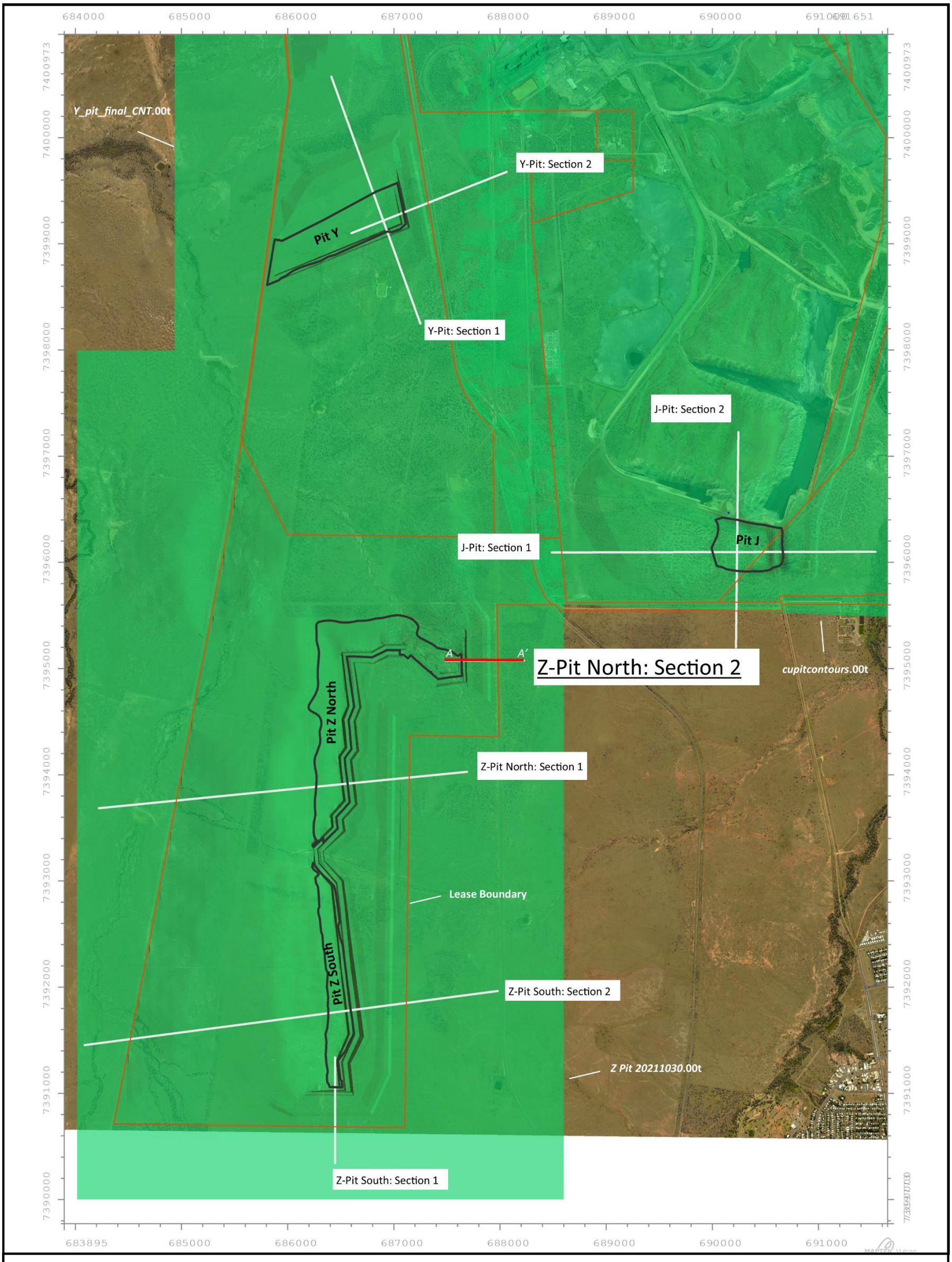



*Figure 4-43 Z-Pit North Cross Section 1*




**Curragh West**

**Final Landform (*cupitcontours*.00t, *Y_pit_final_CNT*.00t and *Z Pit 20211030*.00t)**

**Cross Section Locations: Z-Pit North Section 2**

*Figure 4-44 Z-Pit North Cross Section 2 Location Plan*

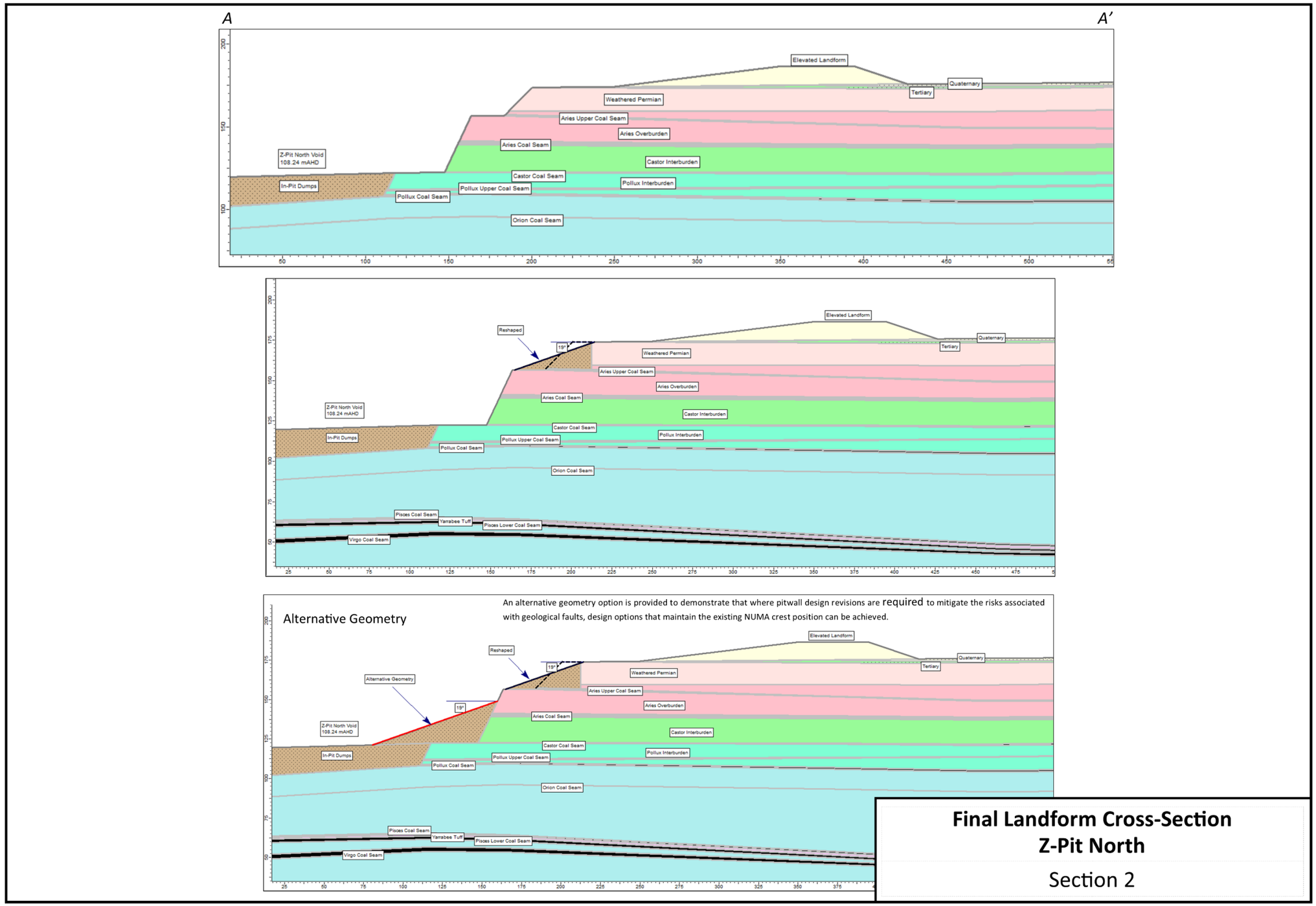
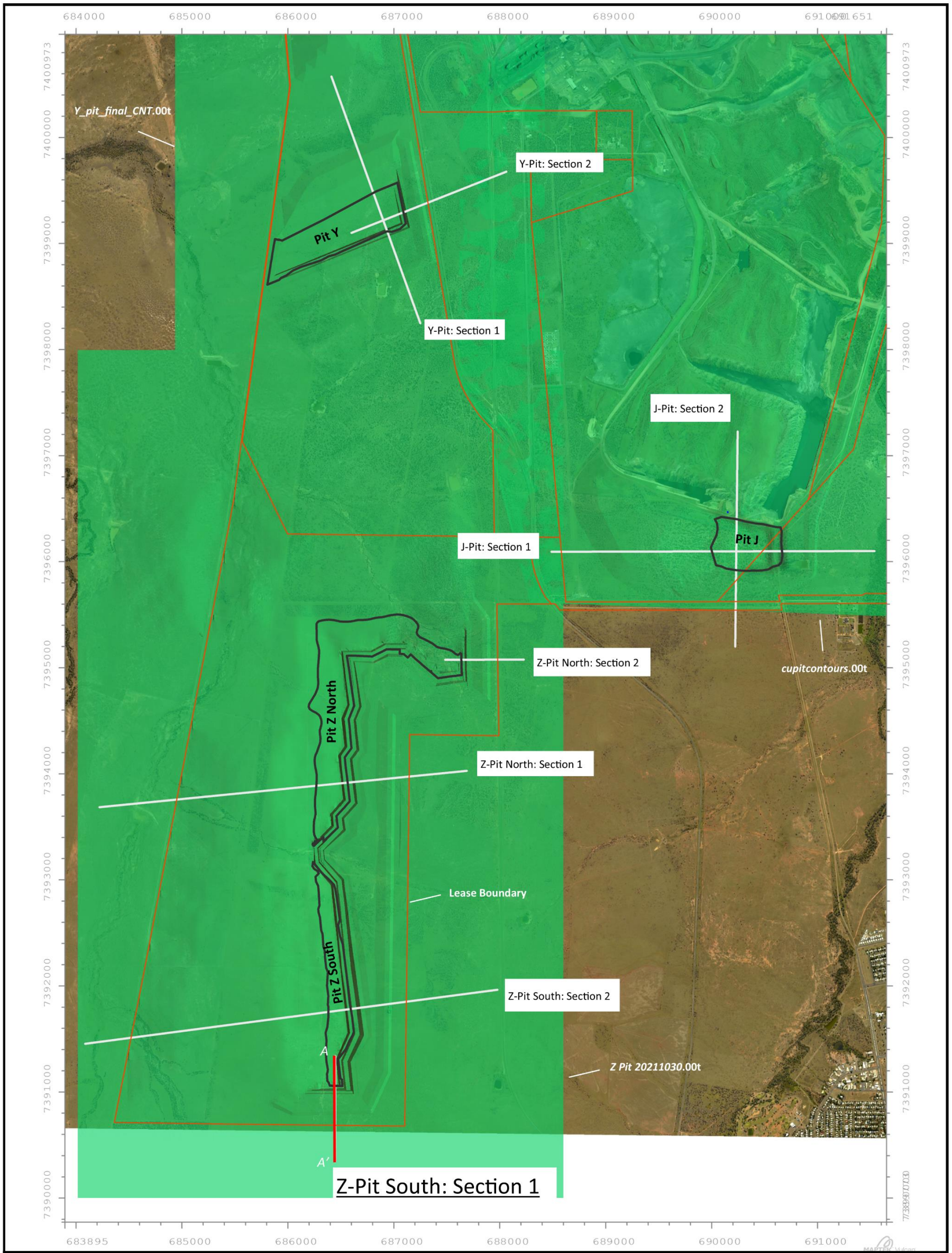



*Figure 4-45 Z-Pit North Cross Section 2*




**Curragh West**

**Final Landform (*cupitcontours*.00t, *Y_pit_final_CNT*.00t and *Z Pit 20211030*.00t)**

**Cross Section Locations: Z-Pit South Section 1**

*Figure 4-46 Z-Pit South Cross Section 1 Location Plan*

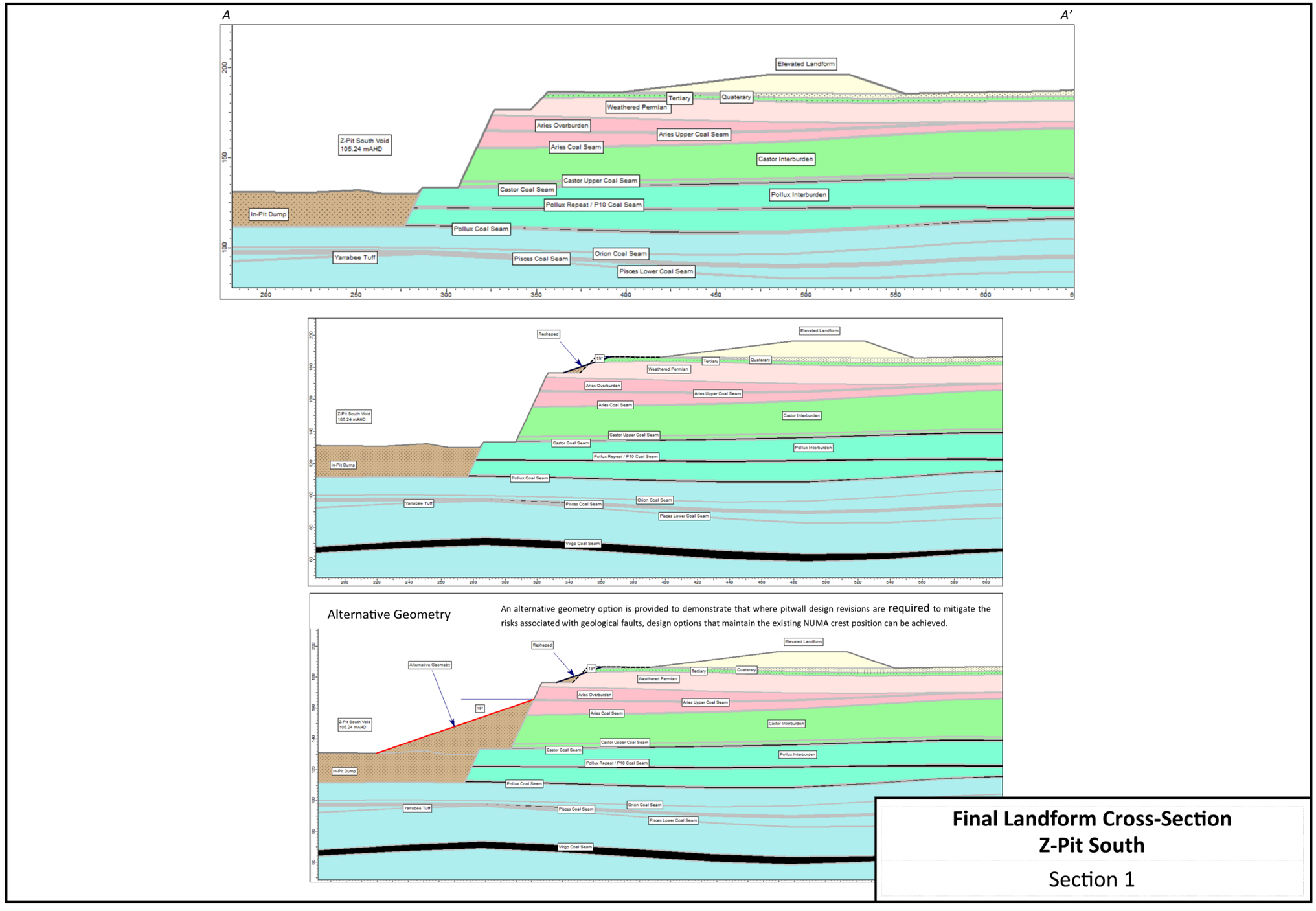
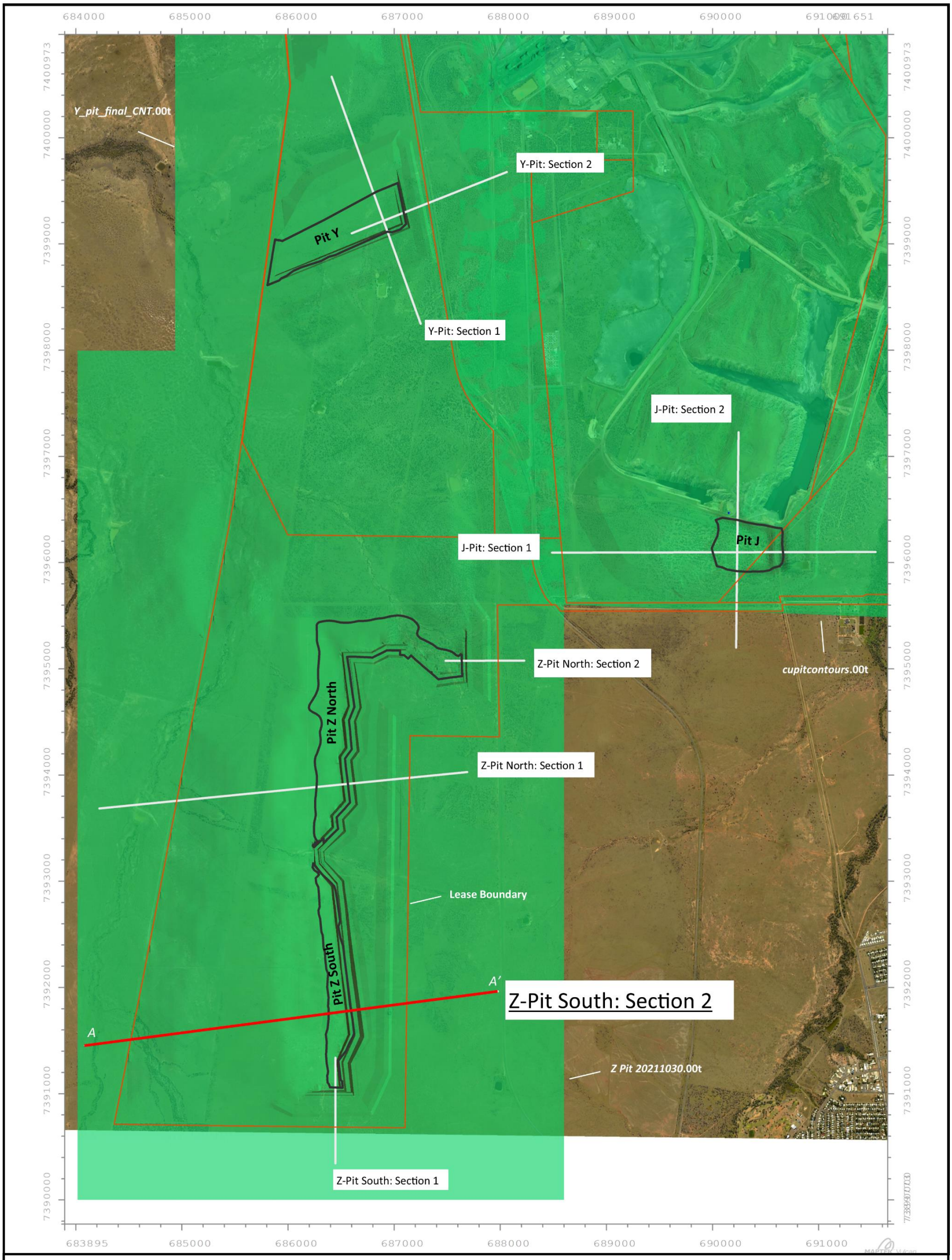



*Figure 4-47 Z-Pit South Cross Section 1*




**Curragh West**

**Final Landform (*cupitcontours*.00t, *Y_pit_final_CNT*.00t and *Z Pit 20211030*.00t)**

**Cross Section Locations: Z-Pit South Section 2**

*Figure 4-48 Z-Pit South Cross Section 2 Location Plan*

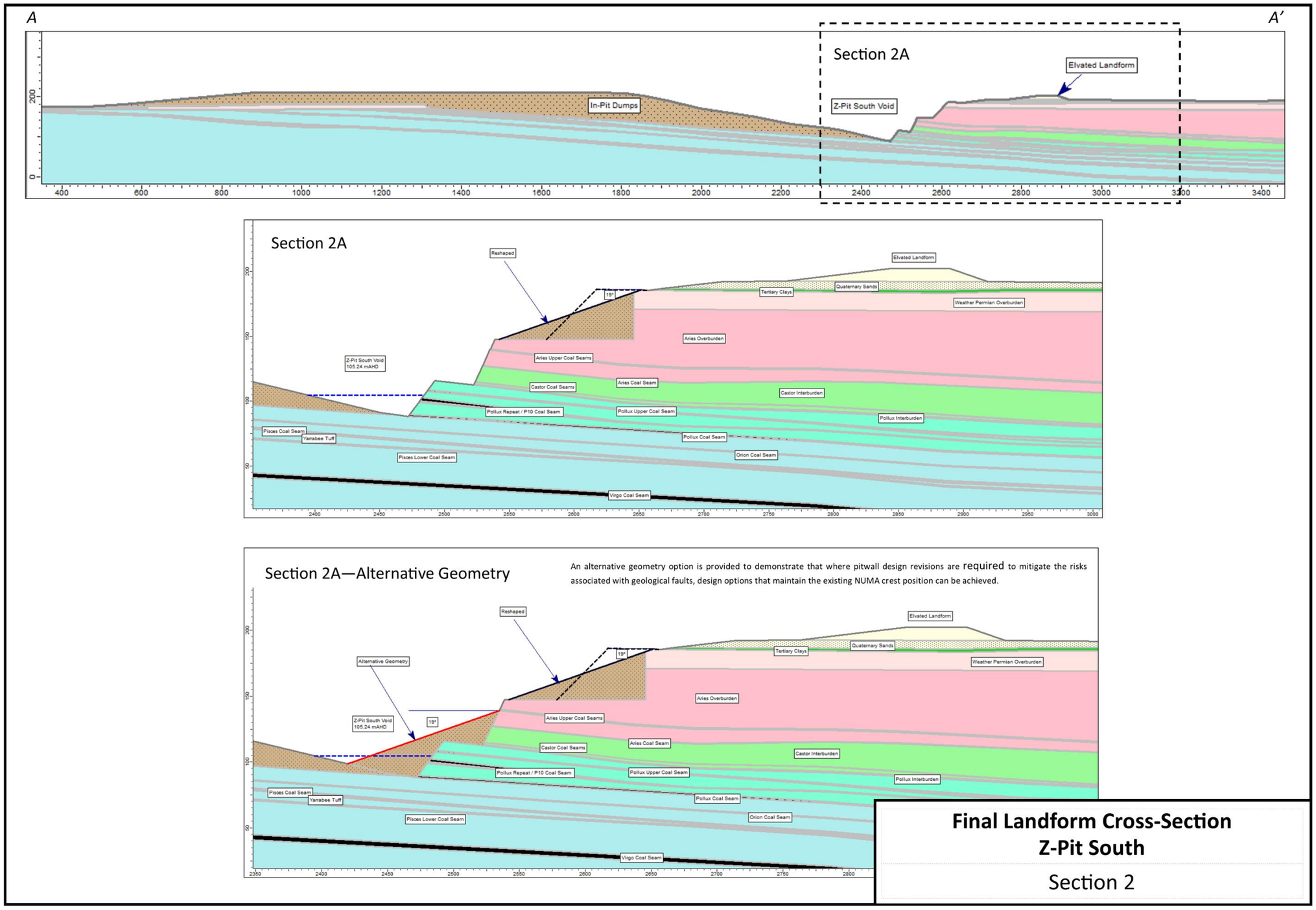



*Figure 4-49 Z-Pit South Cross Section 2*

# 5. Slope Stability Analysis – Adopted Methodology

## 5.1 Adopted Geotechnical Ground Models

The adopted geotechnical ground models have been developed in Rocscience's proprietary software SLIDE 2.0 (Slide) and are based on the supplied final landform designs, flood levels and geological, geotechnical and hydrogeological data.

Two-dimensional limit equilibrium slope stability analysis has been completed for twenty-three (23) cross-section final landform slope geometries, which are presented in Section 4.

## 5.2 Material Parameters

### 5.2.1 Spoil Dump Material Parameters

### 5.2.2 In-Pit Spoil Dumps

In general, the spoil is observed to consist of spoil materials derived from fresh to weathered Permian rock. In considering the data presented in Simmons and McManus (2004) Hawley and Cunning (2017), and site observations, the in-pit spoil materials have been classified as Category 2 Spoil for the purpose of this work (refer to Figure 5-1 and Figure 5-2). It is noted however that the Simmons and McManus (2004) spoil classification may not be applicable for all circumstances due to the limitation in its application as outlined by Simmons and McManus (2004) and Hawley and Cunning (2017).

### 5.2.3 Out-of-Pit Spoil Dumps

The out-of-pit dump composition appears to be highly variable with the following material types observed:

- Sands and Gravels;
- Clayey Sands;
- Low to High Plasticity Clays, Silty Clays and Sandy Clays; and,
- Highly Weathered to Slightly Weathered Permian Rock.

The adopted material strength parameters (Table 5-1) for the out-of-pit dump spoil have been taken from the following report:

- *RA002_201706_02_Rev0 Slope Stability Analysis for Out of Pit Dumps_Rev0*, dated November 2017.

*Table 5-1 Adopted Out-of-Pit Spoil Dump Material Parameters*

| Material Name | Unit Weight (kN/m3) | Apparent Cohesion (kPa) | Friction Angle (°) |
|---|---|---|---|
| **Spoil Dump Materials** | 18 | 3 | 28 |

Table 1
**Shear Strength Parameters for Categories and Mobilisation Modes**
*(Parameter standard deviations in italicised parentheses)*

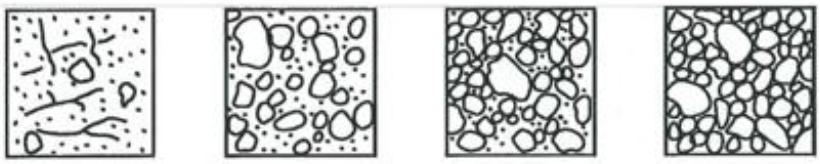
| Category | Unsaturated | | | Saturated | | | Remoulded |
|---|---|---|---|---|---|---|---|
| | γ (kN/m³) | c' (kPa) | ϕ' (deg) | γ (kN/m³) | c' (kPa) | ϕ' (deg) | c'=0 kPa, ϕ' (deg) |
| 1 | 18 *(1)* | 20 *(10)* | 25 *(2.5)* | 20 *(1)* | 0 *(0)* | 18 *(3)* | 18 *(1.5)* |
| 2 | 18 *(1)* | 30 *(15)* | 28 *(3)* | 20 *(1)* | 15 *(7.5)* | 23 *(2.5)* | 18 *(1.5)* |
| 3 | 18 *(1)* | 50 *(15)* | 30 *(2)* | 20 *(1)* | 20 *(10)* | 25 *(2.5)* | 18 *(1.5)* |
| 4 | 18 *(1)* | 50 *(15)* | 35 *(2.5)* | 20 *(1)* | 0 *(0)* | 30 *(1.5)* | 28 *(2)* |

*Figure 5-1 Shear Strength Parameters for Categories and Mobilisation Modes (Simmons & McManus, 2004).*

Table 2
**Spoil Categories and Attributes**

| CATEGORY | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| **Description Attributes** | **Weighting** *(excl. Age)* | Fine-grained clay-rich high plasticity | Fine-grained low plasticity with larger clasts | Larger clasts with fine matrix, low plasticity | Large blocks, minor fines, minor slaking |
| **Predominant Particle Size** | 3/31=**9.7%** *(11.6%)* | Clay | Sand | Gravel | Cobbles |
| **Consistency: cohesive cohesionless** | 7/31=**22.6%** *(26.9%)* | Soft to Firm Loose | Stiff Med. Dense | Hard Dense | XLS+ rock Very Dense |
| **Structure** | 7/31=**22.6%** *(26.9%)* | Matrix only | Matrix supported | Framework supported | Framework only |
| **Liquid Limit** | 9/31=**29.0%** *(34.6%)* | High (>50) | Intermediate (35 – 50) | Low (20 – 35) | Not Plastic (<20) |
| **Age** | 5/31=**16.1%** | 0 - 2y | 2 - 10y | 10 - 30y | >30y |

*( Note: XLS+ rock refers to rock of extremely low strength, or higher)*



Category 1 (matrix only) | Category 2 (matrix supported) | Category 3 (framework supported) | Category 4 (framework only)

Figure 6 Spoil structure control ranking (use with Table 2)

*Figure 5-2 Spoil Categories and Attributes (Simmons and McManus, 2004).*

## 5.3 In-Situ Alluvial Material Parameters

### 5.3.1 Alluvial Clays

The material strength parameters adopted for in-situ clays have been based on available Atterberg Limits test data available for Curragh. Mesri (1993) calculations were undertaken to develop the material parameters presented in Table 5-2 and Table 5-3 which represent a curved Mohr-Coulomb failure envelope, with friction angle reducing with increasing normal stress.

*Table 5-2 Adopted Clay Material Parameters – Quaternary Clays*

| Normal Stress (kPa) | Shear Stress (kPa) |
|---|---|
| 0.5 | 0.9 |
| 2 | 2.7 |
| 5 | 5.8 |
| 10 | 10.3 |
| 20 | 18.3 |
| 50 | 39.1 |
| 100 | 69.6 |
| 150 | 97.4 |
| 225 | 136.4 |
| 300 | 173.2 |
| 400 | 219.9 |
| 1000 | 470.5 |

*Table 5-3 Adopted Clay Material Parameters – Tertiary Clays*

| Normal Stress (kPa) | Shear Stress (kPa) |
|---|---|
| 0.5 | 1.5 |
| 2 | 4.3 |
| 5 | 8.6 |
| 10 | 14.5 |
| 20 | 24.4 |
| 50 | 48.5 |
| 100 | 81.6 |
| 150 | 110.7 |
| 225 | 150.0 |
| 300 | 186.1 |
| 400 | 230.9 |
| 1000 | 459.1 |

### 5.3.2 Alluvial Sands and Gravels

Consideration has been given to available laboratory test data and the observed pitwall performance associated with these materials. Adopted material strengths for the Sands and Gravels are provided in Table 5-4.

*Table 5-4 Adopted Sand Material Parameters*

| Material Name | Unit Weight (kN/m3) | Apparent Cohesion (kPa) | Friction Angle (°) |
|---|---|---|---|
| **Sands & Gravels** | 18 | 0 | 35 |

## 5.4 Permian Rock Mass Strength

The rock mass strength parameters presented in Table 5-8 and Table 5-9 have been developed from available geological and geotechnical data (i.e. geotechnical borehole data and laboratory test data) and field observations using Rocscience's proprietary software RocData incorporating disturbance factors (D) of 0 and 0.7, for a non-blast affected and a blast affect rock mass, respectively

### 5.4.1 Coal Material Strength

The adopted Coal material strength parameters were obtained from Martin & Stacey (2018) (Table 5-5).

*Table 5-5 Adopted Coal Material Strength Parameters*

| Material | Unit Weight | Apparent Cohesion (kPa) | Friction Angle (°) |
|---|---|---|---|
| **Coal** | 15 | 35 | 35 |

### 5.4.2 Tuff Material Strength

The adopted tuff material strength parameters are presented in Table 5-6 and have been derived from available direct shear test results.

*Table 5-6 Adopted Tuff Material Strength Parameters*

| Material | Unit Weight | Apparent Cohesion (kPa) | Friction Angle (°) |
|---|---|---|---|
| **Yarrabee Tuff** | 24 | 50 | 23 |

### 5.4.3 Adopted Hydraulic Conductivity

Adopted hydraulic conductivity values are presented Table 5-7 and were provided by SLR for the presented analysis.

*Table 5-7 Adopted hydraulic conductivity values for the considered material types*

| Material Name | Hydraulic Conductivity | |
|---|---|---|
| | $K_h$ (m/s) | Anisotropy $K_z/K_x$ |
| **Quaternary Sands & Gravels** | $4.75x10^{-4}$ | $4.43x10^{-3}$ |
| **Quaternary Clays** | $5.79x10^{-5}$ | $4.67x10^{-3}$ |
| **Tertiary Clays** | $1.69x10^{-6}$ | $2.3x10^{-1}$ |
| **Weathered Permian Rock** | $1.69x10^{-6}$ | $2.3x10^{-1}$ |
| **Aries and Castor Interburden** | $9.99x10^{-9}$ | $3.01x10^{-2}$ |
| **Cancer, Aries and Castor Coal Seams** | $6.62x10^{-7}$ | $1.69x10^{-1}$ |
| **Pollux Interburden** | $9.11x10^{-9}$ | $9.69x10^{-3}$ |
| **Pollux and Orion Coal Seams** | $6.39x10^{-5}$ | $1.14x10^{-2}$ |
| **Pisces Interburden** | $6.34x10^{-6}$ | $5x10^{-3}$ |
| **Pisces Seam Coal Seam** | $1.08x10^{-7}$ | $3.27x10^{-2}$ |
| **Burngrove Formation (Virgo Interburden)** | $1.41x10^{-9}$ | $1.62x10^{-2}$ |
| **Spoils** | $1.736x10^{-4}$ | 0.246 |

*Table 5-8 General Rock Mass Strength Parameters – Curragh Main*

| Parameter | Weathered Permian | Aries Overburden | Castor Interburden | Pollux Interburden | Pisces Interburden |
|---|---|---|---|---|---|
| Unit Weight | 24 | 25 | 25 | 25 | 25 |
| Adopted Mean Rock Strength (MPa) | 4.0 | 13.5 | 13.9 | 19.0 | 21.8 |
| Number of Samples | 5 | 77 | 55 | 84 | 67 |
| GSI* | 65 | 65 | 65 | 65 | 65 |
| Mi | 7 | 7 | 7 | 7 | 10 |
| D | 0 | 0 | 0 | 0 | 0 |
| Apparent Cohesion (kPa) | 172 | 447 | 486 | 659 | 797 |
| Friction Angle (°) | 37 | 42 | 41 | 41 | 43 |
| **Parameter** | **Weathered Permian** | **Aries Overburden** | **Castor Interburden** | **Pollux interburden** | **Pisces Interburden** |
| Unit Weight | 24 | 25 | 25 | 25 | 25 |
| Adopted Mean Rock Strength (MPa) | 4 | 14 | 14 | 19 | 22 |
| Number of Samples | 5 | 77 | 55 | 84 | 67 |
| GSI* | 65 | 65 | 65 | 65 | 65 |
| Mi | 7 | 7 | 7 | 7 | 10 |
| D | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Apparent Cohesion (kPa) | 124 | 311 | 341 | 461 | 581 |
| Friction Angle (°) | 32 | 36 | 35 | 36 | 38 |

*GSI is based on available geotechnical borehole data (Figure 5-3).

*Table 5-9 General Rock Mass Strength Parameters – Curragh North*

| Parameter | Weathered Permian | Aries Overburden | Castor Interburden | Pisces Interburden | Virgo Interburden |
|---|---|---|---|---|---|
| Unit Weight | 23 | 25 | 25 | 25 | 25 |
| Adopted Mean Rock Strength (MPa) | 1.8 | 22.0 | 29.4 | 26.6 | 34.7 |
| Number of Samples | 13 | 157 | 29 | 281 | 60 |
| GSI* | 65 | 65 | 65 | 65 | 65 |
| Mi | 7 | 7 | 7 | 10 | 10 |
| D | 0 | 0 | 0 | 0 | 0 |
| Apparent Cohesion (kPa) | 110 | 629 | 784 | 818 | 1056 |
| Friction Angle (°) | 31 | 45 | 47 | 46 | 47 |
| **Parameter** | **Weathered Permian** | **Aries Overburden** | **Castor Interburden** | **Pisces Interburden** | **Virgo Interburden** |
| Unit Weight | 23 | 25 | 25 | 25 | 25 |
| Adopted Mean Rock Strength (MPa) | 2 | 22 | 29 | 27 | 35 |
| Number of Samples | 13 | 157 | 29 | 281 | 60 |
| GSI* | 65 | 65 | 65 | 65 | 65 |
| Mi | 7 | 7 | 7 | 10 | 10 |
| D | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Apparent Cohesion (kPa) | 82 | 421 | 513 | 581 | 747 |
| Friction Angle (°) | 26 | 40 | 42 | 41 | 42 |

*GSI is based on available geotechnical borehole data (Figure 5-3).

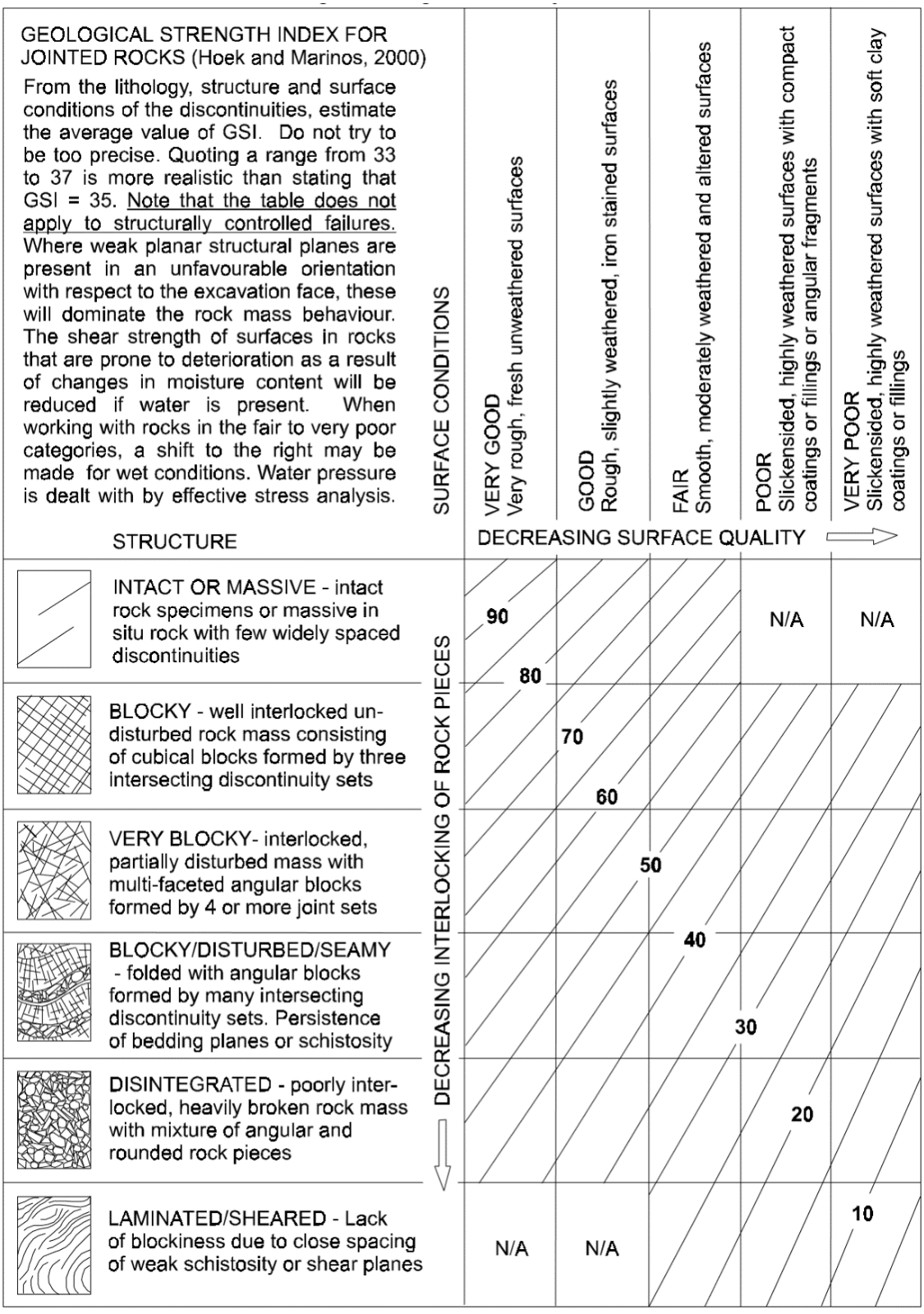



*Figure 5-3 Summary of GSI classifications (Hoek and Marinos, 2000)*

## 5.5 Adopted Slope Stability Analysis Methodology

Deterministic slope stability analysis, using two-dimensional limit equilibrium methods and Rocscience's proprietary software SLIDE 2.0 (Slide), has been undertaken for the twenty-three (23) selected cross-section locations through the supplied final landform designs for Curragh.

The following assumptions, comments and qualifications are made in relation to the analyses completed:

- Static and dynamic scenarios have been considered. To consider the potential impacts of earthquakes (i.e. dynamic scenarios) a peak ground acceleration (g) of 0.02 has been applied, equivalent to an event with an exceedance probability of 2% in 50 years (refer to Section 2.3). The potential for liquefaction has not been assessed;
- For design acceptance criteria, a minimum factor of safety (FoS) of 1.5 for static conditions and 1.1 for dynamic conditions have been adopted for these analyses;
- The Spencer method has been adopted for these analyses;
- The Path Search search method has been adopted for these analyses;
- The slope stability analysis considers 'Global' or 'Overall Slope' Stability of the slope. It does not consider small failures, rockfalls etc. or instability that could arise as a result of erosions or geomorphological processes;
- A Disturbance (D) Factor of 0.7 has been applied when determining Hoek-Brown material parameters for a blast affect Permian rock mass;
- A Disturbance (D) Factor has been applied to a width equal to approximately half the bench height, where the final landform comprises final excavated pitwall geometries in the Permian rock;
- For the purpose of these analyses a slope angle of 7-degrees in the soil materials, and 19-degrees for spoil materials derived from Permian rock has been assumed. It is understood that this is to help prevent and minimise surface erosion, rather than to maintain long-term stability of the relevant final landform slopes;
- The analysis of final excavated pitwall geometries in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s); and,
- Groundwater and surface water can have a significant and adverse impact on the stability of pitwalls and must therefore be appropriately understood and considered. Limited groundwater and/or hydrogeological information is available.
    - The Steady State FEA tool provided in Slide has been utilised to model groundwater movement and hydrostatic pressures through the materials based on the adopted ground models, for the adopted water levels (Section 2.4 and Section 2.5 and material hydraulic conductivities (Table 5-7);
    - Flood levels have been adopted as per Section 2.4;
    - The final void geometries have been adopted as per Section 2.5; and,
    - The possibility of perched water tables has not been considered.

# 6. Slope Stability Analysis Results

The analysis results for the critical failure surfaces analysed are provided in Table 6-1 to Table 6-16. Analysis outputs are provided in Appendix A. The slope stability analysis considers 'Global' or 'Overall Slope' Stability of the slope. It does not consider small failures, rockfalls etc. or instability that could arise as a result of erosions or geomorphological processes.

*Table 6-1 Analysis Results for the Adopted Geotechnical Ground Models - Curragh North*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **U-Pit: Section 1 (Figure 4-5)** | Planned Final Landform Option - Highwall Side | 1.7 | 1.6 |
| | Planned Final Landform Option - Lowwall Side | 1.8 | 1.6 |
| **S-Pit: Section 1 (Figure 4-7)** | Planned Final Landform Option - Highwall Side | 1.8 | 1.7 |
| | Planned Final Landform Option - Lowwall Side | 2.0 | 1.8 |

*Table 6-2 Analysis Results for the Adopted Geotechnical Ground Models - X-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **X-Pit East: Section 1 (Figure 4-9)** | Planned Final Landform Option - Highwall Side | 1.6 | 1.5 |
| | Planned Final Landform Option - Lowwall Side | 3.1 | 2.8 |
| **X-Pit West Section 1 (Figure 4-11)** | Planned Final Landform Option - Highwall Side | 2.3 | 2.1 |
| | Planned Final Landform Option - Lowwall Side | 3.8 | 3.2 |

*Table 6-3 Analysis Results for the Adopted Geotechnical Ground Models -I-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **I-Pit North: Section 1 (Figure 4-13)** | Planned Final Landform Option – Eastern Face | 2.7 | 2.4 |
| | Planned Final Landform Option – Western Face | 3.0 | 2.7 |
| **I-Pit South: Section 1 (Figure 4-15)** | Planned Final Landform Option – Eastern Face | 3.5 | 3.1 |
| | Planned Final Landform Option – Western Face | 4.1 | 3.5 |

*Table 6-4 Analysis Results for the Adopted Geotechnical Ground Models -Main Other*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Main Other: Section 1 (Figure 4-13)** | Planned Final Landform Option – Eastern Face | 2.6 | 2.4 |
| | Planned Final Landform Option – Western Face | 2.7 | 2.4 |

*Table 6-5 Analysis Results for the Adopted Geotechnical Ground Models -The Void*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **The Void: Section 1 (Figure 4-13)** | Planned Final Landform Option - Highwall Side | 1.8 | 1.7 |
| | Planned Final Landform Option - Lowwall Side | 2.9 | 2.6 |

*Table 6-6 Analysis Results for the Adopted Geotechnical Ground Models -D-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **D-Pit: Section 1 (Figure 4-15)** | Planned Final Landform Option - Highwall Side | 2.1 | 1.9 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.6 | 1.4 |
| | Planned Final Landform Option - Lowwall Side | 2.3 | 2.1 |

*Table 6-7 Analysis Results for the Adopted Geotechnical Ground Models - E Pit North and F Pit North*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **E-Pit North Section 1 (Figure 4-17)** | Planned Final Landform Option - Highwall Side | 2.3 | 2.3 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.9 | 1.8 |
| | Planned Final Landform Option - Lowwall Side | 2.2 | 2.0 |
| **F-Pit North Section 1 (Figure 4-19)** | Planned Final Landform Option - Highwall Side | 2.2 | 2.1 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.9 | 1.8 |
| | Planned Final Landform Option - Lowwall Side | 3.5 | 3.1 |

*Table 6-8 Analysis Results for the Adopted Geotechnical Ground Models - F-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **F-Pit Section 1 (Figure 4-21)** | Planned Final Landform Option - Highwall | 1.9 | 1.8 |
| | Planned Final Landform Option - Lowwall | 2.7 | 2.4 |

*Table 6-9 Analysis Results for the Adopted Geotechnical Ground Models – E, H and C-Pit Void*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **E, H C-Pit Void: Section 1 (Figure 4-21)** | Planned Final Landform Option – Eastern Face | 2.6 | 2.4 |
| | Planned Final Landform Option – Western Face | 2.1 | 2.0 |
| **E, H C-Pit Void: Section 1 (Figure 4-25)** | Planned Final Landform Option – Eastern Face | 2.4 | 2.1 |
| | Planned Final Landform Option – Western Face | 3.1 | 2.7 |

*Table 6-10 Analysis Results for the Adopted Geotechnical Ground Models -L-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **L-Pit Section 1 (Figure 4-23)** | Planned Final Landform Option - Highwall Side | 2.7 | 2.6 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 2.0 | 1.9 |
| | Planned Final Landform Option - Lowwall Side | 2.1 | 1.9 |

*Table 6-11 Analysis Results for the Adopted Geotechnical Ground Models - K-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **K-Pit: Section 1 (Figure 4-25)** | Planned Final Landform Option - Highwall Side | 2.6 | 2.5 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.8 | 1.7 |
| | Planned Final Landform Option - Lowwall Side | 2.9 | 2.7 |
| **K-Pit: Section 2 (Figure 4-27)** | Planned Final Landform Option - Highwall Side | 2.1 | 2.0 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.8 | 1.7 |
| | Planned Final Landform Option - Lowwall Side | 2.7 | 2.3 |

*Table 6-12 Analysis Results for the Adopted Geotechnical Ground Models -G-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **G-Pit Section 1 (Figure 4-29)** | Planned Final Landform Option - North Face | 3.1 | 2.7 |
| **G-Pit Section 1 (Figure 4-29)** | Planned Final Landform Option - Southern Face | 3.6 | 3.0 |

*Table 6-13 Analysis Results for the Adopted Geotechnical Ground Models -Ramp 9*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Ramp 9 Section 1 (Figure 4-31)** | Planned Final Landform Option - Highwall Side | 2.5 | 2.3 |
| **Ramp 9 Section 1 (Figure 4-33)** | Planned Final Landform Option - Highwall Side | 2.4 | 2.2 |

*Table 6-14 Analysis Results for the Adopted Geotechnical Ground Models - J-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **J-Pit: Section 1 (Figure 4-35)** | Planned Final Landform Option - Highwall Side | 1.7 | 1.5 |
| | Planned Final Landform Option - Lowwall Side | 2.8 | 2.5 |
| **J-Pit: Section 2 (Figure 4-37)** | Planned Final Landform Option - Highwall Side | 2.1 | 2.0 |
| | Planned Final Landform Option - Lowwall Side | 1.9 | 1.8 |

*Table 6-15 Analysis Results for the Adopted Geotechnical Ground Models - Y-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Y-Pit Section 1 (Figure 4-39)** | Planned Final Landform Option - Highwall Side | 2.5 | 2.4 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 2.1 | 2.0 |
| | Planned Final Landform Option - Lowwall Side | 3.5 | 3.1 |
| **Y-Pit Section 2 (Figure 4-41)** | Planned Final Landform Option - Highwall Side | 2.3 | 2.2 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 2.2 | 2.0 |

*Table 6-16 Analysis Results for the Adopted Geotechnical Ground Models -Z-Pit*

| Cross Section | Scenario | Estimated Static Factor of Safety | Estimated Dynamic Factor of Safety |
|---|---|---|---|
| **Z-Pit North: Section 1 (Figure 4-43)** | Planned Final Landform Option - Highwall Side | 2.4 | 2.3 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.9 | 1.7 |
| | Planned Final Landform Option - Lowwall Side | 1.6 | 1.5 |
| **Z-Pit North: Section 2 (Figure 4-45)** | Planned Final Landform Option - Highwall Side | 2.5 | 2.3 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 2.1 | 1.9 |
| **Z-Pit South: Section 2 (Figure 4-49)** | Planned Final Landform Option - Highwall Side | 2.0 | 1.9 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 1.9 | 1.8 |
| | Planned Final Landform Option - Lowwall Side | 1.9 | 1.8 |
| **Z-Pit South: Section 1 (Figure 4-47)** | Planned Final Landform Option - Highwall Side | 2.6 | 2.5 |
| | Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side | 2.0 | 1.9 |

# 7. Discussion and Recommendations

Two-dimensional limit equilibrium slope stability analysis has been completed with the estimated static and dynamic Factors of Safety (FoS) for the critical failure surface analysed presented for CCPL's consideration. The estimated FoS should only be used as a general guide for assessing potential geotechnical hazards and risks associated with the 'long-term' stability of the final landform designs. It is noted that the term 'long-term' slope stability has not been defined or quantified.

Deterministic analysis results for the final landform designs, based on the adopted ground models and analysis methodology and assumptions indicate that the final landform designs meet the adopted design acceptance criteria with FoS equal to or greater than 1.5 returned for the critical failures analysis for static conditions and 1.1 for dynamic conditions (Section 5.5) for global stability. The analyses do not consider the potential impacts that factors such as erosion and other geomorphological processes could have on the 'long-term' geotechnical stability of the final landform or other small failures, rockfalls etc.

The natural ground conditions have an inherent level of variability and uncertainty because of the various ways in which they have formed and modified over time. Understanding and managing the geological uncertainty and the associated risks inherently on the design process is a critical part of mine design and planning processes. At present the level of geological uncertainty varies across Curragh. This is quite normal in a mining environment where the geological uncertainty reduces as more data becomes available and designs are progressed through a design process from concept to detailed design, and then into construction.

Past pitwall performance at Curragh indicates that geological structures are a key factor requiring consideration as part of the CPS and design process. The analysis of cross-sections that include remnant pitwalls in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s). The ability to identify geological fault locations and geometries accurately for the final pitwall is limited by existing data coverage and density. Fault interpretations and geotechnical ground models for final pitwalls are to be developed as mining progresses and/or additional geology and geotechnical data is collected and interpreted (i.e. via the CPS).

Where adverse fault orientations and interactions, relative to pitwall geometries and locations are present, the planned final pitwall geometries (as provided) may not be appropriate for CCPLs 'long-term' final landform stability requirements. In such cases alternative geometry options may be required. Example alternative geometry options have been provided to demonstrate that where pitwall design revisions are required to mitigate the risks associated with geological faults, design options that maintains the existing NUMA crest position can be achieved.

Due to potential surface erosion mitigation requirements and in order to meet the adopted design acceptance criteria for 'long-term' slope stability, it may be necessary to re-shape softwalls and spoil dumps to reduce overall slope angles. A re-shaped slope angle of approximately 19-degrees has been considered in the analysis undertaken for ground models that consider re-shaping of softwalls constructed in blasted Permian rock. The associated cut-fill balance of these options is to be further investigated as detailed design works are completed.

The analysis presented in this report considers the existing final landform design options outlined in Section 1.2.

The slope stability analyses presented in this document should be reviewed and updated when new geological, geotechnical and/or hydrogeological data becomes available or as material changes are made to existing data or the design options are developed.

The following recommendations are provided in relation to detailed design of the final landforms:

- The construction of the final landform designs, including cut-fill and backfill volumes, are to be reviewed and developed;
- An erosional stability assessment, including an assessment of dispersive soils and potential for piping and cavity formation, is necessary to confirm the maximum slope angles and/or mitigation options for the various soil materials (including spoil materials) necessary to ensure the 'long-term' final landform performance requirements. The final landform designs, and if deemed necessary the geotechnical slope stability analysis, are to be updated based on the outcomes of the erosion assessment;
- A geomorphological assessment is necessary to identify potential geomorphological processes that could impact on the 'long-term' final landform performance. The final landform designs, and if deemed necessary the geotechnical slope stability analysis, are to be updated based on the outcomes of the geomorphological assessment;
- Geological, geotechnical and hydrogeological data collection strategies for the final pitwalls are to be developed and implemented to inform the detailed design process;
- The hydrogeological and hydrological models should be developed, and an associated groundwater investigation program implemented;
- Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels in the alluvial soil profile; and,
- As the final landform designs are progressed, and additional geological, geotechnical, hydrogeological and/or hydrological data is obtained, further mine planning analysis and more detailed and extensive slope stability analysis may be required. This should include assessment of all slope geometries, remnant pitwalls and final voids, and mine planning evaluation of risk and cost. It is recommended that detailed design include probabilistic slope stability analysis.

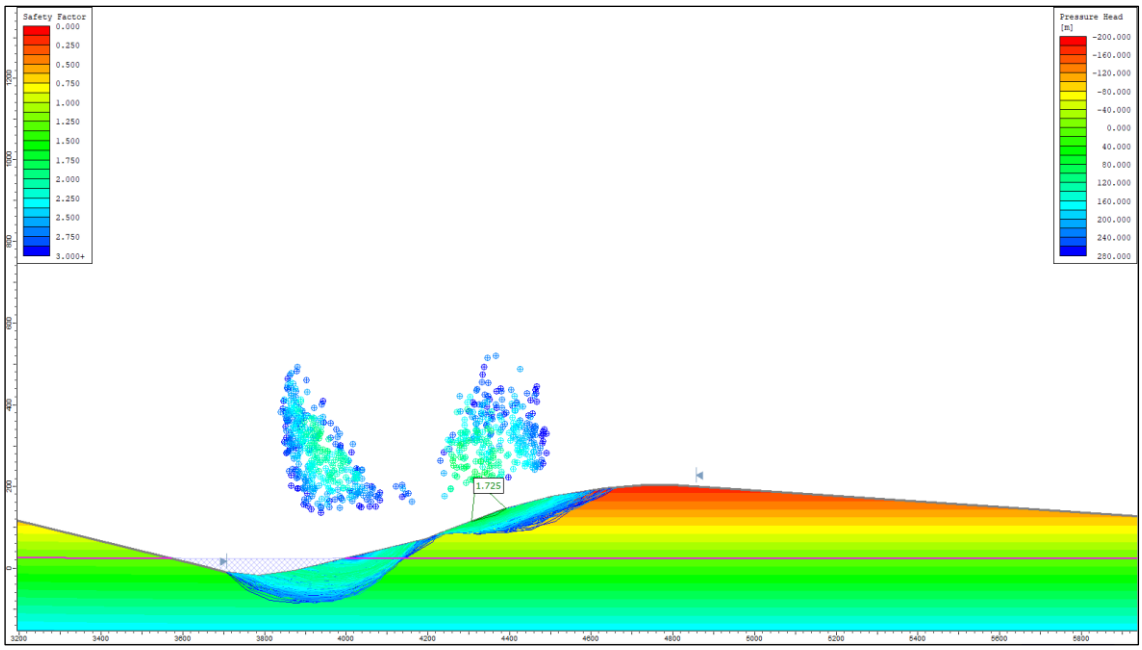
## 8. Qualification

The following qualifications are made in relation to the analysis and recommendations presented in this report:

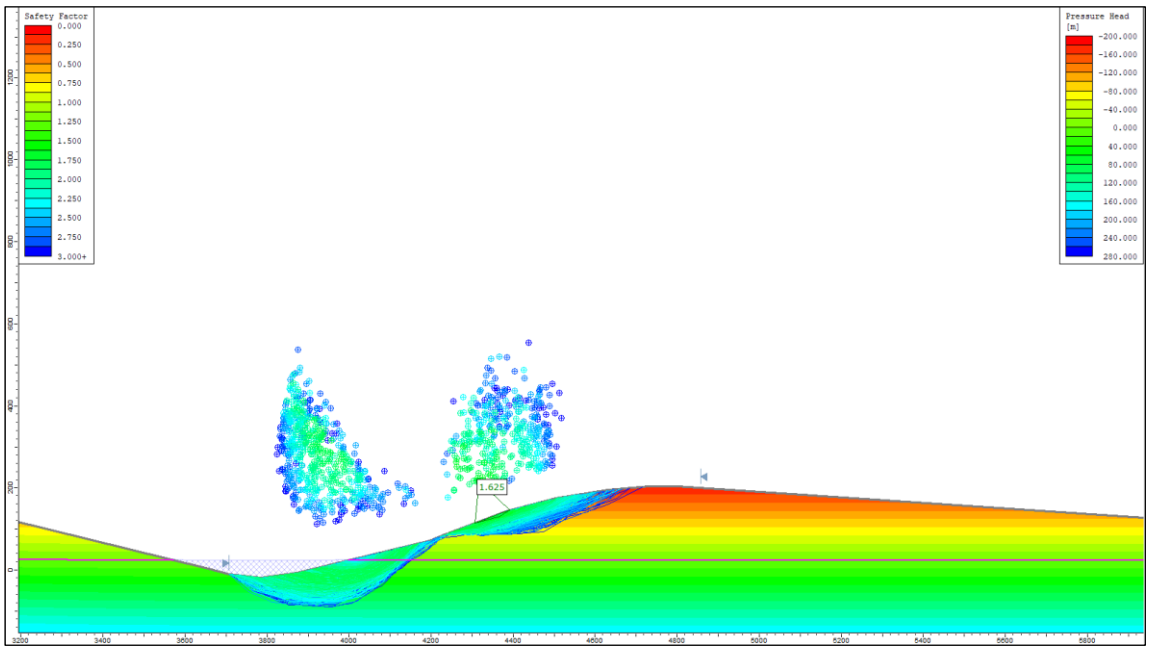
- This document has been prepared by R&A for CCPL and may only be used and relied upon by CCPL for the purpose agreed between R&A and CCPL as set out in relevant sections of this memorandum. R&A otherwise disclaims responsibility to any person other than CCPL arising in connection with this report.
- It has been assumed that all data supplied by CCPL is true and accurate and that all available and relevant data has been supplied. R&A has not independently verified or validated the data supplied by CCPL and does not accept liability in connection with unverified information, including errors and omissions in this document which were caused by errors or omissions in that information.
- No geotechnical investigations or laboratory testing have been commissioned or undertaken as part of this work.
- The adopted groundwater levels, NUMA water levels, phreatic surfaces and hydraulic conductivity values have been obtained from the data supplied by SLR.
- It is noted that the term 'long-term' slope stability has not been defined or quantified.
- The slope stability analysis presented has been undertaken in line with industry standard practices, but does not constitute geotechnical 'certification' of the Curragh final landform designs.
- The analysis, outputs, opinions, conclusions and recommendations provided in this document are based on the adopted geotechnical ground models and analysis methods. The adopted geotechnical ground models presented in this report may be constrained by available data type, density and accuracy. Therefore, it is possible that the actual ground conditions will vary from those interpreted and assumed in the adopted ground models.
- The potential three-dimensional variability of ground conditions over relatively short distances may result in differing interpretations being made with respect to ground conditions and material properties. The analysis, outputs, conclusions and recommendations presented in this report can only be relied upon at the specific locations which relate to the adopted ground conditions and ground models for which the presented assessments and analysis have been based. Furthermore, the application of the information presented in this report may warrant additional assessment and analysis.
- The geotechnical slope stability analysis does not consider the potential impacts of erosion and other geomorphological processes on the 'long-term' geotechnical stability of the final landform or small failures, rockfalls etc.
- It is understood that detail design, including further geotechnical slope stability analysis, will be undertaken as additional geological, geotechnical and hydrogeological data is obtained and interpreted, and uncertainty is reduced, as part of the CPS.
- If the content of this document, including the adopted methods and terminology, is unclear or not fully understood clarification should be sort.

If it is known, or subsequently becomes known, that any of the qualifications, assumptions or interpretations made in this report are incorrect, R&A must be notified immediately, and the applicability of the slope stability analysis and any associated recommendations reviewed. If considered necessary, the slope stability analysis and report will be updated and the report re-issued.

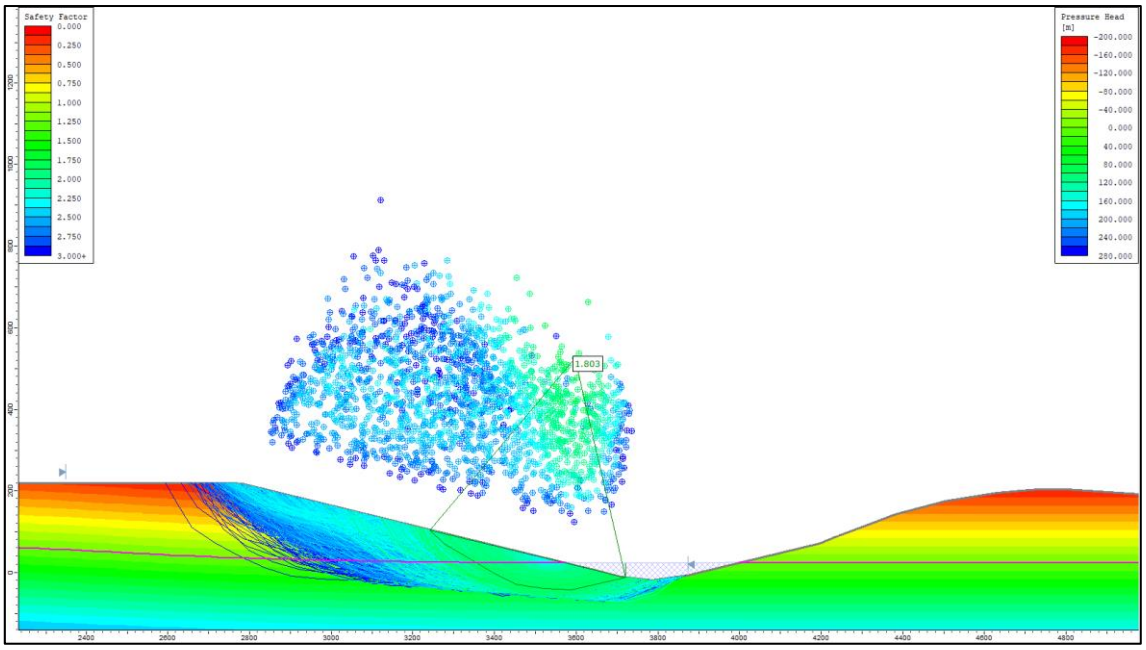
# **Appendix A** – Limit Equilibrium Slope Stability Analysis Outputs



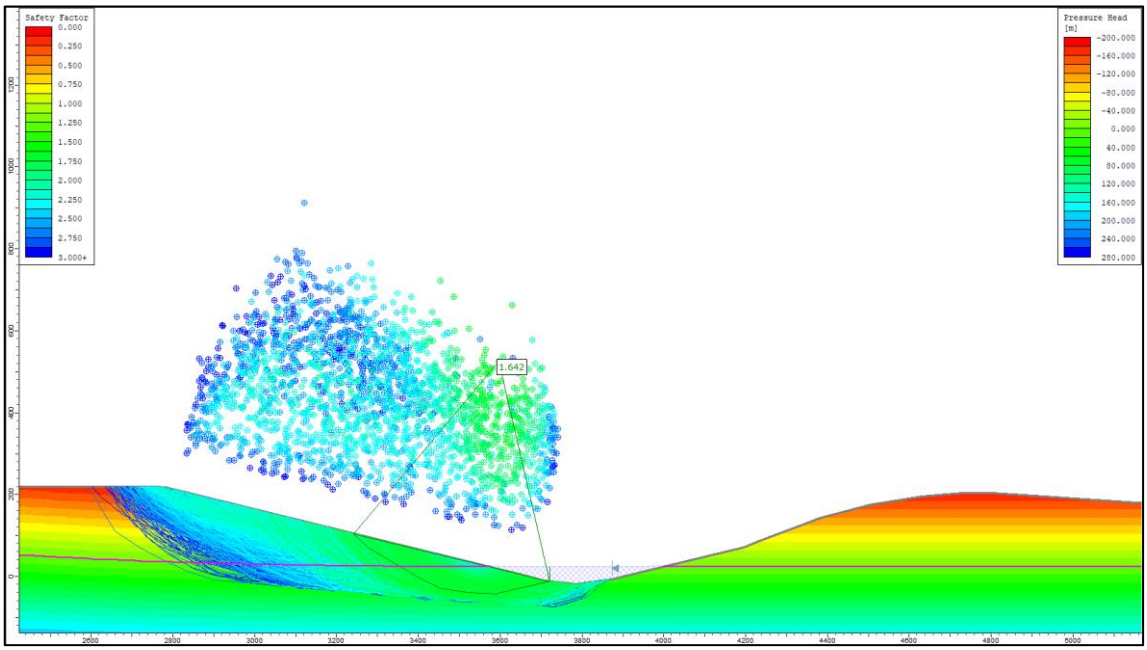

*Appendix A 1 U-Pit Cross Section 1 – Highwall Analysis – Static*



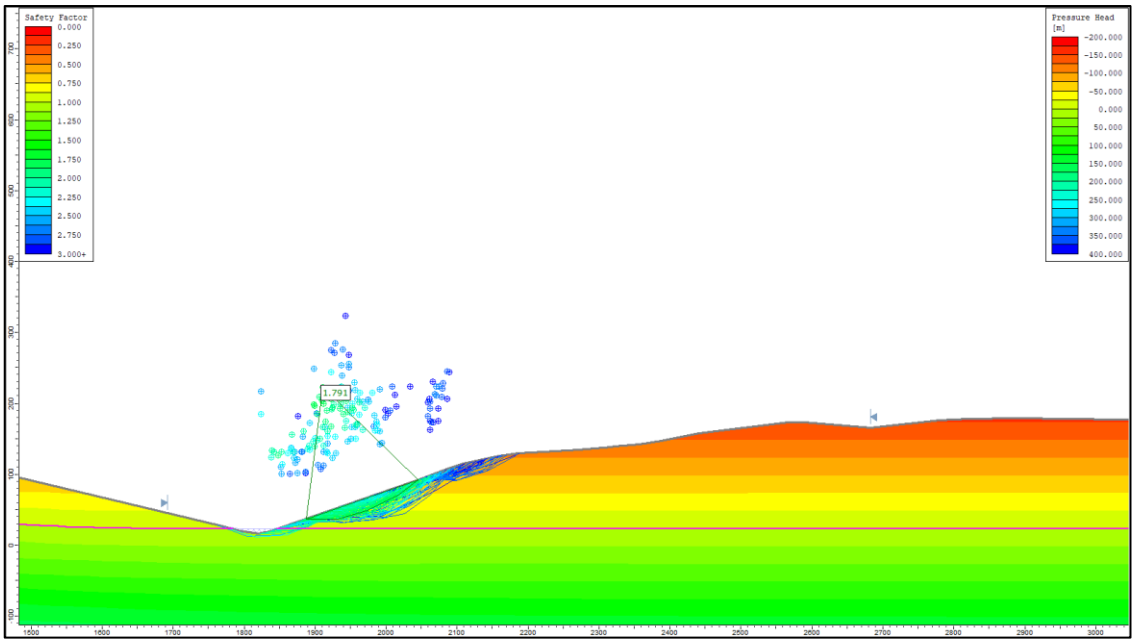

*Appendix A 2 U-Pit Cross Section 1 – Highwall Analysis – Dynamic*



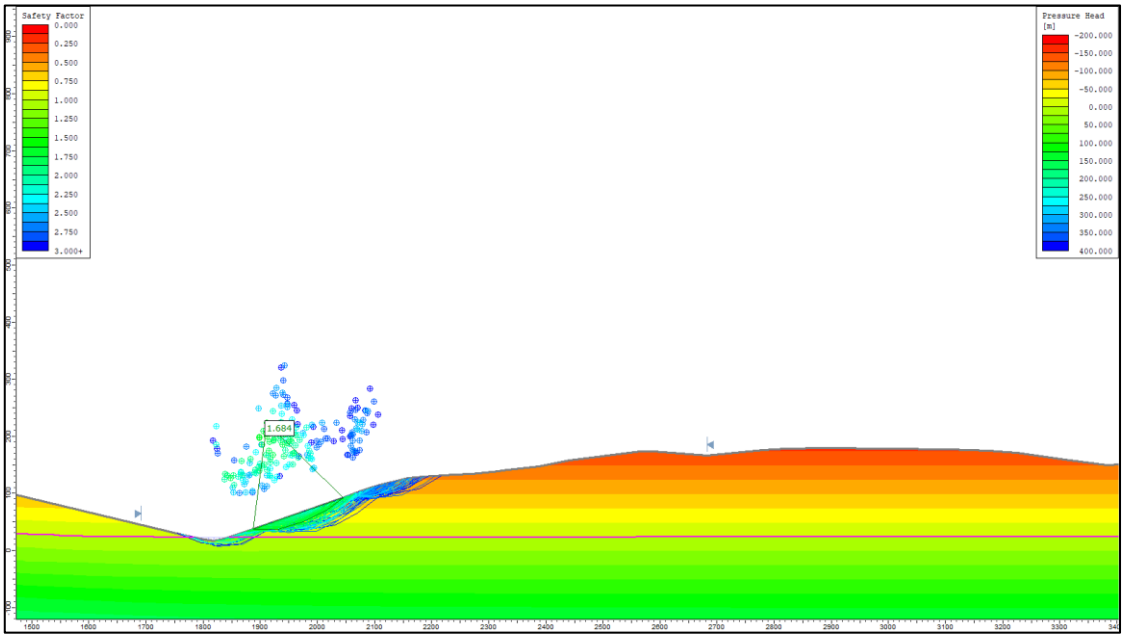

*Appendix A 3 U-Pit Cross Section 1 – Lowwall Analysis – Static*



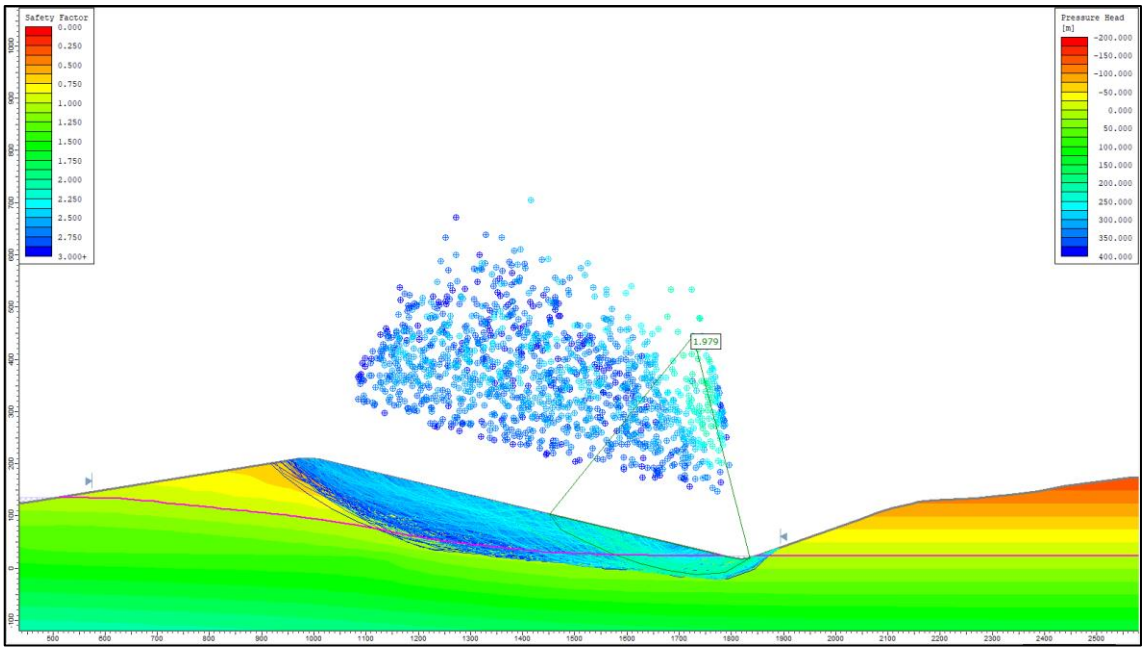

*Appendix A 4 U-Pit Cross Section 1 – Lowwall Analysis – Dynamic*



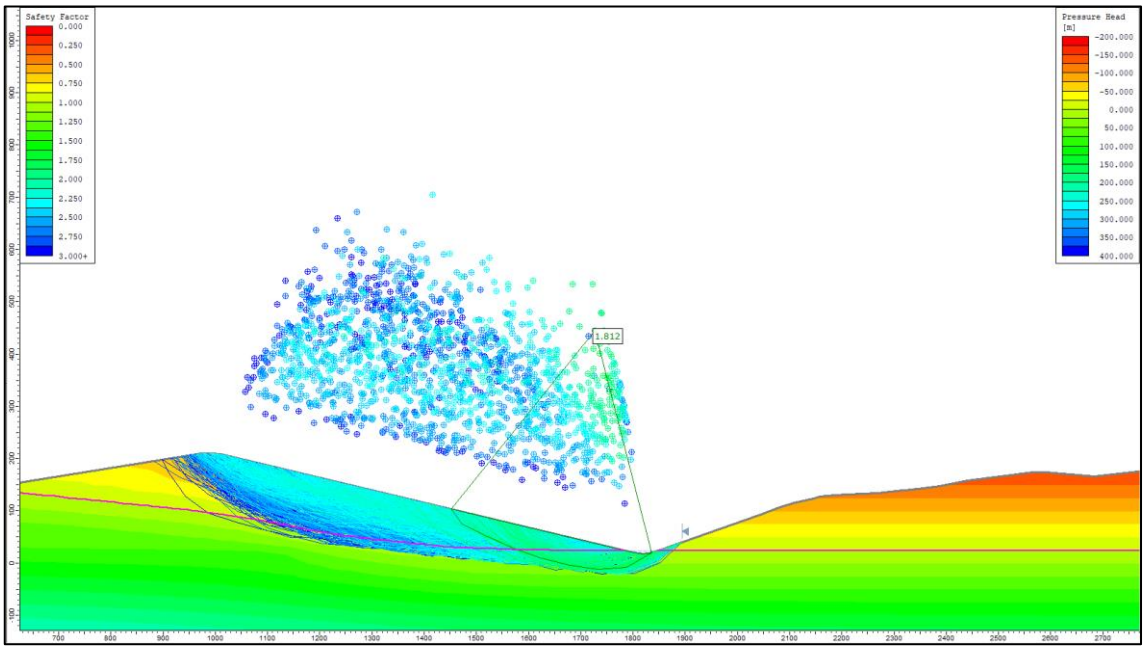

*Appendix A 5 S-Pit Cross Section 1 – Highwall Analysis – Static*



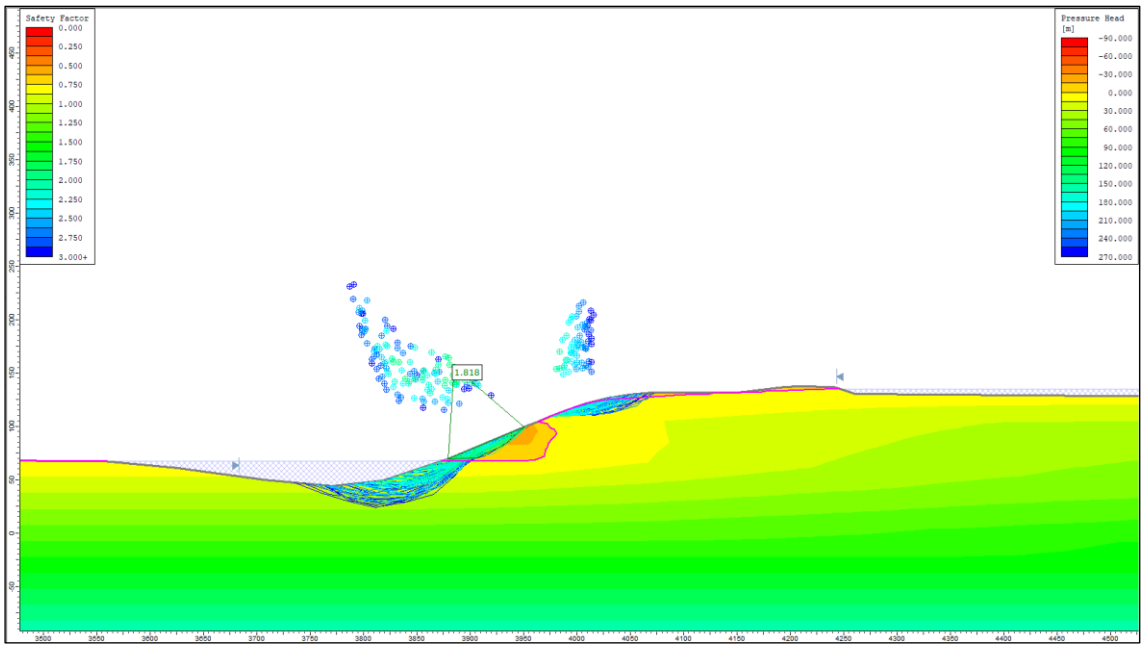

*Appendix A 6 S-Pit Cross Section 1 – Highwall Analysis – Dynamic*



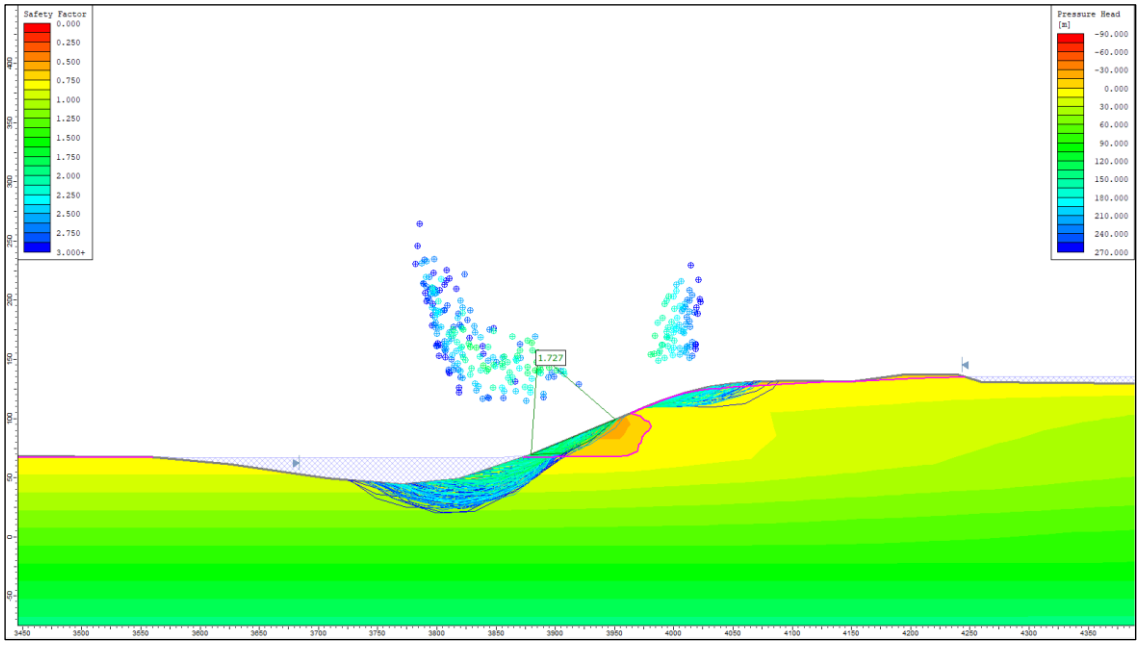

*Appendix A 7 S-Pit Cross Section 1 – Lowwall Analysis – Static*



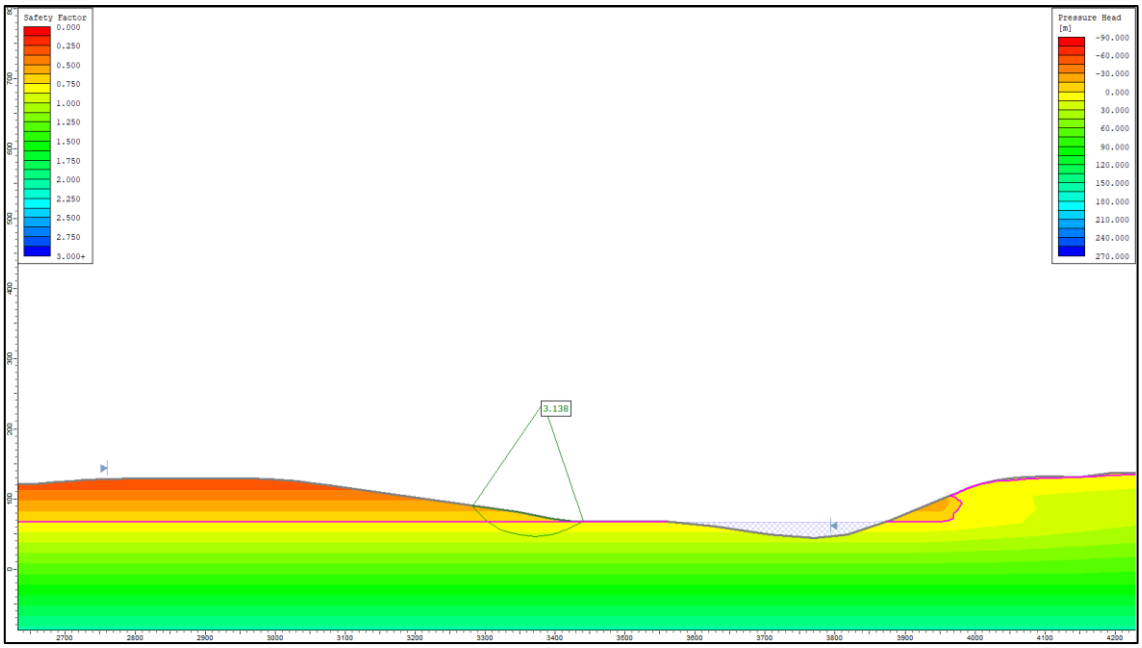

*Appendix A 8 S-Pit Cross Section 1 – Lowwall Analysis – Dynamic*



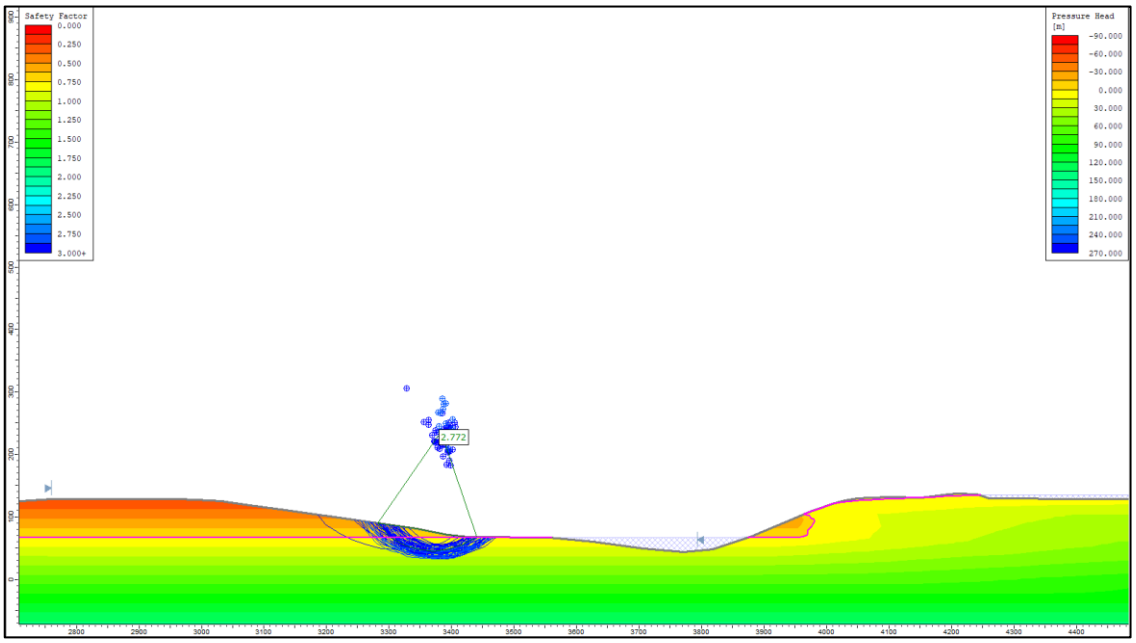

*Appendix A 9 X-Pit East Cross Section 1 – Highwall Analysis – Static*



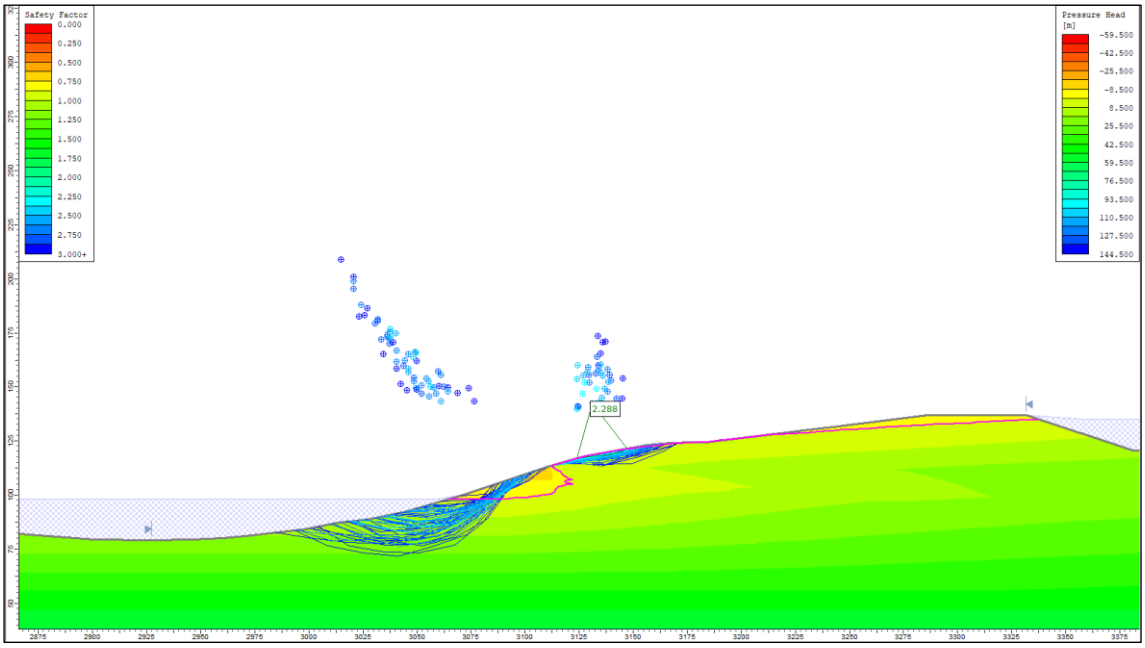

*Appendix A 10 X-Pit East Cross Section 1 – Highwall Analysis – Dynamic*



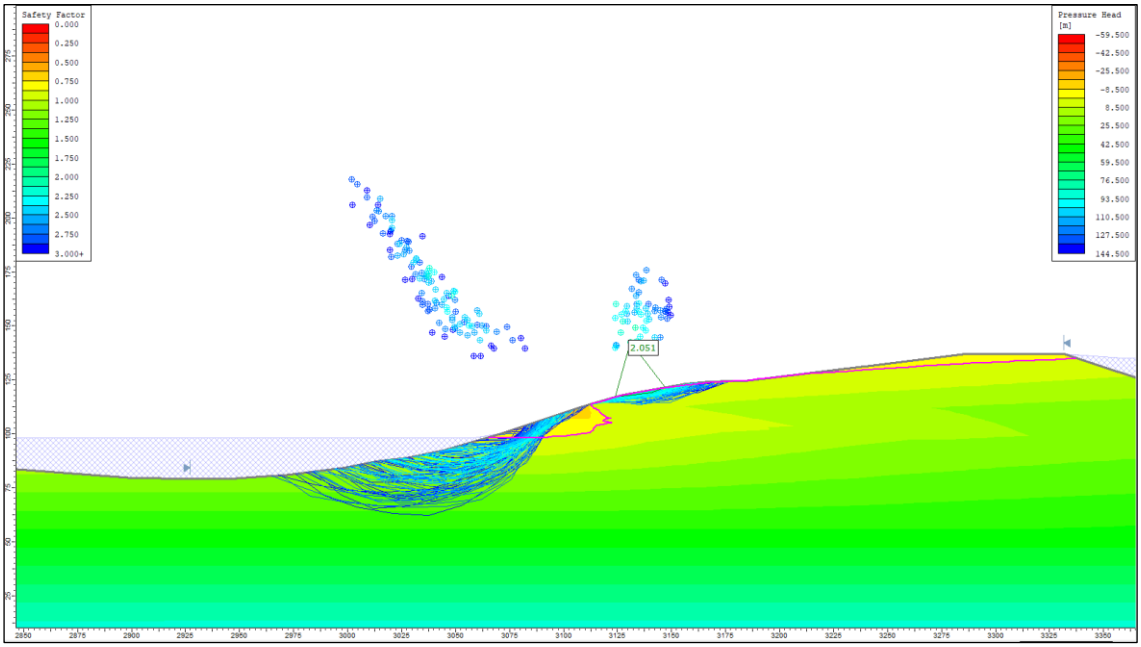

*Appendix A 11 X-Pit East Cross Section 1 – Lowwall Analysis – Static*



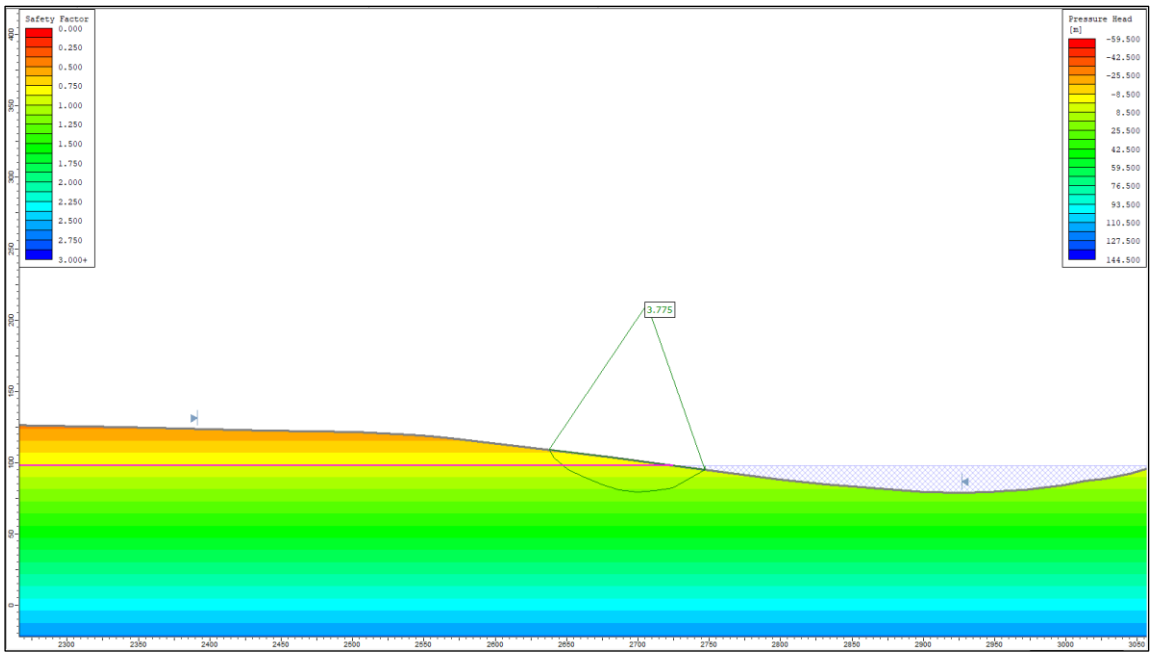

*Appendix A 12 X-Pit East Cross Section 1 – Lowwall Analysis – Dynamic*



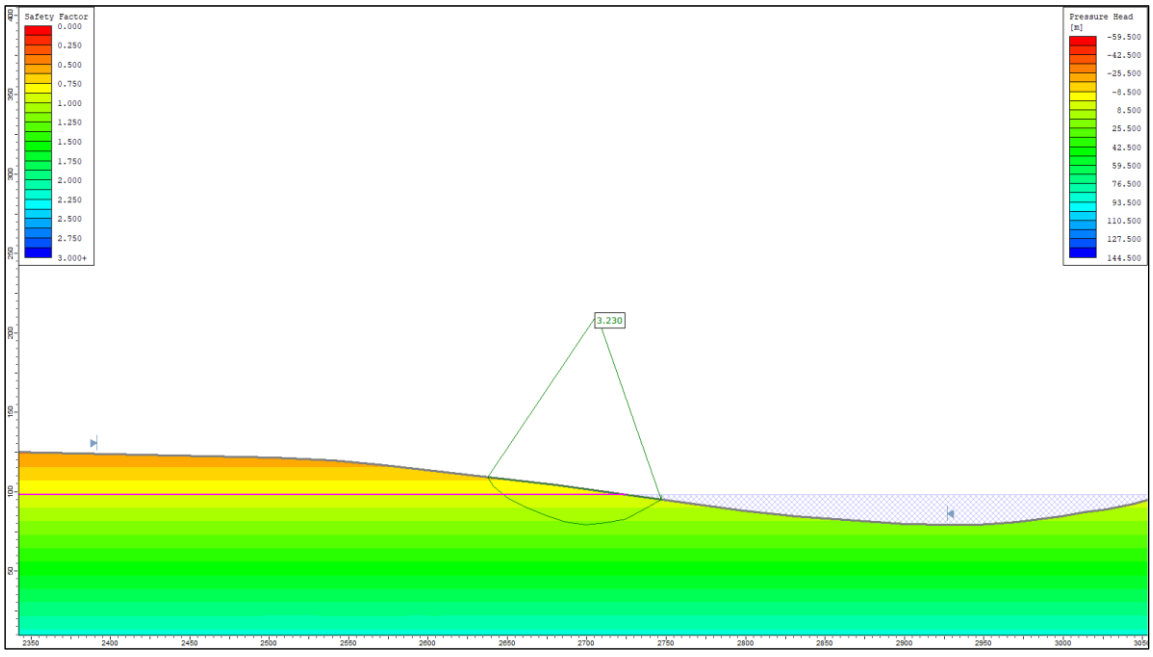

*Appendix A 13 X-Pit West Cross Section 1 – Highwall Analysis – Static*



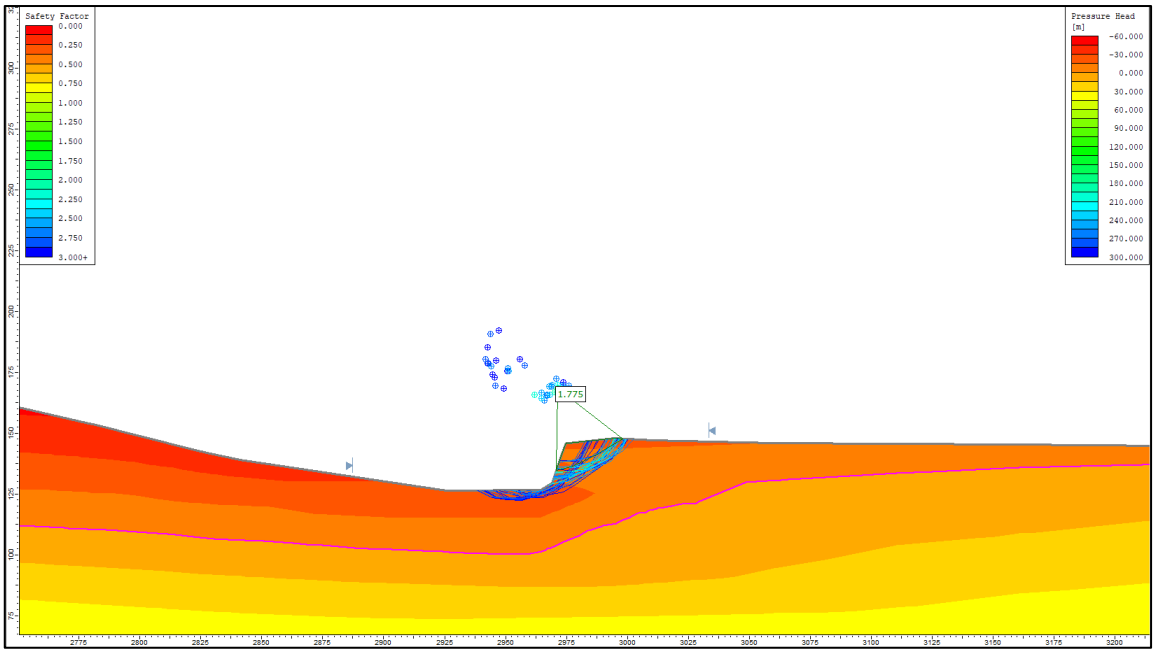

*Appendix A 14 X-Pit West Cross Section 1 – Highwall Analysis – Dynamic*



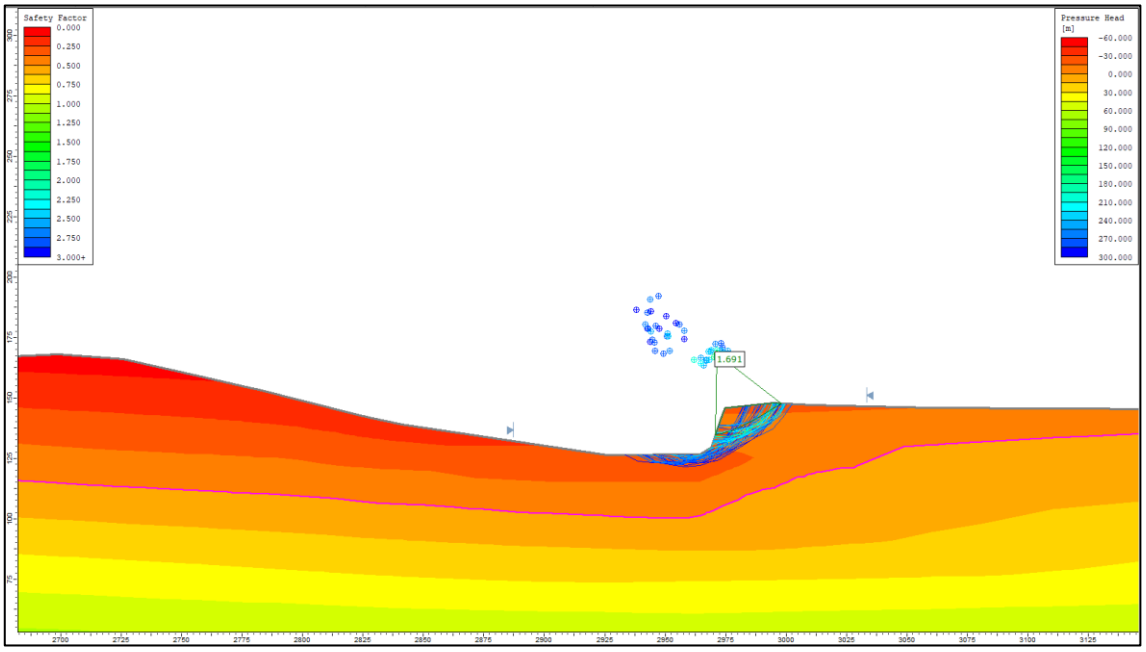

*Appendix A X-Pit West Cross Section 1 – Lowwall Analysis – Static*



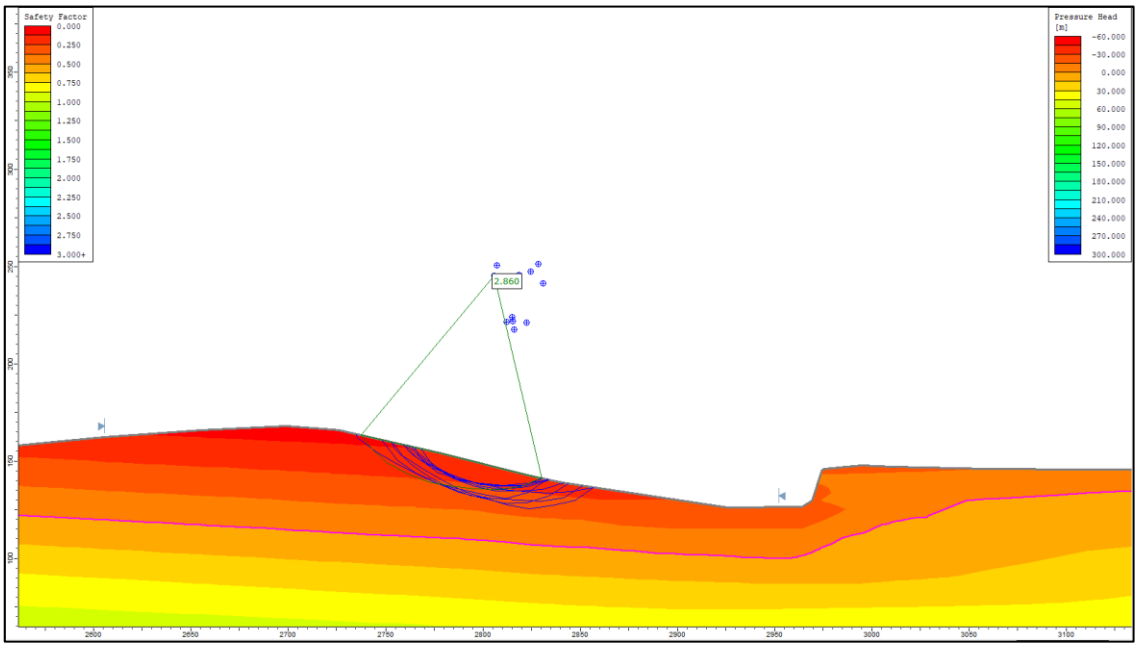

*Appendix A 15 X-Pit West Cross Section 1 – Lowwall Analysis – Dynamic*



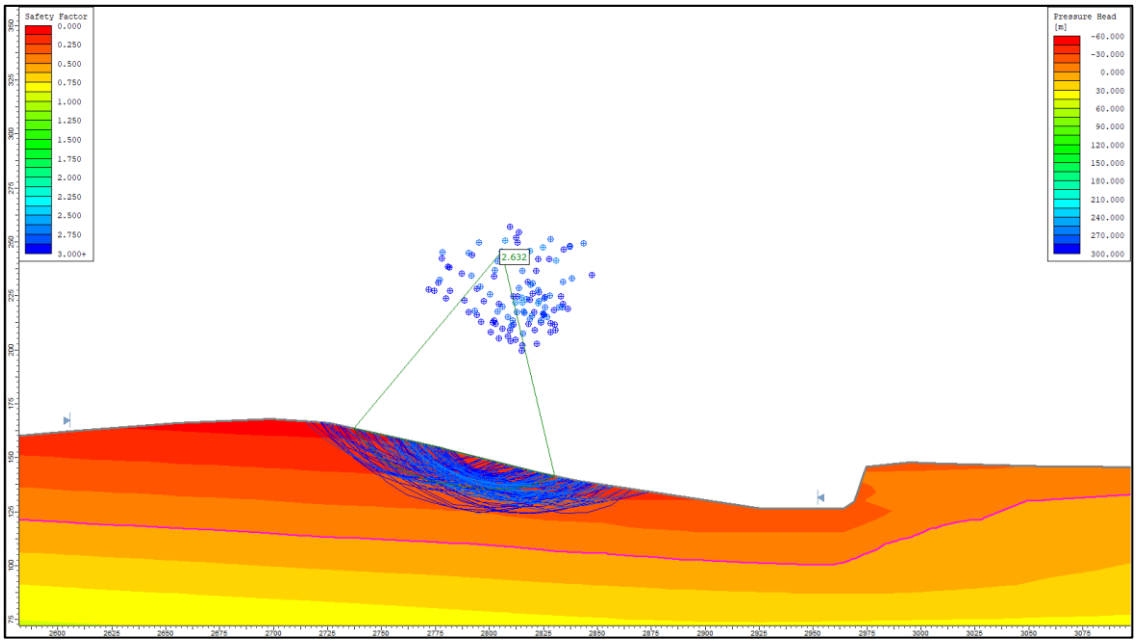

*Appendix A 16 I-Pit North, Main Other and The Void Cross Section 1 – The Void Highwall Analysis – Static*



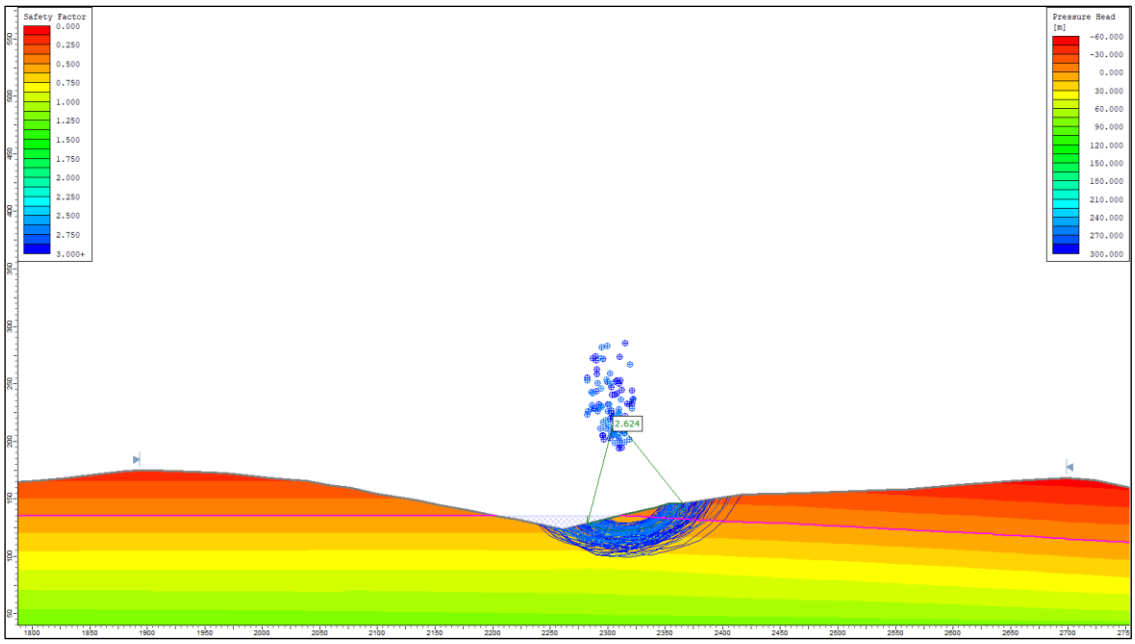

*Appendix A 17 I-Pit North, Main Other and The Void Cross Section 1 – The Void Highwall Analysis – Dynamic*



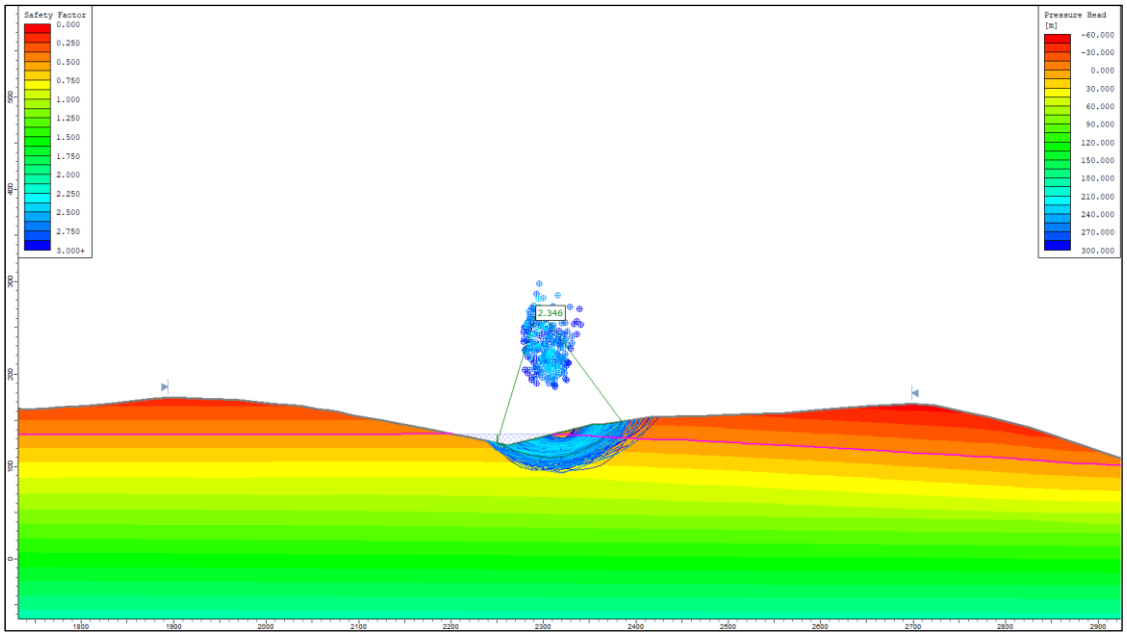

*Appendix A 18 I-Pit North, Main Other and The Void Cross Section 1 – The Void Lowwall Analysis – Static*



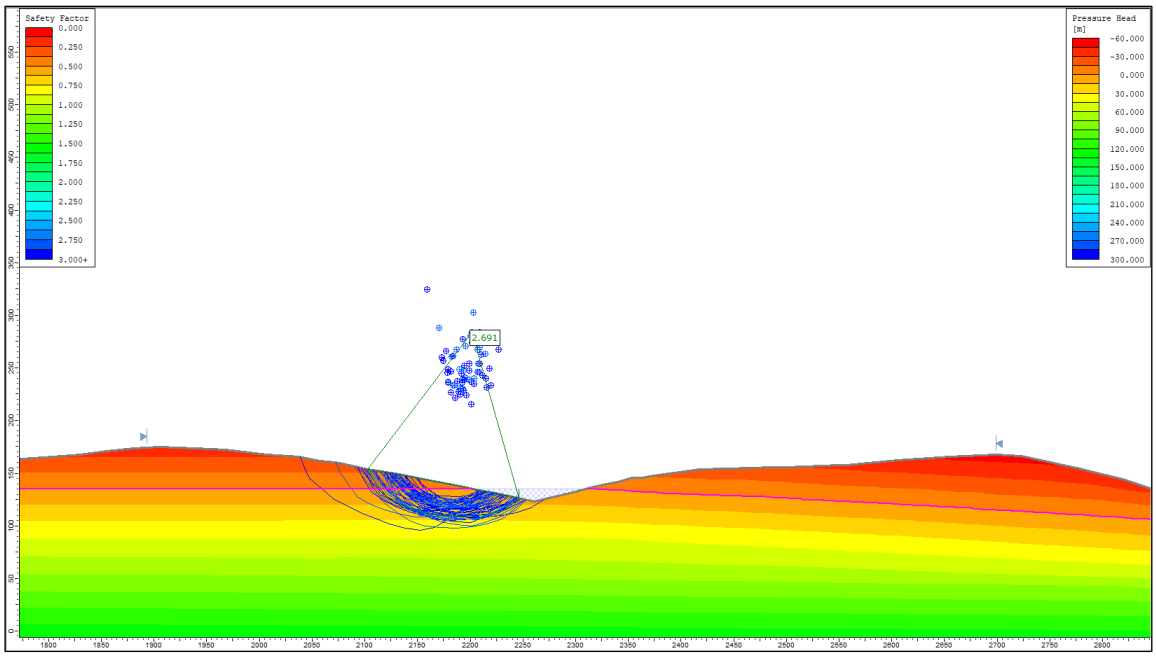

*Appendix A 19 I-Pit North, Main Other and The Void Cross Section 1 – The Void Lowwall Analysis – Dynamic*



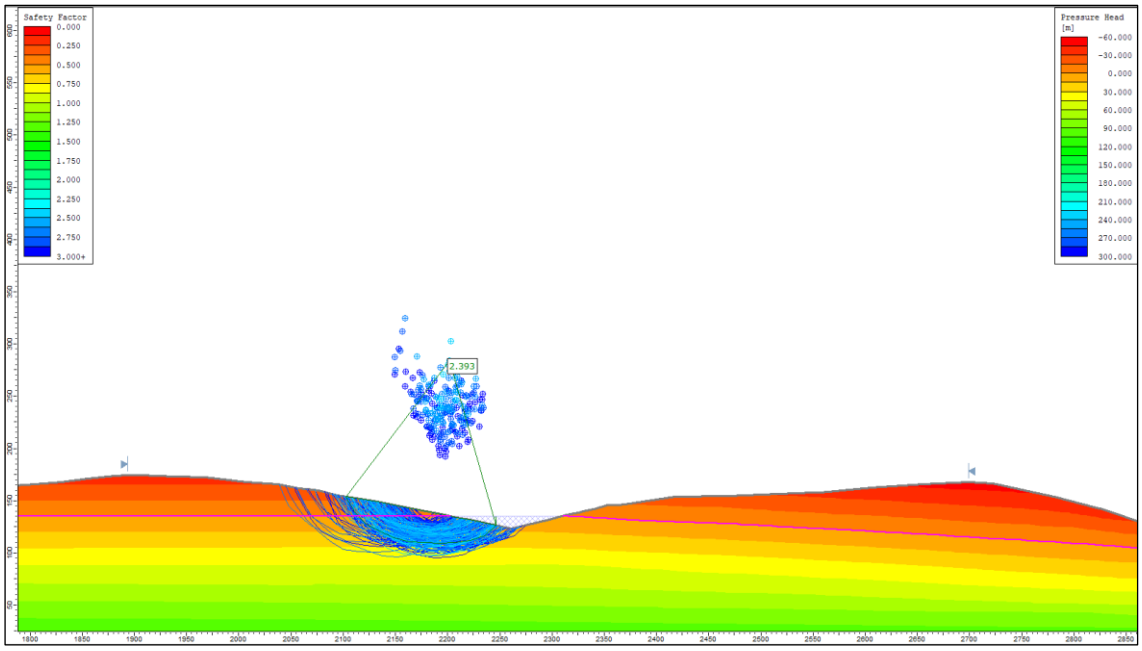

*Appendix A 20 I-Pit North, Main Other and The Void Cross Section 1 – Main Other Eastern Lowwall Analysis – Static*



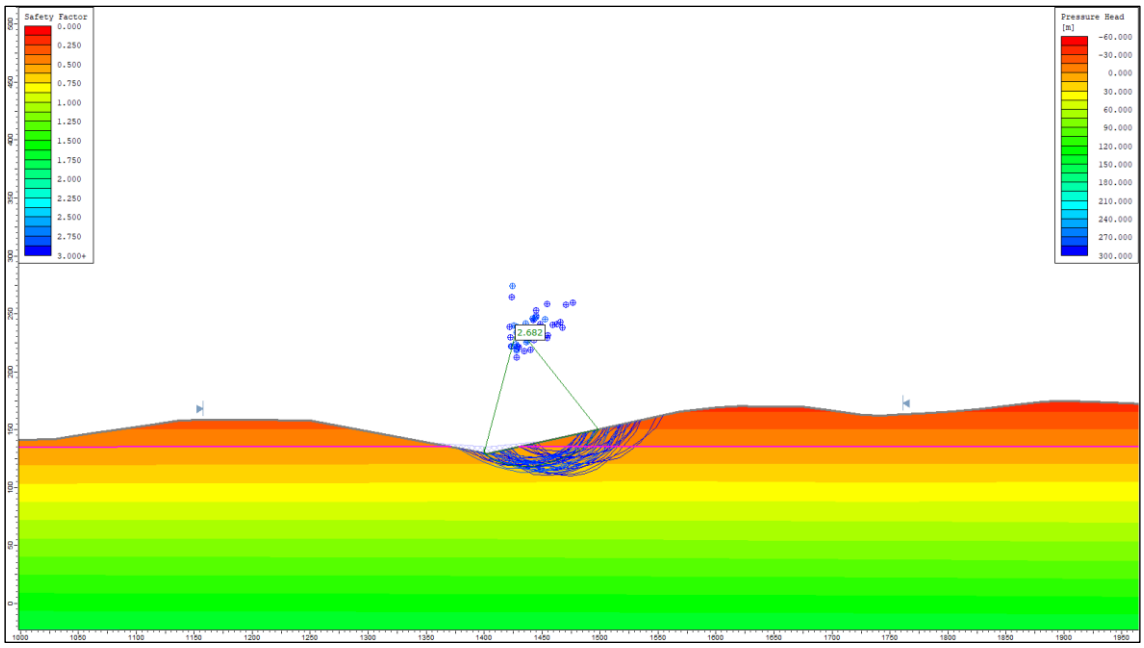

*Appendix A 21 I-Pit North, Main Other and The Void Cross Section 1 Main Other Eastern Lowwall Analysis – Dynamic*



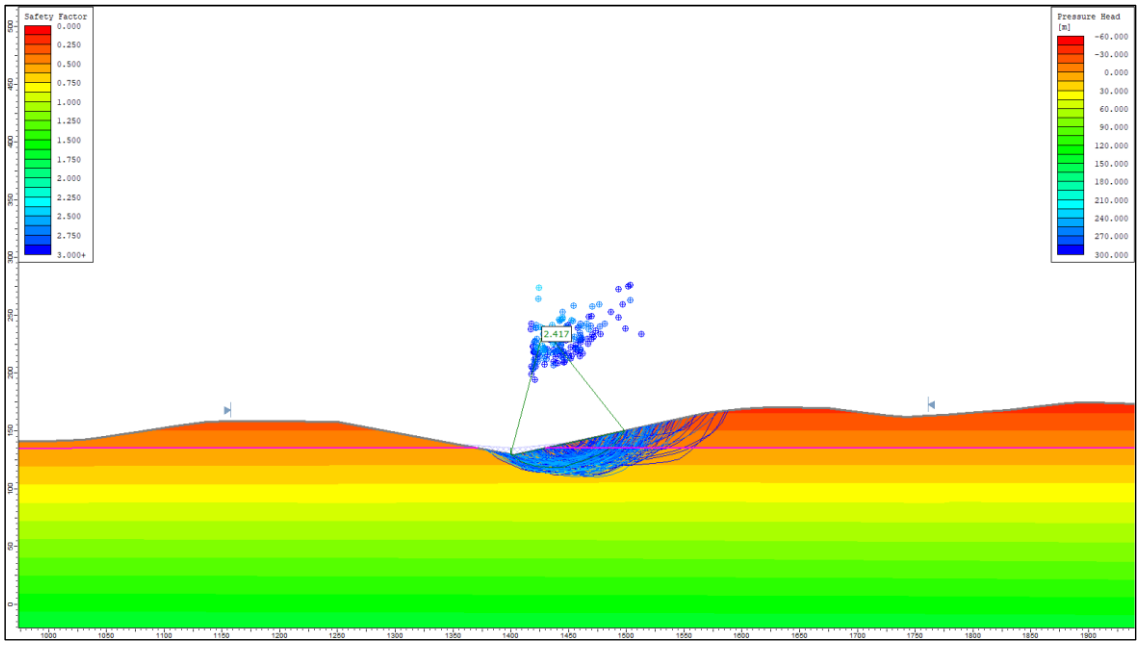

*Appendix A 22 I-Pit North, Main Other and The Void Cross Section 1 – Main Other Western Lowwall Analysis – Static*



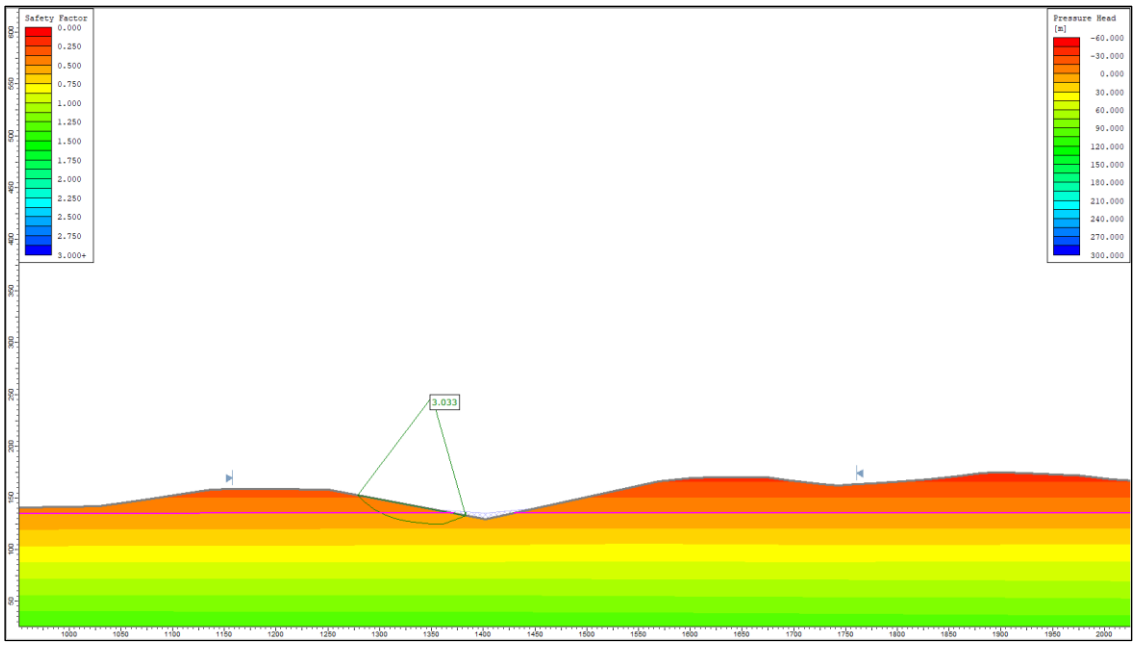

*Appendix A 23 I-Pit North, Main Other and The Void Cross Section 1 – Main Other Western Lowwall Analysis – Dynamic*



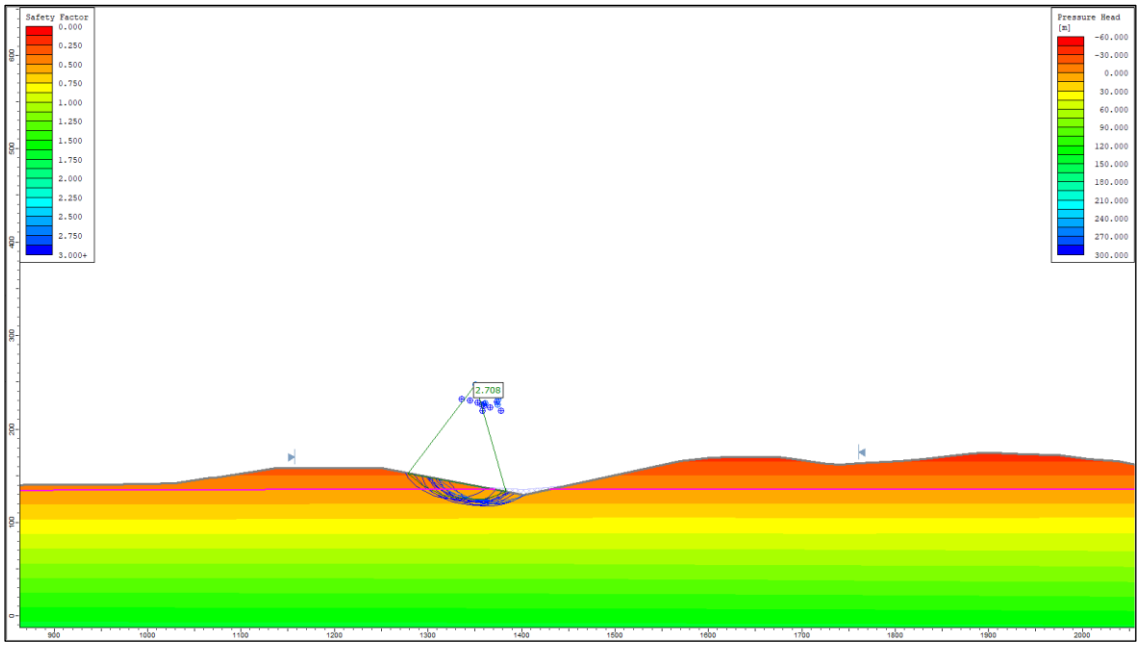

*Appendix A 24 I-Pit North, Main Other and The Void Cross Section 1 – I-Pit North Eastern Lowwall Analysis – Static*



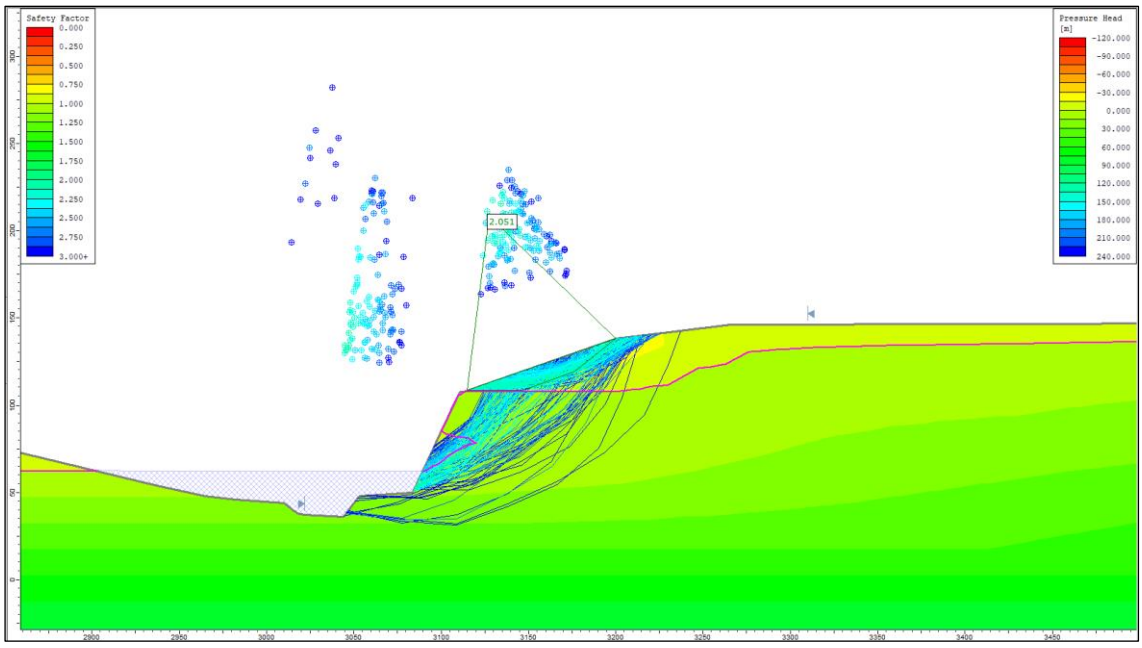

*Appendix A 25 I-Pit North, Main Other and The Void Cross Section 1 – I-Pit North Eastern Lowwall Analysis – Dynamic*



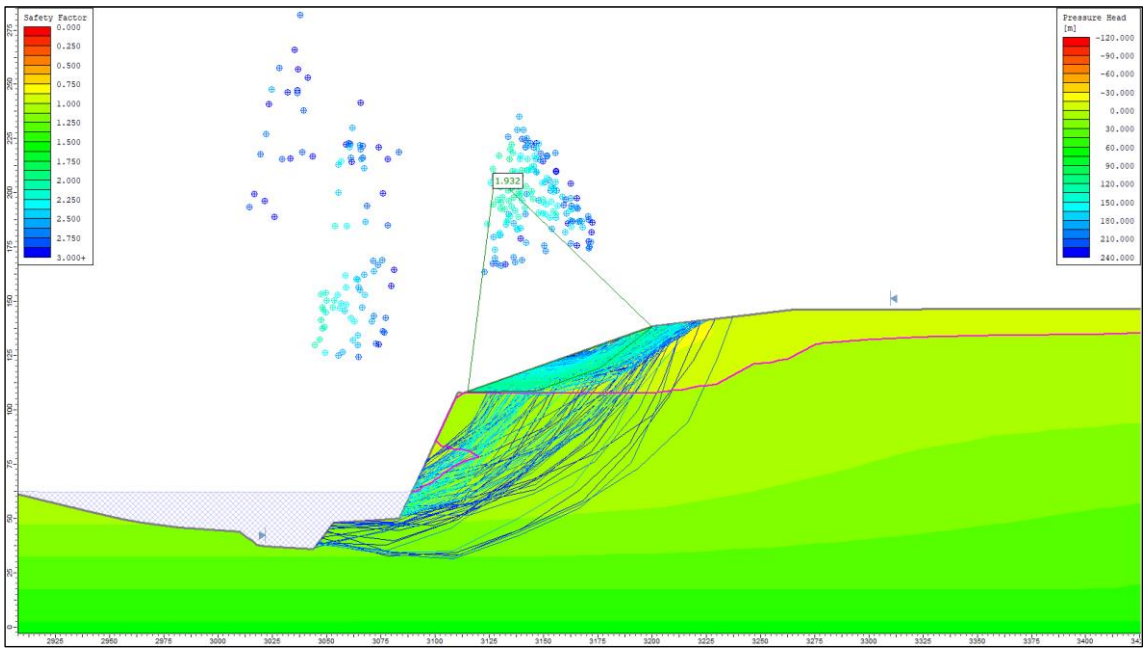

*Appendix A 26 I-Pit North, Main Other and The Void Cross Section 1 – I-Pit North Western Lowwall Analysis – Static*



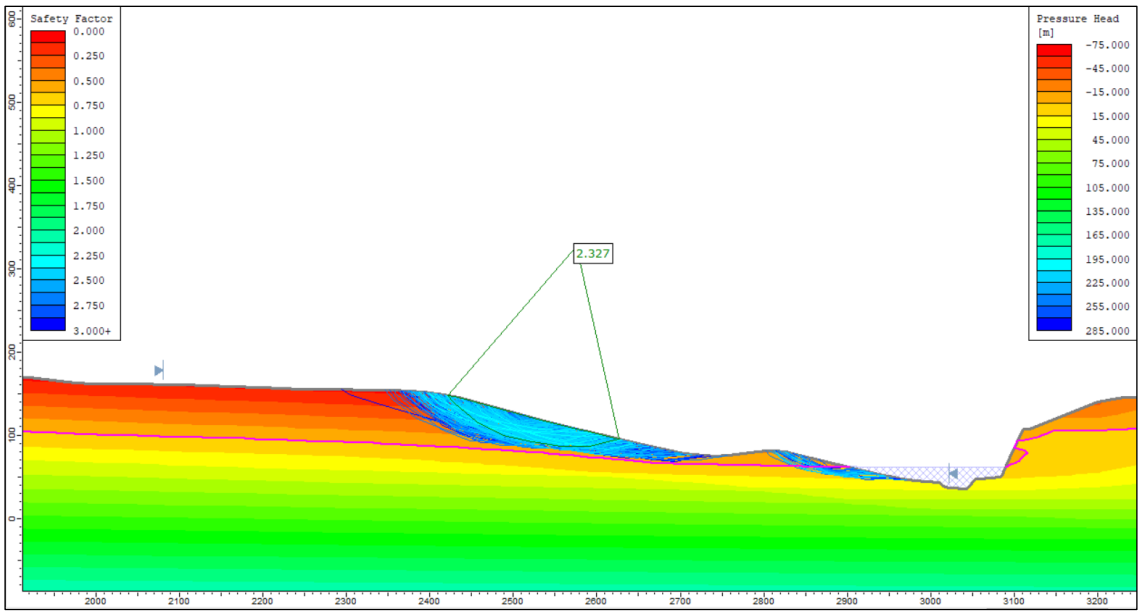

*Appendix A 27 I-Pit North, Main Other and The Void Cross Section 1 – I-Pit North Western Lowwall Analysis – Dynamic*



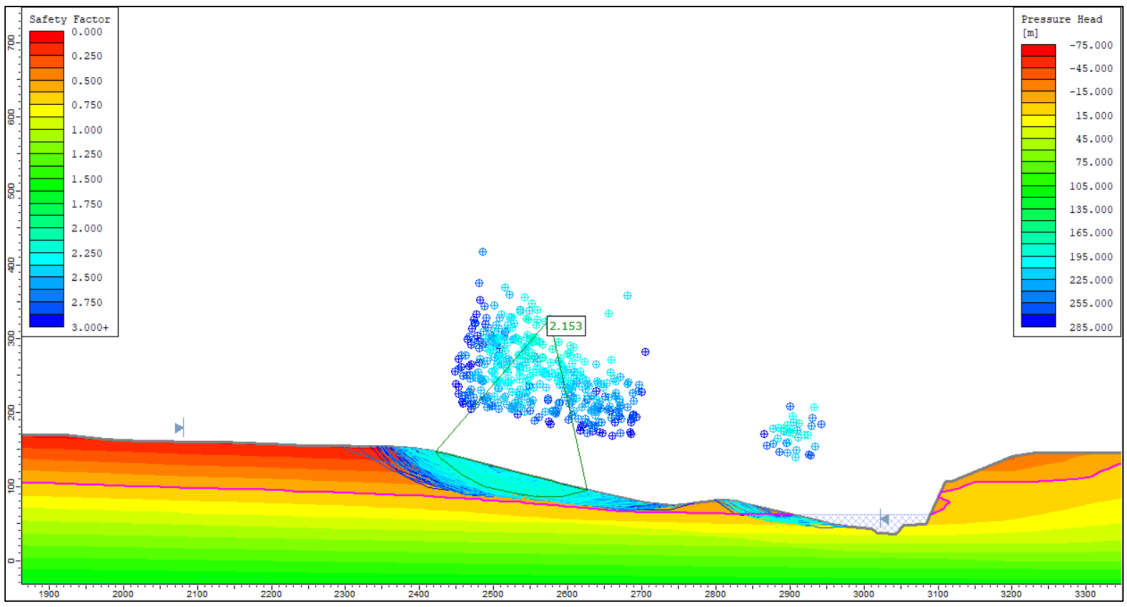

*Appendix A 28 D-Pit and I-Pit South Cross Section 1 – D-Pit Highwall Analysis – Static*



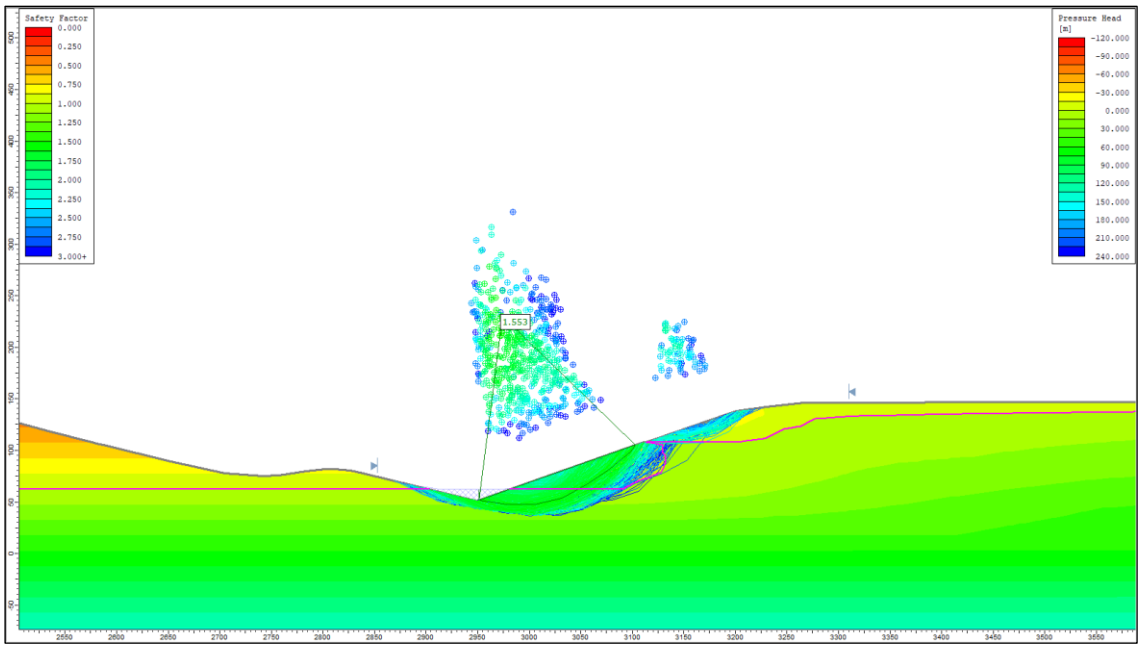

*Appendix A 29 D-Pit and I-Pit South Cross Section 1 – D-Pit Highwall Analysis – Dynamic*



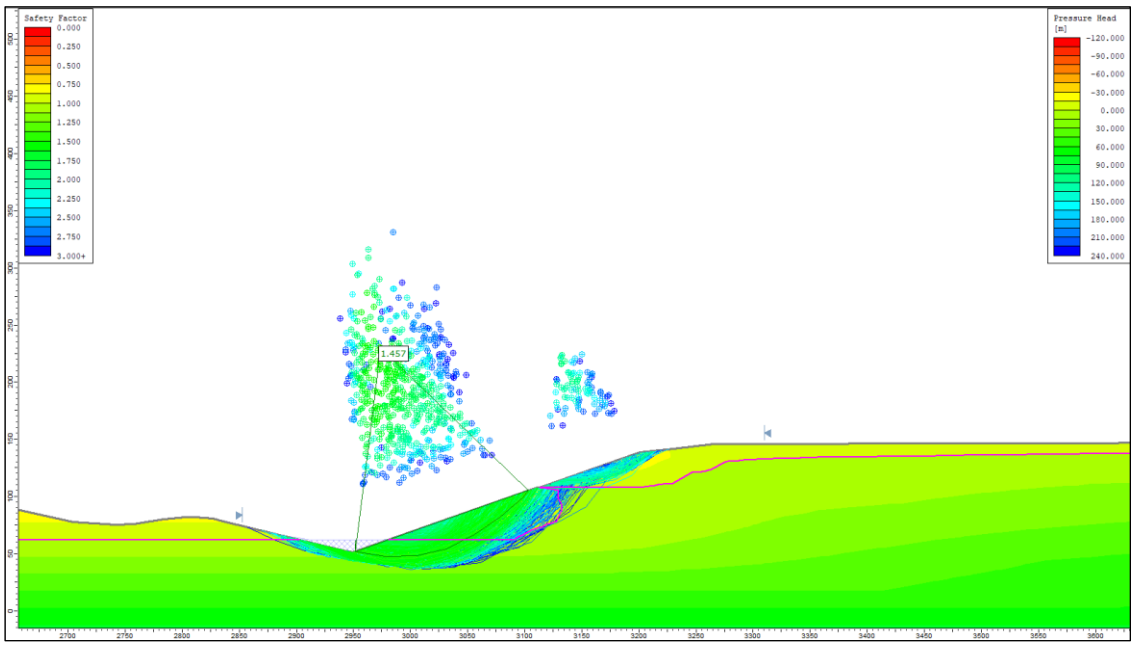

*Appendix A 30 D-Pit and I-Pit South Cross Section 1 – D-Pit Lowwall Analysis – Static*



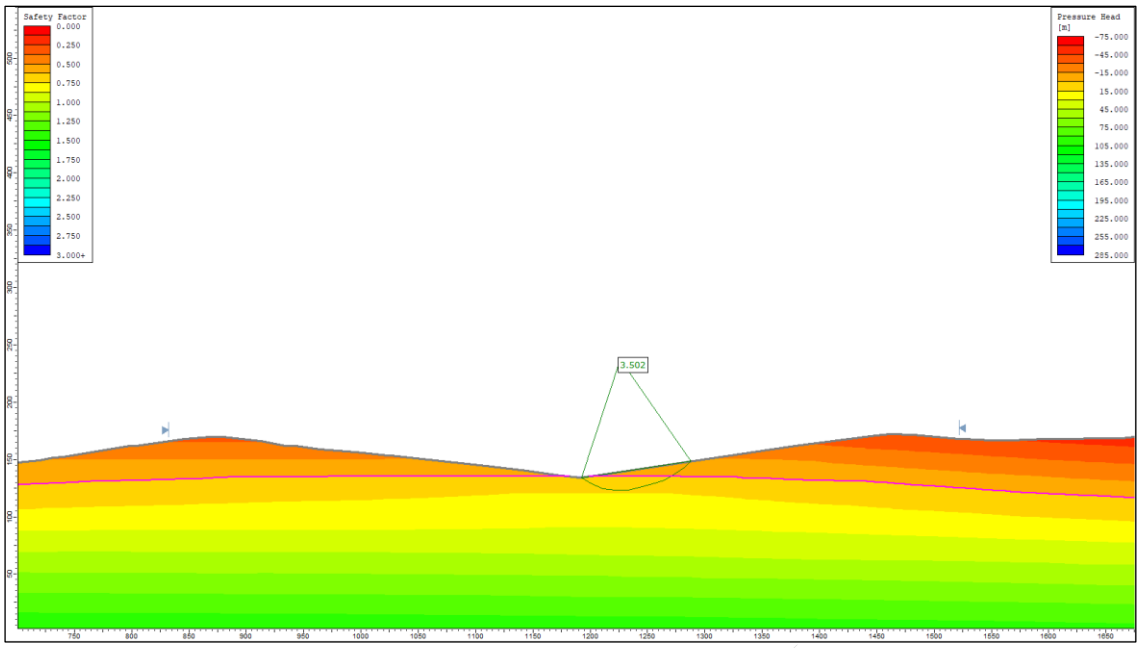

*Appendix A 31 D-Pit and I-Pit South Cross Section 1 – D-Pit Lowwall Analysis – Dynamic*



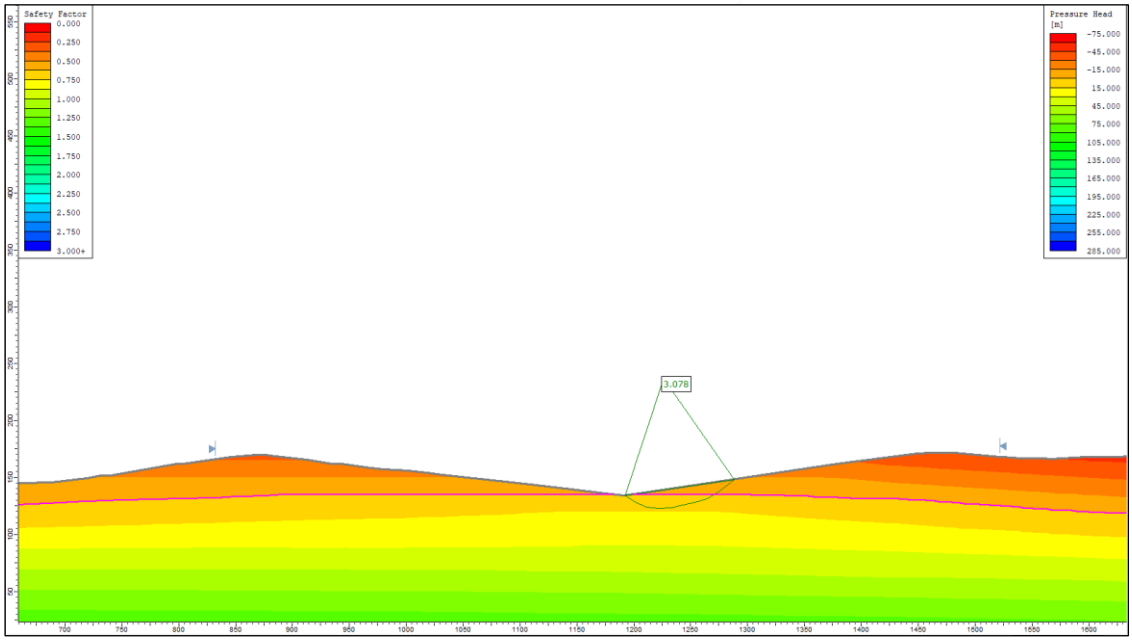

*Appendix A 32 D-Pit and I-Pit South Cross Section 1 – D-Pit Highwall Alterative Geometry Analysis – Static*



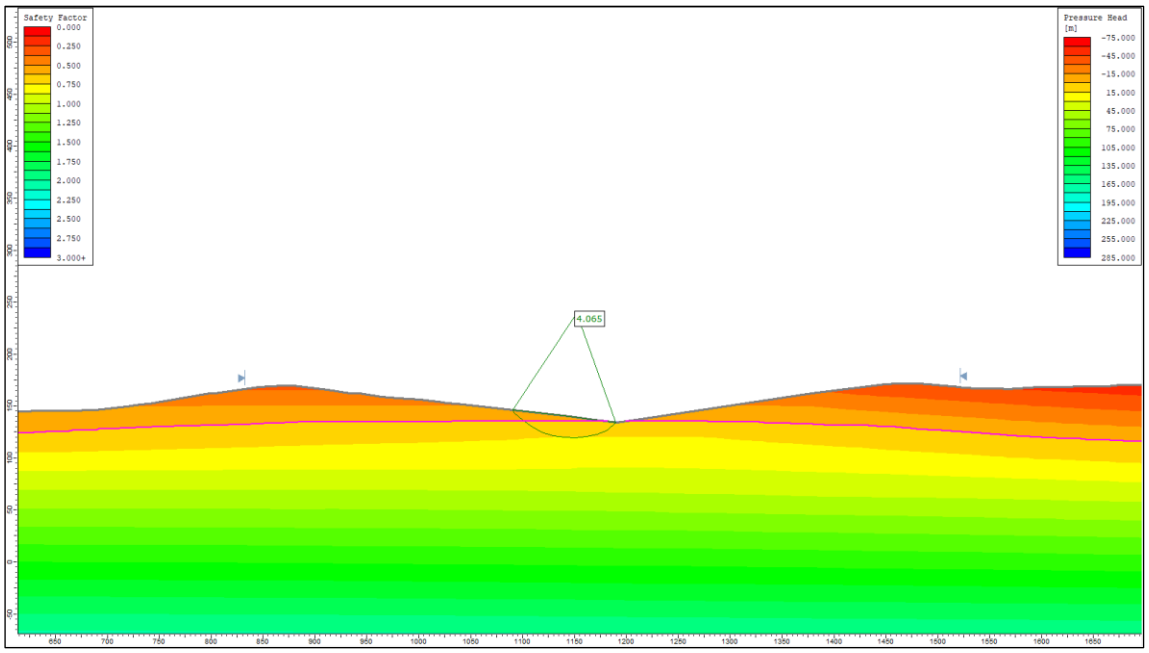

*Appendix A 33 D-Pit and I-Pit South Cross Section 1 – D-Pit Highwall Alterative Geometry Analysis – Dynamic*



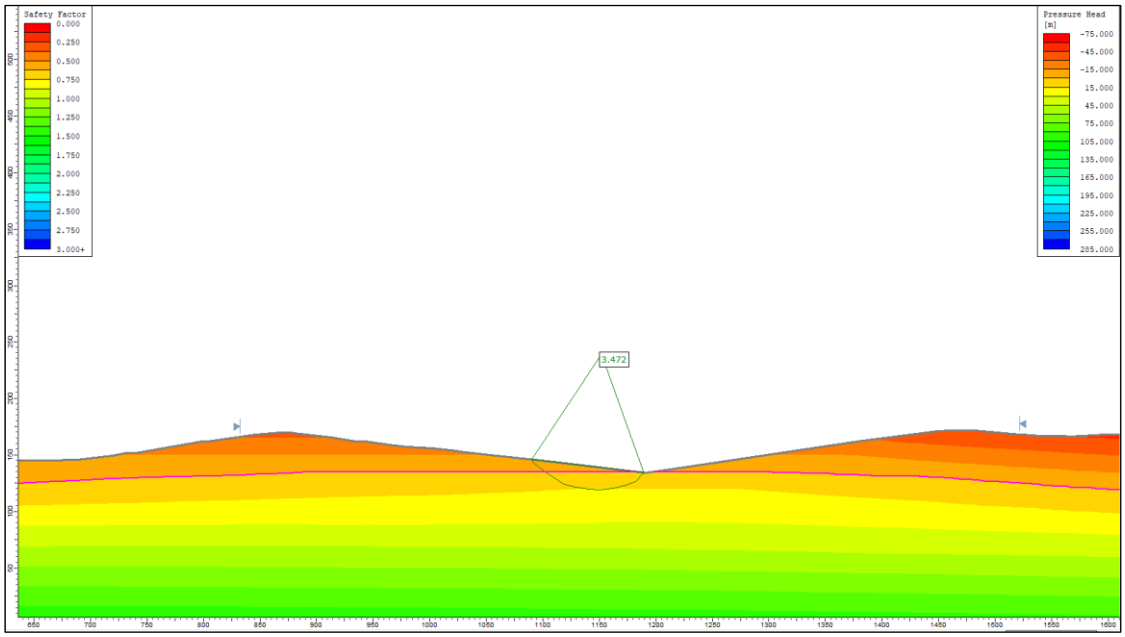

*Appendix A 34 D-Pit and I-Pit South Cross Section 1 – I-Pit South Eastern Lowwall Analysis – Static*



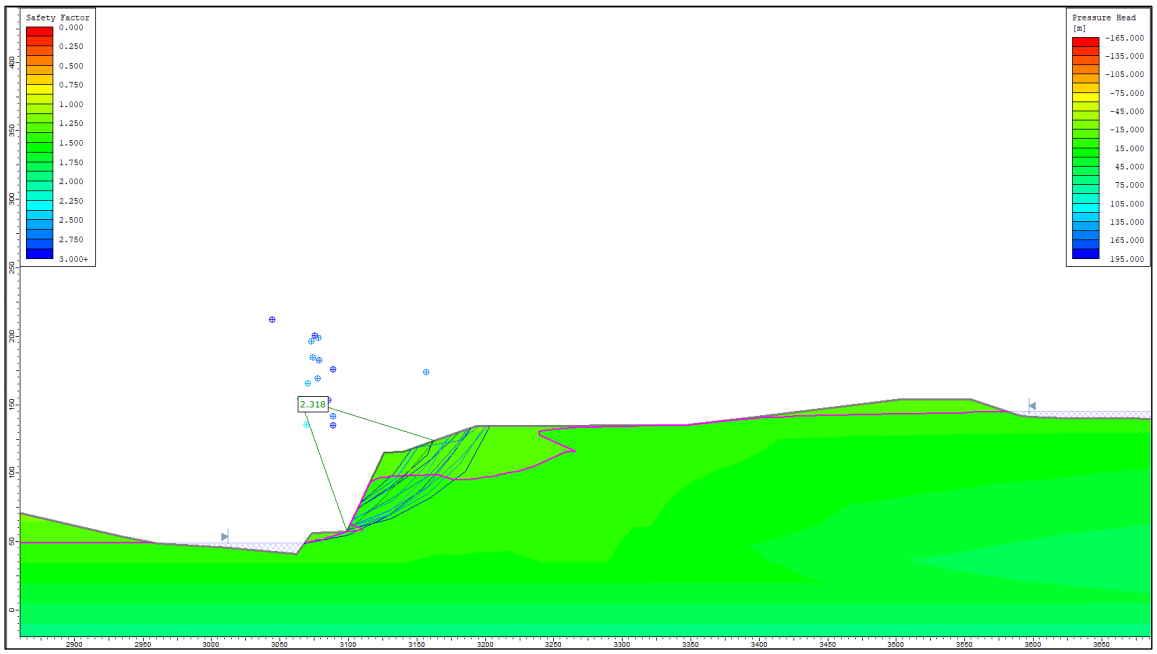

*Appendix A 35 D-Pit and I-Pit South Cross Section 1 – I-Pit South Eastern Lowwall Analysis – Dynamic*



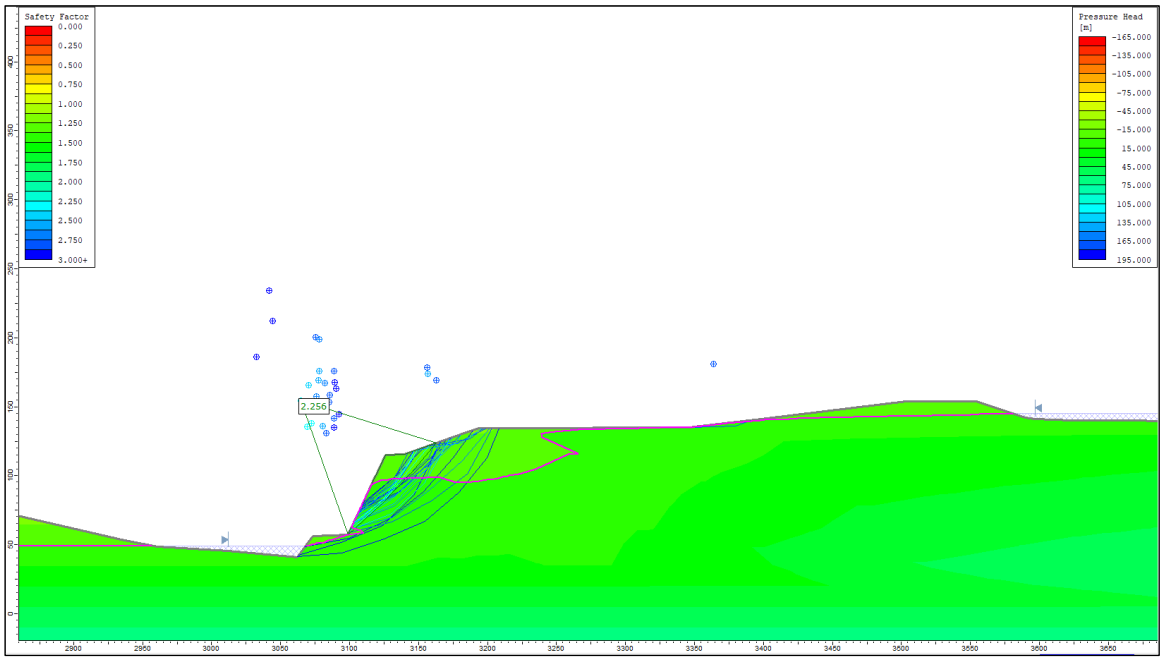

*Appendix A 36 D-Pit and I-Pit South Cross Section 1 – I-Pit South Western Lowwall Analysis – Static*



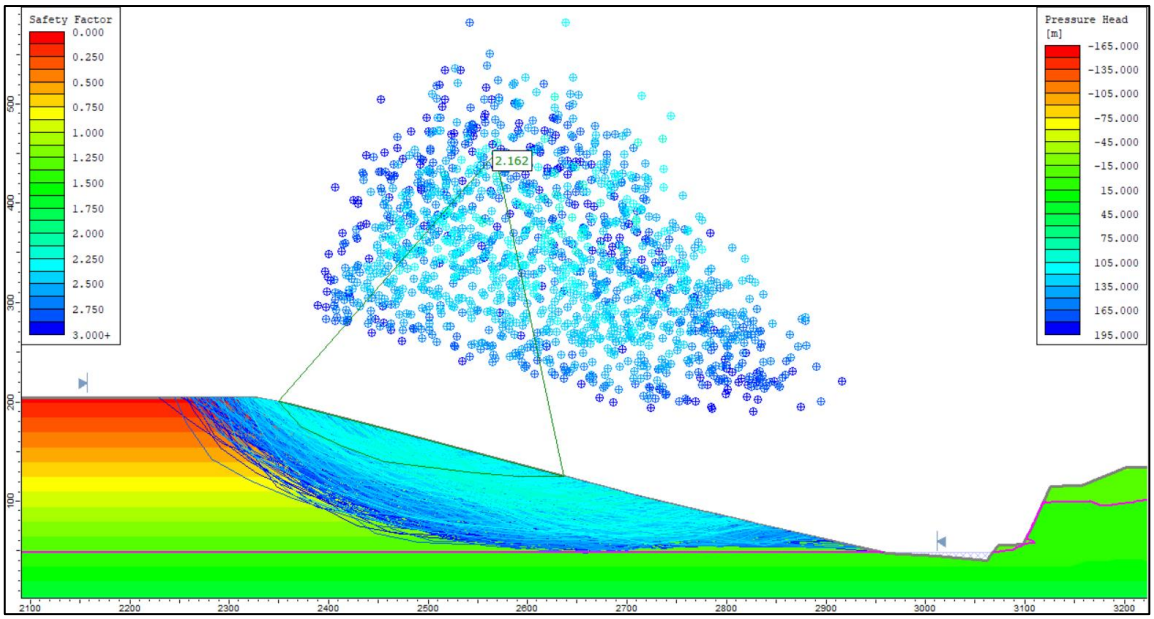

*Appendix A 37 D-Pit and I-Pit South Cross Section 1 – I-Pit South Western Lowwall Analysis – Dynamic*



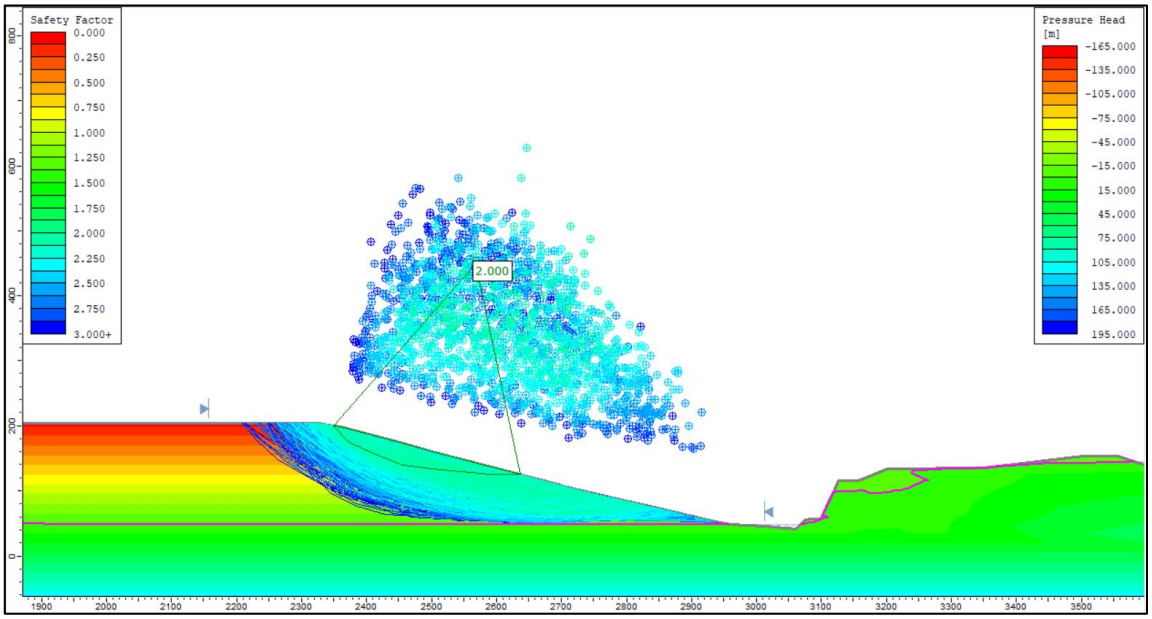

*Appendix A 38 E-Pit North Cross Section 1 – Highwall Analysis – Static*



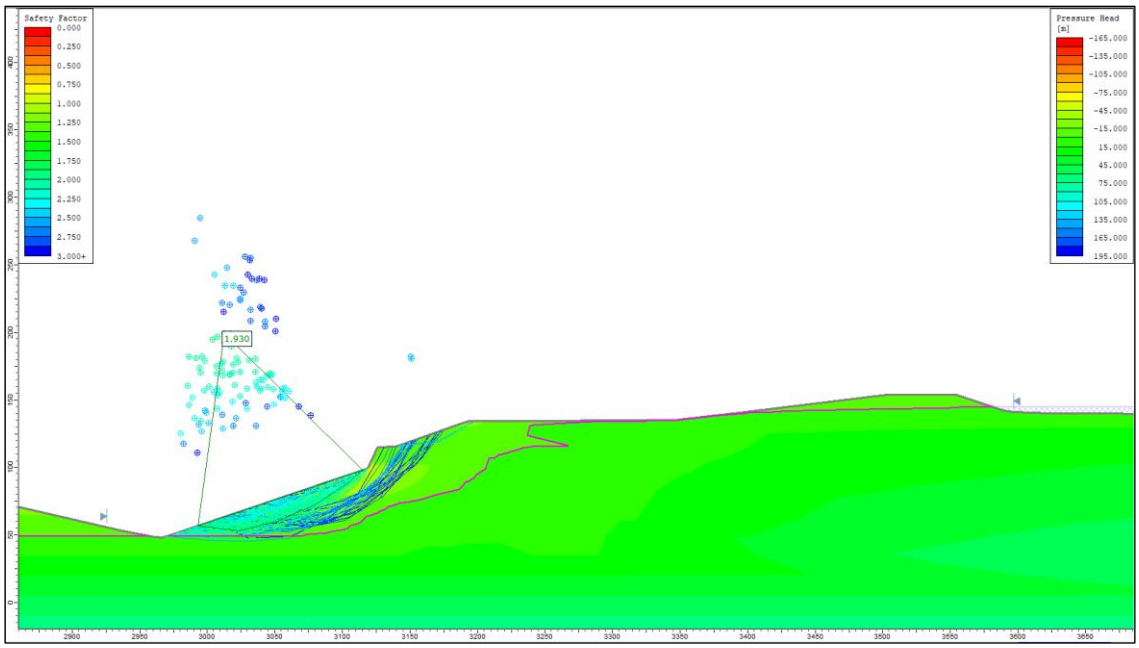

*Appendix A 39 E-Pit North Cross Section 1 – Highwall Analysis – Dynamic*



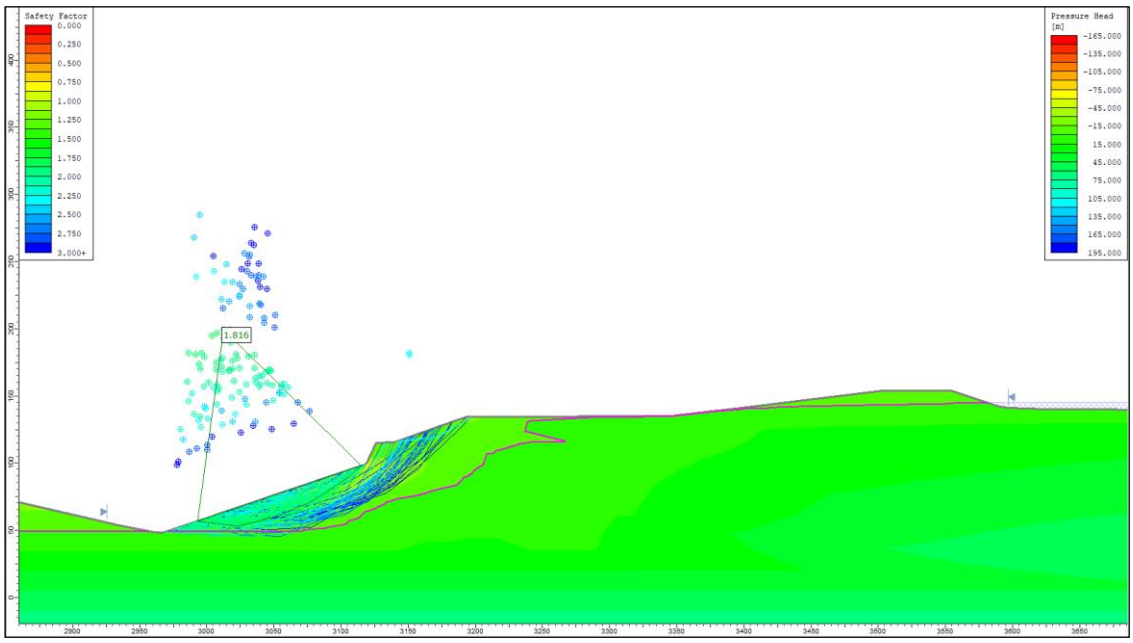

*Appendix A 40 E-Pit North Cross Section 1 – Lowwall Analysis – Static*



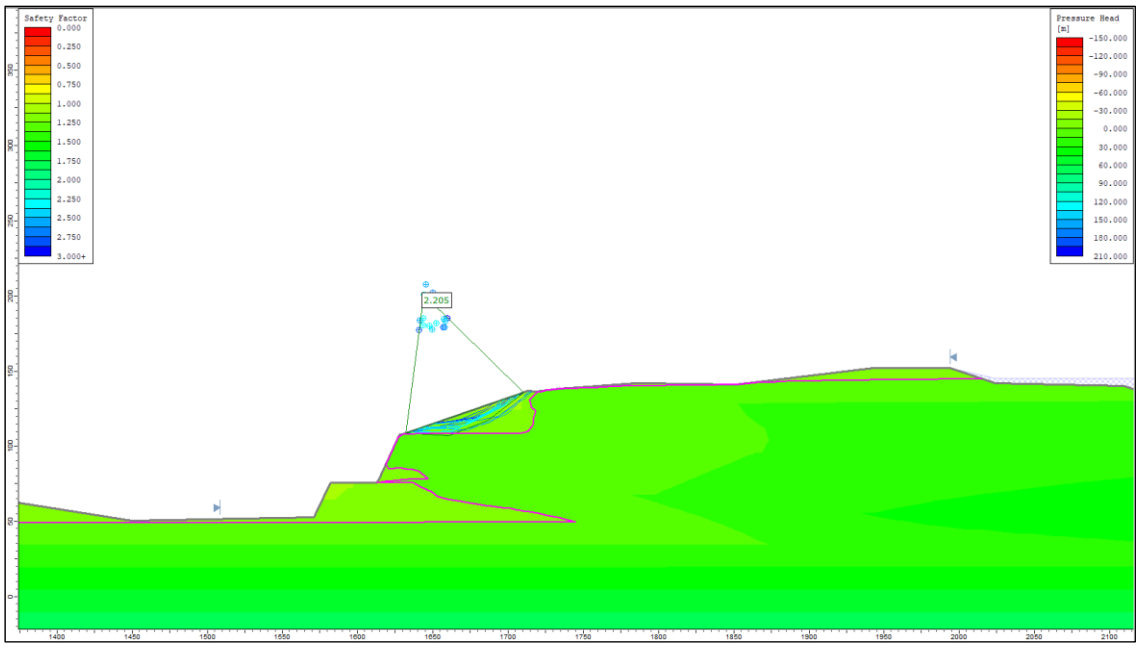

*Appendix A 41 E-Pit North Cross Section 1 – Lowwall Analysis – Dynamic*



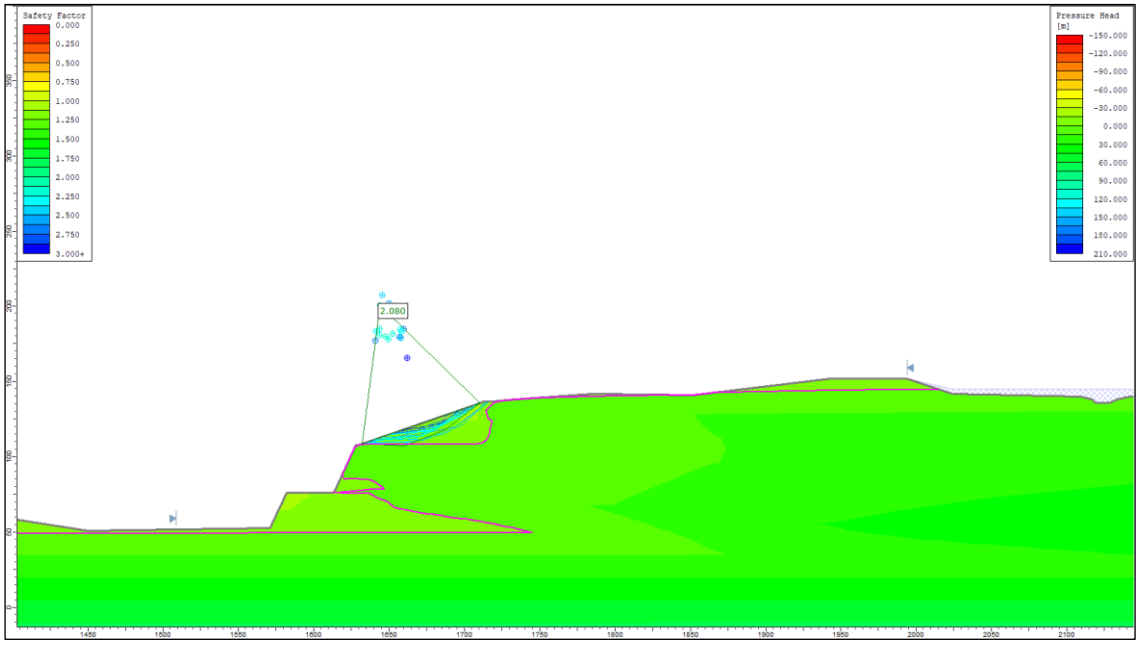

*Appendix A 42 E-Pit North Cross Section 1 – Highwall Alternative Geometry Analysis – Static*




*Appendix A 43 E-Pit North Cross Section 1 – Highwall Alternative Geometry Analysis – Dynamic*



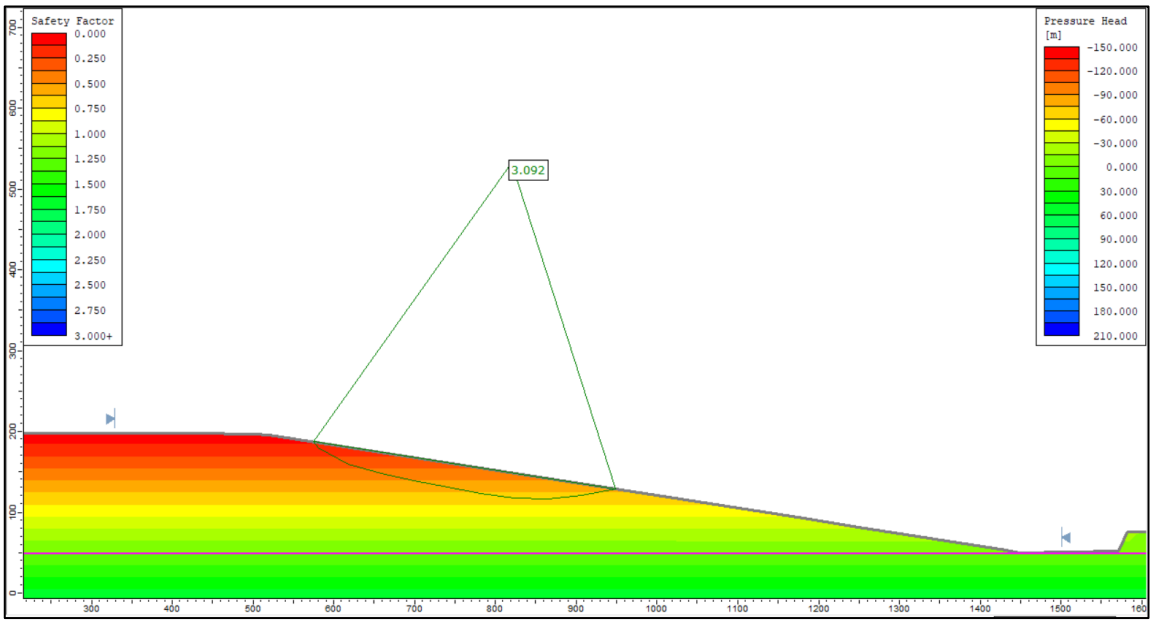

*Appendix A 44 F-Pit North Cross Section 1 – Highwall Analysis – Static*



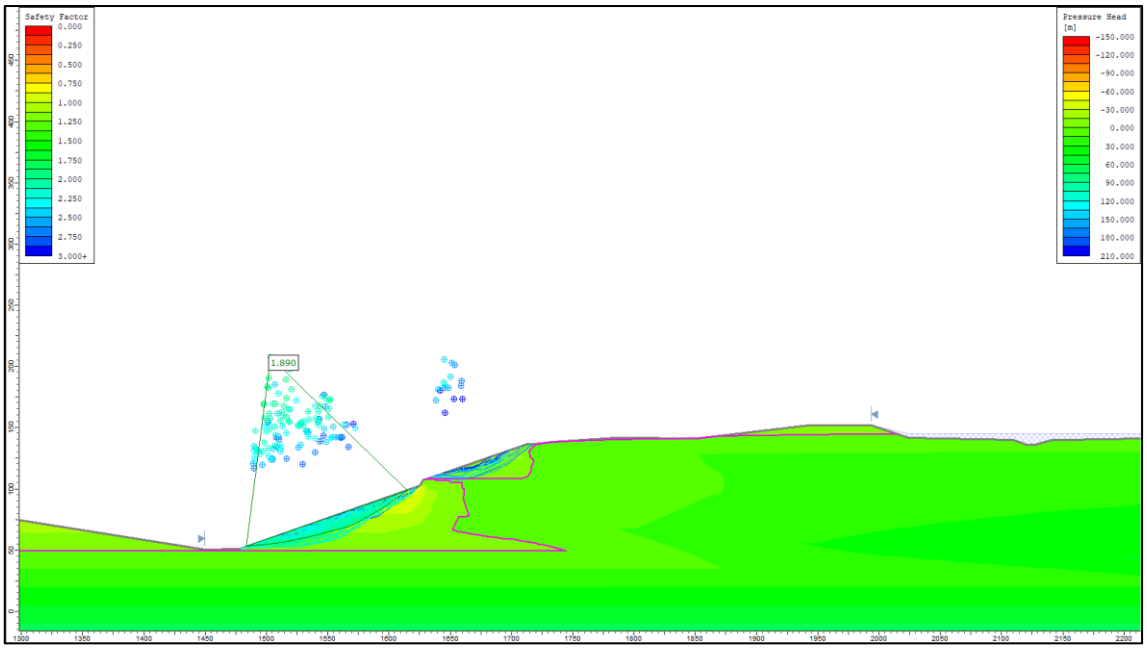

*Appendix A 45 F-Pit North Cross Section 1 – Highwall Analysis – Dynamic*



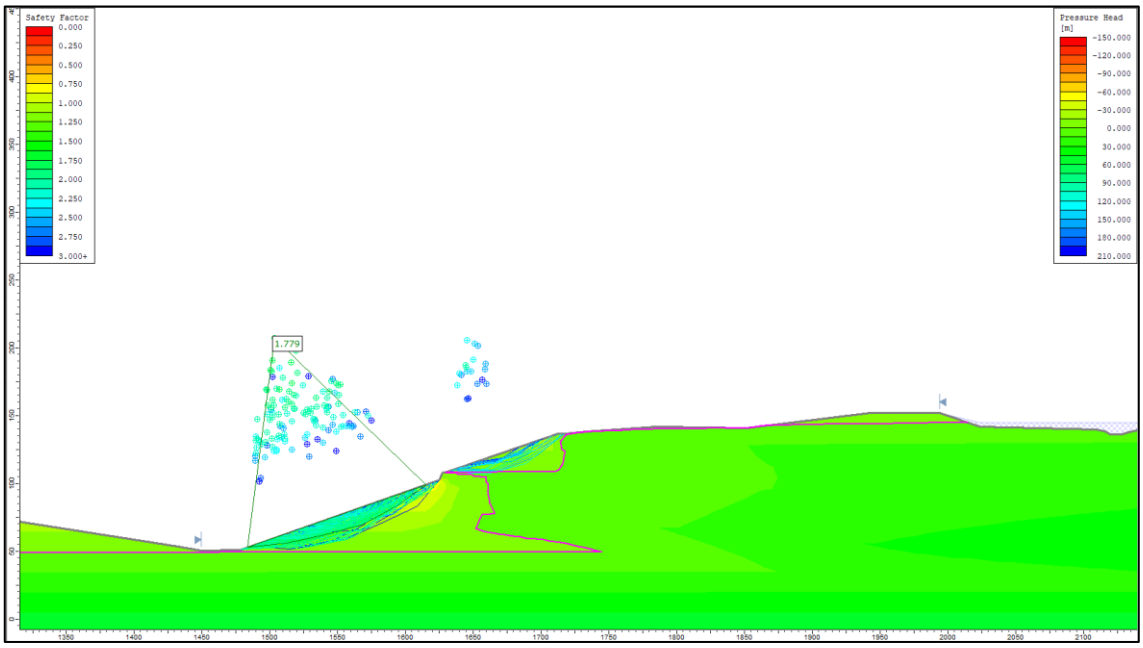

*Appendix A 46 F-Pit North Cross Section 1 – Lowwall Analysis – Static*



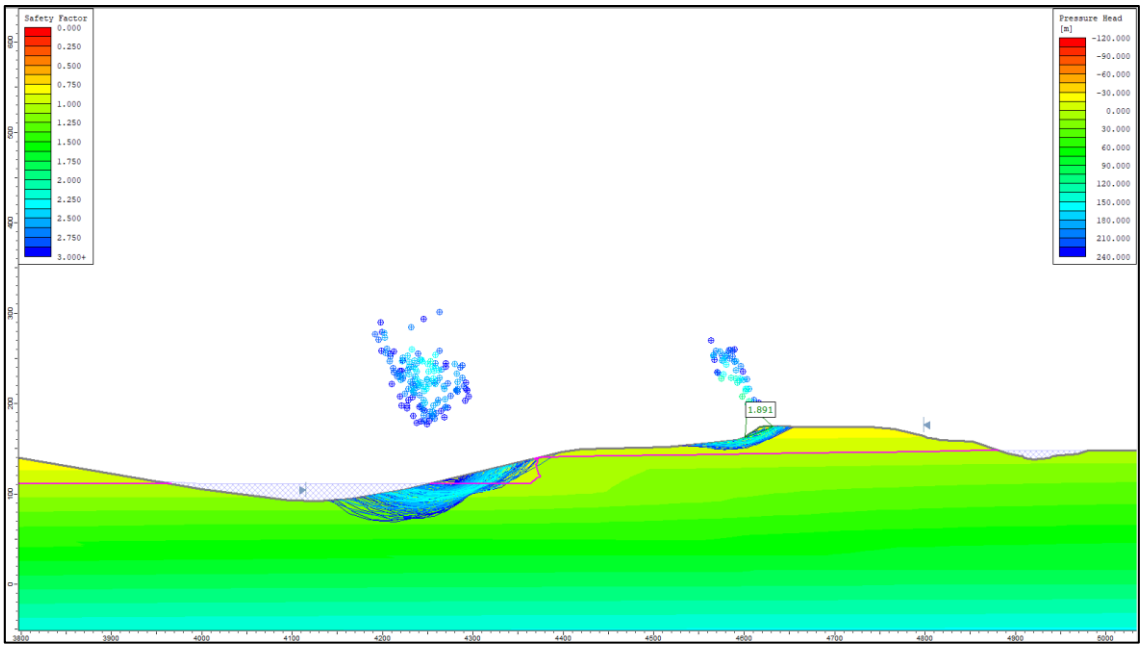

*Appendix A 47 F-Pit North Cross Section 1 – Lowwall Analysis – Dynamic*



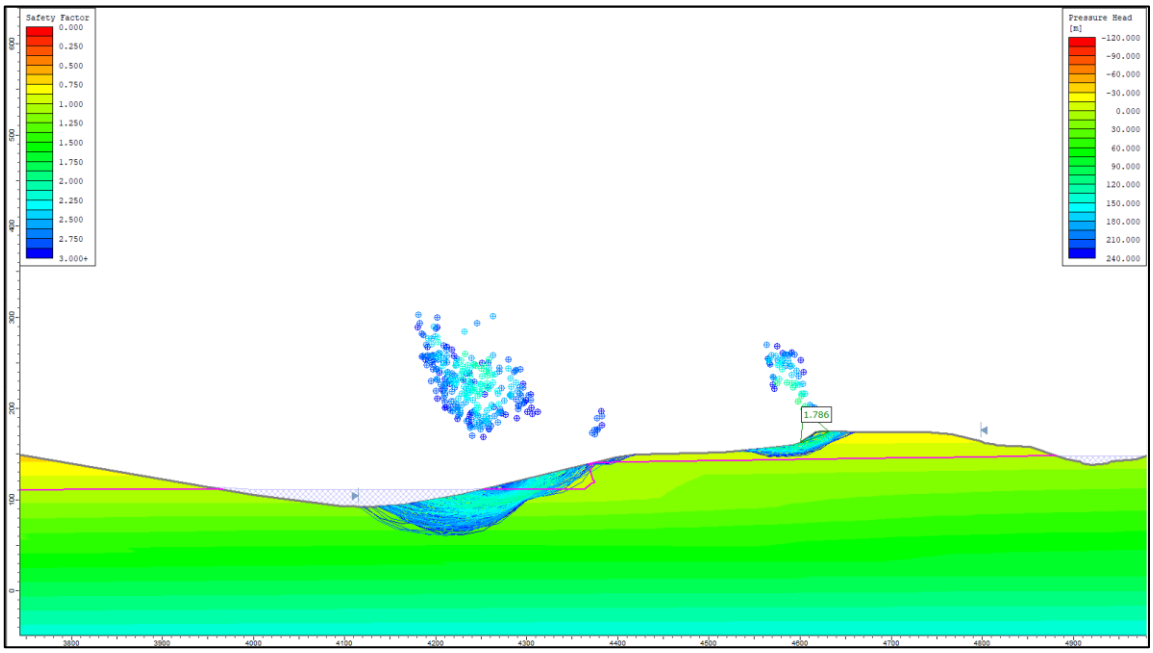

*Appendix A 48 F-Pit North Cross Section 1 – Highwall Alternative Geometry Analysis – Static*



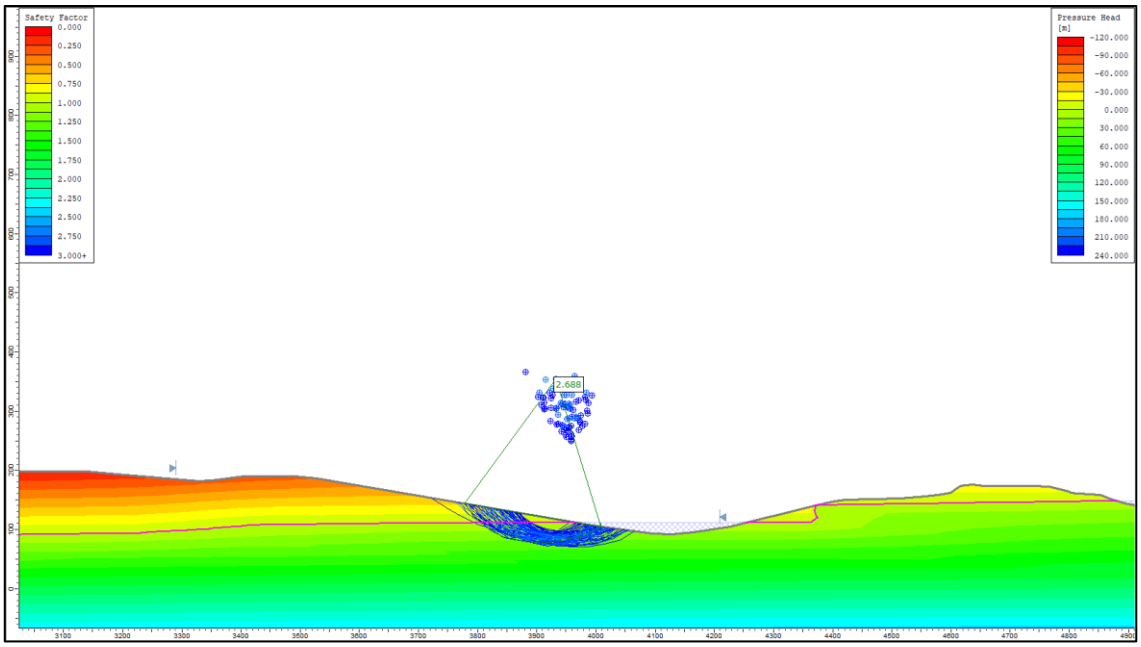

*Appendix A 49 F-Pit North Cross Section 1 – Highwall Alternative Geometry Analysis – Dynamic*



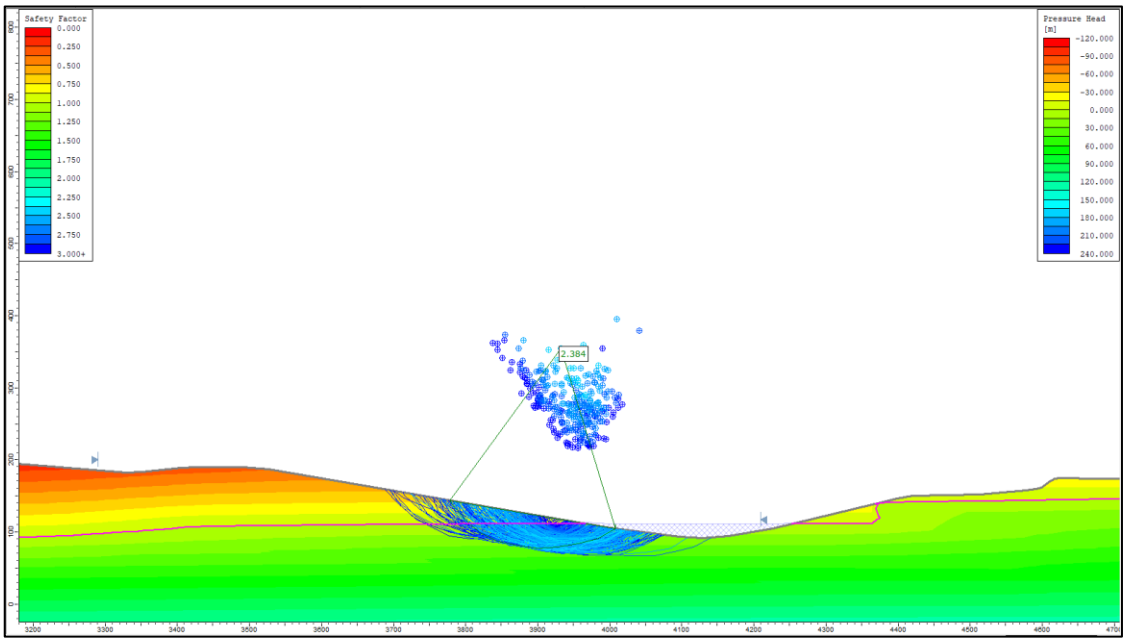

*Appendix A 50 F-Pit Cross Section 1 – Highwall Analysis – Static*



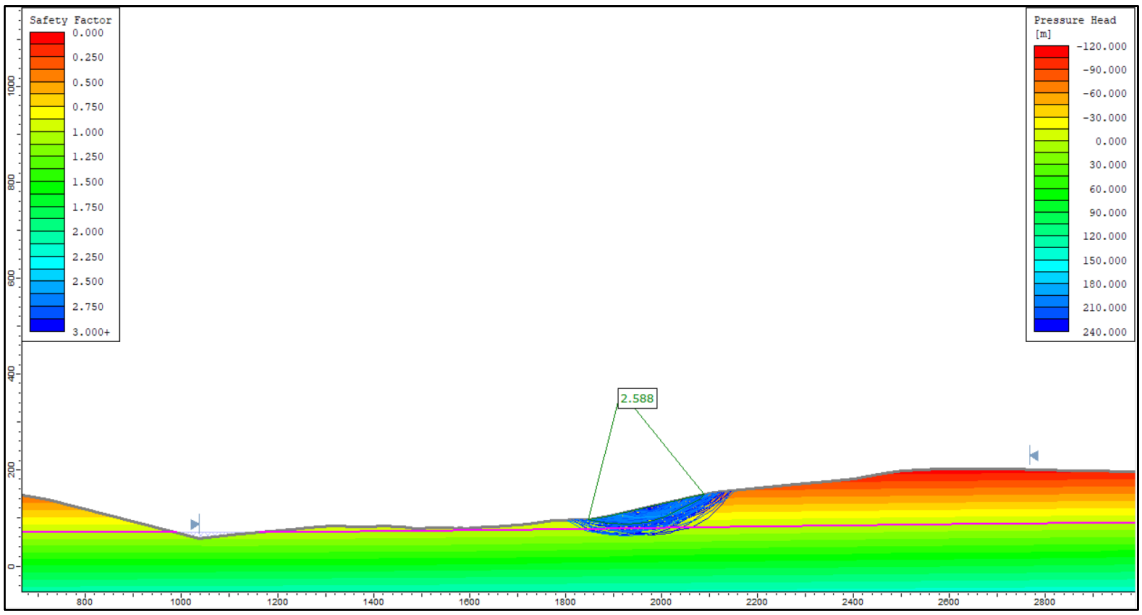

*Appendix A 51 F-Pit Cross Section 1 – Highwall Analysis – Dynamic*



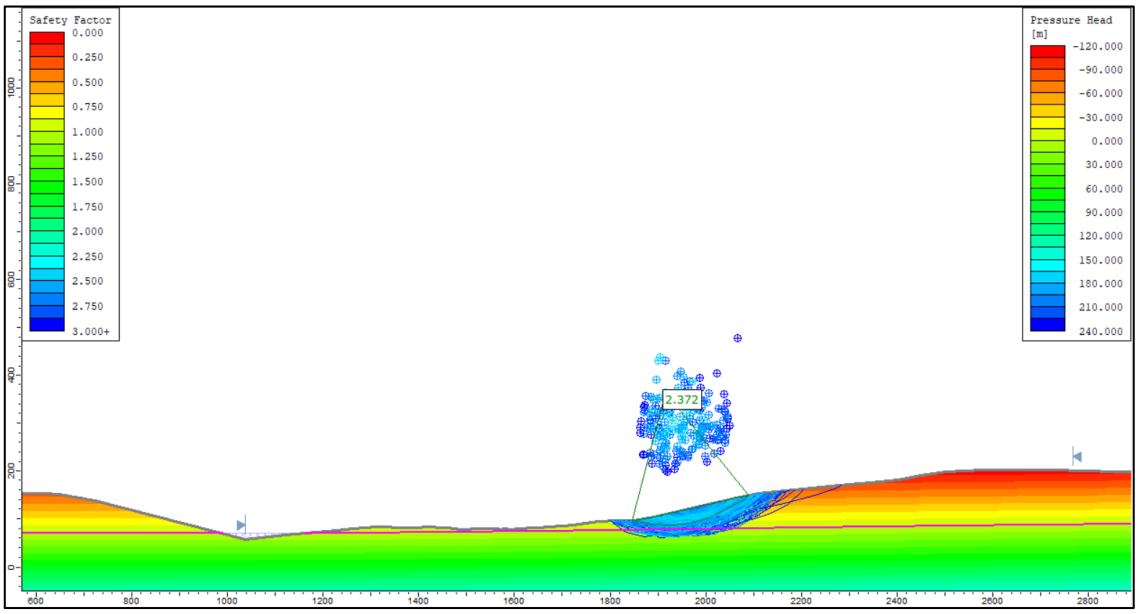

*Appendix A 52 F-Pit Cross Section 1 – Lowwall Analysis – Static*



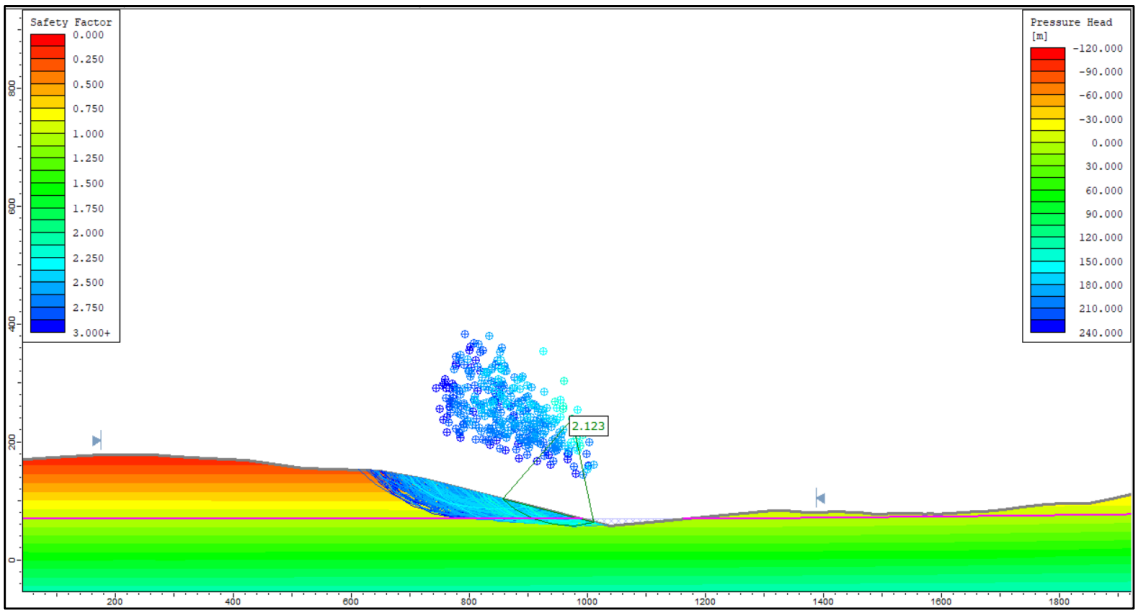

*Appendix A 53 F-Pit Cross Section 1 – Lowwall Analysis – Dynamic*



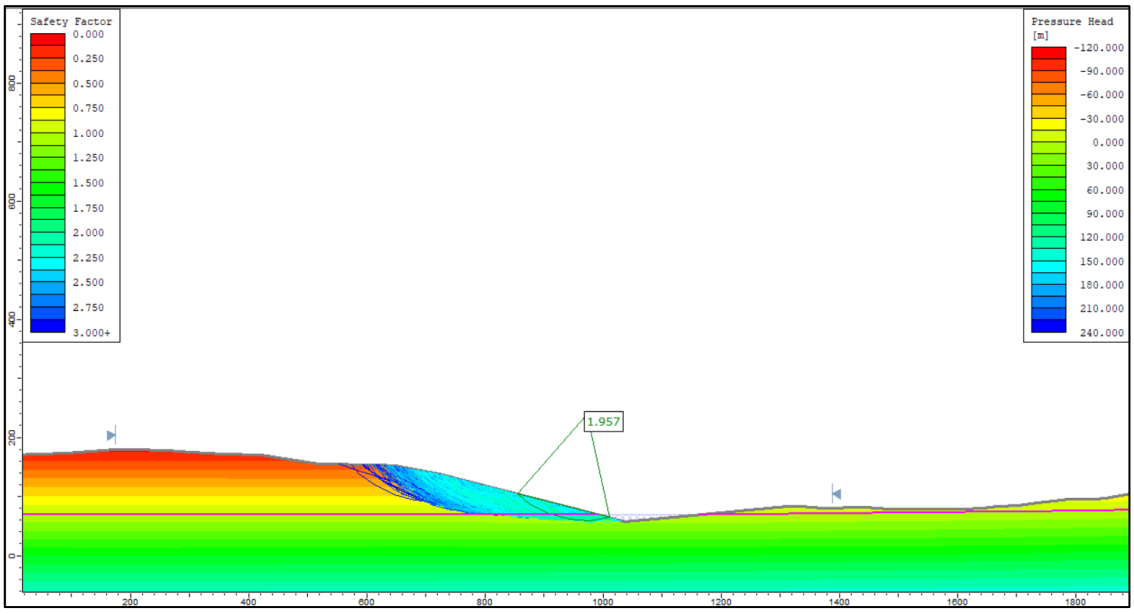

*Appendix A 54 E, C and H-pit Void Cross Section 1 – Eastern Pitwall Analysis – Static*



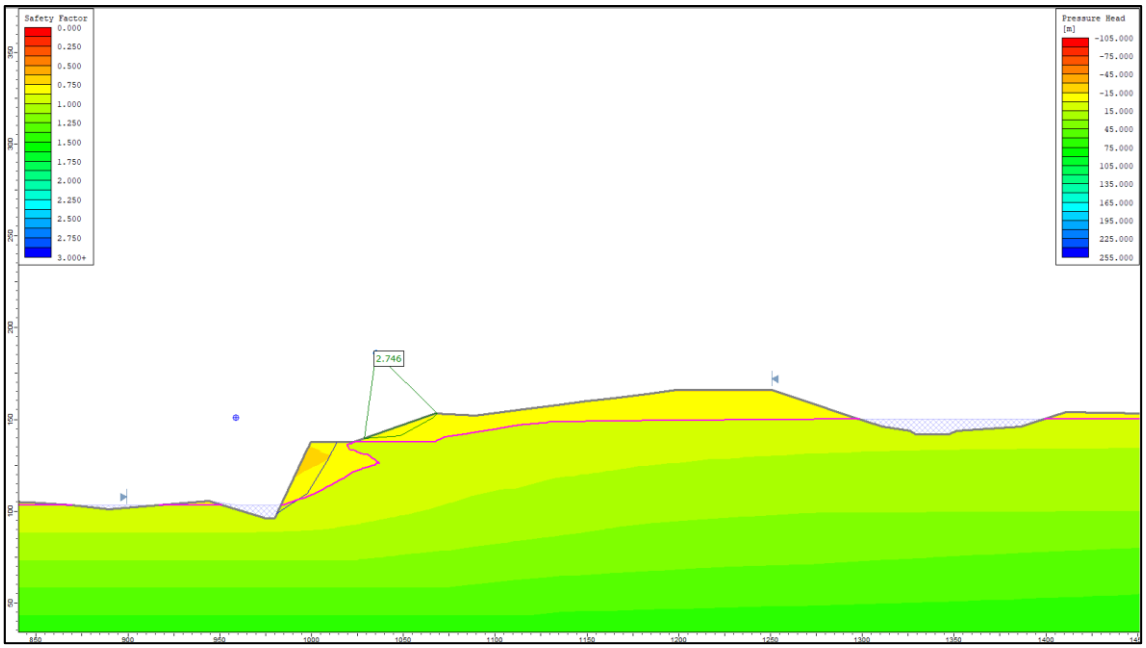

*Appendix A 55 E, C and H-pit Void Cross Section 1 – Eastern Pitwall Analysis – Dynamic*



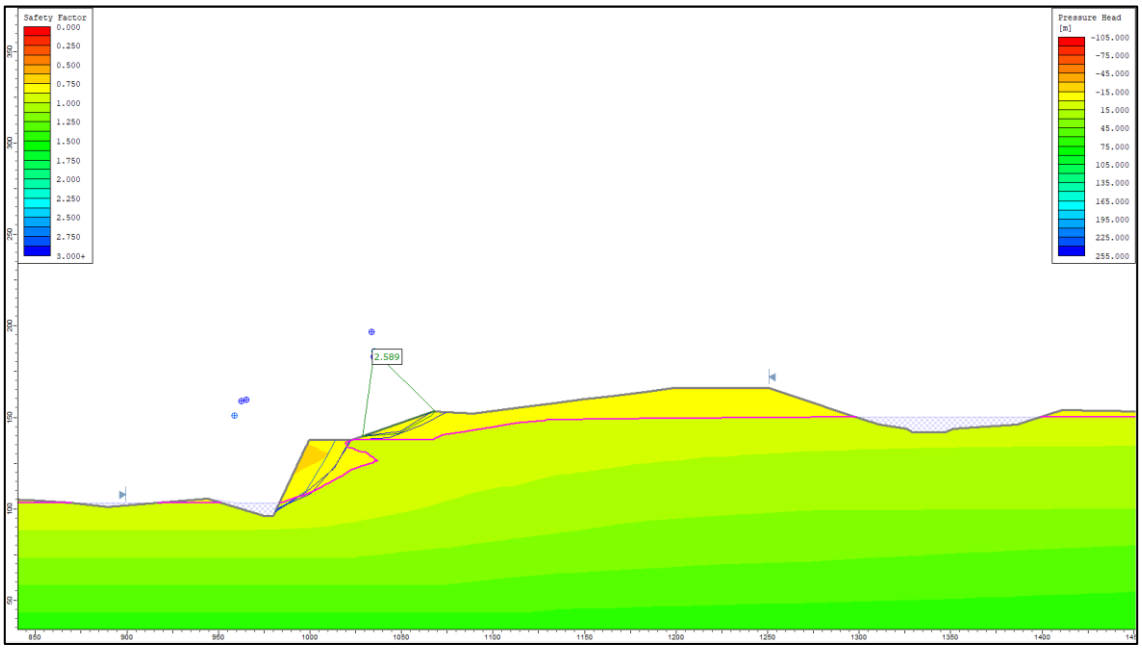

*Appendix A 56 E, C and H-pit Void Cross Section 1 – Western Pitwall Analysis – Static*



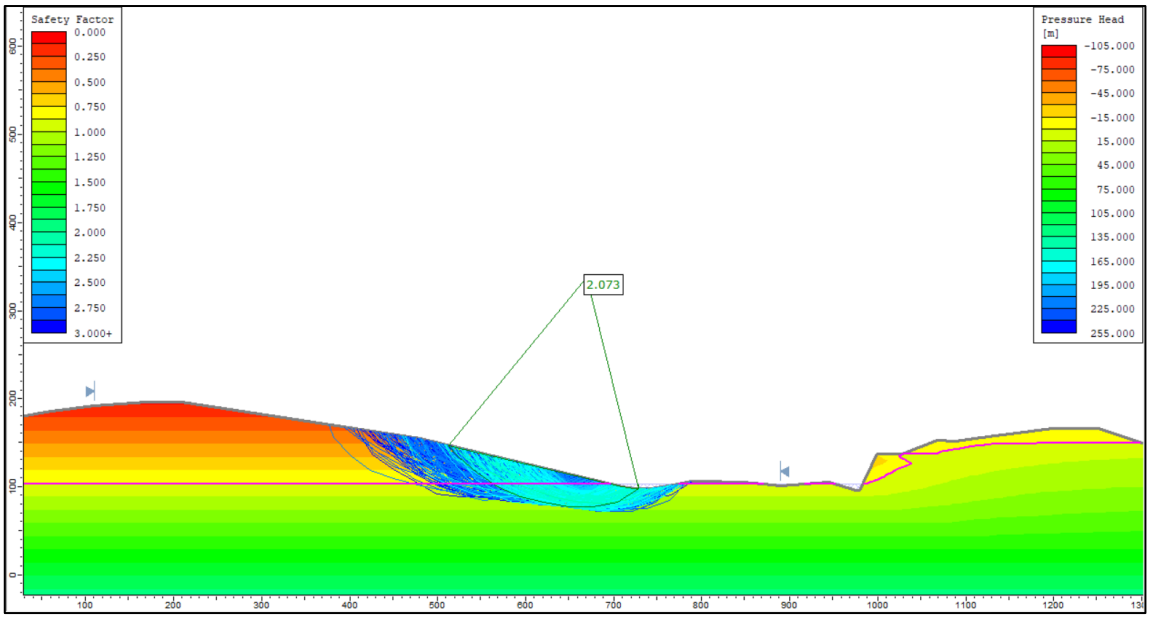

*Appendix A 57 E, C and H-pit Void Cross Section 1 – Western Pitwall Analysis – Dynamic*



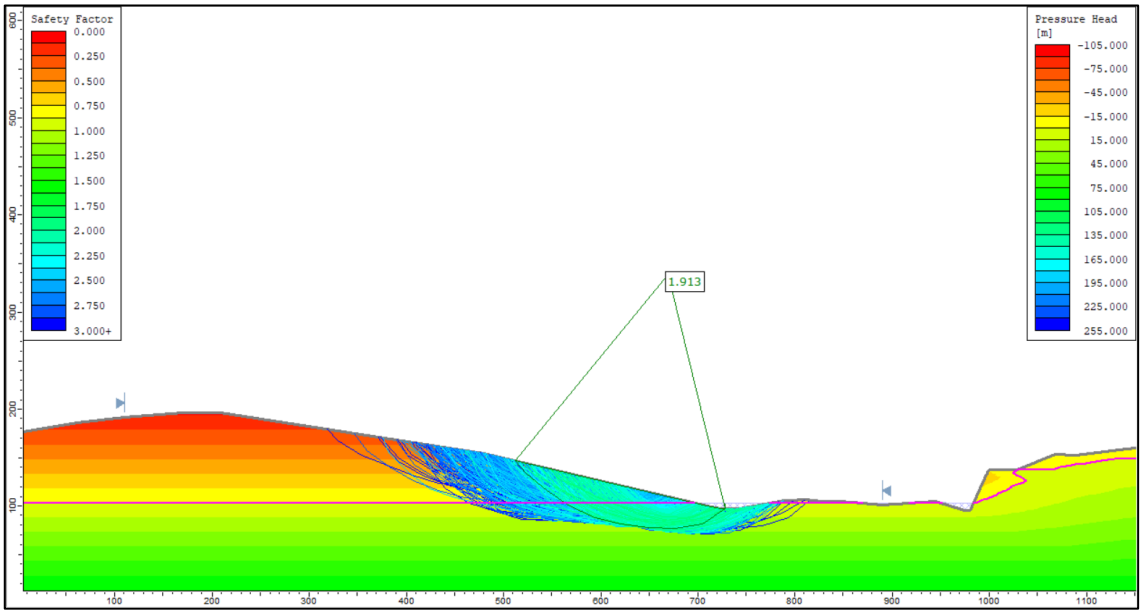

*Appendix A 58 L-Pit Cross Section 1 – Highwall Analysis – Static*



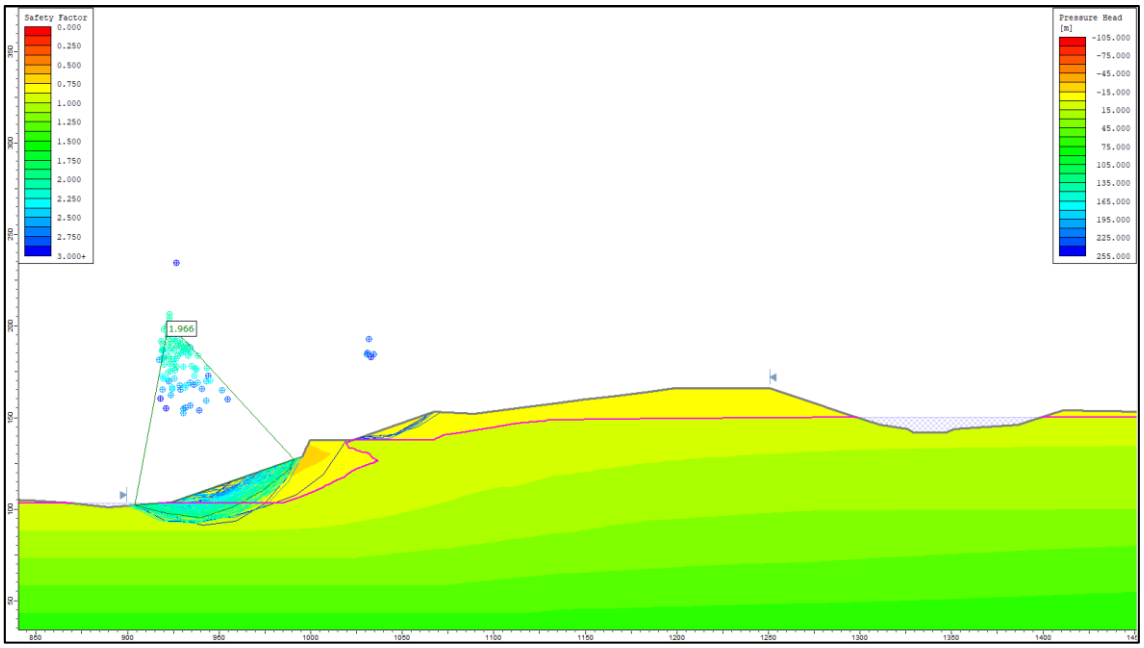

*Appendix A 59 L-Pit Cross Section 1 – Highwall Analysis – Dynamic*



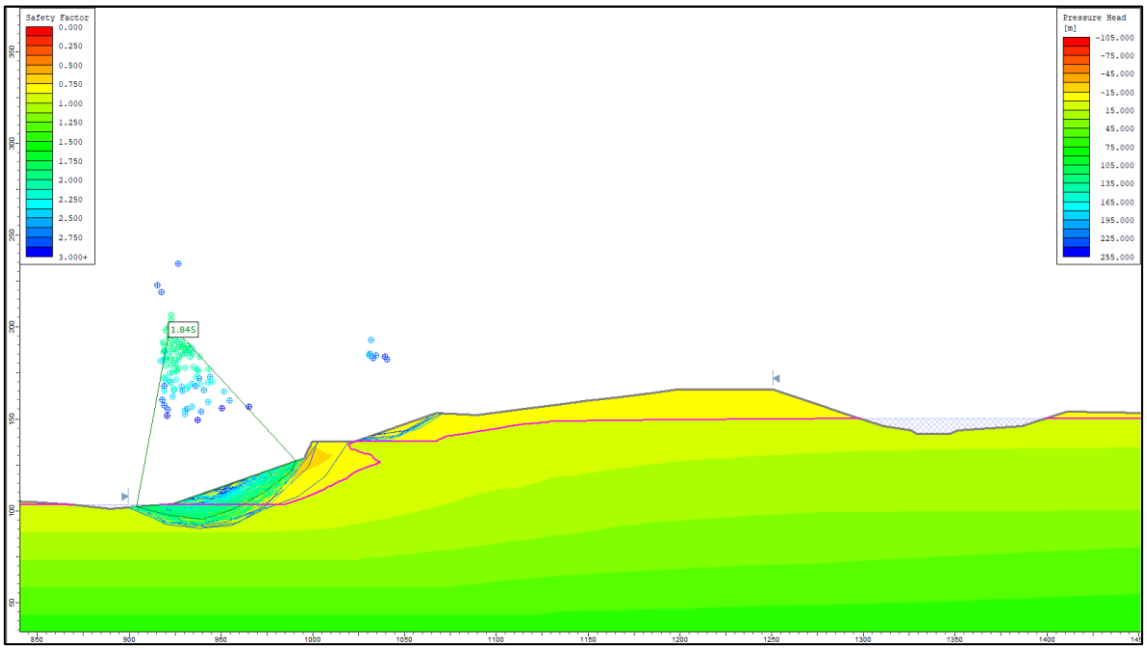

*Appendix A 60 L-Pit Cross Section 1 – Lowwall Analysis – Static*



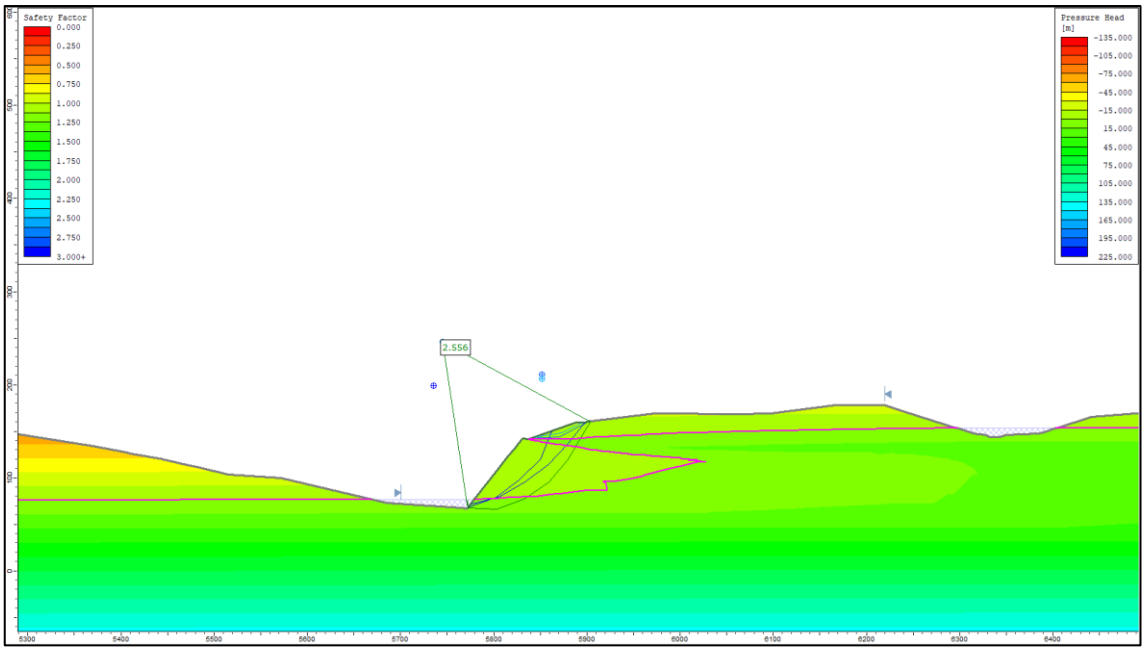

*Appendix A 61 L-Pit Cross Section 1 – Lowwall Analysis – Dynamic*



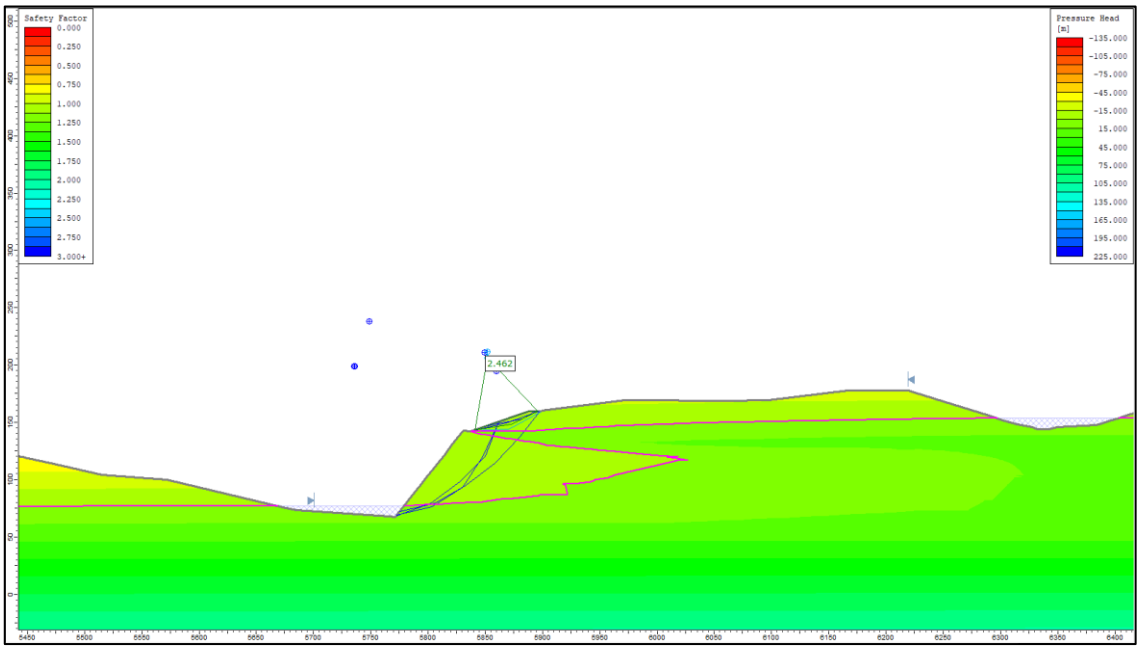

*Appendix A 62 L-Pit Cross Section 1 Alternative Geometry – Highwall Analysis – Static*



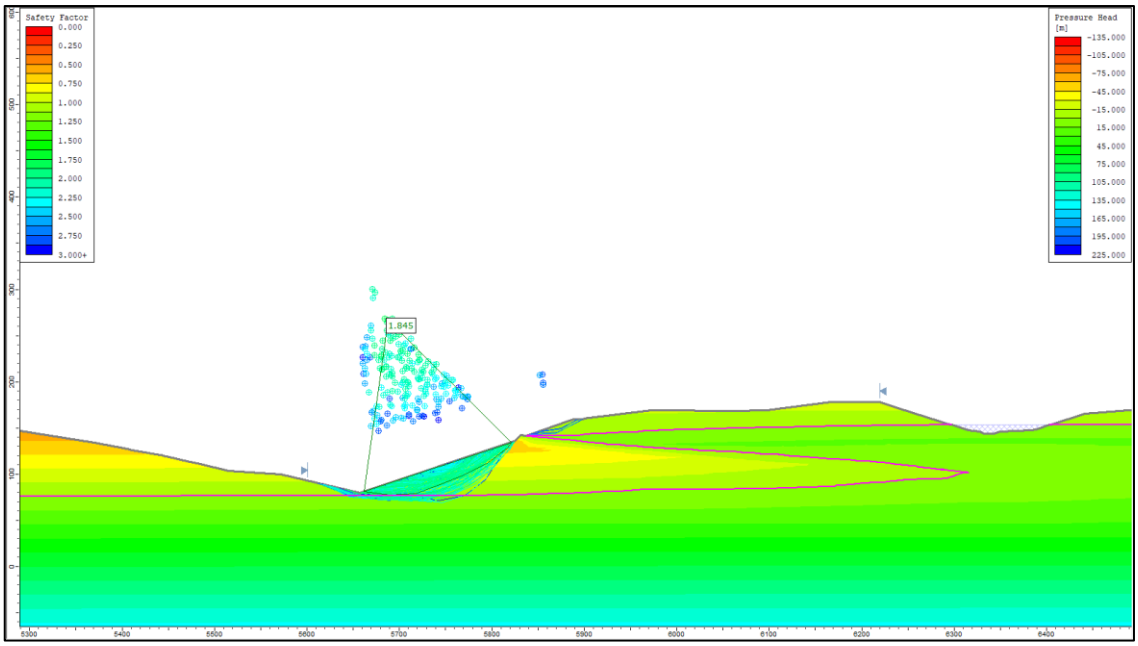

*Appendix A 63 L-Pit Cross Section 1 Alternative Geometry – Highwall Analysis – Dynamic*



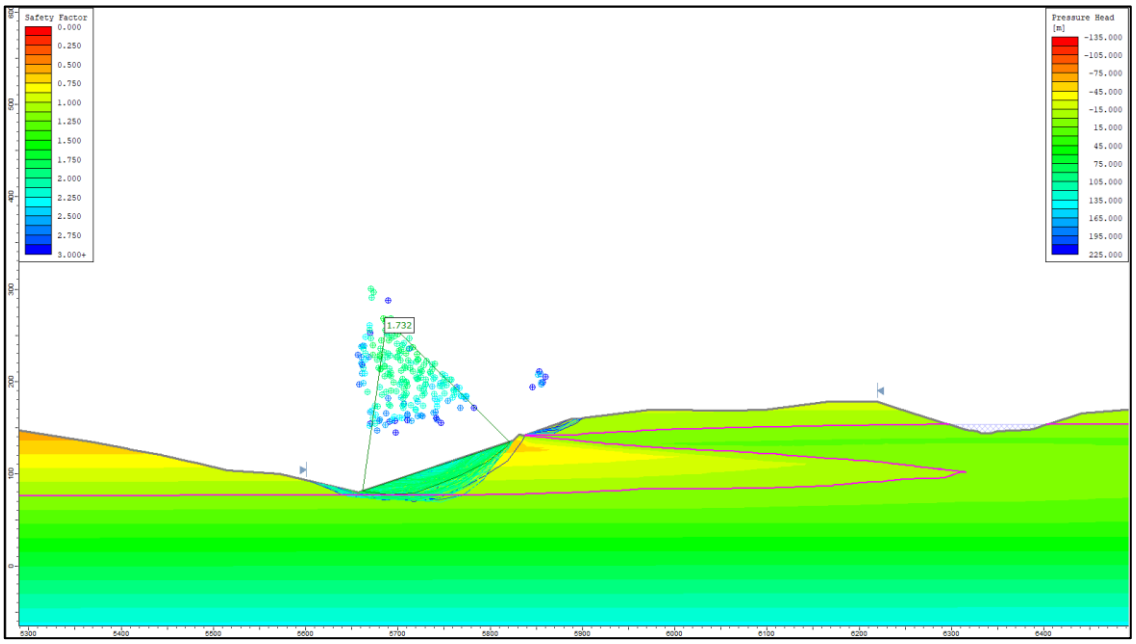

*Appendix A 64 K-Pit Cross Section 1 – Highwall Analysis – Static*



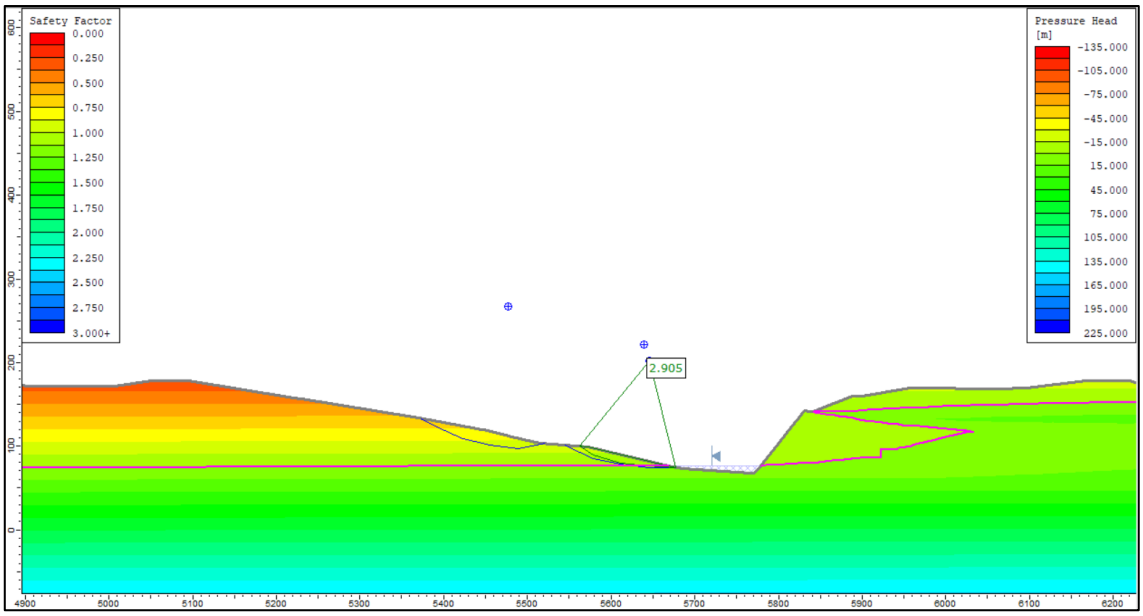

*Appendix A 65 K-Pit Cross Section 1 – Highwall Analysis – Dynamic*



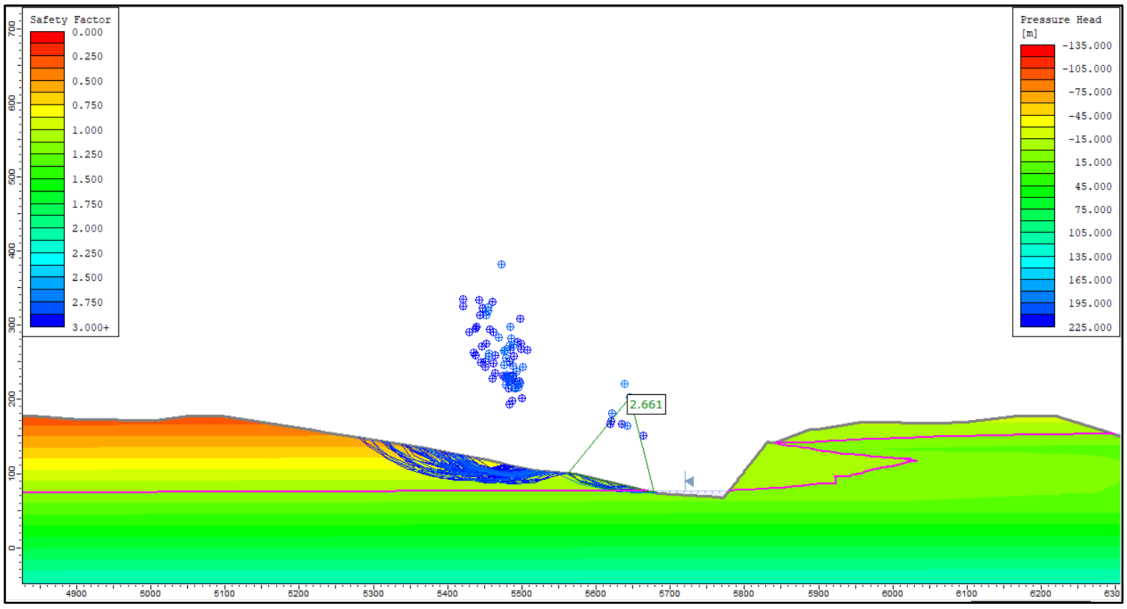

*Appendix A 66 K-Pit Cross Section 1 – Highwall Alternative Geometry Analysis – Static*



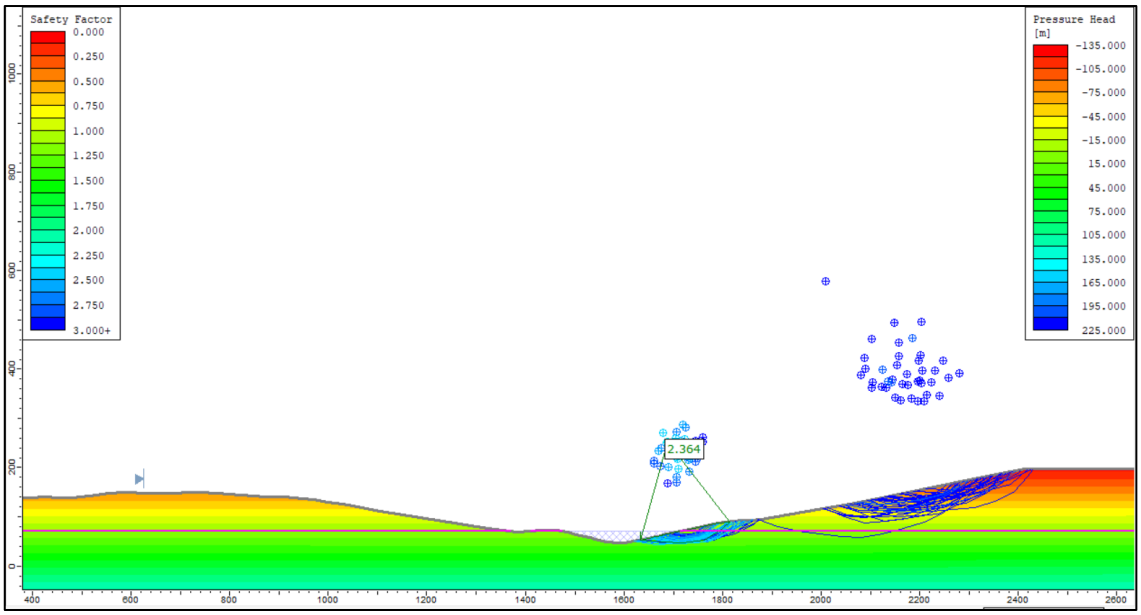

*Appendix A 67 K-Pit Cross Section 1 – Highwall Alternative Geometry Analysis – Dynamic*



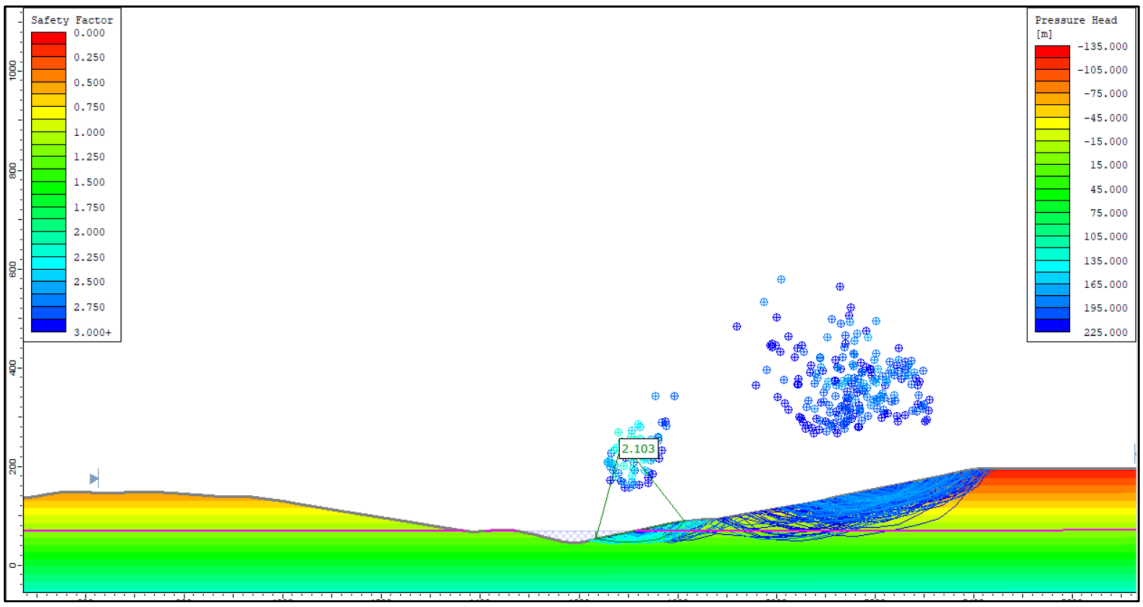

*Appendix A 68 K-Pit Cross Section 1 – Lowwall Analysis – Static*



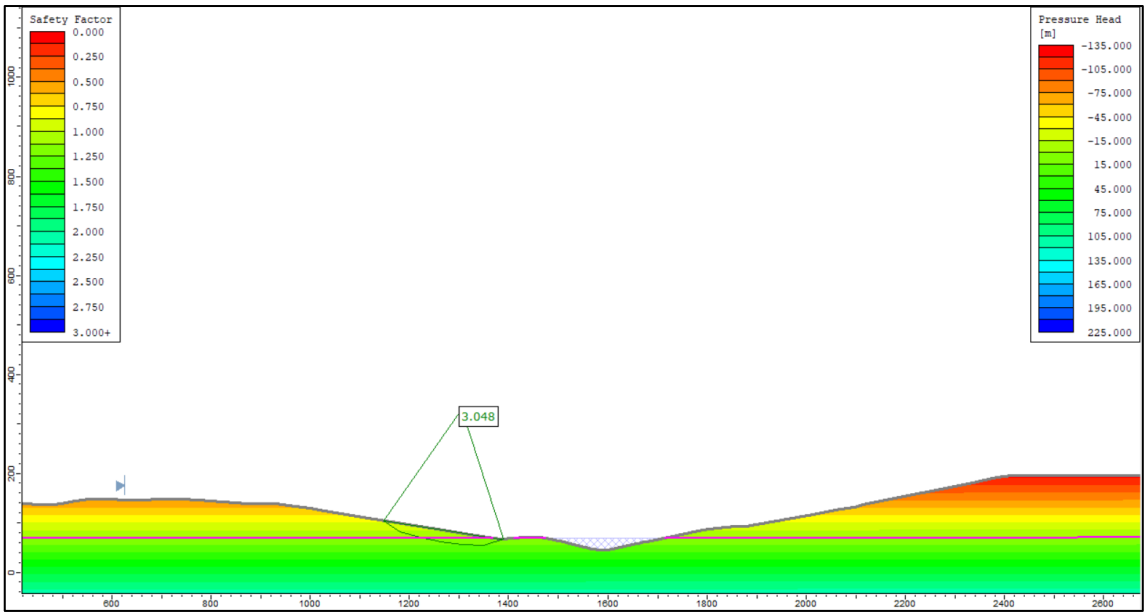

*Appendix A 69 K-Pit Cross Section 1 – Lowwall Analysis – Dynamic*



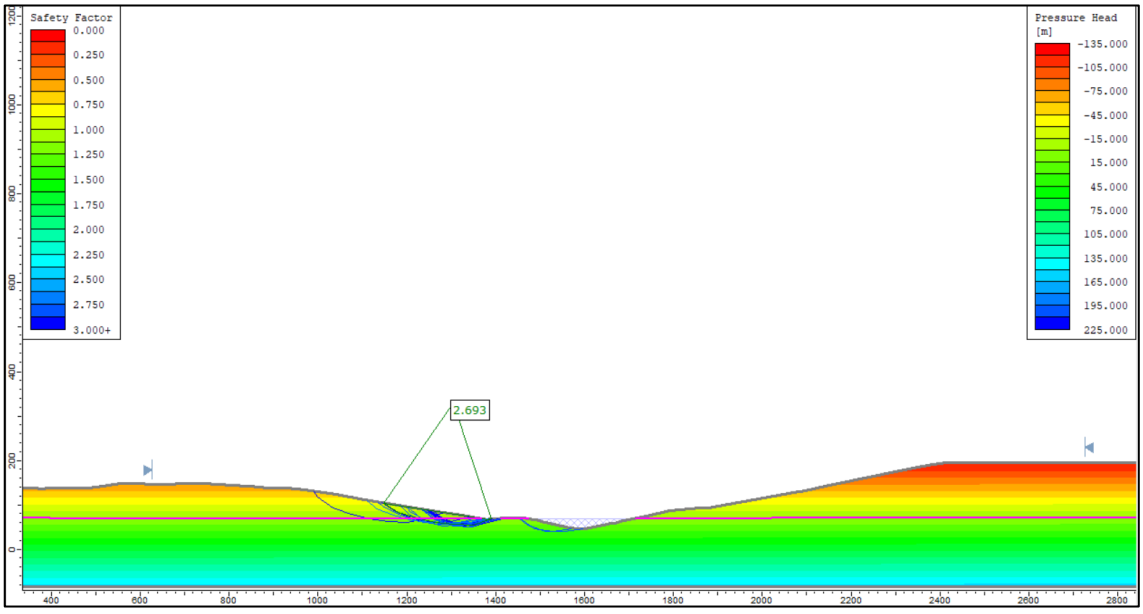

*Appendix A 70 E, C and H-pit Void Cross Section 1 – Eastern Pitwall Analysis – Static*



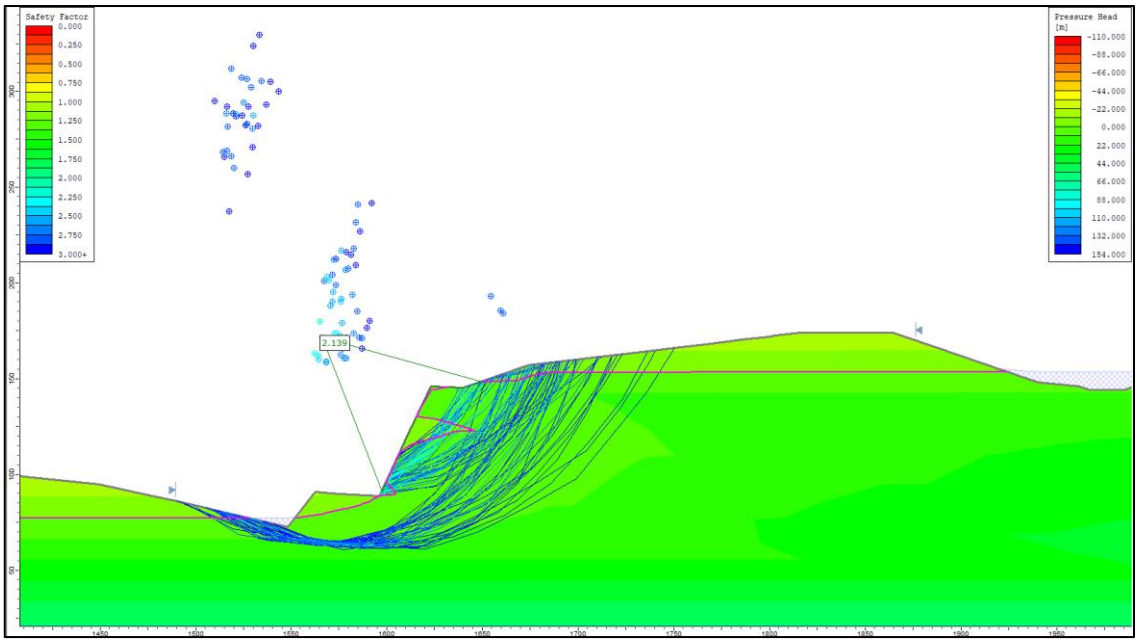

*Appendix A 71 E, C and H-pit Void Cross Section 1 – Eastern Pitwall Analysis – Dynamic*



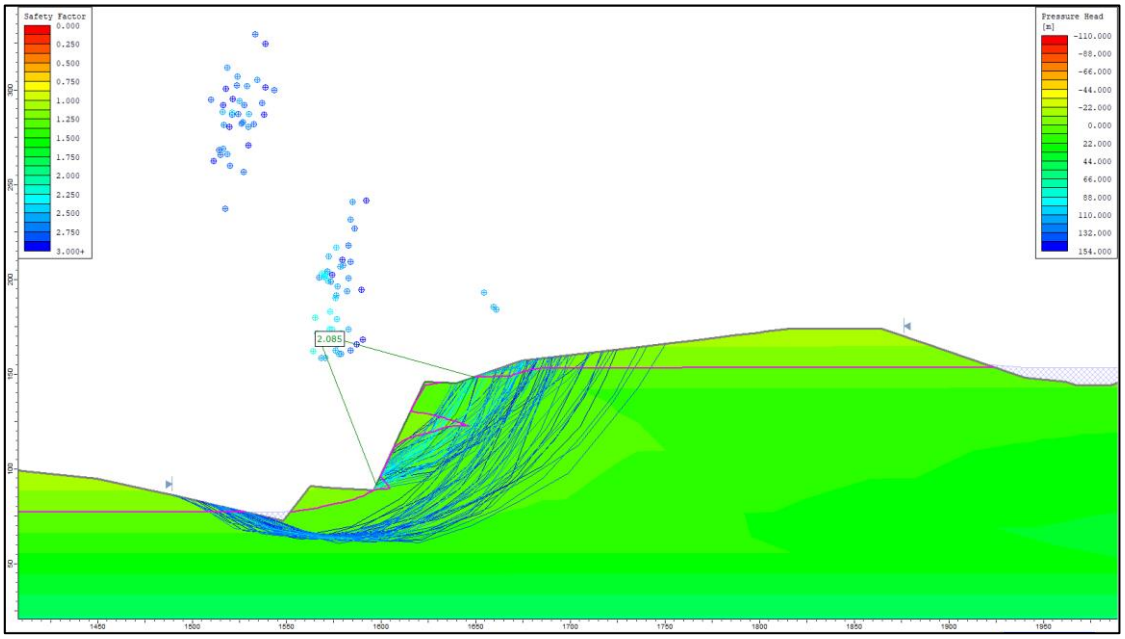

*Appendix A 72 E, C and H-pit Void Cross Section 1 – Western Pitwall Analysis – Static*



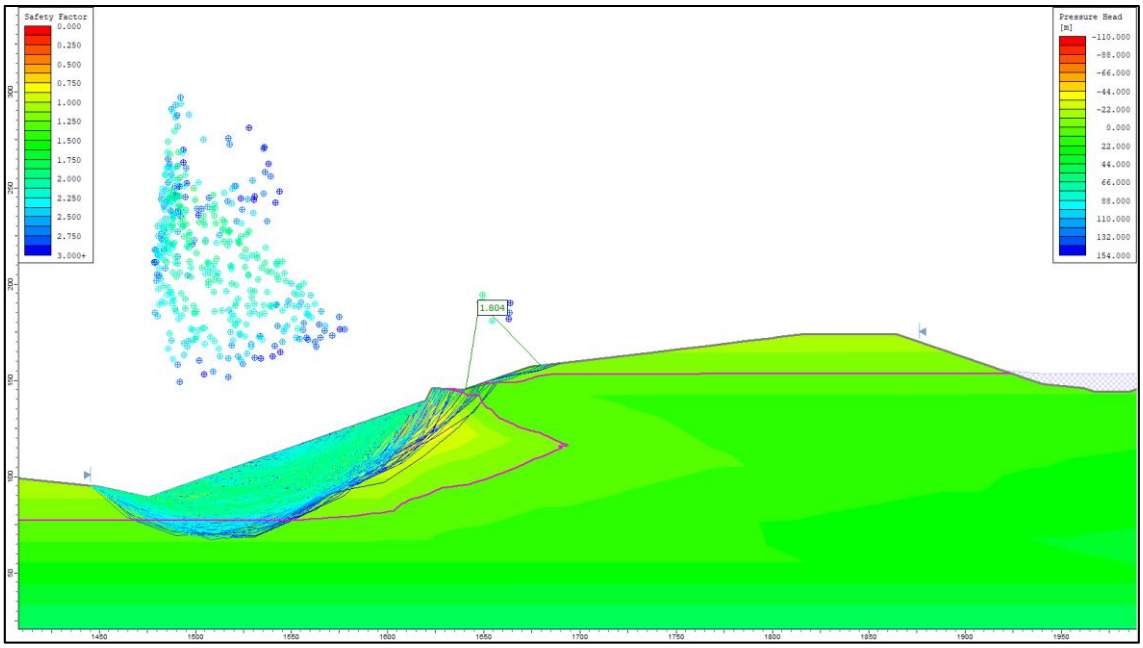

*Appendix A 73 E, C and H-pit Void Cross Section 1 – Western Pitwall Analysis – Dynamic*



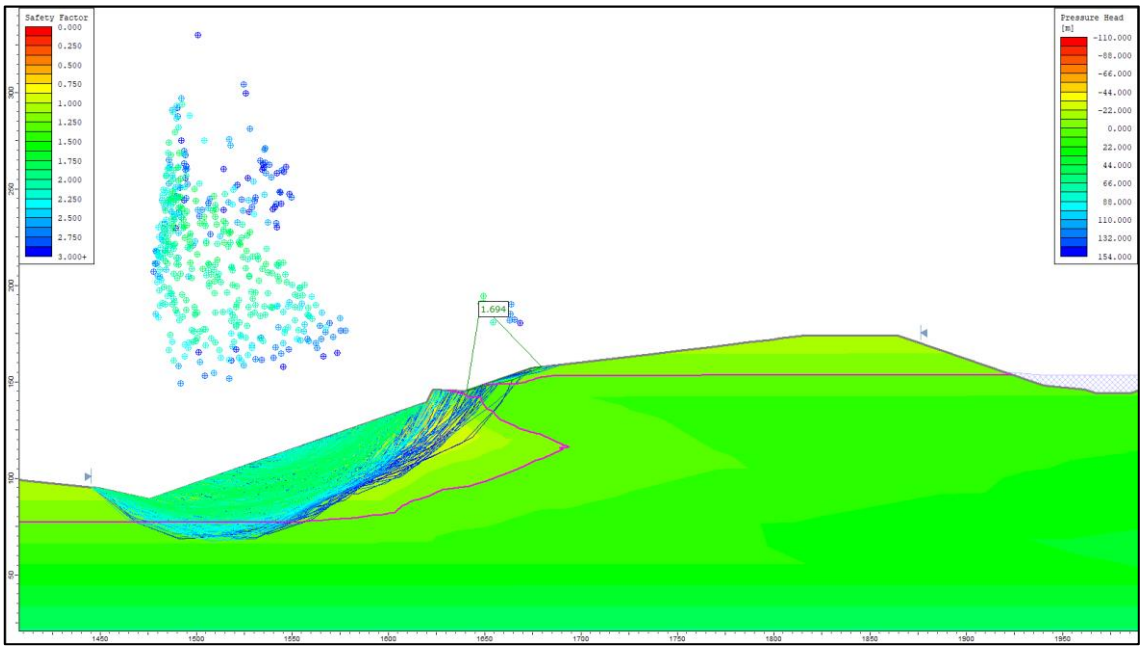

*Appendix A 74 K-Pit Cross Section 2 – Highwall Analysis – Static*



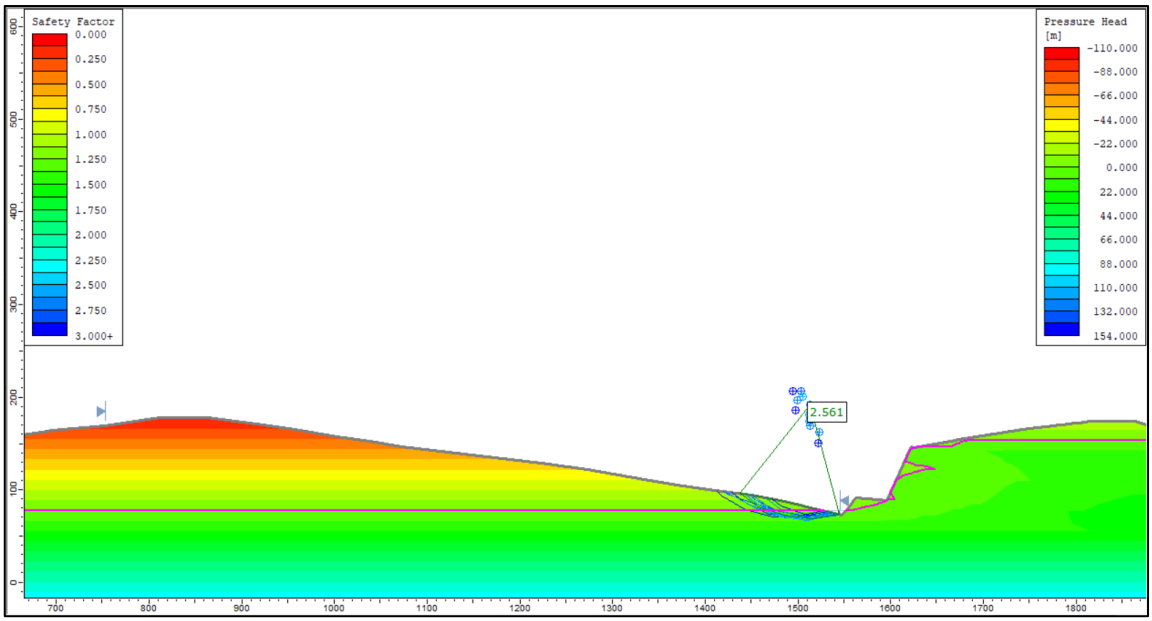

*Appendix A 75 K-Pit Cross Section 2 – Highwall Analysis – Dynamic*



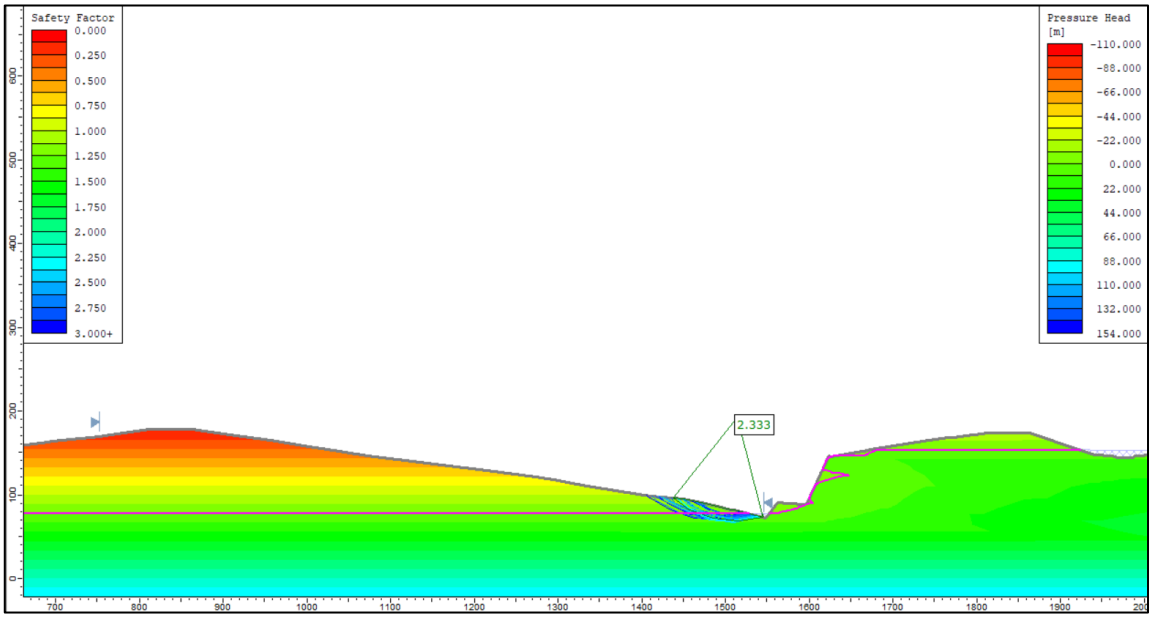

*Appendix A 76 K-Pit Cross Section 2 – Highwall Alternative Geometry Analysis – Static*



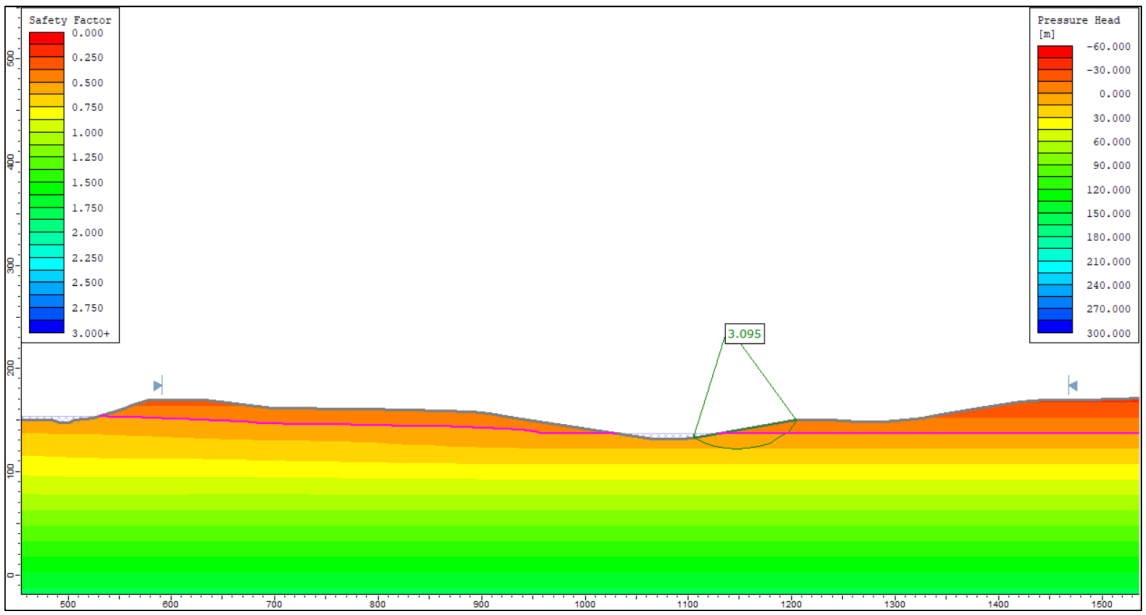

*Appendix A 77 K-Pit Cross Section 2 – Highwall Alternative Geometry Analysis – Dynamic*



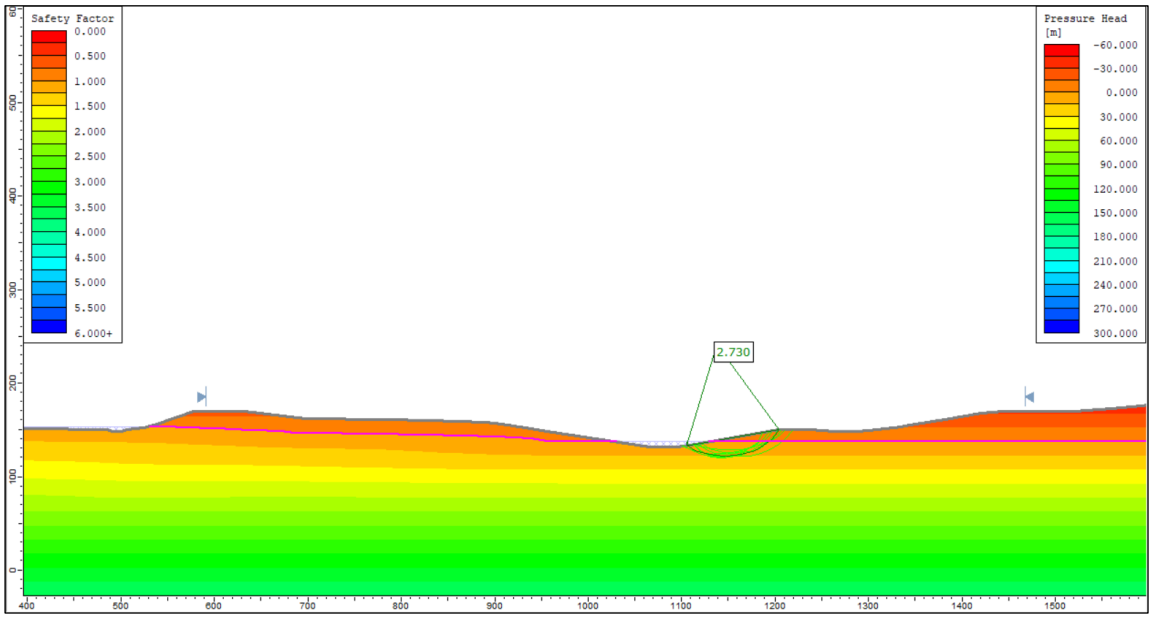

*Appendix A 78 K-Pit Cross Section 2 – Lowwall Analysis – Static*



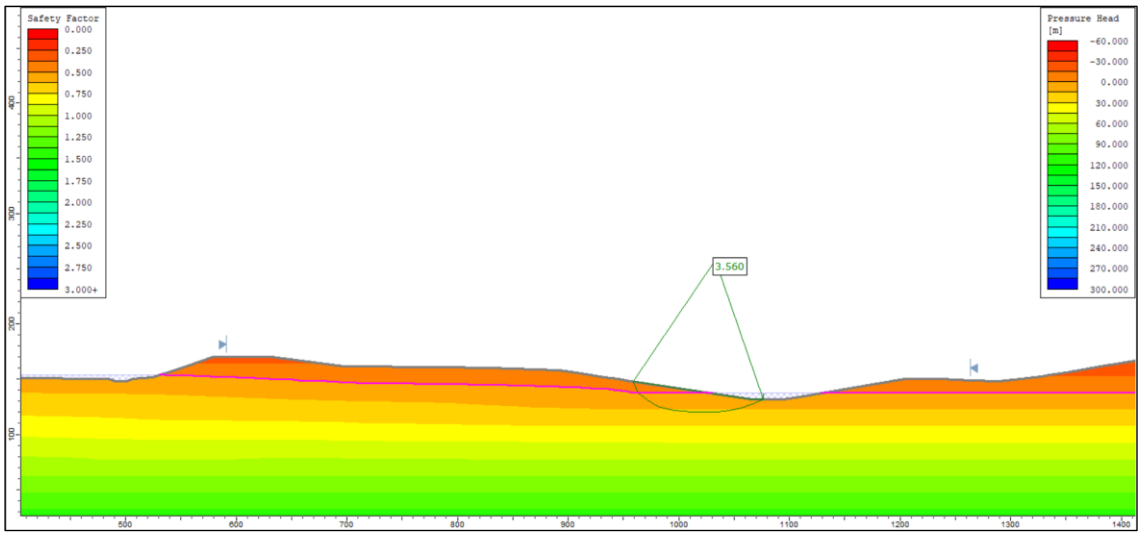

*Appendix A 79 K-Pit Cross Section 2 – Lowwall Analysis – Dynamic*



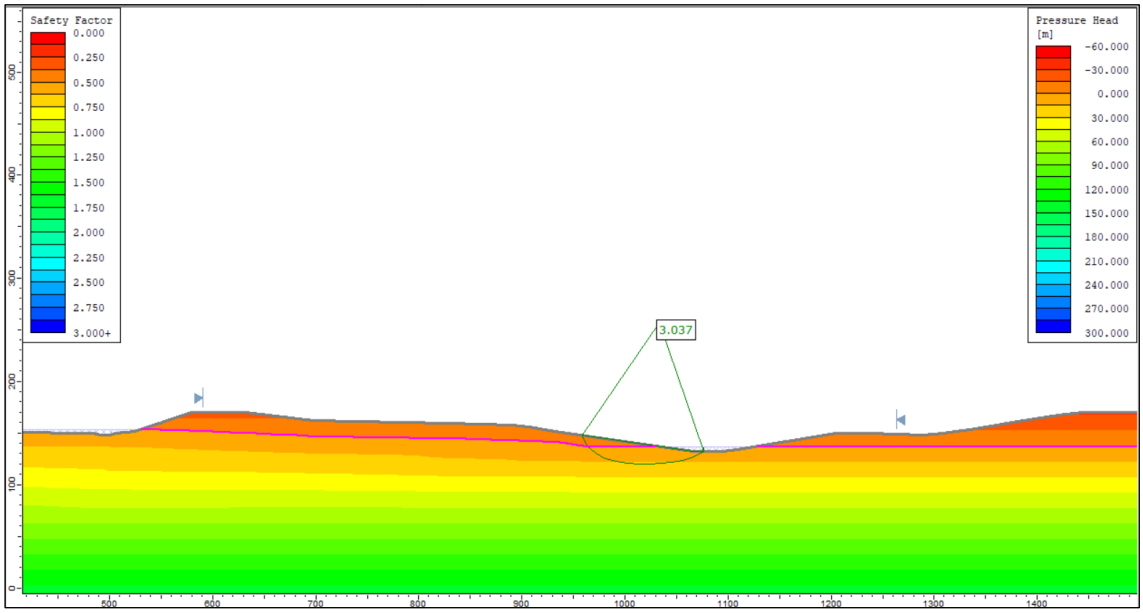

*Appendix A 80 G-Pit Cross Section 1 – North Pitwall - Static*



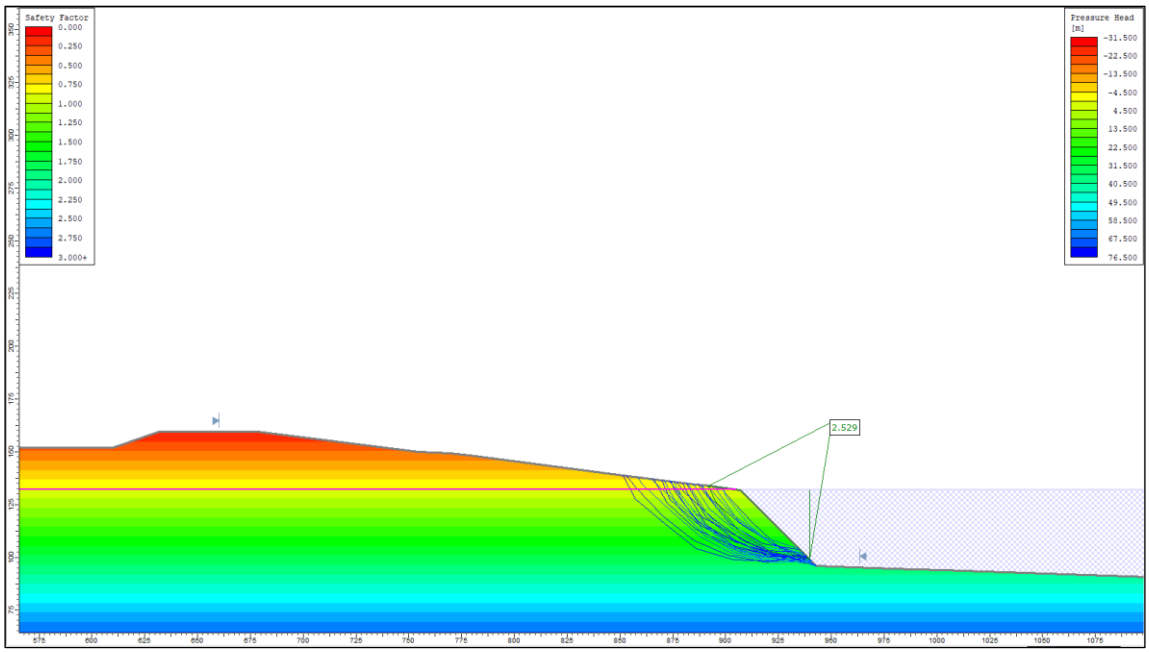

*Appendix A 81 G-Pit Cross Section 1 – North Pitwall – Dynamic*



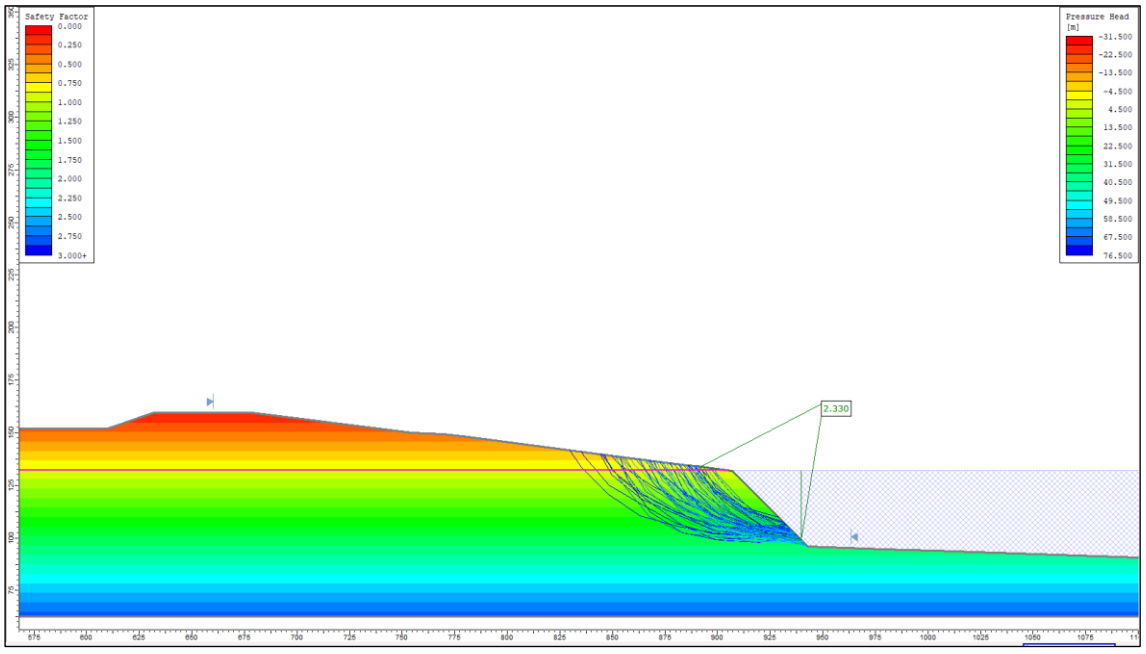

*Appendix A 82 G-Pit Cross Section 1 – Southern Pitwall – Static*



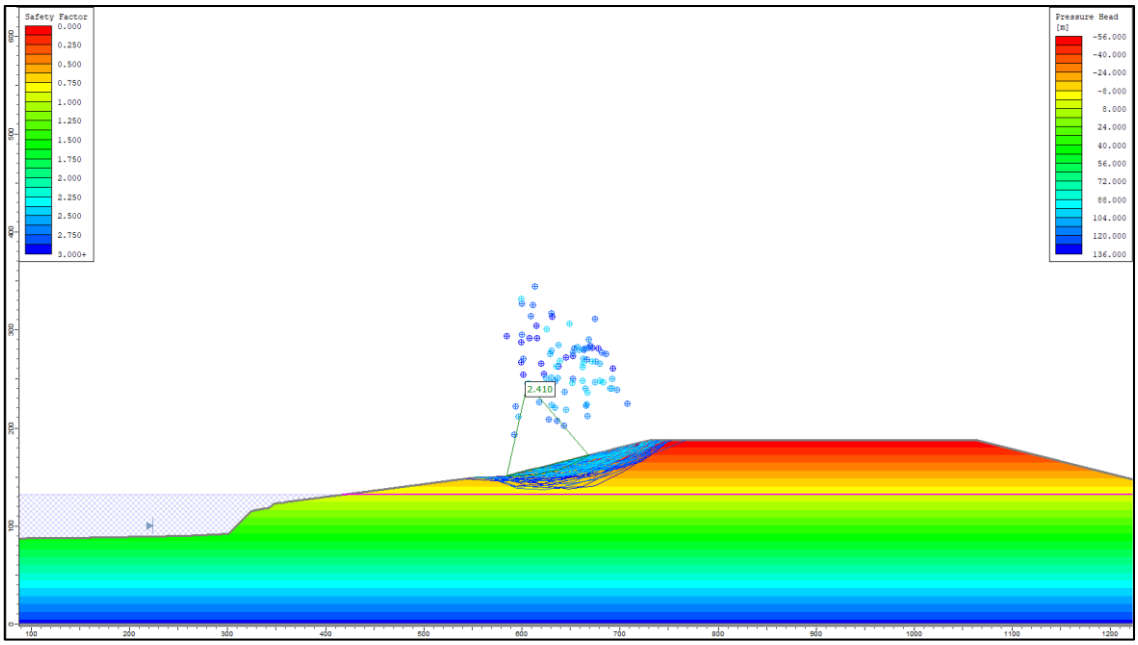

*Appendix A 83 G-Pit Cross Section 1 – Southern Pitwall – Dynamic*



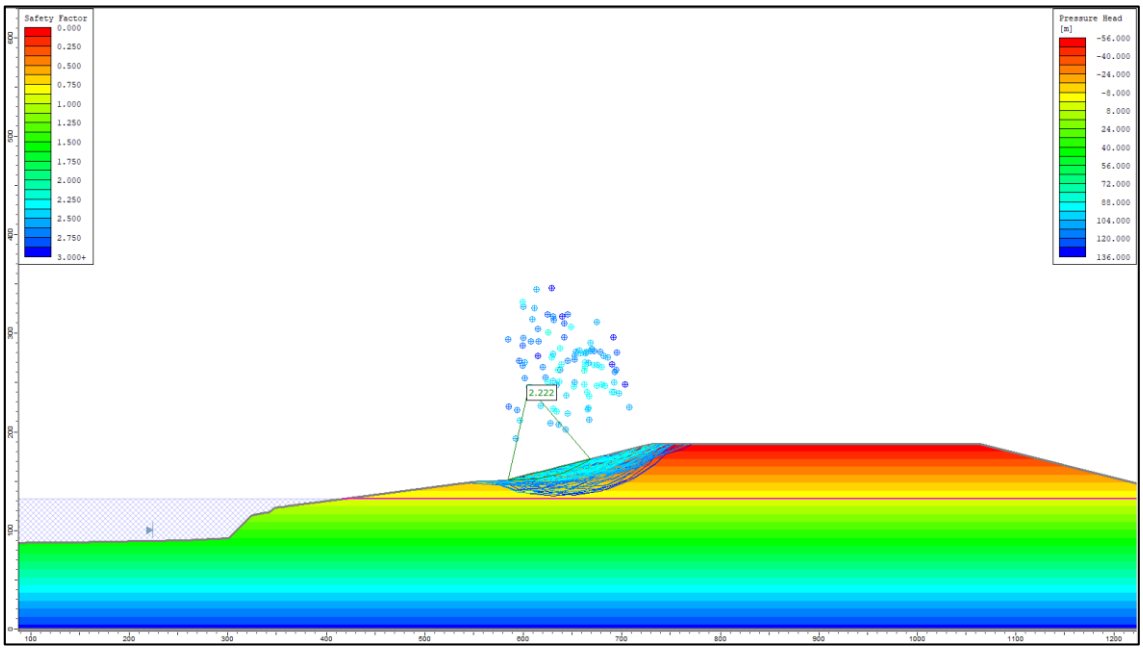

*Appendix A 84 Ramp 9 Cross Section 1 – Highwall Analysis – Static*



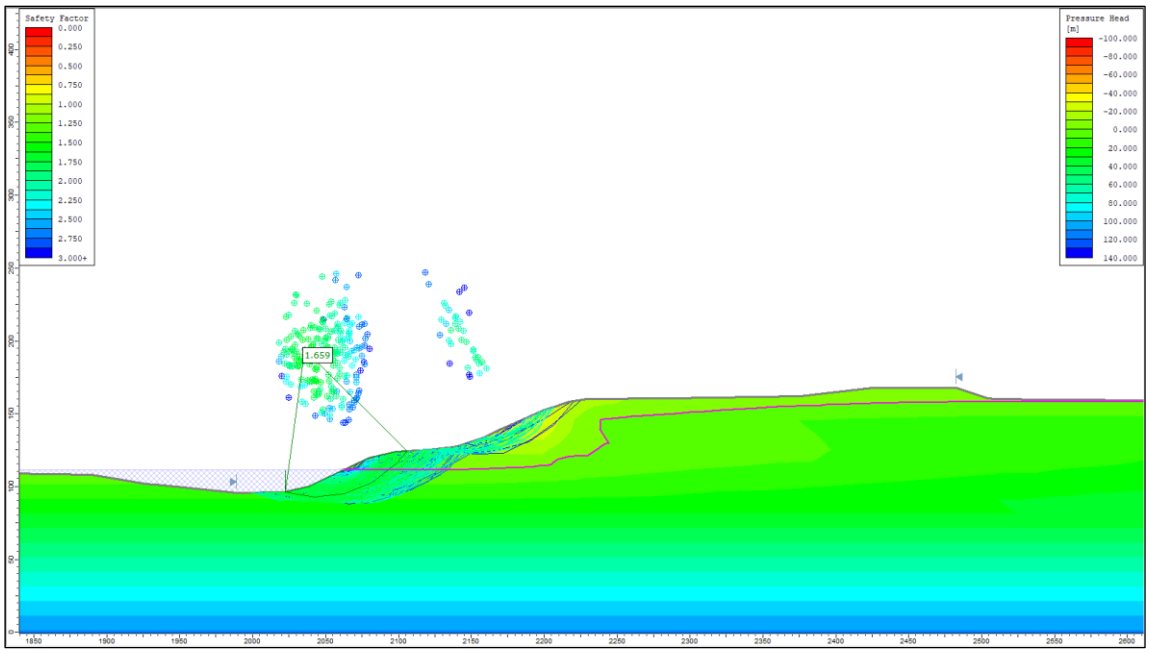

*Appendix A 85 Ramp 9 Cross Section 1 – Highwall Analysis – Dynamic*



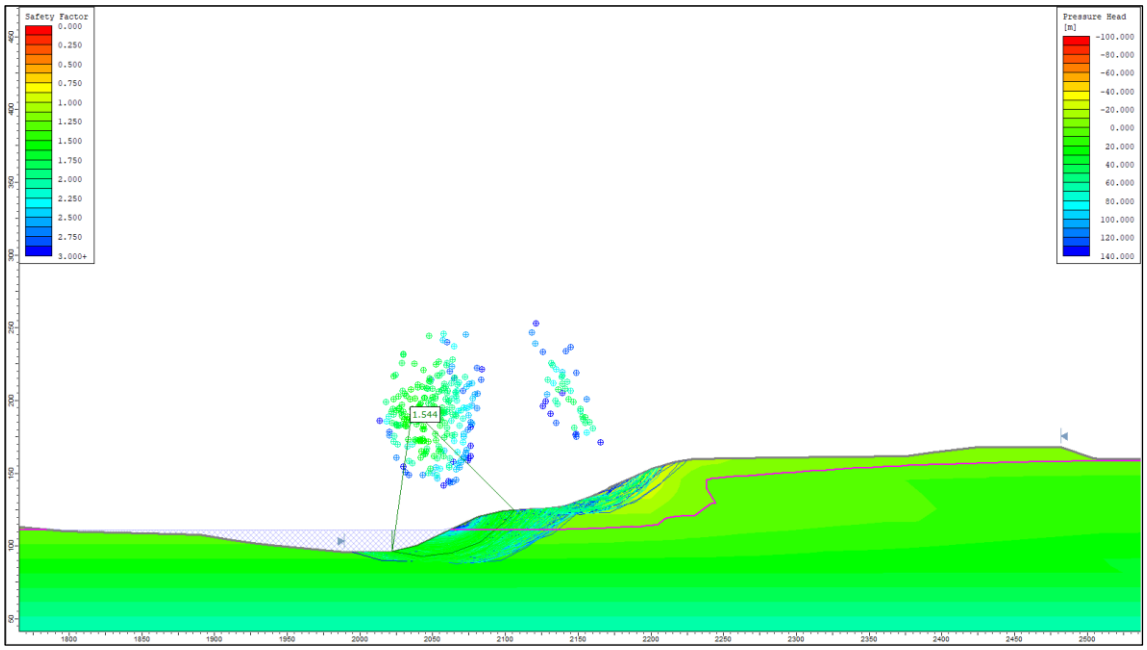

*Appendix A 86 Ramp 9 Cross Section 2 – Highwall Analysis – Static*



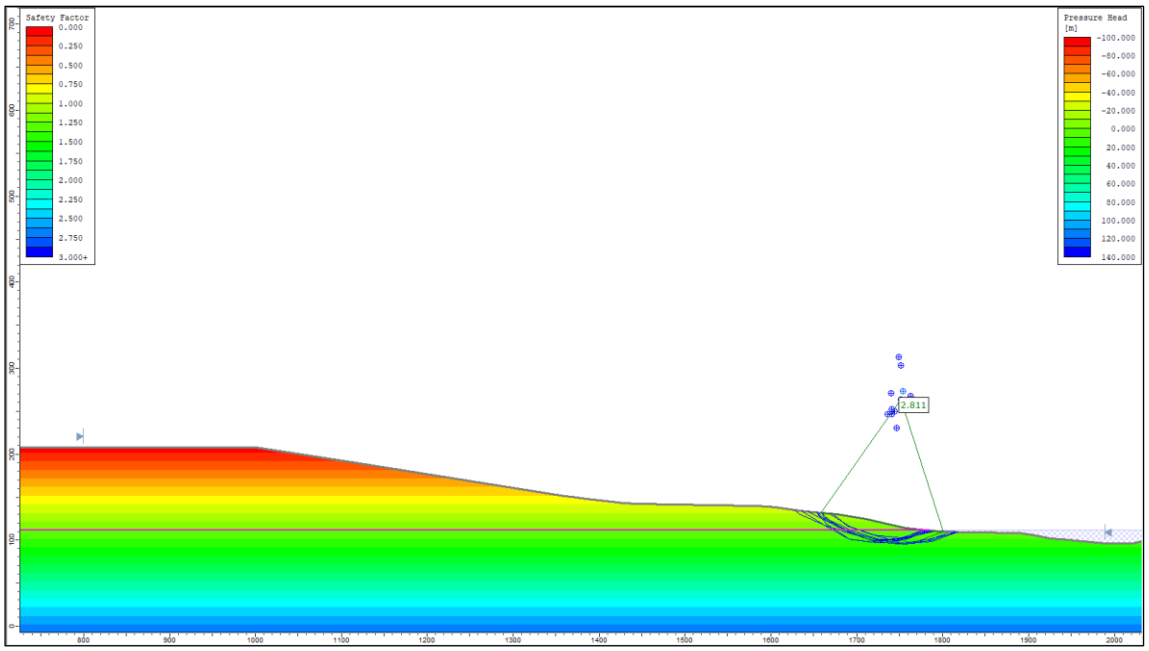

*Appendix A 87 Ramp 9 Cross Section 2 – Highwall Analysis – Dynamic*



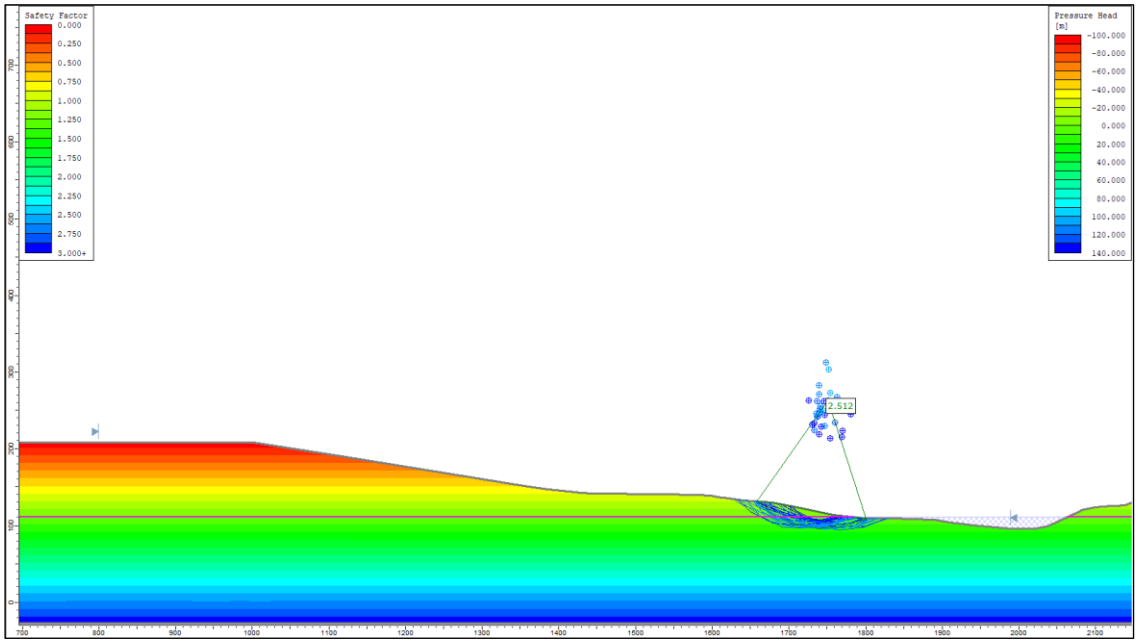

*Appendix A 88 J-Pit Cross Section 1 – Highwall Analysis – Static*



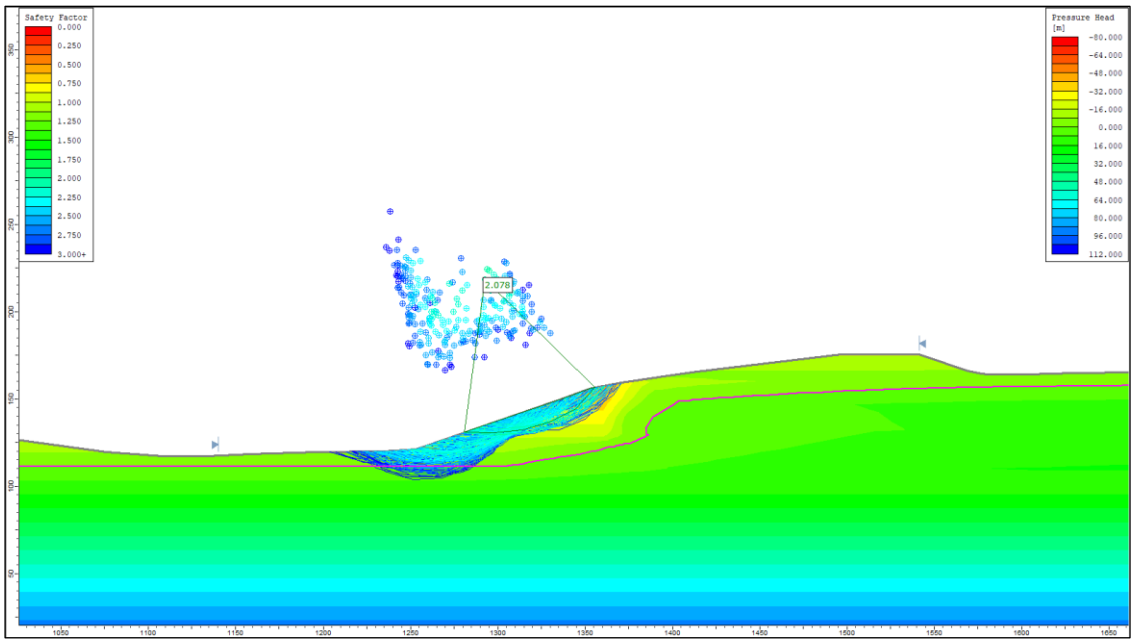

*Appendix A 89 J-Pit Cross Section 1 – Highwall Analysis – Dynamic*



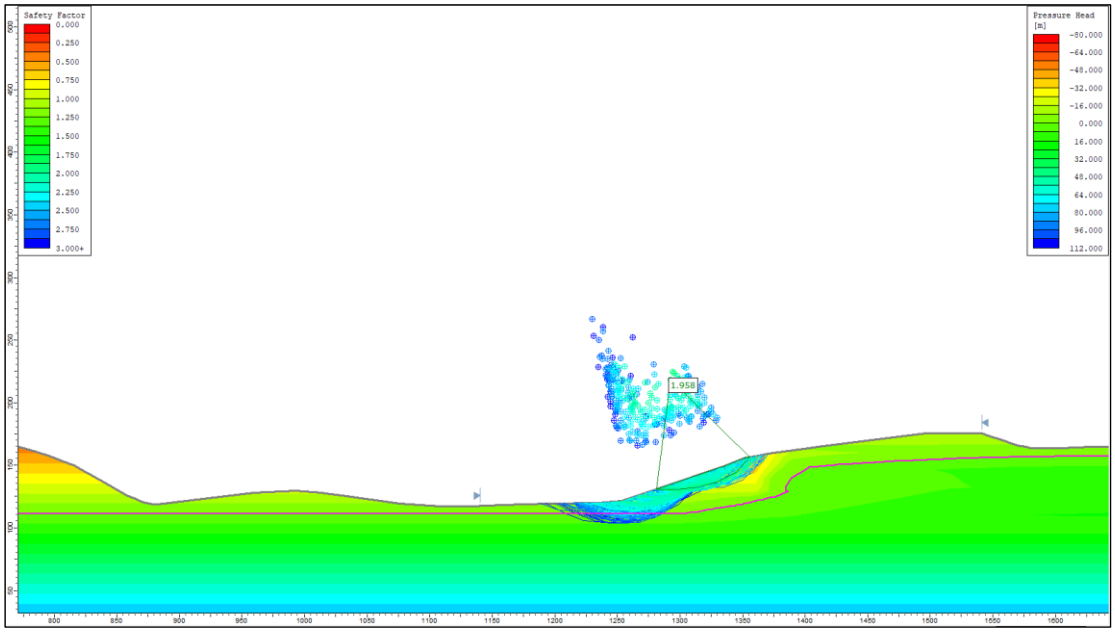

*Appendix A 90 J-Pit Cross Section 1 – Lowwall Analysis – Static*



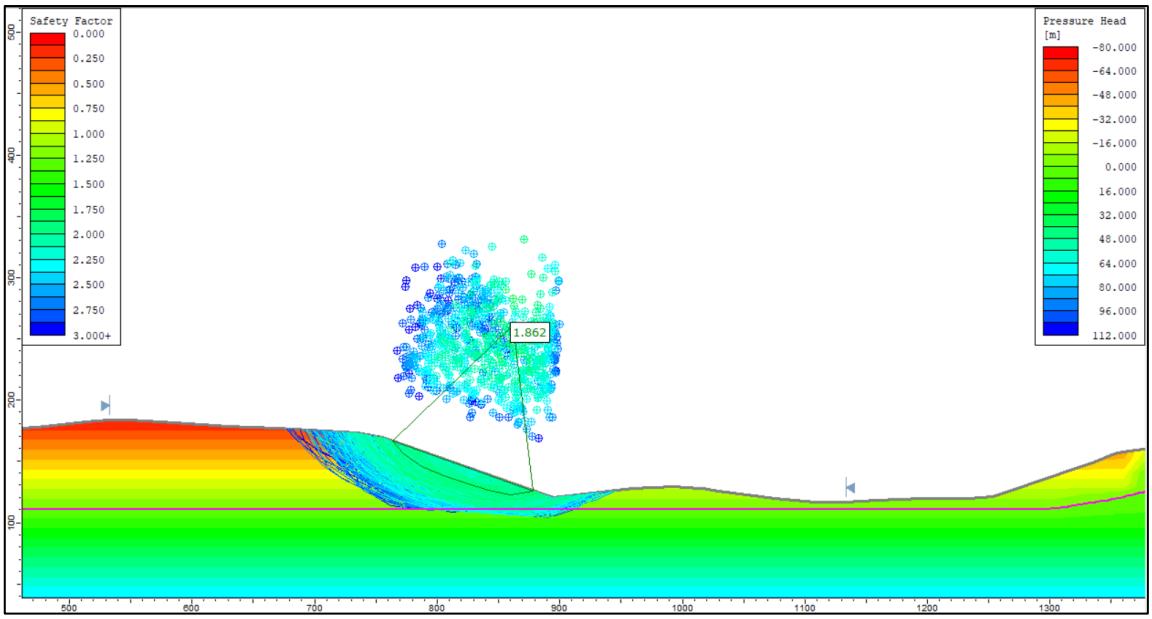

*Appendix A 91 J-Pit Cross Section 1 – Lowwall Analysis – Dynamic*



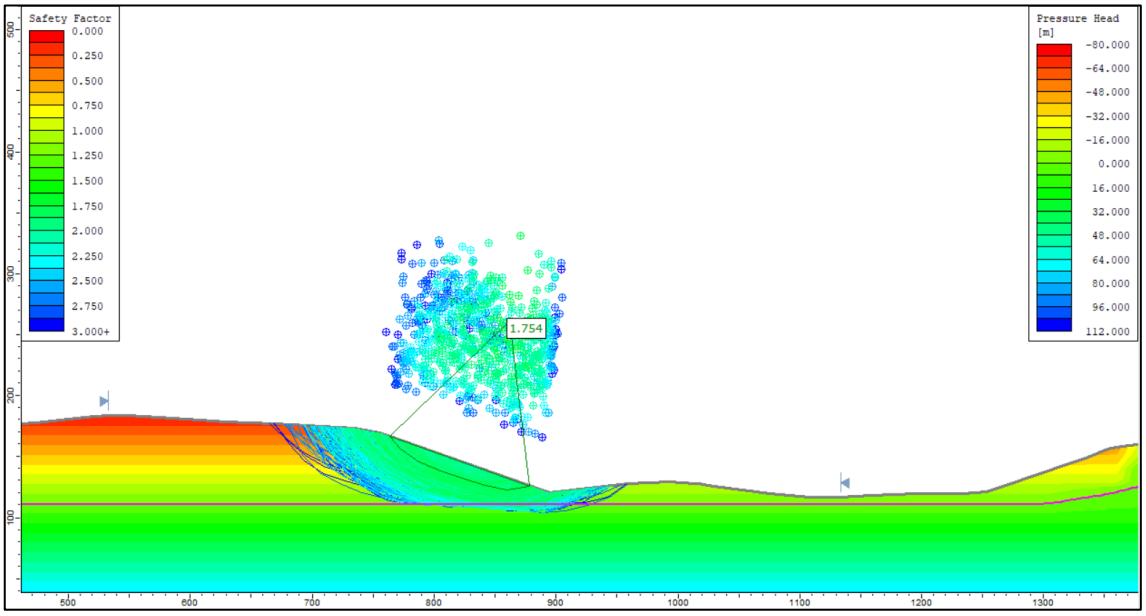

*Appendix A 92 J-Pit Cross Section 2 – Highwall Analysis – Static*



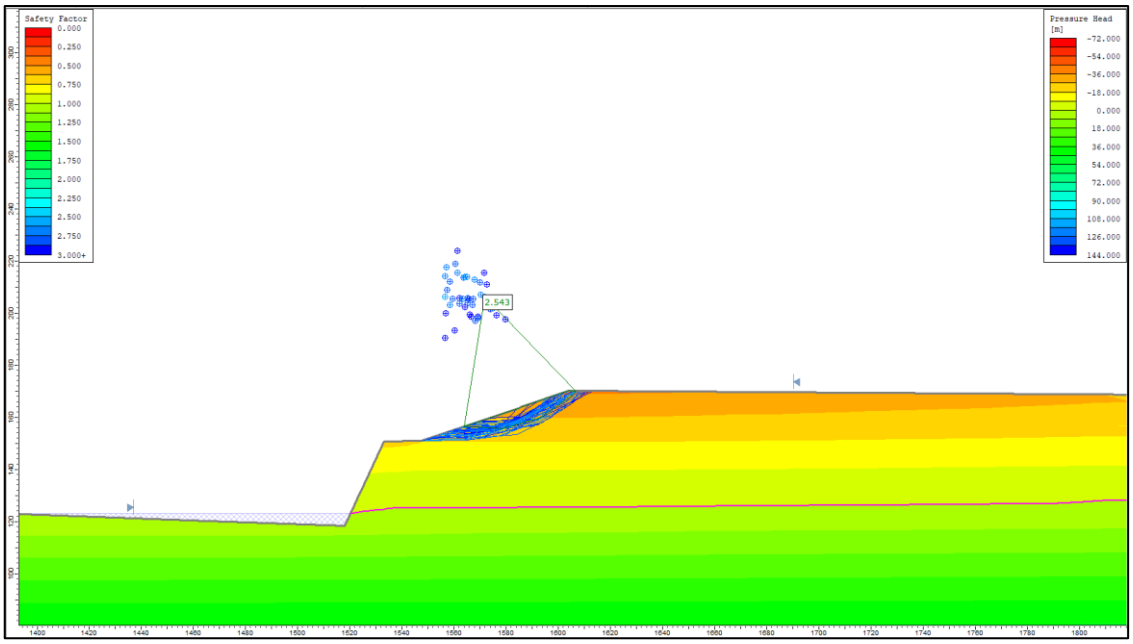

*Appendix A 93 J-Pit Cross Section 2 – Highwall Analysis – Dynamic*



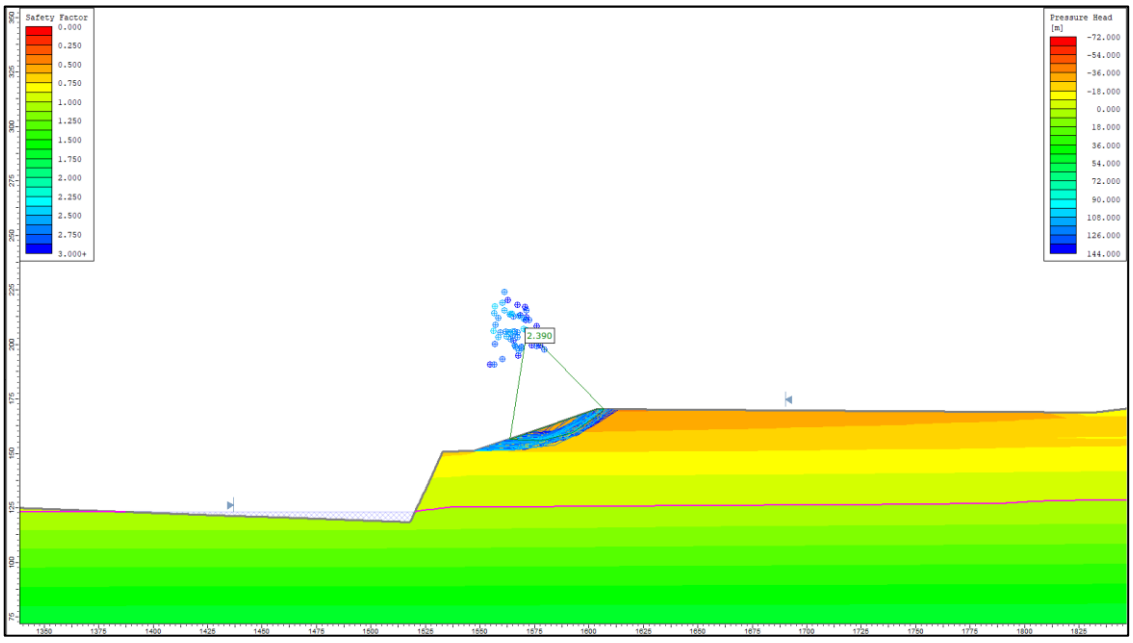

*Appendix A 94 J-Pit Cross Section 2 – Lowwall Analysis – Static*



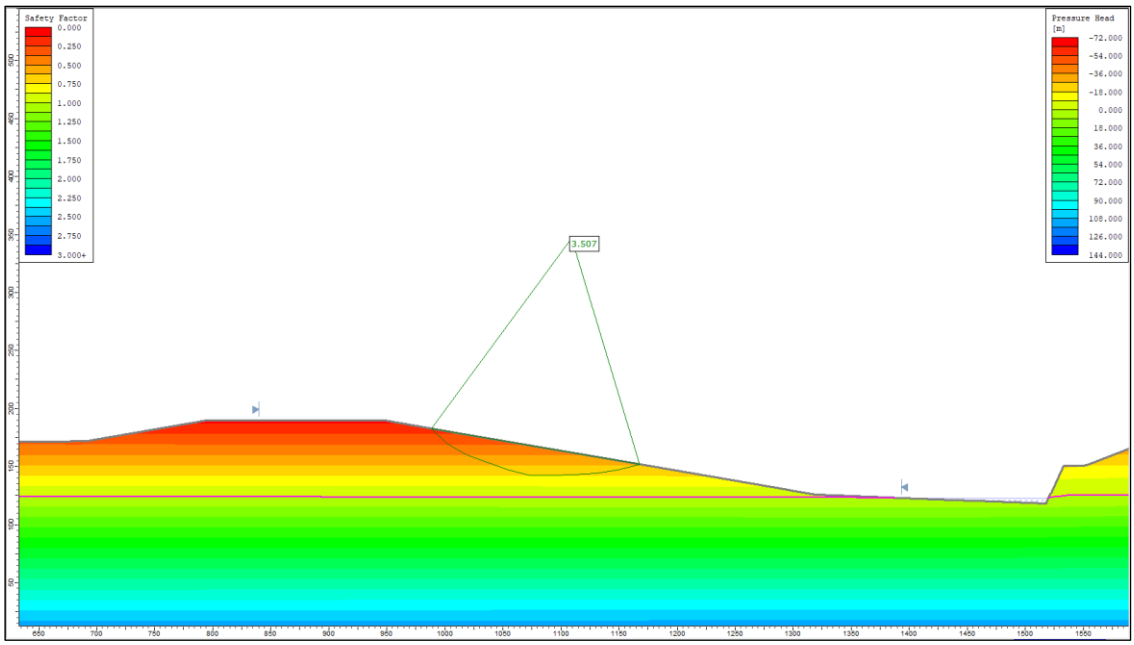

*Appendix A 95 J-Pit Cross Section 2 – Lowwall Analysis – Dynamic*



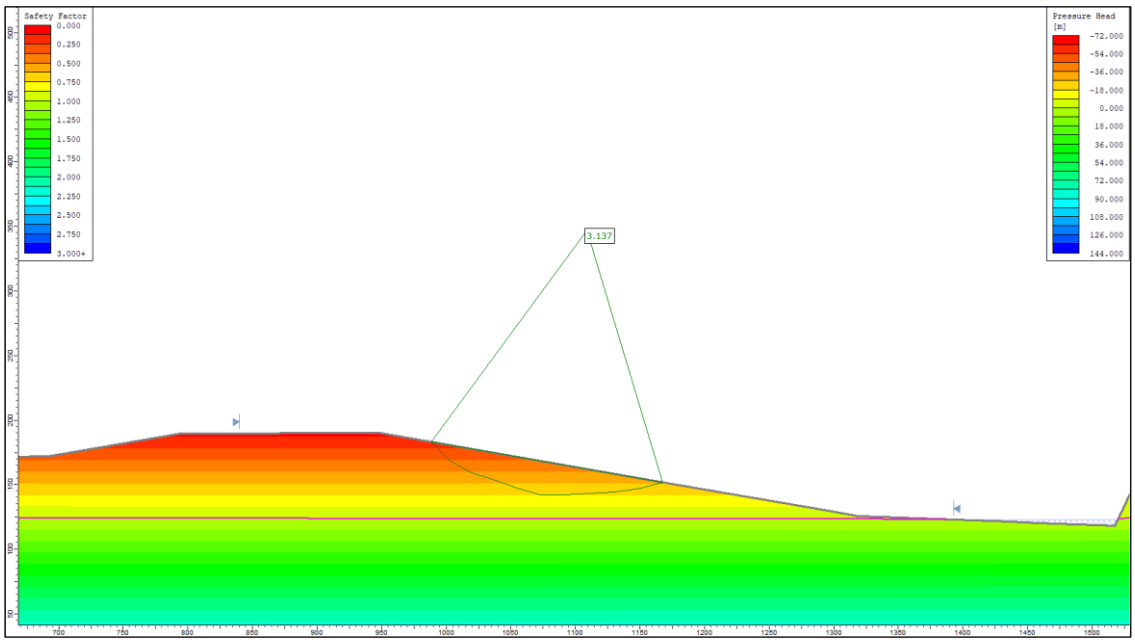

*Appendix A 96 Y-Pit Cross Section 1 – Highwall Analysis – Static*



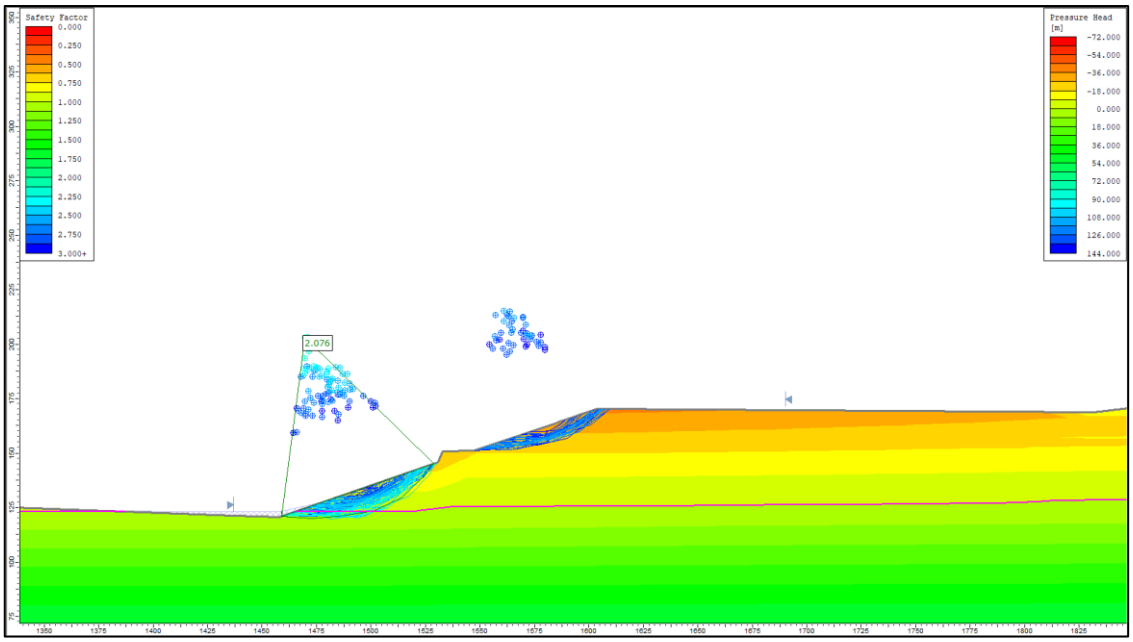

*Appendix A 97 Y-Pit Cross Section 1 – Highwall Analysis – Dynamic*



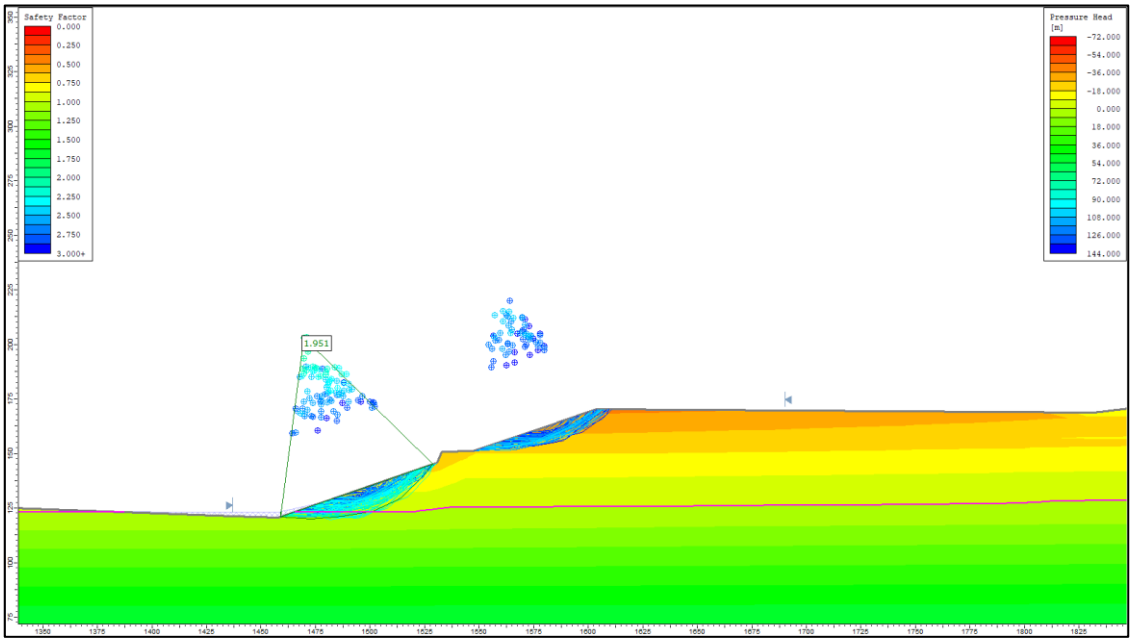

*Appendix A 98 Y-Pit Cross Section 1 – Lowwall Analysis – Static*



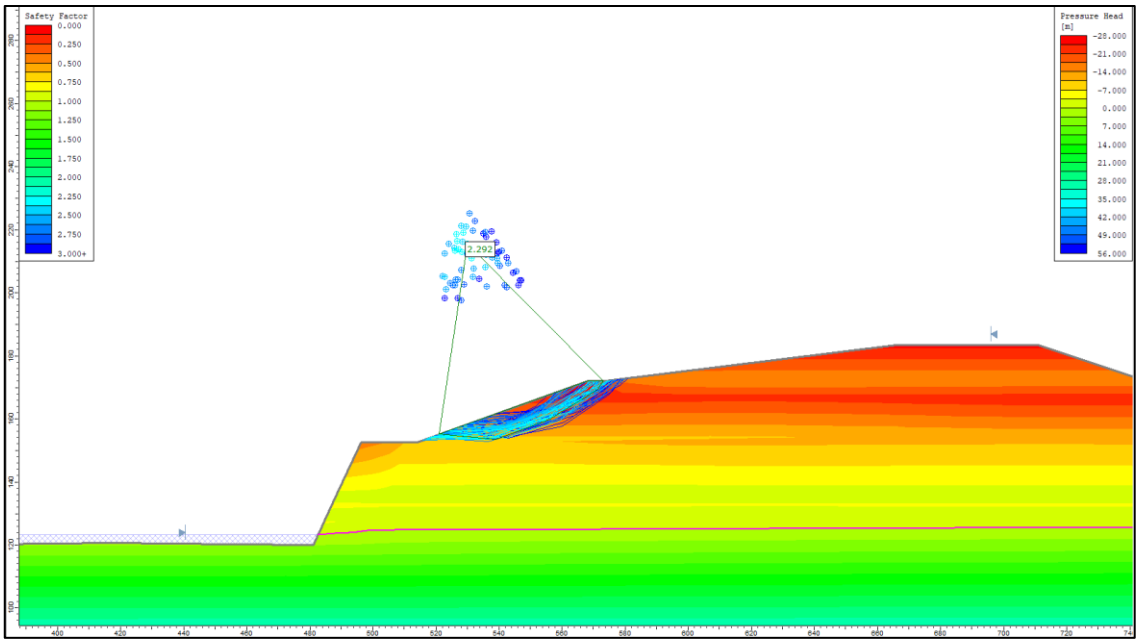

*Appendix A 99 Y-Pit Cross Section 1 – Lowwall Analysis – Dynamic*



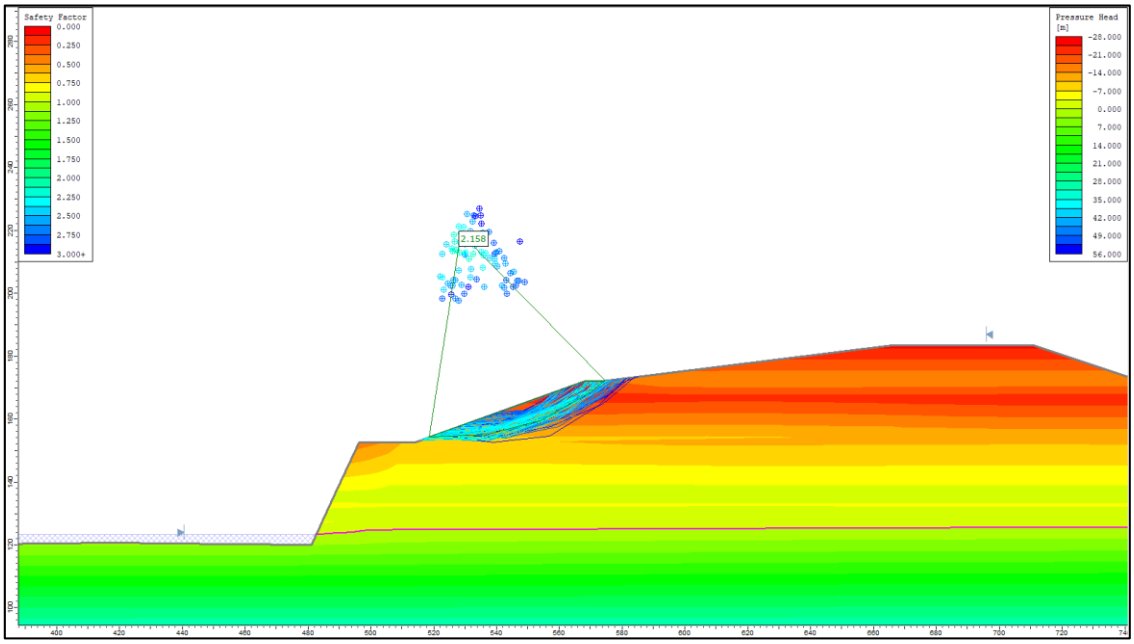

*Appendix A 100 Y-Pit Cross Section 1 Alternative Geometry – Highwall Analysis – Static*



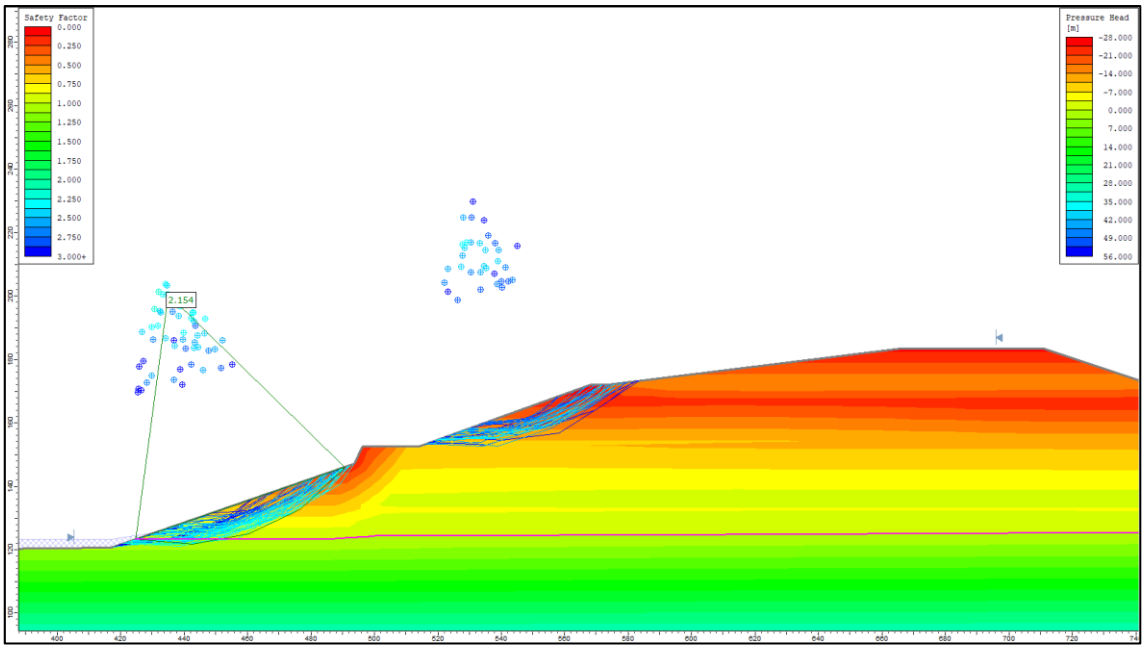

*Appendix A 101 Y-Pit Cross Section 1 Alternative Geometry – Highwall Analysis – Dynamic*



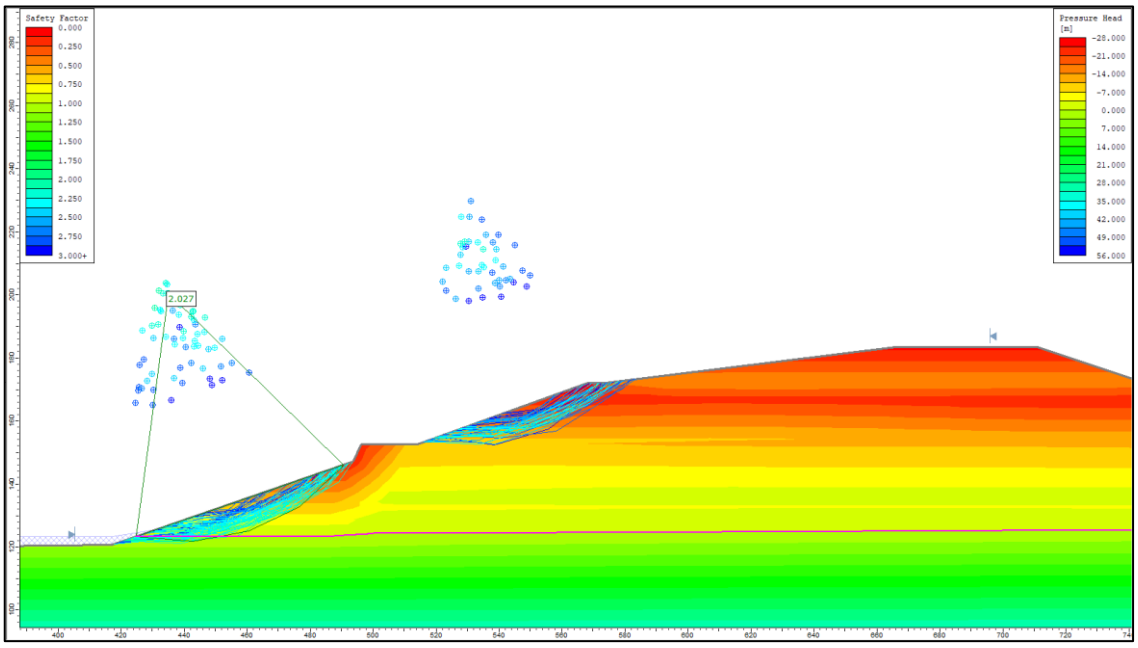

*Appendix A 102 Y-Pit Cross Section 2 – Highwall Analysis – Static*



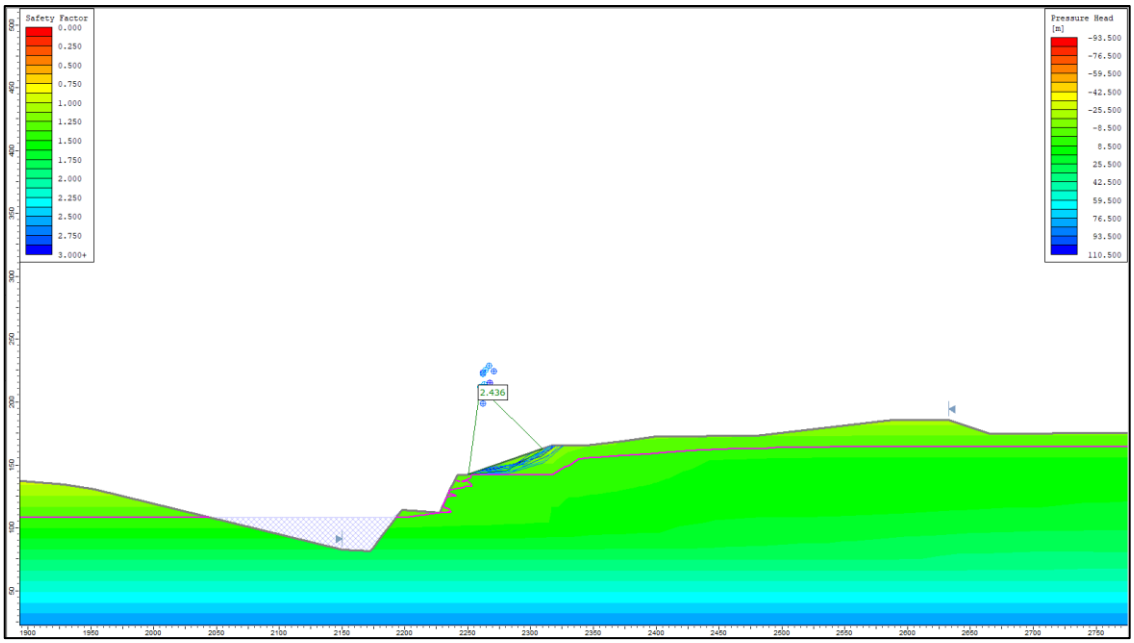

*Appendix A 103 Y-Pit Cross Section 2 – Highwall Analysis – Dynamic*



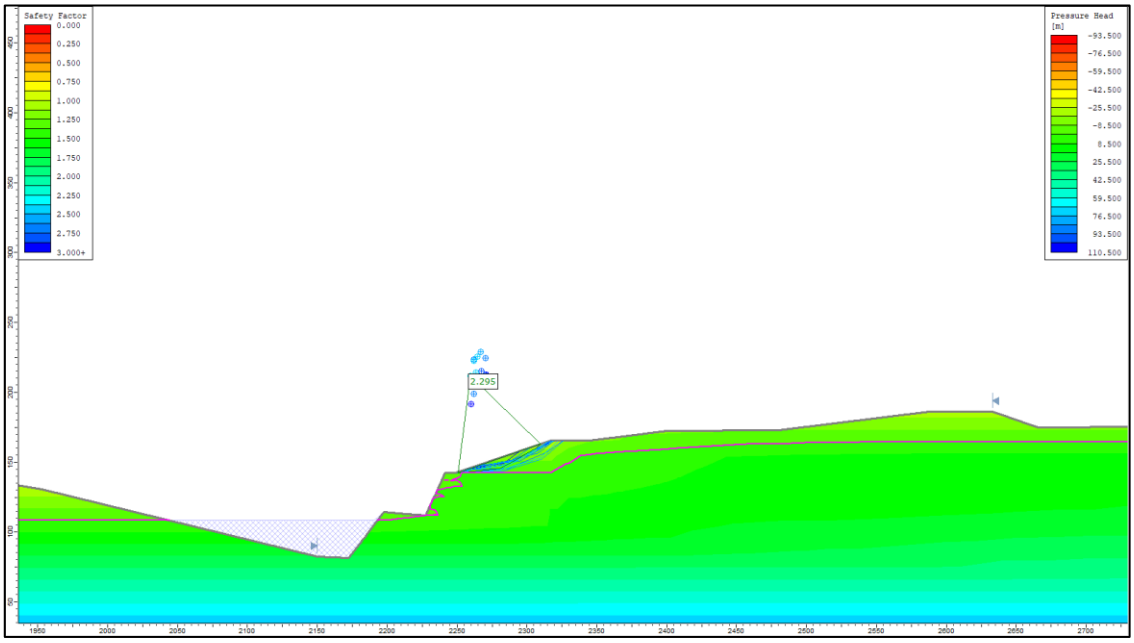

*Appendix A 104 Y-Pit Cross Section 2 Alternative Geometry – Highwall Analysis – Static*



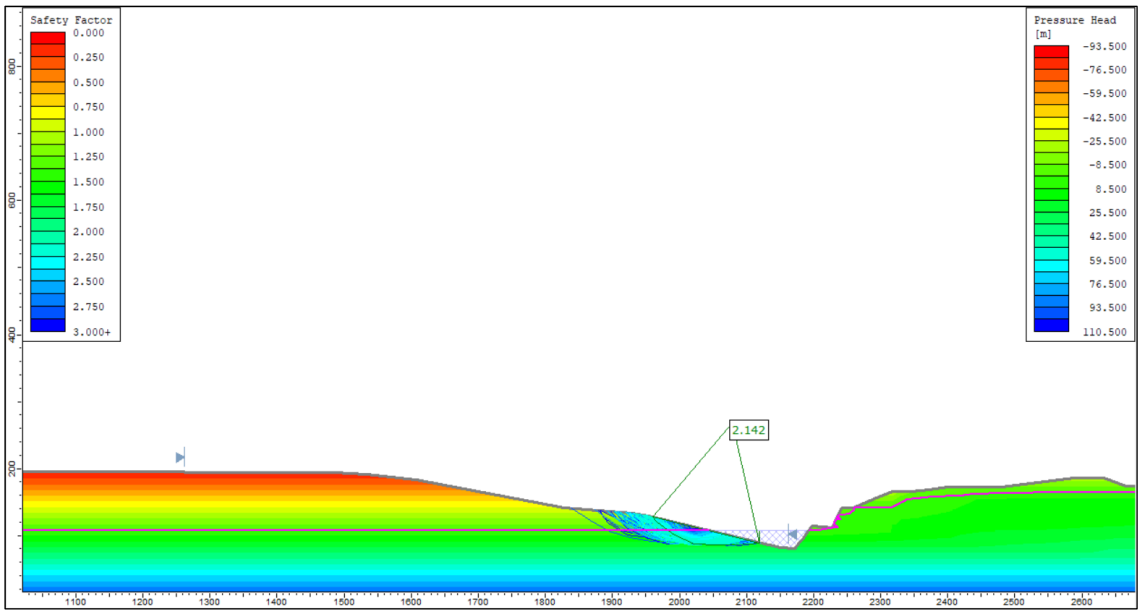

*Appendix A 105 Y-Pit Cross Section 2 Alternative Geometry – Highwall Analysis – Dynamic*



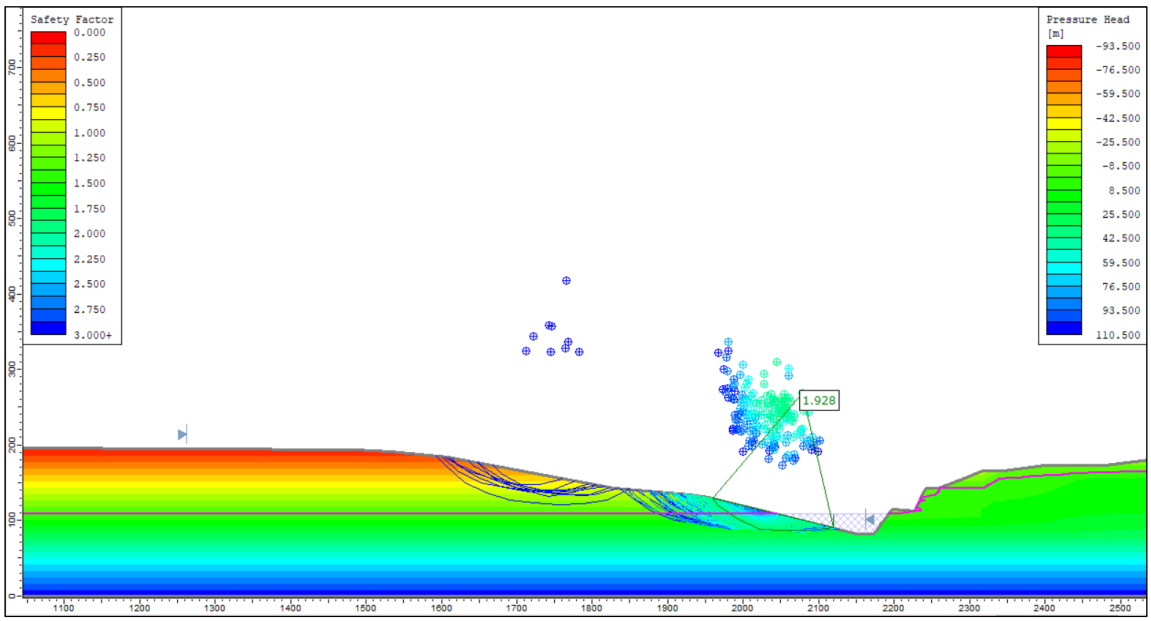

*Appendix A 106 Z-Pit North Cross Section 1 – Highwall Analysis – Static*



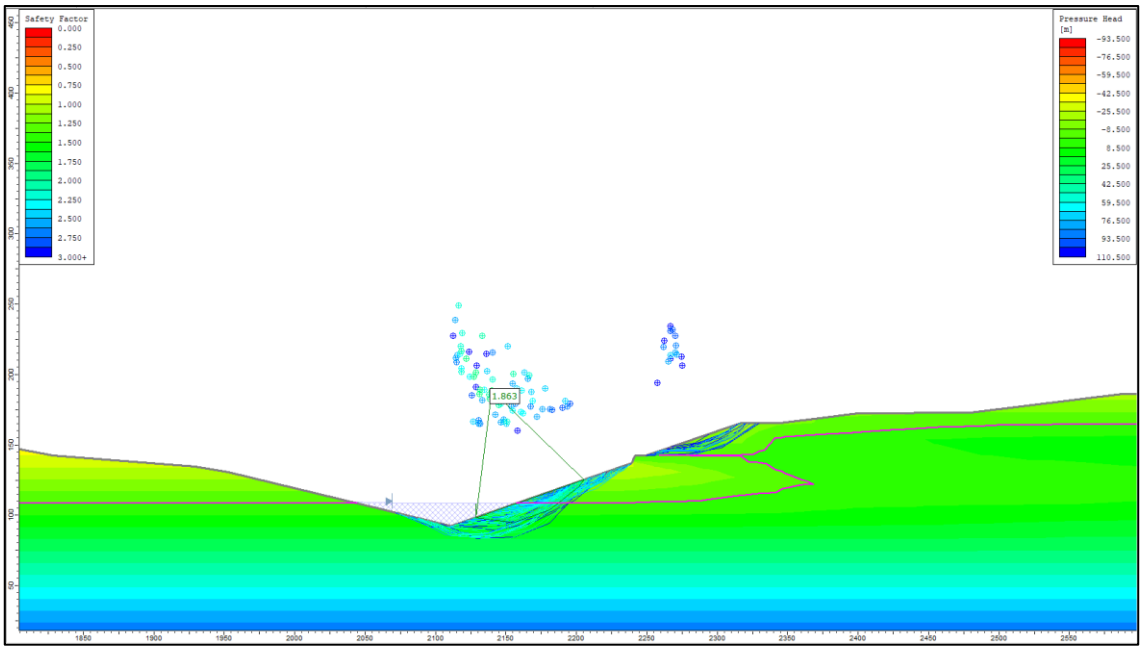

*Appendix A 107 Z-Pit North Cross Section 1 – Highwall Analysis – Dynamic*



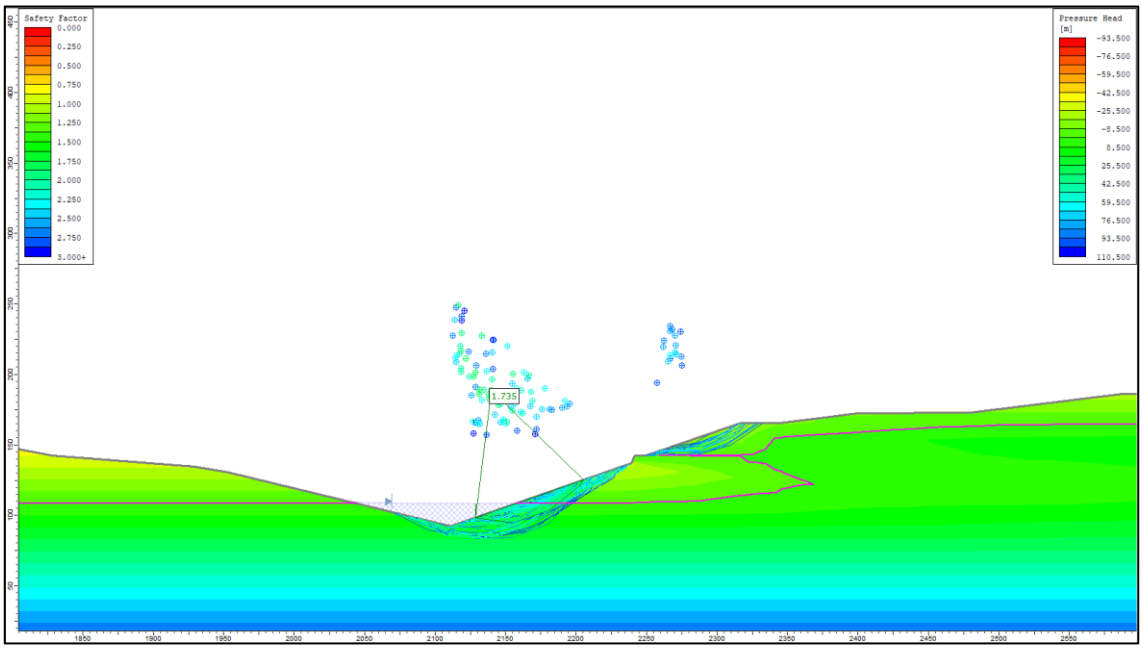

*Appendix A 108 Z-Pit North Cross Section 1 – Lowwall Analysis – Static*



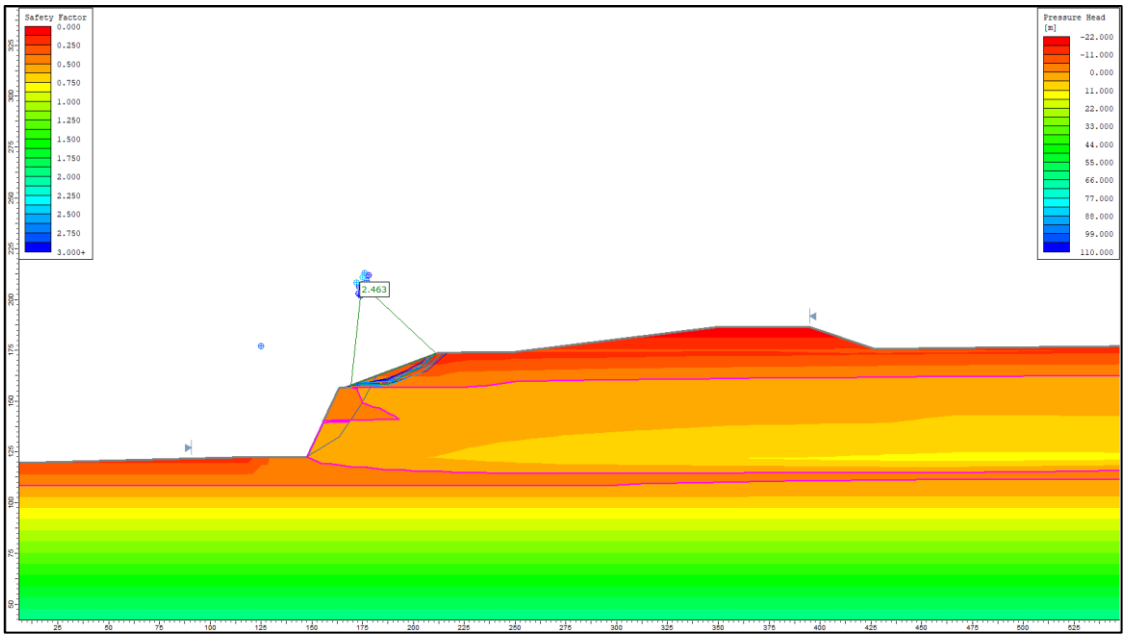

*Appendix A 109 Z-Pit North Cross Section 1 – Lowwall Analysis – Dynamic*



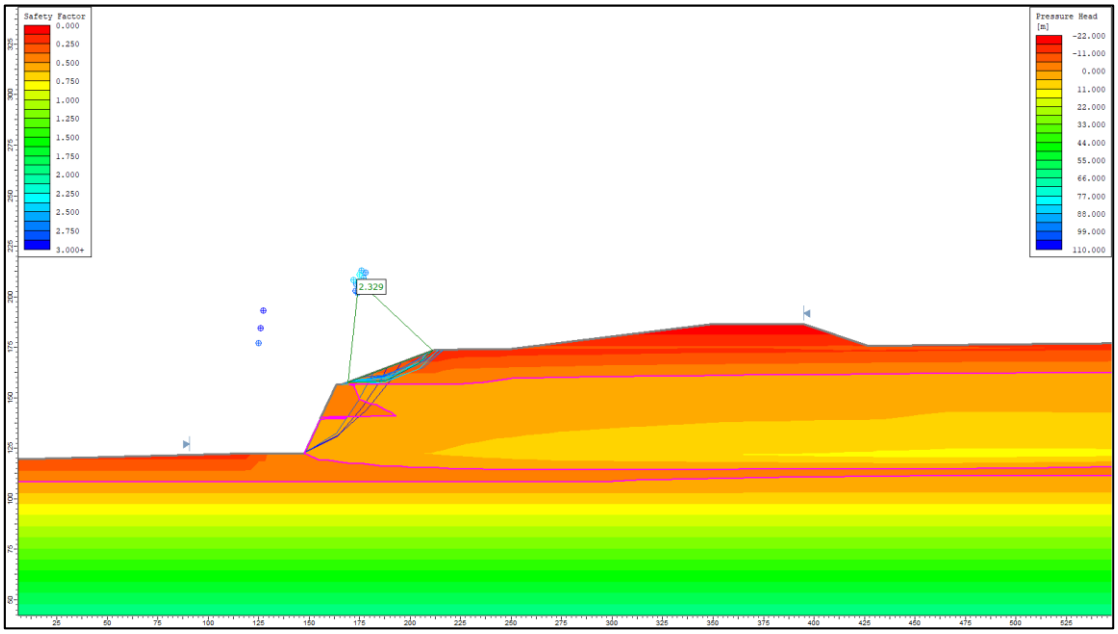

*Appendix A 110 Z-Pit North Cross Section 1 Alternative Geometry – Highwall Analysis – Static*



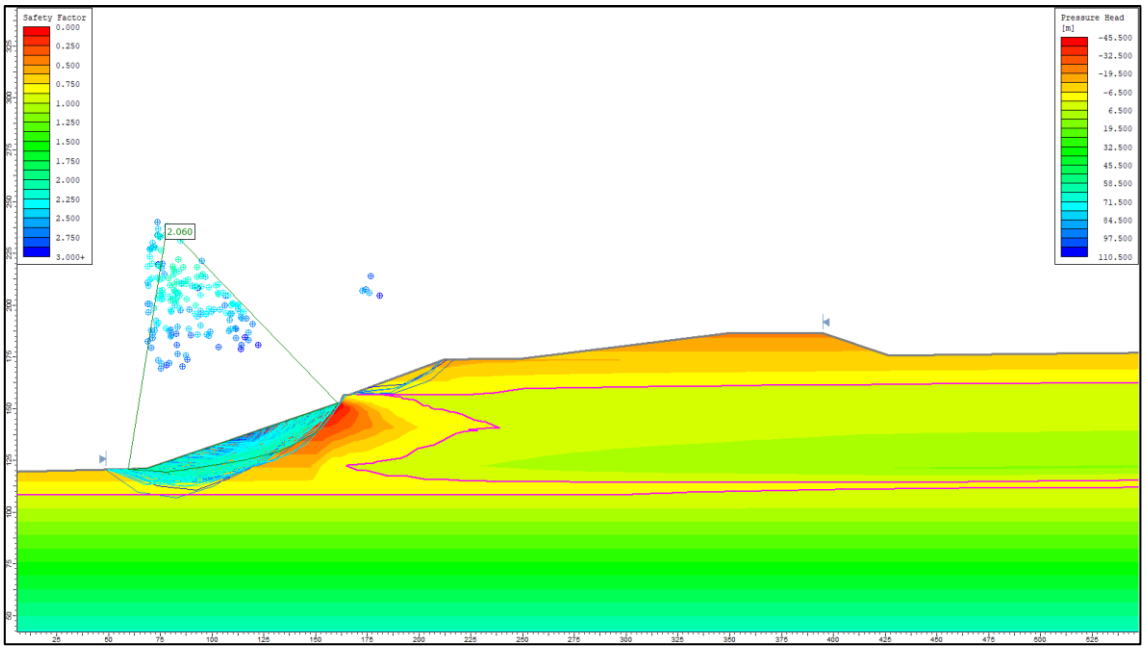

*Appendix A 111 Z-Pit North Cross Section 1 Alternative Geometry – Highwall Analysis – Dynamic*



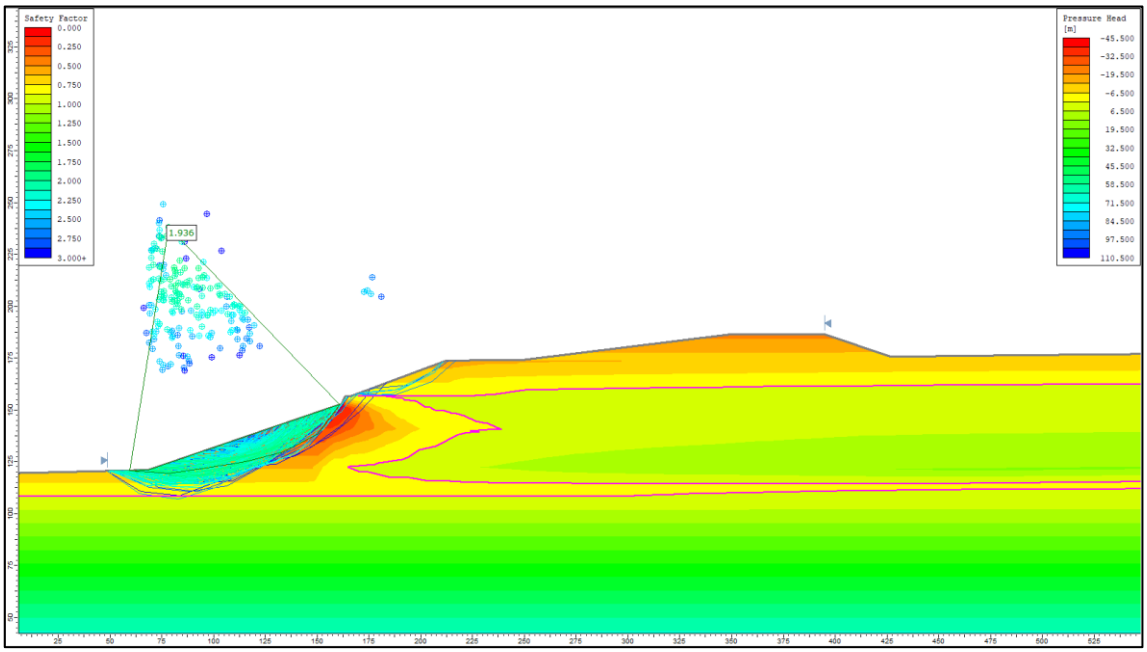

*Appendix A 112 Z-Pit North Cross Section 2 – Highwall Analysis – Static*



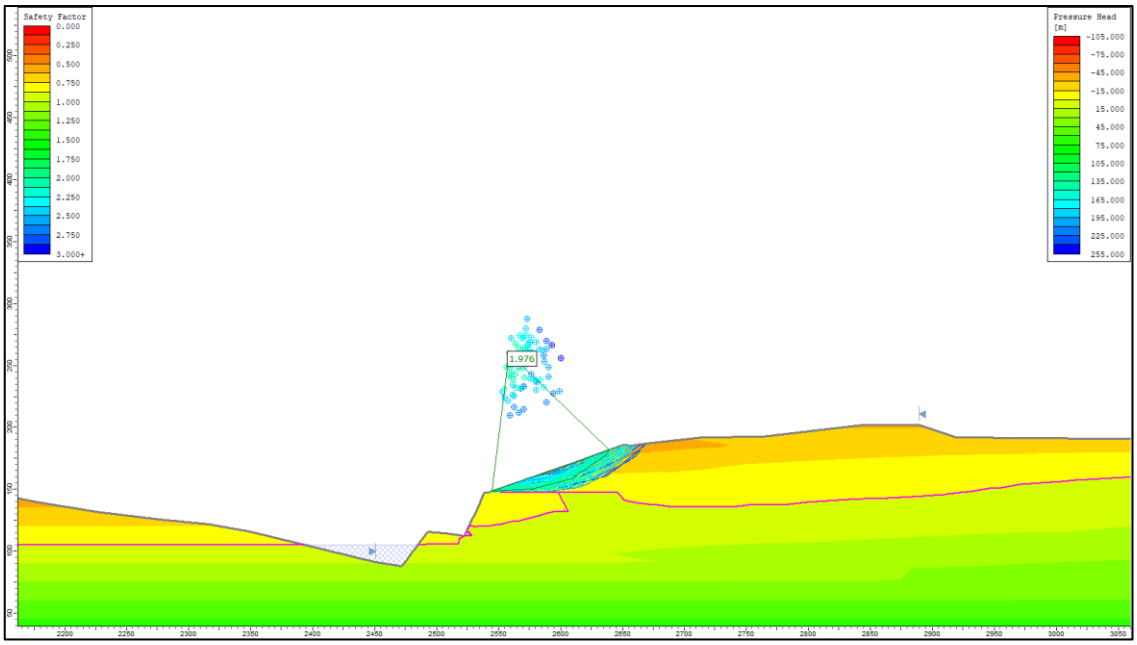

*Appendix A 113 Z-Pit North Cross Section 2 – Highwall Analysis – Dynamic*



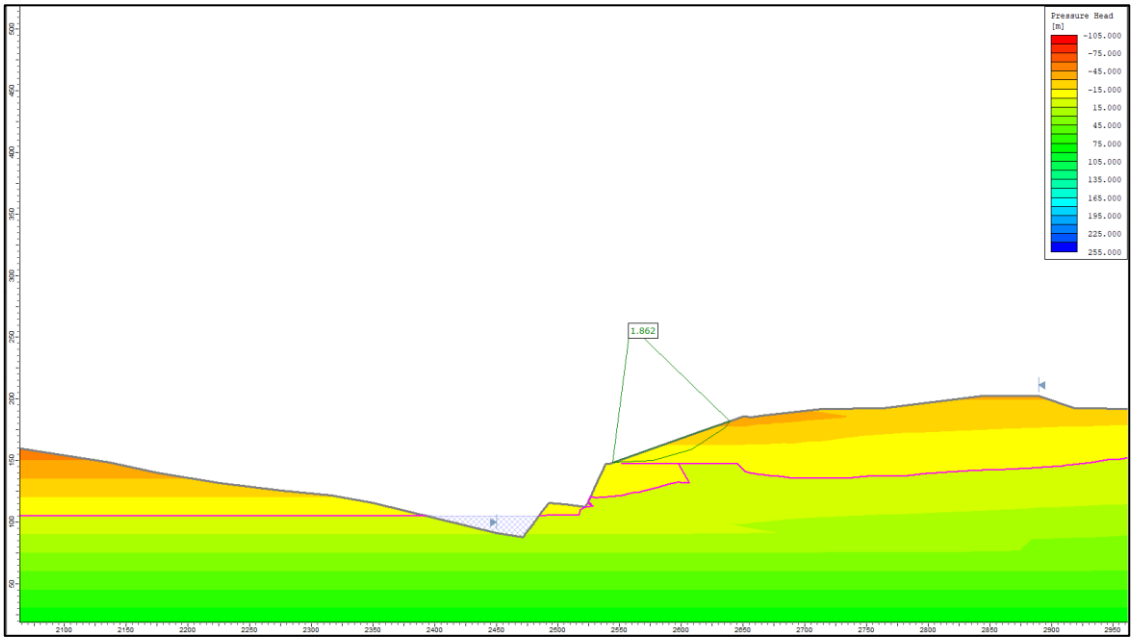

*Appendix A 114 Z-Pit North Cross Section 2 Alternative Geometry – Highwall Analysis – Static*



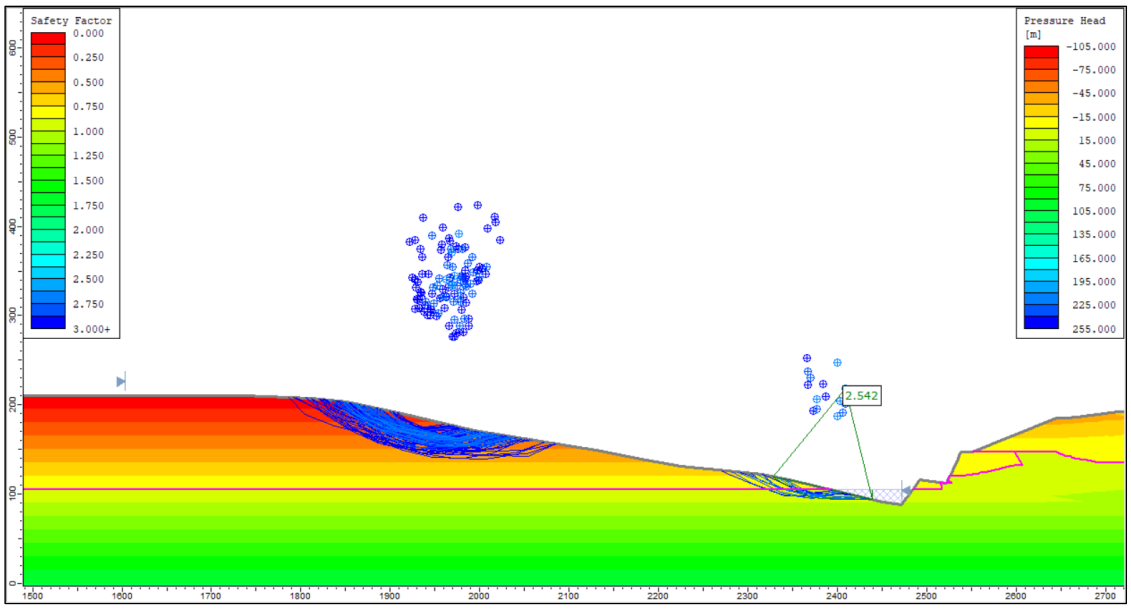

*Appendix A 115 Z-Pit North Cross Section 2 Alternative Geometry – Highwall Analysis – Dynamic*



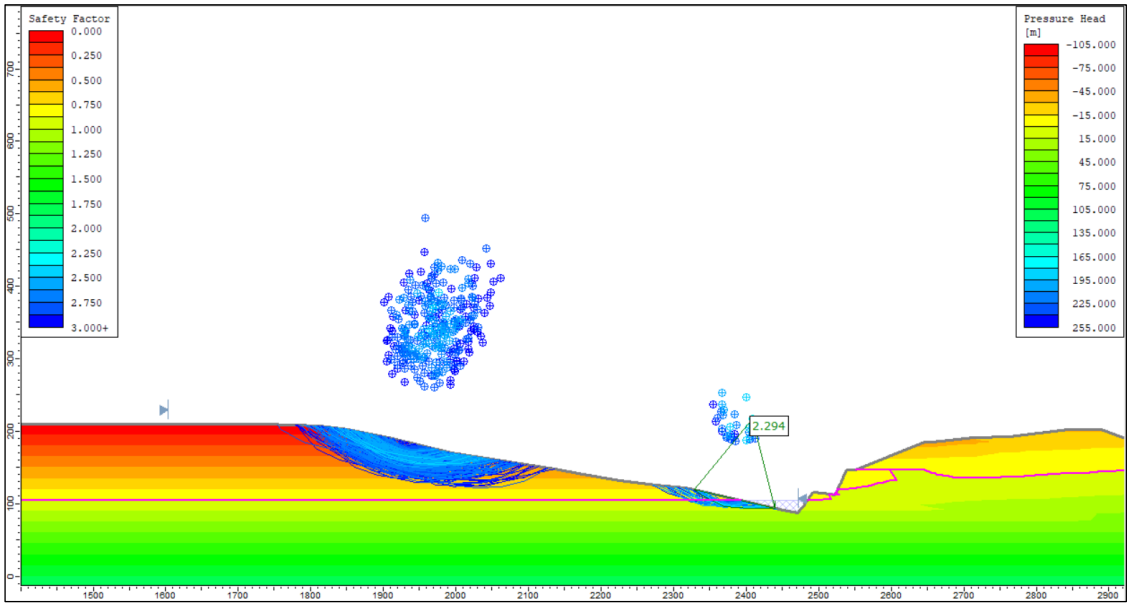

*Appendix A 116 Z-Pit South Cross Section 2 – Highwall Analysis – Static*



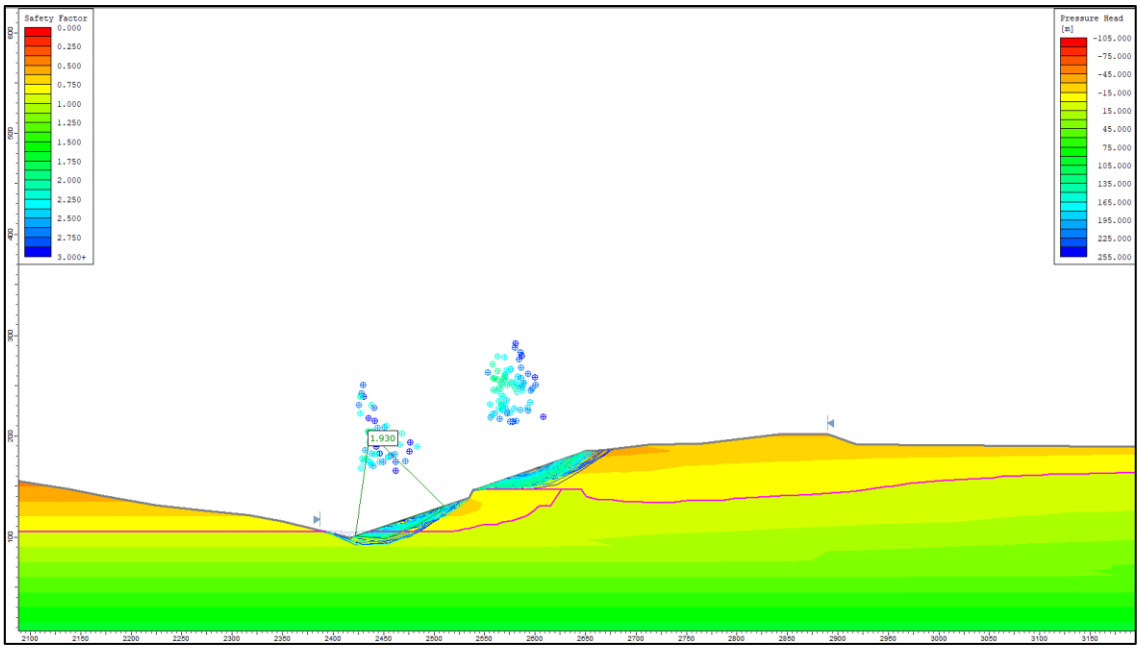

*Appendix A 117 Z-Pit South Cross Section 2 – Highwall Analysis – Dynamic*



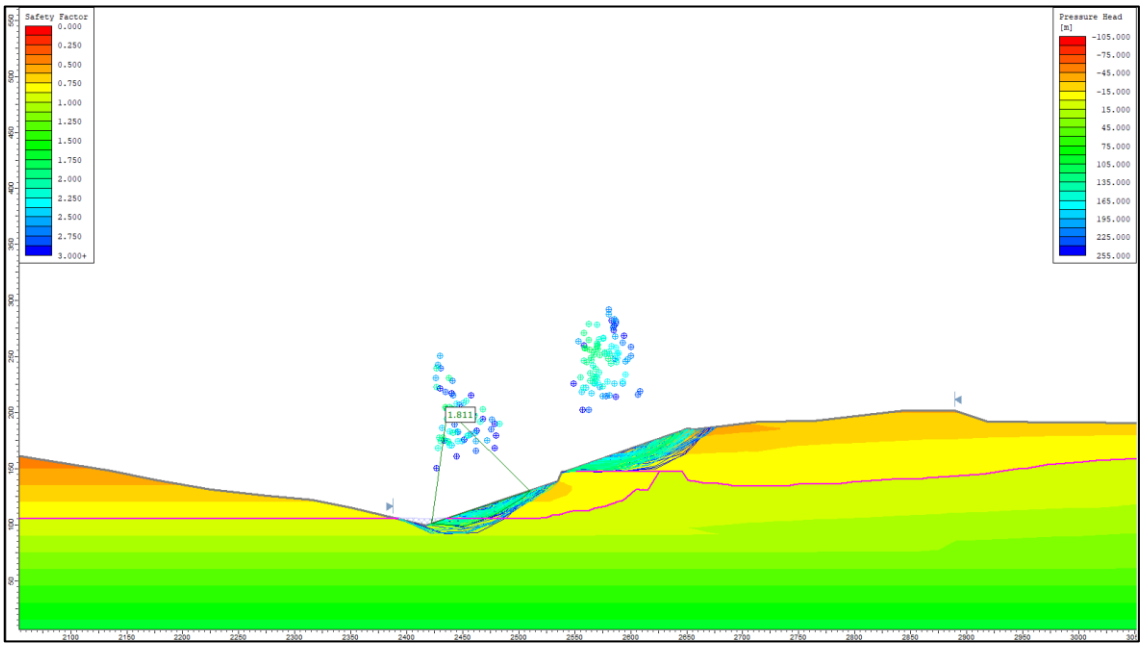

*Appendix A 118 Z-Pit South Cross Section 2 – Lowwall Analysis – Static*



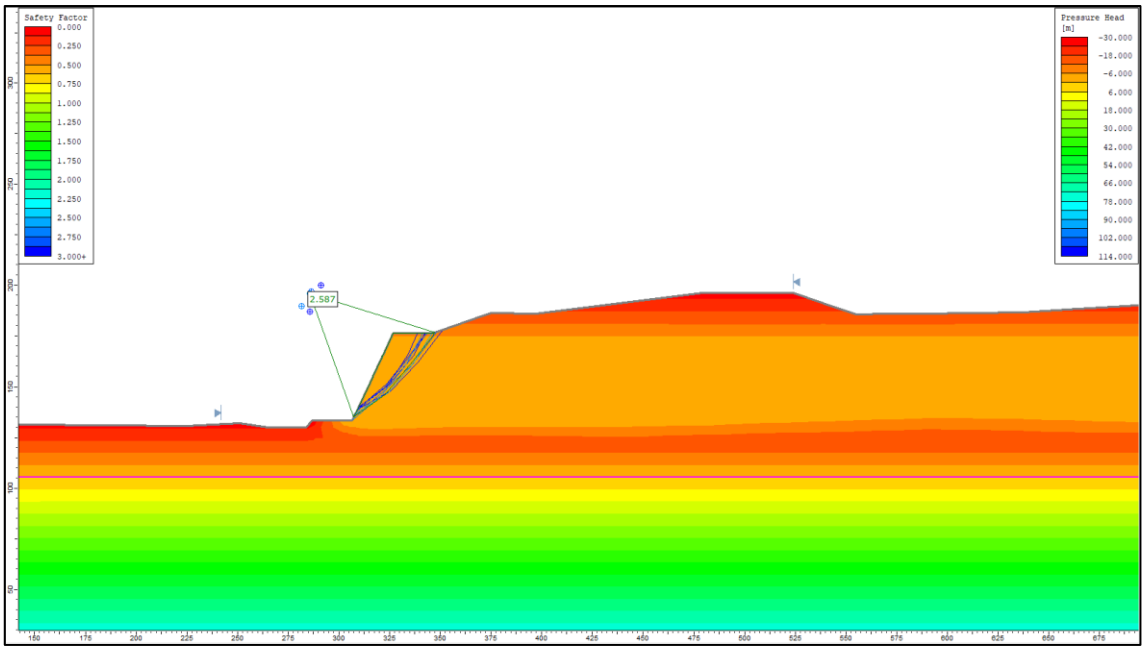

*Appendix A 119 Z-Pit South Cross Section 2 – Lowwall Analysis – Dynamic*



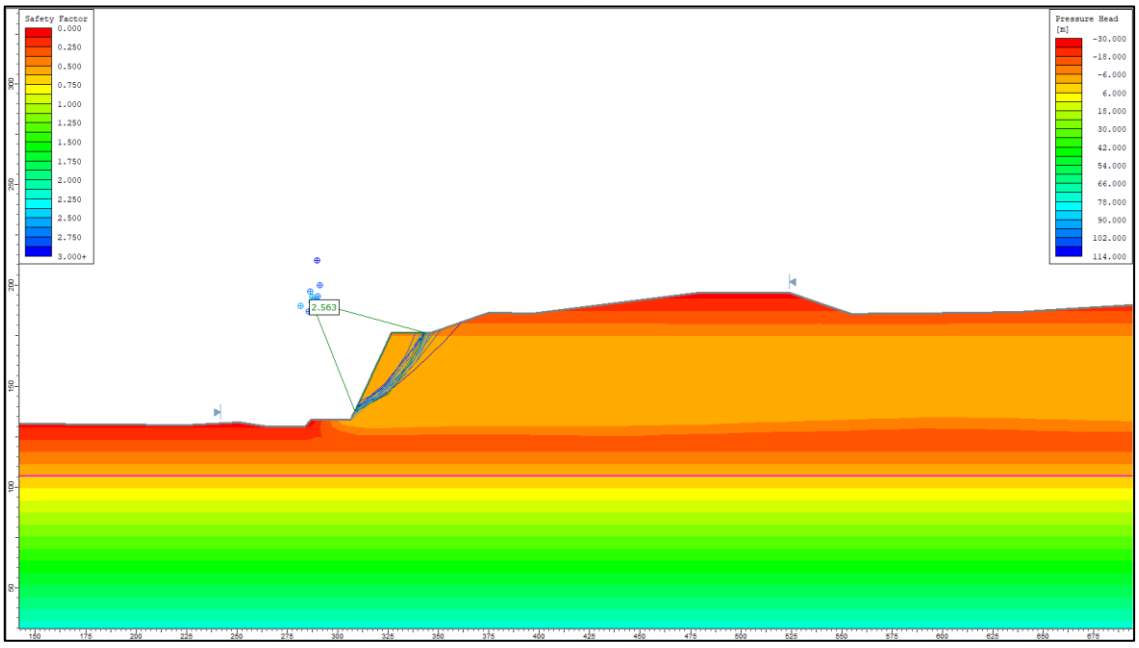

*Appendix A 120 Z-Pit South Cross Section 2 Alternative Geometry – Highwall Analysis – Static*



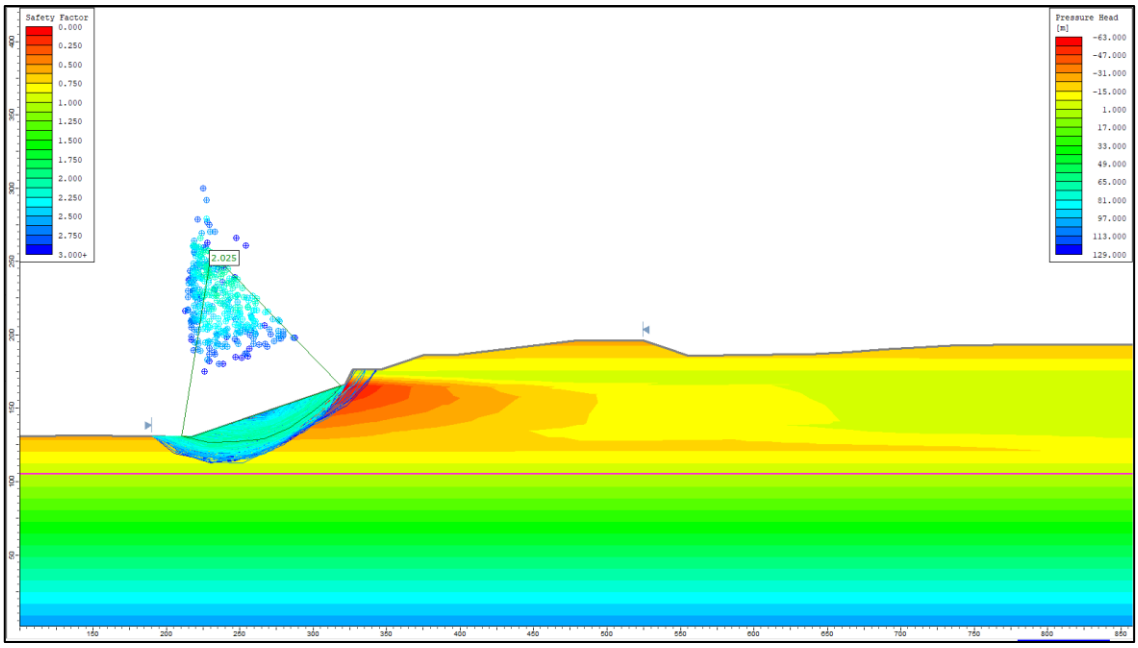

*Appendix A 121 Z-Pit South Cross Section 2 Alternative Geometry – Highwall Analysis – Dynamic*



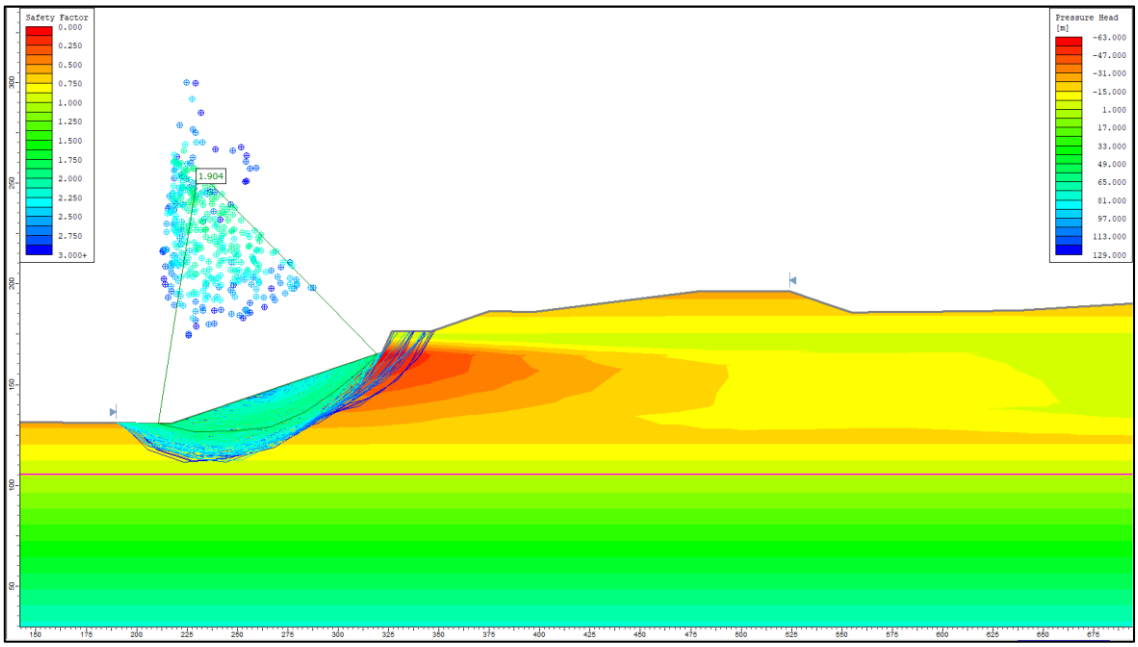

*Appendix A 122 Z-Pit South Cross Section 1 – Highwall Analysis – Static*




*Appendix A 123 Z-Pit South Cross Section 1 – Highwall Analysis – Dynamic*




*Appendix A 124 Z-Pit South Cross Section 1 Alternative Geometry – Highwall Analysis – Static*




*Appendix A 125 Z-Pit South Cross Section 1 Alternative Geometry – Highwall Analysis – Dynamic*

# **Appendix B** – Design Risk & Opportunities Register

| Item | Risk Scenario | Actions & Recommendations |
|---|---|---|
| **1** | Geological and geotechnical risk and uncertainty:<br>• Variations in the geological and structural models resulting in changes to adopted lithological unit, unit thicknesses, geological structures (i.e. faults, joints etc.), rock mass conditions, material properties etc. impacting the final landform design option include pitwall crest and toe limits; and,<br>• Impacts of erosion and geomorphological process on geotechnical stability. | Geological and geotechnical data collection programs for the final pitwalls are to be developed and implemented.<br>An erosional stability assessment, including an assessment of dispersive soils and potential for piping and cavity formation, is necessary to confirm the maximum slope angles and/or mitigation options for the various soil materials (including spoil materials) necessary to ensure the 'long-term' final landform performance requirements. The final landform designs, and if deemed necessary the geotechnical slope stability analysis, are to be updated based on the outcomes of the erosion assessment.<br>A geomorphological assessment is necessary to identify potential geomorphological processes that could impact on the 'long-term' final landform performance. The final landform designs, and if deemed necessary the geotechnical slope stability analysis, are to be updated based on the outcomes of the geomorphological assessment. |
| **2** | Hydrogeological and hydrological risk and uncertainty:<br>• Variations in the hydrogeological and hydrological models resulting in changes to adopted lithological unit hydraulic properties, changes in groundwater levels, changes in flood water level etc. impacting the final landform design option. | The hydrogeological and hydrological models should be developed, and an associated ground water investigation program implemented, to further inform the slope stability analysis.<br>Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels. |
| **3** | Variations to the proposed final landform design options arising from:<br>• Variations in the geological and structural model;<br>• Variations in the hydrogeological and hydrological models;<br>• Outcomes of erosion studies;<br>• Outcomes of geomorphological studies; and/or,<br>• Changes to or limitations in the final pitwall construction methodology, crest and toe locations, and availability of materials. | Complete a mine planning cost and risk analysis to understand the implications of changing the final landform, achieving the existing final landform and/or revising the PRCP.<br>The proposed final landform design option construction methodologies, and design options are developed.<br>Undertake detailed design work to develop final pitwall construction methodologies. |

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Document Status

| Revision Number | Author | Approved for Issue | |
|---|---|---|---|
| | Name | Name | Date |
| **A** | M Gaughan | M Raine | 9/11/2023 |
| **0** | M Gaughan | M Raine | 9/11/2023 |
| **1** | M Gaughan | M Raine | 20/11/2023 |

| | | Risk Assessment | | | | | | Risk Treatment Plan | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Risk no.** | **Category** | **Risks at Closure** | **Hazards / source of risks / threats** | **Description of Consequences / Impacts** | **Consequence rating** | **Likelihood of event** | **Risk Rating** | **Controls/treatment/actions** | **Reasons for treatment selection** | **Performance measures and constraints** | **Reporting and Monitoring Requirements** | **Resource Requirements** | **Timing** | **Responsibility** |
| 1 | Mine Layout, LOM and Sequencing | Changes to mine planning resulting in non-compliance with PRCP schedule. | Uncertainty in mining areas that have not yet commenced<br>Economic drivers<br>Unable to anticipate final void locations over long time periods accurately<br>Future conversion of MDLs to MLs | Need to amend PRCP schedule for delivery of rehabilitation<br>Delays to rehabilitation<br>Final void locations | 3 - Moderate | 3 - Possible | 13 - Significant | Communication of PRCP schedule to all employees including mine engineers and planners.<br>Regular reviews of the mine plan against the PRCP Schedule<br>If mine changes are unavoidable, undertake PRCP amendment.<br>PRCP schedule to have general year timeframes until mining commencement. | There are limited controls available as changes to mine plan occur regularly. However, informing the business of the impacts to the PRCP is a suitable control.<br>Different mine plan may mean disturbance is not undertaken, PRCP schedule not met and therefore rehabilitation is not required. | Not applicable | Not applicable | Not applicable | As required | Environment Team |
| 2 | Mine Layout, LOM and Sequencing | Change in mining methods | Technology advances<br>Geology<br>Potential for underground operations<br>Switching between truck and shovel and dragline in pit | Delay in rehabilitation<br>Change in EOML landform resulting in rehabilitation delivery changes<br>Change in final landform therefore may not meet milestone criteria | 3 - Moderate | 3 - Possible | 13 - Significant | Communication of PRCP schedule to all employees including mine engineers and planners.<br>Regular reviews of the mine plan against the PRCP Schedule<br>If mine changes are unavoidable, undertake PRCP amendment. | There are limited controls available as changes to mine plan occur regularly. However, informing the business of the impacts to the PRCP is a suitable control.<br>Different mine plan may mean disturbance is not undertaken, PRCP schedule not met and therefore rehabilitation is not required. | Not applicable | Not applicable | Not applicable | As required | Environment Team |
| 3 | Mine Layout, LOM and Sequencing | Changes in infrastructure requirements over mine life (e.g. tailings/rejects storage) | Infrastructure performance | Final landform changes caused by changed waste volumes / sources / swell factors | 2 - Minor | 5 - Almost Certain | 16 - Significant | Develop life of mine tailings/rejects strategy | A life of mine tailings/rejects strategy will assess the long term storage over the life of mine. This has been identified as an action out of the PRCP risk assessment and will be managed internally by Coronado Curragh. | Not applicable | Not applicable | Not applicable | As required | Environment Team |
| 4 | Pits | Pits walls are geotechnically unstable | Uncertain geology<br>Unforeseen faulting<br>Significant climatic events<br>Pit walls not shaped to landform design<br>Seismic activity | Unable to achieve milestone criteria<br>Unable to relinquish<br>Wider landform impacts<br>Final void widens | 2 - Minor | 3 - Possible | 8 - Medium | Geotechnical study completed by Raine Associates<br>Final landform design includes geotechnical considerations<br>Final landform construction QA/QC<br>Geotechnical inspections | A geotechnical assessment has been undertaken and included in the final landform design. QA/QC processes will be in place for the construction of the final landform highwalls to ensure the design criteria is met. Annual inspections will then take place to ensure that the design is suitable. | Geotechnical criteria | Geotechnical inspections | Personnel to perform inspections | Annually | Environment Team |
| 5 | Pits | Unauthorised access to site resulting in injury or fatality due to fall from height | Public interest and illegal attempts to access<br>Fall from height | Serious injury or fatality | 4 - Significant | 1 - Rarely | 10 - Medium | Fencing and security measures will be installed to prevent unauthorised access to the site while works are occurring.<br>Signage and bunds | Unauthorised access will be managed on site and these controls will continue during rehabilitation. | Unauthorised access to be prevented through the use of general site practices | Any incidents or security breaches will be investigated | Existing site security processes | During rehabilitation until the site is deemed safe and secure | Environment Team |
| 6 | Pits | Contamination of groundwater from void water. | Void water<br>Not fully understood groundwater movements | Groundwater modelling shows voids act as sinks and won't interact with shallow aquifers.<br>Contaminated groundwater which could seep to the surface<br>Unable to meet milestone criteria. | 2 - Minor | 2 - Unlikely | 5 - Low | Groundwater modelling shows that the pits will act as sinks<br>Groundwater and surface water monitoring. | There is no evidence of groundwater contamination from the current voids filled with water. Ongoing groundwater monitoring will identify any potential contamination | Groundwater water quality criteria | Groundwater quality monitoring | Monitoring personnel and equipment | Annually | Environment Team |
| 7 | Levees / Stable Embankments | Stable embankments fail resulting in floodwater inundation of voids. | Inappropriate design<br>Inadequate construction / not to design / QA/QC<br>Incorrect material used in construction<br>Livestock or other activities impacting stability<br>Events greater than 0.1% AEP<br>Changes to the catchment from current flood modelling<br>Climatic variation<br>Lack of maintenance | Erosion and instability of landform<br>Landform unable to prevent floodwater entering the residual void<br>Void water unlikely to enter floodplain due to void capacity | 2 - Minor | 2 - Unlikely | 5 - Low | Obtain signoff on design, construction and rehabilitation treatment from appropriately qualified person<br>Undertake regular monitoring and observation<br>Establish groundcover to avoid erosion<br>Undertake any maintenance or repair work as required<br>Rehabilitation inspections | QA/QC signoff will ensure that the construction meets the design<br>Ongoing monitoring and observation will allow any maintenance or repair needed to be identified early and rectified. | Final landform design | Rehabilitation inspection | Environmental Practitioner for inspection | Annually | Environment Team |
| 8 | Overburden | Final landform is not constructed to design. | Contractors not abiding by design<br>Inadequate QA/QC | Landform failure could erosion and sedimentation, unsustainable vegetation and therefore increased costs for remediation. | 3 - Moderate | 1 - Rarely | 6 - Medium | Implement a QA/QC process for the construction of landforms.<br>Third party PRCP schedule audits | QA/QC processes for the construction of landforms will reduce the chance of the landform not being to design. | Final landform design | Rehabilitation inspection | Personnel to perform QA/QC | During construction of landform | Environment Team |
| 9 | Overburden | Incorrect placement of materials resulting in erosion and/or geotechnical instability. | Contractors not abiding by design.<br>Characterisation of materials inadequate<br>Mine scheduling impacting placement in dump | Erosion and sedimentation of landform impacting waterways<br>Unable to relinquish or meet milestone criteria | 4 - Significant | 3 - Possible | 18 - Significant | Visual assessment of area prior to rehabilitation to assess material type.<br>Waste characterisation for current and forward disturbance<br>Waste characterisation program<br>Develop a Life of Mine Material Balance and Dumping Strategy | By including the final landform in the mine planning this would result in less second handling of material.<br>A visual inspection by an environmental practitioner | Final landform design | Erosion and stability criteria | Environmental Practitioner for inspection | Prior to construction of landform | Environment Team |
| 10 | Overburden | Waste characterisation inadequate | Waste rock is not properly characterised<br>Historical works | Erosion<br>Rework of historical rehabilitation required<br>Double handling of material resulting in higher costs | 3 - Moderate | 3 - Possible | 13 - Significant | Spoil and soil characterisation report has been completed by SLR.<br>Ongoing waste characterisation sampling. | Plans to undertake ongoing waste characterisation will reduce this risk and associated impacts. | Not applicable | Waste material sampling | Sampling personnel and equipment | During operations and closure | Environment Team |
| 11 | Tailings | Failure of cover/embankment leads to internal and external instability of out-of-pit storage facility. | Breach of cover<br>Not built to design | Loss of tailings material<br>Environmental harm<br>Non-compliance with EA<br>Significant remediation. | 2 - Minor | 1 - Rarely | 3 - Low | RPEQ signoff on design and construction of cover. | It is best practice to have a RPEQ design the cover and certify the construction. | Full RPEQ signoff | Rehabilitation monitoring | RPEQ | After constructing cover | Environment Team |
| 12 | Tailings | Seepage of in-pit tailings contaminants into alluvium groundwater. | Insufficient containment measures / cover design<br>Over filling the void | Cover design will be developed by a RPEQ and therefore is likely to be effective.<br>Environmental harm<br>Unable to relinquish. | 3 - Moderate | 1 - Rarely | 6 - Medium | RPEQ signoff on design and construction of cover<br>Groundwater monitoring.<br>No more filling of A Pit with tailings | As above.<br>Groundwater monitoring will provide an early detection system for identifying seepage. | Full RPEQ signoff<br>Groundwater criteria | Groundwater monitoring | Monitoring personnel and equipment | Annually | Environment Team |
| 13 | Diversion | Permanent watercourse diversion failure | Design not suitable<br>Diversion not constructed to design<br>Severe weather events impacting diversion integrity<br>Livestock, feral animals or other activities impacting diversion<br>Insufficient maintenance | Sedimentation and erosion of watercourse<br>Exceedance in water quality criteria<br>Watercourse does not stabilise | 3 - Moderate | 2 - Unlikely | 9 - Medium | Develop appropriate design by RPEQ<br>Obtain RPEQ signoff on design, construction and rehabilitation treatment<br>Undertake regular monitoring and observation of diversion stability<br>Establish riparian zone to assist with stability<br>Undertake any maintenance or repair work as required. | RPEQ signoff will ensure that the design meets the current standards for diversion longevity<br>Ongoing monitoring and observation will allow any maintenance or repair needed to be identified early and rectified. | Diversion design | Diversion completion criteria | RPEQ | Annually | Environment Team |
| 14 | Infrastructure | Unknown contamination i.e. hydrocarbons, PCBs, asbestos, radiation, PFAS. | Spills that were not reported<br>Minor leaks over time<br>Activities that cause contamination that was previously unknown (e.g. fire extinguisher) | Environmental harm to surrounding area<br>Unable to meet milestone criteria | 3 - Moderate | 2 - Unlikely | 9 - Medium | Hazardous substances SOP<br>Water management plan<br>Waste management plan<br>Mine affected water storage<br>Bunding<br>Inspections<br>Any uncertain material disposed of in pit with rejects/tailings<br>Contaminated sites register<br>Land contamination assessments | Best practice standards in place for preventing, reporting, monitoring and remediating any potential contamination | Milestone criteria | Inspection of potentially contamination activities | Company representative to undertake inspection | Annually | Environment Team |
| 15 | Infrastructure | Insufficient capacity for disposal of infrastructure demolition on site. | In pit disposal at the time of rehabilitation. | Increased costs for disposal of demolition waste to a licensed facility. | 2 - Minor | 2 - Unlikely | 5 - Low | Waste Management Plan<br>Develop Detailed Demolition Plan closer to closure<br>Approved landfill on site | An internal Detailed Demolition and Decommissioning Plan will be developed prior to closure in accordance with the CCPL Closure Standards. | N/A | N/A | Contractor to develop Plan | 5 years from closure | Environment Team |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | Water Management Infrastructure and Dams | Stored water does not meet stock water quality requirements. | Erosion and runoff from final landform<br>Ineffective drainage in final landform<br>Presence of mine affected water | Unable to meet milestone criteria<br>Delay in relinquishment. | 2 - Minor | 3 - Possible | 8 - Medium | Sample water quality regularly<br>Desilt water storages if required<br>Ongoing water quality monitoring. | Ongoing water quality sampling and monitoring will identify any issues that require treatment or remediation. | Surface water quality criteria | Surface water quality monitoring | Monitoring personnel. | Annually | Environment Team |
| 17 | Revegetation | Topsoil / growth media quality is not suitable/sufficient for revegetation establishment. | Insufficient or incorrect amelioration applied<br>Topsoil sampling not undertaken<br>Incorrect stockpiling of topsoil<br>Insufficient topsoil<br>Incompetent topsoil<br>Over stripping topsoil<br>Not stripping topsoil<br>Dumping over topsoil stockpiles<br>Inaccurate inventory | Revegetation does not establish and therefore criteria cannot be met<br>Increase in erosion<br>Delays in rehabilitation delivery. | 3 - Moderate | 1 - Rarely | 6 - Medium | Amelioration to be applied in accordance with evidence based recommendations.<br>Topsoil stockpiling as per PRCP methodology<br>Progressive rehabilitation<br>Rehabilitation history and trials (>20 years) | Testing of topsoil will provide the evidence needed for amelioration recommendations | Sampling and analysis | Maintain topsoil sampling records<br>Undertake maintenance as required | Soil Scientist | Prior to stripping and application | Environment Team |
| 18 | Revegetation | Grass competition results in insufficient woodland development | Topsoil contains Buffel/grass seed | Unable to meet post mining land use and milestone criteria | 3 - Moderate | 3 - Possible | 13 - Significant | Controlled burns<br>Insufficient surface preparation (e.g. ripping depths)<br>Rehabilitation history and trials (>20 years)<br>Strategic topsoil placement<br>Minimise exotic grass seed in woodland areas | Rehabilitation checks after each milestone will be undertaken | Material availability or type<br>Topsoil thickness | Maintain rehabilitation records | Rehabilitation auditor | Following topsoil application | Environment Team |
| 19 | Revegetation | Seed mix does not meet specifications for required PMLU. | Incorrect seed mix used<br>Inappropriate application<br>Not available<br>Quality of seed mix | Rehabilitation does not meet the criteria in PRCP schedule. | 2 - Minor | 2 - Unlikely | 5 - Low | Seed mix contains minimum species requirements<br>Seed QA/QC and certification<br>Pre-order seed mix in advance to ensure availability<br>Appropriate storage of seed | The correct seed mix promotes vegetation which aligns with the proposed PMLU | Viability testing of seed to ensure effectiveness | Maintain records of seed mix supplied and used | Rehabilitation specialist | Prior to seeding | Environment Team |
| 20 | Revegetation | Declared weeds in excess of milestone criteria allowance and impacting revegetation success. | Cattle bringing in weeds<br>Main road adjacent to site<br>Machinery introducing weeds<br>Weeds on underlying property | Weeds impact the success of desired species<br>Unable to meet milestone criteria. | 2 - Minor | 4 - Likely | 12 - Medium | Undertake weed control measures e.g. weed spraying<br>Machinery to be washed prior to site entry<br>Weed declarations<br>Rehabilitation monitoring<br>Analogue sites to establish baseline weed | The weed control measures in the PRCP include best practice methodologies. | Surrounding properties and underlying land users may impact the control of weeds.<br>The PRCP schedule contains criteria relating to weeds. | Vegetation monitoring including weeds | Monitoring personnel and equipment. | Annually and prior to topsoil stripping | Environment Team |
| 21 | Revegetation | Overgrazing damaging rehabilitation areas. | Overgrazing | Introduction of weeds<br>Damage to rehabilitation<br>Unable to meet milestone criteria<br>Delay in relinquishment<br>Erosion and sedimentation | 3 - Moderate | 2 - Unlikely | 9 - Medium | Fencing of rehabilitation areas until well established<br>Landholder engagement<br>Rehabilitation Monitoring | The control measures have been selected with a focus on engaging with the landholder and limiting live stock accessibility. | The PRCP schedule includes final milestone criteria for meeting the post mining land use. | Rehabilitation Monitoring | Monitoring personnel and equipment. | Annually or as required | Environment Team |
| 22 | General | Pests damaging rehabilitation areas. | Feral animals e.g. pigs | Impact on vegetation establishment<br>Cause erosion and sedimentation | 2 - Minor | 3 - Possible | 8 - Medium | Undertake pest eradication measures<br>Engage with neighbours for joint management<br>Fence rehabilitation areas until established | The feral animal control measures in the PRCP include best practice methodologies. | Surrounding properties and underlying land users may impact the control of pests.<br>The PRCP schedule contains criteria relating to pests. | Pest control (weed and feral animal) monitoring | Monitoring personnel and equipment. | Annually or as required | Environment Team |
| 23 | General | Inadequate monitoring data to support relinquishment. | Failure to undertake monitoring<br>Insufficient records/data control<br>Monitoring data doesn't align with milestone criteria<br>Insufficient monitoring sites | Unable to relinquish<br>Non-compliance with criteria<br>Potential failures in rehabilitation. | 4 - Significant | 3 - Possible | 18 - Significant | Undertake rehabilitation monitoring in accordance with the PRCP<br>Sufficient record keeping<br>Review monitoring against milestone criteria | Internal record keeping procedures will be used to ensure monitoring is undertaken in accordance with the Rehabilitation Monitoring Program. | Weather may act as a constraint for monitoring at times but this should be supplemented when appropriate. | Rehabilitation Monitoring | Monitoring personnel and equipment. | Annually or as required | Environment Team |
| 24 | Weather | Significant rainfall event and flood impacting rehabilitation success (excluding pit). | Significant flood event (>0.1 % AEP event) | Excessive erosion<br>Loss of material resources<br>Damaged revegetation<br>Additional costs to re-establish vegetation<br>Weed introduction<br>Delay in relinquishment<br>Unestablished rehabilitation failure | 4 - Significant | 1 - Rarely | 10 - Medium | The proposed final landform has been designed to prevent flood water impacting the residual void<br>Added erosion and sediment controls in flood risk areas<br>Progressive rehabilitation to minimise exposed areas<br>Seeding at optimal time for rainfall<br>Seed immediately after topsoil application to establish groundcover as soon as possible<br>Establish species suitable for the climate<br>Exclusion of grazing until rehabilitation has stabilised<br>Rehabilitation monitoring | The mine plan has been designed to consider flood risk as a first defence. As added protection erosion and sedimentation controls, a specialised revegetation plan and monitoring will be implemented. | The PRCP schedule includes final milestone criteria for meeting the post mining land use. | Rehabilitation Monitoring | Monitoring personnel and equipment. | Annually | Environment Team |
| 25 | Weather | Drought impacting rehabilitation success. | Drought<br>Limited water supplies<br>Climate change | Impacts to revegetation success<br>Potential impacts to soil quality<br>Additional costs to re-establish vegetation<br>Delay in relinquishment<br>Delay in rehabilitation schedule. | 4 - Significant | 2 - Unlikely | 13 - Significant | Limited controls available<br>Allow additional time in PRCP schedule to compensate for potential risk<br>Reference to analogue sites in criteria to account for regional fluctuations in weather<br>Allow contingency for weather events in PRCP schedule<br>Consider acceleration of rehabilitation rates in the wet years where land is available<br>Species selection | There are limited controls available for a drought situation and therefore comparisons to reference sites should be used. | The PRCP schedule includes final milestone criteria for meeting the post mining land use. | Rehabilitation Monitoring | Monitoring personnel and equipment. | Annually | Environment Team |
| 26 | Weather | Uncontrolled bushfire damaging rehabilitation. | Bushfire<br>Lightening strike<br>Public road adjacent to site (Cigarette butts)<br>Machinery / vehicle | Impacts to revegetation success<br>Additional costs to re-establish vegetation<br>Delay in rehabilitation delivery | 4 - Significant | 3 - Possible | 18 - Significant | Low vegetation cover or connectivity in surrounding area<br>Controlled burns<br>Grazing to manage fuel loads<br>Landholder bushfire management<br>Fire breaks<br>Rural fire service<br>Water trucks, carts, equipment and people available | There are limited controls available for a bushfire. However, bushfire management and consultation with surrounding landholders is the appropriate treatments available. | The PRCP schedule includes final milestone criteria for meeting the post mining land use. | Rehabilitation Monitoring | Monitoring personnel and equipment. | Annually | Environment Team |
| 27 | Social / HR | Landholder agreements for retainment of infrastructure | No current landholder agreements<br>Change in landholder | Missed opportunity for using infrastructure to support PMLU<br>Uncertainty on future land owners and their expectations on retaining infrastructure<br>Unable to leave infrastructure post-mining | 2 - Minor | 2 - Unlikely | 5 - Low | Engage with stakeholders over life of mine<br>Obtain agreements where for infrastructure the landholders wish to retain | Landholder engagement over the life of mine will ensure that opportunities to retain infrastructure for post mining use is optimised. | Not applicable | Update Community Consultation Register | Personnel to engage with landholders | Over mine life and closure | Environment Team |
| 28 | Social / HR | Stakeholder support of post-mining land uses change | Change in community / stakeholder priorities / expectations | Damage to relationships<br>Impacts on ongoing operations/engagement | 3 - Moderate | 3 - Possible | 13 - Significant | Ongoing stakeholder engagement over life of mine | Ongoing consultation to manage post mining land use expectations of stakeholders. | Not applicable | Update Community Consultation Register | Personnel to engage with stakeholders | Over mine life and closure | Environment Team |
| 29 | Social / HR | Impacts of closure on local community | Reliance of community on Curragh | Employment loss<br>Business loss | 3 - Moderate | 2 - Unlikely | 9 - Medium | Ongoing stakeholder engagement over life of mine<br>Communication of PRCP schedule and planned closure | Ongoing consultation to manage post mining land use expectations of stakeholders. | Not applicable | Update Community Consultation Register | Personnel to engage with stakeholders | Over mine life and closure | Environment Team |
| 30 | Social / HR | Potential changes to regulator rehabilitation expectations / interpretation impacting PRCP schedule amendments | Political drivers<br>Community complaints/interest<br>Climate change<br>Lack of industry performance | Regulatory non-compliance<br>Additional costs to address changed expectations / interpretations<br>Delay in relinquishment | 3 - Moderate | 3 - Possible | 13 - Significant | Industry interest groups.<br>Departmental consultations<br>Approved PRCP schedule | Limited controls available. Awareness and consultation have been proposed. | Not applicable | Not applicable | Not applicable | Over mine life and closure | Environment Team |

# Progressive Rehabilitation and Closure Plan Schedule template

## Instructions

**General Instructions:**

- **This form can be used for completing a PRCP schedule for the submission of a progressive rehabilitation and closure plan (PRC plan).**
- **See the PRCP schedule section of the PRC plan guideline (ESR/2019/4964) for further information requirements.**

- A default value of one (1) Rehabilitation Area (RA) is represented by one RA sheets below (RA1).
- A default value of one (1) Improvement Area (IA) is represented by one IA sheet below (IA1).

- To record additional RAs for your project make a copy of the RA sheet below and update it to the relevant RA number (i.e. RA2).
- To record additional IAs for your project make a copy of the IA sheet below and update it to the relevant IA number (i.e. IA2).
- To remove the IA sheet if there is no IA for your project, delete the IA sheet below.

- Each RA and IA sheet contains **two separate excel tables** (yellow and blue) for recording the time-based rehabilitation milestones.
- Add a new column or row to each table as required for your information requirements.

- Two (2) separate sheets below exist for recording the "Rehabilitation Area Milestones" and "Improvement Area Milestones".
- Delete the Improvement Area Milestone sheet if it does not apply to your project.
- Delete additional rows in either sheet if they do not apply to your project.
- See the PRC plan guideline for a list of reference milestones and further information for developing additional site-specific milestones where appropriate.

## Further Instructions when inputting PMLUs

**Headings under Rehabilitation Area (RA) sheets**

Rehabilitation area - The rehabilitation area must align with the spatial information included in the rehabilitation planning part of the PRC plan. This area must have the same PMLU and same milestones applied to the whole area.

Relevant activities - The relevant activities must align with the activities identified in the rehabilitation planning part of the PRC plan. The relevant activities are those undertaken within the rehabilitation area prior to land becoming available for rehabilitation.

Total size of rehabilitation area (ha) - Total size of rehabilitation area in hectares.

Commencement of first milestone - The applicant must nominate a date for when the first milestone for the rehabilitation area will commence. The milestone reference for the first milestone must be included in the heading.

PMLU - The PMLU must align with those identified in the rehabilitation planning part of the PRC plan and in the proposed final site design.

Date area is available - The PRCP schedule must identify when land within the rehabilitation area becomes available for rehabilitation. If the whole rehabilitation area becomes available at once there should be only one date. If the rehabilitation areas becomes available progressively there should be multiple dates. These dates should reflect the information provided in the rehabilitation planning part of the PRC plan.

Cumulative area available (ha) - The PRCP schedule must identify the area of land within the rehabilitation area that will become available at a given time.

Milestone completed by - The PRCP schedule must identify completion dates for milestones to be completed.

Cumulative area achieved (ha) - The PRCP schedule must show how progressive rehabilitation is being achieved over the life of the mine. This section must reflect the proposed rehabilitation work required for the rehabilitation area to achieve stable condition. The milestone reference to be included refers back to the Rehabilitation Area Milestones sheet with the detailed milestone criteria. The milestones must be achieved consecutively.

**Headings under Rehabilitation Area Milestones sheet**

Rehabilitation milestone & Milestone criteria - The “rehabilitation milestone” is a short description of the rehabilitation activities. The "milestone criteria" must be able to demonstrate achievement of the milestone.

## Further Instructions when inputting NUMAs

**Headings under Improvement Area (IA) sheets**

Improvement area - The improvement area must align with the spatial information included in the rehabilitation planning part of the PRC plan. This area must have the same NUMA and same milestones applied to the whole area.

Relevant activities - The relevant activities must align with the activities identified in the rehabilitation planning part of the PRC plan. The relevant activities are those undertaken within the improvement area prior to land becoming available for improvement.

Total size (ha) - Total size of improvement area in hectares.

Commencement of first milestone - The applicant must nominate a date for when the first milestone for the improvement area will commence. The milestone reference for the first milestone must be included in the heading.

NUMA - The NUMA must align with those identified in the rehabilitation planning part of the PRC plan and in the proposed final site design.

Date area is available - The PRCP schedule must identify when land within the improvement area becomes available for improvement. If the whole improvement area becomes available at once there should be only one date. If the improvement areas becomes available progressively there should be multiple dates. These dates should reflect the information provided in the rehabilitation planning part of the PRC plan.

Cumulative area available (ha) - The PRCP schedule must identify the area of land within the improvement area that will become available at a given time.

Milestone completed by - The PRCP schedule must identify completion dates for milestones to be completed.

Cumulative area achieved (ha) - The PRCP schedule must show how progressive improvement is being achieved over the life of the mine. This section must reflect the proposed management work required for the improvement area to achieve sufficient improvement. The milestone reference refers back to the Improvement Area Milestones sheet with the detailed milestone criteria. The milestones must be achieved consecutively.

| Post-mining land uses (PMLU) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | RA1 | | | | | | | | | | | | | |
| **Relevant activities** | Overburden Dumps and Ramps | | | | | | | | | | | | | |
| **Total rehabilitation area size (ha)** | 9,497 | | | | | | | | | | | | | |
| **Commencement of first milestone: RM2** | 2023 | | | | | | | | | | | | | |
| **PMLU** | Open Woodland | | | | | | | | | | | | | |
| **Date area is available** | 10/12/23 | 10/12/24 | 10/12/25 | 10/12/26 | 10/12/27 | 10/12/28 | 10/12/29 | 10/12/30 | 10/12/31 | 10/12/32 | 10/12/33 | 10/12/34 | 10/12/35 | 10/12/36 |
| **Cumulative area available (ha)** | 300 | 300 | 300 | 800 | 1,050 | 1,400 | 1,550 | 2,300 | 3,000 | 3,700 | 4,200 | 4,500 | 5,000 | 5,300 |
| **Milestone completed by** | 10/12/25 | 10/12/26 | 10/12/27 | 10/12/28 | 10/12/29 | 10/12/30 | 10/12/31 | 10/12/32 | 10/12/33 | 10/12/34 | 10/12/35 | 10/12/36 | 10/12/37 | 10/12/38 |
| **Milestone Reference** | | | | | | | | | | | | | | |
| **RM2** | 120 | 220 | 320 | 470 | 620 | 770 | 920 | 1070 | 1270 | 1470 | 1670 | 1870 | 2070 | 2320 |
| **RM3** | | | 120 | 220 | 320 | 470 | 620 | 770 | 920 | 1070 | 1270 | 1470 | 1670 | 1870 |
| **RM4** | | | 120 | 220 | 320 | 470 | 620 | 770 | 920 | 1070 | 1270 | 1470 | 1670 | 1870 |
| **RM11** | | | | | | | | | | | | | 120 | 220 |

**1) Insert new columns to the yellow table to include further rehabilitation milestone dates.**
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**4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/12/37 | 10/12/38 | 10/12/39 | 10/12/40 | 10/12/41 | 10/12/42 | 10/12/43 | 10/12/44 | | | | | | | |
| 5,800 | 6,400 | 7,000 | 7,500 | 8,000 | 8,500 | 9,000 | 9,497 | | | | | | | |
| 10/12/39 | 10/12/40 | 10/12/41 | 10/12/42 | 10/12/43 | 10/12/44 | 10/12/45 | 10/12/46 | 10/12/47 | 10/12/48 | 10/12/49 | 10/12/50 | 10/12/51 | 10/12/52 | 10/12/53 |
| **Cumulative area achieved (ha)** | | | | | | | | | | | | | | |
| 2570 | 2820 | 3070 | 3570 | 4070 | 4620 | 5170 | 5920 | 6670 | 7420 | 8170 | 8920 | 9497 | | |
| 2070 | 2320 | 2570 | 2820 | 3070 | 3570 | 4070 | 4620 | 5170 | 5920 | 6670 | 7420 | 8170 | 8920 | 9497 |
| 2070 | 2320 | 2570 | 2820 | 3070 | 3570 | 4070 | 4620 | 5170 | 5920 | 6670 | 7420 | 8170 | 8920 | 9497 |
| 320 | 470 | 620 | 770 | 920 | 1070 | 1270 | 1470 | 1670 | 1870 | 2070 | 2320 | 2570 | 2820 | 3070 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| 10/12/54 | 10/12/55 | 10/12/56 | 10/12/57 | 10/12/58 | 10/12/62 | 10/12/63 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| 3570 | 4070 | 4620 | 5170 | 5920 | 8920 | 9497 |

| Post-mining land uses (PMLU) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | RA2 | | | | | | | | | |
| **Relevant activities** | Infrastructure activities requiring a land contamination study | | | | | | | | | |
| **Total rehabilitation area size (ha)** | 128 | | | | | | | | | |
| **Commencement of first milestone: RM1** | 2049 | | | | | | | | | |
| **PMLU** | Light Grazing | | | | | | | | | |
| **Date area is available** | 10/12/48 | | | | | | | | | |
| **Cumulative area available (ha)** | 127.8 | | | | | | | | | |
| **Milestone completed by** | 10/12/52 | 10/12/54 | 10/12/56 | 10/12/61 | | | | | | |
| **Milestone Reference** | **Cumulative area achieved (ha)** | | | | | | | | | |
| **RM1** | 128 | | | | | | | | | |
| **RM2** | | 128 | | | | | | | | |
| **RM3** | | | 128 | | | | | | | |
| **RM4** | | | 128 | | | | | | | |
| **RM6** | | | | 128 | | | | | | |

**1) Insert new columns to the yellow table to include further rehabilitation milestone dates.**
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**3) Insert new rows to the blue table to include additional rehabilitation milestone references.**
**4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).**

| Post-mining land uses (PMLU) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | RA3 | | | | | | | | | |
| **Relevant activities** | Miscellaneous Activities - topsoil stockpiles, roads, laydowns, cleared areas | | | | | | | | | |
| **Total rehabilitation area size (ha)** | 464 | | | | | | | | | |
| **Commencement of first milestone: RM1** | 2049 | | | | | | | | | |
| **PMLU** | Light Grazing | | | | | | | | | |
| **Date area is available** | 10/12/48 | | | | | | | | | |
| **Cumulative area available (ha)** | 464 | | | | | | | | | |
| **Milestone completed by** | 10/12/50 | 10/12/52 | 10/12/54 | 10/12/59 | | | | | | |
| **Milestone Reference** | **Cumulative area achieved (ha)** | | | | | | | | | |
| **RM1** | 464 | | | | | | | | | |
| **RM2** | | 464 | | | | | | | | |
| **RM3** | | | 464 | | | | | | | |
| **RM4** | | | 464 | | | | | | | |
| **RM9** | | | | 464 | | | | | | |

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| Post-mining land uses (PMLU) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | RA4 | | | | | | | | | |
| **Relevant activities** | Blackwater Creek Watercourse Diversion | | | | | | | | | |
| **Total rehabilitation area size (ha)** | 156 | | | | | | | | | |
| **Commencement of first milestone: RM10** | 2044 | | | | | | | | | |
| **PMLU** | Watercourse | | | | | | | | | |
| **Date area is available** | 10/12/44 | | | | | | | | | |
| **Cumulative area available (ha)** | 156 | | | | | | | | | |
| **Milestone completed by** | 10/12/45 | | | | | | | | | |
| **Milestone Reference** | **Cumulative area achieved (ha)** | | | | | | | | | |
| **RM10** | 156 | | | | | | | | | |

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**4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).**

| Post-mining land uses (PMLU) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | RA5 | | | | | | | | | |
| **Relevant activities** | Water Infrastructure | | | | | | | | | |
| **Total rehabilitation area size (ha)** | 65 | | | | | | | | | |
| **Commencement of first milestone: RM6** | 2044 | | | | | | | | | |
| **PMLU** | Light Grazing | | | | | | | | | |
| **Date area is available** | 10/12/44 | | | | | | | | | |
| **Cumulative area available (ha)** | 65 | | | | | | | | | |
| **Milestone completed by** | 10/12/47 | 10/12/49 | 10/12/54 | | | | | | | |
| **Milestone Reference** | **Cumulative area achieved (ha)** | | | | | | | | | |
| **RM6** | 65 | | | | | | | | | |
| **RM3** | | 65 | | | | | | | | |
| **RM4** | | 65 | | | | | | | | |
| **RM9** | | | 65 | | | | | | | |

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**3) Insert new rows to the blue table to include additional rehabilitation milestone references.**
**4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).**

| Post-mining land uses (PMLU) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | RA6 | | | | | | | | | |
| **Relevant activities** | Out-of-Pit Tailings Storage Facility | | | | | | | | | |
| **Total rehabilitation area size (ha)** | 185 | | | | | | | | | |
| **Commencement of first milestone: RM7** | 2021 | | | | | | | | | |
| **PMLU** | Light Grazing | | | | | | | | | |
| **Date area is available** | 10/12/21 | | | | | | | | | |
| **Cumulative area available (ha)** | 185 | | | | | | | | | |
| **Milestone completed by** | 10/12/33 | 10/12/35 | 10/12/40 | | | | | | | |
| **Milestone Reference** | **Cumulative area achieved (ha)** | | | | | | | | | |
| **RM7** | 185 | | | | | | | | | |
| **RM3** | | 185 | | | | | | | | |
| **RM4** | | 185 | | | | | | | | |
| **RM9** | | | 185 | | | | | | | |

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**4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).**

| Post-mining land uses (PMLU) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | RA7 | | | | | | | | | |
| **Relevant activities** | Stable Embankments | | | | | | | | | |
| **Total rehabilitation area size (ha)** | 367 | | | | | | | | | |
| **Commencement of first milestone: RM8** | 2042 | | | | | | | | | |
| **PMLU** | Fauna Habitat and Ecosystem Services | | | | | | | | | |
| **Date area is available** | 10/12/42 | | | | | | | | | |
| **Cumulative area available (ha)** | 367 | | | | | | | | | |
| **Milestone completed by** | 10/12/45 | 10/12/55 | | | | | | | | |
| **Milestone Reference** | **Cumulative area achieved (ha)** | | | | | | | | | |
| **RM8** | 367 | | | | | | | | | |
| **RM12** | | 367 | | | | | | | | |

**1) Insert new columns to the yellow table to include further rehabilitation milestone dates.**
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**3) Insert new rows to the blue table to include additional rehabilitation milestone references.**
**4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).**

| Post-mining land uses (PMLU) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | RA8 | | | | | | | | | |
| **Relevant activities** | In-pit tailings | | | | | | | | | |
| **Total rehabilitation area size (ha)** | 68 | | | | | | | | | |
| **Commencement of first milestone: RM12** | 2042 | | | | | | | | | |
| **PMLU** | Open Woodland | | | | | | | | | |
| **Date area is available** | 10/12/42 | | | | | | | | | |
| **Cumulative area available (ha)** | 68 | | | | | | | | | |
| **Milestone completed by** | 10/12/43 | 10/12/45 | 10/12/55 | | | | | | | |
| **Milestone Reference** | **Cumulative area achieved (ha)** | | | | | | | | | |
| **RM7** | 68 | | | | | | | | | |
| **RM2** | 68 | | | | | | | | | |
| **RM3** | | 68 | | | | | | | | |
| **RM4** | | 68 | | | | | | | | |
| **RM11** | | | 68 | | | | | | | |

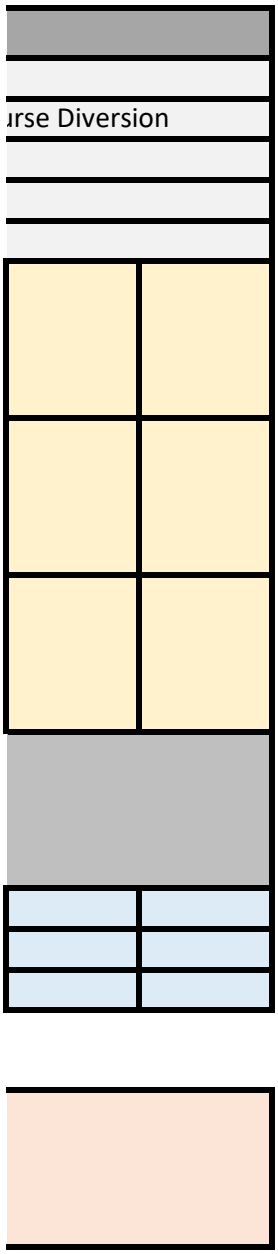
**1) Insert new columns to the yellow table to include further rehabilitation milestone dates.**
**2) Insert new columns to the blue table to match rehabilitation milestone dates.**
**3) Insert new rows to the blue table to include additional rehabilitation milestone references.**
**4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).**

| Post-mining land uses (PMLU) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | RA9 | | | | | | | | | |
| **Relevant activities** | Existing Overburden Rehabilitation | | | | | | | | | |
| **Total rehabilitation area size (ha)** | 1653 | | | | | | | | | |
| **Commencement of first milestone: RM9** | 2023 | | | | | | | | | |
| **PMLU** | Light Grazing | | | | | | | | | |
| **Date area is available** | 10/12/23 | | | | | | | | | |
| **Cumulative area available (ha)** | 1653 | | | | | | | | | |
| **Milestone completed by** | 10/12/28 | | | | | | | | | |
| **Milestone Reference** | **Cumulative area achieved (ha)** | | | | | | | | | |
| **RM9** | 1653 | | | | | | | | | |

**1) Insert new columns to the yellow table to include further rehabilitation milestone dates.**
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**3) Insert new rows to the blue table to include additional rehabilitation milestone references.**
**4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).**

| Post-mining land uses (PMLU) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Rehabilitation area** | | | | RA10 | | | | |
| **Relevant activities** | | | | Minne Creek and Bonnie Doon Creek Watercou | | | | |
| **Total rehabilitation area size (ha)** | | | | 61 | | | | |
| **Commencement of first milestone:** | | | | | | | | |
| **PMLU** | | | | Water Course | | | | |
| **Date area is available** | Construction date + 1 year | 10/12/44 | | | | | | |
| **Cumulative area available (ha)** | 61 | 61 | | | | | | |
| **Milestone completed by** | Date available + 1 | 10/12/45 | | | | | | |
| **Milestone Reference** | **Cumulative area achieved (ha)** | | | | | | | |
| **RM3** | 61 | | | | | | | |
| **RM4** | 61 | | | | | | | |
| **RM10** | | 61 | | | | | | |

**1) Insert new columns to the yellow table to include further rehabilitation milestone dates.**
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**4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).**


urse Diversion

| Non-use management area (NUMA) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Improvement area** | | | | IA1 | | | | |
| **Relevant activities** | | | | Voids | | | | |
| **Total size (ha)** | | | | 1499 | | | | |
| **Commencement of first milestone: MM1** | | | | 2028 | | | | |
| **NUMA** | | | | Residual Void | | | | |
| **Date area is available** | 10/12/28 | 10/12/30 | 10/12/31 | 10/12/35 | 10/12/38 | 10/12/42 | 10/12/43 | |
| **Cumulative area available (ha)** | 30 | 151 | 396 | 541 | 688 | 1338 | 1499 | |
| **Milestone completed by** | 10/12/31 | 10/12/32 | 10/12/33 | 10/12/34 | 10/12/35 | 10/12/36 | 10/12/37 | 10/12/38 |
| **Milestone Reference** | | | | | | | | |
| **MM1** | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 420 |
| **MM2** | 0 | 0 | 50 | 100 | 150 | 200 | 250 | 300 |

**1) Insert new columns to the yellow table to include further management milestone dates.**
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**3) Insert new rows to the blue table to include additional management milestone references.**
**4) Insert the relevant number in the "Milestone reference" column (i.e. MM1).**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| 10/12/39 | 10/12/40 | 10/12/41 | 10/12/42 | 10/12/43 | 10/12/44 | 10/12/45 | 10/12/46 | 10/12/47 | 10/12/48 |
| **Cumulative area achieved (ha)** | | | | | | | | | |
| 490 | 550 | 640 | 730 | 840 | 950 | 1060 | 1170 | 1280 | 1390 |
| 350 | 420 | 490 | 550 | 640 | 730 | 840 | 950 | 1060 | 1170 |

| | | |
|---|---|---|
| | | |
| | | |
| 10/12/49 | 10/12/50 | 10/12/51 |
| | | |
| 1499 | | |
| 1280 | 1390 | 1499 |

| Milestone reference | Rehabilitation milestone | Milestone criteria |
|---|---|---|
| RM1 | Infrastructure Decommissioning and Removal | (a) With the exception of any infrastructure to remain as part of the post-mining land use (PMLU) or where infrastructure is agreed to be retained by the landholder as evidenced by a signed landholder agreement, the following are complete:<br>i) All services (water, electricity, gas, etc.) disconnected;<br>ii) All hazardous materials removed;<br>iii) All buildings demolished and removed;<br>iv) All pipelines decommissioned;<br>v) All fencing removed;<br>vi) All roads decommissioned; and<br>vii) All boreholes decommissioned.<br>(b) All general waste and demolition waste has been:<br>i) Removed; or<br>ii) Disposed of where authorised by environmental authority EPML00643713. |
| RM2 | Landform Development and reshaping/reprofiling | (a) All major earthworks completed.<br>(b) Average slope angle of 16%.<br>(c) Installation of erosion and sediment control systems to design and certified by an appropriately qualified person.<br>(d) Slopes create surface which is free draining with the exception of minor ponding. |
| RM3 | Surface Preparation | (a) Topsoil or growth medium placed at a depth ≥200 mm (millimetres) for approximately 65% of overburden dump area.<br>(b) Topsoil or growth medium placed at a depth ≥200 mm (millimetres) to 100% of all other areas.<br>(c) Contour ripping completed at a depth 600-750 mm.<br>(d) Amelioration products have been applied where appropriate and required. |
| RM4 | Revegetation | (a) The seed mix contains species appropriate for the nominated PMLU.<br>(b) Seed mix applied at a rate ≥10 kilograms per hectare (kg/ha).<br>(c) Livestock are excluded from newly seeded areas via physical or virtual fencing. |
| RM5 | Remediation of Contaminated Land | (a) Preliminary site investigation (PSI) completed.<br>(b) A detailed site investigation (DSI) has been completed where the PSI completed under criterion RM2(a) identifies contamination is present, or is likely to be present, and said contaminated material is likely to result in a risk to human health or cause environmental harm.<br>(c) Where contaminated material is identified, all contaminated material is either:<br>i. Remediated;<br>ii. Removed and disposed of at a licenced facility; or<br>iii. Disposed of as per the Contaminated Land Investigation Document (CLID) and Site Management Plan (SMP).<br>(d) The site suitability statement states the land is not contaminated land and is not unsuitable for the proposed PMLU.<br>(e) Auditor certifies, as per Environmental Protection Act 1994 (EP Act) (Qld), that all contaminated materials have been remediated, or removed and disposed of.<br>(f) Land is removed from Environmental Management Register if applicable. |
| RM6 | Rehabilitation of Dams | (a) All dams, which are to remain as part of the PMLU or are to be retained as evidenced by a written and signed landholder agreement for their retainment, comply with the following:<br>i. Safely accessible by humans and livestock;<br>ii. All contaminated sediment has been removed; and<br>iii. Electrical conductivity is ≤ 7500 µS/cm.<br>(b) All dams which are not to remain or be retained under criterion RM1(a), comply with the following:<br>i. Where present, liners are removed;<br>ii. All contaminated sediment has been removed; and<br>iii. Earthworks are completed to decommission dam walls. |
| RM7 | Installation of cover system / cap | (a) Installation of cover system is designed and signed off by an appropriately qualified person.<br>(b) The out-of-pit TSF is designed and completed to the following:<br>i. Geotechnical analysis confirms the tailings storage facility (TSF) is geotechnically stable.<br>ii. The TSF has been fully encapsulated with a cap of ≥2m of non-acid forming (NAF) material. Additional cover material may be required to maintain final design heights following settlement ;<br>iii. The TSF maintains a water shedding profile, other than minor ponding.<br>(c) The in-pit TSF is designed and completed to the following:<br>i. At least 1 m of inert material covers the tailings. Additional cover material may be required to maintain final design heights following settlement ; |
| RM8 | Stable Embankment Development | (a) Stable embankment is built to a height suitable to keep 0.1% AEP flood event from infiltrating residual voids.<br>(b) The watercourse side slope is built to a maximum of 19° and is applied with rock mulch. |
| RM9 | Achievement of Stable Condition (Light Grazing) | (a) Average vegetative groundcover is >50%.<br>(b) 5 Year average pasture yield of 1,500kg DM/ha<br>(c) Presence of 3P (pastural, perennial and productive) grass species.<br>(d) Proportion of Category 3 restricted invasive plant species and Weeds of National Significance are not >10% of total vegetative groundcover.<br>(e) Soil testing demonstrates the following quality parameters are met:<br>i. Electrical Conductivity <800 dS/m;<br>ii. pH 5.5 – 9; and<br>iii. Exchangeable sodium percentage <15%.<br>(f) Rill erosion <0.3 m deep and no gully erosion present.<br>(g) Surface water runoff quality on site complies with the most current version of the contaminant limits in Table C2 and Table C3 in the EA EPML00643713.<br>(h) Groundwater quality complies with the most current version of the contaminant limits in Table C13 in the EA EPML00643713.<br>(i) Stored water quality meets the requirements for stock watering under the ANZEEC Guidelines.<br>(j) All fencing used to prevent stock access to revegetation has been removed, except where fencing is agreed to be retained by the landholder as evidenced by a signed landholder agreement.<br>(k) Risk Assessment completed demonstrates risks in the rehabilitation area are similar to hazards in neighbouring unmined landscapes subject to a similar PMLU. |
| RM10 | Achievement of Stable Condition (Watercourse) | (a) Groundcover average of >75%.<br>(b) Proportion of Category 3 restricted invasive plant species and Weeds of National Significance, are not >10% of total vegetative groundcover.<br>(c) Groundcover diversity an average of >6 species.<br>(d) For the Blackwater Creek Diversion in Zone B1 only a Median height of plants approximately 125 cm<br>(e) Plant diversity an average of >6 species |
| RM11 | Achievement of Stable Condition (Open Woodland) | (a) Key species presence:<br>i. At least one Eucalyptus species.<br>ii. At least two Acacia species.<br>(b) Evidence of second-generation recruitment of native tree/shrub species.<br>(c) Evidence of native fauna utilising area.<br>(d) Proportion of Category 3 restricted invasive plant species and Weeds of National Significance, are not >10% of total vegetative groundcover.<br>(e) Soil testing demonstrates the following quality parameters are met:<br>i. Electrical Conductivity <800 dS/m;<br>ii. pH 5.5 – 9; and<br>iii. Exchangeable sodium percentage <15%.<br>(f) Rill erosion <0.3 m deep and no gully erosion present.<br>(g) Surface water runoff quality on site complies with the most current version of the contaminant limits in Table C2 and Table C3 in the EA EPML00643713.<br>(h) Groundwater quality complies with the most current version of the contaminant limits in Table C13 in the EA EPML00643713.<br>(i) Risk Assessment completed demonstrates risks in the rehabilitation area are similar to hazards in neighbouring unmined landscapes subject to a similar PMLU.<br>(j) Average groundcover on slopes >7% is >50% (this includes the proportion of rock, litter, and groundcover vegetation).<br>(k) Evidence of flowering and/or fruiting on tree and shrub species.<br>(l) Evidence of litter breakdown and nutrient recycling |
| RM12 | Achievement of Stable Condition (Fauna Habitat) | (a) Evidence of native fauna utilising area.<br>(b) Rill erosion <0.3 m deep and no gully erosion present.<br>(c) Geotechnical investigations of the stable embankments demonstrate geotechnical stability has been achieved. |

**1) Insert new rows below the table to record more Rehabilitation Area Milestones for the project**
**2) Ensure all Rehabilitation Milestones recorded in this table align with those included in the RA sheets in this form.**
**3) See the PRCP guideline before developing site-specific Rehabilitation Area Milestones**

| Milestone reference | Management milestone | Milestone criteria |
|---|---|---|
| MM1 | Landform Development and reshaping/reprofiling | (a) Highwall slopes have a maximum of 65°.<br>(b) Highwall safety bunds are constructed in accordance with The Department of Industry and Resources (1997) Guideline Safety Bund Walls Around Abandoned Open Pit Mines or as recommended by an appropriately qualified person. |
| MM2 | Achievement of sufficient improvement | (a) Signage along highwalls and end walls.<br>(b) Geotechnical investigations of the high wall, low wall, end wall and ramp walls demonstrates geotechnical stability has been achieved.<br>(c) All highwalls achieve a Static Factor of Safety >1.5 and Dynamic Factor of Safety >1.1.<br>(d) Groundwater and void lake monitoring / modelling confirms that the void acts as a sink.<br>(e) Residual voids are protected from possible inflow from nearby watercourses.<br>(f) The void will not cause environmental harm outside of the tenure boundaries. |

**1) Insert new rows below the table to record more Improvement Area Milestones for the project**
**2) Ensure all Management Milestones recorded in this table align with those included in the IA sheets in this form.**
**3) See the PRCP guideline before developing site-specific Improvement Area Milestones**

# Technical Memorandum

| | | | |
|---|---|---|---|
| **To:** | Ronnie Lawton | **From:** | Matthew McIntosh |
| **Company:** | Coronado Global Resource Inc. | **SLR Consulting Australia** | |
| **cc:** | | **Date:** | 3 October 2023 |
| | | **Project No.** | 626.030156.00001 |

**RE: Curragh Mine**
**Review of Existing Rehabilitation and Completion Criteria**

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# 1.0 Introduction

SLR Consulting Pty Ltd (SLR) has been commissioned by Coronado Global Resource Inc. (Coronado) to collect and review information for rehabilitation completion criteria and post-mining land-use (PMLU) for the Curragh Mine (the project site). This will support the progressive rehabilitation completion plan (PRCP) request for information (RFI) and feedback received from the Department of Environment and Science (DES) on 26 April 2023. This feedback advises that the current PMLUs assigned to various rehabilitation areas should be reassessed with a view to creating two distinct PMLUs (i.e. 'light grazing' and 'open woodland'). A subsequent review of completion criteria would naturally follow the creation of the two new PMLUs.

The purpose of this technical memorandum is to provide recommendations on PMLU delineation and completion criteria for the project site. This is achieved by providing the following:

- A desktop review of existing rehabilitation outcomes and recommendations.
- A site visit to collect qualitative data on current rehabilitation at the project site.
- The provision of recommended PMLU delineation and completion criteria for these PMLUs.
- The provision of recommendations for increasing rehabilitation success in the context of these recommended completion criteria for 'light grazing' and 'open woodland' PMLUs.

# 2.0 Background to rehabilitation at Curragh

The desktop review included a review of the current Rehabilitation Management and Monitoring Plan version 6 (RMMP; Curragh, 2021) and previous rehabilitation monitoring reports for the project site. The key objectives of this desktop review were as follows:

- Determine previous and current rehabilitation methodologies employed across the project site.
- Identify current rehabilitation criteria for PMLUs.
- Provide a summary of key outcomes and constraints previously identified for current PMLUs and rehabilitation completion criteria.

The following plans and procedures are currently implemented and relevant to rehabilitation at the project site:

- Topsoil Management Plan, version 7 (Document No.: EM PLAN 1.1) (Curragh, 2020).
- Erosion and Sediment Control Management Plan, version 6 (Document No.: EM PLAN 1.2) (Curragh, 2019a).
- Rehabilitation Management and Monitoring Plan (RMMP), version 6 (Document No.: EM PLAN 1.3) (Curragh, 2021).
- Blackwater Creek Diversion Monitoring and Maintenance Plan, version 6 (Document No.: EM PLAN 1.4) (Curragh, 2019b).
- Topsoil Management Procedure, version 5 (Document No.: EMS PROC 1.3) (Curragh, 2019c).
- Rehabilitation Procedure, version 2 (Document No.: EMS PROC 1.5) (Curragh, 2019d).
- Rehabilitation Monitoring Procedure, version 3 (Document No.: EMS PROC 1.6) (Curragh, 2019e).

## 2.1 Rehabilitation history

Rehabilitation of mining areas has been undertaken at the project site for over 30 years, with some of the oldest rehabilitation commencing at Ramp 6 north, which was seeded in 1988. The long history of rehabilitation at the project site has resulted in a variety of rehabilitation strategies being implemented for a variety of outcomes. Additionally, studies to measure rehabilitation responses to fire have been undertaken at the project site, which are detailed in McKenna (2018).

SLR are currently reviewing available information to elucidate and describe the history of rehabilitation at the project site. This information, where available, is summarised herein to provide context on current rehabilitation outcomes and recommendations.

## 2.2 To date, no rehabilitation areas at the project site have been certified under section 318ZD of the Environmental Protection Act 1994 (EP Act). Rehabilitation strategies and seed mixes

A variety of rehabilitation strategies have been implemented at the project site over time. These include, but may not be limited to:

- The direct planting of tube-stock,
- Strip seeding into linear patches and inter-patches of spoil and topsoil, and
- Seeding into broad areas of ripped topsoil.

The predominant strategy implemented across rehabilitation areas at the project site has been seeding. However, a known instance of direct planting of tube-stock is within the Blackwater Creek diversion area, where a mixture of tube-stock plantings and direct seeding strategies were used (Curragh, 2018). Strip seeding methods ceased in 2008 with seeding into ripped topsoil being the predominant strategy implemented after this point. It is speculated that several small-scale trial areas of direct tube-stock planting have also been undertaken within rehabilitation areas, which have likely included the addition of fauna habitat structures (pers. comms. Kim Exmann) (e.g., hollow logs) (see **Section 3.0** of this document).

In addition to a variety of seeding strategies being implemented at Curragh, seed mixes have also varied considerably since the commencement of rehabilitation. A summary of

seed mixes used at the project site over time is provided in **Table 1**. Where taxonomic updates are available based on the current Queensland flora census (Queensland Herbarium, 2022) these updates are applied in **Table 1**, including an indication of which species are non-native but naturalised in Queensland. An overview of these taxonomic changes are provided in **Table 2**. The Australian Plant Name Index (APNI; 2023) was used to aid in determining current names for species. It should be noted that Buffel Grass (*Cenchrus ciliaris*) is not currently included in seed mixes (pers. comms. Kim Exmann)

To aid in future rehabilitation outcomes, grasses (Poaceae) listed in **Table 1** were considered for their potential to constitute 3P (palatable, productive and perennial) species. A comprehensive list of 3P grasses is not currently published. However, based on a review of publicly available information on the grasses in **Table 1**, it is likely that all have the potential to equate to a 3P species.

**Table 1 Past and recent seed mixes at Curragh**

| Family | Scientific name | Common name | Year | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1988 | 1989 | 1992 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2005 | 2006 | 2008 | 2010 | 2011 | 2016 | 2017 | 2018 | 2019 | 2021-2023 |
| Apocynaceae | *Carissa ovata* | Currant Bush | | | | | | | | | | | | | | | | | | X | | | X |
| Casuarinaceae | *Casuarina cristata* | Belah | X | X | X | X | X | X | | | | X | | | | | X | X | | X | | X | |
| Casuarinaceae | *Casuarina glauca* | Swamp Oak | | | X | | | | | | | | | | | | | | | | | | |
| Chenopodiaceae | Salt bush mix | - | | | | | | | | | | | | | | | | | | | | | X |
| Leguminosae | **Acacia ampliceps* | Salt Wattle | | | | | | | | | X | | X | X | X | | X | | | | | | |
| Leguminosae | *Acacia aneura* | Mulga Wattle | X | | | | | | | | | | | | | | | | | | | | |
| Leguminosae | *Acacia bancroftiorum* | Bancroft's Wattle | | | X | | X | | X | X | X | X | X | X | X | X | X | X | | X | | X | |
| Leguminosae | *Acacia complanata* | Flat-stemmed Wattle | | | | | | | X | X | X | X | X | X | X | X | X | X | | | | X | |
| Leguminosae | *Acacia cretata* | - | | | | | | | | | | X | X | X | X | X | X | X | | X | | X | |
| Leguminosae | *Acacia decora* | Showy Wattle | | | | | | | | | | | | | | | | | | | | | X |
| Leguminosae | *Acacia excelsa* | Ironwood Wattle | | | | | | | | | | | | | | | | | | | | | X |
| Leguminosae | *Acacia harpophylla* | Brigalow | | X | | X | X | X | | | | X | | | | X | X | X | | X | | X | |
| Leguminosae | *Acacia holosericea* | Soapbush Wattle | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X | | X | |
| Leguminosae | *Acacia macradenia* | Zig-zag Wattle | | | | | | | X | X | X | X | X | X | X | X | | X | | X | | X | |
| Leguminosae | *Acacia podalyriifolia* | Queensland Silver Wattle | | | | | | X | X | X | X | X | X | X | X | X | X | | | X | | X | |
| Leguminosae | *Acacia rhodoxylon* | Ringy Rosewood | | | | | | | | | | | | | | | | | | | | | X |
| Leguminosae | *Acacia salicina* | Sally Wattle | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X | | X | |
| Leguminosae | **Acacia saligna* | Golden Wreath Wattle | X | X | | X | X | X | X | X | X | X | X | X | | X | X | X | | | | X | |
| Leguminosae | *Acacia shirleyi* | Lancewood | | | X | X | | | | | | X | | | | X | X | | | X | | X | X |
| Leguminosae | *Acacia stenophylla* | Shoestring Acacia | | | X | X | X | X | | | | X | X | X | X | | | X | | | | X | |
| Leguminosae | *Acacia victoriae* | Bramble Wattle | | | | | | | | | | | | | | | | | | | | | X |
| Leguminosae | *Cassia brewsteri* | Leichhardt Bean | | | | | | | | | | | | | | | | | | X | | X | X |
| Leguminosae | **Chamaecrista rotundifolia* | Round-leaf Cassia | | | | | | | | | | X | | | | | | X | | | | X | |
| Leguminosae | **Clitoria ternatea* | Blue Butterfly Pea | | | | | | | | | | | | X | | X | | X | X | X | | X | |
| Leguminosae | *Erythrina vespertilio* | Bat's Wing Coral Tree | | | | | | | | | | | | | | | | | | X | | | X |
| Leguminosae | *Lysiphyllum carronii* | Northern Bean Tree | | | | | | X | | | | X | | | | | | X | | | | X | |
| Leguminosae | *Lysiphyllum hookeri* | Bauhinia | | | | | | | | | | | | | | | | | | X | | X | X |
| Leguminosae | *Senna artemisioides* | Silver Senna | | | | | | | | | X | X | X | X | X | X | X | X | | | | X | |
| Leguminosae | *Senna notabilis* | Cockroach Bush | | | | | | | X | X | X | X | X | X | X | X | X | X | | | | X | |
| Leguminosae | **Stylosanthes hamata* | Caribbean Stylo | | | | | | | | | | X | | X | | X | | X | | | | X | |
| Leguminosae | **Stylosanthes scabra* | Shrubby Stylo | | | | | | | | | | X | | X | | X | | X | | | | X | |
| Leguminosae | *Vachellia bidwillii* | Corkwood Wattle | | | | | | | | | | | | | | | | | | X | | X | |
| Meliaceae | *Owenia acidula* | Emu Apple | | | | | | | | | | | | | | | | | | X | | X | X |
| Myrtaceae | *Corymbia citriodora ssp. variegata* | Lemon-scented Gum | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | X | X |
| Myrtaceae | *Corymbia tessellaris* | Moreton Bay Ash | | | | | | | | | | | | | | | X | | | X | | | |

| Family | Scientific name | Common name | Year | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1988 | 1989 | 1992 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2005 | 2006 | 2008 | 2010 | 2011 | 2016 | 2017 | 2018 | 2019 | 2021-2023 |
| Myrtaceae | *Eucalyptus argophloia* | Queensland Western White Gum | | | X | | | | | | | | | | | | | | | | | | |
| Myrtaceae | *Eucalyptus camaldulensis* | River Red Gum | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | X | |
| Myrtaceae | *Eucalyptus cambageana* | Dawson River Blackbutt | | | | | | | | | | | X | X | X | X | X | X | | X | | X | |
| Myrtaceae | *Eucalyptus crebra* | Narrow-leaved Ironbark | X | | | | | | | | | | | | | | X | X | | X | | X | X |
| Myrtaceae | *Eucalyptus drepanophylla* | Grey Ironbark | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | X | |
| Myrtaceae | *Eucalyptus longirostrata* | Grey Gum | | | X | | | | X | X | X | X | X | X | X | X | X | X | | X | | X | |
| Myrtaceae | *Eucalyptus melanophloia* | Silver-leaved Ironbark | | | X | | | | | | | | | | | | | | | | | | |
| Myrtaceae | *Eucalyptus moluccana* | Grey Box | | | X | | | | | | | | | | | | | | | | | | |
| Myrtaceae | *Eucalyptus ochrophloia* | Yapunyah | | | X | | | | | | | | | | | | | | | | | | |
| Myrtaceae | *Eucalyptus woollsiana* | - | | | X | | | | | | | | | | | | | | | | | | |
| Myrtaceae | *Eucalyptus populnea* | Poplar Box | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | | X | | X | X |
| Myrtaceae | *Eucalyptus punctata* | Grey Gum | | | | X | X | X | | | | X | | | | | | X | | | | X | |
| Myrtaceae | *Eucalyptus tereticornis* | River Blue Gum | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | X | |
| Myrtaceae | *Eucalyptus thozetiana* | Thozet's Box | | | | | | X | X | X | X | X | X | X | X | | X | X | | X | | X | |
| Myrtaceae | *Melaleuca bracteata* | Black Tea-tree | | | | | | | | | | | | | | | | | | X | | X | |
| Myrtaceae | *Melaleuca leucadendra* | Weeping Paperbark | | | | | | | | | | | | | | | | | | X | | | |
| Picrodendraceae | *Petalostigma pubescens* | Quinine Bush | | | | | | | X | X | X | X | X | X | X | X | X | | | X | | X | X |
| Pittosporaceae | *Pittosporum angustifolium* | Gumby Gumby | | | | | | | | | | | | | | | | | | | | | X |
| Poaceae | *Astrebla lappacea* | Curly Mitchell Grass | | | | | | | | | | | | | | | | | | X | | X | X |
| Poaceae | *Astrebla squarrosa* | Bull Mitchell Grass | | | | | | | | | | | | | | | | | | | | | X |
| Poaceae | *Bothriochloa bladhii* | Forest Bluegrass | | | | | | | | | | | | | | | | | | | | | X |
| Poaceae | *Bothriochloa ewartiana* | Desert Bluegrass | | | | | | | | | | | | | | | | | | X | | X | |
| Poaceae | **Bothriochloa insculpta* | Creeping Bluegrass | | | | | | | | | | | | | | | | | | | | | X |
| Poaceae | **Bothriochloa pertusa* | Indian Bluegrass | | | | | | | | | | | | | | | | X | X | | X | X | |
| Poaceae | **Cenchrus ciliaris* | Buffel Grass | | | | | | | | | | X | | X | | | | X | | | | X | X[1] |
| Poaceae | **Chloris gayana* | Rhodes Grass | | | | | | | | | | X | | X | | X | | X | X | X | X | X | |
| Poaceae | **Cynodon dactylon* | Couch Grass | | | | | | | | | | | | | | | | | | X | | X | X |
| Poaceae | *Dichanthium sericeum* | Silky Blue-grass | | | | | | | | | | | | X | | X | | X | | | | X | X |
| Poaceae | *Digitaria brownii* | Cotton Grass | | | | | | | | | | | | | | | | | | X | | X | |
| Poaceae | **Digitaria didactyla* | Blue Couch | | | | | | | | | | | | | | | | | | X | | X | X |
| Poaceae | **Echinochloa esculenta* | Japanese Millet | | | | | | | | | | | | | | | | | | X | | X | X |
| Poaceae | *Heteropogon contortus* | Black Speargrass | | | | | | | | | | | | | | | | | | X | | X | X |
| Poaceae | **Megathyrsus maximus* | Guinea Grass | | | | | | | | | | X | | | | | | X | | | | X | |
| Poaceae | **Panicum coloratum* | Klein Grass | | | | | | | | | | | | X | | X | | X | X | | | X | |
| Poaceae | *Paspalidium caespitosum* | Brigalow Grass | | | | | | | | | | | | | | | | | | X | | X | X |
| Poaceae | **Setaria incrassata* | Vlei Bristle Grass | | | | | | | | | | X | | X | | | | | | | | | |
| Poaceae | *Themeda triandra* | Kangaroo Grass | | | | | | | | | | | | | | | | | | X | | X | X |

| Family | Scientific name | Common name | Year | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1988 | 1989 | 1992 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2005 | 2006 | 2008 | 2010 | 2011 | 2016 | 2017 | 2018 | 2019 | 2021-2023 |
| Poaceae | **Urochloa mosambicensis* | Sabi Grass | | | | | | | | | | | | X | | X | | X | X | | X | X | |
| Rhamnaceae | *Alphitonia excelsa* | Red Ash | | | | | | | | | | | | | | | | | | X | | | |
| Rutaceae | *Geijera parviflora* | Wilga | | | | | | | | | | | | | | | | | | X | | X | X |
| Sapindaceae | *Atalaya hemiglauca* | Whitewood | | | | | | | | X | X | X | X | X | X | X | X | X | | X | | X | |
| Scrophulariaceae | *Eremophila maculata* | Spotted Emu Bush | | | | | | | | | | | | | | | | | | X | | X | X |
| Sterculiaceae | *Brachychiton rupestris* | Queensland Bottle Tree | | X | X | X | X | | | | | X | | | | | | X | | X | | X | |

* Indicates naturalised species that are non-native to Queensland as identified in the Queensland flora census (Queensland Herbarium, 2022). Note, *Acacia amplicens* is not provided within the Queensland flora census, however, is not identified to occur in Queensland in ALA (2023).

1 Site representatives have advised that Buffel Grass is not currently included in seed mixes. However, Buffel Grass was returned from the literature review and has therefore been included.

**Table 2 Taxonomic updates applied to Curragh seed mix**

| Previously used scientific name | Current provided scientific name |
|---|---|
| *Acacia bancroftii* | *Acacia bancroftiorum* |
| *Digitaria sericeum*[1] | *Dichanthium sericeum* |
| *Eucalyptus punctata*[2] | *Eucalyptus punctata* |
| *Eucalyptus pilligaensis* | *Eucalyptus woollsiana* |
| *Panicum maximum* | *Megathyrsus maximus* |
| *Senna oligophylla* | *Senna artemisioides spp. oligophylla* (abbreviated to *S. artemisioides*) |
| *Themeda australis* | *Themeda triandra* |

1 *Digitaria sericeum* is not a species name recognised in the APNI (APNI, 2023). It is speculated that the use of this name is an error and this name in seed mixes over the 2019 to 2023 period is intended to be for *Dichanthium sericeum*.

2 *Eucalyptus punctata* is not currently recognised in the Queensland flora census (Queensland Herbarium, 2022), however the taxonomic resolution of this species is uncertain as this species is recognised as current in the APNI (2023). Therefore, the application of this name has been retained herein.

## 2.3 Previously approved outcomes

### 2.3.1 Existing performance criteria

Section 6 of the RMMP (Curragh, 2021) describes progressive certification criteria for mine domains. Certification criteria are based on Landform level and transect based assessments for safe, stable and non-polluting landforms, 'light grazing and open woodland' PMLU criteria, and 'open grassland' PMLU criteria described in **Table 3**, **Table 4**, and **Table 5**, respectively.

Mine domains are described in Section 4.2 of Curragh (2021) as follows:

- Rehabilitated land in Domain 1 contains areas that have been disturbed by mining activities i.e., reshaped spoil, roads and infrastructure suitable for an open woodland ecosystem with a slope range of <16%. The PMLU description for this disturbance type includes 'light grazing and open woodland'. Existing performance criteria for this PMLU are shown in **Table 3**.
- Rehabilitated land in Domain 2, i.e., tailings storage facilities, tailings embankments and mine site ramps and will be suitable for open grassland with a slope range of <25%. The PMLU description for this disturbance types includes 'open grassland'. Existing performance criteria for this PMLU are shown in **Table 5**.
- Domain 3 includes all active pit voids. This domain includes areas that are unable to be rehabilitated to a PMLU and are non-use management areas (NUMAs).

Rehabilitation slope criteria described in section 3 of Curragh (2021) are shown in **Table 6**. This section of Curragh (2021) also identifies slopes of >16% may be trialed at Curragh North Spoil Dumps. However, if monitoring shows that the rehabilitation of slope angles >16% for these spoil dumps are not performing, then suitable control strategies are to be implemented, and design criteria will be modified accordingly.

**Table 3 Safe, stable and non-polluting rehabilitated landform completion criteria performance matrix**

| Performance criteria | Completion criteria | |
|---|---|---|
| | Not yet conforming | Acceptable |
| Slope >10% with a maximum slope of 16% unstable | Yes | **No** |
| Slope ≤10% with a maximum slope of 16% stable | No | **Yes** |
| Landform design achieves appropriate erosion rates. Engineered structures to control water flow. | No | **Yes** |
| Signs of continued erosion greater than that exhibited on representative unmined areas within the mining leases (i.e. active gully erosion) | Yes | **No** |
| Certification that Class 2 declared pest plants are successfully managed by weed management program | No | **Yes** |
| Fauna presence (evidence of active use of rehabilitated site by native fauna (e.g., bird nests, scats, etc.)). | No | **Yes** |

**Table 4 Light grazing and open woodland completion criteria performance matrix Domain 1.**

| Performance criteria | Completion criteria | |
|---|---|---|
| | Not yet conforming | Acceptable |
| Tree canopy cover (%) (combined canopy and sub-canopy). Preliminary value was determined to be 8.5% from the 2021 monitoring. | No | **Yes** |
| Key species presence:<br>- At least one *Eucalyptus* species.<br>- At least two *Acacia* species. | No | **Yes** |
| Evidence of second-generation recruitment of native tree/shrub species. | No | **Yes** |
| Mean ground cover requirement (≥50% total cover). | <50% | **≥50%** |
| Evidence of litter breakdown and nutrient recycling. | No | **Yes** |
| Evidence in rehabilitation reporting that topsoil and spoil chemistry satisfies the following:<br>- Soil salinity content is <800µS/m with the aim of attaining <400µS/m.<br>- Soil pH is between 5.5 and 9.0.<br>- Soil exchangeable sodium percentage (ESP) is <15%. | No | **Yes** |

**Table 5 Open grassland completion criteria performance matrix Domain 2.**

| Performance criteria | Completion criteria | |
|---|---|---|
| | **Not yet conforming** | **Acceptable** |
| Use of rehabilitated land meets specified yield. Preliminary value not provided within the 2021 monitoring report. | TBC | **TBC** |
| Presence of native grass and pasture species. | No | **Yes** |
| Evidence of second-generation recruitment of native tree/shrub species. | No | **Yes** |
| Mean ground cover requirement (≥50% total cover). | <50% | **≥50%** |
| Evidence of litter breakdown and nutrient recycling. | No | **Yes** |
| Evidence in rehabilitation reporting that topsoil and spoil chemistry satisfies the following:<br>- Soil salinity content is <800µS/m with the aim of attaining <400µS/m.<br>- Soil pH is between 5.5 and 9.0.<br>- Soil ESP is <15%. | No | **Yes** |

**Table 6 Slope criteria for rehabilitation**

| | **Slope criteria** |
|---|---|
| Boxcut spoil | Typical slope of 14%, maximum slope of 16% |
| Strip spoil | Typical slope of 10%, maximum slope of 16% |
| Out of pit | Typical slope of 12%, maximum slope of 16% |
| Final void | As described in the CRVA document |
| Haulage ramps | Typical slope of 22 to 27% |
| | Dip direction at coal dip of 5 to 9%. |

## 2.4 Rehabilitation monitoring

A variety of rehabilitation monitoring reports and related documents were available for review. These included Lanyonscapes (2011), Lanyonscapes (2012), Lanyonscapes (2013), Lanyonscapes (2014), CQG (2016), CQG (2017), Curragh (2018), WSP (2020a), WSP (2020b), WSP (2021a), WSP (2021b), WSP (2022a), WSP (2022b) and WSP (2023). McKenna *et al.* (2016) provides a summary presentation of rehabilitation monitoring outcomes and recommendations over the 2002 to 2016 period.

The above documents were reviewed to identify key rehabilitation outcomes and recommendations. Focus was given to contemporary rehabilitation monitoring outcomes and recommendations as these likely reflect the current condition of rehabilitation across the project site.

### 2.4.1 Summary of key outcomes and recommendations from rehabilitation monitoring

A summary of key rehabilitation outcomes and recommendations based on a review of the aforementioned documents is provided below:

#### McKenna et al. (2016):

- Buffel Grass competition impacts on tree and shrub establishment.
- There is a good survival rate and establishment of trees in bare spoil.
- The benefits of fertiliser are limited.
- The time of seed sowing should coincide with wet season rainfall.
- Coarse Coal Reject has the potential to work well for rehabilitation. However, this may be operationally difficult.
- Brigalow (*Acacia harpophylla*) can be established from seed.
- The patch - interpatch method of strip seeding into topsoil and spoil should be continued.
- Fuel reduction burning is recommended.

#### Rehabilitation monitoring over 2018 to 2022

- Dry climatic conditions affect the success of rehabilitation establishment and condition over time.
- High groundcover percentages result in competition and impact the establishment and success of tree and shrub species.
- Evidence of tree and shrub species recruitment varies significantly between monitoring plots and it is speculated that competition from grass cover is the key impact.
- The dominant ‘habitat type across monitoring plots is grassland due to introduced grass species outcompeting native grasses and the establishment of tree and shrub species.
- It has been recommended that the spoil strip and topsoil rehabilitation method is continued (short strips/patches of strips). This is because this patch and interpatch method has been proven to promote tree and shrub growth. This is due to the exclusion of Buffel Grass contaminated topsoil and possibly due to lower soil fertility. Without the introduction of spoil as a rehabilitation medium, it is likely that the rehabilitation areas will continue to underperform in relation to *Eucalyptus* species diversity and *Eucalyptus* recruitment.
- It has been recommended that a PMLU of grazing is considered in rehabilitated areas that contain 100% topsoil. This has been recommended as remediation works, including tree planting and seeding, are unlikely to be required. This may result in the establishment of additional reference monitoring sites.
- Where recalcitrant bare areas (>0.1ha), particularly within rehabilitation polygons where groundcover is underperforming (i.e. <50%), are tested and remediation plans are developed to enable these areas to progress towards future progressive certification.

- It has been recommended that older rehabilitation areas (i.e. pre-2015) are best suited to a PMLU of a ‘healthy woodland ecosystem’ that includes a mixture of values for both flora, fauna and pasture grazing.
- Buffel Grass should be excluded from rehabilitation seed mixes due to its impact on native tree and shrub recruitment.
- Establish monitoring transects within spoil strips for comparison with the open woodland/pasture grass areas.
- Results from pasture grass monitoring indicate that the rehabilitation areas will support light to very light grazing pressure only.
- Grass species richness is low and is mostly limited to the occurrence of Buffel Grass. The lack of seed sources for other grass species (particularly native species) may be a limiting factor for sites where site conditions for Buffel Grass are sub-optimal (i.e. in areas where seeding was undertaken spoil).

# 3.0 Site visit

A site visit was undertaken over the 7 to 9 August 2023 to collect on-the-ground qualitative information on key constraints identified during the desktop assessment process. Additionally, the site visit was undertaken with a view of collecting incidental observations to support the development of recommendations towards the suitability of current PMLU completion criteria. Qualitative information collected during the site visit is provided in **Table 7**.

Additional observations obtained during the site visit are provided below:

- Trees/woody perennials appear to germinate and do well in areas of spoil compared to areas where topsoil has been applied. Introduced grasses do well and likely outcompete woody perennial seedlings where topsoil and nutrients are abundant.
- Rubber Vine (*Cryptostegia grandiflora*), Athel Pine (*Tamarix aphylla*), Parkinsonia (*Parkinsonia aculeata*), Parthenium (*Parthenium hysterophorus*), Mexican Poppy (*Argemone sp.*), Leucaena (*Leucaena leucocephala*), Prickly Pear (*Opuntia sp*.), Mimosa Bush (*Vachellia farnesiana*) and Harrisia Cactus (*Harrisia martini*) are present either as dominant stands or isolated components of rehabilitation and general mining areas, particularly near permanent or ephemeral water sources. Introduced grasses, particularly Buffel Grass, are dominant in the ground layer throughout all rehabilitation areas.
- Secondary establishment of parasitic plants, Mistletoe (*Amyema sp.*) and Sandalwood (*Santalum lanceolatum*) in older rehabilitation areas dominated by *Acacia spp*., including Brigalow. This indicates fauna values and usage of these areas, particularly of birds, such as the Mistletoebird. Other bird species, predominately honeyeaters, were common in this area too where mature *Acacia spp*. were flowering.
- In some rehabilitation areas, small, and sparsely scattered, stands of heavily canopied trees shade out Buffel Grass in the groundcover. This was observed for Brigalow, Sally Wattle (*Acacia salicina*) and Thozet's Box (*Eucalyptus thozetiana*). A dense layer of leaf litter was often present under these small, isolated stands of trees. Its should be noted that this was only very infrequently observed in rehabilitation areas.
- Splitting out old rehabilitation areas into distinct 'open woodland' and 'grazing' PMLUs is impractical due to the small size and scale of patches within a broad area. This is particularly due to many of these areas being designed for a combined 'open woodland and grazing' PMLU. Splitting these into distinct units is not likely to provide informed rehabilitation outcomes.

**Table 7 Notes and photographs taken at rehabilitation areas during the site visit.**

<table>
<tr><th>Note</th><th>Description and photographs</th></tr>
<tr><td>1</td><td>Curragh North.<br>Indicative of slope for final rehab of area. Early rehab (~1yrs at an estimate). Woody perennial species observed to be germinating include: Bramble Wattle (Acacia victoriae), Showy Wattle (Acacia decora), Sally Wattle, Soapbush Wattle (Acacia holosericea), Narrow-leaved Ironbark (Eucalyptus crebra), Corymbia sp., Bats-wing coral tree (Erythrina vespertilio). Bramble Wattles were beginning to flower at a very young age. No native grasses observed.<br>Introduced flora species observed include: Sorghum sp., Buffel Grass, Red Natal Grass (Melinis repens), Klein Grass (Panicum coloratum), Mimosa Bush (Vachellia farnesiana), Parkinsonia.<br>Soils in area appear to be dispersive. Rehabilitated landform is uphill from a watercourse. Variety of native and introduced forbs. Slope appears suitable. Macropod tracks observed.<br>GPS coordinates of note: -23.306383°, 148.857988°<br>  </td></tr>
<tr><td>2</td><td>Curragh North.<br>Unsure of rehab age (10yrs at a guess). Minor rill erosion but slope appears stable.<br>Woody Perennial species observed: Eucalyptus sp., Narrow-leaved Ironbark, Sally Wattle, Showy Wattle and Bramble Wattle. Eucalypts and Wattles flowering and fruiting. Possible woody perennial species recruitment, however dense groundcover makes this difficult to confirm. Trees and shrubs of a decent size and density.<br>Groundcover dominated by Buffel Grass. Klein Grass, Red Natal Grass, and Black Speargrass (Heteropogon contortus) were associated to sub-dominant. Rhodes Grass (Chloris gayana) and Shrubby Stylo (Stylosanthes scabra) were associated with the community. Low abundance of native and introduced forbs. It is suspected that spoil was used as a medium for trees to establish, or topsoil was thinly spread, hence the density and occurrence of grass species.<br>Fauna observations: macropod tracks and scats, evidence of Feral Pigs, Striated Pardalote, Red-backed Fairy-wrens, Golden-headed Cisticola.<br>GPS coordinates of note: -23.300688°, 148.855054°<br>  </td></tr>
<tr><td>3</td><td>Curragh North</td></tr>
</table>

| Note | Description and photographs |
|---|---|
| | Rehab slightly older than that at Note 1. Lower density of woody perennials compared to Note 1. Slope appears stable and minimal erosion.<br>Woody perennials observed to be germinating include: Soapbush, Showy, and Bramble Wattles and Bat's Wing Coral Tree.<br>Buffel Grass dominant and dense in ground layer. Other introduced grasses include: *Sorghum sp*., Red Natal Grass, Rhodes Grass, Sabi Grass (*Urochloa mosambicensis*), and Indian Bluegrass (*Bothriochloa pertusa*). Minor abundance of native and introduced forbs.<br>Area may have been rehabbed during a drier period, hence the reduced abundance and density of woody perennials compared to Note 1.<br>Fauna observations: Willie Wagtails and Fairy-wrens.<br>GPS coordinates of note: -23.284707°, 148.856264°<br>  |
| **4** | **Curragh South**<br>Unsure of rehabilitation age. Suspected pre-2015. Slope very gradual. Soils possibly dispersive and low incidence of erosion.<br>Mature, flowering Brigalow present. Sally Wattle and Shoestring Wattle (*Acacia stenophylla*). The dominance of Brigalow, Sally Wattle and Shoestring Wattle varies. Poplar Box (*Eucalyptus populnea*), *Corymbia sp*. And Narrow-leaved Ironbark also present, but in low abundance. *Amyema sp*. and Sandalwood present (Sandalwood flowering and fruiting). Brigalow and Shoestring Wattle observed to be recruiting, but predominantly from suckers. Minor abundance and density of shrub species, which was predominantly comprised of Ruby Saltbush (*Enchylaena tomentosa*). Small, dense pockets of Brigalow shading out Buffel Grass in the groundlayer.<br>Buffel Grass dominant and dense in ground layer with associated Black Speargrass. Rubber Vine, Leucaena and Shrubby Stylo present.<br>Fauna observations: Macropod tracks and scats. Various honeyeaters observed and heard along with Mistletoebirds and Fairy-wrens, one termite mound.<br>GPS coordinates of note: -23.448129°, 148.874016°<br>  |
| **5** | **Curragh South**<br>Grazing rehabilitation. very gentle slope and low incidence of erosion. |

| Note | Description and photographs |
|---|---|
| | Area dominated by dense Buffel Grass. Little to no woody perennial species present. Curragh advised that reseeding of tree species had occurred in recent times (~1yr), however no evidence of germination was found. It is likely that the dense covering of Buffel Grass is outcompeting seedling tree and shrubs.<br>Fauna observations: Swamp Harrier, Wedge-tailed Eagle, Black-faced Woodswallows, and Martins.<br>GPS coordinates of note: -23.449283°, 148.872957°<br>    |
| **6** | **Curragh South**<br>Old rehab. unsure of age. Curragh interested in relinquishing this rehabilitation area. Low incidence of erosion<br>Dominated by Sally Wattle in most areas observed. Other occasional tree species include *Corymbia sp*. *Acacia spp*., Sandalwood, and Whitewood (*Atalaya hemiglauca*). Shrubs as per trees with Soapbush and Showy Wattles included in upper shrub layer and Ruby Saltbush in lower shrub layer. *Eucalyptus/Corymbia* not overly abundant compared to *Acacia spp*. and Whitewood. Leaf litter a bit denser in this rehab area and some evidence of decomposition and cycling into soil. Topsoil is being formed from litter breakdown. Small number of native and introduced forbs. Minor recruitment of *Acacia spp*.<br>Buffel Grass dominant and dense in ground layer. Shrubby Stylo, Harrisia Cactus present in shrub layer. Parthenium present in lower areas on opposite site of drainage line at base of slope.<br>Fauna observations: Honeyeaters and Fairy-wrens.<br>GPS coordinates of note: -23.511029°, 148.864231°<br>     |
| **7** | **Curragh South – Blackwater Creek Diversion**<br>Photos show broader engineered floodplain, mid-slope rock armouring, and rock armouring on margins of watercourse. Photos also show transition from natural rock formations within watercourse to those modified and included for the diversion. Evidence of some erosion, based on exposure of geo-fabric, on banks of watercourse. Most of the floodplain is dominated by Buffel Grass. Some Eucalypts present on immediate banks of watercourse. Leucaena abundant in areas along margins of the watercourse.<br>Fauna observations: No fauna observations in rock armouring, Ducks observed in flowing water in bed of creek. |

| Note | Description and photographs |
|---|---|
| | GPS coordinates of note: -23.509772°, 148.885533° |
| |      |
| **8** | **Curragh South**<br>Older rehabilitation. Unsure of age. Curragh interested in relinquishing this area.<br>Variety of native tree and shrub species established, which are also flowering and fruiting. Native tree and shrub species include a mix of Eucalypts, Corymbia, and Acacia. Three different sub-species of Silver Senna (*Senna artemisioides*) are present, all of which were flowering and fruiting.<br>Buffel Grass is dominant and dense as groundcover.<br>Small dam located nearby, which has Rushes and Leucaena is dominant around its margins.<br>GPS coordinates of note: -23.492296°, 148.864403° |
| |     |
| **9** | **Curragh South**<br>One year old rehabilitation.<br>Native tree and shrub species observed to be germinating include: Abutilon sp. Bramble, Soapbush and Sally Wattles, and Bat's Wing Coral Treel. No Eucalypts were observed to be germinating. Native grasses observed to be establishing include: Mitchell Grass (*Astrebla sp.*), Black Speargrass, *Sporobolus sp*., *Eragristis sp*. and *Bothriochloa sp*. Native forbs observed include *Sclerolaena sp*.<br>No Buffel Grass was used in the seed mix (pers. comm. Kim Exmann), however Buffel Grass was dominant in the groundcover. Other introduced flora species observed include: Leucaena, Parkinsonia, Parthenium, Stinking Passion Flower (*Passiflora foetida*), Indian Bluegrass, Purpletop Chloris (*Chloris inflata*) Klein Grass, Rhodes Grass, Red Natal Grass, and Phasey Bean (*Macroptilium lathyroides*).<br>Introduced grasses are the dominant vegetation component of the rehabilitation area. Bat's Wing Coral Tree is the most abundant woody perennial and Wattles occur in low abundance.<br>Fauna observations: Wallaroos, predator scat, Brown Quail, Golden-headed Cisticola, and ants.<br>GPS coordinates of note: -23.498042°, 148.873930° |

| Note | Description and photographs |
|---|---|
| |     |
| **10** | **Curragh South**<br>Unsure of rehabilitation age. Small grove of Thozet's Box, which are flowering and fruiting. No recruitment was observed. *Sclerolaena sp*. and Ruby Saltbush dominant in low shrub layer.<br>Buffel Grass is mostly absent under the trees despite being dominant in surrounding rehabilitated landform.<br>Suspected tube-stock planting or small area of spoil. Logs in area are likely to be artificially placed as fauna habitat.<br>GPS coordinates of note: -23.458443°, 148.847752°<br>    |
| **11** | **Curragh South**<br>Unsure of rehabilitation age. It is, however, evident that rehabilitation methods of strip seeding into spoil have been implemented at this site. Minor erosion present in areas where groundcover was sparse.<br>Localised area with greater density of *Eucalyptus sp*. compared to surrounding strips dominated by Buffel Grass. Other strips dominated by *Eucalyptus sp*. are also present in area. Sandalwood and Acacia sp. are present in the upper shrub layer with Ruby Saltbush and Silver Senna occurring in the lower shrub layer. Several dainty native grass species were observed growing in bare areas. These species were not observed growing at other rehabilitation locations and are likely present due to reduced competition from Buffel Grass. These dainty native grass species included: *Sporobolus caroli* and *Enneapogon sp.*<br>Buffel Grass was dense and dominant in surrounding strips. Vlei Bristle Grass (*Setaria incrassata*) was also observed growing in Buffel Grass dominated areas.<br>GPS coordinates of note: -23.454979°, 148.852558° |

| Note | Description and photographs |
|---|---|
| |      |
| **12** | **Curragh South**<br>Area rehabilitated in 2018 with the intent of 'open grassland' PMLU. Area ripped and reseeded in 2022 with tree species. No evidence of recent (one year) germination of tree species during the site visit in 2023. Very minor and sparse presence (<10) of Eucalyptus sp. in general area, however these individuals are not likely to be associated with seeding in 2022.<br>Buffel Grass dense and dominant in area with several other introduced grasses also being present. These introduced grasses are likely to be impacting the germination and establishment of reseeding activities undertaken in 2022.<br>GPS coordinates of note: -23.415840°, 148.869896° |
| |  |

# 4.0 Discussion and recommendations

## 4.1 Existing rehabilitation and previously approved outcomes

Rehabilitation of mining areas has been undertaken for over 30 years at the project site. Over this period, a variety of rehabilitation strategies and seed mixes have been trialed, which has resulted in differences in how vegetation communities have established within rehabilitation areas. However, rehabilitation activities have chiefly been undertaken to achieve two key PMLU outcomes, which are:

- 'Light grazing and open woodland':
  - This being a 'combined' PMLU where rehabilitation areas contain a combination of grazing areas dominated by grasses and wooded areas dominated by Myrtaceous species and Acacias.
- 'Open grassland':
  - This PMLU is comprised of large areas dominated by grass species.

Historical methods implemented in areas intended to be rehabilitated to a light grazing and open woodland PMLU include strip seeding into separate areas of spoil and topsoil. Over time, these areas have developed into heterogenous landscapes. The heterogeneity of these landscapes is influenced by the application of topsoil, where grasses establish, and spoil, where trees and shrubs generally establish and grasses occur in low density. In contrast to this, areas intended to be rehabilitated to an open grassland PMLU have generally been uniformly applied with topsoil, where introduced grasses, most notably Buffel Grass, form a dominant and dense coverage. The broad application of topsoil in rehabilitation areas has been the preferred method since 2008. However, seed mixes in these areas have included both grass and woody perennial species (i.e. Eucalypts and Acacias). To date, no rehabilitation areas at the project site have been relinquished based on the outcomes of rehabilitation monitoring and correspondence with DES.

Rehabilitation monitoring has been undertaken at the project site since the 1990's. Several key outcomes and recommendations have been uniformly reported on over this time, which are summarised below:

- Seeding into spoil and topsoil strips (short strips/patches of strips) should be continued at the project site. This is due to inherent impacts to the establishment of tree and shrub species because of competition with grasses, which dominate and outcompete germinating woody perennials. Buffel Grass has been identified as the key species resulting in these competitive impacts. Woody perennials establish more readily in areas where spoil has been applied due to spoil being disadvantageous for the establishment of grasses. Spoil is also less likely to be contaminated with Buffel Grass seed, which is abundant in topsoil due to the prevalence of this introduced species within the surrounding region. Conversely, grasses establish very readily in areas where topsoil has been applied. Without the reintroduction of spoil as a rehabilitation medium, it is likely that rehabilitation areas will continue to underperform in relation to *Eucalyptus* and *Acacia* species diversity and second-generation recruitment of these species.
- Variation in seasonal wet and dry periods have impacts on the ability for newly seeded areas to establish vegetative cover. Seeding during dry periods limits the success of rehabilitation, therefore time of seed sowing should coincide with wet season rainfall. Additionally, dry periods negatively affect the condition of established rehabilitation, most notably in the groundcover.

- The control of pest flora species is recommended across the rehabilitation areas, particularly Weeds of National Significance and species classified as restricted invasive species in Queensland.
- It has been recommended that a PMLU of light grazing is considered in rehabilitated areas that contain 100% topsoil. This has been recommended as remediation works, including tree planting and seeding, are unlikely to be required.
- It has been recommended that older rehabilitation areas (i.e. pre-2015) are best suited to a PMLU of a 'healthy woodland ecosystem' that includes a mixture of values for both flora, fauna and pasture grazing.
- Results from pasture grass monitoring indicate that the rehabilitation areas will support light to very light grazing pressure only.
- Buffel Grass should be excluded from rehabilitation seed mixes due to its impact on native tree and shrub recruitment. It should be noted that, during SLRs 2023 site visit, it was advised that Buffel Grass has been removed from rehabilitation seed mixes at the project site (pers. comms. Kim Exmann).

SLR's observations during the 2023 site visit unequivocally support these previous monitoring outcomes and recommendations, which have been repeatedly documented in rehabilitation monitoring reports for the project site.

## 4.2 Contemporary amendments to PMLUs and completion criteria

Despite previously approved PMLUs, rehabilitation strategies historically implemented over a >30-year period, and existing approved rehabilitation outcomes for the project site, DES have advised that changes to the delineation of PMLUs are required. Specifically, the existing combined PMLU of 'light grazing and open woodland' is not suitable and areas previously heterogeneously rehabilitated with the intention of achieving this PMLU require to be separated into individual PMLU units. Areas with a rehabilitation objective of open grassland do not require separation into separate units due to woody perennial species generally being absent from these areas. These grassland areas are readily identifiable via spatial imagery.

Based on SLRs observations during the 2023 site visit, it is advised that the separation of the existing combined PMLU of 'light grazing and open woodland' into individual PMLU units is:

- generally impractical,
- broadly unachievable, and
- is in direct conflict with the rehabilitation strategies (strip seeding) implemented over an extensive period of time for the previously approved outcome.

This is advised because of the heterogeneity of these broad areas where spoil and topsoil have been applied, the often-small size of spoil patches where trees have established, and relative intermittency of tree establishment. Establishing consistent criteria and methods for determining and isolating wooded stands within these heterogenous rehabilitation areas will likely prove to be impractical. Based on this, it is recommended that a single PMLU is selected as the broad outcome for these heterogeneous areas. It is herein proposed that a PMLU for existing rehabilitation be 'light grazing'. This is because of the abundance and density of grass, specifically Buffel Grass, across all existing rehabilitation. However, it should be noted that monitoring considerations will have to be applied to areas where spoil has previously been applied and grass cover is subsequently lower. The presence of trees within this light grazing PMLU that is proposed to be broadly applied are beneficial as shade

trees for cattle and also perform ecosystem functions by providing resources for local native fauna. Therefore, it is not recommended that trees are removed from these areas and it is recommended that woody perennial species are included in future seed mixes for light grazing PMLUs. It is, however, understood that woody perennial species have a low likelihood of establishing in areas where topsoil is applied for rehabilitation due to competition from Buffel Grass.

Open woodland should still be considered as a PMLU for future rehabilitation at the project site. However, rehabilitation methodologies should be implemented to support the success of this PMLU. Additionally, areas intended as this PMLU should be clearly demarcated in rehabilitation plans. In these areas, spoil should be applied as the rehabilitation medium to support the establishment of woody perennial species and reduce competition from introduced grasses.

Future considerations for light grazing PMLUs should include a higher density application rate for native grass species to aid in reducing the prevalence of Buffel Grass that inherently and unintentionally establishes in rehabilitation areas due to the abundance of existing seed in topsoil.

Recommended PMLUs and milestone criteria for these PMLUs at the project site are provided in **Table 8**.

**Table 8 Proposed milestone criteria for rehabilitation relevant to light grazing and open woodland PMLUs[1]**

| Reference Milestone | Rehabilitation Milestone | Milestone Criteria |
|---|---|---|
| RM9 | Achievement of Stable Condition (Light Grazing) | Average vegetation cover is >50% |
| | | Use of rehabilitated land meets specified yield. Preliminary value of 2,000kg/ha is proposed. However, this value is to be revised as necessary based on ground-truthed data. |
| | | Presence of 3P grass species |
| | | Proportion of Category 3 restricted invasive plant species and Weeds of National Significance (WoNS) are not >10% of total vegetative cover. |
| | | Soil testing demonstrates the following quality parameters are met:<br>- Electrical conductivity (EC) is <800dS/m;<br>- pH range of 5.5-9.0; and<br>- Exchangeable sodium percentage (ESP) is <15%. |
| | | Rill erosion is limited to <0.3m deep and no gully erosion is present. |
| | | Surface water run-off quality complies with the most current version of the contaminant limits in Table C2 and Table C3 in the EA EPML00643713. |
| | | Groundwater quality complies with the most current version of the contaminant limits in Table C13 in the EA EPML00643713. |
| | | Stored water quality meets the requirements for stock watering under the ANZECC Guidelines. |
| | | All fencing used to prevent livestock access to revegetation has been removed, except where fencing is agreed to be retained by the landholder as evidenced by a signed landholder agreement. |

| Reference Milestone | Rehabilitation Milestone | Milestone Criteria |
|---|---|---|
| | | Risk Assessment completed demonstrates risks in the rehabilitation area are similar to hazards in neighbouring unmined landscapes subject to a similar PMLU. |
| RM11 | Achievement of Stable Condition (Open Woodland) | Key species presence:<br>- At least one *Eucalyptus* or *Corymbia* species.<br>- At least two *Acacia* species. |
| | | Evidence of second-generation recruitment of native tree/shrub species. |
| | | Evidence of native fauna utilising area. |
| | | Proportion of Category 3 restricted invasive plant species and Weeds of National Significance (WoNS) are not >10% of total vegetative cover. |
| | | Soil testing demonstrates the following quality parameters are met:<br>- EC is <800dS/m;<br>- pH range of 5.5-9.0; and<br>- ESP is <15%. |
| | | Rill erosion is limited to <0.3m deep and no gully erosion is present. |
| | | Surface water run-off quality complies with the most current version of the contaminant limits in Table C2 and Table C3 in the EA EPML00643713. |
| | | Groundwater quality complies with the most current version of the contaminant limits in Table C13 in the EA EPML00643713. |
| | | Risk Assessment completed demonstrates risks in the rehabilitation area are similar to hazards in neighbouring unmined landscapes subject to a similar PMLU. |
| | | Average groundcover on slopes >7% is >50% (this includes the proportion of rock, litter, and groundcover vegetation). |
| | | Evidence of flowering and/or fruiting on tree and shrub species |
| | | Evidence of litter breakdown and nutrient recycling through Landscape Function Assessment. |

1 A full suite of rehabilitation milestones and milestone criteria for Curragh are provided in the PRCP, which is currently under review by SLR.

# 5.0 References

Australian Plant Name Index (APNI). (2013). An Australian Government Initiative. Available from: https://www.anbg.gov.au/apni/

CQG Consulting (CQG). (2016). Blackwater Creek Diversion Rehabilitation Revegetation Progress Report 2015. March 2016.

CQG Consulting (CQG). (2017). Blackwater Creek Diversion Rehabilitation Revegetation Progress Report 2016. March 2017.

Curragh. (2018). Blackwater Creek Diversion Rehabilitation Revegetation Progress Report 2018.

Curragh. (2019a). Erosion and Sediment Control Management Plan. Version 6. Document No.: EM PLAN 1.2

Curragh. (2019b). Blackwater Creek Diversion Monitoring and Maintenance Plan. Version 6. Document No.: EM PLAN 1.4

Curragh. (2019c). Topsoil Management Procedure. Version 5. Document No.: EMS PROC 1.3

Curragh. (2019d). Rehabilitation Procedure. Version 2. Document No.: EMS PROC 1.5.

Curragh. (2019e). Rehabilitation Monitoring Procedure. Version 3. Document No.: EMS PROC 1.6

Curragh. (2020). Topsoil Management Plan. Version 7. Document No.: EM PLAN 1.1.

Curragh. (2021). Rehabilitation Management and Monitoring Plan. Version 6. Document No.: EM PLAN 1.3.

Lanyonscapes. (2011). Blackwater Creek Diversion. Monitoring Data – General Overview.

Lanyonscapes. (2012). Blackwater Creek Diversion Revegetation Maintenance. Maintenance Progress Report. September 2012.

Lanyonscapes. (2013). Blackwater Creek Diversion Revegetation Maintenance. Maintenance Progress Report. September 2013.

Lanyonscapes. (2014). Blackwater Creek Diversion Revegetation Maintenance. Maintenance Progress Report. September 2014.

McKenna, P., Erskine, P., Glenn, V. (2016). Rehabilitation Monitoring for Closure Success Presentation.

McKenna, P. (2018). Measuring Rehabilitation Responses to Fire using Transects and Remote Sensing. Thesis submitted for the degree of Master of Philosophy at The University of Queensland.

Queensland Herbarium. (2022). Census to the Queensland Flora and Fungi 2022. 16 May 2023. The State of Queensland.

WSP. (2020a). Progressive Rehabilitation Certification Report (2019). April 2020.

WSP. (2020b). Curragh 2020 Rehabilitation Monitoring Report. September 2020.

WSP. (2021a). Curragh 2020 Rehabilitation Monitoring Report. January 2021.

WSP. (2021b). 2020 Blackwater Creek Diversion Monitoring Report. January 2021.

WSP. (2022a). Curragh 2021 Rehabilitation Monitoring Report. March 2022.

WSP. (2022b). Curragh 2022 Rehabilitation Monitoring Report. November 2022.

WSP. (2023). Blackwater Creek Diversion 2022 Rehabilitation Monitoring. May 2023.