Mt Buller and Mt Stirling Alpine Resort Management Board (RMB)

Mt Buller Sustainable Water Security | Off Stream Storage Project

Geotechnical Risk Assessment

August 2016

Table of contents

Table index

Figure index

Appendices

1. Introduction

1.1 General

The Mt Buller and Mt Stirling Alpine Resort Management Board (RMB) is responsible for the management of the Mt Buller and Mt Stirling Resorts. These Resorts cover an area of 5000 hectares in north-east Victoria. The RMB has a series of performance obligations and objectives associated with its management of Mt Buller and Mt Stirling. One of these objectives is the provision of a safe and reliable water supply.

The Mt Buller Alpine Resort (the Resort) has significant constraints on its water supply. The water requirements of the Resort are determined by the need to service the resident and visitor populations, and to maintain the amenity and functionality of the Resort during winter for skiing and snow-play.

The RMB has established the Mt Buller Sustainable Water Security Project which encompasses a series of projects designed to assist it in meeting its obligation to provide a secure and reliable water supply to the Resort, both now and in the future. One component of the Mt Buller Sustainable Water Security Project is the development of an Off-Stream Storage facility and an associated upgrade of the Resort water supply and treatment infrastructure. Based on a number of previous investigations, assessments and reviews, the RMB have determined that a 100 ML on-mountain storage is required to assist it in meeting future water supply demands.

GHD Pty Ltd (GHD) was engaged by the RMB to undertake geotechnical and hydrogeological investigations as part of a proposed water storage development as part of the Mt Buller Sustainable Water Security – Off Stream Storage Project.

GHD were commissioned by RMB to provide services for the design phase of the project.

It is a requirement that a Geotechnical Risk Assessment Report be prepared when a planning permit is required under the Erosion Management Overlay (EMO) of the Alpine Resorts Planning Scheme. This report presents the findings of the Land Stability Geotechnical Risk Assessment for the Mt Buller Sustainable Water Security Project – Off Stream Storage Project.

This report reviews and qualitatively assesses the landslide risks identified at the proposed project sites in accordance with the requirements of the Alpine Resorts Planning Scheme EMO and Australian Geomechanics, ‘Practice Note Guidelines for Landslide Risk Management’, Volume 42 No.1, March 2007.

1.2 Proposed project works

The proposed project involves the construction of a 100 ML, HDPE lined water storage by cut and fill methodologies. A full drainage blanket is to be installed below the HDPE liner. The proposed southern bank of the storage comprises the natural excavated ground whilst the northern boundary of the storage is formed by an earthfill embankment. Owing to the fact that the dam is to be fully lined, no zoning of the earthfill embankment is planned. Additional infrastructure associated with the project includes:

- Storage drainage – connecting to existing aqueduct;
- Storage transfer pump station;
- Sun Valley pipeline – to allow transfer of water from the new storage to the Sun Valley Reservoir;
- Raw water supply pipeline to treatment plant and low level reticulation network;
- Raw water supply break tank and booster pump station;

- Raw water supply pipeline from booster pump station to new water storage;
- Summit carpark access road re-alignment;
- Control Centre access road;
- An environmental watering system; and
- Stockpile areas.

This infrastructure is detailed in the concept design report and can be seen in the concept design drawings presented in Figure 1.

The major construction processes involved in the proposed works are as follows:

- Excavation of the existing soils under the embankment footprint to form suitable stepped foundations;
- Excavation of the internal reservoir footprint to a base level of between RL 1724.23 m and 1724.05 m, resulting in cuts of up to 10.27 m below existing surface level;
- Construction of compacted embankments, ranging between 11.45 m vertical height (internal) and 17.8 m vertical height externally. Embankment slopes are planned to be 2.5 H to 1 V downstream and have a crest RL of 1735.5 m;
- Using the two areas to the east and west of the site nominated for temporary stockpiling of excavated spoil/fill, oversize fractions and topsoil materials;
- Earthworks consisting of small cuts will be undertaken to construct the pump stations, storage drainage outlet and pump station as well as associated infrastructure;
- Construction of a new road to the south of the dam; and
- Trenching and backfilling within the existing slopes to install service pipelines.

1.3 Scope of study

The scope of this assessment includes the following:

- Review of concept design documents of the Mt Buller Sustainable Water Security Project;
- Review of the geotechnical information available from geotechnical investigations carried out during site selection and concept and design of the storage facility;
- Review of site visit records and geomorphological and geological mapping of the site;
- Risk assessment of the site in relation to existing geohazards affecting the proposed storage and associated infrastructure. In this regard, and as discussed later, the risk assessment presented herein does not attempt to address issues associated with the dam embankments, and the challenges associated with a fault tree analysis as well as “what if” scenarios. Those are issues that will be considered within the detailed design of the dam embankments. Suffice to say, that herein, and by way of demonstration of the fully operational and fully functional situation, illustrative dam embankment assessments have been included to illustrate performance of the dam system; and
- Completion of this report providing advice on risk minimisation strategies, if required.

1.4 Available information

A review of available information was undertaken as part of the assessment. This included:

- 1:250,000 scale Warburton Geological Map produced by the Geological Survey of Victoria;
- Mount Buller Storage Options, General Arrangement Services, Draft GHD Drawing no. 31-30733-FIG62.
- GHD Report, *“Factual Geotechnical Report*”, doc no 31/30733/13/230606, June 2014;
- GHD Report, “*Factual Hydrogeological Report*”, doc no, 31/30733/231823, June 2014;
- GHD Report, *“New 100 ML Concept Design Report*”, doc no 31/30733/232855, May 2014;
- GHD 2015 Mt Buller Sustainable Water Security Project – Off-Stream Storage. Review of Alpine Bog Ecology, Hydrogeology and Additional Investigations. Report #242542, Report for the Mt Buller and Mt Stirling Alpine Resort Management Board; and
- GHD Report, “Off-Stream Storage Concept Design Summary” doc no. 31/3073322/253326, July 2016.

1.5 Sources of information

Plans of the proposed project were reviewed along with the concept design reports which included slope stability assessments of the cut and fill slopes of the water storage cuttings and embankments. Concept design drawings showing the extents of the works are shown in Appendix A. Details relating to the slope stability analysis carried out for the project are presented in the Concept Design Report.

Information on geotechnical investigations that have been carried out at the site and laboratory testing of site soils was obtained from the concept design stage Geotechnical Factual Report. Detailed LiDAR topographic information of the site and surrounding area was also made available for this project.

Using the LiDAR information several possible landslide features were identified across the general project area. The existing and potential landslide locations and their relation to the proposed works are shown in Figure 1 of this report.

1.6 Limitations

This Report is confidential and has been prepared by GHD for Mt Buller and Mt Stirling Alpine Resort Management Board (RMB) (the Client) and:

- May only be used and relied on by the Client;
- Must not be copied to, used by, or relied on by any person other than the Client; and
- May only be used for the purpose of geotechnical hazard and risk assessment and project related planning approvals (and must not be used for any other purpose).

GHD and its servants, employees and officers expressly disclaim responsibility to any person other than the Client arising from or in connection with this Report.

This Report should not be altered, amended or abbreviated, issued in part or issued incomplete in any manner whatsoever without prior checking and approval by GHD which GHD may provide or withhold in its absolute discretion. GHD expressly disclaims responsibility for any liability which may arise from circumstances of issue of this Report in part or incomplete or its modification in any way whatsoever.

To the maximum extent permitted by law, all implied warranties and conditions in relation to the services provided by GHD and this Report are expressly excluded.

The services undertaken by GHD in connection with preparing this Report were limited to those specifically detailed in Section 1.3 of this Report.

GHD has prepared this Report on the basis of information provided by the Client, which GHD has not independently verified or checked (Unverified Information). GHD expressly disclaims responsibility in connection with the Unverified Information, including (but not limited to) errors in, or omissions from, this Report which were caused or contributed to by errors in, or omissions from, the unverified Information.

GHD expressly disclaims responsibility for any error in, or omission from, this Report arising from or in connection with any of the Assumptions being incorrect.

The opinions, conclusions and any recommendations in this Report are based on information obtained from, and testing undertaken at or in connection with, specific sample points at site. Site conditions at other parts of the site may be different from the site conditions found at the specific sample or observation locations.

Site conditions (including the presence of any hazardous substances and/or site contamination) may change after the date of this Report. GHD expressly disclaims responsibility:

- Arising from, or in connection with, any change to the site conditions; and
- To update this Report if the site conditions change.

2. Description of Site

2.1 Surface conditions

The site location and a layout of the proposed works is presented on GHD Plan "Project Concept Design" – Revision D in Appendix A. The project site is situated towards a broad ridge which runs eastwards from the peak of Mount Buller. The plateau formed by this broad ridgeline continues to the south for approximately 400 m before descending to the river valley to the south which is in the Goulburn River Catchment. Immediately towards the north, the slope increases in steepness towards Boggy Creek which is in the Delatite River catchment. The existing slopes are utilized as ski runs during the winter months and are as such generally vegetated with grasses and low shrubs. Areas of rock outcrop are present towards the south east of the proposed storage area. The graveled Summit Road currently traverses from east to west across the proposed storage location. Indicative slope angles and topographical contours as well as the location of all main components of the project assessed in this report are displayed on Figure 1.

The proposed pump station and drainage blanket outlet are situated on the northward facing slope immediately to the north of an existing walking track.

The proposed main pipeline runs from the proposed water storage to the existing treatment plant around the base of a very steep slope on which the Control Building is constructed and then traverses across and down the slope towards the existing treatment plant. The proposed pipeline alignment coincides with an existing vehicular access track. Some evidence of recent ground disturbance was found along the track towards the treatment plant. This is thought to be associated with maintenance or repair of existing pipelines running through this area. Another pipeline returning treated water to the reservoir is proposed to be constructed along the same alignment.

A large scale historical landslide appears to have occurred where a major groundwater outflow or spring occurs towards the north west of the storage location. This is thought to have resulted from the over-steepening of the weathered granite material as the spring flows eroded the soil material. Smaller scale landslides caused by similar processes are located immediately to the north of the proposed pipeline alignment. A series of smaller scale landslides are present immediately to the south of the proposed main pipeline alignment. It is considered that these possible failures have occurred along the boundary between basalt rock and the underlying carbonaceous mudstone, with a possible failure surface coinciding with this boundary.

Areas of historical ground disturbance either in the form of filling or excavation are evident over much of the project areas. These are expected to be due to the construction of ski runs and infrastructure and clearing of the mountain. Photographs showing surface conditions are presented in Appendix B

2.2 Summary of geotechnical investigations

Extensive geotechnical investigations have been carried out at the site for the concept design stage from November 2013 to March 2014. Investigations have primarily focused on the storage location.

Fifteen (15) geotechnical boreholes and nine (9) geotechnical test pits were drilled and excavated across the storage footprint. Details of the geotechnical investigations and geotechnical logs are presented in the concept design geotechnical investigation report (June 2014).

The site investigations were undertaken to characterise conditions within the footprint of the proposed water storage, to determine potential borrow materials, and establish groundwater conditions.

Lithological logs including bore construction details have been documented in the 2014 geotechnical factual report by GHD.

2.3 Regional geology

The geology of the site is shown on the 1:250,000 scale Warburton geological map. This map is of large scale and lacks detail of the summit of Mt Buller. The map indicates the presence of two Tertiary Eocene to Oligocene age outcrops of Older Volcanics tholeiitic basalt overlying the Devonian age Mount Stirling Granodiorite.

2.4 Subsurface conditions

The subsurface intrusive investigations confirmed the regional mapping, with granite rock being confirmed as the basement rock in a number of investigation locations. The granite was intruded during the Devonian period with a subsequent period of uplift, exhumation and weathering. Eventually the granite formed a prehistoric land surface for an uncertain period of time. During this period the rock surface became deeply weathered and soil like. With increasing depth beneath the project area the granite becomes less weathered and more competent.

Since the early Tertiary period, the granite has been capped in places with a relatively complex lithological profile comprising several phases of deposition of sediments and volcanics. These filled a palaeovalley formed in the Devonian granite which still exists beneath the project area. The commencement of valley infilling began in the early Tertiary and was possibly related to the relatively rapid uplift of the area. A significant deposit of colluvium comprising mostly cobble and boulder size high strength sandstone was deposited into the base of the valley. The colluvial material has been interpreted to depths of between 0.7 m (test pit TP03) and 21.2 m (borehole BH15). These colluvial sediments comprise variable mixtures of matrix to clast supported cobbles and boulders. The cobbles and boulders are typically of high to very high strength meta-sandstone. The matrix was generally of sandy clays, gravels, sands and sandy silts. The sediments are interpreted to be ancient (Tertiary age) landslide deposits.

Subsequent volcanic activity released basalt of the Older Volcanics onto the valley floor. A period of deposition then commenced in a swampy environment potentially formed when lava flows and/or colluvial deposits dammed former drainage lines allowing water to collect in the base of the valley. These swamp deposits formed organic rich carbonaceous clays and silts which have subsequently lithified to weak mudstones with minor impersistant coal seams. These sediments were encountered during the geotechnical investigation at depths from 6.0 to 15.5 m below surface level at the time of investigations. A second, later lava flow deposited an upper capping of basalt over the valley infill sediments. This basalt layer has protected the valley fill materials from erosion during the uplift of the area. The upper basalt layer is variably weathered, from extremely weathered to fresh, due to the exposure of this rock at surface for much of the last 30 to 40 million years. Outcrops of basalt in a fresh state are generally restricted to localised occurrences in the south east portion of the proposed storage area.

A layer of residual soils exists across the site tending to be clay rich, being either derived from the basalt, or granitic geology. A layer of sandy clay topsoil is present beneath much of the storage area to a depth of approximately 200 to 400 mm.

A series of geological sections showing the interpreted subsurface geology at the proposed storage location site are presented in Appendix C. The position of the section lines is shown in Figure 1.

Whilst the intrusive geotechnical and geological investigation work was focused on the storage area, basic geological mapping was completed at the proposed stockpile storage areas, at the proposed treatment plant site and at the two proposed tank sites. The results of this mapping are presented in Figure 1.

The main pipeline appears to traverse several geological units including the weathered granite, slightly weathered to fresh basalt and weak carbonaceous mudstone. Several springs were noted in the vicinity of the pipeline alignment.

The proposed treatment plant location is situated in an area thought to be dominated by weathered granites. A “raft” of less weathered sandstone has been mapped towards the top of the slope. This rock is expected to be relatively blocky leading to the possibility of rockfall hazards in any cuts required for the construction of the proposed treatment plant.

The proposed header tank is situated in an area of weathered granites and fill materials.

The proposed tank towards the north-west of the treatment plant is positioned in an area of weathered granite. Several groundwater springs were noted in the vicinity of this proposed tank.

2.5 Groundwater conditions

A hydrogeology study was carried out for the site and is discussed in a separate report prepared by GHD (refer to Section 1.4). This work resulted in the establishment of a groundwater monitoring network, and since then, an on-going monitoring program has been implemented at the storage site. An updated hydrogeological monitoring report was prepared following an initial review of groundwater data in 2015 (GHD 2015) which incorporated additional groundwater level, and groundwater quality monitoring information.

The hydrogeology of the off-stream storage site is relatively complex with groundwater being found within volcanic flows, interflow sediments, residual soils and weathered granite, and the more competent granite. In general a perched water table was encountered in the upper 3 m beneath surface. This groundwater level is highly variable. A deeper more consistent water table exists beneath the site at a depth of approximately 13 to 14 m beneath surface.

The depth to water is variable across the site, depending upon the geologic unit, and the topography. Groundwater can be intersected within 2 m of the surface, particularly near springs or in the steeper topographies of the site. In other areas, nearer and slightly north of the Summit Road, groundwater can be deeper and over 12 to 14 m depth below the surface (GHD 2015).

Over 12 months of water level monitoring data is available for some monitoring bores, including continuous monitoring (automated data collection) from a number of monitoring bores at, and hydraulic up-gradient of mapped Alpine bog areas. Review of the water level monitoring information indicates that most bores exhibit a significant decline in water levels over the summer period, however significant water level recovery occurs rapidly with recharge events (rainfall, snowfall). Water level from monitoring bores near Alpine Bogs have a more subdued seasonal response, relative to those further up-gradient (hydraulically and topographically), and they too can also exhibit rapid water level recovery following recharge.

Springs and associated bogs were observed to the north of the storage location. This indicates that the water table level is at the surface at these locations.

Additional springs were located along the proposed main pipeline alignment. Minor seeps or springs were observed on the southern (upper) parts of the proposed pipeline alignment. Significant flowing springs transmitting considerable water were observed exiting the surface of the track adjacent to the existing treatment plant. The location of mapped springs or seeps are presented on Figure 1.

2.6 Acid sulphate soils

The occurrence of Acid Sulphate Soils (ASS) can be present in the form of:

- **PASS** – Soil that contains unoxidised iron (metal) sulphides. When exposed to oxygen through excavation, drainage or disturbance, these soils produce sulphuric acid; and
- **Actual Acid Sulphate Soil** – Potential ASS that has been exposed to oxygen and water, and has generated acidity.

These soils are rich in organics and were formed in low oxygen or anaerobic depositional environments. They are rich in sulphides and when oxygen is introduced, the sulphides oxidise to sulphate, with resultant soils having low pH and potentially high concentrations of the heavy metals. When water levels rise, pH and heavy metals are subsequently mobilised into the environment and can potentially impact deep-rooted vegetation, aquatic flora and fauna, and can be aggressive to reactive materials (e.g. concrete, steel) of foundations, underground structures (e.g. piles, pipes, basements) or buried services in contact with groundwater.

2.6.1 Potential acid sulphate soils/rocks in the study area

In Victoria, ASS materials are commonly associated with Holocene age geology (i.e. Recent Quaternary) or lithified sedimentary rocks that may contain disseminated pyrite (when unweathered).

A review of published mapping was undertaken which included the CSIRO Australian Soil Resource Information System (CSIRO 2014). Whilst it is noted that the mapping is regionally based, it indicates there to be an extremely low risk of encountering ASS. Although considered unlikely, there may be disseminated pyrite in the carbonaceous mudstone. This pyrite may oxidise upon exposure and produce acid. This hazard should be assessed at detailed design stage by targeted sampling and laboratory testing.

2.7 Geological model

As part of the detailed design of the storage facility, indicative cross sections of the basin have been interpreted from the geotechnical investigation results. These cross sections show the interpreted geological profiles based on a 3D geological model developed using the geotechnical investigation data including boreholes, test pits and seismic refraction data. The interpreted geological sections are presented in Appendix C. Images of the geological block model are presented in Appendix D.

2.8 Geological features

2.8.1 Historical landslides

Historical landslides and land forms that could potentially be prone to instability at the site have been identified by visual observation during the site inspections and by digital terrain analysis. The following is a discussion on the landslide areas identified on the site and surrounding the site that may impact on or be impacted on by the project which should be read in conjunction with Figure 1:

Landslide Zone 1 – An area approximately 100 m to the west of the storage site shows evidence of significant historical slope instability. This feature occurs towards the top the ridge line and has formed on a low angle slope. It is anticipated that this failure was triggered by high groundwater outflows (springs) in this location possibly concentrated by the geological structure or weathering extent of granitic rock at this location. Evidence of recent instability was not observed. However, alteration of the toe or upper reaches of the landslide may cause reactivation of movement.

The landslide zone is not located within the proposed works footprint and is situated downhill from the proposed Control Centre Carpark stockpile zone. Although the proposed stockpile zone is approximately 50 m south of the main scarp of the landslide, appropriate care and attention should be taken to not allow the stockpile zone to encroach the main scarp or crown of the existing slip feature. The stockpile area should be clearly delineated before use.

Landslide Zone 2 – A series of small scale relict features possibly indicating instability occur towards the north of the proposed storage area. These features are also thought to be due to outflows of groundwater (springs) in these locations. As with Landslide Zone 1 it is unclear if the groundwater seepage and associated instability is related to structural controls such as faults or difference in geology and weathering or a combination of both. The instability manifests at surface as shallow, low angle “slumps” which are vegetated and have a total width in the order of 10 m. No evidence of recent instability was observed. The proposed storage location is situated approximately 50 m south of the areas of instability. The proposed pump station and associated pipelines should be located away from these areas. Alteration of the toe or upper reaches of the landslide may cause reactivation and should therefore be avoided.

Landslide Zone 3: Small relict features were identified to the south of the proposed main pipeline alignment. These areas are thought to be due to localised translational failure of the basalt rock on top of the carbonaceous mudstone geology. These locations may however also represent areas that have been informally quarried for aggregate since the commencement of ski-field operation. The shallow (assumed less than 1.5 m depth) pipeline construction is not anticipated to have a significant effect on the slope stability within this zone.

2.8.2 Springs

Springs are found frequently across the project area. This is thought to be primarily controlled by intersection of lithological boundaries and the surface. Whilst no springs have been encountered within the proposed storage area footprint, springs have been found near where excavations for the header tank, main pipeline and pipeline to the Stage 1B tank are planned. Instability of excavations may result from intersection of groundwater springs and should be controlled by battering back trenches or via the use of trench shields. Construction of pipelines should include provision of water stops to prevent the migration of spring water along a backfilled trench. These springs are marked on Figure 1.

3. Risk assessment

3.1 General

A qualitative slope stability and geotechnical risk assessment has been carried out to consider potential damage to property post construction of the project in accordance with AGS (2007) Guidelines as required by the Erosion Overlay Guidelines.

The following sections describe the assumptions for the risk assessment and the basis for selecting the likelihood and consequence ratings (Section 3.2 and 3.4 respectively), while Section 3.4.1 provides a risk assessment and mitigation matrix for each individual hazard.

This assessment only reviews the direct risk from the mobilisation of soil and rock. Landslides that result in an uncontrolled release of water from the storage (i.e. dam burst/failure) are considered outside the scope of this report. Management of dam related hazards have been preliminarily assessed in the concept design process and will be further assessed during the detailed design process (in accordance with ANCOLD guidelines). Additional assessment of material shear strengths of the highly variable geological materials encountered at the site and further stability analyses will be completed as part of this process. A preliminary risk assessment only has been completed for dam related geotechnical hazards in this report. **This preliminary risk assessment is indicative only and will be superseded by further assessments of risk to be completed during the detailed design process.** Section 3.4.2 presents the results of the preliminary risk assessment of dam related geotechnical hazards.

3.2 Hazard analysis

The site was reviewed to determine potential geohazards. The hazard analysis took into account pre-existing features and potential hazards caused by the proposed works. As discussed above, hazards from an uncontrolled release from the storage have been addressed in the concept design report and are outside the scope of this report.

The hazard analysis reviewed the following primary failure mechanisms:

- Natural Landslide;
- Cut Excavations;
- Fill Embankments; and
- Rockfall.

The hazards identified at the site are listed with their assessed likelihood of failure in the following section.

3.3 Likelihood of failure

The likelihood of slope failure due to the various failure mechanisms at the site is provided in Table 2. These ratings are qualitative indications of how *likely* a failure is without consideration of the *consequences* of this failure. The assessment of the likelihood of failure of each hazard has been determined based on the following factors:

- Site observations made during the site inspection;
- Subsurface conditions observed during the geotechnical investigations; and
- Engineering geological experience.

Appendix E contains brief descriptions of the rating types for likelihood of failure, possible consequences of failure and risk level implications. The likelihood reported below is without remediation measures in place.

3.4 Consequences of failure

Consequences from the geotechnical hazards identified above have been determined based on observations made during the site investigation. Hazards likely to impact the infrastructure, surrounding residential houses and council infrastructure have been assessed.

For the hazards identified, the associated consequences have been estimated based on the ratings shown in Appendix E. The most critical consequence was used in review of the site. As discussed above, the consequences from an uncontrolled release of water from the storage are considered outside the scope of this report.

3.4.1 Risk rating

The following matrix has been used to rate each of the risks identified based on the likelihood and consequence determined. The risk matrix is based on the AGS Guidelines for Landslide Risk Assessment, 2007.

Table 1 Risk rating matrix

		Consequences				
		Catastrophic	Major	Medium	Minor	Insignificant
Likelihood	Almost certain	VH	VH	VH	H	M or L
	Likely	VH	VH	H	M	L
	Possible	VH	H	M	M	VL
	Unlikely	H	M	L	L	VL
	Rare	M	L	L	VL	VL
	Not credible	L	VL	VL	VL	VL

Risk ratings for each of the hazards identified are summarised in Table 2.

The risk ratings also present the adopted control measures implemented in the design of the project to mitigate the associated hazard. The residual risk rating is the risk believed to be associated with the project post construction.

Table 2 Risk rating and control measures for identified hazards

Hazard Ref. #	HAZARD	Initial risk rating			Control measures	Residual risk rating		
		Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
Existing Natural Shallow Landslides								
1	Landslide Zone 1 – Large, shallow translational/rotational landslide (pre and post construction)	Possible (implied indicative approximate annual probability of 10^{-3})	Insignificant	Very Low	The landslide zone is outside of the designated works area so will not be impacted by the project nor will impact on the project. Ensure all stockpiles are kept within the designated area. Requirement that surface water is controlled during construction and not concentrated on this slope.	Possible (implied indicative approximate annual probability of 10^{-3})	Insignificant	Very Low
2	Landslide Zone 2 – Small, shallow, translational/rotational landslide (pre and post construction)	Possible (implied indicative approximate annual probability of 10^{-3})	Insignificant	Very Low	The landslide zone is outside of the designated works area so will not be impacted by the project nor will impact on the project. Ensure all stockpiles are kept within the designated area. Requirement that surface water is controlled during construction and not concentrated on this slope. Site pump station away from head of landslides.	Possible (implied indicative approximate annual probability of 10^{-3})	Insignificant	Very Low
3	Landslide Zone 3 – Small/Medium Translational Slides (during construction of pipe trench)	Likely	Minor	Moderate	Pipeline trenches through failure zone to be left open only for time required to construct and backfill pipeline trenches. Restrict length of open trenches through landslide zone to 10 m in excavated length. Limit depths of trench. Halt work in adverse weather conditions and inspect uphill side for any signs of movement each morning. Undertake geotechnical investigations (test pitting) along route to determine if slip surface is present within depth of pipeline	Likely	Minor	Moderate

Hazard Ref. #	HAZARD	Initial risk rating			Control measures	Residual risk rating		
		Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
Stockpile Areas								
4	Slope instability of spoil stockpiles	Likely	Medium to Minor	Low	Shape stockpiles and control runoff	Likely	Medium to Minor	Low
5	Slope instability at Control Centre Carpark location	Rare	Insignificant	Very Low	Ensure stockpile area does not extend between allocated boundary	Rare	Insignificant	Very Low
6	Slope instability at Eastern/Shaky Knees Stockpile location	Unlikely	Minor	Low	Ensure adequate under stockpile drainage is installed to allow drainage of surface water away from stockpile	Rare	Minor	Very Low
Cut Excavations								
7	Slope instability of trenches during construction of pipelines	Possible	Minor	Moderate	Excavation batter angles must be at or shallower than angles recommended by geotechnical engineer for both temporary and permanent batter slopes and/or braced. Works to be halted in adverse weather. Cut excavations to be inspected by geotechnical engineer at regular intervals Stop work in adverse weather. Localised flattening of batters where trench intersects spring	Unlikely	Minor	Low
8	Erosion along backfilled pipe trenches as spring water flow enters and flows along backfilled	Possible	Minor	Moderate	Include water stop barriers at regular intervals along pipeline alignments, spacing to be determined	Unlikely	Minor	Low

Hazard Ref. #	HAZARD	Initial risk rating			Control measures	Residual risk rating		
		Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
	trenches							
9	Slope instability from break tank cutting. Slope likely to be currently at limit equilibrium	Likely	Major	Very High	Undertake geotechnical investigation, engineering design and slope stability assessment during detailed design. Reduce batter angles or other stabilisation or retaining methods. Excavation angles must be at or below angles recommended by geotechnical engineer for both temporary and permanent batter slopes, and may require support. Works to be halted in adverse weather. Cut excavations to be inspected by geotechnical engineer at regular intervals	Unlikely to possible	Major	Moderate
10	Slope instability from pump station excavations to north of storage location	Possible	Medium	Moderate	Excavation angles must be at or below angles recommended by geotechnical engineer for both temporary and permanent batter slopes Works to be halted in adverse weather. Cut excavations to be inspected by geotechnical engineer at regular intervals Position works away from existing springs and areas of instability	Unlikely	Medium	Low
11	Slope instability due to aqueduct outlet construction	Possible	Medium	Moderate	Excavation angles must be at or below angles recommended by geotechnical engineer for both temporary and permanent batter slopes Works to be halted in adverse weather. Cut excavations to be inspected by geotechnical engineer at regular intervals Position works away from existing springs and areas of instability	Unlikely	Medium	Low

Hazard Ref. #	HAZARD	Initial risk rating			Control measures	Residual risk rating		
		Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
12	Slope instability due to environmental watering system construction and operation	Possible	Minor	Moderate	Water inflow volumes into the bog areas should not exceed the water flow entering the areas prior to construction. Careful management of the water flow will be required. Include water stop barriers at regular intervals along pipeline alignment section spacing to be determined. Excavation batter angles must be at or shallower than angles recommended by geotechnical engineer for both temporary and permanent batter slopes and/or braced. Works to be halted in adverse weather. Cut excavations to be inspected by geotechnical engineer at regular intervals Stop work in adverse weather. Localised flattening of batters where trench intersects spring Ensure proper maintenance checks of structures and pipelines is undertaken Leaking pipes or pits are to be repaired immediately	Possible	Minor	Moderate

Hazard Ref. #	HAZARD	Initial risk rating			Control measures	Residual risk rating		
		Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
13	Slope instability during operational life of constructed infrastructure	Possible	Medium	Moderate	Ensure proper maintenance checks of structures and pipelines is undertaken Leaking pipes, tanks or storage are to be repaired immediately Erosion protection measures are used to prevent or halt any erosion The project area is to be monitored for stability and movement on a regular basis (before and after snow season). If areas of movement or instability are observed a geotechnical engineer should be consulted immediately	Unlikely	Medium	Low

3.4.2 Preliminary Dam Related Risk rating

As previously discussed, this preliminary risk assessment is indicative only and is used here to demonstrate the types of hazard which will be assessed at a later stage. Dam related risks will be assessed during detailed design in accordance to ANCOLD and risks mitigated within the detailed design stage.

The following matrix has been used to rate each of the risks identified based on the likelihood and consequence determined. The risk matrix is based on the AGS Guidelines for Landslide Risk Assessment, 2007. Risk ratings for each of the hazards identified are summarised in Table 3.

The risk ratings also present the adopted control measures implemented in the design of the project to mitigate the associated hazard.

The preliminary residual risk rating is the risk believed to be associated with the dam components of the project post construction and assumes that the dam will be constructed as per a developed detailed design accordance with ANCOLD and ICOLD best practice, utilising all risk mitigation and defensive measures as detailed in the detailed design documentation

Table 3 Preliminary risk rating and control measures for identified dam related hazards

Hazard Ref. #	HAZARD	Preliminary Initial risk rating			Control measures	Preliminary Residual risk rating		
		Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
Dam Embankment								
DAM1	Slope instability of storage embankments (post construction)	Unlikely to Rare	Major	Moderate to Low	Designed with FoS>1.5 for normal operation in accordance with ANCOLD	Unlikely to Rare	Major	Moderate to Low
DAM2	Internal erosion of storage embankments (Piping)	Possible	Major	High	The storage facility is to be lined with HDPE liner and has an under liner drainage system to collect any leakage Provide groundwater monitoring instruments for embankment works	Unlikely to Rare	Major	Moderate to Low
DAM3	Global failure of slope below storage and embankment	Unlikely to Rare	Major (to Catastrophic)	High	Undertake engineering design and slope stability assessment during detailed design in accordance with ANCOLD.	Unlikely to Rare	Major	Moderate to Low
DAM4	Excessive settlement of storage embankment	Rare	Major	Low	The depth to bedrock is shallow and soils at the site are generally over consolidated. Settlement predictions are compensated for in design.	Unlikely	Minor	Low
DAM5	Erosion of outer face of fill embankment	Likely	Medium	Moderate	Protection of soil surface with vegetation, rock armour or erosion protection matting (or combination of these methods)	Possible to Unlikely	Medium	Moderate to Low

Hazard Ref. #	HAZARD	Preliminary Initial risk rating			Control measures	Preliminary Residual risk rating		
		Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
Cut Excavations in storage area								
DAM6	Slope Instability in internal cut of storage area (Construction and Post-Construction)	Possible	Minor	Moderate	Undertake engineering design and slope stability assessment during detailed design. Reduce batter angles or other stabilisation methods. Excavation angles must be at or below angles recommended by geotechnical engineer for both temporary and permanent batter slopes Works to be halted in adverse weather. Cut excavations to be inspected by geotechnical engineer at regular intervals during construction.	Unlikely	Medium	Low

3.5 Semi-Quantitative Risk Assessment

A semi-quantitative assessment (preliminary) has been carried out for risk to life for hazards assessed where residual risk-to-property has remained at a level of moderate or above. These hazards are:

- Slope instability of the break tank cutting – moderate residual risk-to-property level due to higher level of consequence for the structure should slope failure occur;
- Trenched construction of pipelines through Landslide Zone 3 – moderate level of risk-to-property due to higher level of likelihood due to previously identified mode of slope failure in this area; and
- Operation of environmental watering system - moderate level risk-to-property due to increased likelihood of failure in area where previously identified instability associated with natural springs has been identified.

The assessment considers only the risk posed to people once control and mitigation measures have been put in place.

This quantitative risk assessment does not extend to the dam related hazards identified to have a moderate to low residual risk as determined in the preliminary risk assessment of dam related hazards detailed in Section 3.4.2. All dam related hazards will be further assessed and mitigated in accordance to ANCOLD best practice guidelines. The assessment in accordance with ANCOLD procedures will be completed at detailed design stage after further analysis is completed and is outside the scope of this geotechnical risk assessment.

Due to a lack of background data provided for historical landslides in the vicinity of the study area to calculate probability, this assessment should be considered as falling within the basic level of assessment as defined by the AGS. However, conservative values for probability have been adopted. The probability of a landslide occurrence has been based directly on the frequency estimated for the hazards as described in Section 3.3.

Quantitative risk has been assessed as the annual probability of loss of life of the individual most at risk using the calculation provided in AGS (2007). No assessment has been made of societal risk to groups.

Risk has been calculated from:

$R_{(LoL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$

Where:

- $R_{(LoL)}$ is the risk (annual probability of loss of life (death) of an individual);
- $P_{(H)}$ is the annual probability of the hazardous event occurring;
- $P_{(S:H)}$ is the probability of spatial impact;
- $P_{(T:S)}$ is the spatial temporal probability, i.e. the probability of the individual occupying the area at time of the event; and
- $V_{(D:T)}$ is the vulnerability of the individual (probability of loss of life of the individual given the impact).

Values of anticipated ski trail use were derived from visitor data reported by the Victorian Alpine Resorts Coordinating Council have been adopted for this assessment.

The semi-quantitative risk assessment results and recommended acceptable and tolerable limits are presented in Tables 4 and 5.

Table 4 Landslide Risk Assessment – Semi-quantitative indicative risk-to-life for selected persons most-at-risk

Location	Mechanism placing element at hazard	Risk type	Likelihood of landslide event occurring and adopted indicative annual probability P(H)	Probability of spatial impact – effect being realised due to event P(S:H)	Temporal probability P(T:S) duration of exposure to hazard	Vulnerability V(D:T)	Semi-quantitative estimate of risk	Comment	
Break tank cut above Grimus run	Slope instability from break tank cutting. Slope likely to be currently at limit equilibrium	Risk of loss of life of individual most at risk: weekly resort visitor (skier)	Possible 10^{-3} pa	Ski season only, 6 days skiing per week, 6 hours per day, width occupancy of ski run wrt slide footprint 5 of 7m, 5 passes on run per day = 0.04	Risk to skier: Use proportion of run length (10m slide width over 600m run length), and with downgrading assumption that spend only 10% of time on this downhill run due to lift times, queues, etc. = 0.002	Likelihood of fatality based on assumption of being struck by landslide but not buried = 0.5	Individual Most-at-Risk (weekly resort visitor) R(DI) 10^{-6} pa	Acceptable to general community.	$R(DI) = 1x10^{-6}$ pa
Environmental watering system downslope of dam	Slope instability due to system construction and operation. Slopes mapped as susceptible to shallow landsliding.	Risk of loss of life of individual most at risk: weekly resort visitor (skier)	Possible 10^{-3} pa	Ski season only, 6 days skiing per week, 6 hours per day, width occupancy of ski run wrt slide footprint 3 of 50 m, 1 pass on run per day = 0.003	Risk to skier: Use proportion of run length (10m slide width over 600m run length), and with downgrading assumption that spend only 10% of time on this downhill run due to lift times, queues, etc. = 0.002	Likelihood of fatality based on assumption of being struck by small landslide but not buried = 0.1	Individual Most-at-Risk (weekly resort visitor) R(DI) 10^{-9} pa	Acceptable to general community.	$R(DI) < 1x10^{-6}$ pa

Landslide Zone 3 – pipeline trench (construction phase)	Slopes mapped as susceptible to shallow landslide.	Risk of loss of life of individual most at risk: Pipeline construction worker	Likely 10^{-2} pa	Worker may not be in area of failure on pipe alignment, assume 1.0m deep failure,30m width across section of open trench, 300m total length = 0.1	Assumptions: Construction works include one month of trenching and pipe laying works in this zone. Six day working week at 10 hour days, 50% of time directly exposed = 1x10-4	Likelihood of fatality based on assumption of being struck by landslide (small trench collapse) but not buried. = 0.1	Individual Most-at-Risk (pipeline worker) R(DI) 10^{-6} pa	Acceptable to general community.	R(DI) = 1×10^{-6} pa

(1) No further scenarios were assessed since these worse case situations illustrated that acceptable risk-to-life levels would eventuate from less critical risk-to-property assessments.
(2) This risk assessment has been conducted in accordance with the guidelines provided in AGS (2007c & 2007d). A risk assessment considers the combination of likelihood of a landslide event occurring and the consequences should that even occur. The risk appraisal compares the assessed risk with a level of risk deemed acceptable or tolerable. Tolerable or acceptable risks are frequently established by government agencies or the Councils of Local Government Areas.
(3) This assessment of risk of instability has been conducted for particular sites within the Alpine Resort that may be impacted. The assessment has been conducted to appraise the current risk of landsliding and the modification of that risk as a result of possible future development. Issues such as cosmetic cracking and other damage have not been considered as part of this appraisal. Loss of amenity has not been considered. It is important that these reservations be noted when considering the outcomes of this assessment.
(4) The assessment has been conducted through semi-quantitative means.
(5) Vulnerability estimates derived from AGS (2000),

Table 5 Recommendations for acceptable and tolerable risk in AGS (2007c) and AGS (2007d) for importance level 2 structure and the person most-at-risk

Situation	Acceptable Risk		Tolerable Risk	
	Risk to Property	Risk to Life	Risk to Property	Risk to Life
New slopes, new development or existing landslide	LOW or VERY LOW	10^{-6} per annum	MODERATE, LOW or VERY LOW	10^{-5} per annum
Existing slopes or existing development	LOW or VERY LOW	10^{-5} per annum	MODERATE, LOW or VERY LOW	10^{-4} per annum

Note 1: AGS (2007c) Table 1 adopted for risk to life, AGS (2007d) Table C10 for risk to property.

Note 2: This table applies for Importance Level 2 structures only.

3.5.1 Risk evaluation – risk-to-life

For the project as proposed, this assessment of risk-to-life for the three hazards considered indicate an annual probability of loss of life for the individual most-at-risk during operation is equal to or below the AGS (2007) recommended limit of acceptability of 1 x 10^{-6} pa and 1 to 5 orders of magnitude below the limit of tolerability i.e. 1 x 10^{-5} pa. This was calculated for the individual considered the most critical person-at-risk which was the weekly resort visitor (skier). For the construction phase risk of the pipeline trench in Landslide Zone 3, the individual risk was slightly above the recommended acceptable limit but within the limit of tolerability. For this construction case, the conservative exposure values adopted will be reduced through safety in design and good construction practice and supervision.

For the operations phase considering the risk to life of skiers, values adopted are considered conservative, particularly as a failure is considered more likely to occur during periods of high groundwater levels, which typically occur outside of the ski season (i.e. spring melt rather than winter) when fewer people are present in the area.

4. Summary

4.1 Geohazard risks

The results of the qualitative risk assessment indicate that all the hazards identified have an initial risk rating of between “Very Low” and “Very High”.

Based on the mitigation measures implemented in the design and specified for the construction of the Mt Buller Off-Stream Storage Project, as shown in Table 4, the residual risk to and from the proposed project has been assessed qualitatively as ‘Very Low’, ‘Low’ or “Moderate” for all reviewed geohazards providing all control measures are implicated.

Where moderate risk levels have been identified a semi-quantitative assessment of risk has been completed in order to allow a better understanding of the level of risk.

The control measures to mitigate the risks for each piece of infrastructure are listed below. Mitigation measures associated with risks associated with the dam structure will be detailed and incorporated into design at the detailed design stage in accordance with ANCOLD guidelines.

4.1.1 Storage location

It is recommended that:

- Engineering design and slope stability assessment during detailed design confirms the batter angles for the storage excavation based on parameters obtained from further laboratory testing;
- During construction the excavation batter angles be constructed at or below angles recommended by geotechnical engineer for permanent and temporary slopes;
- Excavation works are to be halted during and immediately following adverse weather;
- Cut excavations to be inspected by geotechnical engineer at regular intervals during construction;
- The storage embankment batter angles be designed with FoS of >1.5;
- The storage is fully lined with inclusion of under liner drainage system to collect leakage to minimise risk of embankment internal erosion; and
- The outer face of the fill embankment should be protected from erosion by the use of vegetation, rock armour or erosion protection matting or a combination of these methods.

4.1.2 Stockpile areas

It is recommended that:

- Stockpiles do not go beyond their designated boundaries (particularly at the Control Centre Carpark); and
- Ensure adequate under stockpile drainage is installed at the eastern stockpile area.

4.1.3 Pipelines

It is recommended that:

- Excavation angles must be constructed at or below angles recommended by geotechnical engineer for both temporary and permanent batter slopes;
- Works to be halted in adverse weather;
- Cut excavations to be inspected by geotechnical engineer at regular intervals;
- Stop work in adverse weather. Localised flattening of batters where trench intersects springs; and
- Trenches to include impermeable water stops to prevent erosion along backfilled trenches after trench intersects springs.

4.1.4 Pump station to north of proposed storage location

It is recommended that:

- Excavation angles must be constructed at or below angles recommended by geotechnical engineer for both temporary and permanent batter slopes;
- Works to be halted in adverse weather;
- Cut excavations to be inspected by geotechnical engineer at regular intervals; and
- Position works away from existing springs and areas of instability.

4.1.5 Aqueduct outlet

It is recommended that:

- Excavation angles must be constructed at or below angles recommended by geotechnical engineer for both temporary and permanent batter slopes;
- Works to be halted in adverse weather;
- Cut excavations to be inspected by geotechnical engineer at regular intervals; and
- Position works away from existing springs and areas of instability.

4.1.6 Environmental watering system

It is recommended that:

- Excavation angles must be constructed at or below angles recommended by geotechnical engineer for both temporary and permanent batter slopes;
- Works to be halted in adverse weather;
- Cut excavations to be inspected by geotechnical engineer at regular intervals;
- Stop work in adverse weather;
- Localised flattening of batters where trench intersects springs;
- Trenches to include impermeable water stops to prevent erosion along backfilled trenches after trench intersects springs;
- Water inflow volumes into the bog areas should not exceed the water flow entering the areas prior to construction. Careful management of the water flow will be required;
- Works to be halted in adverse weather;
- Stop work in adverse weather. Localised flattening of batters where trench intersects spring;

- Ensure proper maintenance checks of structures and pipelines is undertaken;
- Leaking pipes or pits are to be repaired immediately; and
- Any watering should only be undertaken in accordance with a project specific Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP) based on pre-determined trigger levels and associated monitoring.

4.1.7 Operational life of constructed infrastructure

It is recommended that:

- Ensure proper maintenance checks of structures and pipelines is undertaken;
- Leaking pipes, tanks or storage are to be repaired immediately;
- Erosion protection measures are used to prevent or halt any erosion; and
- The project area is to be monitored for stability and movement on a regular basis (before and after snow season). If areas of movement or instability are observed a geotechnical engineer should be consulted immediately.

Additional risk mitigation options have been suggested for consideration to manage these risks or to reduce them further. These methods are detailed in Section 4.2.

4.2 General mitigation methods

General mitigation methods associated with works associated with good hillside practice should also be followed across the project area. These practices include:

- Minimising the extent of vegetation cleared during construction and reinstatement of vegetation post construction, where possible;
- Endure adequate drainage across the site;
- Construction to be completed over the summer period;
- Conduct visual inspection of dam before and after snow season to identify any deterioration;
- All cut excavations to be inspected by a geotechnical engineer or engineering geologist during construction;
- Any water seepages or leaks noticed around the storage location or associated infrastructure should be investigated and repaired as soon as practically possible;
- No excavations into or at base of steep slopes (slopes greater than 2H:1V) without inspection and approval by geotechnical engineer or engineering geologist; and
- Erosion protection works should be applied to batters to prevent erosion and promote revegetation.

5. Conclusions

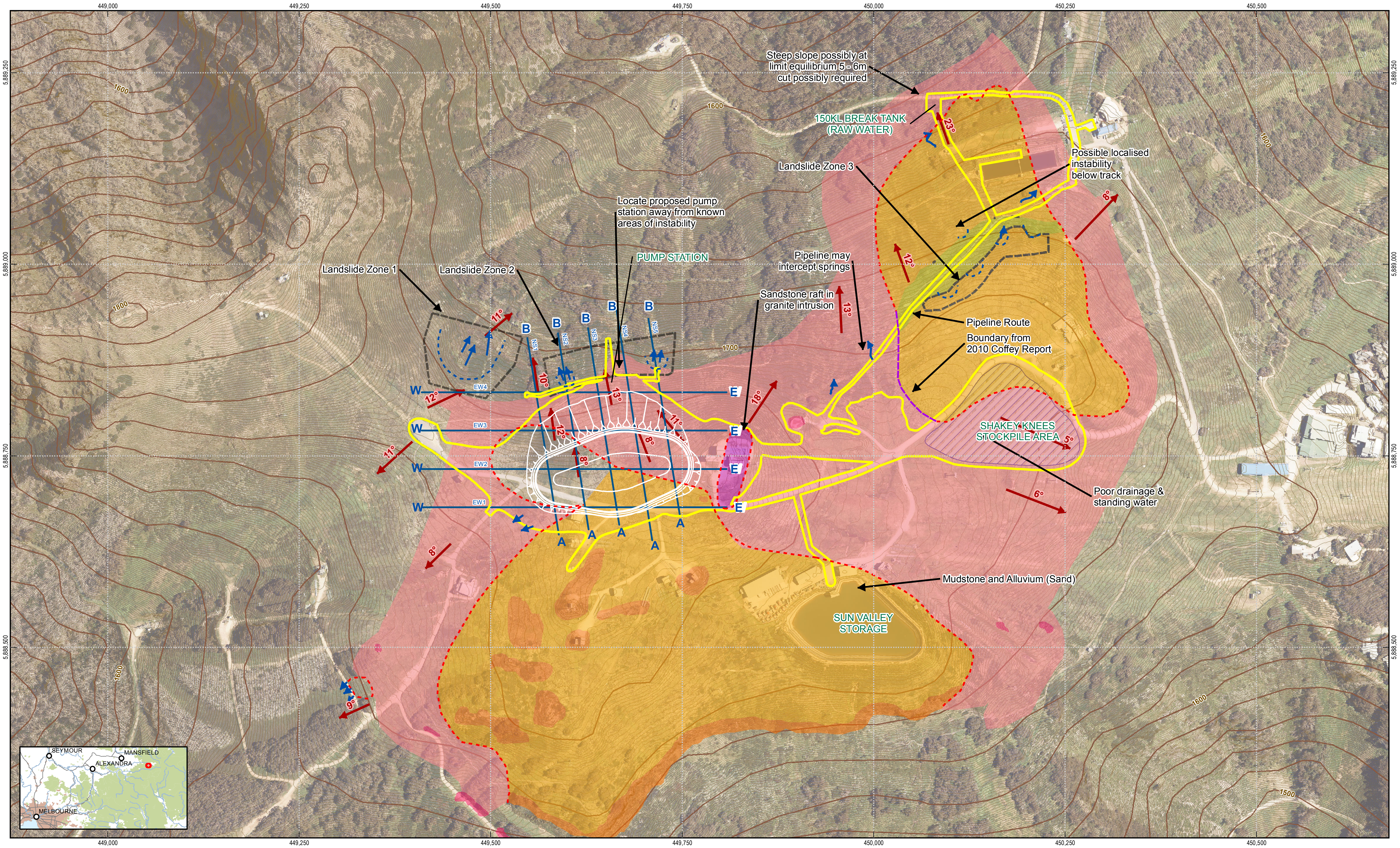
Where control measures are fully adopted, ten hazards associated with the proposed off-stream storage project were assessed qualitatively as having a residual risk rating of low or below. In accordance with Clause 3.2 of the EMO further quantitative or semi-quantitative risk assessment is not deemed necessary for this project provided all recommended control measures in Table 4 are adopted.

Qualitatively assessed residual risk levels of three hazards were found to be at “Moderate” level. In line with Clause 3.2 of the EMO a semi-quantitative assessment was completed for these hazards. This semi-quantitative (risk-to-life) assessment found the assessed risk to life falls within published limits of tolerability.

Further geotechnical assessment of the risk of the project is not required (other than those associated with the dam structure as required by ANCOLD guidelines at detailed design stage). Based on the findings of this report, the site is considered suitable for the proposed development providing the recommendations given in Table 4 and Section 4.2 are followed.

A copy of the Erosion Management Overlay – Schedule 1 Management of Geotechnical Hazard and associated insurance certificate is presented in Appendix F.

Figures



Paper Size A3

0 25 50 100 150 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Project Construction Footprint
- 2010 Coffey Report geological boundary
- Inferred geological boundary
- Remnant landslide feature
- Spring/groundwater discharge
- Contour Major
- Contour LiDAR 1m
- Temporary Stockpiles
- Storage Footprint
- Indicative Slope Lines
- Geological Section Lines
- Landslide zone
- Tertiary / Cainozoic basalt outcrop (basic volcanic)
- Possible Tertiary / Cainozoic basalt outcrop
- Eocene alluvial outcrop (mudstone)
- Devonian granite outcrop
- Possible Devonian granite outcrop
- Devonian / Ordovician Sandstone outcrop

Mt Buller & Mt Stirling Resort Management
Mt Buller Sustainable Water Security Project

Job Number	31-30733
Revision	A
Date	03 Aug 2016

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Geological and Geotechnical Risk Assessment Mapping

Figure 1

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Data source: Outcropping and Inferred Surface Geology, 2010, & 2014. Created by:tworth

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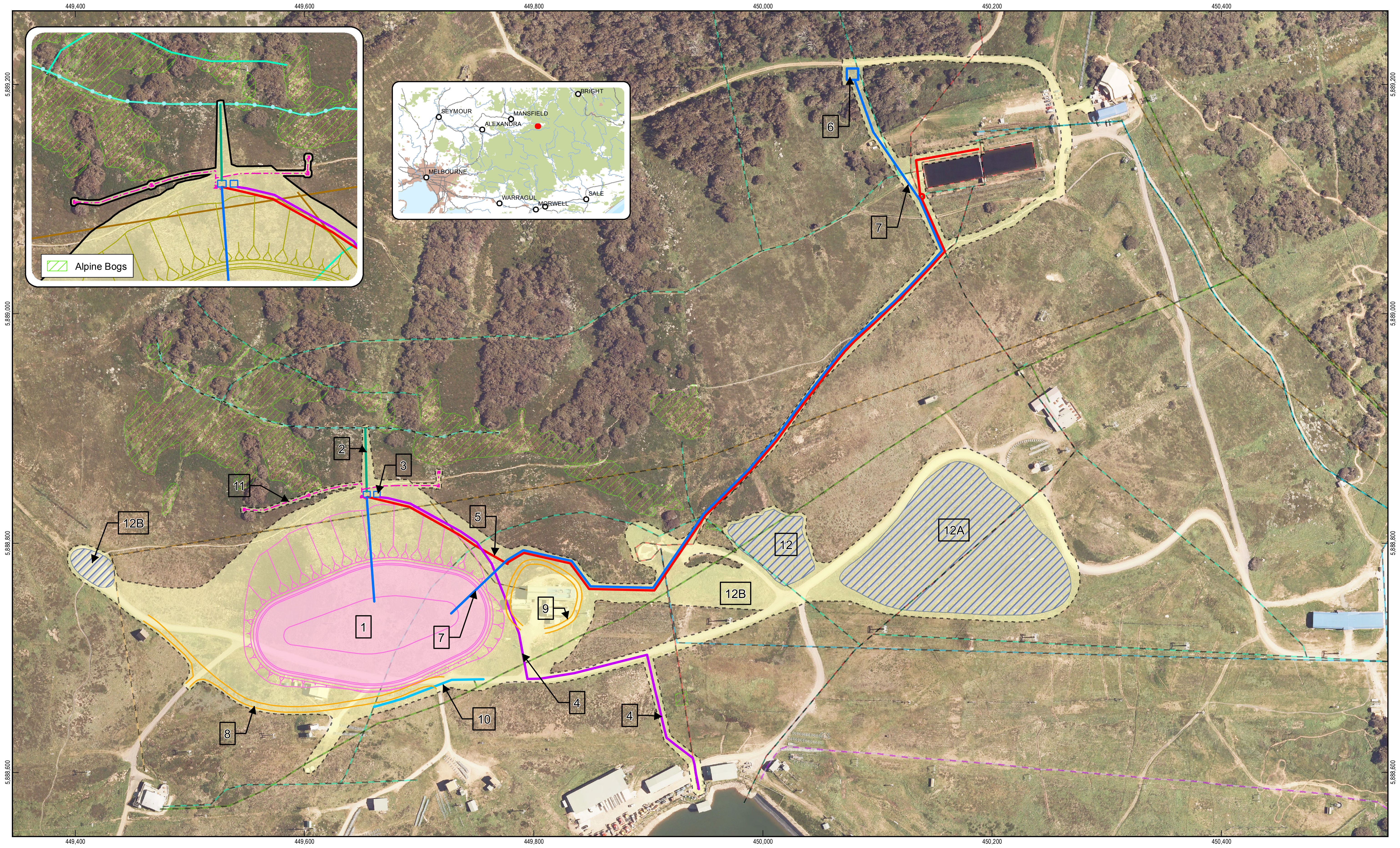
Appendices

Appendix A – Concept design drawing



Paper Size A3

0 25 50 100

Metres

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

New Infrastructure

- Construction footprint
- Proposed stockpiles(12)
- Dam Option (1)
- Buller Irrigation Pipeline(11)
- New Road Alignments (8,9)
- Kofflers Water Supply Pipeline(10)
- Outlet Pipeline(2)
- Storage Tank(6)
- Sun Valley Water Supply Pipeline(4)
- Treatment Supply Pipeline(5)
- Water Supply Pipeline(7)
- Water Supply Pump(3)
- Aqueduct

Exisiting Water Infrastructure (approximate location)

- Water main
- Sewerage Main
- Sewerage Rising Main
- Recycled Water Main
- Gas Main
- Sewerage Main
- Water Infrastructure
- Potable Water Pipeline

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Mt Buller & Mt Stirling Resort Management
Mt Buller Sustainable Water Security Project

Job Number	31-30733
Revision	A
Date	28 Jul 2016

Project Concept Design

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G:\31\30733\GIS\Maps\Working\31-30733_0_Project-Concept-Design_A3L - Copy.mxd

Data source: Mt Buller & Mt Stirling Resort Management, Aerial imagery, 2011; ARI, bog mapping. Created by:tworth

Appendix B – Existing surface condition photographs

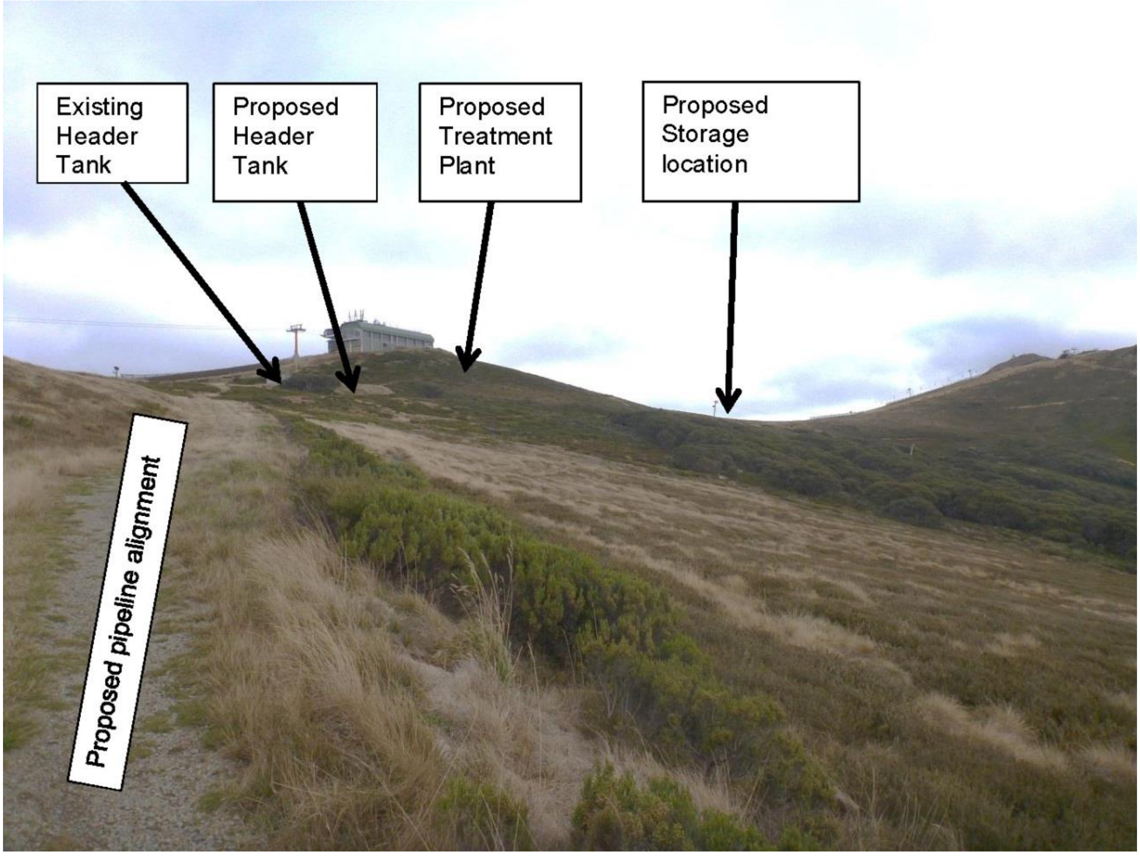


Plate 1. Looking southwest along proposed main pipeline alignment.

Plate 2. Area of sloping and possibly unstable ground at southern edge of Koflers Stockpile area.

Plate 3. Groundwater Seepage at lowest point of proposed Koflers Stockpile area.

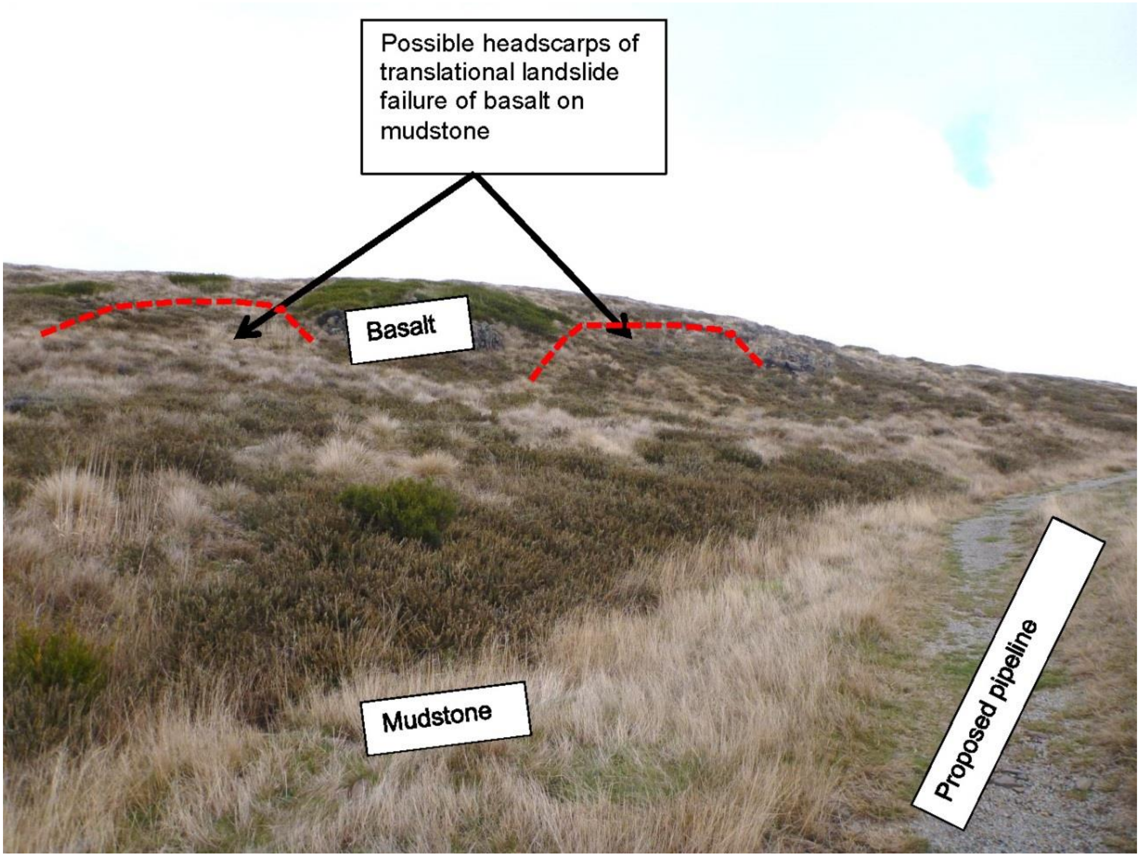


Plate 4. Possible areas of instability to south of main pipeline alignment.

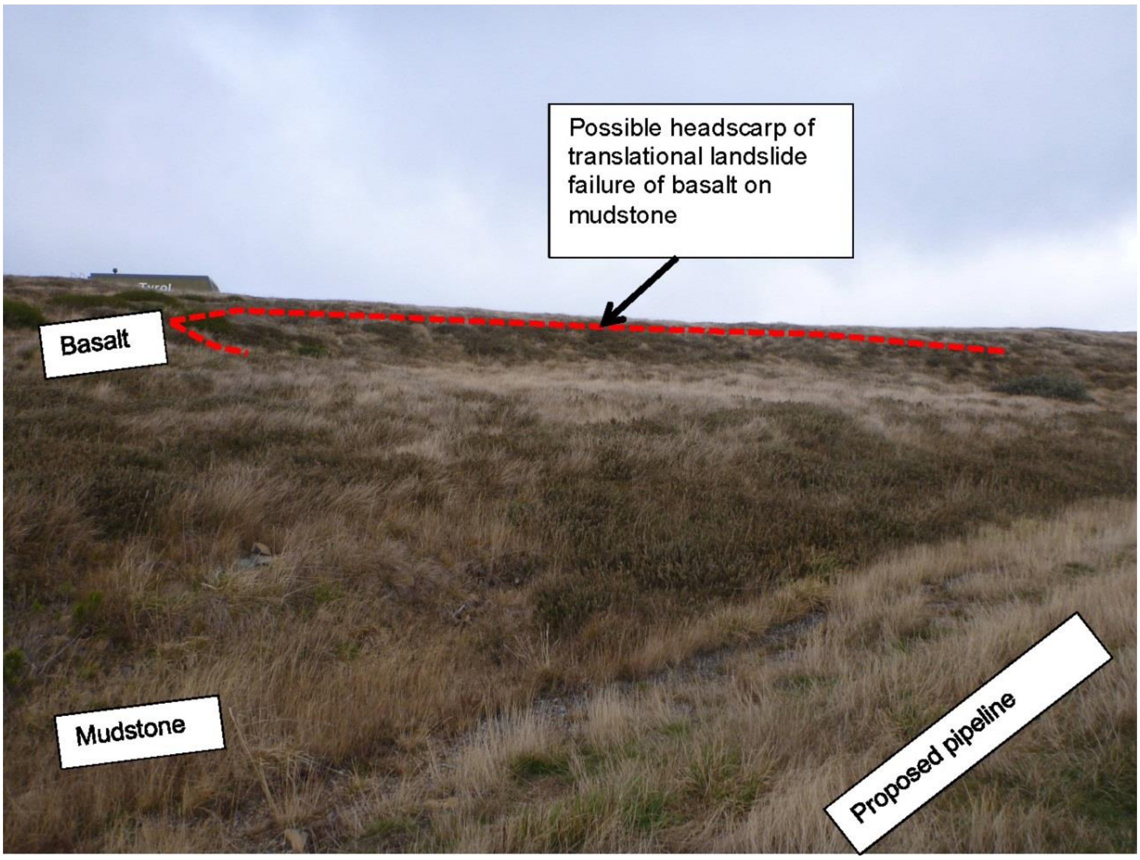
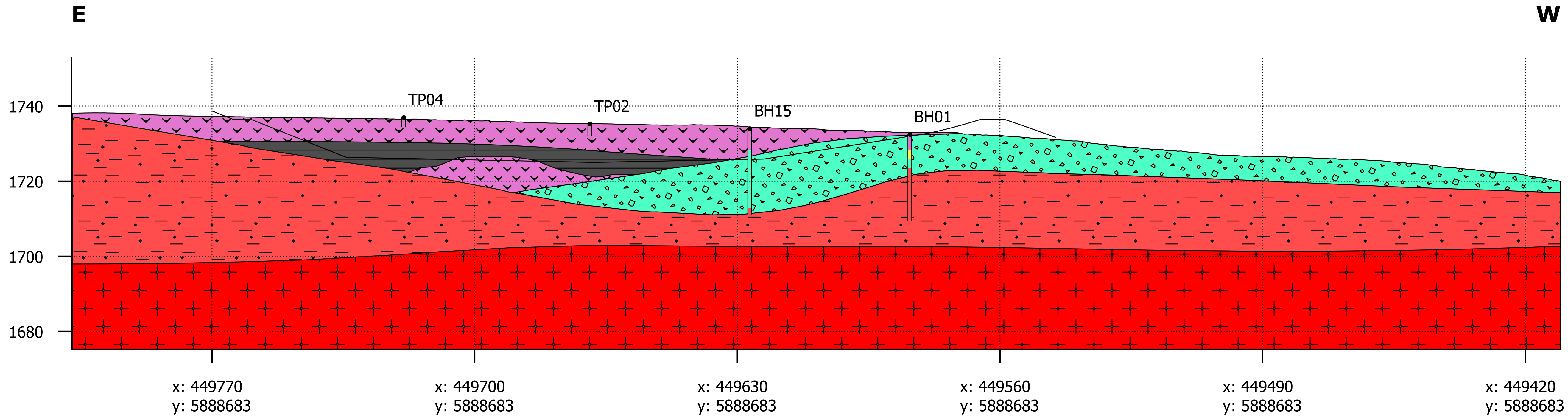


Plate 5. Possible area of instability to south of main pipeline alignment.

Appendix C –Interpreted geological sections

Geological Section - East to West (EW1)



Legend

Geological Units

Upper basalt	Basalt
Granite (MW)	Granite (XW)
Carbonaceous mudstone	Colluvium

Location

A: 449808, 5888683

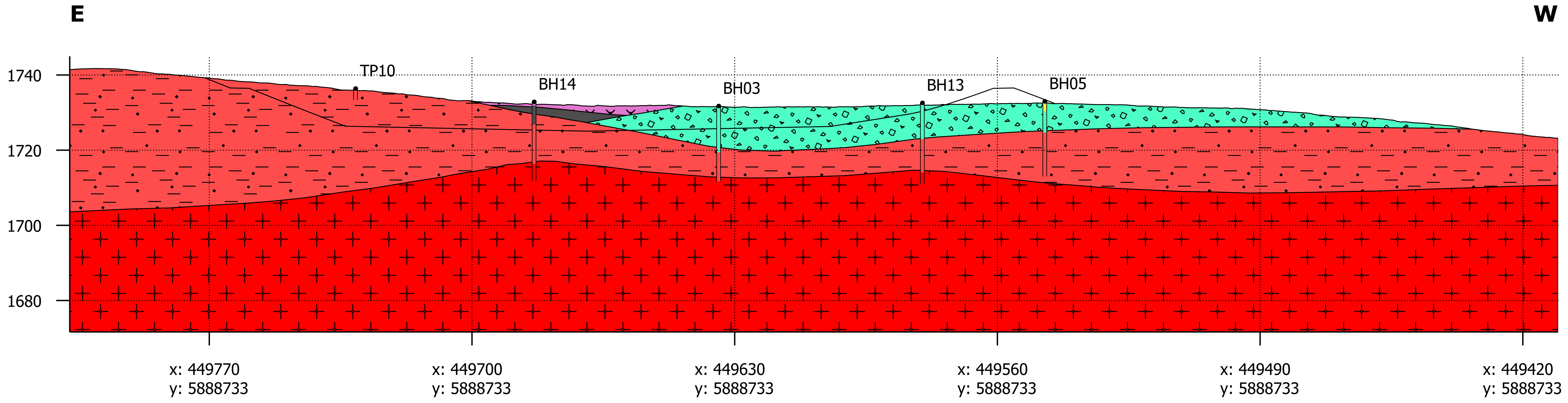
B: 449410, 5888683

Scale: 1:1,200

Vertical exaggeration: 1x

0m 50m

Geological Section - East to West (EW2)



Legend

Geological Units

- Upper basalt
- Colluvium
- Granite (MW)
- Lake Alluvium
- Granite (XW)

Scale: 1:1,200

Vertical exaggeration: 1x

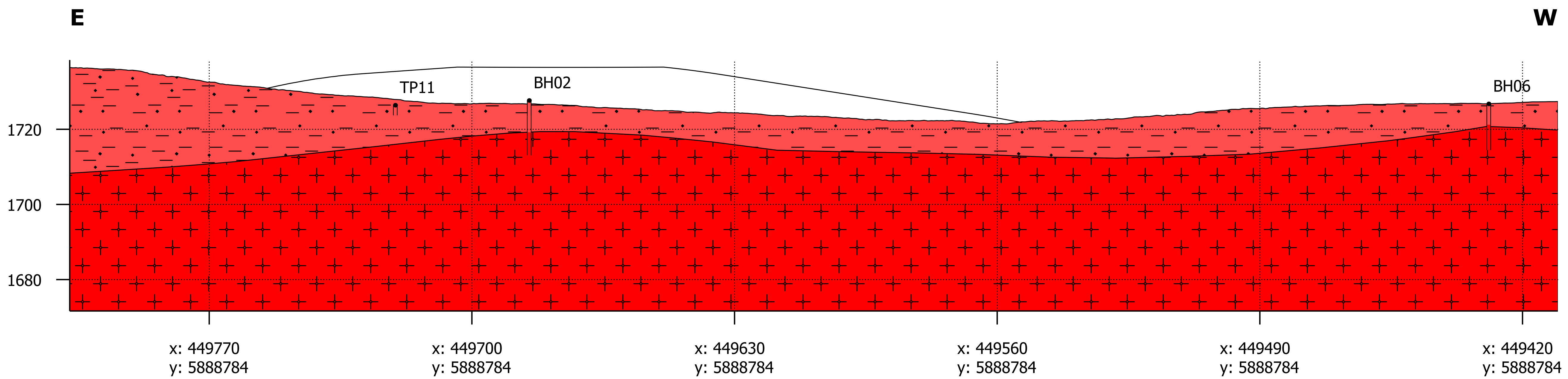
0m 50m

Location

A: 449807, 5888733

B: 449411, 5888733

Geological Section - East to West (EW3)



Legend

Geological Units

- Granite (MW)
- Granite (XW)

Scale: 1:1,200

Vertical exaggeration: 1x

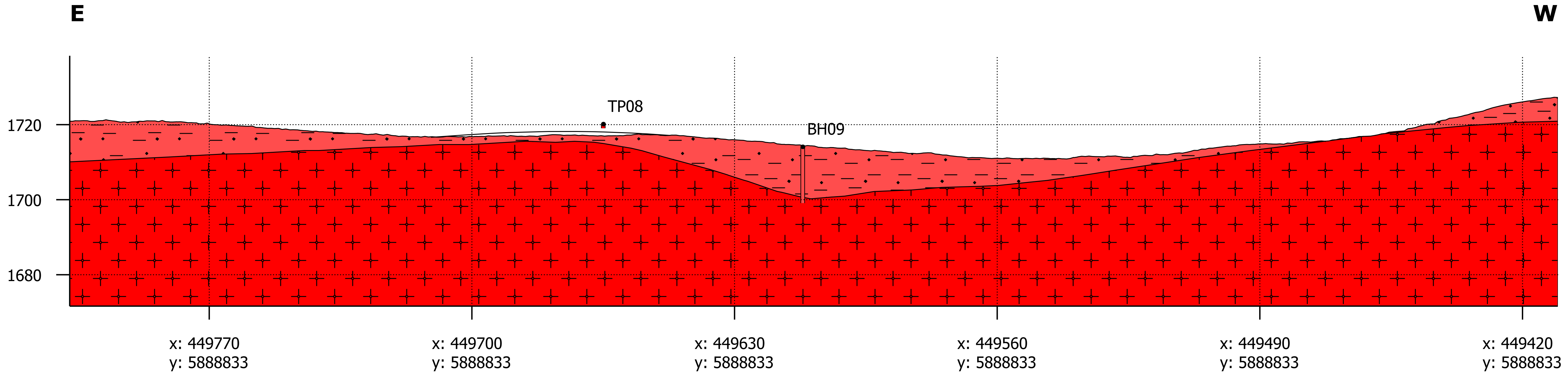
0m 50m

Location

E: 449807, 5888784

W: 449411, 5888784

Geological Section - East to West (EW4)



Legend

Geological Units

- Granite (MW)
- Granite (XW)

Scale: 1:1,200

Vertical exaggeration: 1x

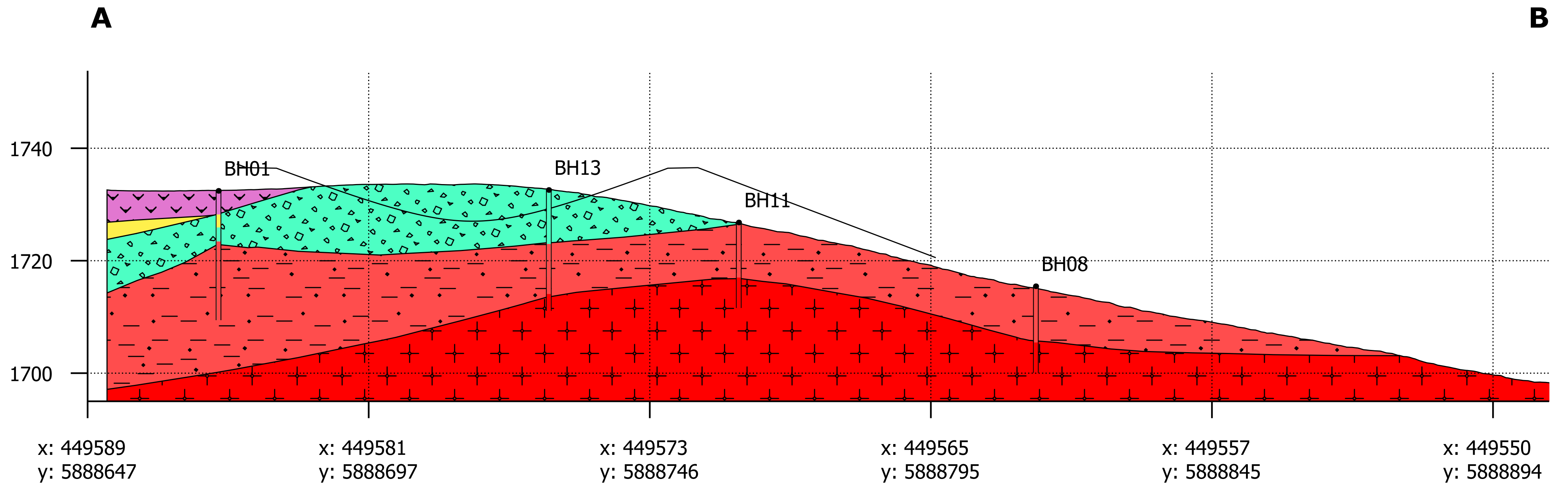
0m 50m

Location

E: 449807, 5888833

W: 449411, 5888833

Geological Section - North to South (NS1)



Legend

Geological Units

- Upper basalt
- Colluvium
- Granite (MW)
- Granitic Alluvium
- Granite (XW)

Scale: 1:1,000

Vertical exaggeration: 1x

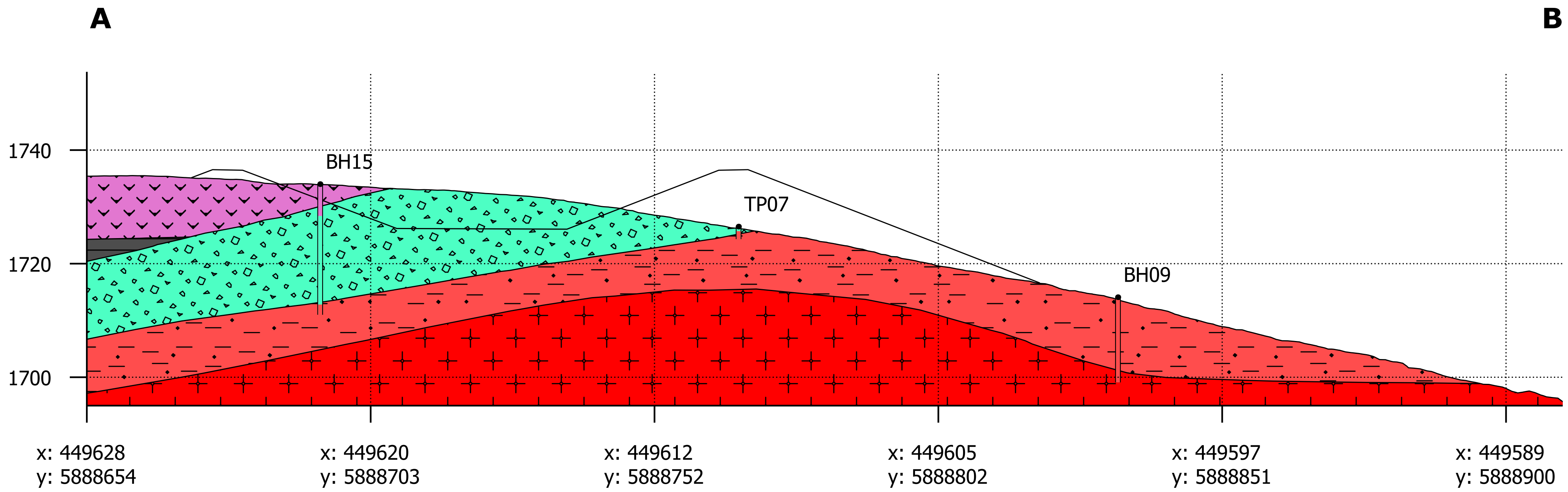
0m 50m

Location

A: 449589, 5888647

B: 449548, 5888904

Geological Section - North to South (NS2)



Legend

Geological Units

Upper basalt	Basalt
Granite (MW)	Granite (XW)
Carbonaceous mudstone	Colluvium

Location

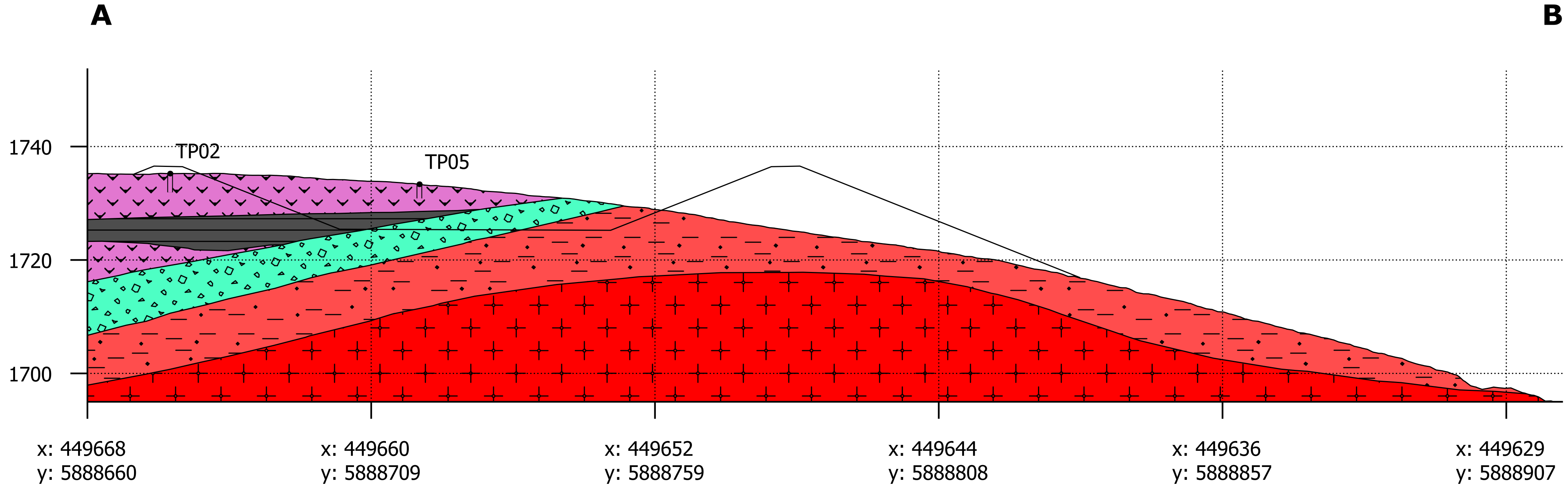
A: 449628, 5888654

B: 449588, 5888910

Scale: 1:1,000

Vertical exaggeration: 1x

Geological Section - North to South (NS3)



Legend

Geological Units

- Upper basalt
- Basalt
- Granite (MW)
- Granite (XW)
- Carbonaceous mudstone
- Colluvium

Location

A: 449668, 5888660

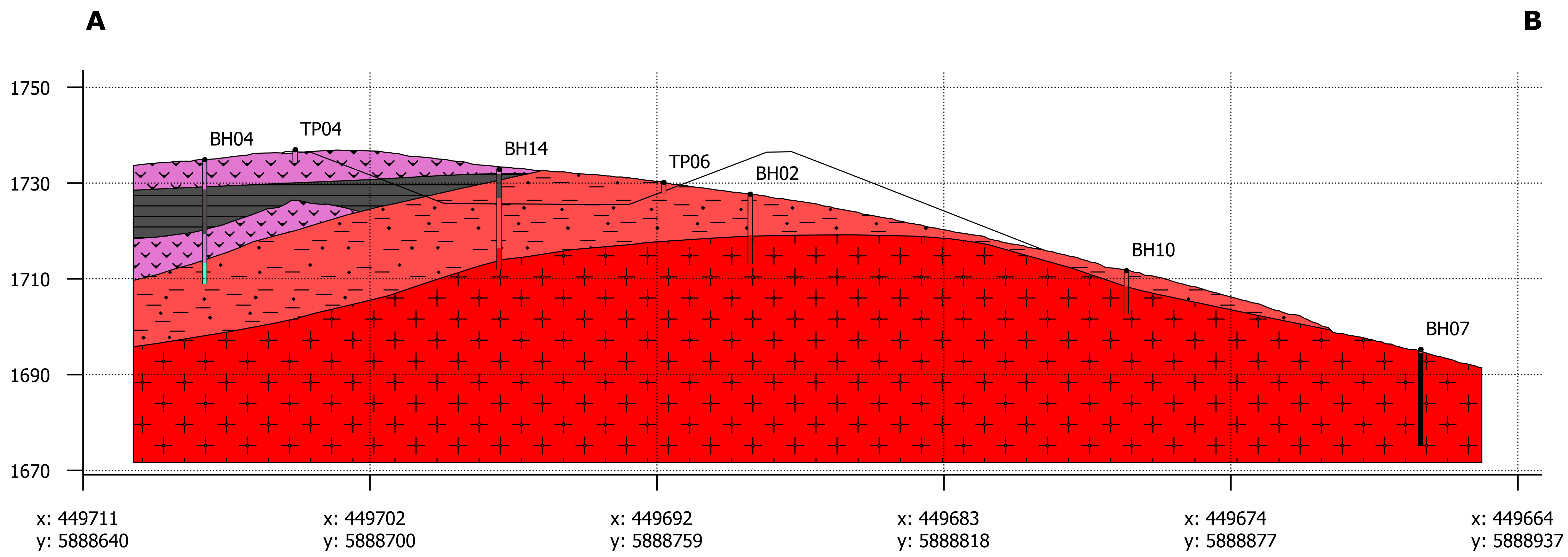
B: 449627, 5888917

Scale: 1:1,000

Vertical exaggeration: 1x

0m 50m

Geological Section - North to South (NS4)



Legend

Geological Units

- Upper basalt
- Basalt
- Granite (MW)
- Granite (XW)
- Carbonaceous mudstone

Location

A: 449711, 5888640

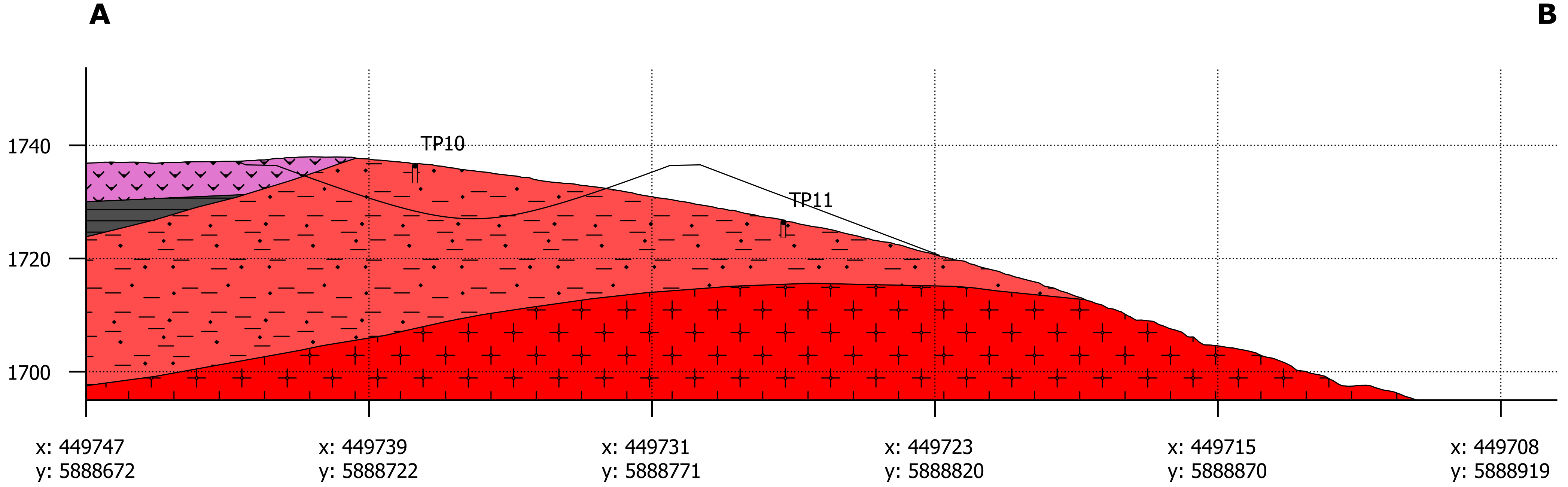
B: 449664, 5888942

Scale: 1:1,100

Vertical exaggeration: 1x

0m 50m

Geological Section - North to South (NS5)



Legend

Geological Units

- Upper basalt
- Granite (MW)
- Carbonaceous mudstone
- Granite (XW)

Location

A: 449747, 5888672

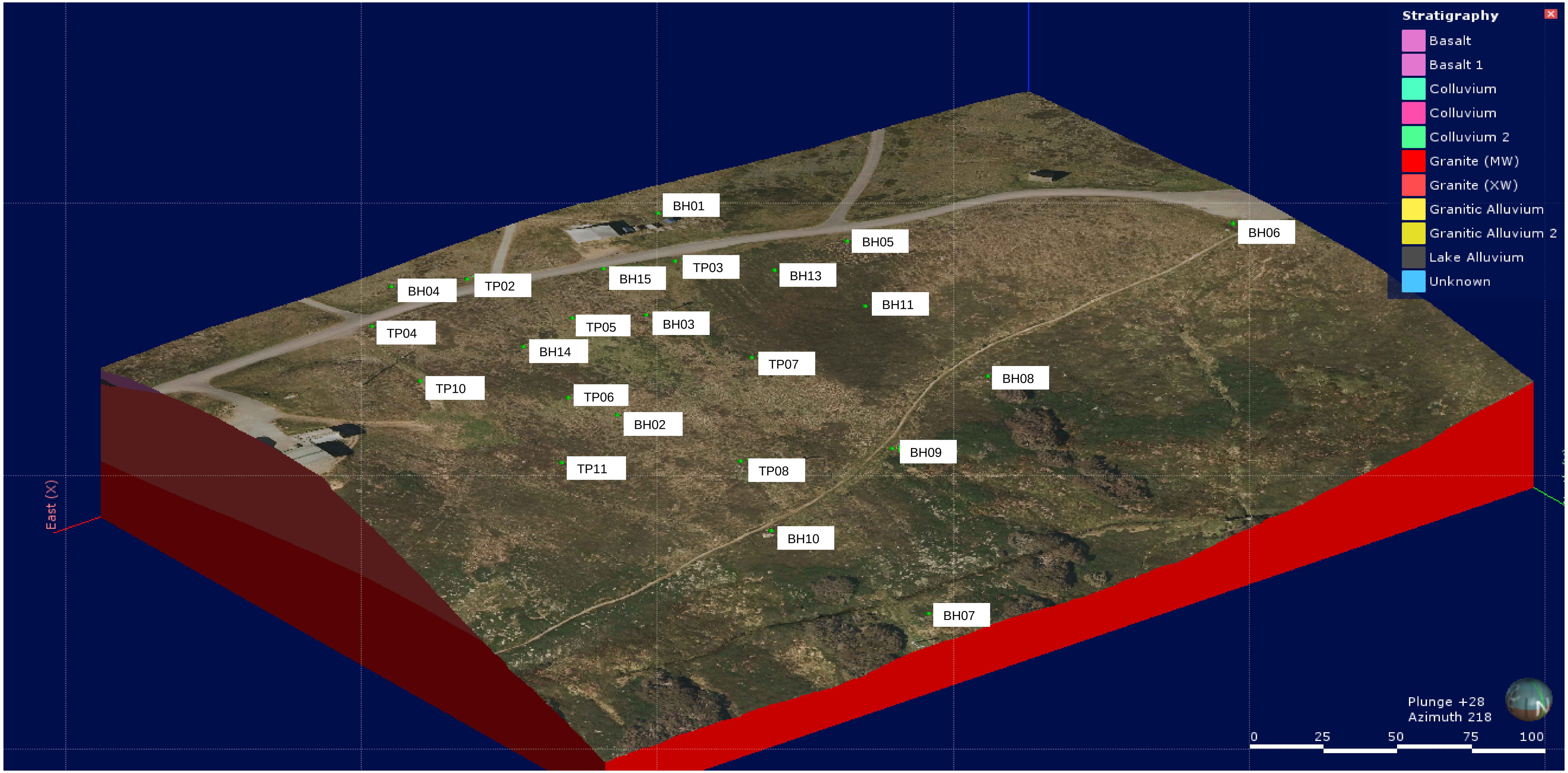
B: 449706, 5888929

Scale: 1:1,000

Vertical exaggeration: 1x

0m 50m

Appendix D – Geological model images



Mt Buller and Mt Stirling Alpine Resort Management Board
Mt Buller Sustainable Water Security Project
Geotechnical Investigation Locations - Storage Area

scale as shown date 7 October 2014

job no 31 / 30733 / 13
file ref

©

Figure D1

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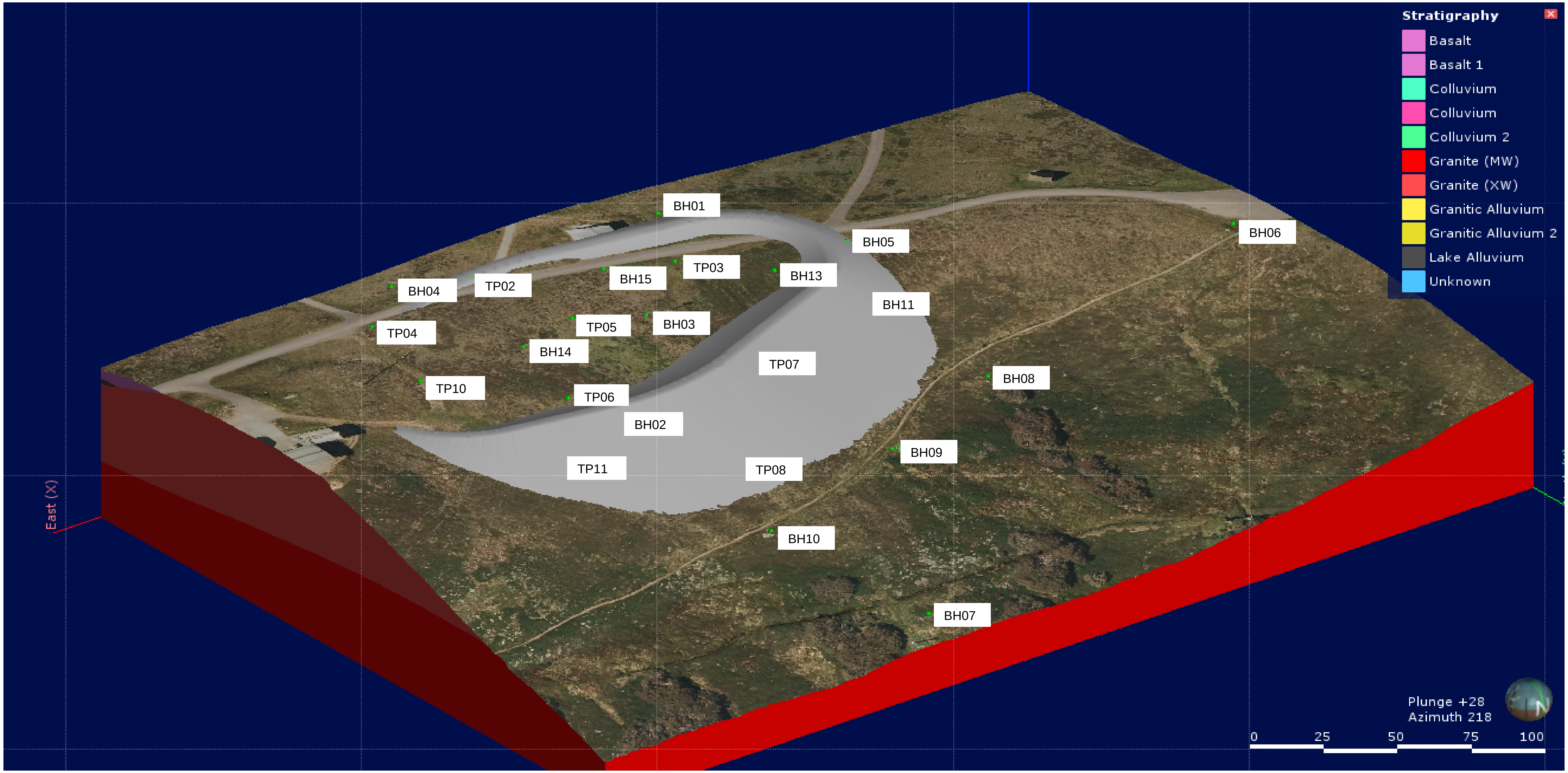
G:Geo _projects\Job No\Geotechnical investigation locations - D1 9/10/2014



Mt Buller and Mt Stirling Alpine Resort Management Board
Mt Buller Sustainable Water Security Project
Proposed Storage Location

scale	as shown	date	7 October 2014

job no 31 / 30733 / 13
file ref

Figure D2

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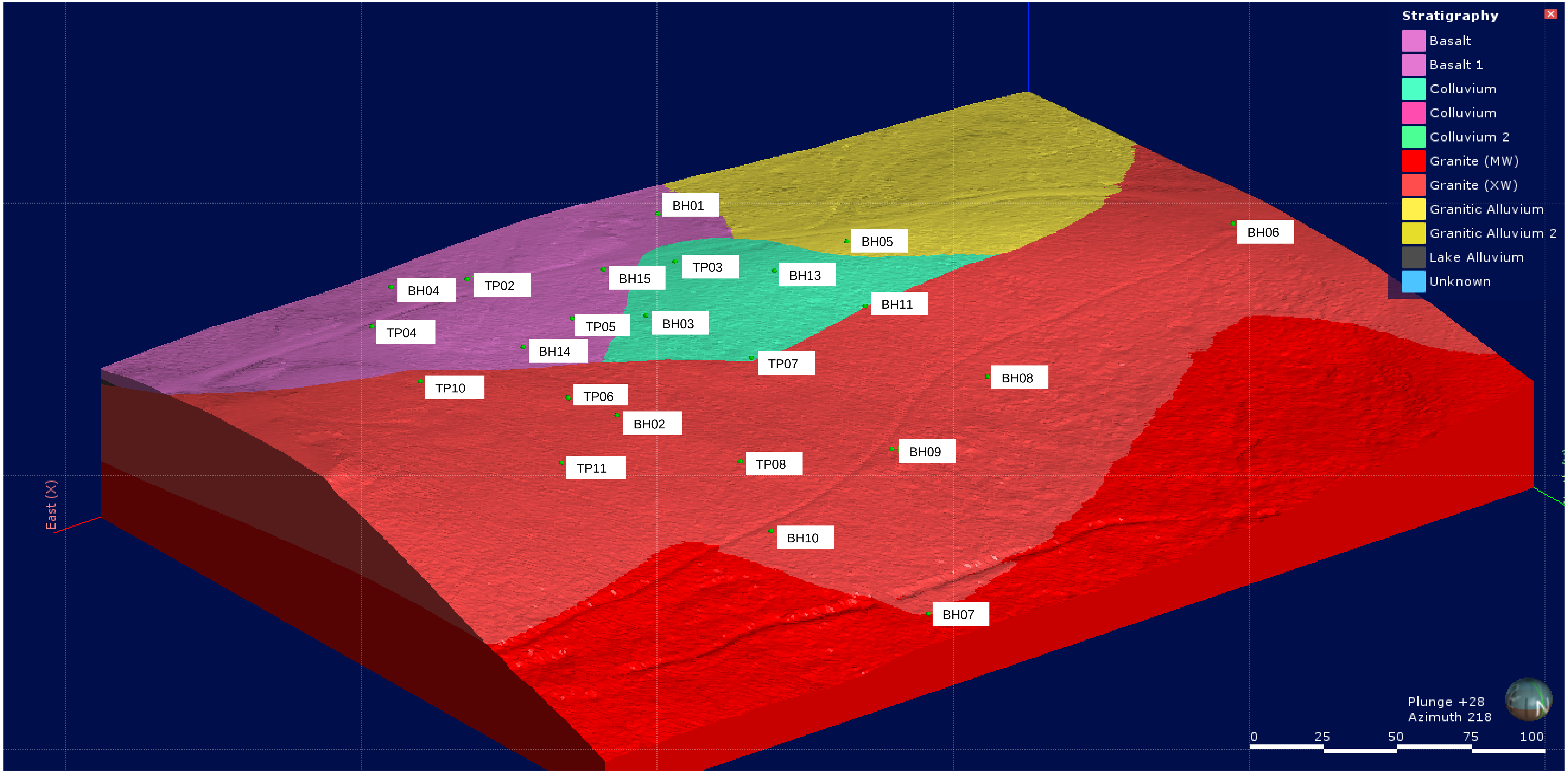


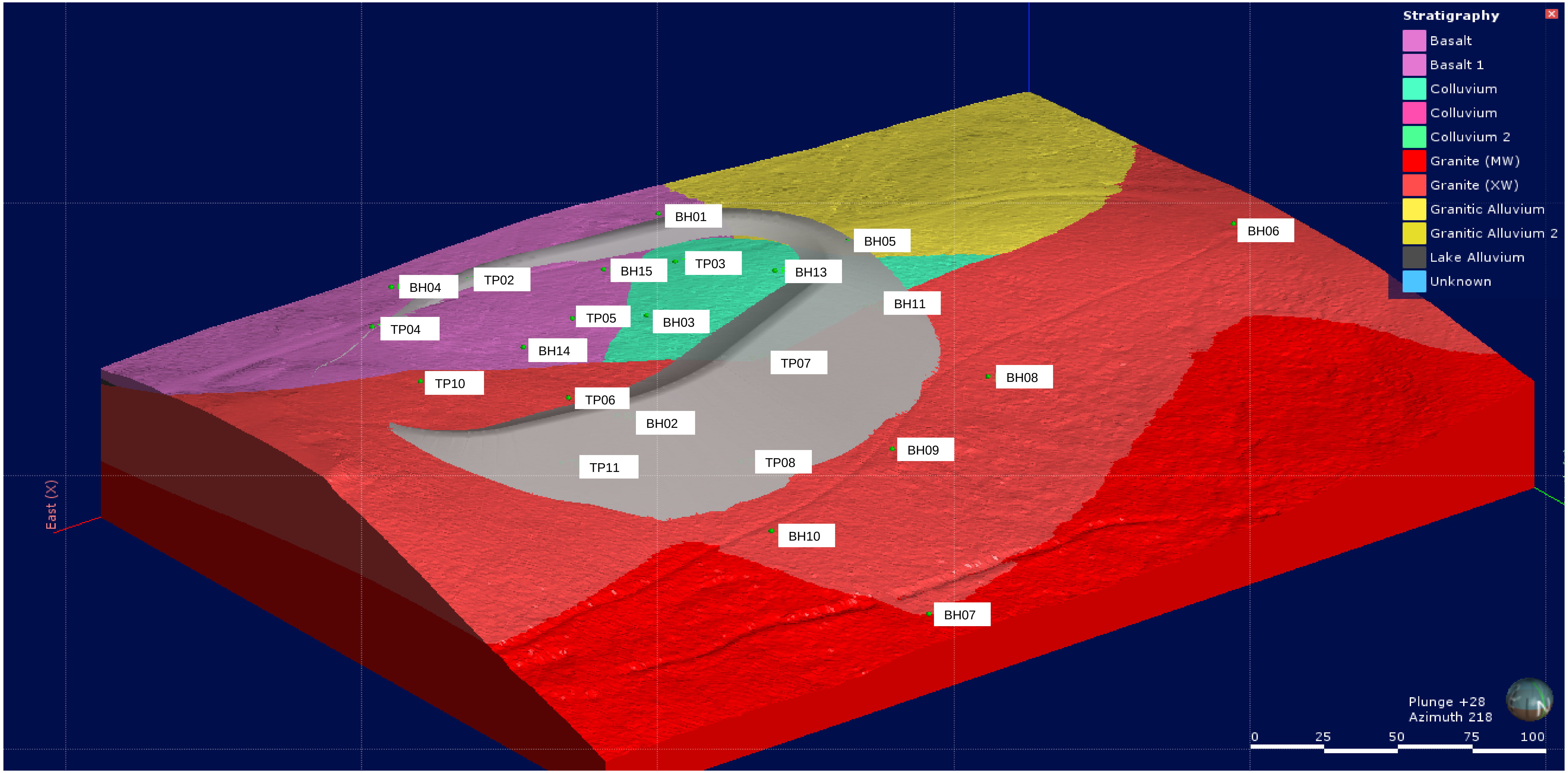
Mt Buller and Mt Stirling Alpine Resort Management Board
Mt Buller Sustainable Water Security Project
Interpreted Surface Geology- Storage Area

scale	as shown	date	7 October 2014

job no 31 / 30733 / 13
file ref

Figure D3

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



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Mt Buller and Mt Stirling Alpine Resort Management Board
Mt Buller Sustainable Water Security Project
Interpreted Surface Geology and Proposed Dam Structure

scale as shown date 7 October 2014

job no 31 / 30733 / 13
file ref

Figure D4

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Appendix E – Qualitative terminology for use in assessing risk to property

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

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

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

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

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

Appendix F – Erosion management overlay – Schedule 1 management of geotechnical hazard

DEPARTMENT OF PLANNING & COMMUNITY DEVELOPMENT

ALPINE RESORTS PLANNING SCHEME
Erosion Management Overlay – Schedule 1 Management of Geotechnical Hazard

FORM 1
Declaration and/or verification made by geotechnical engineer or engineering geologist as part of a geotechnical report

Name of application: _______Mount Buller Off Stream Storage Project____________________________
Address of subject site: ________Summit Road, Mt Buller, 3723____________________
I, _________Andrew Leventhal________________ of ________GHD Geotechnics______________
(insert name) (trading or company name)
on ___________________03 August 2016____________________
(insert date)

certify that I am a geotechnical engineer or engineering geologist as defined by the Erosion Management Overlay (Schedule 1 – Management of Geotechnical Hazard) and I have: (tick appropriate box):

☐ ~~prepared the Geotechnical Report referenced below in accordance with the Australian Geomechanics Society's Geotechnical Risk Management Guidelines and Clause 3 of the EMO1~~

~~or~~

☑ technically verified that the geotechnical report referenced below has been prepared in accordance with the AGS's Geotechnical Risk Management Guidelines and Clause 3 of the EMO1.

Geotechnical report details:

Report title: Mt Buller Sustainable Water Security – Off Stream Storage Project – Geotechnical Risk Assessment

Report date: August 2016

Report reference: 31\3073313\233153 Rev 2

Author: Alistair Schofield

Author's affiliation: Member of Australian Geomechanics Society, Fellow of Geological Society of London

Documentation relied upon in report preparation:

1:250k Warburton Geological map produced by the geological survey of Victoria;

GHD Report, "Off-Stream Storage Concept Design Summary" doc no. 31/3073322/253326, July 2016,

GHD Report; *"Factual Geotechnical Report"*, doc no 31/30733/13/230606, June 2014.

I am aware that the Geotechnical Report I ~~have either prepared or~~ am technically verifying for the above development is to be submitted in support of a development application for the proposed development __Mount Buller Off Stream Storage__ requiring approval from the Minister for Planning. (name of development)

Further, I am covered under a current professional indemnity insurance policy held by GHD Pty Ltd of at least $2 million, evidence of which is attached with this form.

Name __Andrew Leventhal

Signature ________________________________

Date ___03 August 2016

Reviewer's affiliation: BE (Hons), MEngSc, FIEAust, CPEng, NER.
Member Australian Geomechanics Society, Past National Chairman AGS, Past Chair AGS Landslide Risk Management Sub-Committee

State Government Victoria

DEPARTMENT OF PLANNING & COMMUNITY DEVELOPMENT

ALPINE RESORTS PLANNING SCHEME
Erosion Management Overlay – Schedule 1 Management of Geotechnical Hazard

FORM 1
Declaration and/or verification made by geotechnical engineer or engineering geologist as part of a geotechnical report

Name of application: _______Mount Buller Off Stream Storage Project_____________________________
Address of subject site: ________Summit Road, Mt Buller, 3723____________________
I, ________Alistair Schofield ___________ of ________GHD Pty Ltd_______________
(insert name) (trading or company name)
on ________________03 August 2016____________________
(insert date)

certify that I am a geotechnical engineer or engineering geologist as defined by the Erosion Management Overlay (Schedule 1 – Management of Geotechnical Hazard) and I have: (tick appropriate box):

☑ prepared the Geotechnical Report referenced below in accordance with the Australian Geomechanics Society's Geotechnical Risk Management Guidelines and Clause 3 of the EMO1

~~or~~

☐ ~~technically verified that the geotechnical report referenced below has been prepared in accordance with the AGS's Geotechnical Risk Management Guidelines and Clause 3 of the EMO1.~~

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GHD Report; *"Factual Geotechnical Report"*, doc no 31/30733/13/230606, June 2014.

I am aware that the Geotechnical Report I have either prepared ~~or am technically verifying~~ for the above development is to be submitted in support of a development application for the proposed development __Mount Buller Off Stream Storage__ requiring approval from the Minister for Planning.
(name of development)

Further, I am covered under a current professional indemnity insurance policy held by GHD Pty Ltd of at least $2 million, evidence of which is attached with this form.

Name ___Alistair Schofield___ Signature ______________

Date ____03 August 2016

State Government Victoria

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Direct Line: +612 9285 4060
Direct Fax: +61 2 9995 7297
Email: stevensont@willis.com

Issue Date: 2 December 2015

To Whom It May Concern

Certificate of Placement - Professional Indemnity Insurance

In our capacity as Insurance Broker to the Named Insured shown below, we confirm having arranged the following insurance, the details of which are correct as at the Issue Date:

Named Insured:	GHD Pty Ltd and Subsidiaries
Form:	Civil Liability Wording which includes coverage for the Trade Practices Act and the Competition and Consumer Act
Policy Number:	B080113856P15
Limit of Indemnity:	AU$2,500,000 any one claim and in the aggregate
Period of Insurance:	1 December 2015 at 4.00pm to 1 December 2016 at 4.00pm
Insurer:	Certain Underwriters at Lloyd's of London

WILLIS AUSTRALIA LIMITED
A.C.N. 000 321 237
PROFESSIONAL RISKS PRACTICE

Signed for and on behalf of
Willis Australia Limited

Disclaimer:
This document has been prepared at the request of our client and does not represent an insurance policy, guarantee or warranty and cannot be relied upon as such. All coverage described is subject to the terms, conditions and limitations of the insurance policy and is issued as a matter of record only. This document does not alter or extend the coverage provided or assume continuity beyond the Expiry Date. It does not confer any rights under the insurance policy to any party. Willis Australia Limited is under no obligation to inform any party if the insurance policy is cancelled, assigned or changed after the Issue Date.

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	A Schofield	T O'Shannessy G Granger	T O'Shannessy* G Granger*	G Jones	G Jones*	04/07/2014
1	A Schofield	T O'Shannessy	T O'Shannessy*	G Jones	G Jones*	09/10/2014
2	A Schofield	A. Leventhal		G. Jones		03/08/2016

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