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Landform Evolution Modelling

Isaac River Coking Coal Project

In Support of the Progressive Rehabilitation and Closure Plan

Prepared for Bowen Coking Coal Pty Ltd | 4 November 2020
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### Document history and status

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1.0 Introduction

1.1 Project location

The Isaac River Coking Coal Project (the Project) will be developed and operated by Coking Coal One Pty Ltd, a wholly owned subsidiary of Bowen Coking Coal Pty Ltd (BCC).

The Project is 28 kilometres (km) to the east of Moranbah in the Bowen Basin in Central Queensland (Qld) and is within the Isaac Regional Council Local Government Area (the IRC LGA). Access to the Project will be via the Peak Downs Highway and Daunia Road / Annandale Road approximately 8.5 km west of Coppabella.

1.2 Scope

The scope of this report is to complete final landform evolution modelling (LEM) of the proposed final landform for the Project that meets the requirements of the Guideline: Progressive rehabilitation and closure plans (PRC plan guideline). LEM has been done for the waste rock dump (WRD1) and the open-cut pit (OC1).

This report includes the following:

• Section 2.0 presents a summary of the Project and the final landform designs;
• Section 3.0 presents the LEM model used to predict long-term erosion potential of the landform;
• Section 4.0 presents and discusses the results obtained from the model; and
• Section 5.0 presents limitations and assumptions of the model and landform design as well as conclusions and recommendations for future trials.

1.3 Link to the PRC plan guideline

The PRC plan guideline states that the PRC plan must include all supporting information required by the Department of Environment and Science (DES) to reach a decision on the ‘soundness’ of the rehabilitation strategies and delivery techniques to meet the approved land outcomes. The post-mining land use (PMLU) completion criteria described in Table 34 of the PRC plan requires the final landform to meet four basic assessment criteria. The final landform must be:

• safe (ie erosion gullies not presenting a danger to grazing cattle / people);
• non-polluting (ie sediment runoff does not impede offsite assets);
• stable (ie stability does not compromise the PMLU or surrounding environment); and
• self-sustaining (ie the growth medium can support the desired PMLU of pasture grazing).

This report predicts that erosion potential for WRD1 and OC1, following final landform development and establishment of pasture, will achieve levels of erosion comparable to the national average.
2.0  Project information

2.1  Description of Project

The climate of the Project and surrounding areas is referred to as a local steppe climate. The location is classified as a hot semi-arid climate (BSh) by Köppen and Geiger. These climates tend to have hot summers and warm to cool winters, with some to minimal rainfall. High variability in rainfall, temperature and evaporation are common in Central Queensland.

The Project will have a PMLU of pasture grazing, with exception of OC1 which will act as a temporary water storage after rainfall but will otherwise be available for pasture grazing. Progressive rehabilitation will occur through the life of the Project, with final decommissioning expected to commence at year five (ie 2025). Staged treatments will be applied as soon as areas become available; however, the rehabilitation of the mine industrial area (MIA) will take place once infrastructure has been decommissioned. Rehabilitation activities are anticipated to be completed in year seven (ie 2027), not including any rehabilitation monitoring that will be required prior to relinquishment.

2.2  Soils

Once rehabilitated, the final landforms will be reshaped, sheeted with soil and then revegetated. If the underlying overburden do not impede infiltration and are not prone to tunnelling, the stability of the final landform will depend largely on the soil characteristics.

A soil assessment was performed for the Project as part of the preliminary studies (CDM Smith 2020). The findings from the soil assessment, about land stability can be summarised as:

- two soil types were found to be representative of the Project:
  - brown Vertosols; and
  - grey Vertosol.
- both soils show a low to medium erosion susceptibility due to clay texture and flat terrain;
- exchangeable sodium percentage (ESP) indicates that there are some areas of increased potential for structural decline if soils are disturbed; and
- dispersibility tests show that the soils exhibit some dispersion potential and, if disturbed, could be susceptible to erosion.

2.2.1  Management

Topsoil and subsoil will be stripped and stockpiled. The soil stripping procedure will be designed to maximise the salvage of suitable soil so pastures can be reinstated to a condition that will support pasture grazing. Stockpiles will be formed in low mounds with the intention to minimise height (3 metres (m) maximum) and maximise the surface area (dependant on available space). Stockpiling using a greater number of low mounds, rather than a few large stockpiles, is preferable to reduce soil degradation and retain its value for vegetation growth. Revegetating stockpiles will minimise weed infestation and maintain organic matter, soil structure and microbial activity.

2.3  Final landform

The intent of the proposed final landform design is to create a gentle sloping landform, suitable for pasture grazing, which blends into the surrounding landscape (Figure 1). All final faces will be battered to a stable slope of 15% or less (8.52 degrees).
2.3.1 WRD1 design

WRD1 has been designed to manage issues relating to landform stability and provide favourable outcomes including a PMLU of pasture grazing.

The shape and size of WRD1 has been refined to minimise potential erosion. The landform characteristics that have the most influence are:

- managing the direction of surface water runoff and the separation of mine-affected and clean water;
- maintaining geotechnical stability of the highwall mining panels until highwall mining has been done;
- providing for a stable final landform that can sustain the desired PMLU; and
- minimising the overall area of disturbance.

Most of WRD1 will be shaped through the construction of the landform during mining operations. All faces will be battered to a stable slope angle which will resemble the surrounding landscape. The slope length and slope angle will remain constant around the entire landform. Once operations cease, the final landform will be ripped, soiled and seeded.

2.3.2 OCI design

The disturbance area of OCI is relatively small, and the coal is steeply dipping, so a terrace mining approach has been planned.

The main elements for the final landform of OCI are:

- partially backfilling the pit, from the collapse of internal batters, to minimise the volume of the pit;
- reprofiling of all slopes to minimise the potential for erosion; and
- diverting surface flows away from OCI, where possible.

The backfilling of OCI will involve collapsing the internal batters through dozers or blasting, followed by reprofiling of the subsequent slopes. All highwall mining ‘portals’ will be sealed via the backfilling / re-contouring so that none are accessible from the final landform surface. While slope lengths vary for different areas, the slope angle will remain constant.

2.4 Target erosion rate

The pre-mining erosion rate was calculated using the revised universal soil loss equation (RUSLE) and a Qspatial data series provided by DES which is based on the Australia Soil Resource Information System (ASRIS). The resulting pre-mining erosion rates are given in tonnes per hectare per year (t/ha/y) in Table 1, noting that the pre-mining terrain is relatively flat.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Erosion rate (t/ha/y)</th>
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<tr>
<td>Minimum</td>
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</tr>
<tr>
<td>Maximum</td>
<td>13.4</td>
</tr>
<tr>
<td>Median</td>
<td>1.1</td>
</tr>
</tbody>
</table>

There is currently no broad agreement on what constitutes an 'acceptable' rate of erosion on a rehabilitated landform. There are a few Australian studies that have attempted to quantify erosion rates. The Prediction of Sheet and Rill Erosion Over the Australian Continent: Incorporating Monthly Soil Loss Distribution (Lu et al. 2001) is one
such study. The study relied upon remote sensing technology to determine national and state averages of erosion and found:

- the average Australian soil erosion rate is 6.3 tonnes per hectare per year (t/ha/y);
- a low rate of erosion is defined as less than 0.5 t/ha/y;
- a medium rate of erosion is defined as 0.5-10 t/ha/y; and
- a high erosion rate is defined as greater than 10 t/ha/y.

Landloch (2013) have shown that rehabilitated mine slopes have a low tendency to rill with an average erosion rate of <5 t/ha/y. Avoiding rill formation will ensure landform stability and reduce the likelihood of excessive erosion. The elimination of rilling will also reduce the potential of channelised flow, which can result in gully erosion.

It is important to note that erosion rates can vary from year to year depending on climatic conditions. Therefore, maximum annual erosion rate will also be examined as a secondary performance indicator.

Regarding the pre-mining erosion rates and the studies mentioned above, a target average erosion rate of <5 t/ha/y has been adopted with the maximum erosion rate at any point on the landform of <10 t/ha/y.
3.0 Water erosion prediction project modelling

3.1 The model

The water erosion prediction project (WEPP) runoff / erosion model (the Model) is a two-dimensional hillslope model, initially developed for agricultural purposes by the United States Department of Agriculture (USDA). The Model integrates hydrology, vegetation science, hydraulics and erosion mechanics to predict erosion at the hillslope and watershed scale. The Model has been used in the design of landforms for mines across Australia. For example, Howard and Roddy (2012) have shown that observed cumulative erosion rates for mined landforms in Western Australia, generally agree with WEPP model predictions.

The Model was used to simulate final landform stability parameters for a 100 year period including data for rainfall, runoff, and sediment loss for the final landforms of WRD1 and OC1. The Model was also used to determine percentage reductions in erosion rates from increasing vegetation cover.

3.2 Model inputs

Model inputs can be broken up into four components: climate, material properties, topography and surface conditions.

3.2.1 Climate

A 100 year synthetic climate file was generated using the CLIGEN stochastic weather generator. CLIGEN has been widely used and validated in Australia (Yu 2003). The following data was imported into CLIGEN to generate this file:

- 125 years of patched daily temperature (maximum and minimum), rainfall and solar radiation sourced from the Bureau of Meteorology (BoM) SILO data drill (https://www.longpaddock.qld.gov.au/silo/); and
- 26 years of pluviograph (6 minute rainfall intensity) data (88% complete) from the BoM’s Moranbah Water Treatment Plant weather station (034038), located approximately 30 km west-northwest of the Project.

Various parameters were then adjusted in the generated climate file to match the inputted data more closely. These include average precipitation on a wet day, maximum 30 minute rainfall intensity and time to peak rainfall intensity.

3.2.1.1 Validation

The CLIGEN climate file has been compared to the 125 years of patched data from the BoM SILO data drill to verify the accuracy of the model. The patched data and the CLIGEN climate file show a high level of consistency in terms of both annual rainfall totals (Figure 2) and extreme storm events (Figure 3). Therefore, the CLIGEN climate data file is appropriate for use in LEM.
Figure 2  Average monthly rainfall comparison (CLIGEN and historical data)

Figure 3  Average recurrence interval comparison (CLIGEN and historical data)
3.2.2 Material properties

The Model has been run for two soil types, based on average values derived from the physical and chemical attribute data taken from the Project (CDM Smith 2020). The soil parameters inputted into the Model are summarised in Table 2. Interrill erodibility, rill erodibility, critical shear and effective hydraulic conductivity were calculated via the Model for WRD1 and OC1.

Table 2 Soil parameters

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Sand</th>
<th>Clay</th>
<th>Rock</th>
<th>Organic matter</th>
<th>Cation exchange capacity (CEC)</th>
</tr>
</thead>
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<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>milliequivalents per 100 grams of soil (meq/100g)</td>
</tr>
<tr>
<td>Brown Vertosols</td>
<td>22</td>
<td>49</td>
<td>2</td>
<td>2.6</td>
<td>26.0</td>
</tr>
<tr>
<td>Grey Vertosols</td>
<td>26</td>
<td>53</td>
<td>2</td>
<td>2.9</td>
<td>34.2</td>
</tr>
</tbody>
</table>

1. Values based on median results from the CMD Smith (2020) soil assessment

3.2.3 Topography

Table 3 gives slope parameters of WRD1 used in the Model. Only one model was required since the slope angle and height of WRD1 is constant for the entire landform.

Table 3 WRD1 parameters

<table>
<thead>
<tr>
<th>Slope ID</th>
<th>Height</th>
<th>Length</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS1</td>
<td>23.9</td>
<td>161.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

Table 4 summarises slope parameters of OC1 used in the Model. Slopes XS4 and XS5 have multiple sections, which are given in Table 4 and presented in Figure 4.

Table 4 OC1 parameters

<table>
<thead>
<tr>
<th>Slope ID</th>
<th>Height</th>
<th>Length</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS2</td>
<td>24.0</td>
<td>162.0</td>
<td>15.0</td>
</tr>
<tr>
<td>XS3</td>
<td>24.3</td>
<td>164.0</td>
<td>15.0</td>
</tr>
<tr>
<td>XS4a</td>
<td>16.3</td>
<td>110.0</td>
<td>15.0</td>
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<td>XS4b</td>
<td>0.1</td>
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<td>8.5</td>
<td>57.0</td>
<td>15.0</td>
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<td>XS5a</td>
<td>26.0</td>
<td>175.0</td>
<td>15.0</td>
</tr>
<tr>
<td>XS5b</td>
<td>23.7</td>
<td>160.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>
3.2.4 Surface conditions

The Model was run for four groundcover scenarios ranging from 0-80%. Groundcover was kept constant for the scenarios because vegetation growth rates for pastures in the area are not currently known.

Rill spacing was set to 0.5 m for the landforms when bare and 0.3 m when vegetated. Surface roughness was set to 0.03 m, which is typical of a smooth surface that would develop after many rainfall events.

The scenarios were modelled for both the brown and the grey Vertosols, to provide perspective on the erodibility of each soil type.
4.0 Results

4.1 Brown Vertosols

The average and maximum annual erosion rates, modelled using soil parameters from the brown Vertosols, are given in Table 5 and Table 6 respectively. The results were obtained from 100 years of predicted rainfall data and under various surface conditions.

Table 5 Average annual erosion rate

<table>
<thead>
<tr>
<th>Slope ID</th>
<th>Bare soil</th>
<th>Soil with 30% groundcover</th>
<th>Soil with 60% groundcover</th>
<th>Soil with 80% groundcover</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS1</td>
<td>152.71</td>
<td>24.71</td>
<td>7.50</td>
<td>4.05</td>
</tr>
<tr>
<td>XS2</td>
<td>153.35</td>
<td>24.81</td>
<td>7.53</td>
<td>4.07</td>
</tr>
<tr>
<td>XS3</td>
<td>154.68</td>
<td>24.99</td>
<td>7.58</td>
<td>4.09</td>
</tr>
<tr>
<td>XS4</td>
<td>152.13</td>
<td>24.05</td>
<td>7.32</td>
<td>3.96</td>
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<tr>
<td>XS5a</td>
<td>161.51</td>
<td>25.90</td>
<td>7.87</td>
<td>4.27</td>
</tr>
<tr>
<td>XS5b</td>
<td>152.06</td>
<td>24.63</td>
<td>7.48</td>
<td>4.04</td>
</tr>
</tbody>
</table>

1. Units are in t/ha/y

Table 6 Maximum annual erosion rate

<table>
<thead>
<tr>
<th>Slope ID</th>
<th>Bare soil</th>
<th>Soil with 30% groundcover</th>
<th>Soil with 60% groundcover</th>
<th>Soil with 80% groundcover</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS1</td>
<td>276.69</td>
<td>49.53</td>
<td>16.15</td>
<td>9.17</td>
</tr>
<tr>
<td>XS2</td>
<td>277.77</td>
<td>49.71</td>
<td>16.20</td>
<td>9.20</td>
</tr>
<tr>
<td>XS3</td>
<td>280.02</td>
<td>50.05</td>
<td>16.29</td>
<td>9.25</td>
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<tr>
<td>XS4</td>
<td>287.29</td>
<td>50.31</td>
<td>16.46</td>
<td>9.36</td>
</tr>
<tr>
<td>XS5a</td>
<td>291.63</td>
<td>51.68</td>
<td>16.84</td>
<td>9.60</td>
</tr>
<tr>
<td>XS5b</td>
<td>275.55</td>
<td>49.38</td>
<td>16.10</td>
<td>9.14</td>
</tr>
</tbody>
</table>

1. Units are in t/ha/y

4.2 Grey Vertosols

The average and maximum annual erosion rates, modelled using soil parameters from the grey Vertosols, are given in Table 7 and Table 8 respectively. The results were obtained from 100 years of predicted rainfall data and under various surface conditions.
Table 7  Average annual erosion rate

<table>
<thead>
<tr>
<th>Slope ID</th>
<th>Bare soil</th>
<th>Soil with 30% groundcover</th>
<th>Soil with 60% groundcover</th>
<th>Soil with 80% groundcover</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS1</td>
<td>171.48</td>
<td>26.75</td>
<td>8.15</td>
<td>4.38</td>
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<tr>
<td>XS2</td>
<td>172.22</td>
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<td>8.19</td>
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<tr>
<td>XS3</td>
<td>173.71</td>
<td>27.04</td>
<td>8.22</td>
<td>4.44</td>
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<td>172.46</td>
<td>26.36</td>
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<tr>
<td>XS5a</td>
<td>181.66</td>
<td>28.08</td>
<td>8.53</td>
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<tr>
<td>XS5b</td>
<td>170.72</td>
<td>26.66</td>
<td>8.11</td>
<td>4.36</td>
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</table>

1. Units are in t/ha/y

Table 8  Maximum annual erosion rate

<table>
<thead>
<tr>
<th>Slope ID</th>
<th>Bare soil</th>
<th>Soil with 30% groundcover</th>
<th>Soil with 60% groundcover</th>
<th>Soil with 80% groundcover</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS1</td>
<td>308.32</td>
<td>53.48</td>
<td>17.47</td>
<td>9.84</td>
</tr>
<tr>
<td>XS2</td>
<td>309.56</td>
<td>53.63</td>
<td>17.53</td>
<td>9.88</td>
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<td>17.40</td>
<td>9.80</td>
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</tbody>
</table>

1. Units are in t/ha/y

4.3 Discussion

Table 5-Table 7 show that the final landform will experience high erosion rates with a groundcover of 30% or less. However, the final landform is unlikely to develop excessive rilling and can be considered stable with a groundcover of at least 80% (ie average erosion rate of <5 t/ha/y).

XS4 showed the lowest average erosion rates of any of the slopes that were modelled, while also having the second longest length. The reduced average erosion rate is likely due to the 6 metre (m) bench located in the middle of the slope (see Figure 4).

Table 6-Table 8 show that slopes ranging from 0-60% groundcover will be vulnerable to very high erosion rates in the event of extreme rainfall. This reinforces the importance of establishing groundcover as soon as practicable. Once groundcover reaches 80%, nearly all slopes had an acceptable maximum annual erosion rate (<10 t/h/yr). The only exceptions were slopes XS4 and XS5a when modelled using the grey Vertosol.
5.0  Conclusions

5.1  Limitations

The following limitations apply to the WEPP model:

- it is uncalibrated and requires experimental data (ie sediment loss, runoff and rainfall) for each material to improve accuracy;
- it does not predict deposition patterns;
- it does not adjust hillslope elevation in response to erosion;
- it does not consider gulley and tunnel erosion; and
- it does not account for weathering, surface armouring and pedogenesis.

Other limitations to the accuracy of the results presented in Section 4.0 include:

- topsoil availability and quality at closure;
- interactions with the underlying overburden; and
- effects of climate change on future rainfall event intensities, durations and / or frequencies.

5.2  WEPP modelling

The Model was run using desktop data and final landform designs to estimate the potential annual erosion rate (t/ha/y) for a variety of surface conditions and slope parameters.

The Model indicated that, given current final landform designs, WRD1 and OC1 will require a surface condition of at least 80% groundcover before the average and maximum annual erosion rates reach acceptable limits (<5 t/ha/y and <10 t/ha/y respectively). Once 80% groundcover is achieved, the Model shows a lower maximum erosion rate for the final landform than was calculated for some areas of the pre-mining landform (Table 1).

5.3  Recommendations and future studies

The following recommendations and future studies are made from this report:

- the Model will require calibrating by laboratory flumes, rainfall simulator field plots and / or natural field plots, allowing the calculation of interrill erodibility, rill erodibility, critical shear and effective hydraulic conductivity;
- progressive rehabilitation of the final landform will be important to provide sufficient groundcover (≥80%) as early as possible to stabilise the landform and minimise the potential for erosion;
- until sufficient groundcover is achieved, temporary erosion and sediment controls (ie catch drains or diversion bunds) should be installed on any outer slopes (WRD1);
- the fertility and dispersibility of the soil stockpiles regarding the impact on vegetation establishment and growth will need to be assessed at closure and treated with ameliorants where required.
References

CDM Smith 2020, Chapter 4 – Land: Isaac River Project, prepared for BCC by CDM Smith Pty Ltd.


Landloch 2013, Landform design study | Carmichael Coal Project, Report prepared for GHD by Landloch Pty Ltd.


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