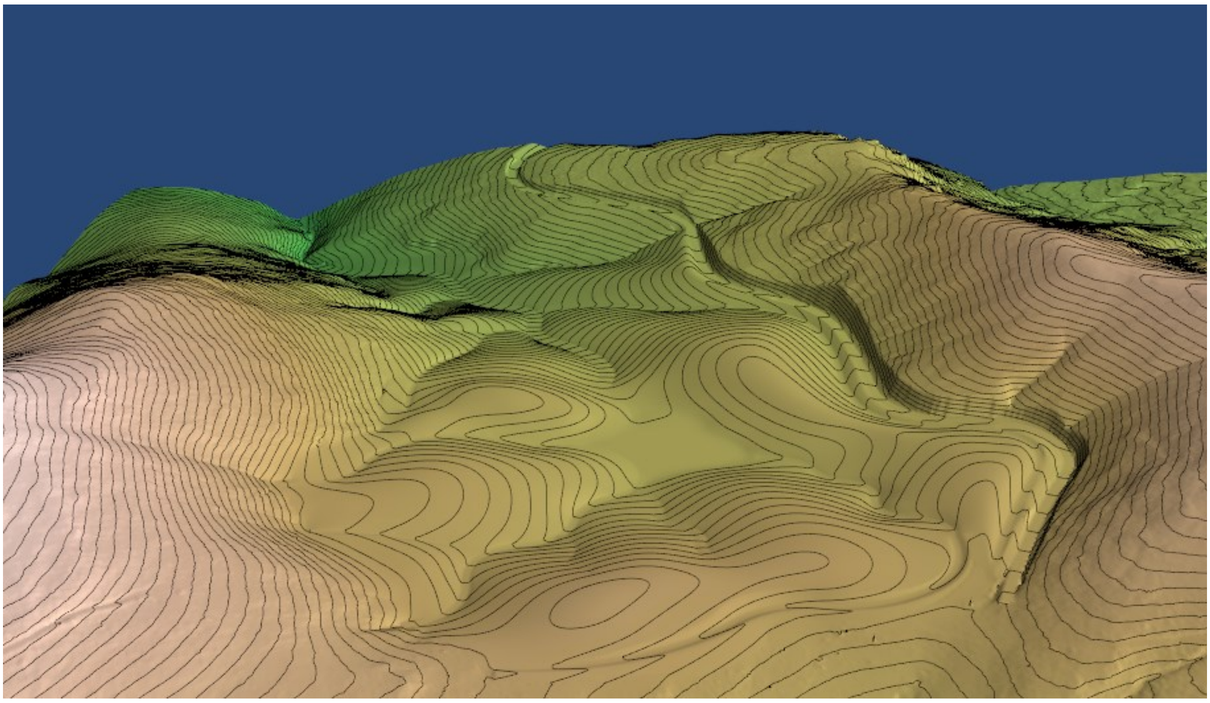
Alinta Energy

Oven Mountain Pumped Storage Scheme

Conceptual Landform Design of the Permanent Spoil Emplacement Areas

June 2024

Confidential



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WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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Abbreviations

The Project	Oven Mountain Pumped Hydroelectric Energy Storage Project
PSE	Permanent Spoil Emplacement
ARI	Annual Recurrence Interval
REZ	Renewable Energy Zone
TF	Topography Factor
BoD	Basis of Design
LEM	Landform Evolution Model
PSDs	Particle Size Distribution
RUSLE	Revised Universal Soil Loss Equation
WEPP	Water Erosion Prediction Project
D_{50}	Nominal Rock Size Diameter

Executive summary

The Oven Mountain Pumped Hydroelectric Energy Storage Project (the Project) is a proposed 'off river' 900MW electricity project located adjacent to the Macleay River between Armidale and Kempsey New South Wales, Australia. The Project comprises an upper dam and lower dam linked by a tunnel feeding an underground hydroelectric power station.

The Project was available for public inquiry for two months to October of 2023, and as part of the Response to submissions, in March 2024 Alinta Energy appointed WSP Australia to assist with the conceptual landform design of the Permanent Spoil Emplacement (PSE) areas.

Because of the nature of the terrain, access between the upper and lowers dams by large earth moving equipment is not practical. Consequently, the surplus volumes of spoil generated need to be managed separately at the upper and lower sites. At the upper end of the project, excavation of the dam will generate surplus rock, some of which will be used in the construction of the dam wall, but a surplus of some 1,74,000 m^3 will need to be placed into the upper PSE.

At the lower end of the project where the tunnels will be excavated, most of the surplus material from tunnelling, the machine shafts, and the lower dam, together with ancillary infrastructure will need to be placed either into the lower PSE or the laydown area. The total surplus of material at the lower end is estimated at around 1,810,700 m^3.

A geomorphic design approach has been used for both the upper and lower PSEs, that is, the landforms have been designed to emulate natural landforms with non-linear profiles tending to be convex on the ridge lines, with runoff flowing sideways to concave-shaped drainage lines. The drainage density or number of drains per unit area has been determined based on both natural analogues and a balance between constraining the spacing of drainage lines to limit the erosional risk associated with flows to the drainage lines, while also avoiding overly complex layouts that would be difficult to construct.

The following should be noted:

<u>Upper PSE</u>

This PSE is located on a relatively flat area but within steep topography on either side of the PSE. The site is constrained by the access road, the presence of sensitive flora (namely Pultenaea sp. Werrikimbe NP (*Pultenaea rubescens*) to the south and Guthries Grevillea (*Grevillea guthrieana)* to the north-east), and steep terrain to the west.

The design intent is to accommodate all the surplus material from the upper excavations at the upper PSE site due to the difficulties in moving material from the upper to lower areas associated with the steep terrain and winding roads. To be able to do this, due to the various constraints, it is necessary to impact a small portion of the Guthries Grevillea area. This allows the Pultenaea sp. Werrikimbe area to be avoided and maintain an exclusion boundary of 30m around this area. The management and offset of the impact on the Guthries Grevillea are not addressed in this report.

Key parameters for the upper PSE are:

- The PSE has an average slope of 17 degrees with maximum slopes of up to 21 degrees, tying into the steep natural ground on the eastern side of the final landform. These steep slopes will require due care during construction but are unavoidable to be able to accommodate the required volumes.
- The erosional risk has been computed using the Einstein-Brown equation which is also used in the SIBERIA Landscape Evolution Model (LEM) and found to be low, although with the need for some rock armouring in the drainage lines. This computation is based on the combination of catchment area and slope (raised to a power) at any point on the surface and is referred to as the Topographic Factor (TF). Importantly, this is a static risk assessment only, as opposed to a dynamic assessment such as obtained with an LEM where the movement of material and progressive erosion is modelled. It is likely that an LEM will be required for this project at some point in the future to confirm the erosion risk.

It should also be noted that detailed soils erodibility laboratory testing has not been undertaken yet, and the TF used is based on experience in the Hunter Valley, adjusted for the rainfall erosivity at the site. A TF of 30 has been targeted, which is roughly half that used in the Hunter Valley on most sites.

The appropriateness of a TF = 30 will need to be confirmed through flume testing prior to or in the early stages of construction.

- As indicated above, the drainage lines on the PSE will require armouring. There is 2.2km of drains in total, and these will require 5,400 m³ of riprap with a median size (D_{50}) of 250 mm. While these drains have been designed for the 1 in 100-year Average Recurrence Interval (ARI) event, the design approach is to limit the velocities to less than 3 m/s by ensuring they are wide with shallow flow depths for the design event. Consequently, with lower velocities during most rainfall events, sediment will accumulate within the voids between rocks, and vegetation will establish. The benefit of this approach is that soil and vegetation will interlock with the rock, significantly improving its ability to withstand flood events to well beyond the design event.
- Water management for the upper PSE will be challenging due to the steep drop off on almost all sides of the construction footprint. Water affected by sediment is proposed to be contained within a series of three sediment ponds, all sized in accordance with the Landcom Managing Urban Stormwater: Soils and Construction, Volume 1 (Landcom N. S. W., 2004), otherwise colloquially referred to as the 'Blue Book'. Some small parts of the site are outside of the boundaries of the water collection system, and will require sediment fencing or similar, but these are very localised. It is assumed at this stage based on current indications is that there will not be any geochemical impacts associated with the spoils. This will need to be confirmed through testing and monitoring.

Lower PSE

The lower PSE is in a valley. This is not ideal as it means there will be water flows into the area to be managed during construction, but post construction, the spoils will largely fill the valley, with run-on from natural ground limited to the areas on the south-western side. The site is the most favourable in the area that will be able to achieve the required volumes. The topography is steep, and the site is constrained by the access road to the north-east. To accommodate the required volumes, the PSE extents have been pushed up to the ridge line to the south-east, and up part but not all the slope to the south-west. Drainage on the PSE has been provided to collect areas of concentrated flow off the natural surface post-construction, with temporary diversion drainage required during construction.

Key parameters are:

- The lower PSE will have an average slope of 14 degrees with maximum slopes of up to 22 degrees, tying into the steep natural ground on the southern side of the final landform.
- The erosional risk for the current design is generally low, although with the need for rock armouring of the drainage lines where flow is concentrated—and for some areas of diffuse run-on where some additional erosion protection may be required. As for the upper PSE, a TF = 30 has been used, and this will need to be confirmed through more detailed soils erodibility testing prior to or in the early stages of construction.
- The lower PSE has some 2.43 km of drainage lines, for which 7,100 m³ of riprap with a D_{50} of 250 mm will be required. The design approach is as for the upper PSE, using shallow flows and relatively low velocities.
- Water management for the lower PSE is also challenging – while a sediment control dam is planned to be located at the toe, the slope of the valley limits the capacity that can be reasonably achieved. Consequently, the dam cannot contain the full catchment area (based on the Blue Book requirements) and the works will need to be staged with clean catchments directed around the toe dam. Water management drains on the side slopes will also be required to ensure clean runoff from the edges is diverted around the construction footprint.

  As the work progresses up the valley, additional storage will likely be obtained by forming a shallow dam on the constructed landform well away from the outer edges to increase the sediment settling capacity. The sizing and detailing of these measures will be undertaken at detailed design, although provisional designs are included in this report.

Note that, as for the upper PSE, it is assumed that geochemical impacts from the spoils will be limited and settling of sediment is the primary focus of the water management system.

Because tunnelling is more confined than the open blasting for the dam excavations, there is some increased risk of impacts on the spoils associated with the tunnelling operations, which will need to be confirmed through testing and monitoring.

Concluding comments

The required volumes for the PSEs at Oven Mountain can be obtained within the proposed sites, albeit with extension of the upper PSE footprint into the area containing Guthries Grevillea. Erosional stability for the geomorphic designs appears to be good, although there is the need for rock armouring of the drainage lines.

The greatest challenge for the site appears to be the management of water, given that the upper PSE is constrained in terms of opportunities for water control, and the lower PSE is constructed in a valley with associated water management challenges during construction. Sediment dams have been sized for both sites based on the Landcom (Blue Book) requirements, although at the lower PSE there are constraints, primarily the steepness of the valley sides and floor, that limit the ability to get the full capacity for the Blue Book requirements. As indicated, it is likely that for the lower PSE the work will need to be staged, with interim storage obtained on the landform as it progresses. The adequacy of these dams will be confirmed as additional geochemical work is undertaken on the quality of runoff and seepage from the spoils and as part of the final design work.

1 Introduction

Oven Mountain Pumped Hydro Energy Storage Project (the Project) is a proposed "off river" project located adjacent to the Macleay River between Armidale and Kempsey within the New England Renewable Energy Zone (REZ). The Project will produce up to 900 MW of electricity. The Project comprises an upper dam and lower dam linked by tunnels, with an underground hydroelectric power station.

The Project submitted its Environmental Impact Statement (EIS) in August 2023, and the EIS was then available for public inquiry from September 2023 to October 2023. As part of the Response to Submissions, in March 2024, Alinta Energy appointed WSP Australia to assist with the landform design of the PSE Areas.

The Project will have an upper reservoir which will both have an excavation to form storage and a dam wall, with the dam wall to be built using excavated rock. Surplus spoil from this excavation will be placed into the Upper PSE located in the general vicinity of the reservoir (indicated in Figure 1.1 and highlighted in red).

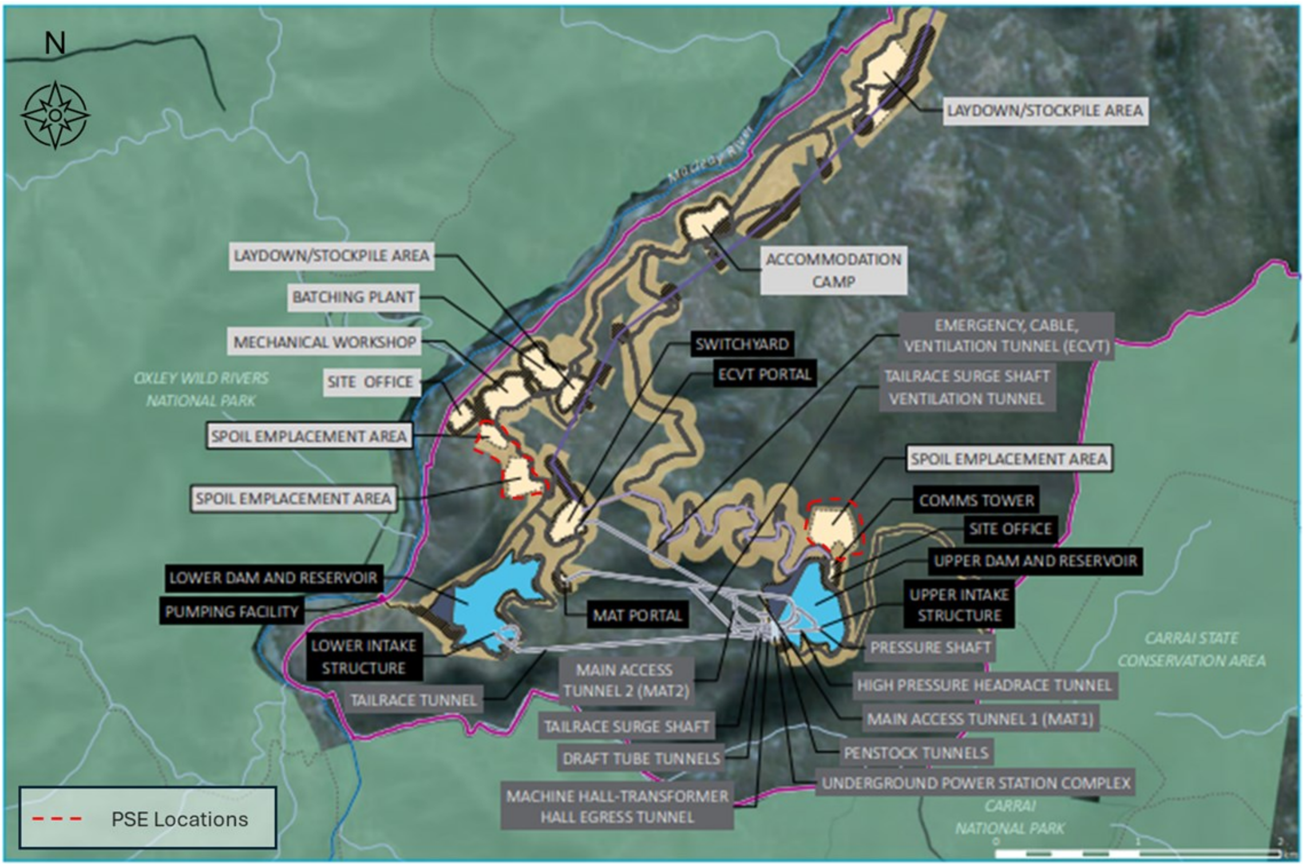

Figure 1.1 Oven mountain pumped hydro energy storage project site layout (Appendix Q, EMM, Figure 2.1)

The lower portion of the site will have the main infrastructure, laydown areas, the lower reservoir and associated ancillary works. Tunnelling will be undertaken mainly from the lower extents. These activities will generate surplus spoil which will then be placed into the lower PSE (refer to Figure 1.1, spoil emplacement areas to the north of the lower dam and reservoir).

1.1 Scope of work

The WSP scope of work included the following:

- Compile a Basis of Design (BoD) as inputs to the design process. This information is included in this document rather than a stand-alone document.

- To design and provide conceptual landform designs for the two PSEs for the Project. The designs are required to satisfy the following requirements of the project:
  - Accommodate the required surplus volumes in the PSEs, bearing in mind that access from the upper area to the lower area is constrained by the road width and gradients. Hauling of large volumes to the lower area from the upper reservoir is not considered feasible.
  - Use geomorphic design principles to produce landforms that are erosionally stable assuming they will have a vegetated soil on the outer surface, with or without rocky material. Note that geotechnical stability has not been assessed as part of this work, but it is expected that slopes flatter than 1V:2.5H are likely to be geotechnically stable without a significant phreatic surface in the PSEs. This has still to be confirmed at detailed design.
  - Ensure the landforms can be constructed safely, typically be limiting the slopes to be not steeper than 1V:2.75H (20 degrees). The steep terrain makes it challenging to accommodate the required volumes without some steep slopes, and there are small areas that are slightly steeper than this, up to 1V:2.5H (22 degrees).
  - Review the issues raised in the submissions made to ensure that outstanding issues have been addressed as far as is practical.

The objective of this report is to present the design as guided by the scope of works and to ensure that key concerns raised by stakeholders with regards to the landform have been assessed.

1.2 Data provided

The following inputs were provided by Alinta Energy:

- The proposed final PSE locations including shape files of the footprints and the required volumes.
- Recent survey data.
- The proposed project disturbance boundary as a shape file, together with the location of proposed infrastructure, water management dams etc.
- Exclusion areas.

2 Pre-construction overview of the proposed PSE sites

2.1 Overview

The work undertaken to date for the landform design has not included a site inspection – this will be undertaken prior to construction. However, based on the information provided in the various environmental studies, the sites are characterised by undisturbed valley with steep rocky sides. The average natural gradient at the upper PSE is 13.6 degrees, while that at the lower PSE is 21.5 degrees. Note that these gradients relate to the proposed footprints of the PSEs only.

Vegetation is a mixture of dry and wet sclerophyll forests, with the dry forests dominating most of the site. Ground cover is dense, much of which is regenerating from the 2019 bushfire season.

Plans of the existing areas showing the contours and proposed location of the upper PSE and lower PSE are shown in Section 2.2 below.

2.2 Site limitations

2.2.1 *Upper PSE*

The footprint extent of the Upper PSE is shown in Figure 2.1.

Figure 2.1 Upper PSE footprint

The upper PSE, is constrained by the following:

- The site access road impacts the PSE slightly in the south. The road location is largely fixed due to the road longitudinal slope requirements with flatter gradients separating steeper gradients, with the road cut close to the PSE.
- There is various flora of concern, primarily the Pultenaea sp. Werrikimbe area to the south, and the Guthries Grevillea to the north-east.
- Gradients of the natural terrain steepen significantly to the west, which limits the extent to which the footprint can be extended in that direction. The natural slopes are around 20 degrees in that area, which is close to the maximum targeted slope for the PSE.

2.2.2 Lower PSE

The footprint extent of the Lower PSE is shown in Figure 2.2.

The lower PSE is constrained as follows:

- The site access road is located on the north-east side of the PSE. This will be constructed prior to the PSE being established, which will then define the north-east boundary of the PSE.
- The rest of the site is limited only by some steeper slopes on the natural environment, mainly on the south-western edge.

Figure 2.2 Lower PSE footprint extent.

3 Basis of design

3.1 Target volumes

Initial work on the volumes of material were assessed by AusHydro and AECOM. WSP have not undertaken any detailed modelling of the works to confirm the overall volumes but did review the proposed final volumes in terms of the indicated bulking factors.

It is important to note that the process of blasting and handling rock, including haulage and placement, is subject to several variabilities. This includes the exact nature of the material compared to what has been predicted, the design of the blasts and how they perform on site. As well, the consolidation of the material during placement which can be impacted by handling, layer thicknesses, and the rainfall conditions during construction can all impact the construction. Several of these will only be established as the construction occurs, and some can be managed on site if needed, although with limitations. For example, blasting can be optimised to produce a smaller sized rock and a denser PSE, reducing the volume requirements, but with associated increased costs and risks in terms of environmental impacts.

The currently predicted surplus volumes are 1,741,000 m^3 for the upper PSE and 1,810,00 m^3 for the lower PSE, this being the volume as measured post-placement into the PSEs.

The computation assumes that:

Upper PSE

- Weathered material will be stripped from the dam area. The net increase in volume after excavation and then placement into the PSE is around ten per cent.
- Rock will be excavated from the dam floor and either reused in the dam wall construction or placed into the PSE. Approximately half the excavated volume will be re-used in the dam wall. The net increase in volume after excavation and placement is indicated to be around 25 to 36 per cent.

The predicted increase in volume indicated appears to be reasonable, though slightly conservative. Other similar open cut excavation projects have around 20 to 25 per cent net bulking, but this varies from site to site, and there are several factors that can increase that value to around 30 per cent. For the upper PSE, the main consideration is likely to be the bulk excavation in hard rock, which could easily result in larger rock fragments, and the potential for the excavation to extend slightly deeper than intended due to overbreak during blasting. Given that the main purpose of the works is to create storage, overbreak should be easy to manage though, simply by adjusting future blasts to be shallower where needed.

Lower PSE

The lower PSE has several variables that can be adjusted, including the storage allowance for drought reserve, and reuse of suitable material both in the dam wall construction and for other uses on site. There is also more flexibility at this area for the placement of materials, including the option to place more material into the laydown area, depending on the timing and suitability of the material and the space required for the construction activities on the laydown area. At this stage, the laydown area is excluded from the total volume computations with the option to then adjust the final landform of the lower PSE if the volumes reduce. This is unlikely to reduce the final volumes to be placed into the lower PSE by more than 20 per cent but could provide a useful contingency of up to 20 per cent of the final volumes if required. The material handling will be as follows:

- Limited weathered material will be stripped from the dam area. The net increase in volume after excavation and then placement into the PSE is around 10 per cent.
- Rock will be excavated from the dam floor and either reused in the dam wall construction, used for other construction such as road base or aggregate, or placed into the PSE. Approximately 30 per cent of the excavated volume will be re-used. The net increase in volume after excavation and placement is indicated to be around 20 to 30

per cent since around one third of the material to be placed into the PSE will come from tunnelling or underground excavations, where rock produced would be of a smaller size. The risk of overbreak in the tunnels is greater than for the dam excavations, so that the contingency provided by having additional capacity for material to be placed into the laydown area is significant.

The predicted increase in volume indicated appears to be reasonable, with other tunnelling projects in the same range in terms of increased volumes after excavation and placement. At detailed design, the management of risks around the scheduling of the works and the suitability of the material will need to be undertaken to ensure that the contingencies provided are appropriate.

3.2 Basis of design requirements

Design objectives are set out below (Table 3.1) based on those developed for similar projects elsewhere. These objectives are intended to provide a base for discussion with the Regulator and Community around the requirements of the PSE landform for the project and should not be seen as the final objectives. These will then be finalised ahead of detailed design. The Completion Criteria (Table 3.2) then set out the measurable components that will need to be achieved for the design objectives to be met. These are also subject to review and finalisation should the objectives change.

Table 3.1 Oven Mountain proposed design objectives

Aspect	Objective
Landforms	As natural as possible, including minimising the use of linear or engineered structures
	Sympathetic with the landforms in the surrounding area, particularly from a visual, water management, and ecological perspective
	Suitable drainage density
	Safe, long-term stability and non-polluting
	Provide suitable access for vehicles and/or all-terrain vehicles for rehabilitation, weed control and firefighting with tracks typically spaced at around 200 metres measured on the slope to allow for spraying from vehicles
Water management	Integrate the drainage of the emplacement area with the surrounding drainage network, including any upstream flows and residual run-on water
	Minimise downstream water flows and velocities with any changes to be quantified and addressed through suitable design
	Minimise valley infill as far as is practical, or minimise run-on from natural terrain where construction in a valley must be undertaken
	Create natural drainage lines that are long-term sustainable having regard to the selection of suitable underlying materials, including rock sizing and grading. Minimise the use of large rocks in drainage lines
	Minimise the concentration of water on landforms unless this is consistent with accepted drainage density and geomorphic design practices
	Minimise the generation and dispersion of sediment into the downstream environment
Erosional stability	Minimise steep slopes, particularly slopes that will be difficult to construct, access and maintain (such as slopes over 18° or 1V:3H). This has been increased to 20° or 1V:2.75H for the Oven Mountain sites.

Aspect	Objective
	The final surface of the landform must be long-term sustainable with sufficient topsoil (or some other suitable growth medium) to maintain a soil water profile and sustain vegetation
	Maximise the revegetation of the final surface
Land Use	Native vegetation and habitat must be consistent with the approved rehabilitation management plan
	Landform design to align with proposed final land use
Constructability	The emplacement area must be constructible having regard to the: — Availability of suitable material, including topsoil where proposed. — Erosion and sediment control. — Access. — Initial shaping of natural ground. — Progressive rehabilitation where practical, and — Shaping of temporary benches prior to dozing down.

Table 3.2 Completion criteria

Objective	Sub-objective	Completion criteria	Measurement tools
Final landforms are compatible with the landscape	— Non-linear natural looking landform. — Sympathetic with the surrounding area. — Minimise the use of large rocks in drainage lines (taken to be over large).	— Final landform is representative of typical landforms in the area (but still appropriate to the materials on the outer surface). — Rocky drains blend into the overall landscape.	— Visual assessment via 3D models. — Long sections and cross sections show smooth integration with adjacent natural surface. — Max rock size to be appropriate to the channel width and appropriate for easy handling.
Landforms are erosionally stable	— Suitable drainage density to limit overland flow lengths. — Drainage integrated with the surrounding drainage network. — Drainage lines long-term sustainable in terms of underlying materials, including rock sizing and grading. — Minimise valley infill (to limit run on) where practical or limit run-on areas where not practical. — Minimise the concentration of water on landforms where not required. — Minimise changes to stream power and velocities above and below the landforms.	— Soil loss range of between 5 and 20t/ha/year measured at any time within the next 500 years, but with a target overall soil loss measured in the long term of less than or equal to 5t/ha/year average or 10t/ha/year maximum. — Erosion/deposition processes within parameters of surrounding landscape and similar landforms relative to materials present	— As built design reports including erosion risk assessment (qualitative). — LEM (such as SIBERIA or CAESAR-Lisflood) will confirm acceptable future outcomes (by others). This will likely be a requirement for the Regulator to demonstrate long term sustainability and compliance. — While we would normally benchmark acceptable erosion rates against natural landforms of similar materials within the existing landscape bounds, this is unlikely to be practical. We propose to use generally accepted erosion rates as indicated in the completion criteria together with a review of the landform performance as determined by the LEM.
Landforms are geotechnically stable	— Ensure placed material for the landform is stable geotechnically by ensuring slopes within the final surface are appropriate to the materials being used.	— Slopes to be geotechnically stable as assessed by a competent geotechnical engineer. — Any slopes with a lower factor of safety to require individual sign off based on a risk assessment for that feature.	— Slope stability within the landform itself. Requires a geotechnical study.

Objective	Sub-objective	Completion criteria	Measurement tools
	— Ensure overall geotechnical stability considering the strength of materials underlying the PSE, bedding angles, and the possible impact of groundwater on the overall stability.	— Overall landform to be geotechnically stable as assessed by a competent geotechnical engineer (by others). — Any overall landforms with a lower factor of safety to require individual sign off based on a risk assessment for that feature. — Groundwater seepage and fluctuating dam water level management strategy if required and where appropriate.	— Slope stability analyses for the overall PSEs including the footprint and accounting for groundwater conditions. — Evaluation will also assess possible impact of groundwater seepage on the overall stability.
Landforms are appropriate for intended land use	— Landform to be safe for access where required. — Access tracks to be provided for rehabilitation, weed control and firefighting. — Minimise steep slopes that will be difficult to access and maintain (such as slopes over 18deg (1V:3H) or 20deg (1V:2.75H) at Oven Mountain.	— Landform to meet capability classes. — Slopes to be no steeper than 18deg (1V:3H) or up to 20deg (1V:2.75H) for Oven Mountain except where steeper slopes are required to tie into the existing natural landform or as localised areas adjacent to drains. — Where practical, access tracks to be left in the landform.	— Land capability assessment to be undertaken where needed. — Slopes and access to be documented in the design report.
Landform to be suitable and safe for access	— Determine what level of access is required given the relatively steep natural terrain in the general area. — Ensure the design then meets the requirements for suitable and safe access	— Appropriate slopes to allow limited access on foot or by 4x4 for appropriate activities such as maintenance and management. — Ensure long-term access is appropriate to the rehabilitation management plan.	— Report on design slopes, length of slopes and access tracks. — Institutional tools such as land ownership and access controls post operation of the Project.

Objective	Sub-objective	Completion criteria	Measurement tools
Landform to limit impacts on water quality	— Minimise the generation and dispersion of sediment into the downstream watercourses. — Outer surface to be geochemically benign to not impact on water quality downstream. — Groundwater ingress and/or seepage from the PSE to be managed where needed to limit impact on water quality.	— Surface water quality from runoff off the landforms to remain within the agreed parameters. — Ground water quality downstream of the landforms to remain within the agreed parameters. — Groundwater associated with perched aquifers flowing on to surface of landforms (if and where applicable) to be incorporated into the landform surface water management.	— Design report to document sediment control measures such as sediment ponds immediately downstream of the landform. — Design report to flag construction issues and management such as measures to limit impacts on water quality downstream.
Landform revegetation	— The final surface of the landform must be long-term sustainable with sufficient topsoil (or some other suitable growth medium and amelioration, if required) to maintain a soil water profile and sustain vegetation. — Maximise the revegetation of the final surface. — Native vegetation and habitat must be consistent with the approved rehabilitation management plan	— These issues to be addressed in a separate rehabilitation management plan.	— Not addressed here.

Objective	Sub-objective	Completion criteria	Measurement tools
Landform constructability	— The emplacement area must be constructible having regard to the: — construction methodology accounting for any problematic materials, either erosionally sensitive (such as dispersive material) or of concern geochemically. — availability and storage of suitable materials, including topsoil. — temporary erosion and sediment control measures. — construction access and temporary benching. — progressive rehabilitation where practical.	— Landform design to include areas for topsoil storage where practical. — Adequate temporary sediment control measures to be provided where needed. — Temporary benches for the final surface to be provided. — Design to allow for safe access during construction, and progressive rehabilitation where practical.	— Detailed design report to document: — Management of any problematic materials. — Areas of the landform flatter than 1V:4H to be highlighted in the design report for topsoil storage. — Temporary features including sediment control and benches. — High level access planning (detail planning by others).

4 Design methodology and outcomes

The design team at WSP have been implementing geomorphic landform designs in Australia since 2012. Over that period, geomorphic designs have been implemented on some twenty sites, ranging in size from 100 ha to 4500 ha. These are predominantly open-cut coal mines in New South Wales (NSW) but also include sites with similar topographical environments to Oven Mountain such as Snowy 2.0.

Over this period, the design methodology has been adapted to align both with the local landforms and the constraints of the highly variable climatic conditions in Australia. However, the basis of a geomorphic design approach is always the same - one assesses what makes natural landforms stable over geological time periods, and one then applies similar concepts to the landform being designed. A key element of this work, though, is understanding what landforms are relevant to the material being placed into the constructed landform. Since the main driver is to limit erosion of the landform, most of the focus is on the outer layers of the final landform, which tend to be vegetated soils or a mixture of loose rock and vegetated soils. In the natural environment, the appropriate natural analogue for these outer layers are alluvial landforms. These landforms are formed by the deposition of sediment transported by river systems and do not have significant bedrock.

Unfortunately, alluvial landforms tend to be flat, in our experience, with an average grade of 3 to 4 degrees. To design geomorphic landforms steeper than this, it becomes necessary to use erosion risk assessment methodologies to limit the erosion risk on unarmoured surfaces and then to place rock armouring or other suitable alternatives in the drainage lines.

The approach is then to use a target drainage density like what would be found on an alluvial analogue since most of the surface will be unarmoured (excluding the drainage lines). The current designs have a drainage density of 150 m/hectare which is approximately double that for most alluvial analogues we have worked on. This higher value is indicative of the steep surfaces which required more drainage lines to limit the overland flow length. The surface has been assessed using a 3D erosion risk assessment as discussed further in Section 4.1.5.

There are three further points to be made here:

- The static erosion risk assessment used by WSP is based on the equations used in the Siberia LEM. We have used the static erosion risk assessment in parallel with LEMs on numerous sites and found a high degree of confidence in identifying the point at which rilling is likely to occur, provided one understands what combination of catchment area and slope will trigger rill formation for a specific soil with a specified revegetation strategy in a particularly climatic environment. However, the method identifies risk only, and while it is a useful tool in the design process, it does not model material movement or demonstrate the long-term stability of the landform. An LEM is likely to be required at some point in the Project to demonstrate long-term erosional stability.
- Rock armouring is required for the drainage lines. This is in theory a potential area of weakness since, if flood events larger than the design event occurs, there will be damage to the drainage lines. To address this risk, we have adopted an approach used currently on most of our sites in NSW in the drainage design that uses wider drains with a shallow design flow depth when compared to the optimal conveyance drain profile which is closer to a circular cross-section. This design approach then targets velocities of 3 m/s or less for the design event, in this case the 1:100-year Average Recurrence Interval (ARI) event. Effectively, for more frequent flood events, the rock provides roughness, but the vegetated soils are then able to withstand the tractive stresses during the floods. This approach facilitates both sediment accumulation within the rock voids and revegetation of the drains.
- We have found that this natural process results in rock that is bedded into the soil matrix that accumulates within the voids, resulting in a far higher erosional resistance than loosely placed rock. In the longer term, the drains are expected to be able to withstand much larger flood events than the design event.
- The original design undertaken for the EIS was unclear as to whether there would a rock cladding on the outer surface with minimal runoff, or a vegetated soils surface with or without a high rock content for which there would be significant runoff. The designs undertaken here all assume a vegetated soil surface with runoff, but this does not preclude the possibility that in some areas, the rock content on the outer surface may be high to limit erosional risk.

This is especially true on an ay steeper area or on parts of the north facing slopes where vegetation tends to be less dense due to hotter drier conditions compared to areas that are more shaded.

4.1 Upper PSE

The upper PSE will be constructed on a small flatter plateau at the top of the valley. The design outcomes are discussed below.

4.1.1 Overall layout

The overall pre-construction layout of the proposed landform design surface is shown in Figure 2.1, including the currently proposed upper PSE extent. The proposed design is shown in Figure 4.1

The PSE will be formed by constructing on a localised flatter area and shaping the landform into the existing ridge to the east. The crest is lower than the adjacent southern ridge and is expected to blend into the natural environment (refer Section 4.1.3).

Figure 4.1 Proposed design extents for Upper PSE

4.1.2 PSE Capacity

The initial designs excluded all sensitive areas, including the Pultenaea sp. Werrikimbe to the south and the Guthries Grevillea to the north, that is, staying within the construction envelope shown in Figure 4.1. Using that footprint and limiting the slopes to not exceed the target value resulted in a capacity of only 1,080,000 m^3 of spoil or a deficit of approximately 686,400 m^3 on the target volumes.

Various options were considered to try to resolve this issue, such as increasing re-use, or relocating some of the material from the upper areas to the lower areas. Access constraints associated with the narrow and relatively steep access road prevent the movement of large volumes of material away from the site.

Consequently, the option of leaving the Pultenaea sp. Werrikimbe area undisturbed and extending into part of the Guthries Grevillea area to the north was considered, with the northern boundary of the PSE extending some 135 m in this zone.

This adjustment allowed a capacity of 1,741,000 m^3 to be obtained, which is within 1.4% of the target. The small shortfall can be resolved at detailed design and is likely well within the tolerances of the overall volumes for this stage of the project. This is then the preferred landform design option and is discussed below. The mitigation of the impacts of this on the Guthries Grevillea area will need to be resolved through off setting and possible inclusion of these species in the final rehabilitated surface if this is an appropriate ecological option.

The fill for the proposed surface is shown in Figure 4.2, with a maximum height of around 35m above the existing ground.

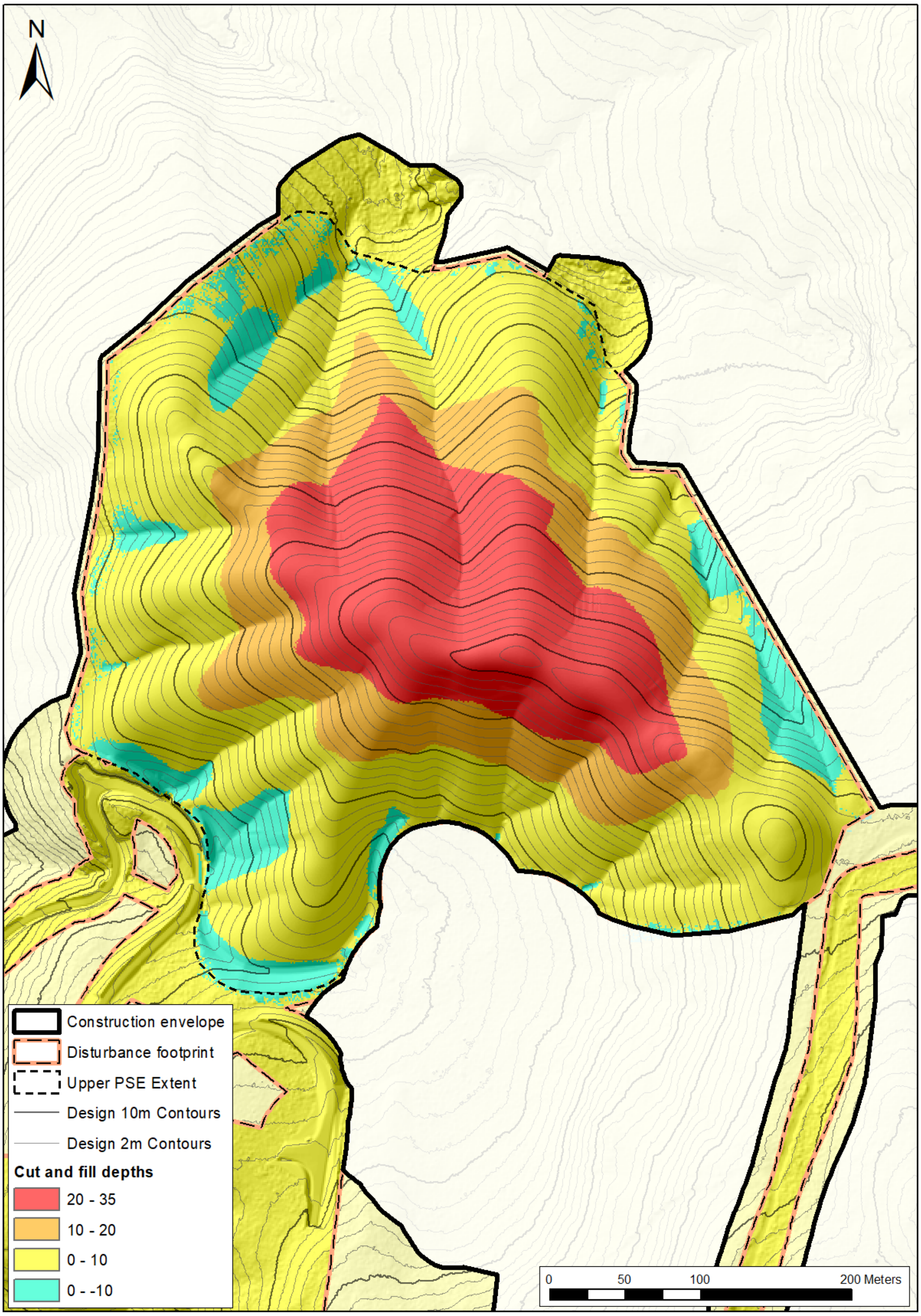

Figure 4.2 Fill volumes showing the height of the fill.

4.1.3 Visual assessment

The 3D views of the proposed design for the upper PSE are shown in Figure 4.3 to Figure 4.5. It is considered that the landform will blend well into the natural topography as evident from the eye-level views from the valley below the PSE (Figure 4.5).

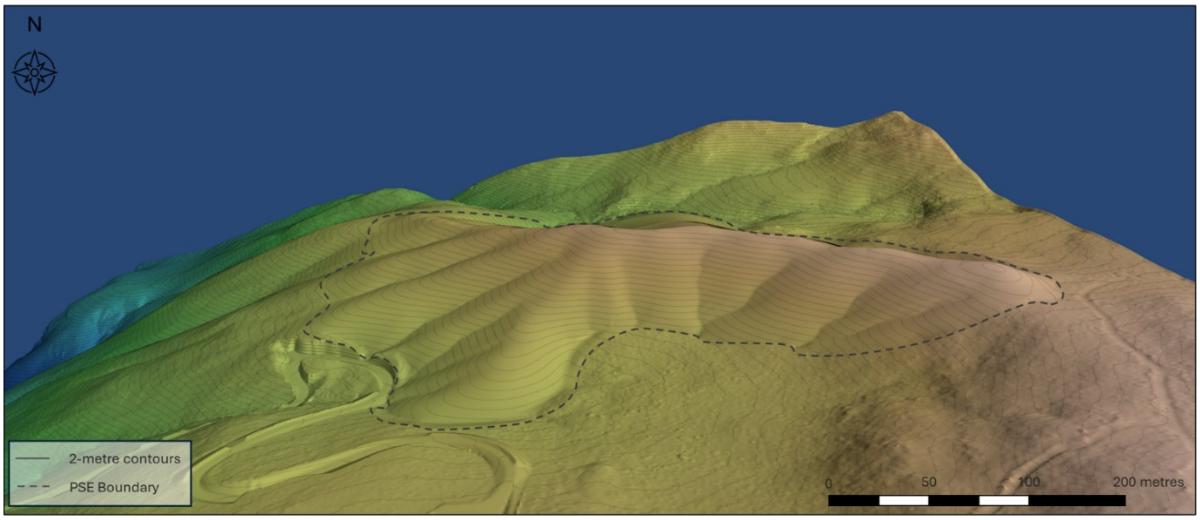

Figure 4.3 Views from the South (upper PSE)

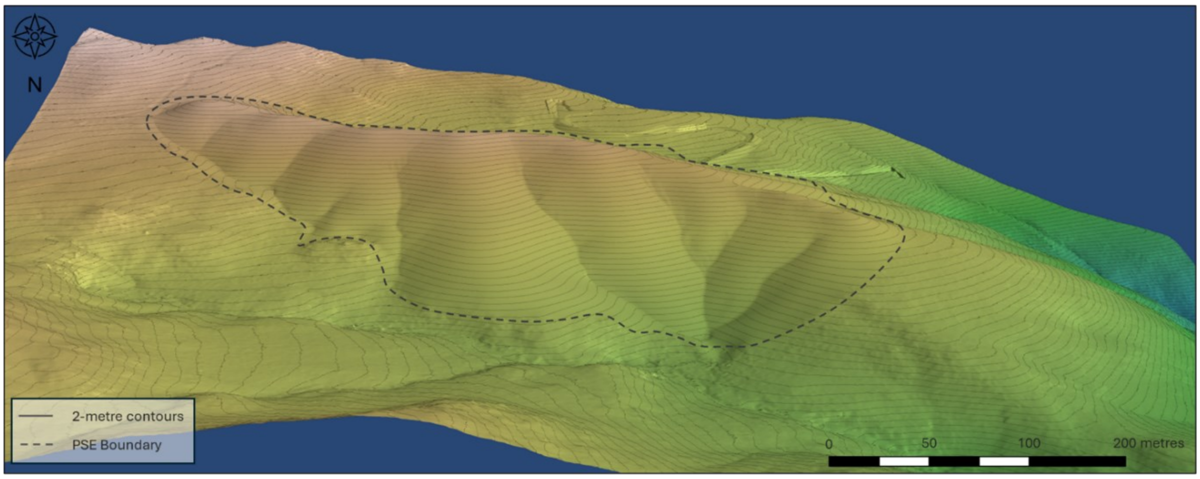

Figure 4.4 Views from the North (upper PSE)

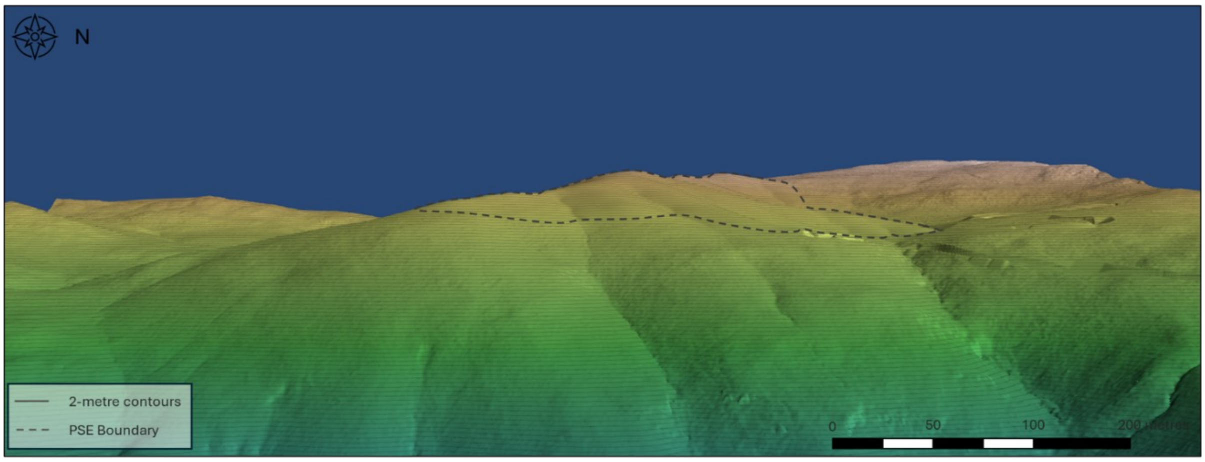

Figure 4.5 Views from the bottom of the valley – eye level view (upper PSE)

4.1.4 Slopes

Limiting the slope angle is primarily required to facilitate ease of construction and ongoing maintenance rather than an erosional stability risk. This is because the erosion risk assessment takes account of both the slope and the catchment area, and a steep slope with limited catchment is not necessarily an issue.

The preferred maximum slope is 18° (or 1V:3H) for ease of cross-ripping with a dozer as part of the rehabilitation process. However, there are localised areas on the upper PSE, mainly at the edges of drains, where the slope is steeper than 18 degrees, with slopes of generally up to 20 degrees (or 1V:2.75H). Some localised areas of the landform around the interface with the natural ground are steeper, up to 22 degrees (or 1V:2.5H). This is because the constructed landform needs to tie into the naturally high slope angles of the surrounding valley which are in places are up to 38 degrees (or 1V:1.25H). Slopes at this angle are used on some steeper landforms and are also widely used in the Pilbara, and provided due care is taken, they can be safely constructed, primarily limiting the access of equipment to appropriate slope angles. Certain equipment such as rubber tyred vehicles cannot operate safely on these steeper slope angles.

It should be noted that, although the geotechnical stability has not been assessed here, for most sites without the risk of a significant phreatic surface developing in the PSE, a slope flatter than 22 degrees (or 1V:2.5H) is expected to be stable, provided there is no risk of a wider failure through instability of the underlying natural rock material. While this will need to be confirmed at detailed design, the risk of an elevated phreatic surface for this PSE is considered low due to the site being largely proud of the surrounding environment and high up in the terrain.

The slope angles across the upper PSE are shown in Figure 4.6.

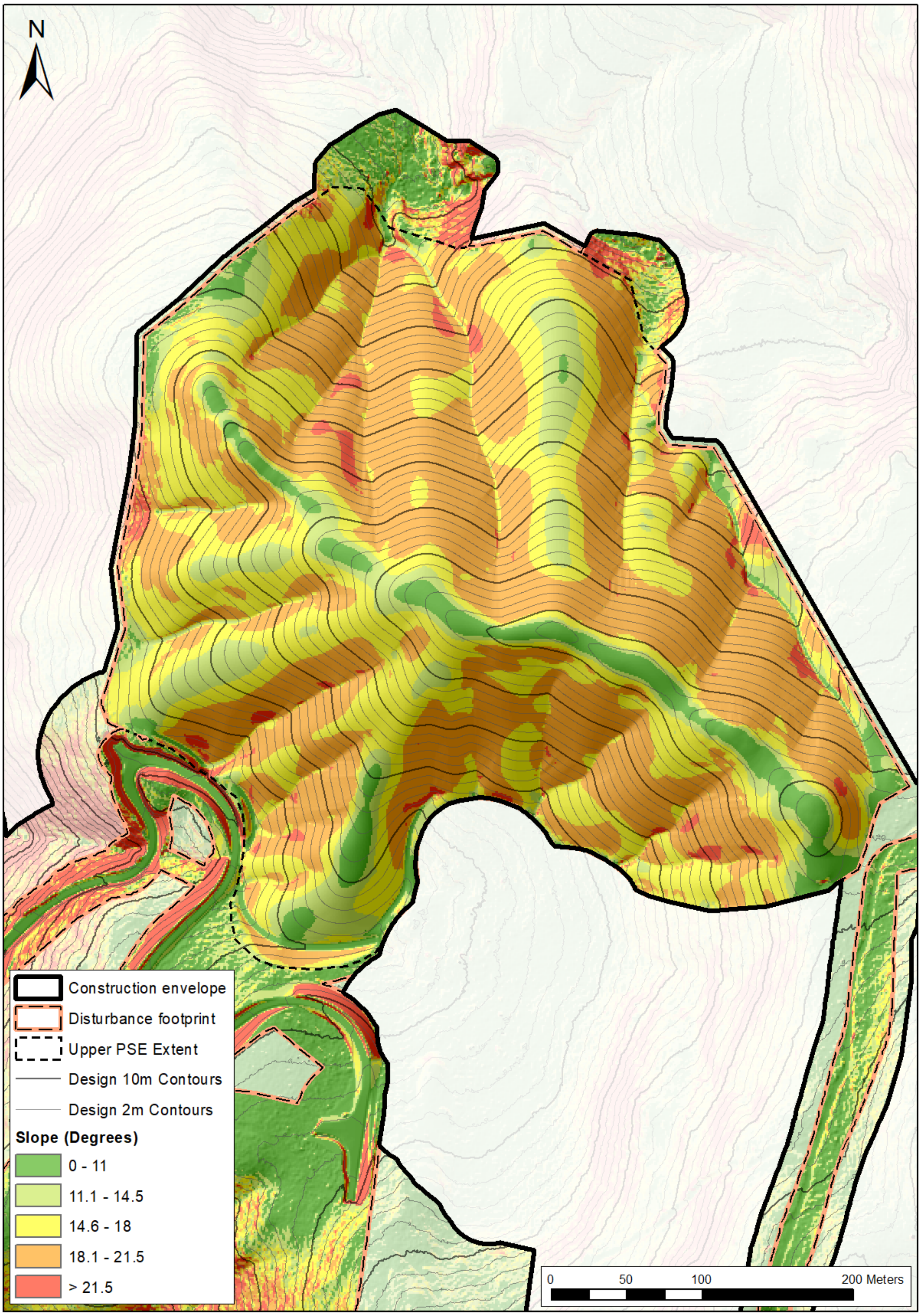

Figure 4.6 Slopes for the upper PSE indicated as degrees.

The overall breakdown of slopes in the final landform is given in Table 4.1.

Table 4.1 Overall slopes for the upper PSE

Slope Angle (Degrees)	Slope Area (ha)	Percentage of Total Area	Cumulative Percentage
<11	1.26	7.1	7.1
11-14.5	2.10	11.6	18.7
14.5-18	5.56	30.4	49.1
18-21.5	8.86	47.6	96.7
>21.5	0.62	3.3	100.0
Total	18.40	100.0	100.0

4.1.5 Erosion risk and rock armouring

4.1.5.1 Erosion risk

The assessment of erosive risk as set out below is a computation of the risk of scour on the three-dimensional landform. It is based on the Einstein-Brown equation and assesses the combination of catchment area and slope which is then reported as the Topography Factor (TF). The Einstein-Brown equation is also used in the SIBERIA LEM to determine rill initiation, although the intention here is not to replicate a LEM since the assessment is a static assessment and does not model dynamic material movement over time, but rather highlights area of risk of scour.

The computation of TF on its own does not allow the assessment of erosion risk since the acceptable value still needs to be determined. This can be done in several ways:

- Particle Size Distribution (PSDs) can be used to assess what height of slope at a particular angle would be stable with and without vegetation. This can be computed for a simple surface using the Revised Universal Soil Loss Equation (RUSLE), bearing in mind, as noted in the peer review by SLR (SLR, 2023) that RUSLE has many limitations. These primarily relate to extending RUSLE beyond its original intent – RUSLE does not model gully erosion and is thus not suited to modelling larger 3D surfaces. It can, however, provide an indication of the erosional limits of a planar surface of appropriate size.

  While there is soils data available for the site, as noted by SLR, there are issues still to be managed including some loose sandy materials, clay soils with high levels of ESP and dispersion that will need to be managed, as well as shallow stony clay loam soils. There is not yet certainty in the preferred materials to be used, nor what level of basal cover will be achieved on these soils, that is, the extent to which the long-term revegetation strategy will stabilise the material.

  This is not an uncommon problem for sites—to be able to model the erosional risk, one needs a reasonable level of confidence in both the nature and availability of soils to be placed on the outer surface and the revegetation strategy. Typically, this is determined using the second option below.

- Once a full inventory of available soils is available, the preferred soils to be used can be assessed for erosion risk through laboratory testing. Most commonly, this involves flume testing of the material. From the observed erosion under different flow conditions and slope angles, the erosion risk can then be assessed using a 2D model like the Water Erosion Prediction Project (WEPP). This allows specific rainfall events to be modelled, typically using long rainfall sequences such as 100years of rainfall data (real or simulated) and incorporating specific high intensity rainfall events. This work has not been undertaken at Oven Mountain yet but would be recommended as part of the detailed design phase.

- Where sites have been operating over a period, the erosional performance of the observed landforms can be used to calibrate erosion risk. Clearly this doesn't apply to Oven Mountain.

- Lastly, one can use experience from other sites in the region, adjusted for the rainfall erosivity of the specific site and with some high-level allowance for the erodibility of the soils. The WSP have been working on geomorphic landforms in the Hunter Valley since 2012. Over this period, we have both designed landforms, and then been able to monitor their performance, initially through site observations, but lately utilising high-density LiDAR to be able to quantify erosion rates. The assessments have also been used in parallel with LEM modelling on several sites, with comparable outcomes. The approach has allowed us to develop a strategy around the appropriate TF for various sites, including a high-level erosion risk assessment for Oven Mountain as discussed further below.

Key to the approach are the following points. Firstly, it is overly optimistic to design landforms using an erosional risk based on the fully vegetated surface, since it is common to experience periods of drought where vegetation will not be established for some time, typically several years. There is a need to limit erosion during this period. Secondly, paradoxically, it is also impractical in most instances to design landforms for an erosional risk based on an unvegetated surface. Most soils in NSW, if left unvegetated, will only be stable for low landforms with comparatively flat slopes. Consequently, we typically design the landforms for an erosion risk that would be roughly half to one-third of what one would consider for a fully vegetated landform. This means that there is then a need to manage the erosion risk prior to vegetation establishing, and this is normally done through deep ripping to increase infiltration, and other means such inclusion of mulch or roughness.

The assumption then is that the site will be able to utilise soils that are reasonable for application on to hillslopes, and that where there are problematic soils, these can be managed through addition of ameliorants such as gypsum for dispersivity, or organic material if required. This does not preclude the use of gravel capping or rock cladding locally if and where required, bearing in mind that the erosional risk on a geomorphic landform varies across the surface, so that portions such as ridge lines have much lower erosional risk than areas of flow concentration, so mitigation can be area specific.

Importantly, the high-level assessment used for this design evaluation is not the end of the process, but only the initial design approach. As the Project progresses, there will be a need to validate the erosion risk using flume testing of materials, and we would recommend the use of an LEM to then confirm the long-term stability.

The sequencing of the above work as proposed for Oven Mountain is not abnormal – most sites will only obtain detailed soils inventories and confirmation of the rehabilitation strategy during the initial construction phases, sometimes even later in the process. The key element here is that the designs can be adjusted, and mitigating measures implemented provided the initial design work has been appropriately precautionary. In our experience, the adjustments required after assessment using an LEM are typically quite small and can be addressed by small changes in the final surface or other mitigation measures such as the addition of rocky material into the outer surface.

From experience in the Hunter Valley through periods of both drought and high rainfall intensity, the target TF for Oven Mountain has been set at a value of 30, which is roughly half the value generally used in the Hunter Valley to account for the increased rainfall erosivity. Where TF values greater than 30 are indicated, rock armouring is likely to be required. The design intent is to limit these areas to be primarily in the drainage lines.

The modelled erosion risk for the conceptual design of the upper PSE is shown below in Figure 4.7.

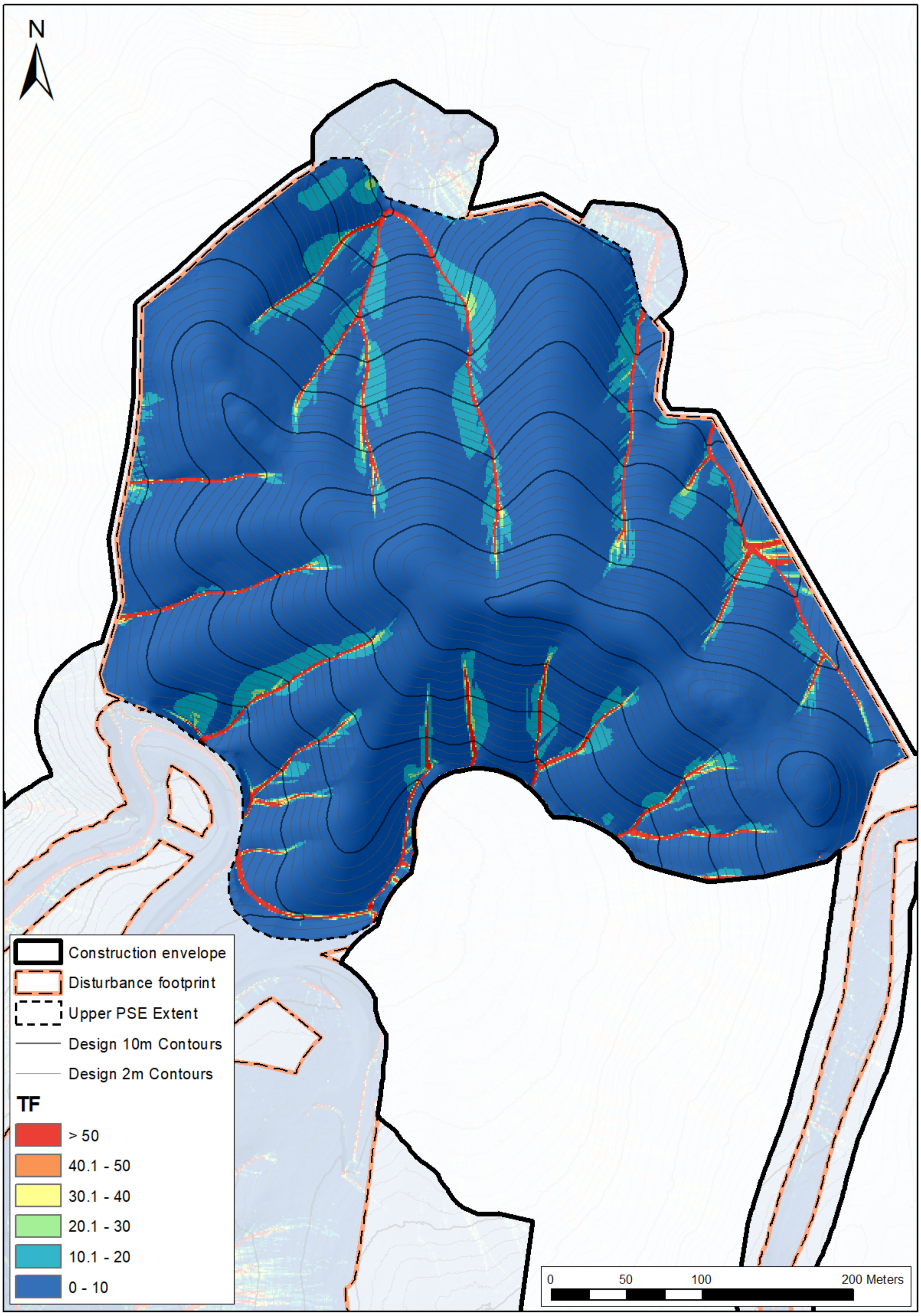

Figure 4.7 Plan of the proposed upper PSE landform indicting the Topography Factor (target TF <= 30)

It is evident that most of the landform has an erosion risk well below the target value of 30, except for the drainage lines where rock armouring will be provided.

4.1.5.2 Rock armouring

From the above work, an initial assessment of rock requirements for the geomorphic landform has been made using peak flows from the Rational Method, and hydraulic modelling using WSP's in-house software. An initial storm event of 1:100-year ARI was modelled, but this work should not be seen as the final design for the surface, but rather an indication of what peak velocities would result. The aim was to have a design where velocities are going to be lower than 3 m/s (refer Figure 4.8), however the modelling indicates that in some localised areas around the toe of the drains show velocities up to 4.0 m/s, primarily due to some unevenness in the drainage line profiles causing localised higher velocities. At detailed design these drains will be kept slightly wider and with an even based to reduce the velocities to around the target.

From the initial computations, we expect that approximately 5,400 m^3 of rock armouring would be required for some 2,200 m of drainage lines, typically durable rock with a D_{50} grading of 250 mm. This material will require screening prior to placement into the drains.

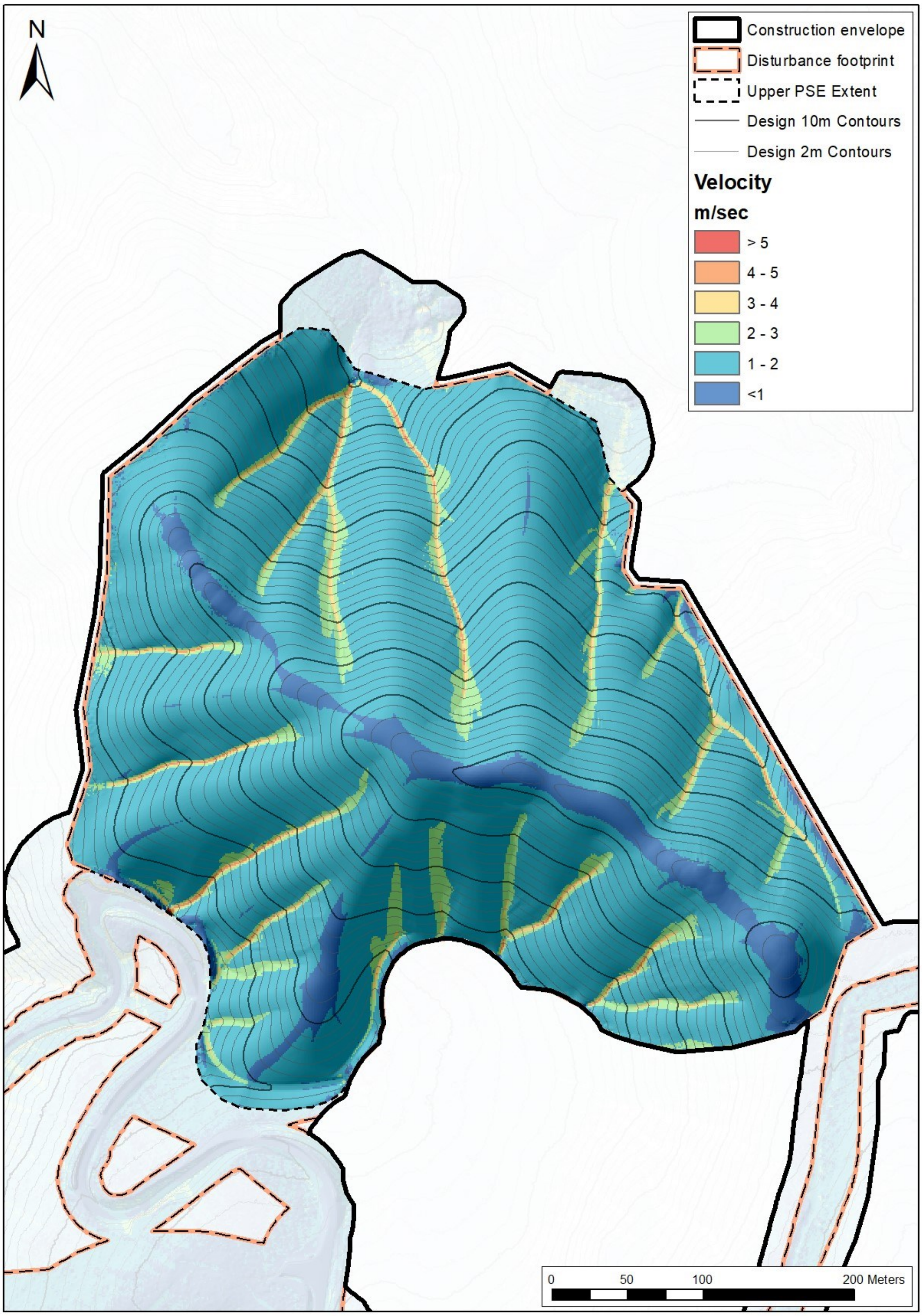

Figure 4.8 Flow velocities for the 1:100-year ARI event (units m/s)

4.1.6 Sediment and seepage collection dams

The main challenge for water management at this site is that the landform will be constructed on a ridge, with flows shedding off the area into relatively steep drainage lines. The location limits the potential to contain runoff and seepage, other than in relatively small sediment dams local to the site together with sediment fencing.

The current expectation indicated from the geological assessment is that the spoil will be geochemically inert, and that, because the blasting is on an open excavation, the risk of impacts associated with nitrates will be low. This will need to be confirmed at detailed design.

An initial assessment of the required storage for sediment only has been undertaken using the 5-day 95th percentile rainfall depths with a relatively high runoff rate of around 0.79, as set out in the 'Blue Book'. We have allowed for an assumed sediment capacity of 50% of the water storage volume and this results in the required sediment dam storage volumes given in Table 4.2 for areas draining to the north and south respectively. It is worth noting that this design criteria are more conservative than what is specified in The Projects LSEA and EIS, which utilise a 5-day 85th percentile rainfall depth.

Note that there will be portions of the western draining final surface where the construction of drainage and dams is unlikely to be practical due to the steepness of the terrain in these areas water management can be applied to the temporary benches prior to final shaping, but post shaping, sediment fencing likely will need to be used as a primary strategy.

Table 4.2 Upper PSE Sediment dam sizing

Dam ID	Catchment Area (ha)	Water Storage Required – Blue Book 5 Day 95th Percentile (m³)	Sediment Storage Required – (m³)	Total Volume – Water and Sediment (m³)	Draft Design Storage (m³)
Dam - 1	4.8	2,010	1,010	3,020	6,000
Dam - 2	5.4	2,260	1,130	3,390	2,000
Dam - 3	4,5**	1,930	970	2,900	6,000

* Sediment storage is at least 50% of total water storage volume.

** note that this assumes diversion of the clean catchment. If the clean catchment is not diverted, the catchment area will increase to 14.1ha

From Table 4.2, Dam 1 and Dam 3 are of sufficient size for the design rainfall event, however Dam 2 has 41% less capacity than the Blue Book requirement. To manage this issue, an option may be to expand the height of the dam wall, which is at present 5m. Another option may be to stage the construction process with an initial smaller dam at the toe, and a diversion of the upstream catchment past the dam.

Initial evaluation of options for these storage requirements are shown in Figure 4.9. The exact details of the storage have still to be addressed at detailed design stage.

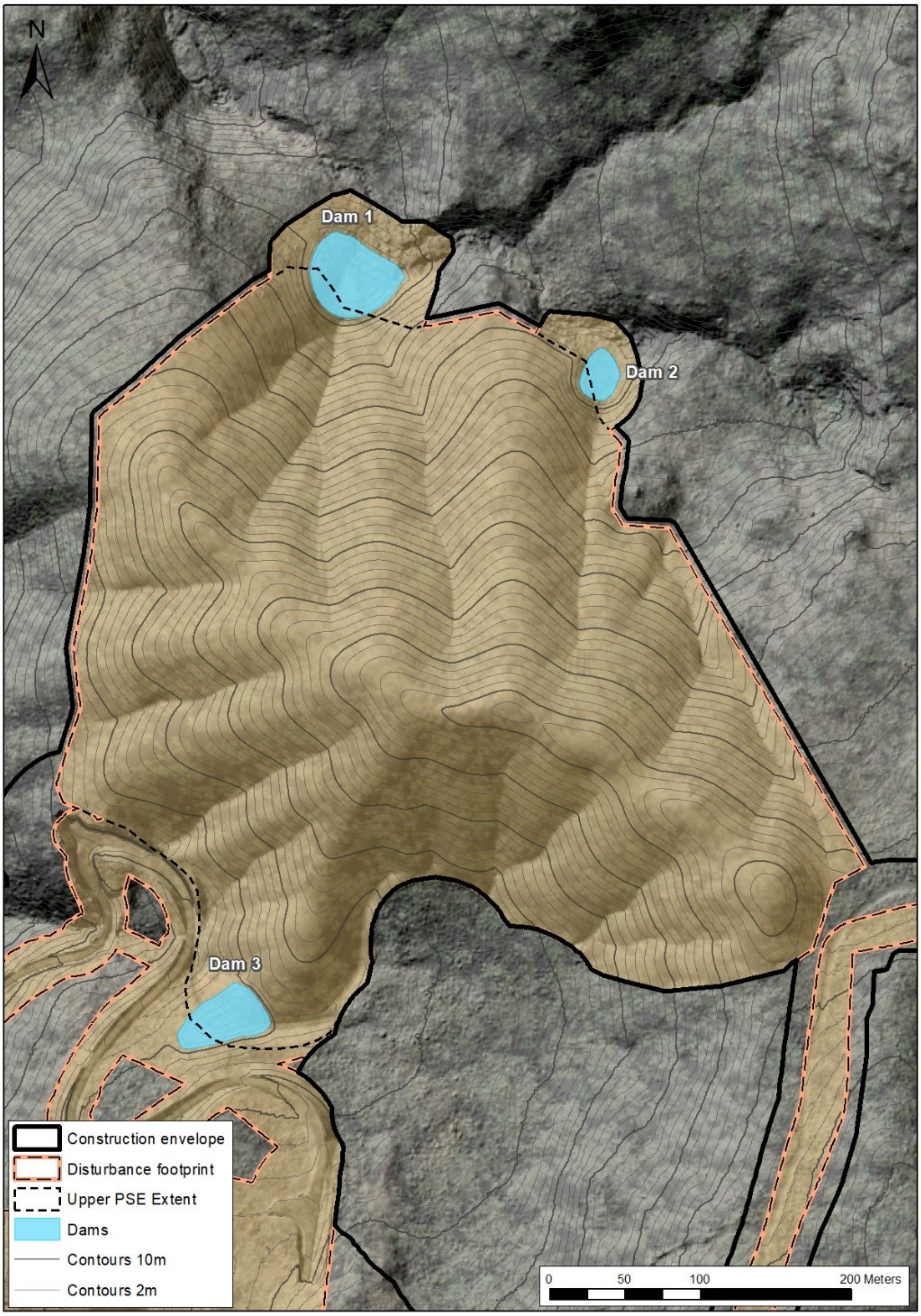

Figure 4.9 Initial Blue Book dam locations

It is intended for these dams to be in operation until the surface has stabilised and the landform can be integrated back into the natural catchment, at which point they can be removed.

4.2 Lower PSE

The lower PSE will be constructed in a valley. While this is not the preferred option as set out in the design objectives, there are no alternative sites that have been identified in the general area. The boundaries for the site are defined by the access road on the north-eastern side of the site.

The completed PSE will extend to the top of the catchment to the south, and the access road will act as a potential separation of clean and dirty water with a with a dirty water drain located immediately downslope of the access road. This means that the valley will be largely filled with only limited run-on from the natural slopes adjacent to the PSE, primarily from the area to the south-west. During construction, there will also be a catchment shedding on to the site from the south-east. The design outcomes are discussed below.

4.2.1 Overall layout

The overall pre-construction layout of the proposed landform design surface is shown in Figure 2.2, including the currently proposed lower PSE extent. The proposed design is shown in Figure 4.10.

Figure 4.10 Proposed Lower PSE design.

The PSE will be formed by building from the toe of the valley back up towards the top of the valley - the management of water during construction is a key issue for this site, with upstream flows needing to be temporarily drained around the active areas as discussed in Section 4.2.6.

4.2.2 PSE capacity

The key intent was to ensure that all the spoil required to be placed in the lower areas could be accommodated within the lower PSE. It should be noted that some of the initial spoil will also need to be used for the construction of the laydown area, likely to be mainly weathered material from the initial road and adit construction. The current design excludes the requirements for the laydown area at the stage. This is deliberately conservative, allowing for a possible reduction of the final extents of the lower PSE once the nature of the material and scheduling are more clearly understood.

The initial designs, which were confined within the provided construction boundary extents and limiting the slopes to not exceed the target value resulted in a capacity of only 1,383,000m^3 of spoil or a deficit of approximately 444,300m^3 on the target volumes.

To accommodate the required volumes entirely within this PSE, the footprint was extended to the west and south, along the ecologically surveyed limits of the area. By doing so, a capacity of 1,810,700m^3 was obtained, within 1.1% of the target volume. Given that there is additional capacity of possibly up to 20 per cent in the lay down area, this design was considered appropriate for this stage of the design, i.e., the conceptual phase.

The fill for the proposed surface is shown in Figure 4.11, with a maximum height of around 35 m.

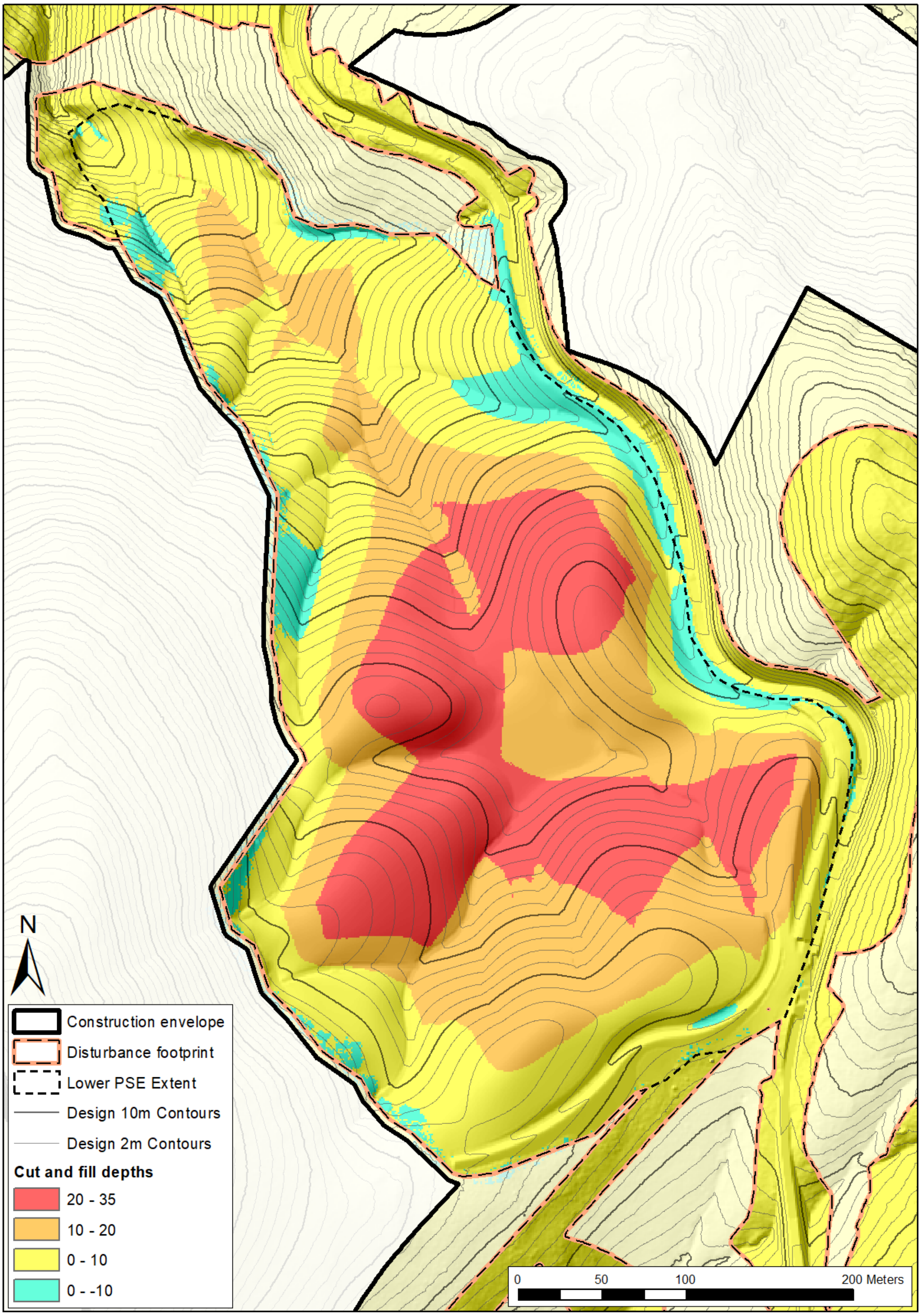

Figure 4.11 Fill volumes showing the height of the fill.

4.2.3 *Visual assessment*

The 3D views of the proposed design for the lower PSE are shown in Figure 4.12 to Figure 4.14. It is considered that the landform will blend well into the natural topography as evident from the eye-level views from the valley below the PSE (Figure 4.14).

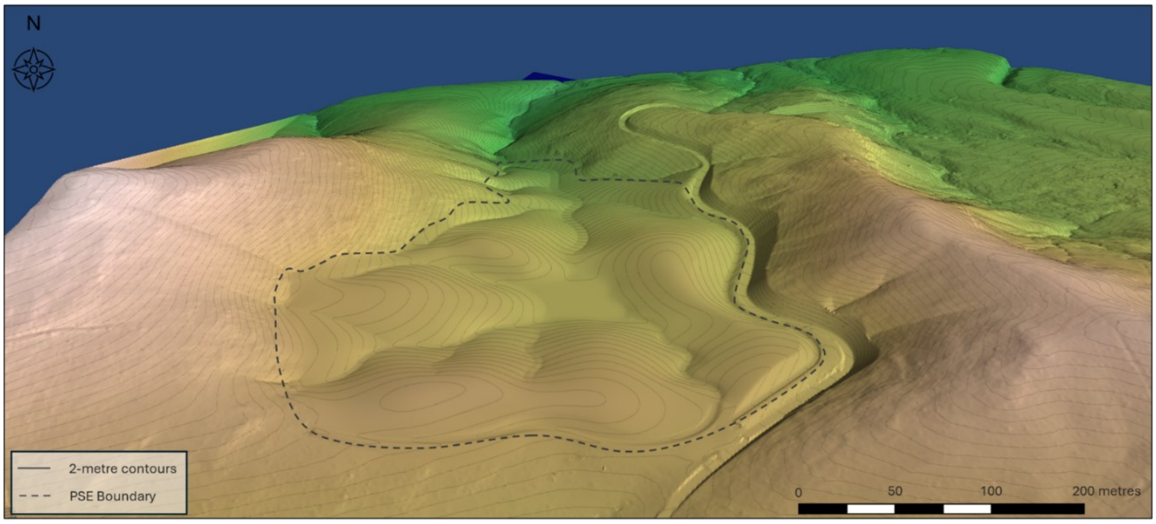

Figure 4.12 Views from the South (lower PSE)

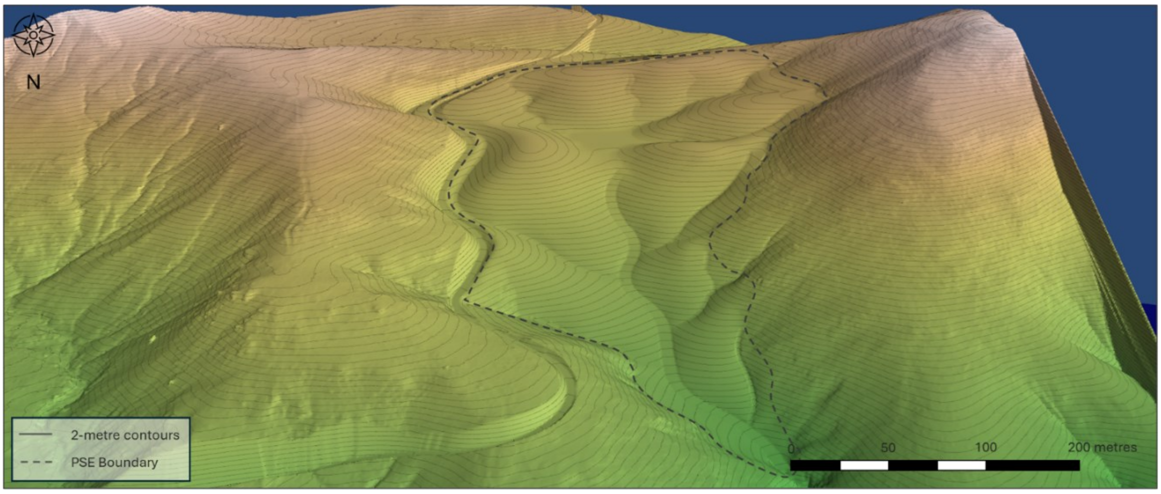

Figure 4.13 Views from the North (lower PSE)

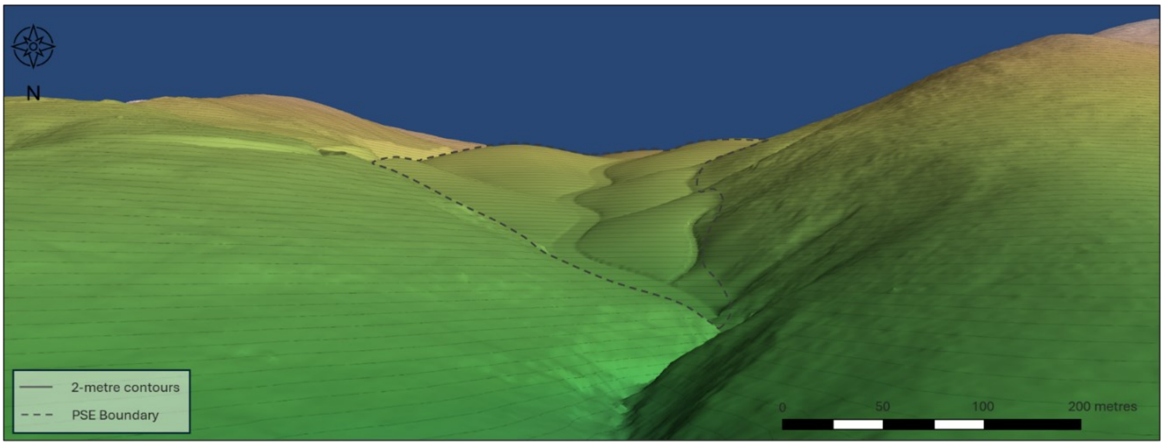

Figure 4.14 Views from the bottom of the valley – eye level view (lower PSE)

4.2.4 Slopes

As for the upper PSE, the intent is to limit slopes to 20 degrees (or 1V:2.75H), with only limited areas steeper than this, potentially up to 22 degrees (1V:2.5H). The slope angles across the lower PSE are shown in Figure 4.15.

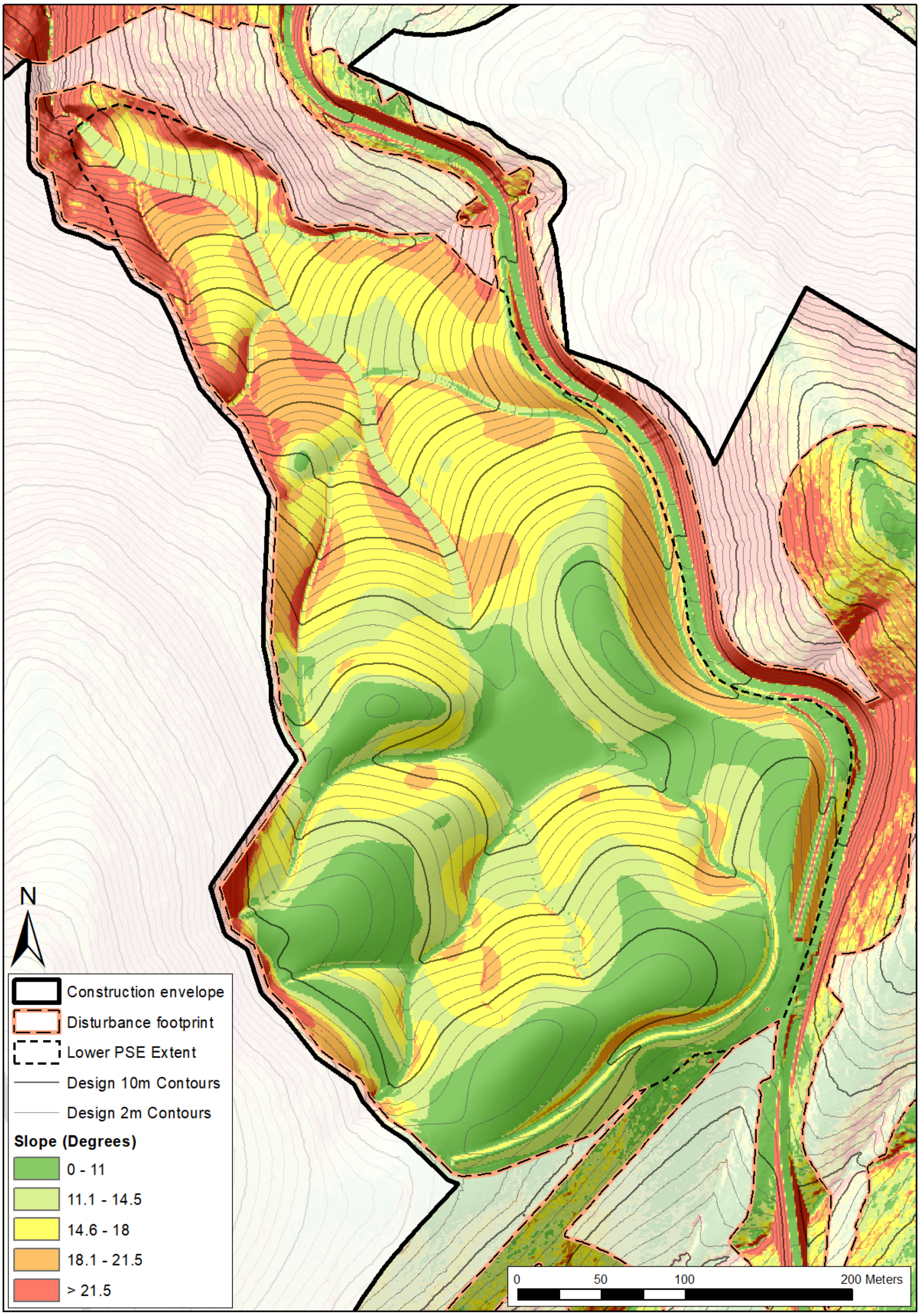

Figure 4.15 Slopes for the lower PSE (as degrees)

The overall breakdown of slopes in the final landform is given in Table 4.3.

Table 4.3 Overall slopes for the lower PSE

Angle (Degrees)	Slope Area (ha)	Percentage of Total	Cumulative Percentage
<11	4.16	27.6	27.6
11-14.5	3.67	24	51.6
14.5-18	4.19	26.9	78.5
18-21.5	2.51	15.8	94.3
>21.5	0.98	5.7	100.0
Total	15.51	100.0	100.0

4.2.5 Erosion risk and rock armouring

4.2.5.1 Erosion risk

The assessment of erosive risk uses the approach described in Section 4.1.5.

The modelled erosion risk for the conceptual design of the lower PSE is shown below in Figure 4.16.

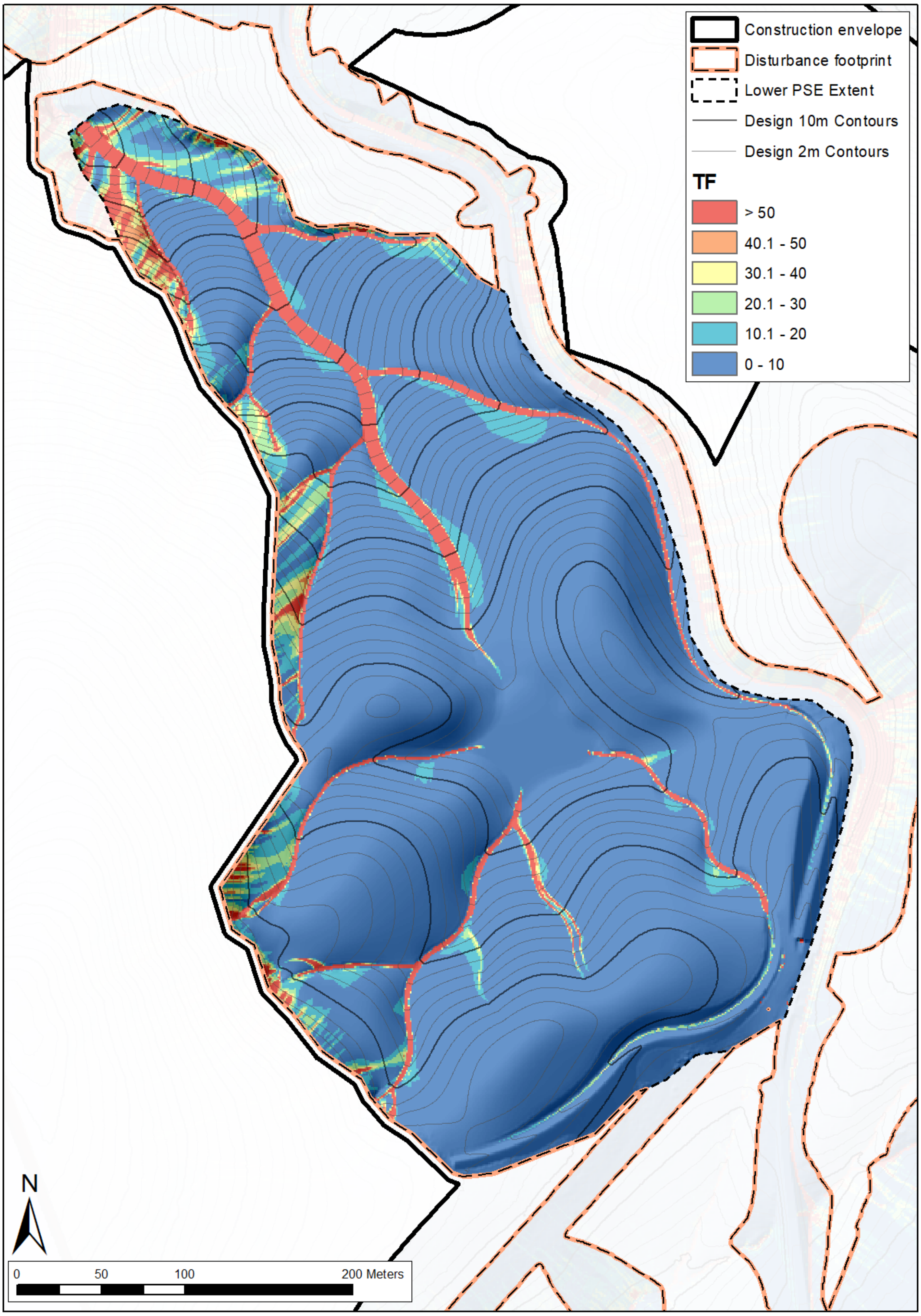

Figure 4.16 Topography Factor (target TF <= 30)

Some of the steeper areas on the south-west, have increased erosion risk associated with run-on off the slopes, and some rock cladding will likely be required in that area. It is very limited in extent.

4.2.5.2 Rock armouring

From the above work, an initial assessment of rock requirements for the geomorphic landform as for the upper PSE. An initial storm event equivalent to the 1:100-year ARI was modelled, which indicates that velocities are generally less than 3.5 m/s (refer to Figure 4.17), but that along the western perimeter where the drains tie into the steep natural ground, there are some velocities up to 4.5 m/sec. This risk will be managed at detailed design by widening the drains to reduce the overall velocity.

From the initial computations, we expect that approximately 7,100 m^3 of rock armouring would be required for the 2.43km of drainage lines, typically durable rock with a D_{50} grading of 250 mm. This material will require screening prior to placement into the drains.

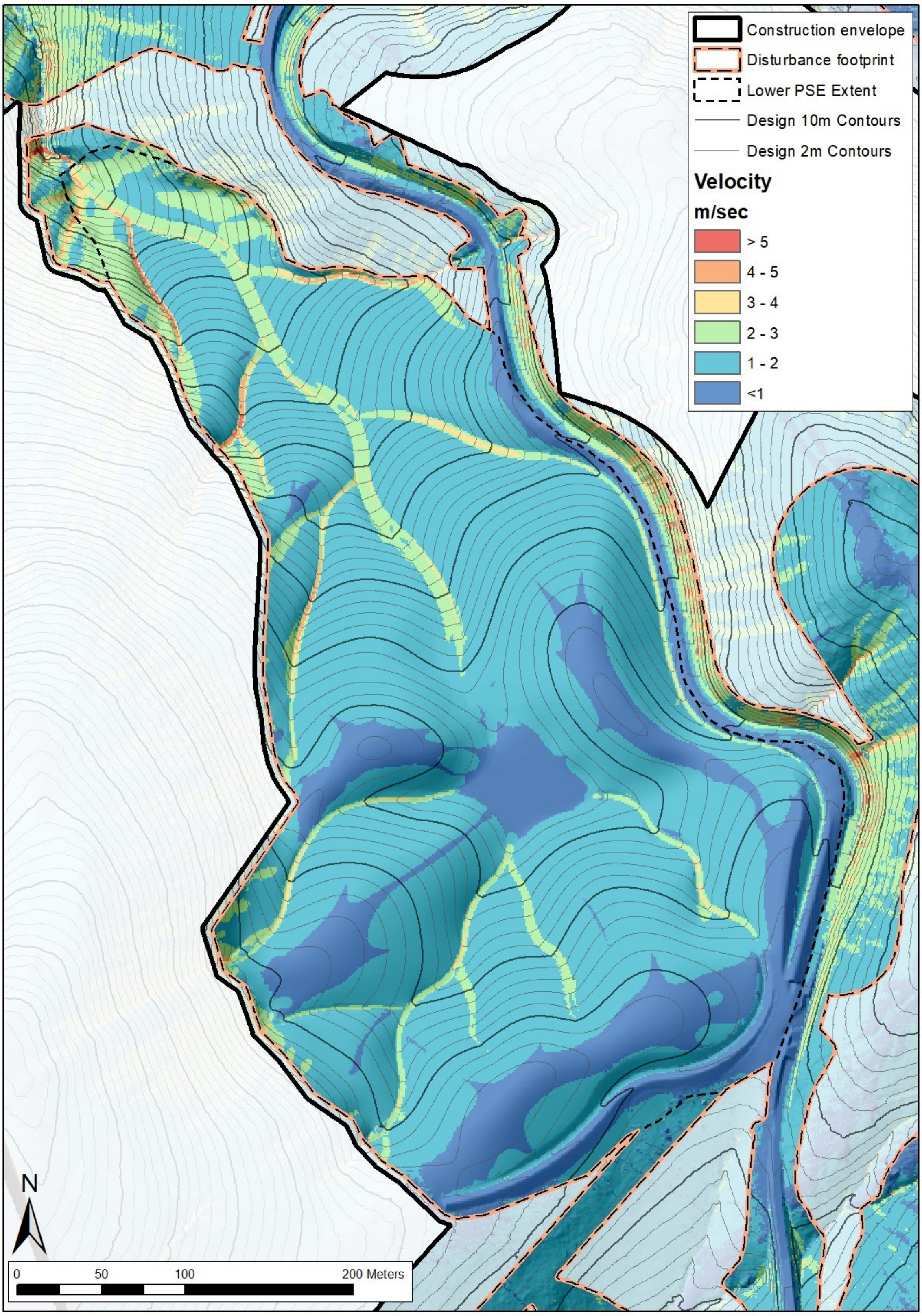

Figure 4.17 Modelled velocities (m/s) for lower PSE proposed design surface (units = m/s)

4.2.6 Sediment and seepage collection dams

The main challenge for water management at the lower PSE is that the landform will be constructed in a valley, with water draining towards the operational area. This impact is reduced slightly by the access road on the northern side which will cut-off a portion of the clean catchment.

The remainder of the clean catchment will need to be diverted by temporary drainage lines placed on the edges of the construction area which will then be replaced as the spoil moves up the valley. The final landform incorporates the flow from the upstream natural environment by having drainage lines that pick up each of the main areas where flow is concentrated off the natural landform is collected by rock armoured drainage lines.

The ability to cut drains on to the sides of the PSE during construction has still to be assessed on site, but on similar sites elsewhere in NSW, this has been easier than expected with shallow excavation normally possible except where there is exposed bedrock.

Water containment will then be implemented by a sediment dam at the toe of the PSE. This would receive all the runoff from the PSE during construction. As for the upper PSE, the current expectation from the geological assessment is that the spoil will be geochemically inert. Blasting is more confined than for the upper PSE, however, and the potential for impacts from blasting on the spoil may be greater. This will need to be confirmed at detailed design.

We have considered both the required storage for containment of sediment only using the 5-day 95th percentile rainfall depths with a high runoff rate of around 0.79 and assumed sediment capacity of 50% of the water storage volume. These calculations result in the required sediment dam storage volumes given in Table 4.4, with the conceptual dam location shown in Figure 4.18.

Table 4.4 Lower PSE sediment dam sizing

Dam ID	Catchment Area (ha)	Water Storage Required – Blue Book 5 Day 95th Percentile (m^3)	Sediment Storage Required – 0.5x Blue Book Water Storage (m^3)	Total Volume – Water and Sediment (m^3)	Design Volume Achieved (m^3)
Dam - 1	16.3**	6,990	3,500	10,490	6,000

* Sediment storage is at least 50% of total water storage volume.

** This assumes the clean catchment will be diverted around the dam. If this is not achieved, the catchment will increase to 23.9ha

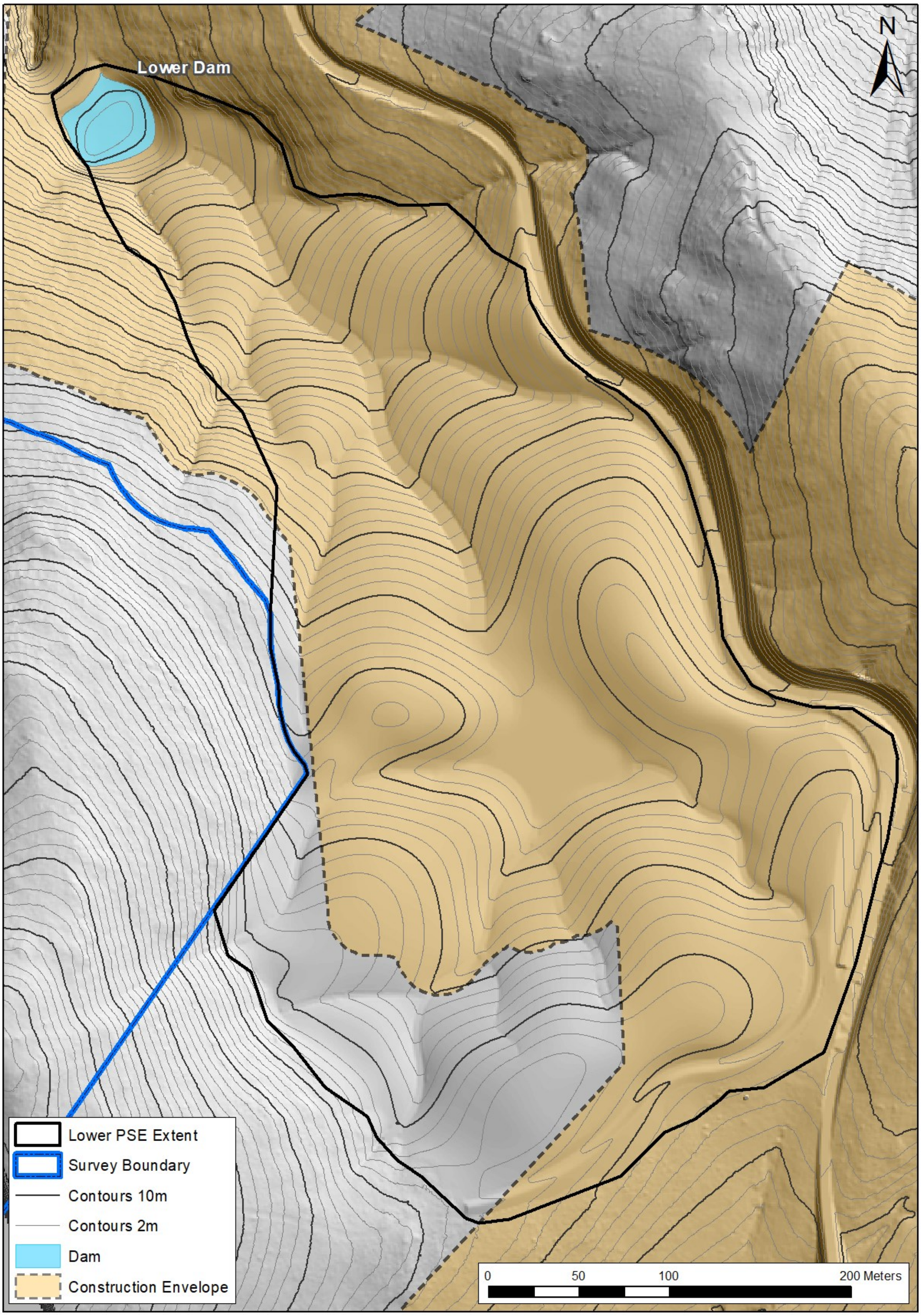

Figure 4.18 Initial sediment dam storage location

The lower PSE sediment dam has been based on the residual catchment after diversion of the clean water. As currently sized, the dam does not have sufficient capacity for the Blue Book requirements, even with a wall height that is close to 18m in height when measured from the toe of the dam wall. On the upstream side the dam is only around 10m in height, reflecting the steep nature of the valley floor below the dam.

There are options to manage this issue by staging the construction, with an initial smaller dam on the toe and diversion of a far greater catchment area upstream past the dam. As the landform is constructed in a series of terraces, provision can then be made to store runoff on a series of ponds on the spoils, provided these are not too deep or located to close to the outer edge to present a risk of piping failure. These shallow ponds could potentially also have a temporary lining to limit ingress.

It is envisaged that, by planning progressive raising of the lower PSE and incorporating a new series of diversions further upslope together with additional storage on the surface, a suitable smaller dam on the toe can be constructed. A terrace has been provided higher up on the landform for flood attenuation, and this area will also be suitable for sediment control of flows off the upper terraces once the PSE reaches this level.

It is proposed that the detailed sizing and design of the water management dams for the lower PSE can be addressed at detailed design. It is highlighted here that there are some challenges to be overcome to ensure the risk of spilling of water of an unsuitable quality is appropriate to the legal requirements, but there are options to achieve this. It is intended for these dams to be in operation until the surface has stabilised and can be integrated back into the natural catchment.

5 Conclusions

The conceptual designs for the upper and lower PSE can accommodate the required volumes, expected to be around 1,741,000m³ at the upper site and 1,810,700m³ at the lower site. This excludes the potential to place additional material at the lower site into the laydown area.

The geomorphic design approach allows the management of runoff both from the surfaces and from adjacent natural landforms. The landforms are expected to be erosionally stable, with some 12,500 m^3 of rock required for the various drainage lines on the surface.

The landforms are likely to blend in well to the overall existing surface and connect the landform to the natural environment. Slopes across the surface area restricted to less than 1V:3H, or 18 degrees as far as possible to allow for easy cross-ripping with a dozer. However, this was not always achieved, and there are some slopes up to 1V:2.75H or 20 degrees, particularly where the steep natural landforms tie into the PSE. It should be noted that:

- The proposed design for the upper PSE has an average slope of 17.2 degrees. Around 49.1% of the surface is flatter than 1V:3H, and 96.7% flatter than 1V:2.75H; and
- The proposed design for the lower PSE has an average slope of degrees 14.2. Around 78.5% of the surface is flatter than 1V:3H, and 94.3% flatter than 1V:2.75H.

Water management and storage for both sites are challenging, for the upper PSE because it is located on a ridgeline, and at the lower PSE due to steepness of the valley floor and sides downstream of the PSE. Both sites will require upstream catchment management during construction, and water management dams on the downstream toe to limit potential impacts on the downstream environment.

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