



**LANDFORM EVOLUTION  
MODELLING SIMULATIONS  
TO SUPPORT REHABILITATION  
LANDFORM DESIGN:  
DAUNIA MINE**

March 2026

Whitehaven Coal Limited



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## EXECUTIVE SUMMARY

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Landloch has been engaged by Whitehaven Coal Limited (Whitehaven) to carry out SIBERIA landform evolution modelling for the final landform design at the Daunia Mine (DNM). The modelling is to support revision 3 of the DNM Progressive Rehabilitation and Closure Plan (PRC Plan).

SIBERIA input parameters were derived for two surfaces, vegetated clay soil (80% groundcover) and a vegetated soil-rock mixture (50% groundcover). SIBERIA input parameters were derived through a process of laboratory-based erodibility testing, long-term WEPP runoff/erosion modelling, and analysis of 100 years of WEPP model output of daily runoff and erosion. In assigning SIBERIA parameters, it was assumed that the vegetated clay soil is applied to land surfaces with gradients of  $\leq 15\%$  and the vegetated soil-rock mixture is applied to land surfaces with gradients between 15% and 25%.

SIBERIA landform evolution model simulations indicate that the DNM Final Landform Design has a low tendency to promote ongoing rill and gully erosion provided the correct surface materials and the target levels of vegetation groundcover are achieved.

At a vegetation groundcover level of 80%, the soil-covered slopes with lower gradients ( $\leq 15\%$ ) are not prone to significant levels of gully erosion. At a vegetation groundcover of 50%, the soil-rock mixture covered slopes with steeper gradients (25%) are more prone to erosion in the initial 100 years. Gully erosion is predicted to occur in the north where the inward facing curves wrap around the void. It is possible that the eroded sediment from these batters could be directed in the void, minimising its impact. Alternatively, this area could be armoured with slightly larger diameter rock in order to increase the erosion resistance while not changing the overall proportion of rock and fines. Such an approach is recommended if erosion monitoring data suggests that gully erosion is indeed occurring.

The average annual erosion rates for both the vegetated soil and vegetated soil-rock mixture surfaces are predicted to reduce through time. This indicates that the DNM Final Landform Design is predicted to trend towards increased erosional stability through time, and that the gullies that may be present are predicted to reduce in activity through time. The long-term erosion rates for both the vegetated soil and vegetated soil-rock mixture surfaces are predicted to reach a steady long-term annual erosion rate that has a low tendency to promote ongoing rill and gully erosion.

The model output has assumed the use a clay soil or a soil-rock mixture as the surface material. Clay soils were found to be the dominant soils across DNM. Permian spoil is also likely available for use in the creation of a soil-rock mixture. Weathered sediments and clays were found to be unsuitable for plant growth and prone to very high rates of erosion. They should not be used to create a soil-rock mixture for use in rehabilitation.

## 1 INTRODUCTION

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Landloch has been engaged by Whitehaven Coal Limited (Whitehaven) to carry out SIBERIA landform evolution modelling for the rehabilitation landform design at the Daunia Mine (DNM). The results are to support a revision of the Progressive Rehabilitation and Closure Plan (PRC Plan) for DNM. The third revision of the rehabilitation design is referred to as 'DNM Final Landform Version LF3.1.3' in this report.

### 1.1 Objectives of landform design

The key consideration for a landform design is to demonstrate that the rehabilitated landform can be expected to be erosionally stable in the long term while supporting the target Post Mining Land Use (PMLU). As part of that assessment, this study reports:

- Materials to be used in landform rehabilitation and their erodibility.
- WEPP erosion modelling outputs that considered the interactions between 2-D landform slope profile geometry, material erodibility, rainfall depths and erosivity, and vegetation groundcover levels to identify profile geometries that achieve acceptable erosion rates over a 100-year period. The DNM Final Landform design was informed by the 2-D erosion modelling results
- Landform evolution simulations using the SIBERIA landform evolution model (LEM) to assess erosional stability of the DNM Final Landform Design over a period of 300 years.

### 1.2 Post mining land uses

The PMLUs for the DNM Final Landform Design include grazing and woodland. The grazing PMLU is adopted for slopes with gradients  $\leq 15\%$  and rehabilitation surfaces used in the LEM for this PMLU include vegetated soils. The woodland PMLU is adopted for slopes with gradients  $> 15\%$  and rehabilitation surfaces used in the LEM for this PMLU include a vegetated surface containing a soil-waste rock mixture.

Non-Use Management Areas (NUMA) are also proposed for the final void areas.

## 2 BACKGROUND

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### 2.1 Materials

#### 2.1.1 Soils

Broad scale (less detailed) soils mapping for DNM is available from QLD Globe<sup>1</sup>. Two soil groups have been identified using this mapping, friable earths (e.g. vertosols and Dermosols) and sodosols. More detailed soil surveys of DNM occurred in 2004 (covering areas shared with the neighbouring Poitrel mine) and 2008 (specifically covering DNM). GT Environmental Services (2012) also completed a soil survey of an additional 250 ha of undisturbed land as part of the development of a topsoil stripping

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<sup>1</sup> QLD Globe (<https://qldglobe.information.qld.gov.au/>) is an online portal of location-based information curated by the Queensland Government.

plan. The 2008 survey is most relevant to this study and included 195 soil inspection sites (Landloch 2022). Soil groups identified in this more detailed survey included vertosols, dermosols, chromosols, and sodosols, consistent with the broad scale mapping<sup>2</sup>. The soils were dominated by vertosols and dermosols (~95% of the survey area), with only a small amount (~5%) of chromosols and sodosols.

The soil resource available for rehabilitation is stored within existing soil stockpiles. Soil stockpile sampling was undertaken in February and March 2022, in which a total of 88 samples were collected from 22 soil stockpile locations (Landloch 2022). All 88 samples were assessed for field texture, pH<sub>w</sub>, and salinity (EC<sub>1:5</sub>), and a subset of 22 samples were further assessed for exchangeable cations and fertility.

The stockpiled soils were all categorised as being red/brown in colour and having a clay loam to medium clay texture. This is consistent with vertosols and dermosols. A summary of the properties of stockpiled soils (Landloch 2022) is given in Table 1.

### 2.1.2 Wastes (spoils)

Geochemical and physical characterisation data for wastes (spoils) were collated from multiple assessments conducted across DNM (Landloch 2022). Broad spoil characteristics were found to be similar across all studies and two spoil management groups were identified:

- Unweathered zone materials – Fresh Permian spoil; and
- Weathered zone materials – Weathered sediments and clays.

A summary of the properties of spoils (Landloch 2022) is given in Table 1.

#### 2.1.2.1 Fresh Permian spoil

Generally, fresh Permian spoil is a rocky material consisting primarily of sandstone, siltstone, and claystone rock types. The characteristics of fresh Permian spoil can vary between the strata location and degree of carbonaceous inclusions present. Examples of Permian spoils are shown in Figure 1 (from Landloch (2017)).

Fresh Permian spoil has an abundant rock content (30–81% >20mm diameter, median 55%). The rock fraction has medium to low slake durability using the classification scheme of Gamble (1971)<sup>3</sup> and medium slake durability using the scheme of Dick *et al.* (1994)<sup>4</sup>. Slake durability values, based on 9 samples<sup>5</sup>, range from 50–77%, with a median value of 62%. Six (6) of the 9 samples have slake durability ≥60% and 4 of the 9 samples have slake durability ≥70%. Therefore, Permian spoil from DNM is considered to be commonly of medium durability.

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<sup>2</sup> Chromosols and sodosols are similar in that they are both texture contrast soils, but differ in that sodosol subsoils are sodic and chromosol subsoils are not.

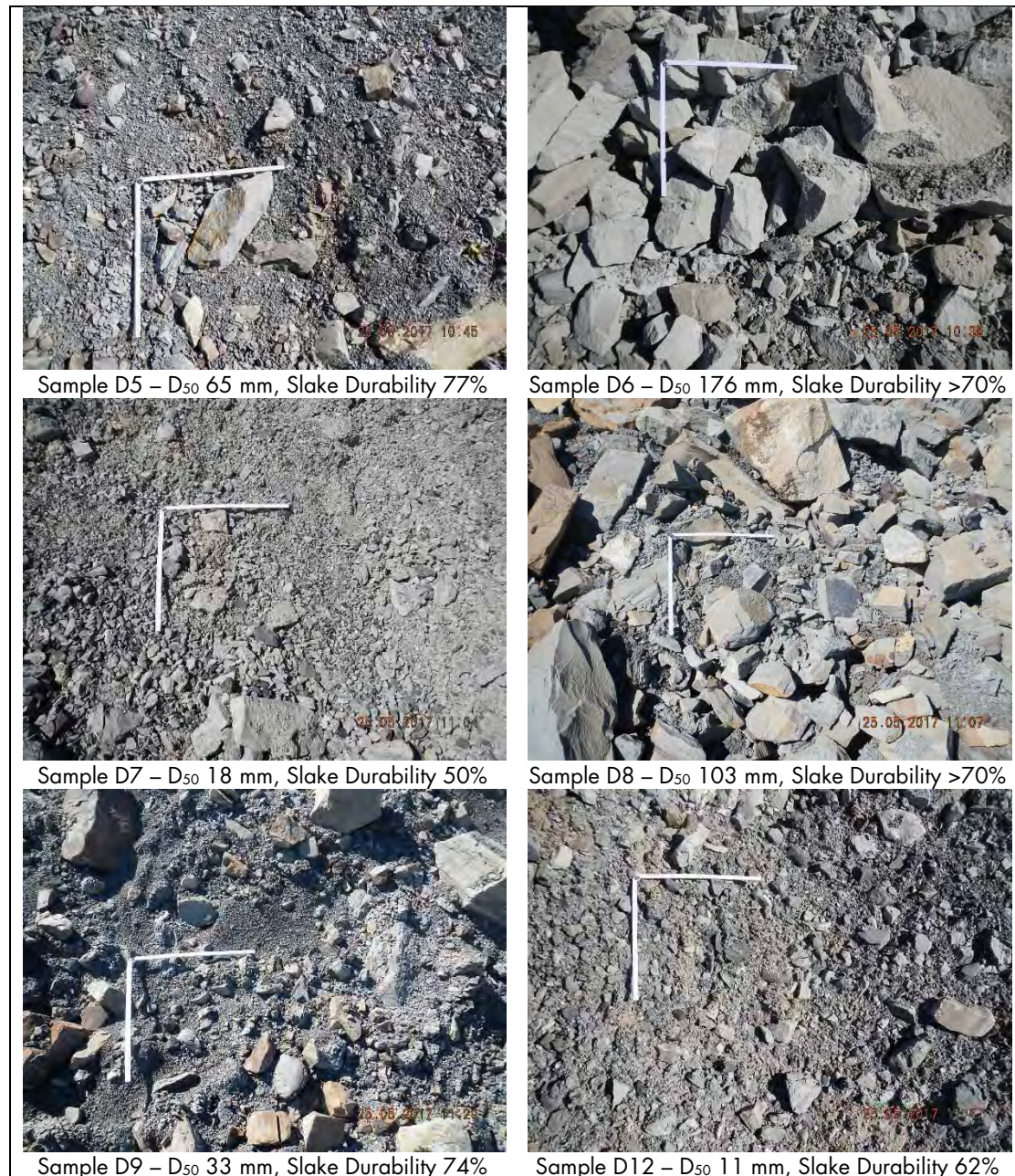
<sup>3</sup> Gamble's slake durability classification scheme used 6 groupings: very low <30%, low 30-60%, medium 60-85%, medium high 85-95%, high 95-98%, very high >98%.

<sup>4</sup> Dick's slake durability classification scheme used 3 groupings: low <50%, medium 50-85%, high >85%

<sup>5</sup> Seven (7) samples were tested for slake durability. A further 2 samples were not tested but were similar in terms of weathering status to those found to have slake durability values >70%.

Medium durability spoil can be expected to revert to a mixture of rock, gravel, and fine particles (Pennsylvania DOT 2022), with a sufficient rock content to provide persistent higher erosion resistance (compared to soils or weathered spoils).

Within the fine fraction (<2 mm diameter particles) the proportion that is clay-sized (<0.002 mm) is ~25% (Landloch 2017), consistent with a clay loam texture. The fine fraction is sodic (ESP 8–17%) and potentially dispersive (Landloch 2017, 2022), but the abundant rock content and will counteract the tendency for this material to be structurally unstable and prone to tunnel erosion. For example, a material with 55% rock content and 45% fines content with a clay content of 25% (within the fines) is ~11% clay by weight when the entire material mass is considered.



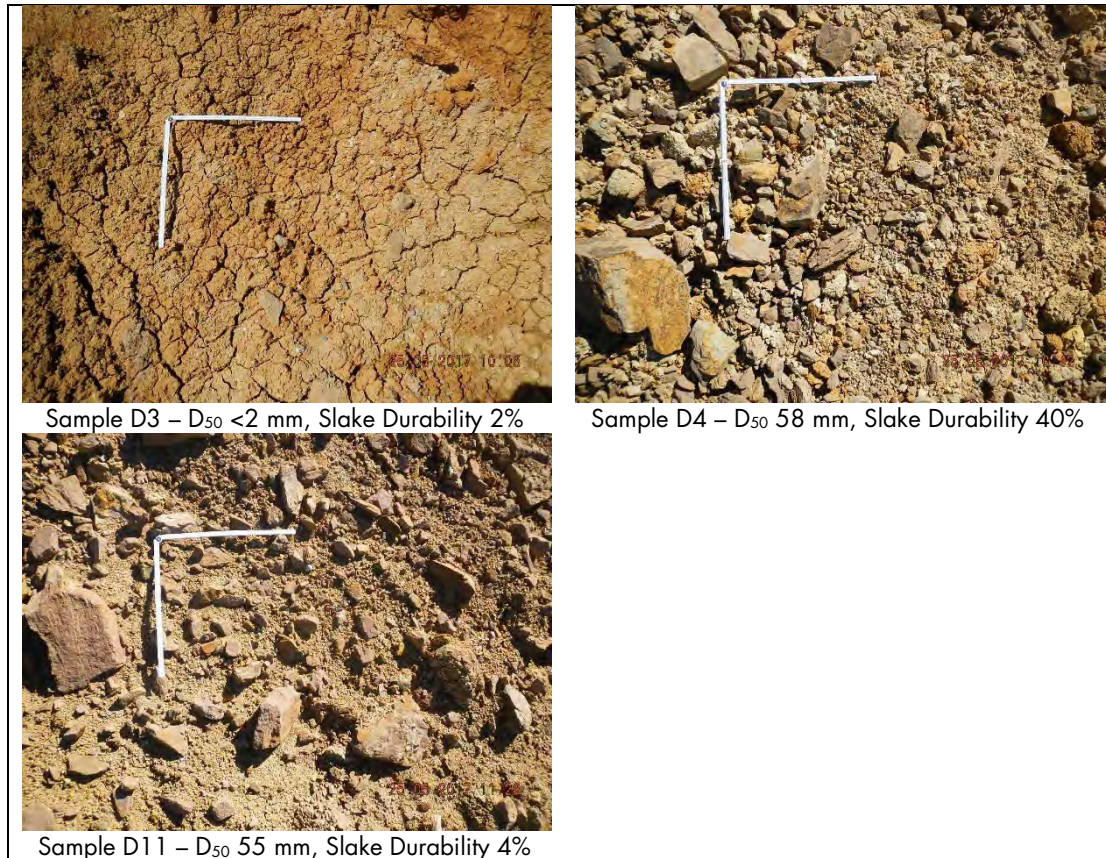
**Figure 1:** Examples of Permian spoil from DNM (Landloch 2017). The D<sub>50</sub> listed is the mean rock size of particles greater than ~2 mm diameter.

### 2.1.2.2 Weathered sediments and clays

Weathered sediments and clays are weathered spoils that contain an abundance of rock (~55–58% >20 mm, median 57%). Examples of weathered sediments and clays are shown in Figure 2 (from Landloch (2017))<sup>6</sup>.

The rock fraction has very low to low slake durability using the classification scheme of Gamble (1971) and low slake durability using the scheme of Dick *et al.* (1994). Slake durability values, based on 3 samples, range from 2–40%, with a median value of 4%. Therefore, weathered sediments and clays from DNM are considered to be commonly of very low durability. Very low durability spoil can be expected to revert over time to fine particles with little to no rock or gravel (Pennsylvania DOT 2022).

Within the fine fraction (<2 mm diameter particles) the proportion that is clay-sized (<0.002 mm) is ~45% (Landloch 2017), consistent with a clay to clay loam texture. The fine fraction is sodic (ESP 20%) and potentially dispersive (Landloch 2017, 2022). They are likely to be prone to hardsetting and to tunnel and gully erosion.



**Figure 2:** Examples of weathered sediments and clays from DNM (Landloch 2017).

<sup>6</sup> Sample D11 reported in Landloch (2017) is mislabeled a Permian spoil in Table 6 of that report, when it is in fact a weathered sediment spoil.

### *2.1.3 Representativeness of materials assessed for erodibility*

Landloch undertook a field inspection and subsequent selection of soils and spoils for use in erodibility testing (Landloch 2017). Examples of clay soil and Tertiary (weathered sediments) and Permian spoils were collected and assessed for erodibility using simulated rainfall and overland flows. Additional samples of soil, siltstone and sandstone (Fresh Permian) were collected in 2025. Two mixtures, one of clay soil and sandstone and one of clay soil and siltstone were made and tested for erodibility. The properties of the soils and Permian spoils tested for erodibility, along with a broader summary of soils and spoils reported in Landloch (2022) are given in Table 1. Tertiary spoils (weathered sediments) were not considered further in this study because they were found to be unlikely to support vegetation and hence unsuitable for use at the surface of a rehabilitated landform (Landloch 2022) and were predicted to erode at very high rates (long average erosion rates of ~2,000t/ha/y) when unvegetated (Landloch 2017).

Comparison of the soil and spoils assessed for erodibility with the broader summary of material properties show that they have:

- pH<sub>w</sub> values (strongly alkaline) consistent with pH<sub>w</sub> values of the materials more broadly (neutral to strongly alkaline for soils and moderate to strongly alkaline for Permian waste).
- EC<sub>1:5</sub> values (low) consistent with EC<sub>1:5</sub> values of the materials more broadly (low to moderate for soils and low to moderate for Permian waste).
- Soil ECEC values (moderate) consistent with ECEC values of the soils more broadly (moderate)
- Permian spoil ECEC values (low) lower than ECEC values for Permian spoils more broadly (moderate to high). A lower ECEC value is likely due in part to the fresh nature of these materials (1–6 months since disturbance). A low ECEC is unlikely to significantly alter the erodibility of these materials because erodibility will be dominated by the high abundance of coarse fragments (the fines will have only a small impact on overall material erodibility).
- Soil ESP values (non-sodic) consistent with ESP values of the soils more broadly (non-sodic to sodic).
- Permian spoil ESP values (sodic to strongly sodic) consistent with ESP values of the Permian spoil more broadly (strongly sodic).
- Soil clay content values (38%) consistent with clay content values of the soils more broadly (>30%).
- Permian spoil clay content values (20%) consistent with clay content values of the Permian spoils more broadly (<25%).
- Soil rock content values (0.1%) consistent with rock content values of the soils more broadly (<20%).
- Permian spoil rock content values (65–80%) consistent with rock content values of the soils more broadly (>30%).
- Permian spoil rock slake durability values (moderate) consistent with slake durability values of the Permian spoil more broadly (moderate).

Based on this assessment, it was concluded that the materials assessed for erodibility are consistent with the soil and spoil materials more broadly and therefore representative of these materials.

**Table 1:** Summary of soil and spoil properties and properties of soil and spoils assessed for erodibility.

Analysis	Units	Summary of Material Properties*			Materials Assessed for Erodibility 2017 <sup>^</sup>				Materials Assessed for Erodibility 2025 <sup>†</sup>		
		Red/Brown Clay Soils	Fresh Permian	Weathered Sediments & Clays	Clay Soil	Fresh Permian	Soil-Rock Mixture		Permian Sandstone	Permian Siltstone	Clay Soil
							Clay Soil	Fresh Permian			
pH <sub>w</sub>	pH Units	7.8–8.7 Slightly to strongly alkaline	8.4–9.7 Moderately to strongly alkaline	6.4–8.8 Slightly acid to strongly alkaline	8.6 Strongly alkaline	9.7 Strongly alkaline	8.6 Strongly alkaline	9.2 Strongly alkaline	8.3 Moderately alkaline	8.0 Moderately alkaline	7.4 Slightly alkaline
EC <sub>1:5</sub>	dS/m	0.15–0.43 Low to moderate	0.18–0.82 Low to moderate	0.51–1.20 Moderate to high	0.14 Low	0.24 Low	0.14 Low	0.15 Low	0.25 Low	0.51 Moderate	0.07 Low
ECEC	meq/100g	13–28 Moderate	23–32 Moderate to high	23–32 Moderate to high	23 Moderate	6.9 Low	23 Moderate	10 Low	No Data	No Data	No Data
ESP	%	1.7–7.8 Non-sodic to sodic	10–25 Strongly sodic	4–19 Sodic to strongly sodic	3.1 Non-sodic	17 Strongly sodic	3.1 Non-sodic	7.5 Sodic	No Data	No Data	No Data
Clay Content	%	>30	<25	>35	38	24	38	26	35	35	40
Rock Content	%	<20	>30	<20	0.1	81	0.1	80	91	83	0.1
Emerson Dispersion (fines)	Class	3b–7 Slightly dispersive to stable	2 Dispersive	2 Dispersive	No Data	No Data	No Data	No Data	2 Dispersive	3 Slightly dispersive	3 Slightly dispersive
Slake Durability	%	N/A Low rock content	50–75 Moderate	<50 Low	N/A Low rock content	50–75 Moderate	N/A Low rock content	50–75 Moderate	Moderate	Moderate	N/A Low rock content

\* Landloch (2022); <sup>^</sup> Landloch (2017) <sup>†</sup> Reported in this report.

## 2.2 Material erodibility

Four surfaces considered as part of this LEM study (soil and soil-rock mixture) were assessed for erodibility using simulated rainfall and overland flume studies. Examples of these materials packed into flumes is given in Figure 3.

The 3 material mixtures shown in Figure 3 (excluding the red clay soil) contain ~30% fines (<2 mm) and were established to achieve the optimal fines to coarse mixing ratio and hence the optimal erosion resistance for these materials. Despite looking rocky, there are still appreciable fines that can act to support vegetation growth.



**Figure 3:** Red clay soil (top left), red clay soil-Fresh Permian mixture (top right), brown clay soil-sandstone mixture (bottom left), and brown clay soil-siltstone mixture (bottom right) during overland flow study.

The optimal mixing ratio used for the soil-rock mixtures were established using the particle size distribution data for each material, and assuming that the optimal mixing ratio would be such that the minimum void ratio was achieved. That is, the mixing ratio at which the finer particles found within the soil and the Permian spoil fill the voids around the larger rock found within the Permian spoil. Bodman and Constantin (1965) found that the minimum void ratio was achieved when the mixing ratio of fine and coarse particles was 20–40% fines to 60–80% coarse particles. This result aligns with earlier work by Westman and Hugill (1930) who showed that at 30% fines, the void volume is minimised in a coarse-fine (binary) system.

For the DNM red soil and Permian waste rock, creation of a soil-rock mixture such that the fines completely fill the void space required mixing 1 part clay soil (100% fines) to 4 parts Permian spoil (20% fines). This mixing ratio would yield a mixture that has 36% fines and 64% coarse particles. For the 2025 mixtures that included brown clay soil and sandstone/siltstone, the mixing ratio of 1 part clay soil to 2 parts sandstone/siltstone would yield a similar amount of fines (~40%).

If mixtures contain a larger proportion of fines, the result would be a mixture in which the coarse particles are not frequently in direct contact with each other. This would reduce the erosion resistance of the mixed material. If mixtures contained a smaller proportion of fines, the result would be a mixture in which the voids between the rock are not completely filled. Such a material would have 'holes' between the rock that rainfall would percolate through and potentially become less available to the surface root systems of vegetation.

Erodibility parameters for the red clay topsoil reported by Landloch (2017) were used. For the soil-rock mixture, critical shear and rill detachment values reported by Landloch (2017) was used as these were similar to those measured in 2025. The measured infiltration capacity was very high for the soil-rock mixture assessed in 2017 and this would cause the models to predict essentially no runoff and erosion. A lower effective hydraulic conductivity (12mm/hr) was adopted, based on the values measured for the brown clay soil-rock mixtures assessed in 2025. The critical shear and rill detachment values for materials tested in 2025 (brown clay soil mixed with sandstone or siltstone) produced similar erosion results to the soil-rock mixture tested and reported in 2017.

### **3 WEPP 2-D EROSION SIMULATIONS**

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#### **3.1 The WEPP model**

WEPP was developed by the United States Department of Agriculture to predict runoff, erosion, and deposition for hillslopes akin to mine landform batter slopes (Flanagan and Livingston 1995). WEPP is a simulation model with a daily input time step, although shorter time steps are used by internal calculations on days when rainfall occurs. Plant and soil characteristics important to erosion processes are updated every day. When rainfall occurs, those plant and soil characteristics are considered in determining the likelihood of runoff. If runoff is predicted to occur, the model computes sediment detachment, transport, and deposition at points along the batter slope profile.

The erosion component of WEPP uses a steady-state sediment continuity equation as the basis for the erosion computations. Soil erosion in interrill areas is calculated as a

function of the effective rainfall intensity and runoff rate. Soil erosion in rills is predicted to occur if the flow shear stress is greater than the soil's critical flow shear stress, and when the sediment load of the flow is below its transport capacity. Deposition in rills is computed when the sediment load is greater than the capacity of the flow to transport it.

## 3.2 Slope geometries

WEPP runoff and erosion simulations were carried out for:

- Batter slopes 140m high at a uniform gradient of 15%, surfaced with clay soil with vegetation groundcover levels of 50% and 80%.
- Batter slopes 140m high at a uniform gradient of 25% gradient, surfaced with a soil-rock mixture with vegetation groundcover levels of 0% and 50%.

## 3.3 Vegetation groundcover impacts

### 3.3.1 Achievable groundcover

A monitoring report for DNM (ELA 2019) reports vegetative cover of 95% on a 6-year old rehabilitation site. Landloch (2017) observed high levels of vegetation cover during a site inspection (Figure 4).

Estimates of vegetation groundcover for non-rocky soil surfaces near DNM were further sourced from the pasture groundcover dataset supplied by the QLD Government's FORAGE data service<sup>7</sup>. The data is derived from Landsat satellite imagery. Groundcover was assessed for a 35,275ha parcel of land adjacent to but excluding DNM and the neighbouring Poitrel mine. These were excluded because they are currently in a disturbed state and would have low groundcover levels as a result. Average total groundcover from 1988 through to 2024 is 87% and the 20<sup>th</sup> and 80<sup>th</sup> percentile values are 84% and 94%, respectively.



**Figure 4:** Groundcover (grass) on rehabilitated area at DNM (Landloch 2017).

<sup>7</sup> <https://www.longpaddock.qld.gov.au/forage/about/>

A review of the grazing land management (GLM) land types in the vicinity of DNM that included rocky soil types was also completed. GLM land type mapping is a spatial representation of land types of Queensland as described by the Queensland Department of Agriculture and Fisheries. Grazing land types are mapped across Queensland by associating regional ecosystems spatial data to each GLM land type. The *Lancewood-bendee-rosewood* (FT17) and *Narrow-leaved ironbark on ranges* (FT20) GLMs are present near DNM. Both these GLMs are noted as suitable for cattle breeding and contain shallow rocky soils on steep slopes (FutureBeef 2011). They have an average annual groundcover level of 48–71%, based on data from the QLD Government's FORAGE data service.

Consequently, it was concluded that vegetative groundcover levels of  $\geq 80\%$  are achievable on rehabilitation carried out on soil at DNM and  $>50\%$  for rocky soils. Erosion modelling considered a groundcover level of 0% and 50% for the soil-rock mixture and 50% and 80% for the clay soil.

### 3.3.2 Accounting for vegetation impacts

The effect of vegetation groundcover was considered in two ways:

1. The effect on surface detachment; and
2. The effect on infiltration capacity.

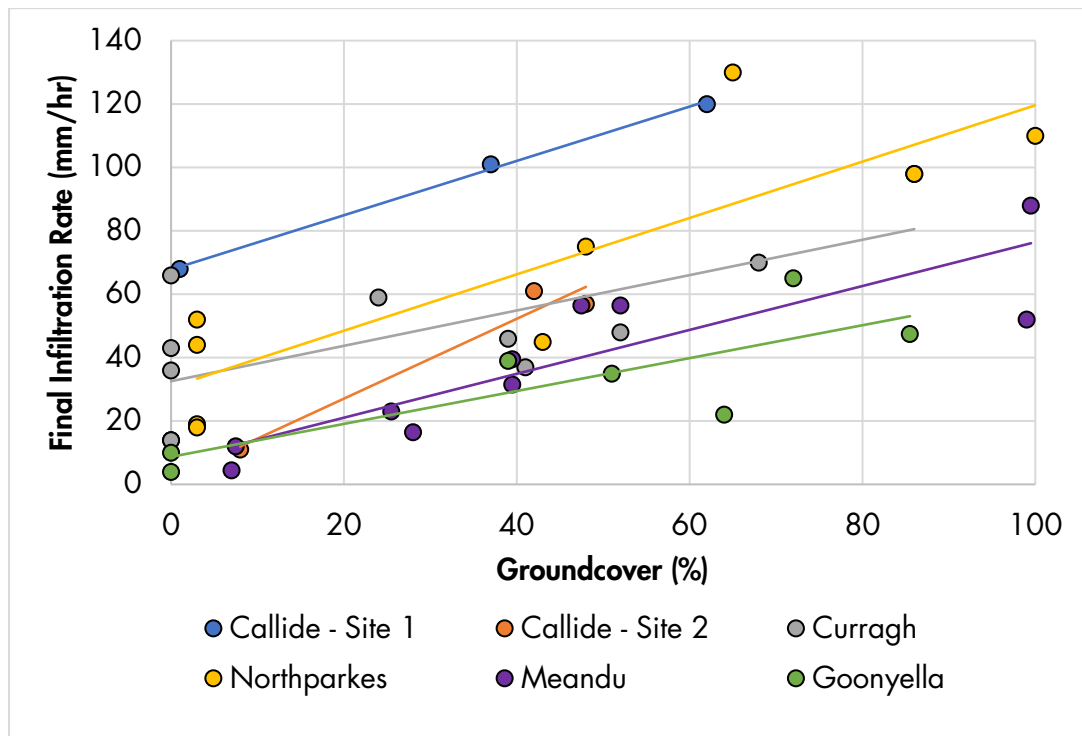
The effect on surface detachment was considered by applying cover factors (used to reduce erosion predicted from an unvegetated surface to that of the vegetated surface) taken from Rosewell (1993), accounting for the fact that the surface has already undergone consolidation (i.e. the surface is not freshly tilled). These cover factors are based on the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al.* 1997). The cover factors used were 1.00 for 0% groundcover, 0.158 for 50% groundcover, and 0.029 for 80% groundcover.

The effect of groundcover on infiltration capacity has been assessed by Landloch staff on numerous Australian mine sites, including Callide (2 sites), Curragh, Goonyella, Meandu, and Northparkes (Figure 5).

These studies showed that for every 10% increase in groundcover, there is a measured 5–13mm/hr increase in final (steady) infiltration rate. The average increase in final infiltration is 8mm/hr for every 10% increase in groundcover. The effect of groundcover on the clay soils from DNM was considered by increasing the measured final infiltration rate by 8mm/hr for every 10% increase in groundcover. Therefore, for 50% groundcover, an increase in steady infiltration rate of 35mm/hr was applied, and for 80% groundcover an increase in steady infiltration rate of 56mm/hr was applied. This was done in addition to the application of the cover factor to account for the effect on detachment capacity.

These factors were used to represent a consolidated surface supporting a vegetation system dominated by grasses with some scattered trees. It assumes that vegetation is randomly distributed at the stated average cover level across the entire area being modelled.

It is intended that the vegetation will be established in a surface that consists solely of soil or in a surface that contains a mixture of soil and durable rock (in the circumstance that a rock armour element is introduced). In both cases (soil or soil-rock mixtures), the cover factor can be applied to reduce erosion to account for the reduced detachment and particle trapping that occurs when vegetation is present. The increased infiltration would also be applicable in both cases because the growth and extension of roots would still occur within the fine fraction of the surface material, be it a soil or a soil-rock mixture.



**Figure 5:** Measured relationships between groundcover levels and steady infiltration rates for 6 locations on Australian mine site.

### 3.4 Climate

All simulations used a synthetic 100-year climate file prepared to match daily, monthly and annual characteristics of the Moranbah climate.

### 3.5 WEPP modelling assumptions

The erosion model simulations are based on two key assumptions:

- There will be no uncontrolled discharge of runoff from landform tops onto rehabilitated batter slopes; and
- The assumed groundcover levels will be achieved sustainably, with those levels being set as triggers for investigation and remedial action should monitoring indicate that they are not being achieved.

In considering vegetation groundcover, this report specifically considers vegetation that is in contact with the land surface. Practically, this means a combination of grass cover and anchored (not readily moved) surface litter. Groundcover impacts do not consider rock. Where rocky materials have had erodibility measured experimentally and those parameters are used in WEPP simulations, then effects of the rock are already accounted for within the parameters used.

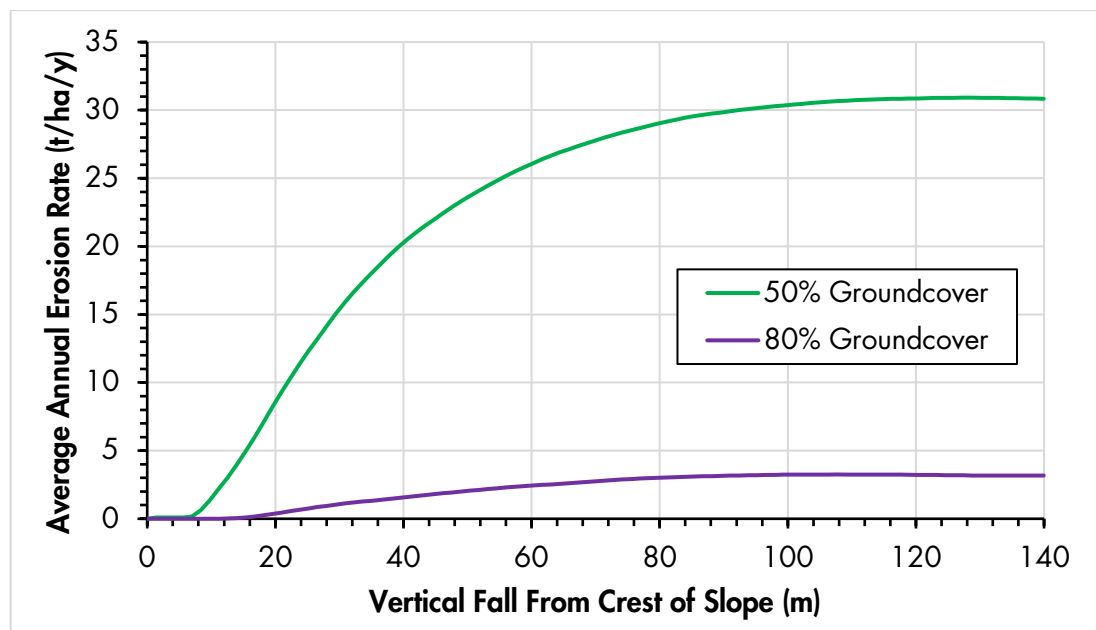
It should be recognised there are also underlying assumptions of good rehabilitation practice such that:

- There will not be discharges of concentrated flows onto any batter slopes at any point of their rehabilitation;
- Batter slopes will not be formed with flow-concentrating profiles, e.g. variations in surface elevation such that there is cross-slope concentration of flow into consistent depressions running downslope;
- Any cross-slope ripping will be carried out strictly on the contour; and
- Soil management (including stripping, stockpiling, replacement, amendment, and fertilisation) will be carried out effectively to maximise rapid and persistent vegetation growth.

## 4 WEPP MODEL RESULTS

### 4.1 Vegetated clay soil

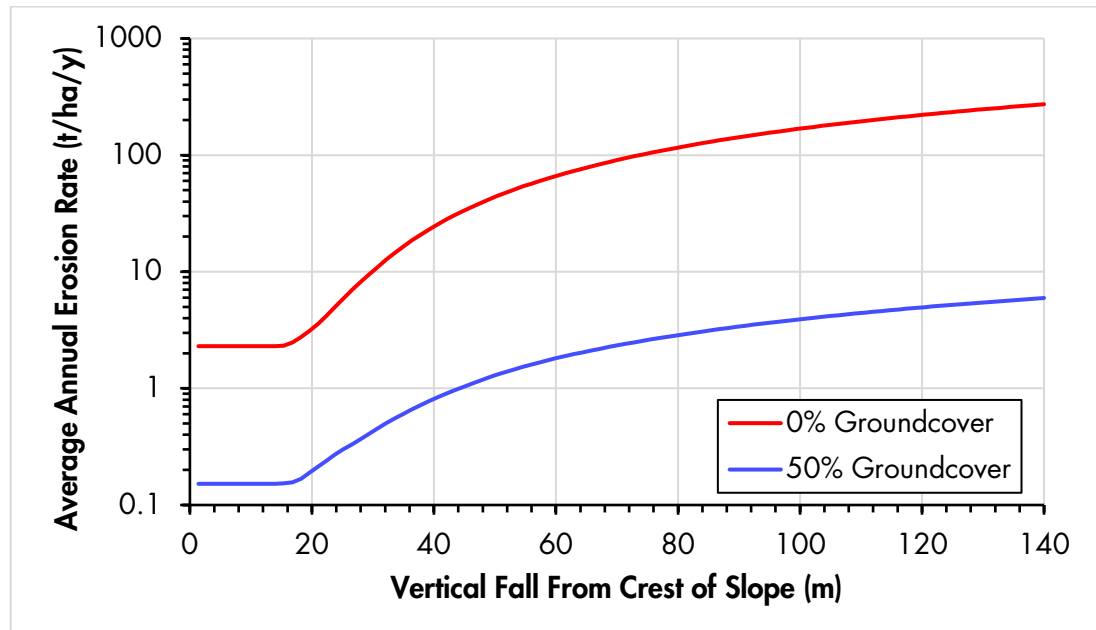
WEPP model predictions indicate that 140 m high batter slopes on uniform gradients of 15% rehabilitated with a soil will have a low tendency for rill and gully erosion provided a groundcover level of 80% can be sustainably achieved (Figure 6). Erosion potential is higher using the lower groundcover level (50%), with predicted rates likely to lead to an increased risk of rill and gully erosion.



**Figure 6:** Predicted long-term erosion rates along 15% uniform gradient batter slope sheeted with clay soil. Groundcover levels of 50% and 80% were modelled.

## 4.2 Bare and vegetated soil-rock mixture

WEPP model predictions indicate that 140m high batter slopes on uniform gradients of 25% rehabilitated with a soil-rock will have a low tendency for rill and gully erosion provided a groundcover level of 50% can be sustainably achieved (Figure 7). Erosion potential is higher when the surface remains bare, with predicted rates likely to lead to an increased risk of rill and gully erosion.



**Figure 7:** Predicted long-term erosion rates along a 25% uniform gradient batter slope sheeted with soil-rock mixture. Groundcover levels of 0% and 50% were modelled.

## 4.3 Implications for the rehabilitation landform design

Based on the WEPP model results outlined above, the materials proposed for use in the DNM Final Landform Design and for the landform evolution modelling are:

- Clay soil with 80% groundcover for slopes with gradients  $\leq 15\%$ ; and
- Soil-rock mixture with 50% groundcover for slopes with gradients  $> 15\%$ .

## 5 SIBERIA 3-D LANDFORM EVOLUTION MODELLING

### 5.1 The SIBERIA model

The SIBERIA landform evolution model predicts the long-term, 3D development of channels and hillslopes (e.g. landform batters) in a catchment based on runoff, erosion, and deposition.

SIBERIA has been successfully applied to explain aspects of the geomorphology of natural landforms (Willgoose 1994) and has been widely used to assess the evolution of constructed waste dumps on mine sites across Australia and overseas (Willgoose 1995; Willgoose and Riley 1993; Boggs *et al.* 2000; Hancock *et al.* 2003; Hancock and Willgoose 2004; Hancock 2004; Mengler *et al.* 2004; Hancock and Turley 2006).

It has also been subjected to numerous validation studies. In general, the validation studies indicate that SIBERIA's predictions of landform evolution are reasonable provided the model is suitably parameterised (Hancock *et al.* 2000; Hancock *et al.* 2003). In one validation study (Hancock 2004) it was noted that erosion rates predicted by SIBERIA for a catchment in the Northern Territory compared favourably to erosion estimates derived using the caesium-137 method. As the two erosion assessment methods use independent input information, the reported agreement is particularly significant.

SIBERIA solves for two variables: elevation, from which slope geometries are determined, and an indicator function that determines where erosion features (channels) exist.

Changes to the predicted erosion features is governed by an activation threshold that is dependent on the runoff discharge and gradient of the slope. When the activation threshold is exceeded, an erosion feature is predicted to develop. In this way, it is possible for a modelled surface to initially have no erosion features and for rills/gullies to develop where the activation threshold is exceeded.

The rate at which rills and gullies develop is controlled by a channelisation function. SIBERIA does not directly input rainfall or material erodibility parameters. Rather, the SIBERIA input parameters define the channelisation function that is a function of both runoff and erosion (Willgoose *et al.* 1989). As a result, SIBERIA parameters are specific to both the climatic regime and the material being considered and must be derived for each specific material located within each specific climatic regime.

## 5.2 SIBERIA input parameters

SIBERIA predicts the long-term average change in elevation of a node (i.e. a point in the landscape) by predicting the volume of sediment lost from that node. The rate of sediment transport through a node ( $q_s$  in units of  $m^3/y$ ) is determined by the equation:

$$q_s = \beta_1 \times q^{m_1} \times S^{n_1} \quad 1)$$

where  $\beta_1$  is the sediment transport rate coefficient (unitless),  $q$  is discharge ( $m^3/y$ ),  $m_1$  is the discharge exponent (unitless),  $S$  is the slope ( $m/m$ ), and  $n_1$  is the slope exponent (unitless). SIBERIA does not directly model discharge, but uses sub-grid effective parameterisation which relates discharge to the area draining through a node as:

$$q = \beta_3 \times A^{m_3} \quad 2)$$

where  $\beta_3$  is the coefficient between discharge and area (unitless),  $A$  is area ( $m^2$ ), and  $m_3$  is the exponent of the area in discharge (unitless).

To run SIBERIA, the parameters  $\beta_1$ ,  $m_1$ ,  $n_1$ ,  $\beta_3$ , and  $m_3$  are needed. There is interaction between all 5 parameters, with the result that an almost infinite number of parameter sets will all show the same rate of erosion, though some aspects of the pattern of erosion that is predicted will vary. Fixed values for  $\beta_3$ ,  $n_1$ , and  $m_3$  are adopted where possible, reducing the difficulty of deriving parameter values. If the batter to be modelled is identical to the batter for which erosion data are available for calibration,  $m_3$  and  $\beta_3$  can be taken as 1.0, and for situations where slope gradient does not affect slope erodibility,  $n_1$  can be taken as 1.5 (Willgoose pers. comm.). This is consistent with Kirkby (1971) who suggests values ranging from 1.3–2.0 are reasonable for soils.

Therefore, two key parameters require fitting against runoff and erosion data:  $\beta_1$  and  $m_1$ . Effectively, the  $\beta_1$  parameter could be described as an erosion rate parameter, as it primarily controls the rate of sediment movement. The  $m_1$  parameter could be described as primarily controlling slope length responses of erosion.

### 5.3 Derivation of parameters

The  $\beta_1$  and  $m_1$  input parameters for SIBERIA are derived by fitting the SIBERIA model equations to time series data of runoff and erosion. However, in most instances, sufficient record lengths of these time series data are not available for the landforms being considered. This is particularly true for landform design planning where the landforms do not yet exist. Therefore, Landloch has developed an alternative approach for deriving the  $\beta_1$  and  $m_1$  SIBERIA input parameters:

- a) Use measurements of material runoff and erosion from laboratory-based flume and rainfall simulations to derive calibrated WEPP model parameters.
- b) Generate daily time-series data of runoff and erosion using WEPP set up with:
  - a. Batter geometries consistent with the geometries of the landform being considered (allowing values for  $\beta_3$ ,  $n_1$ , and  $m_3$  to be fixed).
  - b. A long-term climate sequence (100-years) that is site specific and that contains a frequent, infrequent, rare and very rare events.
- c) Fit WEPP runoff and erosion output data to the SIBERIA model equations to derive values for  $\beta_1$  and  $m_1$  that are both material and site specific.

### 5.4 Model parameters

SIBERIA model parameters derived from WEPP simulations are shown in Table 2. It should be noted that the method of deriving parameters attempts to ensure that the  $m_1$  parameter is optimised so that SIBERIA simulations show a similar impact of slope length to that predicted by WEPP. However, because the two models use different methods to consider impacts of slope length, it is not reasonable to expect complete agreement between the two models over the full range of slope lengths considered.

**Table 2:** Estimated SIBERIA parameters

Material	Groundcover (%)	$m_1$	$\beta_1$
Clay soil – vegetated	80	1.2735	0.0150
Soil-rock mixture – vegetated	50	1.6923	0.000034

### 5.5 Model settings

The Digital Elevation Model (DEM) modelled by SIBERIA included the landform surface meshed into the surrounding landscape. A random roughness ( $\pm 10\text{cm}$ ) was added to the DEM prior to modelling. This was done to reduce triangulation gridding artefacts from the surface of the DEM and to provide a more realistic surface for modelling (landform surfaces are not perfectly smooth). The following SIBERIA outputs were produced for each landform modelled at years 50, 100, 150, 200, 250, and 300:

- Maximum depth of gullies at each output year with gullies defined as having a minimum depth of 0.3m;
- Average erosion (t/ha/y);
- Cumulative erosion (mm) for each output year; and
- Visual outputs showing the evolved DEM over which is draped the predicted material movement (erosion and deposition).

## 5.6 Digital elevation model

The proposed DNM Final Landform Design (DNM Final Landform Version LF3.1.3) was provided to Landloch by Whitehaven (Figure 8). It was informed by WEPP model results for the soils and soil-rock mixtures and vegetation groundcover levels that are to be applied. Different surface materials were applied based on the gradient of the landform, with blue surfaces being modelled as vegetated clay soil and grey surfaces modelled as vegetated clay soil-rock mixture.

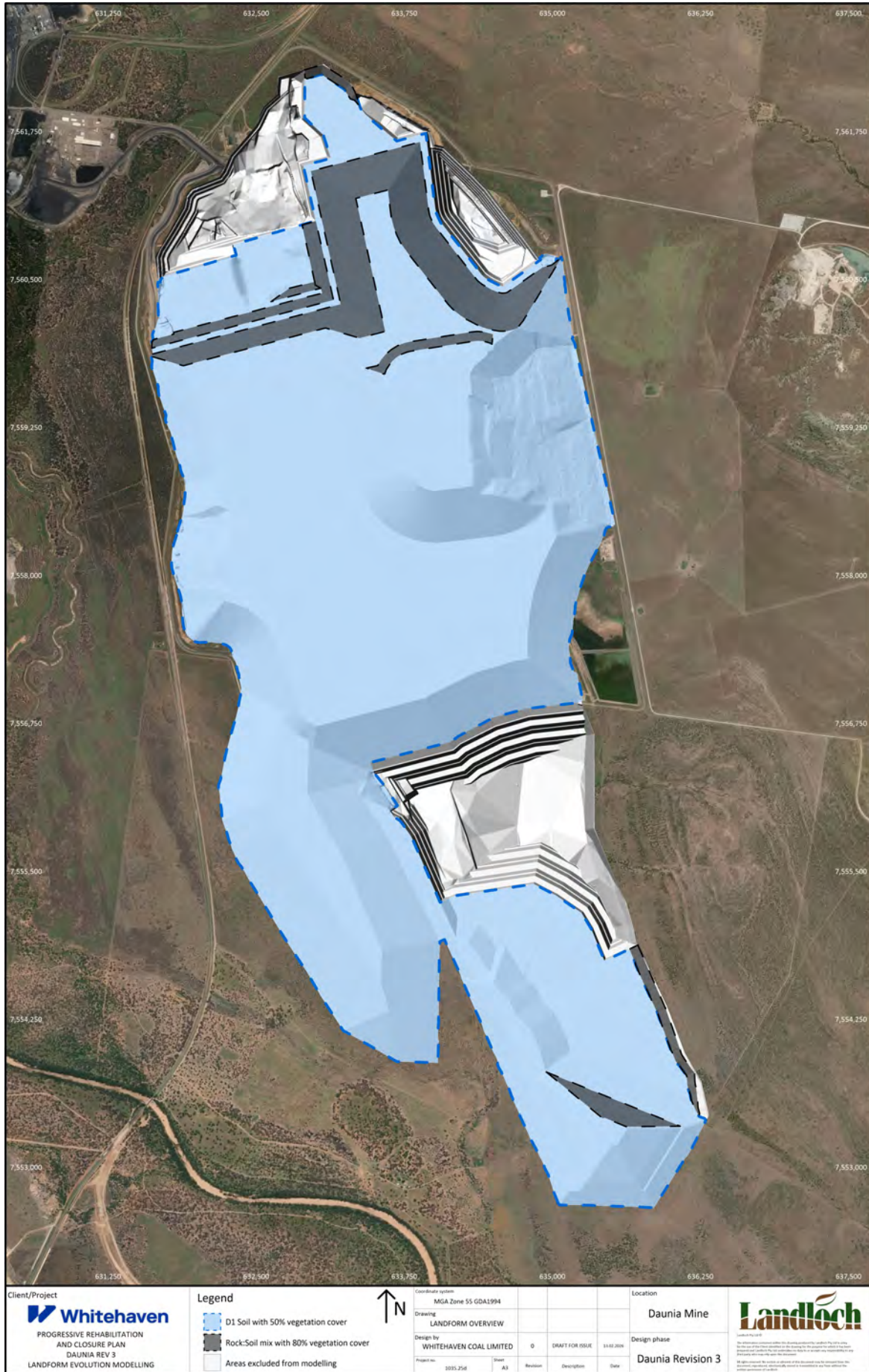
## 5.7 SIBERIA modelling assumptions

The following assumptions apply to the SIBERIA modelling:

- The DEM of the existing land surface and design file for the DNM Final Landform Version LF3.1.3 provided by Whitehaven are assumed to be accurate.
- Vegetated clay soil is applied to surfaces with gradients  $\leq 15\%$  and vegetated soil-rock mixture is applied to surface with gradients  $> 15\%$ .

These modelling assumptions valid for 2-D WEPP modelling also apply for 2-D SIBERIA modelling:

- In considering vegetation groundcover, this report specifically considers vegetation that is in contact with the land surface. Practically, this means a combination of grass cover and anchored (not readily moved) surface litter. Groundcover impacts do not consider rock. Where rocky materials have had erodibility measured experimentally and those parameters are used in WEPP simulations, then effects of the rock are already accounted for within the parameters used.
- Soil management (including stripping, stockpiling, replacement, amendment, and fertilisation) will be carried out effectively to maximise rapid and persistent vegetation growth.
- Any cross-slope ripping will be carried out strictly on the contour.



**Figure 8:** DEM of DNM Final Landform Version LF3.1.3 showing the location of the different rehabilitation surfaces.

## 6 SIBERIA EVOLUTION MODEL RESULTS

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### 6.1 Overview

Using input parameters derived for the vegetated clay soil and vegetated soil-rock mixture applied to the landform, SIBERIA was run for a period of 300 years, with outputs being generated at 50, 100, 150, 200, 250, and 300 years within the simulation period.

At each output year, visualisations of rill/gully development were produced along with a table of maximum gully depths, average annual erosion rates, and cumulative average erosion depths. These rates and depths are calculated for the rehabilitated slopes within the modelling domain and exclude the surrounding undisturbed topography, the final landform top, and NUMA areas.

Negative material movements (i.e. erosion) that exceed 0.3m are considered gully erosion and are reported in the tables. The reported maximum gully depth is calculated as the average of the largest 1% of material movements.

Visualisations for 300 years are shown in the section below. All visualisations (50, 100, 200, and 300 years) are provided in Appendix A.

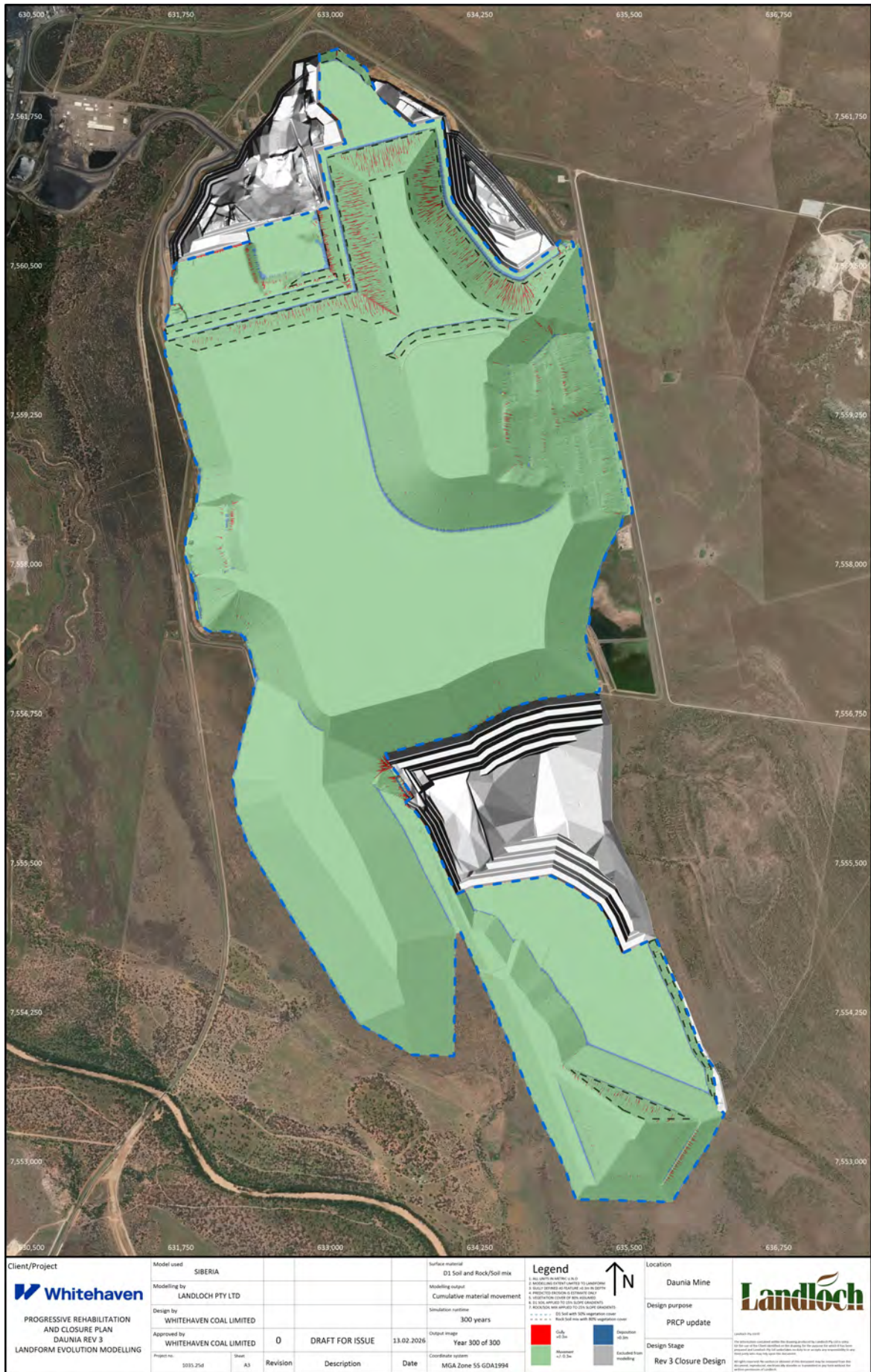
### 6.2 Results

Figure 9 shows SIBERIA output after 300 years of simulation. Results of the SIBERIA landform evolution modelling for Daunia Rev 3 are summarised in Table 3.

At a vegetation groundcover level of 80% (soil covered slopes), predicted erosion rates of the lower gradient slopes ( $\leq 15\%$ ) are low. The maximum gully depth after 300 years is predicted to be 0.4m. These surfaces are not prone to significant levels of gully erosion if the surface conditions (material type and groundcover levels) are achieved.

At a vegetation groundcover of 50% (soil-rock covered slopes), predicted erosion rates of the steeper gradient slopes (25%) are higher than those of the soil-covered slopes. Gully erosion is predicted to occur after 100 years and is located in the north where the inward facing curves wrap around the void. It is possible that the eroded sediment from these batters could be directed in the void, minimising its impact. Alternatively, this area could be armoured with slightly larger diameter rock in order to increase the erosion resistance while not changing the overall proportion of rock and fines. Such an approach is recommended if erosion monitoring data suggests that gully erosion is indeed occurring.

The average annual erosion rates for both the vegetated soil and vegetated soil-rock mixture surfaces are predicted to reduce through time. This indicates that the landform is predicted to trend towards increased erosional stability through time, and that the gullies that may be present are predicted to reduce in activity through time. The long-term erosion rates for both the vegetated soil and vegetated soil-rock mixture surfaces are predicted to reach a steady long-term annual erosion rate (3.0 t/ha/y for the vegetated soil and 3.8 t/ha/y for the vegetated soil-rock mixture) that has a low tendency to promote ongoing rill and gully erosion.



**Figure 9:** Predicted erosion and deposition depths of the DNM Final Landform Version LF3.1.3 after 300 years.

**Table 3:** Predicted erosion rates and gully depths for the DNM Final Landform Version LF3.1.3.

Simulation year	Maximum gully depth (m)	Average annual erosion (t/ha/y)	Cumulative average erosion (mm)
15% uniform slopes sheeted with clay soil supporting 80% groundcover			
50	-	4.0	17
100	-	3.3	30
150	-	3.1	56
200	-	3.1	82
250	0.3	3.0	107
300	0.4	3.0	133
25% uniform slopes sheeted with soil-rock mixture supporting 50% groundcover			
50	-	5.1	18
100	0.5	4.3	34
150	0.5	4.1	63
200	0.7	4.0	91
250	0.8	3.9	119
300	0.9	3.8	146

## 7 CONCLUSIONS

SIBERIA landform evolution model simulations indicate that the DNM Final Landform Version LF3.1.3 has a low tendency to promote ongoing rill and gully erosion provided the correct surface materials and the target levels of vegetation groundcover are achieved.

At a vegetation groundcover level of 80%, the soil-covered slopes with lower gradients ( $\leq 15\%$ ) are not prone to significant levels of gully erosion. At a vegetation groundcover of 50%, the soil-rock mixture covered slopes with steeper gradients (25%) are more prone to erosion in the initial 100 years. Gully erosion is predicted to occur in the north where the inward facing curves wrap around the void. It is possible that the eroded sediment from these batters could be directed in the void, minimising its impact.

The average annual erosion rates for both the vegetated soil and vegetated soil-rock mixture surfaces are predicted to reduce through time. This indicates that the landform is predicted to trend towards increased erosional stability through time, and that the gullies that may be present are predicted to reduce in activity through time. The long-term erosion rates for both the vegetated soil and vegetated soil-rock mixture surfaces are predicted to reach a steady long-term annual erosion rate that has a low tendency to promote ongoing rill and gully erosion.

The model output has assumed the use of a clay soil or a soil-rock mixture as the surface material. Clay soils were found to be the dominant soils across DNM. Permian spoil is also likely available for use in the creation of a soil-rock mixture. Weathered sediments and clays were found to be unsuitable for plant growth and prone to very high rates of erosion. They should not be used to create a soil-rock mixture for use in rehabilitation.

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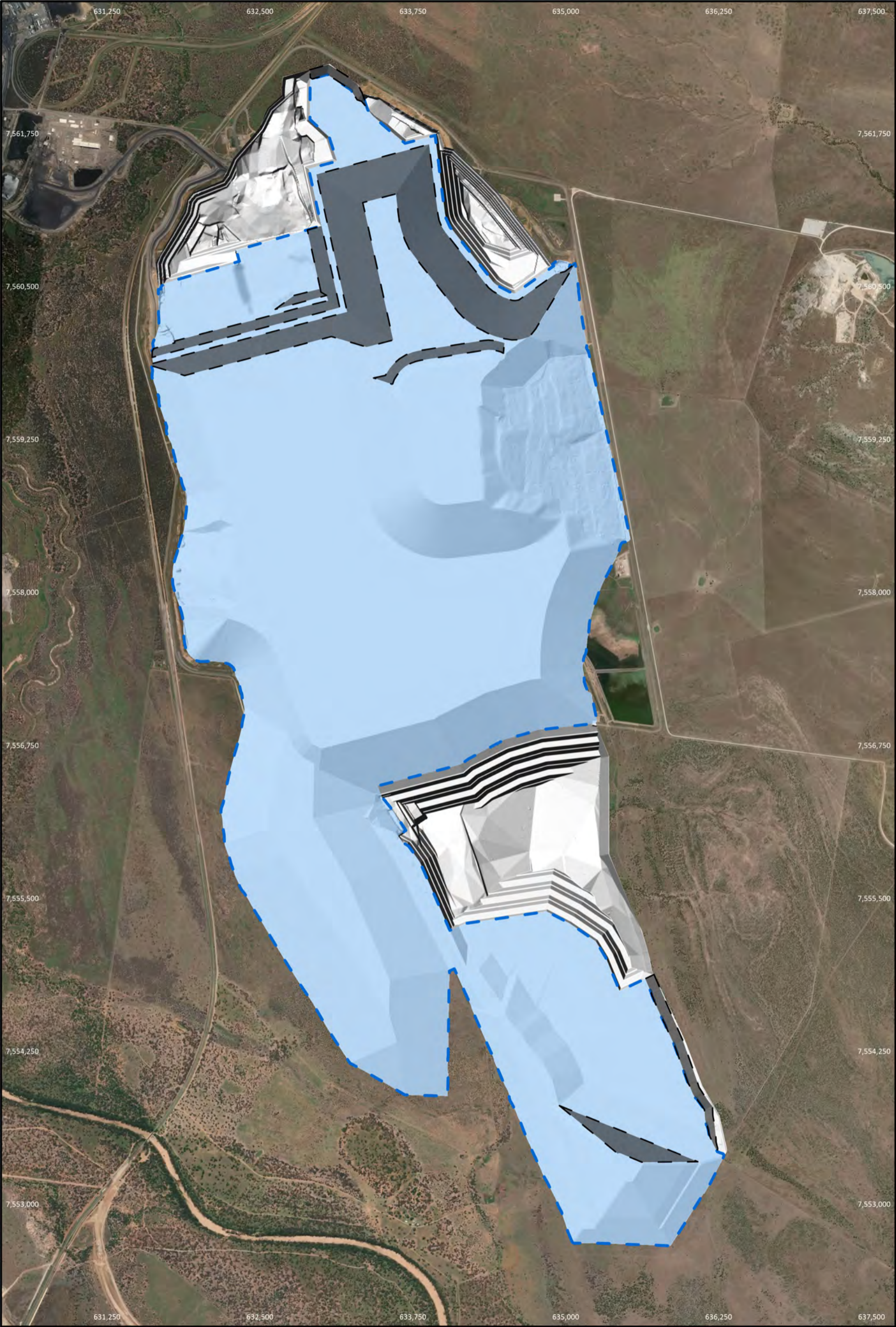
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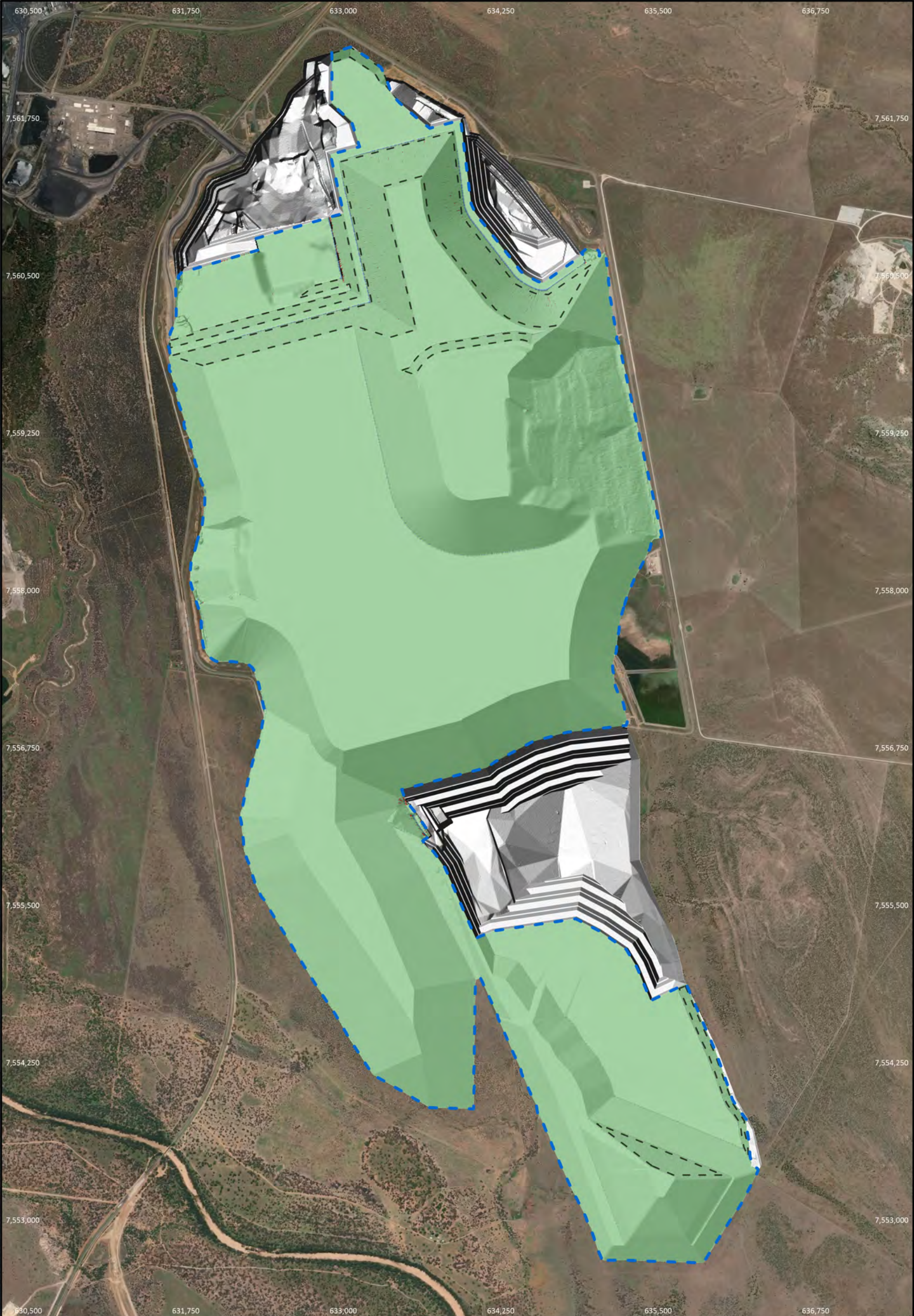
## APPENDIX A: SIBERIA VISUALISATIONS

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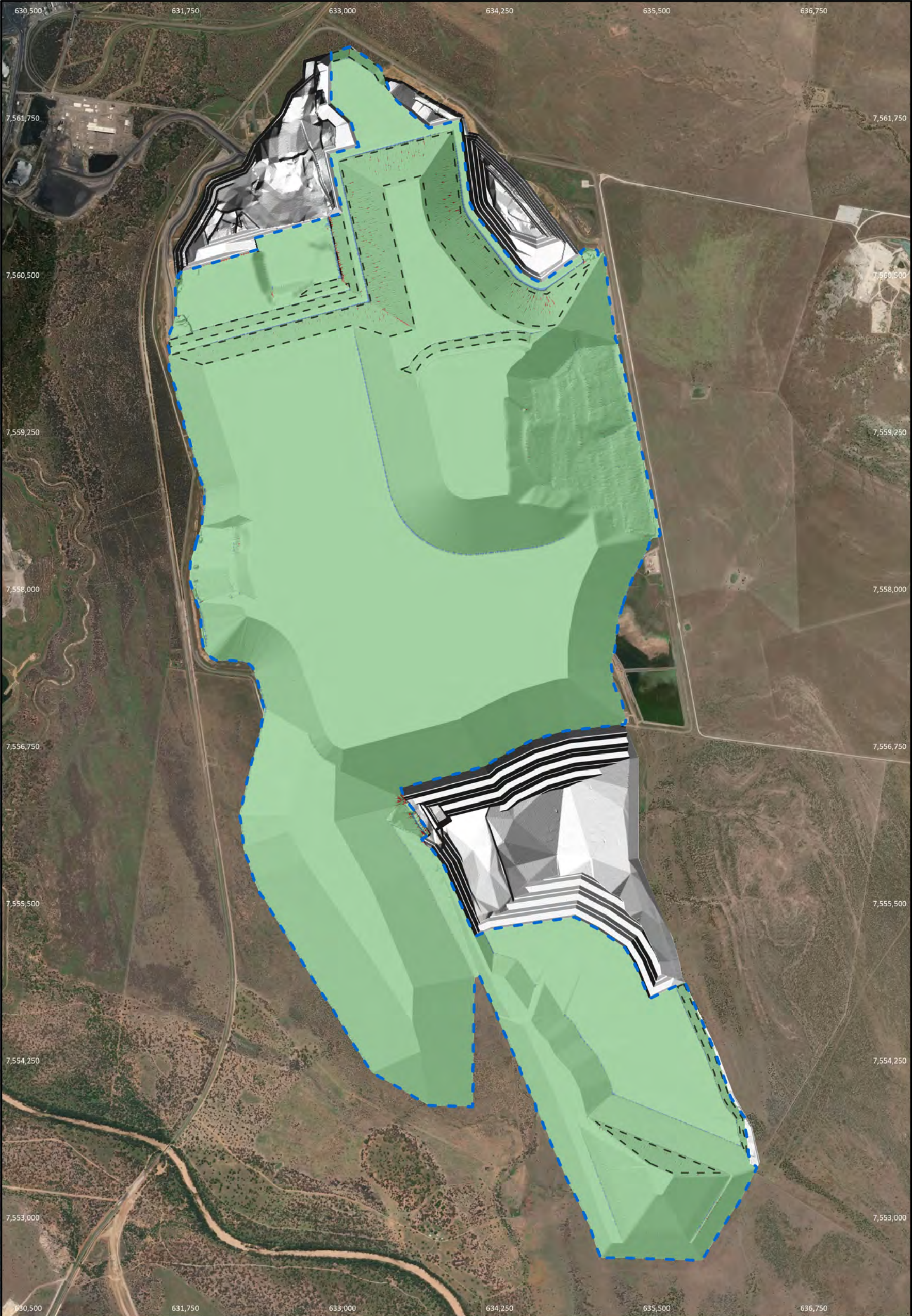
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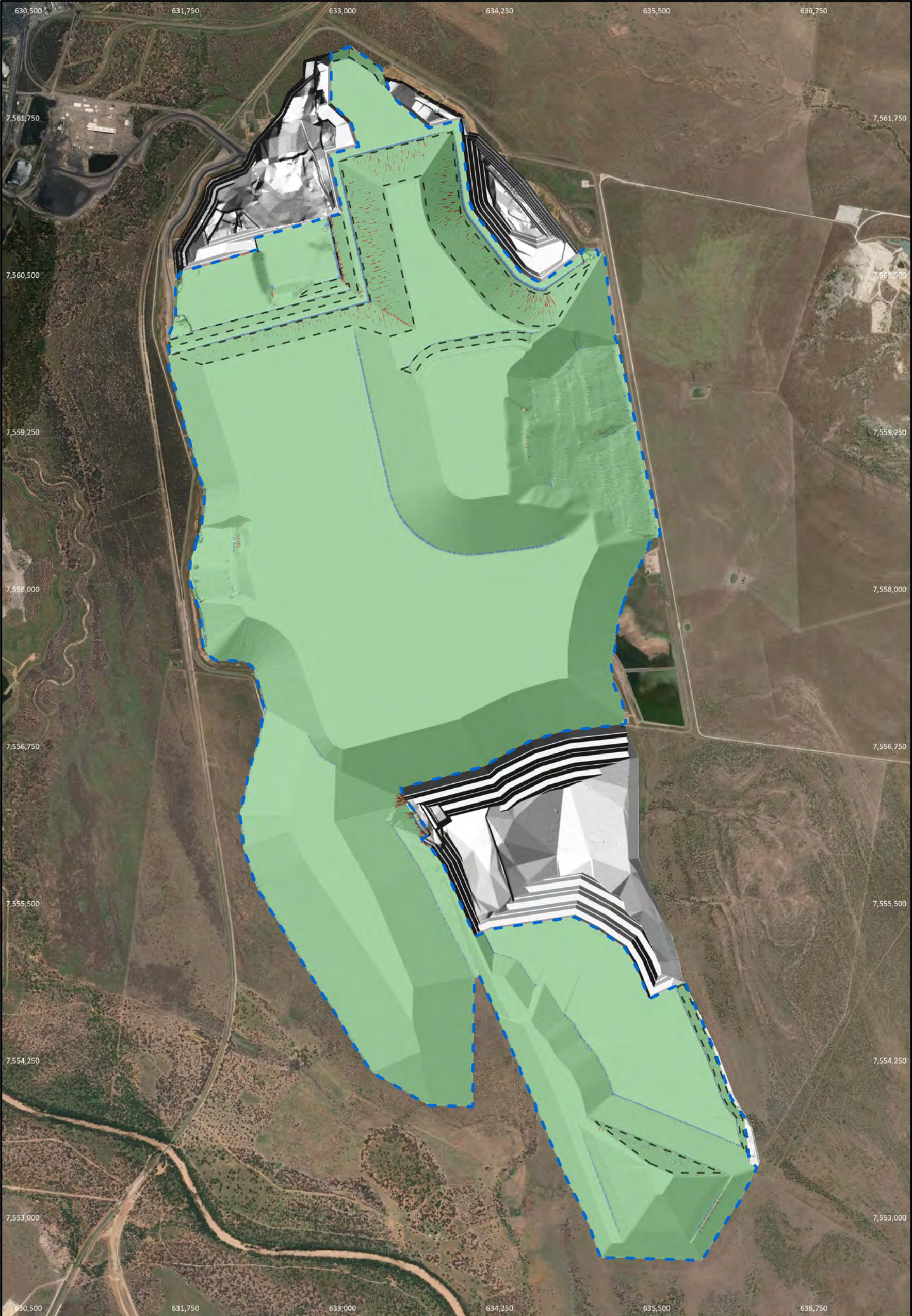
<b>Client/Project</b>  PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING	<b>Legend</b>  D1 Soil with 50% vegetation cover  Rock: Soil mix with 80% vegetation cover  Areas excluded from modelling		Coordinate system MGA Zone 55 GDA1994				Location Daunia Mine	 <small>Landloch Pty Ltd ©</small> The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to or accepts any responsibility to any third party who may rely upon this document. All rights reserved. No portion or element of this document may be reproduced from this document, regardless of the medium, electronically stored or transmitted in any form without the written permission of Landloch.
			Drawing LANDFORM OVERVIEW				Design phase Daunia Revision 3	
			Design by WHITEHAVEN COAL LIMITED	0	DRAFT FOR ISSUE	13.02.2026		
			Project no. 1035.25d	Sheet A3	Revision	Description	Date	



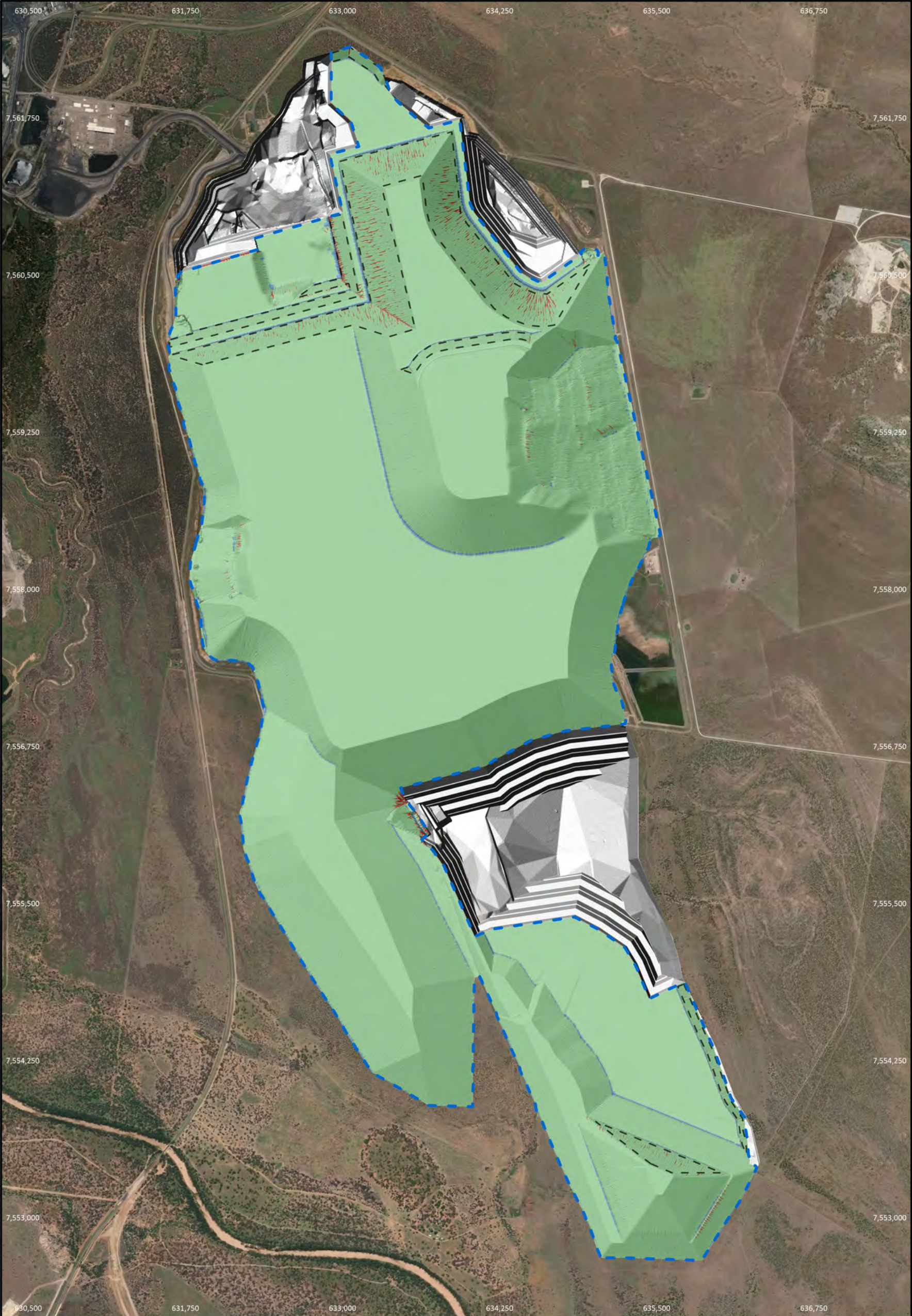
<b>Client/Project</b>  PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING		<b>Model used</b> SIBERIA		<b>Surface material</b> D1 Soil and Rock/Soil mix		<b>Legend</b> 1. ALL UNITS IN METRIC U.N.D. 2. MODELLING EXTENT LIMITED TO LANDFORMS 3. GULLY DEFINED AS FEATURE >0.3m IN DEPTH 4. PREDICTED EROSION IS ESTIMATE ONLY 5. VEGETATION COVER OF 80% ASSUMED 6. D1 SOIL APPLIED TO 15% SLOPE GRADIENTS 7. ROCK/SOIL MIX APPLIED TO 25% SLOPE GRADIENTS - - - - - D1 Soil with 50% vegetation cover - - - - - Rock-Soil mix with 80% vegetation cover 		<b>Location</b> Daunia Mine		
<b>Modelling by</b> LANDLOCH PTY LTD		<b>Modelling output</b> Cumulative material movement		<b>Simulation runtime</b> 300 years		<b>Output image</b> Year 50 of 300		<b>Design purpose</b> PRCP update		
<b>Design by</b> WHITEHAVEN COAL LIMITED		<b>Approved by</b> WHITEHAVEN COAL LIMITED		0	DRAFT FOR ISSUE	13.02.2026	<b>Design Stage</b> Rev 3 Closure Design		<small>Landloch Pty Ltd ©          The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility to any third party who may rely upon this document.          All rights reserved. No section or element of this document may be removed from this document, reproduced, electronically stored or transmitted in any form without the written permission of Landloch.</small>	
<b>Project no.</b> 1035.25d	<b>Sheet</b> A3	<b>Revision</b>	<b>Description</b>	<b>Date</b>	<b>Coordinate system</b> MGA Zone 55 GDA1994					



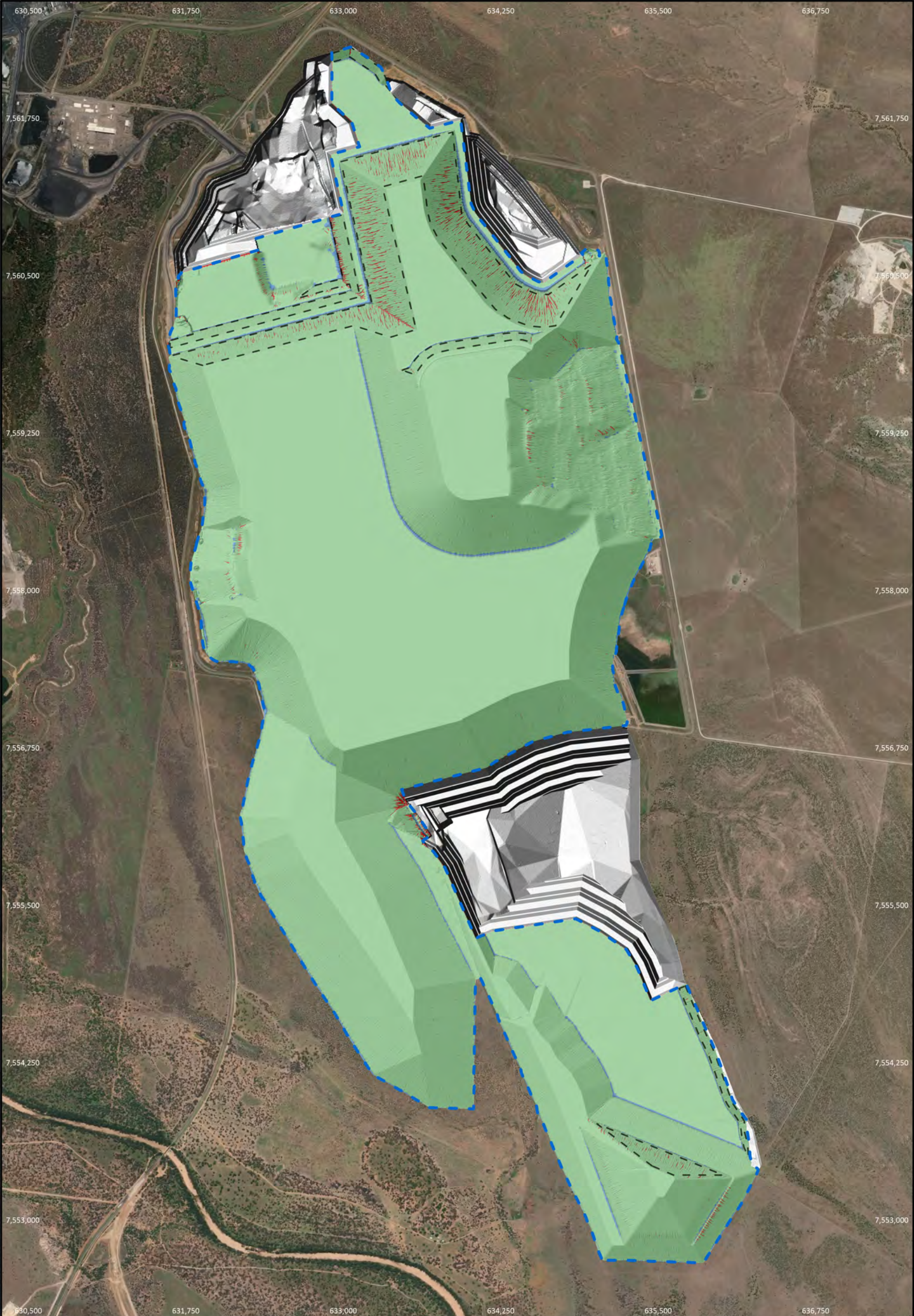
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<b>Modelling by</b> LANDLOCH PTY LTD		<b>Modelling output</b> Cumulative material movement		<b>Simulation runtime</b> 300 years		<b>Output image</b> Year 100 of 300		<b>Design purpose</b> PRCP update			
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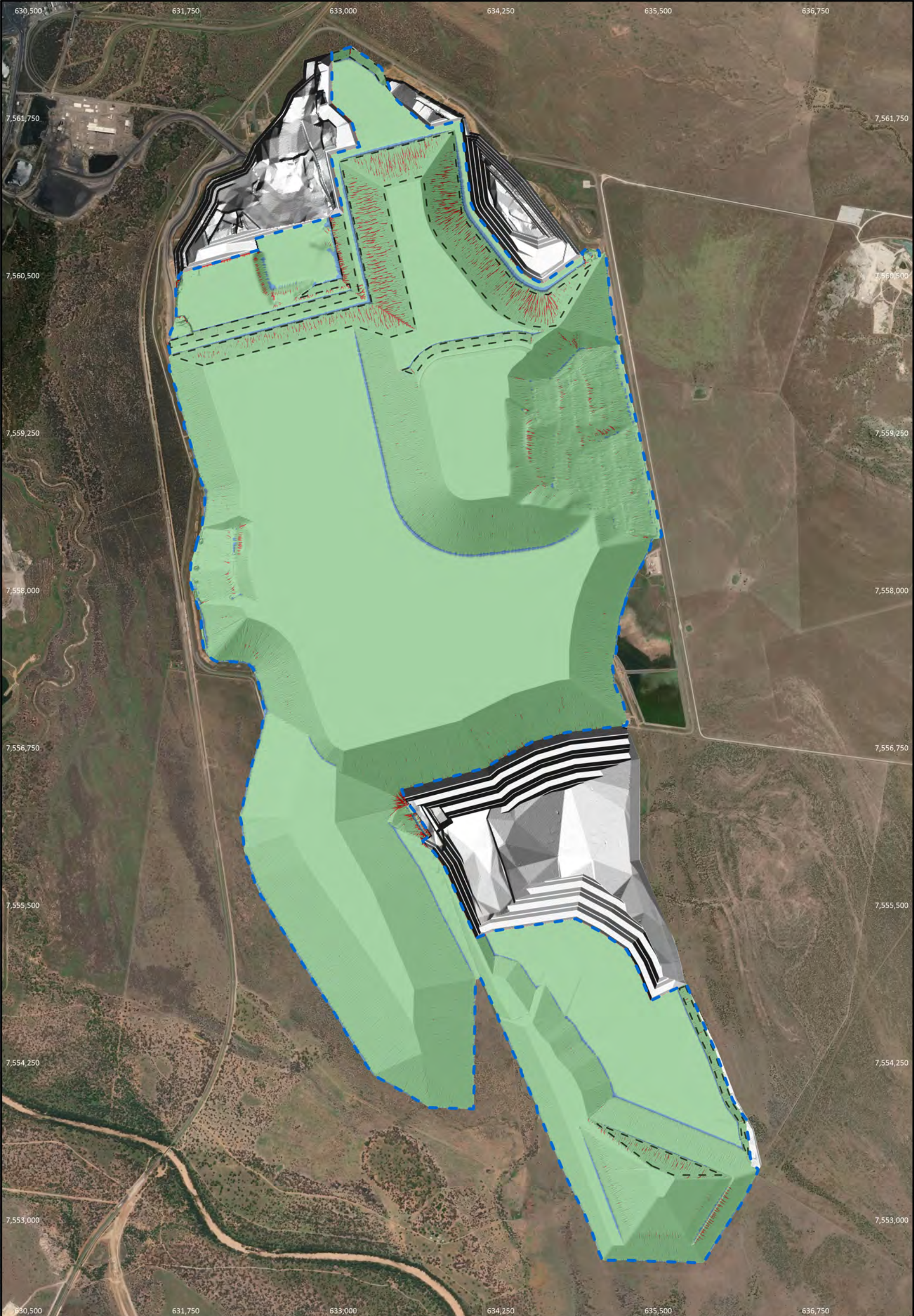
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Project no. 1035.25d	Sheet A3	Revision	Description	Date	Coordinate system MGA Zone 55 GDA1994					




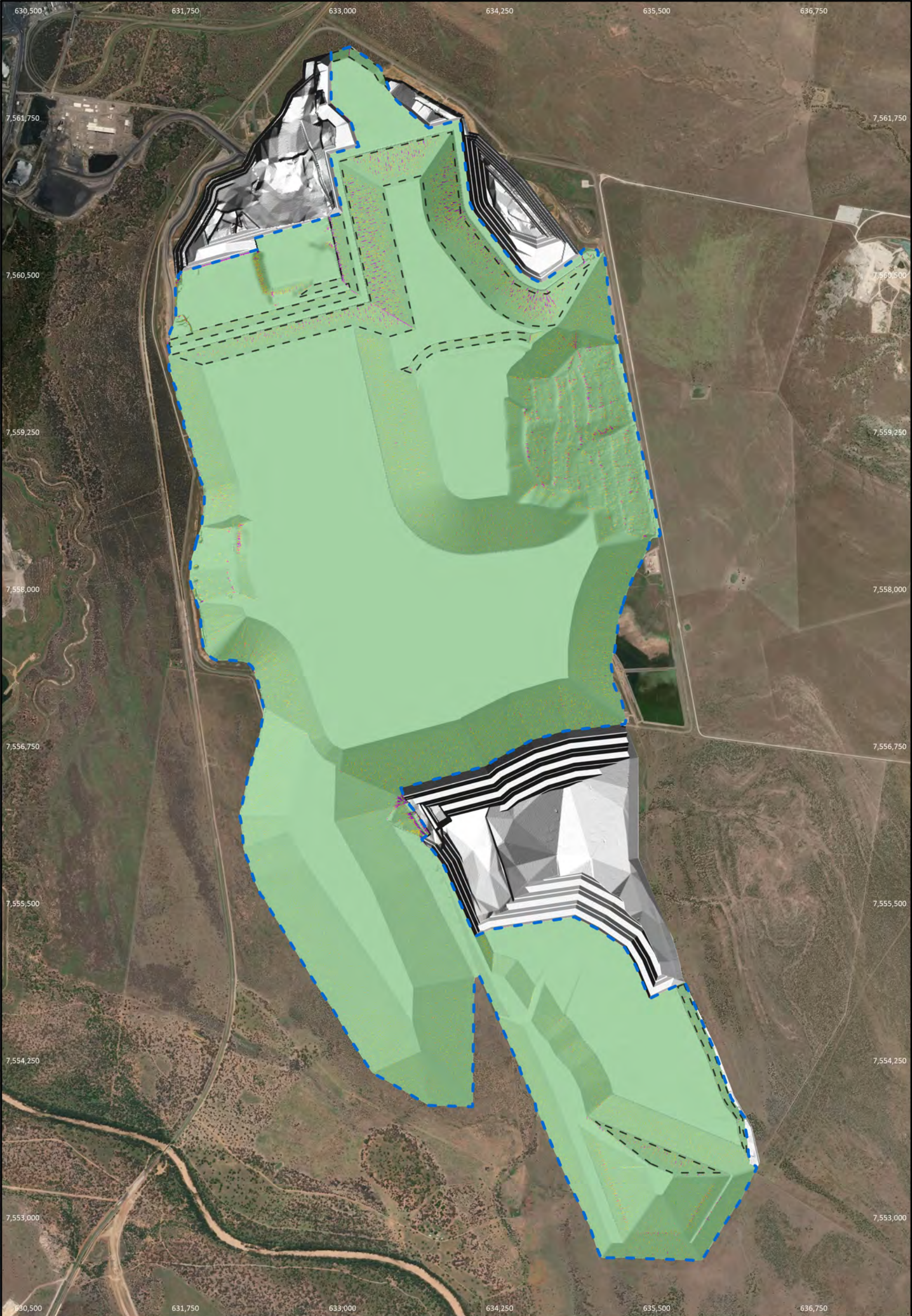
<b>Client/Project</b>  PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING		<b>Model used</b> SIBERIA		<b>Surface material</b> D1 Soil and Rock/Soil mix		<b>Legend</b> 1. ALL UNITS IN METRIC U.N.D. 2. MODELLING EXTENT LIMITED TO LANDFORMS 3. QUANTITY DEFINED AS FEATURE 0.3m IN DEPTH 4. PREDICTED EROSION IS ESTIMATE ONLY 5. VEGETATION COVER OF 80% ASSUMED 6. D1 SOIL APPLIED TO 15% SLOPE GRADIENTS 7. ROCK/SOIL MIX APPLIED TO 25% SLOPE GRADIENTS 8. D1 Soil with 50% vegetation cover 9. Rock-Soil mix with 80% vegetation cover Deposition >0.3m Excluded from modelling Cully >0.3m Movement +/- 0.3m		<b>Location</b> Daunia Mine			
<b>Modelling by</b> LANDLOCH PTY LTD		<b>Modelling output</b> Cumulative material movement		<b>Simulation runtime</b> 300 years		<b>Output image</b> Year 200 of 300		<b>Design purpose</b> PRCP update		Landloch Pty Ltd © <small>The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility to any third party who may rely upon this document.</small>	
<b>Design by</b> WHITEHAVEN COAL LIMITED		<b>Approved by</b> WHITEHAVEN COAL LIMITED		<b>Revision</b> 0		<b>Description</b> DRAFT FOR ISSUE		<b>Date</b> 13.02.2026		<b>Design Stage</b> Rev 3 Closure Design	
<b>Project no.</b> 1035.25d		<b>Sheet</b> A3		<b>Coordinate system</b> MGA Zone 55 GDA1994		<b>Revision</b> Description		<b>Date</b> Date		<small>All rights reserved. No section or element of this document may be removed from this document, reproduced, electronically stored or transmitted in any form without the written permission of Landloch.</small>	



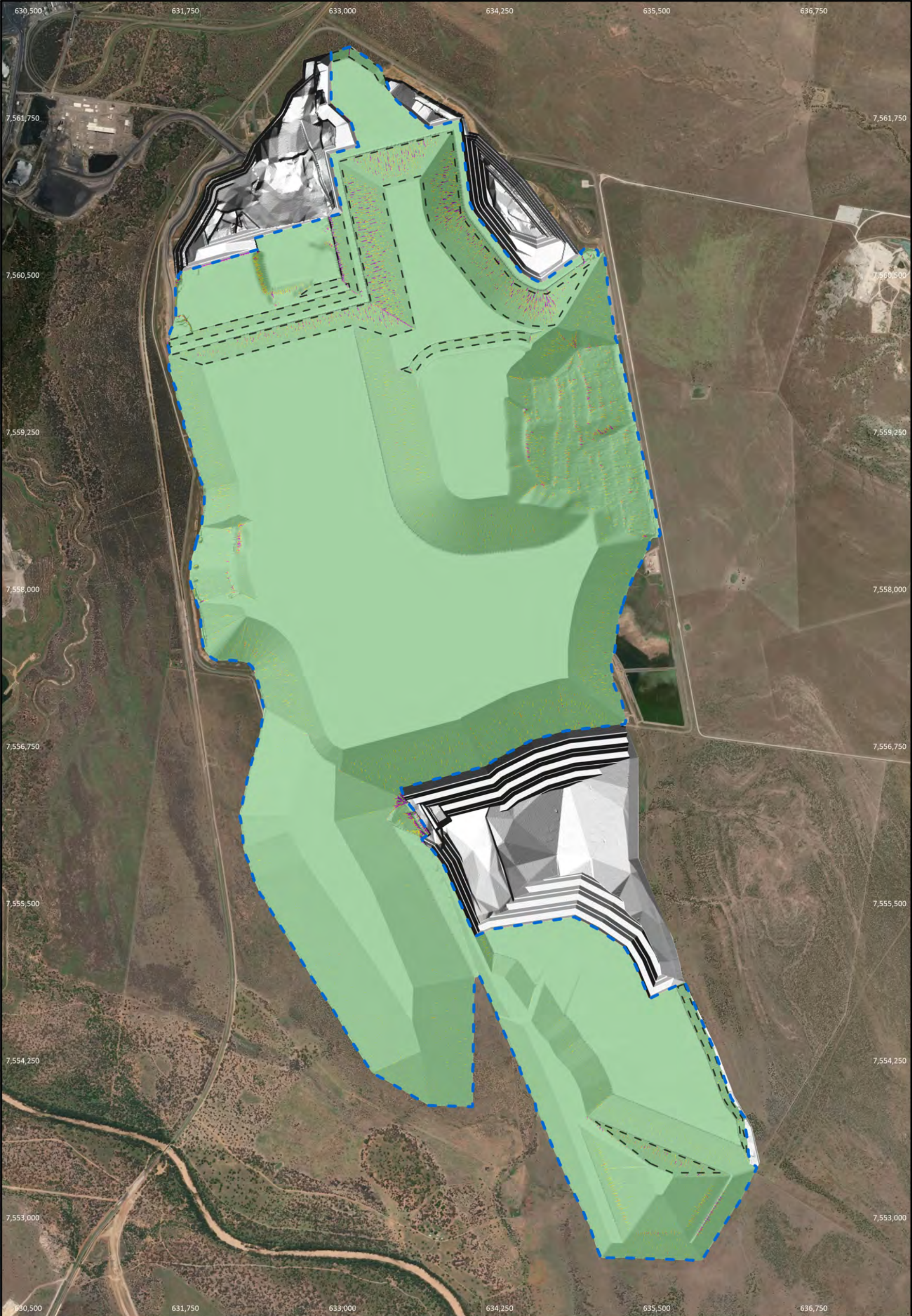
Client/Project		Model used			Surface material		Legend		Location			
 <b>Whitehaven</b> PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING		SIBERIA			D1 Soil and Rock/Soil mix		1. ALL UNITS IN METRIC U.N.D. 2. MODELLING EXTENT LIMITED TO LANDFORMS 3. Gully defined as feature >0.3m in depth 4. PREDICTED EROSION IS ESTIMATE ONLY 5. VEGETATION COVER OF 80% ASSUMED 6. D1 SOIL APPLIED TO 15% SLOPE GRADIENTS 7. ROCK/SOIL MIX APPLIED TO 25% SLOPE GRADIENTS - - - - - D1 Soil with 50% vegetation cover - - - - - Rock-Soil mix with 80% vegetation cover		Daunia Mine		 Landloch Pty Ltd © The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility to any third party who may rely upon this document.	
Modelling by		Design by			Modelling output		Simulation runtime		Design purpose			
LANDLOCH PTY LTD		WHITEHAVEN COAL LIMITED			Cumulative material movement		300 years		PRCP update			
Approved by		Revision			Output image		Coordinate system		Design Stage			
WHITEHAVEN COAL LIMITED		0			Year 250 of 300		MGA Zone 55 GDA1994		Rev 3 Closure Design			
Project no.		Revision			Date		Coordinate system		Design Stage			
1035.25d		A3			13.02.2026		MGA Zone 55 GDA1994		Rev 3 Closure Design			



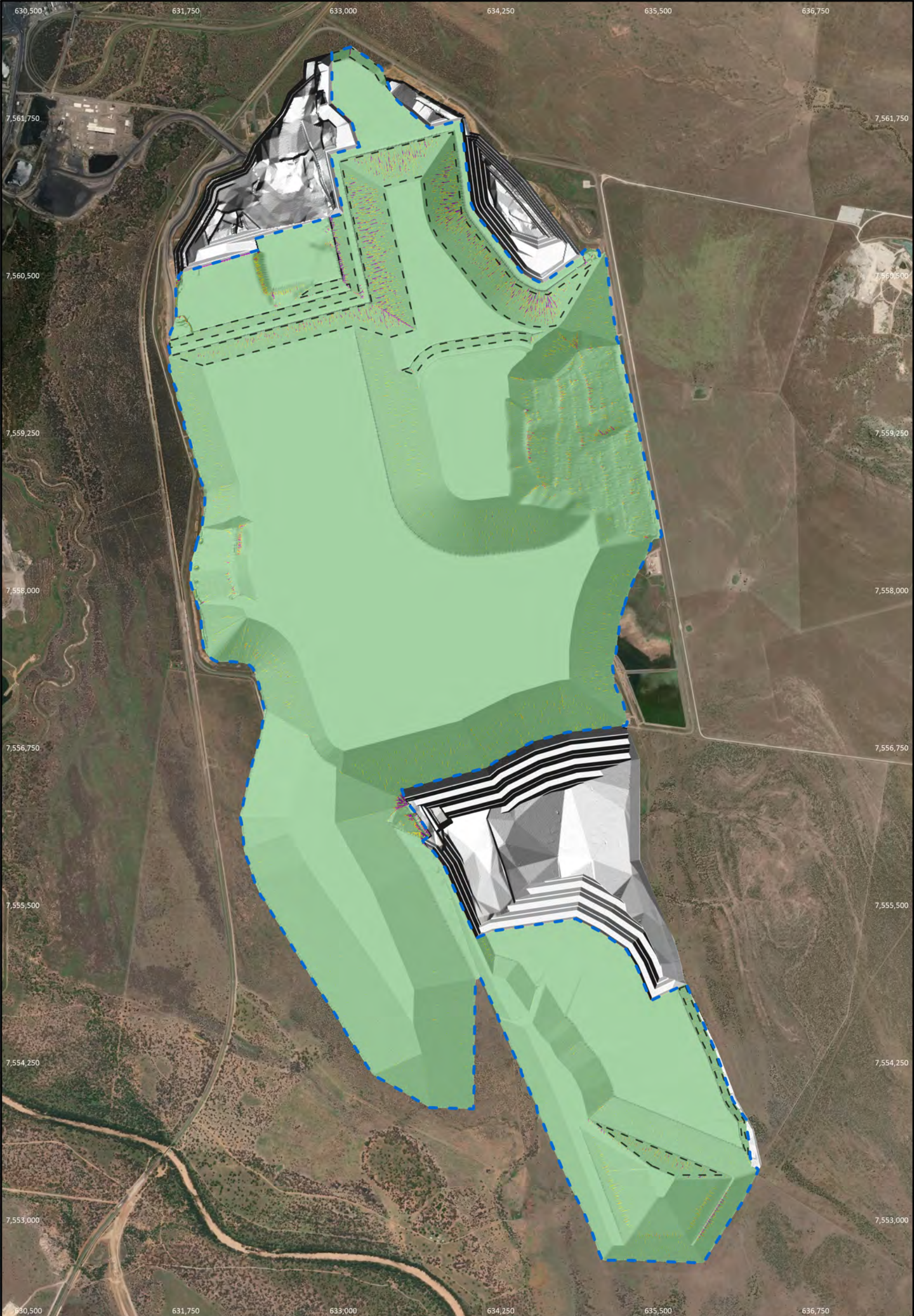
Client/Project		Model used			Surface material		Legend		Location		
Whitehaven		SIBERIA			D1 Soil and Rock/Soil mix		1. ALL UNITS IN METRIC U.N.D. 2. MODELLING EXTENT LIMITED TO LANDFORMS 3. Gully defined as feature >0.3m in depth 4. PREDICTED EROSION IS ESTIMATE ONLY 5. VEGETATION COVER OF 80% ASSUMED 6. D1 SOIL APPLIED TO 15% SLOPE GRADIENTS 7. ROCK/SOIL MIX APPLIED TO 25% SLOPE GRADIENTS 8. D1 Soil with 50% vegetation cover 9. Rock-Soil mix with 80% vegetation cover		Daunia Mine		
PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING		Modelling by			Modelling output				Design purpose		
		LANDLOCH PTY LTD			Cumulative material movement		   		PRCP update		
		Design by			Simulation runtime				Design Stage		
		WHITEHAVEN COAL LIMITED			300 years				Rev 3 Closure Design		
		Approved by			Output image						
		WHITEHAVEN COAL LIMITED			Year 300 of 300						
		Revision			Date						
		0			13.02.2026						
		Description			Coordinate system						
		DRAFT FOR ISSUE			MGA Zone 55 GDA1994						
Project no.		Sheet								<small>Landloch Pty Ltd ©</small> <small>The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility for any third party who may rely upon this document.</small> <small>All rights reserved. No section or element of this document may be removed from this document, reproduced, electronically stored or transmitted in any form without the written permission of Landloch.</small>	
1035.25d		A3									






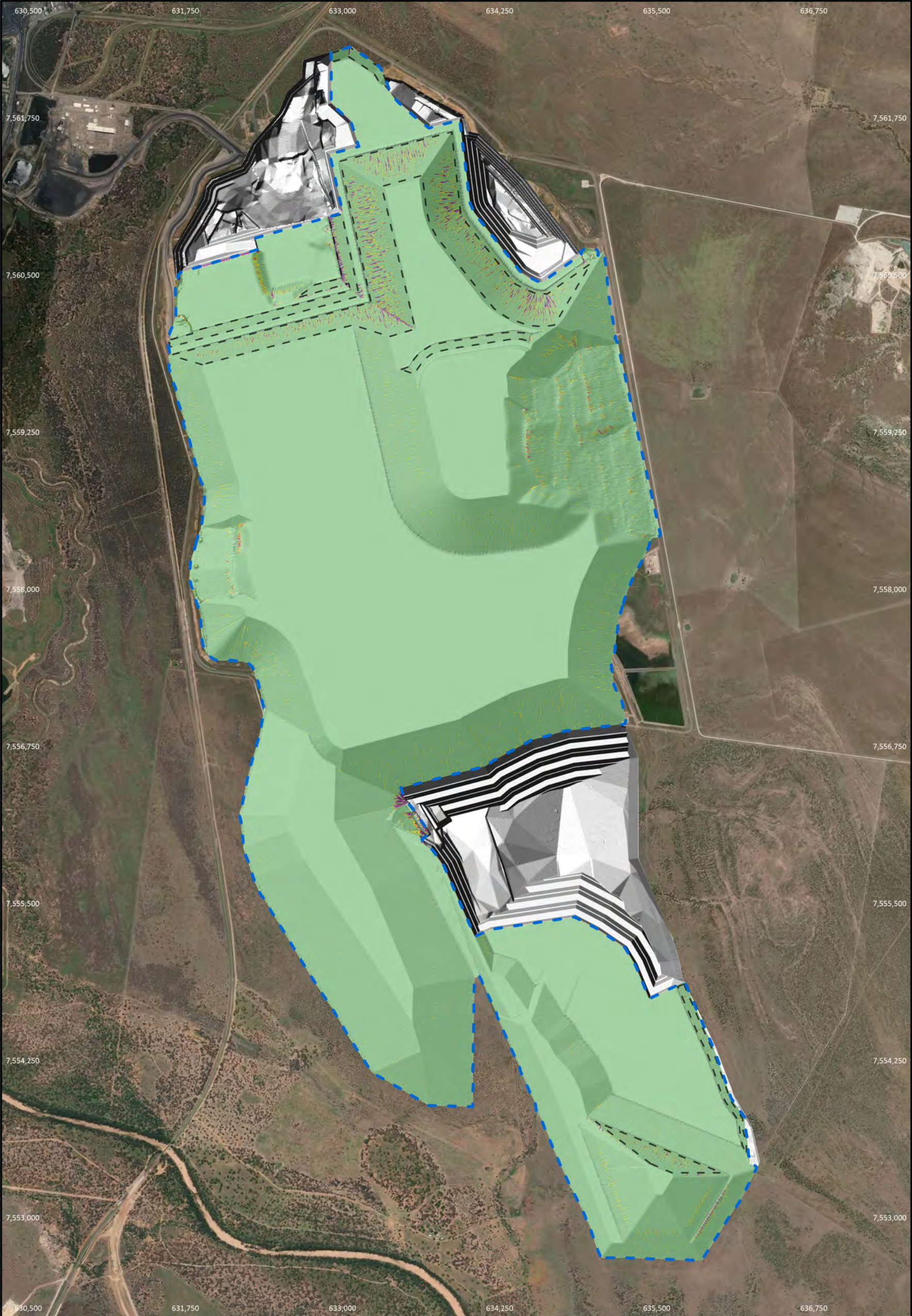
<b>Client/Project</b>  PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING		<b>Model used</b> SIBERIA		<b>Surface material</b> D1 Soil and Rock/Soil mix		<b>Legend</b> 1. ALL UNITS IN METRIC U.N.I.T. 2. MODELLING EXTENT LIMITED TO LANDFORM 3. PREDICTED EROSION IS ESTIMATE ONLY 4. VEGETATION COVER OF 80% ASSUMED 5. D1 SOIL APPLIED TO 15% SLOPE GRADIENTS 6. ROCK/SOIL MIX APPLIED TO 25% SLOPE GRADIENTS - - - - D1 Soil with 50% vegetation cover - - - - Rock-Soil mix with 80% vegetation cover Green Erosion <math>< 5 \text{ t/ha/y}</math> Yellow Erosion <math>> 5 \text{ t/ha/y}</math> Orange Erosion <math>> 7.5 \text{ t/ha/y}</math> Purple Erosion <math>> 10 \text{ t/ha/y}</math>		<b>Location</b> Daunia Mine		
<b>Modelling by</b> LANDLOCH PTY LTD		<b>Modelling output</b> Rate of erosion (t/ha/y)		<b>Simulation runtime</b> 300 years		<b>Output image</b> Year 50 of 300		<b>Design purpose</b> PRCP update		
<b>Design by</b> WHITEHAVEN COAL LIMITED		<b>Approved by</b> WHITEHAVEN COAL LIMITED		0	DRAFT FOR ISSUE	13.02.2026	<b>Design Stage</b> Rev 3 Closure Design		<small>Landloch Pty Ltd ©          The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility to any third party who may rely upon this document.          All rights reserved. No section or element of this document may be removed from this document, reproduced, electronically stored or transmitted in any form without the written permission of Landloch.</small>	
Project no. 1035.25d	Sheet A3	Revision	Description	Date	Coordinate system MGA Zone 55 GDA1994					



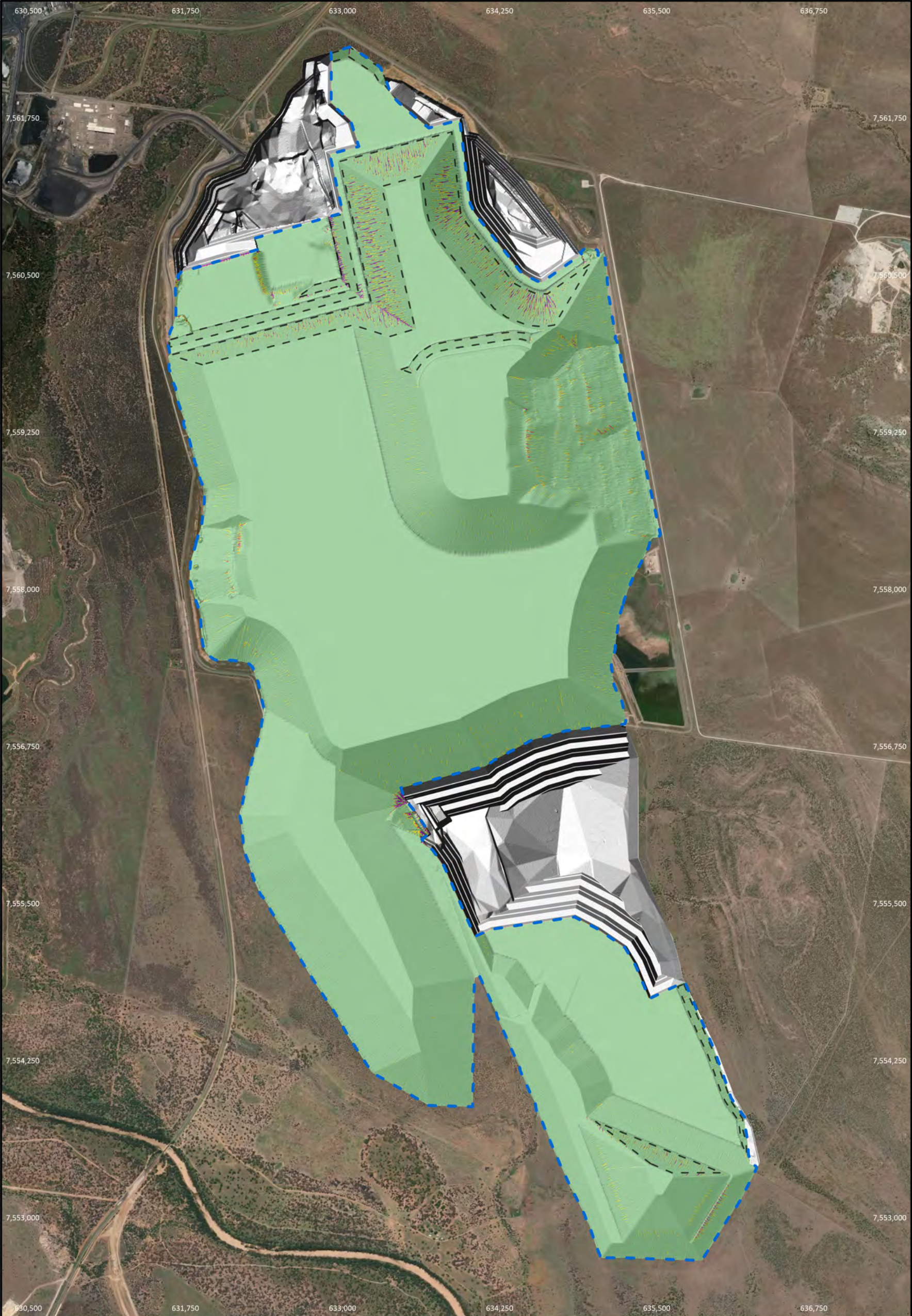
<b>Client/Project</b>  PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING		<b>Model used</b> SIBERIA		<b>Surface material</b> D1 Soil and Rock/Soil mix		<b>Legend</b> 1. ALL UNITS IN METRIC U.N.I.T 2. MODELLING EXTENT LIMITED TO LANDFORM 3. PREDICTED EROSION IS ESTIMATE ONLY 4. VEGETATION COVER OF 80% ASSUMED 5. D1 SOIL APPLIED TO 15% SLOPE GRADIENTS 6. ROCK/SOIL MIX APPLIED TO 20% SLOPE GRADIENTS --- D1 Soil with 50% vegetation cover --- Rock/Soil mix with 80% vegetation cover Erosion <5 t/ha/y Erosion >5 t/ha/y Erosion >7.5 t/ha/y Erosion >10 t/ha/y		<b>Location</b> Daunia Mine			
<b>Modelling by</b> LANDLOCH PTY LTD		<b>Modelling output</b> Rate of erosion (t/ha/y)		<b>Simulation runtime</b> 300 years		<b>Output image</b> Year 100 of 300		<b>Design purpose</b> PRCP update		Landloch Pty Ltd © <small>The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility to any third party who may rely upon this document.</small> <small>All rights reserved. No section or element of this document may be removed from this document, reproduced, electronically stored or transmitted in any form without the written permission of Landloch.</small>	
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<b>Project no.</b> 1035.25d		<b>Sheet</b> A3		<b>Revision</b> 0		<b>Description</b> DRAFT FOR ISSUE		<b>Date</b> 13.02.2026		<b>Design Stage</b> Rev 3 Closure Design	



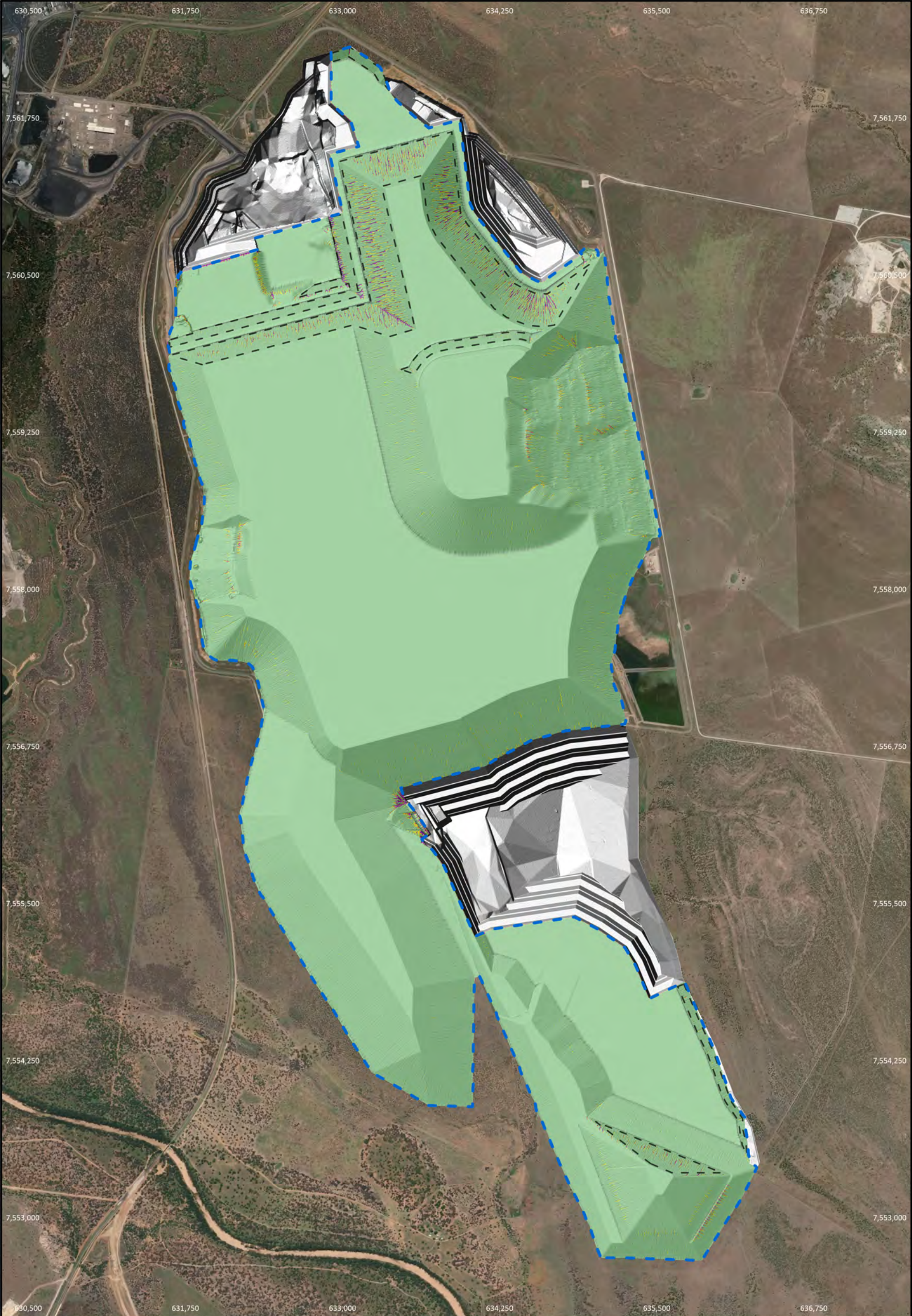
<b>Client/Project</b>  PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING		<b>Model used</b> SIBERIA		<b>Surface material</b> D1 Soil and Rock/Soil mix		<b>Legend</b> 1. ALL UNITS IN METRIC U.N.I.T 2. MODELLING EXTENT LIMITED TO LANDFORM 3. PREDICTED EROSION IS ESTIMATE ONLY 4. VEGETATION COVER OF 80% ASSUMED 5. D1 SOIL APPLIED TO 15% SLOPE GRADIENTS 6. ROCK/SOIL MIX APPLIED TO 20% SLOPE GRADIENTS --- D1 Soil with 50% vegetation cover --- Rock/Soil mix with 80% vegetation cover Erosion <5 t/ha/y Erosion >5 t/ha/y Erosion >7.5 t/ha/y Erosion >10 t/ha/y		<b>Location</b> Daunia Mine 		 Landloch Pty Ltd © The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility to any third party who may rely upon this document.	
<b>Modelling by</b> LANDLOCH PTY LTD		<b>Modelling output</b> Rate of erosion (t/ha/y)		<b>Simulation runtime</b> 300 years		<b>Output image</b> Year 150 of 300		<b>Design purpose</b> PRCP update		<b>Design Stage</b> Rev 3 Closure Design	
<b>Design by</b> WHITEHAVEN COAL LIMITED		<b>Approved by</b> WHITEHAVEN COAL LIMITED		<b>Revision</b> 0		<b>Description</b> DRAFT FOR ISSUE		<b>Date</b> 13.02.2026		<b>Coordinate system</b> MGA Zone 55 GDA1994	
<b>Project no.</b> 1035.25d	<b>Sheet</b> A3	<b>Revision</b>	<b>Description</b>	<b>Date</b>	<b>Coordinate system</b>	All rights reserved. No section or element of this document may be removed from this document, reproduced, electronically stored or transmitted in any form without the written permission of Landloch.					



<b>Client/Project</b>  PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING		<b>Model used</b> SIBERIA		<b>Surface material</b> D1 Soil and Rock/Soil mix		<b>Legend</b> 1. ALL UNITS IN METRIC U.N.I.T 2. MODELLING EXTENT LIMITED TO LANDFORM 3. PREDICTED EROSION IS ESTIMATE ONLY 4. VEGETATION COVER OF 80% ASSUMED 5. D1 SOIL APPLIED TO 15% SLOPE GRADIENTS 6. ROCK/SOIL MIX APPLIED TO 20% SLOPE GRADIENTS --- D1 Soil with 50% vegetation cover --- Rock/Soil mix with 80% vegetation cover Erosion <5 t/ha/y Erosion >5 t/ha/y Erosion >7.5 t/ha/y Erosion >10 t/ha/y		<b>Location</b> Daunia Mine			
<b>Modelling by</b> LANDLOCH PTY LTD		<b>Modelling output</b> Rate of erosion (t/ha/y)		<b>Simulation runtime</b> 300 years		<b>Output image</b> Year 200 of 300		<b>Design purpose</b> PRCP update		<b>Design Stage</b> Rev 3 Closure Design	
<b>Design by</b> WHITEHAVEN COAL LIMITED		<b>Approved by</b> WHITEHAVEN COAL LIMITED		<b>Revision</b> 0		<b>Description</b> DRAFT FOR ISSUE		<b>Date</b> 13.02.2026		<small>Landloch Pty Ltd ©          The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility to any third party who may rely upon this document.          All rights reserved. No section or element of this document may be removed from this document, reproduced, electronically stored or transmitted in any form without the written permission of Landloch.</small>	
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<b>Client/Project</b>  PROGRESSIVE REHABILITATION AND CLOSURE PLAN DAUNIA REV 3 LANDFORM EVOLUTION MODELLING		<b>Model used</b> SIBERIA		<b>Surface material</b> D1 Soil and Rock/Soil mix		<b>Legend</b> 1. ALL UNITS IN METRIC U.N.I.T 2. MODELLING EXTENT LIMITED TO LANDFORM 3. PREDICTED EROSION IS ESTIMATE ONLY 4. VEGETATION COVER OF 80% ASSUMED 5. D1 SOIL APPLIED TO 15% SLOPE GRADIENTS 6. ROCK/SOIL MIX APPLIED TO 20% SLOPE GRADIENTS --- D1 Soil with 50% vegetation cover --- Rock/Soil mix with 80% vegetation cover Erosion <5 t/ha/y Erosion >5 t/ha/y Erosion >7.5 t/ha/y Erosion >10 t/ha/y		<b>Location</b> Daunia Mine			
<b>Modelling by</b> LANDLOCH PTY LTD		<b>Modelling output</b> Rate of erosion (t/ha/y)		<b>Simulation runtime</b> 300 years		<b>Output image</b> Year 250 of 300		<b>Design purpose</b> PRCP update		Landloch Pty Ltd © <small>The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility to any third party who may rely upon this document.</small>	
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<b>Modelling by</b> LANDLOCH PTY LTD		<b>Modelling output</b> Rate of erosion (t/ha/y)		<b>Simulation runtime</b> 300 years		<b>Output image</b> Year 300 of 300		<b>Design purpose</b> PRCP update		Landloch Pty Ltd © <small>The information contained within this drawing produced by Landloch Pty Ltd is solely for the use of the Client identified on the drawing for the purpose for which it has been prepared and Landloch Pty Ltd undertakes no duty to accept any responsibility to any third party who may rely upon this document.</small> <small>All rights reserved. No section or element of this document may be removed from this document, reproduced, electronically stored or transmitted in any form without the written permission of Landloch.</small>	
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