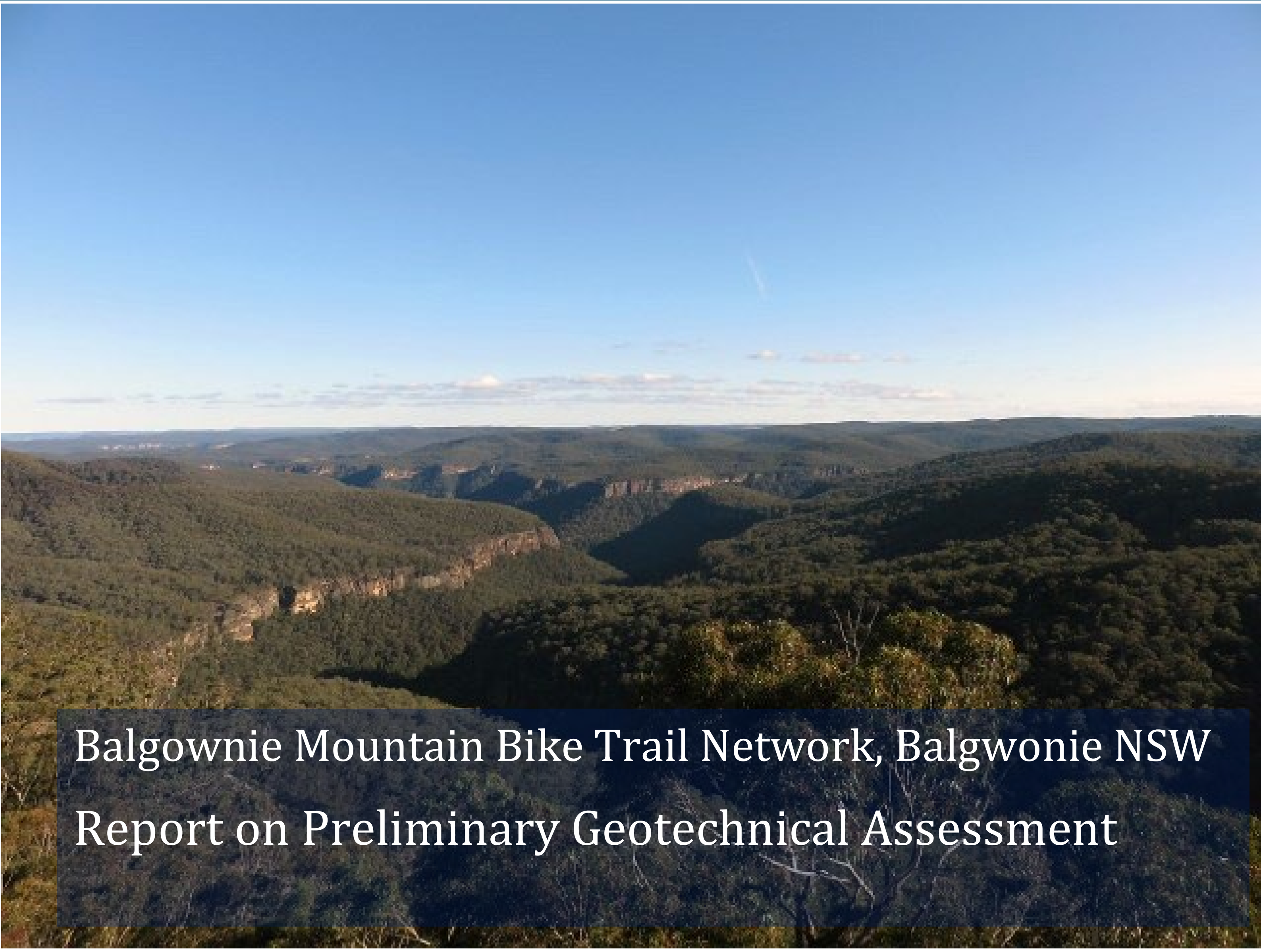
TERRA INSIGHT



Balgownie Mountain Bike Trail Network, Balgwonie NSW

Report on Preliminary Geotechnical Assessment

Prepared for:

Niche Environment and Heritage

Our Ref: TERRA22-223.Rep1.Rev1

Prepared for:
Niche Environment and heritage
PO Box 31
Fairy Meadow NSW 2519

4 April 2023

Attention: Mr K Whitaker,

RE: Balgownie Mountain Bike Trail Network, Balgwonie NSW
Report on Preliminary Geotechnical Assessment

Dear Kai

Please find enclosed our geotechnical report for the above site in relation to a proposed Mountain Bike Trail Network. This report should be read in conjunction with the attached document ‘About Your Report’ in Appendix A. Should you have any questions please contact the undersigned.

For and on behalf of Terra Insight

Karen Gates
Principal Engineer/ Director
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1 Introduction

It is understood that a Mountain Bike Network is proposed for the mid and lower slopes of the Illawarra Escarpment above Balgownie, Tarrawanna and Corrimal. We understand the scheme will comprise approximately 20 kilometres of trails, including supporting infrastructure and services such as trail heads, exits, parking, and amenities areas. At the request of Niche (the client), TerraInsight Pty Ltd (Terra) has performed this preliminary geotechnical assessment with the following objectives:

- Geotechnical information to facilitate the assessment of the suitability of the scheme;
- Identification of geotechnical hazards that may impact the proposed development;
- Land slide risk assessment in accordance with the National Parks and Wildlife Service guidelines and AGS 2007. The Transport for NSW landslide risk guidelines were also referenced.

We understand that Niche requires the following:

a) A review of readily available history of slope instability upon the site or related land.
b) A plan of the site and related land from survey and field measurements with existing contours (at 1 metre intervals) and key features identified. The site plan should show the locations of the proposed development and identifiable geotechnical hazards.
c) A geotechnical model including:
    - Details determined from site inspections (a site inspection is required in all cases);
    - Site investigations may be required (site investigation will require site mapping, delineation of different site conditions and may involve sub surface investigation to determine soil/rock parameters and groundwater conditions. Boreholes and/or test pit excavations or other methods necessary to adequately assess the geotechnical/geological model for the site also need to be identified); and
    - Any other information used in preparation of the geotechnical report.
d) Photographs and/or drawings and GIS data of the site and related land adequately illustrating and recording all geotechnical features referred to in the geotechnical report.
e) An assessment of the risk posed by all reasonably identifiable geotechnical hazards which have the potential to either individually or cumulatively impact upon people or property upon the site or related land or surrounding sites to the proposed development in accordance with the AGS 2007 guidelines.
f) A conclusion as to whether the site is suitable for the proposed development to be carried out, either conditionally or unconditionally. This must be in the form of a specific statement that the site is suitable for the development proposed to be carried out with an acceptable risk in accordance with the measures and methods to be applied to the site including but not limited to recommendations on:
g) Any conditions that may be required for the ongoing mitigation and maintenance of the site and the proposal, from a geotechnical viewpoint.

2 Scope of work

The scope of work we proposed to undertake to achieve the above requirements is detailed below:

- Desktop study/review of any existing information (geology, topography, slope heat mapping, historical stability mapping, existing information for nearby sites where available). We note that we have access to historical stability mapping for the slope of the Illawarra Escarpment but this has not been digitised;
- Analysis will be used to divide the area of trails into areas of similar terrains based on topography, geology, and landslide risk which will be digitised. Terrain analysis allows preliminary geological models to be developed which can then be ground truthed during site inspections and can be further defined with limited subsurface site reconnaissance. This allows the areas to broadly grouped in terms of geotechnical conditions and required construction works.
- Inspection of the site to assess general site conditions and potential geohazards such as landslides, soils creep, erosion, drainage. This will include mapping of surface features and photographic records of site inspection.
- At this stage, the requirement for subsurface investigation is not defined and is likely to be driven by the findings of the initial site walkover inspections. Most of the site are likely to be assessable only by foot. This limits investigations to visual inspection, limited depth hand augers and DCPs testing (a test which used a weight to probe into the ground to determine soil strength and depth to rock). Some machinery may be able to access parts of the trails from nearby maintenance paths or set down areas. This means that limited test pitting or shallow depth augur holes may be possible in some locations. We have not provided an allowance for sub surface investigations along the alignments. This scope will need to be developed based on the field observations. No allowance has been made for deep investigation (> 2m) using drilling rigs.
- Visual assessment of stability of slopes in accordance with NSW RMS slope analysis methods or AGS 2007 guidelines in accordance with the NPWS guidelines.
- Preparing a geotechnical report including a summary of investigation methodology, factual data, geotechnical hazards identified and risk mitigation measures to inform design of the proposed trails.

3 Desk Study Findings

3.1. Site details

The site includes an area of approximately 2.5km^2, below Brokers Point Escarpment and the residential areas of Balgownie, Tarrawanna and Corrimal to the east as shown in Figure 1 and detailed in Table 3.1. The site is comprised of five lots within the Illawarra Escarpment State Conservation area. From south to north these are:

- Two lots in Balgownie area – Lot 3 of DP774626 and Lot 157 of DP751301;
- Two Lots in the Tarrawanna Area – Lot 175 of DP880539 and Lot 1 of DP1185547; and
- One Lot in the Corrimal Area – Lot 22 of DP838639.

Within the centre of the site, the proposed trails are bounded by a private property identified as Lot 2 of DP793302 and is associated with the old Corrimal Colliery. Terra has been involved with land stability and geotechnical assessment pertaining to the residential development of this site and inclusion of existing structures of heritage interest. The Corrimal Colliery includes an access road which connects to Hawthorn Street and follows a ridge that splits the site into the two areas hereafter referred to as follows:

- Area NE - comprised of the 'northeast portion' where the lower slopes fall to the southeast; and
- Area SW – comprised of the 'southwest portion' where the lower slopes fall to the south.

Table 3-1: Summary of site identification information

Street Address	Off Cleveland Road, Huntley NSW	
Title Identifiers	Lots 101 to 103 DP856793 and Lot 18 DP 3083	
Area (approximate)	145 ha	
Local Government Area	Wollongong City Council	
Current Zoning	C1 National Parks and Nature Reserves, C2 Environmental Conservation, C3 Environmental Management	
Current Site Use(s)	The site use is consistent with its current zoning, currently used for Mountain Bike and bush walking recreational activities.	
Proposed Site Use	Mountain Bike Trail Network	
Surrounding Land Use	East and South	Mostly in use as residential properties on the footslogs of the Illawarra escarpment and includes Towradgi Creek along the southern side of the site.
	North and West	Illawarra Escarpment, Brokers Nose and national park/nature reserves

3.2. Proposed Site development

The Mountain Bike Network includes about 27 trails to be created or upgraded, the trails extend from the foot slopes of the Illawarra Escarpment to the base of the very steep slopes just below the escarpment, with trails crossing natural drainage channels and wrapping around the private property towards the centre of the site. The proposed development includes the following:

- Supporting infrastructure and services such as trail heads, exits, parking and amenities
- Small to large, single and two way bridges; and
- Floating Trails.

3.3. Local and regional geology

Online Geological zMapping accessed using MinView shows the proposed bike trail is underlain by the Illawarra Coal Measures Group on the mid to lower slopes and the Narrabeen Group on the mid to upper slopes of the escarpment. These Groups, the respective subgroup, units, and lithologies are shown in Figure 2.

The Illawarra Coal Measures and Narrabeen Group are sedimentary rock layers located in the Sydney Basin and formed during the late Permian period and early Triassic period respectively. The Illawarra Coal Measures formed in a lower delta plain and alluvial fan environment. The Narrabeen Group formed in a fluvial environment. These strata are up to 500m to 600m thick each and are typically near horizontally bedded.

The Illawarra Coal Measures are composed mainly of shale, quartz-lithic sandstone, conglomerate rocks, chert, with sporadically carbonaceous mudstone and coal seams.

The Narrabeen Group composed mainly of quartz-rich sandstone, shale and mudstone.

The lower slopes of the site are underlain by recently deposited alluvial valley deposits which are expected to be underlain by the Illawarra Coal Measures Group at depth. Distinct features attributed to these units are discussed further in Section 3.9. Notable features in the geological mapping include the following:

- The site is intersected by the Bulli Coal, Balgownie Coal, Wongawilli Coal, Tongarra Coal and Woonona Coal Seams;
- The Corrimal Fault is mapped through the middle of the site in a northwest to southeast direction near the boundary between Area SW and Area NE. The fault is a strike slip fault and is not known to have been recently active.
- A syncline is mapped to the southwest of the site.

3.4. Aerial Images

Select historical aerial photography of the site (refer to Figure 3) were observed for any significant activities within the properties trail network. The images indicate the following:

Table 3-2: Summary of review of aerial Images

Year of image	Observations noted
1948-51	Imagery shows activity at the Corrimal Colliery 'Pit Top' on the mid slopes of the escarpment, below Brokers Nose. Some earthwork activities are visible around the Pit Top and a dam is visible to the northeast. The location of the old train line is visible from the Pit Top across the contours of the slope to an 'Incline' to the northeast. The old train line is comprised of a filled embankment likely comprised of fill material won from the mine. The old incline connects to a railway at the toe of the slope and is relatively narrow with minor filling activities evident. A cleared area from the middle of the old train line is visible extending down the slope to the incline at the toe of the slope. The clearing appears to be similar to easements along power lines.
1961	Imagery shows significant earthworks along a new incline from the Pit Top to the lower slopes of the escarpment in the North-east Area. The earthworks include cutting on the mid-section and filling on the lower section of the incline to form a working platform for the train line. On the lower slopes, a sorting yard with large structures are visible, surrounding these structures, stockpiling of mine tailings is visible.
1993	The mine entry adit was sealed in 1991. Subsequently, all surface railways and inclines have been decommissioned and are now mostly obscured by vegetation. The cut portion of the incline has been filled in the location of the access road to the mine. On the lower slopes of the incline, coalwash reject fill is visible in parts near Tarrawanna Soccer Field.
2021	No significant changes are visible, residential development has occurred to the north of Tarrawanna Soccer Field. The site is obscured by tree vegetation

3.5. Soil landscapes and soil formation

An excerpt from the NSW Espade site, shown in Figure 4, indicates that the site is underlain by the following main soil landscapes:

- Gwynneville (9029gw): Located on the foot slopes of the Illawarra Escarpment, slopes typically 3 to 25%, landforms include steep hills, moderately inclined foot slopes, characterised by localised structural benches up to 80m wide, localised bedrock outcrops and deep colluvial deposits. Outside residential areas the vegetation comprises of tall open-forests. Soils are comprised of sandy loam topsoils, sandy clay and clays in the subsoils.

- Illawarra Escarpment (9029ie): Located along the upper slopes of the Illawarra Escarpment. Topography comprised of a debris mantle covering the upper slopes and benches of the escarpment, steep to very steep slopes, with gradients of 20 to 50%. Includes the cliffs of the escarpment, bedrock outcrops are typically absent below the escarpment, streamlines unidirectional and large boulders common. Vegetated with mostly uncleared open and closed forest. Mass movement, slumping and landslips are common with gully erosion and sheet erosion occurring after severe rain. Soils are comprised of sandy topsoils and subsoils comprised of sandy clays. The depth of talus varies, typically less than 2m.

The descriptions of the Gwynneville and Illawarra Escarpment landscapes are provided in Appendix B. The main limitations to development identified in the soil landscape reports associated with these soil landscapes are:

- Gwynneville Soil landscape:
  - Localised Stoniness
  - Moderate soil erodibility
  - Stable to slightly reactive surface movement potential
  - Steep slopes
  - Mass movement and localised rockfall hazard
  - Erosion hazard
- Illawarra Escarpment Soil landscape :
  - Stoniness
  - Low water holding capacity
  - Moderately reactive soils
  - Steep slopes
  - Mass movement (slope instability), extreme rock fall, and erosion hazards due to surface waters

3.6. Historical Slope Mapping

The site is located on the foot slopes of the Illawarra Escarpment. The slopes of this area have been mapped on several occasions for landslide risk, since the early 1970s. The extent of the mapping available is limited to the western parts of the site, however, is expected to be general consistent across the site contours. This mapping has not been digitised to any extent, and when viewed in Google Earth, is not to a reliable accurate scale when overlaid on surface features.

The 1970's Bowman mapping comprises six-zones of stability mapping for the greater City of Wollongong based on shear-strength lithology data, information on existing landslips, slope angles and unstable topographic positions to rank the rock units in their likelihood of slope failure and is used as a guide for residential and commercial development. The survey identified that:

- Water is generally the primary initiator of slope failure;
- Topographic positions play a secondary role especially in the case of gully heads which appear to be joint controlled and on steep slopes with slopes greater than the stable angles of repose for specific materials;
- Water access through permeable strata, faults and weathered dykes have minor importance when considering slope stability in Wollongong; and
- Subsidence resulting from mining apparently has not had a notable effect on slope stability in the Wollongong area.

An excerpt from the 1970's mapping covering the site, documented by Bowman (1972) is shown in Figure 5. The land stability zoning and zoning descriptions are shown in Figure 5. The mapping shows an alternating instability zoning across the slopes of the site which are generally consistent with the underlying geology mapping of the site. 'Stable slopes' are mapped at the toe of the slopes, transitioning into 'stable land with some minor areas of slope instability' on the lower slopes of the site. On the lower-mid slopes, the slopes are zoned as 'Less stable' land, transitioning into 'stable land' and alternating between zones defined as 'Topographically unstable for development' and 'stable land' on the steeper upper mid slopes and escarpment slopes. The zones are defined as follows:

- **Zone 1, Stable land** - No landslip problems.
- **Zone 2, Stable land with some minor area of slope instability** - Normally moderately level land which is however underlain by soil which is unstable in certain topographic positions.
- **Zone 3, Less stable land** - Most of the land may be safely utilized although some areas are unsuitable. Generally, topographically elevated more than land in categories above.
- **Zone 4: Moderately Unstable land:** Thorough investigation required before development, Generally, topographically higher relief land underlain by potentially unstable material.
- **Zone 5, Topographically unstable for development** - Topographically unstable for development owing to steep slope and/or topographic position and nature of soil.

More recent mapping has been undertaken by Flentje and Chowdhury (reference Managing Landslide Hazards on the Illawarra Escarpment. 2005). This paper provides an image which maps known landslides, debris flows, and topples/rock falls identified on the Illawarra Escarpment. An excerpt from this mapping is shown in Figure 6. The mapping shows the following:

- One large scale and two small to medium scale slips in the former Corrimal Colliery Property. The eastern two slips have occurred along the access road to the Colliery and to our knowledge, based in previous inspections of this property, are associated with filling activities along the road shoulder especially were positioned across drainage gullies. The western slip is situated above the pit top and appears to be associated with the failure a very steep slope (potentially a cutting) in alignment with a drainage channel.
- A slip is recorded along the banks of Towradgi Creek downstream of the site. This slip occurred on the creek bank slopes where the drainage channel is nearby to the creek bank. The bank is about 4m high and very steeply sloping and is expected to have occurred potentially from filling associated with the neighbouring property and erosional processes on along the toe of the slope adjacent the creek.

3.7. Surface hydrology

Surface drainage modelling was undertaken based on elevation data sourced from ELVIS - Elevation and Depth - Foundation Spatial Data as shown in Figure 7. The modelling was undertaken to identify major and minor channels based on the catchment areas surrounding the drainage paths. The modelling shows several major channels that fall to the south, from the base of the escarpment to the south and through the lower slopes of the site towards Towradgi Creek which drains to the east. This is hereafter referred to as the Southern Drainage Area. The northeast area of the Site has several minor channels which flow down a concave like slope feature on the mid slopes (here after referred to as the North-East Drainage Area).

3.8. Slope Heat Mapping

Slope heat mapping are shown in Figure 7 based on elevation data sourced from ELVIS - Elevation and Depth - Foundation Spatial Data. Slope mapping is separated to highlight moderate slopes (>10 degrees), steep slopes (>18 degrees), very steep slopes (>27 degrees), and extreme slopes (>45 degrees). General observations of this mapping indicate the following:

- Extremely steep slopes (>45 degrees) are rare across the site. There are confined mainly to localised areas on the Escarpment on the western edge of the Site.
- Very steep slopes (>27 degrees but < 45 degrees) are not common on the site. These slopes are localised to the mid slopes, the upper mid slope benches, and the escarpment slopes.
- Steep slopes (>18 degrees but < 27 degrees) or steeper slopes cover less than 25% of the Site. On the lower slopes, steeply sloping terrain is rare and localised around the drainage channels. On the mid slopes of the Site, these slopes are common and increase in occurrence around a gully feature to the northeast. On the upper mid slopes, the benches are steeply sloping or greater. The upper escarpment slopes are steeply sloping or greater.
- Moderate slopes (10 to 18 degree) or steeper cover about 50% of the site. On the lower slopes these moderate slopes are less common, typically along the drainage channels and the access road ridge line. On the mid slopes, the moderate slopes highlight poorly defined narrow benches that extend across the length of the site and are comprise of large concave shaped slopes with an internal gully network on the northeast area of the site. The upper mid slopes comprised of wide well defined natural benches. Clear signs of cutting

and filling are visible on the lower slopes to the east of the Corrimal Colliery.

Signs of increased slope movement are associated with steeper slopes on the site, localised slopes around drainage channels, heads of gullies, filled areas and the escarpment slopes. No obvious signs of recent large and moderate scale slope movement are visible in the heat mapping; however, areas of greater tree cover have reduced the detail in the slope mapping, especially on the mid and upper slopes. On the lower slopes, the detail on the slopes is clearer and show undulations that are associated with soil creep.

3.9. Topography, Slope Heat Mapping and Land Stability

The site is located on the upper, middle, and lower slopes of the Illawarra Escarpment. Geomorphology has been used to divide the Site into Terrain Units as shown in Figure 9. These Terrain units are used to define parts of the Site with similar:

- Topography;
- Subsurface geology;
- Subsurface soil profiles; and
- Landslide risk.

The Major Terrain units derived for the site are summarised in Table 3.2.

Table 3-3: Summary of Major Terrain Units

Terrain Unit	Geology	Description	Slope Details	Slope stability
T1 - Lower slopes	From the lower to the upper slopes of the unit, the geology includes the Pheasants Nest Formation, Erins Vale Formation and then the Wilton Formation. This terrain unit also includes the Woonona Coal Seam above the Erins Vale Formation and Tongarra Coal Seam above the Wilton Formation. The lithology of these units comprises of shale, sandstone, claystone, siltstone and coal and carbonaceous shale.	The topography mainly falls to the south and east with the slopes pivoting around a ridge along the Colliery Access Road. This terrain unit is situated on the lower Escarpment slopes, comprised of gentle slopes with common moderate slopes and rare steep slopes. Moderate and steeper slopes are present along the drainage channels that fall through the terrain unit. As the terrain unit is on the lower slopes, drainage courses are well defined between 30m to 50m across.	Typically <10 degrees, areas between 10 to 18 degrees common and localised areas along drainage channels are >18degrees. Local relief of about 60m on the southern portion and 40m on the northeast portion.	Stability mapping indicates this unit is situated on stable land with minor areas of instability. The upper section of terrain unit overlaps less stable land. No significant signs of mass movement, slope creep evident in slope heat mapping. Local increased instability expected around steep drainage channels.
T2 - Lower mid slopes	Includes the upper units of the Illawarra Coal Measures. Form the lower to upper elevated parts of this terrain unit, the geology is comprised of an undifferentiated unit of the Illawarra Coal Measures, overlain by the Wongawilli Coal Unit, Eckersley Formation and Coal Cliff Sandstone Unit. The lithology is comprised of sandstone, siltstone, claystone and coal. This terrain unit also includes the Balgownie Coal and Bulli Coal Seam.	This terrain unit includes the area on the lower mid slopes of the site, comprised of poorly defined benches that fall with steep slopes typically to the southeast. On the northeast side of the terrain unit a gully network is present (North-easter Drainage area) and has formed narrow ridges and gullies with steep to very steep slopes. Aerial imagery shows earthworks within this area associated with the Corrimal Colliery. Earthworks include filling along the contours to form a train line across the northeast portion of the terrain unit and include earthworks associated with old inclines from the Colliery and train line to the lower slopes of the site.	Level to moderate benches (<18 degrees), with steep slopes (18 to 27 degrees) and common very steep slopes around gullies (>45 degrees). Local relief of about 80m on the southern portion and 110m on the northeast portion.	Stability mapping indicates this unit is comprised of stable land with some minor areas of slope instability and includes a topographically unstable area though the upper section of the terrain unit. Increased signs of slope movement, associated with steeper slopes on the benches, the heads of gullies and along the gullies, with these features notable on the northeast portion of the terrain unit.

Terrain Unit	Geology	Description	Slope Details	Slope stability
T3 – Upper mid slopes	Comprises of units of the Narrabeen Group, including from the lower site elevations to upper site elevations within this terrain unit, the Wombarra Claystone, Scarborough Sandstone and Stanwell Park Claystone Units.	The terrain unit is situated on the upper mid slopes of the escarpment and comprised of well-defined benches about 50m to 150m across. The benches fall with steep to very steep intermediate slopes, notably along the Scarborough Sandstone unit. Along the Claystone units, the topography is gently sloping. Poorly defined incised drainage channels fall across the unit.	Level to moderate benches (<18 degrees) Steep to Very Steep intermediate bench slopes (typically 25 to 40 degrees) Local relief of about 70m to 90m.	Stability mapping indicates this unit comprises alternating "topographically unstable land" and "stable land with minor areas of slope instability". Increased likelihood of slope movement on the steep to very steep slopes between the benches and along the poorly defined drainage channels. With gully erosion and sheet erosion occurring after severe rain.
T4 – Escarpment slopes	Comprises units of the Narrabeen Group, including the Bulgo Sandstone Unit on the lower levels of the terrain overlain by the Hawksbury Sandstone Unit on the upper elevations of this terrain unit.	Situated on the very steep to extremely steep slopes just below the escarpment, which then fall onto the near level benches of Terrain Unit 3. No works are proposed for this area. Talus material expected to average about 2.0m depth.	Near Vertical escarpment slopes, very steep lower slopes (30 to 45 degrees) Local relief of about 90m to 100m.	Stability mapping indicates this unit is unstable land. Signs of slope instability common, increased risk of rock falls from near vertical escarpment.
T5 – Alluvial Terrain	Comprises of quaternary aged alluvial fan deposits, comprised of fluvially deposited quartz-lithic sand, silt, gravel and clay. Expected to be underlain, at depth, by the Pheasants Nest Formation.	Situated at the toe of the escarpment, between Terrain Unit 1 and the residential areas to the south of the site. Comprises the upper portion of Towradgi Creek. The alluvial drainage course is about 100m wide with a near level cross fall, falling to the east. The channel banks fall with moderate to steep slopes to the base of the creek which is level across the channel. The base of the creek includes a shallow incised flow path about 0.5m to 1.0m deep and there is evidence of older meanders through the base of the channel.	Creek bank slopes moderate to steeply at about 15 to 30 degrees with a near level channel base. Creek banks with a local relief of 7m to 10m.	Signs of slope instability where slopes are very steeply sloping and where the active creek channel meanders into the creek banks. Potential for instability where the creek banks have been filled.

3.10. Terrain Unit Site Observations

Observations of the site were made at the time of the site inspection. Photographs taken of the general site conditions are provided in Appendix C. The site observations have been divided into the five terrain units. Field Observation locations and descriptions are included in Figure 10. It is noted that the:

- 'Minor gullies' were typically incised less than 0.5m or gently sloping
- 'Major gullies' were typically, deeply incised, wide, very steeply sloping and include large boulders within the channel.

Terra has observed the site as part of the investigation. Known slips and slips observed during the site inspection are included in Figure 10. These slips are typically associated with cutting and filling activities in topographically unstable positions and more extremely sloping natural slopes. Observations within the Terrain Units are as follows:

Table 3-4: Terrain Unit 1 Site Observations

Terrain Unit	Area	Key Observations	Areas of Interest
T1	**SW**	− Terrain unit 1 comprises moderate slopes that fall to the south with wide moderately to steeply sloping gullies though the unit, typically draining to the south. − The trails traverse across ridge slopes, gully slopes, over major gullies and minor gullies as shown on Photograph 1 to 3. − No signs of significant slope movement were observed within this unit. Signs of soil creep were common, although typically minor to moderate, with increased signs of soil creep on the steep slopes along the gullies and sporadic moderate to steep slopes though the unit. − Large boulders were commonly observed on the surface of the site, assumed to originate from rock outcrops on the mid slopes or from rollout from the escarpment. No recent boulder rollouts were observed in this unit. − Seepages were observed in parts as shown in Photograph 4. − Erosion along the trails have occurred in parts as shown in Photograph 5. − Several drainage channels where proposed bridges were inspected. These locations are shown in Photographs 6 to 8. These channels comprised of cobble and boulder lined gullies about 6m to 15m across. Erosion along the overburden soils along the creeks was common.	Trail 1 Bridge. Trail 3 Bridge Trail 15 Bridge
T1	**NE**	− This section of Terrain Unit 1 is situated on the moderate lower slopes on the northeast area of the site, a view of the foot slopes is shown in Photograph 9. − Historic earthworks are observed in this area, these include old dams and filled embankments as shown in Photograph 10. − Several gullies flow through unit and have steep slopes. − Trail 30 crosses a wide channel base as shown in Photograph 11. − Some channels are incised and expose rock at shallow depth as shown in Photograph 12 and 13 adjacent to Trail 30. − Trails 28 and 32 follow a gentle ridge as shown in Photograph 14. − Trail 35 traverses down locally steep slopes and crosses incised minor channels as shown in Photograph 15 and 16.	Trail 30 wide channel crossing. Trail 35 incised channels.

Table 3-5: Terrain Unit 2 Site Observations

Terrain Unit	Area	Key Observations	Areas of Interest
T2	**SW**	– Includes a small section to the southwest of the Corrimal Colliery Property. – Slopes are steeply sloping with poorly defined terraces. – This area includes the section below the power lines as shown in Photograph 1. This section is situated below an access road from the Corrimal Colliery to the Escarpment Trail. – Several minor gullies are observed in this area, the gullies are shallow and incised as shown in Photograph 2 to 3. – Seepages springing from the toe of the steep slopes on the level benches were observed to be common as shown in Photograph 4. – Trail 21 and Trail 25b traverse up steep to very steep slopes that are bounded by near level benches as shown in Photograph 5 and 6. Lean in trees on the steep slopes indicate signs of soil creep as shown in Photograph 7. Some boulders are observed on the slope and are expected to have originated from outcropping rock along the crest of the benches. – Off the trail, on the access road form the Corrimal Colliery a small landslip has occurred on the filled side of the road. The slip is a rotational slip and has occurred due to excess runoff and poor filling practices. The slip is distant from any trails and is unlikely to impact the trail and is shown in Photograph 8.	Upper access Road slip. General steep areas throughout section.
T2	**NE**	– Slopes are steep and locally very steep in two main sections of this area. – On the steep lower slopes of T2, Trail 30 traverses up a steep ridge with signs of soil creep as shown in Photograph 9. Rock is shallow along the ridge crest and outcrops towards a gully to the south as shown in Photograph 10. – Trail 31 crosses a gully network (shown in Photograph 11) that has been effected by filling activities. Slopes from the northeast fall very steeply towards the base of the gully with rock outcrops at the top. This area is in the old Colliery incline. Fill is comprised of coarse gravel and cobbles as shown in Photograph 12 and appears to be to depths greater than 2m. Signs of soil creep are observed within the fill in the gully as shown in Photograph 13. Some deep incised channels have formed within the fill as shown in Photograph 14. Upslope of the trail, slopes are very steep, slips have occurred, these slips are shallow in depth and appear to be associated with filling activities along the crest of a very steep slope uphill of the trail as shown in Photographs 15 and 16. – Trail 32 intersects Trail 33 at a creek crossing and crosses a creek on the lower slopes of T2. The creek is wide and comprises of large cobbles as shown in Photographs 17 and 18. – Old Train Line is comprised of a partially cut and imported fill embankment. The fill is composed of coarse material. The fill generally appears stable in most locations as shown in Photograph 19. Increased movements in the fill are observed along the drainage channels, comprised of small scale and larger slips in minor and major channels respectively as shown in Photograph 20 and 21. A slip is observed in filled section of location of Trail 28 as shown in Photograph 22. The slip is inactive, and an existing trail is	Steeper upper and lower section, poorly defined bench, increased movement risk. Bedrock outcrops. Trail 31 gully slopes. Trail 32, two creek crossings. Filled Old Train Line.

		present on the slip. Rock outcrops are observed above the Old Train Line, washout and slips have occurred along the overburden soils as shown in Photograph 23 and 24. Impact from these slips are manageable.	

Table 3-6: Terrain Unit 3 and 4 Site Observations

Terrain Unit	Key Observations	Areas of Interest
T3	– Comprised of steep to very steep slopes and level benches. – Trail 21 and 22 is located along a level bench at the toe of a very steep slope as shown in Photograph 1. – Seepages were observed to be common along the toe of the very steep slopes, on the level benches as shown in Photograph 2. These seepages are expected to spring up below the sandstone unit due to less permeable claystone units. – The very steep slope includes rock outcrops along the crest of the bench as shown in Photograph 3 and 4. The trail was proposed to traverse up the slope over the rock outcrop. A second option was accessed where rock was not outcropping and traversed up a very steep section. A slip has occurred along the steep section as shown in Photograph 5, with tension cracks extending past the crest of the bench as shown in Photograph 6. – Trail 22 continues across the near level bench slopes and crosses several minor drainage channels as shown in Photograph 7. – Trail 24 comprised of a straight section down a very steep bench slope, adjacent to a minor channel as shown in Photograph 8. The trail then continues onto moderately sloping hummocky terrain with minor gullies as shown in Photograph 9. Trail 24 crosses a deeply incised boulder filled major gully with signs of creek bank instability as shown in Photograph 10 and 11. – Trail 25a is situated along the lower slope of the very steep bench, rock appears to be shallow on the slope as shown in Photograph 12. – Trail 33 crosses a major channel on the very steep slopes. An existing trail is present in the location and is comprised of cobbles and boulders with no significant movements observed in the location as shown in Photograph 13. The trail continues across the slope to the level terrain at the toe as shown in Photograph 14. – Erosion is observed on some of the existing trails along the very steeply sloping benches as shown in Photograph 15.	Trail 21, 22 24, 24a and 33 transitions down very steep slopes and proximity to gullies.
T4	– Comprised of the very steep slopes on the upper slopes of the escarpment and includes the vertical rock outcrops at the top of the escarpment. – No trails are proposed for this section, the Upper Access Road and Trail 22 are situated along the level terrain below this unit. A photograph of the terrain unit is shown in Photograph 16.	Very steep slopes, mass landslide risk onto trail.

Table 3-7: Terrain Unit 5 Site Observations

Terrain Unit	Key Observations	Areas of Interest
T5	– Situated at the toe of the escarpment at the head of Towradgi Creek. – Comprised of a wide alluvial channel with an incised creek through the centre. – Some soil creep is observed on the very steep creek banks away from the channel as shown in Photograph 1 and 2. – Where the creek meanders near the very steep creek banks, increased	Trail 1 Bridge Location. Very steep creek banks.

	movement is observed – These areas are observed to be away from the proposed trails as shown in Photographs 3 to 5. Where the trails are near these slopes, they may need to be moved. − Trails 1 and 5 intersect this area and traverse down the very steep creek banks onto the level terrain below the creek. − A bridge is proposed for Trail 1 where it crosses the creek, the bride location is shown in Photographs 6 and 7. − Erosion is common along the existing trails falling towards T5 as shown in Photograph 8.	

3.11. Subsurface Observations

Dynamic Cone Penetrometer (DCP) Testing was undertaken in four bridge locations across the site. These locations are shown in Figure 11 and referred to Bridge 1 to Bridge 4. The DCP logs are attached in Appendix D. The DCP testing indicated the following:

- In the location of Bridge 1, within T5, DCP testing was undertaken on both sides of the creek above the incised creek banks at an elevation of about 0.5m to 1.0m above the active river flow. Soft material was encountered to about 1.0m depth and refused at about 1.3m depth on both sides of the creek. It is expected the DCP refused on weathered material at these depths.
- In the location of Bridge 2 in T1, DCP testing was undertaken on both sides of the creek about halfway up the creek banks. The DCP test encountered soft material to about 0.9m depth, underlain by stiff material to about 3.0m depth. It is expected that this material likely comprises surficial alluvial soils and deep residual soils.
- In the location of Bridge 3 in T1, DCP testing was undertaken on both sides of the creek. The DCP test refused at shallow depth on the eastern side of the creek and at depths of 1.0m on western side of the creek. It is expected that the DCP likely refused on cobbles or boulders within colluvial soils.
- In the location of Bridge 4 in T1, DCP testing was undertaken in three locations across the creek. The channel comprised of a wide gully with an incised active channel on the western side of the gully. The gully was full of large boulders and cobbles with the cobbles and boulders in the channel more exposed. The DCP tests was undertaken on the western side of the channel encountered soft soils to 1.0m depth, underlain by stiff soils to 1.5m depth and very stiff soils thereafter. It is expected that the western side is likely underlain by some colluvial soils, overlying residual soils which grade into extremely weathered material at depths of 2.0m to 3.0m. Within the centre of the gully the DCP refused at shallow depth, likely on cobbles.

4 Geotechnical Site Characterisation

4.1. Interpreted subsurface conditions by Terrain Units

The Site is located on a hill side area with the depth to rock expected to be relatively shallow. The soil profile likely to be encountered across the site will be comprised of:

- Topsoil: Comprised of a shallow to deep organic soil layer at depths estimated to be between 0.5m to 1.0m; underlain by
- Fill: present along the Old Train Line and Incline. Comprised of coarse shale and coalwash reject gravel and cobbles, placed in an uncontrolled manner.
- Alluvium: Comprised of cobbles and gravels along the centre of the drainage gullies where the soils are undergoing erosional processes to depths varying between 0.5m and 1.0m below the base of the gullies and comprised of sands silts and clays in depositional environments within T5 to depths of 1.0m at the base of the creek.
- Colluvium: comprised silty and sandy clays with cobbles and gravels expected to be encountered across most locations across the site, averaging depths of about and 1.0m to 2.0m across the site, decreasing in depth towards bench crests and ridge lines; underlain by
- Residual Soil: A shallow to moderate subsoil of medium plasticity which grades into
- Weathered Material which grades into less weathered rock. This is likely to be comprised of siltstone and shales in T5 and T1, shales and sandstones in T2, sandstone on the very steeply portions of the site in T3 and claystone's on the more level terrain. Weathered material was observed to be shallow in incised gullies at the toe of slopes in T1 NE, was not observed at shallow depth in T1 SW. In T2 and T3 rock outcrops were observed at shallow depth towards the crest of the steeply sloping benches.

4.2. Minor Terrain Units

Based on site observations, areas within the Major Terrain Units have been identified. These have been referred to as Minor Terrain Units. These Minor Terrain units are shown in Figure 12 and include the following:

- **Lower Risk Terrain (LT)** – Comprised of slopes away from major drainage channels, typically near level to moderately sloping, located throughout the entire site, includes some minor drainage channels.
- **Gully Terrain (GT)** – Slopes surrounding major channels throughout the entire site, typically to the steeply sloping extents of the channels.
- **Terrain Unit 2.1 (T2.1)** – Steep slopes on the lower and upper portions of Terrain Unit 2;
- **Terrain Unit 3.1 (T3.1)** – Very Steep slopes on the upper and lower portions Terrain Unit 3 associated with the steeply sloping benches.
- **Fill Terrain (FT)** – Slopes associated with the cut and fill activities of the Old Train Line and old incline.

5 Preliminary Landslide Risk Assessment

5.1. Introduction

This landslide risk assessment relates to the proposed development of the site as a Mountain Trail Bike Park. The landslide risks considered herein, are those that directly impact on proposed development of the site (eg property such as the trails) and the users and maintainers of those trails.

Assessment of landslide risk considers the frequency (eg probability) of that hazard and the consequences (eg impact) of that particular failure events when it occurs. Consequences of an event are related to the vulnerability of the person or structure likely to be affected by the landslide event. It is noted that the following guidelines for assessing risk are available within Australia:

- Appendix C Australian Geomechanics Journal, Vol. 42, No. 1, dated March 2007. Important information in relation to the use of this risk assessment method is provided in Appendix E of this report. This risk assessment guidelines provided information on the assessment of damage to property and risk of loss of life. It was mainly developed for habitable structures and their users. It includes information on determine probabilities of slides and vulnerabilities of people exposed to slides, but does not provide vulnerabilities specifically for mountain trail bike riders.
- Transport for New South Wales Landslide risk Manual (ver 4): This was designed to access the risk of land slide on main road assets and their users. It includes guidance on vulnerabilities of pedestrians and the public who may use these roads but provides limited guidance specifically for bike riders.

To our knowledge there is limited guidance specifically defined for mountain trial bike riders and their vulnerability to a landslide event. The design of mountain bike trials typically looks at the design of the track in respect to the skill and safety of the rider. It is noted that bike riders are specifically different in terms of vulnerability to other users of property or roads in that:

- They can travel at relatively faster speeds than a pedestrian, in some cases approaching that of a car. In the case of mountain bike trails, their ease of manoeuvrability means they may actually travel faster on a trail/road then a car possible could;
- They are more vulnerable than a car or building occupant who is protected to some degree by the car or building structure. Although safety equipment may be worn, it has limited capacity to reduce injuries caused by impact with the ground by a rider at speed;
- Riders of mountain bikes generally can manoeuvre around or over obstacles, even at speed, with some degree of skill. This is part of the aesthetics of a mountain bike trail. Mountain bike trails are rated in terms of difficulty, and this provides guidance (and to some degree controls) the level of skill of the bike rider that may use a certain trail.

In terms of this assessment detailed herein, we note that the onus is on the owner (or potential owner or party) to decide whether the assessed level of risk is acceptable, considering possible economic consequences of the risk and geotechnical constraints.

5.2. Potential landslide risks

Desktop studies using aerial photo, stability maps, and survey from online elevation data show several areas of potential land stability issues as follows:

- Lower Risk Terrain: This area covers most of the site, typically level to moderately sloping land away from major drainage channels, typically shows minor signs of slope instability that will not significantly impact the proposed bike trails. These areas may be impacted by higher risk slopes upslope or downslope of the area.
- Gully Terrain: These areas are situated around the major drainage channels throughout the site. These drainage channels have typically formed moderate to steeply sloping banks and are incised with vertical banks in parts. These slopes are more vulnerable to slope instability due to erosional processes. Bridges are proposed for most of these trail and gully intersections.
- Fill Terrain: These areas are mainly associated with the earthworks conducted during the operation of the Corrimal Colliery. These areas include the filled old train line across the mid slopes within Terrain Unit 2 and the old Incline

that extends down Terrain Unit 2 and Terrain Unit 1 from the eastern side of the Corrimal Colliery. Increased signs of slope movement are observed in these areas due to the earthwork activities.

- Terrain Unit 2.1: This area includes the steeper slopes within Terrain Unit 2 which may be subject to localised land slippage.
- Terrain Unit 3.1: The area includes the steeper slopes within Terrain Unit 3 which may be subject to localised land slippage.
- Terrain Unit 4: This area includes the very steep slopes on the upper portion of the escarpment. No trails are proposed for this area, however, large scale slips and rockfalls may result in debris or flow out zones that may affect the site downgradient. These will be considered as part of the risk of land slide on the lower terrains units.
- Terrain Unit 5: This area includes the alluvial terrain at the toe of the slope. Increased instability is expected along the slopes that fall towards the base of the creek channels and along the active incised channels.

Based on AGS 2007, recent site observations and knowledge of slope conditions in the general area, potential landslide hazards/ events that could affect the proposed trails at the time of the assessment include:

- Lower Risk Terrain:
  - Localised soil creep;
  - Localised failure;
  - Rock Fall; and
  - Large scale slope failure.
- Gully Terrain:
  - Localised soil creep;
  - Local failure of slopes on trail crossings; and
  - Local failure of slopes impacting bridge and boardwalk structures.
- Fill Terrain:
  - Localised soil creep;
  - Localised failure of slopes
  - Rock falls from within Area; and
  - Large scale slope failure
- Terrain Unit 2.1:
  - Localised soil creep;
  - Localised failure of slope
  - Rock falls from within Area; and
  - Large scale slope failure
- Terrain Unit 3.1:
  - Localised soil creep;
  - Localised failure of slope within Area
  - Rock falls from within Area; and
  - Large scale slope failure
- Terrain Unit 5:
  - Localised soil creep;
  - Local failure of slopes nearby drainage channel impacting trails; and
  - Local failure of slopes nearby drainage channel impacting boardwalks and bridges.

The likelihood of the above hazards/landslide events occurring and the possible consequences to future property are assessed using the AGS and RMS methods on the following sections.

5.3. Risk to Property by AGS methods

Risk to property is assessed based on the proposed conditions of the site, including any risk management implemented as part of the proposed works to the site. As there is no structure currently on this part of the site, the existing risk has not been assessed.

Risk assessment for property loss was undertaken using the Risk Matrix according to AGS (2007). The Risk Matrix defines a qualitative terminology for likelihood, consequence and risk. The frequency estimate is expressed as an annualised probability, considering the probability of spatial impact and is expressed qualitatively as likelihood.

The result of this assessment is summarised in Table 5.1. As the structures proposed are mainly trails, boardwalks and bridge structures, an assigned Importance Level of Structure of 'One' has been adopted in accordance with AGS, 2007 (Appendix D, pg 86). The acceptable level of risk for a type one structure is "moderate". This assessed level of risk post the proposed site works, is based on the advice provided within this report being implemented on the site (refer section 7).

Table 5-1: Landslide event - current and future likelihood and consequences to property

Event	Likelihood	Consequences to property*	Level of Risk
Lower Risk Terrain			
Localised soil creep	Likely	Insignificant	Low
Localised failure	Unlikely	Minor	Low
Rock Fall	Unlikely	Minor	Low
Large scale slope failure	Rare	Medium	Low
Gully Terrain			
Localised soil creep;	Almost Certain	Insignificant	Low
Local failure of trail crossings; and	Likely	Minor	Moderate
Local failure of slopes impacting bridge and boardwalk structures.	Likely	Medium	High
Local failure of slopes impacting piered bridge and boardwalk structures	Unlikely	Medium	Moderate
Fill Terrain			
Localised soil creep;	Almost Certain	Insignificant	Low
Localised failure of slope	Likely	Minor	Moderate
Rock fall from cuttings above trail	Likely	Minor	Moderate
Large scale slope failure	Unlikely	Medium	Moderate
Terrain Unit 2.1			
Localised soil creep;	Almost Certain	Insignificant	Low
Localised failure of slope	Likely	Minor	Moderate
Rock falls from within Area; and	Possible	Minor	Moderate
Large scale slope failure	Unlikely	Medium	Moderate
Terrain Unit 3.1			
Localised soil creep;	Almost Certain	Insignificant	Low
Localised failure of slope	Likely	Minor	Moderate
Rock falls from within Area; and	Likely	Minor	Moderate
Large scale slope failure	Unlikely	Medium	Moderate
Terrain Unit 5			
Localised soil creep	Almost Certain	Insignificant	Low
Local failure impacting trails	Likely	Minor	Moderate
Local failure impacting bridges and boardwalks	Unlikely*	Medium	Low

Note to Table: * It is assumed that the recommendations in Section 7 are adopted/implemented.

The risk assessment above has assumed the following:

- The approximate cost of damage is estimated to be proportional to the amount of trail the event can impact, with increased costs in the locations of structures such as the bridges and boardwalk. Given the length of the entire trail network and relatively low-cost construction, the consequence to property for events such as local failure to large-scale failure is accessed to be minor to medium i.e. these events may impact about 1% to 20% of the trails with costs increasing to 40% in the case of events impacting structures such as bridges.
- Events such as soil creep and rock falls are expected to have an insignificant to minor impact to the trail, requiring only maintenance to resolve.
- No trails are proposed for Terrain Unit 4.

5.4. Risk of loss of life using AGS and RMS Risk Assessment methods

The aim of the land slide risk assessment is to qualitatively or quantitatively allow appropriate identification and assessment of the risk associated with each asset and the asset user by identifying hazards (e.g. the potential failure mechanisms), the likelihood of failure, and the potential consequences.

In the AGS assessment method, the risk to 'Loss of Life' is considered for potential landslide events as follows:

$$R\ (LOL) \quad = P\ (H)\ x\ P\ (S{:}H)\ x\ P(S{:}T)\ x\ V\ (D{:}T)$$

Where

P(H) is the probability of landslide per annum

P(S:H) is the probability of spatial impact which considers the potential travel distance, size of the slide and the geometry of the site.

P(T:S) is the temporal spatial probability which considers the time a person may be on site and the time they may occupy the part of the site impacted by the landslide.

V(D:T) is the vulnerability of the individual on the site.

Similarly, the RMS (TfNSW) method assesses risk in a qualitative format deriving an Annualised Risk Level (ARL). As the assets area trails rather than structures, the RMS method of assessment (Slope Risk Analysis Version 4) which is better suited to roads, is deemed the more appropriate method of assessment. The RMS ARL is based on the following:

Probability or Likelihood Analysis

The probability of a land slide event occurring is assessed in terms of the likelihood of landslide occurring and the detachment probability. The combination of these two probabilities results in a Likelihood of the event (L) which is generally equal to the combined factor of the P(H) and P(S:H) components adopted by AGS.

Consequence analysis

The purpose of consequence analysis is to identify the effects of the hazards on people and property. The elements at risk that the RMS method covers include the road itself and road uses (for example passengers in vehicles, pedestrians and bike users). Consequence analysis considers the following:

- Temporal Probability (T) – will the structure or person be present when the failure occurs. In terms of the trail users, this probability is a function of the volume of trail users on the trail. These trails are expected to be in low use during severe weather (when a landslide is more likely to occur) and are expected to have between 100 to 600 users per trail per day in the peak season; and
- Vulnerability (V) – refers to the probability of the event causing death or injury assuming that the person is within the zone of influence of the event, or a vehicle (or bike) impacts the debris or is loss in a void. It is noted that vulnerability reduces as the speed of vehicles reduces and protection of the vehicle increases. Vulnerability assessed by the RMS method is essentially similar to that adopted by the AGS method.

It is noted in this case, the RMS guide for Slope Risk Analysis accesses the risk specifically for vehicles and pedestrians. People travel at speed in cars, they are generally to some extent protected by vehicle safety requirements. Pedestrians, although not having the same level of protection, travel at considerable reduced speed.

At present there is no risk assessment process by TfNSW which considers the use of roads specifically by motorcycle bike riders (or cyclist such as mountain trail bike riders) who may be travelling at similar speeds to slow moving vehicles (but without the same level of protection of a vehicle).

TERRA has used available published vulnerability data to assess the likely impact of landslides on mountain bike riders based on likely speed (30km/hr to 50km/hr for downhill riders) and the lack of protection. Reference has also been made to design guides for mountain bike trails. Based on these Terra has assessed vulnerabilities for mountain trail bike riders which is summarised in Table 5.2.

Table 5-2: RMS Vulnerability Table and Adopted Vulnerability for Mountain Bike Riders

RMS Vulnerability Table for People and Vehicles					TERRA adaptation of RMS Vulnerability
Vulnerability Rating	**Probability Range**	**People in the Open**	**Vehicle Impacting Mixed Debris Landslide**	**Vehicle Crossing Embankment Failure Area**	**Mountain Bike Rider**
V1	>0.5	Unable to evade rockfall or other debris (movement very/extremely rapid), or buried		Lost into a deep, narrow void	Unable to evade rockfall or other debris (movement very/extremely rapid), or buried, lost in a deep narrow void, speed governed by very steep terrain
V2	0.1-0.5	May be able to evade debris		Lost in a shallow void	May be able to evade debris, lost in a shallow void, speed governed by steep terrain
V3	0.01-0.1	Most people able to evade debris	Loose or wet mixed soil/rock debris a highway speed	Stepped surface with 0.1m to 0.2m steps at highway speeds	Most riders able to evade debris and shallow voids, speed governed by moderate terrain
V4	0.001-0.01		Loose or wet mixed soil/rock debris at urban speeds	Stepped surface with 0.1m to 0.2m steps at urban speeds	Almost all riders able to evade debris and shallow voids, likely on gentle terrain.
V5	<0.001			Stepped surface with 0.1m to 0.2m at low speeds	Existing trail obstacles greater risk to rider, areas impacted by soil creep, trail level, good visibility

Notes to table: *The RMS guide identifies voids regarded as 'deep and narrow' as voids that would cause an extreme deceleration rate on impact and 'shallow' voids causing not as a significant deceleration if impacted.*

Assessed level of risk (ARL)

The likelihood (L), consequence (C) and vulnerability (V) levels are used to derive the overall Assessed Risk Level (ARL) associated with each of the identified hazards. We note that when using the RMS qualitative assessment method for assessing risk, the ranking associated with each "level of risk" decreases as the contribution of that "level of risk increases". For example:

- As the probability of an event increases, the Likelihood ranking decreases from L5 to L1; and
- As the level of assessed risk increases, the ARL decreases from ARL5 to ARL1.

An ARL of 3 is generally considered to be "As Low As Reasonably Practical" (eg ALARP) or a risk of loss of life in the order of $1X10^{-4}$. The main hazard identified for the trails are listed in Section 5.2. The results of the assessment are detailed in Table 5.3.

Table 5-3: RMS Slope Risk Assessment

Event	Likelihood	Temporal Probability	Vulnerability (Direct impact*)	Consequence (Direct impact*)	ARL (Direct Impact*)
Lower Risk Terrain					
Localised soil creep	L2	T3	V5	C5	ARL4
Localised failure	L5	T3 (T5)	V2 (V1)	C2 (C4)	ARL4 (ARL5)
Rock Fall	L5	T3 (T5)	V2 (V1)	C2 (C4)	ARL4 (ARL5)
Large scale slope failure	L6	T3 (T5)	V2 (V1)	C2 (C4)	ARL5 (ARL5)
Minor terrain unit - Gully					
Localised soil creep	L1	T3	V5	C5	ARL3
Local failure of trail crossings	L3	T3 (T5)	V2 (V1)	C2[S] (C4)	ARL2 (ARL4)
With additional measures implemented	L3	T2(T5)	V3 (v2)	C3 (C4)	ARL3 (ARL4)
Local failure of slopes impacting bridge and boardwalk structures	L5	T3 (T5)	V2 (V1)	C2 (C4)	ARL4 (ARL5)
Fill Terrain					
Localised soil creep;	L1	T3	V5	C5	ARL3
Localised failure of slope	L3	T3 (T5)	V3 (V2)	C3 (C4)	ARL3 (ARL4)
Rock and slumping fall from cuttings above trail	L3	T3 (T5)	V3 (V2)	C3 (C4)	ARL3 (ARL4)
Large scale slope failure	L5	T3 (T5)	V2 (V1)	C2 (C4)	ARL4 (ARL5)
Terrain Unit 2.1					
Localised soil creep;	L1	T3	V5	C5	ARL3
Localised failure of slope	L3	T3 (T5)	V2 (V1)	C2 [S] (C4)	ARL2 (ARL4)
With additional measures implemented	L3	T2(T5)	V3 (v2)	C3 (C4)	ARL3 (ARL4)
Rock falls from within Area; and	L4	T3 (T5)	V2 (V1)	C2 (C4)	ARL3 (ARL3)
Large scale slope failure	L5	T3 (T5)	V2 (V1)	C2 (C4)	ARL4 (ARL5)
Terrain Unit 3.1					
Localised soil creep;	L1	T3	V5	C5	ARL3
Localised failure of slope	L3	T3 (T5)	V2 (V1)	C2 [S] (C4)	ARL2 (ARL4)
With additional measures implemented	L3	T2(T5)	V3 (v2)	C3 (C4)	ARL3 (ARL4)
Rock falls from within Area; and	L3	T3 (T5)	V2 (V1)	C2 [S] (C4)	ARL2 (ARL4)
With additional measures implemented	L3	T2(T5)	V3 (v2)	C3 (C4)	ARL3 (ARL4)
Large scale slope failure	L5	T3 (T5)	V2 (V1)	C2 (C4)	ARL4 (ARL5)
Terrain Unit 5					
Localised soil creep	L2	T3	V5	C5	ARL4
Local failure impacting trails	L3	T3 (T5)	V3 (V2)	C2 (C4)	ARL3 (ARL4)
Local failure impacting bridges and boardwalks	L5	T3 (T5)	V2 (V1)	C2 (C4)	ARL4 (ARL5)

Notes to table: **Direct impact risks are bracketed.* [S] Consequence is *increased due to increased speed of riders in steeper terrains.*

5.5. Landslide Risk Evaluation and Management

The AGS risk assessment for "Damage to Property" indicates the following:

- In all terrain categories, the level of risk for soil creep is deemed low.
- Low level of risk for the 'Lower Risk Terrain' encountered throughout the site.
- Moderate to high for the Gully Terrain and Terrain Unit 5. This is due to topographically unstable positions, susceptibility to erosion and increased cost of boardwalk/bridge structures. This risk is revaluated to moderate assuming the recommendations in Section 6 (pier foundations) are implemented.
- Moderate for Terrain Unit 2.1, 3.1 and 4.

Construction of non-habitable structures (trails etc) are classed as Importance level 1 structures and can accept a moderate level of risk. High risk is generally considered unacceptable for Level 1 structures. A high risk was determined for structures in the Gully Terrain. However, this can be reduced to moderate by adoption of foundations that are better suited to the landslide risk, such as piers. Given the limited sections of trail affected by high risk of probability damage, a cost benefit analysis of a bridge supported on shallow foundations which may be subject to movement and the need to do minor repairs on a bridge supported on piers (which is less likely to need repairs but will be more costly to install) is recommended. It is likely that with the support of a cost benefit analysis and if the risk to loss of like is managed at ALARP, a high risk may be deemed tolerable on the understanding that should a bridge or board walk be affected by landslide it may need replacement. Consequently, where the bridges in the gully areas are supported on piers the risk is deemed acceptable and where supported on high level footings or risk to damage of property is deemed within the tolerable range.

The RMS risk assessment in terms of "Loss of Life" indicates the following:

- Hazards associated with local failure of trail crossings within the gully terrain, localised slope failure in Terrain Unit 2.1 and 3.1 and rockfalls within Terrain Unit 3.1 are accessed as the highest risk with ARL2. These hazards are elevated for mountain bikers in these locations due to the speed they can travel (because of increased slopes) and increased vulnerability when they encounter a voids or debris pile. It is noted that MTB Trail Difficulty Rating Systems will likely be implemented as part of the management of the site. This system sorts riders by experience and trail difficulty. Riders with higher skills levels will therefore have reduce vulnerability to these sections of the trails. The vulnerability on these sections of the trail can also be addressed by appropriate design of the trail in these areas to effectively reduce the speed of the bike riders in these sections or to provide greater line of site of potential hazards. These areas could adopt berms and outfalls as part of the trail, which will manage speed of the riders as well as drainage on these sections of the trail, which will also improve the stability of the trail, minimising potential for erosion and the need for maintenance.
- Hazards associated with direct impact has been accessed to have a lower risk than trail users impacting the on trial hazards. This is due to the very low likelihood that a trail bike ride will be present at the exact time the event occurs.

The ALARP risk management process is as follows:

- Where a site is not deemed ALARP and the risk is deemed not tolerable, works or risk management must be undertaken to reduce the risk to ALARP and tolerable levels.
- Where a site is deemed to have tolerable or acceptable risk and is deemed ALARP, the ALARP assessment can be used to determine a reasonable annual cost that should be adopted to ensure the risk remains ALARP. These works can include maintenance works and inspection activities.

Based on the risk assessment, Areas of Concern (AOC) with increased risk and geotechnical constraints, impacting nearby trails are identified and include the following:

- **AOCB1 to AOCB7** – Potential bridge sites over major channels, or channels that are deeply incised.
- **AOC1** – Trail 31, through the gully impacted by the old incline in T2
- **AOC2** – Old Train Line, in the location of the slips around a gully in T2.
- **AOC3** – Trail 21 and 22, in the location of the very steep slopes associated with the natural benches in T3.
- **AOC4** – Trail 24 and 24a, in the location of the very steep slopes associated with the natural benches in T3.

Recommendations to address these areas are provided in section 6 of this report.

5.6. Societal Risk

Where there is a potential for a large number of persons to be killed in one landslide event there should be an assessment of societal risk. In this case, societal risk applies to direct impact hazards rather than on trail obstacles that could cause harm or cause loss of life on an individual basis. Direct impact risks have been accessed to be ARL4 to ARL5, equivalent to annual probability of 1.E-5 to 1.E-6 respectively for the individual and are deemed acceptable risk on the individual basis. From a societal risk perspective, this acceptable risk decreases with increasing potential number of facilities. Depending on the proposed use of the trails, the acceptable societal risk can be accessed using Image 1 below taken from 'A review of landslide acceptable risk and tolerable risk' (Sim et al 2022). Provided that areas of increased use (trail heads, potential competition areas etc.) are away from higher risk direct impact hazard areas and the number of potential fatalities is considered in respect to the hazard and hazard risk, in most cases the societal risk is acceptable e.g. the number of users at a trail head in Terrain Unit 2.1 with a direct impact hazard risk of ARL4 (1.E-5) has an acceptable societal risk up to about 80 people.

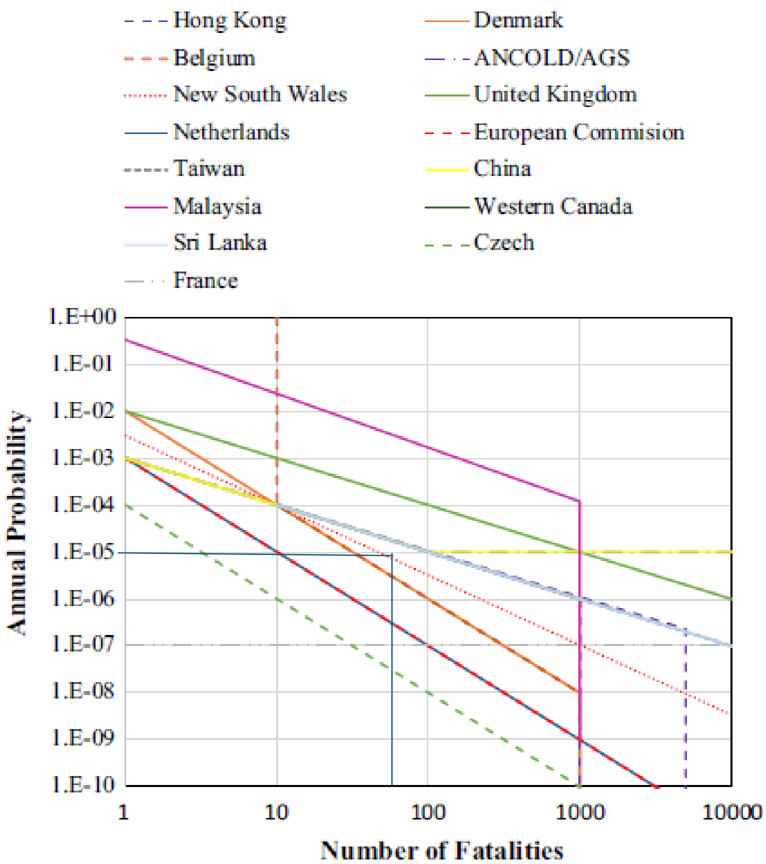


Image 1: Societal Risk criteria of different nations (Sim et al 2022).

6 Geotechnical Recommendations

Based on the risk assessments, several areas require risks to be reduced to ALARP levels. These areas include the areas of Gully Terrain, Terrain Unit 2.1, Terrain Unit 3.1. Specifically, within these higher risk terrain areas, areas of concern (AOC) have been identified for more detailed design consideration. It is noted that the risk in these areas is elevated due to the increased speed (and less reaction time provided) for mountain bike riders as they approach a potential hazard. This risk can be reduced by:

- Implementing trail design which improves line of sight for trail bike riders of a potential approaching landslide associated hazard, so that it can be avoided. This will reduce the temporary probability that a rider will encounter a landslide;
- Implementing trail design which controls the speed at which riders approach a potential landslide hazard allow more reaction time. This could be incorporated into the ride to make it more enjoyable/challenging. This will reduce the vulnerability of a rider encountering a landslide and should also assist in some cases where drainage is improved, will reduce the probability of a landslide occurring;
- Implementing measures to reduce the potential of landslide in critical areas. This will reduce the probability of a landslide occurring.

Recommendations for these higher risk terrain areas and AOCs are included in the following sections. Lower Risk areas should be able to implement the design guidelines in *Australian Mountain Bike Trail Guidelines* (MTBA 2019).

6.1. Geotechnical Hazard Risk Management

In the locations of AOC1, AOC2 and ACO3 and AOC4, the trails are located below rock outcrop slopes and impacted by increased local slope instability. The following is recommended to manage local slope failure risk and rock falls to acceptable levels of ALARP:

- AOC1 – In AOC1, the trail will be required to traverse across deep uncontrolled fill that is prone to soil creep. The trail can comprise of full bench construction with safe batters' angles (about 25 degrees or less) on the upslope and downslope side of the trail. To traverse across the slope grade reversals are recommended to manage flows and reduce speed on the trail.
- AOC2 – Slips have occurred on the cut slopes above the trail and in the old train line filled embankment around a drainage channel. The Old Train Line is level and allows for adequate safe distance away from the cutting. In the location of slip in the fill the embankment, the trail shall be set back away from the backscarp of the filled terrain about the height of the filled embankment and hazard signage shall be implemented. Alternatively, the failed embankment slope can be reprofiled at safe batter angles with adequate erosion protection.
- AOC3 and AOC4 – In AOC3 Trail 21 follows the toe of the very steep slopes with rock outcrops. The steep section of the slope is about 20m high and averages about 30 to 40 degrees. It is recommended that Trail 21 is moved at least 10m to 15m downslope, so it is on level terrain away from the slope. For AOC3 and AOC4, where the trail traverses up the slope, any loose boulders that can impact the trail are to be removed, boulders that cannot be removed and jointed rock within the outcrop are to be stabilised with rock bolts or similar. The trail is to comprise of a full bench and should have rockfall hazard warning signage along the trail. Surface water can be trained to flow away from these section using swales into natural gullies.

6.2. Surface Protection, Storm Water and Vegetation

To minimise the likelihood of localised slips along the trails, surface water flows shall be managed to minimise impact of the trail on the normal slope insitu moisture regimes. Surface water flows should be diverted and trained to flow away from the trails into natural drainage features where erosion protection can be implemented. Where trails cross natural drainage channels, erosion protection controls to depths below the soft material shall be implemented. These controls could include and are not limited to rock lined chutes, rock culvert drains, rolling dip drains and hardened spoon drains. Appropriate use of grade reversals can also help manage water off the trails and assist in controlling excessive speeds, reducing the risk for riders.

Where trails are located nearby to natural drainage channels that are prone to erosion or slumping, {such as within a distance (L) from the base of the active channel equal to the depth of the creek (D) multiplied by 2; or a distance (L) from the crest of the active channel equal to depth of the creek (D)}, erosion controls should be implemented.

Clearance of vegetation should be kept to a minimum. Large scale clearing can result in a rise in the groundwater table, which in turn can increase the likelihood of slope failure (eg landslide). Bare slopes should be revegetating with grasses or small to medium sized plants. Existing trees on the slopes should not be removed (with the exception of those within the path of the trail). Sick or dying trees, which may fall, should be removed before they can impact on the slope.

6.3. Type of structure permissible

Light weight flexible structures are preferable because they can tolerate reasonable movement due to soil creep, with minimal signs of distress and maintain their functionality.

6.4. Site maintenance and inspection

Inspection of the site should be undertaken on an annual basis or after an extreme rainfall event (greater than 100mm in a 24-hour period). Maintenance shall be undertaken where required to ensure site drainage remains operational.

6.5. Proposed Design Solutions for Bridges

Terra has identified six potential bridge locations that cross major channels that may require additional measures to meet ALARP. These locations are referred to as AOCB1 to AOCB7. Subsurface testing has been undertaken in locations for AOCB1 to AOCB4, however, these recommendations are recommended for similar drainage channels not identified by Terra.

The drainage channels that may be subject to local slumping due to erosional processes. It is recommended the footings for the bridges and boardwalks across these are:

- Founded on stiff or better natural material.
- A distance (L) from the base of the active channel equal to the depth of the creek (D) multiplied by 2; or
- A distance (L) from the crest of the active channel equal to depth of the creek (D).
- For footings supported with the distance (L), footings should be supported on piers taken to below the base of the creek where they will not be susceptible to erosion or to extremely weathered material which is less likely to be prone to erosion.
- Footings founded on boulders is not recommended, boulders are subject to erosional processes which can cause undercutting and movement of boulders. Alternatively, works could be done to stabilise the boulder in situ that may allow for the footing to be chemset into the boulder. The latter would only be acceptable where the risk of the boulder moving and the need for further works long term to maintain the stability of the boulder is understood by the designer and maintainer of the boardwalk.

The creek exposed banks are prone to erosion from surface waters and creek flows. Scour protection should be provided to the creek banks, around the structure footings, and upstream and downstream of the hard structures in the form of reno mattresses or placed large boulder and cobble size rock.

6.6. Footings Recommendations

The following is recommended:

- For the proposed boardwalks and bridges in higher risk terrain units (Gully Terrain, Terrain Unit 2.1 and Terrain Unit 3.1), all footings for the same structure should be founded on strata of similar stiffness/density and reactivity to minimise the risk of differential movements. The footings would need to be taken to a depth below the active erosion occurring in the area and below the soft to firm near surface soils as described in Section 6.3. It is recommended that the boardwalk and bridges is supported on the stiff colluvial, and residual soils expected at depths of at least 1.0m across most locations.
- Within the lower risk terrain, footings can be founded on soft to firm natural soils below the topsoil.
- Pad footings and shallow piers (eg bucket piers screw footings) supported in the stiff colluvial or residual soils at

depths of at least 1.0m can be designed based on allowable bearing capacity of 100kPa. Footings founded on soft to firm natural soils can be designed based on an allowable bearing capacity of 50kPa across the lower risk areas. This material is expected to be present across the site, typically to depths of 0.5m to 1.0m.

- Piers can also be adopted. Piers can comprise hand excavated bucket piers or hand driven piers such as screw piers, surefoot ™ or similar. Given boulders and cobbles were observed and encountered during the investigation, an allowance shall be made for difficult driving conditions in some locations with local removal of boulders required or relocation of the footing to bridge the boulder. Alternatively, works could be done to stabilise the boulder in situ that may allow for the footing to be chemset into the boulder. The latter would only be acceptable where the risk of the boulder moving and the need for further works long term to maintain the stability of the boulder is understood by the designer and maintainer of the boardwalk.
- Where higher capacity footings are required, institu testing is required to identify depths of suitable material. Bored, driven or screw piers designed to bear on the very stiff colluvial and residual soils at depths below 1.5m or deeper can be design on an ultimate end bearing capacity of 1.0MPa. A geotechnical strength reduction factor of 0.40 shall be applied to the ultimate end bearing for piers.
- Where footings are located in areas of high erosion, surface protection and storm water management shall be implemented. This could include local drainage works to divert water into define flow paths under the boardwalk, which can be protected, rather than allow sheet flow across the slopes or localised drainage gullies to be developed during wet weather events.

6.7. Earthworks

6.7.1. Site preparation

Ground preparation should allow for the stripping of topsoil and very soft to soft materials. The stripped soil should be suitable for landscaping purposes once processed to exclude cobbles and foreign material (where present). Surplus excavated materials may need to be exported or disposed of off the site. Where fill is to be placed on a slope or reprofiled, the slope will need to be terraced to allow placement in horizontal layers to key into the slope, rather than placement of fill parallel to the slope which is likely to result in subsequent slippage.

For higher risk terrain areas, the trail is recommended to be full bench construction with back slopes and appropriate sloped treads into natural slopes with edge restraint where appropriate.

Footings for boardwalks and bridges would need to be taken to a depth below the active erosion occurring in higher risk terrain units. Any boulders located within the footprint of the boardwalk or immediately upgradient, which may fall towards the elevated boardwalk or bridge, will need to be removed prior to construction of the boardwalk or secured in place.

Where boulders are encountered during the installation, the footings are to be relocated or the boulder removed or secured in situ.

6.7.2. Ease of excavation

This ease with which materials can be excavated onsite has been assessed using the Kirsten eight-point classification system provided in Table 6.1 below.

Table 6-1: Kirsten's eight-point excavation classification system

Class	Material Type	Description of Excavatability
1	Soil / Detritus	Hand spade (Dozer D3)
2		Hand pick and spade
3		Power tools
4	Rock	Easy ripping (Dozer D7)
5		Hard ripping (Dozer D8)
6		Very hard ripping (Dozer D9)

7		Extremely hard ripping / blasting (Dozer D10)
8		Blasting

All soils are expected to meet a Kirsten Classification of Class 2 to 3 and should be readily excavated using conventional earthmoving equipment such as hydraulic excavators, backhoes, and dozers.

6.7.3. Temporary and permanent retention of slopes

Temporary and permanent slopes may be required for the development as recommended in Table 6. Cut and fill batters in excess of 1.0m in height may require retention by structural retaining walls.

Table 6-2: Design Slopes for Cut/fill Slopes

MATERIAL DESCRIPTION	PERMANENT SLOPES	TEMPORARY SLOPES
Fill	1V:2H	1V:1H
Topsoil/Alluvium	1V:3H	1V:2H
Colluvium	1V:2H	1V:1H
Residual Clay	1V:2H	1V:1H
Extremely Weathered Rock	1V:2H	1V:1H
Highly to Moderately Weathered Rock	1V:1H	1V:1.5H

7 Conclusions and Recommendations for Further Assessment

Based on desk studies (topography, subsurface geology etc), the site can be divided into five areas based on topography as follows:

- **T1 Lower slopes** - The topography mainly falls to the south and east with the slopes pivoting around a ridge along the former Corrimal Colliery access road. This terrain unit is situated on the lower Illawarra Escarpment slopes, comprised of gentle slopes with common moderate slopes and rare steep slopes. Moderate and steeper slopes are present along the drainage channels that flow through the terrain unit. As the terrain unit is on the lower slopes, drainage courses are well defined between 30m to 50m across.
- **T2 Lower mid slopes** - This terrain unit includes the area on the lower mid slopes of the site, comprised of poorly defined benches that fall with steep slopes typically to the southeast. On the northeast side of the terrain unit, a gully network is present and has formed narrow ridges and gullies with steep to very steep slopes. Aerial imagery shows earthworks within this area associated with the Corrimal Colliery. Earthworks include filling along the contours to form a train line across the northeast portion of the terrain unit and include earthworks associated with old inclines from the Colliery and train line to the lower slopes of the site.
- **T3 Upper mid slopes** - The terrain unit is situated on the upper mid slopes of the escarpment and comprised of well-defined benches about 50m to 150m across. The benches fall with steep to very steep slopes, notably along the Scarborough Sandstone unit. Along the Claystone units, the topography is gently sloping. Poorly defined incised drainage channels fall across the unit.
- **T4 Escarpment slopes** - Situated on the very steep to extremely steep slopes just below the Illawarra Escarpment, which then fall onto the near level benches of Terrain Unit 3. No works are proposed for this area. Talus material expected to average about 2.0m depth.
- **T5 Alluvial Terrain** - Situated at the toe of the Illawarra Escarpment, between Terrain Unit 1 and the residential areas to the south of the site. Comprised of the upper portion of Towradgi Creek. The alluvial drainage course is about 100m wide with a near level cross fall, falling to the east. The channel banks fall with moderate to steep slopes to the base which is level across the channel. The base of the creek includes a shallow incised flow path about 0.5m to 1.0m deep and there is evidence of older meanders through the base of the channel.

Based on site observations, several localised areas within the above terrain units were identified that have slight variations to conditions encountered elsewhere in the terrain unit and will require more detailed design consideration. These areas were classified into the following Minor Terrain Units:

- **Lower Risk Terrain (LT)** – Comprised of slopes away from major drainage channels, typically near level to moderately sloping, located throughout the entire site, includes some minor drainage channels. The risk in this terrain unit is accessed as low for
- **Gully Terrain (GT)** – Slopes surrounding major channels throughout the entire site, typically to the steeply sloping extents of the channels.
- **Terrain Unit 2.1 (T2.1)** – Steep slopes on the lower and upper portions of Terrain Unit 2.
- **Terrain Unit 3.1 (T3.1)** – Very Steep slopes on the upper and lower portions Terrain Unit 3 associated with the steeply sloping benches.
- **Fill Terrain (FT)** – Slopes associated with the cut and fill activities of the Old Train Line and old incline.

The AGS risk assessment indicates the following:

- In all terrain categories, the level of risk for soil creep is deemed low.
- Low level of risk for the 'Lower Risk Terrain' encountered throughout the site.
- Moderate to high for the Gully Terrain, and Terrain Unit 5 due to topographically unstable positions, susceptibility to erosion and increased cost of boardwalk/bridge structures. This risk is revaluated to moderate assuming the recommendations in Section 6 are followed.
- Moderate for Terrain Unit 2.1, 3.1 and 4.

The RMS risk assessment indicates the following:

- Hazards associated with local failure of trail crossings within the gully terrain, localised slope failure in Terrain Unit 2.1 and 3.1 and rockfalls within Terrain Unit 3.1 are accessed as the highest risk with ARL2. These hazards

are elevated for mountain bikers in these locations due to the speed they can travel (because of increased slopes) and increased vulnerability when they encounter a voids or debris pile.
- Hazards associated with direct impact has been accessed to have a lower risk than trail users impacting the on trial hazards due to the low likelihood that a rider will be present at time of failure.

Provided that areas of increased use (trail heads, potential competition areas etc.) are away from higher risk direct impact hazard areas and the number of potential fatalities is considered in respect to the hazard and hazard risk, the societal risk is deemed acceptable.

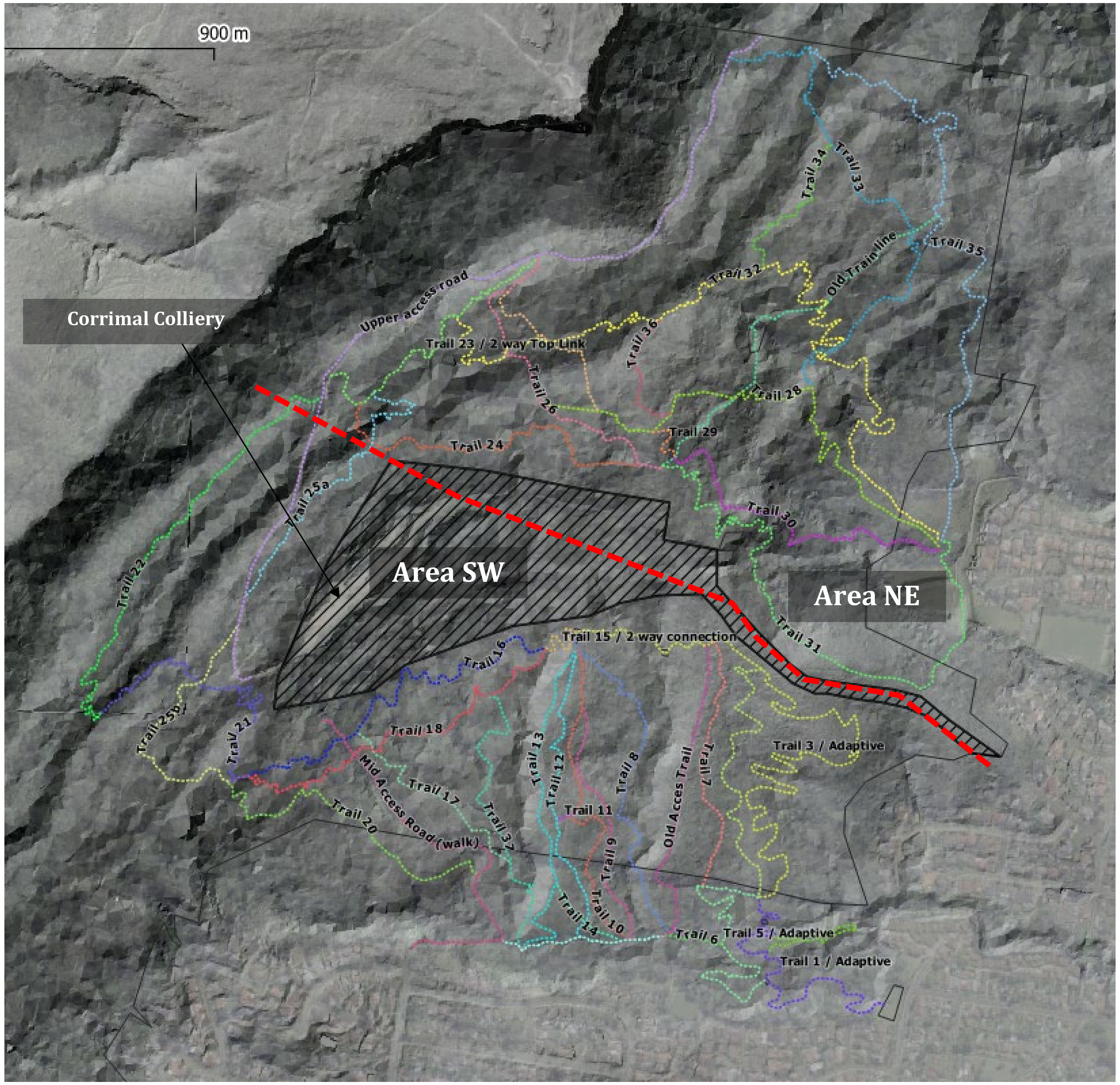
Areas of Concern (AOC) with increased risk and geotechnical constraints, impacting nearby trails are identified and include the following:

- **AOCB1 to AOCB7** – Potential bridge sites over major channels, or channels that are deeply incised.
- **AOC1** – Trail 31, through the gully impacted by the old incline in T2
- **AOC2** – Old Train Line, in the location of the slips around a gully in T2.
- **AOC3** – Trail 21 and 22, in the location of the very steep slopes associated with the natural benches in T3.
- **AOC4** – Trail 24 and 24a, in the location of the very steep slopes associated with the natural benches in T3.

The following is recommended:

- A detailed design of areas of higher risk to incorporate appropriate drainage measures to reduce probability of landslide, to improve line of site as riders approach the section, to warn riders of potential for hazards, to limit users of these sections to experienced riders and to limit the speed at which rider may approach potential hazards.
- Pavement investigations to confirm subgrade conditions and design CBRs to allow design of the pavement within the proposed carparking areas.
- Subsurface investigation for any proposed amenity buildings in the areas of the carparks including wastewater effluent if required.
- Dynamic Cone Penetrometer Testing in the location of proposed bridges across major channels and in boardwalks in higher risk areas to confirm depth of founding material.

Figures



Balgownie Design_v2 Balgownie Design
- BRIDGE
- Creek landslip
- Fly over Down
- HUB
- Landslip
- LARGE BRIDGE
- Lower Access Road
- Mass Landslip
- Mid Access Road (walk)
- NPWS zone
- Old Acces Trail
- Old Train line
- Short Road.
- SMALL BRIDGE
- Trail 1 / Adaptive
- Trail 10
- Trail 11
- Trail 12
- Trail 13
- Trail 14
- Trail 15 / 2 way connection
- Trail 16
- Trail 17
- Trail 18
- Trail 19 / 2 way connection
- Trail 2 / Adaptive
- Trail 20
- Trail 21
- Trail 22
- Trail 23 / 2 way Top Link
- Trail 24
- Trail 25a
- Trail 25b
- Trail 26
- Trail 27
- Trail 28
- Trail 29
- Trail 3 / Adaptive
- Trail 30
- Trail 31
- Trail 32
- Trail 33
- Trail 34
- Trail 35
- Trail 36
- Trail 37
- Trail 4 / Adaptive
- Trail 5 / Adaptive
- Trail 6
- Trail 7
- Trail 8
- Trail 9
- Trail Head / Carpark
- Upper access road

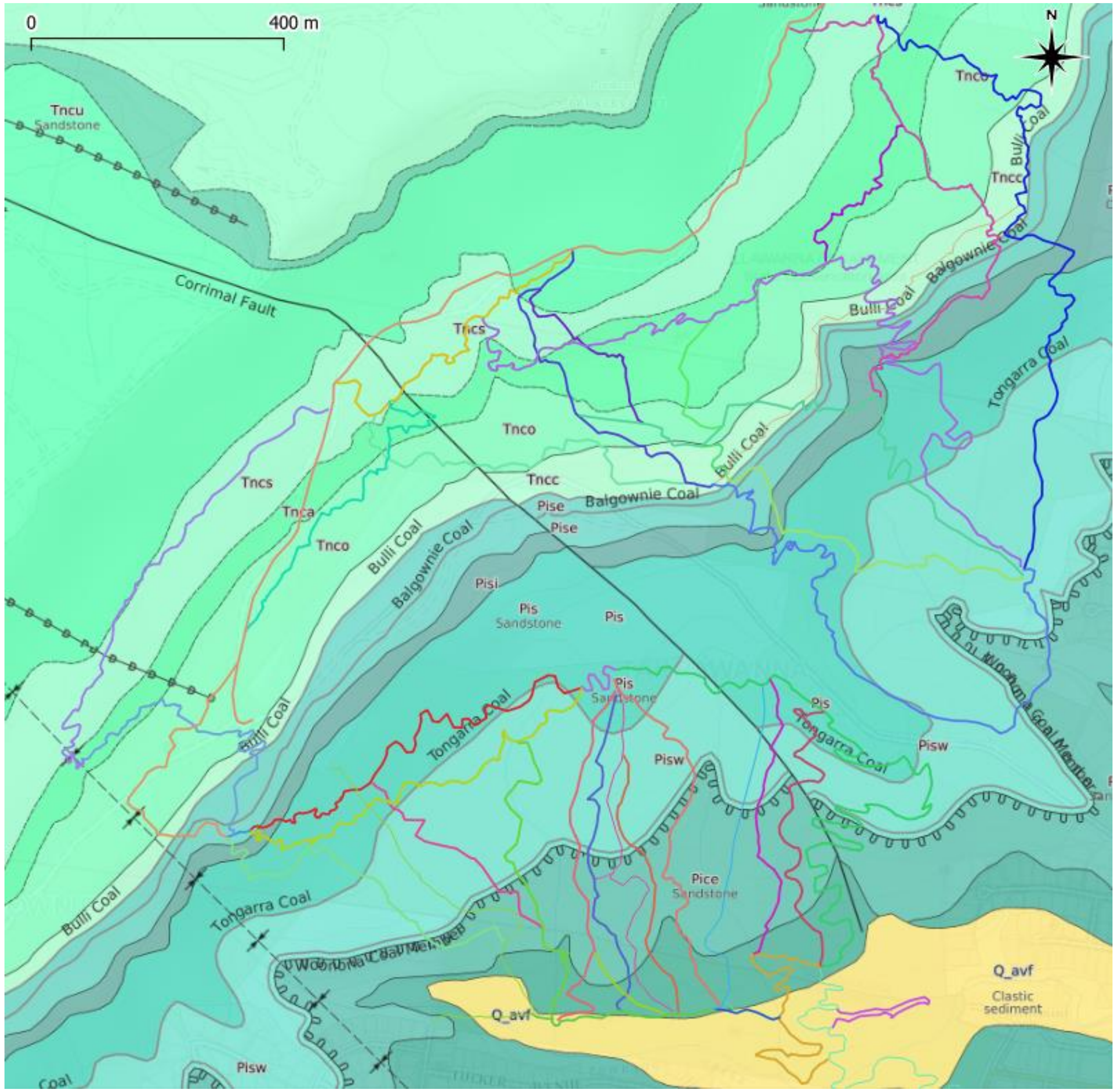
Site Plan

revision	description	drawn	approved	date
	Site location	SB	KEG	4/04/2023

N

TERRA INSIGHT

scale	NTS	client:	Niche Environment and Heritage
original size	A3	project	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
		title:	Site Locations
		project no: TERRA22-223	figure no: FIGURE 1



Symbol	Group	Subgroup	Unit	Lithology
Tuth	Ungrouped Triassic Units	-	Hawkesbury Sandstone	Medium-to coarse-grained quartz sandstone with minor shale and laminate lenses.
Tng_b	Narrabeen Group	Gosford	Gosford Subgroup and Bald Hill Claystone (undifferentiated)	Interbedded quartzose and quartz-lithic sandstone and mudrock and chocolate shale.
Tncu		Clifton	Bulgo Sandstone	Fine-to medium-grained grey-brown to green quartz-lithic sandstone with lenticular brown/shale/claystone ad siltstone interbeds; sporadic minor polymictic pebble conglomerates down sequence.
Tncs			Stanwell Park Claystone	Brown and brown-grey shale up sequence, grading to olive-green and grey shale down sequence; fine- to coarse-grained quartz-lithic green-grey sandstone, rare pebbles polymictic conglomerate beds.
Tnca			Scarborough Sandstone	Coarse-grained quartz-lithic sandstone (fines up sequence), sporadically pebbly down sequence.
Tnco			Wombarra Claystone	Green-grey to brown shale and claystone, minor fine-grained thin-bedded quartz-lithic sandstone; calcareous foraminifera recorded.
Tncc			Coal Cliff Sandstone	Medium-grained quartz-lithic sandstone with calcareous-cemented; also contains sideritic oolites.
Pis	Illawarra Coal Measures	Sydney	-	Quartz-lithic sandstone, siltstone, mudstone, claystone, tuffaceous claystone, carbonaceous claystone, coal, torbanite, minor conglomerate.
Pisi			Wongawilli Coal	Coal, carbonaceous shale, claystone, and tuff. Tuff and claystone form distinctive bands.
Pise			Eckersley Formation	Sandstone, siltstone, claystone and coal.
Pisw			Wilton Formation	Dark claystone and dark siltstone, interbedded with sandstone; bioturbation, sideritic concretions, plant fossils.
Pice		Cumberland	Erins Vale Formation	Fine-to medium-grained lithic sandstone, matrix is carbonaceous with secondary calcite, sporadically bioturbated, minor quartz pebble conglomerate up sequence.
Picp			Pheasants Nest Formation	Shale, siltstone, sandstone with lenticular coal seams; sporadic thin cherty tuff(s) and syenite intrusives (in the southwest).
Q_avf	Alluvium	Alluvial Valley Deposits	Alluvial fan deposits	Fluvially-deposited quartz-lithic sand, silt, gravel, clay.

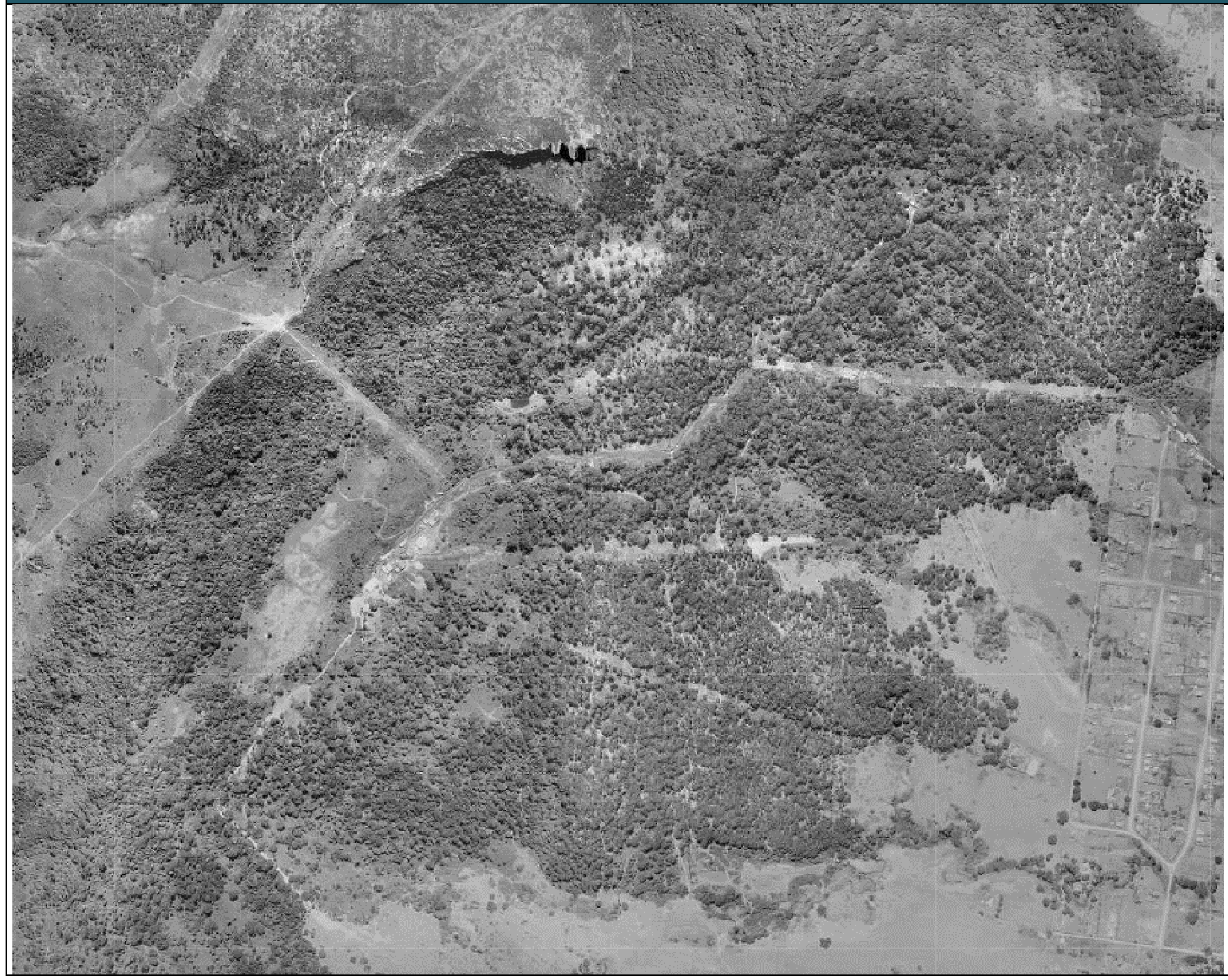
revision	description	drawn	approved	date
	Site geology	SB	KEG	1/12/2022

N

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
title:	**Site Geology**
scale	NTS
original size	**A3**
project no:	**TERRA22-223**
figure no:	**FIGURE 2**

1948-51	1961



revision	description	drawn	approved	date
	Historical Aerial Imagery	SB	KEG	1/12/2022

N

TERRA INSIGHT

scale	NTS
original size	**A3**

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
title:	**Historical Aerial Images**
project no: **TERRA22-223**	figure no: **FIGURE 3**

1993	2021
	

revision	description	drawn	approved	date
	Historical Aerial Imagery	SB	KEG	1/12/2022

N

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
scale	NTS
title:	**Historical Aerial Images**
original size	**A3**
project no:	**TERRA22-223**
figure no:	**FIGURE 3**

Soil Landscape Mapping

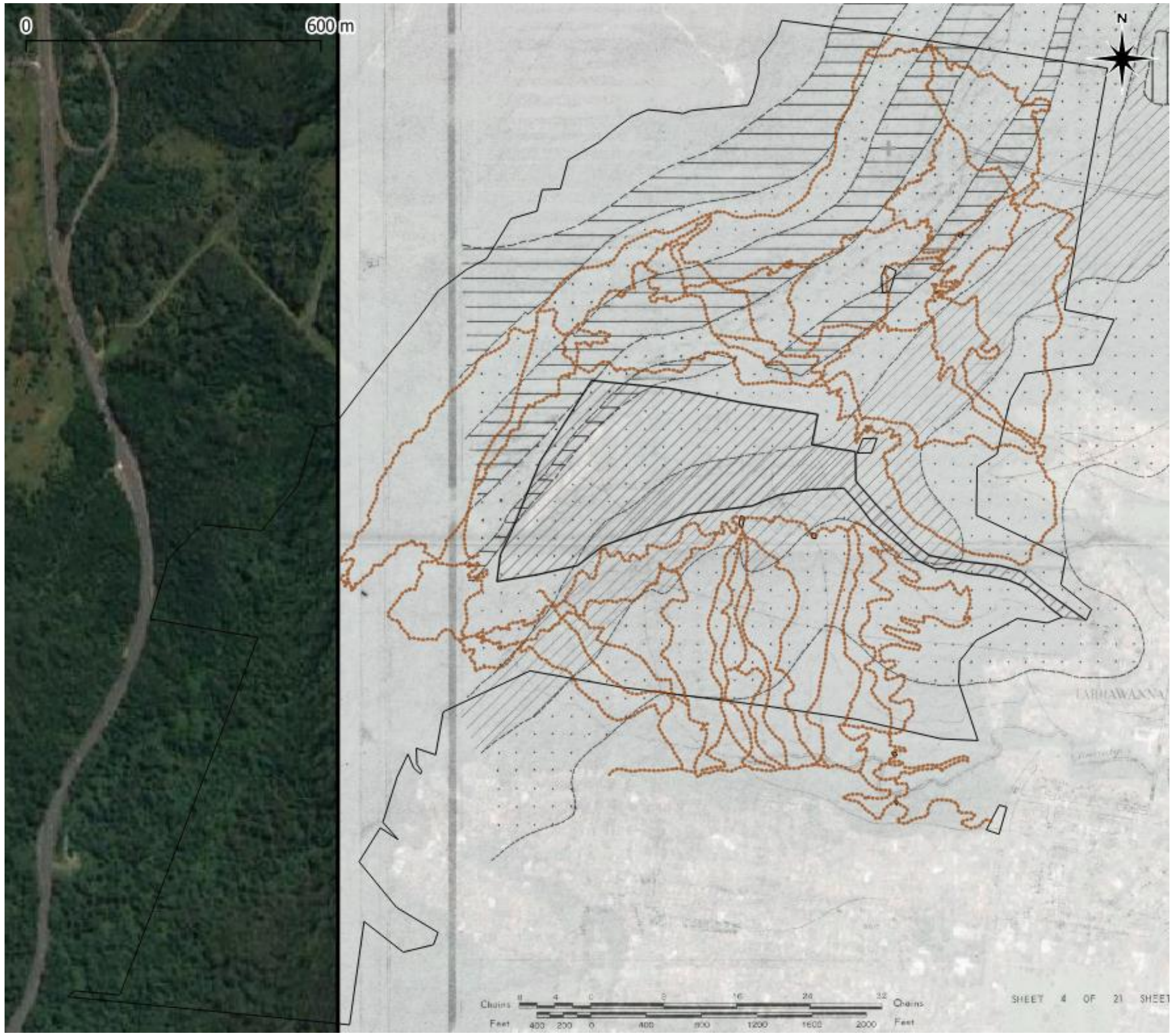
revision	description	drawn	approved	date
	Site location	XJ	KEG	1/12/2022

N

TERRA INSIGHT

scale	NTS
original size	A3

client:	Niche Environment and Heritage
project	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
title:	Soil Landscape Mapping
project no: TERRA22-223	figure no: FIGURE 4



Stability	Zone/Symbol	Land Stability	Description
INCREASING STABILITY	1	Stable land	No landslip problems
	2	Stable land with some minor area of slope instability	Normally moderately level land which is however underlain by soil which is unstable in certain topographic positions,
	3	Less stable land	Most of the land may be safely utilized although some areas are unsuitable. Generally, topographically elevated more than land in categories above.
	4	Moderately unstable land	Thorough investigation required before development. Generally, topographically high relief land underlain by potentially unstable material.
	5	Topographically unstable for development	Topographically unstable for development owing to steep slope and/or topographic position and nature of soil.
	6	Essentially unstable land	Best left undeveloped. Some area may be developed after detailed site evaluation.

Bowman (1970's) Stability Mapping

revision	description	drawn	approved	date
	Site location	SB	KEG	1/12/2022

N

TERRA INSIGHT

scale	NTS
original size	A3

client:	Niche Environment and Heritage
project	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
title:	Site Locations
project no: TERRA22-223	figure no: FIGURE 5

Flentje et al 2005 Landslip Mapping

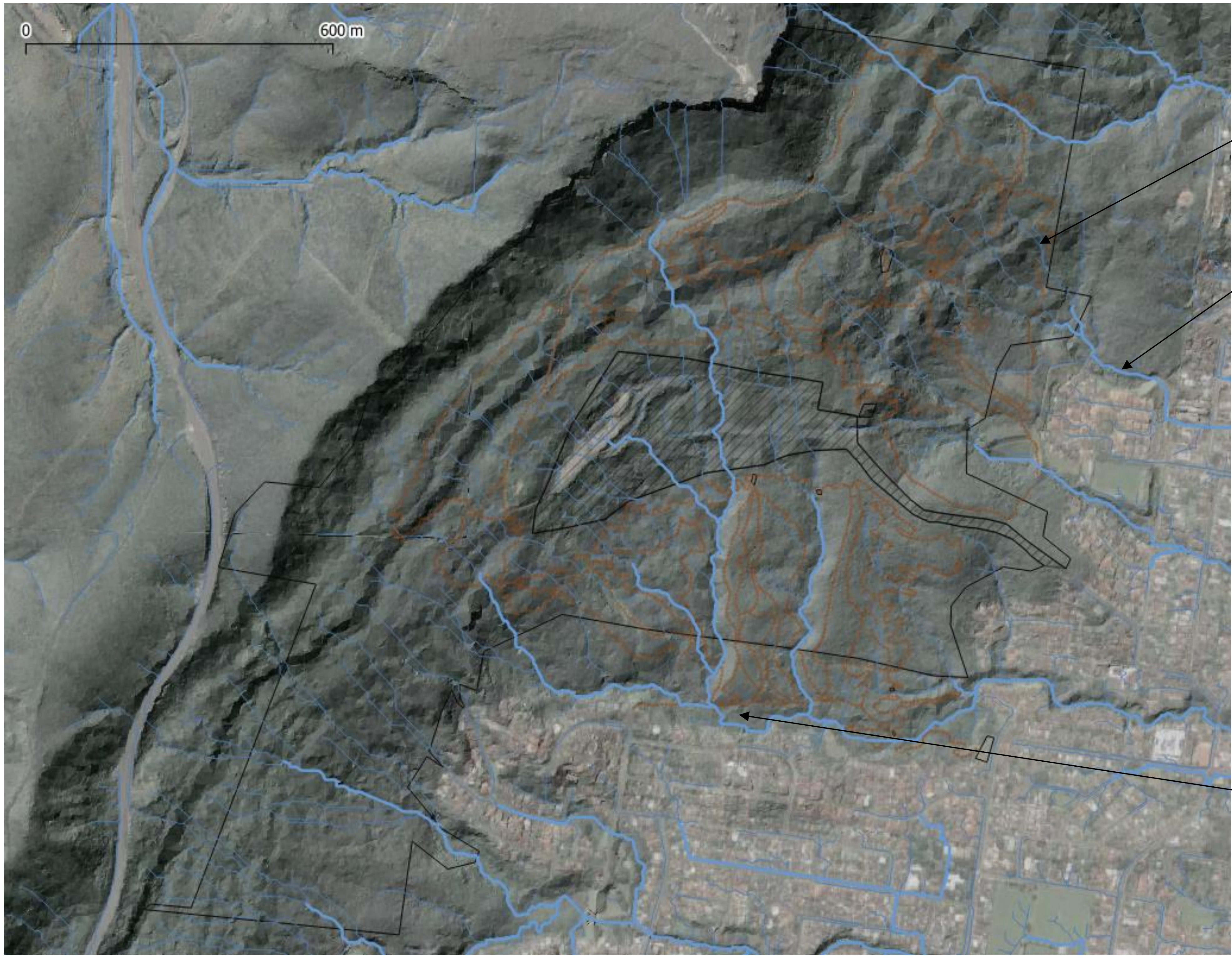
revision	description	drawn	approved	date
	Site location	XJ	KEG	1/12/2022

N

TERRA INSIGHT

scale	NTS
original size	A3

client:	Niche Environment and Heritage
project	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
title:	Flentje Landslip Mapping
project no: TERRA22-223	figure no: FIGURE 7



Surface Hydrology

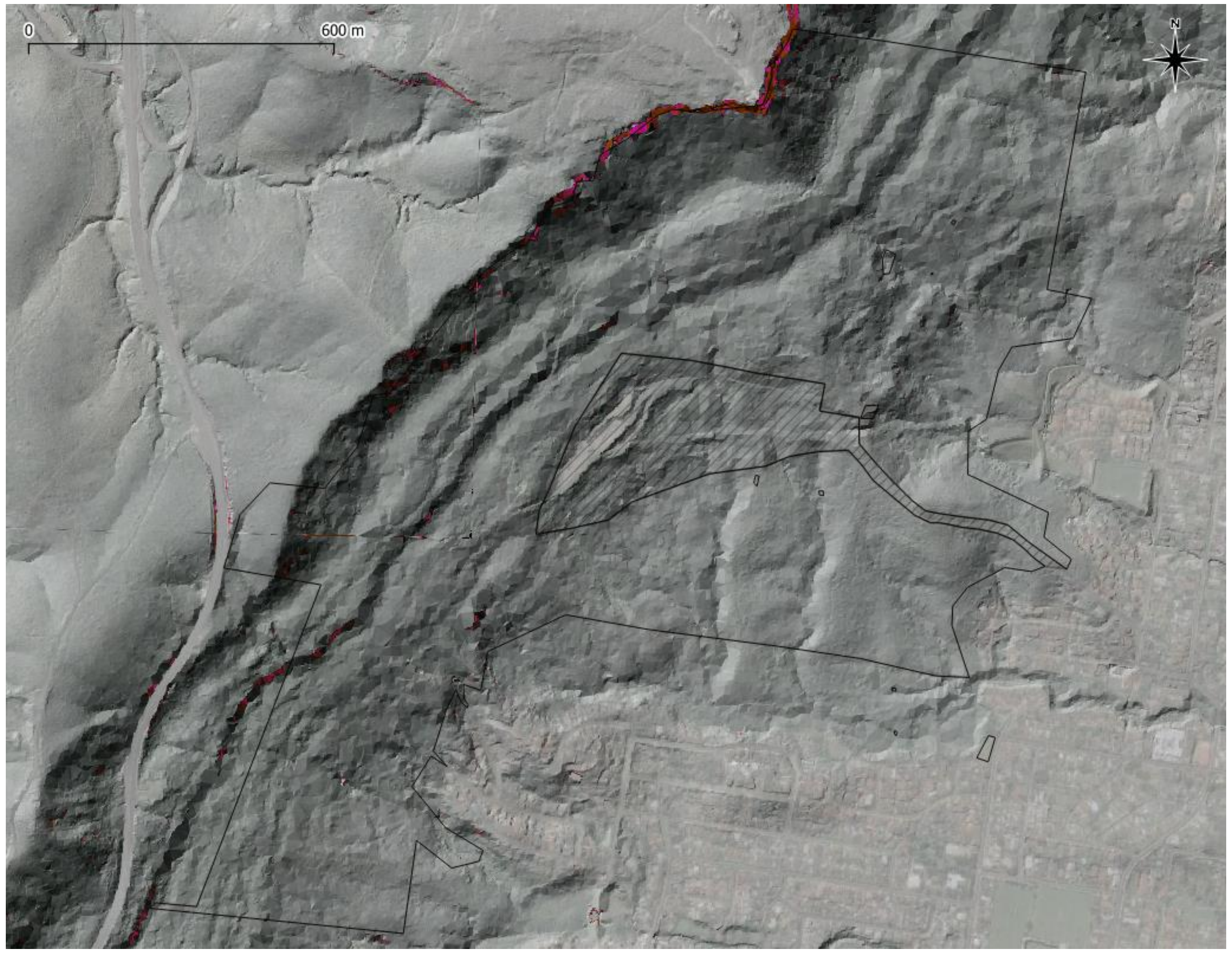
revision	description	drawn	approved	date
	Site location	XJ	KEG	1/12/2022

N

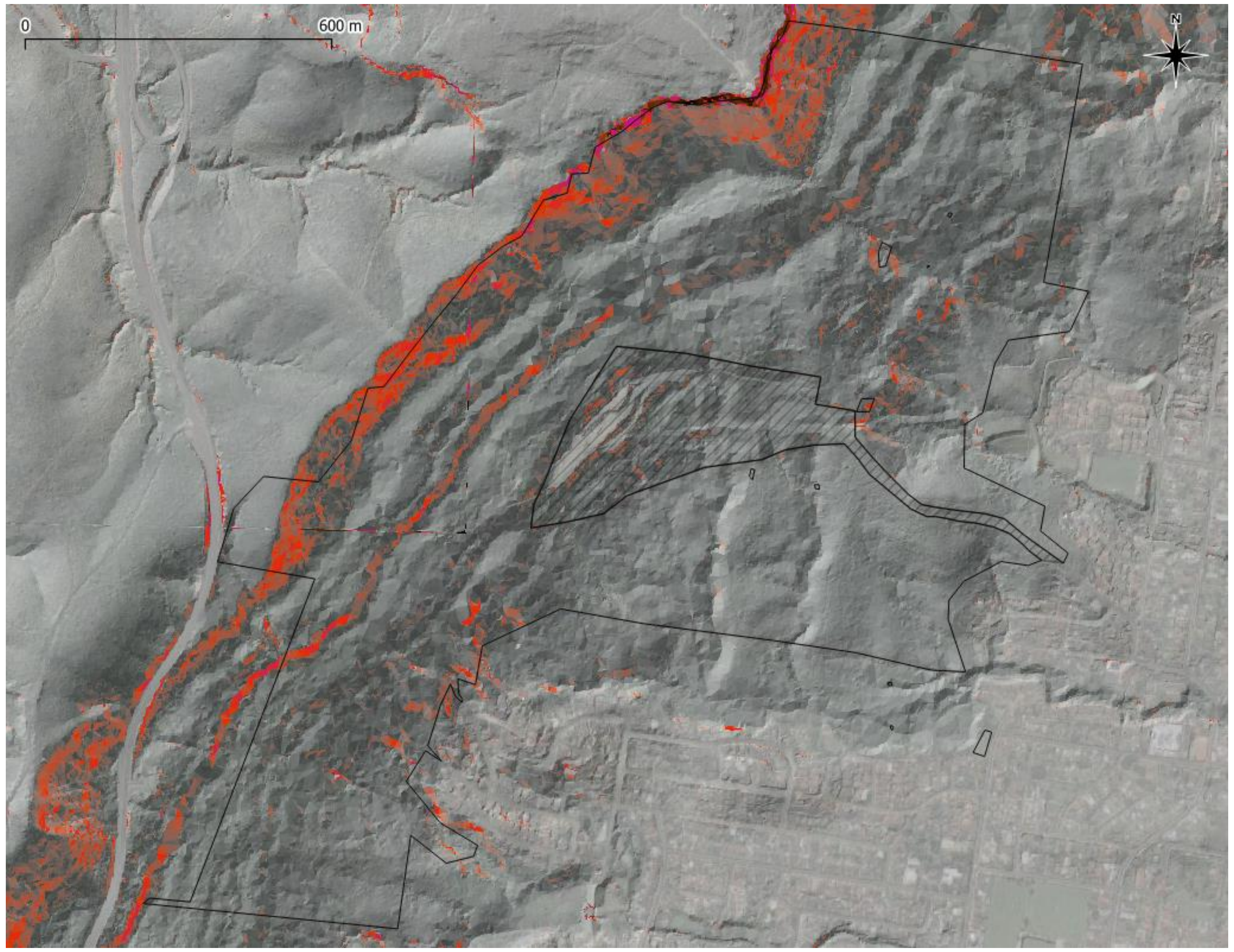
TERRA INSIGHT

scale	NTS
original size	A3

client:	Niche Environment and Heritage
project	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
title:	Surface Hydrology
project no: TERRA22-223	figure no: FIGURE 7



Slopes > 45 degrees (Extreme) Heat Mapping



Slopes > 27 degrees (Very Steep) Heat Mapping

revision	description	drawn	approved	date
	Site location	XJ	KEG	1/12/2022

< 10 Gentle
<18 Moderate
<27 Steep
<45 Very Steep
<64 Extreme
< 84 Cliff
Vertical

N

TERRA INSIGHT

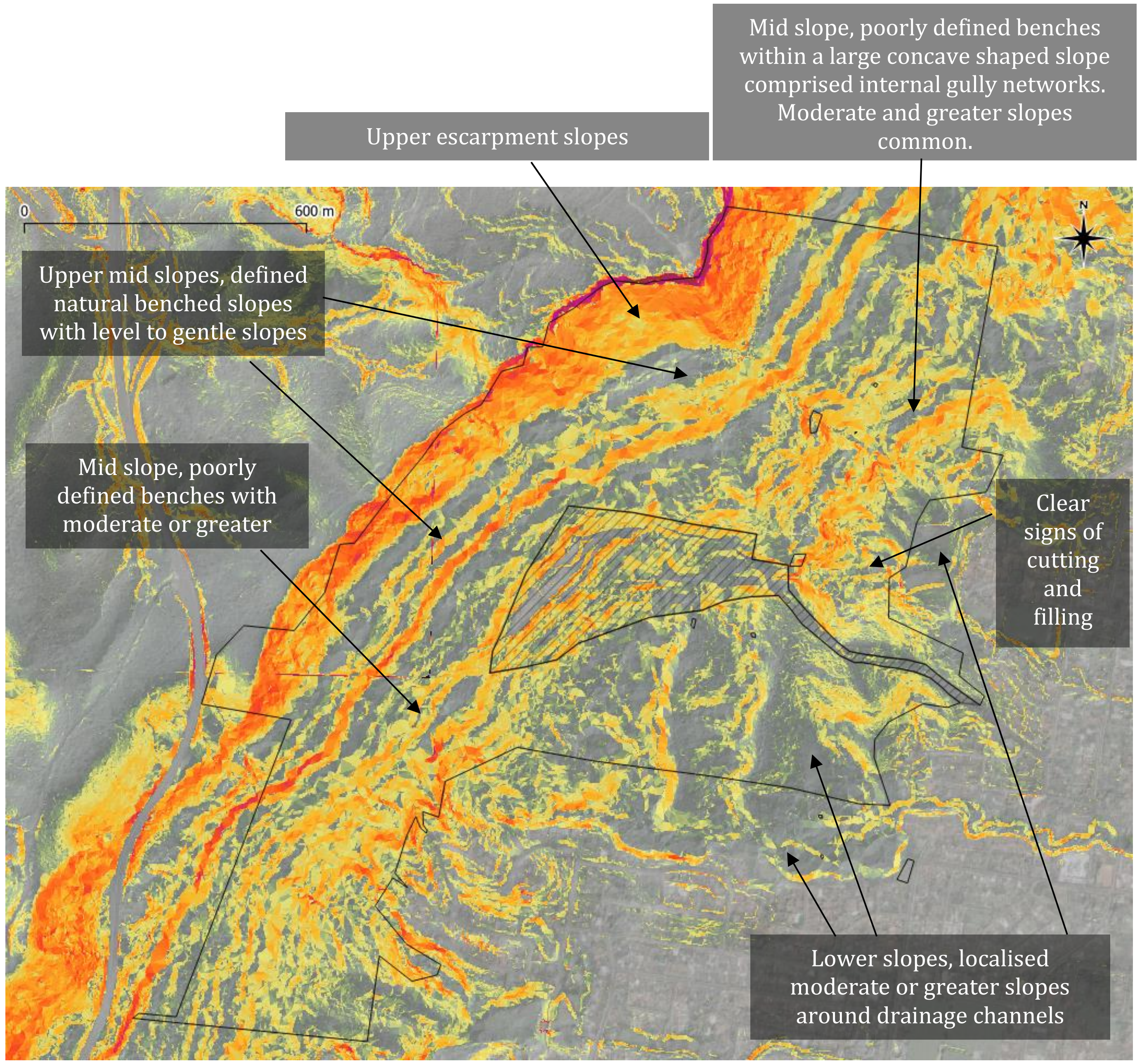
scale	NTS
original size	A3

client: **Niche Environment and Heritage**

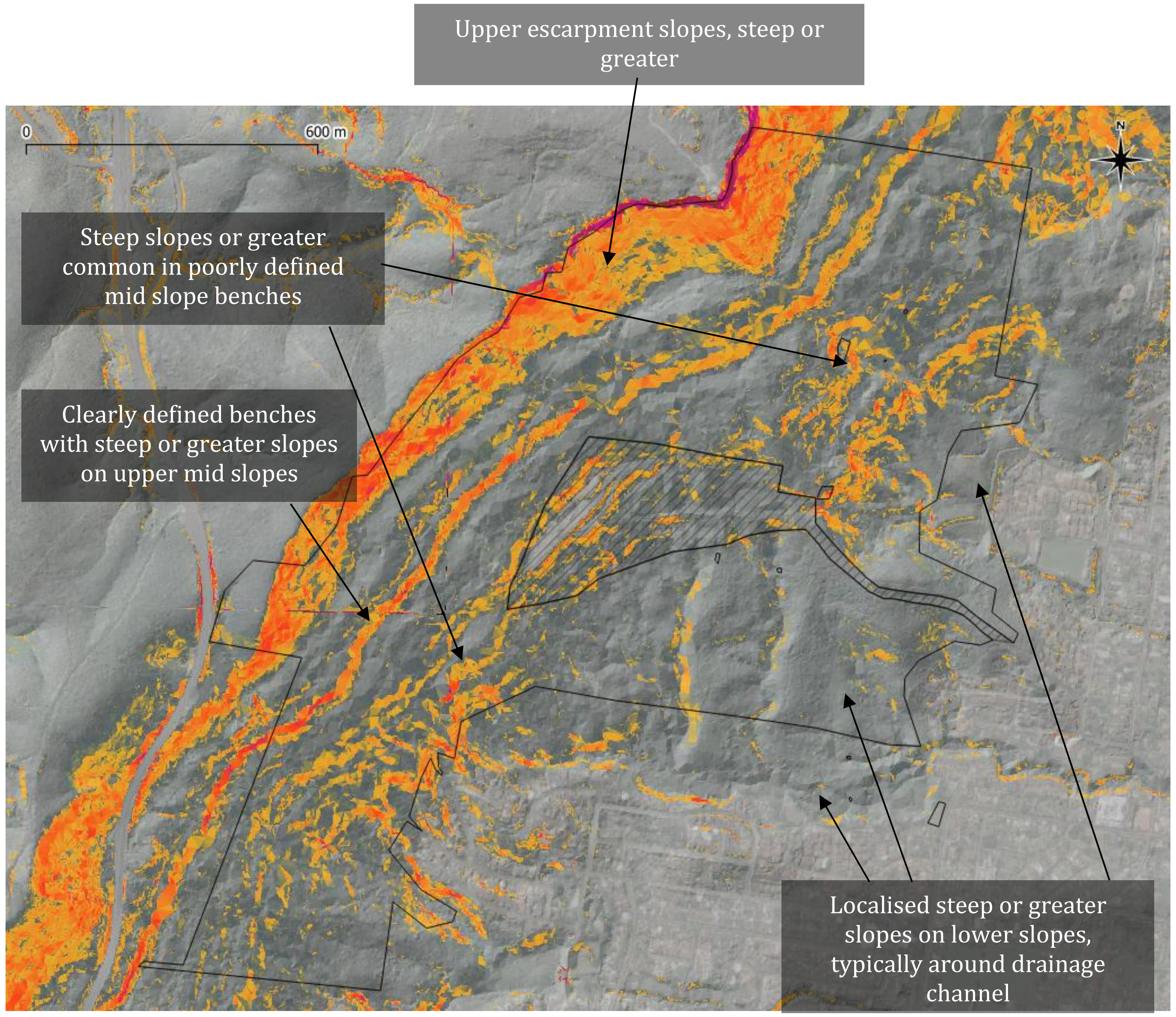
project: **Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**

title: **Slope Heat Mapping**

project no: **TERRA22-223** figure no: **FIGURE 8A**



Slopes > 10 degrees (moderate) Heat Mapping



Slopes > 18 degrees (steep) Heat Mapping

revision	description	drawn	approved	date
	Site location	XJ	KEG	1/12/2022

< 10 Gentle
<18 Moderate
<27 Steep
<45 Very Steep
<64 Extreme
< 84 Cliff
Vertical

N

TERRA INSIGHT

client:	Niche Environment and Heritage
project	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
title:	Slope Heat Mapping
scale	NTS
original size	A3
project no: TERRA22-223	figure no: FIGURE 8B

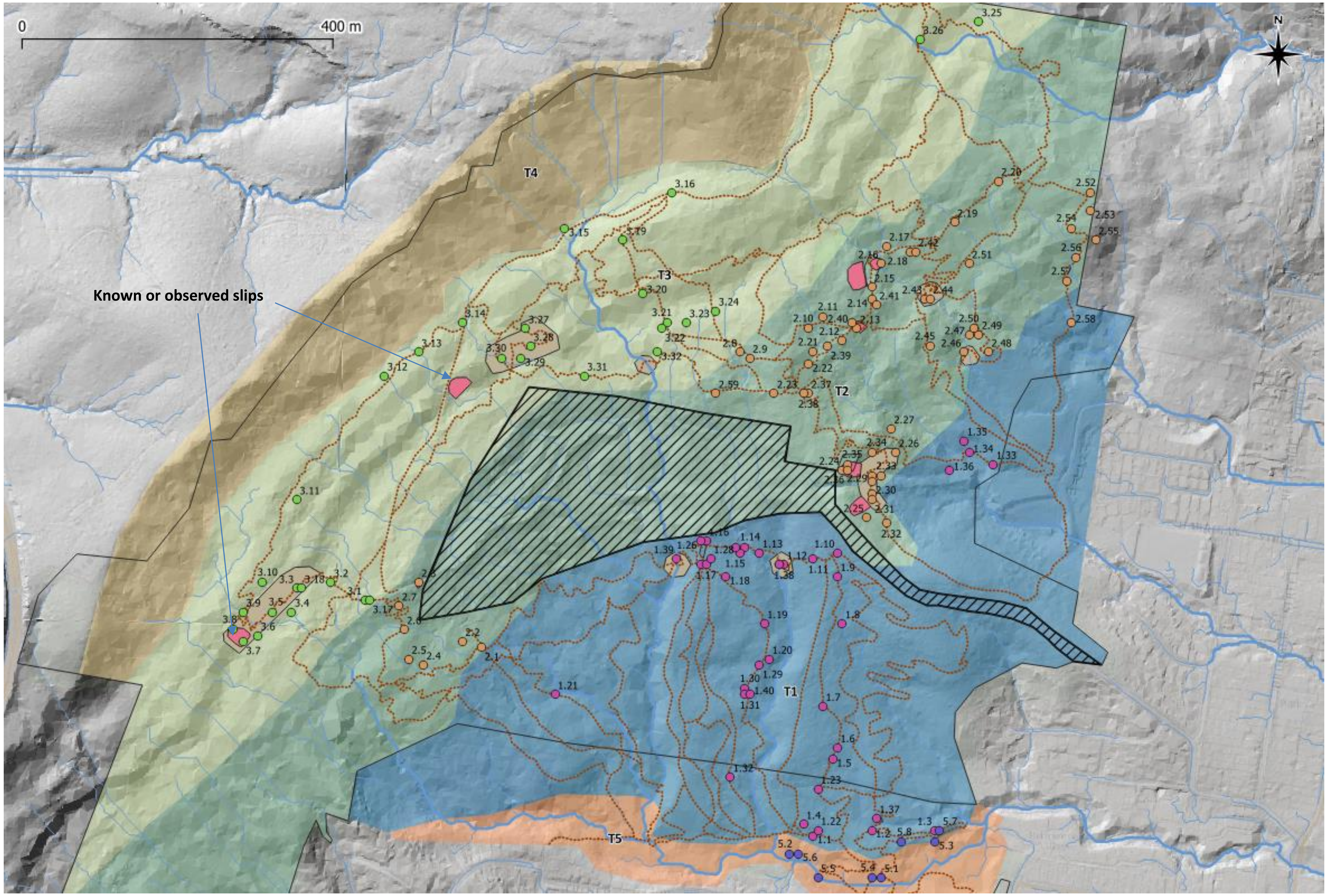
Major Terrain Units

revision	description	drawn	approved	date
	Site location	XJ	KEG	1/12/2022

N

TERRA INSIGHT

client:	Niche Environment and Heritage
project	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
title:	**Major Terrain Units**
scale	NTS
original size	**A3**
project no:	**TERRA22-223**
figure no:	**FIGURE 9**



Site Observations

revision	description	drawn	approved	date
	Site Observations	XJ	KEG	1/12/2022

N

TERRA INSIGHT

scale	NTS
original size	A3

client:	**Niche Environment and Heritage**
project	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
title:	**Major Terrain Units**
project no: **TERRA22-223**	figure no: **FIGURE 10**

Point	Observation
1.1	Seepage, open stained some boulders on slope level terrain, seepage origin not clear
1.2	Bridge location
1.3	Drainage management of flat track
1.4	Boulders in slope
1.5	Gently to moderate slope, boulders on slope surface cobbles too.
1.6	Dryer slopes, little erosion on track across slope, some recent track management
1.7	Minor signs of slope movement
1.8	Track split, wide undulating gully, falling to steeper slopes, possible movement
1.9	Rutting filled with rock amour
1.10	Junction
1.11	Similar terrain to assent, no significant signs of mass movement, tree vertical, boulders on slope
1.12	FRP bridge, 6.5m span across gully full of talus
1.13	Track near incomes gully, 3m high
1.14	FRP bridge incised creek. Gully network, 1m exposure yellow white clay below topsoil appears colluvial boulders on clay matrix
1.15	Slopes similar throughout Terrain Unit
1.16	Track formed a water course potential rock amour
1.17	Water management into gullies using swales, keeping off track
1.18	Remove jumps, resurface, berms to help with water management
1.19	Big Boulder
1.20	VSt gully
1.21	Bridge, very steep banks boulders in base downstream
1.22	Notable seepage over ground
1.23	Green trail is 1m wide, blue trail narrow
1.24	FRP Bridge over creek, spans 6.5m
1.25	FRP Bridge, approx. 6-7m span
1.26	Heavy erosion through trail, generally running east to west, will be kept as a watercourse, potentially rock armored for upkeep
1.27	Possums MTB track
1.28	Plan is to push water through middle track and across right track and into gulley
1.29	Lot of movement
1.30	Low lying bridge through gully, water runs through mine previously
1.31	Erosion heavy near edge of gully
1.32	Moist to wet
1.33	Very steep slopes, historic filling activity, old dam like feature in current location. Steep to very steep along track.
1.34	Crossing wide drainage coarse to the east
1.35	Steep to very steep upslope pink tape found
1.36	Incised gully to the south rock outcropping on channel about 1.0m to 2.0m deep
1.37	Bridge
1.38	Bridge
1.39	15m long bridge supported over rock in creek
1.40	Creek

Point	Observation
2.1	Gully network, well vegetated, boulders steep terrain
2.2	Possible seepage area, wet before, dry currently
2.3	Sip
2.4	Blow outs
2.5	Not part of trail significant erosion in gully
2.6	Level area, drainage consideration, potential old rail bench. Terrace very steep slopes toe and downslope. Mining remains spread throughout (cut nearby) photos show proposed track up very steep slopes
2.7	Standing at toe of externally steep slopes. Switch backs, earthworks required, rock depth not clear boulders on slope.
2.8	Seepage
2.9	Possibly an old road running north to south. Planning to reroute around it to avoid areas with seepage
2.10	Some soil creep visible
2.11	Seepage zone
2.12	Old coal line, seepage along gulley to the Southwest
2.13	Old slip
2.14	Washout
2.15	Landslip southeast of trail, on weathered Rock outcrop
2.16	Landslip through coal wash fill where path used to be, watercourse runs through
2.17	small slip
2.18	shaft
2.19	Seepage, watercourse slightly further along trail
2.20	watercourse and old railway track
2.21	slip
2.22	filled area
2.23	man-made slope
2.24	old landslip, filling along edge
2.25	filled through this area
2.26	Slopes become very steep along a ridge, some signs of soil creep and undulated surface - appears related to erosion processes
2.27	Angular blocks observed on ridge crest, rock expected to be shallow, slopes fall steeply to very steep on ridge side slopes
2.28	Steep to very steep colluvial slopes in gully, possible shale reject fill in base.
2.29	Gully network, several gullies, shale reject in base supporting old pipes, water flow in current location
2.30	Difficulty piercing through fill - cobble shale reject
2.31	Old slip above trail track straddles less steep slopes below upper very steep slopes
2.32	Slopes become moderate to steep
2.33	Gully network
2.34	Rock outcrop down slope Boulder risk
2.35	Slip on gully slopes at crest - washout
2.36	Washout along crest, appears filled, only surficial large trees still upright - away from track, fill from drainage feature from mine road
2.37	Moderately sloping locally steep no issues seen
2.38	Fill embankment coarse CWR
2.39	Areas of seepage
2.40	Old slip in fill embankment
2.41	Some minor washouts on trails, typically along drainage lines
2.42	Vst cutting upslope
2.43	Bridge location, moderate locally steep slopes into gully, trail comes down ridge, no issues found
2.44	Base of creek full of CWR and shale cobbles, 1.0m incised channel incised about 3m across gully base about 10m across

Point	Observation
2.45	Existing trail
2.46	CWR and shale cobble filled drainage gully
2.47	Bedrock outcrop sandstone
2.48	Plenty of boulders, gentle to moderate
2.49	Rock outcrop on ridge slopes
2.50	Very steep to the north
2.51	Drainage gully
2.52	Existing trail
2.53	Seepage
2.54	Seepage gentle to moderate slopes
2.55	Sandstone Boulder outcrops, ways down for trail
2.56	Little Gilles across trail steep to very steep slopes
2.57	Rocky terrain
2.58	Incised channel boulders throughout
2.59	Filled embankment
3.1	Bridge DCP
3.2	Change or geology possibly rock outcrop upslope - Boulder risk
3.3	Toe of geology change, very steep slopes, boulders on slope, washout and tree falls with rain
3.4	Spring location
3.5	Jointed rock outcrop
3.6	Boulders creek and bridge
3.7	Slump
3.8	Back scarp clear, uphill progression on level terrace behind, seepage through unit boundary
3.9	Rock outcrop through gully comprised of shale
3.10	Nice gently sloping land
3.11	Boulder slope
3.12	Previous line will have some floating boardwalks, bridge location at point
3.13	Long bridge here, wide moderate gully, Boulder and clay infilled
3.14	Hummocks terrain
3.15	Several locations of seepage across track
3.16	Gutter like feature parallel to road on left
3.17	FRP floating bridge for erosion
3.18	Transition between claystone and sandstone, high risk of falling rocks due to sandstone boulders falling
3.19	Very steep area, evidence of soil creep, unlikely to impact trail
3.20	Transitions to very steep slopes
3.21	Watercourse, potential floating FRP, second bridge slightly further down
3.22	Wide boggy area
3.23	Dam
3.24	Between first and second dam
3.25	Seepage along toe
3.26	Rocky very steep section across creek Boulder movement risk
3.27	Rocky slopes
3.28	Very steep rock slope - difficult area
3.29	Wrapping along toe seems feasible rock fall risk above
3.30	Very steep rock location rock outcrops
3.31	Minor gullies throughout hummocks terrain
3.32	Wide erosion all incised gully boulders in creek signs of slippage along creek banks up slope

Point	Observation
5.1	Small bridge
5.2	Entry, creek some wash away, boulders present, erosion along entry track photos taken
5.3	Very steeply sloping bluff, centre of wide gently sloping gully, very steeply sloping, falling towards jump area
5.4	Area used as rolling area, base of gully/creek
5.5	Incised creek, flowing water through base of gully up to 6m high max point
5.6	Creek/bike track main entrance
5.7	Large jump area,
5.8	Secondary entrance to jump area, steep heavy erosion

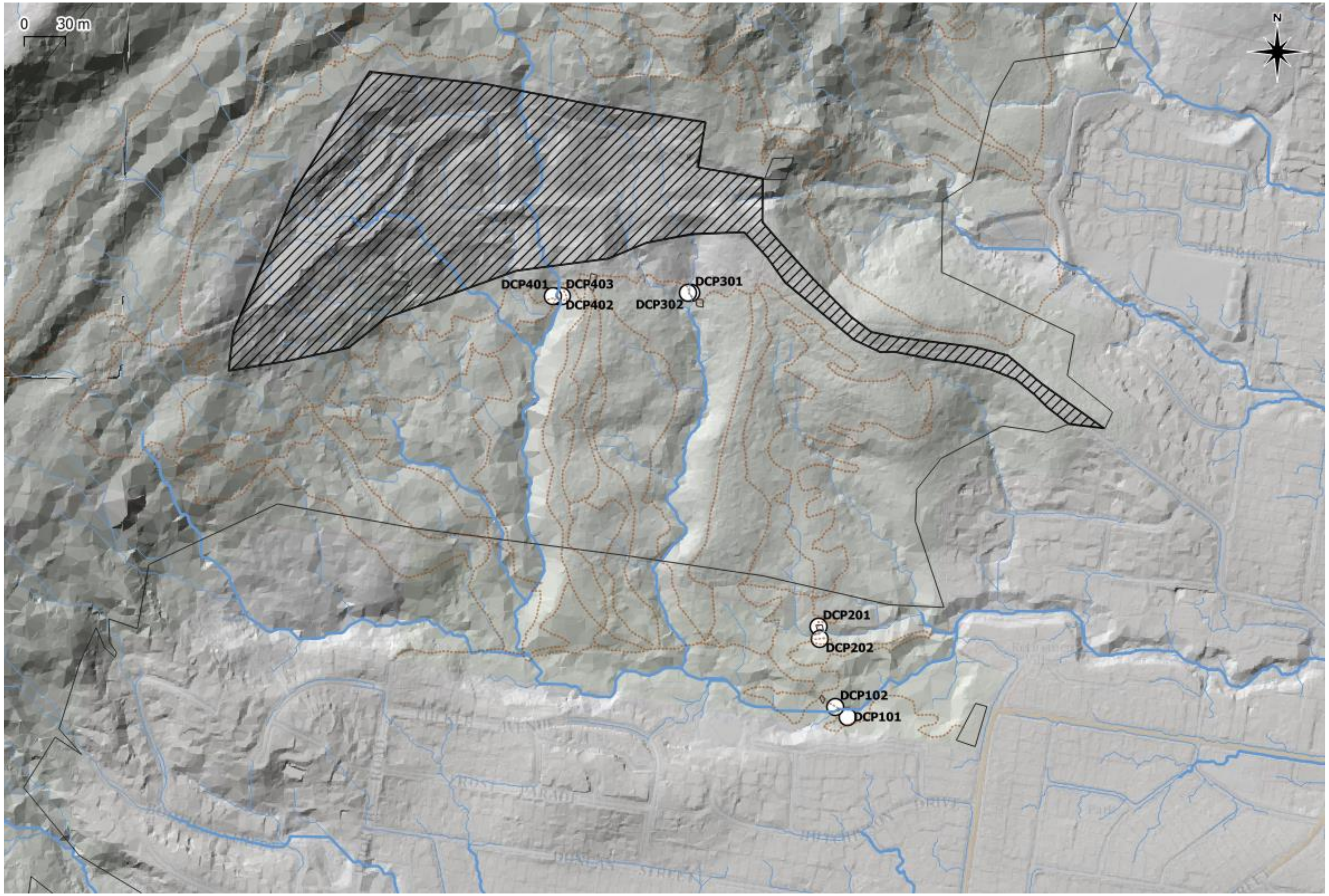
revision	description	drawn	approved	date
	Site Observations	XJ	KEG	1/12/2022

N

TERRA INSIGHT

scale	NTS
original size	A3

client:	Niche Environment and Heritage
project	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
title:	Major Terrain Units
project no: TERRA22-223	figure no: FIGURE 10



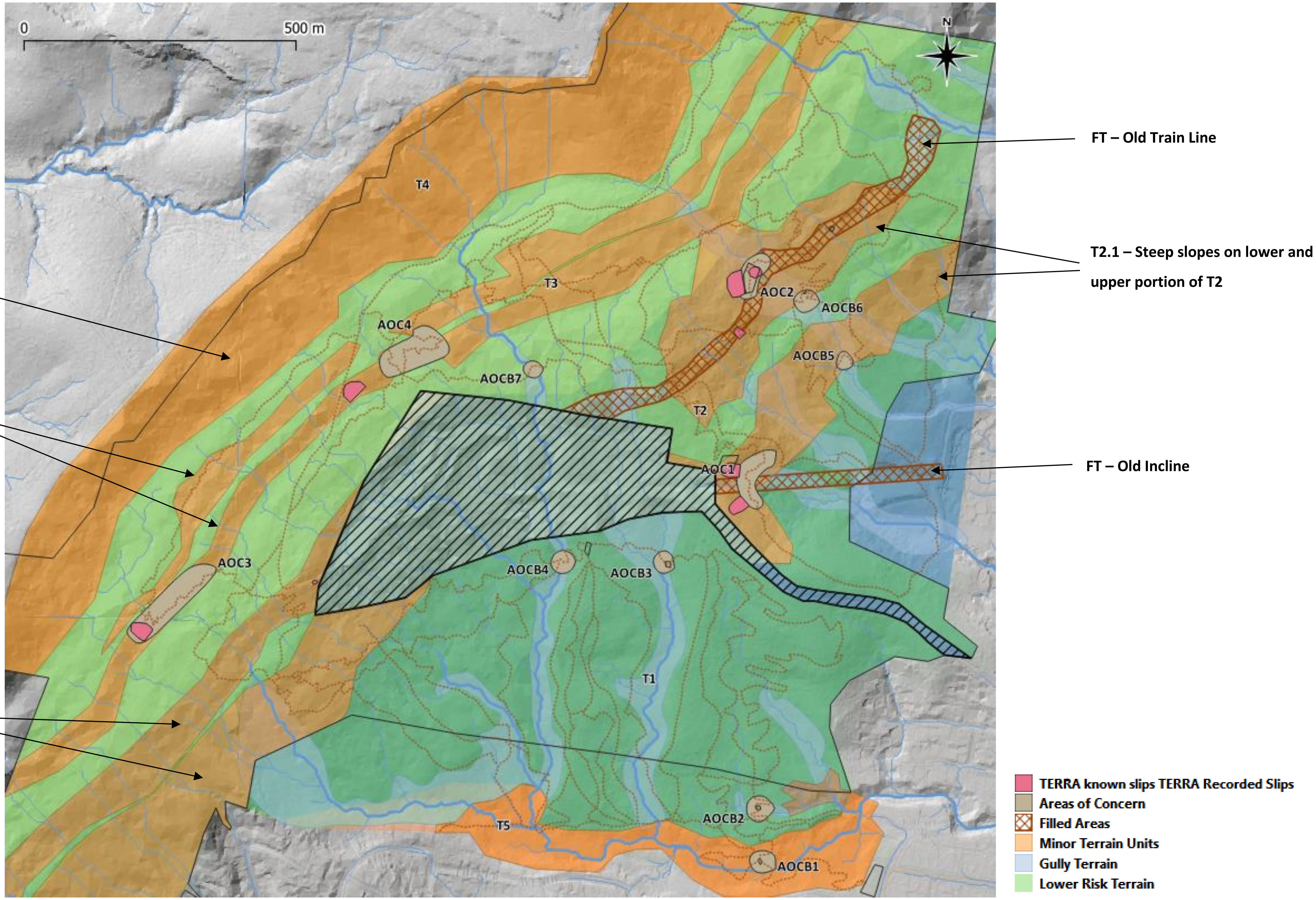
DCP Test Locations

revision	description	drawn	approved	date
	Site location	XJ	KEG	1/12/2022

N

TERRA INSIGHT

client:	Niche Environment and Heritage
project	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
title:	DCP Test Locations
scale	NTS
original size	A3
project no:	TERRA22-223
figure no:	FIGURE 11



Minor Terrain Units

revision	description	drawn	approved	date
	Site location	XJ	KEG	1/12/2022

N

TERRA INSIGHT

client:	Niche Environment and Heritage
project	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
scale	NTS
original size	A3
title:	Major Terrain Units
project no: TERRA22-223	figure no: FIGURE 12

Appendix A: Your Report

Your Report

These notes have been prepared to help you understand the advice provided in Your Report and its limitations.

Your Report is based on what you tell us

Your Report has been developed based on the information you have provided such as the scope and size of your project. It applies only to the site investigated. If there are changes to the proposed works, then the advice provided within Your Report may need to be reviewed

Your Report is written with your needs in mind

The advice provided within Your Report is also not relevant to another purpose other than that originally specified at the time the report was issued. Please seek advice from Terra Insight before you share Your Report with another third party – except for the purpose for which the report was written.

Terra Insight assumes no responsibility and will not be liable to any other person or organisation for, or in relation to, any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in Your Report.

Your Report is based on what we observed

The advice provided within Your Report assumes that the site conditions, revealed through selective point sampling (undertaken in accordance with normal practices and standards) at a particular point in time, are indicative of the actual conditions on your site. However, the nature of the materials underlying your site is affected by natural processes and the activity of man. Under no circumstances can it be considered that these findings represent the actual state at all points. The subsurface conditions may vary significantly on the other parts of the site, particularly where no nearby sampling and testing work has been carried out.

As a result conditions on your site can change with time; they can also vary spatially. As a result, the actual conditions encountered may differ from those detailed within Your Report. Although nothing can be done to change the actual site conditions which exist, steps can be taken to gain a better understanding of the subsurface conditions underlying your site and reduce the potential for unexpected conditions to be encountered

The advice within Your Report also relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it. Only Terra Insight is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If the details of your project have changed, the site conditions have changed or a significant amount of time as elapsed since our report was written, the advice provided within Your Report may need to be reviewed.

Your Report has been written by a Professional

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

Your Report is better when it is kept together

Your Report presents all the findings of the site assessment and should not be copied in part or altered in any way. Keeping Your Report intact reduces the potential for yourself or other design professionals to misinterpret the report.

Your Geo-Environmental Report

If Your Report is for geotechnical purposes only, it will not relate any findings, conclusions, or recommendations about the potential for hazardous materials to exist at the site unless you have specifically asked us to do so. If your report is written for Geo-Environmental purposes the following should be noted in addition to the above:

- Advancements in professional practice regarding contaminated land and changes in applicable statues and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in Your Report should be verified if you propose to use this report more than 6 months after its date of issue;
- Your Report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. The assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, which includes budget and timing;
- The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice. Any interpretation in Your Report is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment.
- We may have relied on data and other information provided by you and other qualified individuals in preparing Your Report. We have not verified the accuracy or completeness of such data or information except as otherwise stated in Your Report. For these reasons Your Report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.
- For each purpose, a tailored approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible quantify, risks that both recognised and potential contamination posed in the context of the agreed purpose. If the proposed use of the site changes, the assessment may no longer be valid and will need to be reviewed.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Appendix B: Soil Landscapes

gw	GWYNNEVILLE	Residual

Landscape—footslopes of the Illawarra Escarpment and isolated rises of the Wollongong Plain. Local relief 10–70 m; slopes 3–25%. Broad to moderately (250–850 m) rounded ridges and gently to steeply inclined slopes. Structural benches and occasional rock outcrop. Extensively cleared tall open orest and open forest.

Soils—shallow (50–100 cm) Brown Podzolic Soils (Db1.11, Db3.11) and Xanthozems (Gn4.34) on upper slopes, Lithosols (Um1.43, Uc1.23) on simple slopes and shallow (<50 cm) Brown Earths (Uf6.13) on midslopes and lower slopes.

Limitations—extreme erosion hazard, steep slopes, mass movement hazard, local flooding. Reactive subsoils and impermeable, low wet bearing strength clay subsoils.

LOCATION

Wollongong Plain between Austinmere and Dapto and the lower portion of the Illawarra Escarpment between Coledale and Bong Bong Pass.

LANDSCAPE

Geology

Illawarra Coal Measures—resistant interbedded quartz lithic sandstone, grey siltstone and claystone, carbonaceous claystone, clay and laminite.

Topography

Undulating to steep hills (local relief 10–70 m, slope gradients 3–25%). Landform elements include broad to moderate ridges (250–800 m), steeply inclined to moderately inclined foot slopes, and isolated rises on the coastal plain. This soil landscape is characterised by localised structural benches up to 80 m wide, localised bedrock outcrops and deep colluvial deposits.

Vegetation

In residential areas, the original tall open-forest (wet sclerophyll forest) and open-forest (dry sclerophyll forest) have been extensively cleared. Remaining species include bangalay, blackbutt, grey ironbark, swamp mahogany, forest red gum, spotted gum (Corrimal only), two-veined hickory and black wattle.

Landuse

Landuse is predominantly urban residential. Developed suburbs include Gwynneville, Bellambi, Dapto, Bulli, Figtree and Woonona Heights. Dairy production occurs on improved pastures, and stands of native timber are found in the vicinity of Mount Kembla.

Existing Erosion

Evidence of widespread previous mass movement includes isolated collapsed batters and indications of previous slumps and landslides. Localised moderate gully and sheet erosion occur near Dapto.

SOILS

Dominant Soil Materials

gw1—Friable brown sandy loam. Moderately pedal sandy loam to loam with rough-faced peds. This material usually occurs as topsoil.

Organic matter content is high. Peds range from 2–10 mm and are crumb to polyhedral. Colour varies from brownish black (10YR 3/2) to dull yellowish brown (10YR 5/3). The pH is slightly acid (pH 6.5). Sandstone fragments and gravels are common to abundant (10–90%) and range from 2–600 mm.

gw2—Friable sandy clay loam. Moderately pedal sandy clay loam with rough-faced peds. This material occurs as either topsoil or subsoil.

Peds range from 2–10 mm and are crumb to polyhedral. Colour varies from brownish black (10YR 3/2) to dull yellowish brown (10YR 5/3). The pH is slightly acid (pH 6.5). Sandstone fragments and gravels are common to abundant (10–90%) and range from 2–600 mm.

gw3—Brown pedal clay. Moderately pedal, light to heavy clay with rough-faced peds. This material occurs as subsoil.

Texture increases from light to heavy clay with depth. Peds are small, 5–20 mm, and are polyhedral or blocky. Colour varies from brown (7.5YR 4/6) to dull yellowish brown (10YR 5/4). Occasional orange mottles occur at depth. The pH ranges from moderately acid (pH 5.0) to slightly acid (pH 6.5). Gravel and rocks vary from rare to common. Roots are absent.

Occurrence and Relationships

Soil material distribution is variable throughout this landscape, reflecting previous mass movement.

Ridges. 10–30 cm of friable brown loam (**gw1**) overlies bedrock [Lithosols (Um1.43, Uc1.23)]. Depth is <50 cm.

Upper slopes and mid slopes. 10–30 cm of friable brown loam (**gw1**) overlies up to 100 cm brown pedal clay (**gw3**) [Brown Podzolic Soils (Db3.11) and Xanthozems (Gn4.34)]. Boundaries between soil materials are clear to gradual. Depth is >150 cm.

Lower slopes and localised positions on mid slopes. 20–50 cm of brown pedal clay (**gw2**) overlies either **gw3** or bedrock [Xanthozems (Gn4.34), Brown Earths (Uf6.13)]. Boundaries are gradual. Depth is <60 cm.

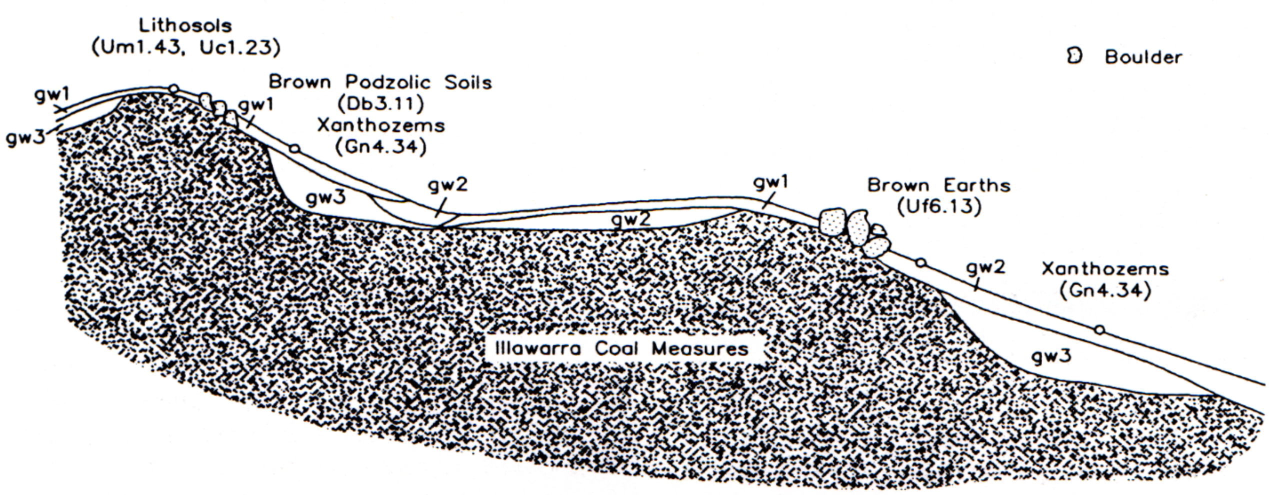
LIMITATIONS TO DEVELOPMENT

Soil Limitations

gw1 High permeability
Low available water-holding capacity
Stoniness (localised)

gw2 High permeability
Stoniness

gw3 Low permeability
Stoniness (localised)



■ ***Schematic cross-section of Gwynneville soil landscape illustrating the occurrence and relationship of the dominant soil materials.***

Fertility

Fertility of **gw1** and **gw2** is moderate. Nutrient status and storage potential are high. **gw3** has low permeability and low fertility. Soils are shallow and have poor root penetration at depth. General fertility is moderate.

Erodibility

Soil erodibility is moderate. Soils are finely graded with coherent structures and moderately graded peds.

Erosion hazard

The erosion hazard for this soil landscape for non-concentrated flows is extreme. Calculated approximate soil loss during the first 12 months of urban development ranges up to 560 t/ha for topsoil and 500 t/ha for exposed subsoil. Soil erosion hazard for concentrated flows is moderate.

Surface Movement Potential

The soil materials vary from stable to slightly reactive.

Landscape Limitations

Steep slopes
Mass movement hazard
Rock fall hazard (localised)
Erosion hazard

Urban Capability

Low to moderate capability for urban development. Localised steep areas not capable of development.

Rural Capability

Generally capable of sustaining grazing but not capable of regular cultivation.

ie	ILLAWARRA ESCARPMENT	Colluvial

Landscape—steep to very steep slopes on Quaternary talus. Local relief is 100–300 m; slope gradients 20–50%. Large landslips are very common. Mostly uncleared tall open-forest (wet sclerophyll forest) and closed-forest (rainforest).

Soils—deep colluvial soils Red Podzolic Soils (Dr3.21) and Brown Podzolic Soils (Dr4.21) occur on mid-slopes. Siliceous Sands (Uc4.21) occur along drainage lines. Lithosols (Uc5.11) occur where the talus is recent.

Limitations—mass movement and rock fall hazard. Steep slopes and extreme erosion hazard. Reactive, low wet bearing strength subsoils. Low to moderate soil fertility.

LOCATION

Along the Illawarra Escarpment from Stanwell Park to Bong Bong Pass.

LANDSCAPE

Geology

Quaternary talus—blocks of sandstone, deep colluvial detritus and soil materials. [The talus appears to be more widespread than mapped by Geological Survey (1974)].

Topography

Debris mantle covering the upper slopes and benches of the Illawarra Escarpment. Step to very steep slopes, gradients 20–50%. Local relief is 100–300 m. This soil landscape includes the cliffs of the escarpment. Large landslips are a very common feature. Below the escarpment bedrock outcrop is absent. Large surface and sub-surface sandstone boulders 2–25 m across are commonplace. Stream lines are unidirectional.

Vegetation

Mostly uncleared tall open-forest (wet sclerophyll forest) and closed-forest (rainforest). Tall open forest is dominated by blackbutt and includes lilly pilly, sandpaper fig, moreton bay fig, small-leaved fig, Port Jackson fig, deciduous fig, coachwood and red cedar.

Rainforest of the escarpment includes grey myrtle, brush bloodwood, whitewood and cabbage tree palm. Fuller (1980) has studied the vegetation of the escarpment.

Landuse

Undisturbed forest and State Recreation Areas occur—e.g., at Mount Kembla. A number of coalmine entrances are located in this soil landscape, and the urban fringes of Mount Ousley, Woronora Heights, Coledale and Thirroul extend onto its foot slopes.

Existing erosion

Indications of mass movement, including major slumping and landslips, are commonplace. Minor gully erosion (up to 50 cm) and sheet erosion are obvious after severe rain.

SOILS

Dominant Soil Materials

ie1—Loose dark brown sand. Loose sand to occasionally weakly pedal loam with a sandy fabric and rough-faced peds. This material occurs as topsoil.

Peds are polyhedral to crumb and range from <20–50 mm. Colour varies from dark brown (10YR 3/3) to brownish black (7.5YR 3/1) to brownish grey (7.5YR 4/1). The pH ranges from moderately acid (pH 5.5) to slightly acid (pH 6.5). Sandstone fragments varying from 2–200 mm are very common. Roots are common.

ie2—Moderately pedal sandy clay loam. Moderately pedal sandy clay loam to fine sandy loam with polyhedral to angular blocky rough-faced peds. This material occurs as subsoil.

Colour varies from dull yellowish brown (10YR 4/3) to brown (7.5YR 4/3) to reddish brown (5YR 4/8). The pH ranges from strongly acid (pH 4.5) to moderately acid (pH 5.5). Sandstone fragments and boulders are abundant.

ie3—Moderately pedal sandy clay. Moderately pedal sandy clay to heavy clay with polyhedral to sub-angular blocky rough-faced peds. This material occurs as subsoil.

Colour varies from dark reddish brown (2.5YR 3/6) to reddish brown (5YR 4/6) to dark brown (7.5YR 4/6). This material is often mottled (red, white or orange). The pH ranges from strongly acid (pH 4.5) to neutral (pH 7.0). Sandstone fragments and boulders are abundant.

Occurrence and Relationships

The depth of talus material varies but is usually >2 m.

Recently deposited talus. Up to 50 cm of stony sand (**ie1**) [Lithosols (Uc5.11)] occurs directly below cliffs.

Mid-slopes. Up to 20 cm of brown sand (**ie1**) usually overlies 80 cm of moderately pedal clay loam (**ie2**) which in turn overlies up to 100 cm of occasionally mottled pedal clay (**ie3**) [Red Podzolic Soils (Dr3.21) and Brown Podzolic Soils (Db4.21)].

Drainage lines. Up to 100 cm (**ie1**) (Siliceous Sands (Uc4.21) occurs.

LIMITATIONS TO DEVELOPMENT

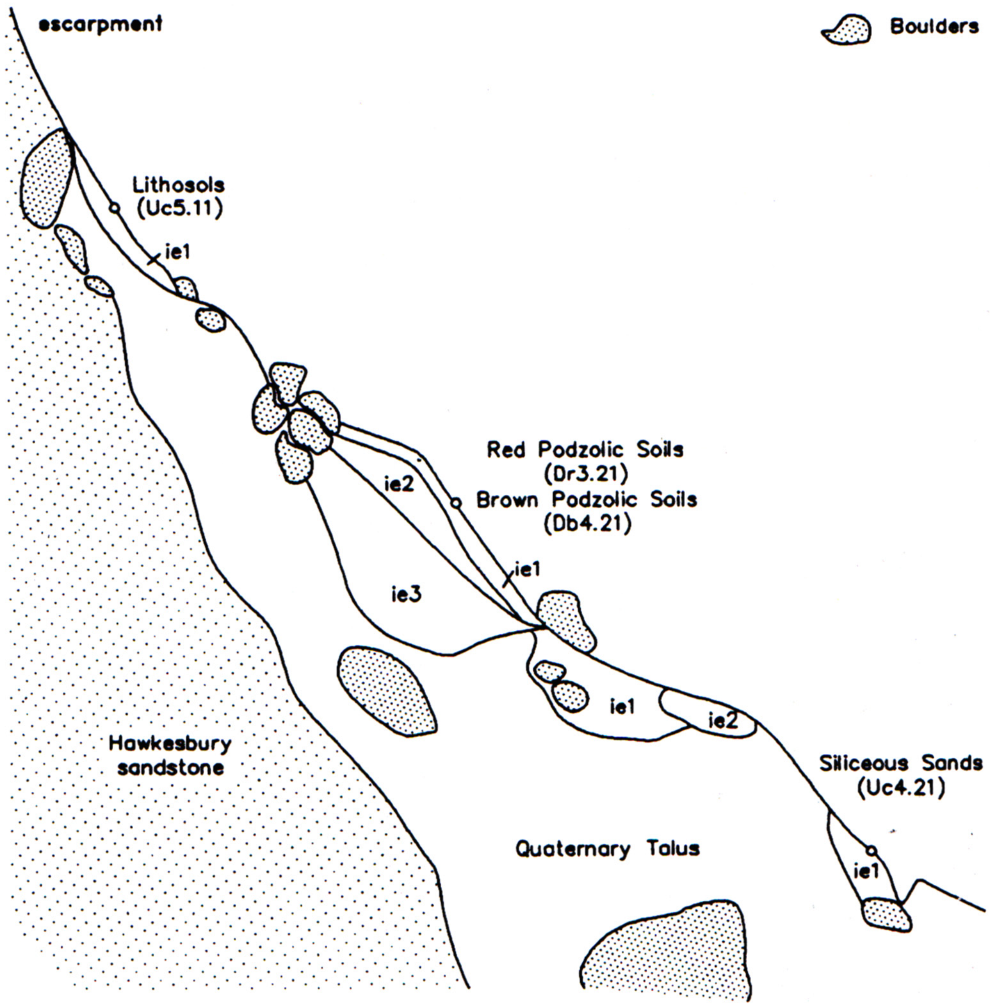
Soil Limitations

ie1 High permeability

Low available water-holding capacity
Stoniness
Low to medium plasticity

ie2 High permeability
Low available water-holding capacity
Stoniness
Low to medium plasticity

ie3 Low permeability
Low available water-holding capacity
Stoniness
Low to medium plasticity



■ *Schematic cross-section of Illawarra Escarpment soil landscape illustrating the occurrence and relationship of the dominant soil materials.*

Fertility

Fertility of individual soil materials is low. General soil fertility is moderate. Soils are acid, have moderate CEC and low to moderate nutrient status with low to moderate available water-holding capacities. Although stony the soils are generally very deep and well structured, allowing large soil volumes available for roots.

Erodibility

ie1 has low erodibility as it consists of highly permeable coarse sand grains. The other soil materials (**ie2**, **ie3**) are moderately erodible.

Erosion Hazard

The erosion hazard for this soil landscape for non-concentrated flows is extreme. Calculated approximate soil loss during the first 12 months of urban development ranges up to 1 415 t/ha for topsoil and 1 230 t/ha for exposed subsoil. Soil erosion hazard for concentrated flows is high to extreme.

Surface Movement Potential

Sandy soils are stable. **ie3** is moderately reactive. Potential movements may be set off by poor drainage. Special foundation designs may be required in areas of mass movement hazard.

Landscape Limitations

Steep slopes
Mass movement
Extreme rock fall hazard
Extreme erosion hazard
Moderately reactive soils

Urban Capability

Generally not capable of urban development.

Rural Capability

Not capable of being cultivated or grazed.

Appendix C: Site Images

Terrain Unit 1 Photograph 1: Typical terrain along trails in T1, SW. Photo taken along Trail 7.

Terrain Unit 1 Photograph 2: View of steeply sloping gully slopes along T1 SW. Photo taken along Trail 8.

Terrain Unit 1 Photograph 3: View of minor gullies that the trail traverses. Photo taken along Trail 8.

Terrain Unit 1 Photograph 4: Area of seepage observed at the toe of T1. Photo taken along Trail 6.

revision	description	drawn	approved	date
	Plate1	XJ	KEG	1/12/2022

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
scale	NTS
Title	**Images of the site – Terrain Unit 1**
original size	**A3**
project no:	**TERRA22-223**
Plate no:	**1**

Terrain Unit 1 Photograph 5: Erosion along trail above Trail 12.

Terrain Unit 1 Photograph 6: Boulder filled creek along active channel.

Terrain Unit 1 Photograph 7: View of proposed crossing in location of Trail 15, 16 and 18 junction.

Terrain Unit 1 Photograph 8: View of wide channel base to the east.

revision	description	drawn	approved	date
	Plate2	XJ	KEG	1/12/2022

TERRA INSIGHT

client:	Niche Environment and Heritage
project:	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
scale	NTS
Title	Images of the site – Terrain Unit 1
original size	A3
project no:	TERRA22-223
Plate no:	2

Terrain Unit 1 Photograph 9: Slopes at the toe of T1, NE.

Terrain Unit 1 Photograph 10: View of old earthworks with drainage channel nearby Trail 30.

Terrain Unit 1 Photograph 11: Wide channel that Trail 30 crosses.

Terrain Unit 1 Photograph 12: Incised creek near Trail 30.

revision	description	drawn	approved	date
	Plate3	XJ	KEG	1/12/2022

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
scale	NTS
Title	**Images of the site – Terrain Unit 1**
original size	**A3**
project no:	**TERRA22-223**
Plate no:	**3**

Terrain Unit 1 Photograph 13: Outcropping rock at shallow depth within incised creek.

Terrain Unit 1 Photograph 14: Gentle ridge slope that Trails 12 and 13 follows in T1, NE.

Terrain Unit 1 Photograph 15: Locally steep slopes that Trail 35 follows.

Terrain Unit 1 Photograph 16: Incised minor gullies along Trail 35.

revision	description	drawn	approved	date
	Plate3	XJ	KEG	1/12/2022

TERRA INSIGHT

client:	Niche Environment and Heritage
project:	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
scale	NTS
Title	Images of the site – Terrain Unit 1
original size	A3
project no:	TERRA22-223
Plate no:	4

Terrain Unit 2 Photograph 1: View of section below power lines, comprised of moderate to steep slopes.

Terrain Unit 2 Photograph 2: Drainage channel along steep slopes along Trail 16.

Terrain Unit 2 Photograph 3: View of drainage channel continuing over poorly defined bench along Trail 16.

Terrain Unit 2 Photograph 4: Signs of seepage along level benches.

revision	description	drawn	approved	date
	Plate1	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	Niche Environment and Heritage
project:	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
Title	Images of the site – Terrain Unit 2
scale	NTS
original size	A3
project no:	TERRA22-223
Plate no:	1

Terrain Unit 2 Photograph 5: View of level bench below steep section along Trail 21. Boulders visible

Terrain Unit 2 Photograph 6: View of steep terrain along Trail 21. Boulders visible.

Terrain Unit 2 Photograph 7: Signs of soil creep observed along the existing trail on steep slopes along Trail 21.

Terrain Unit 2 Photograph 8: View of slip along access road from the Corrimal Colliery.

revision	description	drawn	approved	date
	Plate2	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	Niche Environment and Heritage
project:	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
scale	NTS
Title	Images of the site – Terrain Unit 2
original size	A3
project no:	TERRA22-223
Plate no:	2

Terrain Unit 2 Photograph 9: Steep ridge along Trail 30, with signs of soil creep.

Terrain Unit 2 Photograph 10: Outcropping rock at crest of ridge near Trail 30.

Terrain Unit 2 Photograph 11: View of gully network that Trail 31 traverses from ridge to the northeast.

Terrain Unit 2 Photograph 12: View of coalwash like fill in the base of the gully network.

revision	description	drawn	approved	date
	Plate3	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
scale	NTS
Title	**Images of the site – Terrain Unit 2**
original size	**A3**
project no:	**TERRA22-223**
Plate no:	**3**

Terrain Unit 2 Photograph 13: Soil creep common within the gully.

Terrain Unit 2 Photograph 14: Deep incised channels formed within the fill.

Terrain Unit 2 Photograph 15: Slip on very steep slopes upslope of Trail 31.

Terrain Unit 2 Photograph 16: View of slip upslope of Trail 31.

revision	description	drawn	approved	date
	Plate4	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
Title	**Images of the site – Terrain Unit 2**
scale	NTS
original size	**A3**
project no:	**TERRA22-223**
Plate no:	**4**

Terrain Unit 2 Photograph 17: View of Trail 32 and 33 bridge intersection.

Terrain Unit 2 Photograph 18: View of Trail 32 and 33 bridge intersection.

Terrain Unit 2 Photograph 19: View of the filled side of the Old Train Line.

Terrain Unit 2 Photograph 20: Material and some washout along crest of filled side of Old Train Line.

revision	description	drawn	approved	date
	Plate5	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
scale	NTS
Title	**Images of the site – Terrain Unit 2**
original size	**A3**
project no:	**TERRA22-223**
Plate no:	**5**

Terrain Unit 2 Photograph 21: Significant washout along the slip near a major drainage channel.

Terrain Unit 2 Photograph 22: View of old slip across filled section of Old Train Line along Trail 28.

Terrain Unit 2 Photograph 23: Slippage of overburden soils above rock outcrop on cut side of slip.

Terrain Unit 2 Photograph 24: View of overburden soil washout.

revision	description	drawn	approved	date
	Plate6	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	Niche Environment and Heritage
project:	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
scale	NTS
Title	Images of the site – Terrain Unit 2
original size	A3
project no:	TERRA22-223
Plate no:	6

Terrain Unit 3 Photograph 1: View of level terrain below very steep benches.

Terrain Unit 3 Photograph 2: Seepage along the level terrain along the toe of the steep bench slopes.

Terrain Unit 3 Photograph 3: Outcropping rock above Trail 21 and 22.

Terrain Unit 3 Photograph 4: Outcropping rock above Trail 21 and 22

revision	description	drawn	approved	date
	Plate1	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
Title	**Images of the site – Terrain Unit 3 and 4**
scale	NTS
original size	**A3**
project no:	**TERRA22-223**
Plate no:	**1**

Terrain Unit 3 Photograph 5: Slip along steep section of Trail 22.

Terrain Unit 3 Photograph 6: Tension cracks progressing along the crest of the bench.

Terrain Unit 3 Photograph 7: Minor channel along Trail 22 along the level terrain.

Terrain Unit 3 Photograph 8: View where Trail 24 traverses down a very steep bench slope (left) with adjacent drainage channel to the (right).

revision	description	drawn	approved	date
	Plate2	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
Title	**Images of the site – Terrain Unit 3 and 4**
scale	NTS
original size	**A3**
project no:	**TERRA22-223**
Plate no:	**2**

Terrain Unit 3 Photograph 9: Hummocky terrain along Trail 24.

Terrain Unit 3 Photograph 10: Deeply incised channel full of boulders that Trail 24 crosses.

Terrain Unit 3 Photograph 11: Bank instability observed along the channel banks near Trail 24 crossing.

Terrain Unit 3 Photograph 12: Outcropping rock in the location of Trail 25a.

revision	description	drawn	approved	date
	Plate3	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	Niche Environment and Heritage
project:	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
scale	NTS
Title	Images of the site – Terrain Unit 3 and 4
original size	A3
project no:	TERRA22-223
Plate no:	3

Terrain Unit 3 Photograph 13: Trail 33 crossing over channel, comprised of cobbles.

Terrain Unit 3 Photograph 14: View of Trail 33 as it continues down the very steeply sloping bench.

Terrain Unit 3 Photograph 15: Erosion along existing trails on the very steeply sloping portion of the trail.

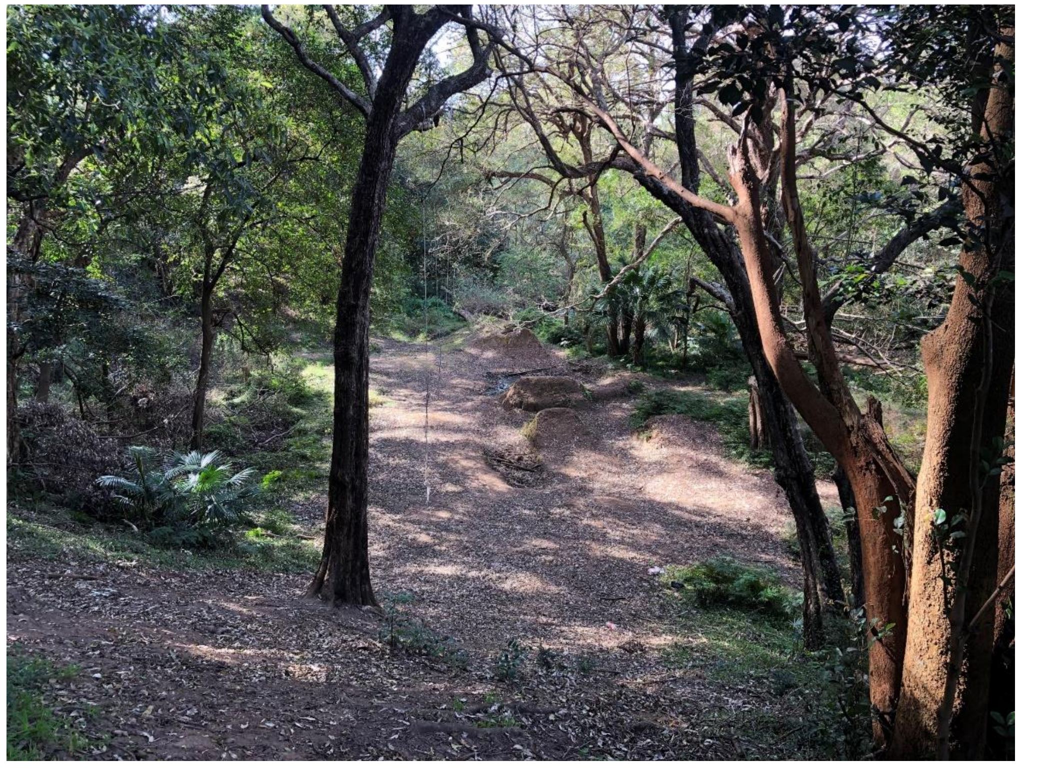
Terrain Unit 4 Photograph 16: View of Terrain Unit 4 slopes from the Upper access road.

revision	description	drawn	approved	date
	Plate4	XJ	KEG	2/12/2022

TERRA INSIGHT

client:	Niche Environment and Heritage
project:	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
scale	NTS
Title	Images of the site – Terrain Unit 3 and 4
original size	A3
project no:	TERRA22-223
Plate no:	4

Terrain Unit 5 Photograph 1: View of soil creep on very steep slopes away from the drainage channel.



Terrain Unit 5 Photograph 2: View of steep slopes to level base of alluvial terrain.

Terrain Unit 5 Photograph 3: View of increased erosion along the active river channel.

Terrain Unit 5 Photograph 4: View of very steep slopes along the active river channel.

revision	description	drawn	approved	date
	Plate1	XJ	KEG	1/12/2022

TERRA INSIGHT

client:	Niche Environment and Heritage
project:	Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW
scale	NTS
Title	Images of the site – Terrain Unit 5
original size	A3
project no:	TERRA22-223
Plate no:	1

Terrain Unit 5 Photograph 5: Slumping along sections of the river.

Terrain Unit 5 Photograph 6: Trail 1 Bridge Location looking northwest.

Terrain Unit 5 Photograph 7: Trail 1 Bridge Location looking southeast.

Terrain Unit 5 Photograph 8: Erosion along trails into Terrain Unit 5.

revision	description	drawn	approved	date
	Plate2	XJ	KEG	1/12/2022

TERRA INSIGHT

client:	**Niche Environment and Heritage**
project:	**Geotechnical Investigation Balgownie Mountain Bike Trail Network, Balgownie NSW**
scale	NTS
Title	**Images of the site – Terrain Unit 5**
original size	**A3**
project no:	**TERRA22-223**
Plate no:	**2**

Appendix D: DCP Logs

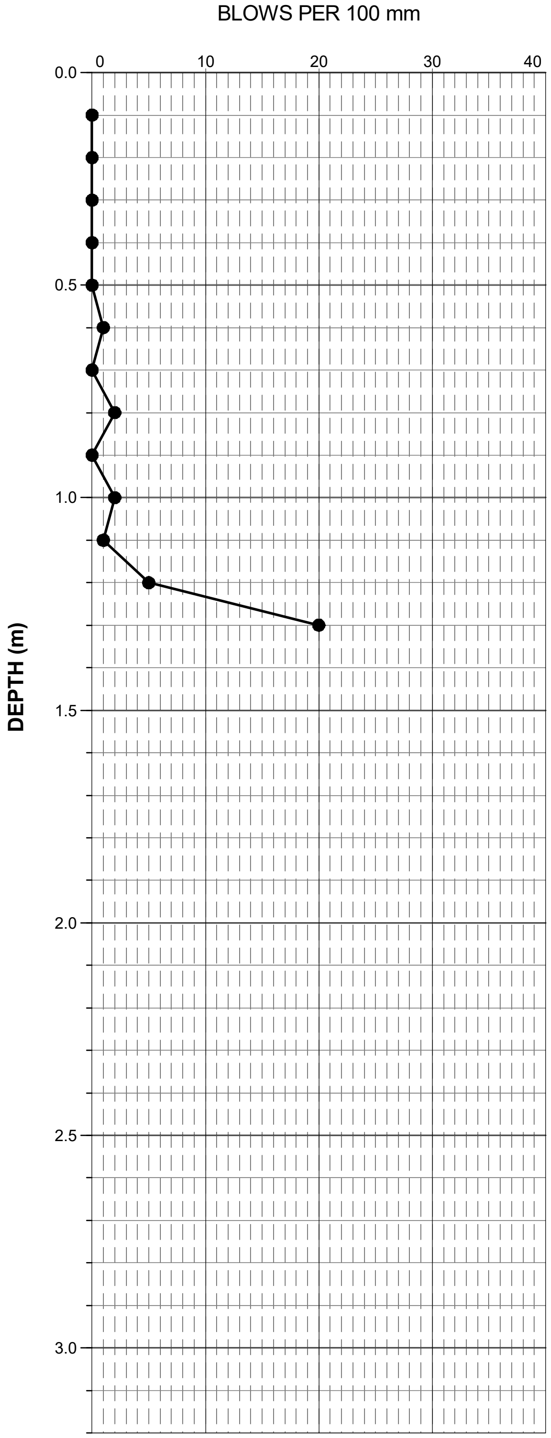
TERRA INSIGHT

9 KG DYNAMIC CONE PENETROMETER

Hole ID **DCP101**

CLIENT : Niche Environment and Heritage	POSITION :	SHEET : 1 OF 1
CONTRACTOR :	EASTING : 305077.7 m	STATUS :
PROJECT : Geotechnical Investigation	NORTHING : 6193527.3 m	LOGGED BY : XJ
LOCATION : 36	COORD. SYS. : MGA94 Zone 56	DRILL DATE : 10/10/2022
PROJECT No. : TERRA22-223	GROUND RL : 25.00 m AHD	

DEPTH (m)	NO OF BLOWS PER 100 mm
0.10	0
0.20	0
0.30	0
0.40	0
0.50	0
0.60	1
0.70	0
0.80	2
0.90	0
1.00	2
1.10	1
1.20	5
1.30	20



Final Depth (m)	1.20

RIG :	CHECKED BY :	REMARK
INCLINATION :	CHECKED DATE :	Target
AZIMUTH :	APPROVED BY :	
HOLE DIA. :	APPROVED DATE :	

TERRAINSIGHT 1.00 LIB.GLB Log IS DCP WITH TEXT AND PLOT TERRA22-474 LOGS.GPJ <<DrawingFile>> 23/11/2022 15:56 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: TerraInsight 1.00 lib 2017-12-04 Prj: TerraInsight 1.00 2017-12-04

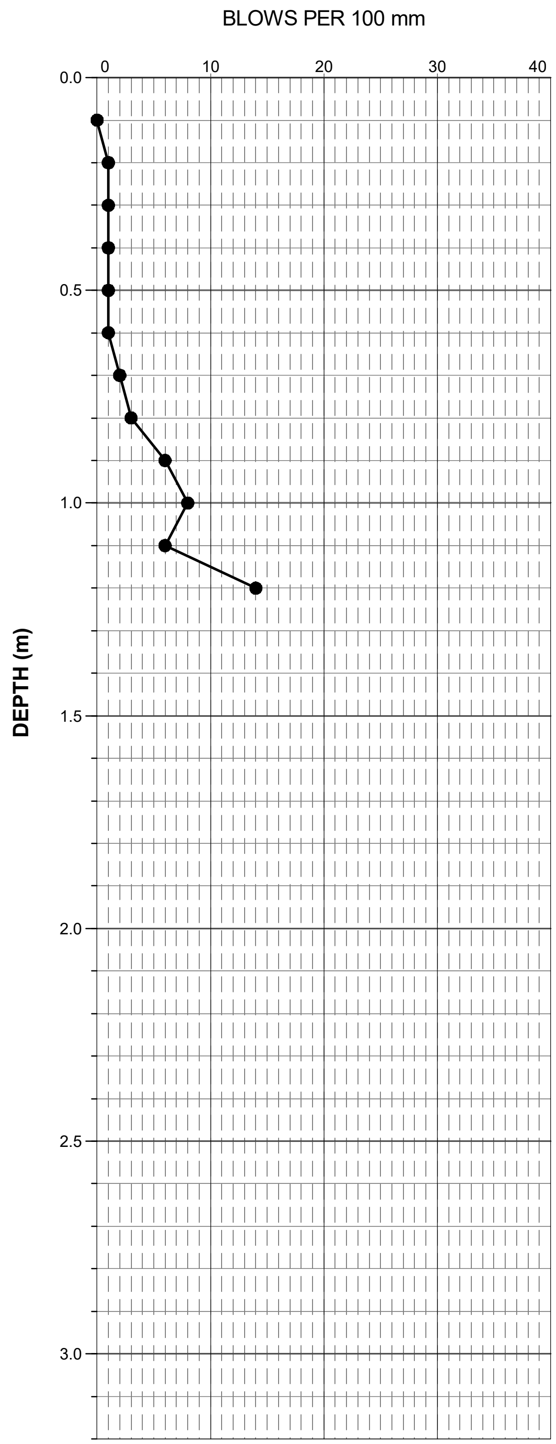
9 KG DYNAMIC CONE PENETROMETER

TERRA INSIGHT

Hole ID **DCP102**

CLIENT : Niche Environment and Heritage	POSITION :	SHEET : 1 OF 1	
CONTRACTOR :	EASTING : 305059.8 m	STATUS :	
PROJECT : Geotechnical Investigation	NORTHING : 6193541.5 m	LOGGED BY : XJ	
LOCATION : 36	COORD. SYS. : MGA94 Zone 56	DRILL DATE : 10/10/2022	
PROJECT No. : TERRA22-223	GROUND RL : 25.00 m AHD		

DEPTH (m)	NO OF BLOWS PER 100 mm
0.10	0
0.20	1
0.30	1
0.40	1
0.50	1
0.60	1
0.70	2
0.80	3
0.90	6
1.00	8
1.10	6
1.20	14



Final Depth (m)	1.10

RIG :	CHECKED BY :	REMARK
INCLINATION :	CHECKED DATE :	Target
AZIMUTH :	APPROVED BY :	
HOLE DIA. :	APPROVED DATE :	

TERRAINSIGHT 1.00 LIB.GLB Log IS DCP WITH TEXT AND PLOT TERRA22-474 LOGS.GPJ <<DrawingFile>> 23/11/2022 15:56 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: TerraInsight 1.00 lib 2017-12-04 Prj: TerraInsight 1.00 2017-12-04

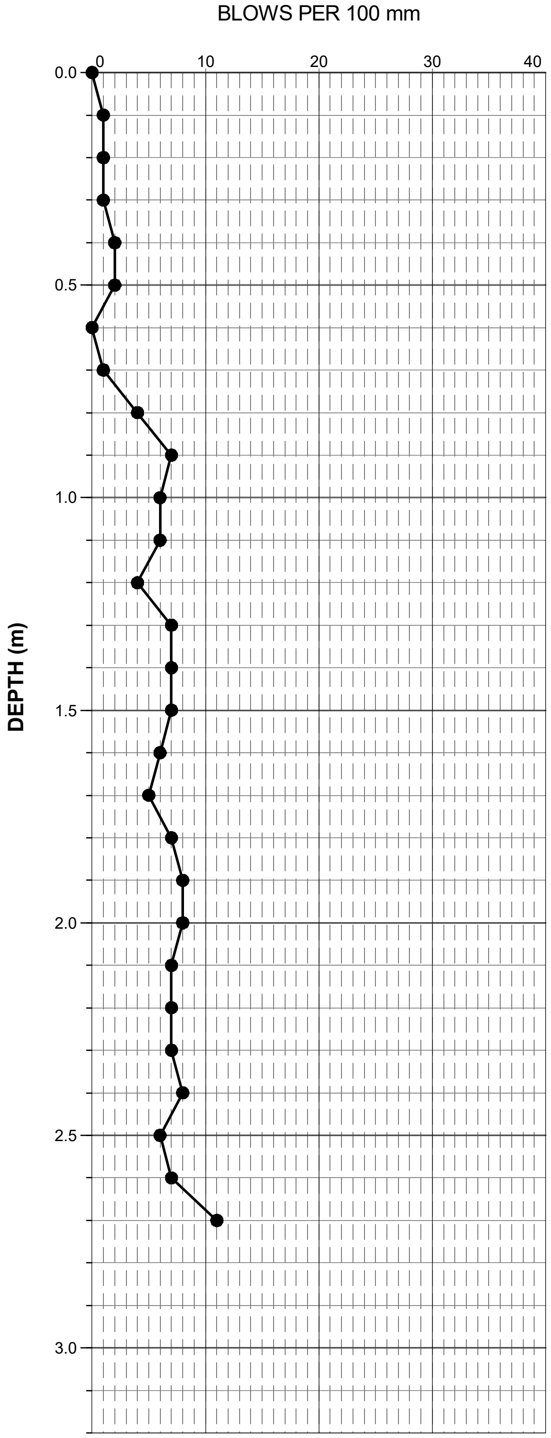
9 KG DYNAMIC CONE PENETROMETER

TERRA INSIGHT

Hole ID **DCP201**

CLIENT : Niche Environment and Heritage	POSITION :	SHEET : 1 OF 1
CONTRACTOR :	EASTING : 305032.4 m	STATUS :
PROJECT : Geotechnical Investigation	NORTHING : 6193658.7 m	LOGGED BY : XJ
LOCATION : 36	COORD. SYS. : MGA94 Zone 56	DRILL DATE : 10/10/2022
PROJECT No. : TERRA22-223	GROUND RL : 30.00 m AHD	

DEPTH (m)	NO OF BLOWS PER 100 mm
0.00	0
0.10	1
0.20	1
0.30	1
0.40	2
0.50	2
0.60	0
0.70	1
0.80	4
0.90	7
1.00	6
1.10	6
1.20	4
1.30	7
1.40	7
1.50	7
1.60	6
1.70	5
1.80	7
1.90	8
2.00	8
2.10	7
2.20	7
2.30	7
2.40	8
2.50	6
2.60	7
2.70	11



Final Depth (m)	2.70

RIG :	CHECKED BY :	REMARK
INCLINATION :	CHECKED DATE :	Target
AZIMUTH :	APPROVED BY :	
HOLE DIA. :	APPROVED DATE :	

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9 KG DYNAMIC CONE PENETROMETER

TERRA INSIGHT

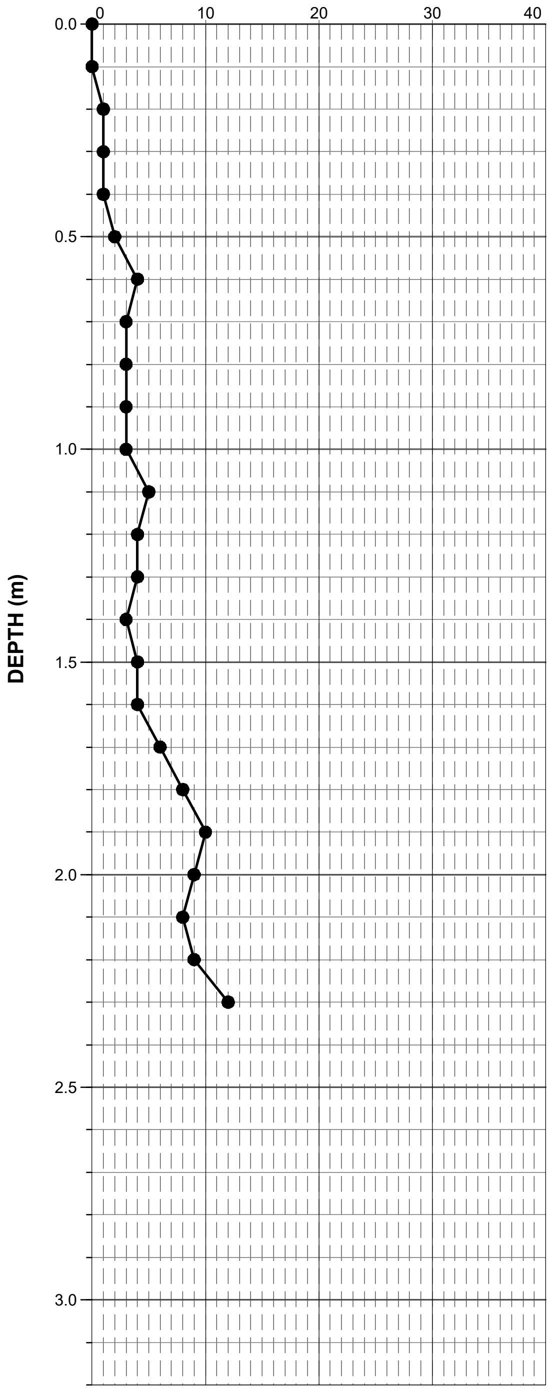
Hole ID **DCP202**

CLIENT	: Niche Environment and Heritage
CONTRACTOR	:
PROJECT	: Geotechnical Investigation
LOCATION	: 36
PROJECT No.	: TERRA22-223

POSITION	:
EASTING	: 305034.7 m
NORTHING	: 6193641.5 m
COORD. SYS.	: MGA94 Zone 56
GROUND RL	: 30.00 m AHD

SHEET	: 1 OF 1
STATUS	:
LOGGED BY	: XJ
DRILL DATE	: 10/10/2022

DEPTH (m)	NO OF BLOWS PER 100 mm
0.00	0
0.10	0
0.20	1
0.30	1
0.40	1
0.50	2
0.60	4
0.70	3
0.80	3
0.90	3
1.00	3
1.10	5
1.20	4
1.30	4
1.40	3
1.50	4
1.60	4
1.70	6
1.80	8
1.90	10
2.00	9
2.10	8
2.20	9
2.30	12



Final Depth (m)	2.30

RIG	:	CHECKED BY	:
INCLINATION	:	CHECKED DATE	:
AZIMUTH	:	APPROVED BY	:
HOLE DIA.	:	APPROVED DATE	:

REMARK
Target

TERRAINSIGHT 1.00 LIB.GLB Log IS DCP WITH TEXT AND PLOT TERRA22-474 LOGS.GPJ <<DrawingFile>> 23/11/2022 15:56 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: TerraInsight 1.00 lib 2017-12-04 Prj: TerraInsight 1.00 2017-12-04

TERRA INSIGHT

9 KG DYNAMIC CONE PENETROMETER

Hole ID **DCP301**

CLIENT : Niche Environment and Heritage	POSITION :	SHEET : 1 OF 1
CONTRACTOR :	EASTING : 304834.2 m	STATUS :
PROJECT : Geotechnical Investigation	NORTHING : 6194143.0 m	LOGGED BY : XJ
LOCATION : 36	COORD. SYS. : MGA94 Zone 56	DRILL DATE : 10/10/2022
PROJECT No. : TERRA22-223	GROUND RL : 82.00 m AHD	

DEPTH (m)	NO OF BLOWS PER 100 mm
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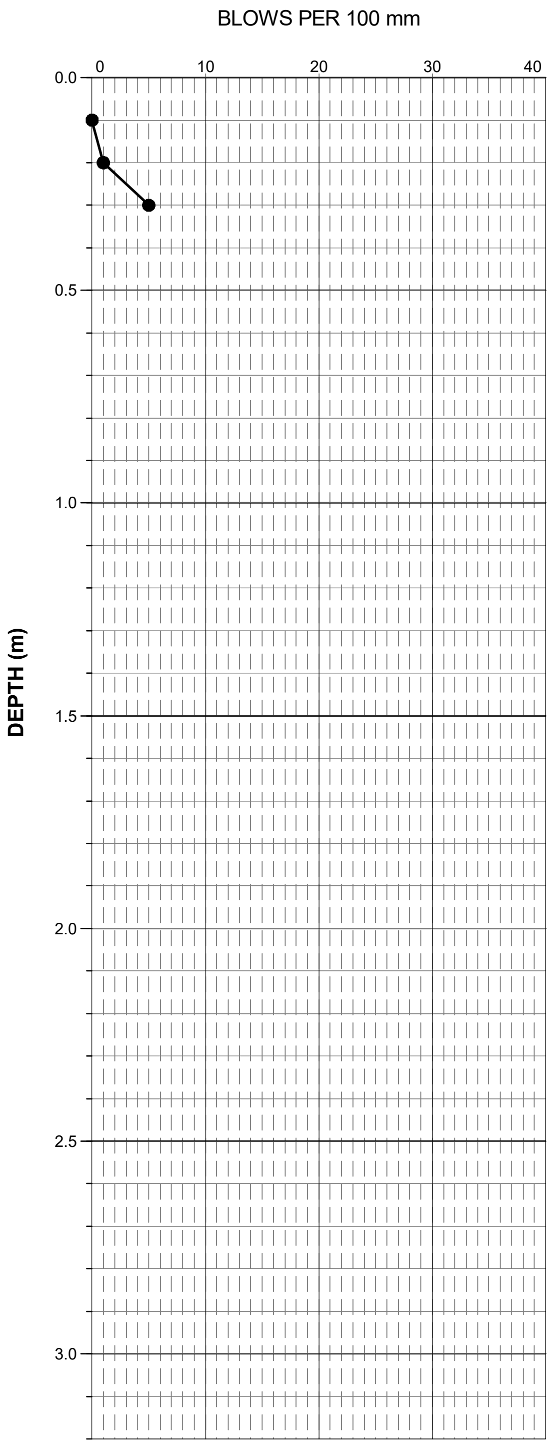
0.20	1
0.30	5



Final Depth (m)	0.20

RIG :	CHECKED BY :	REMARK
INCLINATION :	CHECKED DATE :	Refusal
AZIMUTH :	APPROVED BY :	
HOLE DIA. :	APPROVED DATE :	

TERRAINSIGHT 1.00 LIB.GLB Log IS DCP WITH TEXT AND PLOT TERRA22-474 LOGS.GPJ <<DrawingFile>> 23/11/2022 15:56 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: TerraInsight 1.00 lib 2017-12-04 Prj: TerraInsight 1.00 2017-12-04

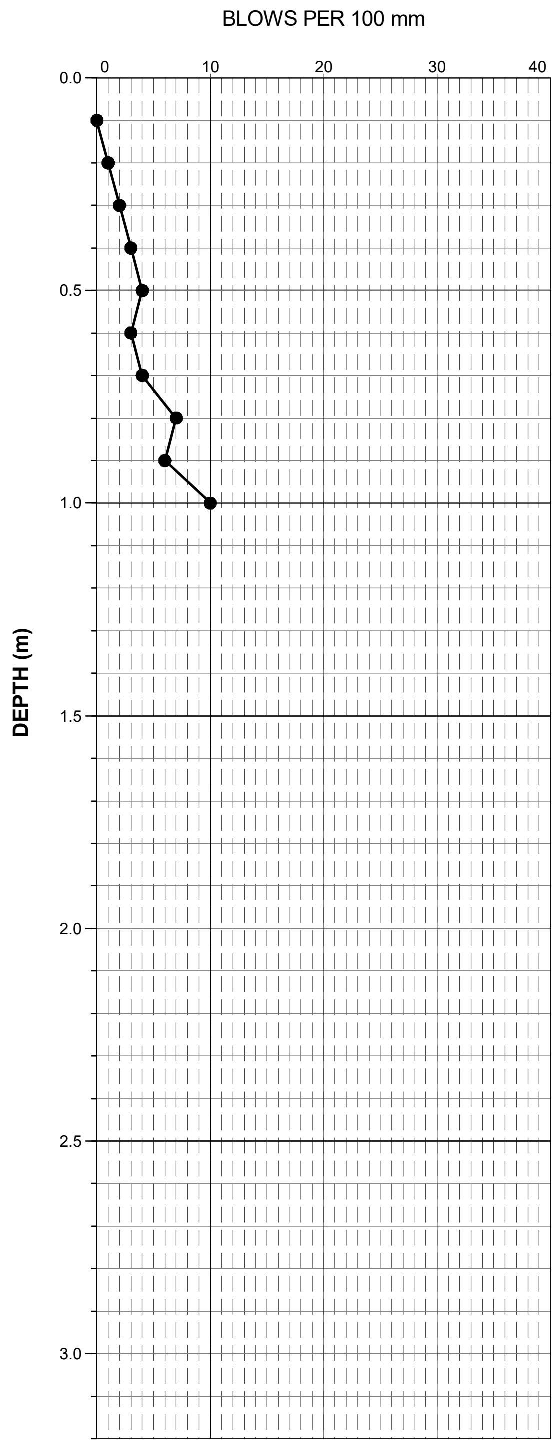
9 KG DYNAMIC CONE PENETROMETER

TERRA INSIGHT

Hole ID **DCP302**

CLIENT : Niche Environment and Heritage	POSITION :	SHEET : 1 OF 1
CONTRACTOR :	EASTING : 304829.5 m	STATUS :
PROJECT : Geotechnical Investigation	NORTHING : 6194142.5 m	LOGGED BY : XJ
LOCATION : 36	COORD. SYS. : MGA94 Zone 56	DRILL DATE : 10/10/2022
PROJECT No. : TERRA22-223	GROUND RL : 82.00 m AHD	

DEPTH (m)	NO OF BLOWS PER 100 mm
0.10	0
0.20	1
0.30	2
0.40	3
0.50	4
0.60	3
0.70	4
0.80	7
0.90	6
1.00	10



Final Depth (m)	0.90

RIG :	CHECKED BY :	REMARK
INCLINATION :	CHECKED DATE :	Refusal
AZIMUTH :	APPROVED BY :	
HOLE DIA. :	APPROVED DATE :	

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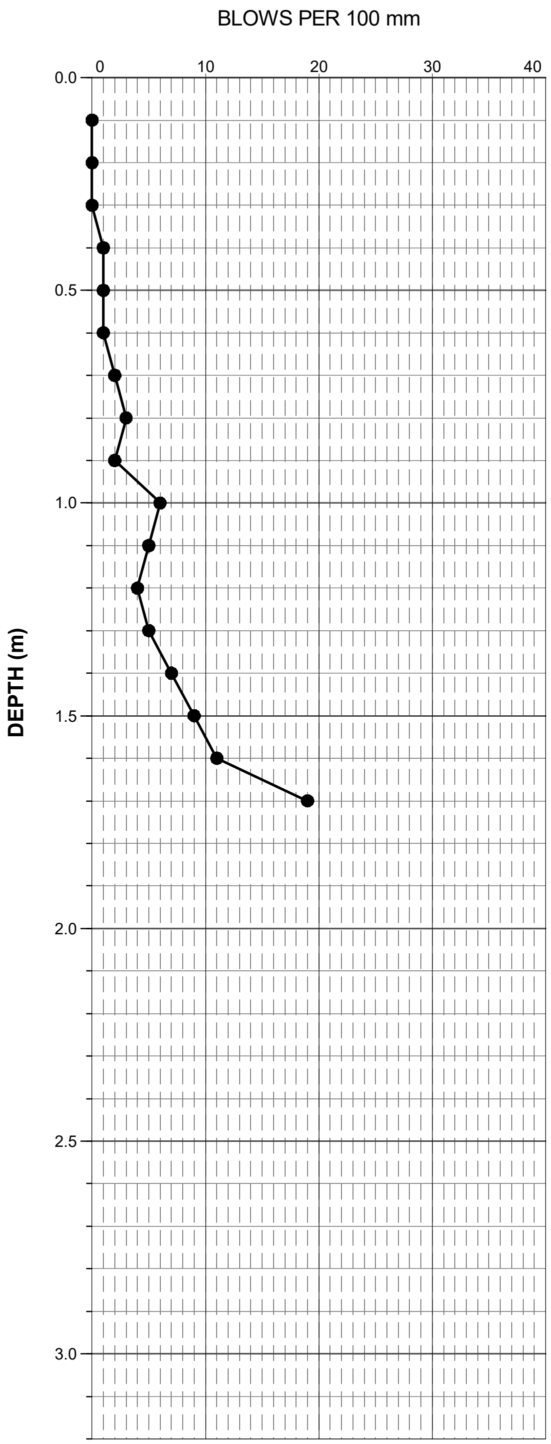
TERRA INSIGHT

9 KG DYNAMIC CONE PENETROMETER

Hole ID **DCP401**

CLIENT	: Niche Environment and Heritage	POSITION	:	SHEET	: 1 OF 1
CONTRACTOR	:	EASTING	: 304631.8 m	STATUS	:
PROJECT	: Geotechnical Investigation	NORTHING	: 6194134.5 m	LOGGED BY	: XJ
LOCATION	: 36	COORD. SYS.	: MGA94 Zone 56	DRILL DATE	: 10/10/2022
PROJECT No.	: TERRA22-223	GROUND RL	: 92.50 m AHD		

DEPTH (m)	NO OF BLOWS PER 100 mm
0.10	0
0.20	0
0.30	0
0.40	1
0.50	1
0.60	1
0.70	2
0.80	3
0.90	2
1.00	6
1.10	5
1.20	4
1.30	5
1.40	7
1.50	9
1.60	11
1.70	19



Final Depth (m)	1.60

RIG	:	CHECKED BY	:	REMARK
INCLINATION	:	CHECKED DATE	:	Target
AZIMUTH	:	APPROVED BY	:	
HOLE DIA.	:	APPROVED DATE	:	

TERRAINSIGHT 1.00 LIB.GLB Log IS DCP WITH TEXT AND PLOT TERRA22-474 LOGS.GPJ <<DrawingFile>> 23/11/2022 15:56 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: TerraInsight 1.00 lib 2017-12-04 Prj: TerraInsight 1.00 2017-12-04

9 KG DYNAMIC CONE PENETROMETER

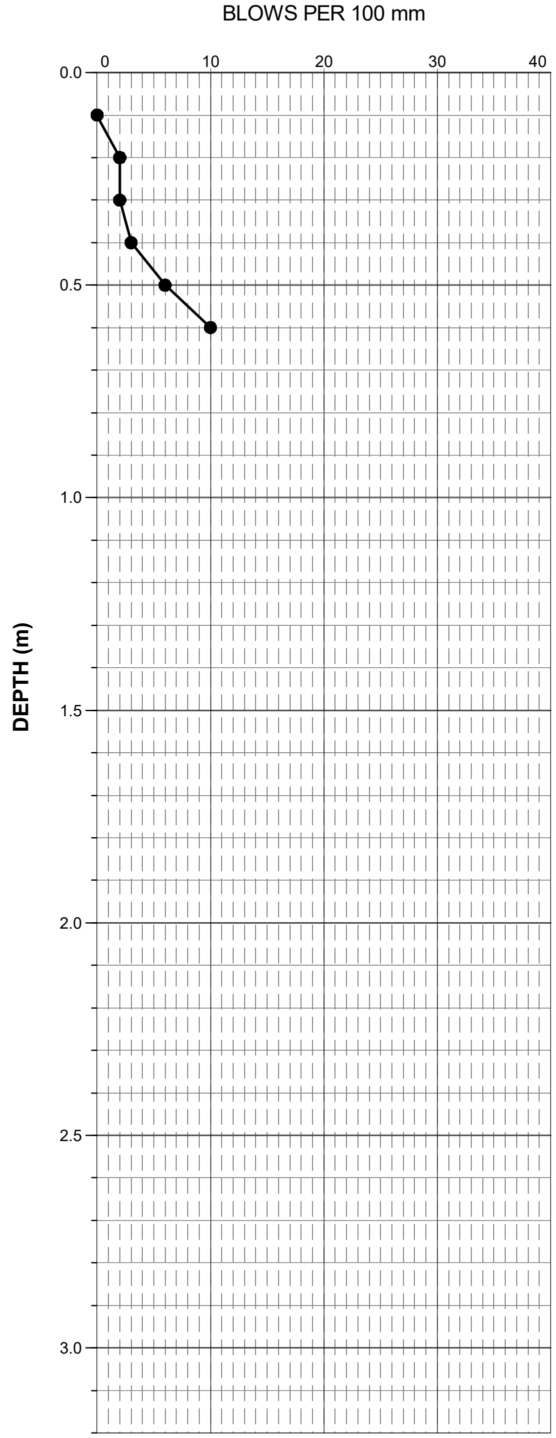
TERRA INSIGHT

Hole ID **DCP402**

CLIENT : Niche Environment and Heritage	POSITION :
CONTRACTOR :	EASTING : 304641.7 m
PROJECT : Geotechnical Investigation	NORTHING : 6194135.1 m
LOCATION : 36	COORD. SYS. : MGA94 Zone 56
PROJECT No. : TERRA22-223	GROUND RL : 92.50 m AHD

SHEET : 1 OF 1
STATUS :
LOGGED BY : XJ
DRILL DATE : 10/10/2022

DEPTH (m)	NO OF BLOWS PER 100 mm
0.10	0
0.20	2
0.30	2
0.40	3
0.50	6
0.60	10



Final Depth (m)	0.50

RIG :
INCLINATION :
AZIMUTH :
HOLE DIA. :

CHECKED BY :
CHECKED DATE :
APPROVED BY :
APPROVED DATE :

REMARK
Refusal

TERRAINSIGHT 1.00 LIB.GLB Log IS DCP WITH TEXT AND PLOT TERRA22-474 LOGS.GPJ <<DrawingFile>> 23/11/2022 15:56 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: TerraInsight 1.00 lib 2017-12-04 Prj: TerraInsight 1.00 2017-12-04

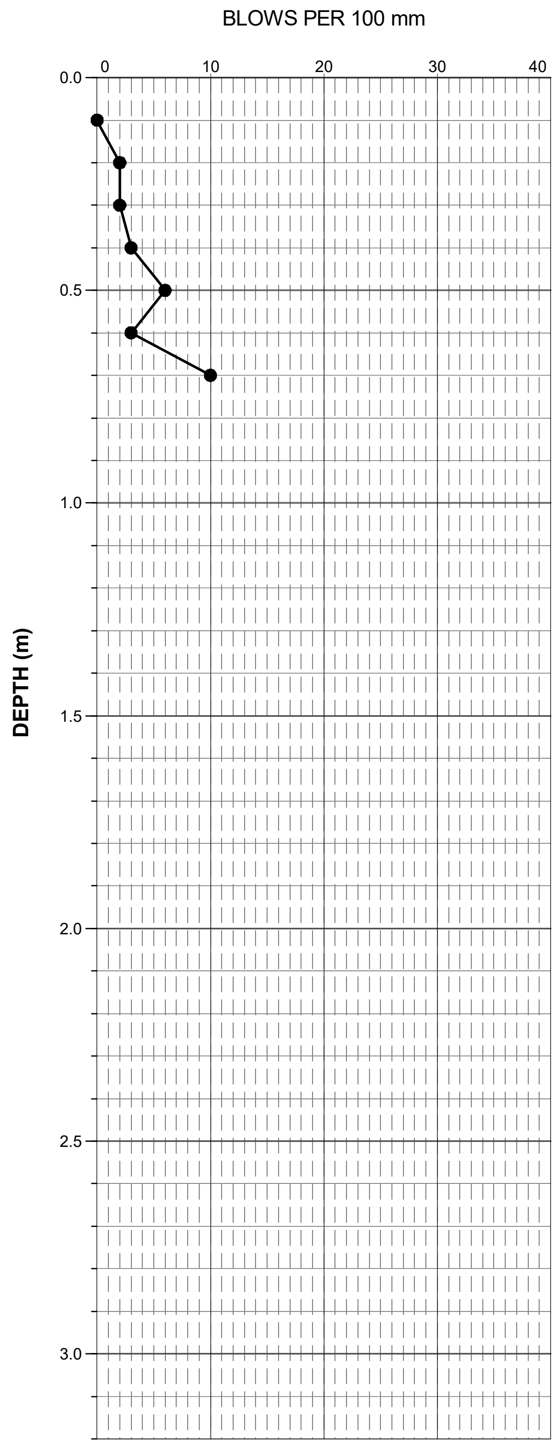
9 KG DYNAMIC CONE PENETROMETER

TERRA INSIGHT

Hole ID **DCP403**

CLIENT : Niche Environment and Heritage	POSITION :	SHEET : 1 OF 1
CONTRACTOR :	EASTING : 304644.0 m	STATUS :
PROJECT : Geotechnical Investigation	NORTHING : 6194135.0 m	LOGGED BY : XJ
LOCATION : 36	COORD. SYS. : MGA94 Zone 56	DRILL DATE : 10/10/2022
PROJECT No. : TERRA22-223	GROUND RL : 93.00 m AHD	

DEPTH (m)	NO OF BLOWS PER 100 mm
0.10	0
0.20	2
0.30	2
0.40	3
0.50	6
0.60	3
0.70	10



Final Depth (m)	0.60

RIG :	CHECKED BY :	REMARK
INCLINATION :	CHECKED DATE :	Refusal
AZIMUTH :	APPROVED BY :	
HOLE DIA. :	APPROVED DATE :	

TERRAINSIGHT 1.00 LIB.GLB Log IS DCP WITH TEXT AND PLOT TERRA22-474 LOGS.GPJ <<DrawingFile>> 23/11/2022 15:56 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: TerraInsight 1.00 lib 2017-12-04 Prj: TerraInsight 1.00 2017-12-04

Appendix E: Appendix C of the journal, Australian Geomechanics

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-3}$	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-4}$	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-5}$	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	$5x10^{-6}$	1,000,000 years	200,000 years	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	1: CATASTROPHIC 200%	2: MAJOR 60%	3: MEDIUM 20%	4: MINOR 5%	5: INSIGNIFICANT 0.5%
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or L (5)
B - LIKELY	10^{-2}	VH	VH	H	M	L
C - POSSIBLE	10^{-3}	VH	H	M	M	VL
D - UNLIKELY	10^{-4}	H	M	L	L	VL
E - RARE	10^{-5}	M	L	L	VL	VL
F - BARELY CREDIBLE	10^{-6}	L	VL	VL	VL	VL

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

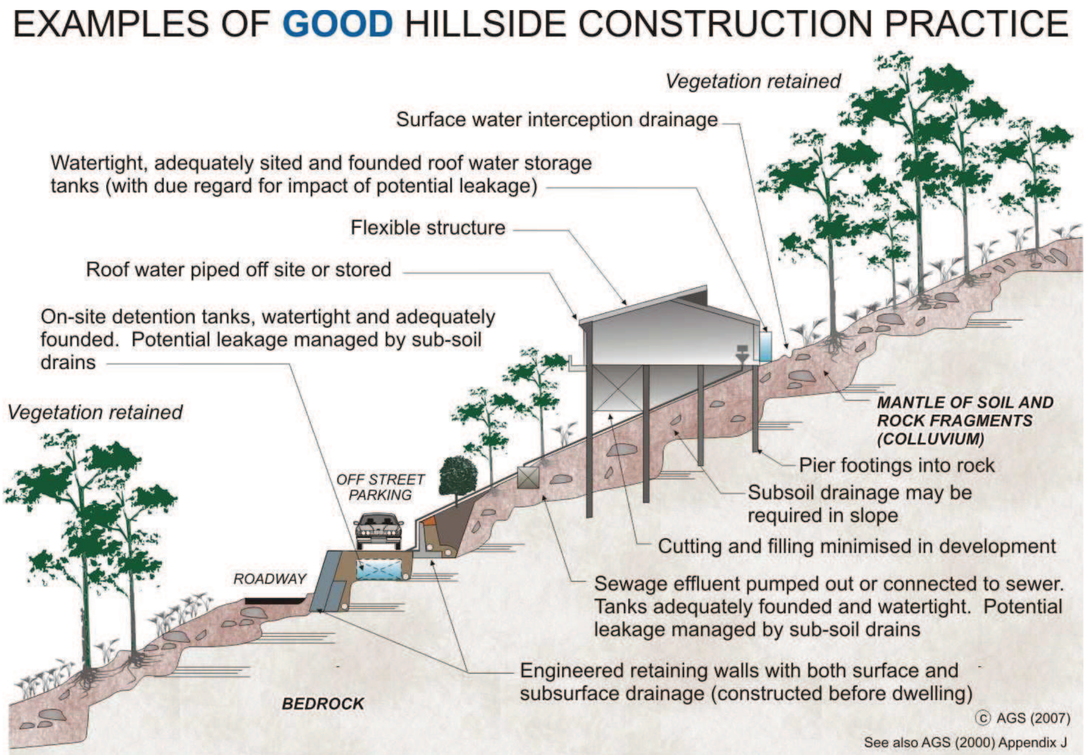
RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

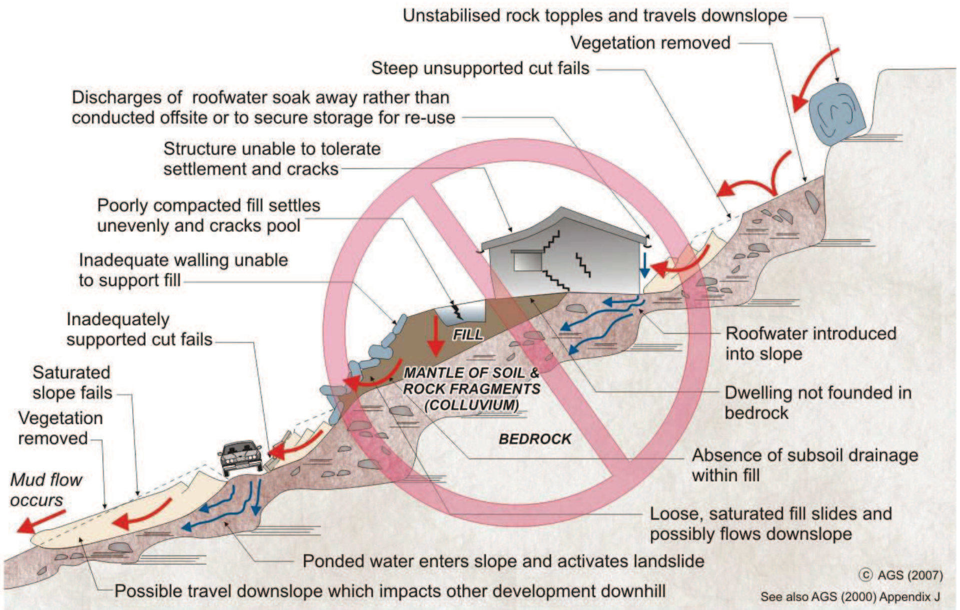
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF **POOR** HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.