Attachment A

Geomorphological assessment

A Geomorphic Assessment and Characterisation of Channel Zones and Floodplains within the Snowy 2.0 Project Area

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For

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Cover Image: Low capacity abandoned channel abuts valley margin on Nungar Creek.
Assessment site 163.

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Introduction and Scope

A geomorphic assessment of streams within the Snowy 2.0 study area was completed to characterise their existing form and susceptibility to change associated with the Snowy 2.0 project. This study is essentially an assessment and interpretation of contemporary character and processes. Characterisation of adjoining floodplain (*sensu* Nanson and Croke 1992) areas was also undertaken with a focus on interpreting permeability between surface alluvium and the underlying groundwater system. This assessment essentially captured a 'snapshot' of geomorphic conditions within the study area.

The study area for the geomorphic assessment is shown in Figure 1 and comprised watercourses in the following Snowy 2.0 project areas:

1. Plateau – including key watercourses located above the proposed headrace tunnel alignment (Eucumbene River, Gooandra Creek, Tantangara Creek, and tributaries) as well as Kellys Plain Creek.
2. Lobs Hole and Marica – including the Yarrangobilly River and its major tributaries.

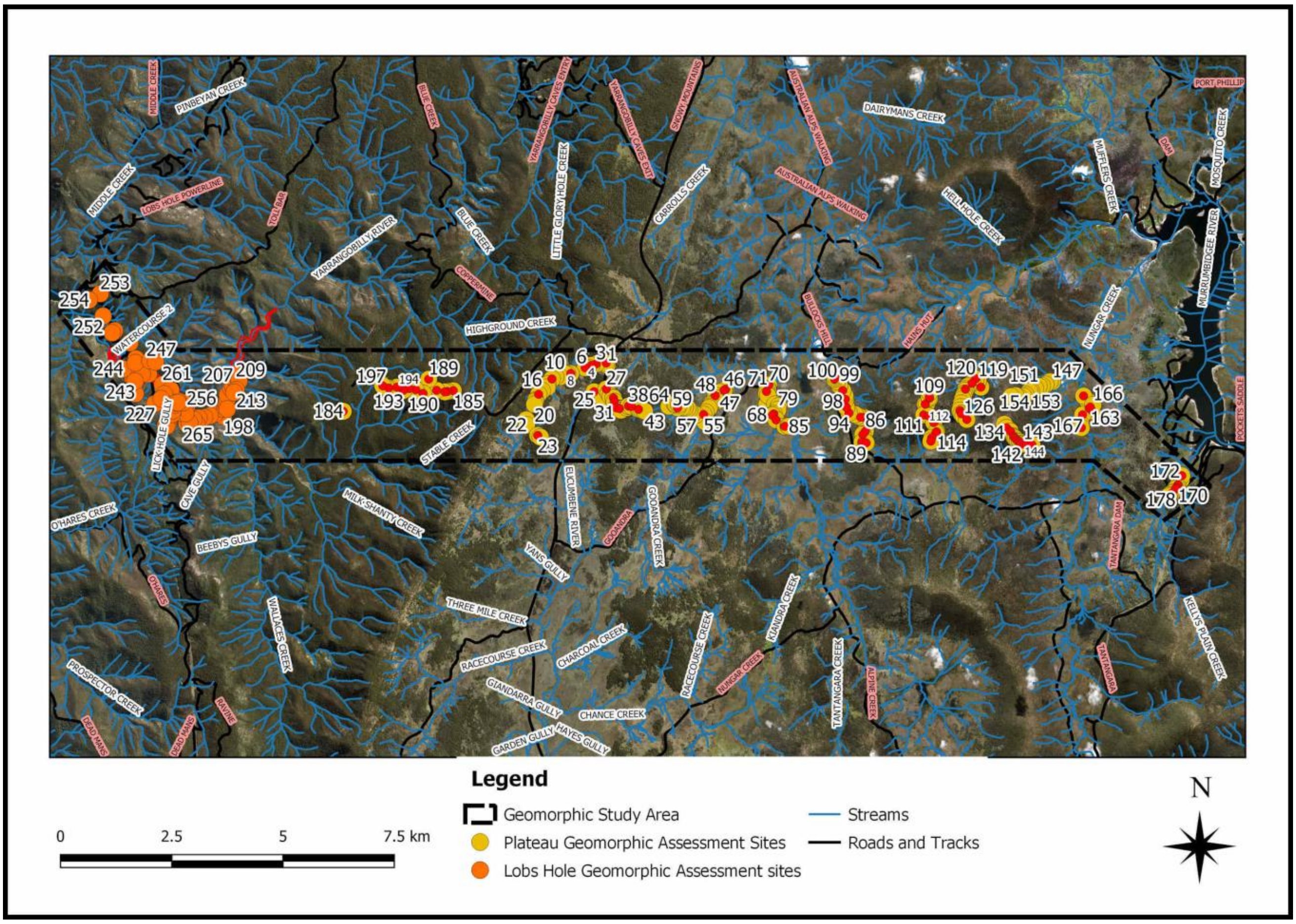


Figure 1: Study area boundary with sites that were assessed for geomorphic characterisation.

Method

The method used to characterise and categorise channel and floodplain zones within the study area had two components; a desktop review of existing information and fieldwork to validate the desktop assessment. These assessments form the basis of an assessment of potential impacts and the resilience of the fluvial environment within the study area.

1. Desktop assessment
    a. Aerial photograph interpretation
    b. Interpretation of relevant GIS layers
        i. Geology (NSW 250k Geology)
        ii. Soils (NSW Great Soil Groups)
        iii. Topography (1m and 10m contours)
        iv. Creeks and Rivers (Strahler watercourse layer)
2. Field work and visual assessment
    a. Naturally exposed sediment profiles
    b. Sediment spear penetration
    c. Identification of geomorphic units
    d. Interpretation of the form and process relationships between geomorphic units

The physical form and behaviour of a stream provide the template within which a riverine ecosystem exists. As a basis of understanding the types of streams that exist in the Study Area, a geomorphic characterisation framework was utilised to categorise streams based on their form and behaviour. The categorisation framework used, River Styles (Brierley and Fryirs, 2002, 2005), is a consistent, documented and tested method for categorising stream type.

A full River Styles assessment entails performing a temporal study and providing recommendations for management and remediation initiatives, but these outputs were superfluous to the scope of this project. Therefore a modified River Styles approach was used to determine the stability of streams within the study area by determining their level of confinement, what the potential is for lateral and vertical adjustment, and what the controls of confinement are.

Fluvial Assessment - The River Styles approach

The River Styles framework (Brierley and Fryirs, 2005) provides a set of procedures from which to integrate catchment-scale geomorphic understanding of river forms, processes and linkages. The framework allows for the description and explanation of the within-catchment distribution of river forms and processes. River Styles record the character and behaviour of rivers throughout a catchment.

The approach is hierarchical, and can be implemented at any desired range of scales. A key component of the technique is the relationship of the river, and any associated floodplains, to the valley, or landscape setting, in which they occur. Key distinctions are confined, partly confined and laterally unconfined, or alluvial, settings which are based upon the potential for lateral and vertical adjustment of the channel. Figure 2 shows schematic plan form views of these River Styles for reference.

A synopsis of River Styles found within the Snowy 2.0 study area;

1. Confined valley settings are defined by the channel abutting valley margin for >90% of the reach length. In these situations there is minimal floodplain, limited potential for adjustment and rivers in this setting are often have a steep gradient.

2. Partly confined valley settings are defined by the channel abutting valley margin between 10-90% of the reach length. Floodplains are common in these settings but are discontinuous and alternate from one side of the valley to another. The shape of the valley (i.e. straight, sinuous, or irregular in width), and the wavelength of the channel crossing the valley floor combine to determine the length of the floodplain pockets.

3. Laterally unconfined, or alluvial, settings are defined by the channel abutting valley margin for less than 10% of the reach length. Floodplains are usually continuous along both sides of the channel in these settings. The main sub-groupings within the alluvial setting are defined by the sinuosity of the channel and the calibre of the sediment and bedload component that is entrained.

3.1. *Alluvial discontinuous* River Styles are characterised by channel forms that are not continuous. Many headwater systems in the flatter high country of South Australia, Victoria, Queensland and NSW are characterised by valleys that lack a continuous channel. Two of the most common sub-types are:

3.1.1. *Intact valley fills* occur on a valley floor that is often flat and featureless but may have a poorly defined or discontinuous channel zone rather than a well-defined continuous channel. Many "intact valley fills" are no longer intact, having been channelised as a response to catchment wide anthropogenic changes to hydrology or by headcut retreat from gullying lower down in the catchment.

3.2. *Alluvial continuous* River Styles contain channel/s that are continuous. This is the most diverse of the three main groups. The numerous sub-groups within this type are defined by the:

- number of channels
- the sinuosity of the channel/s
- the dominant grain size in the channel bed

Categorisation Method & Limitations

The first step for categorising the streams within the study area was to undertake a desktop review of the characteristics that define the boundary conditions. In this study this was based on a review of primary controls such as geology, hydrology and topography, together with analysis of aerial photography of each stream reach.

Analysis of the aerial photographs was undertaken at scales from 1:2000 upwards as the resolution of the photography was not adequate below this level. This photography was overlayed with geology, topography, and soils to help determine stream type.

One of the limitations in the confidence of the aerial photo interpretation was the dense riparian vegetation cover over some streams, particularly those on the plateau west of Nungar Creek. The photo layer was generally examined with the 10 m contour layer on in order to gain a broad scale "feel" for the landscape. More precise interpretations were achieved using the 1 m contour lines derived from a digital elevation model (DEM) based on available LiDAR data. However, much of the stream network assessed within the plateau had narrow channel top widths and in some instances no continuous channel or a discontinuous channel. Hence channel attributes, and even the presence or absence of a channel, were often difficult to discern under dense canopy cover.

The DEM and 1 metre contour lines were used to produce longitudinal profiles and valley cross sections of the many streams within the study area.

The resolution of the aerial photography was also not adequate to determine the dominant bed particle size or identify many of the smaller scale in-stream geomorphic features such as cascades and knickpoints. Large scale features, such as elongate pools, were easily observed and added to the assemblage of geomorphic features that were used to determine form/process associations.

Following the initial aerial photo interpretation, fieldwork was undertaken to confirm the aerial photo interpretation at a sample of sites and to help resolve the categorisation of reaches difficult to interpret on aerial photography.

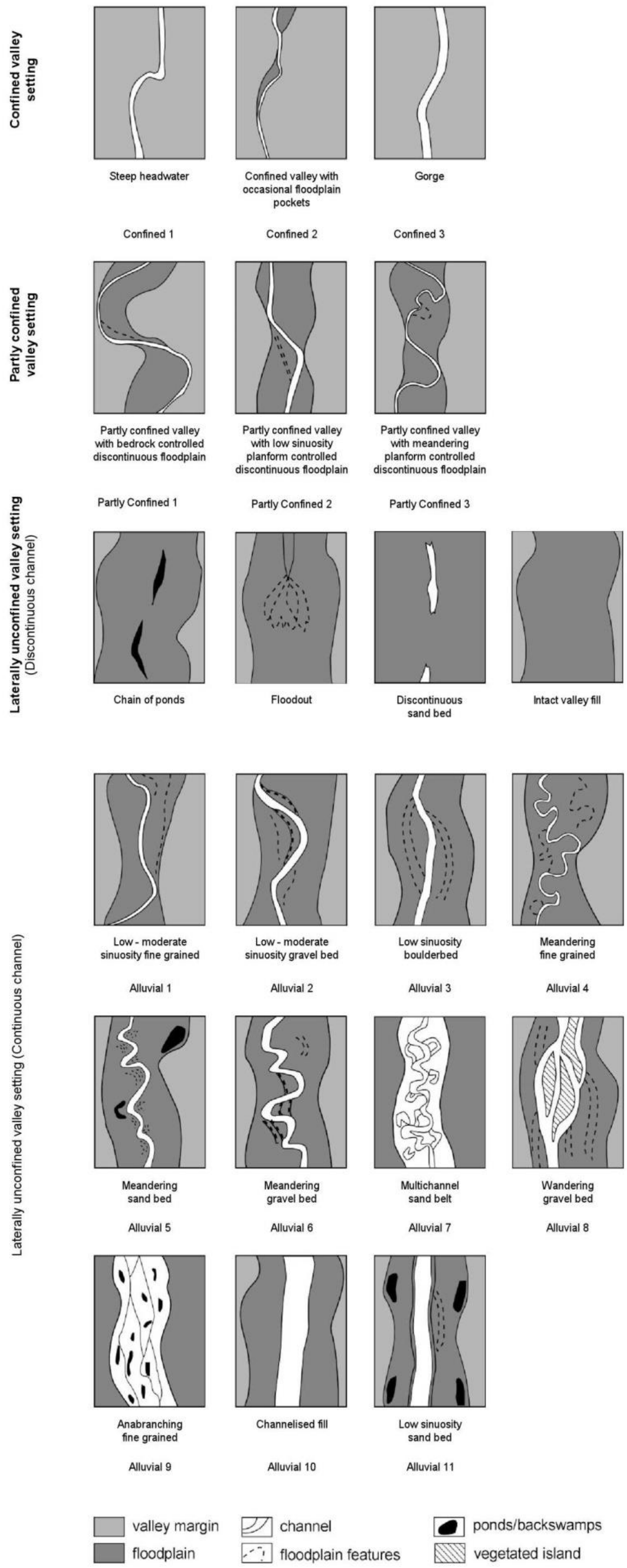


Figure 2: Schematic summary of the range of River Styles (Brierley and Fryirs, 2005).

Lithologic and Sedimentological Assessment Methods

Lithologic Assessment Method

The sub catchments within the study area were divided by their sedimentology and as a weathering product of the underlying bedrock lithology. The rock type presented here is that of the single dominant lithology as shown in the NSW 250K Geology layer (DPI 2003). Other rock types may have been encountered during field reconnaissance but lithological interpretation of the underlying geology was not part of the criteria for the scope of this assessment.

1. Basalt and gabbro[1]. Unnamed tertiary volcanics, Gooandra volcanics and Shaw Hill Gabbro.
    a. Eucumbene River
    b. Gooandra Creek
2. Granodiorite. Unnamed formation.
    a. Tantangara Creek
3. Volcaniclastic deposits; tuff. Temperance Formation
    a. Tantangara Creek
    b. Central Plateau Unnamed Creeks
4. Clastic sediments; Sandstone. Tantangara Formation.
    a. Central Plateau Unnamed Creeks
    b. Nungar Creek
5. Ignimbrite. Kellys Plain Volcanics
    a. Kellys Plain Creek
6. Conglomerate. Byron Range Group
    a. Marica southern tributary
7. Limestone. Byron Range group; Ravine Beds, Yarrangobilly Limestone.
    a. Marica northern tributary
8. Rhyolite. Boraig Group, unnamed unit
    a. Marica northern tributary
    b. Marica southern tributary

Sedimentological Assessment Method

In the absence of subsurface samples collected by auger or corer, the primary tool used to make an assessment of subsurface sediment stack was a sediment spear.

The spear tool consists of three segmented lengths of stainless steel rod that are threaded and can be joined together. The first section has a pointed end, on one end, and at the other end it has a threaded joint. It is 1.05m in length and has 10cm graduations marked on it. The other two steel rods also have threaded ends, at both ends, and are 1.00m in length. They also have 10cm graduations marked on them. Lastly there is a 'T' sectioned handle that attaches to the upper end of the tool. Together they allow penetration to 3.05m.

An assessment of sub surface sediments is made by applying a constant downward pressure to the handle of the spear so as to push the tool into the ground. The resistance to penetration is used as a proxy for the density of the sediment being penetrated.

Soil profiles with a high organic content provide no impediment to penetration and the spear will penetrate smoothly and without resistance. Increasing clay content down profile, or more compact sediments with less organic content, will provide more resistance to penetration. Gravel beds or small rock 'floaters' associated with a saprolite horizon can be felt as vibrations, or as a grinding sensation, as the spear passes through them. If the boundary between softer sediments and the 'gravel' is abrupt then

[1] Basalt and gabbro are chemically the same (Le Bas and Streckeisen 1991). The difference between the two is grainsize.

the horizon being penetrated is interpreted as a gravel lag deposit from an old bedform. If the boundary between softer sediments and the 'gravel' is gradational, and the incidence of clasts increases down profile, then the horizon being penetrated is interpreted as saprolite.

A synopsis of the relationships between weathering products, channel type, and subsurface hydraulic connectivity is provided in the accompanying Tables 1 and 2 in Appendix 3.

Tables 1 and 2

Table 1 and 2 were constructed by combining various disparate sources of information into an easy to read summary, presented in table form. Information that was gathered during the desktop assessment stage and during fieldwork was combined to populate the tables.

For each assessment site the (Column 1) the landform that was interpreted during field assessment is presented in column 2.

Column 3 presents catchment information that was gathered from the GIS Strahler Watercourse layer. Streams on this later that were unnamed were given names that corresponded to the EMM naming protocols. If there was no name attributed to a stream then an appropriate name was assigned and is discussed in the body text. e.g. Unnamed Plateau Streams 1 through 7.

Columns 4 – 7 present information contained in, and interpreted from, the New South Wales 250K Geology layer.

Columns 8 and 9 contain information on the hydraulic connectivity of soils taken from the corresponding GIS layer. In this layer soils are divided into four hydrologic groups that are based on the soil's runoff, or infiltration, potential. This GIS layer references The United States Department Agriculture, Natural Resources Conservation Service and the descriptions for each group are taken from the Purdue University Department of Engineering.

Columns 10 and 11 present a synopsis of inferred hydraulic connectivity that is based upon the mapped Hydraulic Group which was corroborated during the field assessment stage.

The information has been presented in two tables because the characterisation of soils and floodplain deposits at Lobs Hole were quite different from those encountered on the Plateau. The colluvium and soils on the valley margins, and floodplains, of the streams on the plateau are dependent on the lithology of the basement geology. This has been discussed at length in the Plateau characterisations. The processes that are exhibited by the streams on the plateau are consistent with the landscape unit within which they lie; therefore these streams are dealt with together. The streams, especially the Yarrangobilly River, at Lobs Hole are quite different. Similarly, the structure, soils and sediment stack are incongruous with contemporary processes. Interpretation of the form/process associations indicate that the Yarrangobilly River at Lobs Hole is manifestly underfit (Dury 1964).

The floodplain of the Yarrangobilly River has not been deposited in a fining upwards sequence that would indicate vertical accretion. Nor is there any evidence of floodplain construction by lateral accretion during meander migration. The sediments that were encountered in multiple bank exposures on the Yarrangobilly River were those of a basal cobble and boulder layer overlain by very juvenile sediments of silty and granular sand.

All sediments that are located on the floodplain of the Yarrangobilly River are interpreted as silty and sandy loam with negligible clay content and variable silt and sand content. The use of 'sand' in this instance is used as a grainsize descriptor only signifying that grainsize fraction between 63μ and 2000μ (Wentworth 1922). These silty and sandy sediments have infilled the interstitial spaces of the basal cobble layer but their grainsize preserves a high hydraulic connectivity.

There appear to be two distinct sources of the sediment that constitutes the floodplain of the Yarrangobilly River at Lobs Hole. There is the sediment that has been deposited as overbank deposits of the Yarrangobilly River and there is the more juvenile sediment that has originated from tributaries in fan deposits on the floodplain. These overbank sediments have a greater degree of sorting and their grainsize is more uniform than the juvenile sediments of the fan deposits that are prograding from valley margin tributaries out on the floodplain surface. These consist of very juvenile sediments of angular and very angular lithic fragments of varying sizes.

These surficial sediments may be locally variable in grainsize content but generally have a very high hydraulic transfer rate to the underlying gravel lag deposits.

The basal lag deposits consist of large cobbles and boulders with the interstitial spaces infilled with sediment of varying grainsize but generally with a very low clay content. The hydraulic connectivity and transfer rates associated with these lag deposits is extremely high as evidenced by the reduction in channel capacity of tributaries as they flow across the floodplain. Some tributary channels disappear entirely as surface flows are diverted to subterranean pathways in the basal gravel lag deposits.

Limitations

A problem that was experienced during field inspections, and subsequent interpretations of form and process associations, was to determine what processes are natural and what processes are a result of changes to catchment hydraulics. For example, bank susceptibility to undercutting, and block failure, may be seen as a manifest threat to channel stability, and riverine health generally. However, channel evolution, and the reworking of floodplain sediments through meander migration, is a completely natural process. It is the potential rate of change that can be a result of anthropogenic influence. This study lacked a temporal component which could have been used to frame contemporary processes with historic, or prehistoric, processes and conditions. Key insights into pre-existing riverine character were gained by comparison of contemporary channel capacity, planform, and sinuosity, with the capacity and sinuosity of abandoned channels on the adjacent floodplain. Many of the contemporary channels, especially on Nungar Creek and Tantangara Creek, are incised into the floodplain and have unstable banks that are actively reworking floodplain material. In many instances there were dewatering and desiccation features evident on the floodplain proximal to the channel. By comparison, the bank height and channel capacity of abandoned channels extant on the floodplain were significantly less than that of the contemporary channel.

The collection of soil and sediment samples for grainsize analysis, by any method, was not permitted during the completion of the geomorphic field work for the Snowy 2.0 project. Without collecting samples for analysis it is impossible to make an accurate determination of grainsize for the sediment under consideration, especially the finer fractions <63 μ.

Visual assessment of grainsize and the sedimentology of fluvial systems within the study areas was limited to bank exposures along channels or other naturally occurring exposures of sediment.

- Surface sediments

    When trying to make a determination, or assessment, of hydraulic connectivity of any sediment it is most important to consider grainsize and associated pore spaces between the grains. Most importantly, it is imperative to consider the finest fractions of silt (63 μ - 4 μ) and clay (<4 μ) as these fill the interstitial spaces of the coarser sediment fraction.

    It is impossible to determine the clay content accurately by visual examination alone. A determination of clay content would require a sample to be taken for further assessment. This may have been something as precise as a laser particle size analyser or as simple as taking a small sample to make a bolus and ribbon to determine whether any clay was present and whether that clay was either light clay or heavy clay. Similarly, collection of a small amount of sediment and comparing it to a standard grainsize card, through a hand lens, would have greatly enhanced the geomorphic assessment.

- Subsurface sediments

In order to make an accurate assessment of the hydraulic connectivity of subsurface sediments it is necessary to collect samples by sampling bank exposures, or by using a hand auger or a soft sediment coring system.

- Auger sampling, by hand, requires the completion of a 10cm diameter hole and the recovery of samples every 10 to 15cm down profile. The sample interval is determined by the size of the sampler in use on the end of the auger string. The sampler on the 'business end' is often referred to as 'the bucket', the size of which varies according to the sedimentology that is expected to be encountered. The augering continues until refusal is reached or the sediment is below the water table and is too waterlogged to be recoverable. Once the samples have been analysed, and the hole completed, the excess sediment is returned to the hole and the hole is filled in. There is no remaining surface expression of the completed auger hole once the hole is rehabilitated.
- Soft sediment coring is also completed by hand and recovers a core of undisturbed sediment from the sediment profile. The depth of penetration, and sample recovery, is limited by the stability of the hole and is usually restricted to ≤2m.

❖ Temporal aspect

There was no temporal aspect to the study that would have allowed a determination of contemporary catchment condition relative pre-existing conditions. A temporal aspect to the study would have enabled the contemporary conditions to be placed within a trajectory of change and placement within this trajectory would have enabled an estimate of degradation and recovery potential. A temporal component was not required for this report.

Catchment Characterisations

Eucumbene River

Overview

The upper reaches of the Eucumbene River showed some diversity of character through the upland dells and swampy meadows (*sensu* Young 1982, 1986 and Prosser, Chappell and Gillespie 1994) and steeper headwaters. These areas were underlain by Tertiary basalt.

The main trunk of the Eucumbene River through the study area has remarkably little variability but shows a progression, downstream, of locally variable, but increasing channel capacity and floodplain width. This may be explained by uniformity of chemistry and lithology associated with the underlying geology; *viz* the Gooandra Volcanics and Shaw hill gabbro.

Bedrock controls on lateral adjustment that are absent in the upper catchment are more common in the lower reaches of the study area (Site 21 and 22, Figure 8).

Subsurface interpretation - Upland Dell/Swampy Meadow

Three separate sediment spears were completed across the upland swamp at the head of the catchment. Each spear penetrated to refusal at a depth of less than one metre (0.72m, 0.90m, and 0.67m) and each spear encountered organic rich, light to medium silty clay at the surface that graded to heavy clay at the base. Each spear also encountered varying thicknesses of gravelly or granular horizons where the incidence of clasts increased in frequency down profile.

At this position in the landscape there is no mechanism for fluvial transport or sorting of sediments. The profiles are interpreted as organic rich swampy meadow sediments overlying saprolite and bedrock.

The hydraulic connectivity of the soil profile will vary and be dependent upon the volume of clay in each horizon. The surficial sediments of the swampy meadow are silty and organic rich and therefore would have a higher hydraulic connectivity than those sediments lower in the profile. *In situ* weathering of the underlying basalt will produce mainly ferromagnesian swelling clays in the smectite group such as montmorillonite and nontronite (Deer, Howie and Zussman, 1992).

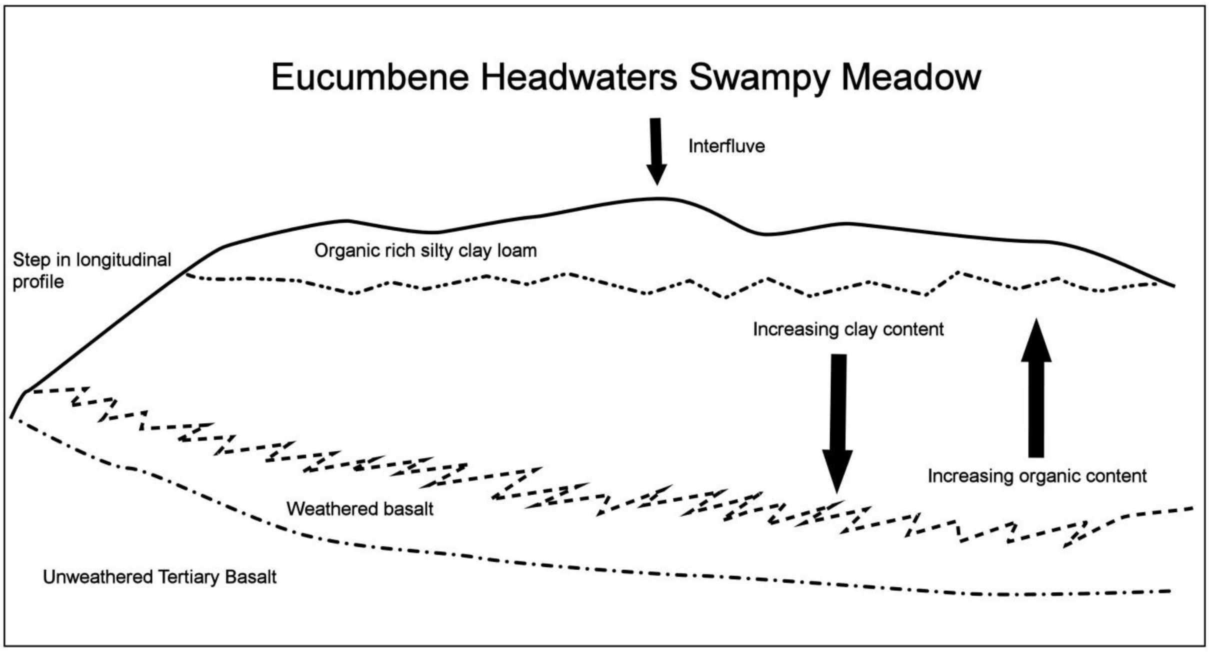


Figure 3: Conceptual diagram showing interpreted subsurface morphology of Eucumbene headwaters swampy meadows.

If these clays remain wetted then they will form an impermeable barrier between the overlying organic rich swamp deposits and the unweathered bedrock below. If swelling clays are allowed to dewater and dry out they form shrinkage cracks from the desiccation and the impermeable barrier is broken.

Sites 23 and 25 (Figure 8) are also swampy meadows that are underlain by the same Tertiary basalt.

Surface Features Characterisations

Location:	Catchment headwaters, swampy meadow unit; upland swamp
Geomorphic assessment Locations:	Plateau assessment locations 1 – 4
River Styles code:	SMG
River Styles categorisation:	Swampy Meadow Group (Figure 4). Intact valley fill, fine grained.
Description:	Usually has a flat and featureless, unincised surface. There may be discontinuous pools and channels or drainage lines present.
Geomorphic condition:	Generally in good condition.
Fragility:	Low. Generally these upland swamps have a high fragility and are susceptible to incision and dewatering from knickpoint migration. There is no evidence to suggest that the swampy meadow unit at the headwaters of the Eucumbene River (Figure 4) is susceptible to knickpoint retreat and incision.
Notes:	There is abundant evidence of damage to, and destabilisation of, low banks of pool from livestock.

The upland swamp (Figure 8) is perched on Tertiary basalt capping with downslope boundary approximating boundary with mafic intrusives of the Gooandra Volcanics.

The basal units of all three spear points on the swampy meadow show heavy clay over an undulating base. The clastic unit overlying basal unit at refusal is interpreted as saprolite.

Figure 4: Swampy Meadow unit at headwaters of Eucumbene catchment. Site 2

Subsurface interpretation - Steep headwaters

Assessment locations 4 and 9 were located at the upper and lower end, respectively, of steep section of the longitudinal profile (Figure 6).

At site six a channel begins to form from a well-defined channel zone. The channel here is discontinuous and takes the form of small runnels a few centimetres deep. Multiple spear points were attempted over an area of approximately 20m.

At three spear point locations the surface soil material exists as a thin veneer over bedrock and is usually less than 0.20m deep. Only in one location was the spear able to penetrate further, and it terminated in bedrock at 0.75m. As in previous tests, the frequency of granular clasts increases down profile until refusal is reached.

At site 8 a spear point was completed that reached refusal at 0.80m. Organic rich swampy meadow sediments overlie light brown to buff coloured basal sediments. Two distinct layers of pebbles and granules were encountered in the profile. The sediment stack at site eight is fundamentally different to that encountered in the upland swamp of sites 2 – 4. The sediment profile is interpreted as a channelised valley fill floodplain deposits (*sensu* Prosser Chappell and Gillespie 1994) and the small bands of pebbles are remnant channel bedload.

Location:	Catchment headwaters, Eucumbene River tributary
Geomorphic assessment	
Locations:	Plateau assessment locations 5 - 11
River Styles code:	LUVS DC
River Styles categorisation:	Laterally unconfined valley setting with a discontinuous channel on channelised fill.

Geomorphic condition:	Moderate; no evidence of active knickpoint migration or bank destabilisation. Channel capacity is low.
Fragility:	Moderate.
Notes:	Assessment location 7 marks the boundary between the thicker organic rich clayey sediments of the swampy meadow unit and the coarser grained colluvium and sediments downslope. At location 7 the depth of cover over bedrock is generally less than 10cm over a wide area with a maximum of cover over bedrock to 40cm. Location 8 (Figure 8) marks the commencement of low capacity, discontinuous channels emplaced within a wider channel zone. As the depth of channels increase there is saprolite and colluvium exposed in the channel banks and base. In both these sites the hydraulic connectivity between the sediments and the underlying bedrock is quite different as compared to the swampy meadow deposits located on weathered basalt. In this steep headwaters section slope is much greater than the upland swamp and consequently there is more available stream power to mobilise sediments. Whether as a channelised flow, or a sheet flow, the finest material is washed down slope.

Figure 5: Low capacity discontinuous channels commence at Assessment Site 5

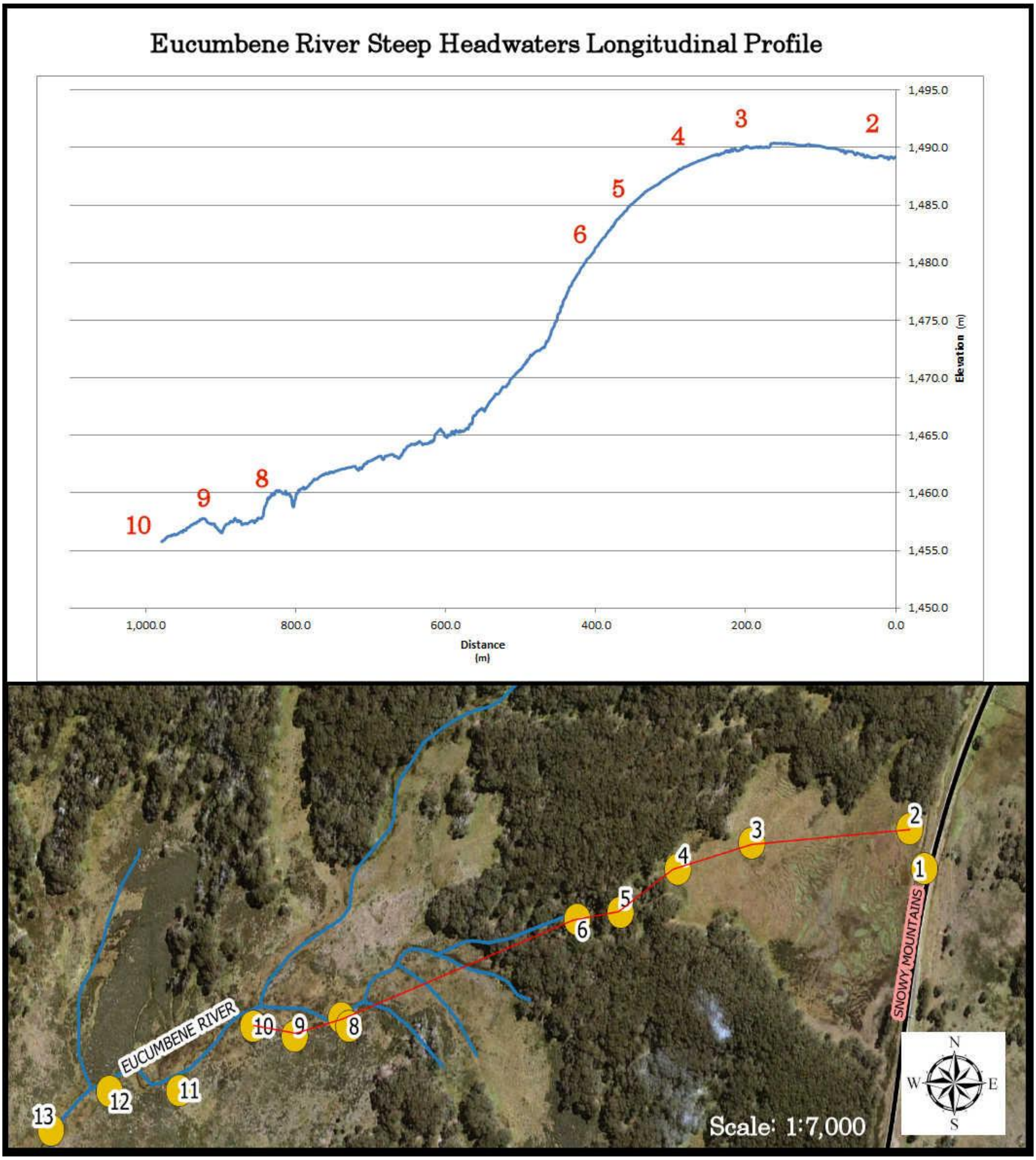


Figure 6: Eucumbene River Assessment Sites 3 - 10 Longitudinal Profile.

Subsurface interpretation - Eucumbene River Trunk

The Eucumbene River assessment sites were Site 8 to Site 24 (Figure 8). At locations 13 and 17 the floodplain width at both of these locations (Figure 7) narrows to less than 30m and 20m, respectively.

Colluvial footslope extends to valley floor margins where a low to moderate sinuosity, low capacity channel occupies a broad channel zone rather than a discreet channel. Exposed bedrock is evident at multiple locations both in banks and as cross channel bedrock bars, especially in the lower reaches of the study area.

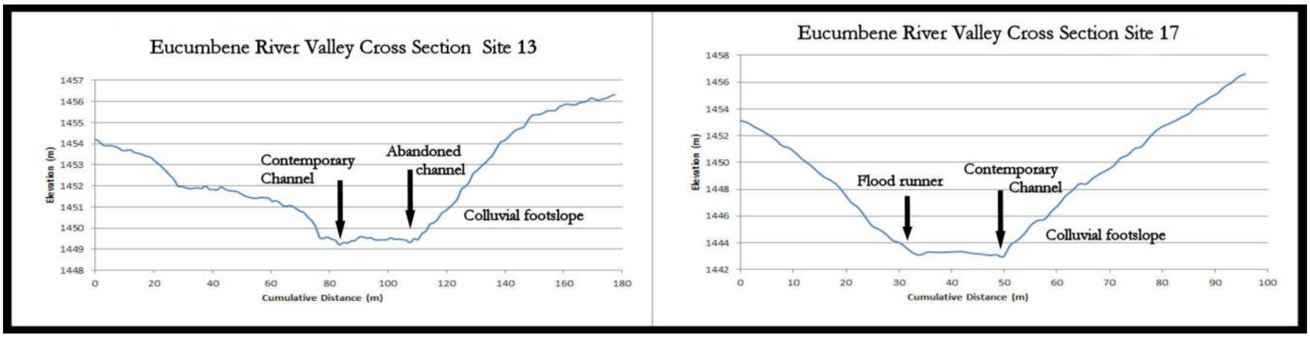


Figure 7: Eucumbene River Valley Cross Sections

The valley floor margins are saturated, boggy ground and characterised by tussocky grass. Rare bank exposures indicate that the sediment profile generally fines upwards and that surficial sediment has a high organic content.

The channel base is characterised by alternating zones of aquatic vegetation and gravel with common coarse and granular sand.

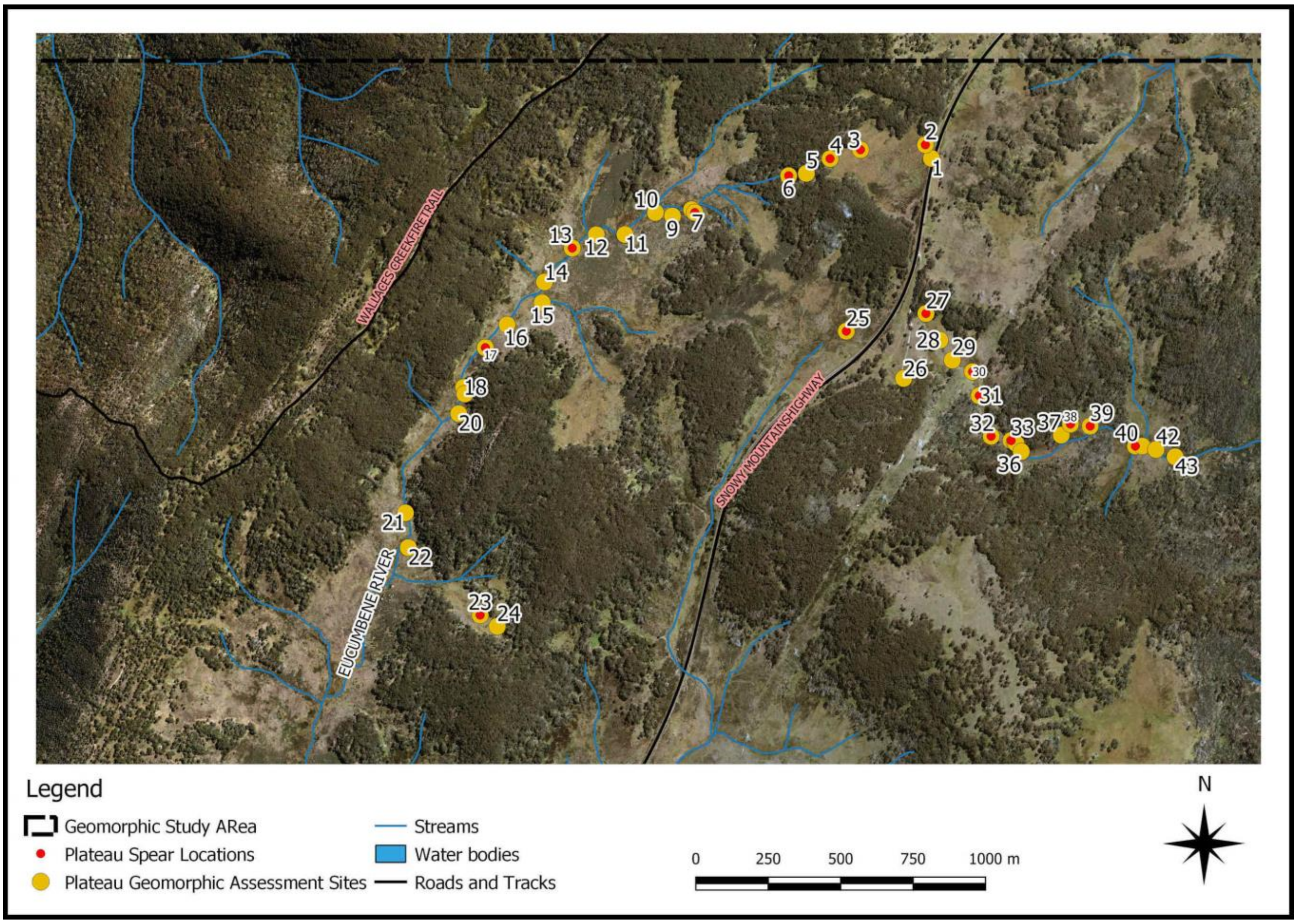


Figure 8: Eucumbene River study area and assessment sites.

The subsurface interpretation is that of a channelised floodplain fill sequence with organic matter content increasing up profile (Figure 9). Surface sediment consists of a dark grey to black silt with minor clay and abundant organics throughout. Thin basal gravel layers were encountered in both spear points and are interpreted as fluvial gravel lags rather than saprolite.

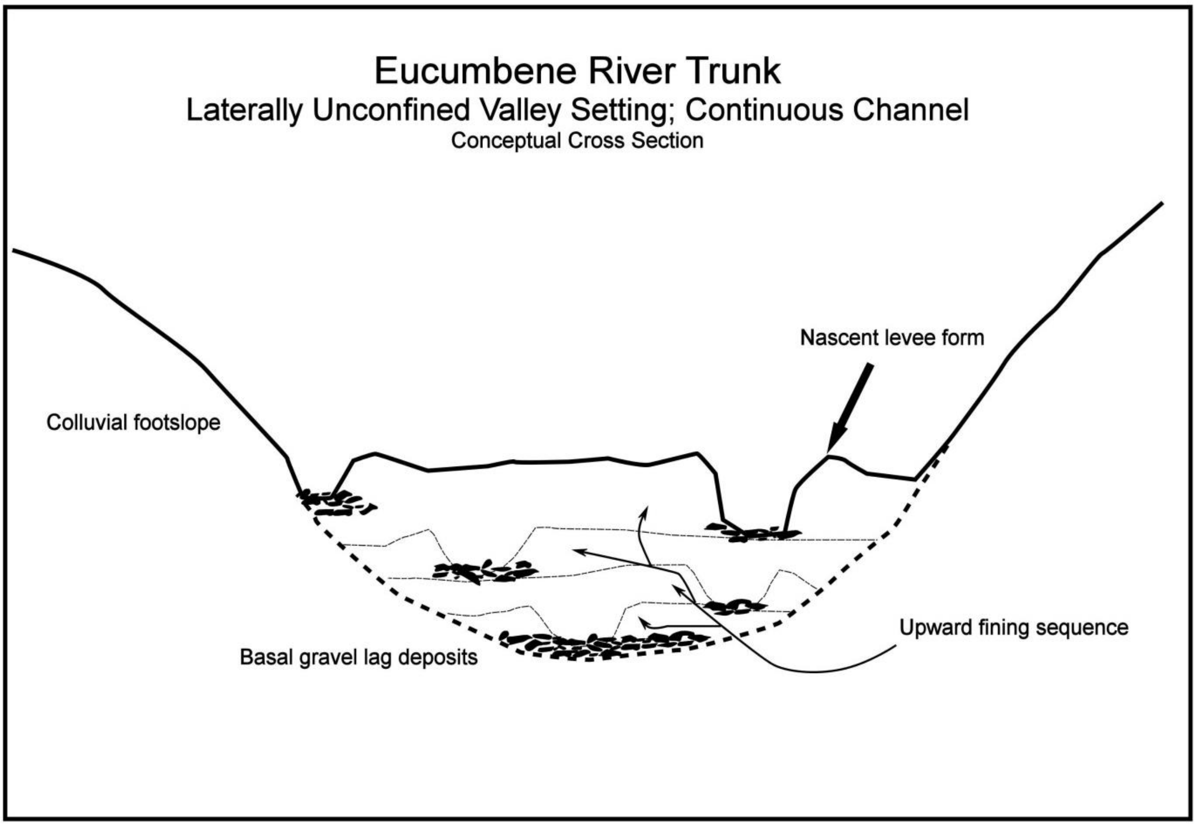


Figure 9: Conceptual diagram showing interpreted subsurface morphology of Eucumbene River.

The organic rich surficial sediments are a silty clay loam and have a high hydraulic connectivity. The passage of water through this surface sediment would be very rapid. Lower in the profile the sediments consist of a light silty clay. The hydraulic connectivity of this underlying sediment is low and passage of water through the lower profile would be very slow. At this point in the catchment the sediment sources from the dominant lithologies of basalt and gabbro here, and upstream, determine high clay content.

Location:	Eucumbene River).
Geomorphic assessment	
Locations:	Plateau assessment locations 12 – 22
River Styles code:	LUV CC
River Styles categorisation:	Laterally unconfined valley setting with a continuous channel.
Geomorphic condition:	Good. A low capacity channel in the upper reach has low bank heights and is coupled with a narrow floodplain. In the lower parts of the reach the channel is incised
Fragility:	Moderate
Notes:	The assessment reach extends downstream to southern edge of the draw down area. Channel morphology shows very little variability throughout the reach. Areas of bedrock control are minor in the upper reaches but increase in frequency downstream (Figure 12). In the upper section of the reach floodplain is discontinuous as the low sinuosity channel migrates across a narrow floodplain. Colluvial footslope extends to channel margin in most instances. The low flow channel shows no instability, has stable banks of low height and the channel is coupled with the floodplain (Figure 11). The channel has a low sinuosity and is characterised by a low energy riffle – run – glide sequence in the upper reach.

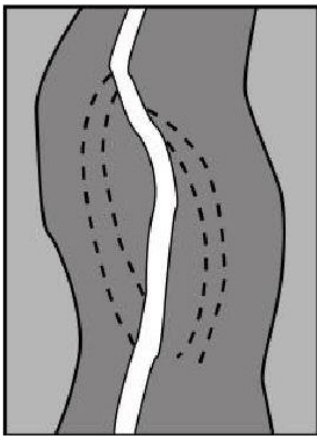


Figure 10: Schematic: Laterally unconfined valley setting with continuous channel, low to moderate sinuosity, gravel bed river.

The channel base is characterised by alternating zones of aquatic vegetation and gravel/pebbles substrate. The substrate is subrounded to subangular and angular with a maximum observed B_{max} of 12cm.

Channel sinuosity and energy increases downstream (Figure 13) as evidenced by increasing rapid – riffle – run sequences with no glides or pools in evidence. The channel meanders across a narrow floodplain that averages approx. 30m. The bank height increases downstream to 60cm and channel width increasing to 1.5m. In some areas, especially in the upper reach, the channel is still coupled with the floodplain and multiple distributary channels disperse flows across the floodplain and main channel capacity decreases.

As energy increases the finer sediment fraction is absent and the substrate consists of coarse gravel and small cobbles to 30cm $B_{max.}$ This coarse substrate effectively armours the channel base from incision.

In the lower areas of the reach channel incision is limited by occasional cross channel bedrock bars that exert a localised base level control.

Figure 11: Eucumbene River at Site 11 confluence. Gravel bed river is pinned against valley margin at left bank.

Figure 12: Localised minor bedrock control at Site 12.

Figure 13: Channel sinuosity increasing downstream at Site 14.

Location:	Tributary entering Eucumbene trunk at left bank
Geomorphic assessment Locations:	Plateau assessment locations 23 – 24 (Figure 8).
River Styles code:	LUVS DC
River Styles categorisation:	Laterally unconfined valley setting, discontinuous channel. Intact valley fill.
Geomorphic condition:	Good
Fragility:	High
Notes:	Tributary exists as a broad treeless depression extending upslope from the Eucumbene River trunk.

There are no distinct channels but flow paths exist as broad areas, or channel zones, defined by sheet flow across the surface (Figure 16, Figure 15).

A spear point penetrated to 0.49m through silt with minor but increasing clay content to refusal. A 'gravelly' layer overlying refusal layer is interpreted as saprolite.

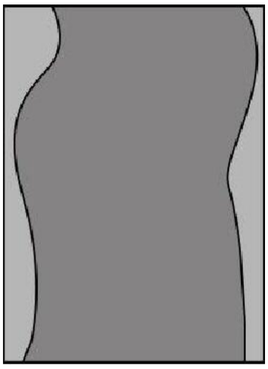


Figure 14: Schematic: Laterally unconfined valley setting with discontinuous channel. Intact valley fill.

Figure 15: Channel zone with no distinct channel at Site 24.

Figure 16: Broad distinct channel zones with discontinuous channel view downslope from Site 23.

Location:	Upland swamp
Geomorphic assessment	
Locations:	Plateau assessment location 25 (Figure 8).
River Styles code:	SMG
River Styles categorisation:	Swampy Meadow Group
Geomorphic condition:	Poor
Fragility:	High
Notes:	Former swamp (Figure 17) has been channelised and dewatered. Spear point encountered organic rich silty clay loam with decreasing organic content down profile. Ten centimetres of granular, or gravelly, material overlies refusal at bedrock 0.98m. Granular material increases in frequency down profile and is interpreted as saprolite.

Figure 17: Channelised and dewatered swampy meadow at Site 25.

Gooandra Creek Tributary 1

Overview

There is a marked increase in the variability of the morphology of Gooandra Creek tributary one that occupies the central western part of the area defined as 'Geomorphic Study Area (Figure 1). A small part of the upper catchment is underlain by the same Tertiary basalt that underlies the upland swamps in the upper Eucumbene catchment. The rest of the catchment is underlain by the Gooandra volcanic suite that underlies the lower Eucumbene reach. Variations of lithology, therefore, cannot be used to explain morphological variability without further study.

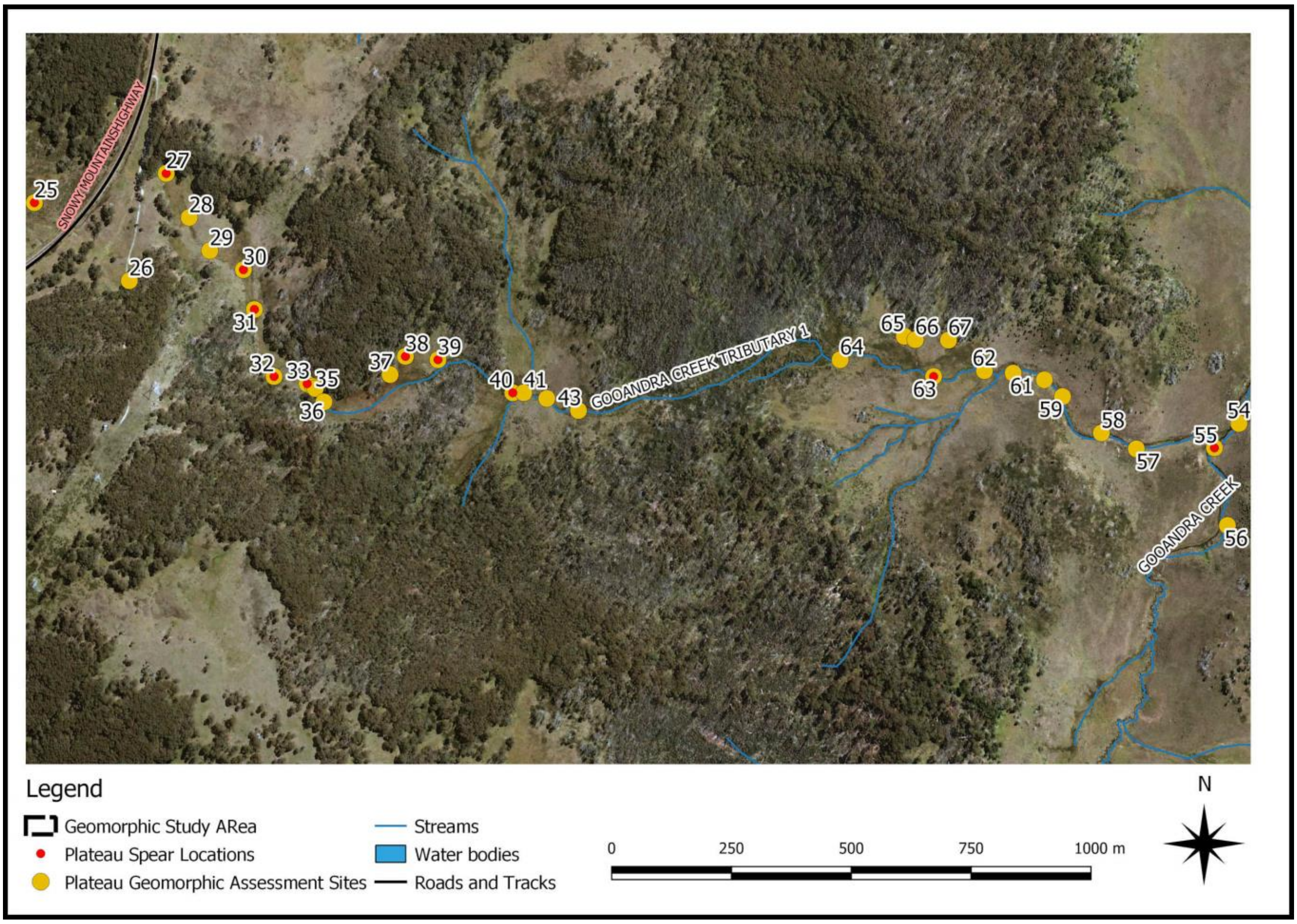


Figure 18: Gooandra Creek tributary 1 study area and assessment sites.

Subsurface interpretation - Upper zone

(Assessment sites 27 to 43)

The upper half of tributary one consists of a series of four steps (marked localised increase of slope) in the longitudinal profile that are separated by intervening areas of comparatively low slope (Figure 20).

The first three steps are not bedrock controlled but consist of boulder fields (possible felsenmeer) (Figure 19) that are masked by fine grained and organic rich more recent sediment that fills the surficial interstitial spaces. At each of these steps the channelised surface flows disappear into the boulder fields and continue as subterranean flows to reappear at the down slope base of step. The fourth step in the profile is bedrock controlled and the channel presents as a series of cascades and falls.

Between each of these steps in the longitudinal profile are zones that are saturated and have developed swampy meadows (*sensu* Young 1986) with varying stages of advancement. These swampy meadows have soil profiles very similar to other swampy meadows already described in that they are organic rich higher in the profile and grade downwards to a more clayey profile. Surficial sediment is consistently a dark grey/black silty organic clay loam (Figure 20).

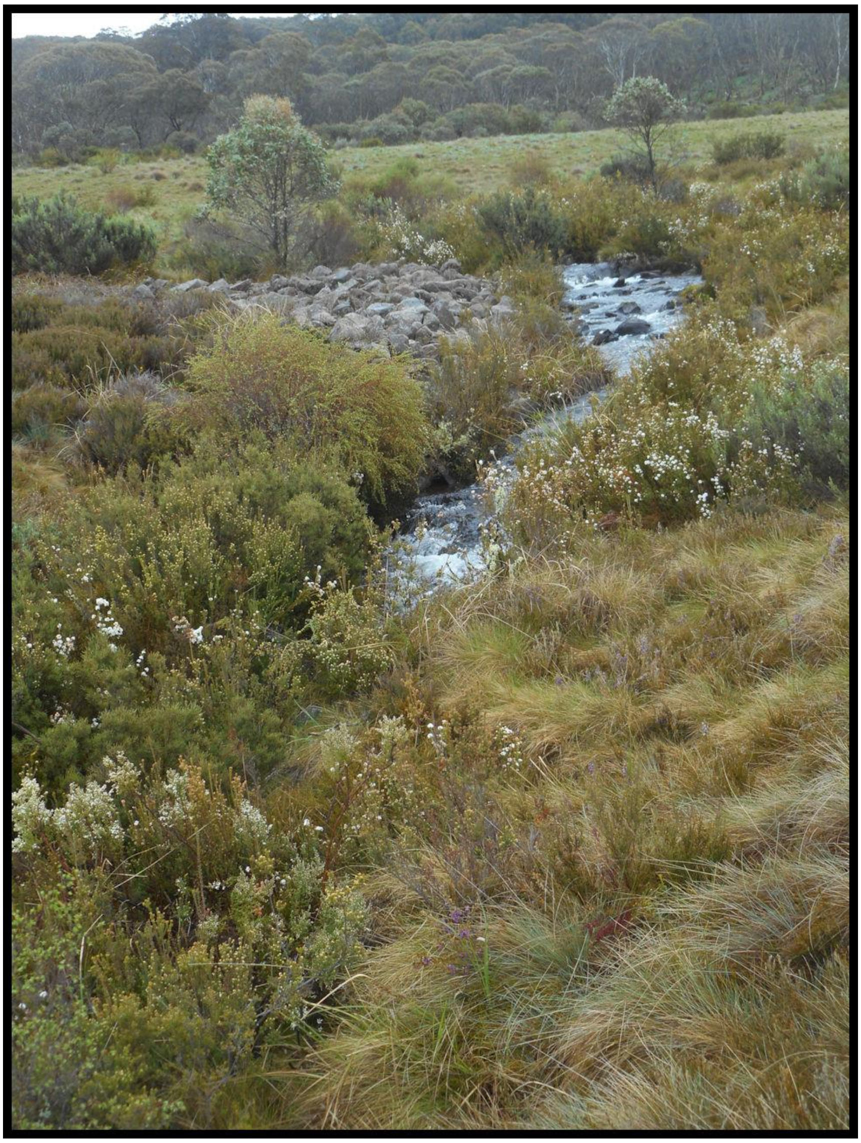


Figure 19: Felsenmeer extending to channel margin on Gooandra Creek tributary one adjacent to Site 43.

The penetration rate of the spear points completed in all of these swampy and, or, boggy zones changes from rapid penetration higher in the profile to a slower penetration rate at depth. Rapid penetration rates can be attributed to higher organic content which decreases with depth. Slower penetration rates are attributed to higher clay or gravel content or penetration of saprolite.

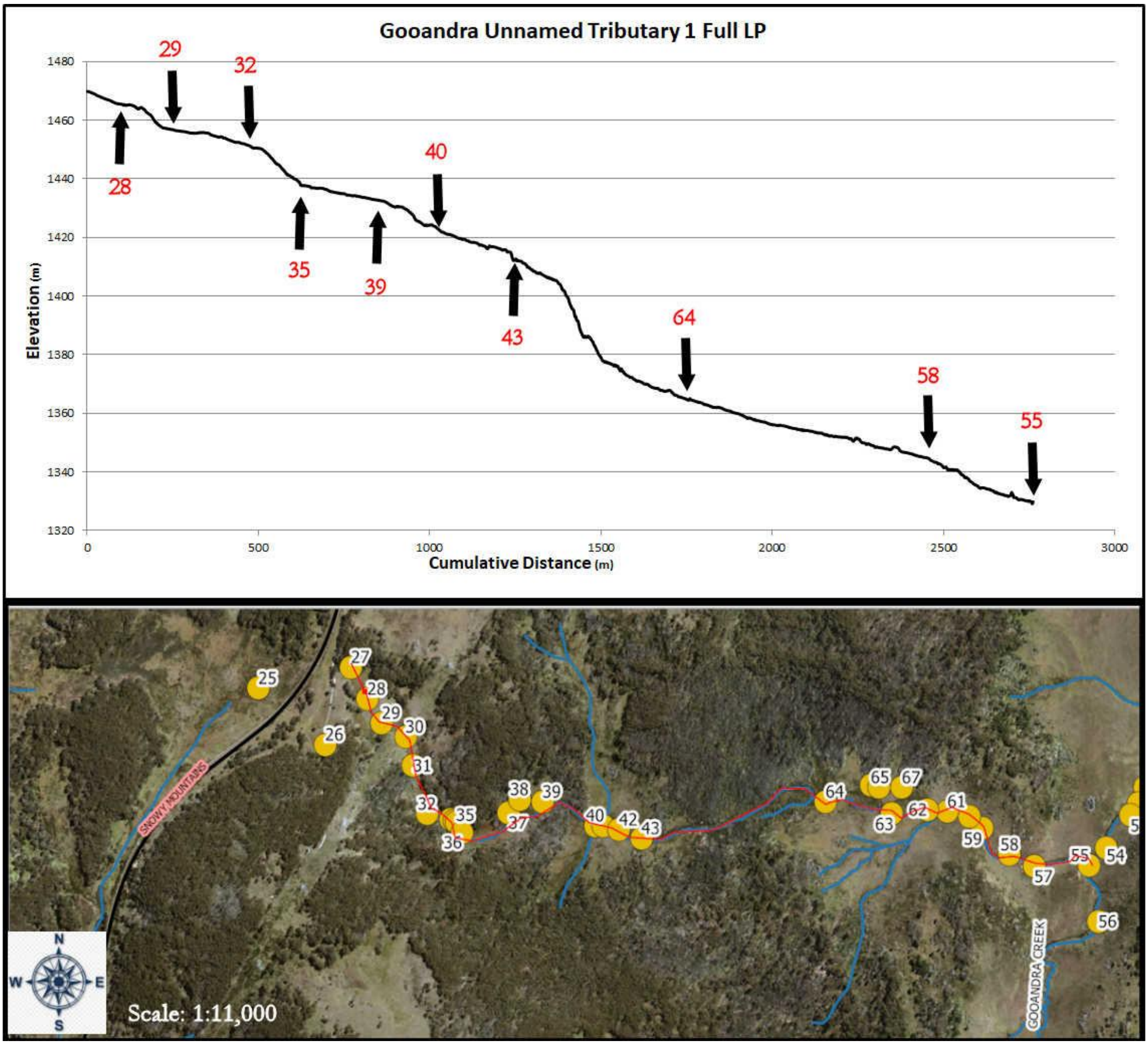


Figure 20: Gooandra Unnamed Tributary 1 Longitudinal Profile

The first three steps in the longitudinal profile are anomalous when considering the upper zone of Gooandra unnamed tributary one (Figure 20). The hydraulic connectivity of these zones with the underlying geology is unknown and was not determined as part of this study..

The intervening boggy and swampy zones show a progressive developmental stage down slope. In the upper reaches the organic content of the surficial material is not well developed at all (Site 27) whereas there is a fully developed swamp at site 37.

These surficial sediments consist primarily of very dark grey to black clayey silt with abundant organics (Figure 28). These surficial sediments present no impediment to penetration of the spear point and provide very little impediment to infiltration and transmission rates.

The organic content decreases down profile and the clay content increases. Some spear points encountered sediments that are classified as valley fill over saprolite while other spear points have an abrupt boundary with the underlying bedrock.

Location:	Swampy Meadow at headwaters of Gooandra Creek tributary 1
Geomorphic assessment Locations:	Plateau assessment locations 29 – 31 (Figure 18)
River Styles code:	SMG
River Styles categorisation:	Swampy Meadow Group, Intact valley fill, fine grained
Geomorphic condition:	Good
Fragility:	Low
Notes:	A broad channel zone occupies part of the valley floor but there is no distinct channel (Figure 21). Sheet flow disappears into valley floor at Site 30 to reappear at Site 31 at base of slope of step in longitudinal profile. Upland swamp is set on Tertiary basalt.

Figure 21: Swampy ground on intact valley fill at headwaters of unnamed Gooandra Creek tributary. Surficial sheet flows become subterranean flows (foreground) at Site 30 View is up slope with site 28 in mid ground, Figure 18.

Location:	First steep step in longitudinal profile
Geomorphic assessment Locations:	Plateau assessment locations 28 – 29
River Styles code:	BF DC
River Styles categorisation:	Boulder field, discontinuous channel
Geomorphic condition:	Good
Fragility:	Low
Notes:	A boulder field forms the step in the longitudinal profile. This field is covered with fine organic rich sediments and is masked by vegetation cover. Sheet flows from up slope disappear into the boulder field (Figure

21) and forms a subterranean flow to re-emerge at base of slope (Figure 22).

Location:	Swampy meadow between two distinct steps in the longitudinal profile
Geomorphic assessment Locations:	Plateau assessment locations 29 – 33
River Styles code:	SMG
River Styles categorisation:	Swampy Meadow Group, channelised valley fill, fine grained
Geomorphic condition:	Moderate
Fragility:	Low
Notes:	There is a steep step in the longitudinal profile between sites 34 and 35. Discontinuous channels, in broad channel zones, characterise the surface of the valley fill upstream of the step (Figure 23). Surface flows that were observed at time of assessment become subterranean flows to re-emerge at Site 35. The step in the long profile consists of a large boulder field obscured by fine clayey sediments and vegetation.

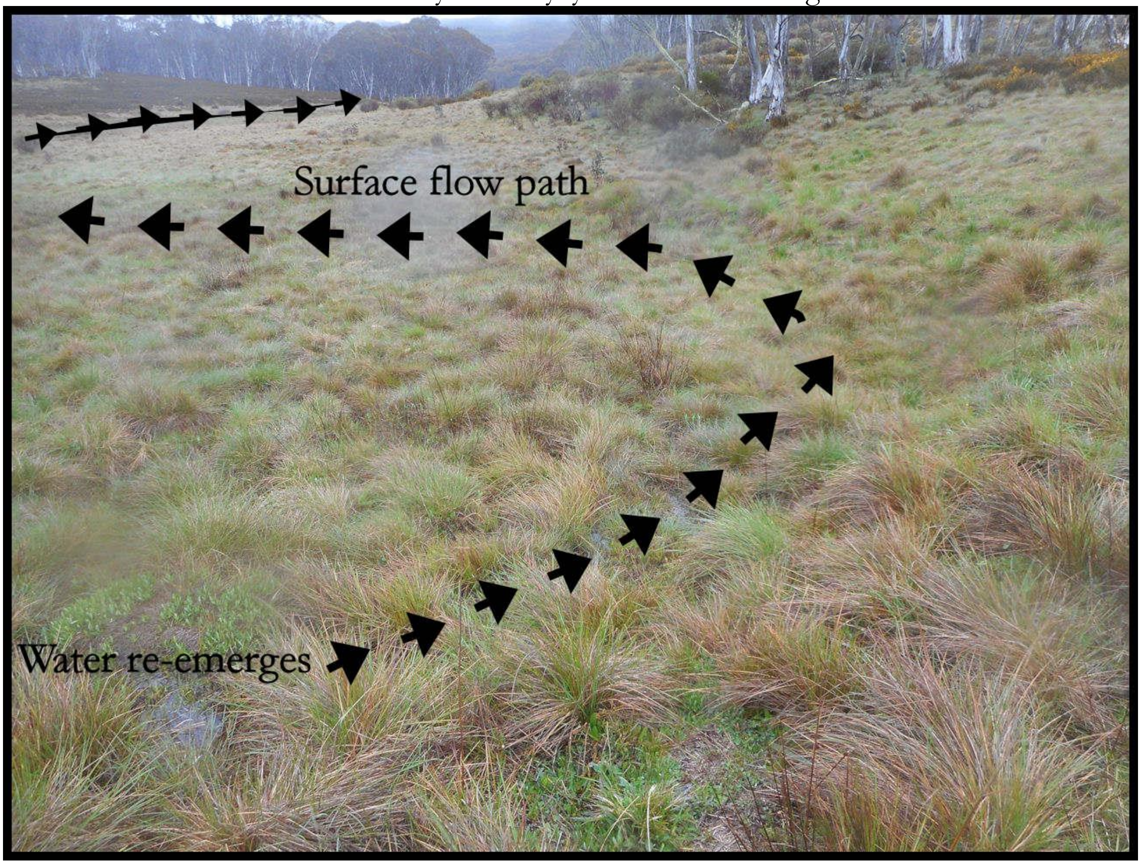


Figure 22: Flowing water at base of slope indicate subterranean flows emergent at base of slope at site 29. View is looking down slope.

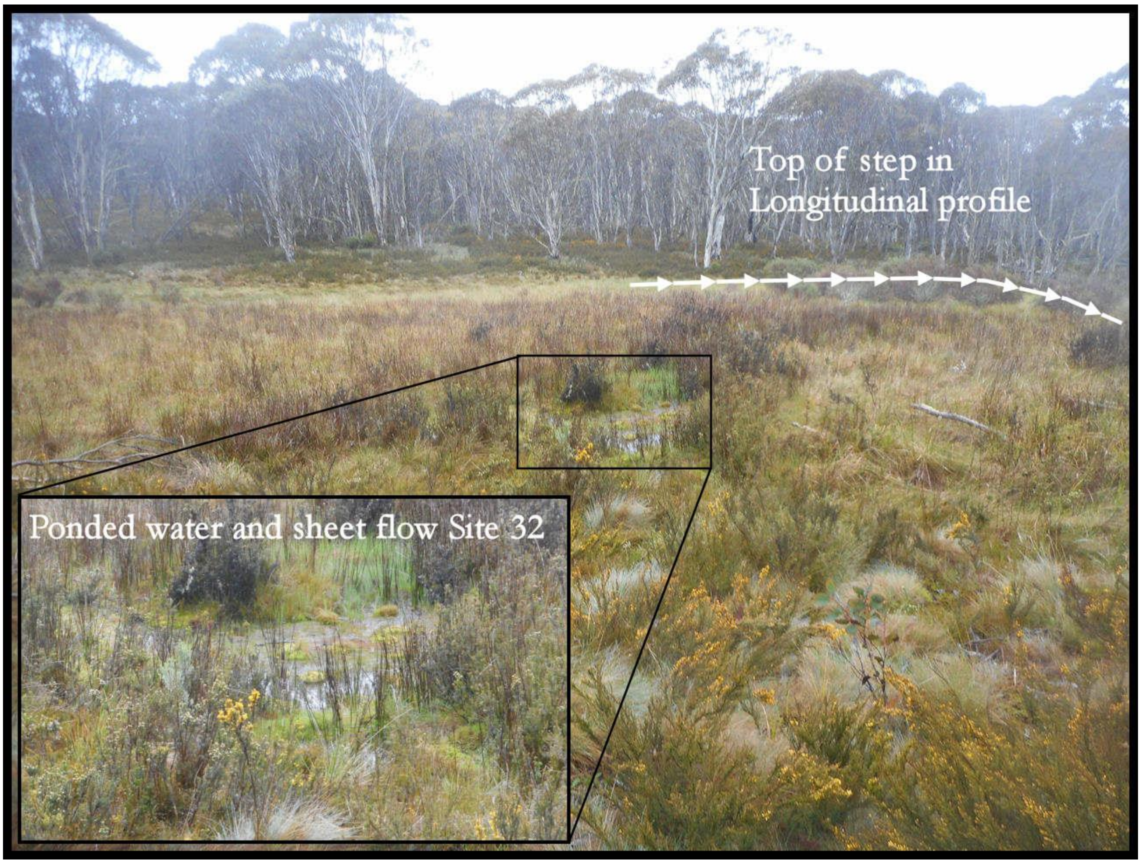


Figure 23: Surficial sheet flow defines broad channel zone above step in longitudinal profile at Site 32.

Location:	Second steep step in longitudinal profile
Geomorphic assessment	
Locations:	Plateau assessment locations 33 - 35
River Styles code:	BF DC
River Styles code:	BF DC
River Styles categorisation:	Boulder field, discontinuous channel
Geomorphic condition:	Good
Fragility:	Low
Notes:	A boulder field forms the step in the longitudinal profile. This field is covered with fine organic rich sediments and is masked by vegetation cover (Figure 24). Sheet flows from up slope disappear into the boulder field and forms a subterranean flow to re-emerge at base of slope site 36 (Figure 25).

Figure 24: Steep face of boulder field at Site 33.

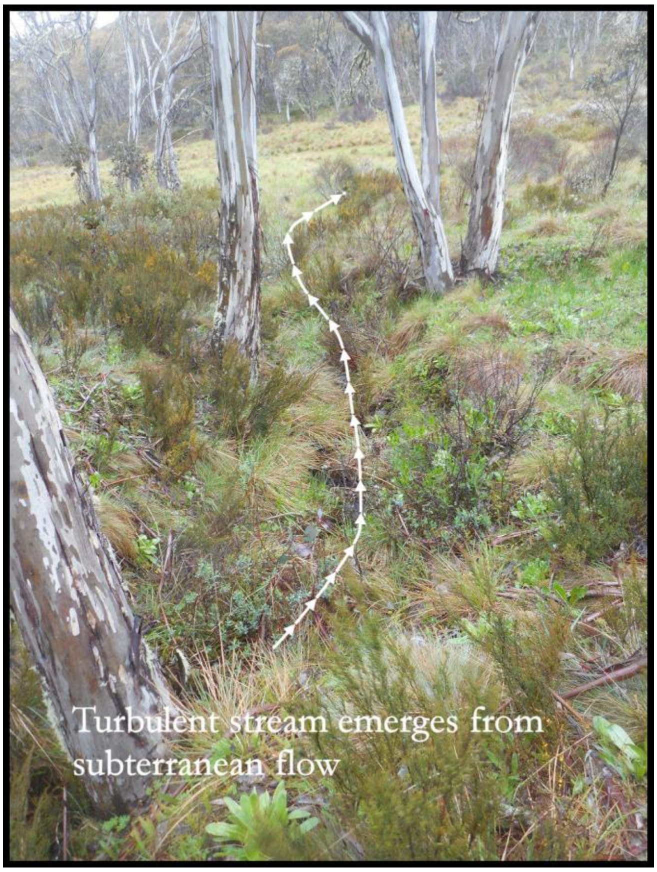


Figure 25: Subterranean flows remerge from base of step in long profile at valley margin at Site 35.

Location:	Intact swamp
Geomorphic assessment Locations:	Plateau assessment locations 36 - 39
River Styles code:	SMG
River Styles categorisation:	Swampy meadows group. Intact swamp on fine grained valley fill.
Geomorphic condition:	Good
Fragility:	Low
Notes:	Swamp on intact valley fill occupies zone of low slope between two steep steps in the longitudinal profile. Swamp is not exposed to damaging impacts and boulder fields at each end force base level control and reduces available stream power. Swamp sediments are characterised as organic rich at surface with increasing silt down profile. Multiple spear points terminate at refusal at 0.45m, on average.

Figure 26: Intact swamp perched on intact valley fill at Site 37.

Location:	Third steep step in longitudinal profile at downstream margin of swamp.
Geomorphic assessment Locations:	Plateau assessment locations 39 - 40
River Styles code:	BF DC
River Styles categorisation:	Boulder field, discontinuous channel
Geomorphic condition:	Good
Fragility:	Low

Notes: A boulder field forms the step in the longitudinal profile (Figure 27). This field is covered with fine organic rich sediments (Figure 28) and is masked by vegetation cover. Sheet flows from up slope disappear into the boulder field and forms a subterranean flow to re-emerge at base of slope at right valley margin. High volume flow channel begins at right valley margin at contact with intact swamp.

Figure 27: The third step in the longitudinal profile at downstream end of swamp. Site 39

Figure 28: Organic rich silty clay masking boulder field at downstream end of swamp. Site 39

Location:	Localised valley widening between two steps in long profile
Geomorphic assessment Locations:	Plateau assessment locations 41 - 43
River Styles code:	LUVS CC
River Styles categorisation:	Laterally unconfined valley setting, continuous channel, gravel bed
Geomorphic condition:	Moderate
Fragility:	Moderate
Notes:	Isolated valley widening at confluence of tributaries entering from both valley margins. Valley floor has two distinct channels.

Surface sediments are very dark brown to black organic rich silt, with minor clay. Bank heights vary between 40 and 60cm. Adjacent to channel the sediments are very fine grained and clayey light grey to buff. The main channel has a variable width between 1.5 and 6.0m. The base flow is turbulent and is characterised by riffle – rapid – run sequences (Figure 30). Channel substrate is gravel and cobbles to a maximum B_{max} of 17cm.

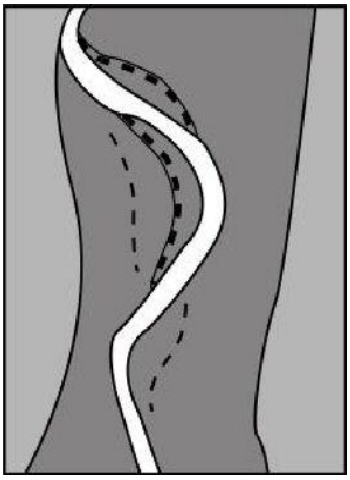


Figure 29: Schematic: Laterally unconfined valley setting with continuous channel gravel bed river

Figure 30: Turbulent flows, low bank heights and variable channel width looking downstream at Site 41.

Location:	Bedrock step in longitudinal profile
Geomorphic assessment Locations:	Plateau assessment location 43
River Styles code:	CVS
River Styles categorisation:	Confined Valley setting, bedrock controlled, steep headwaters
Geomorphic condition:	Good
Fragility:	Very low
Notes:	Cross channel bedrock bar begins over steepening of the longitudinal profile. Low angle boulder field extends from valley margin to channel margin at Site 45 (Figure 19).Turbulent flows on bedrock steps and boulders form cascades and waterfalls to 1.5m drop (Figure 32). There is no continuous floodplain at either bank.

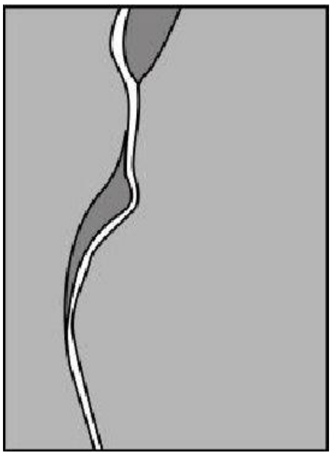


Figure 31: Schematic: Confined valley setting, bedrock controlled with discontinuous floodplain pockets

Figure 32 Cascades at beginning of bedrock step in long profile at Site 43

Subsurface interpretation - Lower Zone Gooandra Creek Tributary 1

(Assessment sites 55 to 67)

Downstream of the bedrock step in the longitudinal profile, at site 43, the tributary has a different morphology than that upstream of bedrock control. There are no well-developed swamps in this lower section, although there is some boggy ground. Steps in the long profile are associated with cross channel bedrock bars rather than felsenmeer. The floodplain is generally narrow only widening at confluences of minor tributaries.

The low flow channel occupies a narrow zone on the valley floor and the boundary with the colluvial footslope is diffuse. Colluvium that contains angular clasts of rock onlap the channel margin where the colluvium is intermixed with proximal overbank deposits of silt and fine sand.

The channel has become incised into the floodplain and there are desiccation features proximal to the channel. This shows that this surface layer has a moderate water transmission rate that does not extend to floodplain margins where there is still standing water amongst the tussocks.

The surface sediment has a moderate infiltration and transmission rate and the subsurface is low to very low.

Location:	Gooandra Creek tributary one downstream of bedrock controlled step in longitudinal profile.

Geomorphic assessment

Locations:	Plateau assessment locations 62 - 64
River Styles code:	LUVS CC
River Styles categorisation:	Laterally unconfined valley setting, continuous channel, gravel bed
Geomorphic condition:	Moderate
Fragility:	Moderate

Notes:

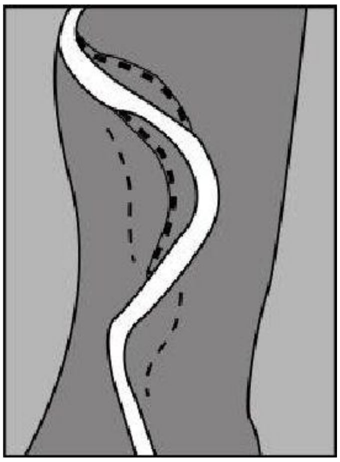


Figure 33: Schematic: Laterally unconfined valley setting with low to moderate sinuosity continuous channel gravel bed river

High angle, low sinuosity channel continues from downstream end of the bedrock step in the long profile. Channel sinuosity is increasing downstream.

There is an isolated valley widening at confluence of tributary entering from right valley margins. Valley floor is a broad, low angle depression (Figure 34) with a moderate sinuosity, low capacity channel, meandering across the valley floor. The valley floor at the confluence is up to 150m wide with a bog at left valley margin. Channel capacity is increasing downstream.

Surface sediments are very dark brown to black organic rich silt with minor clay that indicate that at least some of this area was swamp that is now dewatered. The main channel has is variable in width but is less than 2m. The base flow is turbulent and is predominantly characterised by riffles with rare rapids and even rarer runs. Channel substrate is gravel (Figure 36) and cobbles that effectively armour the channel bed from incision.

At site 63 there is an abandoned channel that indicates that the current channel has migrated to left valley margin and has incised by approximately 1m to bedrock.

Figure 34: Looking upstream from Site 61 there is an abandoned channel at right margin (left of photo) and the contemporary channel has migrated to left margin and has incised into valley fill.

Figure 35: Low capacity channel extends downstream with cobble armouring at Site 63.

Figure 36: Channel width increases downstream but is highly variable. Cobble bed river with riffles and rapids over cobbles at site 62.

Location:	Steepening of longitudinal profile to confluence with Gooandra Creek trunk.
Geomorphic assessment Locations:	Plateau assessment locations 63 - 57
River Styles code:	CVS
River Style s categorisation:	Confined valley setting, bedrock controlled, with discontinuous floodplain
Geomorphic condition:	Good, stable
Fragility:	Low
Notes:	The channel is incised into bedrock (Figure 39) and forms a series of rapids (Figure 38) and cascades (Figure 40) over boulder fields (Figure 38) and cross channel bedrock bars.

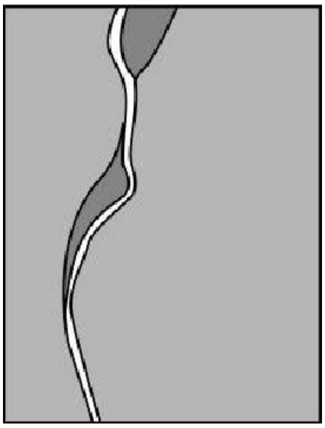


Figure 37: Schematic: Confined valley setting with discontinuous floodplain

Figure 38: Rapids over cobbles and boulders at site 62.

Figure 39: Bedrock control at Site 58.

Figure 40: Cascades over cross channel bedrock bar. Site 58

Gooandra Creek

There is very little variability in channel morphology or processes on Gooandra Creek. There are two small localised widenings of the valley floor that occur at the confluence of tributaries, otherwise the Gooandra Creek is incised into the underlying geology that effectively exerts bedrock control on lateral migration and vertical incision (Figure 41).

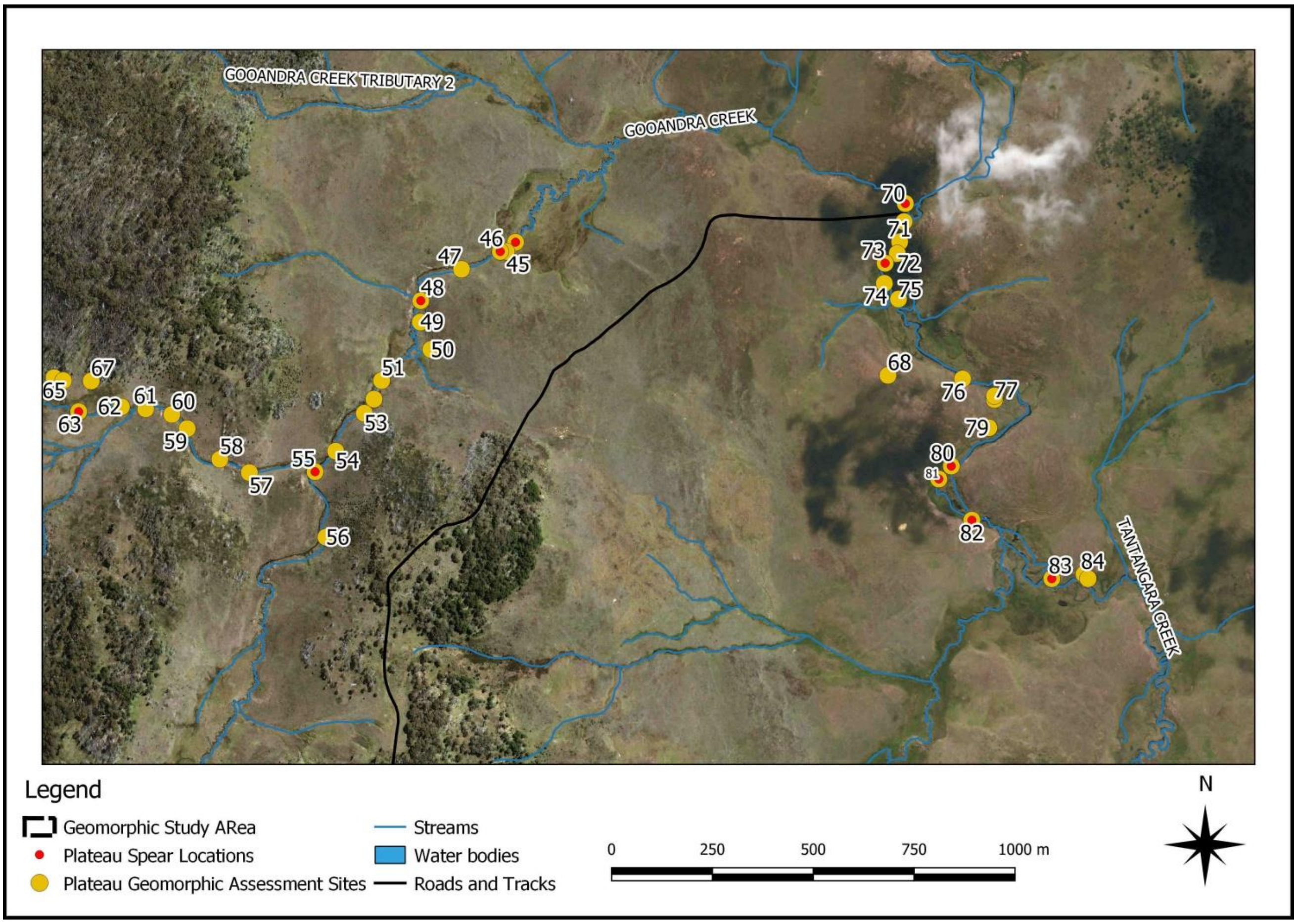


Figure 41: Gooandra Creek and Tantangara Creek assessment locations.

The channel has a high slope through most of the study reach and the channel is characterised by multiple cross channel bedrock bars, associated cascades and rapids, and cobble armouring of the channel. Channel slope decreases on at tributary confluences.

The channel exits from confinement, and bedrock control, at the northern end of the study area adjacent to Site 46 (Figure 41). Here, the valley floor widens to 200m and the sinuosity of the channel increases to tortuous, in places. The channel occupies a narrow band on the floodplain that varies 40m to 60m wide. The contemporary channel meanders within this zone and there are multiple instances of abandoned channels. The distal areas of the floodplain have well developed backswamps at valley margin.

This laterally unconfined, planform controlled is fundamentally different to the bedrock controlled reaches upstream. Vertical bank exposures show what the character of the subsurface sediments is floodplain fill sediments with exposures of gravel lag bedforms (Figure 42). The surficial sediments do not display a well-developed swamp profile. It is a mid-grey clayey silt with abundant roots and common organic detritus. The organic content grades downwards to a dark brown/grey clayey silt with common pebbles and granules in discrete discontinuous layers (Figure 43).

Figure 42: Floodplain fill sediments with relict gravel lag bedform exposed in bank at Site 45. Graduations on sediment spear are 10cm intervals.

Figure 43: Floodplain fill sediments fining upward with increasing organic content. Assessment site 46.

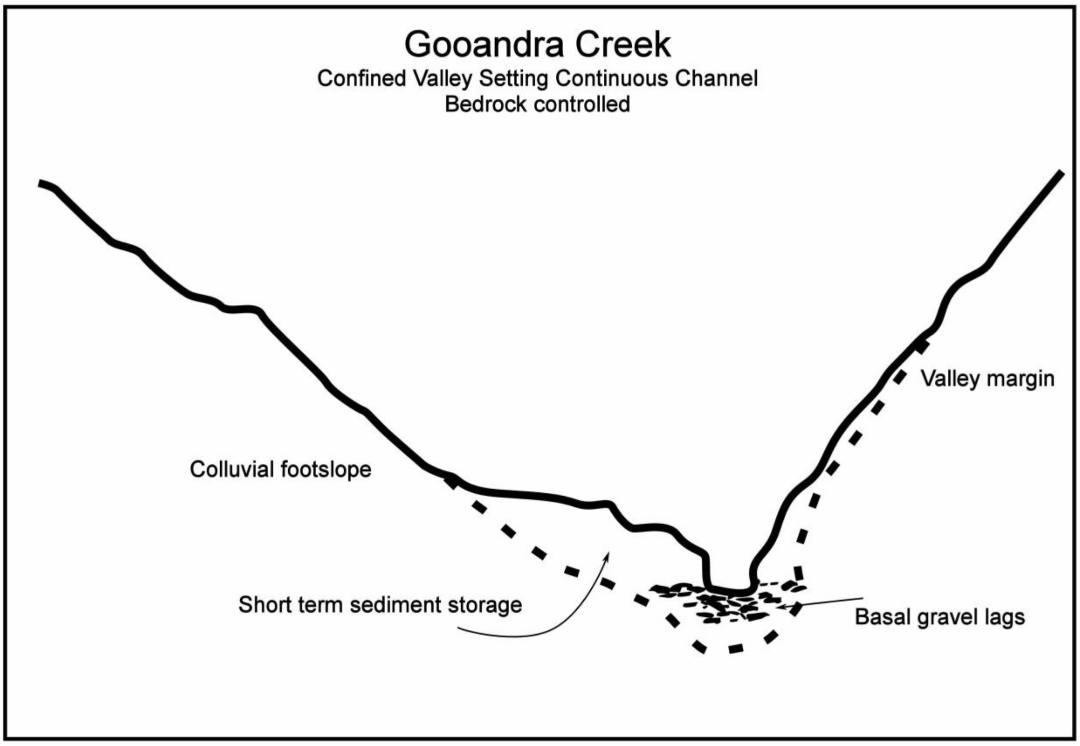
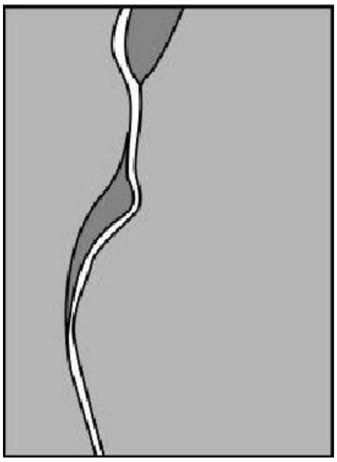


Figure 44: Conceptual diagram showing interpreted subsurface morphology of Gooandra Creek.

The reduced organic content and increased percentage of silt makes these surficial layers more impervious to infiltration and transmission. The basal sediments have a very low transmission rate. Although there are examples of basal gravel lags exposed in the bank (Figure 42) the interstitial spaces are infilled with silty clay.

Location:	Gooandra Creek through draw down zone
Geomorphic assessment Locations:	Plateau assessment locations 56 – 52 (Figure 41)
River Styles code:	CVS CC
River Styles categorisation:	Confined valley setting, continuous channel, discontinuous floodplain pockets, low sinuosity, bedrock controlled.
Geomorphic condition:	Good
Fragility:	Very low
Notes:	This reach is almost a gorge. It has high slope and high energy and there are small discontinuous pockets of sediment that alternate as channel migrates from valley margin to valley margin.



High channel slope is characterised by rapids and riffles with rare runs. There are multiple cross channel bedrock bars within this reach that can be characterised as cascades and rapids (Figure 47). Channel is generally narrow between 1.5 and 2.0m but widens out to 6.0m downstream for a short distance.

The channel has bedrock control both vertically and laterally. Figure 46 shows channel abutting valley margin at Site 58. There is a small area of stored sediment visible at right bank.

Figure 45: Schematic: Confined valley setting with discontinuous floodplain

Figure 46: Channel abuts margin at left bank Site 56 looking upstream.

Figure 47: Cascades over cross channel bedrock bar. Site 54

Location: Gooandra Creek.

Geomorphic assessment Locations: Plateau assessment locations 52 - 47

River Styles code: PCVS CC

River Styles categorisation: Partly confined valley setting, continuous channel, discontinuous floodplain pockets, fine grained, bedrock controlled.

Geomorphic condition: Good

Fragility: Moderate

Notes: The central reach of Gooandra Creek within the study area has a predominantly low sinuosity and discontinuous pockets of floodplain as channel migrates across the narrow floodplain.

In many instances bedrock valley margin extends to channel margin. There is an isolated valley widening, with associated stored sediment commencing at Site 54 where channel exits from confinement (Figure 49).

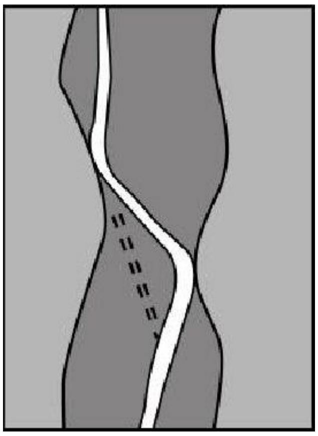


Figure 48: Schematic: Partly confined valley setting with low sinuosity. Discontinuous floodplain.

The valley floor widens to 108m (Site 52) at a tributary confluence at right bank. Here the channel is unconfined, planform controlled and has a high sinuosity for a distance of 175m but this reach is not representative of the character Gooandra Creek within the study area. The floodplain has distal backswamps at valley margin. There are a series of tortuous meanders at the downstream end of the pocket where channel re-enters confinement. Upon re-entering confinement bedrock is evident within the channel and forms a series of cross channel bars that are characterised by very turbulent flows of rapids.

Figure 49: Channel slope has decreased where channel exits from bedrock confinement. Site 54.

Location:	Gooandra Creek.
Geomorphic assessment Locations:	Plateau assessment locations 44 - 47
River Styles code:	LUVS CC
River Styles categorisation:	Laterally unconfined valley setting meandering, gravel bed, planform controlled.
Geomorphic condition:	Good, dynamic
Fragility:	High
Notes:	The channel exits from confinement at Site 49 onto a broad floodplain. It has high sinuosity to tortuous meanders and abandoned channels can be seen as cut off meanders on the floodplain within a broad channel zone of approximately 50m width. Floodplain is 160m across and there are distal backswamps at valley margins. The channel is approximately 2m wide and has a turbulent flows characterised by riffle – rapid sequences. The channel bed is armoured by gravel and cobbles with a maximum clast size of 18cm B_{max}.

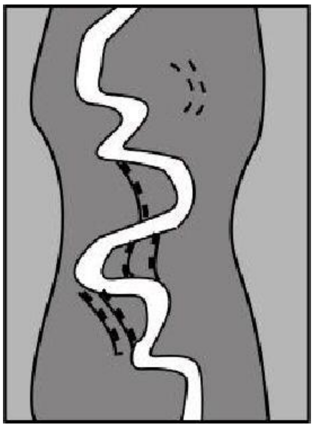


Figure 50: Schematic:
Laterally unconfined valley setting, meandering, gravel bed, planform controlled.

Tantangara Creek

Tantangara Creek (Figure 41) occupies a well-defined valley floor that narrows to 30m and at its widest is 110m. Channel width varies between 2.5m and over 7m in places. There are rare cross channel bedrock

Figure 51: Fining upwards floodplain fill sequence of silty clay. Assessment site 70.

bars but the predominant character of the channel is riffles, with occasional rapids and rare runs.

Floodplain and channel evolution can be seen by examining the common abandoned channels on the floodplain. Overall, these abandoned channels are narrower (2.5m) have lower bank height (around 40cm average) and are perched above the contemporary channel by 1m approximately. There are common desiccation features proximal to the abandoned channel

Figure 52: Relict gravel bedforms exposed in the bank of Tantangara Creek at Assessment site 74.

There are numerous instances, usually at the outside of meander bends, of bank undercutting and failure by block fall, which can be a naturally occurring process. However, recently abandoned channels extant on the floodplain show no evidence of meander migration through this process. Abandoned channels generally have a lower channel capacity and are characterised by low, well vegetated, and stable banks.

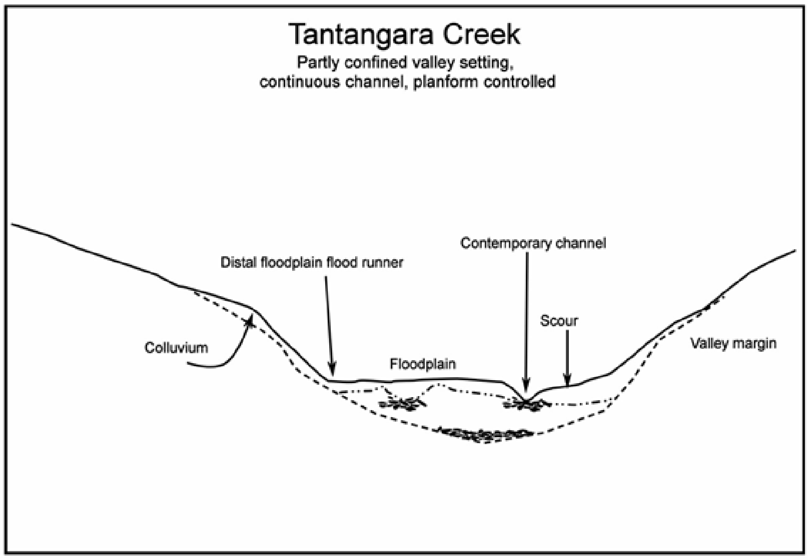


Figure 53: Conceptual diagram showing interpreted subsurface morphology of Tantangara Creek.

The rate at which meander migration currently progressing, coupled with the bank morphology and the lower capacity of the abandoned channels on the floodplain, would indicate that the current rate of meander migration is abnormal. The exposed sub-vertical banks give insight into the subsurface sedimentology and exposes fine silty clay, grey/brown with sub-vertical cracks and abundant roots throughout (Figure 51). The channel bed is armoured with gravel and cobbles with no fine sediment infilling the interstitial spaces between the clasts.

The surficial sediment consists of dark grey/brown silty and sandy organic clay loam. Organic matter decreases down profile where sediment is dark red/brown clayey silt with minor sand. These floodplain fill sediments show better developed swamp profiles at valley margin. Mid pocket sediments reflect boggy ground rather than a well-developed swamp.

The surface sediments have a higher hydraulic connectivity than sediments lower in the profile where sediments consist of silty medium clay with minor pebbles. These clayey sediments would have very slow water transmission transfer rates. Occasionally relict bedforms are exposed in the banks (Figure 52) that show the subsurface morphology and structure in detail. Bank exposures show relict bedforms of gravel lag where interstitial spaces are filled with silty clay. These basal sediments will have a very slow infiltration and transmission rate.

Location: Tantangara Creek

Geomorphic assessment

Locations:	Plateau assessment locations 68 – 85
River Styles code:	PCVS CC
River Styles categorisation:	Partly confined valley setting with continuous channel
Geomorphic condition:	Moderate
Fragility:	Moderate
Notes:	A predominantly low sinuosity, fine grained, planform controlled river where the channel moves from valley margin to valley margin through meander migration.

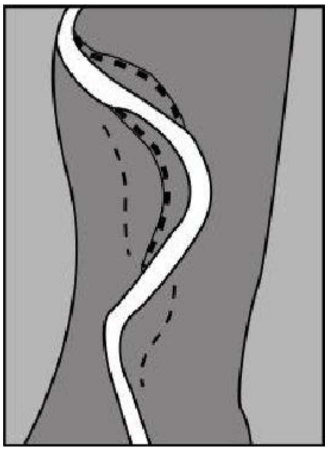


Figure 54: Schematic: Partly confined valley setting, low to moderate sinuosity, gravel bed river

The channel occupies the valley floor and is never fully confined or bedrock controlled. The valley floor width is variable but usually between 30m and 60m. There are isolated valley widenings at tributary confluences where the channel sinuosity increases to tortuous (Figure 55). Sites 85 – 87, which are outside the study area, also show a high sinuosity.

The channel can be characterised as being high energy and having fast flowing turbulent flows of riffles with rare rapids (Figure 56) over two cross channel bedrock bars. The channel bed throughout the reach was armoured with cobbles and gravel.

There are numerous examples of bank failure where turbulent flows are undercutting sub vertical banks that fail and fall into the channel as block fall (Figure 57). Locations of bank failure allow examination of subsurface sediment and show fine silty clay, grey/brown with sub-vertical cracks and abundant roots throughout.

Multiple spear points penetrated to between 70cm and 95cm through resistant sediments to terminate in gravel. These results agreed with what sediments were visible in exposed bank sections.

Bank slumping at site 74 (Figure 52) has exposed the remnant bedforms of coarse gravel that underlie the more recent floodplain deposits.

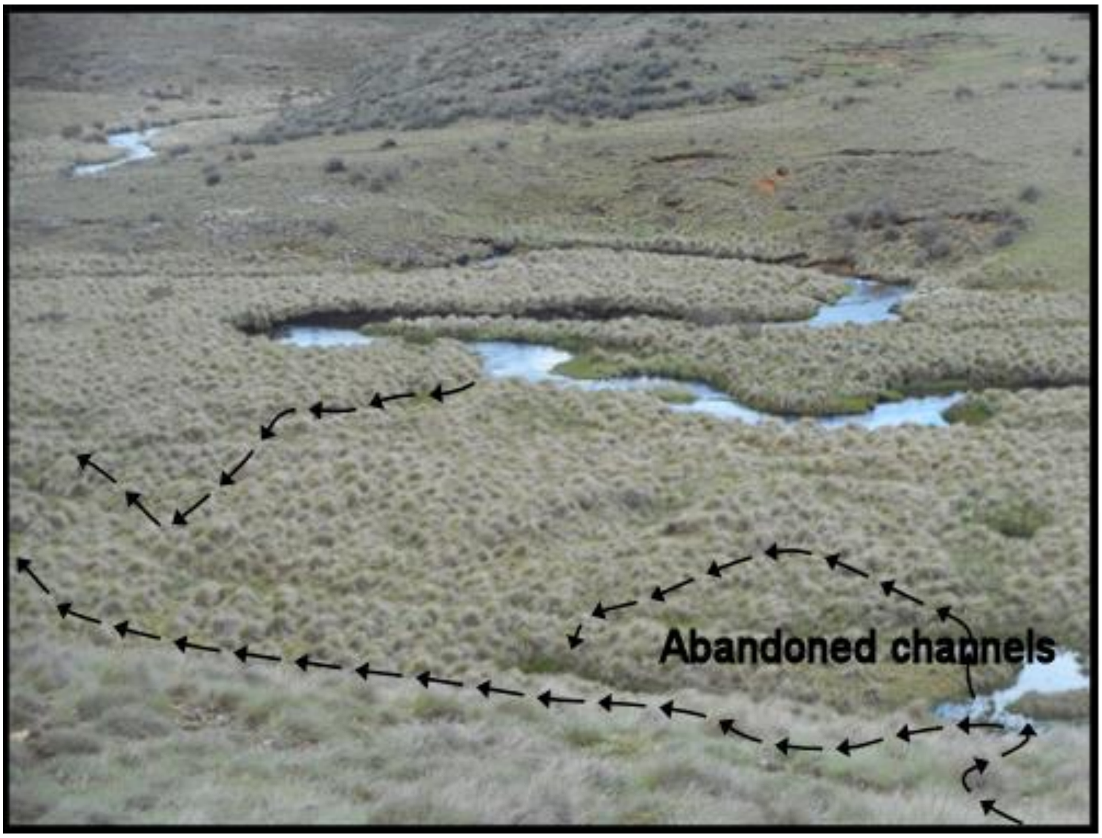


Figure 55: Overview of Site 75, taken from site 68, where valley floor has widened to 106m.

Figure 56: Rapids over cross channel bedrock bar. Site 70

Figure 57: Bank failure and block fall at confluence with Gooandra Creek. Site 69

Unnamed Plateau Creeks

Overview

On the plateau east of Tantangara Creek there are seven unnamed main tributaries that were assessed for the study (Figure 58). For ease of referral these have been named, west to east; unnamed tributary 1 south, 2 north, 3 north, 4 south, 5 north, 6 north and 7 south. These were named this way for no other reason than that was the order of assessment.

Except for Unnamed tributary North 2, which has an individual morphology that is manifestly different from the other six creeks, all other tributaries are morphologically and sedimentologically the same. They are all classified as steep headwaters and have a fine, to very fine and silty substrate with minor pebbles and minor clay.

In the headwaters of each there is no continuous channel evident and the drainage line exists as a broad depression in the valley bottom rather than a discreet channel zone. The sediment here is colluvial and consists of fine sandy silt with common angular clasts that become abundant down profile. This material is common across all tributaries and is interpreted as colluvium over saprolite.

Downslope, where the valley floor widens, the drainage zone becomes better defined, and a discontinuous channel begins to form. As the valley floor widens, and more tributaries join, high angle swamps, or areas of boggy ground occur and effectively entrap sediment that would normally be moving down catchment. These high angle swamps are extremely fragile. Downslope, a continuous channel forms often with a low volume base flow. The saprolite that was exposed in root balls, or in the banks of channels, consisted of very fine to medium grained, silty sand with very low clay content. There were also rare, sub rounded, quartz pebbles and angular lithic fragments of weathered bedrock scattered through the profile and on the surface. The colluvium on the hill slopes shows a very juvenile soil profile with very low organic content.

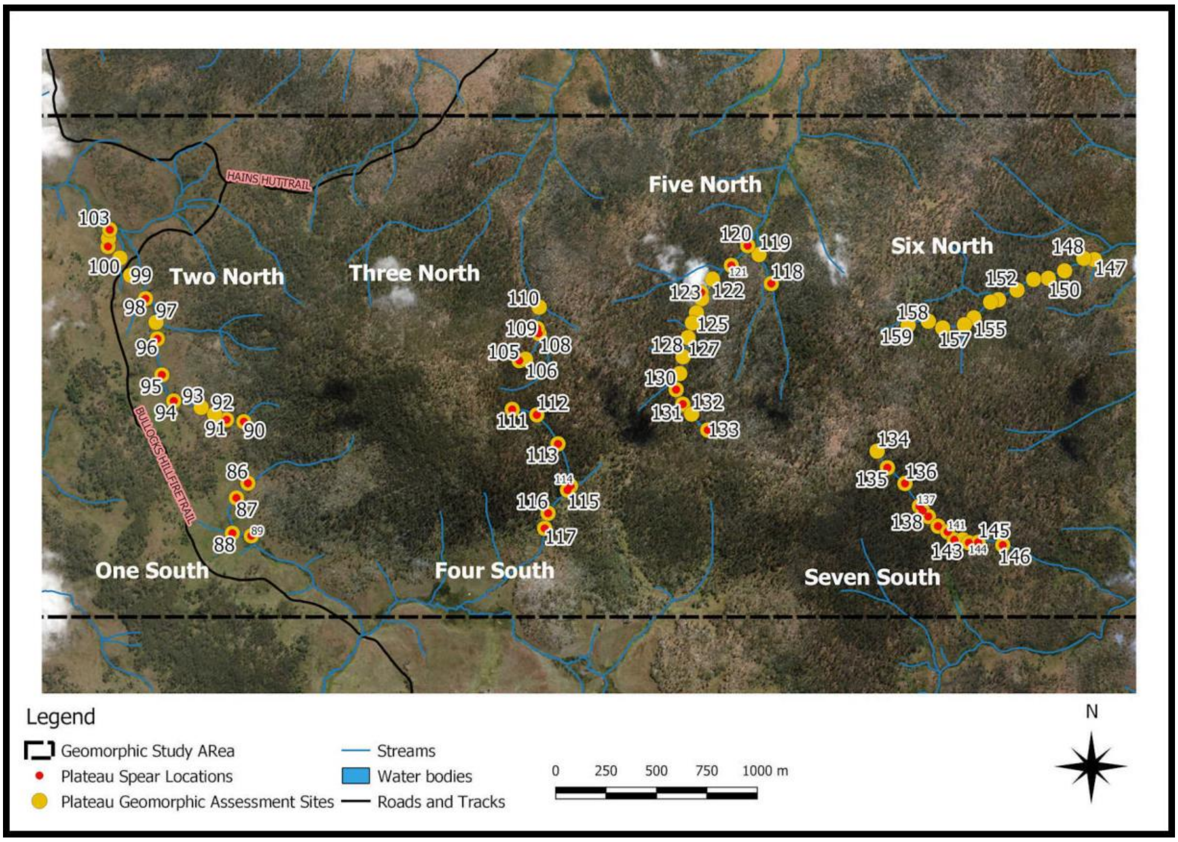


Figure 58: Central Plateau Unnamed Tributaries and assessment sites.

The hydraulic connectivity of this material is quite low and it would have a slow infiltration rate. Once the surface profile was wetted then the transfer of water from surficial colluvium and saprolite to the underlying bedrock would also be slow. Transmission rates through the bedrock are unknown.

In the upper reaches of the unnamed plateau creeks there is no continuous, well defined, channel and drainage lines exist as broad depressions. These depressions are subject to sheet flows during periods of heavy rain and collect fine sediments and organic matter from the adjacent footslope.

This resultant material, being a mix of alluvial and colluvial sediments, has a greater infiltration and transfer rate than the surrounding colluvium. Additionally, the increased organic content would increase porosity and water transmission rates.

As the valley widens downstream, and the channel becomes continuous set within a well-defined valley floor (Figure 62), the sediment on this valley floor becomes progressively more enriched with organic matter. Channel bed sediments consist of organic rich, poorly sorted silt, sand and gravel. This material has a high hydraulic connectivity and fluid transfer rate.

Plateau Unnamed Tributaries

Location:	Central Plateau (Figure 58)	
Geomorphic assessment Locations:	Unnamed tributary 1 South	Assessment sites 086 - 089
	Unnamed tributary 3 North	Assessment sites 105 - 110
	Unnamed tributary 4 South	Assessment sites 111 - 117
	Unnamed tributary 5 North	Assessment sites 118 - 133
	Unnamed tributary 6 South	Assessment sites 134 - 146
	Unnamed tributary 7 North	Assessment sites 147 - 159
River Styles code:	SHVS DC	
River Styles categorisation:	Steep headwaters valley setting with discontinuous channel	

Geomorphic condition: Good
Fragility: High
Notes: All six tributaries are morphologically the same. The same form – process relationships are common to all tributaries draining the central plateau as described in the Overview. The sedimentological character is determined by the underlying bedrock lithology (Table 1)

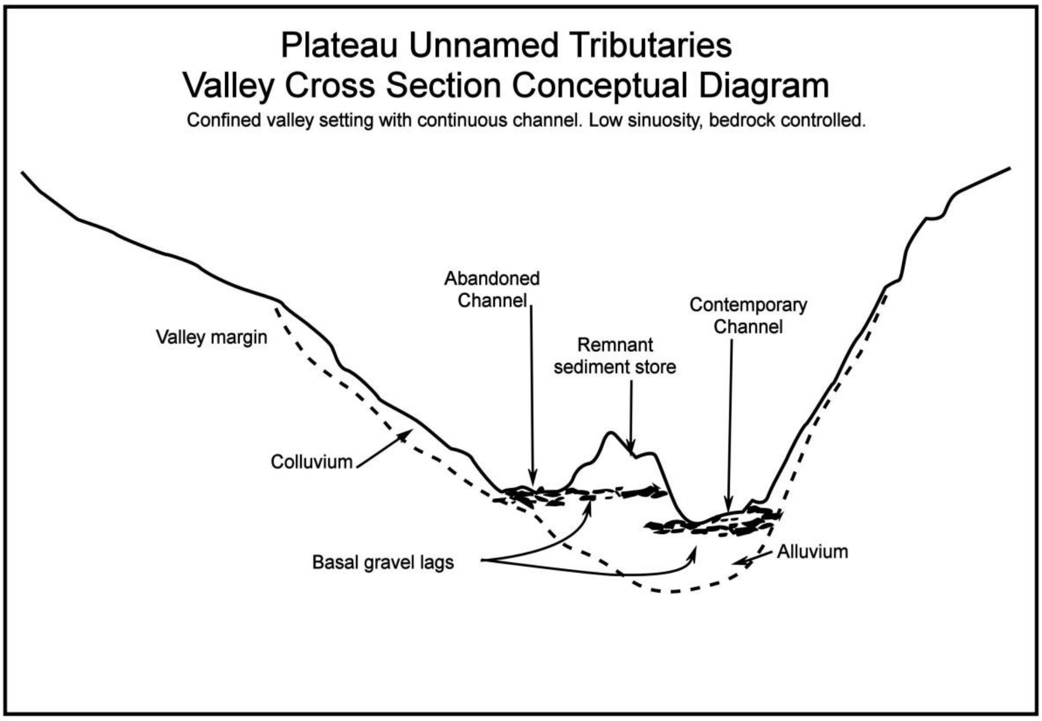


Figure 59: Conceptual diagram showing interpreted subsurface morphology of central plateau unnamed tributaries.

Plateau Unnamed Tributary 2: North

Location: Parallels Bullocks Hill fire trail
Geomorphic assessment
Locations: Plateau assessment locations 90 - 102
River Styles code: PCVS CC
River Styles categorisation: Partly confined valley setting with continuous channel. Low sinuosity, fine grained, planform controlled.
Geomorphic condition: Moderate
Fragility: Moderate

Notes: Steep headwaters stream occupying no more than 10 m of valley floor width. Channel zone is well vegetated and flow consists of low base flow on bedrock step with rapids and small pools (Figure 61). The channel floor sediment is sandy silt with granules and rare pebbles. The channel floor is spongey and silty organics overlain by granule and small pebble lag.

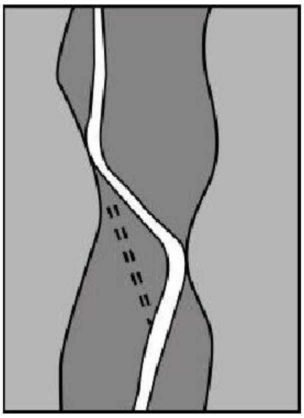


Figure 60: Schematic: Partly confined valley setting with low sinuosity, planform controlled discontinuous floodplain

Channel zone increases in width downstream and channel is incised into the valley floor by approx. 1.5 m. The channel and floodplain continue to increase in width downstream (Figure 62). There is a minor constriction at site 98 where valley floor decreases to seven metres wide and channel width is less than 50 cm. The GIS layer shows this location as being sited on a tributary entering at left bank but the site is actually located on the main channel. Low flow in the channel is characterised as a rapidly moving riffle sequence that indicates increasing slope.

At sites 100 and 101 there are multiple springs entering from left valley margin. At site 103 there is a tributary entering from right valley margin and downstream from this point the valley floor widens dramatically to 120m. Immediately upstream of the Bullocks Hill track crossing the valley floor is 40m.

At site 102 the low flow channel is highly sinuous and has migrated from right valley margin to left valley margin. Channel width is variable to less than 2 m. Channel floor is armoured by gravel lags but saprolite and bedrock is exposed in base of channel (Figure 63).

Contemporary channel zone is approx. 17m across and is inset within the floodplain by approx. 1.5m. Channel flow is a turbulent riffle and rapids sequence.

Figure 61: Channel zone looking upstream from commencement of continuous channel on unnamed tributary 2 north Site 91Inset shows commencement of continuous channel with sediment load of medium to coarse sand with common small pebbles.

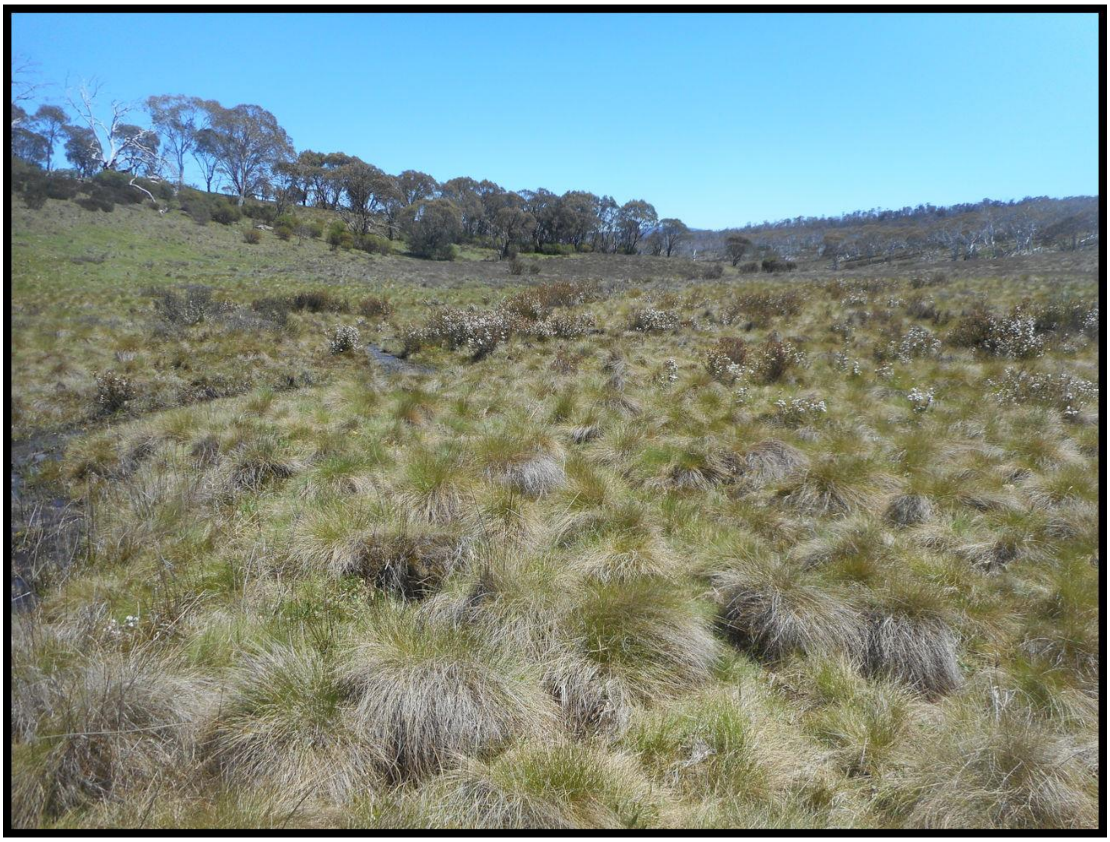


Figure 62: Continuous channel in broad channel zone depression mid pocket on unnamed tributary 2 north Site 94

Figure 63: Saprolite and bedrock exposed in channel at site 100 on unnamed tributary 2 north.

Nungar Creek

During preliminary desktop review, Nungar Creek was interpreted to be a manifestly underfit stream (*sensu* Dury 1964a) where the contemporary processes are unable to produce the current landform. While being geomorphically interesting, a determination of being manifestly underfit would also aid in the assessment of potential lateral migration of the contemporary channel but this is not essential to satisfy the scope of this report.

The valley floor on which Nungar Creek is located is consistently between 130 and 150 m wide. However, its widest point is at a localised valley widening where two tributaries join the trunk and the valley floor widens to 190m.

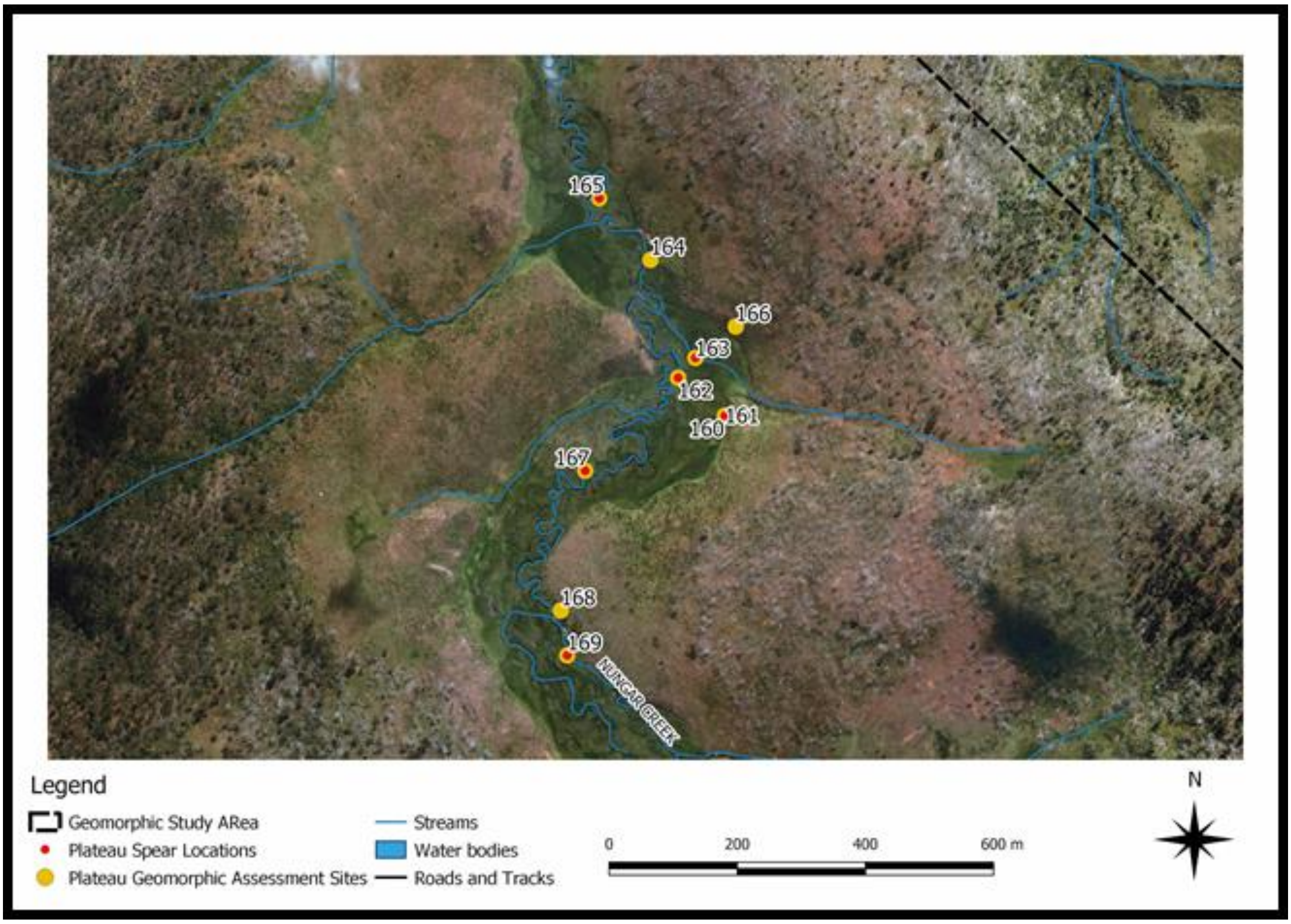


Figure 64: Nungar Creek Assessment Sites.

The contemporary channel is laterally unconfined and has tortuous meanders (Figure 65) actively migrating across the floodplain. There is active bank slumping as channel evolution continues through meander migration. There are common, high sinuosity, abandoned channels that record previous episodes of channel migration.

The Nungar Creek reach that was assessed for this study had no morphological variability at all. It exists as a laterally unconfined, planform controlled, fine grained system with cobble armoured channels.

The soil profiles that are exposed in the banks of Nungar Creek indicate that the surface was not a well-developed swamp (Figure 66). It was boggy ground but does not have the same organic content as other well developed swamp profiles.

Multiple spear points emphasize the bank profiles in that penetration rates decrease down profile which indicates increasing clay content. There are remnant gravel and cobble bedforms exposed in the bank

(Figure 67) and the interstitial spaces between the clasts are filled with silty light clay. This significantly reduces the hydraulic connectivity.

Figure 65: Tortuous meanders on Nungar Creek. Site 167

Figure 66: Bank exposure showing increasing organic content up profile but without a swampy meadow forming.

Figure 67: Relict gravel bedforms exposed in the bank of Nungar Creek at Assessment Site 167.

Location:	Nungar Creek; Eastern end of the plateau study area
Geomorphic assessment Locations:	Plateau assessment locations 160 - 169
River Styles code:	LUV CC
River Styles categorisation:	Laterally unconfined valley setting, continuous channel. Planform controlled, moderate to high sinuosity, fine grained. Meandering, fine grained, cobble bed river
Geomorphic condition:	Moderate
Fragility:	High
Notes:	The study reach of Nungar Creek had no morphological variability. It exists as a laterally unconfined, planform controlled, fine grained system with cobble armoured channels. Channel flows are high velocity and turbulent, mainly consisting of riffle – run and rapid – riffle – run sequences. There are occasional cross channel gravel bars

The valley floor is consistently between 130 and 150 metres wide. However, at its widest point the valley floor widens to 190 metres.

The channel is laterally unconfined and has tortuous meanders actively migrating across the floodplain (Figure 65). There is active bank slumping (Figure 71) and common abandoned channels that record previous episodes of channel migration. Multiple abandoned channels abut valley margin at multiple points (Figure 69). Abandoned channels on floodplain are perched above the contemporary channel. Dewatering of the floodplain adjacent to the contemporary channel is evidenced by de[illegible] A[illegible]oned channels are considerably wider than the current channel; up to 14m

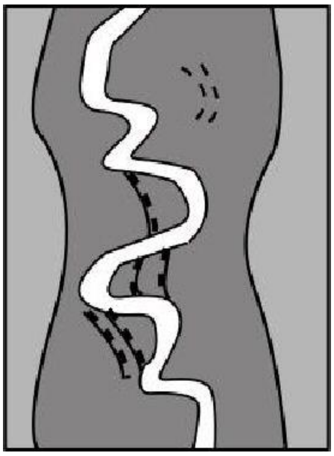


Figure 68: Schematic: Laterally unconfined valley setting, meandering, gravel bed river

and have poorly defined banks to 30cm height (Figure 70). Such a low capacity channel would have been coupled with the floodplain under low flow conditions unlike the contemporary channel that is decoupled at low flow.

Bank instability and block fall has exposed underlying sediment in the bank (Figure 67).

Bank exposures show silty sediment with minor clay grading upwards from a light brown/grey to dark brown/dark grey with increasing organic content.

Figure 69: Overview of Nungar Creek floodplain looking downstream showing a low capacity abandoned channel abutting valley margin. Above site 160

Figure 70: Abandoned channel on floodplain showing low channel capacity and low bank heights. Site 163

Figure 71: bank failure by undercutting and block fall. Site 165

Kellys Plain Creek

Kellys Plain Creek has a laterally unconfined valley setting with continuous channel and is a fine grained, gravel bed, river system. The channel is meandering in the lower reaches where it enters Tantangara Reservoir but in the upper reaches of the study area the channel has a low sinuosity.

There is an artificial constriction of the floodplain in mid pocket. There have been remediation initiatives employed here to rehabilitate an old road crossing and this has impacted the channel and floodplain in mid pocket. The channel here is lined with coarse angular cobbles and most sediment spears fail to penetrate more than 0.20m and end abruptly at refusal on bedrock or very coarse cobbles.

This artificial constriction serves to divide the study area into two distinct zones. Zone one, upstream of the bridge and Zone Two, downstream of Site 170.

In Zone One the surficial sediment is clayey silt with common organics that decrease down profile. The profile coarsens downwards to a bedload lag deposit of gravelly sand with the interstitial spaces filled with light silty clay. At the downstream limit of the study area the surficial sediment is dark grey silty organic and clayey that coarsens downward to gravelly and silty light grey clay overlying basal cobbles. In this zone the infiltration and transmission rate for the surface deposits is high and the subsurface sediment is low.

In Zone Two the surficial sediment is a fine silty organic rich loam that provides no restriction to penetration of the spear. This surface material has no compaction and very minor clay and therefore would present a high hydraulic connectivity.

Underlying this material the sediment stack has increasing frequency of rock fragments down profile. This basal material is saprolite over weathered bedrock and would have a very low infiltration and transmission rate.

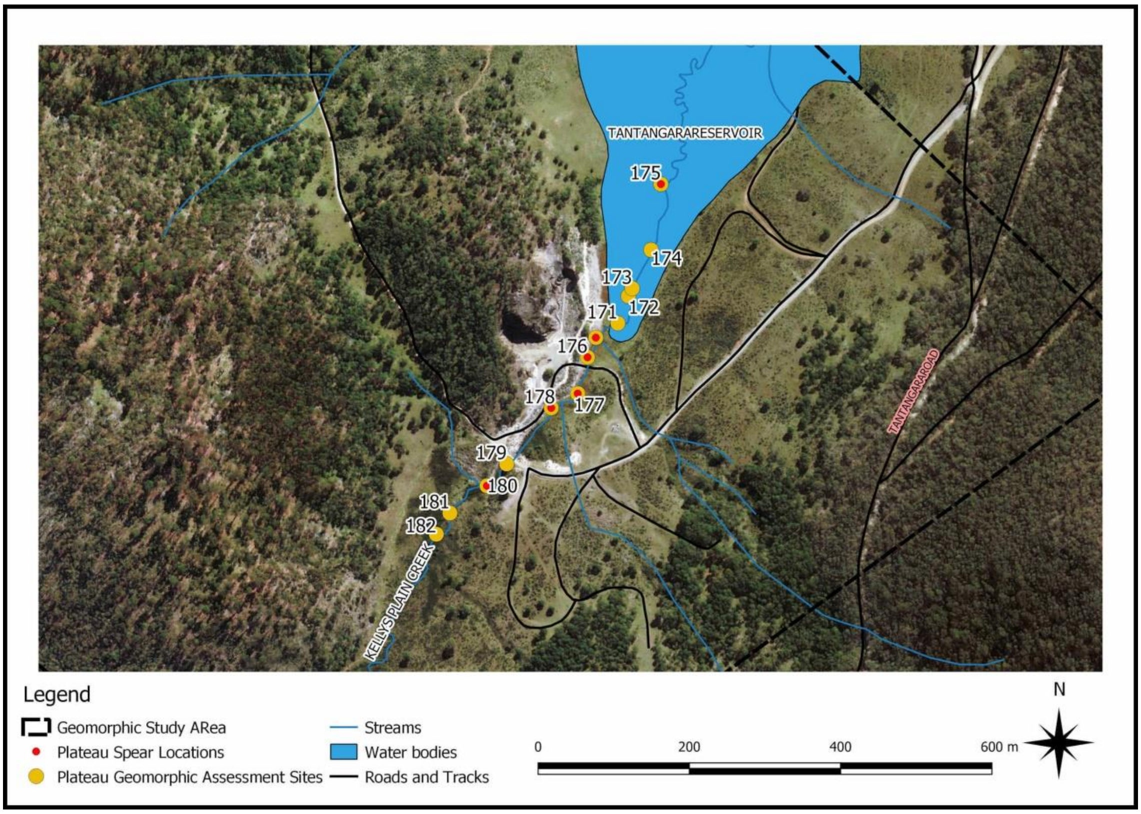


Figure 72: Kellys Plain Creek Assessment Sites.

Location:	Kellys Plain Creek
Geomorphic assessment Locations:	Plateau assessment locations 170 - 182
River Styles code:	PCVS CC
River Styles categorisation:	Partly confined valley setting with continuous channel. Low sinuosity, fine grained, planform controlled.
Geomorphic condition:	Moderate
Fragility:	Moderate
Notes:	There is little variation of form and process associations along Kellys Plain Creek study reach. Mid reach of the study area, downstream from the road crossing at site 179 to site 170,the channel zone has been extensively modified (Figure 74) with boulders and gravel from the adjacent quarry.

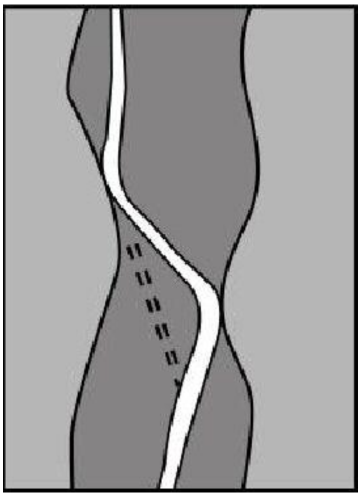


Figure 73: Partly confined valley setting, continuous channel, planform controlled.

The lower end of the reach adjacent to the Tantangara Reservoir is more sinuous than the upper reaches and there are knickpoints migrating upstream (Figure 75).

Figure 74: Kellys Plain Creek looking upstream adjacent to quarry. Site 170

Figure 75: Knickpoint retreat at assessment site 171.

At the location of the quarry the channel abuts left valley margin and is lined with angular to subangular large cobbles and gravel. This material appears to have been placed in the channel as a remediation initiative to stabilise the channel zone and to remediate an old track crossing of the creek.

Downstream of the quarry the channel migrates from left valley margin to right valley margin. There is an active knickpoint at assessment site 170 (Figure 75) that exposes subsurface floodplain fill sediments of silty clay overlying cobble and gravel lag deposits.

Downstream of the knickpoint the channel becomes a slot with channel width of generally less than one metre and 0.75m deep. The channel has incised into the floodplain material and has exhumed remnant gravel and cobble lags (Figure 76).

Figure 76: Basal gravel lag deposits being exhumed by contemporary channel incision after knickpoint retreat.

Immediately upstream of the road crossing (Site 179) the channel has been heavily modified in what appears to be a remediation and stability initiative. At this location the channel has incised and exposed a bedrock sheet in the channel floor. This bedrock exposure will exert local base level control and limit channel incision processes associated with potential knickpoint retreat.

The channel in the reach upstream of site 179 changes character and becomes well vegetated, with stable banks, and channel. The channel is armoured with well-rounded cobbles and gravel

Figure 77: Channel gravel lag armour and well vegetated stable banks of the channel upstream of the crossing. Assessment sites 179 and 182.

Marica

The Marica assessment was conducted primarily to capture a snapshot of the current geomorphic conditions of the streams draining north and south of the proposed site of a surge tank. This assessment seeks to make a determination on the stability of these streams and the potential impact of excess discharge from the surge tank.

Both tributaries can be characterised as steep headwaters with confined valley setting that is bedrock controlled. In the upper reaches of both tributaries there is no continuous channel and the drainage lines exist as a broad depression on intact valley fill. The valley fill consists of colluvium with common angular clasts evident at the surface.

Northern Tributary

Location:	Marica
Geomorphic assessment Locations:	Plateau assessment locations 183, 185 – 189 (Figure 78)
River Styles code:	SH IVF DC
River Styles categorisation:	Steep headwaters, discontinuous channel on intact valley fill.
Geomorphic condition:	Good
Fragility:	High
Notes:	The upper reach of the northern tributary is an intact valley fill of colluvium consisting of silt with abundant gravelly angular rock fragments. Rock fragments increase in frequency down profile as the sediment spear penetrates to bedrock. Further down slope a continuous channel begins to form and the surface material becomes organic rich silt over saprolite.

There is no distinct channel but the upper catchment exists as a broad depression that defines a zone of flow (Figure 81) rather than a distinct channel. Surface sheet flows are evidenced by common litter dams on the surface.

The surface material has a moderate infiltration and transmission potential. Subsurface, the saprolite is generally fine grained and has a low infiltration and transmission potential.

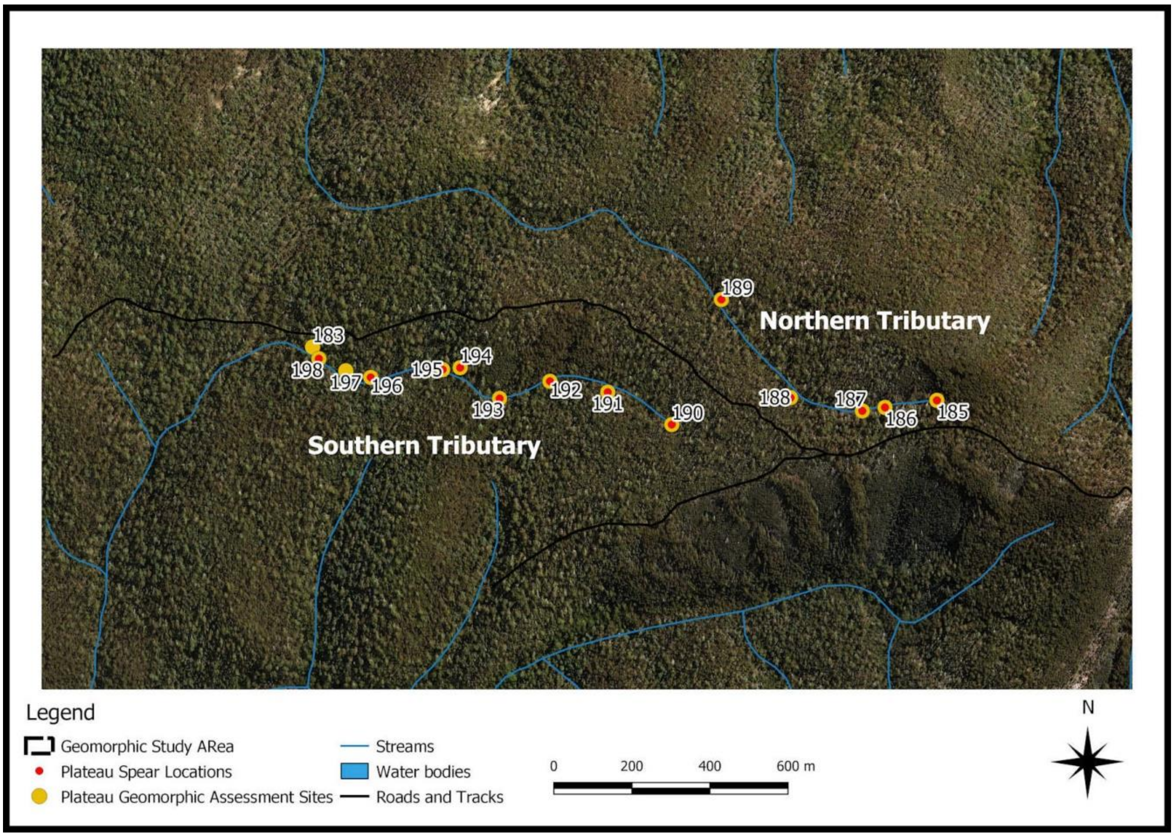
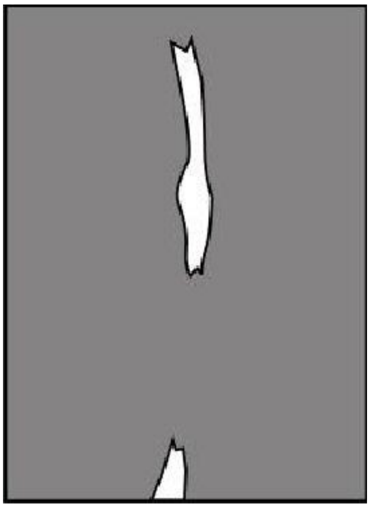


Figure 78: Marica location of Assessment Sites.

Southern Tributary

Location:	Marica
Geomorphic assessment Locations:	Plateau assessment locations 183, 190 – 198 (Figure 78)
River Styles code:	SH IVF DC
River Styles categorisation:	Steep headwaters, discontinuous channel on intact valley fill.
Geomorphic condition:	Good
Fragility:	High
Notes:	The upper reach of the southern tributary is very similar to the northern tributary. It consists of an intact valley fill of colluvium consisting of silt and fine sand with abundant gravelly and angular rock fragments that increase in frequency down profile terminating in saprolite.



The upper reach of the tributary has no continuous channel until site 194. From that locality a channel begins to form, discontinuous at first but continuous from site 196. As the channel begins to form the character of the surficial sediments within the channel zone begin to change. Rather than being dominated by colluvium and saprolitic material (Figure 80) the surface sediment has a greater organic content and is a product of transport by water. This upper profile will have a high infiltration and transfer rate.

Figure 79: Steep headwaters, intact valley fill, discontinuous channel

The subsurface material is a fine grained and silty with very little clay. Sites 188 – 194 have slightly more clay in evidence than other adjacent sites. This fine grained, silty and clayey sediment limits the hydraulic connectivity and restricts the transfer of water through the subsurface.

Figure 80: Clasts of angular colluvium, interpreted as saprolite, exposed on the surface. Site 185

Figure 81: Broad shallow depression in the upper catchment that defines channel zone; no continuous channel.

Lobs Hole

Overview

A geomorphic assessment of the Yarrangobilly River at Lobs Hole was completed from the location of the upstream access tunnel portal to the backwaters of the Talbingo Reservoir impoundment. There was very little variability of the morphology and form process associations of the Yarrangobilly River through the study area.

Nominally, the Yarrangobilly River exists as a partly confined, planform controlled, low sinuosity, gravel bed river with a continuous channel. Channel slope is variable (Figure 82) and is characterised as pool – riffle and pool – rapid – run sequences across cross channel cobble and boulder bars. There are common cross channel bedrock bars with more energetic flows where channel slope is higher. These are characterised as rapids and cascades separated by elongate fast moving runs – glide – pools.

The criteria of assessment were somewhat different to those used on the plateau streams. The criteria used on the Yarrangobilly River, and its tributaries, were channel sinuosity, channel width, bank height and what the controls on vertical and lateral channel adjustment are.

Channel dimensions, channel width and the length of pool/riffle sequences, were measured with a Bushnell range finder. Visual assessments of the maximum cobble and boulder clast size were completed by measuring the Bmax axis with a tape measure. The clast size of finer sediments was assessed with the use of a standard grainsize card and hand magnifying lens. Sediment clast size is described using the Wentworth (1922) criteria (Appendix 1).

The Yarrangobilly River at Lobs Hole flows through a steep sided valley and has a flat valley floor that has a variable width from 130m at site 210 to 140m at the road ford adjacent to site 240 (Figure 82).

The flat valley floor was initially assessed as the Yarrangobilly River floodplain. However, during field work it was discovered that tributaries entering the valley lose channel capacity as they cross the floodplain. Only the largest tributaries, such as Sheep Station Creek and Wallaces Creek, have sufficient flow to have incised a continuous channel across the floodplain. Further investigation found that there is a very coarse layer of cobbles and boulders underlying the floodplain. Small tributaries that enter from valley margin are able to rapidly infiltrate these coarse sediments and flows continue subterraneously. The Yarrangobilly floodplain is not a floodplain in the sense that it has been deposited by vertical accretion of sediments in a fining upwards sequence. The floodplain consists of coarse cobbles and boulders that have been covered with a thin veneer of finer sediments that also partially infill the interstitial spaces.

Additional aerial photo interpretation subsequent to field investigations identifies this area as a paleo channel of the Yarrangobilly River. The contemporary form process associations are unable to account for the planform of the main channel and the cobble lag deposits underlying the floodplain. The Yarrangobilly River is manifestly underfit *sensu* George Dury 1964a. Additional investigations would be necessary to confirm this assessment but that is not essential to satisfy the scope of this study.

One of the clues that indicate a paleo channel of great antiquity is the sediment fans that have built out from small tributaries entering from the valley margin (Figure 83). The accretion rate for these fans would be very slow and indicate extended periods of deposition where inflows became subterranean and sediment load was progressively built as a fan structure across the floodplain. These sediment fans also indicate that the main contemporary Yarrangobilly River channel has been laterally stable for an extended period of time as the sediment fans have not been reworked by channel evolution and meander migration.

Geomorphic Characterisations

Location:	Yarrangobilly River main channel
Geomorphic assessment	
Locations:	Assessment sites 199 – 210, 216 – 218, 220 – 225, 239 – 240, 243 – 244, 255 – 258, 259 – 260, and 262 – 264
River Styles code:	PCVS CC
River Styles categorisation:	Partly confined valley setting, planform controlled, low sinuosity, gravel bed river with a continuous channel
Geomorphic condition:	Good
Fragility:	Low
Notes:	The Yarrangobilly River is a cobble and boulder bed river where the channel has a low sinuosity and migrates across the valley floor to abut valley margin and bedrock control at both banks. Bedrock is exposed in the channel bed and often forms cross channel bedrock bars that exert localised base level controls. The channel is characterised by a series of rapids and cascades over these bedrock bars and turbulent flows abate downstream in elongated glide – run sequences before encountering another bedrock or cross channel boulder and cobble bar. The channel width is variable but approximates 35 m. Basal boulder and cobbles lag deposits are exposed in bank exposures throughout the study area.

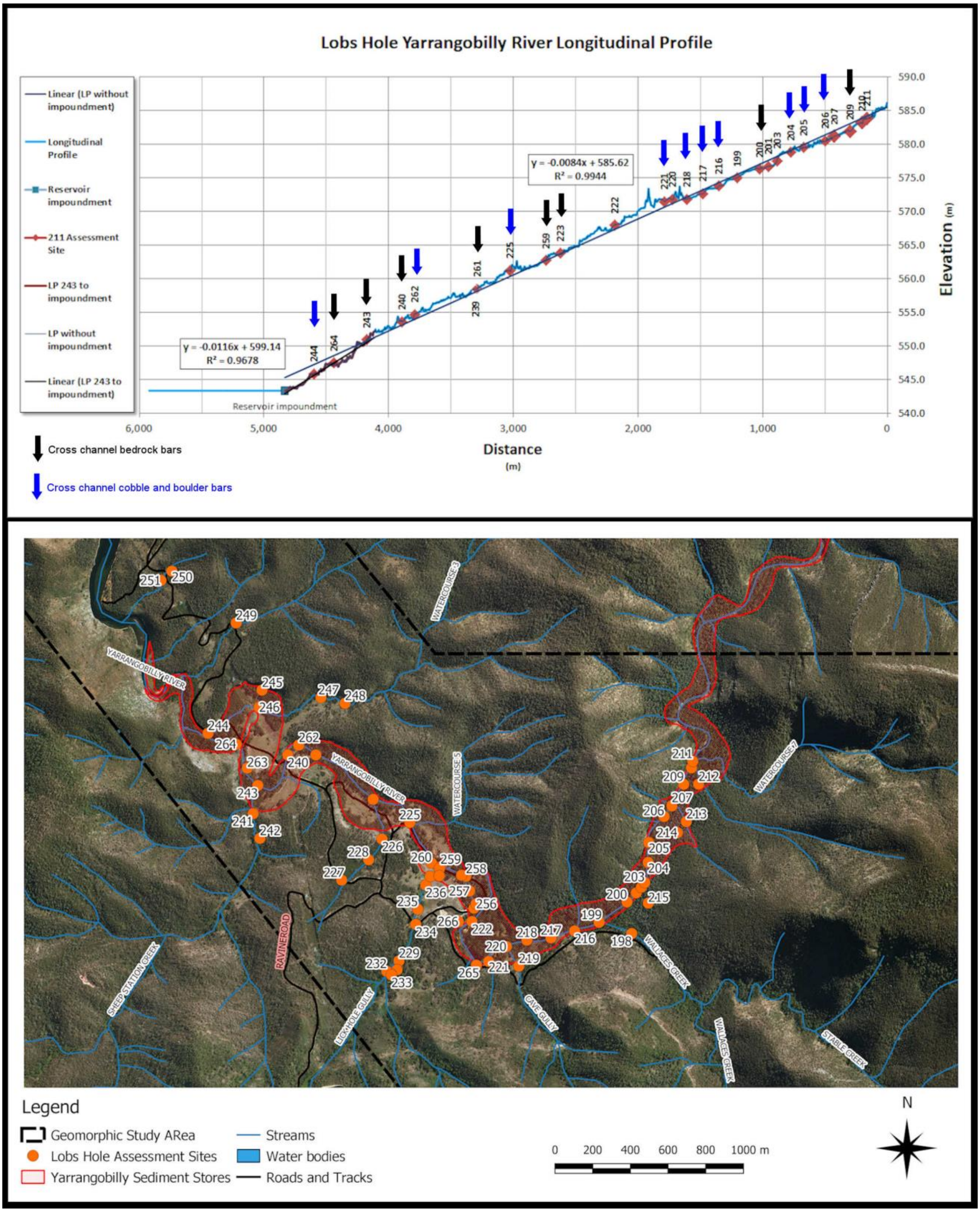


Figure 82: The planform and longitudinal profile of the Yarrangobilly River, Lobs Hole, study area showing the geomorphic assessment sites and the location of cross channel bedrock and cobble bars

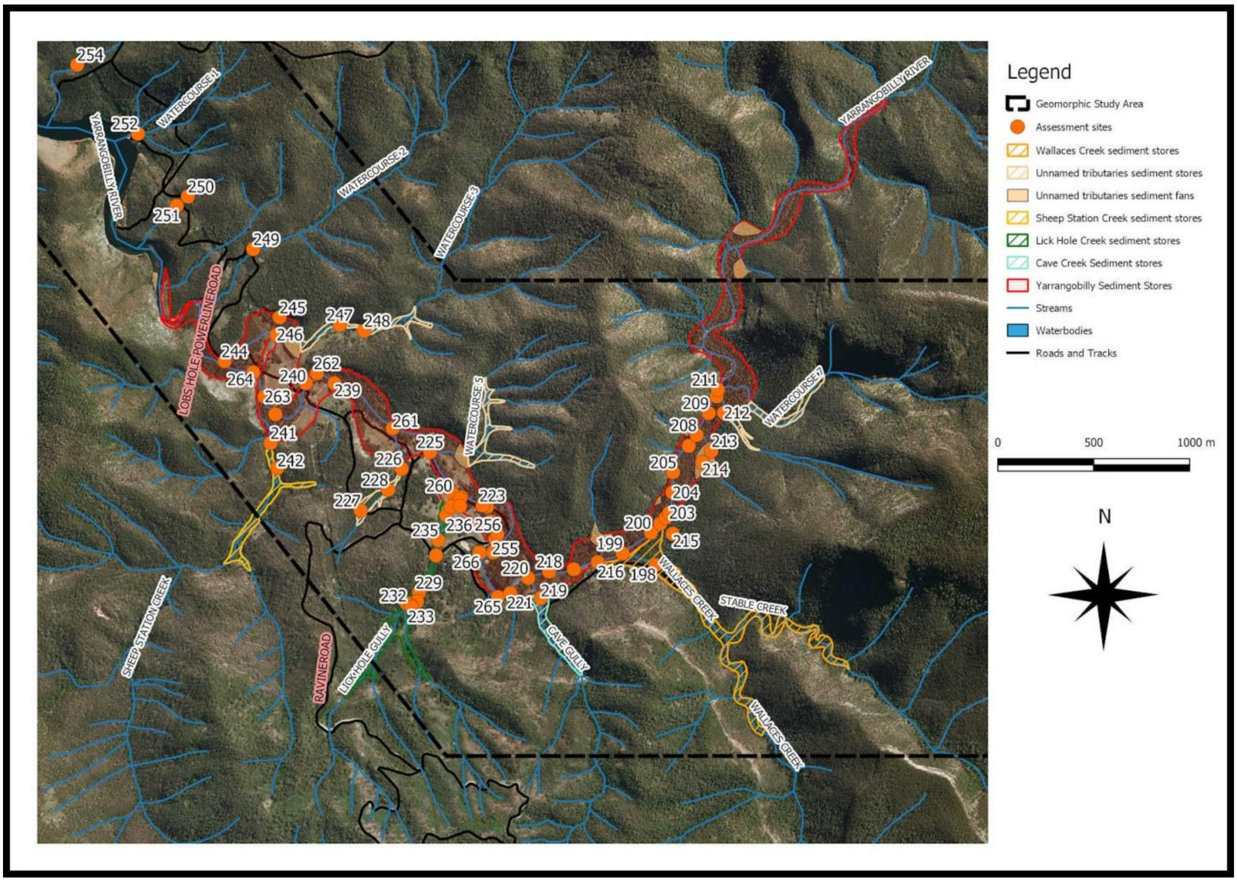


Figure 83: Sediment stores and fans along the Yarrangobilly River and its tributaries, Lobs Hole

Location:	Wallaces Creek
Geomorphic assessment Locations:	Assessment sites 198 – 199 (199 Yarrangobilly confluence)
River Styles code:	CVS CC
River Styles categorisation:	Laterally confined valley setting, low sinuosity, with a continuous channel.
Geomorphic condition:	Good
Fragility:	Low
Geomorphic management:	Conservation
Notes:	Wallaces Creek has a continuous channel that is incised into the floodplain and extends to the Yarrangobilly River. There are discontinuous pockets of floodplain at both banks. Wallaces is a boulder and cobble bed river and boulders and cobbles are exposed in both banks.

Location:	Lobs Hole Watercourses 6 and 7
Geomorphic assessment Locations:	Assessment sites 210 - 212
River Styles code:	SH CC then UVS DC
River Styles categorisation:	Steep headwaters Continuous Channel until the Yarrangobilly Floodplain is reached then Unconfined Valley Setting with discontinuous channel. Surface flows become subterranean and channels become discontinuous
Geomorphic condition:	Good
Fragility:	Low

Notes: The channel capacity of these tributaries decreases as they cross the geomorphic feature initially interpreted as the Yarrangobilly floodplain. Channelised flows entering from valley margins infiltrate surficial sediments that are comprised of silty and sandy loam. As these surface flows become subterranean flows the channel capacity of the tributary decreases and in some instances the surface channels cease altogether.

The tributary flows pass through the coarse boulder and cobble basal channel lag layer of the paleo Yarrangobilly River. The confluences of these tributaries with the contemporary Yarrangobilly River are indistinct, at best, and often there is no confluence as the subterranean flows join the main channel within the cobble layers on the main channel.

Location: Unnamed tributaries 4, 5 and 6

Geomorphic assessment Locations: Unnamed tributary 4; 215 Unnamed tributary 5; 206 and 214 Unnamed tributary 6; 208 and 213

River Styles code: SH CC then UVS DC

River Styles categorisation: Steep headwaters Continuous Channel until the Yarrangobilly Floodplain is reached then Unconfined Valley Setting with discontinuous channel. Surface flows become subterranean and channels become discontinuous

Geomorphic condition:

Fragility: Low

Notes: The channel capacity of these tributaries decreases as they cross the geomorphic feature initially interpreted as the Yarrangobilly floodplain. Channelised flows entering from valley margins infiltrate surficial sediments that are comprised of silty and sandy loam. As these surface flows become subterranean flows the channel capacity of the tributary decreases and in some instances the surface channels cease altogether. The tributary flows pass through the coarse boulder and cobble basal channel lag layer of the paleo Yarrangobilly River. The confluences of these tributaries with the contemporary Yarrangobilly River are indistinct, at best, and often there is no confluence as the subterranean flows join the main channel within the cobble layers on the main channel.

Location: Cave Gully

Geomorphic assessment Locations: Assessment sites 219 – 220 (220 at confluence with Yarrangobilly River)

River Styles code: UVS DC

River Styles categorisation: Laterally unconfined valley setting, planform controlled, low sinuosity, with a discontinuous channel.

Geomorphic condition: Moderate

Fragility: Low

Notes: Cave Gully exits from confinement at valley margin where confinement is exerted by the colluvial footslope. Saprolite is exposed in the left bank prior to exit from confinement. Cave Gully has built a sediment fan of juvenile sediment with subangular to angular clasts scattered throughout. Channel capacity decreases once the channel crosses the floodplain. The channel crossing the sediment fan is less than one metre deep and less than one metre wide. The depth of sediment mid channel is 0.63m.

Figure 84: Cross channel bedrock bar and cascade at assessment site 210.

Figure 85: Rapid - run sequence over cross channel boulder and cobble bars downstream of bedrock bar in Figure 85. Site 210

Location:	Unnamed Tributary 3
Geomorphic assessment Locations:	Assessment sites 221
River Styles code:	SH CC
River Styles categorisation:	Steep headwaters with continuous channel
Geomorphic condition:	Good
Fragility:	Low
Notes:	Unnamed tributary 3 is characterised as steep headwaters, channelised valley fill on colluvium. Saprolite and colluvium exposed in bank upstream of road crossing. Channel joins Yarrangobilly River at a gravel bed chute, or flood runner. Chute mouth has been closed off by deposition of a bar of Yarrangobilly bedload material.

Figure 87: Image 1 (left) is the Yarrangobilly main channel at the confluence with Wallaces Creek. Image 2 (right) is Wallaces Creek at confluence. Both channels are cobble bed rivers and both channels display basal gravel lag deposits in the banks. Site 200

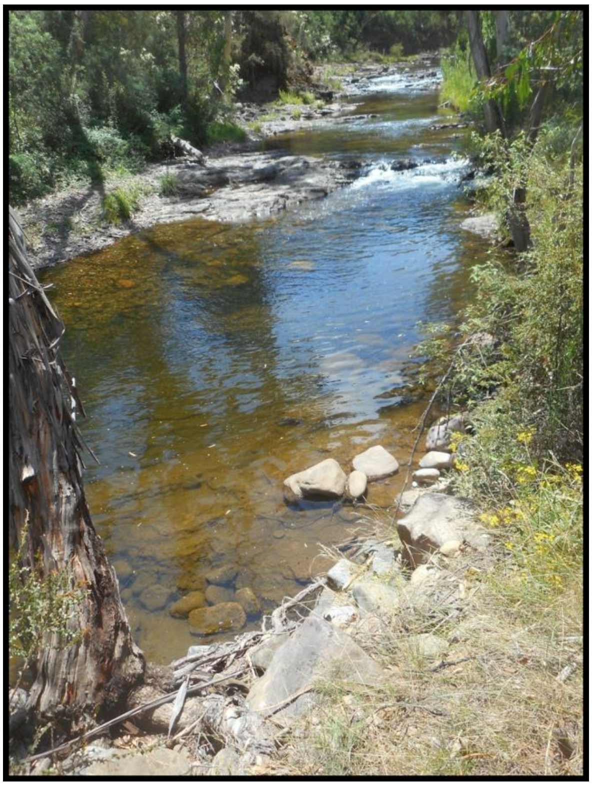


Figure 86 : Main channel of Yarrangobilly River at Assessment site 224.

There are multiple rapids and cascades over cross channel bedrock bars indicating a steepening of channel slope.

The runs between the bedrock bars are scoured to bedrock in places but are generally cobble armoured otherwise.

There are basal gravel lag deposits exposed in the base of left bank in the right foreground of the image.

Figure 88: Channel is incised to bedrock on Unnamed Tributary 5 assessment site 228.

Saprolite and colluvium are exposed in the wall of the left bank.

Location:	Lobs Hole Watercourse 4
Geomorphic assessment Locations:	Assessment sites 261 at Yarrangobilly confluence, 226 – 228
River Styles code:	UVS DC
River Styles categorisation:	Laterally unconfined valley setting, planform controlled, low sinuosity, with a discontinuous channel.
Geomorphic condition:	Poor
Fragility:	High
Notes:	Lobs Hole Watercourse 4 at site 226 is incised to bedrock through colluvial footslope. Channel banks are 4 - 4.5 m and sub vertical. Channel floor has base of bedrock with occasional pools. Colluvium has common orange mottling that indicates subaerial/subaqueous environment after deposition. Upstream of the road crossing at site 227 there is a broad channel zone with no continuous channel. This represents an intact valley fill that is in good condition and has a high fragility.

Location:	Lick Hole Gully
Geomorphic assessment Locations:	Assessment sites 224 and 259 at confluence, 229 – 238
River Styles code:	UVS DC
River Styles categorisation:	Laterally unconfined valley setting, planform controlled, low sinuosity, with a discontinuous channel where it crosses the floodplain. Upstream there is a continuous channel that decreases in capacity upstream
Geomorphic condition:	Moderate
Fragility:	High
Notes:	In the upper reaches of the Lick Hole Gully study area there is a continuous channel less than 2 m wide at right valley margin. The banks

Figure 90: Low capacity channel reworking and transporting sediments at assessment site 232.

consist of organic rich clays with minor silt and approx. 20% clay content. There are rare lithic clasts to 1.5 cm Bmax. The low flow channel has been reworking floodplain sediments and lag deposits of granules and small clasts less than 1 cm remaining.

There are common pools that have deposits of silt and clay. The valley floor appears to be a floodplain that has been stripped out and an inset floodplain now has small channels and abandoned channels.

At left valley margin (site 232) there is an abandoned channel with no well-defined banks but exists as a shallow channel depression approx. 2-4 m wide with variable width and depth.

Lick Hole Gully upstream of road crossing (site 235, Figure 93) occupies a broad channel zone with an inset floodplain 35-50 m wide.

The colluvial footslope extends to both channel margins. Upstream channel is poorly defined with common pools extending into a swampy channel zone (Figure 91).

Downstream of road is a well-defined channel incised in multiple steps of around 40 cm to 1.2 m. Semi intact valley fill that is partially channelised extends between assessment sites 235 and 236 (Figure 93).

The inset floodplain at left bank has incised into a sediment fan deposit with moderate angle slop. High angle slope commences at fan/footslope boundary.

At site 237 there are large cobbles/boulders exposed in left bank that are exhumed floodplain sediments of the Yarrangobilly.

Figure 91: Intact valley fill on Lick Hole Gully above road crossing. Site 234

Figure 93**: Channelised valley fill. Assessment site 235.**

Figure 92: Channelised valley fill with low capacity channel at assessment site 238.

Lick Hole Gully channel loses capacity after it crosses onto Yarrangobilly River floodplain. Channel dimensions are less than 50cm across and less than 40 cm deep and is variable becoming discontinuous upstream of the road crossing at site 239.

There is no surface flow and channel capacity has decreased from upstream. Surface flows progressively infiltrate into floodplain sediments and flows underground.

Surface sediment is silty/organic loam. Spear point encounters fine silty clay to 0.20m then gravel at 0.25m and penetrates to refusal at 0.68m. Spear point has clay coating when removed from hole.

At site 238 the laterally unconfined Lick Hole Gully crosses the floodplain of Yarrangobilly River; however, increasing infiltration into underlying gravel, and cobble, layers reduces available stream power at surface for channel migration, or adjustment.
Lick Hole Gully channel capacity continues to decrease downstream. Surface flows become less voluminous and discontinuous as flows pass into cobble and boulder field of basal floodplain sediments.
From this location the channel becomes discontinuous until road crossing approximately 25m away.

Location:	Sheep Station Creek
Geomorphic assessment Locations:	Assessment sites 241 – 243 (243 is confluence with Yarrangobilly)
River Styles code:	Site 241 PCVS CC; Site 242 CVS CC
River Styles categorisation:	Site 241 Partly confined valley setting, planform controlled, low sinuosity, with a continuous channel Site 242 Confined valley setting with discontinuous pockets of sediment storage

Figure 94:
Sheep Station Creek after exit from bedrock confinement and commencement of flow across the floodplain with diminishing channel capacity. Site 241

Geomorphic condition:	Moderate
Fragility:	Moderate
Notes:	Site 241 is located at the valley margin where the contemporary channel exits from confinement. Upstream of here there are discontinuous pockets of sediment storage that are not floodplain pockets but are channelised valley fill. The channel is exhuming both colluvial and alluvial sediments that are exposed in both banks. Exposed clasts are sub rounded to rounded alluvial sediments and angular to very angular colluvial sediments. The Yarrangobilly channel at the confluence (site 244) is a series of cross channel bedrock bars characterised by rapids, cascades with riffles over partially submerged cobbles (Figure 94).

Figure 95: Yarrangobilly River main channel at confluence with Sheep Station Creek. Site 244

Location:	Lobs Hole watercourse 3 (right bank)
Geomorphic assessment	
Locations:	Assessment sites 244 – 248 (244 is confluence with Yarrangobilly)
River Styles code:	PCVS CC
River Styles categorisation:	Partly confined valley setting, planform controlled, low sinuosity, with a continuous channel
Geomorphic condition:	Moderate
Fragility:	Moderate
Notes:	Sites 247 and 248 are located on the tributary that joins from right valley margin. The channel is pinned against colluvial footslope at right bank and at left bank is low angled organic silt with common sub angular clasts. The channel is moderately sinuous and the channel bed is cobble armoured.

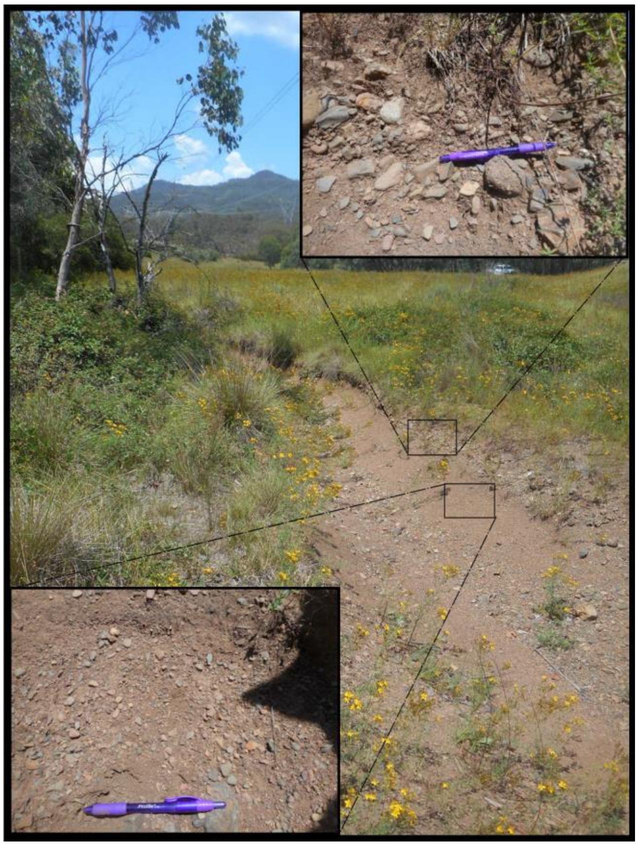


Figure 96: Lobs Hole Watercourse 3 as it flows across the Yarrangobilly floodplain.

Juvenile sediments with abundant subangular and subrounded clasts are evident in the channel bed and bank.

Sites 245 and 246 are located at valley margin extremities of the abandoned channel of the paleo Yarrangobilly. At site 245 there is no defined channel crossing the floodplain or at margin. Valley margin is bedrock with a vertical to sub vertical slope.

There is a continuous channel at left margin 1.5-2 m wide and 1.2 m deep. This is the channel from Unnamed Tributary 6 described at sites 247 and 248. Juvenile sediment of sub angular to sub rounded clasts is exposed in the top of the bank (Figure 96). Lower bank consists of granular rock fragments and silt.

There is a low angle sediment fan that has built out where the tributary debouches onto the floodplain.

Site 244 is the confluence of unnamed tributary 6 and Yarrangobilly River. Unnamed Tributary 6 actually debouches into an abandoned Yarrangobilly River channel at valley margin. Bedrock exposed in right bank of the channel. The main Yarrangobilly river channel is 15-18 m wide cobble and boulder bed river. Channel flow is characterised by a riffle run sequence.

Location:	Lobs Hole watercourse 2 (right bank)
Geomorphic assessment Locations:	Assessment sites 249
River Styles code:	SHVS CC
River Styles categorisation:	Steep headwaters valley setting, continuous channel, bedrock controlled, low sinuosity, with a continuous channel
Geomorphic condition:	Moderate
Fragility:	Moderate

Notes: **Figure 97: Unnamed Tributary 2. Intact valley fill with no defined channel zone upslope of road crossing at assessment site 250.** rage

Figure 98: Intact valley fill with broad channel zone but no distinct channel. Assessment site 251; downslope of road crossing.

along channel margins.

Upstream of the road crossing the channel is a narrow slot of variable depth to 1 m and width to less than 1 m.

Location:	Unnamed Tributary 2 (right bank)
Geomorphic assessment Locations:	Assessment sites 250 – 251
River Styles code:	SHVS IVF
River Styles categorisation:	Steep headwaters valley setting, intact valley fill
Geomorphic condition:	Good
Fragility:	High
Notes:	At site 250 upstream from road crossing there is a steep headwaters valley setting with intact valley fill and no well-defined channel. At site 251, downslope of road crossing, there is an intact valley fill, steep headwaters. While there is no continuous channel there is a channel zone depression across valley floor. Colluvial footslope extends to channel zone margin. There is no well-defined channel.

Figure 99: Very juvenile sediment of angular lithic clasts deposited in a sediment fan extending from tributary mouth into Talbingo reservoir. Site 252

Location:	Lobs Hole Watercourse 1 (right bank)
Geomorphic assessment Locations:	Assessment site 252 at Talbingo Reservoir
River Styles code:	PCVS CC
River Styles categorisation:	Partly confined valley setting, planform controlled, low sinuosity, with a continuous channel
Geomorphic condition:	Moderate
Fragility:	Moderate
Notes:	Sediment fan of gravel and larger very angular clasts form a fan extending out from channel mouth into Talbingo reservoir impoundment (Figure 99).

	The channel has narrow discontinuous floodplain pockets at both banks and has low sinuosity channel morphology from colluvial margin to colluvial margin.
	Upstream the channel is 1.8 m wide and 1.5 m deep and has a steep slope. Channel is armoured with cobbles that are variable size, sub angular to very angular. No rounded clasts.

Location:	Unnamed Tributary 1 (right bank)
Geomorphic assessment Locations:	Assessment sites 253 – 254
River Styles code:	SHVS DC
River Styles categorisation:	Steep headwaters valley setting with a discontinuous channel
Geomorphic condition:	Moderate
Fragility:	Moderate
Notes:	At site 253, the channel is discontinuous upslope of road crossing. Downslope the channel is continuous and is confined by bedrock at its base and by saprolite/colluvium in the banks. There is no floodplain or storage of alluvial deposits at channel margin. The channel is incised into colluvium. Low sinuosity discontinuous channel becomes continuous 50 m (approx.) below road. "V" shaped valley with channel zone occupying 2-3 m of valley floor. At site 254 there is a continuous channel that is approximately 1 m wide and with variable depth of 1.2 - 1.5m. The channel has a low sinuosity and is bedrock controlled. The channel is incised into colluvium and has exposed bedrock in channel base and banks.

Lobs Hole Assessment Sites Synopsis of Channel Confinement and Margin Controls

Yarrangobilly River

Assessment Sites 199 – 210

199	Rapids and riffles with cross channel boulder and cobble bar. Channel width 14m
200	Cross channel bedrock bar with rapids. Channel width 14m
201	Cross channel bedrock bar
202	Elongate reach of cascades over cross channel bedrock bars
204	No bedrock bars. Cobbles and boulder bed
205	Bedrock at right bank. Gravel, cobble and boulder armouring of the bed of the river
206	No bedrock bars. Cobbles and boulder bed. Channel width 14m
207	Cobble and gravel armoured rapid and riffle sequence.
208	Bedrock at right bank but no bedrock base level control

209	Cross channel bedrock bar with rapids and cascades.
210	Bedrock at right bank but no bedrock base level control

Assessment Sites 216 – 218

216	Cobble and boulder bed river
217	Cross channel boulder and cobble bar
218	Cobble and boulder bed river. Start of 105m elongate pool

Assessment Sites 220 – 225

220	Cobble and boulder bed river downstream end of elongate pool at 218
221	Cross channel cobble and boulder bar; bedrock at left bank
222	Riffles and rapids over cobble and boulder bed; bedrock at left bank
223	Plunge pool downstream of multiple cross channel bedrock bars
224	Bedrock exposed in channel forms cross channel bedrock bars
225	Cobble and boulder bed river downstream end of elongate pool

Assessment Sites 239 – 240

239	Cross channel bedrock bar downstream. Cobble bar upstream
240	Bedrock control in right bank. Upstream is a bedrock cross channel bar with a two-step cascade.

Assessment Sites 243 – 244

243	A series of cross channel bedrock bar characterised by rapids, cascades with riffles over partially submerged cobbles.
244	Cobble and boulder bed river with bedrock in right bank

Assessment Sites 255 – 258 Chute on Yarrangobilly

255 – 257	Cobble and boulder bed chute
258	Cobble and boulder bed river with cross channel bedrock bars

Assessment Sites 259 – 260 Confluence with Lick Hole Gully

259	Bedrock exposed in channel floor.
260	Bedrock exposed in channel floor.

Assessment Sites 262 – 264

262	Rapids over cross channel boulder and cobble bars. Bedrock exposed in channel floor downstream.
263	Multiple rapids over bedrock bars and cobble/boulder bars.
264	Cobble and boulder bed river bedrock control.

Yarrangobilly River Tributaries

Assessment Sites 198 - 199 Wallaces

Boulder and cobble bed river. Boulders and cobbles are exposed in both banks

Assessment Sites 211 – 215

211 Lobs Hole Watercourse 7 confluence

Boulders and cobbles exposed in the channel base. Flow would be mostly sub surface through coarse substrate.

212 Lobs Hole Watercourse 6

Channel zone is poorly defined broad depression approx. 3 m across with discontinuous channel.

213 Unnamed Tributary 6

Channel zone is broad depression approx. 4 m across with discontinuous channel

214 Unnamed Tributary 5at colluvial margin.

Angular colluvial clasts exposed in banks and channel base

Assessment Sites 219 and 221 Cave Gully confluence

219 Sediment fan exiting from confinement at valley margin

221 Cave Gully meets Yarrangobilly at cobble bed chute

Assessment Sites 226 – 228 Lobs Hole Watercourse 4 (left bank)

226 Channel floor has base of bedrock with occasional pools.

227 Intact valley fill on colluvium.

Assessment Sites 229 – 238 Lick Hole Gully

230 Tributary is "V" shaped and is incised into alluvium.

231 Continuous channel is less than 2 m wide. The banks consist of organic rich clays with minor silt and approx. 20% clay content.

232 Shallow channel depression approx. 2-4 m wide with variable width.

233 Right margin has slaking and dispersive soils exposed.

234 Broad channel zone is poorly defined with common pools extending into a swampy channel zone.

235 Broad valley floor with channelised fill is 25-30 m wide and low flow channel is inset 52 cm deep and approx. 75 cm wide. There is no flow within channel. All flow is now subterranean.

236 Poorly defined channel is less than 2 m wide with low angled banks. Flows are predominately subterranean.

237 There are large cobbles/boulders exposed in left bank that are exhumed floodplain sediments of the Yarrangobilly.

No surface flow and channel capacity has decreased from upstream. Surface flows progressively infiltrate into floodplain sediments and flows underground.
Surface is silty/organic loam.

238 Lick Hole Gully channel capacity continues to decrease downstream. Surface flows become less voluminous and discontinuous as flows pass into cobble and boulder field of floodplain sediments.

Assessment Sites 241 – 242 Sheep Station Creek (243 is Yarrangobilly Confluence)

241 Channel is exhuming both colluvial and alluvial sediments that are exposed in the banks. Clasts are sub rounded to rounded alluvial sediments and angular to very angular colluvial sediments.

242 Confined valley setting, bedrock controlled with small discontinuous pockets of sediments.

Moderately sinuous channel is pinned against bedrock at valley margin right bank.

243 (Yarrangobilly Confluence)

The tributary banks have deposits of cobbles and small boulders exposed in the banks and base of the channel. Incised valley fill (?) Clasts are subrounded to angular indicating a mix of both fluvial and colluvial deposits, The Yarrangobilly channel is a series of cross channel bedrock bars characterised by rapids, cascades with riffles over partially submerged cobbles.

Assessment Sites 244 – 248 Lobs Hole Watercourse 3 (right bank)

244 Confluence of unnamed tributary 6 and Yarrangobilly River. Bedrock exposed in right bank of main channel. Main channel is 15-18 m wide cobble and boulder bed river. Channel flow is characterised by a riffle run sequence.

245 At right valley margin there is no defined channel crossing the floodplain or at margin. Valley margin is bedrock with a vertical to sub vertical slope. Subsequent aerial photo interpretation identifies this area as an abandoned channel of the Yarrangobilly trunk *sensu* Dury 1964a.

246 Continuous channel at left valley margin. Right valley colluvial margin is 20 m away. Continuous channel is 1.5 - 2m wide and 1.2m deep. Juvenile sediment of sub angular to sub rounded clasts are exposed in the top of the bank. Lower bank consists of granular rock fragments and silt. Tributary channel margins are controlled by abandoned Yarrangobilly River bedload.

247 Channel is pinned against colluvial footslope at right bank. Left bank is low angled organic silt with common sub angular clasts.

248 Moderately sinuous channel is against colluvial footslope margin at left bank. Channel bed is cobble armoured.

Assessment Sites 249 Lobs Hole Watercourse 2 (right bank)

Unnamed tributary 7 at road crossing. Steep headwaters, continuous channel with colluvial margin extending to both bank tops. No sediment storage. Upstream of crossing the channel is a narrow slot of variable depth to 1 m and width to less than 1 m.

Assessment Sites 250 – 251 Unnamed Tributary 2 (right bank)

250 Unnamed tributary 8 upstream from road crossing. Steep headwaters valley setting; intact valley fill with no continuous channel.

251 Intact valley fill, steep headwaters. Colluvial footslope extends to channel zone margin. There is no well-defined channel.

Assessment Site 252 Lobs Hole Watercourse 1 (right bank) at Talbingo Reservoir

Sediment fan of gravel and larger very angular clast form fan extending out from channel mouth.

Channel has narrow discontinuous floodplain pockets at both banks and has low sinuosity channel morphology from colluvial margin to colluvial margin.

Assessment Sites 253 – 254 Unnamed Tributary 1 (right bank)

253 Steep headwaters valley setting with discontinuous channel. Channel is confined by bedrock base and saprolite/colluvial banks. No floodplain. Channel is incised into colluvium.

Low sinuosity discontinuous channel becomes continuous 50m (approx.) below road. "V" shaped valley with channel zone occupying 2 - 3m of valley floor.

254 Steep headwaters valley setting.

There is a continuous channel that is approximately 1m wide with variable depth of 1.2-1.5m. Channel is low sinuosity and bedrock controlled. Channel is incised into colluvium and exposes bedrock in base and wall.

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Appendix 1 - Grainsize classification used in this assessment

For this assessment the clast size classification that has been used is that of Wentworth 1922, where;

Boulders	>256mm	
Cobbles	64mm - 256mm	
Pebbles/Gravel		4mm - 64mm
	Very coarse gravel	32mm – 64mm
	Coarse gravel	16mm – 32mm
	Medium gravel	8mm – 16mm
	Fine Gravel	4mm – 8mm
Granules	2mm – 4mm	
Sand	63µ - 2000µ	
	Very coarse sand	1000µ – 2000µ
	Coarse sand	500µ – 1000µ
	Medium sand	250µ – 500µ
	Fine sand	125µ – 250µ
	Very fine sand	63µ - 125µ
Silt	4 µ - 63 µ	
Clay	<4 µ	

In all practicality, it is impossible to make determination in the field of whether sediment is fine silt or clay. Field assessment methods, with the aid of a hand lens and grainsize card, are limited by the experience of the assessor and their eyesight. To make a determination on the clay content of sediment a sample needs to be taken and made into a bolus from which a ribbon can be made. This technique can differentiate between silt and light, medium or heavy clay.

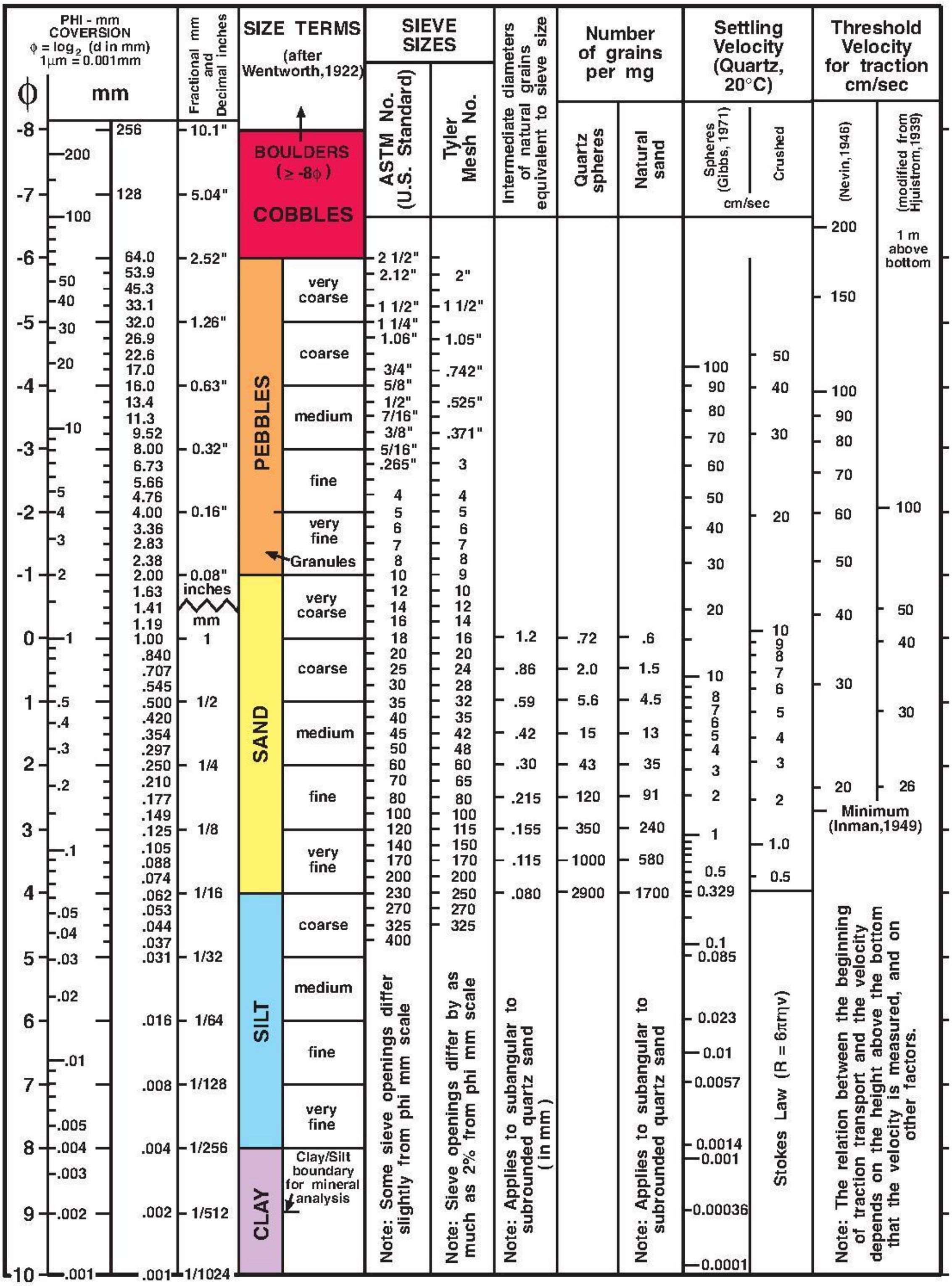

Figure 100: U.S. Geological Survey grainsize classification after Wentworth (1922).

Appendix 2 - River Style codes used in this report

Confinement code

CVS Confined Valley Setting

1. G - Gorge
2. SH - Steep headwaters
3. DF - Discontinuous floodplain pockets
    a. Fine grained
    b. Sand
    c. Gravel

LUVS Laterally unconfined valley setting

1. CC - Continuous channel
2. CF - Channelised Fill
3. CS - Channelised Swamp
    a. Low sinuosity, fine grained
    b. Low sinuosity
    c. Low sinuosity, gravel
    d. Meandering fine grained

LUVS DC Laterally unconfined valley setting, discontinuous channel

PCVS CC Partly confined valley setting, continuous channel

1. Planform Controlled
    a. Meandering, sand
    b. Meandering, gravel
    c. Meandering, fine grained
    d. Low Sinuosity, fine grained
    e. Low sinuosity, sand
    f. Low sinuosity, gravel
    g. Low sinuosity, Cobble
2. Bedrock controlled
    a. Fine grained
    b. Sand
    c. Gravel

PCVS DC Partly confined valley setting, discontinuous channel

SMG Swampy Meadow Group

1. Intact valley fill, sand
2. Intact valley fill, fine grained

Anthropogenic

Confinement Level

Confined
Partly confined
Unconfined – continuous channel
Unconfined – discontinuous channel

Margin Control

Bedrock control
Planform control
Terrace control
Fan control
Dune control
Unconfined

Planform descriptor

None
Discontinuous channel

Continuous channel
Straight
Low sinuosity
Meandering
Wandering
Anabranching
Anastomosing

Floodplain Connection

None
Discontinuous
Planform continuous
Multi-channel continuous
Valley fill

Bed substrate material

Bedrock
Boulder
Cobble
Gravel
Sand
Fine grained

Appendix 3 – Landscape Units and Characterisations

Table 1 Plateau and Marica Landscape Units and Characterisations interpreted at sediment spear locations

Assessment Site	Landscape Unit	Catchment	Geologic Unit	Dominant lithologies	Single Dominant Lithology	Weathering product	Hydrologic Group Code	Hydrologic Group description	Inferred surface hydraulic connectivity	Inferred subsurface hydraulic connectivity
2	Swampy Meadow	Eucumbene	Unnamed	pyroxene, plagioclase with minor amphibole and olivine	Basalt	Iron oxides and hydroxides, clay and silt	B	Moderate water Infiltration and transmission rate	Very High	Very low
3									Very High	Very low
4									Very High	Very low
6	Steep Headwaters		Gooandra Volcanics	pyroxene, plagioclase with minor amphibole and olivine	Gabbro		D	Very Slow water Infiltration and transmission rate	High	Very low
8			Shaw Hill Gabbro	gabbro, diorite, basic intrusive, pyroxenite					High	Very low
13	Eucumbene River		Gooandra Volcanics	gabbro, diorite, basic intrusive, pyroxenite					Moderate	Low
17									Moderate	Low
23	Swampy Meadow		Shaw Hill Gabbro				C	Slow rate of water infiltration and transmission.	High	Very low
25			Gooandra Volcanics	pyroxene, plagioclase with minor amphibole and olivine	Basalt		D	Very Slow water Infiltration and transmission rate	High	Very low
27	Eucumbene Unnamed Tributary	Gooandra Creek	Unnamed	Alkali olivine basalt, minor nepheline basanite			B	Moderate water Infiltration and transmission rate	Moderate	Low
30	Gooandra Creek Tributary 1		Gooandra Volcanics	basalt, breccia, lava, rhyolite, shale	Basalt	Iron oxides and hydroxides, clay and silt			Moderate	Low
31									High	Very low
32									High	Very low
33									High	Very low
38									Very High	Very low
39									High	Low
40									Moderate	Low
63									Moderate	low
44	Gooandra Creek						C	Slow rate of water infiltration and transmission.	Low	very low
46									Low	Very low
48									High	Low
55							B	Slow rate of water infiltration and transmission.	High	Low
70	Tantangara Creek	Tantangara Creek	Temperance Formation	tuff, chert, arenite	Tuff	clay, minor silt and sand	C	Slow rate of water infiltration and transmission.	Moderate	Very low
73									Moderate	Very low

Sediment Spear	Landscape Unit	Catchment	Geologic Unit	Dominant lithologies	Single Dominant Lithology	Weathering product	Hydrologic Group Code	Hydrologic Group description	Inferred surface hydraulic connectivity	Inferred subsurface hydraulic connectivity
80			Unnamed	granodiorite (> 65% plagioclase, > 20% quartz) gabbro	Granodiorite	dissolved oxides and hydroxides, clay from dominant plagioclase and quartz lithic sand	C	Slow rate of water infiltration and transmission.	Moderate	Very low
81									Moderate	Very low
82									Moderate	Very low
83									High	Very low
86	Central Plateau	Unnamed Tributary 1 South	Tantangara Formation	Clastic sediment, sandstone, siltstone, shale	Sandstone	sand and silt, minor clay	C	Slow rate of water infiltration and transmission.	Low	Very low
87									Low	Very low
88			Temperance Formation	Volcaniclastic; tuff, chert, arenite	Tuff	Tuff is generally generated from acid volcanics. e.g. rhyolite that consists mainly of quartz and feldspars. Weathering products are fine sand and silt and clay from feldspar.	C	Slow rate of water infiltration and transmission.	Low	High
89									High	High
90	Central Plateau	Unnamed Tributary 2 North	Tantangara Formation	Clastic sediment, sandstone, siltstone, shale	Sandstone	sand and silt, minor clay	C	Slow rate of water infiltration and transmission.	Moderate	Low
91									Moderate	Low
94			Temperance Formation	Volcaniclastic; tuff, chert, arenite	Tuff		C	Slow rate of water infiltration and transmission.	Low	Very low
95									Low	Very low
96									Low	Very low
98									High	Very low
101									High	High
103									Moderate	Very low
105	Central Plateau	Unnamed Tributary 3 North	Tantangara Formation	Clastic sediment, sandstone, siltstone, shale	Sandstone	sand and silt, minor clay	C	Slow rate of water infiltration and transmission.	Moderate	Low
107									Moderate	Low
109									Moderate	Low
111	Central Plateau	Unnamed Tributary 4 South							Low	Very low
112									Low	Very low
113									Low	Very low
114									High	Very low
115									Low	Very low
116									Low	Very low
117									High	Very low

Sediment Spear	Landscape Unit	Catchment	Geologic Unit	Dominant lithologies	Single Dominant Lithology	Weathering product	Hydrologic Group Code	Hydrologic Group description	Inferred surface hydraulic connectivity	Inferred subsurface hydraulic connectivity
118	Central Plateau	Unnamed Tributary 5 North	Tantangara Formation	Clastic sediment, sandstone, siltstone, shale	Sandstone	sand and silt, minor clay	C	Slow rate of water infiltration and transmission.	High	Low
120									High	Low
121									High	High
123									Low	Very low
130									Low	Very low
131									Low	Very low
133									Low	Very low
135	Central Plateau	Unnamed Tributary 6 South	Tantangara Formation	Clastic sediment, sandstone, siltstone, shale	Sandstone	sand and silt, minor clay	C	These soils have a slow rate of water infiltration and transmission.	Low	Very low
136									Moderate	Very low
137									Low	Very low
138									Low	Low
139									Moderate	Low
140									Moderate	Low
141									High	Moderate
142									High	Moderate
144									Moderate	Low
145									High	Moderate
146									High	Moderate
161	Nungar Creek floodplain	Nungar Creek	Tantangara Formation	Clastic sediment, sandstone, siltstone, shale	Sandstone	sand and silt, minor clay	C	Slow rate of water infiltration and transmission.	Low	Very low
162									Low	Very low
163									Low	Very low
165									Low	Very low
167									Low	Very low
169									Low	Very low
170	Kellys Plain Creek	Kellys Plain Creek	Kellys Plain Volcanics	Felsic extrusives. ignimbrite, tuff, agglomerate, rhyolite	ignimbrite	fine sand, silt and minor clay	B	Moderate water Infiltration and transmission rate	Moderate	High
175							Unknown; marked as water on GIS layer		Moderate	Low
176							B	Moderate water Infiltration and transmission rate	Moderate	Low
177									High	Very low
178									Very High	Very low
180									Very High	Very low

Sediment Spear	Landscape Unit	Catchment	Geologic Unit	Dominant lithologies	Single Dominant Lithology	Weathering product	Hydrologic Group Code	Hydrologic Group description	Inferred surface hydraulic connectivity	Inferred subsurface hydraulic connectivity
184	Marica	Outlier	Byron Range Group	conglomerate, sandstone, shale & nodular limestone	conglomerate	Conglomerate will produce a variable but generally coarser sediment that will have a variable clast lithology. Sand and silt from sandstone. Silt and dissolved load from limestone and silt and clay from shale	B	Moderate water Infiltration and transmission rate	High	Low
185	Marica	Northern Tributary	Ravine Beds, Yarrangobilly Limestone	limestone, sandstone, siltstone, shale	Limestone	Dissolved load and silt with sand, silt and clay produced from other rock types	C	Slow rate of water infiltration and transmission.	Moderate	Very low
186									Moderate	Very low
187									Moderate	Very low
188	Marica	Northern Tributary	Boraig Group	felsic extrusive; rhyolite, tuff, feldspathic sandstone, granophyre	rhyolite	fine sand, silt and minor clay	C	Slow rate of water infiltration and transmission.	Moderate	Very low
189									Moderate	Very low
190	Marica	Southern Tributary							Low	Low
191							B	Moderate water Infiltration and transmission rate	Low	Low
192									Low	Very low
193									Low	Very low
194									Moderate	Very low
195	Marica	Southern Tributary	Byron Range Group	conglomerate, sandstone, shale & nodular limestone	conglomerate	Conglomerate will produce a more variable, but generally coarser, sediment that will have a variable clast lithology. Sand and silt from sandstone. Silt and dissolved load from limestone and silt and clay from shale	B	Moderate water Infiltration and transmission rate	High	Very low
196									High	Very low
198									High	Low

Table 2 Lobs Hole Landscape Units and Characterisations

<table>
<tr><th>Assessment Site</th><th>Landscape Unit</th><th>Catchment/ Subcatchment</th><th>Geologic Unit</th><th>Dominant lithologies</th><th>Single Dominant Lithology</th><th>Weathering product</th><th>Hydrologic Group Code</th><th>Hydrologic Group description</th><th>Inferred surface hydraulic connectivity</th><th>Inferred subsurface hydraulic connectivity</th></tr>
<tr><td>255</td><td rowspan="4">Chute</td><td rowspan="4">Yarrangobilly</td><td>Byron Range Group</td><td>conglomerate, sandstone, shale & nodular limestone</td><td>Conglomerate</td><td>Conglomerate will produce a variable but generally coarser sediment that will have a variable clast lithology. Sand and silt from sandstone.
Silt and dissolved load from limestone and silt and clay from shale</td><td rowspan="9">D</td><td rowspan="12">Very Slow water Infiltration and transmission rate</td><td>Very High</td><td>Very low Bedrock</td></tr>
<tr><td>256</td><td rowspan="3">Ravine Beds Yarrangobilly Limestone</td><td rowspan="3">limestone, sandstone, siltstone, shale</td><td rowspan="3">Limestone</td><td rowspan="3">Dissolved load and silt from limestone, with sand, silt and clay produced from other rock types</td><td>Very High</td><td>Very low Bedrock</td></tr>
<tr><td>257</td><td>Very High</td><td>Very low Bedrock</td></tr>
<tr><td>258</td><td>Very High</td><td>Very low Bedrock</td></tr>
<tr><td>259</td><td>Yarrangobilly River Confluence</td><td>Lick Hole Gully</td><td rowspan="5">Byron Range Group</td><td rowspan="5">conglomerate, sandstone, shale & nodular limestone</td><td rowspan="5">Conglomerate</td><td rowspan="5">Conglomerate will produce variable, but generally coarser, sediment that will have a variable clast lithology. Sand and silt from sandstone.
Silt and dissolved load from limestone and silt and clay from shale</td><td>Very High</td><td>Very low Bedrock</td></tr>
<tr><td>260</td><td>Channel/floodplain margin</td><td>Yarrangobilly</td><td>Very High</td><td>Very High</td></tr>
<tr><td>261</td><td>Yarrangobilly River Confluence</td><td>Lobs Hole watercourse 4</td><td>Very High</td><td>Very low Bedrock</td></tr>
<tr><td>262</td><td rowspan="3">Channel margin</td><td rowspan="5">Yarrangobilly</td><td>Very High</td><td>Very low Bedrock</td></tr>
<tr><td>263</td><td>Very High</td><td>Very low Bedrock</td></tr>
<tr><td>264</td><td>Ravine Beds Yarrangobilly Limestone</td><td>limestone, sandstone, siltstone, shale</td><td>Limestone</td><td>Dissolved load and silt with sand, silt and clay produced from other rock types</td><td>D</td><td>Very High</td><td>Very low Bedrock</td></tr>
<tr><td>265</td><td>Road</td><td rowspan="2">Byron Range Group</td><td rowspan="2">conglomerate, sandstone, shale & nodular limestone</td><td rowspan="2">Conglomerate</td><td rowspan="2">Conglomerate will produce a variable but generally coarser sediment that will have a variable clast lithology. Sand and silt from sandstone.
Silt and dissolved load from limestone and silt and clay from shale</td><td rowspan="2">D</td><td>Very low Road</td><td>Very low Bedrock</td></tr>
<tr><td>266</td><td>Mine waste</td><td>Very High</td><td>Very High</td></tr>
</table>

Assessment Site	Landscape Unit	Catchment/ Subcatchment	Geologic Unit	Dominant lithologies	Single Dominant Lithology	Weathering product	Hydrologic Group Code	Hydrologic Group description	Inferred surface hydraulic connectivity	Inferred subsurface hydraulic connectivity
198	Channelised fill	Wallaces Creek	Ravine Beds, Yarrangobilly Limestone	Limestone, sandstone, siltstone, shale	Limestone	Dissolved load and silt from limestone, with sand, silt and clay produced from other rock types	D	Very Slow water Infiltration and transmission rate	Very High	Very low Bedrock
199	Yarrangobilly River Confluence								Very High	Very low Bedrock
200	Yarrangobilly River	Yarrangobilly							Very High	Very low Bedrock
201									Very High	Very low Bedrock
202									Very High	Very low Bedrock
203									Very High	Very low Bedrock
204									Very High	Very low Bedrock
205									Very High	Very High
206	Yarrangobilly River Confluence	Unnamed tributary 5							Very High	Very low Bedrock
207	Yarrangobilly River	Yarrangobilly							Very High	Very low Bedrock
208	Yarrangobilly River Confluence	Unnamed Tributary 6							Very High	Very low Bedrock
209	Yarrangobilly River	Yarrangobilly							Very High	Very low Bedrock
210	Yarrangobilly River Confluence	Yarrangobilly Lobs Hole watercourse 6							Very High	Very low Bedrock
211	Yarrangobilly River Confluence	Yarrangobilly Lobs Hole watercourse 7							Very High	Very low Bedrock
212	Valley margin at colluvial footslope Sediment fan	Yarrangobilly Lobs Hole watercourse 6							Very High	Very High
213	Valley margin at colluvial footslope	Unnamed Tributary 6							Very High	Moderate
214	Valley margin at colluvial footslope Sediment fan	Unnamed tributary 5							Very High	Very High
215	Colluvial footslope valley margin	Unnamed tributary 4							Very High	Moderate on saprolite
216	Yarrangobilly River	Yarrangobilly							Very High	Very low Bedrock
217									Very High	Very low Bedrock
218									Very High	Very low Bedrock

Assessment Site	Landscape Unit	Catchment/ Subcatchment	Geologic Unit	Dominant lithologies	Single Dominant Lithology	Weathering product	Hydrologic Group Code	Hydrologic Group description	Inferred surface hydraulic connectivity	Inferred subsurface hydraulic connectivity
219	Valley floor margin chute	Cave Gully							Very High	Very low Bedrock
220	Yarrangobilly River Confluence and chute								Very High	Very low Bedrock
221	Yarrangobilly River Confluence	Unnamed Tributary 3	Byron Range Group	Conglomerate, sandstone, shale & nodular limestone	Conglomerate	Conglomerate will produce variable, but generally coarser, sediment that will have a variable clast lithology. Sand and silt from sandstone. Silt and dissolved load from limestone and silt and clay from shale	D	Very Slow water Infiltration and transmission rate	Very High	Bedrock
222	Mine waste	Yarrangobilly	Nil	Nil	Nil	Nil			Very High	Very High
223	Chute		Ravine Beds Yarrangobilly Limestone	Limestone, sandstone, siltstone, shale	Limestone	Dissolved load and silt from limestone, with sand, silt and clay produced from other rock types	D	Very Slow water Infiltration and transmission rate	Very High	Very low Bedrock
224	Yarrangobilly River Confluence	Lick Hole Gully	Byron Range Group	Conglomerate, sandstone, shale & nodular limestone	Conglomerate	Conglomerate will produce variable but generally coarser sediment that will have a variable clast lithology. Sand and silt from sandstone. Silt and dissolved load from limestone and silt and clay from shale	D		Very High	Very High
225	Yarrangobilly River trunk	Yarrangobilly							Very High	Very High
226	Channel zone	Lobs Hole Watercourse 4							Very High	Very Low
227	Road crossing								Very High	Very Low
228	Channel zone								Very High	Very Low
229	Channel zone	Lick Hole Gully							High	Moderate
230									High	Moderate
231									High	Moderate
232									High	Low
233									Low Road	Low
234									Very High	Very High
235									Very High	High
236									Very High	Moderate
237									Very High	Low
238									Very High	Very High
239	Channel zone	Yarrangobilly							Very High	Very High
240	Channel margin								Very High	Very Low Bedrock
241	Valley floor margin	Sheep Station Creek					C	Slow rate of water infiltration and transmission.	Very High	Very High
242	Colluvial footslope valley margin	Sheep Station Creek							Very High	Low
243	Yarrangobilly River Confluence	Sheep Station Creek					D	Very Slow water Infiltration and transmission rate	Very High	Very High

Assessment Site	Landscape Unit	Catchment/ Subcatchment	Geologic Unit	Dominant lithologies	Single Dominant Lithology	Weathering product	Hydrologic Group Code	Hydrologic Group description	Inferred surface hydraulic connectivity	Inferred subsurface hydraulic connectivity
244	Yarrangobilly River Confluence	Lobs Hole watercourse 3	Ravine Beds, Yarrangobilly Limestone	Limestone, sandstone, siltstone, shale	Limestone	Dissolved load and silt from limestone, with sand, silt and clay produced from other rock types			Very High	Very High
245	Valley floor margin	Lobs Hole watercourse 3							Moderate	Very High
246	Valley floor margin	Lobs Hole watercourse 3							Moderate	Very High
247	Channel margin	Lobs Hole watercourse 3							Moderate	Very Low Bedrock
248	Channel margin	Lobs Hole watercourse 3							Moderate	Very Low Bedrock
249	Channel at road crossing	Lobs Hole watercourse 2	Ravine Beds, Yarrangobilly Limestone	Limestone, sandstone, siltstone, shale	Limestone	Dissolved load and silt from limestone, with sand, silt and clay produced from other rock types	D		Very High	Very High
250	Channel zone	Unnamed Tributary 2					C	Slow rate of water infiltration and transmission.	Very High	Very High
251	Channel	Unnamed Tributary 2							Very High	Very High
252	Talbingo reservoir margin	Lobs Hole watercourse 3							Very High	N/A
253	Channel	Unnamed Tributary 1							Very High	Very High
254									Very High	Very High

Appendix 4 Dictionary

Bolus	A small handful of soil which has been moistened and kneaded into a soil ball which just fails to stick to the fingers.
Colluvium	Unconsolidated soil and rock material moved largely by gravity (i.e., mass movement), deposited on a lower slope and/or at the base of a slope.
Felsenmeer	A felsenmeer is a low angled slope whose surface is covered by boulders, or block sized angular rocks, usually associated with alpine and subpolar climates.
Lithology	The description of rocks on the basis of such characteristics as colour, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock or sediment.
Method	A way of doing something, especially a systematic way; implies an orderly logical arrangement (usually in steps)
Methodology	The analysis and comparison of a system of methods followed in a particular discipline
Pedology	Is the study of soils in their natural environment. It is one of two main branches of soil science.
Ribbon (pedology)	Determining soil texture using the ribboning technique. After forming a bolus the moist ball of soil is worked between the thumb and fore finger to create a ribbon. The more sand and silt that there is within a sample then the shorter the ribbon that is able to be formed; sand not being able to form any ribbon. If a ribbon of greater than 100mm is able to be formed easily then this indicates the sample is a heavy clay.
Saprolite	Bedrock that has weathered in situ and in which the structure, and fabric, of the parent material can still be discerned and exhibits extensive inter-crystal and intra-crystal weathering. In pedology, saprolite was formerly applied to any unconsolidated residual material underlying the soil and grading to hard bedrock below.
Soil texture	Soil texture refers to how coarse or fine a soil is: that is, how much sand, silt and clay it contains. Texture has a major influence on how much water a soil can hold. Generally, the smaller and finer the soil particles (the more silt and clay), the more water a soil can hold
Channel Flow Morphology	Changes in channel bedform can indicate changes in channel slope and associated processes. There is a progression of bedforms that indicate increasing slope, they are (Brierley and Fryers, 2005; Knighton 1998; Leopold Wolman and Miller, 1964;

Pool	Pools are areas of low channel gradient where the surface of the water is unbroken and there is no discernible flow velocity. Pools are commonly associated with riffles.
Glide - Run	Glides are like pools but are areas of increased slope and flow. is discernible as

	disturbances to the surface of the water from subsurface turbulence. Glide - Runs are generally uniform and relatively featureless areas of flow. In general terms have low velocity and low water surface gradients.
Riffle	Riffles typically occur in riffle-pool sequences. Quiet flow through deeper areas of channel (pools), with a low flow gradient, is often separated by turbulence over lobate accumulation of coarse bedload materials and localised higher flow gradient.
Cascade	Cascades occur on steep slopes and are characterised by longitudinally and laterally disorganised bed material that that typically comprises cobbles and boulders.
Rapid	Rapids are stair like arrangements of boulders on steep slopes. Characterised by a steep gradient and broken water surface.
Waterfalls (bedrock step):	Waterfalls, or bedrock steps, are characterised by falling flow over bedrock or boulder steps that have a near vertical drop of greater than 1m.

Attachment B

Geophysical investigation

snowy 2.0

GRAVITY AND MAGNETICS FACTUAL AND INTERPRETIVE REPORT

Geophysical Factual and Interpretive Report

Issue A

S2-4100-REP-000016

Prepared for: Snowy Hydro Limited

Date: 02 January 2019

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1. ACRONYMES AND ABBREVIATIONS

Acronym / Abbreviation	Description
FSL	Full Supply Level
Ma	million years ago
SD	standard deviation
ECVT	Emergency Cable Ventilation Tunnel
AFGN	Australian Fundamental Gravity Network
HRT	Headrace Tunnel
km	Kilometres
m	metres
MAT	Main Access Tunnel
SRTM	Shuttle Radar Topography Mission
GA	Geoscience Australia
GSNSW	Geological Survey of NSW
GADDS	Geoscience Australia Geophysical Archive Data Delivery System
BGL	Below Ground Level
ARGN	Australian Regional GPS Network
SH2.0	Snowy Hydro 2.0 – The Project
TRT	Tailrace Tunnel
ERT	Electrical Resistivity Tomography
SRT	Seismic Refraction Tomography
2D SR	2D Seismic Reflection
RL	Relative Level to Australian Height Datum
AHD	Australian Height Datum
KPV	Kelly Plains Volcanics
TTF	Tantangara Formation
GOV	Gooandra Volcanics
LPF	Long Plain Fault
RQD	Rock Quality Designation
Hz	Hertz
nT	Nanotesla
mGal	milligal
TMI	Total Magnetic Intensity
RMS	Root Mean Squarer
MW	Megawatt
EIS	Environmental Impact Statement
BH	Borehole
GIS	Geographic Information System

Acronym / Abbreviation	Description
GIR	Geotechnical Interpretive Report

2. INTRODUCTION

2.1. Project Description

Snowy Hydro Ltd, the owner and operator of the Snowy Mountains Hydroelectric Scheme located in south eastern Australia is undertaking the expansion of the currently existing 3,740 MW capacity hydropower scheme by building Snowy 2.0, a 2,000 MW pumped storage facility.

The proposed pumped storage facility utilises the 685.5 m head difference between Tantangara Reservoir (Full Supply Level (*FSL*) = 1,228.70) on the Murrumbidgee River as the headwater by conveying water through a 26 km long power waterway to Talbingo Reservoir (FSL = 543.20) on the Tumut River as the tailwater.

The project lies within the Kosciuszko National Park and traverses an area not previously impacted by the original Snowy Hydro Scheme, with the exception of Tantangara and Talbingo Reservoirs at either end of the alignment. The alignment can therefore be considered a green field site with no existing site specific geological or geophysical information prior to the Feasibility and current stage of investigation works.

Snowy Hydro Ltd, the owner and operator of the Scheme engaged SMEC Australia Pty Ltd (SMEC) to undertake the Reference Design for the Project.

2.2. Background

The Gravity and Magnetics (potential fields) Survey was undertaken to provide additional information to assist in characterising the structural geology along the headrace tunnel by incorporate existing geological information (borehole information and geological models), to assist the in-filling of inherent gaps created by the widely spaced drilling investigations.

The SMEC Groundwater Interpretive Report outlined areas of higher risk for inflows (e.g. direct hydrologic connection to the surface under Nungar and Tantangara creeks), which may result in adverse environmental impacts along areas of the headrace tunnel. These areas have limited geological information to assist development of the geology model. Limited hydrogeological information also resulted in conservative groundwater model inputs resulting in (initial) adverse groundwater impacts. Discussions with EMM Consulting, who are undertaking the Environmental Impact Assessment (EIS) and observation of unmapped igneous intrusions indicated to need for more information, especially over the HRT, to help refine the numerical groundwater model.

Information collected from groundwater investigations demonstrates that groundwater inflows along the alignment are highly influenced by subsurface geological structures, and where granites are known to exist or have been intersected by drilling (e.g. BH3106, the permeability (and therefore inflow during construction and potential environmental impacts) are greatly reduced by some orders of magnitude. This is likely due to the resulting geodynamic mechanisms of the intrusions, effectively ‘tightening up’ or ‘squizzing’ the surrounding formation.

Characterising the presence of intrusions or granite plutons would therefore be of great value to the projects design and construction. Limited information has been obtained at Zinc Ridge and Tantangara locations where hidden intrusions/plutons are suspected from surface occurrences both directly on, and <150m from the alignment. These structures, where present, are often “blind” or “hidden” and can often have a raft of sediments above them masking their occurrence making them extremely difficult to find via surface mapping alone.

Such intrusions if characterised from the gravity data, would be beneficial to both the geotechnical model and the groundwater model. This new information will also feed into the Three-Dimensional Groundwater Model being produced by EMM Consulting Pty Ltd (EMM) to assess groundwater impact that will be reported in the project’s EIS.

2.3. Objective

The objective of the survey it to provide more information on the structure and geology of the alignment, especially the head Race Tunnel to help refine the geological and groundwater models.

2.3.1. Report Purpose

The purpose of this report is to provide assessment on project specific (potential field) geophysical data collected to:

- Provide assessment of high-resolution ground-based gravity measurements and modelling of data with density contrasts;
- Provide information to feed into refinement of groundwater and geotechnical models in relation to gravity model by characterisation of hidden intrusions (e.g. Plutons granites, dykes, sills) with particular reference to Zinc Ridge, Tantangara/Nungar and Gooandra areas;
- Delineation of fracture zones (e.g. faults/fractured ground wider than the nominal gravity recording spacing);
- Provide reference to areas which require additional investigations.

3. GEOLOGICAL SITE CONDITIONS

3.1. Summary of Regional Geology and Tectonics

The Project Area is situated within the south-eastern portion of the Lachlan Orogen (Fold Belt, Figure 1) of NSW (Stuart-Smith, 1991; Fergusson & Colquhoun, 2018) and is a portion of the structural framework of NSW (Packham, 1969).

The Lachlan Orogen comprises a suite of Ordovician Age (490 - 434 Million years ago) to Devonian Age (410 - 354 Million years ago) sedimentary, igneous and metamorphic rocks that have developed during several orogenic periods. These periods are associated with extensive faulting and have formed major neotectonics structures through the area (Owen & Wyborn, 1979; Wyborn, et al., 1990). During the Cenozoic Era, basaltic volcanism and faulting resulted in differential uplift which affected the evolution of the drainage and geomorphology throughout the region (Sharp, 2004).

This section provides a brief summary of approximately the last 490 million years ago (Ma) which is the period relevant to the formation of the geology within the Project area.

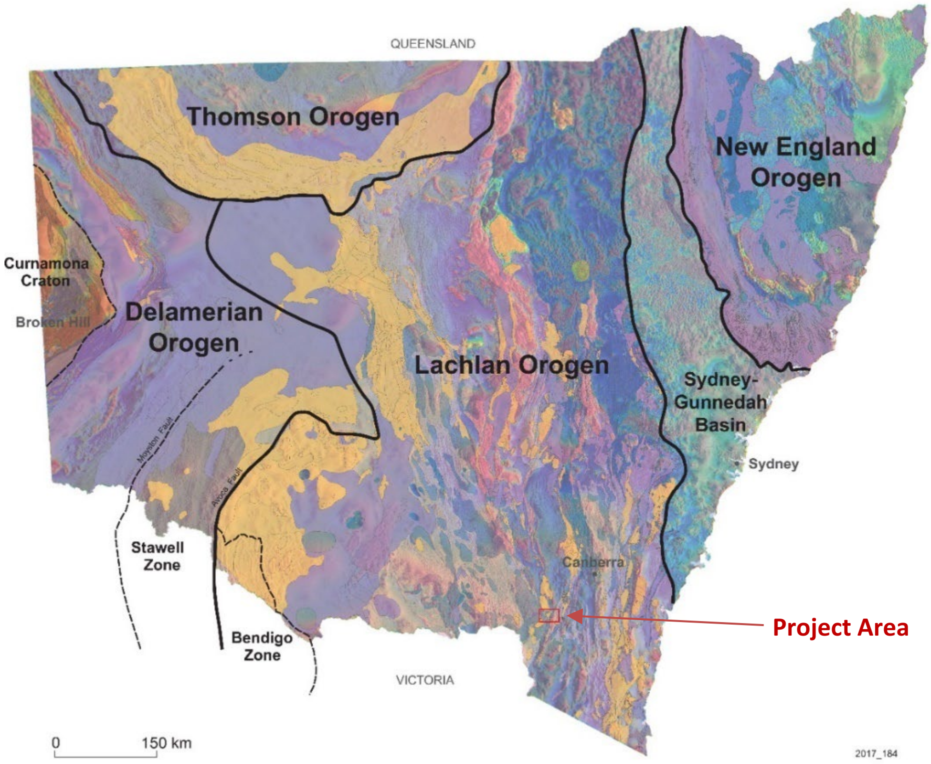

Figure 1: The location of the Lachlan Orogen and the project location highlighted in red. (Source: Geological Survey of New South Wales, Department of Resources & Energy)

The majority of rock units in the Project Area span from the Ordovician to Devonian, aged between 490Ma to 350Ma with the exception of isolated occurrences of Tertiary age basalt. The following is mainly summarised from (Wyborn, et al., 1990).

During the Middle Ordovician (458 Ma to 470 Ma), the rock within the Project Alignment comprised a submarine setting with the Australian continental land mass to the west (Degeling, 1980), the sediments of which are not present within the Project Alignment. Late in the Middle Ordovician, basic volcanic activity began, creating the Macquarie Volcanic Arc that extended through NSW splitting the existing ocean into two, forming the Kiandra Volcanic Field (also known as the Kiandra Volcanic Belt) on the western side. The erupted lavas and pyroclastic sediments formed the Gooandra Volcanics which are present along the central part of the Project Alignment.

Intrusive rocks associated with the Middle Ordovician basic volcanic activity event are also encountered within the Project Alignment and are known as the Shaw Hill Gabbro. Either side of the volcanic arc, marine sedimentary deposits are found, best characterised by chert and reworked volcanic tuff of the Temperance Formation to the east of the Gooandra Volcanics. These Ordovician volcanics and sedimentary rocks are now bounded to the east by the Boggy Plain Fault and to the west by the Long Plain Fault. Other volcanoclastic sedimentary sequences, such as the Bolton or Adaminaby Beds, may also occur at depth below this sequence (but have no surface expression within the Project Area). The Ordovician sediments derived from the volcanism are described as turbidites, often being repetitive layers of a sedimentary sequence (Fergusson & Colquhoun, 2018).

During the Late Ordovician (458Ma to 438Ma), rifting was accompanied by sinking of the volcanic ridge (Degeling, 1980). Late in the Ordovician, uplift (first Benambran Folding Episode) and metamorphism to the west of the Project Area created a new land mass (Wagga Metamorphic Belt), which was being actively eroded. By the early Silurian, up to 2,000 m of sediment had been eroded from the new land mass in the west and deposited into the Tantangara Trough (Wyborn, et al., 1990) creating the Tantangara Formation; another turbidite sequence of alternating sandstone, siltstone and shale.

Towards the end of the Early Silurian, uplift in the Tantangara Trough, possibly during the second phase of the Benambran Fold Episode, resulted in meridional folding within the turbidite sediments, destroying the Tantangara Trough (Owen & Wyborn, 1979).

By the Late Silurian, much of this area rose above sea level due to formation of great batholiths to the east and west of the Project Alignment. This caused crustal rifting and subsequent subsidence between the batholiths (intrusive rocks). The Tumut Trough developed. This was a shallow marine basin within which sandy and volcanic sediments from the batholith areas above were deposited (Wyborn, et al., 1990), possibly including the Ravine Beds and Peppercorn Formation.

The Ravine Beds are an extensive sequence of sedimentary rocks within a large north plunging syncline and relatively steeply dipping limbs. The Ravine Beds are bounded by the Long Plain Fault on the east side.

The Bowning Orogeny then occurred at the Silurian-Devonian time boundary and, soon after, the eruption of S-type subaerial acid volcanics (Kelly's Plain Volcanics) in the Cooleman-Tantangara area marked the final stage of the Silurian-Devonian volcanic cycle (Owen & Wyborn, 1979). Concurrent with this volcanic activity, a large number of co-magmatic granitoid intrusions (Boggy Plain Suite) were emplaced. Further west, around the middle of the Early Devonian, the Boraig Group overlaid the Ravine Beds with a thick pile of acidic volcanics alternating with sedimentary rocks.

The Long Plain Fault, the Kiandra Fault and the Boggy Plain fault all likely to have developed at the end of the Bowning Orogeny, likely from the Mid-Devonian to the Carboniferous Periods (Stuart-Smith, 1991). Faulting was likely due to continued tectonic compression in an approximate east–west direction. A deep crustal detachment connected these faults, which appear to have a dextral reverse slip mode of formation (Stuart-Smith, 1991).

A geological hiatus followed the Devonian (350 Ma) to approximately 20–25 Ma when extensive outpouring of younger Tertiary (Cenozoic) age basaltic lava and some reactivation of faults that both uplifted and warped the landscape occurred. The Tertiary basalts form distinctive flat-topped ridges in the Kiandra and Cabramurra areas. The differential uplift and warping have had an effect on the drainage divides of the headwaters of the Murrumbidgee, Tumut and Snowy rivers (Sharp, 2004) throughout the Cenozoic period.

Figure 2 presents the general currently published geology across the Project area in stratigraphic units that each have a variety of lithologies, a key to the associated unit names and the various lithologies is presented in Table 1. This map is under revision following the recent geological mapping and evaluation of geological units based on the drilling data, which is still being updated during the present drilling program.

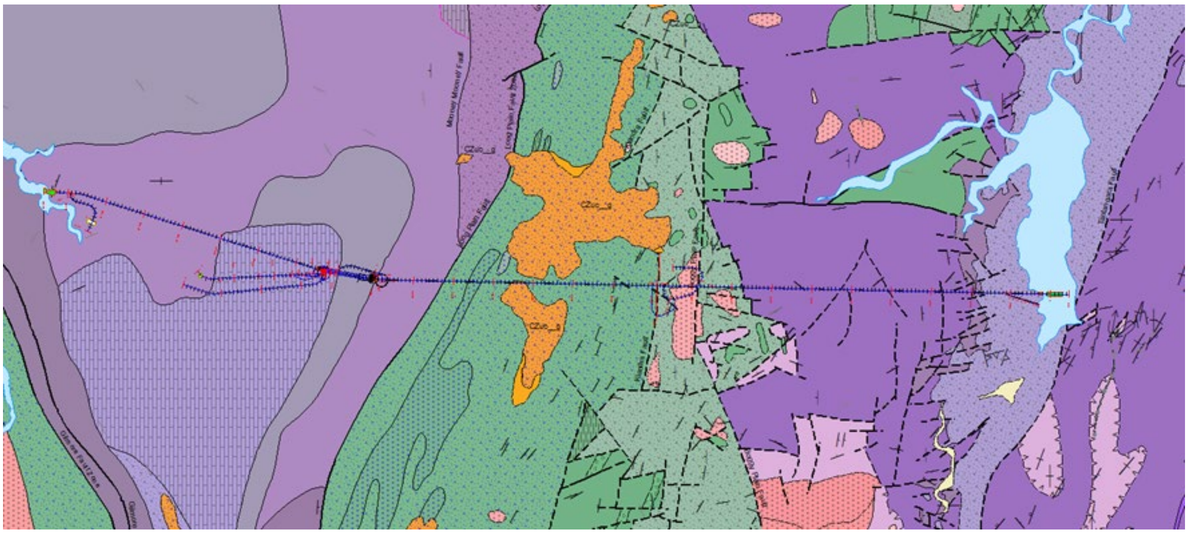

Figure 2: Generalised Geology of the Snowy 2.0 Project Area (for geological unit reference see). The full map and legend is included in Appendix A.

3.2. Site Setting

The Project site is within the northern part of the Snowy Mountains region which spans a plateau and incised valleys between the Tantangara and Talbingo reservoirs. The maximum elevation is approximately 1500 m at Zinc Ridge on the Plateau area, with the maximum water level of Tantangara reservoir being at 1229 m. The lowest point in the surface on the Project alignment is at 534 m at the Talbingo reservoir.

The elevated Plateau area or Kiandra Tablelands roughly comprises the eastern part of the Project Area where there are open grassland slopes and plains, with interspersed tree cover (mainly on the hill slopes) and localised swampy areas. The Plateau area is drained by the Murrumbidgee River catchment and the main tributaries such as the Nungar Creek, Tantangara Creek and Gooandra Creek. This area has a generally low relief of a few hundred metres, with low gradient meandering streams and associated boggy areas.

The western part of the Project area lies below a well-defined escarpment, with deeply incised streams forming what is generally known as the Ravine area. This area is drained by tributaries of the Tumut River (which is now beneath the Talbingo reservoir). The main streams are Yarrangobilly River, Middle Creek and Wallaces Creek. This area has high relief of 500 m to 600 m with slopes commonly steeper than 30^{o} and with many cliff lines.

The soil cover is deepest in the eastern Plateau area along the generally northward flowing streams, with alluvial soil depths up to approximately 15 m but mostly less than approximately 5 m. On the slopes, where erosion is a predominant process, the soil cover is usually less than 3 m and rock outcrop are common.

Across the Ravine area there is generally limited soil cover on the steeper slopes where there is also common outcrop. Much of the terrain is covered in slope wash soils to 1 m to 2 m depth and there are localised deeper colluvial soils with some loose rock scree slopes to several metres thickness. The valley floors are filled with alluvial soils, a variable mix of clay sized particles to coarse gravel and boulders, to an estimated thickness of up to 10 m. These soils are confined by the narrow valley width and stream bends against rocky bluffs and slopes.

Groundwater is recharged from precipitation that includes snowfall over the more elevated parts of the site (>900 m generally) and a base level for the water table is mostly guided by the stream channels. Thus, over the eastern Plateau area the groundwater table can be assumed to be at the surface along the perennial streams, but up to 100 m depth beneath the highest ranges. Over the steep valley areas of the Ravine area the groundwater has a steep westerly trending hydraulic gradient connecting to a surface base level in the major perennial streams such as Yarrangobilly River. In the interfluves, the water table is expected to lie at 50 m to 150 m depth.

Much of the site is remote, with road access limited to the sealed Snowy Mountains Highway striking northward across the middle of the Project Area, plus two all-weather gravel roads; Tantangara Road at the eastern limit of the Project Area, providing access to the Tantangara Reservoir and the Ravine and Pinbeyan Roads, providing access to the Lobs Hole area and the lower Yarrangobilly River. There are several formed earth roads that have only seasonal access, however apart from these tracks there is much terrain where the only access is by foot.

Despite this remote terrain, steep slopes and often inclement weather there are few major geological hazards. Slope instability is quite localised, comprising rockfalls and debris slides off the cliffs and steep rock slopes, creeping scree slopes beneath the basalt country, and localised stream bank failures that are likely only active after heavy rains. Other geological hazards may include soil erosion and sedimentation after stripping of protective vegetation cover, acid leachate if pyrite and other sulphide bearing minerals are exposed and concentrated, and naturally occurring asbestos in a limited number of rock units. Geological hazards at the planned depths of excavation include potentially high geothermal gradients and variable in-situ stress conditions; including low horizontal stress at some shallow depths and high horizontal stress at greater depths. These hazards are outlined in greater detail in Section 15.

3.3. Geological Units

The geological units from the 1: 250,000 Statewide GIS dataset have been adopted for the Project. A general stratigraphic column showing the geological units is shown in Table 1. Much of the description below refers to Owen and Wyborn (1979a and b) and Wyborn, Owen and Wyborn (1990).

Table 1: General Stratigraphic Column Along the Snowy 2.0 Project Alignment

Period	Unit	Description
TERTIARY	CZuc__g	Tertiary Basalt: alkali olivine basalt deposited during uplift periods (Kiandra and Kosciuszko Uplifts).
		Kanimblan Folding *(responsible for gentle tilting of the Kelly's Plain Volcanics, fault wrenching in the Boggy Plain Fault, folding of the Devonian sedimentary units)* **Tabberabberan Folding** *(possible folding of the sedimentary units in Middle Devonian)*
DEVONIAN	Dby	**Byron Range Group**: siltstone, quartzite, shale, sandstone, conglomerate & nodular limestone. Shallow Marine – siliciclastic deposits.
	Dba	**Boraig Group**: rhyolite, rhyodacite, tuff, lapilli tuff, feldspathic sandstone, granophyre deposited in shield building volcanic complexes. Terrestrial - extrusive volcanic deposits.
	Dulk	**Kelly's Plain Volcanics**: dacite ignimbrite, rhyodacite ignimbrite, tuff, agglomerate, rhyolite; porphyritic monzogranite. Terrestrial – volcaniclastic deposits.
	Sbp__i	<u>Kosciuszko Batholith</u> **Boggy Plain Suite:** I-type granitoids; even grained texture, mostly granodiorites and quartz monzogabbros, biotite monzogranite commonly containing hornblende. Shallow crustal - continental I-type deposits.
		Bowning Folding *(folding of Peppercorn Formation which were unconformably overlain by Kelly's Plain Volcanics to the north-west of Tantangara Reservoir)*
SILURIAN	Scpp	<u>Cooleman Plains Group</u> **Peppercorn Formation**: Basal conglomerate, overlain by sandstone, siltstone and cleaved shale, with minor limestone lenses. Shallow Marine – shelf deposits.
	Suer	**Ravine Beds**: Shale, slate, siltstone, conglomerate. Shallow marine shelf deposits.

Period		Description
		Benambran Folding 2nd Phase *(Significant folding event which destroyed a trough leading to the deposition of the Tantangara Formation in a series of anticlines and synclines)*
	Syaa	Yalmy Group **Tantangara Formation**: sedimentary turbidite sequence, Sandstone, siltstone and shale; quartzite. Deep Marine – siliciclastic deposits.
		Benambran Folding 1st Phase *(Responsible for folding, uplift and tilting of Ordovician sediments and volcanics)*
ORDOVICIAN	**Okit_t**	Kiandra Group **Temperance Formation:** Interbedded basaltic tuff, chert, and feldspathic arenite, minor agglomerate. Some monzonite, hornblendite, lamprophyre, quartz monzonite. Deep Marine – volcaniclastic deposits.
	Ouos	**Shaw Hill Gabbro**: Gabbro, diorite, metabasic intrusive rock, pyroxenite. Shallow crustal – continental deposits.
	Okig	Kiandra Group **Gooandra Volcanics**: Metabasalt, basalt breccia (emplaced as pillow lavas), amphibolite, chloritic schists, feldspathic sandstone; aphyric and feldspar-phyric basalt, basaltic lava breccia, rhyolite, shale; fine-grained feldspathic siltstone and shale. Typically, deep marine - extrusive volcanic deposits.
	Oa	Adaminaby Beds: turbidite sequence; sandstone, mudstone, shale; quartzite, quartzitic phyllite, phyllite, slate
	Oa	Bolton Beds: quartz arenite, siltstone and shale forming distal flysch sequence

A full detailed description and detailed information on each of these geological units is available in the GIR_RevB (S2-4100-REP-000012-B).

3.4. Major structural Faults

Major geological structures across the Project Area were developed during the Paleozoic orogenic events which included varying degrees of displacement via faulting.

The faults identified in the published geological maps have been reviewed and outlined in the report by Dr Quigs of Geological Hazards Consulting (2018), which was carried out to assess the general structural orientations and kinematics of faults within the Project Alignment. A list of the five faults/fault zones considered significant in the project area are described at the respective chainages below for easy reference:

- ***Tantangara Fault***: this is a roughly north-south striking reverse fault, dipping east, over 30 km in length, and is east of the intake area. It has no direct effect on the project alignment.
- ***Jindabyne Thrust***: this is a sinistral reverse thrust fault, dipping west, over 10 km length but linked to other fault systems further to the south. It is interpreted to intersect the project alignment at Ch. 4,450 m.
- ***Boggy Plain Faults***: there are two interpreted fault traces;
  - Boggy Plain Fault North: this is a sinistral reverse fault, dipping east at 50° and striking NW to north over a length of about 15 km. It is interpreted to intersect the project alignment at Ch. 7,540 m forming a contact between the Tantangara and Temperance Formations.
  - Boggy Plain Fault South: this is a sinistral reverse fault, dipping west and striking NW over a length of about 22 km. It is interpreted to intersect the project alignment at Ch. 8,800 m,

either being vertical of dipping westwards. It may form part of the contact between the Temperance Formation and the Boggy Plain Suite of intrusive rocks.

- ***Kiandra Fault***: initially placed at the contact between the Temperance Formation and Gooandra Volcanics, this fault is now interpreted to follow a distinct lineament along Gooandra Creek, striking NE and dipping steeply west. It is interpreted to intersect the project alignment at Ch. 10,900 m.

- ***Long Plain Faults***: there are two interpreted fault traces;

  - Long Plain Fault North: this is a revere fault dipping steeply NW but does not intersect the project alignment.

  - Long Plain Fault South: this is a reverse fault, striking NNE and dipping 50-60^{o} eastwards, with a trace length over 23 km, but part of a much longer fault system. The intersection of the project alignment at Ch. 15,400 m is considered to the be the eastern limit of the Long Plain Fault Zone.

  - Additional faulting possibly associated with the Long Plain Fault, such as that intersecting the Boraig Group at about Ch. 17,900 m.

3.5. Igneous Intrusions

Igneous intrusions have been mapped in the Project vicinity with two major geological formations in the form of the Shaw Hill Gabbro and the Boggy Plain Suite. These two formations have been mapped as being present along the tunnel alignment and inferred subsurface boundaries for these formations are presented in later model sections.

The additional hazards/risk comes from igneous intrusions which have not been mapped or been inferred as being present within the tunnel alignment. The risks posed with unknown igneous intrusions can include:

- Mixed face lithologies during tunnelling activities;

- Impact on groundwater levels / inflows / hydraulic connectivity;

- Sudden change in rock strengths or abrasively that could affect tunnelling productivity; and

- Impact on country rock i.e. baked margins, potential increased fracturing due to dilation post emplacement and cooling.

An example of this is within the Tantangara Formation (TTF), where anecdotal evidence suggests that granitic rocks are present at the surface, possible correlations with intrusive plutons can be made with the regional geophysical data, and surface structures are evident from the lidar survey data for the area.

4. AVAILABLE INFORMATION

4.1. General

The project specific GIR was based on information from the geotechnical investigations undertaken along the proposed alignment that was available as of ***Friday 12th October 2018***.

It should be noted that a final and complete set of geotechnical investigation data, including borehole logs, in-situ testing and laboratory testing had not been received at the time of writing and additional drilling programs for underground works and groundwater studies were still underway at the time of writing.

4.2. Regional Geophysical data

Gravity and magnetic geophysical datasets from GSNSW (DIGS database) were assessed with respect to the proposed tunnel alignment. These datasets were used to interpret the gravitational forces affecting rock depth and related densities as well as the amount of magnetism stored in the rocks along the Project alignment. The features encountered provide some basis for interpreting large geological features, such as regional scale faults, that may have an influence within the Project Area. The maps include gravity and magnetic data (1:250,000 scale) for the Canberra, Wagga Wagga, Bega and Tallangatta map sheet areas.

4.2.1. Gravity

The Bouguer map in Figure 3 presents the tunnel intersecting a narrow north-south ridge of moderate Bouguer gravity levels (green colours) straddled by lower gravity (blue colours). This information has been compiled from the Geoscience Australia Geophysical Archive Data Delivery System (GADDS).

The ridge of moderate gravity response is consistent with a ridge of denser rocks of the Gooandra Volcanics and Shaw Hill Gabbro dipping to the north. The western portion of the tunnel alignment intersects a local gravity low (blue colours) possibly indicating a change in shallower geological conditions, weathering zones or geological structures such as granite intrusions.

4.2.2. Magnetics

There are typically two types of magnetic response datasets used for interpreting the earth's magnetic response. Reduced to the Pole (RTP) magnetics displays data that is corrected for the earth's magnetic field while First Vertical Derivative (1stVD) magnetic maps represent the intensity of the magnetic measurement. The magnetic levels are determined by iron content and the mineralisation characteristics of the rock, often referred to as the material magnetic susceptibility, which will change between geological units. Highly mineralised materials with high iron content, such as mafic Volcanics, have a high magnetic susceptibility and are represented by high magnetic responses. Sedimentary rocks, such as sandstone or limestones, represent geological conditions with generally lower levels of magnetic susceptibility.

Within the regional magnetic mapped data, the tunnel alignment is positioned across a local region of distinct variation in magnetic response.

The 1stVD magnetic map (Figure 4) shows the tunnel alignment crossing a northeast to southwest magnetic high. This suggests a possible interconnection to deeper geological structures or could be related to the Gooandra Volcanics with high levels of Fe (iron) compared to other rock units. The boundary of the magnetic response is positioned to the east of the inflection point of the tunnel alignment, where the high amplitude of the features suggests the magnetic geological structure is near the tunnelling depth.

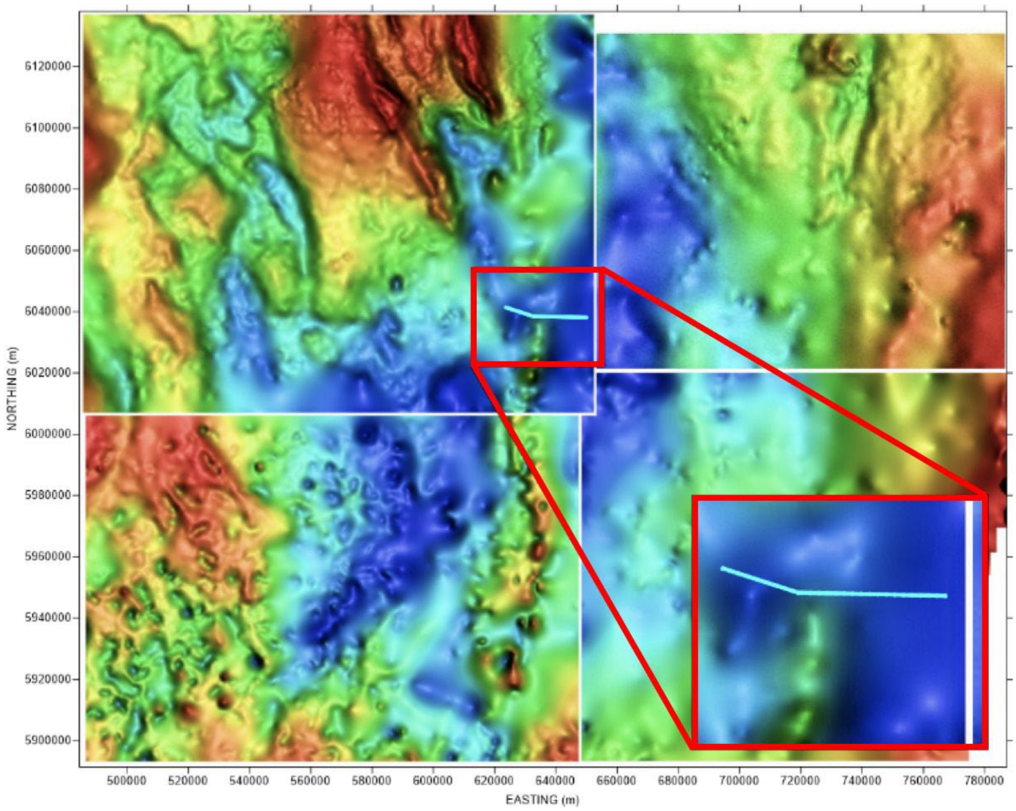

Figure 3 Bouguer Gravity Map with project alignment plotted (blue line).

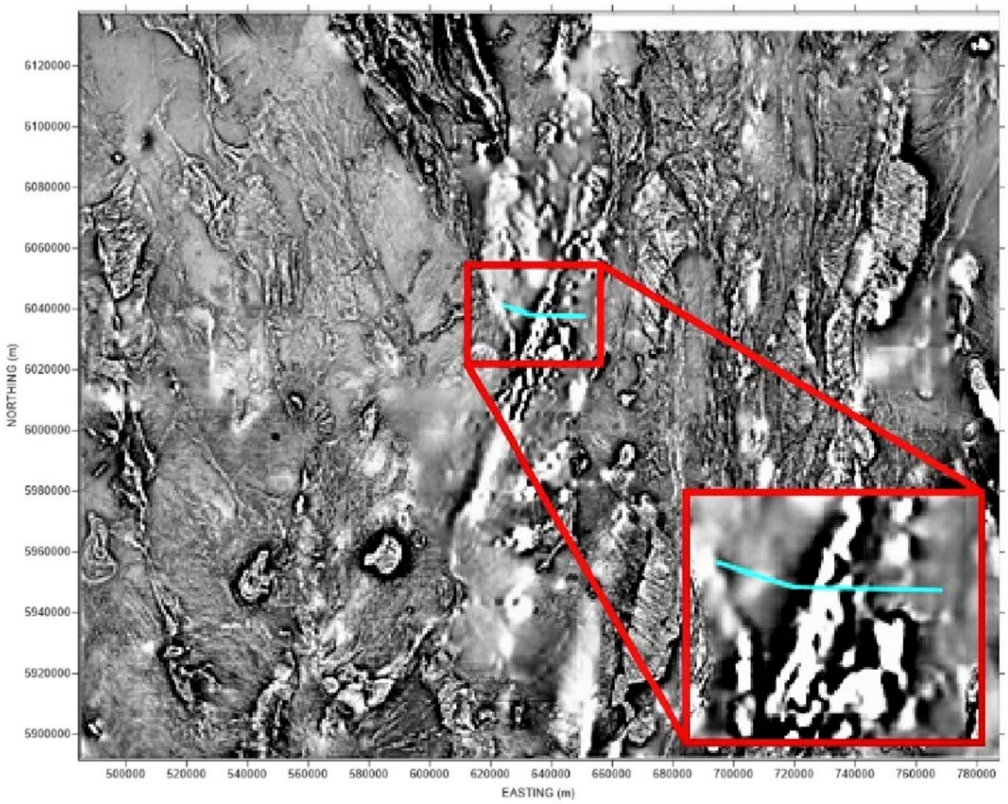

Figure 4: 1stVD Magnetic Data Map with project alignment plotted (blue line).

4.2.3. Regional Geophysics Overview

The regional geophysical data indicates the magnitude of the Long Plain Fault. This fault separates the Project Area into two distinct geological provinces. On the east side of the fault both gravity highs and elevated magnetic levels indicate the potential for presence of considerable masses of basic composition rocks. The limitation of the existing data is that it is on a regional scale, therefore has low resolution within the scope of the Project Alignment. The data does however indicate that a contrast exists between the various rock units for both the gravitational and magnetic fields.

4.3. Previous (Project specific) Geophysical Investigations

Surface Geophysical investigations were undertaken by GHD during the period from 01 May to 02 July 2018, to complement the geotechnical drilling program for the project. Results of this surface geophysics program were provided in Geotechnical Factual Report Ref. 21-26928-GT-RPT-0001-R3, and the GHD factual and interpretive reports.

A brief geophysical interpretation summary for each location where data was collected is provided herein (following Section 4.3.1), based on the information presented within the following listed reports:

- 21-26828-GT-RPT-0001-R2 _App N- Geophysics Seismic Reflection Report;
- 21-26928-GT-RPT-0001-R2 _App O - Geophysics Seismic Refraction;
- 21-26828-GT-RPT-0001-R2 _App P - Geophysics Electrical Resistivity Tomography; and
- 21-26928-GF-RPT-0002-A - Geophysics SRT and ERT Interpretation Report.

SMEC's Internal review comments on the data collection, processing, and results for the Seismic Refraction can be viewed in SMEC_SH2.0 Seismic Reflection data_Review_comment_regesterR2 which has been included in Appendix G of this report for reference.

4.3.1. Surface Geophysics Interpretation

The areas surveyed were proposed to provide shallow subsurface information on vital project features, such as, the Intake Structure at Tantangara Dam, Shallow Headrace Tunnel under Nungar Creek, Main Access Tunnel (MAT) at Gooandra Creek, and Outtake Structures at Talbingo dam. In addition to these locations, a trial of seismic reflection (SL4A) was undertaken over the mapped location of the Long Plain Fault zone and Boggy Plains to attempt to provide geological and structural information around the tunnel invert at depth.

A summary of the surveys including locations, survey line name, geophysical technique applied at the location, and length of each line are provided in Table 3 below and illustrated on Figure 5.

Table 2: Summary of Geophysical Lines and Locations

Location	Line name	Geophysical Technique	Line Length (m)
Tantangara reservoir	SL1A	SRT	675
	SL1B	SRT	150
	SL1C	SRT	150
	SL1D	SRT	150
Nungar Creek	SL2A	SRT & ERT	920 & 930
Gooandra Creek	SL3A	SRT, 2D SR & ERT	2922
Long Plain Fault	SL4A	SRT & 2D SR	1172
Talbingo reservoir	SL6A	SRT	555
	SL6B	SRT	290

Notes: SRT = Seismic Refraction Tomography, ERT = Electrical Resistivity Tomography, 2D SR = 2D Seismic Reflection

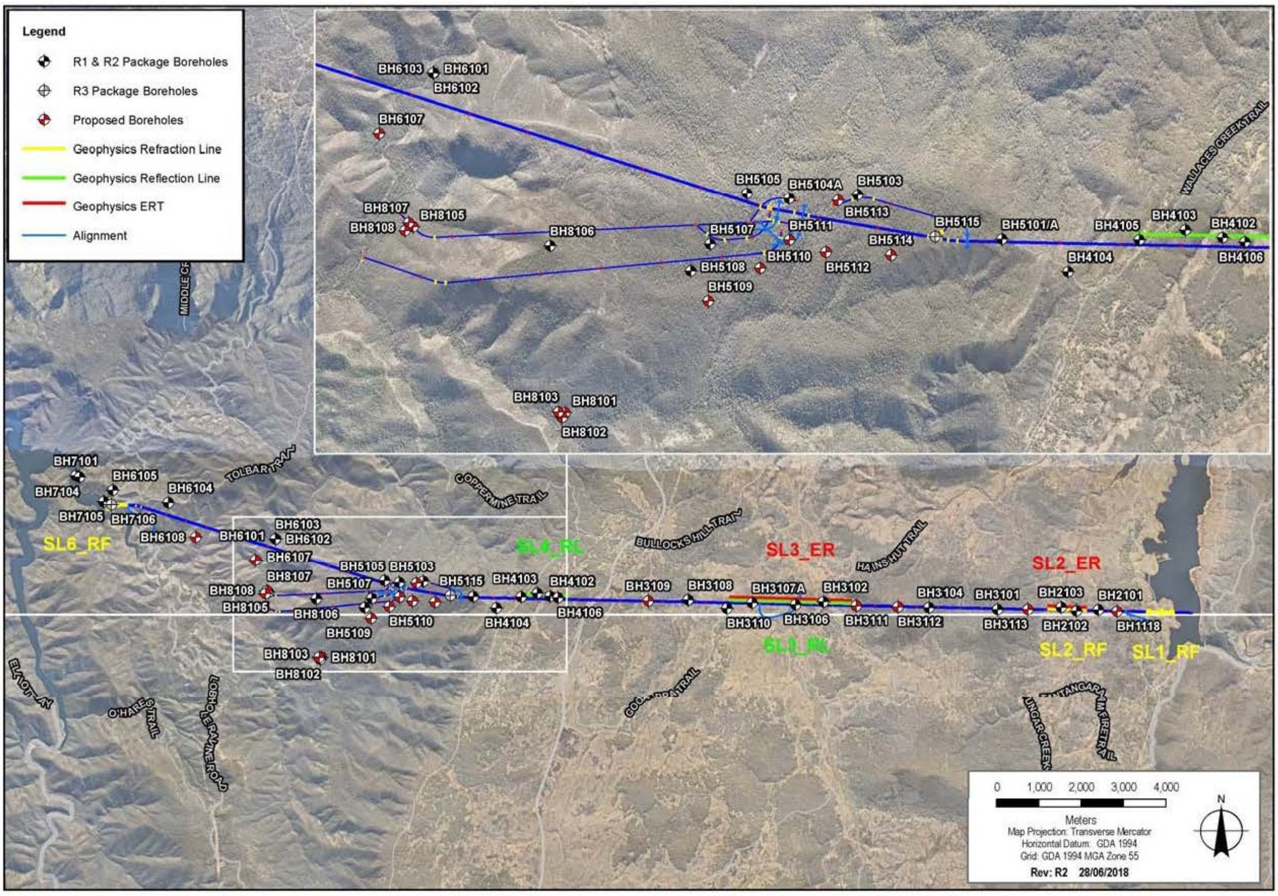

Figure 5: Location map of the GHD geophysical survey lines undertaken.

The following section provides a brief description of the interpreted structures and primary features of the data collected at each of the locations and incorporates how this geophysical information is associated/correlates with the borehole information or geological features.

Full sections of the (GHD) processed profiles are provided in Appendix G and should be viewed in conjunction with the below sections (4.3.2 to 4.3.6) in order to provide context.

4.3.2. Tantangara reservoir - Intake Structure

SRT (SL1A_RF to SL1D_RF)

The lines collected over the proposed intake structure comprised of a single 675 m long East/West line, with three short (150 m) additional perpendicular lines. The data collected for this site shows zones of highly variable seismic velocity, which are likely attributed to variations in the fracture/joint spacing within the dominantly dacite lithology. The results also show areas of deeper weathering within the rock profile that have a primarily north/south trending direction and are likely associated with the regional stress structure of the formation. Based on the regional geological map there are no faults crossing this location. These more deeply weathered zones may be associated with increased permeability and potentially increased inflows during construction of the intake structure. Depth to competent rock (inferred by seismic velocity <2200 m/s) ranges from 3 to 25 m and correlates with the logged borehole information.

4.3.3. Nungar Creek – Shallow Head Race tunnel

ERT/SRT (SL2_RF and SL2A_ER)

This line crosses the Nungar Creek and is characterized by topographic highs at both the western and eastern ends of the line. The maximum depth of investigation for this line was around 50 to 60 m (ERT) and around 50 to 85 m (SRT) below ground level. The lithology information from the boreholes indicates siltstone overlying sandstone, which is evident in the ERT data as changes in resistivity. Zones representing unsaturated soil/weathered rock are also evident from the data, which is supported by the SRT velocity structure also being highly variable. These variations in resistivity are likely due to local differences in the shallow jointing structure and the subsequent porosity of the rock. The depth to inferred competent rock from surface ranges from about 7 to 30 m along the line. The 3400 m/s seismic velocity contour also appears to correlate with the change in lithology to metasandstone at depth. Some deeper weathering structures are also evident from about 400 m west of Nungar creek and directly at the toe of the slope at the east side of the valley. These features are likely the result of increased fracture/joint controlled weathering, shallow groundwater discharge pathways, and possibly provide some of the structural controls of the valley.

4.3.4. Gooandra Creek - Headrace Tunnel

ERT (SL3A_ER)

This ERT line SL3_ER is approximately 2,900 m in length and has an average depth of investigation of around 50 – 60 m below ground level. The line crosses the Gooandra Creek, which is the lowest point along the line. The line also intersects the mapped location of three, north-south striking, faults (Kiandra, Boggy Plains and a Boggy plain North Faults). A drop-in resistivity values along the line have been inferred to represent a contact boundary between the diorite and metasiltstone based on borehole data, however this feature could also be associated with the Boggy Plain Fault.

Some of the lower resistivity zones that coincide with velocity inversions in the SRT profile may be related to faulting and or localised groundwater flow features. General variations in the resistivity in the near surface are likely due to depth of soil and/or changes in saturation levels.

SRT (SL3A_RL)

High degree of lateral variations in weathering exists. Depth to competent rock ranges from 14 m to 45 m along this line. The igneous intrusion associated with the Boggy Plain Suite appears to show as the high to very high velocity areas, however fault structures are not definable by this method.

Seismic Reflection -Trial (SL3A_RL)

This trial of seismic reflection over the same profile as the seismic refraction and ERT shows numerous inferred steeply dipping structures (inferred faults) within the basement. These features have relatively small throws (10 – 15 m). Unfortunately, the orientation of some of the major fault features do not correlate with the geological model which is based on direct field observations.

Granite plutons are known to outcrop in this area and were intersected at ~180mbgl in a production bore near to BH3106, however no structures of this type are evident in the data. This is likely attributed to a low velocity contrast with the surrounding country rocks.

4.3.5. Long Plain Fault

SRT (SL4A_RL)

The structure of the Long Plain Fault at depth appears to be dipping in similar orientation to the mapped structure at the surface. The fractured zone of the Long Plain Fault may be represented by the low velocity /

deeper weathering area which is approximately 250-300 m wide at the surface to the west of the line which narrows slightly at depth.

Seismic Refraction – Trial (SL4A_RL)

The trial reflection profile along the same line shows a very dominate reflector (FU06) that is likely a shear zone associated with the Long Plain Fault. This reflector extends quite deep (~600 m) and is relatively linear to the depth of investigation limit. The fault zone is approximately 250-300 m wide at the surface to the west of the line, narrows slightly at depth, and appears to dip at a shallower angle than is currently mapped. This could suggest some listric (curved) structure to the fault or potentially the presence of a under thrusted block of the Ravine Beds at depth. The Shaw Hill Gabbro has a high amplitude signal which perturbs the signal penetration thus decidedly limits the interpretation of this unit's features.

4.3.6. Talbingo reservoir – Intake structure

The SRT data collected at this location shows that the depth to competent rock ranges from 2 m to 44 m along the line with P-wave velocity for slightly weathered / fresh rock taken as 3200 m/s. The borehole logs indicate that siltstone is the consistent lithology along the line, however given the higher velocity it could more likely be metasiltstone as the P-wave velocities are higher than expected for siltstone and consistent with the velocities for metasiltstone observed elsewhere on the project. There is low velocity feature just above the reservoir full supply level, at roughly between RL 582 and 570 m, which is most likely indicating fractures/joints leading to greater localised weathering at this location.

Another feature of this location is a higher velocity structure (350 m east of the reservoir shoreline) with a north/south trend, evident from 4 m BGL, that expands out at depth, dipping to the east. This feature is likely associated with the presence of a high strength ignimbrite known at this location.

4.4. Geotechnical Investigation Data

Geotechnical investigations have been undertaken along the project alignment by SMEC in 2017 and GHD in 2017 and 2018. Geotechnical investigations and the associated in-situ testing and laboratory testing are still being undertaken at the time of writing this report.

The information used in the development of the geological interpretations used in this report, are contained within is based on information presented within the following reports:

- SMEC Geotechnical Investigation Report (GBR_A_Rev_B) (20181112_GIR_S2-4100-REP-000012-B);
- SMEC Geological Mapping Report (20180710_S2 Geological Mapping Report Rev A);
- SMEC Factual Geological Mapping Reports for Access Roads;
- GHD Factual Reports (21-26928-GT-RPT-0001-R1 to 21-26928-GT-RPT-0001-R3);
- GHD Geophysical Factual Reports; and
- GHD Geophysical Interpretive Reports;

Geotechnical borehole logs, in-situ testing and detailed laboratory test results have not been included in this report. Reference to the reports listed above should be made for details of the borehole logs, in-situ testing and laboratory testing results.

4.4.1. Laboratory Testing

Laboratory tests have been undertaken on samples collected during the geotechnical investigations. Several results of the laboratory testing have been (e.g. Bulk Density) further utilised for input into the geophysical model.

4.4.2. General Notes on Geotechnical information

The project specific GIR along with the associated geological long section was based on information from the geotechnical investigations undertaken along the proposed alignment and data available as of ***Friday 11th January 2018***.

It should be noted that a final and complete set of geotechnical investigation data, including borehole logs, in-situ testing and laboratory testing had not been received at time of writing this report.

5. GRAVITY SURVEYING

5.1. Introduction

The gravity method is defined as a geophysical technique that quantitatively measures differences in gravitational acceleration due to density variations below the earth's surface and subsurface rocks at different locations. A gravity anomaly will arise if a sufficient density contrast exists between two positions on the earth's surface.

These variations are the result of geological factors and the variation of gravity with the latitude of the Earth. These variations are very small, rarely exceeding 10^{-6} of the earth's total gravity field (Sharma, 1997), thus particularly sensitive instruments are required to measure the variations. Hence gravity surveying (the measurement of gravity in the field) combined with accurate measurement of position and elevation (Murray & Tracy, 2001), is an effective technique in the mapping the subsurface geology. These acquired gravity values are also corrected via means of gravity data reduction, to produce Bouguer anomaly profiles that can be utilised for modelling and subsequent interpretation purposes.

5.2. Data Acquisition

The gravity survey was undertaken between the 26th November 2018 and 3rd December 2018. The survey was conducted by Daishsat Geodetic surveyors Pty Ltd, under the fulltime supervision of a SMEC Geophysicists for QA/QC indemnification.

Stations were recorded at approximately 100 m spacing along the alignment from Tantangara reservoir to BH8106 on at the end of Marica ridge track, with crew traversing on foot, either directly along the alignment or as close to as practical via established tracks. Additional regional points were also recorded in Lobs Hole and other accessible locations. A total of 240 new gravity stations were recorded during the survey. During surveying, measurements of relative gravity were made using three Scintrex CG-5 Autograv gravity meters, while positioning information was acquired using Leica GRX1230 geodetic receivers operating in post processed kinematic mode (Figure 5) (for further detail see section 5.4).

Figure 6 Gravity data acquisition underway at station 1001 near Tantangara Revivor.

At each station, gravity readings were averaged for a duration of 20 seconds with a minimum of 2 readings taken having a difference of less than 0.3µms-2. During processing multiple gravity readings taken at each station were averaged and readings with higher standard deviation (SD) were omitted. The instrument was also monitored for any seismic or instrumental noise and the X/Y tilts, temperature and tolerance between readings was monitored during the reading by the Surveyor.

All gravity surveying consisted of measuring data in independent closed loops, which started and finished at the newly established base (Daishsat Base 1539) which was tied into the Australian Fundamental Gravity Network (AFGN) base (see section 5.3 for details). This was due to the fact the crew were based at Cabramurra for the duration of the survey and it was convenient to start and end loops at this location. Loop duration was generally around 5 – 8 hours but in order to ensure data quality was high, a minimum of 2.5% of stations were repeated.

Field notes were recorded by the operator at each station which included the station identifier (line and station number), relative gravity reading, time, measurements of distance and direction offset of the gravity meter from the GPS antenna and approximate slope measurements (for Hammer Zones if required) were recorded. Digital data was recorded by the gravity meter which was downloaded at the end of each day and checked against field notes to ensure consistency prior to processing.

Whenever possible gravity stations were located as far away as practical from abrupt changes in elevation in order to limit the effect of terrain on the gravity meter.

5.3. Datum Control

A primary gravity base station (Daishsat Base 1539) was established just off Gooandra Trail for the purpose of datum and drift control. This base station is located west of an existing fence post (star picket) and marked with a star picket with a base station information tag stamped with the station number (Figure 7 Left). This Base station 1539 was tied to the Australian Fundamental Gravity Network (AFGN) base 2013909231 located at Cooma showground (Figure 7 Right) by a A-B-A loop using multiple gravity meters. Details for this base station and the AFGN base can be found in Appendix E. Because of the large distance between the stations (a travel time of some 5 hours return trip) it was not possible to complete any more than one loop to improve accuracy and confirm the reliability of the value. Results of the ties observed to the AFGN network using all gravity meters are available in Appendix D.

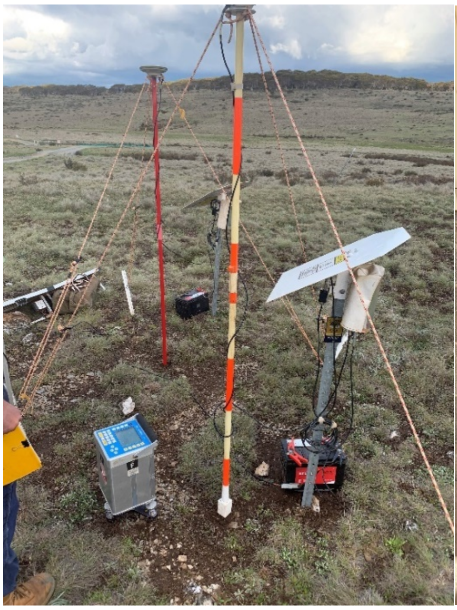

Figure 8: Left - Gravity base 1539 setup with GPS and gravity meter.

Figure 7: Right – AFGN base station tie at Cooma.

5.4. GPS Surveying

FGG surveyed all gravity stations with GPS utilising Leica GRX1230 geodetic receivers. Data was recorded continuously during the day at 5 second intervals and stored on either internal memory or removable PCMCIA cards and downloaded at the completion of each day.

In order to minimise the loss of survey data in the event of a hardware failure, two GPS receivers were used to log data at the base at all times (logging simultaneously).

In instances where dense tree canopies affected GPS signal while surveying, the crew was required to wait for extended periods to acquire accurate horizontal positioning, which in turn allowed for the utilisation of the high accuracy lidar data to cross-check elevations at given points. Subsequently with this method a height observational accuracy (SD) of 0.037m was achieved for the survey.

5.4.1. Control Point Establishment

The primary GPS base station was located coincident with gravity base 1539 and this station was used to establish all local field bases. For processing purposes, the local field base was used to correct the rover data to limit the baseline length (base – rover separation) to less than 20 km distance. Base station 1539 was then used to derive coordinates for the local field base via a static tie with approximately 8 – 10 hours of data providing extremely stable and reliable GPS solutions.

Survey control for the base station (1539) was established using long baseline processing (AUSPOS). This facility is provided by GA and uses the Australian Regional GPS Network (ARGN) base stations situated around Australia. The data processing is accurate to 10-20 mm in the horizontal and 20-30 mm in vertical ellipsoidal height provided sufficient data is observed at the field base.

5.5. Gravity (Data) Processing and Formulae

At the end of each field day the raw gravity data was downloaded from the CG-5 instruments onto a laptop where preliminary quality control was carried out. Any erroneous station numbers were corrected and readings that fell outside of tolerance were removed. Once this was done spreadsheet software was used to average the two 20-second readings for each gravity station, remove the Scintrex Earth Tide Correction and assign each gravity station reading an easting and northing co-ordinate and an ellipsoidal elevation. Geosoft's GRAVRED software was then used to perform gravity reductions to produce a set of observed gravity values that can be used for gridding, imaging and further analysis. The following outlies each individual processing corrections applied to the raw gravity data:

Instrument Scale Factor (SF): This correction is applied to correct each raw gravity reading (in dial units) to a relative gravity unit value based on the meter calibration.

$$RSF = rd \times SF$$

Where:

RSF = scale factor corrected reading in milliGals

rd = raw gravity meter reading in dial units

SF = instrument scale factor (dial units/milliGal)

Earth Tide Correction (ETC): This correction is applied to correct for regular variations in the Earth's gravitational field due to changes in the relative position of the moon and sun. The Scintrex calculated ETC was removed and a new ETC was calculated using Geosoft Formulae.

$$rETC = rSF + ETC$$

Where:

rETC = Earth Tide Corrected reading in milliGals

rSF = Scale Factor Corrected reading in milliGals

ETC = Earth Tide Correction (ETC) in milliGals

Instrument Drift Correction (IDC): This correction is applied to compensate for the daily changes in the gravity meter due to mechanical stresses and strains encountered during surveying. The extension and contraction of the gravity meter spring with slight variations in temperature (obeying Hooke's Law) are the major cause of drift. The drift is assumed to be linear and is calculated by measuring the difference between the last and first base readings.

$$ID = rB2 - rB1 tB2 - tB1$$

Where:

- ID = Instrument Drift in milliGals/hour
- rB2 = 2nd Gravity Base reading in milliGals
- rB1 = 1st Gravity Base reading in milliGals
- t B2 = Time of 2nd Gravity Base reading
- t B2 = Time of 1st Gravity Base reading

Observed Gravity (G_{OBS}): The preceding corrections are applied to each of the raw gravity readings to calculate the earth's relative gravitational attraction at each of the field gravity stations. Absolute gravity values are determined relative to a known Observed gravity value at each base. Observed Gravity values were calculated for both the ISOGAL84 and AAGD07 gravity datums.

$$G_{BOS} = G_{B1} + (r_{ETC} – r_{B1}) – (t – t_{B1}) \text{ x ID}$$

Where:

- G_{B1} = Gravity Base Observed Gravity in milliGals
- r_{ETC} = Earth Tide Corrected reading in milliGals
- r_{B1} = Gravity Base reading in milliGals
- t = Time of field reading
- t_{B1} = Time of Gravity Base reading
- ID = Instrument Drift in milliGals/hour

Once Observed Gravity values were produced, an Excel spreadsheet was used to calculate Infinite Slab Bouguer Anomaly and Spherical Cap Bouguer Anomaly for each gravity station. The following corrections were applied to produce Infinite Slab Geoidal Bouguer Anomaly values:

Theoretical Gravity (G_{T67}): As the Earth is not a perfect sphere, with the polar radius being smaller than the equatorial radius, gravity values vary with latitude. This is due to the differences in the distance from the centre of the Earth's mass and differences in centrifugal accelerations at varying latitudes. The theoretical value of gravity was calculated using the 1967 variant of the International Gravity Formula and used to latitude correct the observed gravity.

$$G_{T67} = 978031.8456 \text{ x } (1 + 0.005278895 \text{ x } \sin^2\phi + 0.000023462 \text{ x } \sin^4\phi)$$

Where:

- ϕ = GDA94 latitude in decimal degrees

Infinite Slab Free-Air Correction (ISFAC): Since gravity varies inversely with the square of distance, it is necessary to correct for changes in elevation between stations to reduce field readings to a datum surface.

$$ISFAC = (0.3087691 – 0.0004398 \text{ x } \sin^2\phi) \text{ x } h_{AHD} – 0.0000001442 \text{ x } h_{AHD}^2$$

Where:

- h_{AHD} = Height of the gravity meter above the Geoid (Ausgeoid09) in meters

Infinite Slab Bouguer Correction (ISBC): This correction accounts for the attraction of material between the station and datum plane that is ignored in the free-air calculation. A value of 2.67 t/m3 was used in the correction to represent solid earth.

$$ISBC = 0.04191 \times \rho \times h_{AHD}$$

Where:

- P = Earth density in gm/cc
- h_{AHD} = Height of the gravity meter above the Geoid (Ausgeoid09) in meters

Infinite Slab Free Air Anomaly (ISFAA): This is obtained by applying the Infinite Slab Free Air Correction (ISFAC) to the Observed Gravity reading.

$$ISAA = G_{OBSG} – G_{T67} + ISFAC$$

Infinite Slab Bouguer Anomaly (ISBA): This is obtained when all the preceding reductions or corrections have been applied to the observed gravity reading.

$$ISBA = G_{OBSG} – G_{T67} + ISFAC – ISBC$$

Complete Infinite Slab Bouguer Anomaly (CISBA): This was obtained by adding the terrain correction to the Geoidal Bouguer Anomaly.

$$CISBA = G_{OBSG} – G_{T67} +ISFAC – ISBC + TC$$

The following corrections were applied to produce Spherical Cap Ellipsoidal Bouguer Anomaly values:

Theoretical Gravity (G_{T80}): The theoretical gravity value for each gravity station was calculated using the closed form of the 1980 International Gravity Formula (Moritz, 1980) and used to latitude correct the observed gravity.

$$G_{T80} = 978032.67715 \times ((1+0.001931851353 \times \sin 2\phi)/\sqrt{(1 - 0.00669438002290 \times \sin 2\phi)})$$

Where:

- ϕ = GDA94 latitude in decimal degrees

Atmospheric Correction (AC): This correction removes the effect of the change in mass of the atmosphere above the ellipsoid by shifting it vertically into the interior of the geoid.

$$AC = 0.874 - 0.000099 \times h_{ELL} + 0.00000000356 \times h_{ELL}^2$$

Where:

- h_{ELL} = Height of the gravity meter above the ellipsoid (GRS80) in meters

Ellipsoidal Free-Air Correction (EFAC): Since gravity varies inversely with the square of distance, it is necessary to correct for changes in elevation between stations to reduce field readings to a datum surface. The free air correction was calculated using GRS80 ellipsoidal heights and the second order approximation equation (Heiskanen and Mortiz, 1969):

$$EFAC = –1 \times (0.3087691 – 0.0004398 \times \sin^2\theta) \times h_{ELL} + (7.2125 \times 10\text{-}7) \times h_{ELL}^2$$

where:

- h_{ELL} = Height of the gravity meter above the ellipsoid (GRS80) in meters
- ϕ GDA94 latitude in decimal degrees

Spherical Cap Bouguer Correction (SCBC): This correction accounts for the attraction of material between the station and datum plane that is ignored in the free-air calculation. The Bouguer correction uses the closed form equation for the gravity effect of a spherical cap of radius 166.7 km based on a spherical Earth with a mean radius of 6,371.0087714 km, height relative to the GRS80 ellipsoid, and an earth density of 2.67 t/m3 was used in the correction to represent solid earth.

$$SCBC = 2 \times \pi \times (6.67428 \times 10^{-11}) \times \rho \times ((1 + \mu) \times h - \lambda \times R)$$

Where:

- π = pi
- ρ = Earth density in gm/cc
- h = height of the gravity meter above the GDA94 ellipsoid in meters
- μ & λ are dimensionless coefficients with following definitions

  $\mu = ((1/3)*\eta^2 - \eta)$

  where:

  $\eta = h/R$

  $\lambda = (1/3)\{(d + f\delta + \delta 2)[(f - \delta)^2 + k]^{1/2} + p + m*\ln(n/(f - \delta + [(f - \delta)^2 + k]^{1/2})\}$

  where:

  $d = 3*\cos^2\alpha - 2$

  $f = \cos\alpha$; Please Note this "f" is NOT the same as the parameter "f" in Free Air Correction above.

  $k = \sin^2\alpha$;

  $p = -6*\cos^2\alpha\sin(\alpha/2) + 4*\sin^3(\alpha/2)$;

  $\delta = R_o/R$;

  $m = -3*\sin^2\alpha\cos\alpha = -3*k*f$ *Note "m" is NOT the same as the parameter "m" in Free Air Correction above.

  $n = 2*[\sin(\alpha/2) - \sin^2(\alpha/2)]$

  $\alpha = S/R_o$, with S = Bullard B Surface radius = 166.735 km.

Ellipsoidal Free Air Anomaly (EFAA): This is obtained by applying the Atmospheric Correction (AC) and Ellipsoidal Free Air Correction (FAC) to the observed gravity reading.

$$EFAA = G_{OBS} - (G_{T80} - AC) - EFAC$$

Spherical Cap Bouguer Anomaly (SCBA): This is obtained when all the preceding reductions or corrections have been applied to the observed gravity reading.

$$SCBA = EFAA - SCBC$$

Terrain Correction (TC): This correction accounts for the attraction of material above the assumed Bouguer slab and for the over-correction made by the Bouguer Correction when in valleys. An earth density value of **2.67 t/m^3** was used in the correction to represent solid earth.

Complete Spherical Cap Bouguer Anomaly (CSCBA): This was obtained by adding the terrain correction to the Bouguer Gravity Anomaly.

$$CSCBA = SCBA + TC$$

5.5.1. Terrain Corrections

Terrain corrections (TC or TC's) were calculated and applied to the final data. The Terrain Correction software, RASTERTC, was used to calculate near zone to far zone corrections. RASTERTC was coded by Geophysical Software and is ideally suited to this project. Details regarding the method and a more in-depth discussion of the algorithm used, can be found at http://www.geopotential.com/.

The terrain correction procedure corrects gravity measurements for the effect of terrain from a distance Rmin to a distance Rmax. Each gravity station is processed independently, and therefore corrections calculated for a particular station do not depend upon possible location errors of other stations. The correction procedure divides the circular area enclosed by Rmax into an inner zone and an outer zone; the radius separating the inner and outer zone is denoted Rmed.

A surface is fitted to the elevations between Rmin and Rmed; this surface is numerically integrated to calculate that portion of the terrain correction that is due to the terrain located in the interval Rmin <= R <= Rmed. Figure 8 below illustrates the subdivision of areas used in the calculation.

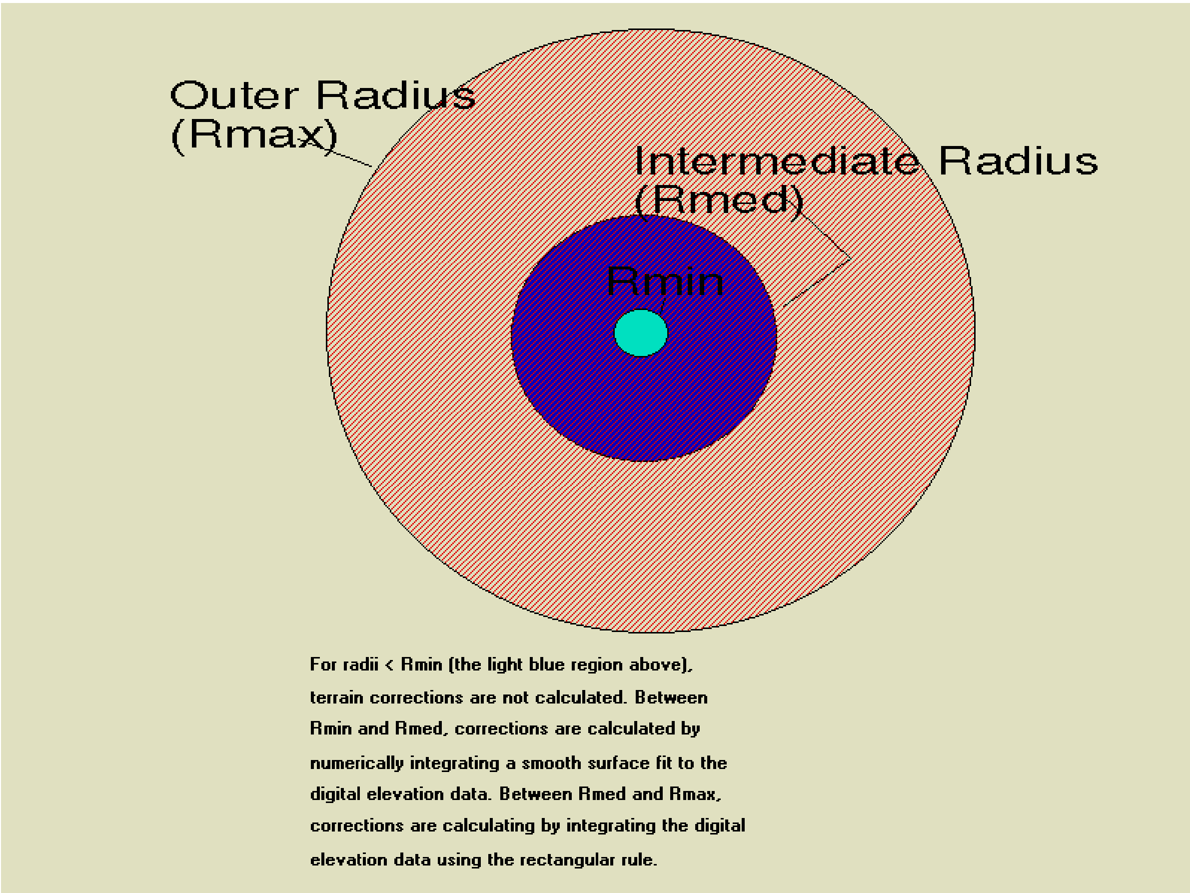

Figure 9 Calculation areas used by RASTERTC

RASTERTC uses triangulation and interpolation procedures to interpolate elevations between Rmin and Rmed. Between Rmed and Rmax, the terrain effect is calculated by assuming that each elevation sample represents the elevation of a rectangular compartment; a line element formula is used to calculate the effect of each such compartment. Terrain compartments lying between Rmed and Rmax that partially intersect the circular radius Rmed are treated in such a way that only the effect of that portion lying outside Rmed is added to the overall terrain effect. A similar procedure is applied to those compartments that partially intersect the outer radius Rmax.

Note that the numerical integration procedure used to calculate the effect of terrain lying between Rmin and Rmed essentially integrates the effect of a line element between the two radii. This integration is repeated to obtain the effect of all the terrain lying within the circular region. The radial portion of the integration is performed using an adaptive technique called QUAN8.

A terrain surface is used close to the station location because the elevations provided by the GNSS are samples and do not actually represent mean elevations of rectangular compartments. The use of a surface provides a terrain representation that should be much closer to reality than the use of compartments of constant mean elevation.

At a certain distance from the station, the procedure of considering the elevation samples as representing the mean elevation of a rectangular compartment should yield numerical results that are not distinguishable from the results that would be obtained by actually using mean elevations of compartments whose size would necessarily be larger than 25m on a side.

In fact, the method used is equivalent to numerically integrating the terrain effect (at distances greater than Rmed) using a rectangular rule. Because the compartment size is relatively small, use of the rectangular rule should be rather accurate.

The elevation of each gravity station is not directly used during the computation of the effect of terrain effects. Instead, the elevation at the horizontal location of the gravity station is calculated from the multiquadric representation of the terrain surface, and this calculated elevation is used in the computation of the effect of terrain. The actual elevation of the gravity station is not used at all.

Numerically, the procedures used for the calculation of the terrain effect are extremely accurate, especially when compared to terrain corrections calculated using template methods. However, the corrections calculated are no better than the terrain data that are used to represent the terrain about each gravity station. Note that all terrain corrections were performed using a rock density of 2.67 tm^{-3}.

5.5.2. Digital Elevation Model (DEM) Preparation

Digital elevation data was sourced from Geoscience Australia's 1 arc-second SRTM (Shuttle Radar Topography Mission) product. A gridded 10m sub sample of the LiDAR survey data was utilised to provide additional DEM resolution.

SRTM digital elevation data was sourced from Geoscience Australia as a mosaic grid covering the entirety of Australia's landmass, and is approximately equivalent to 30m ground resolution. SRTM consisted of a specially modified radar system that flew on-board the Space Shuttle Endeavour during an 11-day mission in February of 2000, which obtained elevation data on a near global scale to generate high resolution, digital topographic elevation models of Earth.

An area was drawn with a buffer of >30km from the outer extents of the project survey data to be terrain corrected, which was then used to export a section of the SRTM mosaic and reproject it to the same datums used in the data processing (MGA zone 55 and AHD). Geosoft's Oasis Montaj software was again used to merge the LiDAR with the SRTM grids (Figure 10).

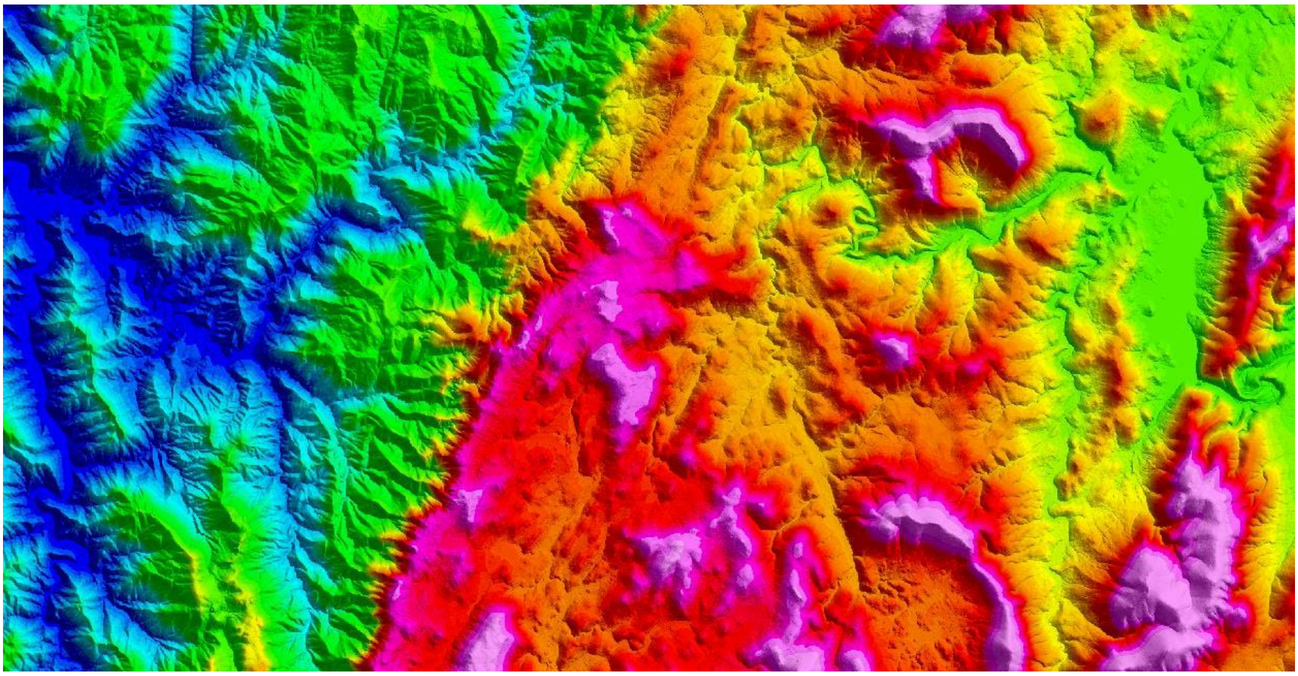

Figure 10: Example Elevation grid used for Terrain Corrections

5.5.3. RASTERTC Corrections

Terrain Correction using SRTM DEM data were calculated using RASTERTC with the following radius parameters:

- Rmin = 30m (SRTM only) / 10m (LiDAR & SRTM)
- Rmed = 450m
- Rmax = 25000m
- Azimuthal Integration Angle = 4 degrees

Rmin was selected to correct for all terrain in the immediate vicinity of the station and coincided with the cell size of the SRTM grid (30m) or LiDAR grid (10m). Rmax was specified to allow correction for the extreme terrain at large distances from the station (outer zone). Rmed was chosen so that the terrain would be "sampled" at an interval close to that of the grid cell size dependent upon the azimuthal integration angle ϕ. During the radial integration, near the maximum radial portion of the integration, the terrain surface is being sampled at approximately Rmed(sin(ϕ)), where R is the maximum radius chosen for the surface integration. For example, at ϕ = 4° and Rmed = 450m, the terrain surface is sampled at 31.4m which is close to the 30m SRTM resolution.

When calculating the RASTERTC correction, the station GNSS elevations were not used. Instead, the elevation at the horizontal location of the gravity station was calculated from the multiquadric representation of the terrain surface, and this calculated elevation was used in the computation of the effect of terrain. The actual elevation of the gravity station is not used at all. The use of the actual elevation, rather than one consistent with the SRTM terrain, effectively leads to gravity stations being located in deep holes or on very steep hills, whereas in fact such terrain features probably do not exist in the immediate vicinity of the gravity station.

5.5.4. Accuracy of the corrections

The terrain correction procedure produced highly accurate corrections. As with any terrain correction procedure, the accuracy of the final correction is dependent on the accuracy of the DEM used.

Indicators of quality are provided for both the inner and outer-most terrain correction as an error code. In the RASTERTC output files, these QF codes are listed under the column headings "QF-Inner" and "QF-Outer", respectively for each processed gravity station. The quality factors should be 0 for both the inner and the outer zones, with other codes described in the following paragraphs.

The QF-Inner error codes provide a rough indicator of how well the terrain in the immediate vicinity of a gravity station is represented by the available elevation samples. In the radial interval Rmin to Rmed, RASTERTC counts the number of samples falling within the 8 octants surrounding the station. If any of these octants are missing elevation samples, the error code notes how many of octants are missing (as described in the table below).

The QF-Outer codes are simple to interpret. A result of 0 means that the outer-zone calculation proceeded successfully. If a portion of the outer-zone terrain is missing from the elevation grids supplied, the value of QF-Outer will reflect the per cent of terrain that was available (rounded to the nearest per cent). For example, if the QF-Outer error code is 91, 9% of the terrain in the outer zones was missing, and that the terrain correction calculated for that particular station is too small.

Upon any error codes being detected, DEM's, data and parameters were checked and recreated if necessary to recalculate the erroneous terrain correction. This method has resulted in zero error codes being recorded for the processed data. Terrain correction details (Error codes) as they related to each station value are viewable in the processed data (Appendix C).

5.6. Gravity Results

After the gravity data corrections (latitude, free air, Bouguer, terrain, etc.) were applied and reduced to the values they would have on a datum of equipotential surface in Microsoft Excel, the spreadsheet was then imported into Golden Software's Surfer 15 program. This data was gridded to produce a colour-shaded contour maps of the Spherical Cap Bouguer anomaly. Figure 11 displays the gridded results of both the GA regional data and the merged survey data.

It is evident that the area has a regional trend that is low in the west and east, and higher around the centre of the alignment, which is also apparent in the Geoscience Australia regional grid.

The regional trend is commonly referred to as the 'low frequency component' reflects the effect of deep masses within the Earth. Removal of the regional trend incorporates predicting deep gravity values from the observed gravity values. These deep values are then removed to leave the effects of controlling gravity values from a source closer to the surface (Murray & Tracy, 2001). A third order regional trend removal was completed using Geosoft Oasis montaj trend.gx script. Geosoft calculates to the n'th order trend of a data channel by (least square) best-fit polynomial (Geosoft, 2005). The lower order polynomials did not alter the data or produce a higher quality image, and the higher order polynomials started to distort the image, making the image very complex by introducing artefacts into the data. The third order polynomial was chosen as the result that best fits the known geology.

The resulting comparison of the new gridded survey data merged with the Geoscience Australia data shows a distinct increase in resolution. The new gravity measurements show improved resolution over the low to both the east and west and the highs that intersect around the centre of the alignment. The low over the western part of the alignment has now been split and compartmentalised into zones of separate lows and highs that are more realistically representative of the mapped geological boundaries. These steep gravity gradients over the Western proportion of the alignment indicate a sharp variation in rock density and likely complex geological structures. The high on the north/western edge is also now very apparent but could be caused by a larger dense unit that lies to the west of the area at depth.

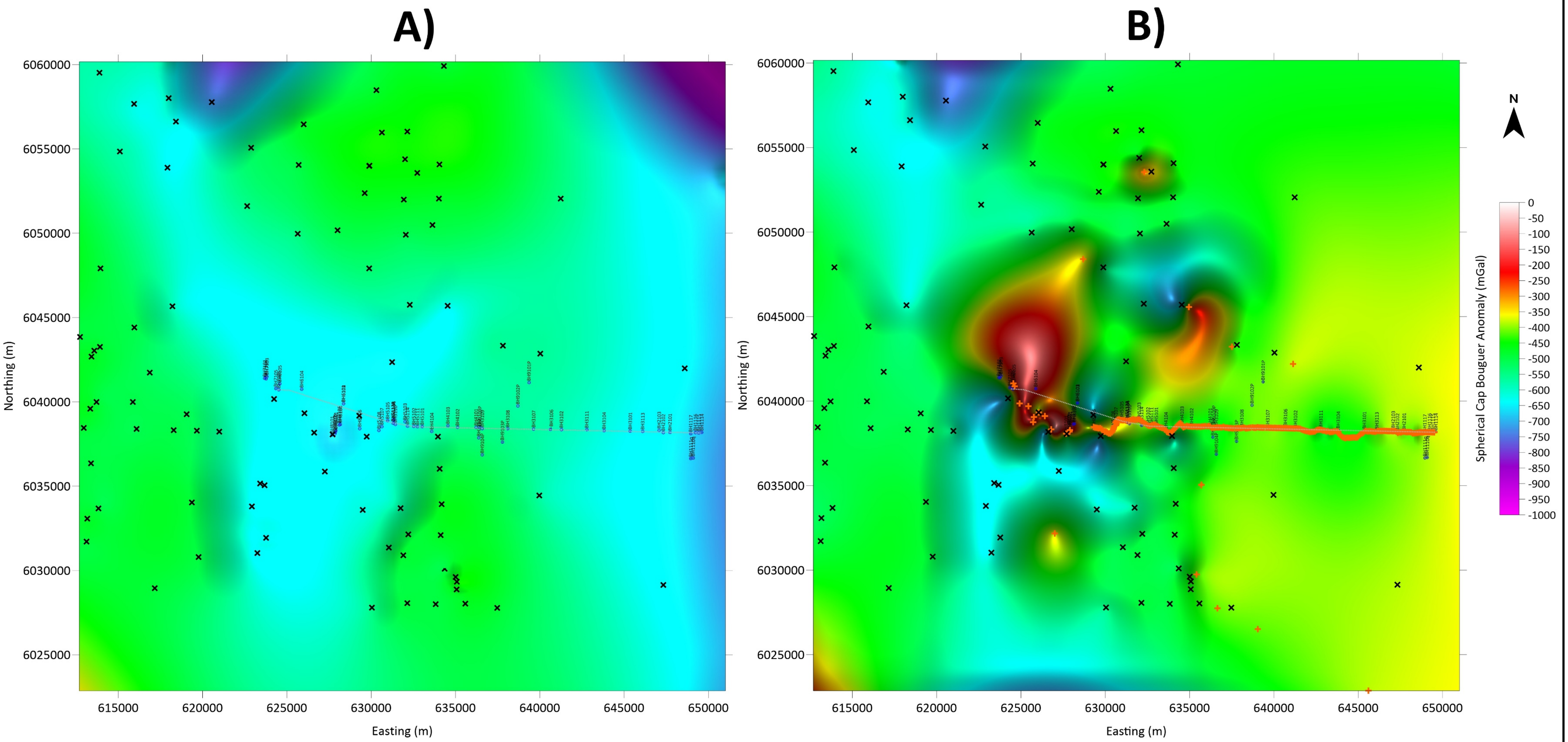

Figure 11: Spherical Cap Bouguer anomaly grid (A) data from Geoscience Australia regional dataset, and (B) data from this project merged with the Geoscience Australia data.

Projection: Universal Transverse Mercator (UTM)
Horizontal/Grid Datum: WGS84 Zone 55(s)

LEGEND

Borehole Locations | GA Gravity stations | Project Alignment | SH2.0 Gravity Stations

revision	description	drawn	approved	date
	DRAFT	RL		19/12/2018

DRAFT_REV01

Scale (meters): 0 5000 10000 15000

Additional data provided by: Australian Government Geoscience Australia; nearmap

drawn	RL
approved	RL
date	19/12/2018
scale	
original size	A3

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client: Snowy Hydro Limited
project: Snowy Hydro 2.0 Potential fields - Gravity and Magnetics survey
title: Regional (GA) data merged with survey data
project no: 30012598_S2-PM-1007
figure no: 11

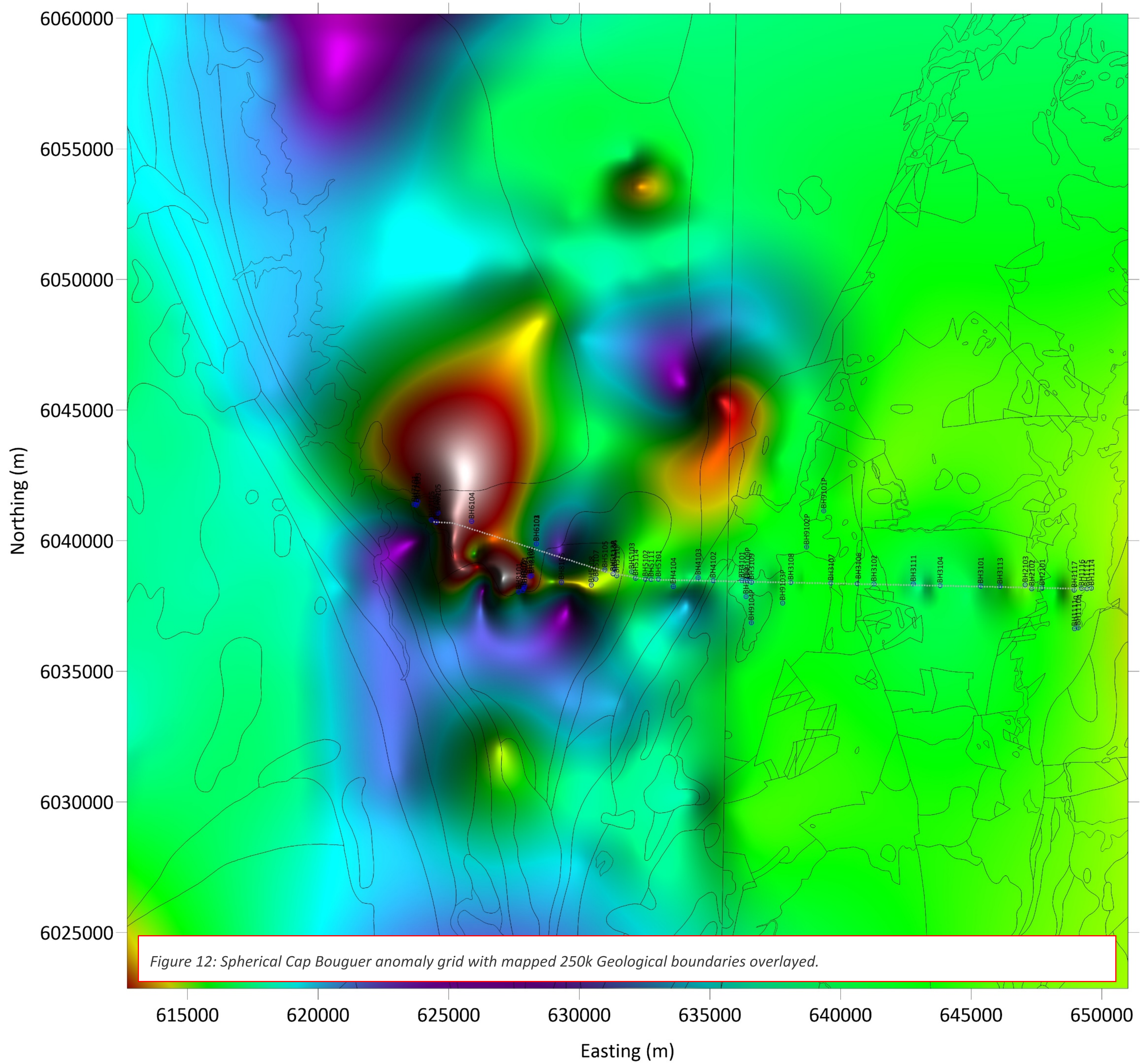

Figure 12: Spherical Cap Bouguer anomaly grid with mapped 250k Geological boundaries overlayed.

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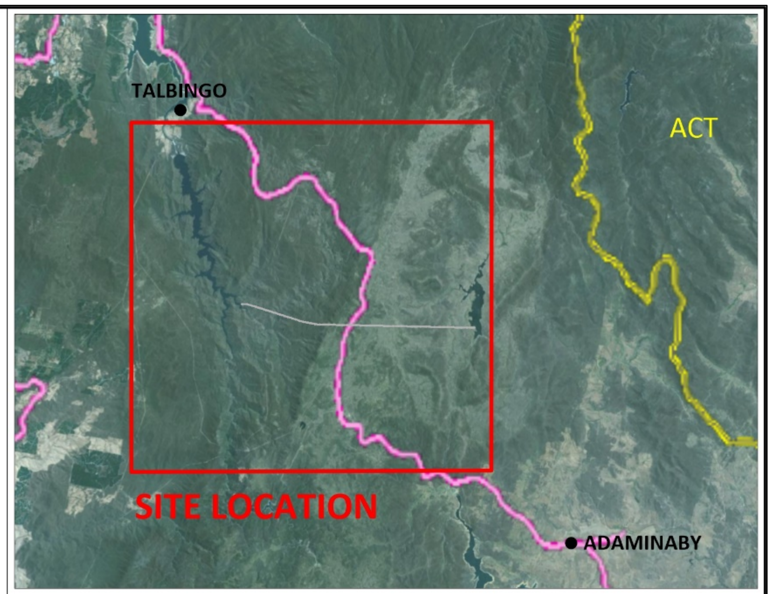

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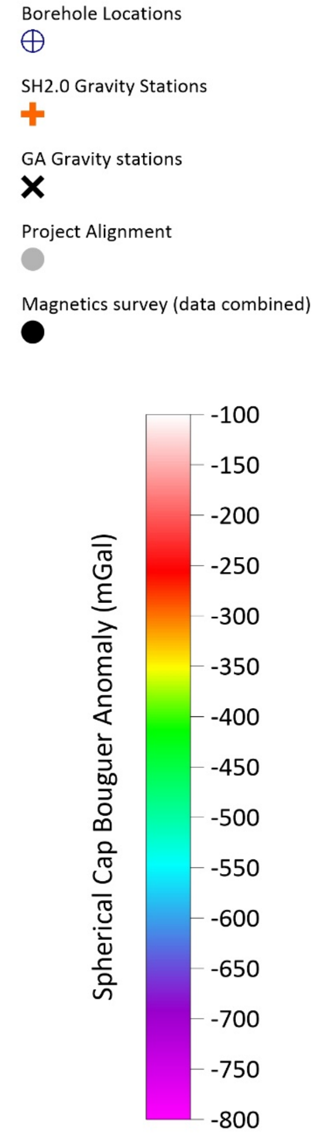

Projection: Universal Transverse Mercator (UTM)
Horizontal/Grid Datum: WGS84 Zone 55(s)

revision	description	drawn	approved	date
	DRAFT	RL		19/12/2018

DRAFT_REV01

0 5000 10000 15000
Scale (meters)

Additional data provided by:
Australian Government
Geoscience Australia
nearmap

drawn	RL
approved	RL
date	19/12/2018
scale	
original size	A3

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client:	Snowy Hydro Limited
project:	Snowy Hydro 2.0 Potential fields - gravity and magnetics survey
title:	Gravity data with 250k Geological boundaries
project no:	30012598_S2-PM-1007
figure no:	12

6. MAGNETICS SURVEYING

6.1. Introduction

The magnetic signature of rocks is due to the concentration, magnetization direction and specific type of magnetic mineral present with the rocks. The most magnetic mineral which occurs naturally in rocks is magnetite (Fe_3O_4) which exhibits a permanent magnetism and is inherently ferrimagnetic. Therefore, the higher the concentration of this mineral present in a rock, the greater its magnetic properties. Igneous rocks typically contain high concentrations of magnetite, when compared to sedimentary and most metamorphic rocks (Mussett and Khan, 2000).

When a magnetised body is subject to an external magnetic field (H), it acquires a certain degree of magnetisation when the applied field (H) is removed. Such a magnetisation (J_i), is said to be induced by the applied magnetising field (H). However, minerals such as magnetite exhibit a strong magnetic response even in the absence of the applied field (Sharma, 1976). This is why rocks containing magnetite in higher concentrations exhibit a permanent or remnant magnetism. The majority of rocks display the induced magnetisation (J_i) to be parallel and proportional to the applied field (H) (Sharma, 1976) thus such a relationship can be expressed as:

$$J_i = kH$$

where:

- J_i = Induced magnetic field
- H = Applied magnetic field
- k = Magnetic susceptibility

This (k) factor is called the magnetic susceptibility and is a characteristic constant for a magnetisable material (Sharma, 1976). This becomes relevant as it allows one to obtain a further distinguishing characteristic from a particular rock type.

The geology present along the project alignment exhibit a magnetic contrast, as shown in section 3.2.2, with characteristic magnetic highs interrelated with the Volcanic units. Thus, modelling of the depth extent and geological contact angles can be further constrained by the addition of magnetic data into the modelling process. This is the primary justification for the acquisition of the high-resolution ground magnetics, to provide further constraint for the gravity data.

6.2. Rock Susceptibility Measurements

Drill core collected for the purpose of geotechnical assessment were utilised for measurement of bulk K magnetic susceptibility to aid the 2D magnetic interpretation.

Indiviual core specimens were subject to measurements using a handheld magROCK Magnetic Susceptibility Meter to obtain their susceptibility values. The complete results of the measurements are available in Appendix F, and an overview of the data is provided in Table 3.

6.3. Data Acquisition

The ground Magnetic survey commenced on the 26th November 2018 and was acquired over a three-day period. The survey was conducted by Daishsat Geodetic surveyors Pty Ltd, with ground support provided by Jindabyne Landscapes personnel, and under supervision of a SMEC Geophysicists for QA/QC indemnification.

The magnetic profile was acquired using a Geometrics G-859 Portable Magnetometer (Figure 13). The unit consists of a sensor placed on the top of a carbon fibre staff connected to a receiving unit, powered by an internal battery. The G-856 has a resolution of 0.1 nT (Nanotesla) (Geometrics, 1992). Field measurements were continuously recorded at 1Hz (approximately a reading every 1m) and stored in the internal memory and downloaded onto a laptop at the end of each survey day. Proton magnetometers are commonly used for survey and observation geophysics. A total of 24,340 new magnetometer readings were acquired.

Table 3: Summary of Magnetic susceptibility values

Formation	Logged Strata	Sample set	Mean Susceptibility (SI*10-3)	StdDev. (±)
Boggy Plain Suite	Diorite	5	1.138	0.051
Boraig Group	Conglomerate	28	0.334	
	Dacite	1	0.116	
	Interlaminated sandstone & siltstone	39	0.290	0.134
	Rhyolite	2	0.261	
	Tuff	3	0.058	
Gooandra Volcanics	Diorite	6	1.059	
	Gneiss	15	0.087	0.019
	Meta-Basalt	3	0.174	
	Phyllite	8	0.087	0.075
	Quartz/Breccia	3	0.189	
	Schist	37	0.087	0.107
	Volcanic	7	0.087	
Kelly Plains Volcanics	Dacite	24	0.152	0.000
	Siltstone	3	0.160	0.069
Ravine Beds East	Gneiss	1	0.725	
	Fault Zone: Siltstone/Volcanic	11	0.558	0.113
	Interbedded Mudstone & Sandstone	12	0.348	0.000
	Interlaminated: Sandstone/Siltstone	31	0.080	0.104
	Sandstone	9	0.138	0.000
Tantangara Formation	Interbedded: Siltstone/Sandstone	6	0.595	
	Meta-Basalt	2	0.609	
	Rhyolite	4	0.363	
	Sandstone	7	0.595	0.000
	Siltstone	7	0.373	0.255
	Volcanic	8	0.392	
Temperance Formation	Diorite	6	0.812	
	Meta-Basalt	1	1.566	
	Schist	9	1.428	0.428
Tumut Ponds	Metasediments	7	0.783	

Figure 13: Left – field setup for magnetic data acquisition.

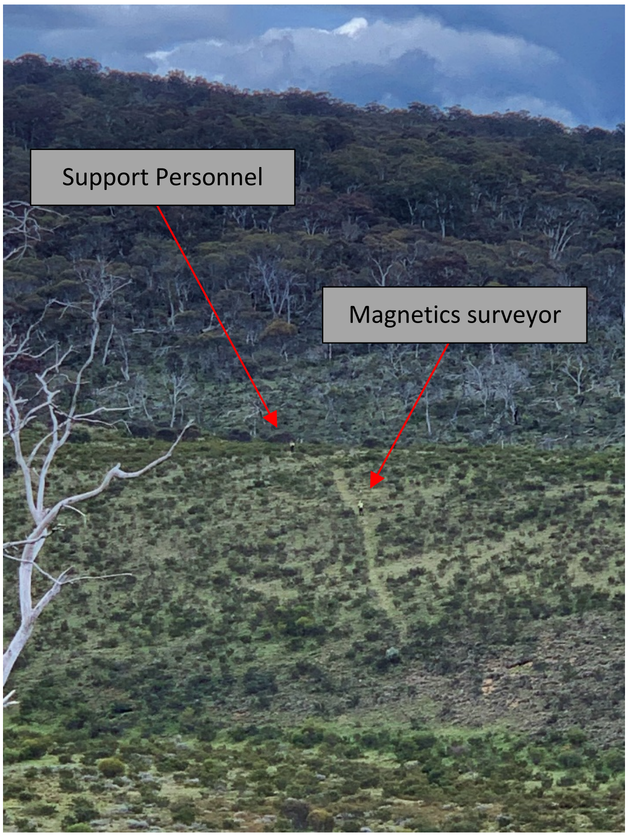

Figure 14: Right – Photo of magnetic data acquisition with equipment and support crew (looking west over Nungar Creek).

6.3.1. Magnetic Base Station

In order to remove fluctuations in the Earth's magnetic field (diurnal variations), two redundant base stations were setup daily to record the Earth's field at a fixed position in an area with no external interference. Redundant stations are ideal in the event one fails during a survey day.

Each base station included a sensor connected to a dedicated Geometrics G-856 Proton Magnetometer. The sensing device is a container filled with a hydrogen atom rich liquid, such as kerosene, surrounded by a coil. A current is passed through the coil to generate a magnetic field. The current in the coil is then turned off and the protons return to their original alignment by processing. The frequency of this process is then measured which in turn provides an accurate field strength measurement.

Each of these base setups were powered by two batteries with enough power to last multiple days. The magnetic base data readings were logged in communication software and synchronized to UTC time for direct correlation with survey (rover) data. Base station data were collected at a rate of 10 Hz.

6.4. Magnetic Results

Throughout the survey, and at the end of each day, the digital data was transferred from both the base station's data-logger and the field rover unit to a fieldwork laptop running Geometrics 'MagMap2000' software where initial plotting and corrections could be applied. Final corrections included, diurnal correction, removal of spikes, heading errors and interpolation of GPS dropouts due to overlying tree cover.

As the survey was collected as a single line profile and in order to create a Total Magnetic Intensity (TMI) grid of the area, data from Geoscience Australia (GA) was integrated. As the GA data is collected via a flown (aircraft) survey, the magnetic intensity signature of an anomaly is often different to a ground survey due to the increased sensor height from surface. Therefore, a sensor altitude/height correction was required between the ground survey data collected and the flown survey data. This correction was achieved via the application of the magnetics processing algorithm in ER Mapper 7.1 (Earth Resource Mapping software).

After the magnetic data was corrected a xyz data file was imported into Golden Software's Surfer 15 program, which was used for plotting the grid shown on Figure 15.

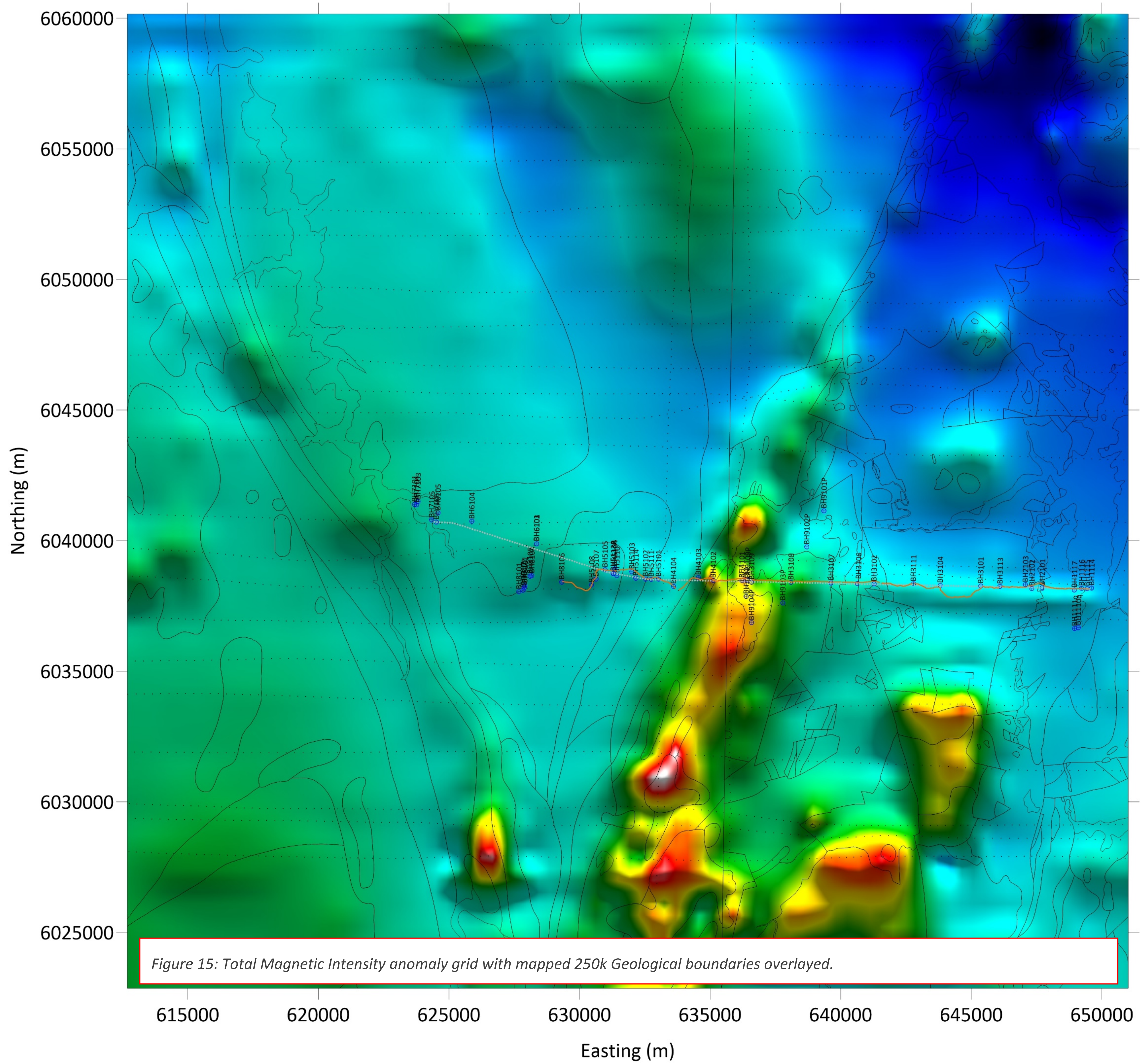

Figure 15: Total Magnetic Intensity anomaly grid with mapped 250k Geological boundaries overlayed.

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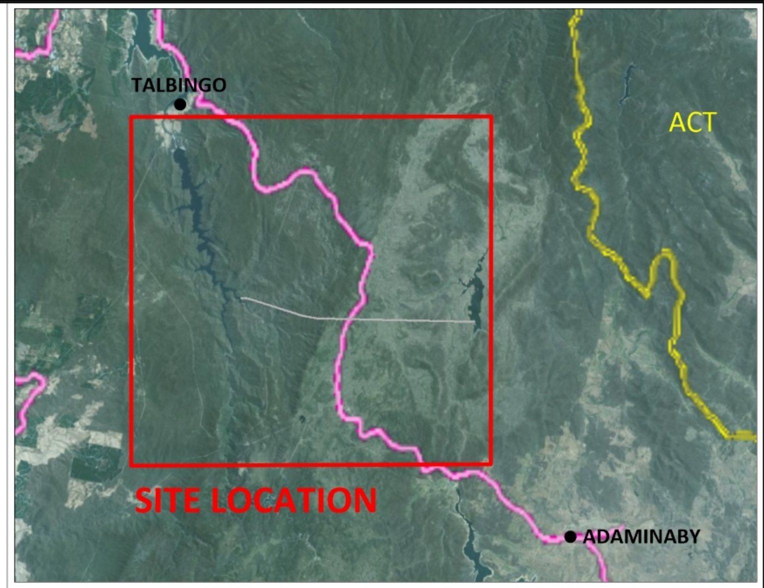


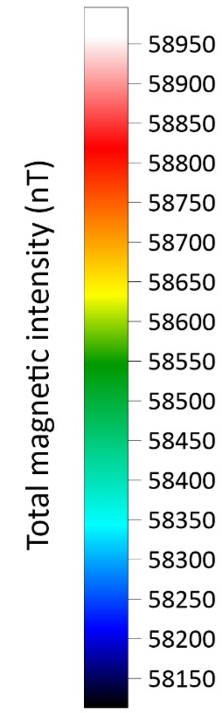
LEGEND

Borehole Locations

Project Alignment

GA Magnetics (flight lines) Data

SH2.0 Magnetics data



Projection: Universal Transverse Mercator (UTM)
Horizontal/Grid Datum: WGS84 Zone 55(s)

revision	description	drawn	approved	date
	DRAFT	RL		19/12/2018

DRAFT_REV01

0 5000 10000 15000
Scale (meters)

Additional data provided by:
Australian Government
Geoscience Australia
nearmap

drawn	RL
approved	RL
date	19/12/2018
scale	
original size	A3

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client: Snowy Hydro Limited

project: Snowy Hydro 2.0
Potential fields - Gravity and Magnetics survey

title: Combined Magnetics data with 250k Geological boundaries

project no: 30012598_S2-PM-1007

figure no: 15

7. GEOPHYSICAL MODELLING AND ASSESSMENT

7.1. Modelling Objectives

The primary objective of the modelling was to try to detect any granitic plutons coincident with the tunnel alignment. Typically, such bodies would be associated with localised low gravity values. The secondary objective was to delineate potential fracture zones which could affect construction and have groundwater implementations.

7.2. Gravity Modelling

When modelling gravity data, there can be many different models that fit a given anomaly. Thus, determining the correct seed or base model to work from can be of great significance to the modelled outcome. This normally starts with having reliable geological constraints to apply to the data. There are also two key methods to interpret Bouguer anomalies, via direct interpretation of the profile, or indirectly. The later of these two involves producing models that are used to compute synthetic gravity anomalies, which can then be compared to the observed Bouguer anomaly (Reynolds, 1997). This process is recognized as forward modelling (Murray & Tracy, 2001). The level of error of a particular model produced is expressed by the calculated root-mean-square error (RMS), thus allowing for the user to modify the model to decrease this error and subsequently create an improved model.

The Forward modelling method was used for modelling as it provides immediate contrast for areas of poor correlation between the collected data (gravity, density) and the assumed geological model. This in turn highlights areas which require more scrutiny or revision of the geological model to resolve the discrepancy.

Models created herein were constructed using 2D polygons of differing geometrical shapes and volumes, and primarily based off the geological boundaries shown in the geotechnical long-section (E-4 - S2-4400-INF-GEO-LS-PWT-RG-180914-001). These model shapes produce a variety of response profiles, the aim is to construct a model which represents geologically sound structures within the model space with minimum (RMS) error. The model was constrained using the measured densities from petrophysical sampling (lab data), along with the information from boreholes, mapped surface geology (applied for lateral constraint), and pre-existing structural data from literature where available.

Most modern software packages will also allow the user to perform inverse modelling operations (Sharma, 1997).This is where the observed anomaly is used to calculate a structured model of the data. The problem with this method is accuracy, and the processing time, which is greatly increased over the forward modelling process of which was applied here.

Models by their nature are non-unique and numerous plausible models may match the data. The number of possible models can be reduced by constraining model inputs such as measured densities, geological contacts from mapping and boreholes, by integrating additional geophysical investigations such as the Magnetics and seismic surveys which are outlined in the previous chapter.

Other operations can be performed to enhance certain features of interest in the data. For example, with gravity data, a Downward or Upward Continuation Operation can be applied. This is effectively the recalculation of the surveyed gravitational field, at a lower or higher level respectively. Hence a Downward continuation will enhance high frequency anomalies by effectively bringing the observation points closer to the ground and conversely the reverse effect occurs for upward continuation. However, none of these operations were applied to the data herein to allow the user to determine differing wavelength anomalies via the direct model response. Furthermore, all these factors were taken into account when producing and constraining the model.

7.3. Data Inputs

The field collected data was processed (corrected) to industry standards with a high degree of resulting accuracy. A high level of confidence in the data exits as a result of the processing, the repeatability of the data, and subsequently tying into the GA run Fundamental Gravity Network (FGN). All these factors allowed for a complete 'Spherical Cap Bouguer' value to be produced which was applied for the modelling procedure. The modelling was based on the following four channels of data:

Table 4 Summary of Modelling inputs.

Channel	Description	Potent terminology
EAST_MGA94_m	Easting	X
NORTH_MGA94_m	Northing	Y
HEIGH_AHD09_m	Height	Z
CSCBA_267_mGal	Complete Spherical Cap Bouguer Anomaly (2.67 t/m^3) (This output channel was chosen because, when plotted, it provided the smoothest profile, with no obvious correlation with topography. The terrain corrections that are included in this channel can be seen to be highly effective when compared to the non-TC version.)	Gz (the vertical gravity field in mgal)

The majority of the data applied to the model was acquired along a single 20 km E-W traverse at 100 m station spacing, which was as close to the proposed tunnel alignment as practical. However, regional stations were also acquired and were included in the modelling if they were within reasonable distance from the traverse. With the addition of these regional stations, the traverse was extended to a total length of just over 25 km.

As is usual when working with gravity data (Gz), a regional (background) field was removed prior to commencement of modelling. The background field represents long wavelength features that are not relevant to the current project as they are caused by deeper crustal features associated with lithospheric conditions. In this case the regional trend took the form of a surface very slightly inclined to the East. Specifically, this slope equalled, for an observation point with map Easting X metres: $dGz = 63.4 + 0.00003 * (X - 637033.1)$.

The dGz value was added to the corresponding Gz value. The subsequent anomalies which remained to be modelled are directly relatable to the geological features and/or geological structures present in the subsurface in the area of the survey.

7.4. Modelling

Modelling of the gravity field was done using Potent™software from Geophysical Software Solutions P/L (GSS) in Canberra, Australia. A starting model was created in Potent, consisting of polygonal cross-section bodies that were based on the simplified geological section from the GBR A RevB. Each body represents a geological formation. As the data were confined to a single traverse, bodies were assumed to be "2-dimensional", meaning that they had infinite strike length. Bodies were assigned a strike of 20° based on the local trend of the geology. Once the geometrical model had been created in Potent, densities, based on petrophysical lab results from bore-holes, were assigned to the various units. The modelling process consisted of adjusting densities and cross-sectional polygons so that the calculated gravity matched as far as possible the observed gravity, while respecting geological constraints such as surface geology, bore-hole logged information and magnetics data. After much trial and error with multiple reiterations, a final model was created which had a gravity response that closely reflected the observed gravity with a low error sum (RMS) 1.68) when cross checked with a density inversion.

7.5. Applied Petrophysical Parameters

The magnetic susceptibility of the rock units, shown in Table 3 of section 6.2 and Table 5 below, were applied where possible to aid and constrain interpretation during the modelling process. however, this data was not used for the final model inversion due to its sparsely distributed information when in comparison to the available density data as it would have required assigning of information to bridge data gaps, therefore potentially introducing error.

The densities applied for each individual formation/body were derived from the laboratory testing of borehole samples that retuned a Bulk Density value which are shown in Table 5. These results were further constrained by divided them into lithological (rock types) and discerning the calculated percentage of that rock type over the formation which to provide better constraint of the density ranges which could be applied to the model. Table 6 shows the assumed mean densities and ranges which were used to constrain the inversion. Note: no densities exist for the Shaw Hill Gabbro thus were inferred from literature. For most cases, the model bodies densities post inversion did not reach the (max/min) density limits set in the model runs with the minor exception of the KPV and BRG highlighted in Table 6 which are still within the Standard Deviation. This provided increased certainty that the resulting model is robust in nature.

Table 5: Summary of Densities collected from laboratory testing.

Formation	Logged Strata	Sample set	Geological Unit Mean Density (g/cm3)	Geological Unit Density StdDev.	Geological Unit Mean Susceptibility (SI*10-3)	Geological Unit Mag Sus StdDev.
Boggy Plain Suite	Diorite	5	2.687	0.020	1.138	0.051
Boraig Group	Conglomerate	28	2.680	0.030	0.334	
	Conglomerate/Sandstone	6	2.685	0.017		
	Dacite	1	2.670		0.116	
	Ignimbrite	3	2.698	0.010		
	Interbedded siltstone & sandstone	14	2.688	0.077		
	Interlaminated sandstone & siltstone	39	2.687	0.051	0.290	0.134
	Rhyolite	2	2.685	0.012	0.261	
	Sandstone	12	2.690	0.035		
	Schist	10	2.683	0.014		
	Siltstone	22	2.674	0.157		
	Tuff	3	2.640	0.017	0.058	
	Volcanic	4	2.658	0.053		
Byron Range Group	Carbonaceous siltstone/mudstone	9	2.670	0.059		
Gooandra Volcanics	Diorite	6	2.823	0.043	1.059	
	Gneiss	15	2.768	0.073	0.087	0.019
	Meta-Basalt	3	2.710	0.039	0.174	
	Phyllite	8	2.754	0.063	0.087	0.075
	Quartz/Breccia	3	2.634	0.039	0.189	
	Rhyolite	19	2.785	0.152		
	Schist	37	2.756	0.078	0.087	0.107
	Siltstone	9	2.790	0.084		
	Volcanic	7	2.790	0.080	0.087	
Kelly Plains Volcanics	Dacite	17	2.62	0.685	0.152	0.000
	Siltstone	3	2.708	0.006	0.160	0.069
Ravine Beds East	Gneiss	1	2.676		0.725	
	Meta-Andesite	1	2.700			
	Phyllite/Gneiss	2	2.743	0.003		
	Siltstone	77	2.734	0.052		
	Conglomerate	22	2.720	0.044		

Formation	Logged Strata	Sample set	Geological Unit Mean Density (g/cm3)	Geological Unit Density StdDev.	Geological Unit Mean Susceptibility (SI*10-3)	Geological Unit Mag Sus StdDev.
Ravine Beds West	Fault Zone: Siltstone/Volcanic	11	2.730	0.022	0.558	0.113
	Interbedded Mudstone & Sandstone	12	2.729	0.038	0.348	0.000
	Interlaminated: Sandstone/Siltstone	31	2.711	0.039	0.080	0.104
	Sandstone	9	2.690	0.058	0.138	0.000
	Siltstone	48	2.720	0.035		
Tantangara Formation	Interbedded: Siltstone/Sandstone	6	2.699	0.032	0.595	
	Meta-Basalt	2	2.694	0.023	0.609	
	Rhyolite	4	2.725	0.039	0.363	
	Sandstone	7	2.677	0.029	0.595	0.000
	Schist	3	2.712	0.026		
	Siltstone	7	2.699	0.030	0.373	0.255
	Volcanic	8	2.675	0.040	0.392	
Temperance Formation	Diorite	5	2.755	0.151	0.812	
	Interlaminated: Sandstone/Siltstone	4	2.768	0.048		
	Meta-Basalt	1	3.000		1.566	
	Schist	9	2.790	0.103	1.428	0.428
	Siltstone	3	2.730	0.044		
Ravine Beds	ignimbrite	21	2.651	0.033		

Table 6: Summary of lithological Density ranges applied to model.

Formation	Density input based on Lithology (rock type) % (g/cm^3)	Min Density (G/cm^3)	Max Density (G/cm^3)	Resulting Model Density (post inversion) (G/cm^3)
Boggy Plain Suite	2.687	2.682	2.721	2.700
Boraig Group	2.682	2.546	2.713	2.667 to 2.710
Byron Range Group	2.670	2.320	2.700	2.700(max)
Gooandra Volcanics	2.764	2.640	2.930	2.766 to 2.850
Shaw Hill Gabbro	Inferred 2.880	Inferred 2.880	Inferred 3.200	2.880
Kelly Plains Volcanics	2.626	2.620	2.709	2.620(min)
Ravine Beds East	2.731	2.400	2.775	2.705 to 2.708
Ravine Beds West	2.720	2.650	2.850	2.738
Tantangara Formation	2.690	2.661	2.743	2.669 to 2.710
Temperance Formation	2.752	2.699	3.010	2.800 to 2.845

7.6. Background Density

The value of interest when modelling gravity is the density contrast between formations. To facilitate this a background density (BD) is defined. This allows actual densities (rather than contrasts) to be assigned to formations; the BD is subtracted from the formation density to give the density contrast that is used in calculations. A commonly used value for the BG is 2.67 g/m^3. However, during modelling it was apparent that formation density generally needed to be assigned near the top of the allowable range for the rock type. To facilitate this a slightly lower BG was used – 2.60 g/m^3.

7.7. Modelling Results

Potential field data such as gravity can be inherently ambiguous with a number of differing geometries allowing a similar solution. The number of possible solutions can be reduced by applying geological insight when creating a model, however a level of uncertainty in the result always remains without conformation of targets by means of drilling to confirm. With this said, the data is caused by direct geological conditions and therefore should be assumed to be such. Thus, the anomalous areas described in this section are to be considered an interpretation of the most likely geological conditions present which fit the anomaly present within the data. Working from East to West trough the model, the following sections will outline the results and features which have significant geological implications to the project. Figure 16 shows the resulting model section which will be used as referenced to provide context for the discussion herein.

7.7.1. Intrusive occurrences within the Kelly Plains Volcanics (KPV)

The Kelly Plains Volcanics is comprised mainly of Diorite, a reasonably dense rock, with a relatively consistent composition. Within this formation intrusives have been observed to occur as surface outcrop as little as 150m off the HRT alignment. These intrusions likely extend to depth of at least 150m and given the mass deficiency which is associated with this area, possibly underly the KPV ~200m below the HRT location as the model suggests.

As Figure 16 displays an intrusion in the modelled cross-section location adjacent to BH2101 with the body labelled ‘Pluton 2’. Figure 17 reflects the plan view location of this body with a green zone of lower density. Intrusives (plutons) probably provides circumstantial cause for the topographical rise and associated geomorphological characteristics of the area between BH117 and BH2101, and likely constitutes the geology of the hill between the two sites. Intrusive bodies have not been encountered by geotechnical drilling to date, however the gravity model suggests that it will be highly likely that interaction with such bodies will occur at the tunnel alignment depth during construction.

It should also be noted that the modelled pluton is off the direct alignment, therefore it is not displayed on the geotechnical long-section model, however intrusives are included within the ground type description for the KPV and therefore an elevated likelihood of intersection of intrusives within this formation and has been geotechnically accounted for.

7.7.2. Granites occurrence within the Tantangara Formation (TTF)

The usual signature of a granite pluton is an unexplained “low” in the gravity profile. Sections of the gravity traverse that pass close to known outcropping granite only show small associated lows (e.g. the pluton adjacent to BH2101). However, this does not preclude the existence of granites where no gravity low exits. It is possible that plutons which exist have densities very close to that of the country rock in which that they have intruded. By way of example, plutons have been modelled at 64435E/~CH5000 (Tantangara formation, near BH3104). Each of these have outcrop near the traverse, but inspection of the profile shows a very subtle discernible low. This is likely explainable by the plutons being of S-Type granite affinity, thus suggesting that they have a very similar mineral affinity to the surrounding ‘country’ rocks which they intruded, and therefore very low-density contrast. A better example of this occurrence can be seen when the data from the Tantangara section is separated out, and a gridded section examined in detail (Figure 17). The contrast zones become more apparent when viewed in this format, along with a broader anomaly which is associated with the deeper basement structure.

7.7.3. Basement structure below the TTF and KPV

When commencing modelling this section, the seed model had the TTF extending to depth which emulated the interpretation of the area from the geotechnical long-section. However, it was immediately apparent that the miss fit with the measured anomaly and the model response in this area, and a mass deficiency. Once the densities from the boreholes were also applied, it was even more apparent that this anomaly was associated with the deeper basement structure under the TTF (Figure 18 – dashed red circled area). As a result, the basement structure under the TTF required adjustment to reflect a generally shallower than inferred and more complex basement surface in order to resolve the anomaly and fit the data. Given that the background density is set to 2.60 g/m^3, which is analogous to that of a granite, for pure illustrative purpose a body was added to reflect this basement interpretation (note that its density reflects that of the background). Subsequently the basement shown on the final model (Figure 16) interacts with the HRT at depth in a couple of locations (primarily ~CH4400 and ~CH6000).

To keep the model geologically sound, a division in the TTF model body was required at ~CH5750, labelled Tantangara W (west), with a slightly lower density applied while still respecting the logged lithology and reported lab result density's in the adjacent borehole (BH3111).

The final modelled basement feature protruding upwards near BH3101 is geologically reasonable given the mapped location of the Jindabyne thrust and constitutes a section of granite ~250-300m along the alignment. There is also discreet visual evidence for the presence of intrusion in close proximity to BH3101, as quartz veining and minor stock-working are observed in the core photos.

The basement section which interacts with the HRT to the west of BH3104 at ~CH6000 (Figure 16) is ~800m wide at tunnel depth and is also distinguished visibly as the purple zone between BH3104 and BH3111 to the west. This section of the model provided a challenge, and it is likely that geologically this area may differ from the model.

Overall a primary outcome of the modelling in this area is that, the basement underlying the KPV/TTF is likely shallower than first thought and is expected to be granitic in composition based on the model densities with a nonconformity surface. This also correlates with the regional geological interpretation by (Owen & Wyborn, 1979) that suggests a Large-scale anatexis in the lower crust accompanied regional metamorphism in the Llandoverian epoch (443.8 ± 1.5 to 433.4 ± 2.8 Ma), which resulted in vast amounts of felsic magma being formed.

The possible flow on effects of this new information is that inflow criteria can be better assigned, and the geological model updated to reflect the interaction with plutons and/or basement at depth.

7.7.4. Fracture Zone (~CH12700)

After modelling the known formations, the only large such unexplained gravity low/mass deficiency was within the Gooandra volcanics. This anomaly appeared to represent a feature just east of BH4101 (63650E).

BH4101 has 3 VWP's installed to over 700m depth which show near hydrostatic heads. The aquifer pumping test (EMM) conducted at this site also indicated a 1:1 horizontal to vertical permeability, and the piezometric head contours indicate a permeable zone. This information along with the steeply dipping foliated volcanics suggests a fracture zone (or zone of dilation).

A 10% increase in fracture spacing and porosity was applied to the GOV density in the model and assumed it to have a 100% saturated pore space. This permitted a resulting reduction in density from the 2.850g/cm^3 to 2.673 g/cm^3 which fits well with the amplitude of the anomaly present supporting a fracture zone. The modelled feature is broader at the surface and narrows at depth which still respects the logged information from BH4101 (with low RQD towards the surface).

The geological defence for this feature is that is appears at the approximate topographical hinge point of the (uplifted block) mountains, and therefore will likely have the most releasing stress imposed in this area. This stress is caused by gravity acting upon the landscape and effectively dragging apart the rocks causing a dilatation point, hypothetically similar to a vertically stood stack of cards falling over in either direction when let go, just on a much larger scale and over much more immense geological time period.

This feature could also be modelled as a broader zone of 10% increased fractured rock with a juxtaposed halo of 5% fractured rock at depth, however this increased the model complexity which would not provide improved certainty or improved model response fit.

This approximately 500m wide fracture zone will possibly yield an increased inflow to the HRT during construction potentially require differing lining treatment/inflow criteria assignment. This zone also coincides with an area of magnetic anomaly. The source or geological occurrence for this anomaly has not been seen within the borehole logs, however may potentially be related to secondary (ferrous compounds) mineralisation associated with the fracture zone.

7.7.5. Magnetic anomalies west of LPF Zone (Ravine East)

The area west of the Long Plain Fault within the Ravine East formation is relatively magnetically quiet, which is expected from sedimentary rock dominated lithologies. However, some small (sharp) magnetic anomalies are visibly present on Figure 16. The source of these anomalies is not yet known; however, they could provide the location for some further investigation and could be associated with some of the following features which are probably hidden under the cover of dense vegetation, or weathered (regolith) surfaces:

- Intrusive dykes (gabbroic or dolerite dykes, other mafic intrusives, possible intermediate dykes);
- Basaltic flows within the sedimentary sequences; and/or
- Mineralisation - both depositional and post-depositional (secondary).

Generally, two types of magnetisation of rocks exist, namely; **Induced magnetisation**, which is proportional to the susceptibility of the material being magnetised and which has the same direction as the Earth's field; and **Remanent magnetisation** (permanent), which can have any direction. Induced magnetisation which is far more common than remanent magnetisation however, in certain cases remanent magnetisation can be orders of magnitude greater than induced magnetisation.

All other factors being constant, the magnetic response of a magnetic body is directly proportional to the magnitude of its magnetisation. Therefore, it’s probable that these anomalies (spikes) which are evident in the magnetic survey profile are associated with discreet and likely structurally controlled features.

There are two smaller anomalies that are juxtaposed the location of BH4104 (~CH16000). These could likely be inferred as associated with the occurrence of fault zones and possible mineralisation associated with these structures at depth.

Further west the profile displays a significant dipole response between BH5103 (~CH17650) and BH5104A (~CH18200), which given the shape of this anomaly, is likely related to a steeply westward dipping structure. BH5104A shows a porphyritic basalt- logged from 17.9 to 72m which could provide context to the anomaly shape here and hypothesis of an associated dyke structure.

Borehole logs from BH5103 (siltstone/sandstone) however shows pervasive pyrite associated with quartz veining which could provide correlation with a potential mineralisation system.

Porphyry deposit mostly contain Cu, Cu-Au and Cu-Mo, and are associated with intrusive stocks of generally felsic and porphyritic nature. These mineralisation systems often occur as (Epigenetic deposits) veins and disseminations in country rock above and adjacent to the upper portions of intrusions where hydrothermal fluids and associated alteration occur.

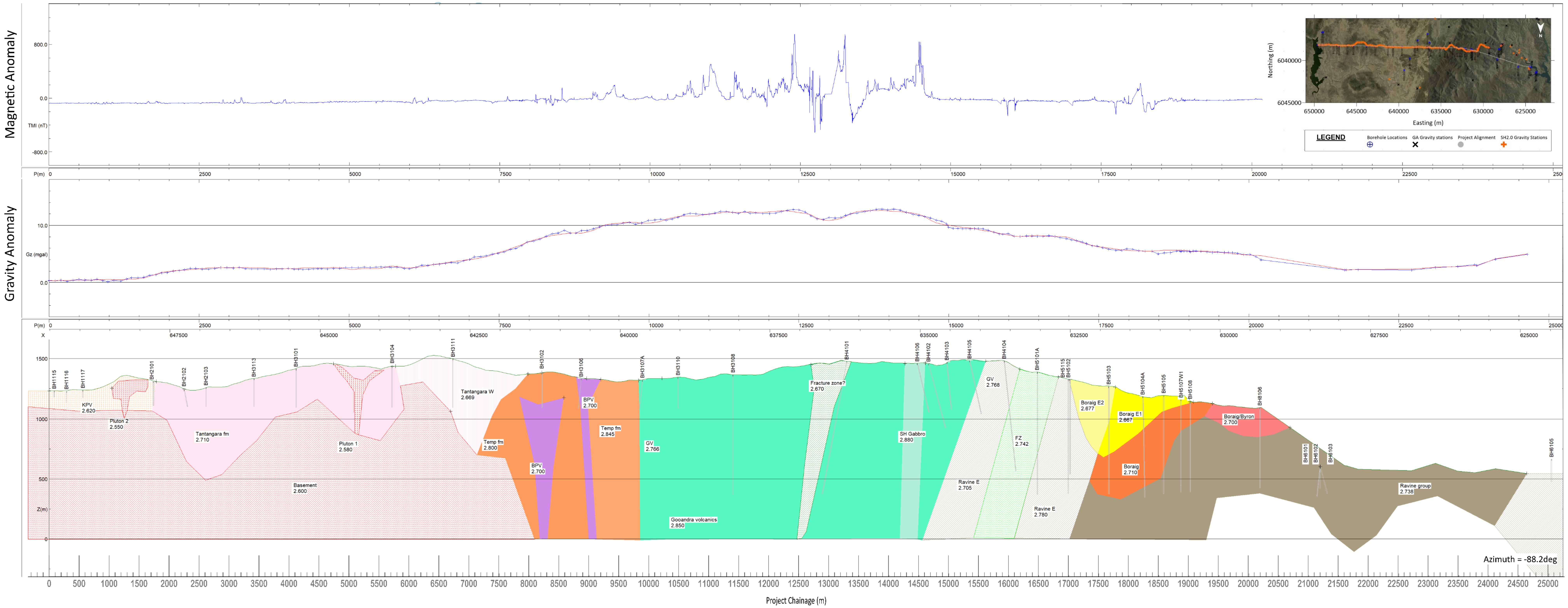
It is possible that this anomaly could be concurrent with both a dyke structure and with a mineralisation system, however evidence for this is purely anecdotal at this stage, and further examination of the core is likely required.

7.7.6. Basement structure under the Ravine Group

The basement structure underlying the Ravine Group is complex to model geophysically. As most of the gravity stations were collected around the location of the ECVT and not on the TRT (waterway) alignment due to access and logistical issues, a lower priority was placed on detailed modelling of this location. Other complexities which may have a bearing on the data collected in Lobs Hole are the locations of historic underground mine workings, as voids are highly detectable by the gravity method, their associated mineralisation systems, and the relation of the geological structures in this area. Figure 20 shows the complex gridded gravity response for this location.

It is postulated that the Yarrangobilly Limestone is likely dipping to the south and underlies the Ravine beds at a depth of ~400-480m below the TRT alignment. Ashley et al (1971) also suggest that the Blowering beds and Goobarragandra Volcanics, which are chemically similar are probably continuous beneath the Ravine beds syncline structure, however the density of these geological units is prospectively higher than that which would aid a geophysical resolution to the model.

To provide a simplistic solution to this area, the basement of the Ravine group (Figure 16) was simply adjusted to provide a reasonable fit to the data. With a back-ground density of 2.60 g/m^3 it could be proposed that the modelled geometry could suggest there maybe intrusive granites underlying the lobs hole area, which could account for the mineralisation systems and thus the associated mining operations, or potentially extensive limestone karst systems at depth which could also provide a plausible modelling solution. Either way further data would be required to constrain the model and provide improved interpretation on the complex geological structures present in this area.



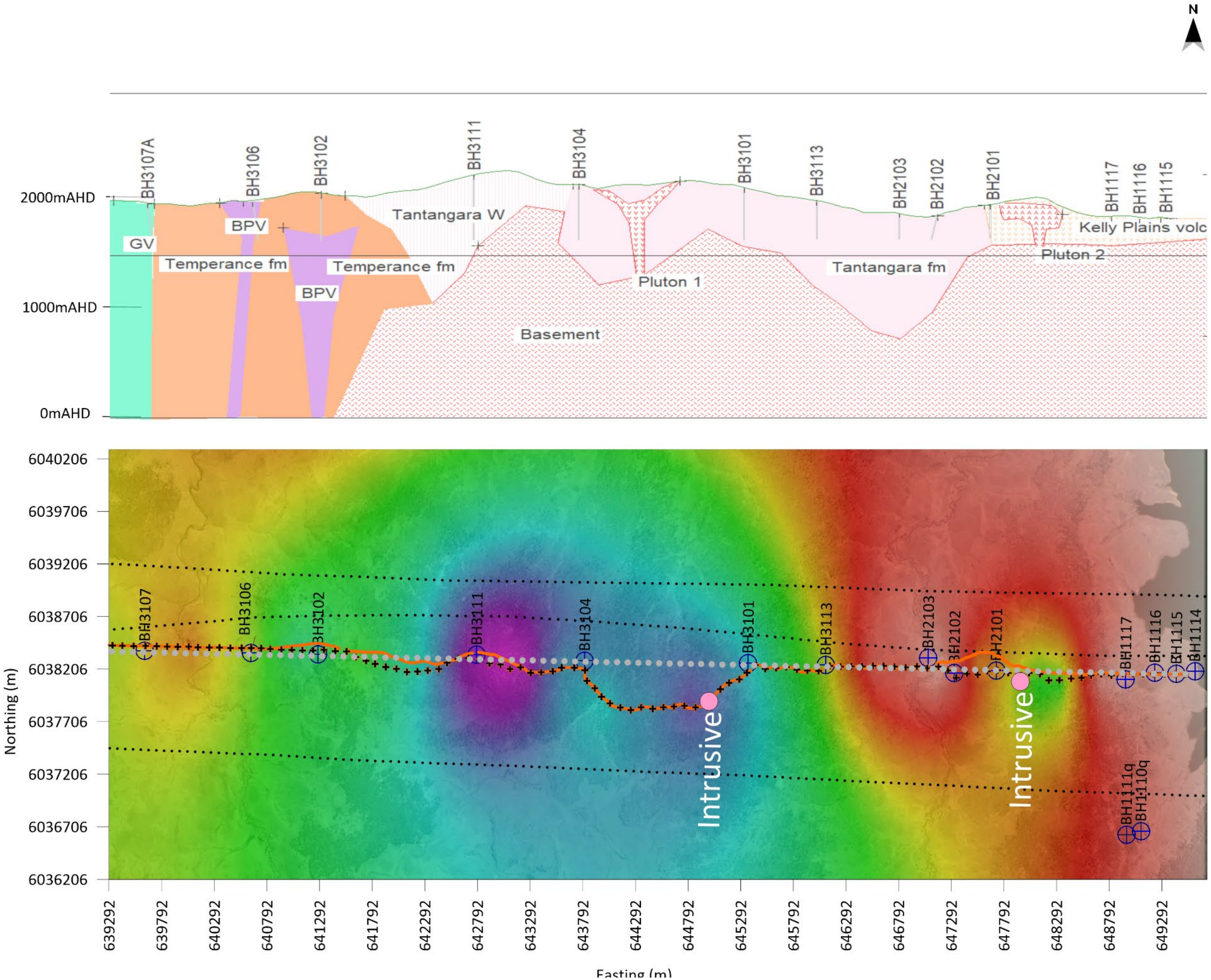
NOT FOR CONSTRUCTION

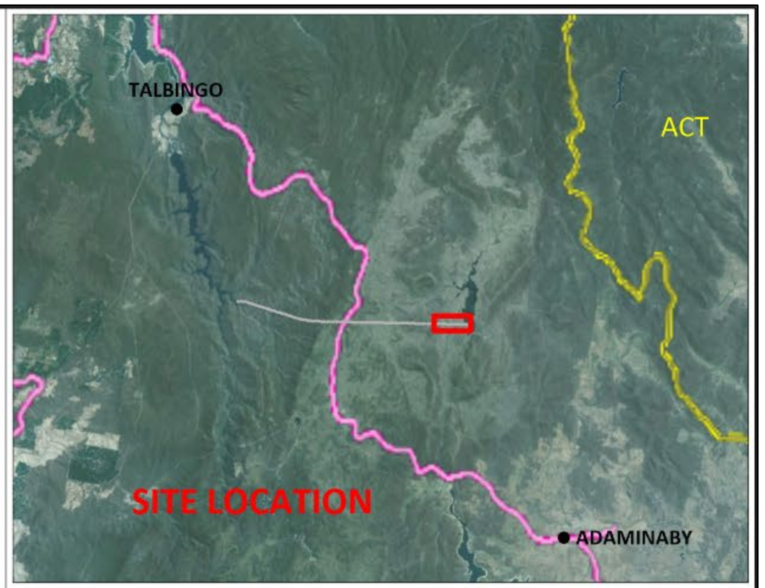
Model Notes:
Density given in G/cm3
Depth (mAHD)
Model section at 2X Vertical Exaggeration

Figure 16: Gravity/Magnetics Model looking East to West (2x Vertical Exaggeration).

Snowy 2.0
Potential Field (Gravity/Magnetics) Model section
Power Waterway

INFORMATION DOCUMENT
S2-PM-1007





LEGEND

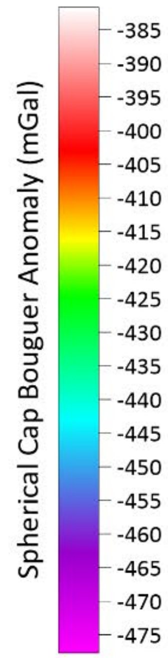
Project Alignment

Borehole Locations

SH2.0 Gravity Stations

GA Gravity stations

Magnetics survey (data combined - BLK=GA/ORG=SH2.0)



Projection: Universal Transverse Mercator (UTM)
Horizontal/Grid Datum: WGS84 Zone 55(s)

Figure 17: Tantangara area Gravity anomaly map.

revision	description	drawn	approved	date
	DRAFT	RL		19/12/2018

DRAFT_REV01

0 5000 10000 15000
Scale (meters)

Additional data provided by: Australian Government Geoscience Australia; nearmap

drawn	RL
approved	RL
date	19/12/2018
scale	
original size	A3

snowy 2.0
SMEC Local People. Global Experience.

client:	Snowy Hydro Limited
project:	Snowy Hydro 2.0 Potential fields - gravity and magnetics survey
title:	Tantangara gravity structure Spherical Cap Bouguer Anomaly map
project no: 30012598_S2-PM-1007	figure no: 17

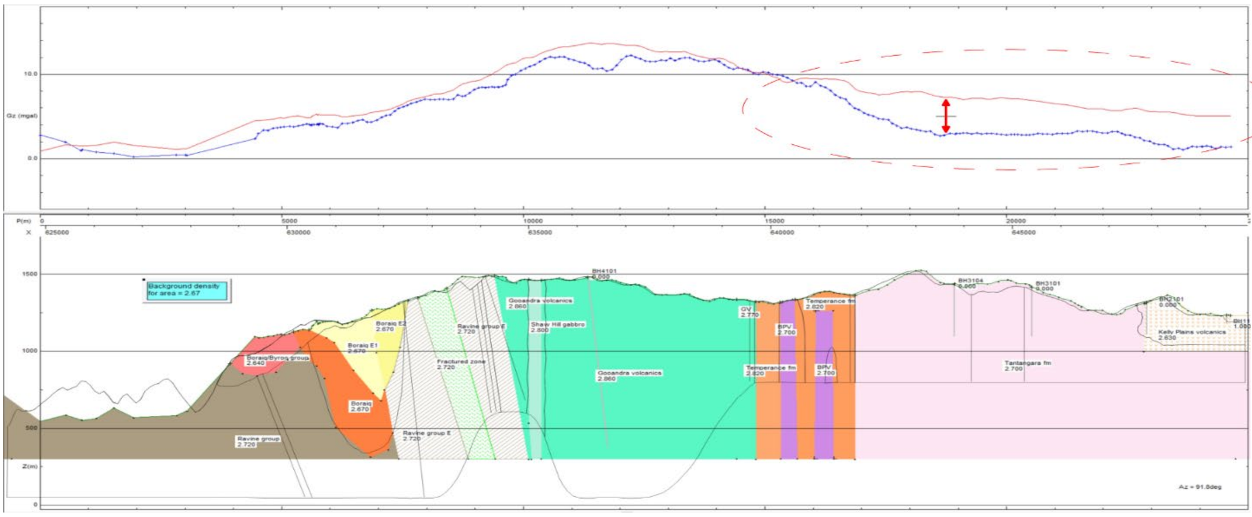


Figure 18: Seed model – displaying the Tantangara formation anomaly (section plotted west to East).

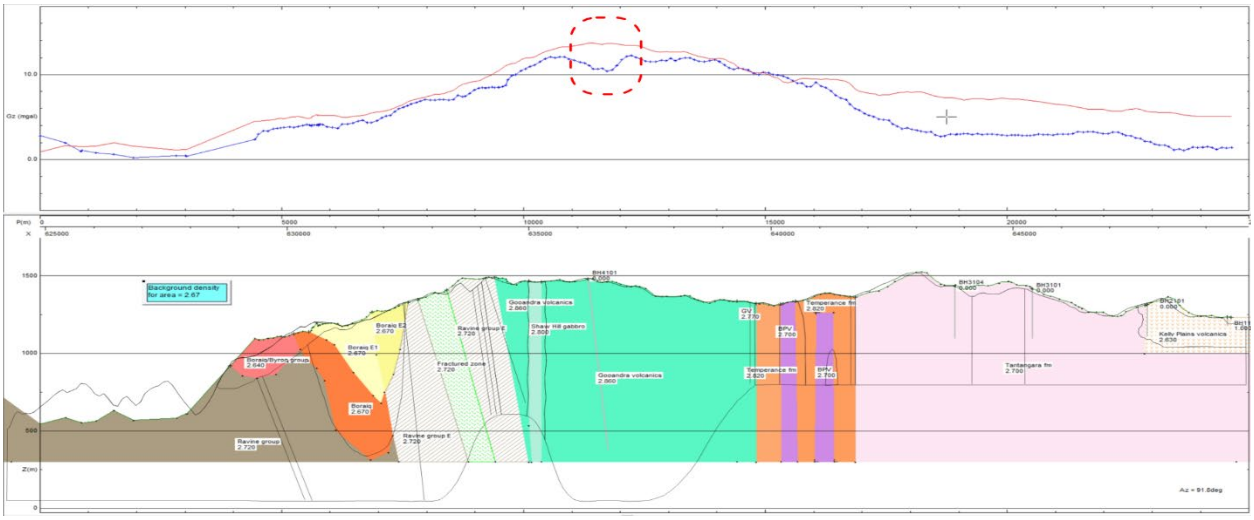


Figure 19: Seed model – displaying the Fracture Zone anomaly (Section plotted west to East).

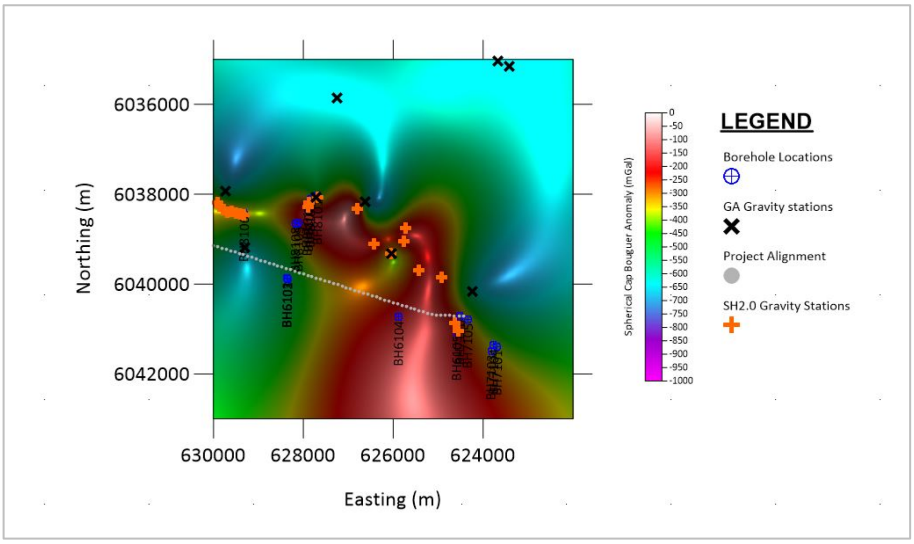


Figure 20: Lobs Hole Spherical Cap Gravity anomaly map displaying complex structure.

8. CONCLUSIONS AND RECOMMENDED

8.1. Conclusions

The Gravity Magnetics survey has produced data which when constrained against known information (rock density, Mag susceptibility, borehole intersects and surface geology and geophysics) has allowed modelling of the two-dimensional geology along the alignment. The resultant modelled geology is considered to have a high degree of reliability and therefore provide a better understanding of the potential geology likely to be encountered along the alignment.

The available information collected to date and the assessment of that information, including results provided in this report indicate areas which have an elevated potential for significant inflows and water table drawdown without inflow control measures. The gravity modelling also highlights the usefulness of the potential field methods and as a new (FGN tied) base station has been established further gravity data acquisition on the project would be simplified. Furthermore, as a gravity model has now been constructed, further modelling and refinement of that model can only improve the geological understanding of the structural elements and provide further risk mitigation by highlighting areas which could be problematic to construction thus allowing a factual data justification for targeted drilling of such areas.

8.2. Recommendations

The following is recommended to reduce the uncertainty with respect to geological structures:

- Additional expansion of the gravity station network to include off alignment stations in order to provide 3-Dimensional model capability;
- Further high-resolution gravity surveying of new power cavern location and western end of the alignment;
- Infilling (50m spacing) and further detailed gravity modelling of problematic zones;
- Detailed geological surface mapping over some of the problematic zones; and
- Construction and integration of a project wide (regional) **Thermal Model** to provide better understanding of thermal pollution impacts and potential tunnel construction risks associated with the additional granites delineated along the alignment.

Of the greatest benefit would be the development of a 3D geophysical model for the alignment. To build one, additional lines running sub parallel to the alignment, off set by between one and two kilometres would be required. These additional lines could also include tie lines running north and south, with some additional regional infill.

9. REFERENCES

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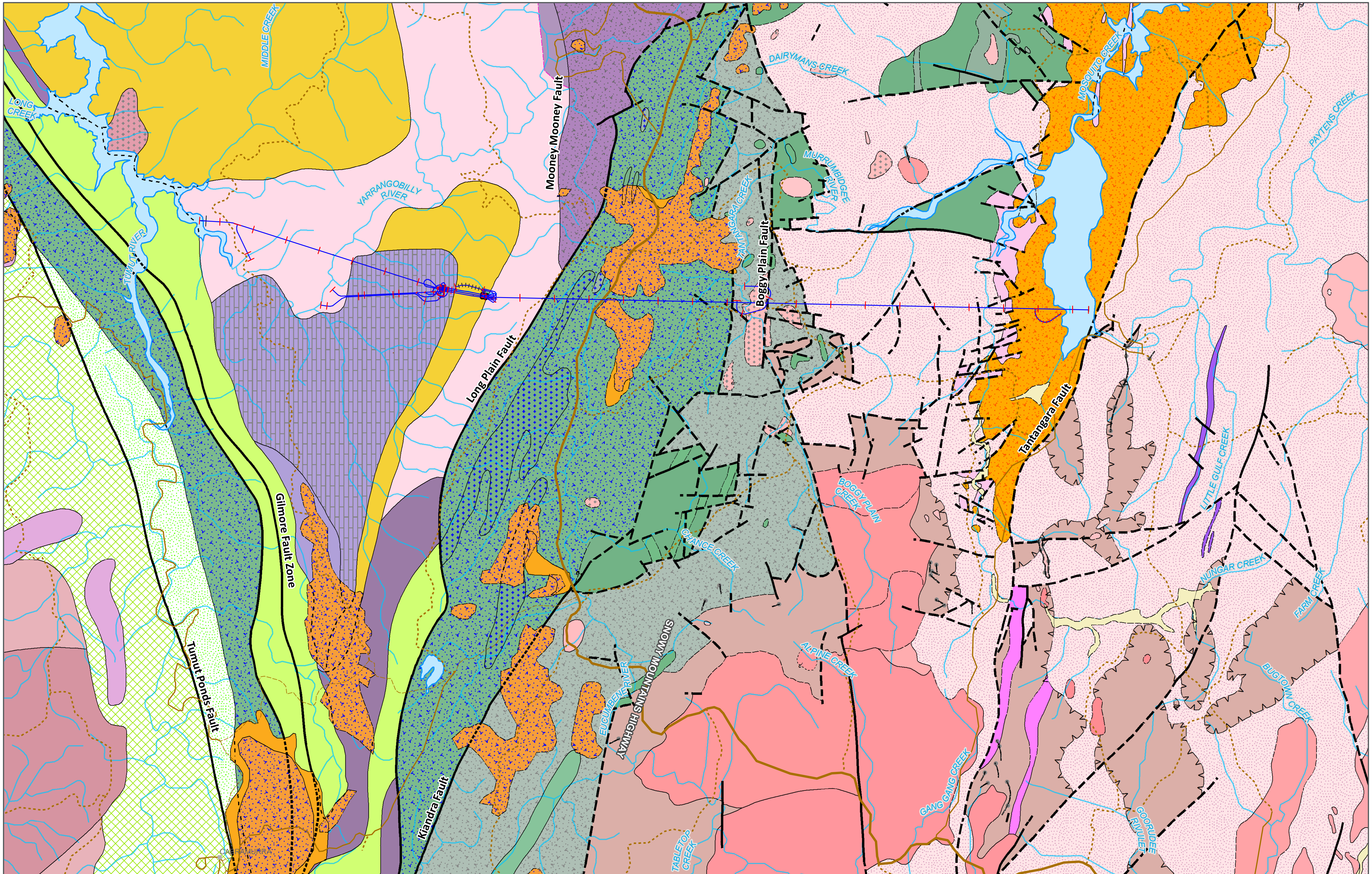
APPENDIX A GEOLOGICAL MAPS AND INFOMATION



DRAWING E-1.1:Published geology	PROJECT TITLE Snowy 2.0	0 1.25 2.5 5 km 1:100,000	PAGE SIZE A3	N COORDINATE SYSTEM GDA 1994 MGA Zone 55
PROJECT NO. 30012598	CREATED BY LB12914	DATE 09/11/2018	SOURCES NSW Seamless Geology 55 East, Geological Survey of NSW. NSW Planning and Environment, Minerals and Resources *et al* (2017)	

snowyhydro Limited renewable energy
SMEC Member of the Surbana Jurong Group

Location: \\aushfsv001\Project Data\Snowy 2.0\30012060 Ref Data ONLY\06 Geology and Terrain\Reports\05 Engineering Geology Report\GIS Interp\Maps\4 - Published Geology.mxd

Last updated by: RC10721 on 9/11/2018 at 11:10

LEGEND

- Watercourse
- Dyke or Vein
- Shear zone (linear), interpretted from airphoto
- Shear zone boundary
- Geological boundary, position approximate
- Geological boundary, position accurate
- Geological boundary, inferred, concealed
- Geological boundary, inferred
- Geological boundary, concealed
- Geological boundary interpreted from geophysical data
- Fault, position approximate
- Fault, position accurate
- Fault, concealed
- Angular unconformity, concealed
- Angular unconformity - accurate
- Ravine Option power waterway alignment
- Plateau Option Power waterway alignment
- GPS waypoints (refer to text)

- Ungrouped Cenozoic igneous units - olivine basalt
- Alluvial sediments
- Alluvium
- water

SILURIAN TO MID DEVONIAN BASINS - DEVONIAN

- Boraig Group (Rhyolite, rhyodacite, tuff, lapilli tuff, feldspathic sandstone, granophyre deposited in shield building volcanic complexes)
- Mountain Creek Volcanics - Rhyolite lava, ignimbrite, tuff; lesser dacite, andesite, agglomerate, feldspathic sandstone, siltstone, black shale
- Byron Range Group (Limestone, siltstone, quartzite, shale, sandstone, conglomerate)
- Kellys Plain Volcanics (Dacite ignimbrite, rhyodacite ignimbrite, tuff, agglomerate, rhyolite; porphyritic monzogranite)

EARLY DEVONIAN INTRUSIONS

- Lobs Hole Monzogranite (Monzogranite)
- Coolamine Igneous Complex - Granodiorite, quartz monzodiorite, quartz monzogabbro, quartz gabbro, minor monzogranite and tonalite
- Free Damper Monzogranite - Biotite monzogranite commonly containing hornblende
- Pennyweight Monzogranite - Biotite monzogranite commonly containing hornblende

SILURIAN TO MID DEVONIAN BASINS - SILURIAN

- Peppercorn Formation (Basal conglomerate, overlain by sandstone, siltstone and cleaved shale, with minor limestone lenses)
- Goobarragandra Volcanics (Grey-blue, massive, medium- to coarse-grained, crystal-rich, densely welded, dacitic ignimbrite. Minor lithologies: pebbly, volcanic sandstone and mudstone; crystal-rich tuffaceous sandstone; limestone; quartzose to quartz-lithic sa
- Tumut Pond Group (Rhythmically bedded grey sandstone (grading to quartzite) and grey slate (grading to phyllite); green, purple and dark grey slates (grading to phyllite)
- Kings Cross Formation - Green, purple and dark grey slate (grading to phyllite)
- Ravine beds (Shale, slate, siltstone, conglomerate)
- Blowering Formation - tuff - Porphyritic dacite crystal-(lithic) ashfall tuff; minor fine to medium-grained dacite crystal-(lithic) ashfall tuff
- Yarrangobilly Limestone - Massive, recrystallised fossiliferous limestone, sporadic margins recrystallised to calc-silicate hornfels

MIDDLE TO LATE SILURIAN INTRUSIONS

- Boggy Plain Suite - cumulophyric textured intrusion - I-type granitoids; cumulophyric texture, mostly granodiorites and quartz monzogabbros
- Boggy Plain Suite - intrusion (I-type granitoids; even grained texture, mostly granodiorites and quartz monzogabbros)
- Boggy Plain Granitic Complex - Biotite monzogranite commonly containing hornblende
- Boggy Plain Granitic Complex - granodiorite phase - Granodiorite, minor quartz gabbro
- Boggy Plain Granitic Complex - gabbro phase - gabbro, quartz gabbro, minor granodiorite
- Crack Hardy Point Monzodiorite - Hornblende-biotite granodiorite, tonalite, quartz monzonite, diorite; sporadic amphibolite xenoliths
- Hell Hole Creek Monzogranite - Medium- to coarse-grained, reddish-pink to weathered light pink monzogranite with pale-green plagioclase phenocrysts to 50 mm; minor medium-grained medium-grey granodiorite, minor quartz gabbro
- Green Hills Granodiorite - Medium- to coarse-grained, light grey to grey, biotite granodiorite; fine- to medium-grained, porphyritic biotite-muscovite granodiorite varying to granite; quartz-rich fine grained metasedimentary xenoliths, biotite-rich enclaves
- Rough Creek Tonalite - Biotite granodiorite and tonalite commonly containing cordierite, common metasedimentary xenoliths
- Unassigned Silurian Intrusions - porphyry - Quartz-feldspar porphyry, massive, foliated, mylonitised (associated with Late Silurian and Early Devonian granite intrusions). In places includes granite, granodiorite and minor porphyries
- Unassigned Silurian Intrusions - tonalite - Medium-grained tonalite and diorite; minor gabbro
- Gang Gang Monzogranite - Biotite-muscovite monzogranite, sodic leucogranite

EARLIEST SILURIAN BASINS

- Tantangara Formation - quartzite - Massive quartzite
- Tantangara Formation (Sandstone, siltstone and shale; quartzite)

MACQUARIE ARC

- Gooandra Volcanics (Metabasalt, basalt breccia (emplaced as pillow lavas), amphibolite, chloritic schists, feldspathic sandstone; aphyric and feldspar-phyric basalt, baslatic lava breccia, rhyolite, shale; fine-grained feldspathic siltstone and shale)
- Gooandra Volcanics - basalt - Aphyric and feldspar-phyric basalt, lava breccia, pillow lava, rhyolite, shale Porphyritic andesite, andesitic breccia, andesitic tuff, possible spilitic basalt, sedimentary rocks intruded by quartz diorite dykes.
- Gooandra Volcanics - gabbro (Ophitic gabbro and dolerite)
- Gooandra Volcanics - siltstone - Fine feldspathic siltstone and shale
- Temperance Formation - agglomerate - Agglomerate, minor tuff and chert
- Temperance Formation - basaltic tuff - basaltic tuff, minor agglomerate
- Temperance Formation - chert
- Temperance Formation - monzonite (Monzonite, hornblendite, lamprophyre, quartz monzonite)
- Temperance Formation - tuff (Interbedded basaltic tuff, chert, and feldspathic arenite, minor agglomerate)
- Shaw Hill Gabbro (Gabbro, diorite, metabasic intrusive rock, pyroxenite)

LATE ORDOVICIAN - BENDOC & MARGULES GROUPS

- Warbisco Shale - Black, laminated to medium-bedded pyritic carbonaceous shale, commonly strongly foliated and folded; minor quartzose sandstone

EARLY ORDOVICIAN - LACHLAN SUPERGROUP

- Adaminaby Group - Turbiditic sequence of sandstone, mudstone, shale; carbonaceous shale, greywacke; chert, quartzite, phyllite, slate
- Abercrombie Formation (Brown and buff to grey, thinly to thickly bedded, fine- to coarse-grained mica-quartz (+/- feldspar) sandstone, interbedded with laminated siltstone and mudstone. Sporadic chert-rich units)

PALEOZOIC MAFIC INTRUSIVES

- Unassigned Palaeozoic intrusions - Dykes and veins

DRAWING E-1.2: Legend for Published Geology	PROJECT TITLE Snowy 2.0	1:100,000	PAGE SIZE A3 / COORDINATE SYSTEM GDA 1994 MGA Zone 55
PROJECT NO. 30012598	CREATED BY LR11993	DATE 22/09/2017	SOURCES NSW Seamless Geology 55 East, Geological Survey of NSW. NSW Planning and Environment, Minerals and Resources *et al* (2017)

snowyhydro Limited renewable energy | SMEC Member of the Surbana Jurong Group

FIGURE NO. E-2 FIGURE TITLE Geological Map Central Project Area

PROJECT NO. 30012598 PROJECT TITLE Snowy 2.0

DATE 09/11/2018

CREATED BY R. Chatfield

SOURCES

1:10,000

PAGE SIZE A1

COORDINATE SYSTEM GDA 1994 MGA Zone 55

snowy 2.0

SMEC

Member of the Surbana Jurong Group

FIGURE NO. E-2 FIGURE TITLE Geological Map Central Project Area	DATE 09/11/2018	0 50 100 200 300 400 Metres 1:10,000	PAGE SIZE A1	COORDINATE SYSTEM GDA 1994 MGA Zone 55
PROJECT NO. 30012598 PROJECT TITLE Snowy 2.0	CREATED BY R. Chatfield	SOURCES		

snowy2.0 SMEC Member of the Surbana Jurong Group

Location: I:\projects\30012598 – Snowy 2.0 Reference Design\110 Detailed Design\117 GIS\Maps\Geological Site Investigations\Tantangara - Talbingo Tunnel Alignment\Geological reporting\Report\Maps 20180816\Geological Map Central Project Area.mxd

Last updated by: RC10721 on 9/11/2018 at 13:10

NOT FOR CONSTRUCTION

SNOWY 2.0
INTERPRETED GEOLOGY LONGITUDINAL SECTION
POWER WATERWAY

INFORMATION DOCUMENT

S2-4400-INF-GEO-LS-PWT-RG-180914-001

snowy hydro Limited renewable energy

snowy 2.0

APPENDIX B MODEL SUMMARY


800.0
0.0
TMI (nT)
-800.0
P(m)
0
2500
5000
7500
10000
12500
15000
17500
20000
22500
25000
X
647500
645000
642500
640000
637500
635000
632500
630000
627500
625000
2000
1000
0
Z(m)
BH1115
BH1116
BH1117
BH2101
BH2102
BH2103
BH3113
BH3101
BH3104
BH3111
BH3102
BH3106
BH3107A
BH3110
BH3108
BH4101
BH4106
BH4102
BH4103
BH4105
BH4104
BH5101A
BH5115
BH5102
BH5103
BH5104A
BH5105
BH5107W1
BH5108
BH8106
BH6101
BH6102
BH6103
BH6105
Az = -88.1deg

Gz (mgal)
10.0
0.0
P(m)
0
2500
5000
7500
10000
12500
15000
17500
20000
22500
25000
X
647500
645000
642500
640000
637500
635000
632500
630000
627500
625000
Z(m)
1500
1000
500
0
BH1115
BH1116
BH1117
BH2101
BH2102
BH2103
BH3113
BH3101
BH3104
BH3111
BH3102
BH3106
BH3107A
BH3110
BH3108
BH4101
BH4106
BH4102
BH4103
BH4105
BH4104
BH5101A
BH5115
BH5102
BH5103
BH5104A
BH5105
BH5107W1
BH5108
BH6106
BH6101
BH6102
BH6103
BH6105
KPV
2.620
Pluton 2
2.550
Tantangara fm
2.710
Pluton 1
2.580
Basement
2.600
Tantangara W
2.669
Temp fm
2.800
BPV
2.700
BPV
2.700
Temp fm
2.845
GV
2.766
Gooandra volcanics
2.850
Fracture zone?
2.670
SH Gabbro
2.880
GV
2.768
FZ
2.742
Ravine E
2.705
Ravine E
2.780
Boraig E2
2.677
Boraig E1
2.667
Boraig/Byron
2.700
Boraig
2.710
Ravine group
2.738
Az = -88.2deg

Gz (mgal)
10.0
0.0
P(m)
0
2500
5000
7500
10000
12500
15000
17500
20000
22500
25000
X
647500
645000
642500
640000
637500
635000
632500
630000
627500
625000
2000
1000
0
Z(m)
-1000
BH1115
BH1116
BH1117
BH2101
BH2102
BH2103
BH3113
BH3101
BH3104
BH3111
BH3102
BH3106
BH3107A
BH3110
BH3108
BH4101
BH4106
BH4102
BH4103
BH4105
BH4104
BH5101A
BH5115
BH5102
BH5103
BH5104A
BH5105
BH5107W1
BH5108
BH8106
BH6101
BH6102
BH6103
BH6105
Az = -88.2deg

Gz (mgal)
10.0
0.0
P(m)
0
2500
5000
7500
10000
12500
15000
17500
20000
22500
25000
X
647500
645000
642500
640000
637500
635000
632500
630000
627500
625000
Z(m)
1500
1000
500
0
BH1115
BH1116
BH1117
BH2101
BH2102
BH2103
BH3113
BH3101
BH3104
BH3111
BH3102
BH3106
BH3107A
BH3110
BH3108
BH4101
BH4106
BH4102
BH4103
BH4105
BH4104
BH5101A
BH5115
BH5102
BH5103
BH5104A
BH5105
BH5107W1
BH5108
BH8106
BH6101
BH6102
BH6103
BH6105
Az = -88.2deg

APPENDIX C PROCESSED GRAVITY DATA

GEOPHYSICS REPORT

APPENDIX C

RAW DATA

APPENDIX D RAW GRAVITY AND MAGNETICS DATA

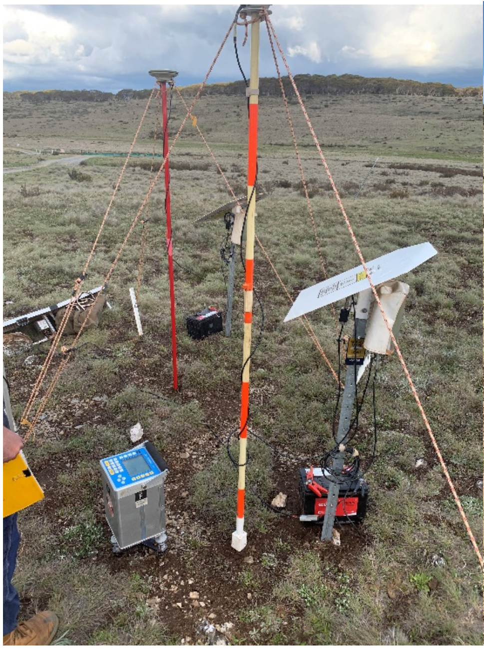
GEOPHYSICS REPORT

APPENDIX D

RAW DATA

APPENDIX E BASE STATION INFORMATION

Station ID: **1539**	Station Name: **Gooandra Base**		Date: **26/11/2018**
HORIZONTAL DETAIL	VERTICAL DETAIL	MARK DETAIL	GRAVITY DETAIL
Easting: 635695.553	Elevation: 1385.739m	Mark Type: Primary Base	Obs Gravity: 979480.323
Northing: 6035038.264	N-Value: 18.943m	Witness Mark: Star Picket	
Zone: 55	(Geoid98)	Witness Plate: N/A	
Latitude: -35.649277		Monument Type: N/A	
Longitude: 148.434901			
Datum: GDA94	Datum: AHD71	Plaque Stamped: 1539	Datum: OBGS07
Order: 1	Order: 3	Map Sheet:	(AAGD07)
Method: AUSPOS	Method: GPS		Units: µms^{-2}



Station ID: 2013909231	Station Name: Cooma Showground		Date: **26/11/2018**
HORIZONTAL DETAIL	VERTICAL DETAIL	MARK DETAIL	GRAVITY DETAIL
Easting: 690698.29	Elevation: 803.0 m	Mark Type: Primary Base	Obs Gravity: 9796414.42
Northing: 5987430.85	N-Value:	Witness Mark: Star Picket	
Zone: 55	(Geoid98)	Witness Plate: N/A	
Latitude: -36.23921		Monument Type: N/A	
Longitude: 149.12215			
Datum: GDA94	Datum: AHD71	Plaque Stamped:	Datum: OBGS07
Order:	Order:	Map Sheet:	(AAGD07)
Method:	Method: GPS		Units: μms^{-2}

GPS/Gravity 1539 - Snowy

FINAL AUSPOS CO-ORDINATES

MGA94 / AHD		GDA94 / GRS80	
EASTING (m)	635695.55	LATITUDE (DMS)	35° 49' 9.93840" S
NORTHING (m)	6035038.26	LONGITUDE (DMS)	148° 30' 7.63819" E
ZONE (UTM, South)	55	ELL HT (m)	1404.67
ORTHO HT (AHD, m)	1385.65		
N (AUSGEOID09, m)	19.02		

CONTROL DETAILS

Observed Gravity ISOGAL84 (mGal)		Observed Gravity AAGD07 (mGal)	
Calculated ObsG	979480.401	Calculated ObsG	979480.323

Gravity Control	GPS Control
Gravity – Daishsat using 1 BAB loop with 2 gravity meters to AFGN station 2013909231 at Cooma Showgrounds. Expected accuracy better than 0.010mGal	**GPS** – Daishsat using multiple static sessions and the AUSPOS online GPS processing system. Expected accuracy of station coordinates better than 0.005m.

MISCELLANEOUS DETAILS

Est. Date:	26/11/2018	Established By:	Hayden Harris	Survey:	18022

DESCRIPTION AND ACCESS

This base station consists of a small star picket protruding from the ground and is witnessed by a Daishsat survey plaque, placed on a large star picket ~ 0.3m to the right. The base is located 75km north west of Cooma, NSW. From Cooma, travel north along the Snowy Mountains Highway (B72) for approximatley 95km before turning right onto the Gooandra Trail (635200e 6035640n UTM Z55). Follow the trail, heading south initially then east, for about 900m where you will find Base 1539 approximatley 20m to the right (south) side of the track.

Field Photo Of Base

APPENDIX F PETROPHYSICAL DATA

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH1114	649605.90	6038179.90	1206.88	18/04/2018	BRTS344	Kelly Plains Volcanics	KPV001	DACITE	2.622	
BH1114	649605.90	6038179.90	1203.65	18/04/2018	BRTS344	Kelly Plains Volcanics	KPV001	DACITE	2.605	
BH1114	649605.90	6038179.90	1200.60	18/04/2018	BRTS344	Kelly Plains Volcanics	KPV001	DACITE	2.615	
BH1114	649605.90	6038179.90	1197.53	18/04/2018	BRTS344	Kelly Plains Volcanics	KPV001	DACITE	2.624	
BH1114	649605.90	6038179.90	1189.28	18/04/2018	BRTS344	Kelly Plains Volcanics	KPV001	DACITE	2.522	
BH1115	649431.30	6038166.00	1229.61	15/02/2018	STS 17267701	Kelly Plains Volcanics	KPV - Unsorted	DACITE	2.610	
BH1115	649431.30	6038166.00	1221.70	15/02/2018	STS 17267701	Kelly Plains Volcanics	KPV - Unsorted	DACITE	2.600	
BH1115	649431.30	6038166.00	1205.61	24/11/2017	BRTS345	Kelly Plains Volcanics	KPV001	DACITE	2.602	
BH1115	649431.30	6038166.00	1203.23	24/11/2017	BRTS345	Kelly Plains Volcanics	KPV001	DACITE	2.614	
BH1115	649431.30	6038166.00	1199.90	15/02/2018	STS 17267701	Kelly Plains Volcanics	KPV001	DACITE	2.620	
BH1115	649431.30	6038166.00	1183.65	15/02/2018	STS 17267701	Kelly Plains Volcanics	KPV002	DACITE	2.580	
BH1116	649225.40	6038173.00	1195.27	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV001	DACITE	2.640	
BH1116	649225.40	6038173.00	1188.88	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV001	DACITE	2.620	
BH1116	649225.40	6038173.00	1176.55	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV001	DACITE	2.641	
BH1116	649225.40	6038173.00	1169.15	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV - Unsorted	DACITE	2.642	
BH1116	649225.40	6038173.00	1168.54	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV - Unsorted	DACITE	2.638	
BH1117	648948.80	6038110.00	1209.93	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV002	DACITE	2.666	
BH1117	648948.80	6038110.00	1204.45	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV002	DACITE	2.628	
BH1117	648948.80	6038110.00	1197.28	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV001	DACITE	2.635	
BH1117	648948.80	6038110.00	1183.33	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV001	DACITE	2.622	
BH1117	648948.80	6038110.00	1179.35	18/04/2018	BRTS346	Kelly Plains Volcanics	KPV001	DACITE	2.630	
BH2101	647776.50	6038216.40	1299.83	27/09/2018	SYD18030.1	Kelly Plains Volcanics	KPV/TTF - Unsorted	DACITE	2.659	
BH2101	647776.50	6038216.40	1259.45	27/09/2018	SYD18030.2	Kelly Plains Volcanics	KPV/TTF - Unsorted	Siltstone	2.699	0.2755
BH2101	647776.50	6038216.40	1215.15	27/09/2018	SYD18030.3	Kelly Plains Volcanics	KPV/TTF - Unsorted	DACITE	2.658	0.15225
BH2101	647776.50	6038216.40	1178.15	27/09/2018	SYD18030.4	Kelly Plains Volcanics	KPV/TTF - Unsorted	DACITE	2.638	0.15225
BH2101	647776.50	6038216.40	1171.43	27/09/2018	SYD18030.5	Kelly Plains Volcanics	KPV/TTF - Unsorted	Siltstone	2.709	0.15225
BH2101	647776.50	6038216.40	1146.16	4/10/2018	SYD1802030.7	Tantangara Formation	TTF001	Siltstone	2.702	0.15225
BH2101	647776.50	6038216.40	1144.94	31/07/2018	142405	Tantangara Formation	TTF001	Siltstone	2.710	0.15225
BH2101	647776.50	6038216.40	1114.45	27/09/2018	SYD1802030.8	Kelly Plains Volcanics	KPV/TTF - Unsorted	Siltstone	2.708	0.1595
BH2102	647252.94	6038193.06	1217.45	28/06/2018	SYD1801311.01	Tantangara Formation	TTF - Unsorted	Interbedded: Siltstone/Sandstone	2.655	
BH2102	647246.62	6038192.51	1200.93	28/06/2018	SYD1801311.02	Tantangara Formation	TTF - Unsorted	Sandstone	2.661	
BH2102	647236.16	6038191.59	1173.57	28/06/2018	SYD1801311.03	Tantangara Formation	TTF - Unsorted	Sandstone	2.674	
BH2102	647225.55	6038190.66	1145.85	28/06/2018	SYD1801311.04	Tantangara Formation	TTF001	Interbedded: Siltstone/Sandstone	2.736	
BH2102	647223.77	6038190.51	1141.19	28/06/2018	SYD1801311.05	Tantangara Formation	TTF001	Sandstone	2.668	
BH2102	647217.45	6038189.95	1124.66	28/06/2018	SYD1801311.06	Tantangara Formation	TTF001	Interbedded: Siltstone/Sandstone	2.704	
BH2102	647208.67	6038189.19	1101.69	28/06/2018	SYD1801311.07	Tantangara Formation	TTF - Unsorted	Interbedded: Siltstone/Sandstone	2.659	
BH2103	646900.00	6038281.60	1210.84	4/06/2018	3392-YP-1	Tantangara Formation	TTF003	Interbedded: Siltstone/Sandstone	2.694	
BH2103	646900.00	6038281.60	1182.75	4/06/2018	3392-YP-1	Tantangara Formation	TTF003	Meta-Basalt	2.677	
BH2103	646900.00	6038281.60	1164.71	4/06/2018	3392-YP-1	Tantangara Formation	TTF003	Schist	2.712	
BH2103	646900.00	6038281.60	1155.34	4/06/2018	3392-YP-1	Tantangara Formation	TTF003	Schist	2.668	
BH2103	646900.00	6038281.60	1155.10	8/05/2018	142402	Tantangara Formation	TTF003	Schist		
BH2103	646900.00	6038281.60	1135.45	4/06/2018	3392-YP-1	Tantangara Formation	TTF001	Schist	2.714	
BH2103	646900.00	6038281.60	1112.95	4/06/2018	3392-YP-1	Tantangara Formation	TTF - Unsorted	Meta-Basalt	2.710	0.609
BH3101	645395.70	6038227.50	1379.75	17/04/2018	SYD1800840.01	Tantangara Formation	TTF - Unsorted	Siltstone	2.670	
BH3101	645395.70	6038227.50	1356.75	17/04/2018	SYD1800840.02	Tantangara Formation	TTF - Unsorted	RHYOLITE	2.750	
BH3101	645395.70	6038227.50	1348.05	17/04/2018	SYD1800840.03	Tantangara Formation	TTF - Unsorted	VOLCANIC	2.670	
BH3101	645395.70	6038227.50	1307.40	17/04/2018	SYD1800840.04	Tantangara Formation	TTF - Unsorted	VOLCANIC	2.680	
BH3101	645395.70	6038227.50	1271.40	17/04/2018	SYD1800840.05	Tantangara Formation	TTF - Unsorted	VOLCANIC	2.720	
BH3101	645395.70	6038227.50	1247.45	17/04/2018	SYD1800840.06	Tantangara Formation	TTF - Unsorted	VOLCANIC	2.670	
BH3101	645395.70	6038227.50	1223.30	17/04/2018	SYD1800840.07	Tantangara Formation	TTF - Unsorted	VOLCANIC	2.660	
BH3101	645395.70	6038227.50	1216.75	17/04/2018	SYD1800840.08	Tantangara Formation	TTF - Unsorted	VOLCANIC	2.670	
BH3101	645395.70	6038227.50	1191.75	17/04/2018	SYD1800840.09	Tantangara Formation	TTF - Unsorted	RHYOLITE	2.700	

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH3101	645395.70	6038227.50	1164.75	17/04/2018	SYD1800840.10	Tantangara Formation	TTF - Unsorted	VOLCANIC	2.740	
BH3101	645395.70	6038227.50	1150.05	4/06/2018	3393-YP-1	Tantangara Formation	TTF001	VOLCANIC	2.768	0.3915
BH3101	645395.70	6038227.50	1121.14	8/05/2018	142402	Tantangara Formation	TTF002	RHYOLITE	2.765	0.3625
BH3101	645395.70	6038227.50	1118.34	4/06/2018	3393-YP-1	Tantangara Formation	TTF001	RHYOLITE	2.682	
BH3102	641301.40	6038407.00	1347.60	18/04/2018	SYD1800841.01	Temperance Formation	TPF - Unsorted	Diorite	3.100	
BH3102	641301.40	6038407.00	1315.25	18/04/2018	SYD1800841.02	Temperance Formation	TPF - Unsorted	Siltstone	2.800	
BH3102	641301.40	6038407.00	1301.15	18/04/2018	SYD1800841.03	Temperance Formation	TPF - Unsorted	Diorite	2.780	
BH3102	641301.40	6038407.00	1266.86	18/04/2018	SYD1800841.04	Temperance Formation	TPF - Unsorted	Diorite	2.730	0.812
BH3102	641301.40	6038407.00	1224.85	18/04/2018	SYD1800841.05	Temperance Formation	TPF - Unsorted	Siltstone	2.720	
BH3102	641301.40	6038407.00	1201.84	19/04/2018	SYD1800841.06	Temperance Formation	TPF - Unsorted	Schist	2.780	
BH3102	641301.40	6038407.00	1185.82	19/04/2018	SYD1800841.07	Temperance Formation	TPF - Unsorted	Meta-Basalt	3.000	1.566
BH3102	641301.40	6038407.00	1154.85	19/04/2018	SYD1800841.08	Temperance Formation	TPF - Unsorted	Schist	2.870	1.18175
BH3102	641301.40	6038407.00	1143.85	19/04/2018	SYD1800841.09	Temperance Formation	TPF001	Schist	3.010	0.754
BH3102	641301.40	6038407.00	1141.85	15/05/2018	SYD1801021.01	Temperance Formation	TPF001	Schist	2.997	2.3055
BH3102	641301.40	6038407.00	1135.49	15/05/2018	SYD1801021.02	Temperance Formation	TPF001	Schist	2.747	1.42825
BH3102	641301.40	6038407.00	1127.13	8/05/2018	142402	Temperance Formation	TPF001	Schist	2.805	1.42825
BH3102	641301.40	6038407.00	1122.69	15/05/2018	SYD1801021.03	Temperance Formation	TPF001	Schist	2.744	1.42825
BH3102	641301.40	6038407.00	1114.85	15/05/2018	SYD1801021.04	Temperance Formation	TPF001	Schist	2.770	1.42825
BH3102	641301.40	6038407.00	1096.65	15/05/2018	SYD1801021.05	Temperance Formation	TPF - Unsorted	Schist	2.790	1.42825
BH3104	643798.00	6038272.40	1382.50	1/06/2018	3394-YP-1	Tantangara Formation	TTF - Unsorted	Sandstone	2.700	
BH3104	643798.00	6038272.40	1335.85	1/06/2018	3394-YP-1	Tantangara Formation	TTF - Unsorted	Siltstone	2.765	
BH3104	643798.00	6038272.40	1311.08	1/06/2018	3394-YP-1	Tantangara Formation	TTF - Unsorted	Siltstone	2.691	
BH3104	643798.00	6038272.40	1279.08	1/06/2018	3394-YP-1	Tantangara Formation	TTF - Unsorted	Siltstone	2.699	0.5945
BH3104	643798.00	6038272.40	1258.86	1/06/2018	3394-YP-1	Tantangara Formation	TTF - Unsorted	Sandstone	2.713	0.5945
BH3104	643798.00	6038272.40	1238.34	1/06/2018	3394-YP-1	Tantangara Formation	TTF - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.713	0.5945
BH3104	643798.00	6038272.40	1206.05	1/06/2018	3394-YP-1	Tantangara Formation	TTF - Unsorted	Sandstone	2.743	0.5945
BH3104	643798.00	6038272.40	1162.08	1/06/2018	3394-YP-1	Tantangara Formation	TTF - Unsorted	Sandstone	2.677	0.5945
BH3104	643798.00	6038272.40	1117.03	28/06/2018	SYD1801314	Tantangara Formation	TTF001	Siltstone	2.692	0.5945
BH3106	640651.04	6038341.69	1312.48	15/05/2018	SYD1801020.01	Temperance Formation	TPF - Unsorted	Diorite	2.716	
BH3106	640655.56	6038342.08	1289.12	18/05/2018	SYD1801020.02	Temperance Formation	TPF - Unsorted	Siltstone	2.730	
BH3106	640661.21	6038342.58	1259.96	18/05/2018	SYD1801020.03	Temperance Formation	TPF - Unsorted	Diorite	2.699	
BH3106	640665.83	6038342.98	1236.11	18/05/2018	SYD1801020.04	Temperance Formation	TPF - Unsorted	Diorite	2.853	
BH3106	640680.46	6038344.26	1160.55	1/06/2018	SYD1801020.07	Boggy Plain Suite	BPS - Unsorted	Diorite	2.721	
BH3106	640686.29	6038344.77	1130.44	1/06/2018	SYD1801020.08	Boggy Plain Suite	BPS001	Diorite	2.682	1.102
BH3106	640690.76	6038345.16	1107.35	1/06/2018	SYD1801020.09	Boggy Plain Suite	BPS - Unsorted	Diorite	2.687	
BH3106	640690.86	6038345.17	1106.83			Boggy Plain Suite	BPS - Unsorted	Diorite	2.720	1.1745
BH3106	640694.27	6038345.47	1089.22	1/06/2018	SYD1801020.10	Boggy Plain Suite	BPS - Unsorted	Diorite	2.686	
BH3107A	639630.68	6038379.77	1295.88	24/10/2018	SYD1802161.7	Gooandra Volcanics	GOV - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.745	
BH3107A	639636.09	6038380.82	1267.52	24/10/2018	SYD1802161.6	Gooandra Volcanics	GOV - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.721	
BH3107A	639643.02	6038382.16	1231.20	24/10/2018	SYD1802161.3	Gooandra Volcanics	GOV - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.695	
BH3107A	639649.41	6038383.41	1197.71	24/10/2018	SYD1802161.2	Gooandra Volcanics	GOV - Unsorted	Sandstone	2.750	
BH3107A	639652.44	6038384.00	1181.82	24/10/2018	SYD1802161.1	Gooandra Volcanics	GOV - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.742	
BH3107A	639656.19	6038384.72	1162.19	24/10/2018	SYD1802161.4	Gooandra Volcanics	GOV - Unsorted	Siltstone	2.749	
BH3107A	639661.32	6038385.72	1135.29	24/10/2018	SYD1802161.5	Temperance Formation	TPF001	INTERLAMINATED SANDSTONE/SILTSTONE (GHD)	2.735	
BH3107A	639663.34	6038386.11	1124.71	4/06/2018	3395-YP-1	Temperance Formation	TPF001	INTERLAMINATED SANDSTONE/SILTSTONE (GHD)	2.782	
BH3107A	639664.29	6038386.30	1119.75	8/05/2018	142402	Temperance Formation	TPF001	INTERLAMINATED SANDSTONE/SILTSTONE (GHD)	2.845	
BH3107A	639665.63	6038386.56	1112.72	4/06/2018	3395-YP-1	Temperance Formation	TPF001	INTERLAMINATED SANDSTONE/SILTSTONE (GHD)	2.753	
BH3108	638114.90	6038449.20	1307.35	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.793	
BH3108	638114.90	6038449.20	1292.20	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.676	
BH3108	638114.90	6038449.20	1257.80	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.688	
BH3108	638114.90	6038449.20	1216.23	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.678	
BH3108	638114.90	6038449.20	1168.35	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV - Unsorted	Schist	2.799	
BH3108	638114.90	6038449.20	1153.05	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV - Unsorted	Schist	2.855	

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH3108	638114.90	6038449.20	1129.64	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV001	Schist	2.765	
BH3108	638114.90	6038449.20	1117.00	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV001	Schist	2.756	
BH3108	638114.90	6038449.20	1104.85	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV001	Meta-Basalt	2.777	
BH3108	638114.90	6038449.20	1071.78	4/06/2018	3396-YP-1	Gooandra Volcanics	GOV - Unsorted	Schist	2.736	
BH3110	639025.00	6038252.40	1281.25	27/06/2018	SYD1801310.01	Gooandra Volcanics	GOV - Unsorted	Sandstone/Siltstone	2.807	
BH3110	639025.00	6038252.40	1253.98	27/06/2018	SYD1801310.02	Gooandra Volcanics	GOV - Unsorted	Siltstone	2.763	
BH3110	639025.00	6038252.40	1230.25	27/06/2018	SYD1801310.03	Gooandra Volcanics	GOV - Unsorted	Diorite	2.823	
BH3110	639025.00	6038252.40	1201.25	27/06/2018	SYD1801310.04	Gooandra Volcanics	GOV - Unsorted	Diorite	2.840	
BH3110	639025.00	6038252.40	1173.23	27/06/2018	SYD1801310.05	Gooandra Volcanics	GOV - Unsorted	Diorite	2.823	
BH3110	639025.00	6038252.40	1151.25	27/06/2018	SYD1801310.06	Gooandra Volcanics	GOV - Unsorted	Diorite	2.906	
BH3110	639025.00	6038252.40	1130.97	27/06/2018	SYD1801310.07	Gooandra Volcanics	GOV001	Diorite	2.782	1.0585
BH3110	639025.00	6038252.40	1104.25	27/06/2018	SYD1801310.08*	Gooandra Volcanics	GOV001	Diorite	2.798	
BH3A08	#N/A	#N/A	#N/A	26/10/2018	SYD1802230	#N/A	#N/A	#N/A	2.649	
BH4101	636233.85	6038499.00	1438.92	18/04/2018	BRTS376	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.630	
BH4101	636242.12	6038499.00	1417.03	18/04/2018	BRTS376	Gooandra Volcanics	GOV - Unsorted	VOLCANIC	2.715	
BH4101	636253.82	6038499.00	1386.06	18/04/2018	BRTS376	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.674	
BH4101	636286.16	6038499.00	1300.47	18/04/2018	BRTS376	Gooandra Volcanics	GOV - Unsorted	VOLCANIC	2.684	
BH4101	636307.49	6038499.00	1244.02	18/04/2018	BRTS376	Gooandra Volcanics	GOV - Unsorted	VOLCANIC	2.790	
BH4101	636324.88	6038499.00	1198.00	18/04/2018	BRTS376	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	3.351	
BH4101	636350.37	6038499.00	1130.55	26/01/2018	BRTS376	Gooandra Volcanics	GOV002	RHYOLITE		
BH4101	636359.51	6038499.00	1106.36	18/04/2018	BRTS376	Gooandra Volcanics	GOV001	RHYOLITE	2.716	
BH4101	636361.55	6038499.00	1100.95	26/01/2018	BRTS376	Gooandra Volcanics	GOV001	RHYOLITE	2.753	
BH4101	636367.61	6038499.00	1084.92	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.706	
BH4101	636371.85	6038499.00	1073.70	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.712	
BH4101	636384.15	6038499.00	1041.15	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.701	
BH4101	636388.87	6038499.00	1028.65	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.780	
BH4101	636409.83	6038499.00	973.18	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.821	
BH4101	636450.53	6038499.00	865.47	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.761	
BH4101	636484.82	6038499.00	774.73	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	VOLCANIC	2.794	
BH4101	636511.56	6038499.00	703.96	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	VOLCANIC	2.916	
BH4101	636525.38	6038499.00	667.39	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.842	
BH4101	636537.94	6038499.00	634.16	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.787	
BH4101	636565.53	6038499.00	561.14	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	VOLCANIC	2.842	
BH4101	636581.65	6038499.00	518.48	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.833	
BH4101	636604.39	6038499.00	458.30	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.858	
BH4101	636607.58	6038499.00	449.87	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.866	
BH4101	636608.68	6038499.00	446.95	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.785	
BH4101	636609.06	6038499.00	445.94	9/01/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE		
BH4101	636621.84	6038499.00	412.13	9/01/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE		
BH4101	636625.64	6038499.00	402.07	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.903	
BH4101	636629.40	6038499.00	392.11	15/03/2018	BRTS388	Gooandra Volcanics	GOV - Unsorted	RHYOLITE	2.889	
BH4102	634843.91	6038536.56	1432.91	23/05/2018	SYD1800839.01	Gooandra Volcanics	GOV - Unsorted	Schist	2.821	
BH4102	634831.74	6038535.06	1409.84	23/05/2018	SYD1800839.02	Gooandra Volcanics	GOV - Unsorted	Schist	2.713	
BH4102	634811.38	6038532.56	1371.28	23/05/2018	SYD1800839.03	Gooandra Volcanics	GOV - Unsorted	QUARTZ	2.630	
BH4102	634802.06	6038531.42	1353.61	23/05/2018	SYD1800839.04	Gooandra Volcanics	GOV - Unsorted	PHYLLITE	2.590	
BH4102	634781.85	6038528.94	1315.31	16/04/2018	SYD1800839.05	Gooandra Volcanics	GOV - Unsorted	Schist	2.930	
BH4102	634770.89	6038527.59	1294.56	16/04/2018	SYD1800839.06	Gooandra Volcanics	GOV - Unsorted	PHYLLITE	2.740	
BH4102	634759.53	6038526.20	1273.02	16/04/2018	SYD1800839.07	Gooandra Volcanics	GOV - Unsorted	Schist	2.760	
BH4102	634747.73	6038524.75	1250.67	16/04/2018	SYD1800839.08	Gooandra Volcanics	GOV - Unsorted	Schist	2.790	
BH4102	634723.36	6038521.76	1204.50	16/04/2018	SYD1800839.09	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.780	
BH4102	634713.11	6038520.50	1185.06	16/04/2018	SYD1800839.10	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.720	
BH4102	634706.26	6038519.66	1172.09	8/05/2018	142402	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.940	0.1305

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH4102	634696.49	6038518.46	1153.57	16/04/2018	SYD1800839.11	Gooandra Volcanics	GOV - Unsorted	Schist	2.690	
BH4102	634693.51	6038518.09	1147.93	16/04/2018	SYD1800839.12	Gooandra Volcanics	GOV - Unsorted	Schist	2.750	
BH4102	634690.54	6038517.73	1142.29	19/04/2018	SYD1800846.01	Gooandra Volcanics	GOV - Unsorted	Schist	2.860	
BH4102	634681.10	6038516.57	1124.41	19/04/2018	SYD1800846.02	Gooandra Volcanics	GOV001	PHYLLITE	2.770	0.2175
BH4102	634663.43	6038514.40	1090.93	19/04/2018	SYD1800846.03	Gooandra Volcanics	GOV - Unsorted	PHYLLITE	2.770	
BH4102	634653.39	6038513.16	1071.90	19/04/2018	SYD1800846.04	Gooandra Volcanics	GOV - Unsorted	PHYLLITE	2.770	
BH4102	634637.97	6038511.27	1042.70	19/04/2018	SYD1800846.05	Gooandra Volcanics	GOV - Unsorted	Schist	2.790	
BH4102	634625.51	6038509.74	1019.08	19/04/2018	SYD1800846.06	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.690	
BH4102	634613.86	6038508.31	997.00	20/04/2018	SYD1800846.07	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.680	
BH4102	634603.42	6038507.03	977.22	20/04/2018	SYD1800846.08	Gooandra Volcanics	GOV - Unsorted	Schist	2.750	
BH4102	634592.10	6038505.64	955.77	20/04/2018	SYD1800846.09	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.760	
BH4102	634578.91	6038504.02	930.78	20/04/2018	SYD1800846.10	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.770	
BH4103	634544.82	6038600.55	1425.32	10/05/2018	SYD1800571.01	Gooandra Volcanics	GOV - Unsorted	Schist	2.760	
BH4103	634539.60	6038598.95	1397.25	10/05/2018	SYD1800571.02	Gooandra Volcanics	GOV - Unsorted	Schist	2.760	
BH4103	634538.44	6038598.60	1390.99	10/05/2018	SYD1800571.03	Gooandra Volcanics	GOV - Unsorted	Schist	2.720	
BH4103	634535.32	6038597.64	1374.21	10/05/2018	SYD1800571.04	Gooandra Volcanics	GOV - Unsorted	Schist	2.640	
BH4103	634532.01	6038596.63	1356.37	10/05/2018	SYD1800571.05	Gooandra Volcanics	GOV - Unsorted	Schist	2.700	
BH4103	634527.10	6038595.13	1329.96	10/05/2018	SYD1800571.06	Gooandra Volcanics	GOV - Unsorted	Meta-Basalt	2.710	
BH4103	634525.16	6038594.53	1319.52	10/05/2018	SYD1800571.07	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.740	
BH4103	634521.79	6038593.51	1301.43	10/05/2018	SYD1800571.08	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.820	
BH4103	634514.54	6038591.29	1262.40	10/05/2018	SYD1800571.09	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.660	
BH4103	634508.55	6038589.46	1230.17	10/05/2018	SYD1800571.10	Gooandra Volcanics	GOV - Unsorted	TUFF	2.730	0.087
BH4103	634502.10	6038587.48	1195.47	10/05/2018	SYD1800571.11	Gooandra Volcanics	GOV - Unsorted	Meta-Basalt	2.710	0.174
BH4103	634499.00	6038586.54	1178.84	10/05/2018	SYD1800571.12	Gooandra Volcanics	GOV - Unsorted	Siltstone	2.750	
BH4103	634496.72	6038585.84	1166.55	10/05/2018	SYD1800571.13	Gooandra Volcanics	GOV - Unsorted	QUARTZ/Breccia	2.700	
BH4103	634496.62	6038585.81	1166.02	23/04/2018	SYD1800572.1	Gooandra Volcanics	GOV - Unsorted	QUARTZ/Breccia	2.634	0.1885
BH4103	634495.42	6038585.44	1159.54	10/05/2018	SYD1800571.14	Gooandra Volcanics	GOV - Unsorted	Siltstone	2.740	
BH4103	634494.46	6038585.15	1154.39			Gooandra Volcanics	GOV - Unsorted	Siltstone	2.990	
BH4103	634494.16	6038585.06	1152.77	10/05/2018	SYD1800571.15	Gooandra Volcanics	GOV - Unsorted	Siltstone	2.720	
BH4103	634492.49	6038584.55	1143.77	23/04/2018	SYD1800572	Gooandra Volcanics	GOV - Unsorted	Schist	2.739	
BH4103	634492.35	6038584.50	1143.03	10/05/2018	SYD1800571.16	Gooandra Volcanics	GOV - Unsorted	Schist	2.730	
BH4103	634490.02	6038583.79	1130.53	10/05/2018	SYD1800571.17	Gooandra Volcanics	GOV001	Schist	2.700	
BH4103	634487.73	6038583.09	1118.17	10/05/2018	SYD1800571.18	Gooandra Volcanics	GOV001	Schist	2.660	
BH4103	634486.74	6038582.79	1112.87			Gooandra Volcanics	GOV001	Schist	2.795	
BH4103	634485.69	6038582.47	1107.23	10/05/2018	SYD1800571.19	Gooandra Volcanics	GOV001	Siltstone	2.760	
BH4103	634483.46	6038581.79	1095.19	10/05/2018	SYD1800571.20	Gooandra Volcanics	GOV001	Schist	2.710	
BH4103	634480.47	6038580.87	1079.10			Gooandra Volcanics	GOV - Unsorted	GNEISS	2.870	0.116
BH4104	633584.22	6038262.20	1477.89	18/05/2018	SYD1800889.01	Ravine Beds East	RBE005	Siltstone	2.400	
BH4104	633581.24	6038263.05	1464.47	18/05/2018	SYD1800889.02	Ravine Beds East	RBE - Unsorted	Siltstone	2.610	
BH4104	633572.91	6038265.44	1426.92	21/05/2018	SYD1800889.03	Ravine Beds East	RBE - Unsorted	Siltstone	2.680	
BH4104	633568.60	6038266.67	1407.51	21/05/2018	SYD1800889.04	Ravine Beds East	RBE - Unsorted	Siltstone	2.670	
BH4104	633559.56	6038269.27	1366.75	21/05/2018	SYD1800889.05	Ravine Beds East	RBE - Unsorted	Siltstone	2.719	
BH4104	633551.40	6038271.61	1329.97	21/05/2018	SYD1800889.06	Ravine Beds East	RBE - Unsorted	Siltstone	2.620	
BH4104	633548.81	6038272.35	1318.35	21/05/2018	SYD1800889.07	Ravine Beds East	RBE - Unsorted	Siltstone	2.730	
BH4104	633543.15	6038273.97	1292.82	5/11/2018	SYD1800889.11	Ravine Beds East	RBE - Unsorted	Siltstone	2.726	
BH4104	633542.94	6038274.03	1291.86	5/11/2018	SYD1800889.11	Ravine Beds East	RBE - Unsorted	Siltstone	2.727	
BH4104	633536.11	6038275.99	1261.12	21/05/2018	SYD1800889.08	Ravine Beds East	RBE - Unsorted	Siltstone	2.730	
BH4104	633525.56	6038279.02	1213.56	21/05/2018	SYD1800889.09	Ravine Beds East	RBE - Unsorted	Siltstone	2.740	
BH4104	633504.12	6038285.16	1116.95	4/05/2018	SYD1800889.10	Ravine Beds East	RBE001	Siltstone	2.730	
BH4104	633499.89	6038286.38	1097.87	4/04/2018	SYD1800572.1	Ravine Beds East	RBE002	Siltstone	2.748	
BH4104	633397.11	6038315.85	634.75	4/05/2018	SYD1800889.10	Ravine Beds East	RBE - Unsorted	Siltstone	2.575	
BH4105	634164.59	6038523.54	1471.99	26/06/2018	SYD1801309.01	Gooandra Volcanics	GOV - Unsorted	Siltstone	2.716	
BH4105	634148.36	6038529.45	1438.10	26/06/2018	SYD1801309.02	Gooandra Volcanics	GOV - Unsorted	Siltstone	2.737	

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH4105	634139.19	6038532.79	1418.94	26/06/2018	SYD1801309.03	Gooandra Volcanics	GOV - Unsorted	Schist	2.680	
BH4105	634127.75	6038536.95	1395.04	26/06/2018	SYD1801309.04	Gooandra Volcanics	GOV - Unsorted	Schist	2.704	
BH4105	634115.54	6038541.40	1369.54	26/06/2018	SYD1801309.05	Gooandra Volcanics	GOV - Unsorted	Schist	2.726	
BH4105	634102.21	6038546.25	1341.70	26/06/2018	SYD1801309.06	Gooandra Volcanics	GOV - Unsorted	Schist	2.736	
BH4105	634086.72	6038551.89	1309.34	25/06/2018	SYD1801309.07	Gooandra Volcanics	GOV - Unsorted	PHYLLITE	2.687	
BH4105	634076.05	6038555.77	1287.07	25/06/2018	SYD1801309.08	Tumut Ponds?	Tumut Ponds?	METASEDIMENTS	2.636	
BH4105	634068.16	6038558.64	1270.58	25/06/2018	SYD1801309.09	Tumut Ponds?	Tumut Ponds?	PHYLLITE	2.632	
BH4105	634055.87	6038563.11	1244.92	25/06/2018	SYD1801309.10	Tumut Ponds?	Tumut Ponds?	PHYLLITE	2.677	
BH4105	634044.21	6038567.36	1220.57	25/06/2018	SYD1801309.11	Tumut Ponds?	Tumut Ponds?	PHYLLITE	2.668	
BH4105	634028.27	6038573.16	1187.28	25/06/2018	SYD1801309.12	Tumut Ponds?	Tumut Ponds?	PHYLLITE	2.674	
BH4105	634011.20	6038579.37	1151.62	25/06/2018	SYD1801309.13	Tumut Ponds?	Tumut Ponds?	PHYLLITE	2.647	
BH4105	634005.32	6038581.51	1139.34	26/06/2018	SYD1801309.14	Tumut Ponds?	Tumut Ponds?	PHYLLITE	2.726	0.783
BH4105	633988.59	6038587.60	1104.41	25/06/2018	SYD1801309.15	Ravine Beds East	RBE001	GNEISS	2.676	0.725
BH4105	633982.20	6038589.93	1091.04	26/06/2018	SYD1801309.16*	Ravine Beds East	RBE - Unsorted	PHYLLITE/GNEISS	2.741	
BH4105	633968.84	6038594.79	1063.16	26/06/2018	SYD1801309.17	Ravine Beds East	RBE - Unsorted	PHYLLITE/GNEISS	2.745	
BH4106	635007.95	6038516.76	1395.88	31/05/2018	SYD1801005.01	Gooandra Volcanics	GOV001	Schist	2.883	0.36975
BH4106	634998.95	6038520.39	1378.37	31/05/2018	SYD1801005.02	Gooandra Volcanics	GOV001	Schist	2.851	0.087
BH4106	634986.37	6038525.48	1353.88	31/05/2018	SYD1801005.03	Gooandra Volcanics	GOV001	Schist	2.901	0.087
BH4106	634969.63	6038532.24	1321.32	31/05/2018	SYD1801005.04	Gooandra Volcanics	GOV001	Schist	2.921	0.087
BH4106	634953.39	6038538.80	1289.71	31/05/2018	SYD1801005.05	Gooandra Volcanics	GOV001	Schist	2.928	0.087
BH4106	634938.85	6038544.68	1261.43	31/05/2018	SYD1801005.06	Gooandra Volcanics	GOV001	Schist	2.889	0.087
BH4106	634923.29	6038550.97	1231.14	31/05/2018	SYD1801005.07	Gooandra Volcanics	GOV001	Schist	2.729	0.087
BH4106	634902.00	6038559.57	1189.72	31/05/2018	SYD1801005.08	Gooandra Volcanics	GOV001	PHYLLITE	2.755	0.087
BH4106	634884.58	6038566.60	1155.83	31/05/2018	SYD1801005.09	Gooandra Volcanics	GOV001	PHYLLITE	2.753	0.087
BH4106	634870.19	6038572.42	1127.84	31/05/2018	SYD1801005.10	Gooandra Volcanics	GOV001	GNEISS	2.741	0.087
BH4106	634860.09	6038576.50	1108.18	31/05/2018	SYD1801005.13	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.768	0.087
BH4106	634859.88	6038576.58	1107.76			Gooandra Volcanics	GOV - Unsorted	GNEISS	2.775	0.087
BH4106	634855.87	6038578.20	1099.98	31/05/2018	SYD1801005.12	Gooandra Volcanics	GOV - Unsorted	GNEISS	2.811	0.087
BH5101	633041.80	6038525.70	1356.15	11/04/2018	SYD1800805.02	Ravine Beds East	RBE - Unsorted	Siltstone	2.740	
BH5101A	633041.80	6038525.70	1108.00	11/04/2018	SYD1800805.03	Ravine Beds East	RBE002	Siltstone	2.720	
BH5101A	633041.80	6038525.70	1014.55	11/04/2018	SYD1800805.04	Ravine Beds East	RBE - Unsorted	Siltstone	2.670	
BH5101A	633041.80	6038525.70	863.49	11/04/2018	SYD1800805.05	Ravine Beds East	RBE - Unsorted	Siltstone	2.760	
BH5101A	633041.80	6038525.70	700.55	11/04/2018	SYD1800805.06	Ravine Beds East	RBE - Unsorted	Siltstone	2.750	
BH5101A	633041.80	6038525.70	661.65	11/04/2018	SYD1800805.07	Ravine Beds East	RBE - Unsorted	Siltstone	2.750	
BH5101A	633041.80	6038525.70	598.07	11/04/2018	SYD1800805.08	Ravine Beds East	RBE - Unsorted	Siltstone	2.760	
BH5101A	633041.80	6038525.70	513.95	11/04/2018	SYD1800805.09	Ravine Beds East	RBE - Unsorted	Siltstone	2.710	
BH5101A	633041.80	6038525.70	440.53	5/11/2018	SYD1800805.13	Ravine Beds East	RBE - Unsorted	Siltstone	2.743	
BH5101A	633041.80	6038525.70	436.38	11/04/2018	SYD1800805.11	Ravine Beds East	RBE - Unsorted	Siltstone	2.750	
BH5101A	633041.80	6038525.70	429.40	11/04/2018	SYD1800805.10	Ravine Beds East	RBE - Unsorted	Meta-Andesite	2.700	
BH5102	632527.00	6038535.00	1282.78	9/04/2018	BRTS391	Ravine Beds East	RBE - Unsorted	SILTSTONE	2.628	
BH5102	632527.00	6038535.00	1252.56	9/01/2018	BRTS391	Ravine Beds East	RBE - Unsorted	SILTSTONE		
BH5102	632527.00	6038535.00	1232.68	9/04/2018	BRTS391	Ravine Beds East	RBE - Unsorted	SILTSTONE	2.688	
BH5102	632527.00	6038535.00	1217.11	9/04/2018	BRTS391	Ravine Beds East	RBE - Unsorted	SILTSTONE	2.721	
BH5102	632527.00	6038535.00	1187.79	9/04/2018	BRTS391	Ravine Beds East	RBE - Unsorted	SILTSTONE	2.751	
BH5102	632527.00	6038535.00	1140.09	9/04/2018	BRTS391	Ravine Beds East	RBE - Unsorted	SILTSTONE	2.735	
BH5102	632527.00	6038535.00	1106.50	9/01/2018	BRTS391	Ravine Beds East	RBE002	SILTSTONE		
BH5102	632527.00	6038535.00	1101.40	9/01/2018	BRTS391	Ravine Beds East	RBE002	SILTSTONE		
BH5102	632527.00	6038535.00	1094.08	9/04/2018	BRTS391	Ravine Beds East	RBE002	SILTSTONE	2.720	
BH5102	632527.00	6038535.00	1091.68	9/04/2018	BRTS391	Ravine Beds East	RBE002	SILTSTONE	2.729	
BH5102	632527.00	6038535.00	1082.13	9/04/2018	BRTS391	Ravine Beds East	RBE002	SILTSTONE	2.719	
BH5102	632527.00	6038535.00	1075.10	9/04/2018	BRTS391	Ravine Beds East	RBE002	SILTSTONE	2.727	
BH5102	632527.00	6038535.00	1043.26	9/04/2018	BRTS391	Ravine Beds East	RBE002	SILTSTONE	2.730	

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH5102	632527.00	6038535.00	1000.19	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.734	
BH5102	632527.00	6038535.00	981.08	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.715	
BH5102	632527.00	6038535.00	952.75	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.701	
BH5102	632527.00	6038535.00	904.31	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.726	
BH5102	632527.00	6038535.00	857.71	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.720	
BH5102	632527.00	6038535.00	828.06	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.735	
BH5102	632527.00	6038535.00	797.30	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.730	
BH5102	632527.00	6038535.00	766.67	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.740	
BH5102	632527.00	6038535.00	715.44	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.713	
BH5102	632527.00	6038535.00	711.29	9/04/2018	BRTS391	Ravine Beds East	RBE002	SILTSTONE	2.741	
BH5102	632527.00	6038535.00	647.08	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.745	
BH5102	632527.00	6038535.00	617.03	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.736	
BH5102	632527.00	6038535.00	579.39	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.730	
BH5102	632527.00	6038535.00	577.75	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.702	
BH5102	632527.00	6038535.00	527.05	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.713	
BH5102	632527.00	6038535.00	478.47	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.750	
BH5102	632527.00	6038535.00	454.50	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.742	
BH5102	632527.00	6038535.00	449.28	9/01/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE		
BH5102	632527.00	6038535.00	445.34	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.740	
BH5102	632527.00	6038535.00	444.75	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.730	
BH5102	632527.00	6038535.00	426.27	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.727	
BH5102	632527.00	6038535.00	403.76	9/04/2018	BRTS391	Ravine Beds East	RBE001	SILTSTONE	2.735	
BH5103	631862.20	6038893.00	1231.42	29/03/2018	SYD1800570.02	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.590	
BH5103	631862.20	6038893.00	1210.51	29/03/2018	SYD1800570.03	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.570	
BH5103	631862.20	6038893.00	1199.45	29/03/2018	SYD1800570.04	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.530	
BH5103	631862.20	6038893.00	1170.59	29/03/2018	SYD1800570.06	Boraig Group	BRG - Unsorted	Sandstone	2.630	
BH5103	631862.20	6038893.00	1146.49	29/03/2018	SYD1800570.07	Boraig Group	BRG - Unsorted	Sandstone	2.630	
BH5103	631862.20	6038893.00	1093.80	29/03/2018	SYD1800570.08	Boraig Group	BRG - Unsorted	Siltstone	2.680	
BH5103	631862.20	6038893.00	1051.59	29/03/2018	SYD1800570.09	Boraig Group	BRG - Unsorted	Conglomerate	2.630	
BH5103	631862.20	6038893.00	1035.58	29/03/2018	SYD1800570.10	Boraig Group	BRG - Unsorted	Conglomerate	2.670	
BH5103	631862.20	6038893.00	977.81	25/05/2018	SYD1800570.35	Boraig Group	BRG - Unsorted	Conglomerate	2.657	
BH5103	631862.20	6038893.00	977.27	29/03/2018	SYD1800570.12	Boraig Group	BRG - Unsorted	Conglomerate	2.680	
BH5103	631862.20	6038893.00	963.84	29/03/2018	SYD1800570.13	Boraig Group	BRG - Unsorted	Sandstone	2.720	
BH5103	631862.20	6038893.00	929.60	29/03/2018	SYD1800570.14	Boraig Group	BRG - Unsorted	TUFF	2.670	
BH5103	631862.20	6038893.00	923.63	29/03/2018	SYD1800570.15	Boraig Group	BRG - Unsorted	TUFF	2.640	
BH5103	631862.20	6038893.00	920.25			Boraig Group	BRG - Unsorted	TUFF	2.640	0.058
BH5103	631862.20	6038893.00	759.42	29/03/2018	SYD1800570.16	Boraig Group	BRG - Unsorted	DACITE	2.670	0.116
BH5103	631862.20	6038893.00	726.76	29/03/2018	SYD1800570.17	Boraig Group	BRG - Unsorted	Conglomerate	2.680	
BH5103	631862.20	6038893.00	708.93			Boraig Group	BRG - Unsorted	Conglomerate	2.705	
BH5103	631862.20	6038893.00	655.50	29/03/2018	SYD1800570.19	Boraig Group	BRG - Unsorted	Conglomerate	2.700	
BH5103	631862.20	6038893.00	622.25	29/03/2018	SYD1800570.20	Boraig Group	BRG - Unsorted	Siltstone	2.730	
BH5103	631862.20	6038893.00	565.50	29/03/2018	SYD1800570.21	Boraig Group	BRG - Unsorted	Sandstone	2.690	
BH5103	631862.20	6038893.00	559.80	29/03/2018	SYD1800570.22	Boraig Group	BRG - Unsorted	Sandstone	2.690	
BH5103	631862.20	6038893.00	536.40	29/03/2018	SYD1800570.23	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.690	
BH5103	631862.20	6038893.00	533.30	29/03/2018	SYD1800570.24	Boraig Group	BRG - Unsorted	Conglomerate/Sandstone	2.690	
BH5103	631862.20	6038893.00	531.60	29/03/2018	SYD1800570.25	Boraig Group	BRG - Unsorted	Conglomerate/Sandstone	2.670	
BH5103	631862.20	6038893.00	480.37	29/03/2018	SYD1800570.26	Boraig Group	BRG001	Sandstone/Conglomerate	2.660	
BH5103	631862.20	6038893.00	471.65	29/03/2018	SYD1800570.27	Boraig Group	BRG - Unsorted	Sandstone/Conglomerate	2.680	
BH5103	631862.20	6038893.00	455.95	17/04/2018	SYD1800570.28	Boraig Group	BRG - Unsorted	Conglomerate	2.680	
BH5103	631862.20	6038893.00	451.25	17/04/2018	SYD1800570.29	Boraig Group	BRG - Unsorted	Conglomerate	2.680	
BH5103	631862.20	6038893.00	445.75	17/04/2018	SYD1800570.30	Boraig Group	BRG - Unsorted	Conglomerate	2.680	
BH5103	631862.20	6038893.00	442.93	17/04/2018	SYD1800570.31	Boraig Group	BRG - Unsorted	Conglomerate	2.700	

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH5103	631862.20	6038893.00	438.88	17/04/2018	SYD1800570.32	Boraig Group	BRG - Unsorted	Conglomerate	2.680	
BH5103	631862.20	6038893.00	419.25	17/04/2018	SYD1800570.33	Boraig Group	BRG - Unsorted	Conglomerate	2.680	
BH5103	631862.20	6038893.00	399.25	17/04/2018	SYD1800570.34	Boraig Group	BRG - Unsorted	Conglomerate	2.690	
BH5103	631862.20	6038893.00	397.58	22/05/2018	SYD1800570.41	Boraig Group	BRG - Unsorted	Conglomerate	2.666	
BH5104A	631293.07	6038853.22	1109.91	28/05/2018	SYD1801057.02	Boraig Group	BRG - Unsorted	IGNUMBRITE	2.683	
BH5104A	631292.75	6038850.24	1088.58	28/05/2018	SYD1801057.03	Boraig Group	BRG - Unsorted	IGNUMBRITE	2.703	
BH5104A	631292.29	6038845.84	1057.05	28/05/2018	SYD1801057.05	Boraig Group	BRG - Unsorted	IGNUMBRITE	2.698	0.0145
BH5104A	631291.55	6038838.83	1006.91	28/05/2018	SYD1801057.07	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.666	
BH5104A	631291.07	6038834.20	973.78	28/05/2018	SYD1801057.08	Boraig Group	BRG - Unsorted	Conglomerate	2.713	
BH5104A	631290.89	6038832.51	961.68	28/05/2018	SYD1801057.09	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.668	
BH5104A	631290.72	6038830.88	950.05	28/05/2018	SYD1801057.10	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.683	
BH5104A	631290.47	6038828.55	933.34	28/05/2018	SYD1801057.11	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.666	
BH5104A	631290.09	6038824.88	907.09	28/05/2018	SYD1801057.12	Boraig Group	BRG - Unsorted	Conglomerate	2.672	
BH5104A	631289.70	6038821.20	880.76	28/05/2018	SYD1801057.13	Boraig Group	BRG - Unsorted	Conglomerate	2.670	
BH5104A	631289.09	6038815.40	839.27	28/05/2018	SYD1801057.14	Boraig Group	BRG - Unsorted	Siltstone	2.677	
BH5104A	631288.65	6038811.20	809.26	28/05/2018	SYD1801057.15	Boraig Group	BRG - Unsorted	Siltstone	2.713	
BH5104A	631288.25	6038807.37	781.83	28/05/2018	SYD1801057.16	Boraig Group	BRG - Unsorted	Siltstone	2.684	
BH5104A	631287.78	6038802.93	750.04	29/05/2018	SYD1801057.17	Boraig Group	BRG - Unsorted	Siltstone	2.668	
BH5104A	631287.33	6038798.65	719.44	29/05/2018	SYD1801057.18	Boraig Group	BRG - Unsorted	Siltstone	2.677	
BH5104A	631286.89	6038794.48	689.62	29/05/2018	SYD1801057.19	Boraig Group	BRG - Unsorted	Siltstone	2.669	
BH5104A	631286.49	6038790.63	662.03	29/05/2018	SYD1801057.20	Boraig Group	BRG - Unsorted	Siltstone	2.642	
BH5104A	631285.99	6038785.92	628.34	29/05/2018	SYD1801057.21	Boraig Group	BRG - Unsorted	Siltstone	2.680	
BH5104A	631285.60	6038782.19	601.65	29/05/2018	SYD1801057.22	Boraig Group	BRG - Unsorted	Conglomerate	2.692	
BH5104A	631285.25	6038778.84	577.71	29/05/2018	SYD1801057.23	Boraig Group	BRG - Unsorted	Conglomerate	2.696	
BH5104A	631284.84	6038774.99	550.16	29/05/2018	SYD1801057.24	Boraig Group	BRG - Unsorted	Conglomerate	2.546	
BH5104A	631284.33	6038770.14	515.45	29/05/2018	SYD1801057.25	Boraig Group	BRG - Unsorted	Conglomerate	2.678	0.3335
BH5104A	631283.99	6038766.82	491.71	29/05/2018	SYD1801057.27	Boraig Group	BRG001	Conglomerate	2.688	
BH5104A	631283.92	6038766.23	487.50	23/10/2018	SYD1802160.2	Boraig Group	BRG001	Interlaminated: Sandstone/Siltstone	2.703	
BH5104A	631283.70	6038764.13	472.47	23/10/2018	SYD1802160.7	Boraig Group	BRG001	Interlaminated: Sandstone/Siltstone	2.690	0.087
BH5104A	631283.64	6038763.57	468.50	23/10/2018	SYD1802160.8	Boraig Group	BRG001	Interlaminated: Sandstone/Siltstone	2.687	0.3915
BH5104A	631283.61	6038763.27	466.35	28/05/2018	SYD1801057.28	Boraig Group	BRG001	Interlaminated: Sandstone/Siltstone	2.680	0.3915
BH5104A	631283.45	6038761.73	455.34	23/10/2018	SYD1802160.10	Boraig Group	BRG001	Interlaminated: Sandstone/Siltstone	2.686	0.23925
BH5104A	631283.39	6038761.14	451.07	28/05/2018	SYD1801057.29	Boraig Group	BRG001	Interlaminated: Sandstone/Siltstone	2.692	0.522
BH5104A	631283.35	6038760.73	448.14	8/05/2018	142402	Boraig Group	BRG001	Interlaminated: Sandstone/Siltstone	2.780	0.45965
BH5104A	631283.00	6038757.40	424.35	28/05/2018	SYD1801057.30	Boraig Group	BRG001	Interlaminated: Sandstone/Siltstone	2.681	
BH5104A	631282.62	6038753.80	398.60	30/05/2018	SYD1801057.31	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.681	
BH5104A	631282.39	6038751.59	382.75	30/05/2018	SYD1801057.32	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.681	
BH5104A	631282.23	6038750.11	372.16	30/05/2018	SYD1801057.33	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.697	
BH5104A	631281.88	6038746.75	348.09	31/05/2018	SYD1801057.34	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.724	
BH5105	630950.00	6038905.60	1174.24	22/05/2018	SYD1800864.01	Boraig Group	BRG - Unsorted	Siltstone	2.392	
BH5105	630950.00	6038905.60	1168.15	23/10/2018	SYD1802158.03	Boraig Group	BRG - Unsorted	Siltstone	2.456	
BH5105	630950.00	6038905.60	1162.28	22/05/2018	SYD1800864.02	Boraig Group	BRG - Unsorted	Siltstone	2.022	
BH5105	630950.00	6038905.60	1147.20	22/05/2018	SYD1800864.03	Boraig Group	BRG - Unsorted	Sandstone	2.716	
BH5105	630950.00	6038905.60	1138.15	22/05/2018	SYD1800864.04	Boraig Group	BRG - Unsorted	Sandstone	2.689	
BH5105	630950.00	6038905.60	1133.65	22/05/2018	SYD1800864.05	Boraig Group	BRG - Unsorted	Sandstone	2.637	
BH5105	630950.00	6038905.60	1129.35	22/05/2018	SYD1800864.06	Boraig Group	BRG - Unsorted	Sandstone	2.632	
BH5105	630950.00	6038905.60	1104.85	30/04/2018	SYD1800864.07	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.640	
BH5105	630950.00	6038905.60	1067.83	30/04/2018	SYD1800864.08	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.660	
BH5105	630950.00	6038905.60	1059.65	30/04/2018	SYD1800864.09	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE (GHD)	2.700	
BH5105	630950.00	6038905.60	1035.89	30/04/2018	SYD1800864.10	Boraig Group	BRG - Unsorted	Siltstone	2.670	
BH5105	630950.00	6038905.60	1025.35	30/04/2018	SYD1800864.11	Boraig Group	BRG - Unsorted	INTERLAMINATED SANDSTONE/SILTSTONE (GHD)	2.680	
BH5105	630950.00	6038905.60	1009.60	8/05/2018	142402	Boraig Group	BRG - Unsorted	INTERLAMINATED SANDSTONE/SILTSTONE (GHD)	2.840	

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH5105	630950.00	6038905.60	1007.35	30/04/2018	SYD1800864.12	Boraig Group	BRG - Unsorted	INTERLAMINATED SANDSTONE/SILTSTONE (GHD)	2.720	
BH5105	630950.00	6038905.60	988.35	7/05/2018	SYD1801003.13	Boraig Group	BRG - Unsorted	Schist	2.710	
BH5105	630950.00	6038905.60	965.65	7/05/2018	SYD1801003.14	Boraig Group	BRG - Unsorted	Schist	2.677	
BH5105	630950.00	6038905.60	935.13	7/05/2018	SYD1801003.15	Boraig Group	BRG - Unsorted	Schist	2.670	
BH5105	630950.00	6038905.60	923.35	7/05/2018	SYD1801003.16	Boraig Group	BRG - Unsorted	Schist	2.676	
BH5105	630950.00	6038905.60	914.35	7/05/2018	SYD1801003.17	Boraig Group	BRG - Unsorted	Schist	2.683	
BH5105	630950.00	6038905.60	888.40	7/05/2018	SYD1801003.18	Boraig Group	BRG - Unsorted	Schist	2.681	
BH5105	630950.00	6038905.60	874.03	7/05/2018	SYD1801003.19	Boraig Group	BRG - Unsorted	Schist	2.702	
BH5105	630950.00	6038905.60	843.96	7/05/2018	SYD1801003.20	Boraig Group	BRG - Unsorted	Schist	2.683	
BH5105	630950.00	6038905.60	830.04	7/05/2018	SYD1801003.21	Boraig Group	BRG - Unsorted	Schist	2.687	
BH5105	630950.00	6038905.60	801.26	7/05/2018	SYD1801003.22	Boraig Group	BRG - Unsorted	Schist	2.705	
BH5105	630950.00	6038905.60	763.19	7/05/2018	SYD1801003.23	Boraig Group	BRG - Unsorted	Siltstone	2.703	
BH5105	630950.00	6038905.60	738.65	7/05/2018	SYD1801003.24	Boraig Group	BRG - Unsorted	CORE LOSS	2.708	
BH5105	630950.00	6038905.60	723.85	7/05/2018	SYD1801003.25	Boraig Group	BRG - Unsorted	CORE LOSS	2.694	
BH5105	630950.00	6038905.60	711.35	7/05/2018	SYD1801003.26	Boraig Group	BRG - Unsorted	RHYOLITE	2.693	0.261
BH5105	630950.00	6038905.60	687.65	7/05/2018	SYD1801003.27	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.680	
BH5105	630950.00	6038905.60	665.65	7/05/2018	SYD1801003.28	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.690	
BH5105	630950.00	6038905.60	636.65	7/05/2018	SYD1801003.29	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.716	
BH5105	630950.00	6038905.60	627.64	23/10/2018	SYD1802158.01	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.725	
BH5105	630950.00	6038905.60	608.05	23/10/2018	SYD1802158.02	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.721	0.261
BH5105	630950.00	6038905.60	602.77	8/05/2018	SYD1801003.30	Boraig Group	BRG - Unsorted	Sandstone	2.710	
BH5105	630950.00	6038905.60	587.30	8/05/2018	SYD1801003.31	Boraig Group	BRG - Unsorted	Sandstone	2.705	
BH5105	630950.00	6038905.60	569.65	8/05/2018	SYD1801003.32	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.680	0.29
BH5105	630950.00	6038905.60	532.35	8/05/2018	SYD1801003.33	Boraig Group	BRG - Unsorted	Interlaminated: Sandstone/Siltstone	2.673	0.232
BH5105	630950.00	6038905.60	516.35	8/05/2018	SYD1801003.34	Ravine Beds West	RBW - Unsorted	Interlaminated: Sandstone/Siltstone	2.740	0.377
BH5105	630950.00	6038905.60	494.35	8/05/2018	SYD1801003.35	Ravine Beds West	RBW - Unsorted	Interlaminated: INTERLAM M SST / M SSLT	2.731	0.348
BH5105	630950.00	6038905.60	459.35	8/05/2018	SYD1801003.36	Ravine Beds West	RBW002	Interlaminated: INTERLAM M SST / M SSLT	2.727	0.348
BH5105	630950.00	6038905.60	448.35	8/05/2018	142402	Ravine Beds West	RBW002	Interlaminated: INTERLAM M SST / M SSLT	2.845	0.348
BH5105	630950.00	6038905.60	426.65	8/05/2018	SYD1801003.37	Ravine Beds West	RBW - Unsorted	Interlaminated: INTERLAM M SST / M SSLT	2.730	0.348
BH5105	630950.00	6038905.60	408.35	8/05/2018	SYD1801003.38	Ravine Beds West	RBW - Unsorted	Interlaminated: INTERLAM M SST / M SSLT	2.721	0.348
BH5107	630645.20	6038487.90	1108.65	3/07/2018	SYD1801312.1	Boraig Group	BRG - Unsorted	Conglomerate	2.677	
BH5107	630645.20	6038487.90	1059.35	2/07/2018	SYD1801312.02	Boraig Group	BRG - Unsorted	Conglomerate	2.687	
BH5107	630645.20	6038487.90	1012.35	2/07/2018	SYD1801312.03	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.717	
BH5107	630645.20	6038487.90	962.35	2/07/2018	SYD1801312.04	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.714	
BH5107	630645.20	6038487.90	924.38	2/07/2018	SYD1801312.05	Boraig Group	BRG - Unsorted	Conglomerate	2.687	
BH5107	630645.20	6038487.90	872.63	2/07/2018	SYD1801312.06	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.685	
BH5107	630645.20	6038487.90	832.65	2/07/2018	SYD1801312.07	Boraig Group	BRG - Unsorted	Conglomerate	2.672	
BH5107	630645.20	6038487.90	775.97	2/07/2018	SYD1801312.08	Boraig Group	BRG - Unsorted	Sandstone	2.676	
BH5107	630645.20	6038487.90	742.65	2/07/2018	SYD1801312.09	Boraig Group	BRG - Unsorted	Conglomerate	2.666	
BH5107	630645.20	6038487.90	697.65	2/07/2018	SYD1801312.10	Boraig Group	BRG - Unsorted	Sandstone/Siltstone	2.728	
BH5107	630645.20	6038487.90	662.65	3/07/2018	SYD1801312.11	Boraig Group	BRG - Unsorted	Sandstone/Siltstone	2.728	
BH5107	630645.20	6038487.90	619.65	2/07/2018	SYD1801312.12	Boraig Group	BRG - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.737	
BH5107	630645.20	6038487.90	574.65	2/07/2018	SYD1801312.13	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.738	
BH5107	630645.20	6038487.90	544.35	27/09/2018	SYD1802038.10	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.741	
BH5107	630645.20	6038487.90	501.65	27/09/2018	SYD1802038.2	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.711	
BH5107	630645.20	6038487.90	500.35	27/09/2018	SYD1802038.3	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.729	
BH5107	630645.20	6038487.90	496.35	31/07/2018	142405	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.730	
BH5107	630645.20	6038487.90	460.35	28/09/2018	SYD1802038.5	Ravine Beds West	RBW002	INTERBEDDED SILTSTONE & SANDSTONE	2.685	
BH5107	630645.20	6038487.90	440.34	16/07/2018	SYD1802038.10	Ravine Beds West	RBW001	Conglomerate	2.714	
BH5107	630645.20	6038487.90	439.12	31/07/2018	142405	Ravine Beds West	RBW002	Conglomerate	2.760	
BH5107	630645.20	6038487.90	417.72	28/09/2018	SYD1802038.8	Ravine Beds West	RBW - Unsorted	Conglomerate	2.750	
BH5107	630645.20	6038487.90	394.35	4/10/2018	SYD1802038.9	Ravine Beds West	RBW - Unsorted	Conglomerate	2.749	

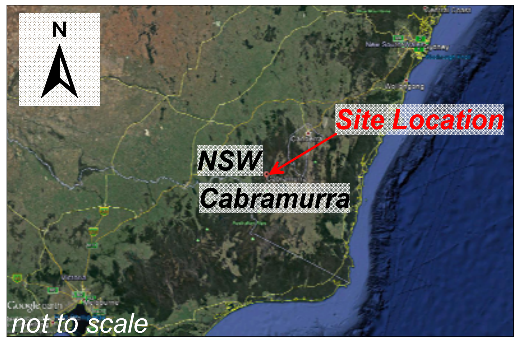
Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH5108	630484.20	6038267.70	1129.63	22/05/2018	SYD1800838.01	Boraig Group	BRG003	#N/A	2.535	
BH5108	630484.20	6038267.70	1072.63	22/05/2018	SYD1800838.03	Boraig Group	BRG - Unsorted	VOLCANIC	2.557	
BH5108	630484.20	6038267.70	1070.95	22/05/2018	SYD1800838.04	Boraig Group	BRG - Unsorted	VOLCANIC	2.653	
BH5108	630484.20	6038267.70	1050.25	22/05/2018	SYD1800838.05	Boraig Group	BRG - Unsorted	VOLCANIC	2.663	
BH5108	630484.20	6038267.70	1043.95	22/05/2018	SYD1800838.06	Boraig Group	BRG - Unsorted	RHYOLITE	2.676	
BH5108	630484.20	6038267.70	1020.55	13/04/2018	SYD1800838.07	Boraig Group	BRG - Unsorted	VOLCANIC	2.670	
BH5108	630484.20	6038267.70	994.65	13/04/2018	SYD1800838.08	Boraig Group	BRG - Unsorted	Siltstone	2.700	
BH5108	630484.20	6038267.70	970.23	13/04/2018	SYD1800838.09	Boraig Group	BRG - Unsorted	Siltstone	2.670	
BH5108	630484.20	6038267.70	937.30	13/04/2018	SYD1800838.10	Boraig Group	BRG - Unsorted	Siltstone/VOLCANIC	2.670	
BH5108	630484.20	6038267.70	915.98	13/04/2018	SYD1800838.11	Boraig Group	BRG - Unsorted	Siltstone	2.710	
BH5108	630484.20	6038267.70	885.95	13/04/2018	SYD1800838.12	Boraig Group	BRG - Unsorted	Siltstone	2.670	
BH5108	630484.20	6038267.70	883.95	13/04/2018	SYD1800838.13	Boraig Group	BRG - Unsorted	Siltstone	2.690	
BH5108	630484.20	6038267.70	862.95	10/05/2018	SYD1801010.01	Boraig Group	BRG - Unsorted	Siltstone	2.670	
BH5108	630484.20	6038267.70	841.95	10/05/2018	SYD1801010.02	Ravine Beds West	RBW - Unsorted	Siltstone	2.700	
BH5108	630484.20	6038267.70	814.08	10/05/2018	SYD1801010.03	Ravine Beds West	RBW - Unsorted	Siltstone	2.700	
BH5108	630484.20	6038267.70	789.95	10/05/2018	SYD1801010.04	Ravine Beds West	RBW - Unsorted	Siltstone	2.730	
BH5108	630484.20	6038267.70	751.65	10/05/2018	SYD1801010.05	Ravine Beds West	RBW - Unsorted	Siltstone	2.730	
BH5108	630484.20	6038267.70	728.95	10/05/2018	SYD1801010.06	Ravine Beds West	RBW - Unsorted	CORE LOSS	2.730	
BH5108	630484.20	6038267.70	700.65	10/05/2018	SYD1801010.07	Ravine Beds West	RBW - Unsorted	FAULT ZONE: Siltstone/VOLCANIC	2.710	
BH5108	630484.20	6038267.70	678.53	10/05/2018	SYD1801010.08	Ravine Beds West	RBW - Unsorted	CORE LOSS	2.710	
BH5108	630484.20	6038267.70	650.65	10/05/2018	SYD1801010.09	Ravine Beds West	RBW - Unsorted	Siltstone	2.720	
BH5108	630484.20	6038267.70	621.95	11/05/2018	SYD1801010.10	Ravine Beds West	RBW - Unsorted	Siltstone	2.720	
BH5108	630484.20	6038267.70	611.25	11/05/2018	SYD1801010.11	Ravine Beds West	RBW - Unsorted	Siltstone	2.716	
BH5108	630484.20	6038267.70	583.65	11/05/2018	SYD1801010.12 issue 2	Ravine Beds West	RBW - Unsorted	Siltstone	2.721	
BH5108	630484.20	6038267.70	559.96	11/05/2018	SYD1801010.13	Ravine Beds West	RBW - Unsorted	FAULT ZONE: Siltstone/VOLCANIC	2.690	
BH5108	630484.20	6038267.70	549.97	14/05/2018	SYD1801010.14	Ravine Beds West	RBW - Unsorted	FAULT ZONE: VOLCANIC	2.680	
BH5108	630484.20	6038267.70	540.65	14/05/2018	SYD1801010.15	Ravine Beds West	RBW - Unsorted	FAULT ZONE: VOLCANIC	2.710	
BH5108	630484.20	6038267.70	524.65	14/05/2018	SYD1801010.16	Ravine Beds West	RBW002	Siltstone	2.738	
BH5108	630484.20	6038267.70	514.25	14/05/2018	SYD1801010.17	Ravine Beds West	RBW002	FAULT ZONE: VOLCANIC	2.720	
BH5108	630484.20	6038267.70	509.95	2/07/2018	SYD1801010.30	Ravine Beds West	RBW002	FAULT ZONE: VOLCANIC	2.748	
BH5108	630484.20	6038267.70	502.95	14/05/2018	SYD1801010.18	Ravine Beds West	RBW002	FAULT ZONE: Siltstone/VOLCANIC	2.730	
BH5108	630484.20	6038267.70	494.65	14/05/2018	SYD1801010.19	Ravine Beds West	RBW002	Siltstone	2.730	
BH5108	630484.20	6038267.70	491.93	8/05/2018	142402	Ravine Beds West	RBW002	Siltstone	2.850	
BH5108	630484.20	6038267.70	479.65	14/05/2018	SYD1801010.20	Ravine Beds West	RBW002	FAULT ZONE: VOLCANIC	2.730	
BH5108	630484.20	6038267.70	448.05	2/07/2018	SYD1801010.29	Ravine Beds West	RBW - Unsorted	FAULT ZONE: Siltstone/VOLCANIC	2.746	0.4785
BH5108	630484.20	6038267.70	438.68	8/05/2018	142402	Ravine Beds West	RBW - Unsorted	CORE LOSS	2.865	
BH5108	630484.20	6038267.70	437.95	14/05/2018	SYD1801010.23	Ravine Beds West	RBW - Unsorted	FAULT ZONE: VOLCANIC	2.740	0.638
BH5108	630484.20	6038267.70	424.95	14/05/2018	SYD1801010.24	Ravine Beds West	RBW - Unsorted	FAULT ZONE: VOLCANIC	2.731	
BH5108	630484.20	6038267.70	413.95	14/05/2018	SYD1801010.25	Ravine Beds West	RBW - Unsorted	Siltstone	2.730	
BH5108	630484.20	6038267.70	392.65	14/05/2018	SYD1801010.26	Ravine Beds West	RBW - Unsorted	Siltstone	2.718	
BH5115	632498.60	6038549.30	1283.83	24/05/2018	SYD1801083.01	Ravine Beds East	RBE - Unsorted	Siltstone	2.640	
BH5115	632498.60	6038549.30	1262.85	24/05/2018	SYD1801083.02	Ravine Beds East	RBE - Unsorted	Siltstone	2.730	
BH5115	632498.60	6038549.30	1223.08	24/05/2018	SYD1801083.03	Ravine Beds East	RBE - Unsorted	Siltstone	2.715	
BH5115	632498.60	6038549.30	1190.30	24/05/2018	SYD1801083.04	Ravine Beds East	RBE - Unsorted	Siltstone	2.738	
BH5115	632498.60	6038549.30	1089.85			Ravine Beds East	RBE001	Siltstone	2.775	
BH5115	632498.60	6038549.30	1087.55	24/05/2018	SYD1801083.07	Ravine Beds East	RBE001	Siltstone	2.756	
BH5115	632498.60	6038549.30	1068.23	28/06/2018	SYD1801313.01	Ravine Beds East	RBE001	Siltstone	2.763	
BH5115	632498.60	6038549.30	1030.85	28/06/2018	SYD1801313.02	Ravine Beds East	RBE001	Siltstone	2.749	
BH5115	632498.60	6038549.30	983.23	29/06/2018	SYD1801313.03	Ravine Beds East	RBE001	Siltstone	2.742	
BH5115	632498.60	6038549.30	956.32	29/06/2018	SYD1801313.04	Ravine Beds East	RBE001	Siltstone	2.735	
BH5115	632498.60	6038549.30	913.83	29/06/2018	SYD1801313.05	Ravine Beds East	RBE001	Siltstone	2.740	
BH5115	632498.60	6038549.30	873.85	29/06/2018	SYD1801313.06	Ravine Beds East	RBE001	Siltstone	2.743	

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH5115	632498.60	6038549.30	839.40	29/06/2018	SYD1801313.07	Ravine Beds East	RBE001	Siltstone	2.742	
BH5115	632498.60	6038549.30	834.27	4/10/2018	SYD1802047.1	Ravine Beds East	RBE001	Siltstone	2.753	
BH5115	632498.60	6038549.30	800.85	4/10/2018	SYD1802047.2	Ravine Beds East	RBE001	Siltstone	2.764	
BH5115	632498.60	6038549.30	756.95	4/10/2018	SYD1802047.3	Ravine Beds East	RBE001	Siltstone	2.764	
BH5115	632498.60	6038549.30	715.04	4/10/2018	SYD1802047.4	Ravine Beds East	RBE001	Siltstone	2.741	
BH5115	632498.60	6038549.30	674.55	4/10/2018	SYD1802047.5	Ravine Beds East	RBE001	Siltstone	2.744	
BH5115	632498.60	6038549.30	633.55	4/10/2018	SYD1802047.6	Ravine Beds East	RBE001	Siltstone	2.753	
BH5115	632498.60	6038549.30	597.03	5/11/2018	SYD1802047.12	Ravine Beds East	RBE001	Siltstone	2.726	
BH5115	632498.60	6038549.30	556.84	4/10/2018	SYD1802047.7	Ravine Beds East	RBE002	Siltstone	2.743	
BH5115	632498.60	6038549.30	553.23	31/07/2018	142405	Ravine Beds East	RBE001	Siltstone		
BH5115	632498.60	6038549.30	547.85	4/10/2018	SYD1802047.8	Ravine Beds East	RBE001	Siltstone	2.765	
BH6101	628370.70	6039896.00	584.50	20/04/2018	SYD1800852.01	Ravine Beds West	RBW - Unsorted	#N/A	2.790	
BH6101	628370.70	6039896.00	575.87	20/04/2018	SYD1800852.02	Ravine Beds West	RBW - Unsorted	#N/A	2.724	
BH6101	628370.70	6039896.00	550.85	20/04/2018	SYD1800852.03	Ravine Beds West	RBW - Unsorted	#N/A	2.720	
BH6101	628370.70	6039896.00	532.92	20/04/2018	SYD1800852.04	Ravine Beds West	RBW - Unsorted	#N/A	2.650	
BH6101	628370.70	6039896.00	507.96	20/04/2018	SYD1800852.05	Ravine Beds West	RBW - Unsorted	#N/A	2.710	
BH6101	628370.70	6039896.00	483.85	20/04/2018	SYD1800852.06	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.700	
BH6101	628370.70	6039896.00	455.85	20/04/2018	SYD1800852.07	Ravine Beds West	RBW002	Conglomerate	2.700	
BH6101	628370.70	6039896.00	444.82			Ravine Beds West	RBW002	Sandstone	2.700	
BH6101	628370.70	6039896.00	443.56	20/04/2018	SYD1800852.08	Ravine Beds West	RBW002	Sandstone	2.702	
BH6101	628370.70	6039896.00	440.55	20/04/2018	SYD1800852.09	Ravine Beds West	RBW002	Conglomerate	2.646	
BH6101	628370.70	6039896.00	421.85	20/04/2018	SYD1800852.10	Ravine Beds West	RBW - Unsorted	Conglomerate	2.720	
BH6102	628372.63	6039895.37	594.32	6/04/2018	3341–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.738	
BH6102	628383.94	6039891.25	546.05	6/04/2018	3341–YP–1	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.708	
BH6102	628389.48	6039889.24	522.41	6/04/2018	3341–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.666	
BH6102	628392.53	6039888.13	509.38	6/04/2018	3341–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.669	
BH6102	628397.53	6039886.31	488.03	6/04/2018	3341–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.699	
BH6102	628405.26	6039883.49	455.04	29/05/2018	SYD1800798.1	Ravine Beds West	RBW001	Conglomerate	2.757	
BH6102	628407.68	6039882.61	444.73	6/04/2018	3341–YP–1	Ravine Beds West	RBW002	INTERBEDDED SILTSTONE & SANDSTONE	2.743	
BH6102	628408.92	6039882.16	439.41	9/04/2018	3341–YP–1	Ravine Beds West	RBW - Unsorted	Conglomerate	2.758	
BH6102	628414.58	6039880.10	415.26	10/04/2018	SYD1800800.01	Ravine Beds West	RBW - Unsorted	Conglomerate	2.710	
BH6102	628416.06	6039879.56	408.95	10/04/2018	SYD1800800.02	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.700	
BH6102	628418.38	6039878.72	399.05	10/04/2018	SYD1800800.03	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.720	
BH6102	628423.94	6039876.69	375.30	10/04/2018	SYD1800800.04	Ravine Beds West	RBW - Unsorted	Conglomerate	2.750	
BH6102	628426.79	6039875.66	363.15	10/04/2018	SYD1800800.05	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.700	
BH6103	628359.97	6039897.82	590.77	22/05/2018	3397–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.720	
BH6103	628349.32	6039899.32	571.38	22/05/2018	3397–YP–1	Ravine Beds West	RBW - Unsorted	Conglomerate	2.700	
BH6103	628335.91	6039901.20	546.95	22/05/2018	3397–YP–1	Ravine Beds West	RBW - Unsorted	Interlaminated: Sandstone/Siltstone	2.677	
BH6103	628330.44	6039901.97	536.98	22/05/2018	3397–YP–1	Ravine Beds West	RBW - Unsorted	Interlaminated: Sandstone/Siltstone	2.631	
BH6103	628322.04	6039903.15	521.68	22/05/2018	3397–YP–1	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.696	
BH6103	628309.53	6039904.91	498.89	22/05/2018	3397–YP–1	Ravine Beds West	RBW - Unsorted	Conglomerate	2.737	
BH6103	628294.99	6039906.95	472.39	22/05/2018	3397–YP–1	Ravine Beds West	RBW002	INTERBEDDED SILTSTONE & SANDSTONE	2.712	
BH6103	628285.54	6039908.28	455.18	22/05/2018	3398–YP–1	Ravine Beds West	RBW002	INTERBEDDED SILTSTONE & SANDSTONE	2.725	
BH6103	628281.56	6039908.84	447.93	8/05/2018	142402	Ravine Beds West	RBW003	INTERBEDDED SILTSTONE & SANDSTONE	2.840	
BH6103	628277.87	6039909.36	441.21	22/05/2018	3398–YP–1	Ravine Beds West	RBW002	INTERBEDDED SILTSTONE & SANDSTONE	2.687	
BH6103	628260.59	6039911.79	409.73	21/05/2018	3398–YP–1	Ravine Beds West	RBW - Unsorted	Conglomerate	2.750	
BH6104	625865.00	6040751.80	490.64			Ravine Beds West	RBW002	INTERBEDDED SILTSTONE & SANDSTONE	2.720	
BH6104	625865.00	6040751.80	490.25	25/05/2018	SYD1801084.01	Ravine Beds West	RBW002	INTERBEDDED SILTSTONE & SANDSTONE	2.714	
BH6105	624549.90	6041048.80	654.05	9/04/2018	3342–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.686	
BH6105	624549.90	6041048.80	630.53	9/04/2018	3342–YP–1	Ravine Beds West	RBW - Unsorted	Interlaminated: Sandstone/Siltstone	2.696	
BH6105	624549.90	6041048.80	611.05	9/04/2018	3342–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.707	
BH6105	624549.90	6041048.80	574.34	24/01/2018	SYD1800229	Ravine Beds West	RBW - Unsorted	Siltstone	2.721	
BH6105	624549.90	6041048.80	574.06	21/02/2018	SYD1800229	Ravine Beds West	RBW - Unsorted	Siltstone	2.700	

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH6105	624549.90	6041048.80	573.45	24/01/2018	SYD1800229	Ravine Beds West	RBW - Unsorted	Siltstone	2.714	
BH6105	624549.90	6041048.80	563.05	9/04/2018	3342–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.724	
BH6105	624549.90	6041048.80	527.66	9/04/2018	3342–YP–1	Ravine Beds West	RBW002	Siltstone	2.725	
BH6105	624549.90	6041048.80	522.76	24/01/2018	SYD1800229	Ravine Beds West	RBW002	Siltstone	2.695	
BH6105	624549.90	6041048.80	520.04	24/01/2018	SYD1800229	Ravine Beds West	RBW002	Siltstone	2.722	
BH6105	624549.90	6041048.80	513.95	12/04/2018	SYD1800576.1	Ravine Beds West	RBW001	Conglomerate	2.654	
BH6105	624549.90	6041048.80	513.05	9/04/2018	3342–YP–1	Ravine Beds West	RBW002	Siltstone	2.723	
BH6105	624549.90	6041048.80	506.42	24/01/2018	SYD1800229	Ravine Beds West	RBW002	Siltstone	2.716	
BH6105	624549.90	6041048.80	499.70	9/04/2018	3342–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.697	
BH6105	624549.90	6041048.80	493.35	9/04/2018	3342–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.651	
BH6105	624549.90	6041048.80	493.00	12/04/2018	SYD1800576.2	Ravine Beds West	RBW - Unsorted	Siltstone	2.670	
BH6105	624549.90	6041048.80	490.07	25/01/2018	SYD1800230	Ravine Beds West	RBW - Unsorted	Siltstone	2.710	
BH6105	624549.90	6041048.80	488.30	9/04/2018	3342–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.711	
BH6105	624549.90	6041048.80	484.75	9/04/2018	3342–YP–1	Ravine Beds West	RBW - Unsorted	Siltstone	2.714	
BH6105	624549.90	6041048.80	481.90	9/04/2018	3342–YP–1	Ravine Beds West	RBW - Unsorted	Conglomerate	2.702	
BH6105	624549.90	6041048.80	478.50			Ravine Beds West	RBW - Unsorted	Siltstone	2.820	
BH7101	623682.60	6041392.40	528.42	12/04/2018	3343–YP–1	UNSORTED	IGNIMRITE	IGNUMBRITE	2.662	
BH7101	623682.60	6041392.40	524.75	12/04/2018	3343–YP–1	UNSORTED	IGNIMRITE	IGNUMBRITE	2.660	
BH7101	623682.60	6041392.40	513.95	12/04/2018	SYD1800797	UNSORTED	IGNIMRITE	IGNUMBRITE	2.642	
BH7101	623682.60	6041392.40	513.18	12/04/2018	3343–YP–1	UNSORTED	IGNIMRITE	IGNUMBRITE	2.660	
BH7101	623682.60	6041392.40	505.05	12/04/2018	3343–YP–1	UNSORTED	IGNIMRITE	IGNUMBRITE	2.657	
BH7101	623682.60	6041392.40	499.75	12/04/2018	3343–YP–1	UNSORTED	IGNIMRITE	IGNUMBRITE	2.659	
BH7101	623682.60	6041392.40	489.75	12/04/2018	3343–YP–1	UNSORTED	IGNIMRITE	IGNUMBRITE	2.706	
BH7104	623762.30	6041356.70	575.79	21/04/2018	SYD1800853.01	UNSORTED	IGNIMRITE	IGNUMBRITE	2.547	
BH7104	623762.30	6041356.70	559.82	21/04/2018	SYD1800853.02	UNSORTED	IGNIMRITE	IGNUMBRITE	2.650	
BH7104	623762.30	6041356.70	547.67	21/04/2018	SYD1800853.03	UNSORTED	IGNIMRITE	IGNUMBRITE	2.640	
BH7104	623762.30	6041356.70	534.33	21/04/2018	SYD1800853.04	UNSORTED	IGNIMRITE	IGNUMBRITE	2.637	
BH7104	623762.30	6041356.70	528.35	30/04/2018	SYD1800853.05	UNSORTED	IGNIMRITE	IGNUMBRITE	2.639	
BH7104	623762.30	6041356.70	515.35	30/04/2018	SYD1800853.06	UNSORTED	IGNIMRITE	IGNUMBRITE	2.651	
BH7104	623762.30	6041356.70	496.98	30/04/2018	SYD1800853.07	UNSORTED	IGNIMRITE	IGNUMBRITE	2.650	
BH7105	624337.20	6040778.80	520.25	9/04/2018	SYD1800799.01	Ravine Beds West	RBW002	Siltstone	2.700	
BH7105	624337.20	6040778.80	512.28	2/07/2018	SYD180799.7	Ravine Beds West	RBW002	Siltstone	2.717	
BH7105	624337.20	6040778.80	509.60	9/04/2018	SYD1800799.02	Ravine Beds West	RBW001	Conglomerate	2.720	
BH7105	624337.20	6040778.80	495.55	9/04/2018	SYD1800799.03	Ravine Beds West	RBW - Unsorted	Conglomerate	2.700	
BH7105	624337.20	6040778.80	486.25	9/04/2018	SYD1800799.04	Ravine Beds West	RBW - Unsorted	Siltstone	2.730	
BH7106	624510.40	6040720.20	572.75	4/10/2018	SYD1802056.1	Ravine Beds West	RBW - Unsorted	Siltstone	2.731	
BH7106	624510.40	6040720.20	537.38	4/10/2018	SYD1802056.2	Ravine Beds West	RBW002	Siltstone	2.726	
BH7106	624510.40	6040720.20	532.70	4/10/2018	SYD1802056.3	Ravine Beds West	RBW002	Siltstone	2.726	
BH7106	624510.40	6040720.20	489.75	4/10/2018	SYD1802056.5	Ravine Beds West	RBW - Unsorted	Conglomerate	2.708	
BH7106	624510.40	6040720.20	460.23	4/10/2018	SYD1802056.6	Ravine Beds West	RBW - Unsorted	Siltstone	2.777	
BH8106	629329.30	6038471.70	1075.15	21/05/2018	SYD1800865.01	Byron Range Group	Byron Range Group - Wea	INTERBEDDED MUDSTONE & SANDSTONE	2.320	
BH8106	629329.30	6038471.70	1054.15	1/05/2018	SYD1800865.02	Byron Range Group	Byron Range Group	Carbonaceous siltstone/mudstone	2.700	
BH8106	629329.30	6038471.70	1032.45	1/05/2018	SYD1800865.03	Byron Range Group	Byron Range Group	Carbonaceous siltstone/mudstone	2.670	
BH8106	629329.30	6038471.70	1016.45	1/05/2018	SYD1800865.04	Byron Range Group	Byron Range Group	Carbonaceous siltstone/mudstone	2.550	
BH8106	629329.30	6038471.70	991.43	1/05/2018	SYD1800865.05	Byron Range Group	Byron Range Group	Carbonaceous siltstone/mudstone	2.630	
BH8106	629329.30	6038471.70	957.15	1/05/2018	SYD1800865.06	Byron Range Group	Byron Range Group	INTERBEDDED MUDSTONE & SANDSTONE	2.660	
BH8106	629329.30	6038471.70	931.45	1/05/2018	SYD1800865.07	Byron Range Group	Byron Range Group	INTERBEDDED MUDSTONE & SANDSTONE	2.720	
BH8106	629329.30	6038471.70	913.15	1/05/2018	SYD1800865.08	Byron Range Group	Byron Range Group	Carbonaceous siltstone/mudstone	2.640	
BH8106	629329.30	6038471.70	895.15	2/05/2018	SYD1800865.09	Byron Range Group	Byron Range Group	Carbonaceous siltstone/mudstone	2.740	
BH8106	629329.30	6038471.70	879.17	2/05/2018	SYD1800865.10	Byron Range Group	Byron Range Group	Carbonaceous siltstone/mudstone	2.720	
BH8106	629329.30	6038471.70	860.75	2/05/2018	SYD1800865.11	Ravine Beds West	RBW - Unsorted	INTERBEDDED MUDSTONE & SANDSTONE	2.710	
BH8106	629329.30	6038471.70	837.15	2/05/2018	SYD1800865.12	Ravine Beds West	RBW - Unsorted	INTERBEDDED MUDSTONE & SANDSTONE	2.730	

Test Location	Test Easting	Test Northing	Test RL	Test Date	Lab Report Number	Formation	Ground Type	Logged Strata	Adopted Density (g/cm3)	mag sus*1.45 adjustment for HQ SI*10-3
BH8106	629329.30	6038471.70	813.75	2/05/2018	SYD1800865.13	Ravine Beds West	RBW - Unsorted	INTERBEDDED MUDSTONE & SANDSTONE	2.710	
BH8106	629329.30	6038471.70	792.45	2/05/2018	SYD1800865.14	Ravine Beds West	RBW - Unsorted	INTERBEDDED MUDSTONE & SANDSTONE	2.730	
BH8106	629329.30	6038471.70	775.41	2/05/2018	SYD1800865.15	Ravine Beds West	RBW - Unsorted	INTERBEDDED MUDSTONE & SANDSTONE	2.730	
BH8106	629329.30	6038471.70	741.43	2/05/2018	SYD1800865.16	Ravine Beds West	RBW - Unsorted	INTERBEDDED MUDSTONE & SANDSTONE	2.690	
BH8106	629329.30	6038471.70	719.05	2/05/2018	SYD1800865.17	Ravine Beds West	RBW - Unsorted	Sandstone	2.660	
BH8106	629329.30	6038471.70	702.44	2/05/2018	SYD1800865.18	Ravine Beds West	RBW - Unsorted	INTERBEDDED MUDSTONE & SANDSTONE	2.710	
BH8106	629329.30	6038471.70	689.11	2/05/2018	SYD1800865.19	Ravine Beds West	RBW - Unsorted	Sandstone	2.680	
BH8106	629329.30	6038471.70	653.45	5/06/2018	SYD1801007.20	Ravine Beds West	RBW - Unsorted	Interlaminated: Sandstone/Siltstone	2.694	
BH8106	629329.30	6038471.70	616.45	5/06/2018	SYD1801007.21	Ravine Beds West	RBW - Unsorted	Sandstone	2.700	
BH8106	629329.30	6038471.70	579.45	5/06/2018	SYD1801007.22	Ravine Beds West	RBW001	Sandstone	2.599	
BH8106	629329.30	6038471.70	561.42			Ravine Beds West	RBW001	Sandstone	2.820	0.13775
BH8106	629329.30	6038471.70	561.10	28/06/2018	SYD1801801	Ravine Beds West	RBW001	Sandstone	2.690	0.13775
BH8106	629329.30	6038471.70	557.05	13/06/2018	SYD1801007.31	Ravine Beds West	RBW001	Sandstone	2.682	0.13775
BH8106	629329.30	6038471.70	544.45	5/06/2018	SYD1801007.23	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.687	0.13775
BH8106	629329.30	6038471.70	512.43	5/06/2018	SYD1801007.24	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.704	0.07975
BH8106	629329.30	6038471.70	480.43	5/06/2018	SYD1801007.25	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.727	0.07975
BH8106	629329.30	6038471.70	460.15	13/06/2018	SYD1801007.31	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.713	0.07975
BH8106	629329.30	6038471.70	459.61	8/05/2018	142402	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.810	0.07975
BH8106	629329.30	6038471.70	455.45	28/06/2018	SYD1801801	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.693	0.07975
BH8106	629329.30	6038471.70	429.15	9/05/2018	SYD1801007.28	Ravine Beds West	RBW - Unsorted	INTERBEDDED SILTSTONE & SANDSTONE	2.658	0.07975

APPENDIX G SEISMIC AND ERT SECTIONS



LEGEND:

Displayed ERT Line Location *(Plan view)* 100

Borehole Location *(Plan / Profile view)*

BH GEOLOGY LEGEND:

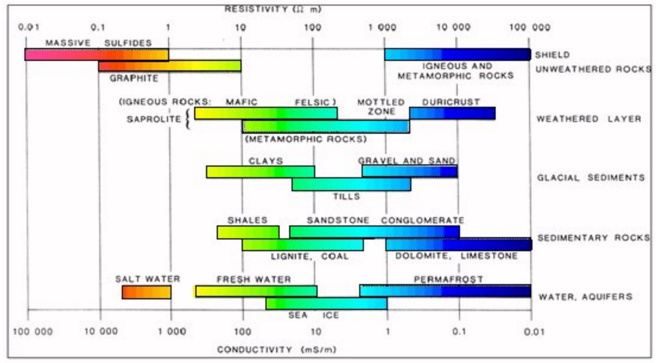
- Soil / Residual
- XW Rock
- HW / MW - SW Rock
- SW - Fr Rock
- Core Loss

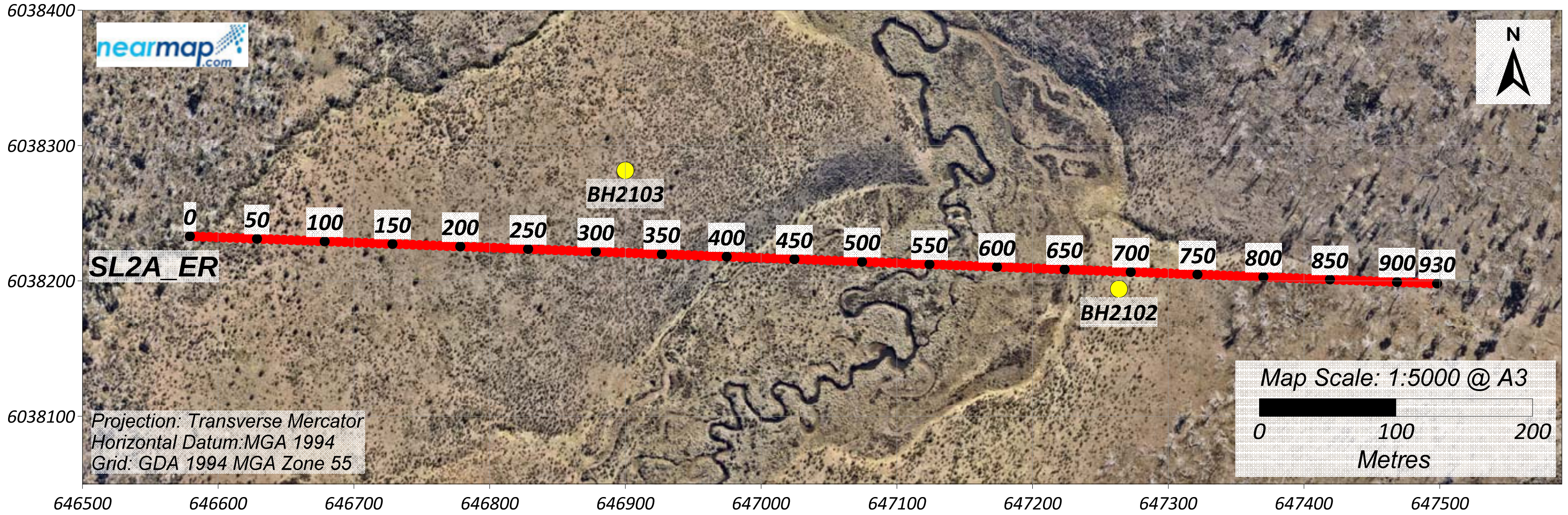
General Geological Description
For detailed subsurface material description refer to Borehole Logs

Disclaimer:

Interpreted resistivity profiles are subject to uncertainties due to resistivity signal to noise ratio and due to the normal limitations of interpretation where a simple 2 or 3 layered model is imposed on a complex site with highly variable conductivity distributions.

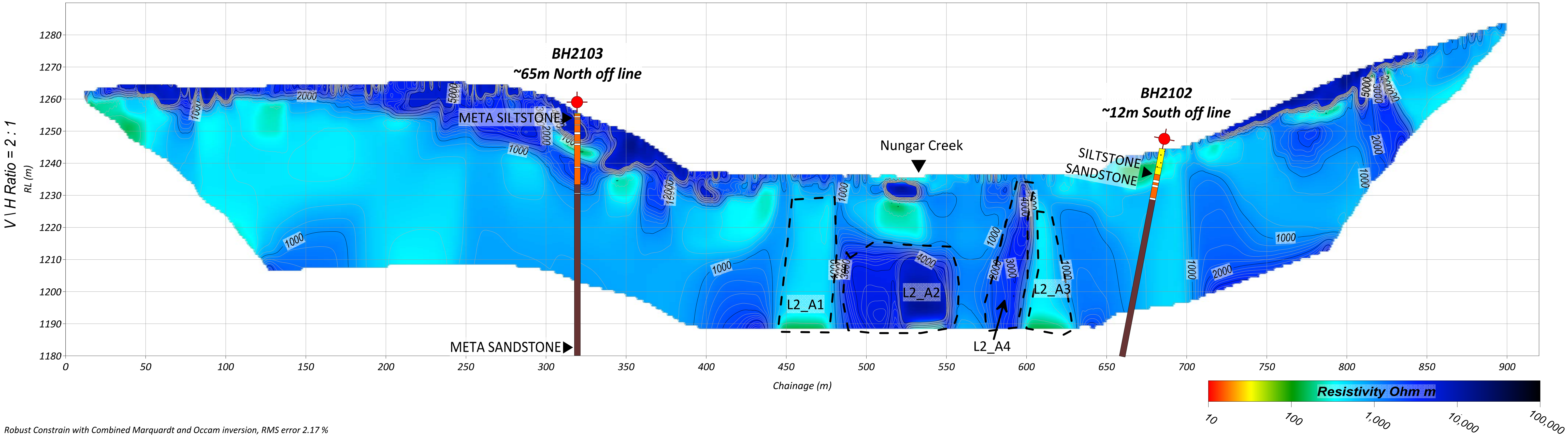
The interpretation derived by GHD and presented in this figure has been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurface conditions to help geotechnical interpretation and planning purposes.





DRAFT

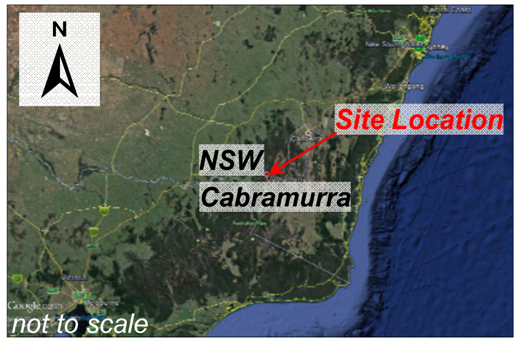
Electrical Resistivity Tomography Survey
Resistivity Model
SL2A_ER
W - E



Robust Constrain with Combined Marquardt and Occam inversion, RMS error 2.17 %

Client: Snowy Hydro Limited	*Horizontal Axis Scale: 1:2400 @ A3* 0 40 80 120 *Metres*	Job No.: **21/212692806**	©
Snowy 2.0 Geotechnical Investigation		Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/	
Geophysical Investigation	*Vertical to horizontal exaggeration 2 : 1*	Snowy 2.0 Geotechnical Investigation Electrical Resistivity Tomography (ERT) SL2A_ER Resistivity Model	
ERT Survey			
scale: as shown; date 13/08/2018		N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/	**Figure B1**

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



LEGEND:

Displayed ERT Line Location *(Plan view)*

Borehole Location *(Plan / Profile view)*

BH GEOLOGY LEGEND:

Soil / Residual

XW Rock

HW / MW - SW Rock

SW - Fr Rock

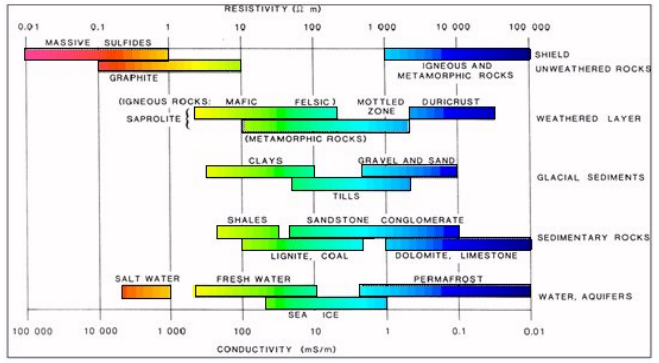
Core Loss

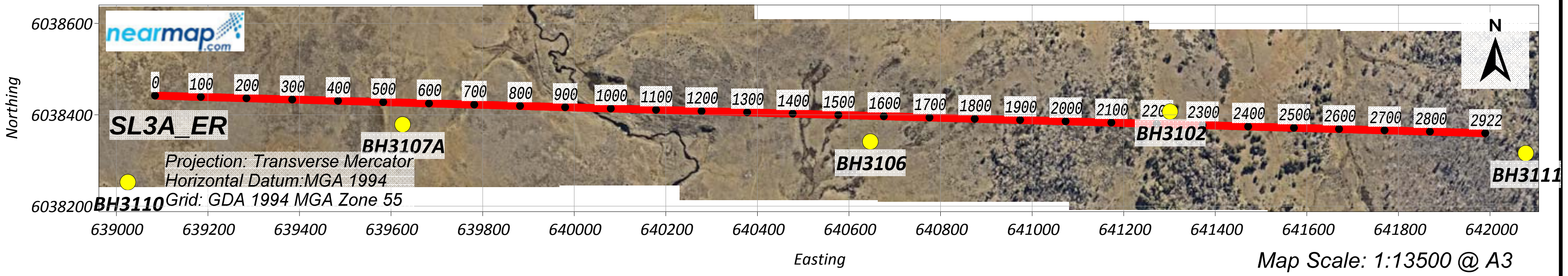
General Geological Description
For detailed subsurface material description refer to Borehole Logs

Disclaimer:

Interpreted resistivity profiles are subject to uncertainties due to resistivity signal to noise ratio and due to the normal limitations of interpretation where a simple 2 or 3 layered model is imposed on a complex site with highly variable conductivity distributions.

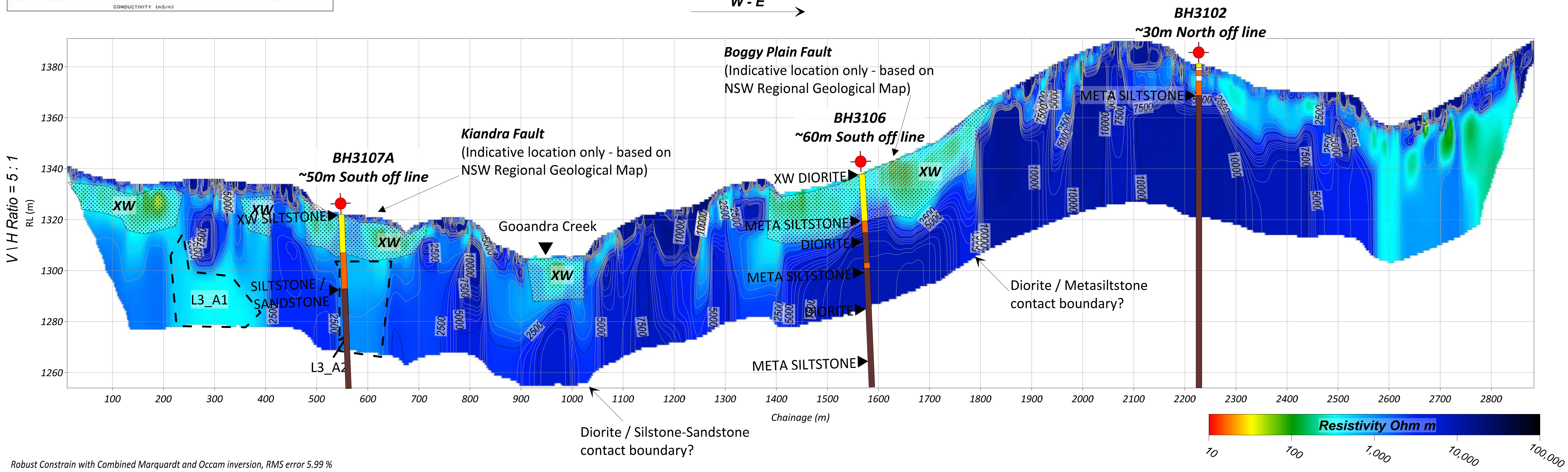
The interpretation derived by GHD and presented in this figure has been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurface conditions to help geotechnical interpretation and planning purposes.





DRAFT

Electrical Resistivity Tomography Survey
Resistivity Model
SL3A_ER
W - E



Robust Constrain with Combined Marquardt and Occam inversion, RMS error 5.99 %

GHD

snowy 2.0

Client: Snowy Hydro Limited
Snowy 2.0 Geotechnical Investigation
Geophysical Investigation
ERT Survey

scale	as shown	date 13/08/2018

Horizontal Axis Scale: 1:7500 @ A3
0 100 200 300
Metres

Vertical to horizontal exaggeration 5 : 1

Job No.: **21/212692806**

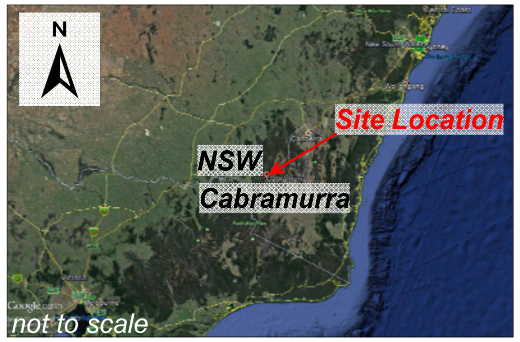
Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Electrical Resistivity Tomography (ERT)
SL3A_ER Resistivity Model

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

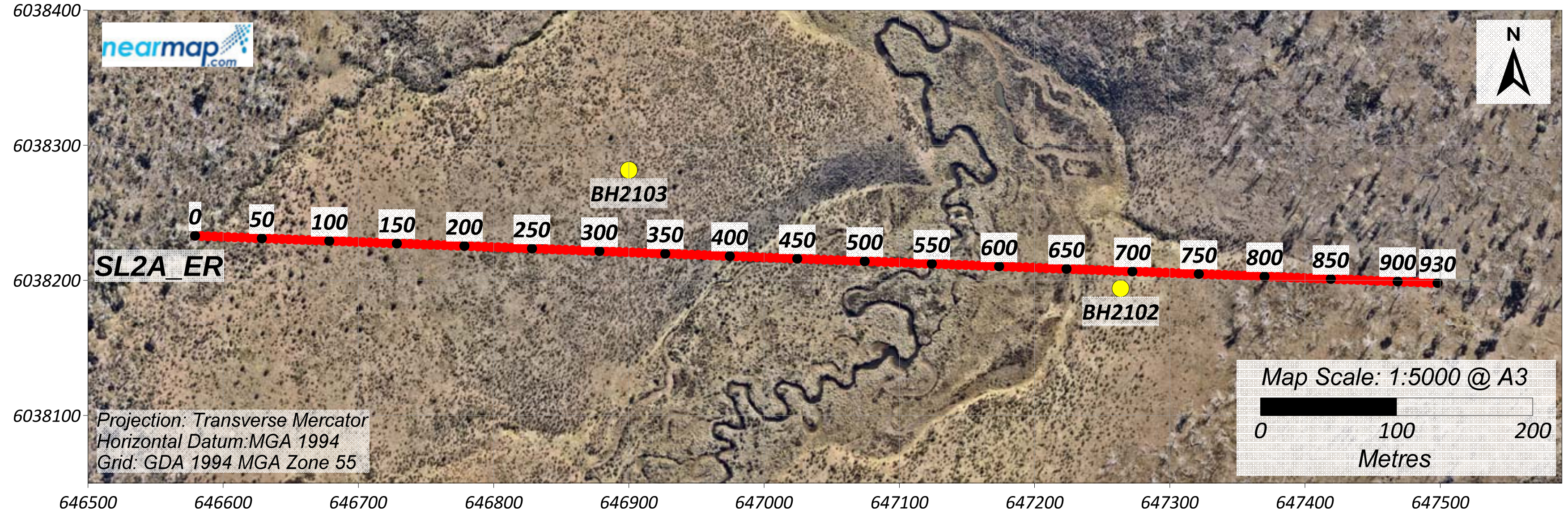
Figure B2

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



LEGEND:

Displayed ERI Line Location *(Plan view)*	100
Borehole *(Plan / Profile View)*	



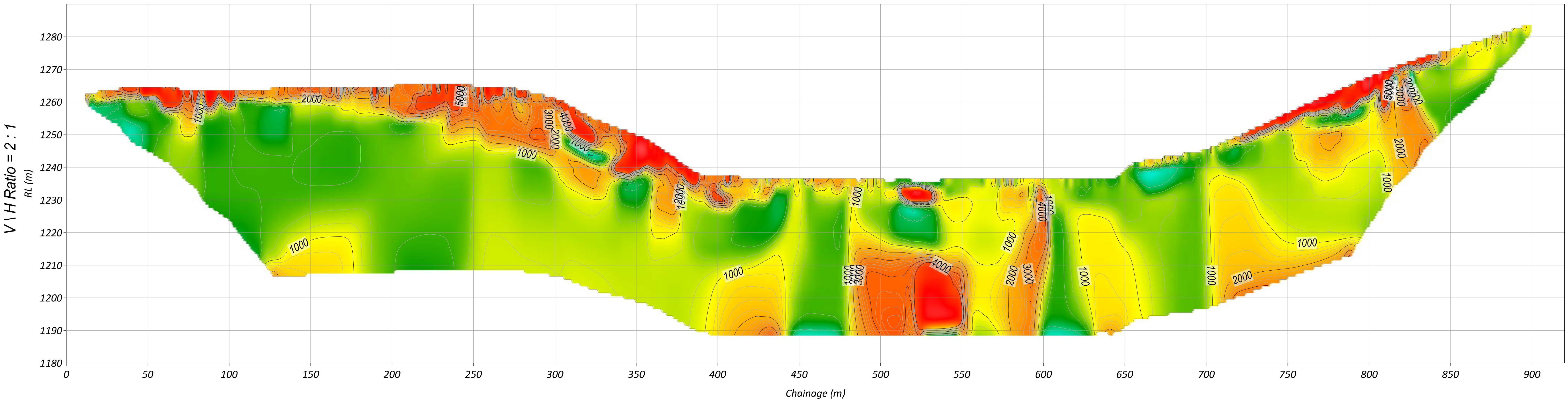
Disclaimer:

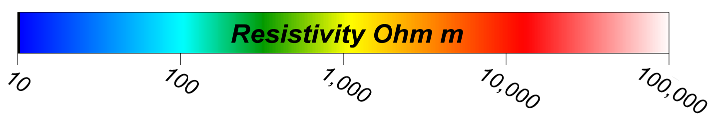
Interpreted resistivity profiles are subject to uncertainties due to resistivity signal to noise ratio and due to the normal limitations of interpretation where a simple 2 or 3 layered model is imposed on a complex site with highly variable conductivity distributions.

The interpretation derived by GHD and presented in this figure has been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurface conditions to help geotechnical interpretation and planning purposes.

DRAFT

Electrical Resistivity Tomography Survey
Resistivity Model
SL2A_ER
W - E

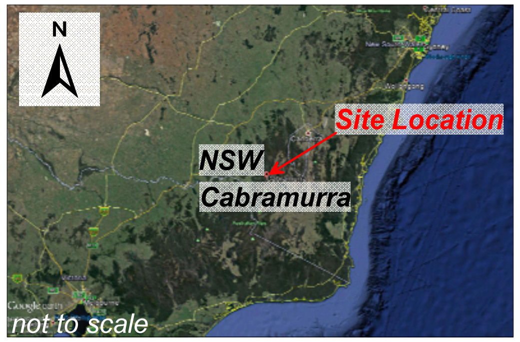




Robust Constrain with Combined Marquardt and Occam inversion, RMS error 3.5 %

Client: Snowy Hydro Limited		Horizontal Axis Scale: 1:2400 @ A3	Job No.: **21/212692806** ©
Snowy 2.0 Geotechnical Investigation		0 40 80 120 Metres	Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Geophysical Investigation			Snowy 2.0 Geotechnical Investigation Electrical Resistivity Tomography (ERT) SL2A_ER Resistivity Model
ERT Survey		Vertical to horizontal exaggeration 2 : 1	
scale	as shown	date 22/06/2018	N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
			Figure 21-26928-GT-RPT-R2_App P-P01

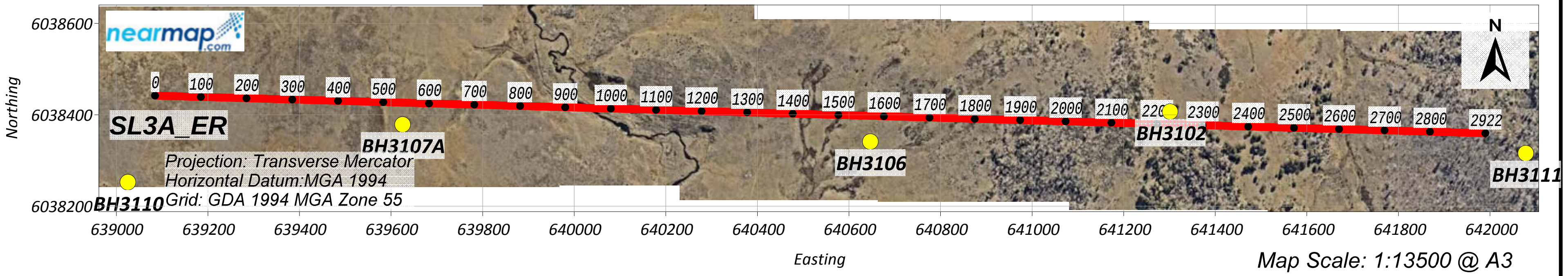
Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



LEGEND:

Displayed ERI Line Location *(Plan view)* 100

Borehole *(Plan / Profile View)*



Map Scale: 1:13500 @ A3

0 200 400 600
Metres

Disclaimer:

Interpreted resistivity profiles are subject to uncertainties due to resistivity signal to noise ratio and due to the normal limitations of interpretation where a simple 2 or 3 layered model is imposed on a complex site with highly variable conductivity distributions.

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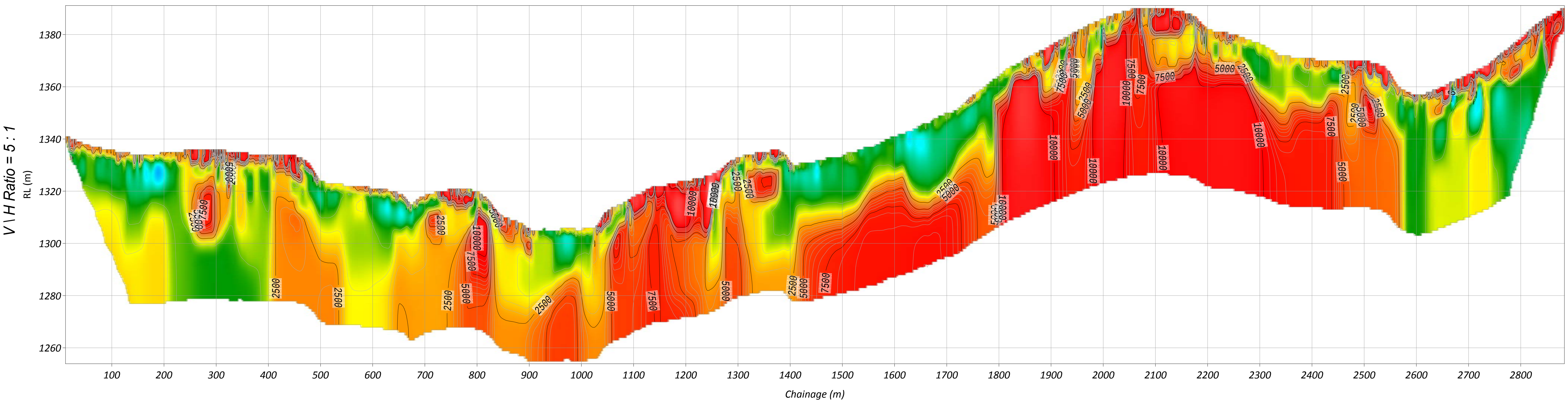
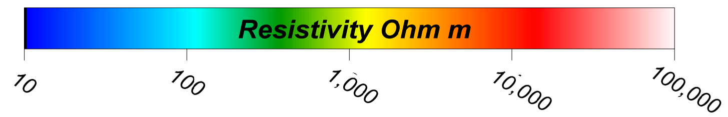
DRAFT

Electrical Resistivity Survey
Resistivity Model
SL3A_ER
W - E





Snowy Hydro 2.0 Sl04 RMS error 1.3%=3.33ms 30 WET iters. 50Hz Width 10.5% initial GRADIENT.GRD Vers. 3.35

Client: Snowy Hydro Limited	
Snowy 2.0 Geotechnical Investigation	
Geophysical Investigation	
ERT Survey	
scale as shown	date 19/06/2018

Horizontal Axis Scale: 1:7500 @ A3

0 40 80 120
Metres

Vertical to horizontal exaggeration 5 : 1

Job No.: **21/212692806**

Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Electrical Resistivity Tomography (ERT)
SL3A_ER Resistivity Model

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure
21-26928-GT-RPT-R2_App P-P02

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

LEGEND:

Displayed SRT Line Location *(Plan view)* — 100

Borehole / FWS Logs *(Plan / Profile View)*

Probable Fault
(F-Normal, Reverse, Undefined)

Possible Fault or Flexure
(P-Normal, Reverse, Undefined)

Tunnel Invert Level

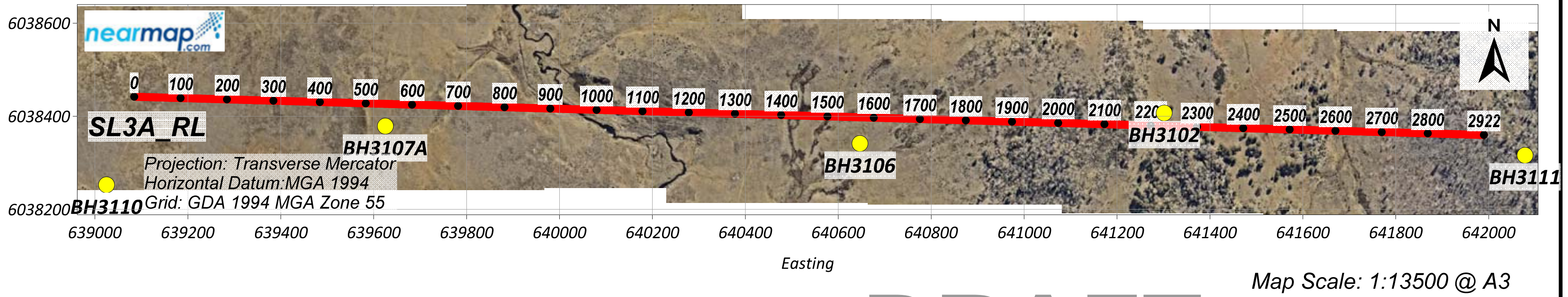
P-wave velocity FWS logs (m/s)

2000 2500 3000 3500 4000 4500 5000 5500 6000 6500

Disclaimer:

Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to intrinsic limitations of seismic reflection method.

The seismic and geological interpretation derived by the GHD and presented in this figure have been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurfaceconditions to help geotechnical interpretation and planning purposes.



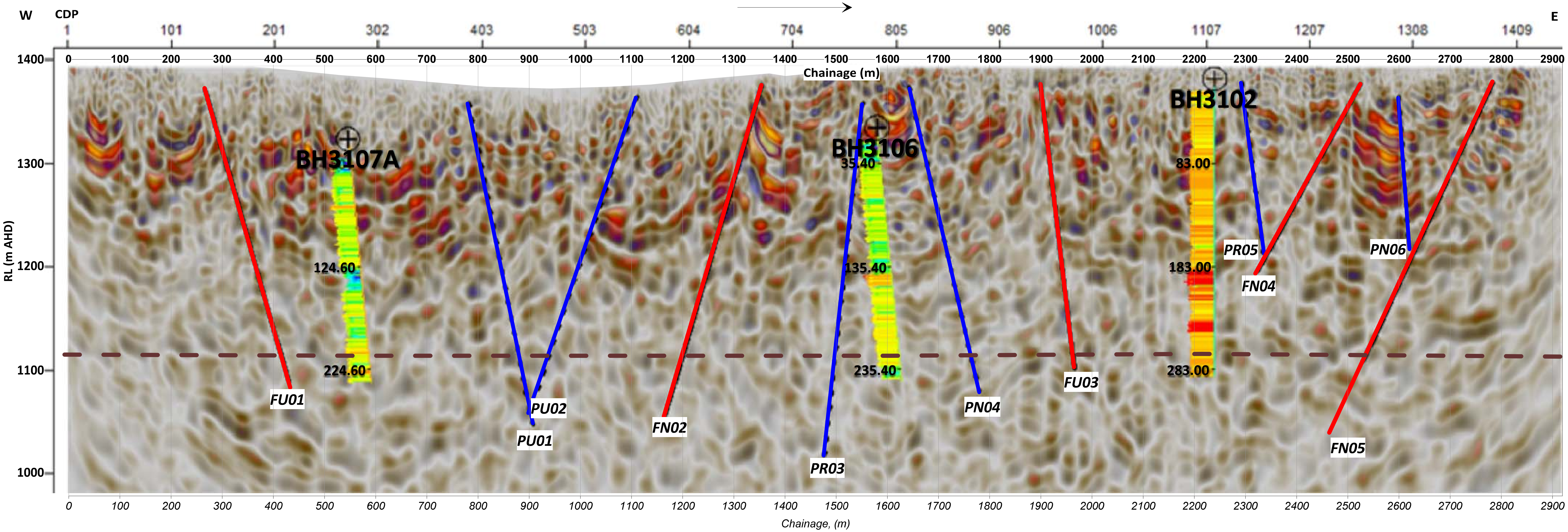
Map Scale: 1:13500 @ A3

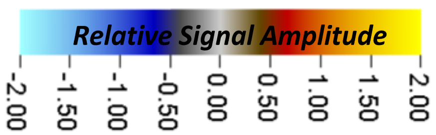
0 200 400 600
Metres

DRAFT

Seismic Reflection Survey
DMO Migrated Time Stack
(depth converted using BH FWS)
SL3A_RL

W - E





Client: Snowy Hydro Limited		
Snowy 2.0 Geotechnical Investigation		
Geophysical Investigation		
Seismic Reflection Survey		
scale	as shown	date 31/07/2018

Horizontal Axis Scale: 1:7500 @ A3

0 100 200 300 400
Metres

Vertical Axis
Not to Scale

Job No.: **21/212692806** ©

Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Reflection Survey
SL3A_RL Migrated depth DMO Stack with Interp.

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure 25

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LEGEND:

Displayed SRT Line Location *(Plan view)*

Borehole *(Plan / Profile View)*

P-wave velocity FWS logs (m/s) 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500

Probable Fault (F-Normal, Reverse, Undefined)

Possible Fault or Flexure (P-Normal, Reverse, Undefined)

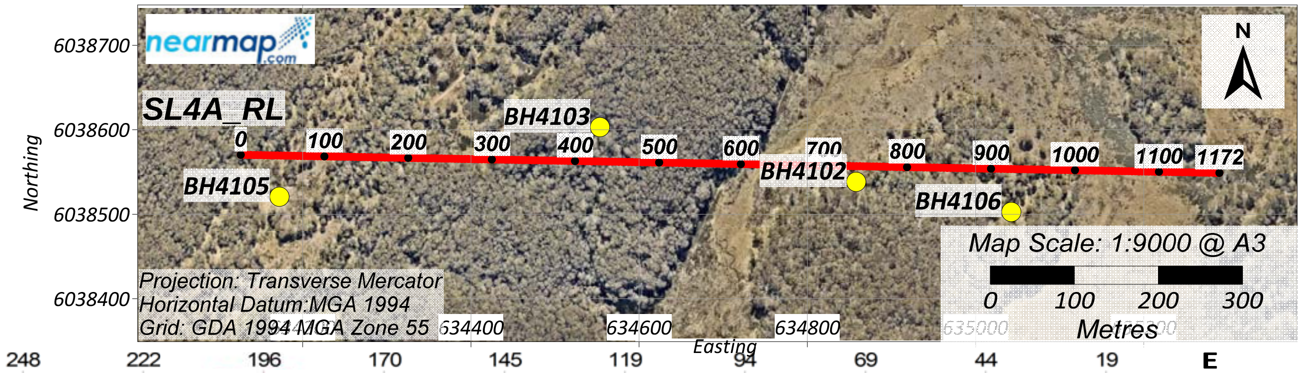
Tunnel Invert Level

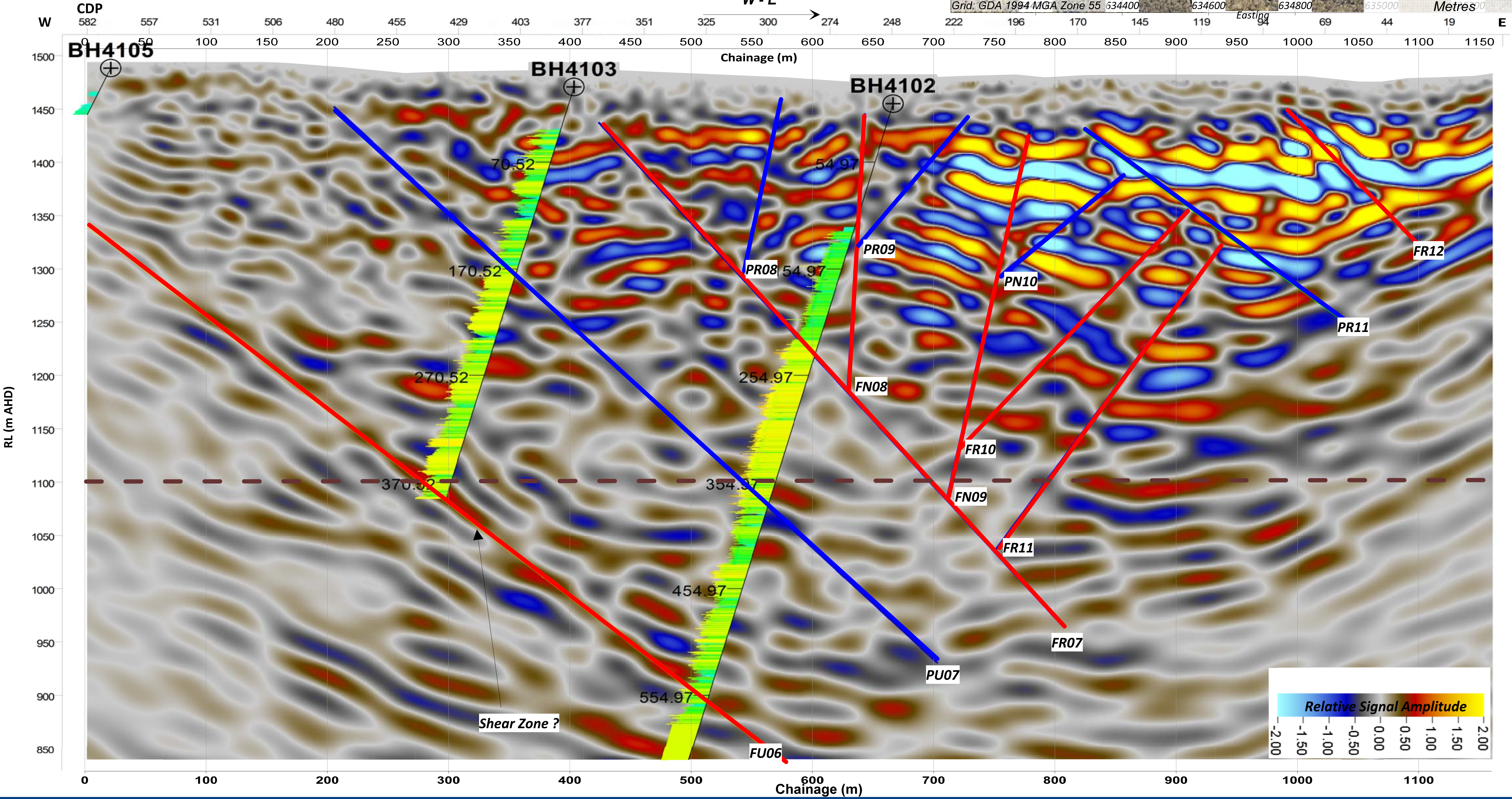
Disclaimer:

Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to intrinsic limitations of seismic reflection method.

The seismic and geological interpretation derived by the GHD and presented in this figure have been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurfaceconditions to help geotechnical interpretation and planning purposes.

Seismic Reflection Survey
Depth Migrated Stack
SL4A_RL
W - E





GHD

snowy 2.0

Client: Snowy Hydro Limited	
Snowy 2.0 Geotechnical Investigation	
Geophysical Investigation	
Seismic Reflection Survey	
scale as shown	date 02/08/2018

Horizontal Axis Scale: 1:3200 @ A3
0 50 100 150
Metres

Vertical Axis: Not to scale

Job No.: **21/212692806** ©

Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Reflection Survey
SL4A_RL Depth Migrated Stack - datum

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure 26

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

LEGEND:

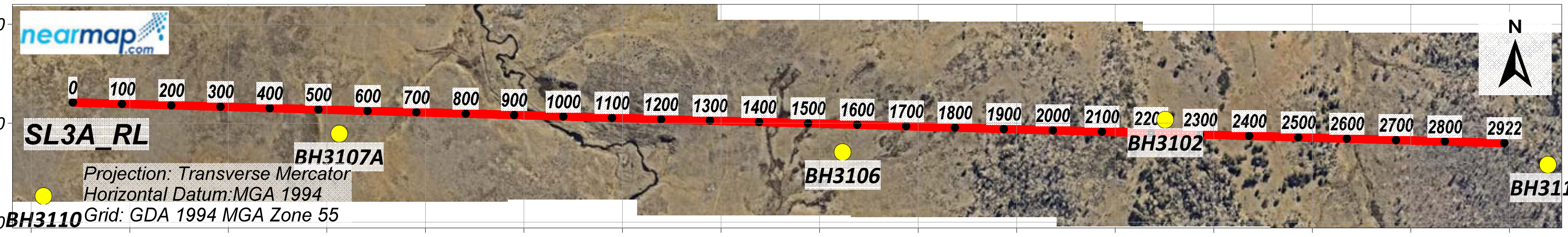
Displayed SRT Line Location *(Plan view)* 100

Borehole *(Plan / Profile View)*

Disclaimer:

Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to intrinsic limitations of seismic reflection method.

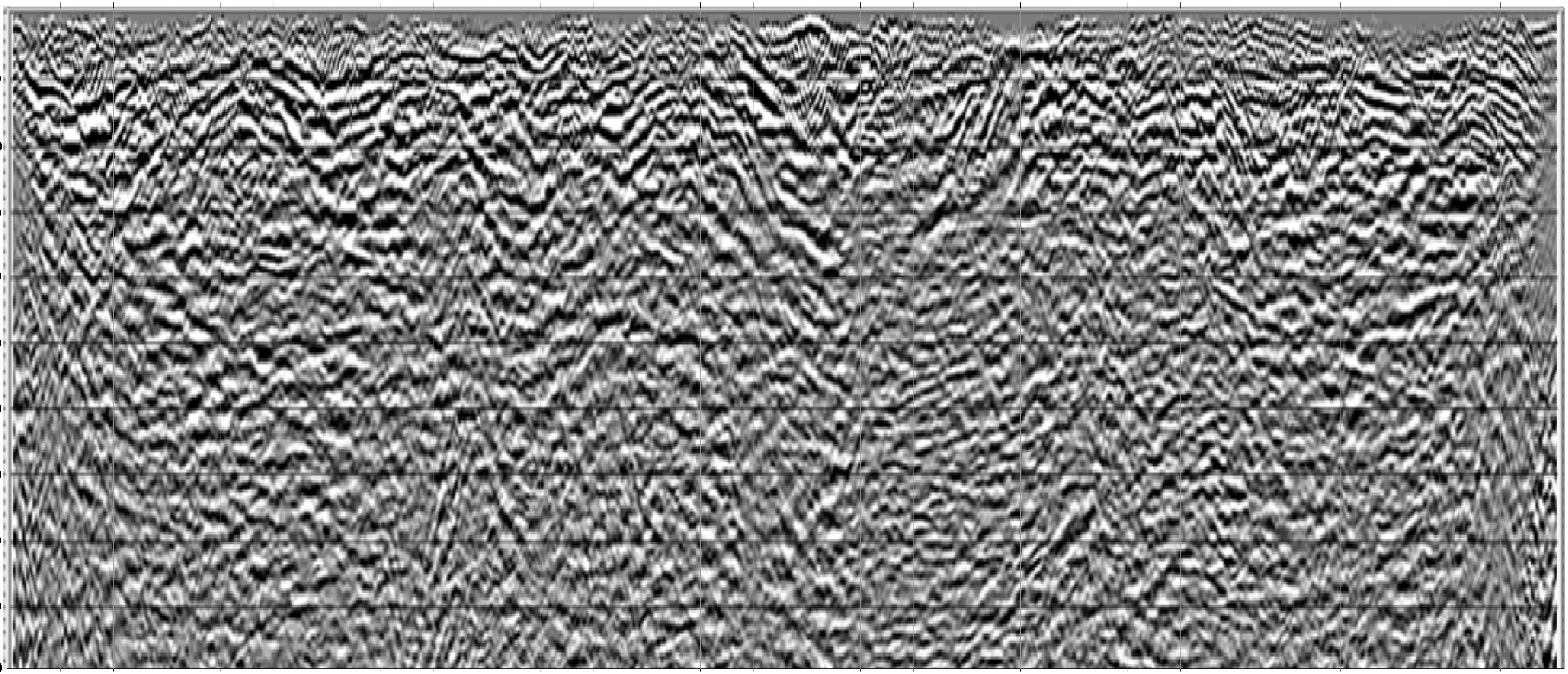
The seismic and geological interpretation derived by the GHD and presented in this figure have been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurfaceconditions to help geotechnical interpretation and planning purposes.



Map Scale: 1:13500 @ A3

0 200 400 600
Metres

Seismic Refraction Tomography Survey
P-wave Velocity Model
SL3A_RL
W - E



Client: Snowy Hydro Limited	
Snowy 2.0 Geotechnical Investigation	
Geophysical Investigation	
Seismic Reflection Survey	
scale as shown	date 22/06/2018

Horizontal Axis Scale: 1:7500 @ A3

0 100 200 300 400
Metres

Vertical Axis:
Not to scale

Job No.: **21/212692806** ©

Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Reflection / Refraction Survey
SL3A_RL DMO Time Stack

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure
21-26928-GT-RPT-R4_App N-N01

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

LEGEND:

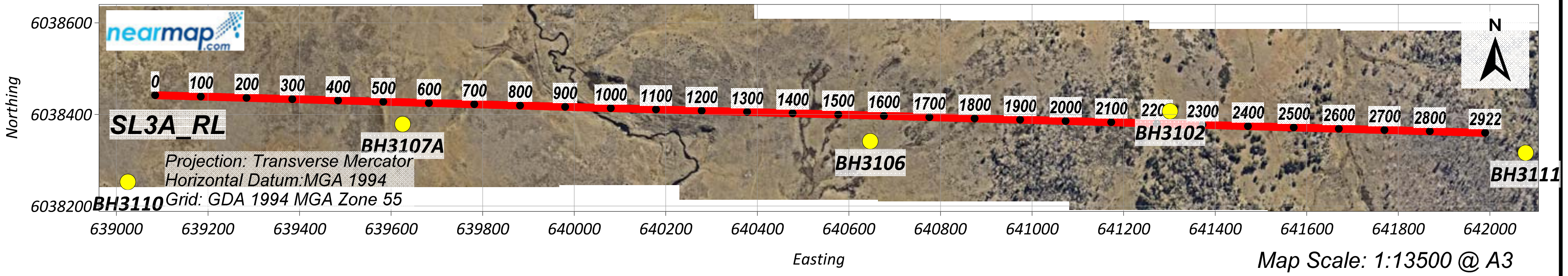
Displayed SRT Line Location *(Plan view)* 100

Borehole *(Plan / Profile View)*

Disclaimer:

Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to intrinsic limitations of seismic reflection method.

The seismic and geological interpretation derived by the GHD and presented in this figure have been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurfaceconditions to help geotechnical interpretation and planning purposes.

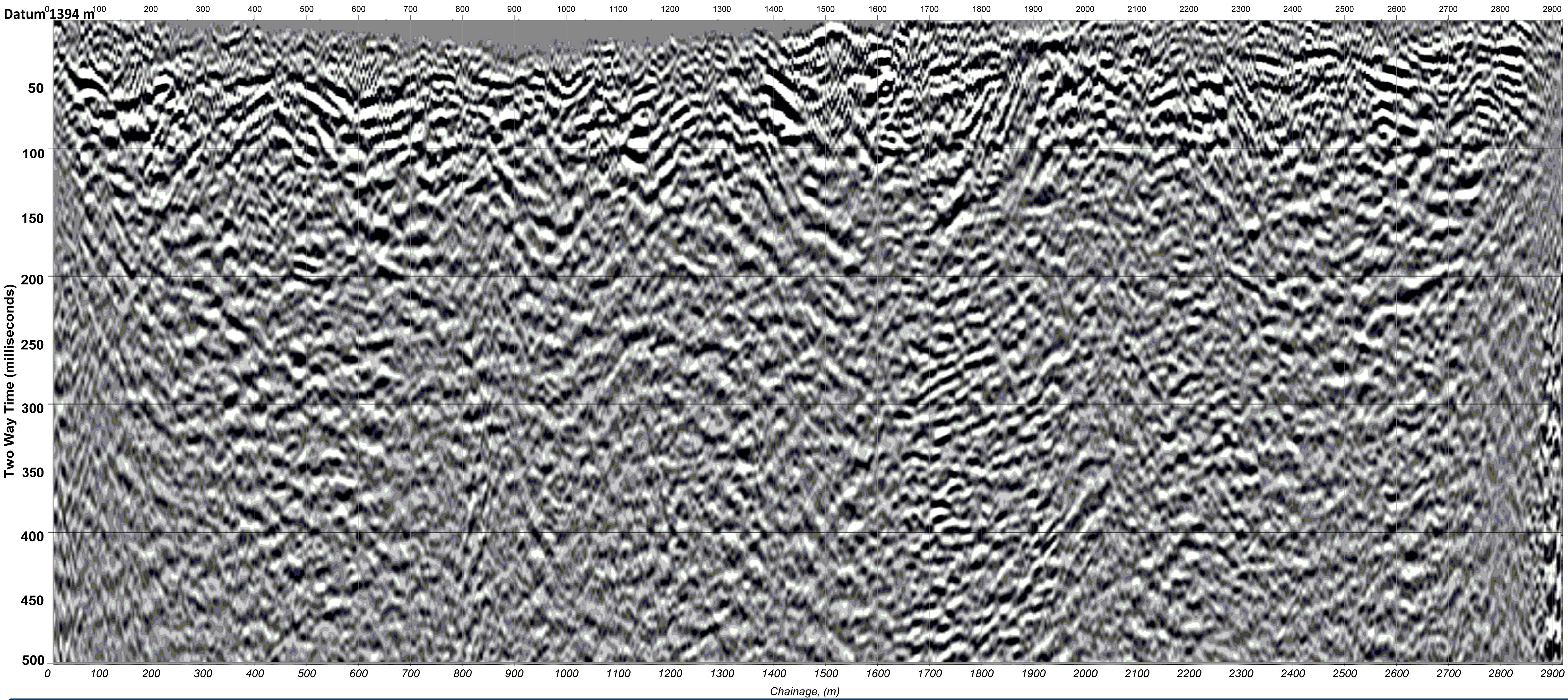


Map Scale: 1:13500 @ A3

0 200 400 600

Metres

Seismic Refraction Tomography Survey
P-wave Velocity Model
SL3A_RL
W - E



Client: Snowy Hydro Limited	
Snowy 2.0 Geotechnical Investigation	
Geophysical Investigation	
Seismic Reflection Survey	
scale as shown	date 22/06/2018

Horizontal Axis Scale: 1:7500 @ A3

0 100 200 300 400

Metres

Vertical Axis:
Not to scale

Job No.: **21/212692806**

©

Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Reflection / Refraction Survey
SL3A_RL DMO Time Stack - datum 1394 m

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure
21-26928-GT-RPT-R4_App N-N02

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

LEGEND:

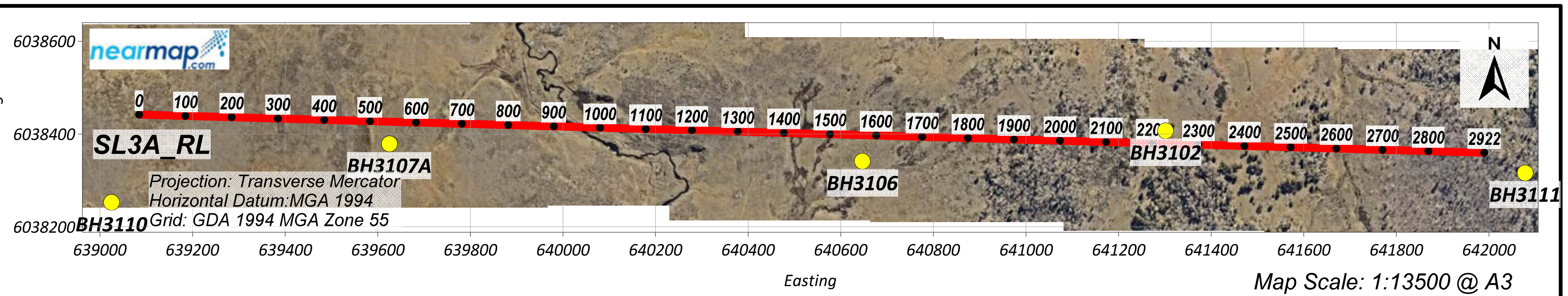
Displayed SRT Line Location *(Plan view)*

Borehole *(Plan / Profile View)*

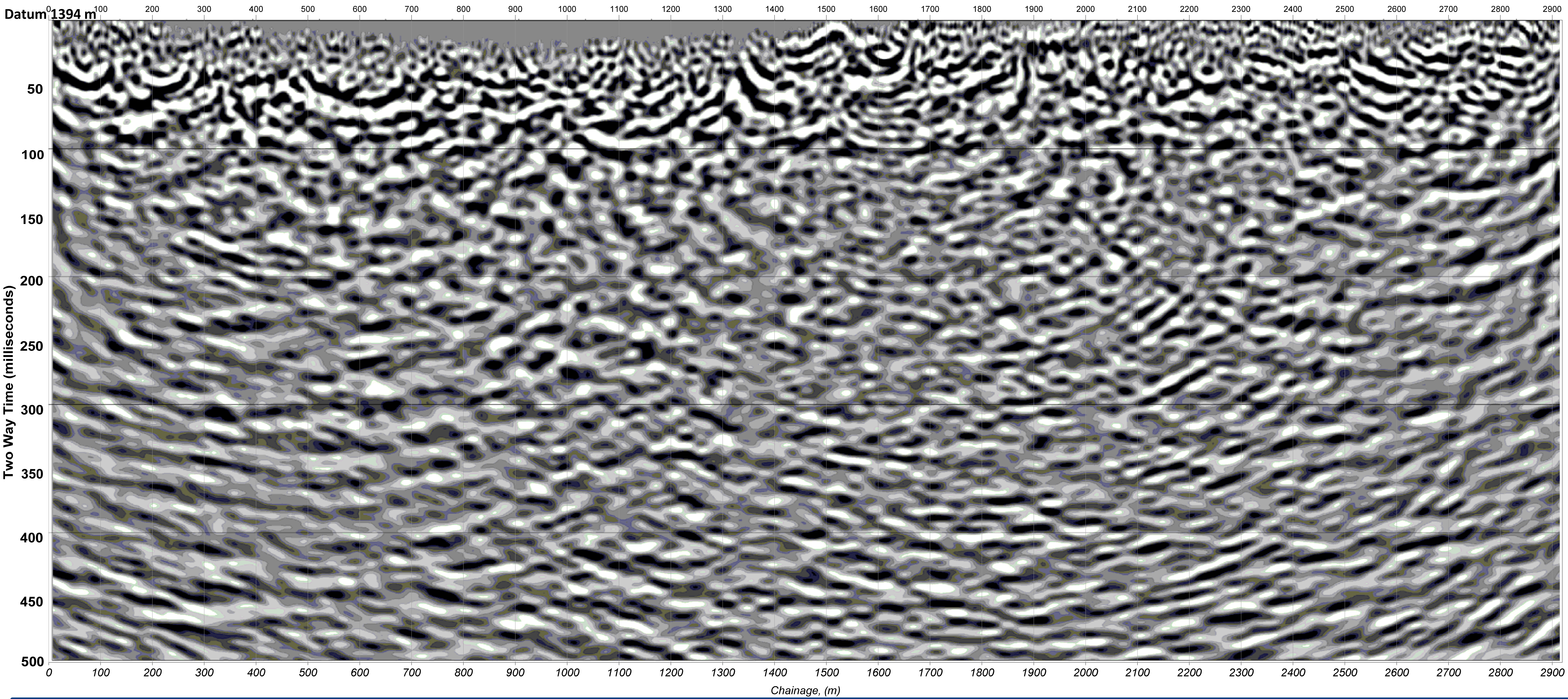
Disclaimer:

Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to intrinsic limitations of seismic reflection method.

The seismic and geological interpretation derived by the GHD and presented in this figure have been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurfaceconditions to help geotechnical interpretation and planning purposes.



Seismic Refraction Tomography Survey
P-wave Velocity Model
SL3A_RL
W - E



Client: Snowy Hydro Limited
Snowy 2.0 Geotechnical Investigation
Geophysical Investigation
Seismic Reflection Survey

scale	as shown	date 22/06/2018

Horizontal Axis Scale: 1:7500 @ A3
0 100 200 300 400
Metres

Vertical Axis: Not to scale

Job No.: **21/212692806**
Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Reflection / Refraction Survey
SL3A_RL DMO Migrated Time Stk - datum 1394 m

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure
21-26928-GT-RPT-R4_App N-N03

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

LEGEND:

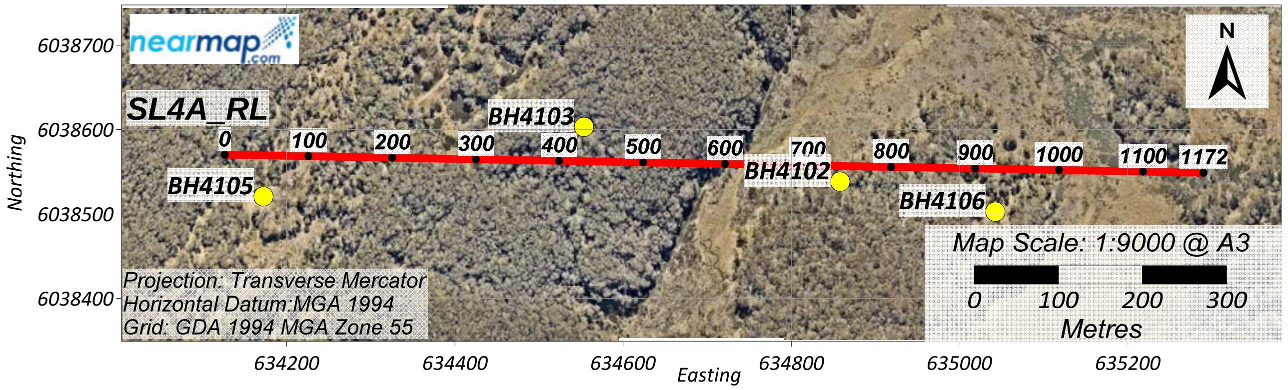
Displayed SRT Line Location *(Plan view)* — 100

Borehole *(Plan / Profile View)*

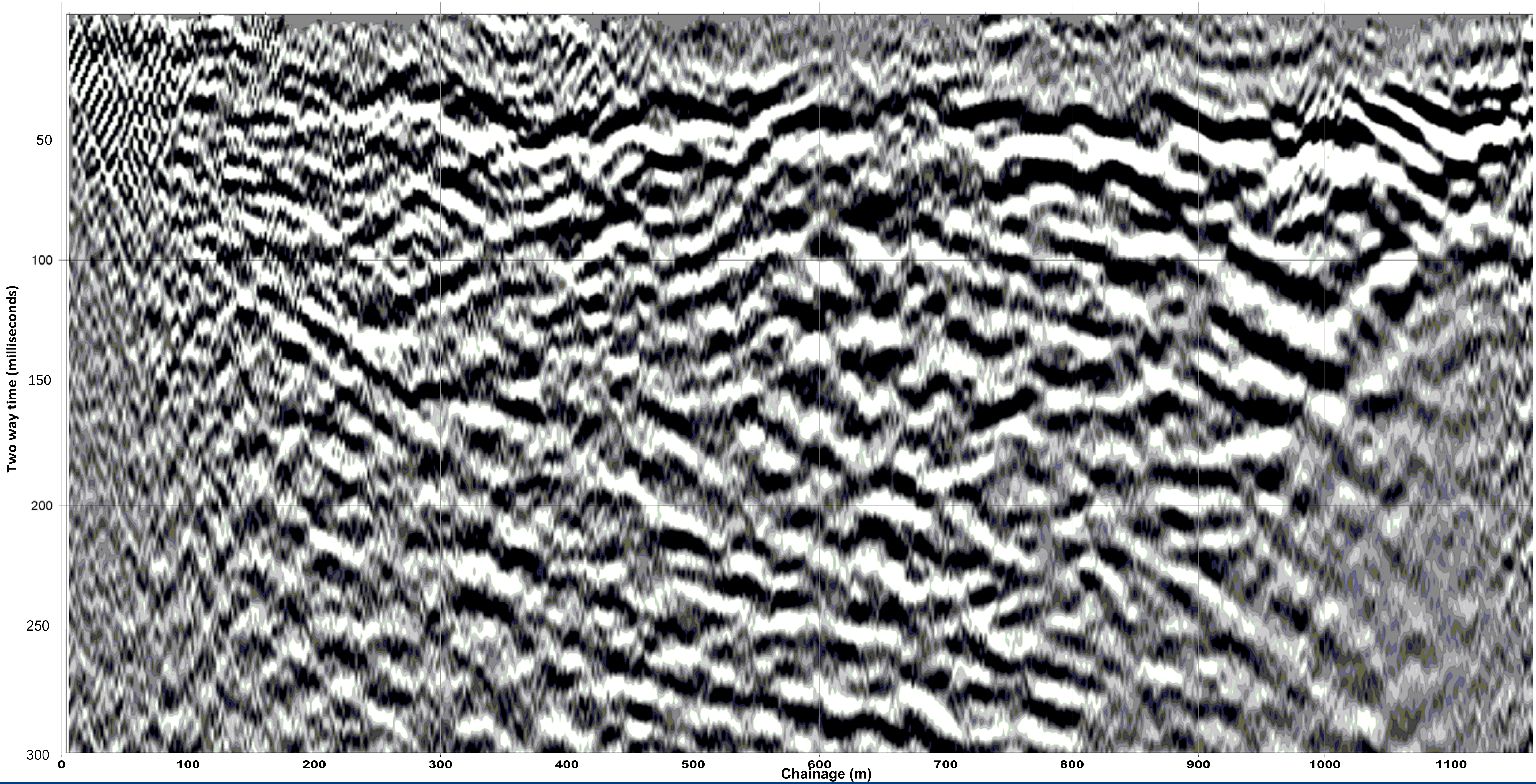
Disclaimer:

Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to intrinsic limitations of seismic reflection method.

The seismic and geological interpretation derived by the GHD and presented in this figure have been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurfaceconditions to help geotechnical interpretation and planning purposes.



W - E



Client: Snowy Hydro Limited		Horizontal Axis Scale: 1:3200 @ A3 0 50 100 150 Metres	Job No.: **21/212692806** Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Snowy 2.0 Geotechnical Investigation			
Geophysical Investigation		Vertical Axis: Not to scale	Snowy 2.0 Geotechnical Investigation Seismic Reflection / Refraction Survey SL4A_RL Residual Stack - surface
Seismic Reflection Survey			
scale	as shown	date 22/06/2018	N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ — **Figure** 21-26928-GT-RPT-R4_App N-N04

GHD

snowy 2.0

©

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LEGEND:

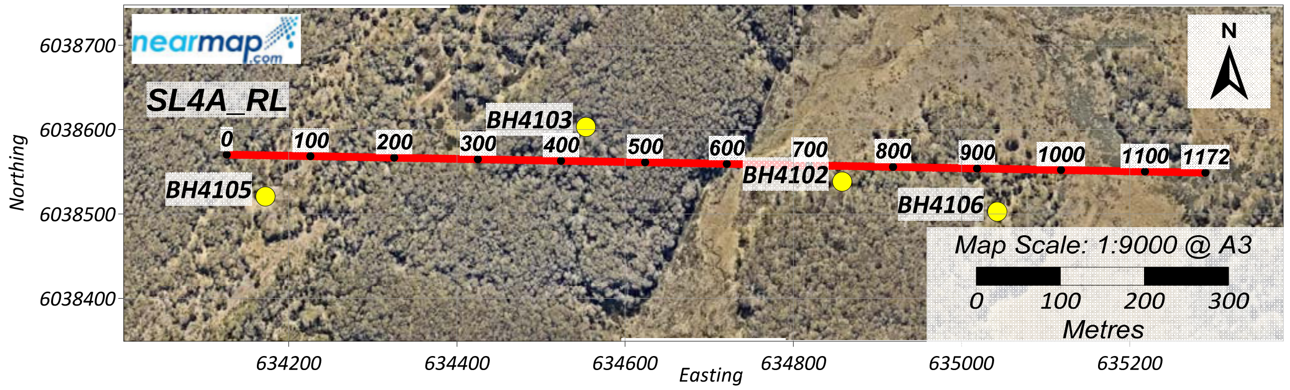
Displayed SRT Line Location *(Plan view)* 100

Borehole *(Plan / Profile View)*

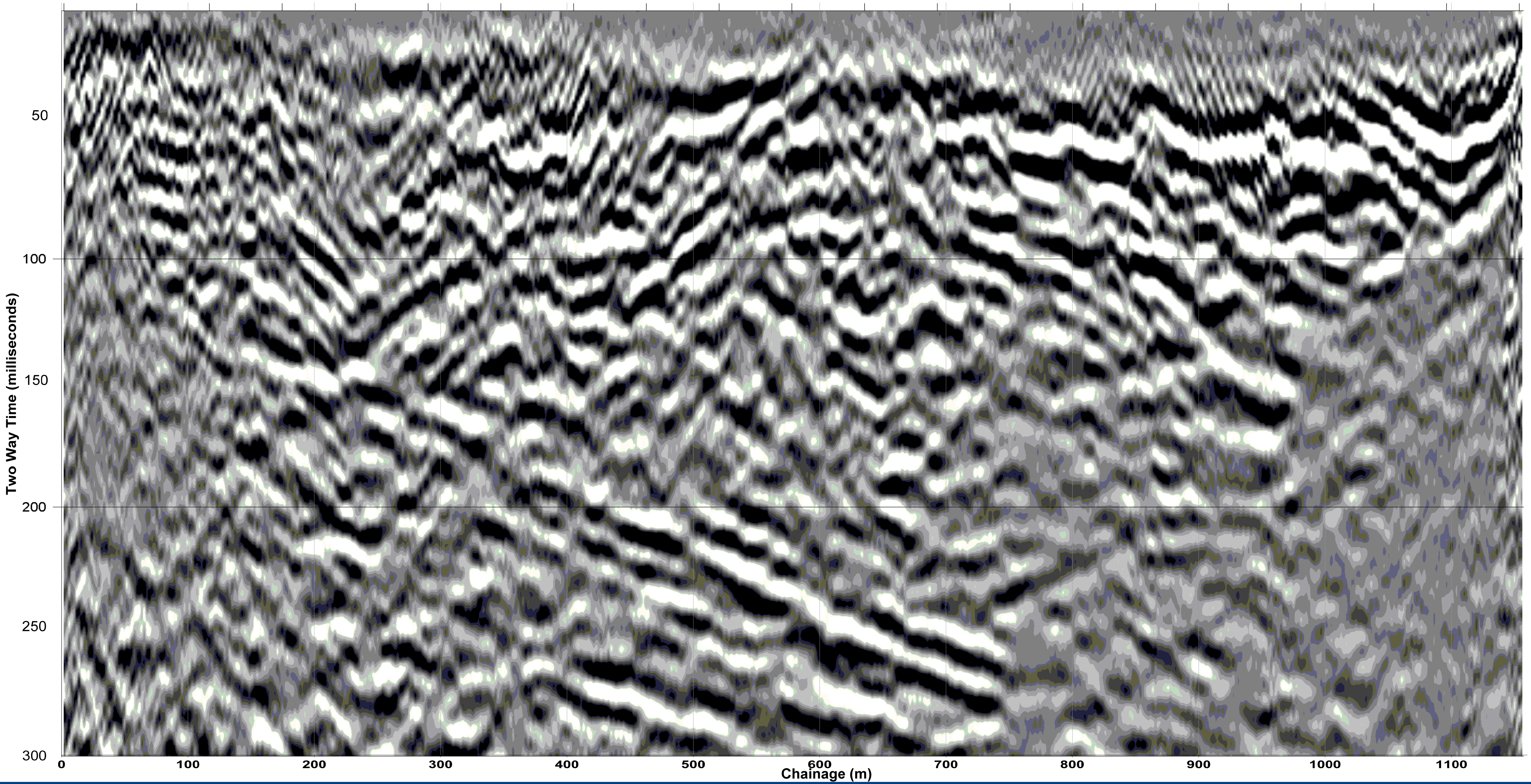
Disclaimer:

Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to intrinsic limitations of seismic reflection method.

The seismic and geological interpretation derived by the GHD and presented in this figure have been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurfaceconditions to help geotechnical interpretation and planning purposes.



W - E →



Client: Snowy Hydro Limited	
Snowy 2.0 Geotechnical Investigation	
Geophysical Investigation	
Seismic Reflection Survey	
scale as shown	date 22/06/2018

Horizontal Axis Scale: 1:3200 @ A3

0 50 100 150

Metres

Vertical Axis: Not to scale

Vertical Axis: Not to scale

Job No.: **21/212692806** ©

Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Reflection / Refraction Survey
SL4A_RL DMO Time Stack

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure
21-26928-GT-RPT-R4_App N-N05

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

LEGEND:

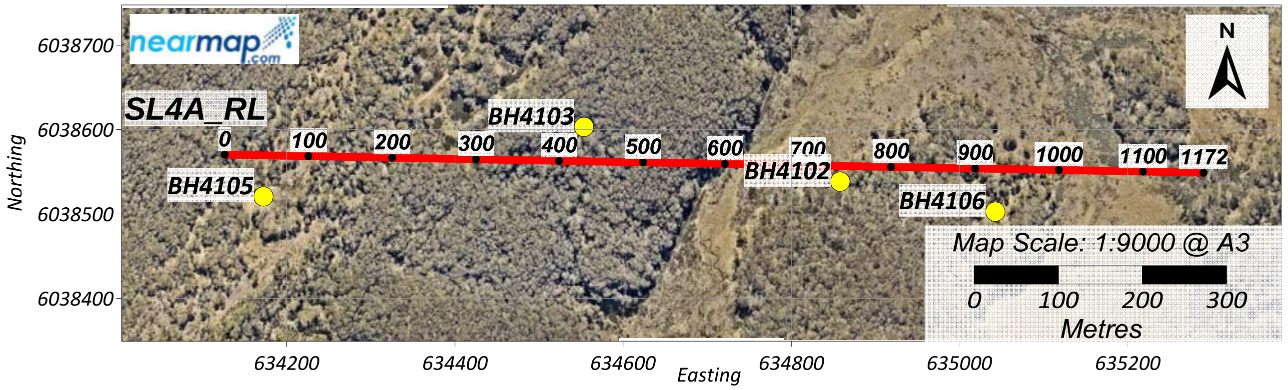
Displayed SRT Line Location *(Plan view)* 100

Borehole *(Plan / Profile View)*

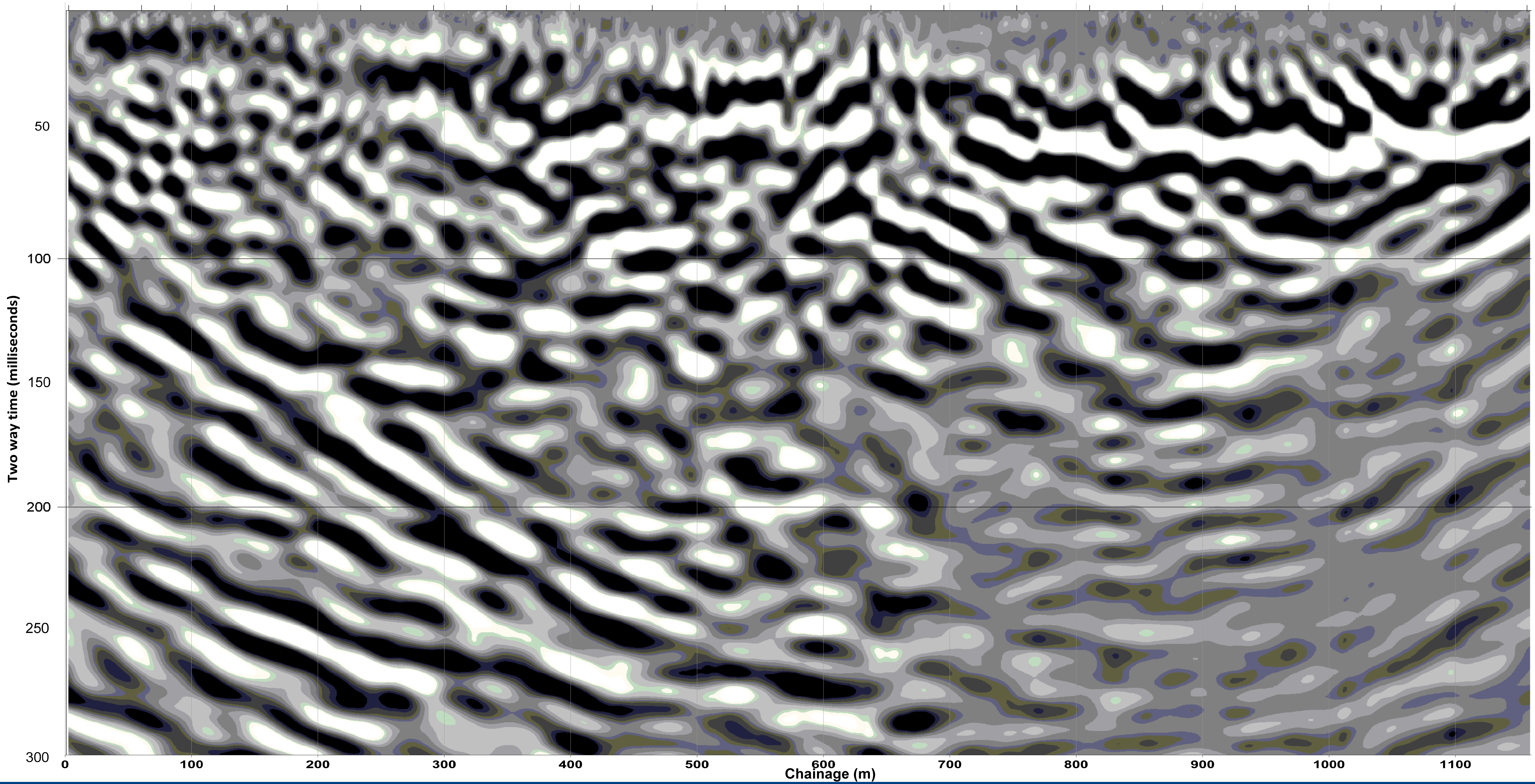
Disclaimer:

Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to intrinsic limitations of seismic reflection method.

The seismic and geological interpretation derived by the GHD and presented in this figure have been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurfaceconditions to help geotechnical interpretation and planning purposes.



W - E



Client: Snowy Hydro Limited		
Snowy 2.0 Geotechnical Investigation		
Geophysical Investigation		
Seismic Reflection Survey		
scale	as shown	date 22/06/2018

Horizontal Axis Scale: 1:3200 @ A3

0 50 100 150

Metres

Vertical Axis:
Not to scale

Job No.: **21/212692806**

Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Reflection / Refraction Survey
SL4A_RL DMO Migrated Time Stack

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure
21-26928-GT-RPT-R4_App N-N06

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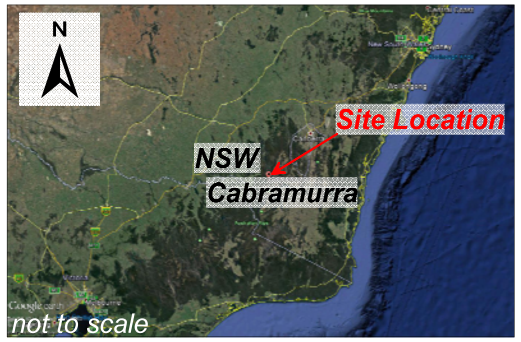
snowy 2.0



LEGEND:

- Surveyed SRT Line Location *(Plan view)*
- Displayed SRT Line Location *(Plan view)*
- Borehole Location *(Plan / Profile view)*
- Seismic shot points *(Profile view)*
- Seismic receivers *(Profile view)*

BH GEOLOGY LEGEND:

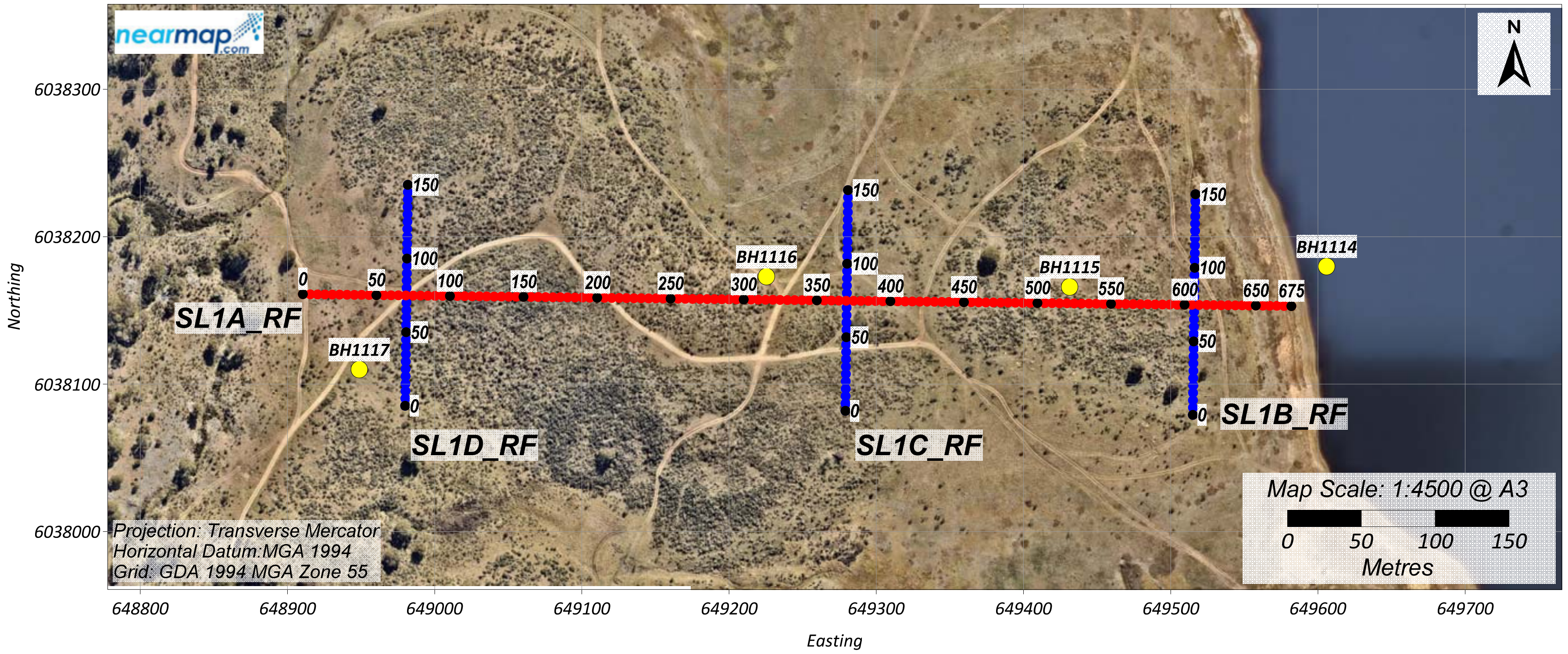
- Soil / Residual
- XW Rock
- HW / MW - SW Rock
- SW - Fr Rock
- Core Loss

General Geological Description
For detailed subsurface material description refer to Borehole Logs

Disclaimer:

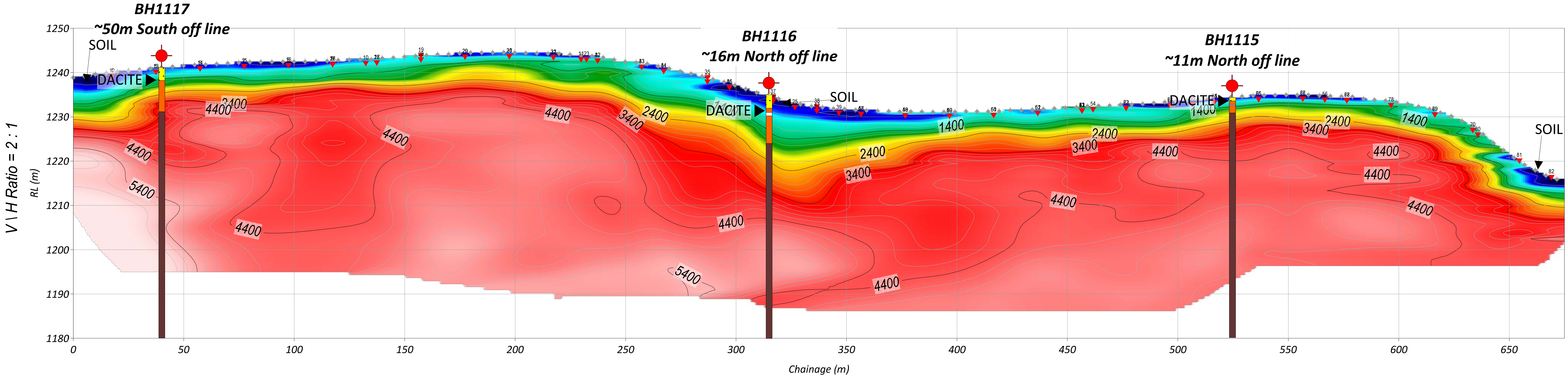
Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to the normal limitations of seismic refraction interpretation where a simple 2 or 3 layered model is imposed on a complex site with highly variable (laterally and vertically) anisotropic weathering and rock conditions.

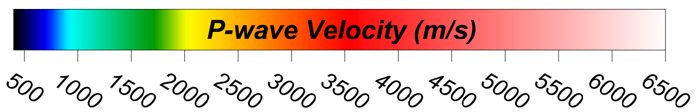
The seismic and geological interpretation derived by the GHD and presented in this figure have been prepared for Snowy Hydro Limited (the client) only as a guide to likely subsurfaceconditions to help geotechnical interpretation and planning purposes.



Seismic Refraction Tomography Survey
P-wave Velocity Model
SL1A_RF
W - E

DRAFT





SNWSL01, 30 WET iterations, RMS error 2.0 %, 1D-Gradient smooth initial model, Version 3.32

Client: Snowy Hydro Limited		Horizontal Axis Scale: 1:1800 @ A3 0 20 40 60 80 Metres	Job No.: **21/212692806** ©
Snowy 2.0 Geotechnical Investigation			Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Geophysical Investigation			Snowy 2.0 Geotechnical Investigation Seismic Refraction Survey SL1A_RF P-wave Velocity Model
Seismic Refraction Survey		Vertical to horizontal exaggeration 2 : 1	
scale	as shown	date 22/06/2018	

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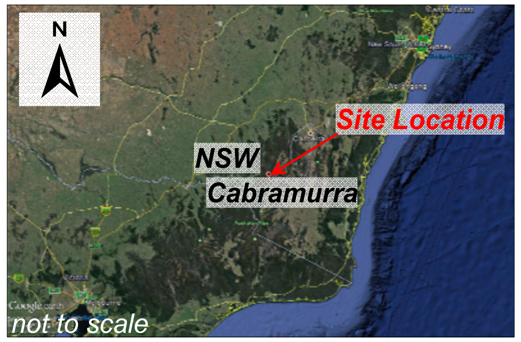
N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure A1



LEGEND:

Surveyed SRT Line Location *(Plan view)*
Displayed SRT Line Location *(Plan view)*
Borehole Location *(Plan / Profile view)*
Seismic shot points *(Profile view)*
Seismic receivers *(Profile view)*

Disclaimer:

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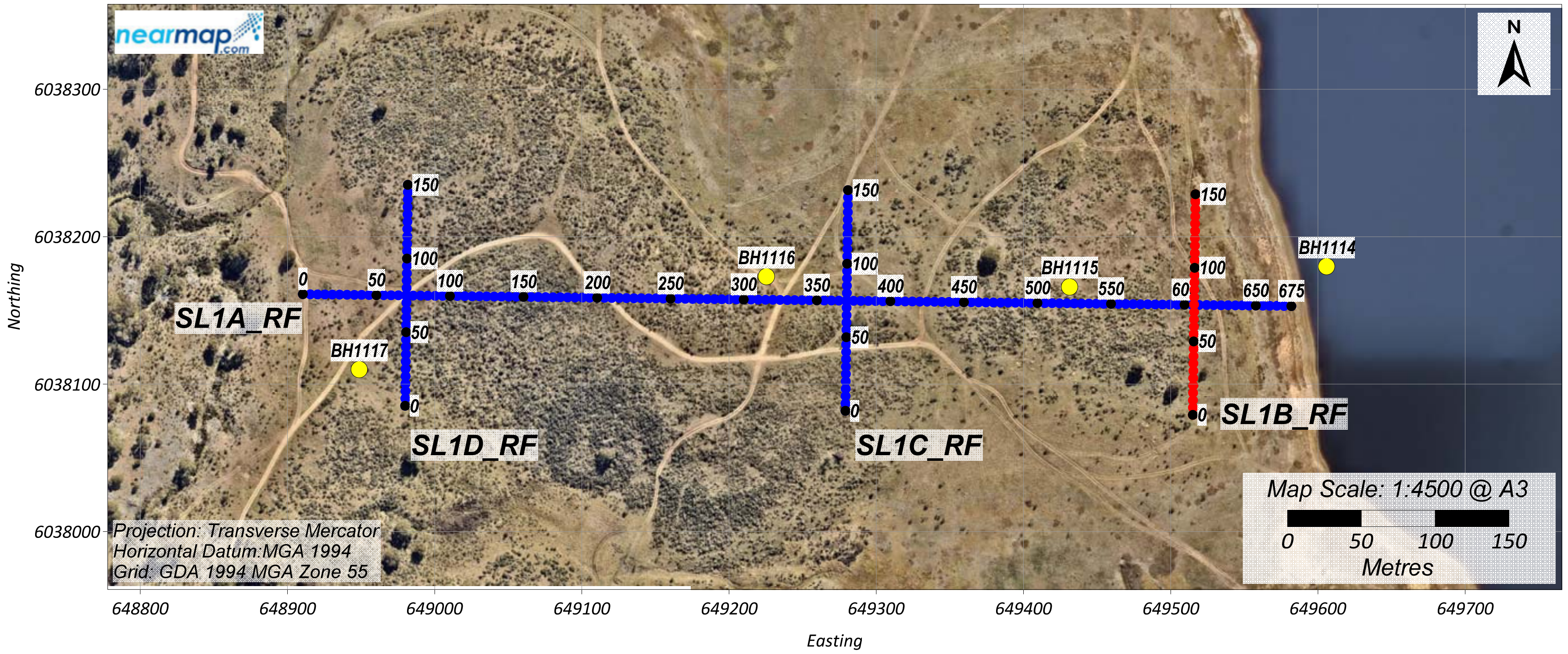
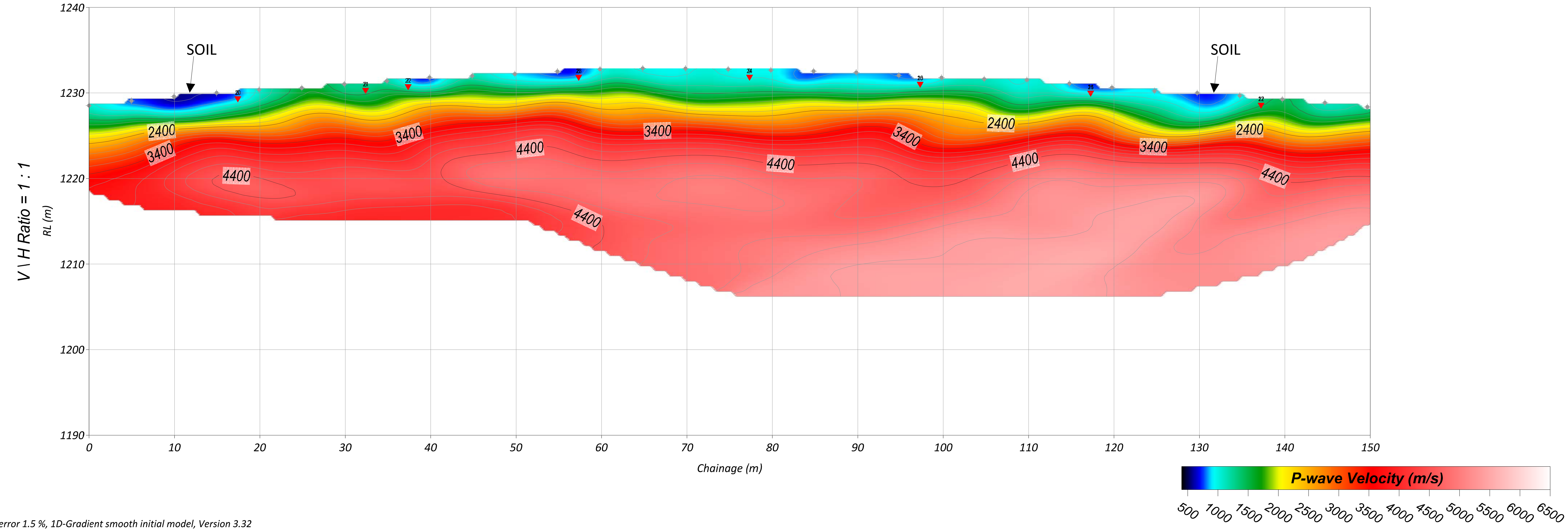


Seismic Refraction Tomography Survey
P-wave Velocity Model
SL1B_RF
S - N

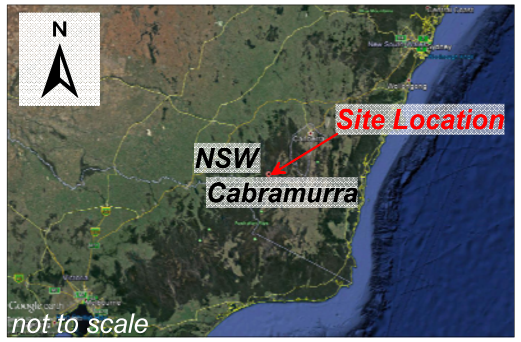
DRAFT



SNWXSL1A, 30 WET iterations, RMS error 1.5 %, 1D-Gradient smooth initial model, Version 3.32

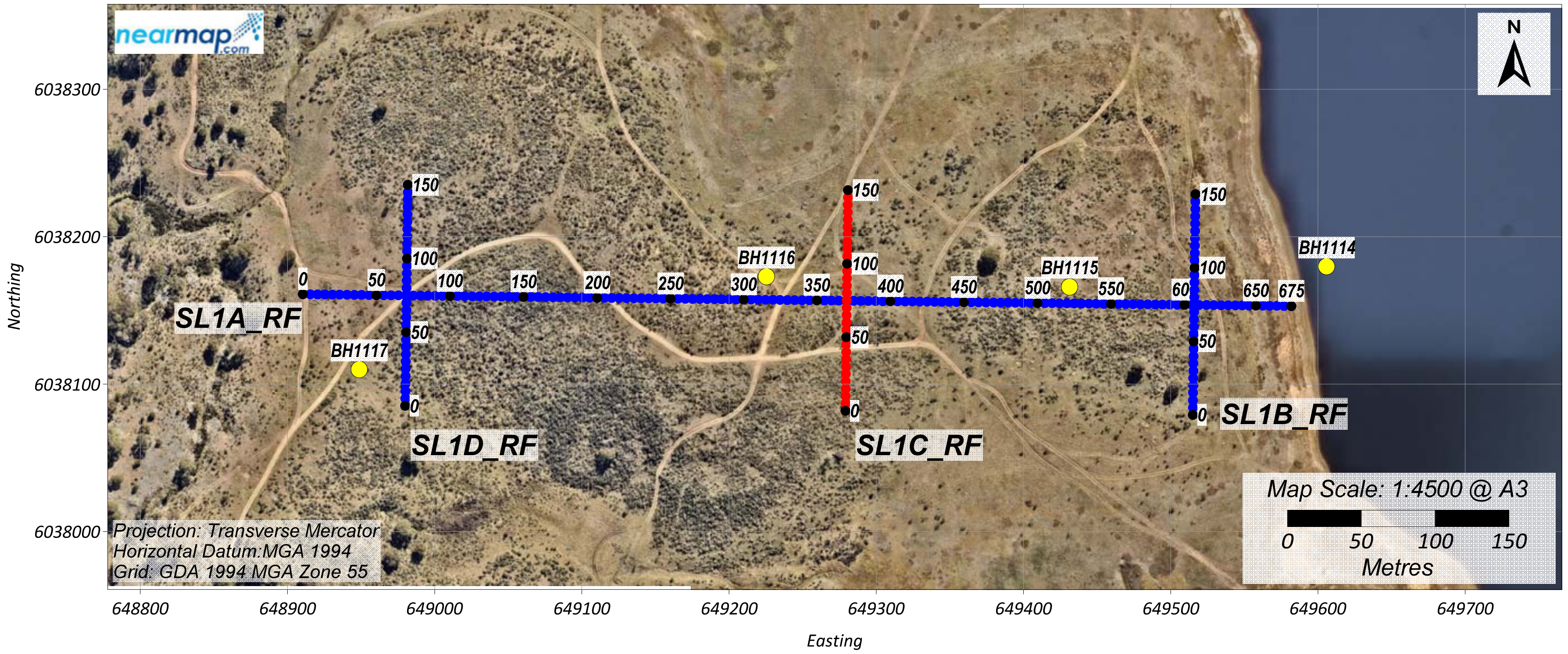
GHD / snowy 2.0	Client: Snowy Hydro Limited Snowy 2.0 Geotechnical Investigation Geophysical Investigation Seismic Refraction Survey scale as shown date 22/06/2018	*Horizontal Axis Scale: 1:500 @ A3* 0 10 20 Metres *Vertical to horizontal exaggeration 1 : 1*	Job No.: **21/212692806** © Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ Snowy 2.0 Geotechnical Investigation Seismic Refraction Survey SL1B_RF P-wave Velocity Model N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ **Figure A2**

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



LEGEND:

- Surveyed SRT Line Location *(Plan view)* — 100
- Displayed SRT Line Location *(Plan view)* — 100
- Borehole Location *(Plan / Profile view)*
- Seismic shot points *(Profile view)*
- Seismic receivers *(Profile view)*



Disclaimer:

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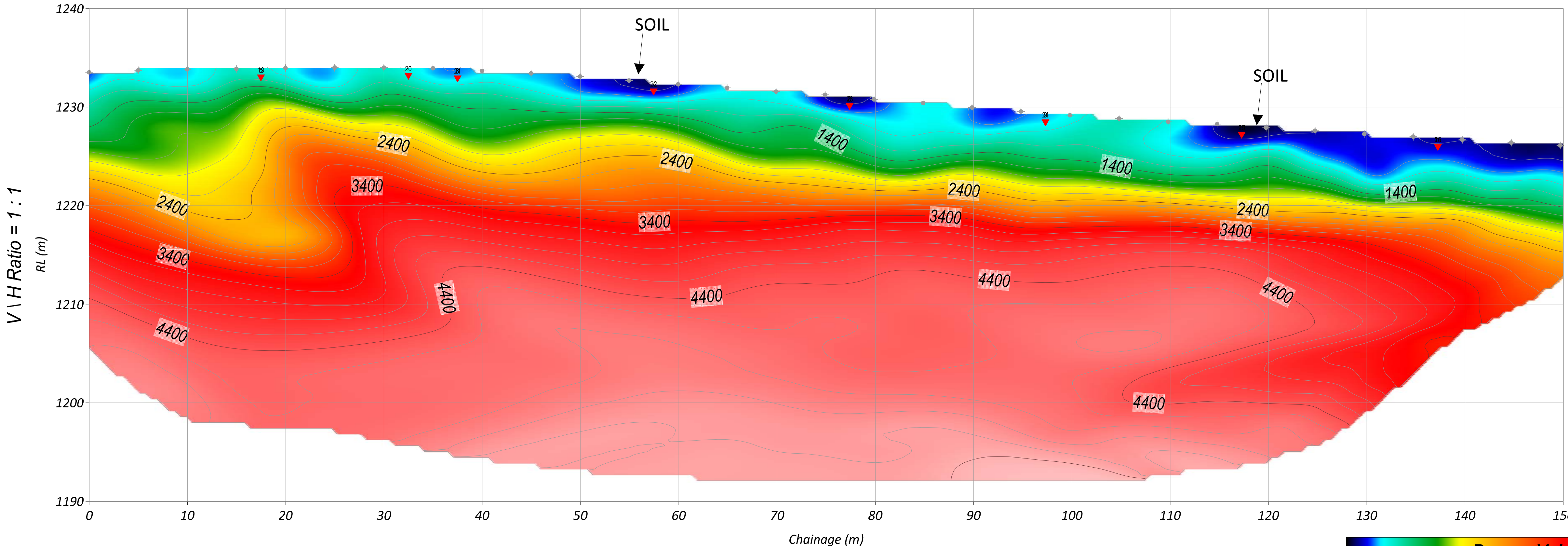
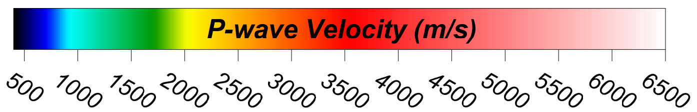
Seismic Refraction Tomography Survey
P-wave Velocity Model
SL1C_RF

S - N

DRAFT

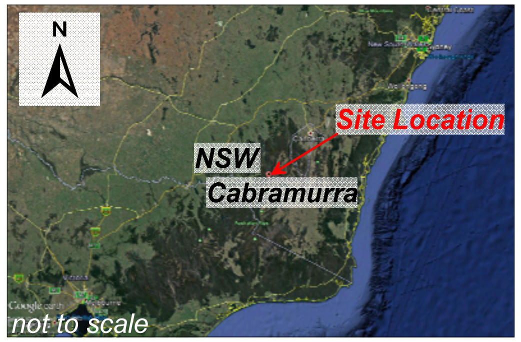




SNWXSL1B, 30 WET iterations, RMS error 1.4 %, 1D-Gradient smooth initial model, Version 3.32

Client: Snowy Hydro Limited	*Horizontal Axis Scale: 1:500 @ A3* (0, 10, 20 Metres)	Job No.: **21/212692806** ©
Snowy 2.0 Geotechnical Investigation		Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Geophysical Investigation	*Vertical to horizontal exaggeration 1 : 1*	Snowy 2.0 Geotechnical Investigation Seismic Refraction Survey SL1C_RF P-wave Velocity Model
Seismic Refraction Survey		
scale: as shown, date 22/06/2018		N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ — **Figure A3**

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



Disclaimer:

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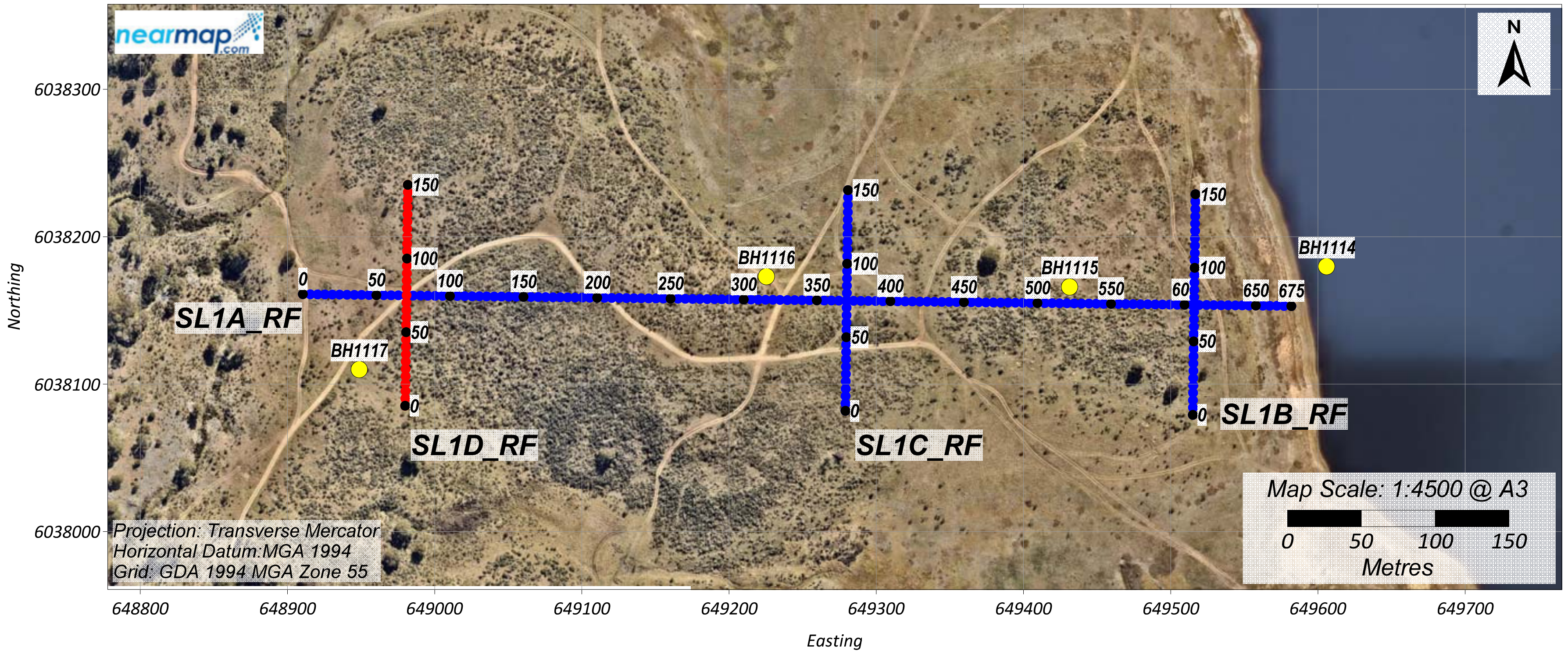
LEGEND:

- Surveyed SRT Line Location *(Plan view)* — 100
- Displayed SRT Line Location *(Plan view)* — 100
- Borehole Location *(Plan / Profile view)*
- Seismic shot points *(Profile view)*
- Seismic receivers *(Profile view)*

BH GEOLOGY LEGEND:

- Soil / Residual
- XW Rock
- HW / MW - SW Rock
- SW - Fr Rock
- Core Loss

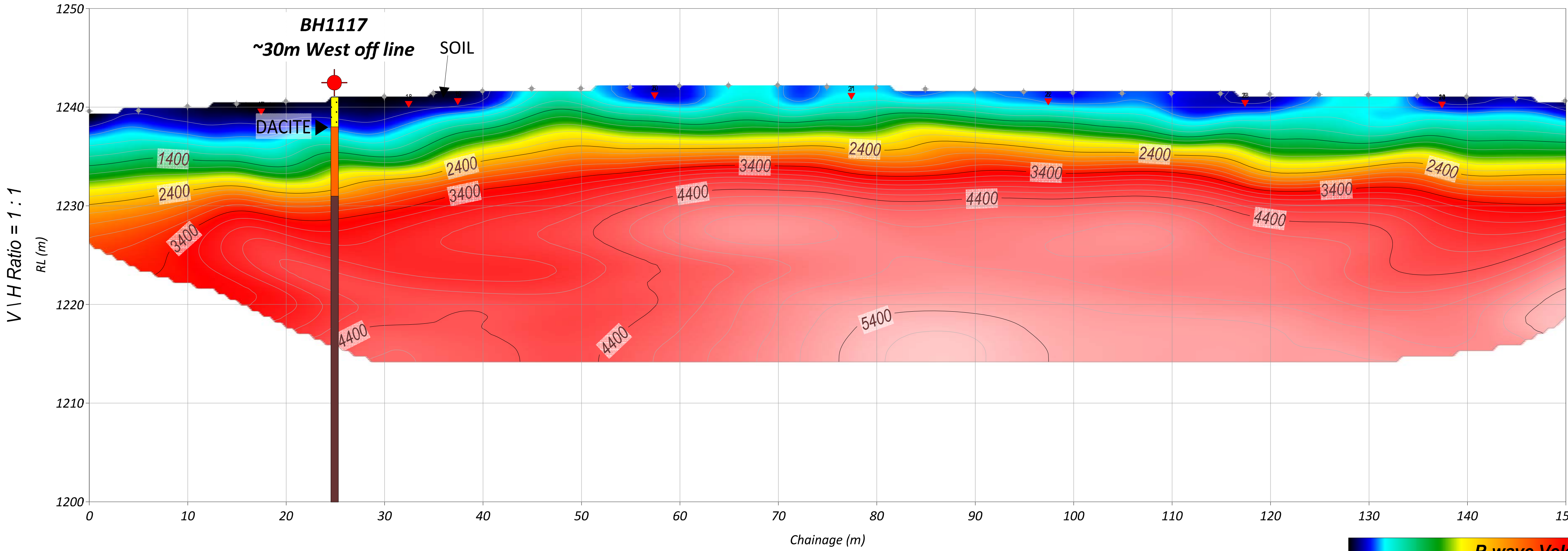
General Geological Description
For detailed subsurface material description refer to Borehole Logs

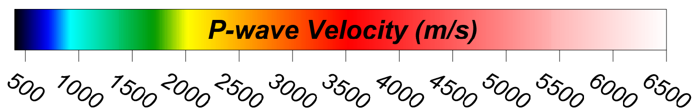


Seismic Refraction Tomography Survey
P-wave Velocity Model
SL1D_RF

S - N

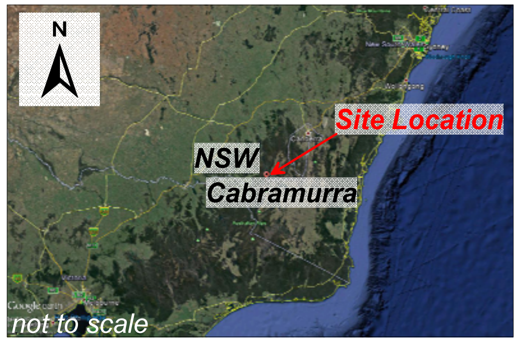
DRAFT





SNWXSL1C, 30 WET iterations, RMS error 1.3 %, 1D-Gradient smooth initial model, Version 3.32

Client: Snowy Hydro Limited		*Horizontal Axis Scale: 1:500 @ A3*	Job No.: **21/212692806** ©
Snowy 2.0 Geotechnical Investigation		0 10 20 Metres	Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Geophysical Investigation			Snowy 2.0 Geotechnical Investigation Seismic Refraction Survey SL1D_RF P-wave Velocity Model
Seismic Refraction Survey		*Vertical to horizontal exaggeration 1 : 1*	
scale	as shown	date 22/06/2018	
Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au			N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ — **Figure A4**



LEGEND:

Surveyed SRT Line Location *(Plan view)*	100
Displayed SRT Line Location *(Plan view)*	100
Borehole Location *(Plan / Profile view)*	
Seismic shot points *(Profile view)*	
Seismic receivers *(Profile view)*	

BH GEOLOGY LEGEND:

- Soil / Residual
- XW Rock
- HW / MW - SW Rock
- SW - Fr Rock
- Core Loss

General Geological Description
For detailed subsurface material description refer to Borehole Logs

Disclaimer:

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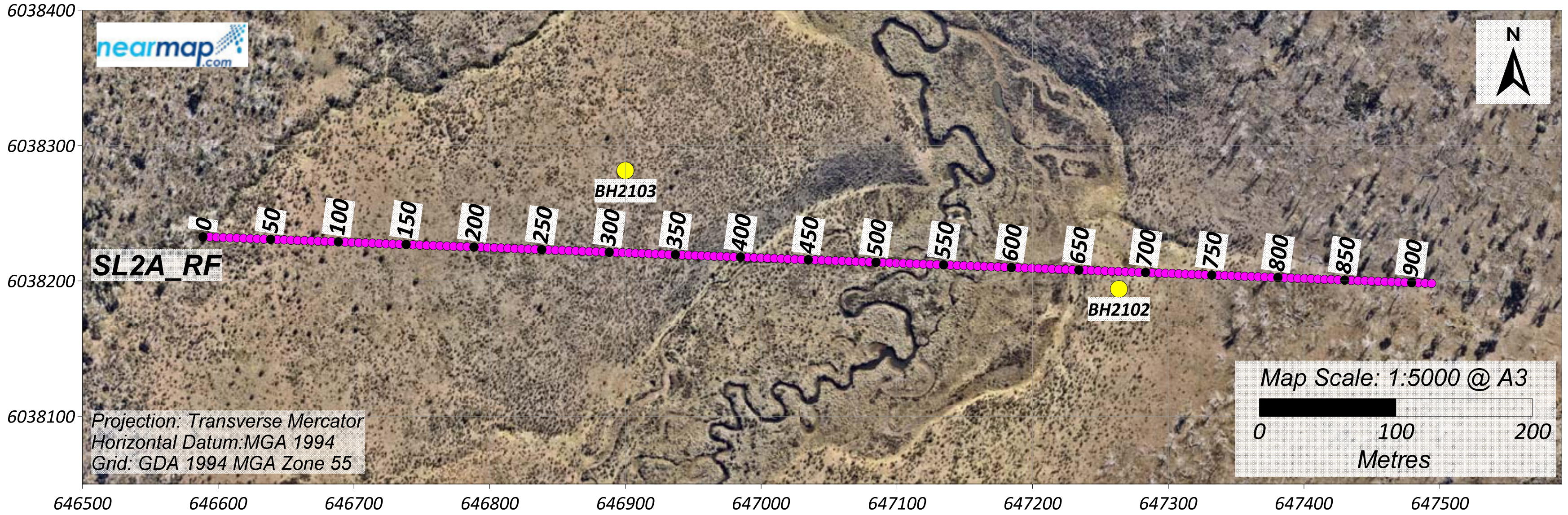
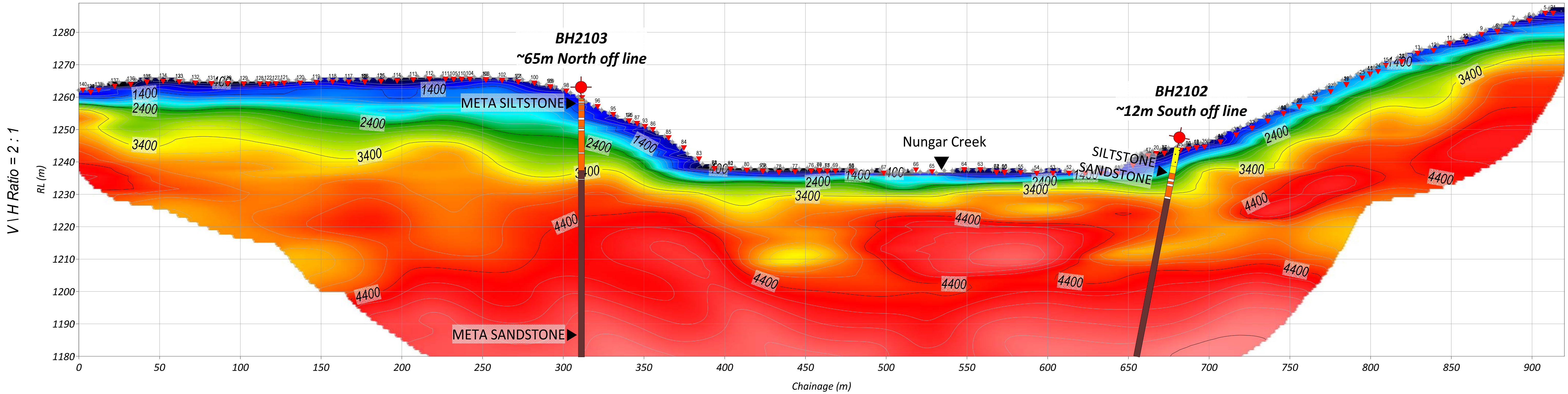
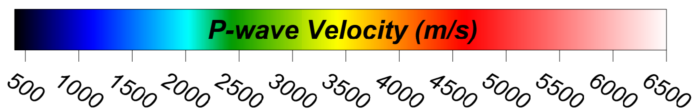


Seismic Refraction Tomography Survey
P-wave Velocity Model
SL2A_RF
W - E

DRAFT





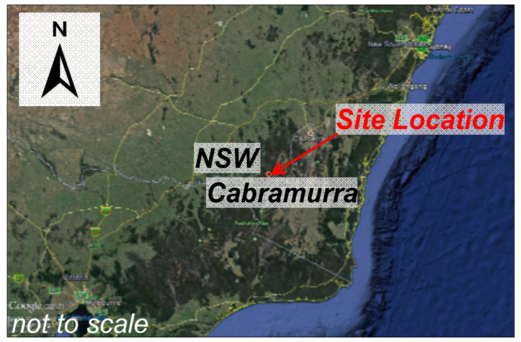
SNWSL02, 30 WET iterations, RMS error 1.4 %, 1D-Gradient smooth initial model, Version 3.32

GHD

snowy 2.0

Client: Snowy Hydro Limited	*Horizontal Axis Scale: 1:2400 @ A3* 0 40 80 120 *Metres*	Job No.: **21/212692806**	©
Snowy 2.0 Geotechnical Investigation		Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/	
Geophysical Investigation		Snowy 2.0 Geotechnical Investigation Seismic Refraction Survey SL2A_RF P-wave Velocity Model	
Seismic Refraction Survey	*Vertical to horizontal exaggeration 2 : 1*		
scale as shown date 23/07/2018		N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/	**Figure A5**

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



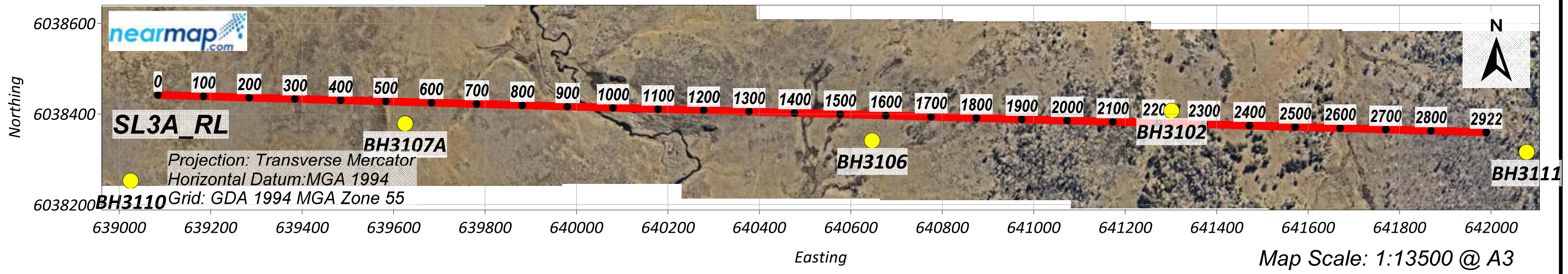
LEGEND:

- Surveyed SRT Line Location *(Plan view)*
- Displayed SRT Line Location *(Plan view)*
- Borehole Location *(Plan / Profile view)*
- Seismic shot points *(Profile view)*
- Seismic receivers *(Profile view)*

BH GEOLOGY LEGEND:

- Soil / Residual
- XW Rock
- HW / MW - SW Rock
- SW - Fr Rock
- Core Loss

General Geological Description
For detailed subsurface material description refer to Borehole Logs



Map Scale: 1:13500 @ A3

0 200 400 600
Metres

Disclaimer:

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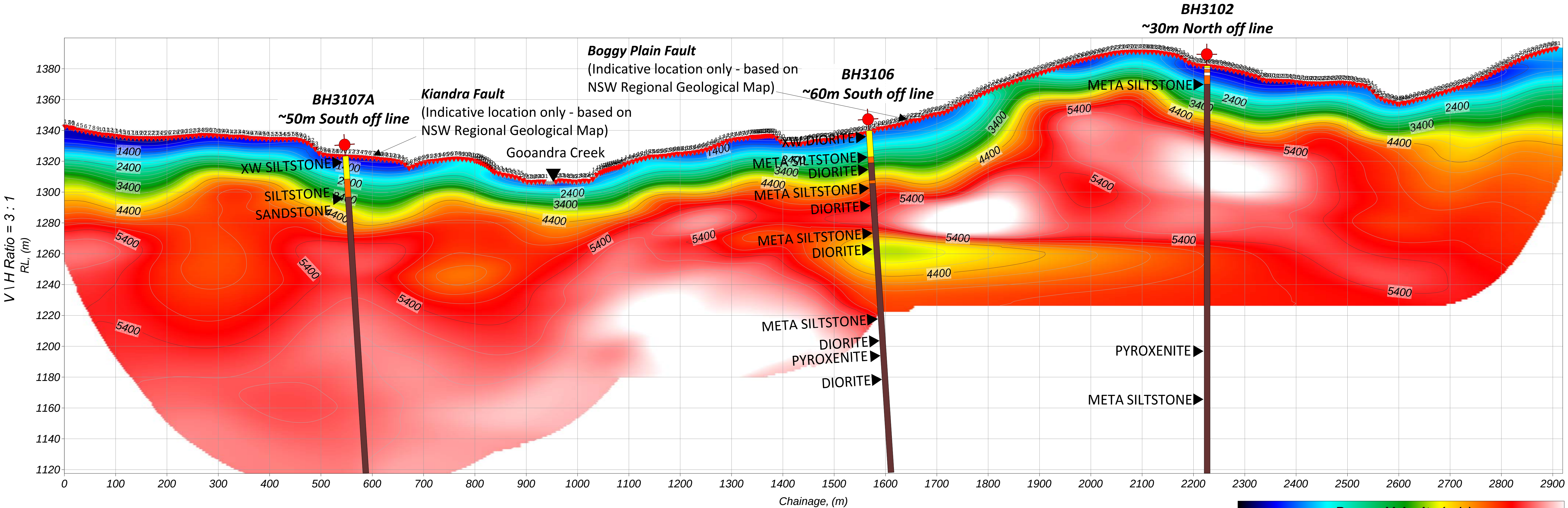
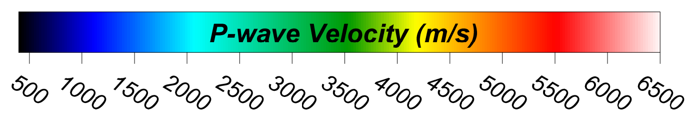
DRAFT

Seismic Refraction Tomography Survey
P-wave Velocity Model
SL3A_RL

W - E





Snowy 2.0 SL03 RMS error 1.9%=4.66ms 30 WET iters. 50Hz Width 10.0% initial GRADIENT.GRD Vers. 3.35

Client: Snowy Hydro Limited	
Snowy 2.0 Geotechnical Investigation	
Geophysical Investigation	
Seismic Refraction Survey	
scale as shown	date 22/06/2018

Horizontal Axis Scale: 1:3200 @ A3

0 100 200 300 400
Metres

Vertical to horizontal exaggeration 3 : 1

Job No.: **21/212692806** ©

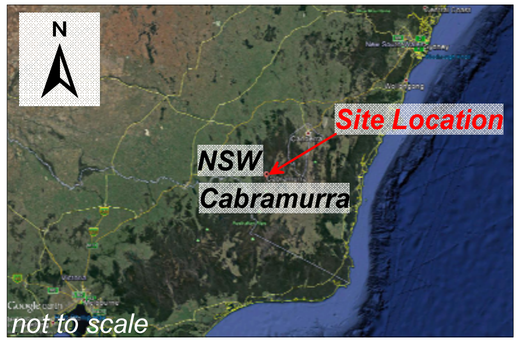
Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Reflection / Refraction Survey
SL3A_RL P-wave Velocity Model

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure A6

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



LEGEND:

- Surveyed SRT Line Location *(Plan view)* — 100
- Displayed SRT Line Location *(Plan view)* — 100
- Borehole Location *(Plan / Profile view)*
- Seismic shot points *(Profile view)*
- Seismic receivers *(Profile view)*

BH GEOLOGY LEGEND:

- Soil / Residual
- XW Rock
- HW / MW - SW Rock
- SW - Fr Rock
- Core Loss

General Geological Description
For detailed subsurface material description refer to Borehole Logs

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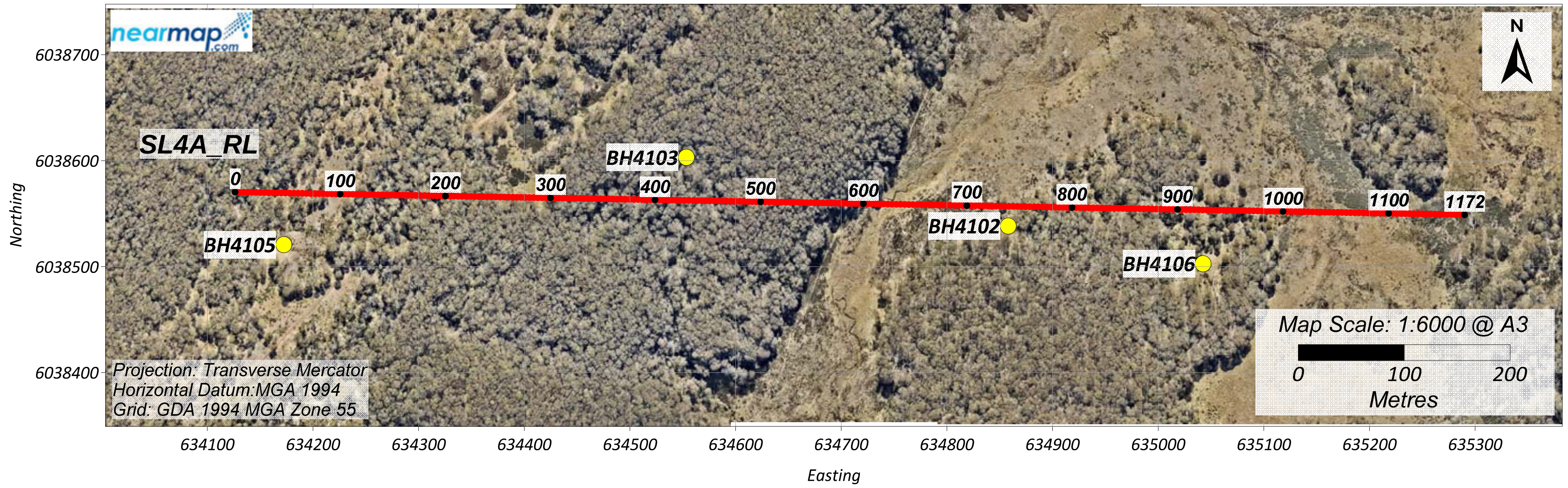
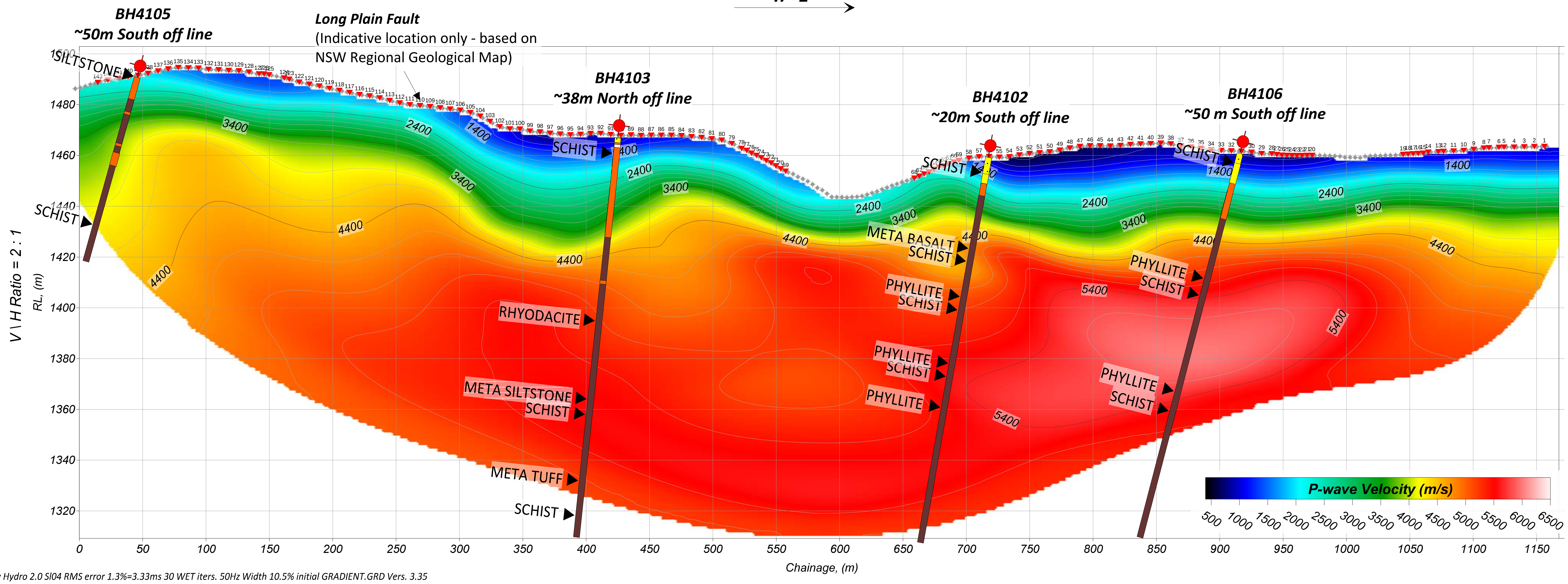


DRAFT

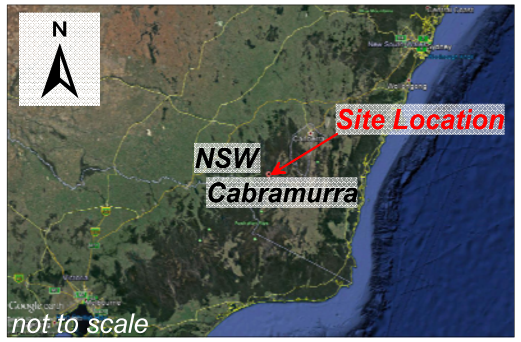
Seismic Refraction Tomography Survey
P-wave Velocity Model
SL4A_RL
W - E



Snowy Hydro 2.0 Sl04 RMS error 1.3%=3.33ms 30 WET iters. 50Hz Width 10.5% initial GRADIENT.GRD Vers. 3.35

Client: Snowy Hydro Limited			Job No.: **21/212692806**
Snowy 2.0 Geotechnical Investigation		Horizontal Axis Scale: 1:3200 @ A3 (0 50 100 150 Metres)	Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Geophysical Investigation			Snowy 2.0 Geotechnical Investigation Seismic Reflection / Refraction Survey SL4A_RL P-wave Velocity Model
Seismic Refraction Survey		Vertical to horizontal exaggeration 2 : 1	
scale	as shown	date 22/06/2018	N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ — **Figure A7**

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



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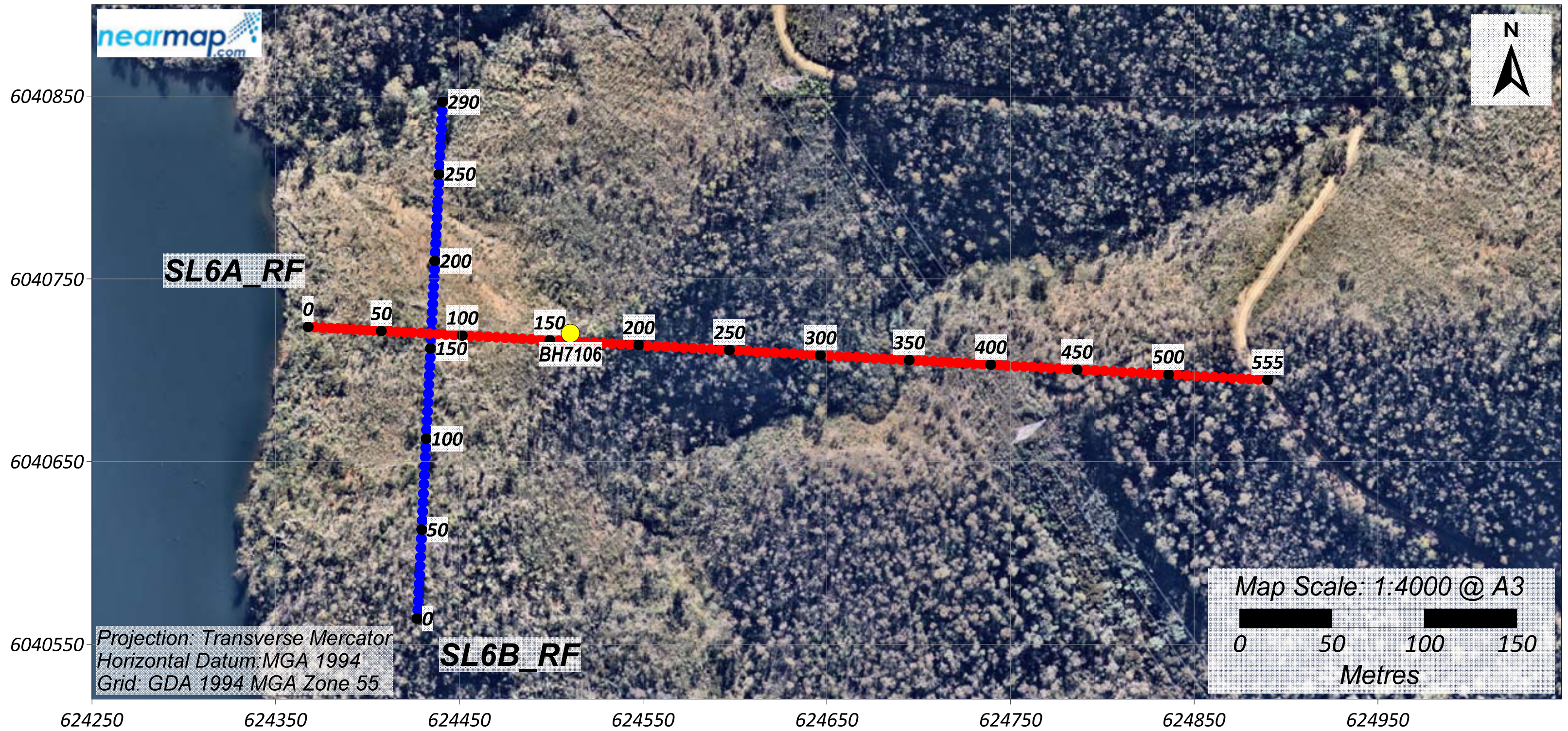
LEGEND:

- Surveyed SRT Line Location *(Plan view)* 100
- Displayed SRT Line Location *(Plan view)* 100
- Borehole Location *(Plan / Profile view)*
- Seismic shot points *(Profile view)*
- Seismic receivers *(Profile view)*

BH GEOLOGY LEGEND:

- Soil / Residual
- XW Rock
- HW / MW - SW Rock
- SW - Fr Rock
- Core Loss

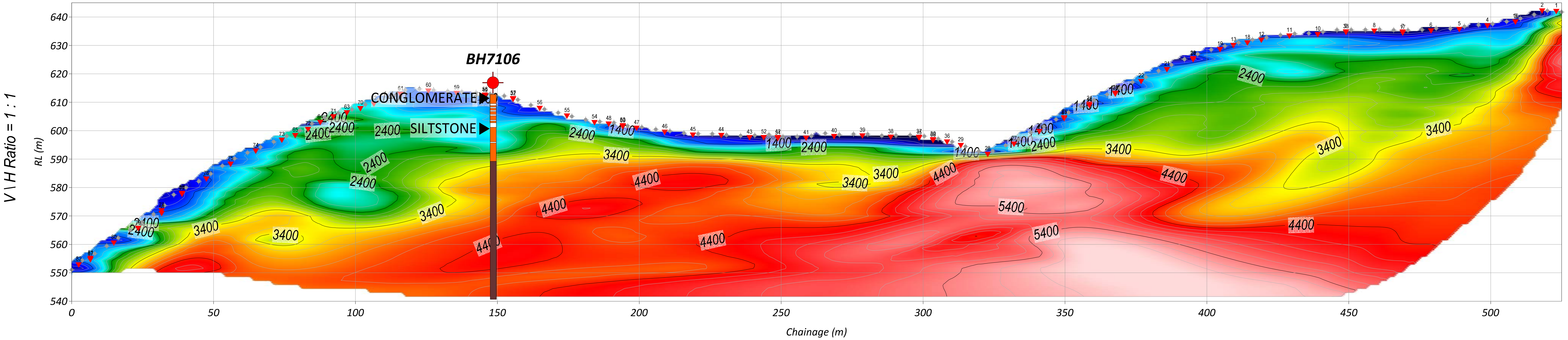
General Geological Description
For detailed subsurface material description refer to Borehole Logs

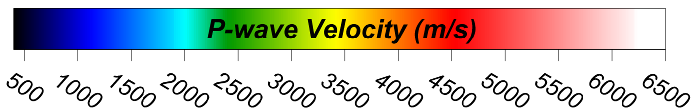


DRAFT

Seismic Refraction Tomography Survey
P-wave Velocity Model
SL6A_RF

W - E

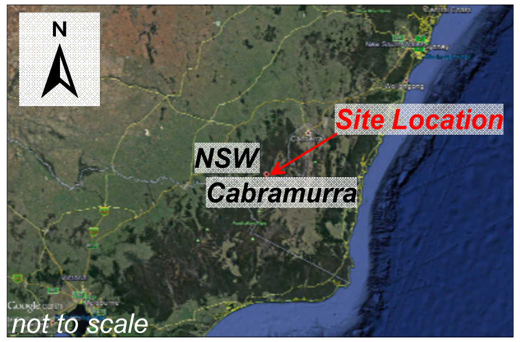




SNWSL06, 30 WET iterations, RMS error 1.7 %, 1D-Gradient smooth initial model, Version 3.32

Client: Snowy Hydro Limited		*Horizontal Axis Scale: 1:1400 @ A3*	Job No.: **21/212692806** ©
Snowy 2.0 Geotechnical Investigation		*0 20 40 60 Metres*	Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Geophysical Investigation			Snowy 2.0 Geotechnical Investigation Seismic Refraction Survey SL6A_RF P-wave Velocity Model
Seismic Refraction Survey			
scale	as shown	*Vertical to horizontal exaggeration 1 : 1*	
date 23/07/2018			N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ — **Figure A8**

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



LEGEND:

- Surveyed SRT Line Location *(Plan view)* — 100
- Displayed SRT Line Location *(Plan view)* — 100
- Seismic shot points *(Profile view)*
- Seismic receivers *(Profile view)*

Disclaimer:

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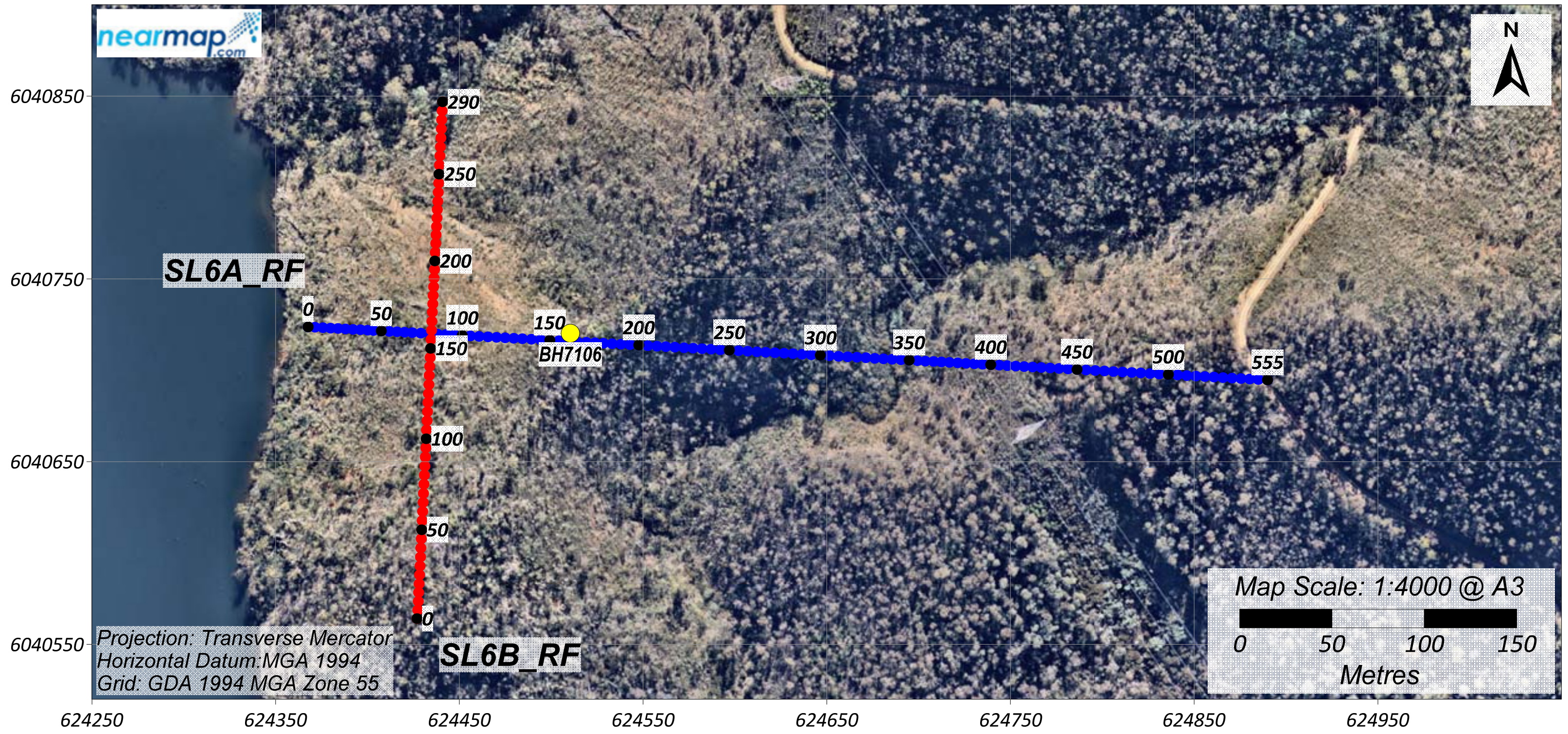
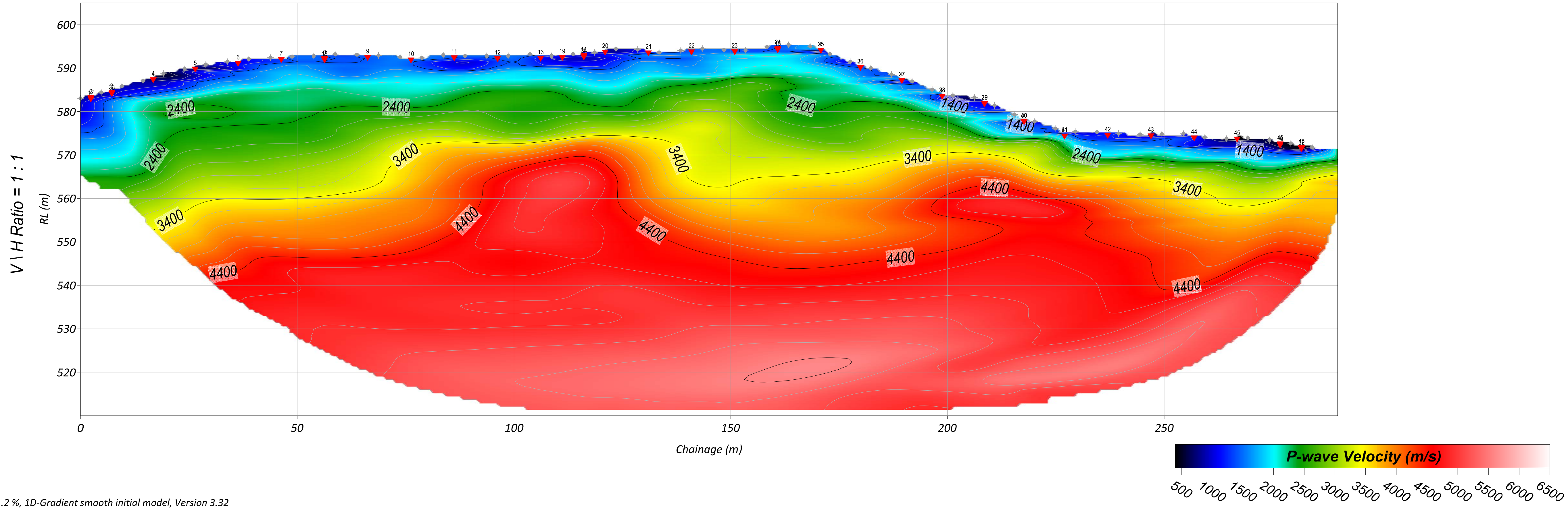


DRAFT

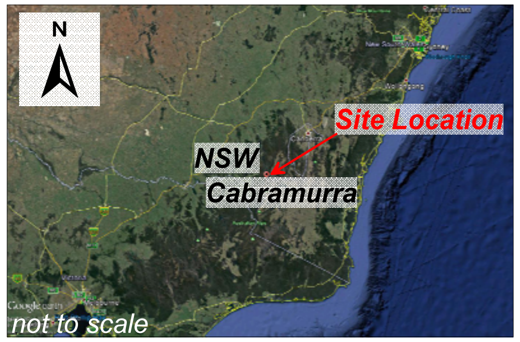
Seismic Refraction Tomography Survey
P-wave Velocity Model
SL6B_RF

S - N



SNWXSL06, 30 WET iterations, RMS error 1.2 %, 1D-Gradient smooth initial model, Version 3.32

Client: Snowy Hydro Limited	Horizontal Axis Scale: 1:1000 @ A3 0 10 20 30 40 Metres	Job No.: **21/212692806** Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Snowy 2.0 Geotechnical Investigation		Snowy 2.0 Geotechnical Investigation Seismic Refraction Survey SL6B_RF P-wave Velocity Model
Geophysical Investigation		
Seismic Refraction Survey	Vertical to horizontal exaggeration 1 : 1	
scale as shown date 23/07/2018		
Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au		N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ — **Figure A9**



LEGEND:

Surveyed SRT Line Location *(Plan view)* 100

Displayed SRT Line Location *(Plan view)* 100

Seismic shot points *(Profile view)*

Seismic receivers *(Profile view)*

Disclaimer:

Interpreted seismic profiles are subject to uncertainties due to seismic signal to noise ratio and due to the normal limitations of seismic refraction interpretation where a simple 2 or 3 layered model is imposed on a complex site with highly variable (laterally and vertically) anisotropic weathering and rock conditions.

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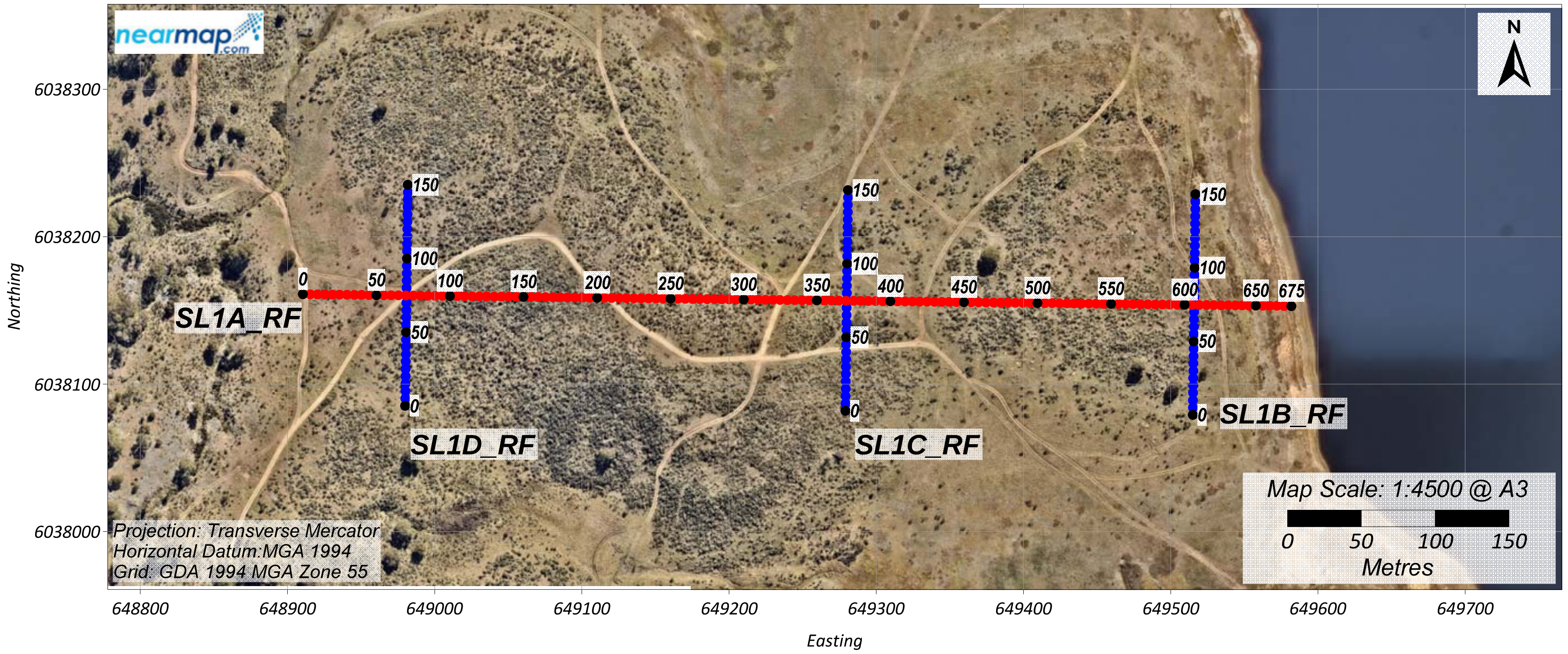
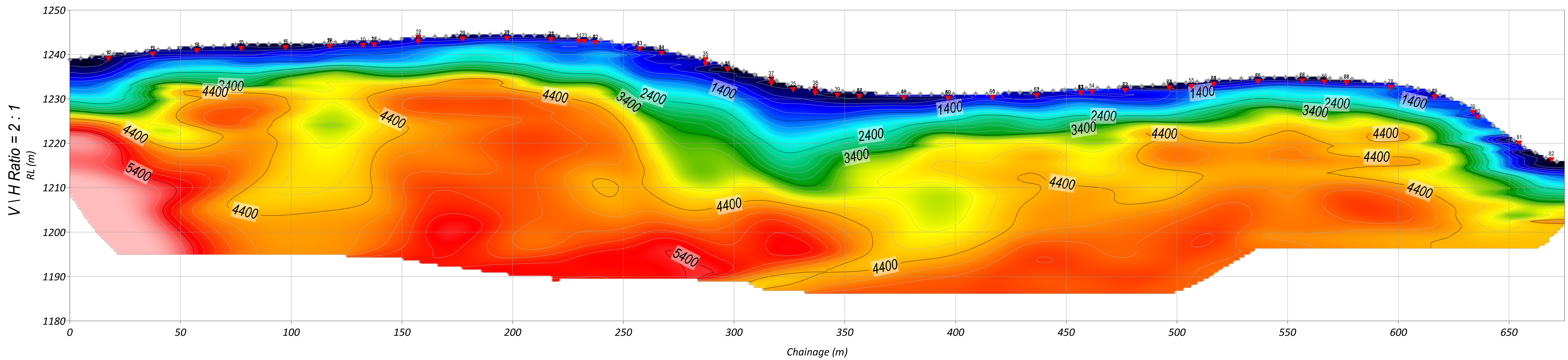
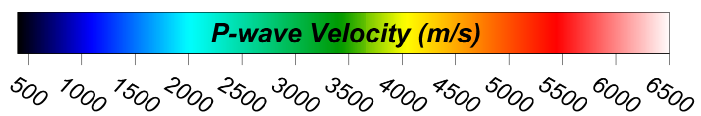


Seismic Refraction Tomography Survey
P-wave Velocity Model
SL1A_RF

W - E





SNWSL01, 30 WET iterations, RMS error 2.0 %, 1D-Gradient smooth initial model, Version 3.32

Client: Snowy Hydro Limited		Horizontal Axis Scale: 1:1800 @ A3 (0 20 40 60 80 Metres)	Job No.: **21/212692806** © Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Snowy 2.0 Geotechnical Investigation			Snowy 2.0 Geotechnical Investigation Seismic Refraction Survey SL1A_RF P-wave Velocity Model
Geophysical Investigation			
Seismic Refraction Survey		*Vertical to horizontal exaggeration 2 : 1*	
scale	as shown	date 22/06/2018	N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ — **Figure** 21-26928-GT-RPT-R2_App O-O1

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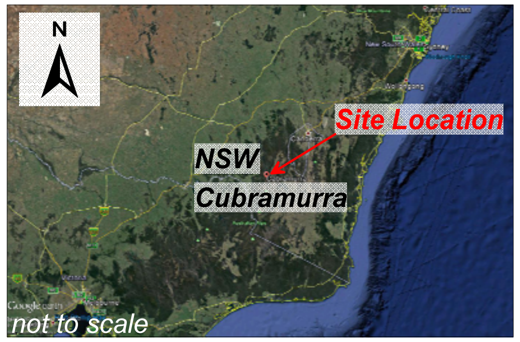

LEGEND:

- Surveyed SRT Line Location *(Plan view)* 100
- Displayed SRT Line Location *(Plan view)* 100
- Seismic shot points *(Profile view)*
- Seismic receivers *(Profile view)*

Disclaimer:

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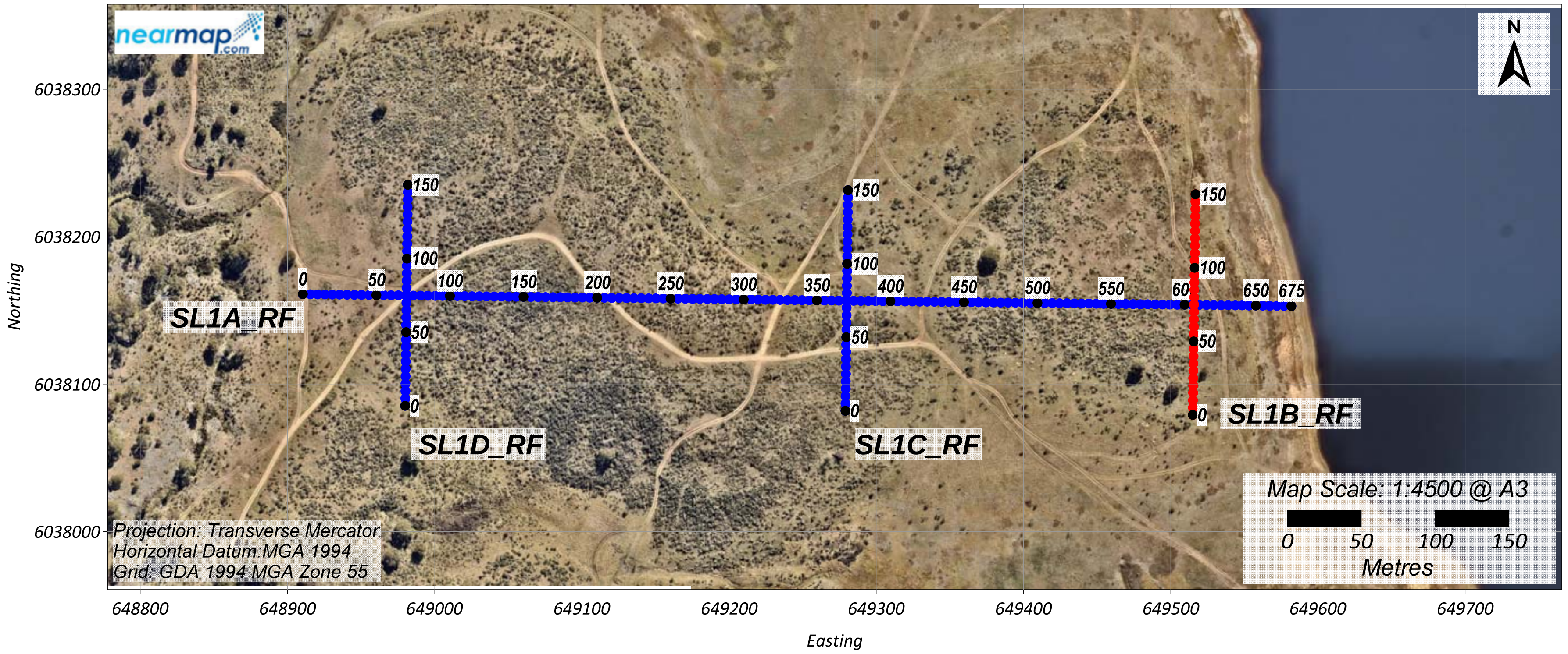
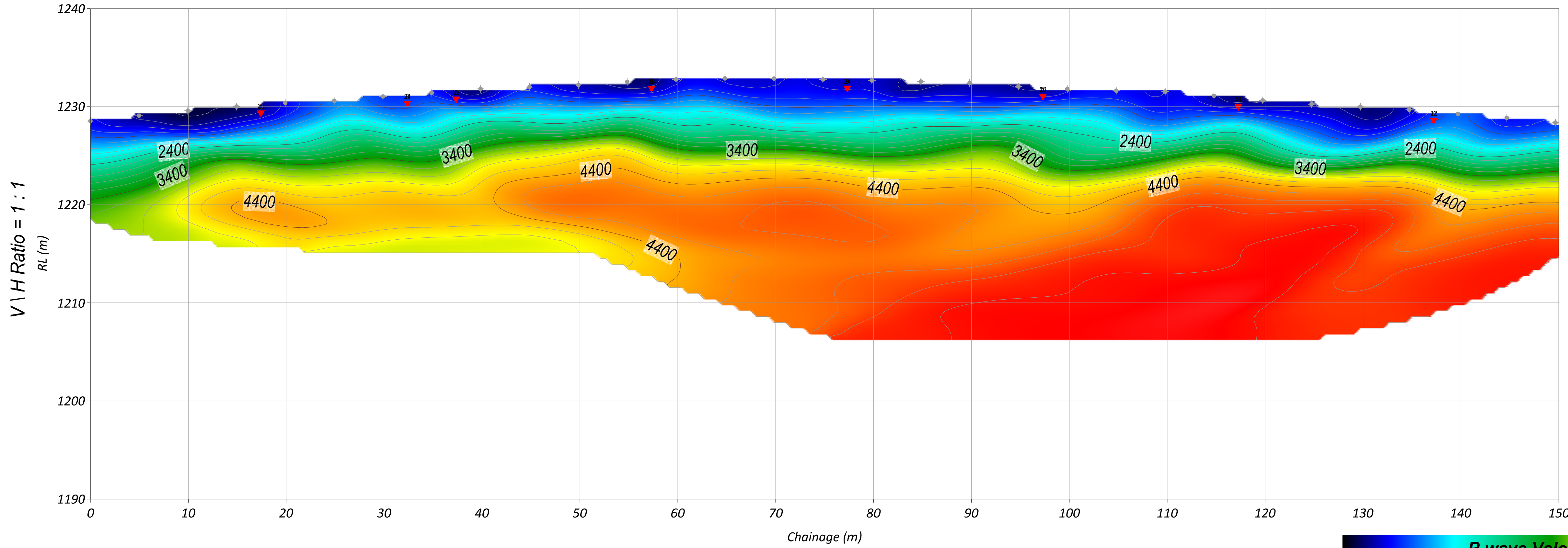
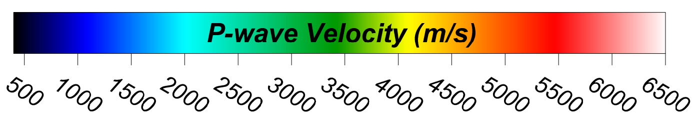


Seismic Refraction Tomography Survey
P-wave Velocity Model
SL1B_RF
S - N

DRAFT

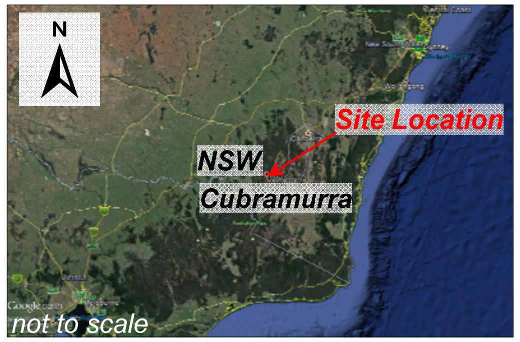




SNWXSL1A, 30 WET iterations, RMS error 1.5 %, 1D-Gradient smooth initial model, Version 3.32

Client: Snowy Hydro Limited	*Horizontal Axis Scale: 1:500 @ A3* 0 10 20 Metres	Job No.: **21/212692806** Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Snowy 2.0 Geotechnical Investigation		Snowy 2.0 Geotechnical Investigation
Geophysical Investigation		Seismic Refraction Survey
Seismic Refraction Survey	*Vertical to horizontal exaggeration 1 : 1*	SL1B_RF P-wave Velocity Model
scale as shown date 22/06/2018		N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ **Figure** 21-26928-GT-RPT-R2_App O-O2

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au



LEGEND:

Surveyed SRT Line Location *(Plan view)* 100

Displayed SRT Line Location *(Plan view)* 100

Seismic shot points *(Profile view)*

Seismic receivers *(Profile view)*

Disclaimer:

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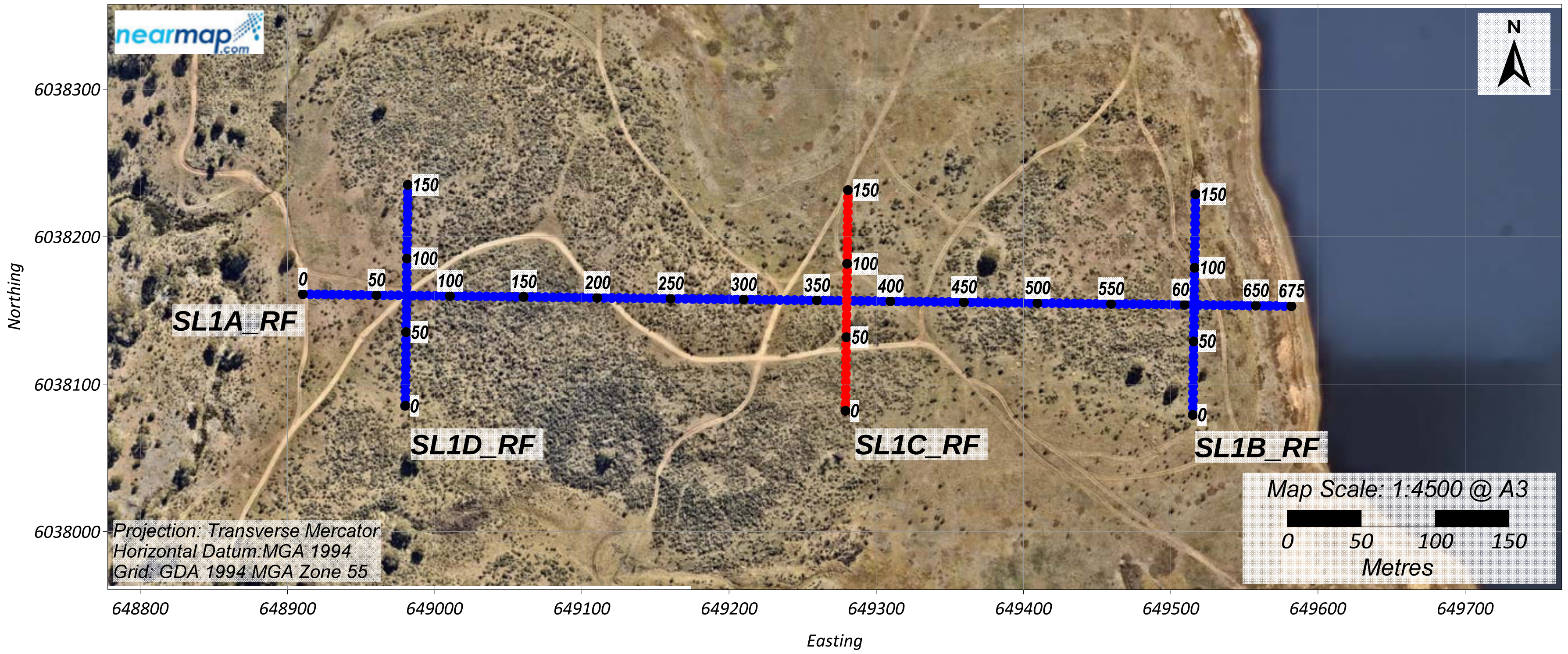
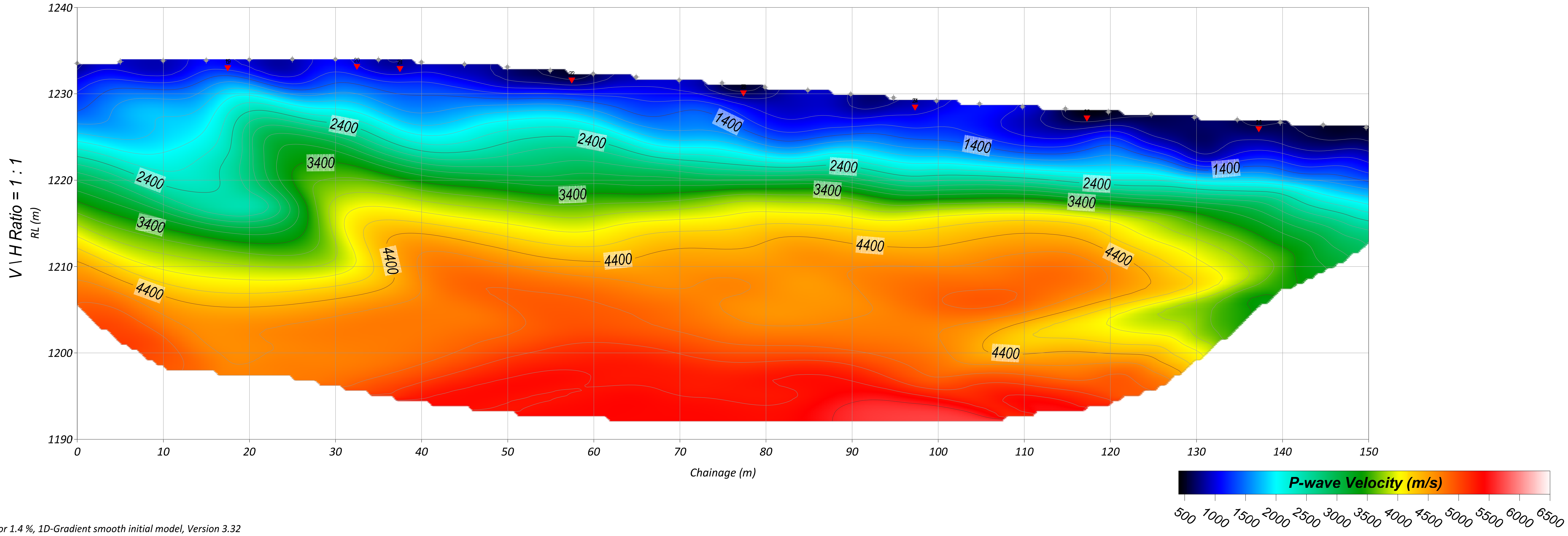


Seismic Refraction Tomography Survey
P-wave Velocity Model
SL1C_RF

S - N

DRAFT



SNWXSL1B, 30 WET iterations, RMS error 1.4 %, 1D-Gradient smooth initial model, Version 3.32

GHD

snowy 2.0

Client: Snowy Hydro Limited			
Snowy 2.0 Geotechnical Investigation			
Geophysical Investigation			
Seismic Refraction Survey			
scale	as shown	date 22/06/2018	

Horizontal Axis Scale: 1:500 @ A3

0 10 20
Metres

Vertical to horizontal exaggeration 1 : 1

Job No.: **21/212692806** ©

Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Refraction Survey
SL1C_RF P-wave Velocity Model

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure
21-26928-GT-RPT-R2_App O-O3

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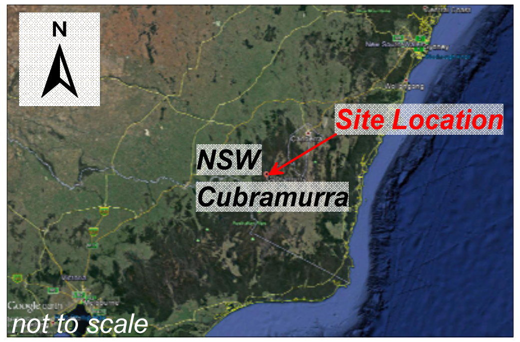

LEGEND:

Surveyed SRT Line Location *(Plan view)* 100

Displayed SRT Line Location *(Plan view)* 100

Seismic shot points *(Profile view)*

Seismic receivers *(Profile view)*

Disclaimer:

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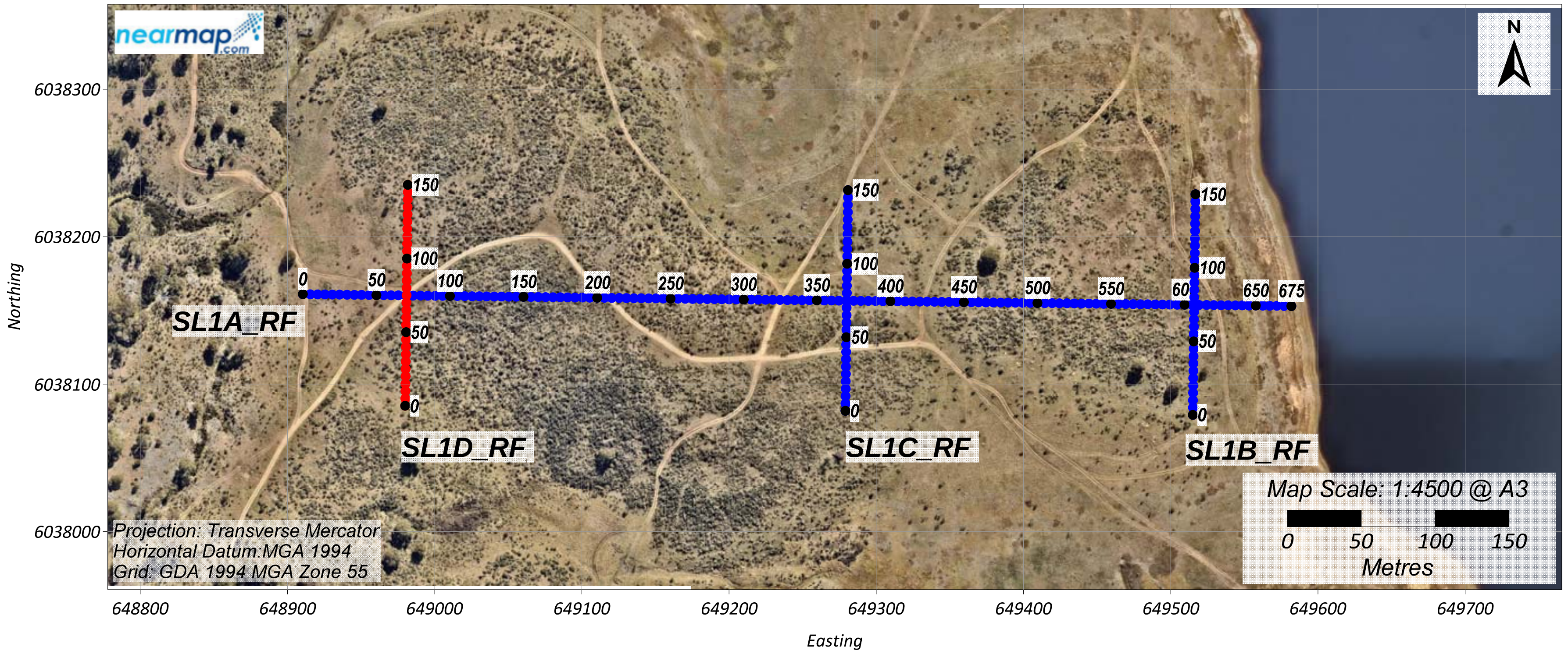
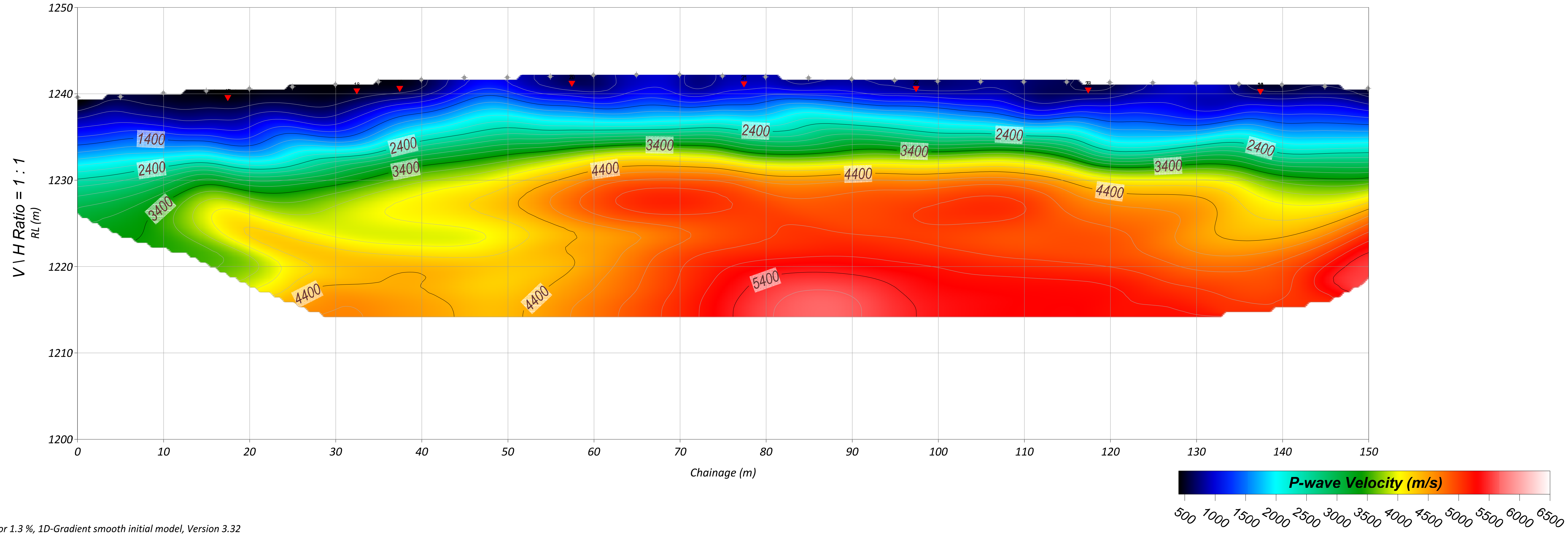


Seismic Refraction Tomography Survey
P-wave Velocity Model
SL1D_RF

S - N

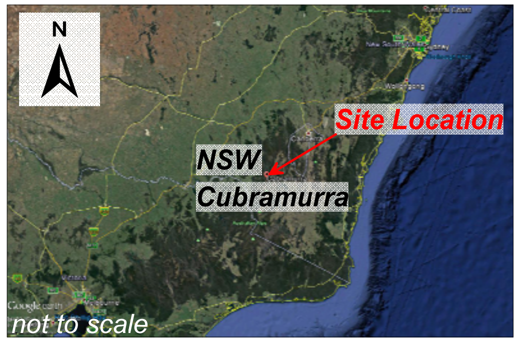
DRAFT



SNWXSL1C, 30 WET iterations, RMS error 1.3 %, 1D-Gradient smooth initial model, Version 3.32

Client: Snowy Hydro Limited	*Horizontal Axis Scale: 1:500 @ A3* 0 10 20 Metres	Job No.: **21/212692806** © Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/
Snowy 2.0 Geotechnical Investigation		Snowy 2.0 Geotechnical Investigation
Geophysical Investigation		Seismic Refraction Survey
Seismic Refraction Survey	*Vertical to horizontal exaggeration 1 : 1*	SL1D_RF P-wave Velocity Model
scale as shown date 22/06/2018		N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/ **Figure** 21-26928-GT-RPT-R2_App O-O4

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

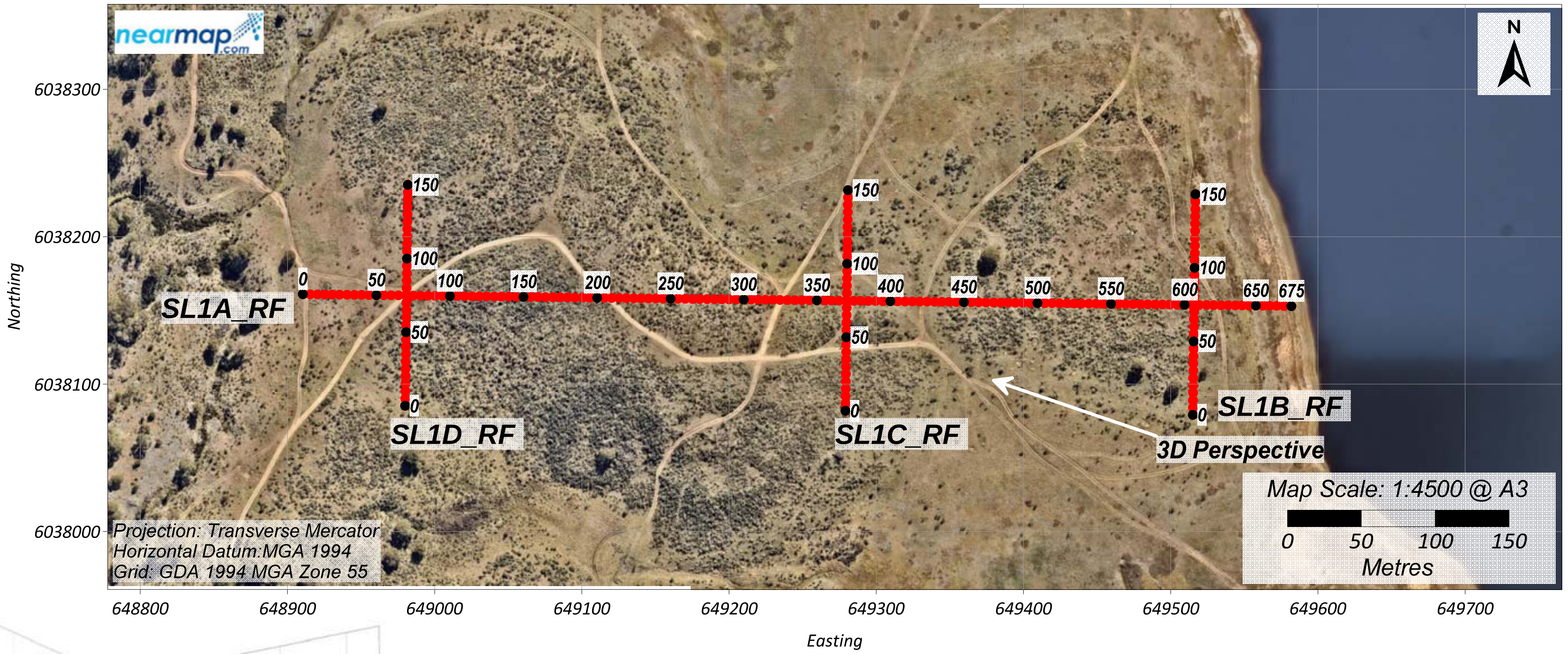


LEGEND:

Displayed SRT Line Location *(Plan view)* — 100

Seismic shot points *(Profile view)*

Seismic receivers *(Profile view)*



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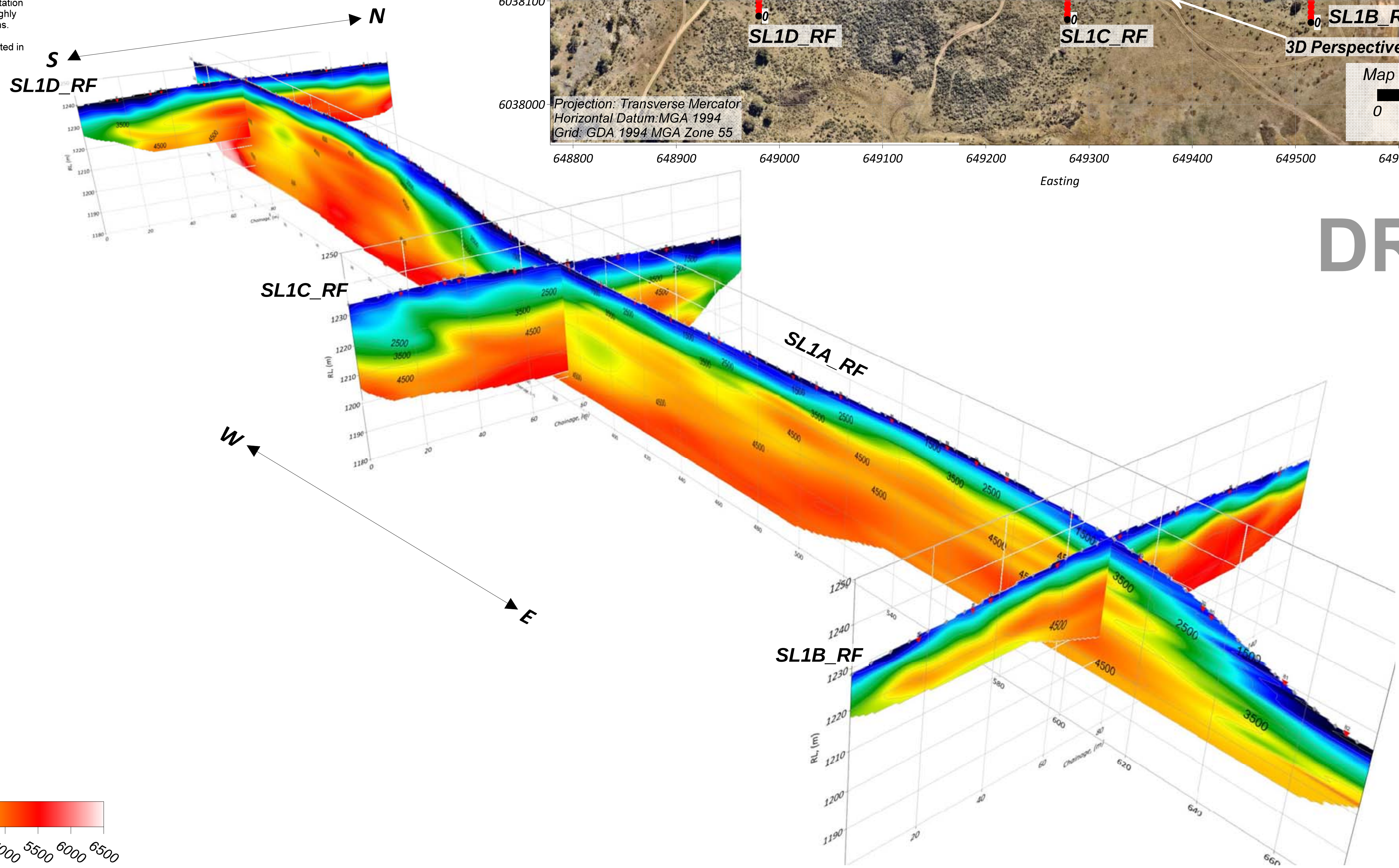
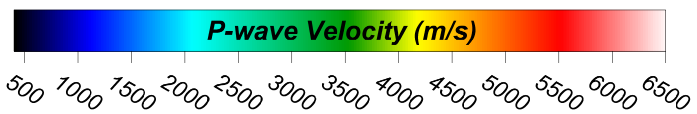
DRAFT





Client: Snowy Hydro Limited	*not to scale*
Snowy 2.0 Geotechnical Investigation	
Geophysical Investigation	
Seismic Refraction Survey	*Vertical to horizontal exaggeration 1 : 1*
scale as shown date 22/06/2018	

Job No.: **21/212692806** ©

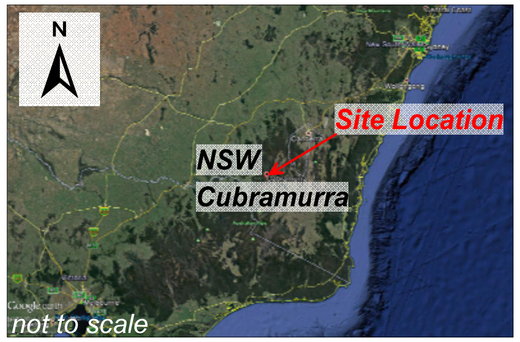
Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Snowy 2.0 Geotechnical Investigation
Seismic Reflection / Refraction Survey 3DView 1
SL1A_RF, SL1B_RF, SL1C_RF and SL1D_RF

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

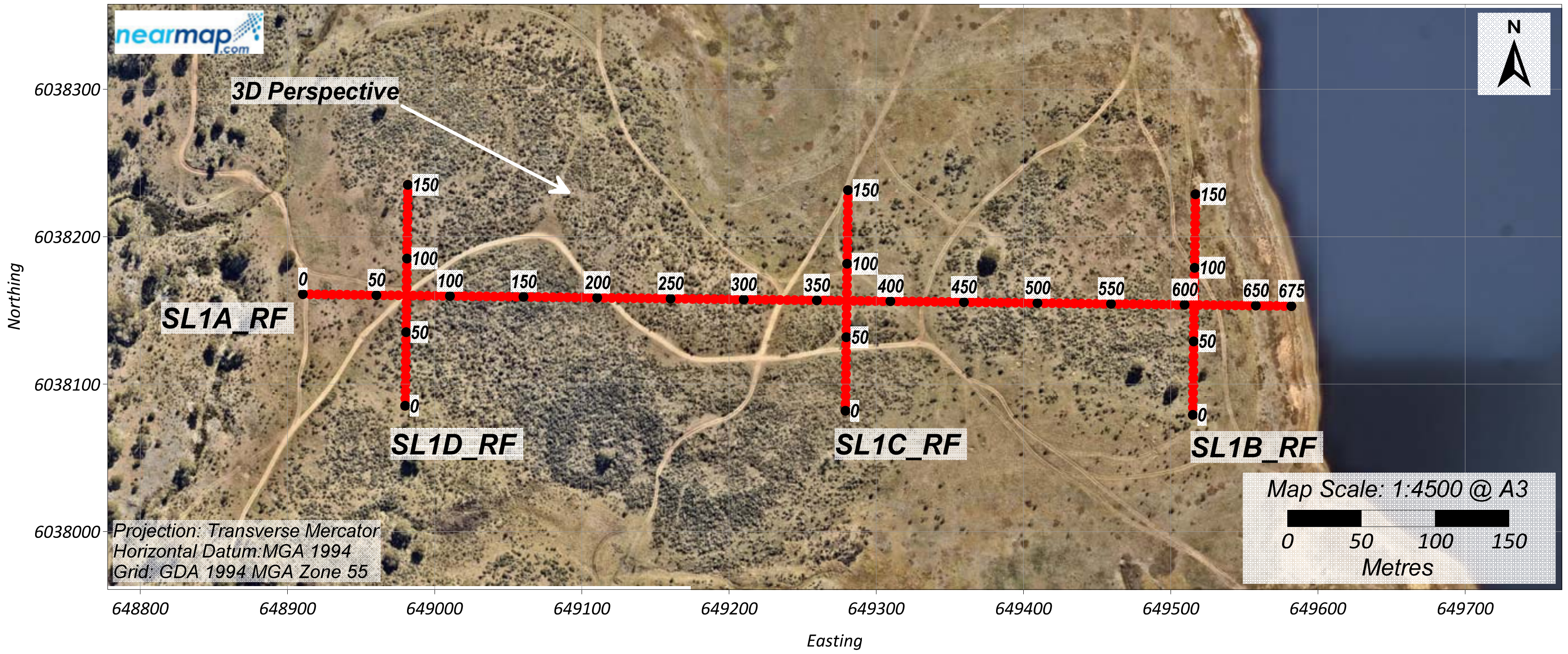
Figure
21-26928-GT-RPT-R2_App O-O5

Level 8, 180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

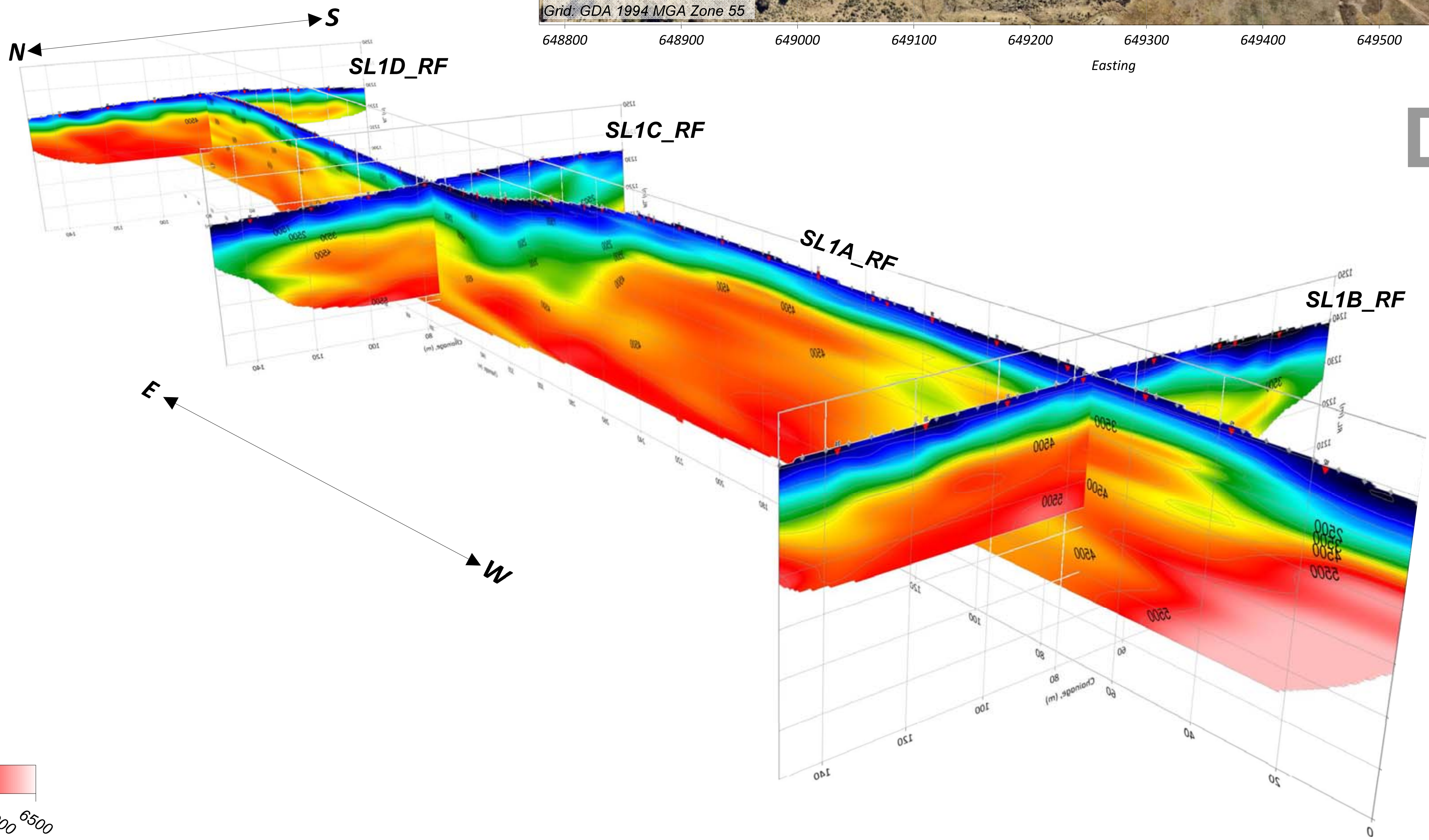


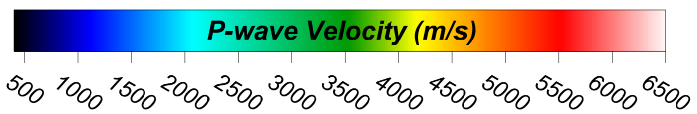
LEGEND:

Displayed SRT Line Location *(Plan view)*	100
Seismic shot points *(Profile view)*	▼
Seismic receivers *(Profile view)*	✦



DRAFT





Client: Snowy Hydro Limited			not to scale	Job No.: **21/212692806** ©
Snowy 2.0 Geotechnical Investigation				Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/ Geophysics/Report/Figures/
Geophysical Investigation				Snowy 2.0 Geotechnical Investigation Seismic Reflection / Refraction Survey 3DView 2 SL1A_RF, SL1B_RF, SL1C_RF and SL1D_RF
Seismic Refraction Survey				
scale	as shown	date 22/06/2018	*Vertical to horizontal exaggeration 1 : 1*	N:/AU/Melbourne/Projects/21/2692806/ Tech/Geophysics/Report/Figures/ — **Figure** 21-26928-GT-RPT-R2_App O-O6

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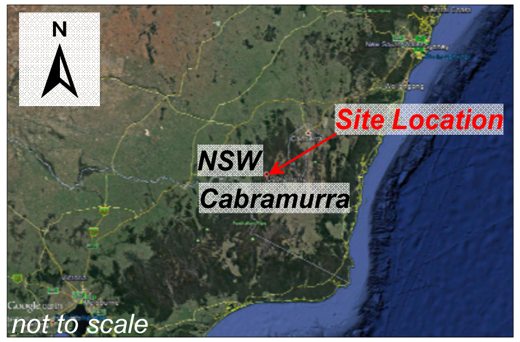
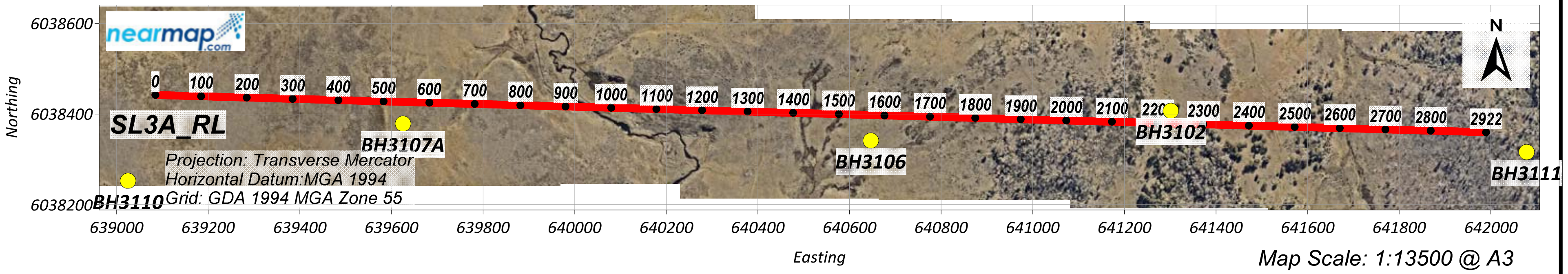


LEGEND:

- Displayed SRT Line Location *(Plan view)*
- Borehole *(Plan / Profile View)*
- Seismic shot points *(Profile view)*
- Seismic receivers *(Profile view)*



Map Scale: 1:13500 @ A3

0 200 400 600
Metres

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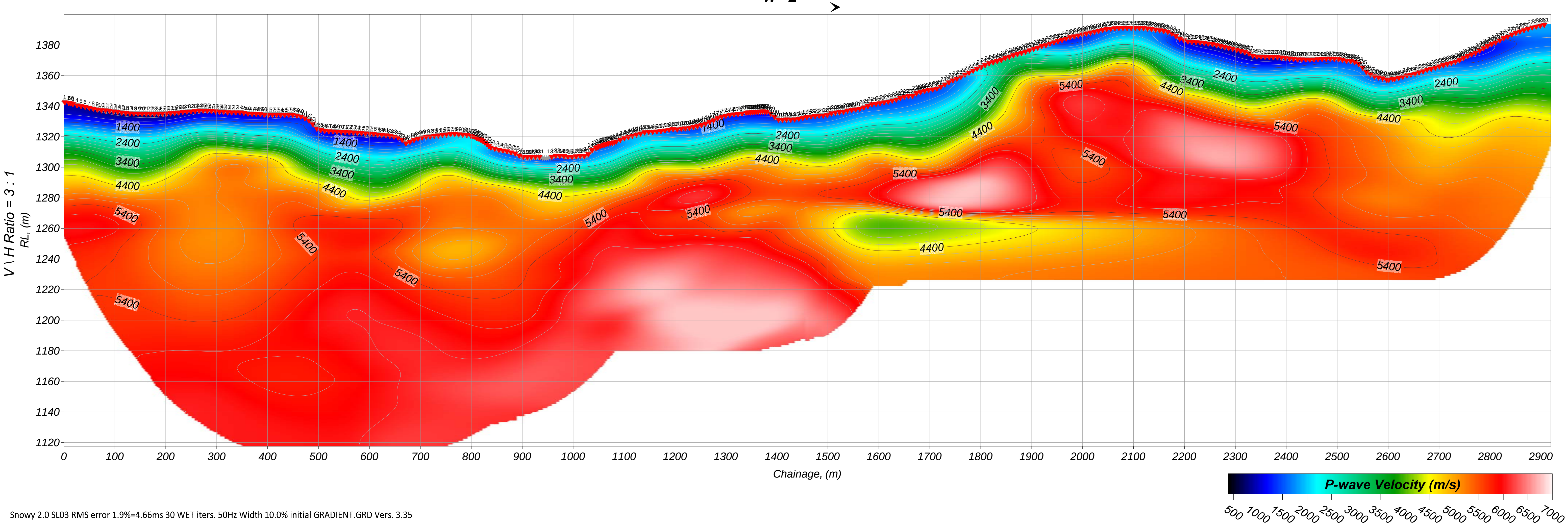
DRAFT

Seismic Refraction Tomography Survey
P-wave Velocity Model
SL3A_RL
W - E



Snowy 2.0 SL03 RMS error 1.9%=4.66ms 30 WET iters. 50Hz Width 10.0% initial GRADIENT.GRD Vers. 3.35

Client: Snowy Hydro Limited	*Horizontal Axis Scale: 1:3200 @ A3*	Job No.: **21/212692806**	©
Snowy 2.0 Geotechnical Investigation	0 50 100 150 *Metres*	Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/	
Geophysical Investigation		Snowy 2.0 Geotechnical Investigation Seismic Reflection / Refraction Survey SL3A_RL P-wave Velocity Model	
Seismic Refraction Survey			
scale as shown date 22/06/2018	*Vertical to horizontal exaggeration 3 : 1*	N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/	**Figure** 21-26928-GT-RPT-R2_App O-07

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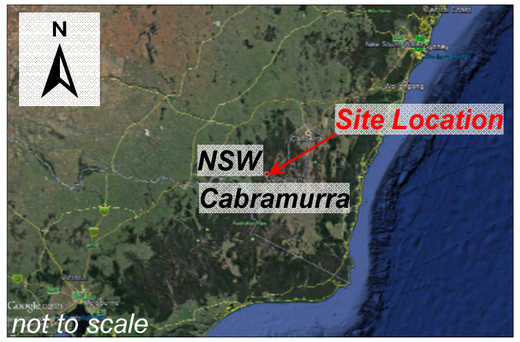


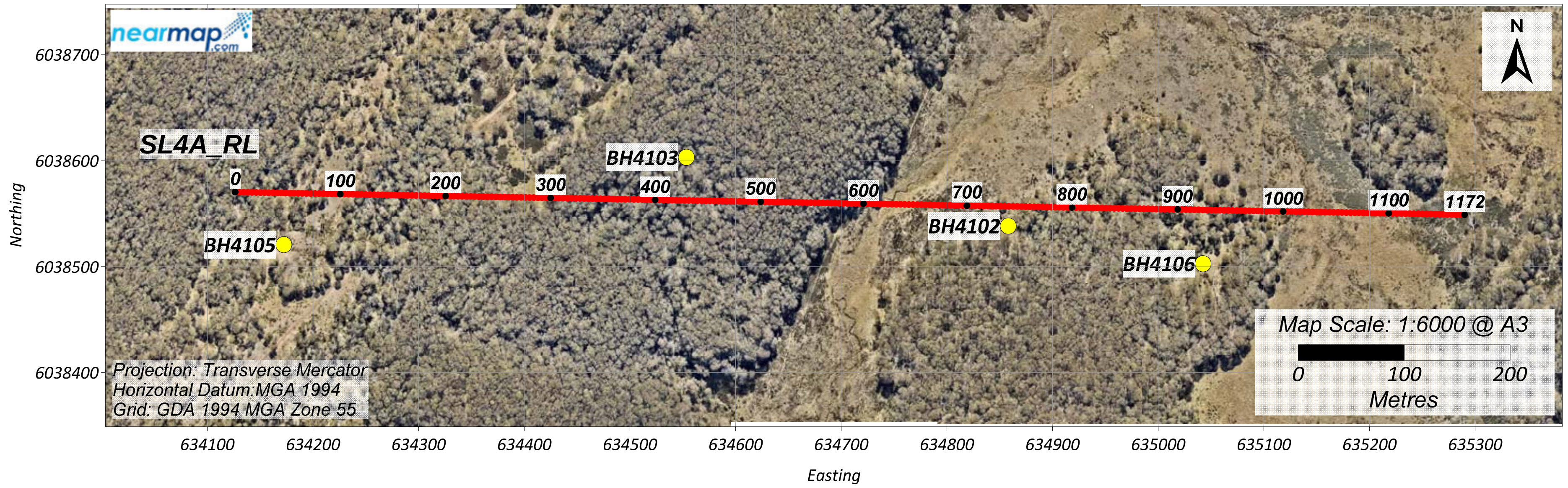
LEGEND:

Displayed SRT Line Location *(Plan view)* 100

Borehole *(Plan / Profile View)*

Seismic shot points *(Profile view)*

Seismic receivers *(Profile view)*



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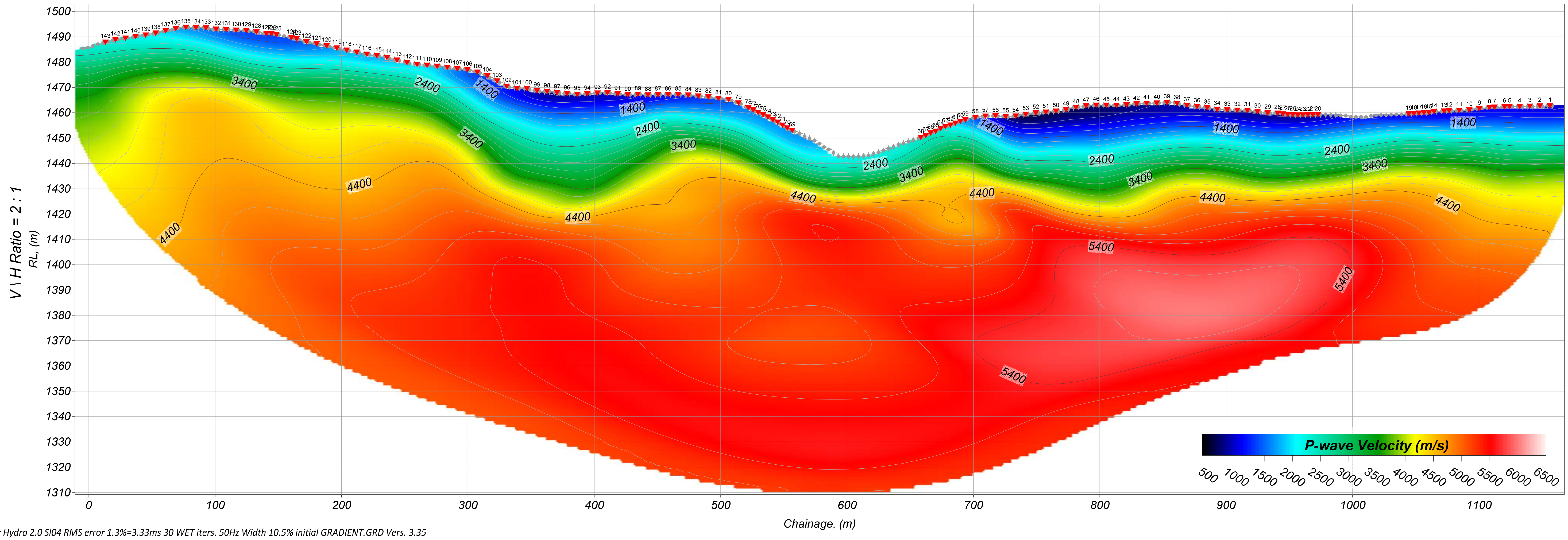
DRAFT

Seismic Refraction Tomography Survey
P-wave Velocity Model
SL4A_RL

W - E



Snowy Hydro 2.0 Sl04 RMS error 1.3%=3.33ms 30 WET iters. 50Hz Width 10.5% initial GRADIENT.GRD Vers. 3.35

GHD

snowy 2.0

Client: Snowy Hydro Limited	
Snowy 2.0 Geotechnical Investigation	
Geophysical Investigation	
Seismic Refraction Survey	
scale as shown	date 22/06/2018

Horizontal Axis Scale: 1:3200 @ A3

0 50 100 150
Metres

Vertical to horizontal exaggeration 2 : 1

Job No.: **21/212692806**

Ref file: N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

©

Snowy 2.0 Geotechnical Investigation
Seismic Reflection / Refraction Survey
SL4A_RL P-wave Velocity Model

N:/AU/Melbourne/Projects/21/2692806/Tech/Geophysics/Report/Figures/

Figure
21-26928-GT-RPT-R2_App O-O8

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