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BALLINA SHIRE COUNCIL

GEOTECHNICAL REPORT ON LANDSLIDE REMEDIATION COAST ROAD, LENNOX HEAD

10644/1-C
July 2011

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10644/1-C ku:ps
14 July 2011

Ballina Shire Council

PO Box 450

BALLINA NSW 2478

Attention: Mr Paul Busmanis

RE: LANDSLIDE REMEDIATION, COAST ROAD, LENNOX HEAD

Please find attached our report on geotechnical studies for the remediation of a landslide at the above location. The report presents the results of field investigations, laboratory testing and slope stability studies and presents options for remediation of the landside and the adjacent areas.

If you have any questions or wish to discuss or clarify any of the issues raised in this report, please contact Philip Shaw at our Brisbane office.

For and on behalf of

SHAW URQUHART PTY LTD

PHILIP SHAW

Principal Geotechnical Engineer

Distribution: Original held by Shaw Urquhart Pty Ltd

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1. INTRODUCTION

This report describes geotechnical studies carried out by Shaw Urquhart Pty Ltd at the site of a landslide on Coast Road, approximately 1km south of Lennox Head. At this location, Coast Road, the main transport route between Lennox Head and Ballina, is located on a fill embankment which carries the two-lane road over a broad embayment in the hillside. The embankment is around 200m long and rises to approximately 7m above the natural ground level. It is understood to have been constructed around 1971, with a footpath berm added in 1995-1996.

In January 2011, a 40m-long section of the north eastern (down-slope) side of the embankment experienced a landslide, and a further 50m of tension cracking extended north westerly along the Coast Road shoulder. The landslide occurred progressively over a number of days and resulted in an approximately 4m-high slip scarp in the edge of the south-bound carriage-way. The south bound lane was closed to traffic and remains closed at the time of preparing this report.

It is understood that the embankment has been subject to creep and on-going minor pavement cracking since 2005.

Shaw:Urquhart was commissioned by Council to carry out geotechnical studies to assess local subsurface and geological conditions, identify the failure mechanism and extent of the failure and formulate options for stabilisation and remediation of the road embankment.

2. FIELD WORK

Field work for the geotechnical studies consisted of the following elements:

- At the request of Council, an initial visit to the site was carried out by a Geotechnical Engineer from our Brisbane office (Dr. Philip Shaw) on the morning of 7 January 2011. Discussions were held with Paul Busmanis, Greg Heathwood and Max Beecher of Council regarding clearing of vegetation and survey work to assist with identifying the extent of the landslide and providing slope geometry for use in slope stability analyses.
- Subsequent to clearing of the vegetation along survey lines and around the perimeter of the landslip, an Engineering Geologist from our Brisbane office visited the site on 12 January 2011 to map the site features and local surface geology and to assess site access for subsurface investigations.
- Eight test pits were excavated at selected locations on 1 February 2011 and a further single test pit (TP3A) was excavated and test pit TP7 deepened on 8 March 2011. The test pits were excavated in the full time presence of an Engineering Geologist who was responsible for locating the test pits, preparing field logs of the soil profiles encountered and retrieving representative soil

samples as required. Test pit locations, with the exception of test pit TP8, were pegged and surveyed by Council.

- Four boreholes were drilled to depths of between 12.75m (borehole BH1) and 15.75m (borehole BH4) between 3 February 2011 and 10 February 2011. The boreholes were all located on the pedestrian access path which runs along the central part the north-eastern embankment batter. Boreholes BH1 and BH2 were located within the landslide area, borehole BH3 was located approximately 10m north-west of the landslide and borehole BH4 was located approximately 60m north-west of the landslide.
- The boreholes were drilled in the full time presence of a Geotechnician who was responsible for locating the boreholes, nominating and directing sampling and testing and preparing field logs of the soil profiles encountered. Boreholes were drilled using auger techniques until an obstruction or increased resistance was encountered. The boreholes were then deepened using diamond coring techniques. The borehole locations were pegged and surveyed by Council.

3 SITE CONDITIONS

3.1 Surface Conditions

The site is located approximately 1km to the south east of Lennox Head where Coast Road crosses a gently-curved fill embankment which carries the two-lane road over a broad embayment in the hillside.

To the south west of the embankment, natural hill slopes rise steeply to the crest of a prominent escarpment. At the base of these slopes, the ground levels out to fall at around 10° to the north east, under the road embankment and towards the nearby coastline.

The height of the crest of the embankment above natural ground is typically around 7m at the south eastern end and 5m towards the north western end. The embankment profiles at selected locations are shown on the survey cross-sections presented in Appendix D. From these survey cross-sections it appears that the down-slope, north eastwards-facing batter was formed at around 30° to 45°, steeper towards the south eastern end. The batter has a stepped profile, with a 3m-wide berm forming a pedestrian access pathway. In the area of the landslide, it appears that around 1m to 1.5m of fill has been placed on the ground to the north east of the embankment for a distance of around 10m to 12m from the toe of the road embankment.

The batter on the up-slope side of the embankment is typically around 2m high and formed at around 30°. The embankment cuts off the natural drainage paths from the adjacent hill slopes and an unlined drain runs along the up-slope side of the embankment to collect surface water flow and channel it into a stormwater pipe crossing under the embankment towards its north western end.

Vegetation cover on the road embankment batters is grass, with long cane grass on the filled area to the north east of the road embankment and areas of scrub and low trees.

The landslide is around 40m in length and occurred towards the south eastern end of the embankment. The rear scarp of the failure, located adjacent to the edge of the south-bound road seal, is approximately semi-circular with a central straight section and, at the time of the investigations, was approximately 3.8m in vertical height at its highest point. The ground level at the base of the scarp, on the pedestrian pathway, appears to have dropped by between 1m and 2.2m and "before and after" survey cross-sections provided by Council indicate that the toe of the embankment has moved down-slope by around 6m to 7m.

A number of large, open ground cracks were noted within the failure zone, resulting in terracing of a section of the rear scarp on the north western end and, what appears to be rotated soil masses, in the central area of the landslide.

3.2 Local Geology and Subsurface Conditions

According to the published geology map of the area (1:100,000 scale "Lismore" sheet), the site is underlain by weathered volcanic rocks of the Tertiary Lismore Basalt. This was confirmed by site observations.

Generally, the site is underlain by varying thickness of embankment fill underlain by natural colluvial soils.

The embankment fill consists predominantly of red brown, silty clay with varying amounts of gravel. Other soils types present include but may not be limited to clayey gravel, clay/gravel/cobble layers and sand.

The natural soils present on site consist predominantly of silty clay and silty gravelly clay, varying in colour from dark grey to blue grey and grey brown, with red brown and orange mottling. The natural clay soils are generally blocky and friable to varying degrees. Layers containing basalt gravel, cobbles and occasional boulders are present. These soils are interpreted to be colluvium and/or hillwash, derived from the down-slope movement of soils from the nearby raised escarpment.

The subsurface conditions encountered in each borehole and test pit are summarised in Table 1.

TABLE 1: SUMMARY OF SUBSURFACE CONDITIONS

Test Location	Generalised Soil Profile				
	FILL	Silty CLAY/Clayey SILT	SAND, Clayey SAND	Gravelly CLAY/Clayey GRAVEL	GRAVEL, COBBLES, BOULDERS
	Depth (m)				
BH1	0.0-4.4	4.4-5.0, 8.6-10.4, 10.85-12.2	--	5.0-8.6	10.4-10.85, 12.2-12.75
BH2	0.0-4.0	4.0-13.9	--	--	13.9-15.0, 15.0-15.6
BH3	0.0-2.9	2.9-3.3, 5.0-6.5, 7.0-12.5, 13.0-14.15	3.3-4.4	4.4-5.0, 6.5-7.0,	12.5-13.0
BH4	0.0-1.6	1.6-2.5, 4.0-10.55, 13.8-14.6	11.0-13.5	2.5-4.0, 14.8-15.4	10.55-11.0, 13.5-13.8, 14.6-14.8, 15.4-15.75
TP1	0.0-2.0	2.0-4.1	--	--	--
TP2	0.0-0.8	0.8-3.0	--	--	--
TP3	0.0-2.1	2.1-4.2	--	--	--
TP3A	0.0-1.8	1.8-5.7, 6.3-6.4	--	--	5.7-6.3
TP4	0.0-1.3	1.3-2.0	--	--	--
TP5	0.0-1.8	1.8-4.1	--	--	--
TP6	0.0-1.0	1.0-3.2	--	--	--
TP7	0.0-4.1	4.1-6.0	--	--	--
TP8	0.0-1.0	1.0-2.5	--	--	--

Engineering logs of the boreholes and test pits are presented in Appendix A along with explanation sheets describing the terms and symbols used. Borehole and test pit locations are shown on Figure 1.

3.3 Groundwater

Groundwater inflows were encountered in a number of the boreholes and test pits in various materials and at different depths. These groundwater levels are summarised in Table 2.

TABLE 2: SUMMARY OF GROUNDWATER INFLOWS AND STANDING WATER LEVELS

Test Location	Depth (m)	Standing Water Level Depth (m)
BH1	NR	NR
BH2	2.8	4.0
BH3	NR	NR
BH4	NR	NR
TP1	2.0	NR
TP2	0.8	NR
TP3	2.3	NR
TP3A	4.2	NR
TP4	1.0	NR
TP5	NE	NE
TP6	1.0	NR
TP7	1.5	NR
TP8	NE	NE

NR –Not Recorded NE – Not Encountered

4. LABORATORY TESTING

Atterberg limits tests along with a direct shear test, were carried out on an undisturbed sample of firm clay from 5.5m depth in borehole BH2.

The results are presented in Appendix B.

The direct shear test obtained peak shear strength parameters of cohesion 68.10kPa and friction angle 37.7° reducing to residual shear strength parameters of cohesion 60.9kPa and friction angle 37.5°. These results are not consistent with expectations for firm clay and have been ignored in the analyses. From discussions with the testing laboratory, the sample may have contained a localised concentration of peat fibres which have resulted in the unexpected higher strength.

5. GEOTECHNICAL ENGINEERING DISCUSSION

5.1 Construction History

From information provided by Council, it is understood that the Coast Road embankment was originally constructed around 1971. A toe berm was constructed around 1995/1996 to provide support for the existing road batter and to form a pedestrian access pathway.

It is understood that the current landslide occurred on or around 7 January 2011 after a period of heavy rainfall. Eyewitness reports indicate that the initial movement comprised tension cracking with minor slumping (in the order of 0.3m) over a limited length of the embankment, but that the movement continued over a period of several days until the rear scarp was around 4m in vertical height over a length of about 40m, with the crest of the scarp at the edge of the bitumen seal.

5.2 Landslide Geometry and Mode of Failure

The landslide is located at the south eastern end of the embankment on the north eastern, sea-ward side. The zone of ground movement is approximately 40m long (north west–south east) by 35m wide (south west – north east). A survey record of topographic features and site observations relating to the landslide is shown on Figure 1.

In plan view, the rear scarp of the landslide is broadly semicircular and has extended approximately 0.8m behind the crest of the embankment batter. The height of the rear scarp of the landslide is around 4m. The body of the landslide is crossed by a number of large, open ground cracks, some of which are shown on Figure 1. The north western side of the landslide is terraced, with approximately three small slip scarps with vertical heights of around 0.2m to 0.6m.

From survey and site observations, the surface of the pedestrian path has dropped by a round 1m at the north western end of the landslide and 2.2m at the south eastern end. Evidence of off-sets of layers of soil in test pit TP7 indicated that the rear scarp of the landslide has a vertical displacement of approximately 2.4m.

In terms of the mode of failure of the landslide, surface survey data and observations from test pit TP7 of the shape of the slip plane indicates that the landslide is formed from two to three rotated blocks and possibly one translational or lateral sliding block of soil, with the base of the landslide located within or at the base of a layer of natural firm silty clay. This model closely fits the geometry of the upper and middle part of the landslide however the lack of evidence of an obvious failure plane or zone of significant soil disturbance at the toe of the landslide is problematic. Also, site observations indicate that the landslide has rotated in a horizontal plane with the centre of rotation in an area approximately 15m north-west of test pit TP5.

An interpreted cross-section geometry of the landslide based on survey Cross-Section 2 is shown on Figure 2.

The trigger for the landslide is speculative, but raised groundwater levels in the natural soils and in permeable soil layers within the embankment are likely to be contributing factors.

5.3 Remedial Works – Within Landslide Area

5.3.1 Computer Stability Analyses

Computer stability analyses of the landslide were carried out with the assistance of the computer program SLOPE/W. The analyses were carried out in two stages, as follows:

- Stability analysis of the landslide to confirm assumptions regarding the soil effective stress shear strength parameters and groundwater conditions at the time of failure.
- Formulation of options for remedial works.

Stability analyses were carried out for the pre-failure batter geometry as interpreted from previous survey provided to Shaw:Urquhart by Council. The analyses indicated that the original batter had a factor of safety of around 1.0 for raised groundwater conditions. It is expected that this would result in initial creep movement of the outer part of the batter followed by larger-scale movement as soil peak shear strength parameters reduced to residual shear strengths. It is understood that heavy rainfall at the time of failure may have raised the groundwater level within the embankment to a critical level.

The stability analyses for the remedial works were carried out using assumed effective stress shear strength parameters for the various soil materials, based on our experience with similar soil types elsewhere. The analyses considered both raised groundwater levels and suppressed groundwater levels where additional drainage measures are proposed. A traffic loading of 20kPa was also assumed.

The design of the remedial works adopted a target factor of safety of not less than 1.5 for long term operating conditions for the re-constructed embankment.

A number of options for remediation of the landslide area were assessed. These included the following:

- Excavation and replacement of the failed soil mass with reconstruction of the outer face of the road embankment and construction of a toe berm to support the new construction. This option does not provide an adequate factor for safety.
- Partial or total excavation of the foundation soils beneath the road embankment in conjunction with the use of geofabric reinforcement and/or improved drainage. These options are feasible and would permit reconstruction of the pedestrian access path.
- Leaving the landslide debris in place and supporting the existing batter using bored piles at the crest of the existing road embankment or supporting a reconstructed batter using bored piles on the existing footpath alignment. Only a

preliminary design has been carried out at this stage but these options are feasible. The footpath alignment would need to be permanently closed unless further works were carried out to stabilise the landslide area.

The geotechnical issues relating to each of the above options are discussed in Section 5.3.2. For the purpose of remedial design, Cross Section 2 has been taken as representative of the landslide area.

5.3.2 Options for Landslide Area Remediation

5.3.2.1 Construction of Toe Berms

This option has been considered in an attempt to minimise the amount of earthworks carried out at the site whilst allowing reconstruction of the pedestrian access path.

It has been assumed that the landslide debris will be excavated and replaced with engineered fill. The outer face of the road embankment will be reinstated with batter slopes no steeper than 1V:2H and two berms. The location of the berms will vary depending on the location of the pedestrian access path but for the purpose of analyses the upper berm has been assumed at RL20.5m and 3m wide and the lower berm has been assumed at RL19m and 2m wide.

Computer stability analyses were carried for a variety of different heights and widths of rock-fill toe berms constructed at the base of the re-constructed embankment to provided additional toe support. The results of the analyses indicated that this option was not feasible as the potential slip surfaces simply moved towards the down-slope side of the embankment without an acceptable increase in factor of safety. This was due to the presence of the soft to firm clay layer within the foundation subsurface profile.

This option does not provide an adequate factor of safety.

5.3.2.2 Partial or Total Excavation & Replacement of Foundation Soils

These options are shown in schematically on Figures 3 to 6 and allow for reconstruction of the pedestrian access path. The requirement for partial or total excavation will depend on the nature of the replacement materials, drainage conditions and the factor safety considered acceptable to Council.

Computer stability analyses indicate that it is necessary to excavate and replace the landslide debris and the low strength foundation soils (soft to firm clay) down to the surface of the stiff clay which was encountered at about 6.5m to 7m depth in boreholes BH1 and BH2. The inferred extent of excavation and replacement for each option is shown on Figures 3 to 6.

In order to maintain stability during excavation and replacement of the foundation soils it is necessary to entirely remove the existing road embankment. Preliminary analyses indicate that a short term factor of not less than 1.3 can be achieved during construction and after the road embankment is removed by excavating at 40° with a 2m wide mid-

height bench. Depending on the actual conditions exposed at the time of construction it may be possible to excavate with steeper slopes.

Test pit TP7 encountered a loose layer of gravel and cobbles in a silty clay matrix with strong seepage and organic odour within the central part of the existing embankment. This suggests that unsuitable material may have been disposed of by encasing it within the core of the embankment.

It has been assumed that the road embankment will be reinstated with batter slopes no steeper than 1V:2H and two berms. The location of the berms will vary depending on the location of the pedestrian access path but for the purpose of analyses the upper berm has been assumed at RL20.5m and 3m wide and the lower berm has been assumed at RL19m and 2m wide as shown on Figures 3 to 6. It has been assumed that the road embankment will be constructed of clayey materials similar to the existing construction.

Different factors of safety are obtained depending on the nature of the material used in the replacement zone, the adequacy of subsurface drainage and whether geofabric reinforcement is used in the reconstruction of the road embankment. The factors of safety for each option are presented in Table 3.

The results of the stability analyses suggest that feasible options are clay replacement in conjunction with geofabric reinforcement or rock fill replacement. The use of geofabric reinforcement in conjunction with the rock fill is not necessary but if used will provide increased global stability.

If graded rock fill is to be used, geofabric separation layers will be required above and below the rock fill. A free draining, durable, well graded, crushed rock fill material with a maximum particle of 150mm is recommended. The material should be placed in layers not exceeding 300mm in thickness and compacted by a minimum of 6 passes of a smooth drum vibrating roller or grid roller of at least 10 tonne static weight. The compaction should continue until no further reduction of the layer surface height occurs.

The free draining rock fill will be able to accommodate seepage from the surrounding area and will not be susceptible to softening during periods of elevated groundwater levels such as may occur during periods of prolonged intense rainfall.

The installation of high strength, uniaxial woven geofabric layers at the base of the re-constructed embankment will assist in improving stability. The analyses indicate that two layers of 200kN working strength uniaxial woven geofabric would be required, installed at the base of the embankment during the early stages of the embankment re-construction.

The lowered groundwater level option assumes that subsurface drains can be installed to lead water from the rock fill replacement zone and permanently maintain a lowered groundwater level beneath the road embankment.

Toe drains and table drains under the embankment should be constructed for the clay fill option to prevent raised groundwater levels developing within the road embankment.

TABLE 3: FACTORS OF SAFETY FOR EXCAVATION & REPLACEMENT

Condition Analysed	Factor of Safety	
	Clay Fill in Replacement Zone	Graded Rock Fill in Replacement Zone
Partial replacement with elevated groundwater levels	1.31*/1.35	1.40*/1.51
Partial replacement with elevated groundwater levels and two layers of 200kN geofabric at base of road embankment fill	1.59	1.64
Partial replacement with lowered groundwater levels	Not considered feasible	1.41*/1.58
Total replacement with elevated groundwater levels	1.35*/1.36	1.45*/1.56
Total replacement with elevated groundwater levels and two layers of 200kN geofabric at base of road embankment fill	1.61	1.74
Total replacement with lowered groundwater levels	Not considered feasible	1.61*/1.69

* Factor of safety of lower berm.

5.3.2.3 Piled Support

These options are shown in schematically on Figures 7 and 8 and been considered to minimise work within the landslide area. The pedestrian access path would need to be permanently closed unless further works were carried out to stabilise the landslide area.

The options involve leaving the landslide debris in place and supporting the existing batter using bored piles at the crest of the existing road embankment (Figure 7) or supporting a reconstructed batter using bored piles on the existing footpath alignment (Figure 8). Only a preliminary design has been carried out at this stage and further detailed analyses would be required, along with the involvement of a specialist piling contractor if these options are to be considered further.

Preliminary design indicates that for the option shown on Figure 7, 20m long, 1200mm diameter piles at 1.8m centres will provide an adequate factor of safety. Lateral deflections at the pile head are estimated to be in the order of 80mm. The piles would be installed from the existing road embankment and for in-service use would require the road to be moved towards the hillside to provide sufficient width for a road shoulder. It is assumed that road crash barriers could constructed within the capping beam. It will also be necessary to construct shotcrete or panel facing on the upstand section of the piles to bridge the gaps between the piles and support the soil.

The option shown on Figure 8 assumes that the outer face of the road embankment will be reconstructed at 1V:2H with the toe supported by a capping beam connected to 15m long, 1200mm diameter piles at 1.8m centres. Lateral deflections at the pile head are estimated to be in the order of 100mm. Preliminary discussions with Wagstaff Piling indicate that to enable this option to be constructed will require a temporary working platform to be constructed across the landslide zone using layers of geofabric and gravel supported on timber piles driven into the underlying natural profile.

If the pedestrian access path is to be reinstated, further stabilisation works will be necessary.

5.4 Remedial Works – Outside of Landslide Area

5.4.1 Computer Stability Analyses

Tension cracks were observed in the road shoulder to the north of the landslide as shown on Figure 1.

Cross Section 6 was selected as being representative of this area and the subsurface profile of borehole BH3 was used in the analyses of the stability of the existing road embankment. The subsurface profile is similar to that at the landslide location in that there is a significant layer of soft to firm clay at depth beneath the road embankment.

For assumed peak shear strength parameters and groundwater conditions similar to those likely to have occurred at the time of the landslide to the south, a factor of safety of about 1.3 was estimated. This is less than would generally be desirable at this location. If the subsidence observed in the existing road embankment is assumed to be due to the presence of the soft to firm clay layers and the shear strength is reduced slightly to take account of strain softening, a factor of safety approaching 1.0 can be readily obtained with the rear scarp of the potential failure surface at approximately the location of the existing tension cracks.

If large scale failure of the road embankment, as has occurred further to the south, is to be avoided, it is recommended that remedial works be carried out to arrest the creep movement and improve the stability of the embankment in the area extending from the current landslide to the car-park area to the north.

5.4.2 Options for Remediation

5.4.2.1 Partial Excavation & Replacement of Foundation Soils

This option is shown in schematically on Figures 9 and 10 and includes provision for the pedestrian access path.

Computer stability analyses indicate that it is necessary to excavate and replace the low strength foundation soils (soft to firm clay and firm to stiff clay) down to the surface of the very stiff clay which was encountered at about 8.2m depth in borehole BH3 which is approximately 1m deeper than at the landslide location. The inferred extent of excavation and replacement is shown on Figures 9 and 10.

In order to maintain stability during excavation and replacement of the foundation soils it is necessary to entirely remove the existing road embankment. Construction excavation batter slopes similar to those recommended in Section 5.3.2.2 will be acceptable.

It has been assumed that the road embankment will be reinstated with batter slopes no steeper than 1V:2H and one berm at about mid-height. The location of the berm will vary depending on the location of the pedestrian access path but for the purpose of analyses the berm has been assumed at RL18m and 3m wide. It has been assumed that the road embankment will be constructed of clayey materials similar to the existing construction.

Different factors of safety are obtained depending on the nature of the material used in the replacement zone, the adequacy of subsurface drainage and whether geofabric reinforcement is used in the reconstruction of the road embankment. The factors of safety for each option are presented in Table 4.

TABLE 4: FACTORS OF SAFETY FOR EXCAVATION & REPLACEMENT

Condition Analysed	Factor of Safety	
	Clay Fill in Replacement Zone	Graded Rock Fill in Replacement Zone
Partial replacement with elevated groundwater levels	1.18*/1.28	1.49
Partial replacement with elevated groundwater levels and two layers of 200kN geofabric at base of road embankment fill	1.58	1.65
Partial replacement with lowered groundwater levels	Not considered feasible	1.64

* Factor of safety of lower berm.

As for the landslide area, the results of the stability analyses suggest that feasible options are clay replacement in conjunction with geofabric reinforcement or rock fill replacement. The use of geofabric reinforcement in conjunction with the rock fill is not necessary but if used will provide increased global stability.

If graded rock fill is to be used, geofabric separation layers will be required above and below the rock fill. A free draining, durable, well graded, crushed rock fill material with a maximum particle of 150mm is recommended. The material should be placed in layers not exceeding 300mm in thickness and compacted by a minimum of 6 passes of a smooth drum vibrating roller or grid roller of at least 10 tonne static weight. The compaction should continue until no further reduction of the layer surface height occurs.

The free draining rock fill will be able to accommodate seepage from the surrounding area and will not be susceptible to softening during periods of elevated groundwater levels such as may occur during periods of prolonged intense rainfall.

The installation of high strength, uniaxial woven geofabric layers at the base of the re-constructed embankment will assist in improving stability. The analyses indicate that two layers of 200kN working strength uniaxial woven geofabric would be required, installed at the base of the embankment during the early stages of the embankment re-construction.

The lowered groundwater level option assumes that subsurface drains can be installed to lead water from the rock fill replacement zone and permanently maintain a lowered groundwater level beneath the road embankment.

Toe drains and table drains under the embankment should be constructed for the clay fill option to prevent raised groundwater levels developing within the road embankment.

5.4.2.2 Piled Support

This option is shown in schematically on Figure 11.

Stability analyses indicate that a piled solution providing lateral support of 300kN/m length of embankment will increase the factor of safety of the existing embankment to greater than 1.5. For the soil profiles in boreholes BH3 and BH4, this can be achieved by installing 12m long, 900mm diameter piles at 1.5m centres along the pedestrian access path alignment. It is recommended that the piles be connected by a capping beam.

In addition to the piles it is recommended that 150mm diameter subsurface drains be drilled into the base of the road embankment as shown on Figure 11 at not less than 3m centres. It will be necessary for the drains to be spaced between the piles.

5.5 Other Necessary Remedial Works

In addition to the specific items discussed for each remedial option it will be necessary to improve the existing stormwater drainage associated with the road embankment.

An adequately sized, fully lined table drain should be constructed on the up-hill side of the embankment. Stormwater collected by this drain should be conveyed in pipes through the embankment and discharged on the down-hill side of the embankment. The discharge should be sufficiently down-slope so as not to result in water infiltrating the embankment foundation. Adequate erosion protection should be provided at both the inlet and outlet structures.

It is recommended that suitably experienced personnel inspect the exposed foundation materials at the time of construction and prior to placing backfill or embankment fill to ensure that the exposed conditions are consistent with the design assumptions.

All earthworks should be carried out in accordance with guidelines of AS3798-2007. It is recommended that fill placement be carried out under Level 1 supervision as described in AS3798.

6.0 PRELIMINARY COST ESTIMATE OF PROPOSED REMEDIAL WORKS

6.1 Earthworks Options

It is understood that preliminary estimates of costs associated with the earthworks options (excavation and replacement) will be prepared by Ballina Shire Council.

There are a number of options and the extent of earthworks required for each option is shown on the various cross sections of Figures 3 to 6 and 9 to 10.

The approximate extent of the various earthworks options is shown in plan view on Figure 12 along with the piling options.

6.2 Piling Options

Wagstaff Piling has assisted Shaw:Urquhart is preparing preliminary cost estimates for the various piling options which are shown on the cross sections of Figures 7 to 8 and 11.

The approximate extent of the various piling options is shown in plan view on Figure 13 along with the earthworks options.

Preliminary cost estimates are as follows:-

Mobilisation/Demobilisation	$50,000
Within Failure Zone - Crest Piles (Refer Section 5.3.2.3)	
Chainage 1020m to 1072.2m 30 No. 1200mm diameter piles at 1.8m centres and 20m long (14N28, W10 @ 150 spiral)	$600,000
Within Failure Zone – Pedestrian Access Path Piles (Refer Section 5.3.2.3)	
Chainage 1020m to 1072.2m Preparation across failure zone – 60 No 210 diameter HW timber piles at 2m centres and 12.5m long 30 No. 1200mm diameter piles at 1.8m centres and 15m long (14N28, W10 @ 150 spiral)	$66,000 $450,000
Outside Failure Zone – Pedestrian Access Path Piles (Refer Section 5.4.2.2)	
Chainage 960m to 1027.5m 46 No 900mm diameter piles at 1.5m centres and 12m long (10N28, W12 @ 100 spiral)	$315,000

Philip Shaw

For and on behalf of

SHAW URQUHART PTY LTD

UNDERSTAND THE LIMITATIONS OF YOUR GEOTECHNICAL REPORT

shaw:urquhart

This report has been based on project details as provided to us at the time of the commission. It therefore applies only to the site investigated and to a specific set of project requirements as understood by Shaw:Urquhart.

If there are changes to the project, you need to advise us in order that the effect of the changes on the report recommendations can be adequately assessed. Shaw:Urquhart cannot take responsibility for problems that may occur due to project changes if they are not consulted.

It is important to remember that the subsurface conditions described in the report represent the state of the site at the time of investigation. Natural processes and the activities of man can result in changes to site conditions. For example, ground water levels can change or fill can be placed on a site after the investigation is completed. If there is a possibility that conditions may have changed with time, Shaw:Urquhart should be consulted to assess the impact on the recommendations of the report.

The site investigation only identifies the actual subsurface conditions at the location and time when the samples were taken. Geologists and engineers then extrapolate between the investigation points to provide an assumed three-dimensional picture of the site conditions. The report is based on the assumption that the site conditions as identified at the investigation locations are representative of the actual conditions throughout an area. This may not be the case and actual conditions may differ from those inferred to exist. This will not be known until construction has commenced. Your geotechnical report and the recommendations contained within it can therefore only be regarded as preliminary.

In the event that conditions encountered during construction are different to those described in the report, Shaw:Urquhart should be consulted immediately. Nothing can be done to change the actual site conditions which exist but steps can be taken to reduce the impact of unexpected conditions. For this reason, the services of Shaw:Urquhart should be retained through the development stage of a project.

Problems can occur when other design professionals misinterpret a report. To help avoid this, Shaw:Urquhart should be retained to work with other design professionals to explain the implications of the report.

This report should be retained as a complete document and should not be copied in part, divided or altered in any way.

It is recommended that Shaw:Urquhart is retained during the construction phase to confirm that conditions encountered are consistent with design assumptions. For example, this may involve assessment of bearing capacity for footings, stability of natural slopes or excavations or advice on temporary construction conditions.

This document has been produced to help all parties involved recognise their individual responsibilities.

shaw:urquhart

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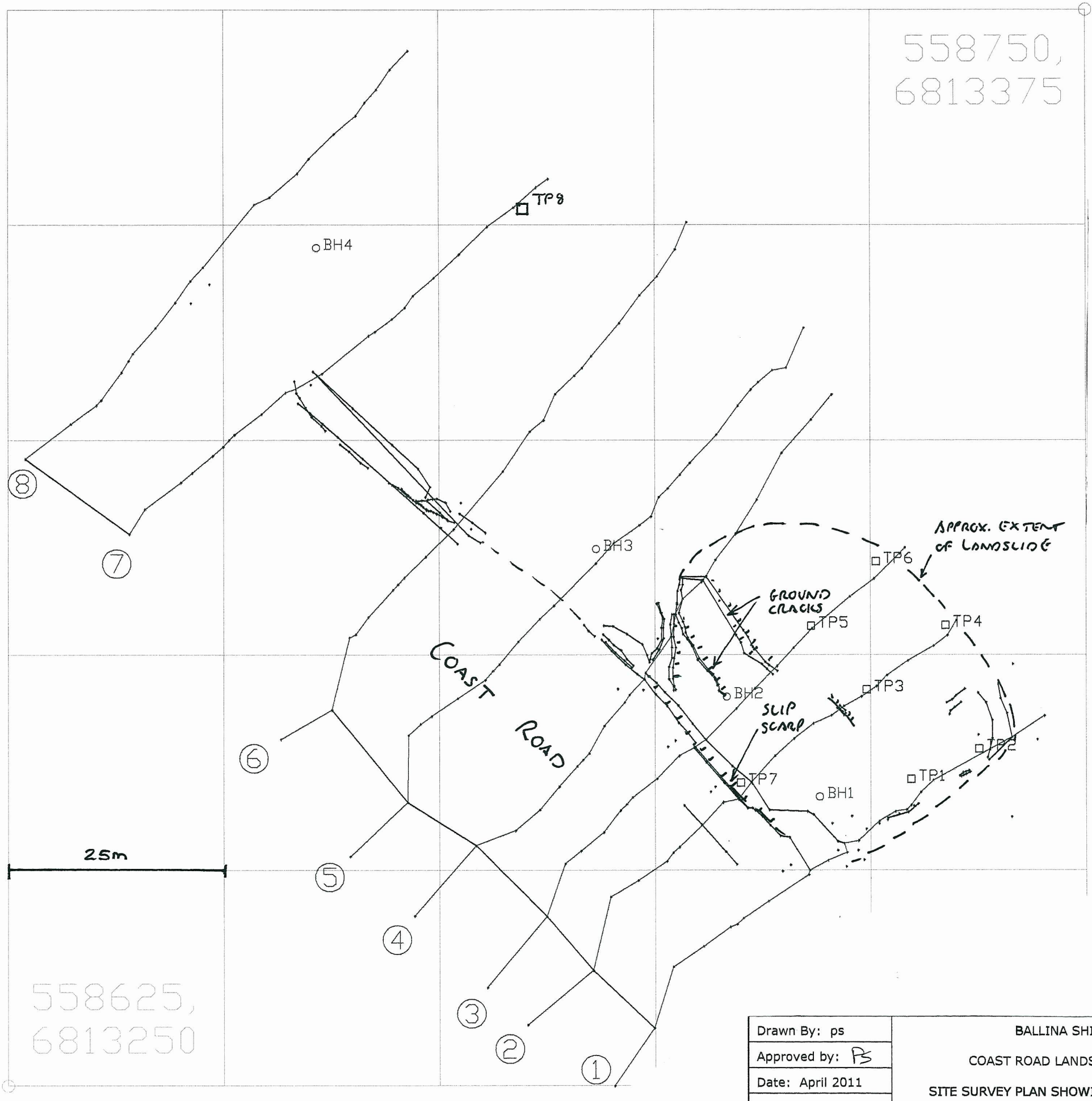

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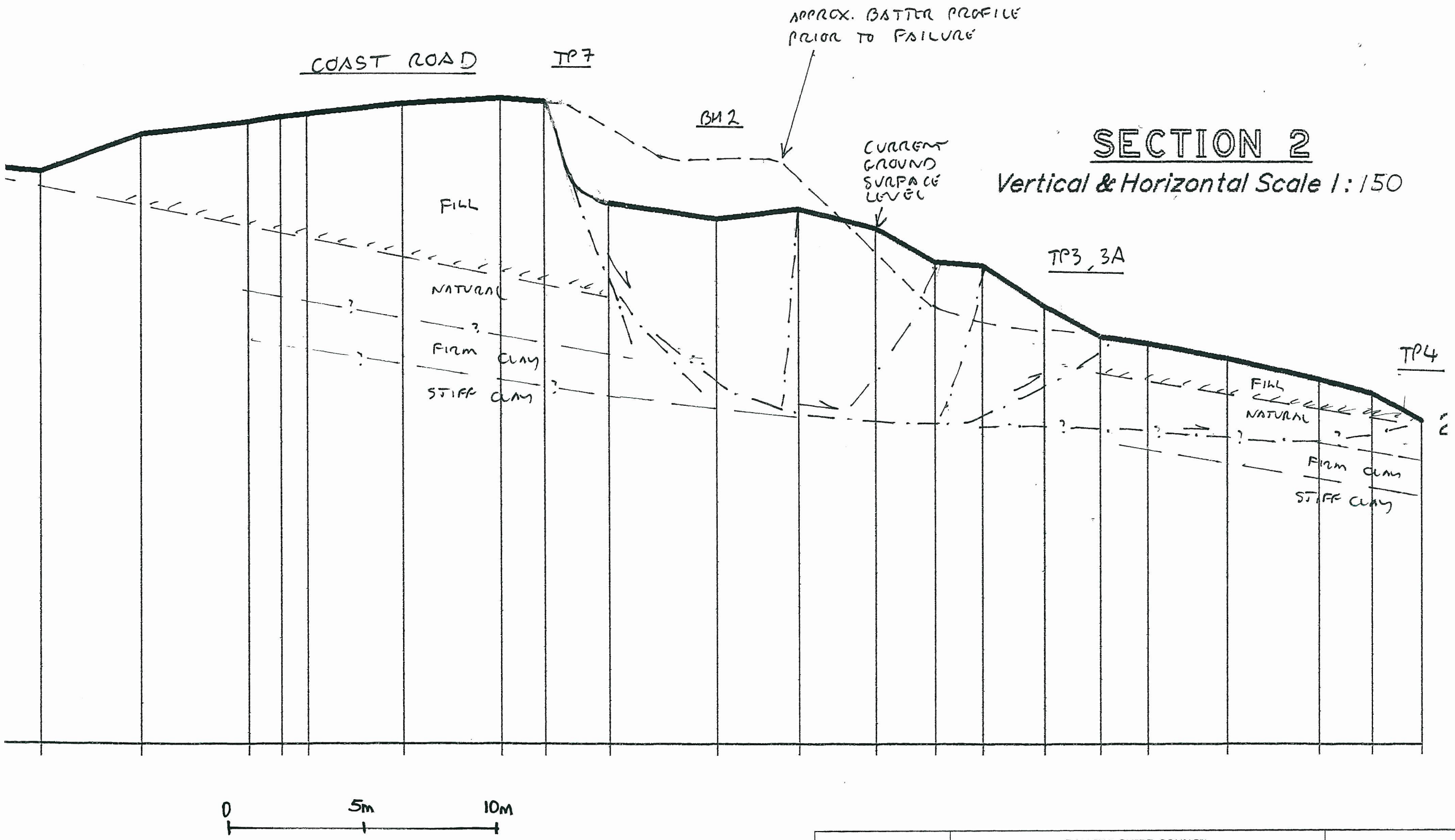
LEGEND

- BH3 ○ - Borehole Location
- TP5 □ - Test Pit Location
- (2) - Cross-Section Number
- Ground Cracks

Drawn By: ps	BALLINA SHIRE COUNCIL	Figure 1
Approved by: PS	COAST ROAD LANDSLIDE REMEDIATION	
Date: April 2011	SITE SURVEY PLAN SHOWING BOREHOLE & TEST PIT LOCATIONS	Job No.: 10644/1
Scale:		

shaw:urquhart

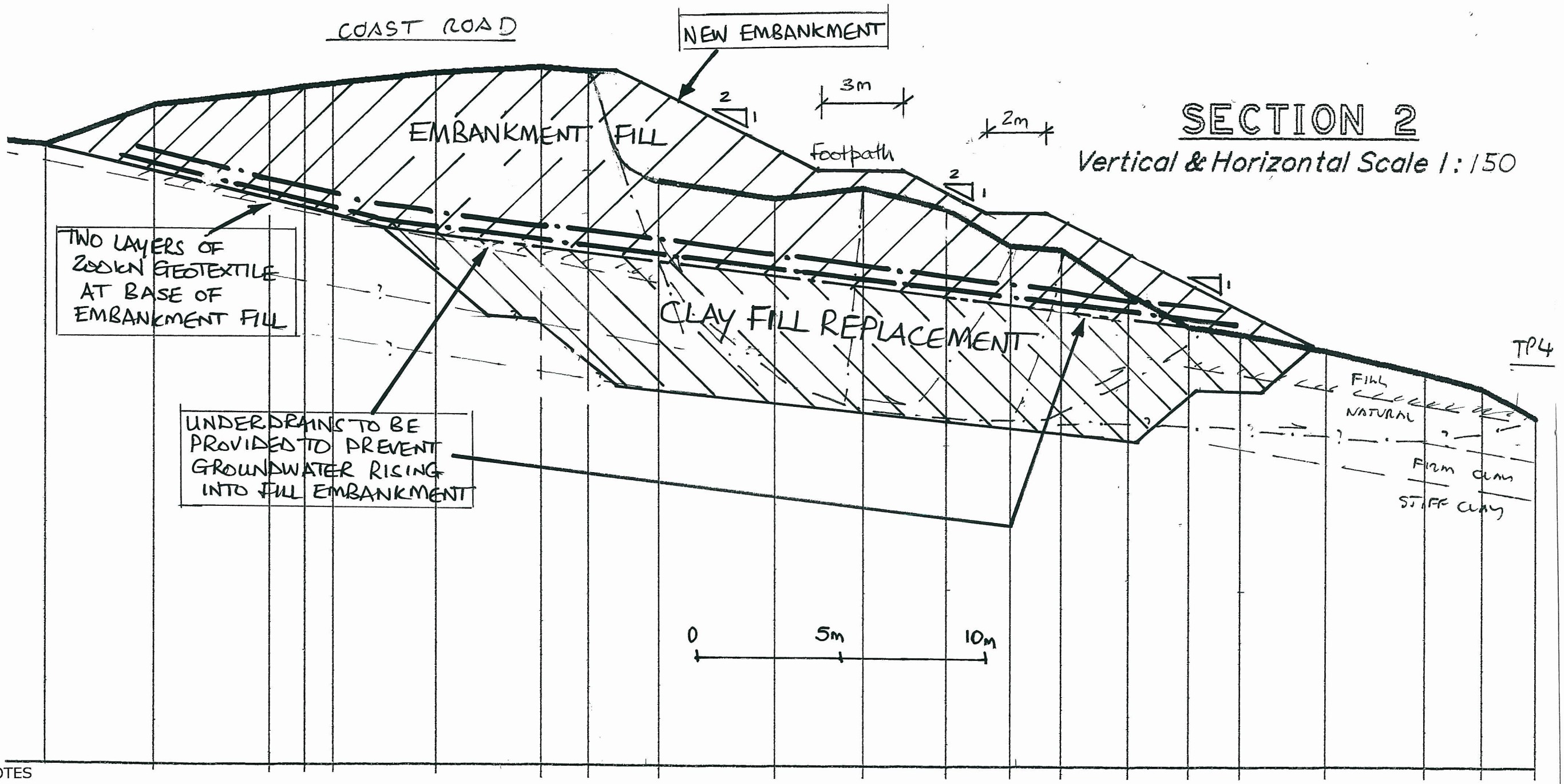


SECTION 2

Vertical & Horizontal Scale 1 : 150

Drawn By: ps	BALLINA SHIRE COUNCIL COAST ROAD LANDSLIDE REMEDIATION INTERPRETED CROSS SECTION GEOMETRY OF LANDSLIDE	Figure 2
Approved by: PS		
Date: April 2011		Job No.: 10644/1
Scale: 1:150		

shaw:urquhart

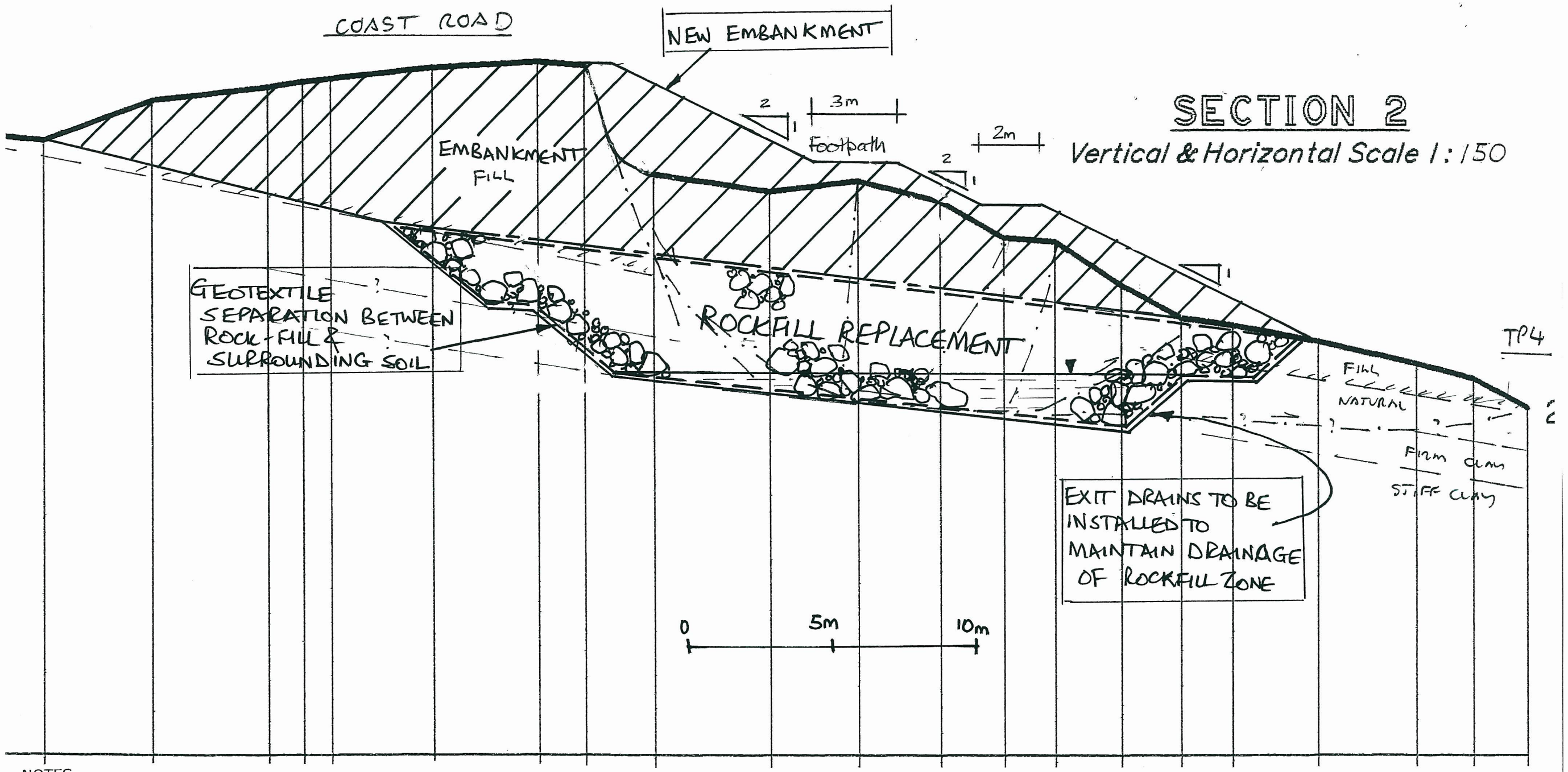


NOTES

1. Drawings are schematic only.
2. All earthworks are to be carried out in accordance with AS3798-2007.
3. Exposed foundation materials shall be inspected by suitably experienced personnel prior to placement of backfill or embankment fill.

Drawn By: ps	BALLINA SHIRE COUNCIL	Figure 3
Approved by: PS	COAST ROAD LANDSLIDE REMEDIATION	
Date: April 2011	PARTIAL EXCAVATION & REPLACEMENT OF FOUNDATION WITHIN LANDSLIDE AREA – CLAY FILL OPTION	Job No.: 10644/1
Scale: 1:150		

shaw:urquhart



SECTION 2

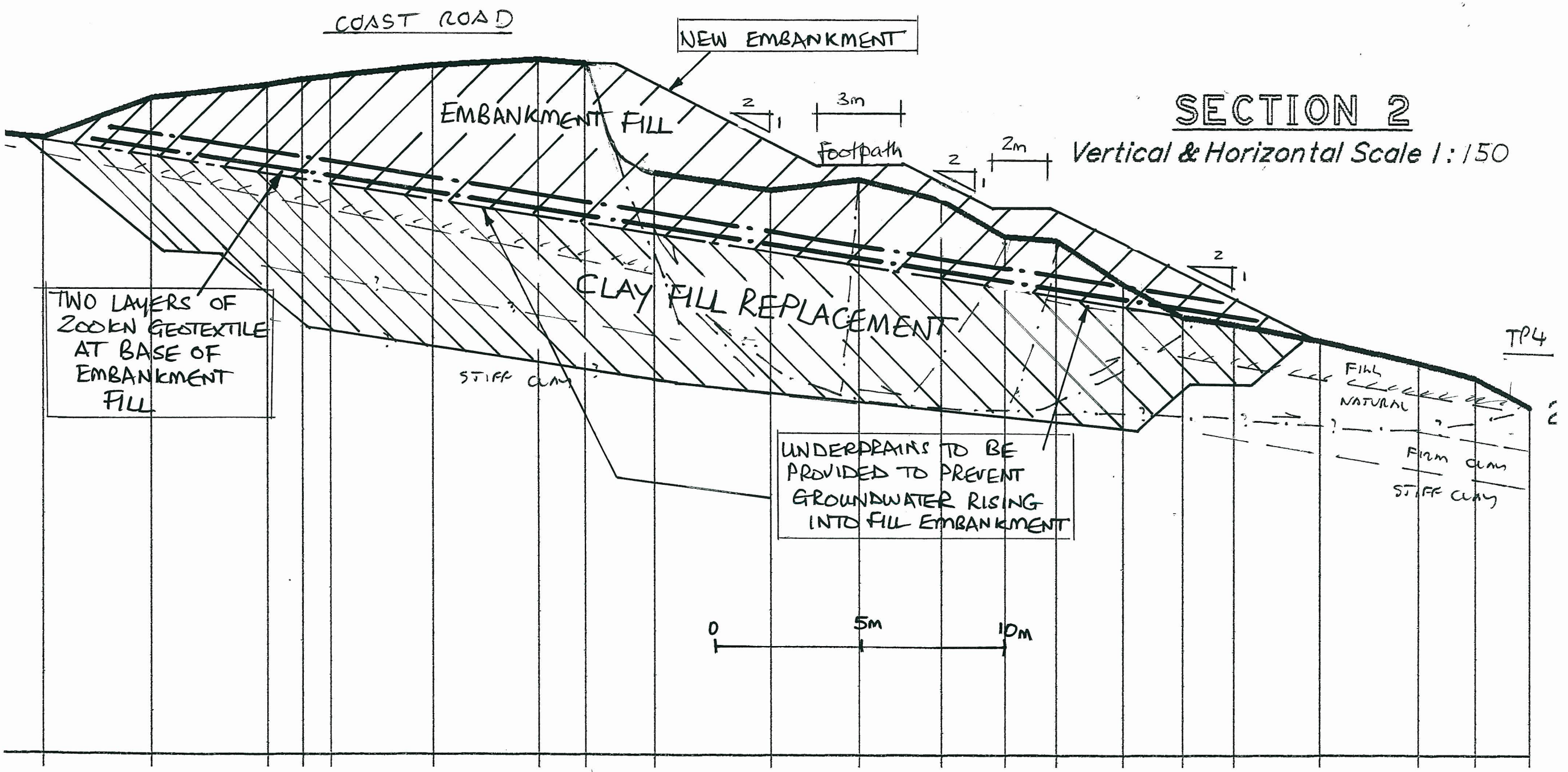
Vertical & Horizontal Scale 1 : 150

NOTES

1. Drawings are schematic only.
2. All earthworks are to be carried out in accordance with AS3798-2007.
3. Exposed foundation materials shall be inspected by suitably experienced personnel prior to placement of backfill or embankment fill.

Drawn By: ps	BALLINA SHIRE COUNCIL COAST ROAD LANDSLIDE REMEDIATION PARTIAL EXCAVATION & REPLACEMENT OF FOUNDATION WITHIN LANDSLIDE AREA – ROCK FILL OPTION	Figure 4
Approved by: PS		
Date: April 2011		
Scale: 1:150		Job No.: 10644/1

shaw:urquhart



SECTION 2

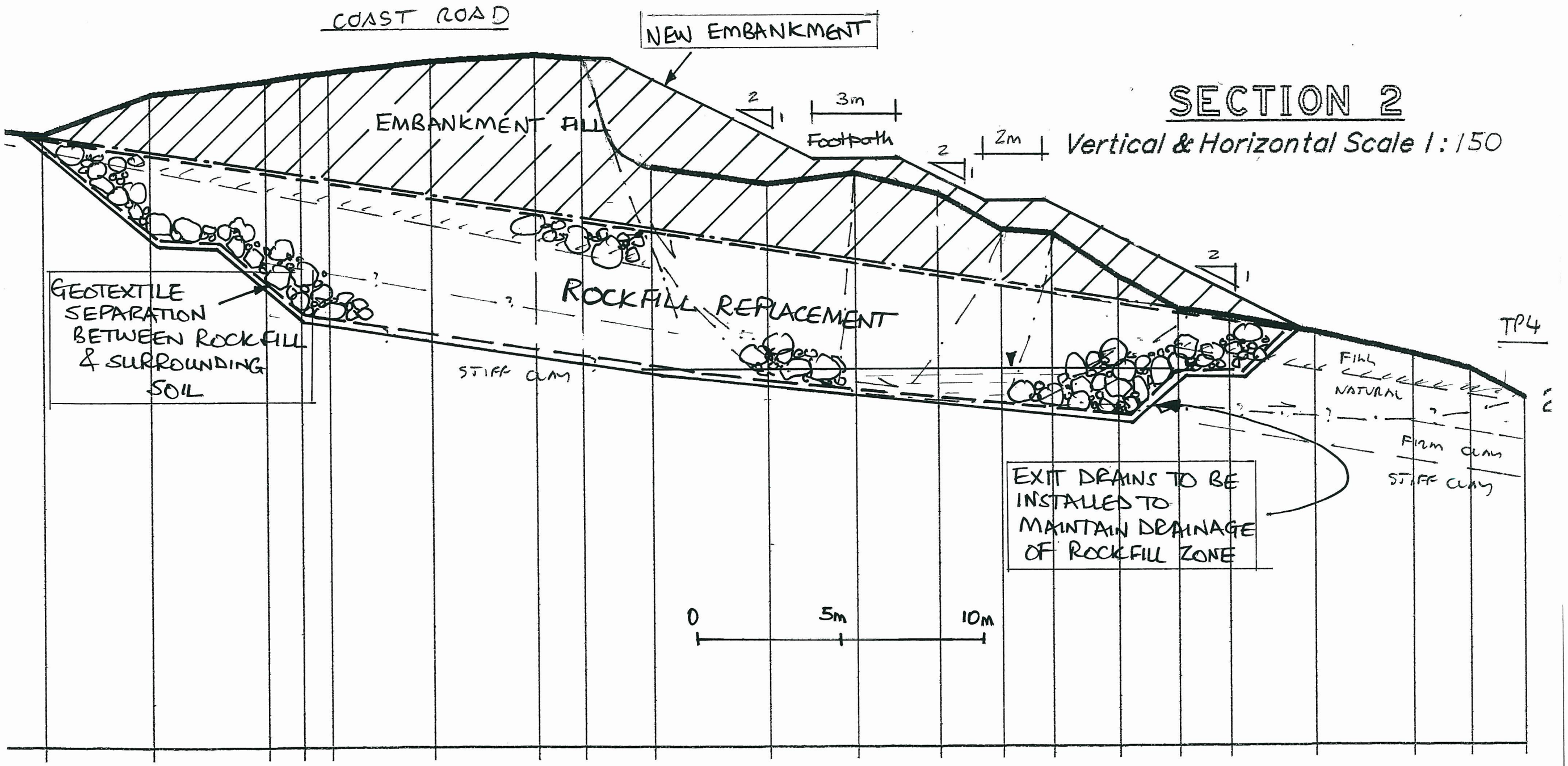
Vertical & Horizontal Scale 1 : 150

NOTES

1. Drawings are schematic only.
2. All earthworks are to be carried out in accordance with AS3798-2007.
3. Exposed foundation materials shall be inspected by suitably experienced personnel prior to placement of backfill or embankment fill.

Drawn By: ps	BALLINA SHIRE COUNCIL COAST ROAD LANDSLIDE REMEDIATION TOTAL EXCAVATION & REPLACEMENT OF FOUNDATION WITHIN LANDSLIDE AREA – CLAY FILL OPTION	Figure 5
Approved by: PS		
Date: April 2011		
Scale: 1:150		Job No.: 10644/1

shaw:urquhart



SECTION 2

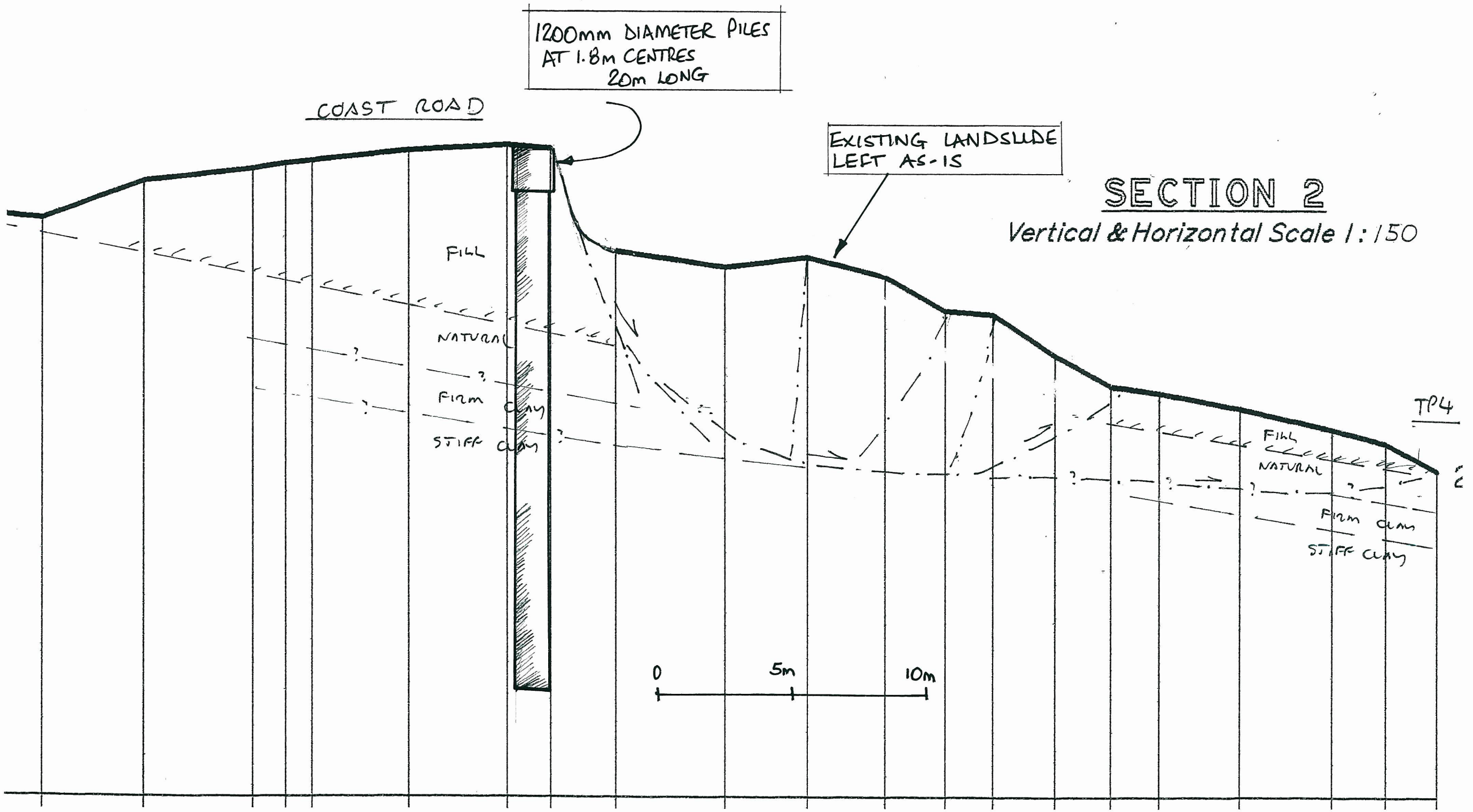
Vertical & Horizontal Scale 1 : 150

NOTES

1. Drawings are schematic only.
2. All earthworks are to be carried out in accordance with AS3798-2007.
3. Exposed foundation materials shall be inspected by suitably experienced personnel prior to placement of backfill or embankment fill.

Drawn By: ps	BALLINA SHIRE COUNCIL	Figure 6
Approved by: PS	COAST ROAD LANDSLIDE REMEDIATION	
Date: April 2011	TOTAL EXCAVATION & REPLACEMENT OF FOUNDATION WITHIN LANDSLIDE AREA – ROCK FILL OPTION	Job No.: 10644/1
Scale: 1:150		

shaw:urquhart



SECTION 2

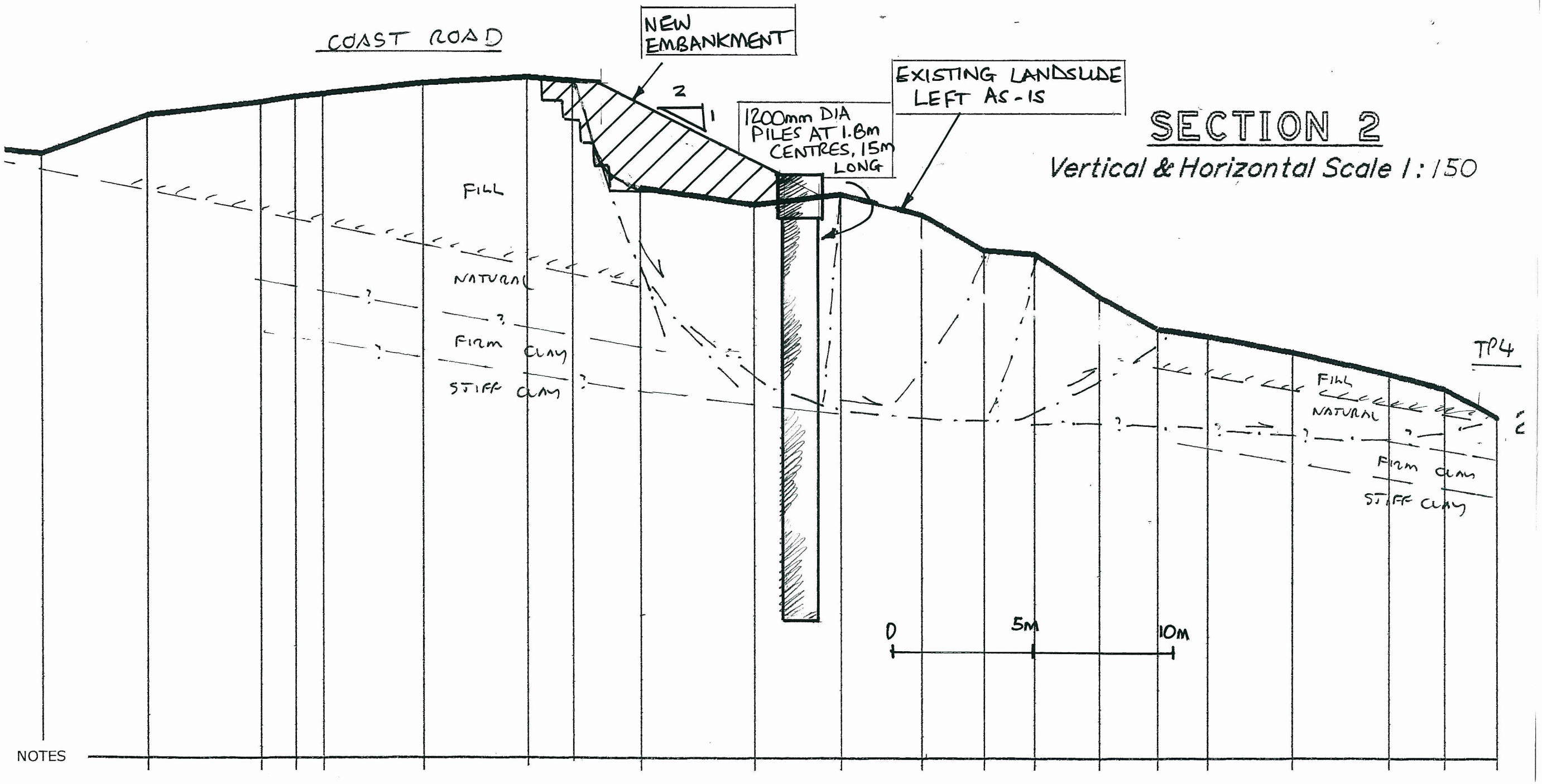
Vertical & Horizontal Scale 1 : 150

NOTES

1. Drawings are schematic only.
2. All earthworks are to be carried out in accordance with AS3798-2007.
3. Exposed foundation materials shall be inspected by suitably experienced personnel prior to placement of backfill or embankment fill.

Drawn By: ps	BALLINA SHIRE COUNCIL	Figure 7
Approved by: BS	COAST ROAD LANDSLIDE REMEDIATION	
Date: April 2011	INDICATIVE PILED RETENTION AT CREST OF EXISTING EMBANKMENT WITHIN LANDSLIDE AREA	Job No.: 10644/1
Scale: 1:150		

shaw:urquhart



SECTION 2

Vertical & Horizontal Scale 1 : 150

NOTES

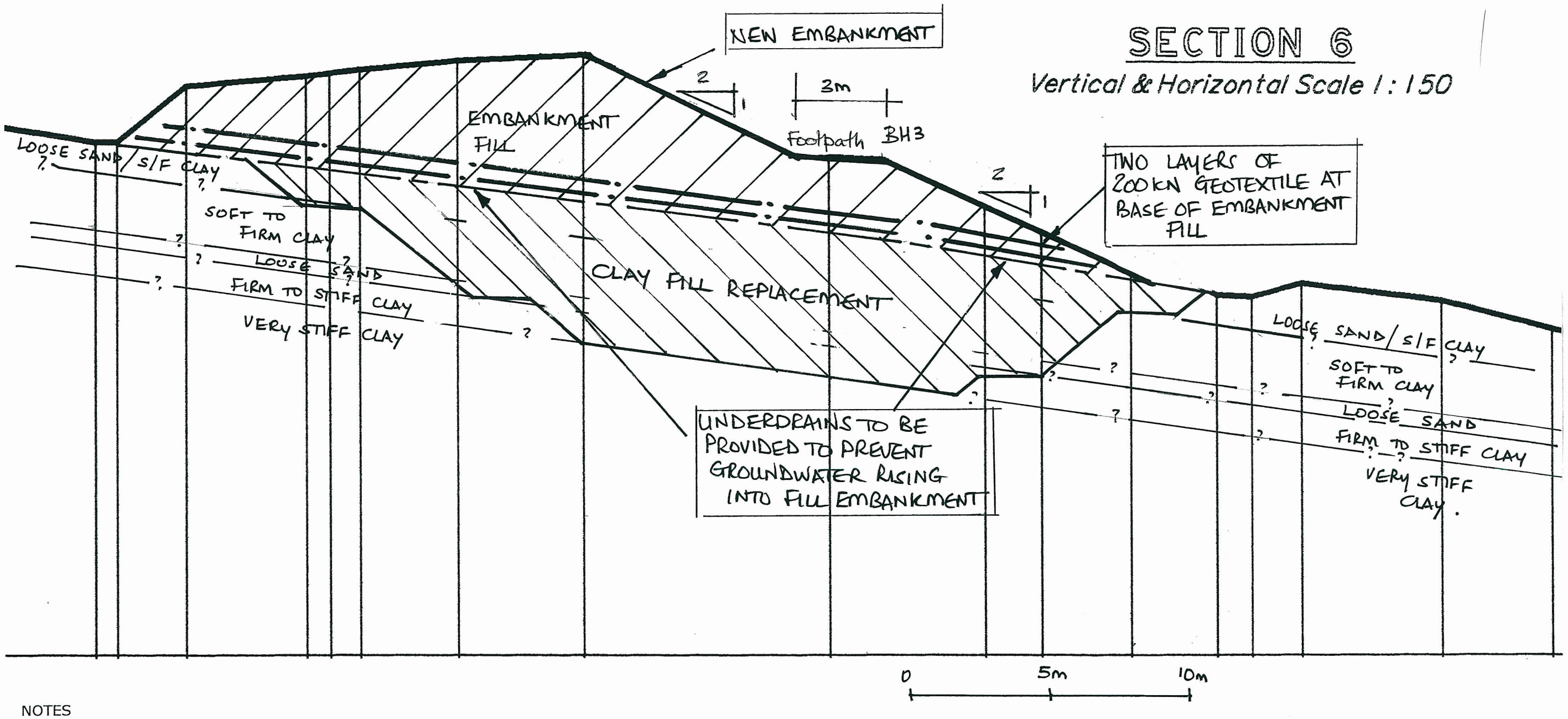
1. Drawings are schematic only.
2. All earthworks are to be carried out in accordance with AS3798-2007.
3. Exposed foundation materials shall be inspected by suitably experienced personnel prior to placement of backfill or embankment fill.

Drawn By: ps	BALLINA SHIRE COUNCIL	Figure 8
Approved by: PS	COAST ROAD LANDSLIDE REMEDIATION	
Date: April 2011	INDICATIVE PILED RETENTION ON FOOTPATH WITHIN LANDSLIDE AREA	Job No.: 10644/1
Scale: 1:150		

shaw:urquhart

SECTION 6

Vertical & Horizontal Scale 1 : 150



NOTES

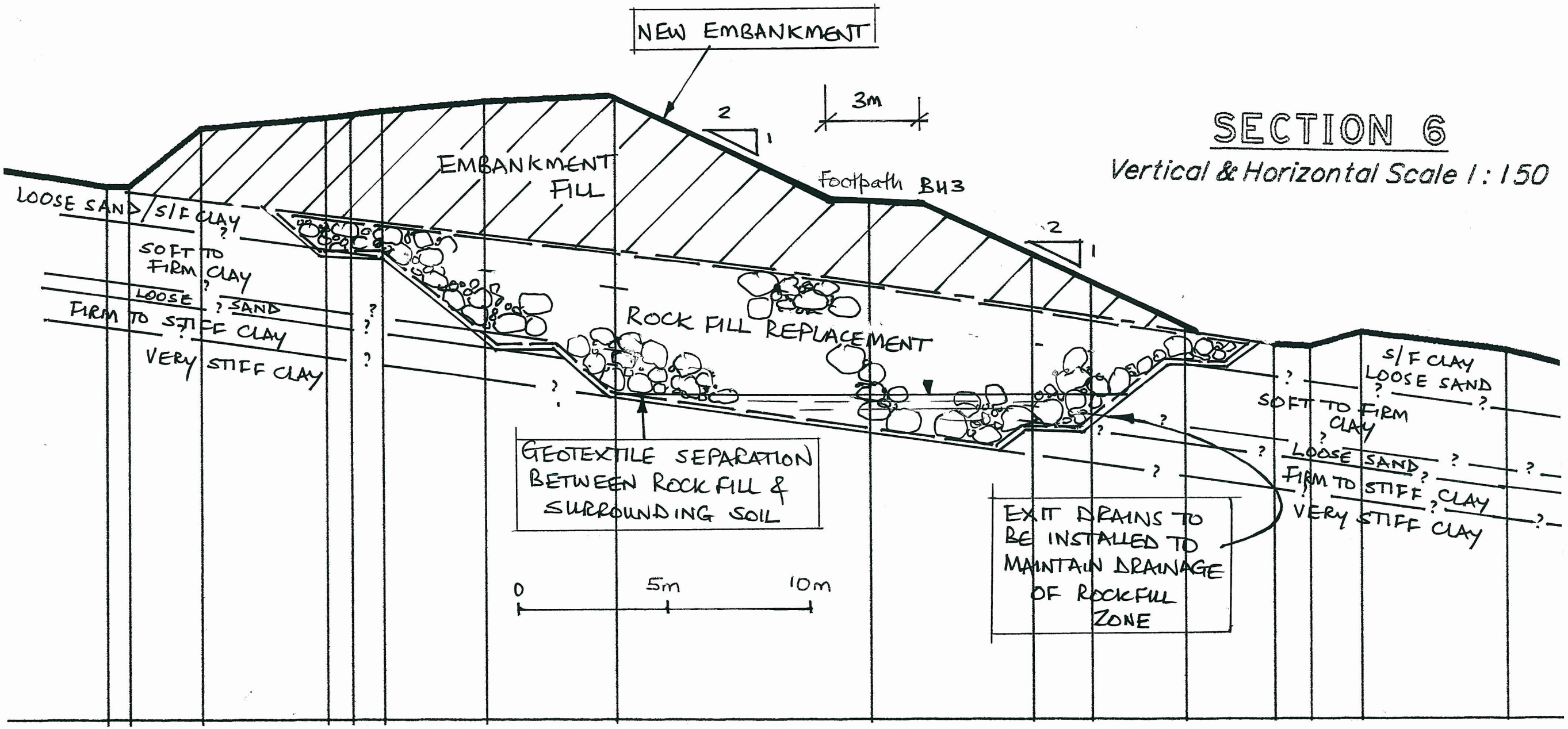
1. Drawings are schematic only.
2. All earthworks are to be carried out in accordance with AS3798-2007.
3. Exposed foundation materials shall be inspected by suitably experienced personnel prior to placement of backfill or embankment fill.

Drawn By: ps	BALLINA SHIRE COUNCIL	Figure 9
Approved by: PS	COAST ROAD LANDSLIDE REMEDIATION	
Date: April 2011	PARTIAL EXCAVATION & REPLACEMENT OF FOUNDATION OUTSIDE LANDSLIDE AREA – CLAY FILL OPTION	Job No.: 10644/1
Scale: 1:150		

shaw:urquhart

SECTION 6

Vertical & Horizontal Scale 1 : 150



NOTES

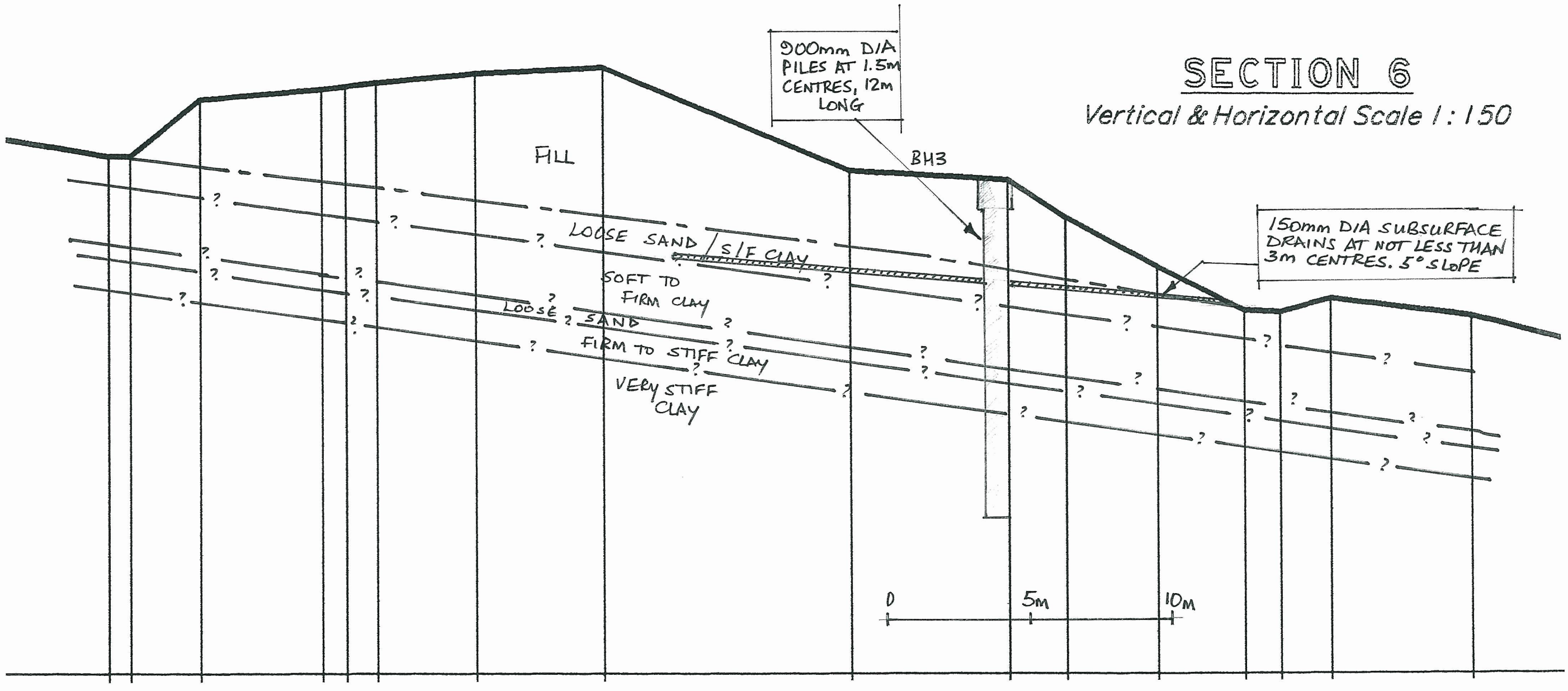
1. Drawings are schematic only.
2. All earthworks are to be carried out in accordance with AS3798-2007.
3. Exposed foundation materials shall be inspected by suitably experienced personnel prior to placement of backfill or embankment fill.

Drawn By: ps	BALLINA SHIRE COUNCIL	Figure 10
Approved by: PS	COAST ROAD LANDSLIDE REMEDIATION	
Date: April 2011	PARTIAL EXCAVATION & REPLACEMENT OF FOUNDATION OUTSIDE LANDSLIDE AREA – ROCK FILL OPTION	
Scale: 1:150		Job No.: 10644/1

shaw:urquhart

SECTION 6

Vertical & Horizontal Scale 1 : 150

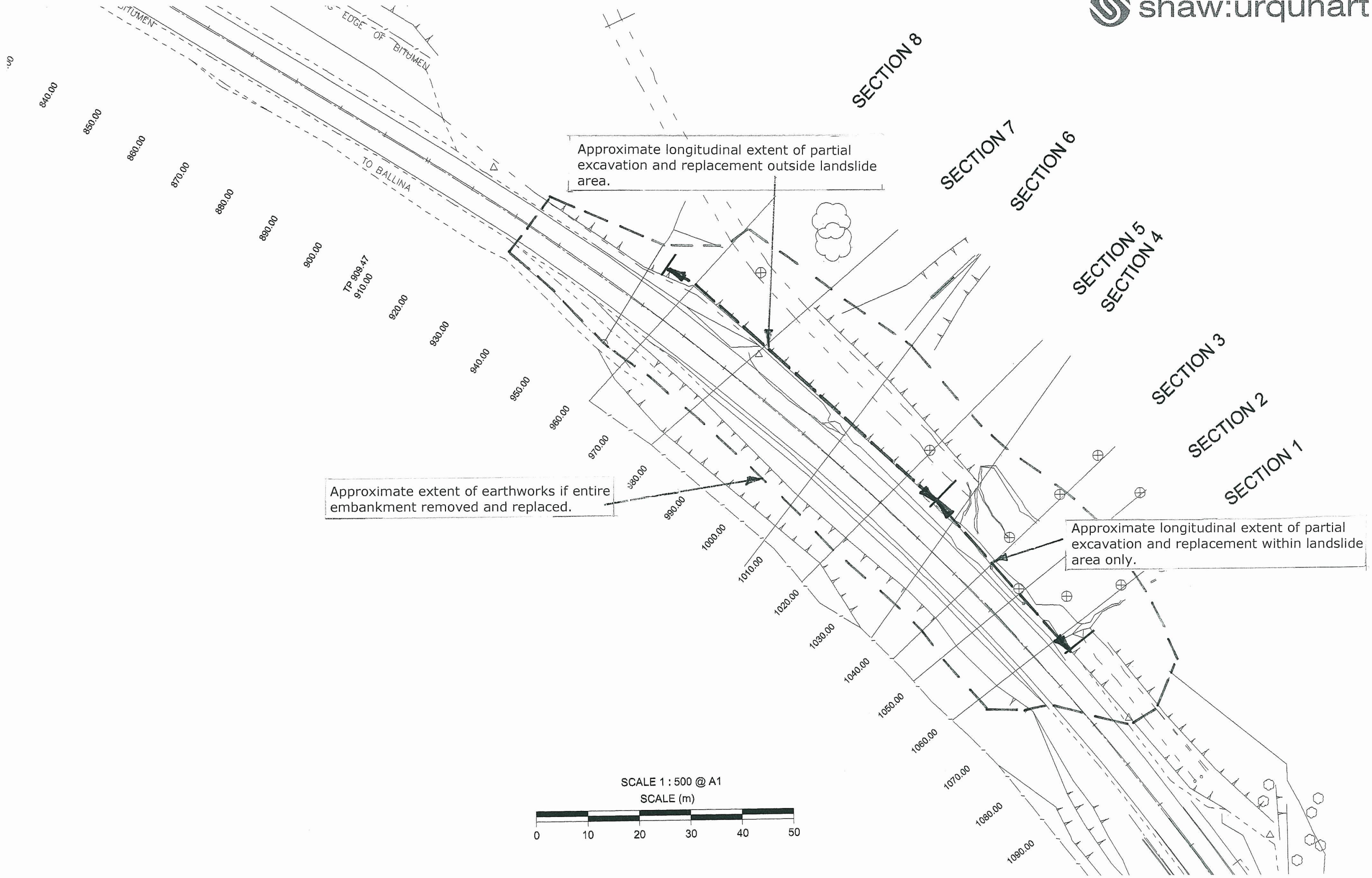


NOTES

1. Drawings are schematic only.
2. All earthworks are to be carried out in accordance with AS3798-2007.
3. Exposed foundation materials shall be inspected by suitably experienced personnel prior to placement of backfill or embankment fill.

Drawn By: ps	BALLINA SHIRE COUNCIL	Figure 11
Approved by: PS	COAST ROAD LANDSLIDE REMEDIATION	
Date: April 2011	PILED RETENTION ON FOOTPATH OUTSIDE LANDSLIDE AREA	
Scale: 1:150		Job No.: 10644/1

shaw:urquhart



SCALE 1 : 500 @ A1

SCALE (m)

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Drawn By: PS	BALLINA SHIRE COUNCIL	Figure 12
Approved by: PS	COAST ROAD LANDSLIDE REMEDIATION	
Date: May 2011	SCHEMATIC PLAN OF EARTHWORKS OPTIONS	
Scale:		Job No.: 10644/1

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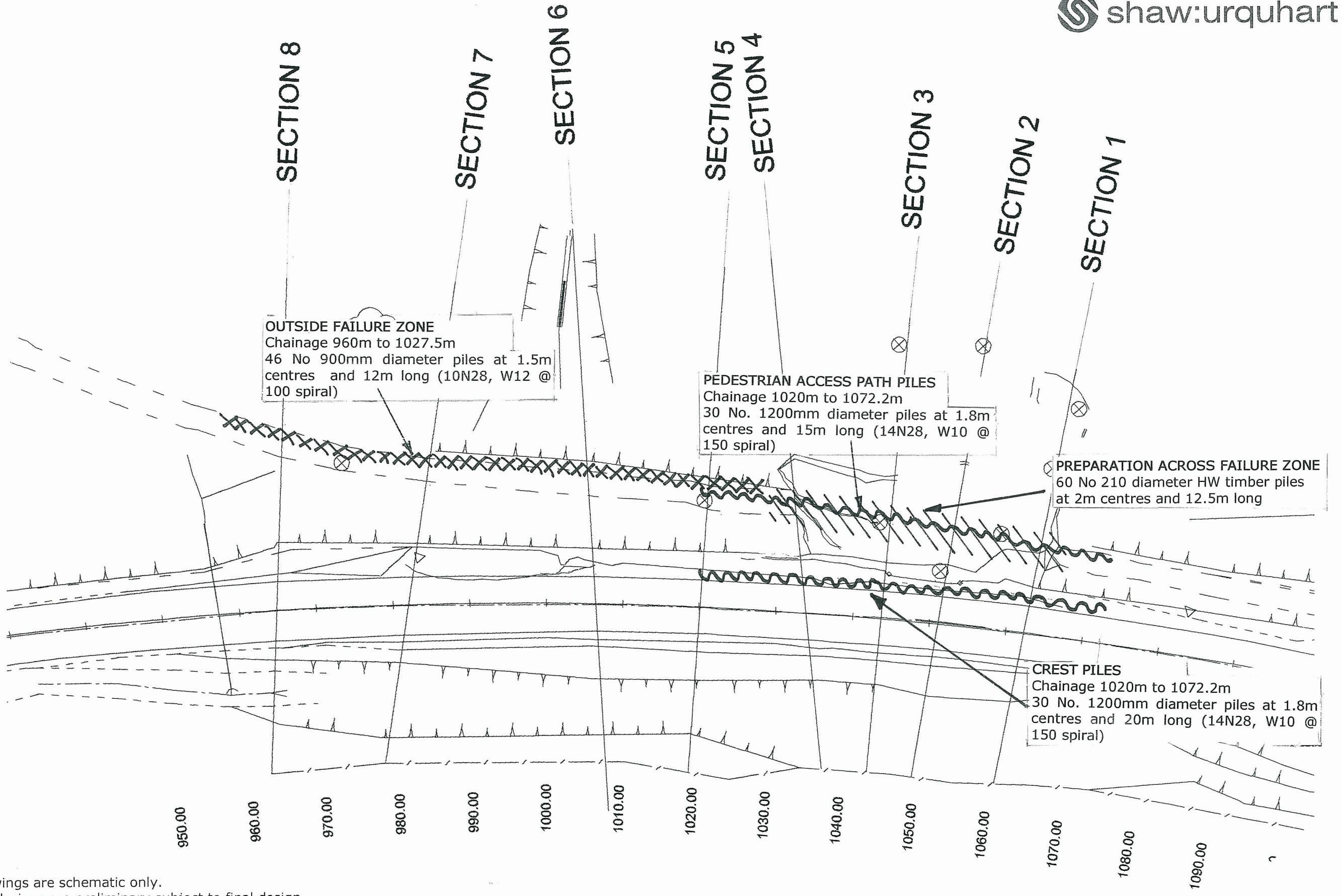

NOTES

1. Drawings are schematic only.
2. Pile designs are preliminary subject to final design.
3. All earthworks are to be carried out in accordance with AS3798 – 2007.
4. Exposed foundation materials shall be inspected by suitably qualified personnel prior to placement of backfill or embankment fill.

Drawn By: PS	BALLINA SHIRE COUNCIL	Figure 13
Approved by: PS	COAST ROAD LANDSLIDE REMEDIATION	
Date: May 2011	SCHEMATIC PLAN OF PILING OPTIONS	
Scale: 1:500		Job No.: 10644/1

APPENDIX A

ENGINEERING LOGS OF BOREHOLES & TEST PITS

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Soil Description

Explanation Sheet (1 of 2)

DEFINITION: In engineering terms soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil.
Other materials are described using rock description terms.

CLASSIFICATION SYMBOL & SOIL NAME
Soils are described in accordance with the Unified Soil Classification (UCS) as shown in the table on Sheet 2.

PARTICLE SIZE DESCRIPTIVE TERMS

NAME	SUBDIVISION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

MOISTURE CONDITION

Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.
Moist	Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH S_u (kPa)	FIELD GUIDE
Very Soft	<12	A finger can be pushed well into the soil with little effort.
Soft	12-25	A finger can be pushed into the soil to about 25mm depth.
Firm	25-50	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50-100	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100-200	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	>200	The surface of the soil can be marked only with the thumbnail.
Friable	-	Crumbles or powders when scraped by thumbnail.

DENSITY OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	ASSESSMENT GUIDE	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: < 5% Fined grained soils: < 15%
With some	Presence easily detected by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 – 12 % Fine grained soils: 15 – 30 %

SOIL STRUCTURE

ZONING		CEMENTED	
Layers	Continuous across exposure of sample.	Weakly cemented	Easily broken up by hand in air or water.
Lenses	Discontinuous layers of lenticular shape.	Moderately cemented	Effort is required to break up the soil by hand in air or water
Pockets	Irregular inclusions of different material.		

GEOLOGICAL ORIGIN
WEATHERED IN PLACE SOILS

Extremely weathered material	Structure and fabric of parent rock visible.
Residual soil	Structure and fabric of parent rock not visible.

TRANSPORTED SOILS

Aeolian soil	Deposited by wind.
Alluvial soil	Deposited by streams and rivers.
Colluvial soil	Deposited on slopes (transported downslope by gravity).
Fill	Man made deposit. Fill may be significantly more variable between tested locations than naturally occurring soils.
Lacustrine soil	Deposited by lakes.
Marine soil	Deposited in ocean basins, bays, beaches and estuaries.

Explanation Sheet (2 of 2) – Soil Description

SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 60 mm and basing fractions on estimated mass)						USC	PRIMARY NAME
COARSE GRAINED SOILS More than 50% of material less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.0 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.		GW	GRAVEL
				Predominantly one size or a range of sizes with more intermediate sizes missing.		GP	GRAVEL
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)		GM	SILTY GRAVEL
				Plastic fines (for identification procedures see CL below)		GC	CLAYEY GRAVEL
		SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes missing		SW	SAND
				Predominantly one size or a range of sizes with some intermediate sizes missing.		SP	SAND
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).		SM	SILTY SAND
				Plastic fines (for identification procedures see CL below).		SC	CLAYEY SAND
FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075mm			IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.				
			DRY STRENGTH	DILATANCY	TOUGHNESS		
		SILTS & CLAYS Liquid limit less than 50	None to Low	Quick to slow	None	ML	SILT
			Medium to High	None	Medium	CL	CLAY
			Low to Medium	Slow to very slow	Low	OL	ORGANIC SILT
		SILTS & CLAYS Liquid limit greater than 50	Low to Medium	Slow to very slow	Low to medium	MH	SILT
			High	None	High	CH	CLAY
			Medium to High	None	Low to medium	OH	ORGANIC CLAY
HIGHLY ORGANIC SOILS		Readily identified by colour, odour, spongy feel and frequently by fibrous texture				Pt	PEAT

• Low plasticity – Liquid Limit W_L less than 35%. • Medium plasticity – W_L between 35% and 50%.

COMMON DEFECTS IN SOIL

TERM	DEFINITION	DIAGRAM
CRACK	A surface or discontinuity across which the soil has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed.	
PARTING	A surface or discontinuity across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.	
SHEARED ZONE	Zone of deformation in clayey soil which may contain roughly parallel, near planar, curved or undulating boundaries containing one or more closely spaced, smooth or slickensided, surfaces. The soil within the shear zone is likely to have been significantly remoulded.	
FISSURE	A near planar, curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	

TERM	DEFINITION	DIAGRAM
SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content and lower strength than elsewhere.	
TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter-connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter.	
TUBE CAST	Roughly cylindrical elongated body of soil different from the soil mass in which it occurs. In some cases the soil which makes up the tube cast is cemented.	

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Rock Description

Explanation Sheet (1 of 2)

The descriptive terms used by Shaw Urquhart Pty Ltd are given below. They are broadly consistent with Australian Standard AS1726-1993.

DEFINITIONS: Rock substance, defect and mass are defined as follows:

Rock Substance - In engineering terms rock substance is any naturally occurring aggregate of minerals and organic material which cannot be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Homogonous material, may be isotropic or anisotropic.

Defect - Discontinuity or break in the continuity of a substance or substances.

Mass - Any body or material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

SUBSTANCE DESCRIPTIVE TERMS:

ROCK NAME Simple rock names are used rather than precise geological classification.

PARTICLE SIZE Grain size terms for sandstone are:

- **Coarse grained** -Mainly 0.6mm to 2mm
- **Medium grained** - Mainly 0.2mm to 0.6mm
- **Fine grained** - Mainly 0.06mm (just visible) to 0.2mm

FABRIC Terms for layering or penetrative fabric (eg. bedding, cleavage etc.) are:

- **Massive** - No layering or penetrative fabric.
- **Indistinct** - Layering or fabric just visible. Little effect on properties.
- **Distinct** - Layering or fabric is easily visible. Rock breaks more easily parallel to layering or fabric.

CLASSIFICATION OF WEATHERING PRODUCTS

Term	Abbreviation	Definition
Residual Soil	**RS**	Soil directly derived from the weathering of rock; the rock structure and fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
Extremely Weathered Material	**XW**	Material is weathered to such an extent that it has soil properties, ie. it either disintegrates or can be remoulded in water. Original rock fabric still visible.
Highly Weathered Rock	**HW**	Rock strength is changed by weathering. The whole of the rock substance is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Some minerals are decomposed to clay minerals. Porosity may be increased by leaching or may be decreased due to the deposition of minerals in pores.
Moderately Weathered Rock	**MW**	The whole of the rock substance is discoloured, usually by iron staining or bleaching, to the extent that the colour of the fresh rock is no longer recognisable.
Slightly Weathered Rock	**SW**	Rock substance affected by weathering to the extent that partial staining or partial discolouration of the rock substance has taken place. The colour and texture of the fresh rock is recognisable; strength properties are essentially those of the fresh rock substance.
Fresh Rock	**FR**	Rock substance unaffected by weathering.

Notes on Weathering:

1. *AS1726 suggests the term "Distinctly Weathered" (DW) to cover the range of substance weathering conditions between XW and SW. For projects where it is not practical to delineate between HW and MW or it is judged that there is no advantage in making such a distinction, DW may be used with the definition given in AS1726.*
2. *Where physical and chemical changes were caused by hot gasses and liquids associated with igneous rocks, the term "altered" may be substituted for "weathering" to give the abbreviations XA, HA, MA, SA and DA.*

ROCK SUBSTANCE STRENGTH TERMS

Term	Abbrev -iation	Point Load Index, I_{s50} (MPa)	Field Guide
Very Low	**VL**	Less than 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with a knife; pieces up to 30mm thick can be broken by finger pressure.
Low	**L**	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show with firm blows of a pick point; has a dull sound under hammer. Pieces of 50mm diameter core may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium	**M**	0.3 to 1.0	Readily scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.
High	**H**	1 to 3	A piece of core 150mm long by 50mm can not be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.
Very High	**VH**	3 to 10	Hand specimen breaks after more than one blow of a pick; rock rings under hammer.
Extremely High	**EH**	More than 10	Specimen requires many blows with geological pick to break; rock rings under hammer.

Notes on Rock Substance Strength:

1. *In anisotropic rocks the field guide to strength applies to the strength perpendicular to the anisotropy. High strength, anisotropic rocks may break readily parallel to the planar anisotropy.*
2. *The term "extremely low" is not used as a rock substance strength term. While the term is used in AS1726-1993, the field guide therein makes it clear that materials in that strength range have soil-like engineering properties.*
3. *The unconfined compressive strength for isotropic rocks (and anisotropic rocks which fail across the planar anisotropy) is typically 10-25 times the point load index (Is50). The ratio may vary for different rock types. Lower strength rocks often have lower ratios than higher strength rocks.*

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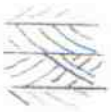
Explanation Sheet (2 of 2) – Rock Description

COMMON DEFECTS IN ROCK MASSES

Term	Definition	Diagram	Map Symbol	Graphic Log (Note 1)
Bedding	In sedimentary or volcanoclastic rocks, the layers produced by each successive deposition episode. Individual beds may be sub-millimeter to several metres in thickness.			
Cross-bedding	Also called cross-lamination. Similar to bedding but produced in sandy and silty sediments by the lateral progression of ripples and dunes. Planes may dip at around 25° to 35° to true bedding and may be planar or curved.			
Parting	A surface or crack across which the rock has little or no tensile strength. Parallel or sub parallel to layering (eg bedding) or a planar anisotropy in the rock substance (eg, cleavage). May be open or closed.			
Joint	A surface or crack across which the rock has little or no tensile strength but which is not parallel or sub parallel to layering or planar anisotropy in the rock substance. May be open or closed.			
Sheared Zone (Note 3)	Zone of rock substance with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge shaped blocks.			
Sheared Surface (Note 3)	A near planar, curved or undulating surface which is usually smooth, polished or slickensided.			
Crushed Seam (Note 3)	Seam with roughly parallel almost planar boundaries, composed of disoriented, usually angular fragments of the host rock substance which may be more weathered than the host rock. The seam has soil properties.			
Infilled Seam	Seam of soil substance usually with distinct roughly parallel boundaries formed by the migration of soil into an open cavity or joint. Infilled seams less than 1mm thick may be described as veneer or coating on joint surface.			
Extremely Weathered Seam	Seam of soil substance, often with gradational boundaries. Formed by weathering of the rock substance in place.			

Notes on Defects:

1. *Defects shown on borehole logs generally show the dip angle relative to the borehole axis. Geology cross-sections and sketches generally show the apparent dip direction and angle.*
2. *Partings and joints are not usually shown on the graphic log unless considered significant.*
3. *Sheared zones, sheared surfaces and crushed seams are faults in geological terms.*

DEFECT SHAPE TERMS

Planar	The defect does not vary in orientation.
Curved	The defect has a gradual change in orientation.
Undulating	The defect has a wavy surface.
Stepped	The defect has one or more well defined steps.
Irregular	The defect has many sharp changes of orientation.

***Note**: The assessment of defect shape is partly influenced by the scale of the observation*

ROUGHNESS TERMS

Slickensided	Grooved or striated surface, usually polished.
Polished	Shiny smooth surface.
Smooth	Smooth to touch. Few or no surface irregularities.
Rough	Many small surface irregularities (amplitude generally less than 1mm). Feels like fine to coarse sand paper.
Very Rough	Many large surface irregularities (amplitude generally more than 1mm). Feels like, or coarser than very coarse sand paper.

COATING TERMS

Clean	No visible coating.
Stained	No visible coating but surfaces are discoloured.
Veneer	A visible coating of soil or mineral, to thin to measure; may be patchy
Coating	A visible coating up to 1mm thick. Thicker soil material is usually described using appropriate defect terms (eg. infilled seam). Thicker rock strength material is usually described as a vein.

BLOCK SHAPE TERMS

Blocky	Approximately equi-dimensional.
Tabular	Thickness much less than length or width.
Columnar	Height much greater than cross section.

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Engineering Log - Borehole

Borehole No.	**BH1**
Sheet	1 of 2
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**3.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**4.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**BD**
Coordinates:	**558719.00mE 6813283.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 20.093 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information						Material Substance					
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
AD	C			20.0	0.5		GP	Silty Sandy GRAVEL: low plasticity, coarse to fine grained, yellow, brown, grey, cobbles and boulders in matrix.	D/M	L/MD	FILL
				19.5							
				19.0	1.0						
RR							CL	Gravelly Silty, CLAY: medium plasticity, red brown, some cobbles.	M	F/St	
				18.5	1.5						
				18.0	2.0						
			U50				CH	Silty CLAY: medium to high plasticity, grey brown, some gravel.			
				17.5	2.5						PP=100kPa
					3.0						
				17.0							
					3.5						
				16.5							
					4.0						
			SPT 4,3,1 N*=4	16.0							
					4.5		CH	Silty CLAY: medium plasticity, grey brown, some fine grained gravel.		St	NATURAL/COLLUVIUM
				15.5							
					5.0						

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

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Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Borehole

Borehole No.	**BH1**
Sheet	2 of 2
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**3.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**4.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**BD**
Coordinates:	**558719.00mE 6813283.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 20.093 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information | **Material Substance**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
RR	C			15.0			CH		VM	St	
							CH	Silty CLAY: high plasticity, grey brown, some fine to coarse grained gravel.			
					5.5						
			U50	14.5						F	
					6.0						
			SPT 3,3,2 N*=5	14.0							
					6.5						
				13.5							
					7.0					St	
			U50	13.0							
					7.5						
				12.5							
					8.0						
				12.0			CH	Silty CLAY: high plasticity, grey to orange brown mottled.	M	St-VSt	
					8.5						
			SPT 5,7,7 N*=14	11.5							
					9.0			Borehole BH1 continued as cored hole			
				11.0							
					9.5						
				10.5							
					10.0						

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

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Engineering Log - Cored Borehole

Borehole No.	**BH1**
Sheet	1 of 1
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**3.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**4.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**BD**
Coordinates:	**558719.00mE 6813283.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 20.093 m

Hole Diameter: 51 | Bearing: | Datum:

Drilling Information | **Material Substance** | **Rock Mass Defects**

method	core-lift	water	RL	depth metres	graphic log / core recovery	material: rock type; grain characteristics, colour, structure, minor components	weathering alteration	estimated strength (EL VL L M H VH EH)	$Is_{(50)}$ MPa D- diametral A- axial	RQD %	defect spacing mm (30 100 300 1000 3000)	defect description: type, inclination, planarity, roughness, coating, thickness (particular / general)
NMLC			11.0	9.0		Continued from non-cored borehole						COLLUVIUM
						Silty CLAY: high plasticity, red brown to orange brown and blue grey mottled, blocky, some fine to coarse grained gravel and cobbles composed of slightly weathered, high strength basalt.				0		Silty CLAY colluvium with varying amounts gravel, cobbles and small boulders composed of weathered basalt.
			10.5	9.5		CORE LOSS						
			10.0	10.0		Silty CLAY: high plasticity, red brown to orange brown and grey mottled, blocky, some fine to coarse grained gravel and cobbles composed of slightly weathered, high strength basalt.				0		
			9.5	10.5		BASALT: grey, fine grained (cobble or small boulder).	SW					
						CORE LOSS						
			9.0	11.0		Silty CLAY: high plasticity red brown to orange brown and grey mottled, blocky, some fine to coarse grained gravel and cobbles composed of slightly weathered, high strength basalt.				<5		
			8.5	11.5						0		
			8.0	12.0		BASALT: grey, slighty weathered, high strength (cobble or small boulder).	SW					
			7.5	12.5		BASALT: grey brown to brownish grey and red brown mottled, fine grained, locally grading to silty clay (extremely weathered Basalt)	XW-HW					
			7.0	13.0		BH1 terminated at 12.75m						
			6.5	13.5								

Method
AS auger screwing
AD auger drilling
RR roller/tricone
CB claw or blade bit
NMLC NMLC core
NQ, HQ, PQ wireline core

Case-Lift
casing used
barrel withdrawn

Graphic Log/Core Recovery
core recovered - hatching indicates material
no core recovered

Water
water level on date shown
water inflow
partial drill fluid loss
complete drill fluid loss
25 water pressure test result (lugeons) for depth interval shown

Weathering/Alteration (W/A)
Fr fresh
SW slightly
MW moderately
HW highly
EW extremely

Strength
EL extremely low
VL very low
L low
M medium
H high
VH very high
EH extremely high

Defects
JT joint
PT parting
SM seam
PL planar
CV curved
IR irregular
RO rough
SO smooth
SL slickensided

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10644/1-C
14 July 2011

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BOREHOLE BH1

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Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Borehole

Borehole No.	**BH2**
Sheet	1 of 3
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**7.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**8.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558708.00mE 6813295.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 19.204 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information | **Material Substance**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
AD				19.0	0.5		SP	Gravelly Silty SAND: fine to medium grained, brown, fine to coarse grained gravel.	D	L	FILL
			SPT 1,2,2 N*=4	18.5	1.0		CH	Silty CLAY: high plasticity, red brown, some fine grained sand.	M	F-St	
				18.0	1.5		CH	Gravelly CLAY: high plasticity, grey brown, fine to coarse grained gravel, with some cobbles.	M/W		
				17.5	2.0						PP=0kPa on auger sample.
				17.0	2.5						
		▶	SPT 1,4,12 N*=16	16.5							PP=25kPa on SPT sample
		▼ 1200hrs 7/2/2011		16.0	3.0		CH	Sandy Silty CLAY: high plasticity, dark grey, with some root fibres, some fine grained gravel, some basalt cobbles and organic odour.	W	S-F	
				15.5	3.5						
			SPT 3,2,5 N*=7	15.0	4.0		GC	Gravelly Silty CLAY: high plasticity, dark grey brown, fine to coarse grained gravel, with discrete silt and clay bands.		St	
				14.5	4.5						
					5.0		CH	Silty CLAY: high plasticity, dark brown to dark grey, with some fine to coarse grained gravel.			NATURAL/COLLUVIUM

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

▼ water level on date shown
▶ water inflow
◀ water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Borehole

Borehole No.	**BH2**
Sheet	2 of 3
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**7.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**8.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558708.00mE 6813295.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 19.204 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information						Material Substance					
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
AD				14.0	5.5		CH	Silty CLAY: high plasticity, dark brown to dark grey, with some fine to coarse grained gravel. *(continued)*	M	F	
WB			U50	13.5							PP=60kPa
				13.0	6.0						
					6.5		CH	Silty CLAY: high plasticity, pale brown.		St	
				12.5							
			SPT 2,2,7 N*=9	12.0	7.0						
					7.5						
			U50	11.5							PP=150kPa
				11.0	8.0						
					8.5		CH	Silty CLAY: high plasticity, grey brown to red brown mottled .		St-VSt	
			SPT 5,7,8 N*=15	10.5							PP=200kPa
				10.0	9.0						
				9.5	9.5						
				9.5	10.0						

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

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Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Borehole

Borehole No.	**BH2**
Sheet	3 of 3
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**7.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**8.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558708.00mE 6813295.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 19.204 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information						Material Substance					
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
WB			U50	9.0	10.5		CH	Silty CLAY: high plasticity, grey brown to red brown mottled . *(continued)*	M	St-VSt	PP=150-200kPa
				8.5	11.0						
				8.0	11.5						
			SPT 5,6,8 N*=14	7.5	12.0		CH	Silty Sandy CLAY: high plasticity, brown to dark grey brown.			PP=150-200kPa
				7.0	12.5						
				6.5	13.0						
			SPT 5,8,12 N*=20	6.0	13.5		CH	Sandy CLAY: high plasticity, brown to dark grey brown, sand content increasing with depth.			
				5.5	14.0		GP	GRAVEL and COBBLES: fine to coarse grained, grey brown to brownish grey, with silty sandy clay matrix.			
				5.0	14.5						
				4.5	15.0			Borehole BH2 continued as cored hole			

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

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Engineering Log - Borehole

Borehole No.	**BH2**
Sheet	2 of 3
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**7.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**8.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558708.00mE 6813295.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 19.204 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information						Material Substance					
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
AD				14.0	5.5		CH	Silty CLAY: high plasticity, dark brown to dark grey, with some fine to coarse grained gravel. *(continued)*	M	F	
WB			U50	13.5							PP=60kPa
				13.0	6.0						
					6.5		CH	Silty CLAY: high plasticity, pale brown.		St	
				12.5							
			SPT 2,2,7 N*=9	12.0	7.0						
					7.5						
			U50	11.5							PP=150kPa
				11.0	8.0						
					8.5		CH	Silty CLAY: high plasticity, grey brown to red brown mottled .		St-VSt	
			SPT 5,7,8 N*=15	10.5							PP=200kPa
				10.0	9.0						
				9.5	9.5						
				9.5	10.0						

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

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Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Cored Borehole

Borehole No.	**BH2**
Sheet	1 of 1
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**7.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**8.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558708.00mE 6813295.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 19.204 m

Hole Diameter: 51 | Bearing: | Datum:

Drilling Information					Material Substance				Rock Mass Defects		
method	core-lift	water	RL	depth metres	graphic log / core recovery	material: rock type; grain characteristics, colour, structure, minor components	weathering alteration	estimated strength (EL VL L M H VH EH)	$Is_{(50)}$ MPa (D- diametral, A- axial)	RQD %	defect spacing mm (30 100 300 1000 3000)	defect description: type, inclination, planarity, roughness, coating, thickness (particular / general)
						Continued from non-cored borehole						
NMLC			4.5	15.0		Silty CLAY/Clayey SILT: high plasticity, brown to orange brown mottled, some fine to coarse grained gravel and occasional cobbles composed of Basalt.				0		COLLIVIUM: Interlayered sequence of clay, gravel and cobbles.
			4.0			GRAVEL and COBBLES: fine to coarse grained, grey brown to brownish grey, composed of very low to low strength Basalt.				< 0		
				15.5		COBBLES: rounded, composed of slighty weathered, high strength Basalt, with matrix of red-brown silty clay.						
			3.5			BH2 terminated at 15.62m						
				16.0								
			3.0									
				16.5								
			2.5									
				17.0								
			2.0									
				17.5								
			1.5									
				18.0								
			1.0									
				18.5								
			0.5									
				19.0								
			0.0									
				19.5								

Method

AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ, HQ, PQ	wireline core

Case-Lift

- casing used
- barrel withdrawn

Graphic Log/Core Recovery

- core recovered - hatching indicates material
- no core recovered

Water

- water level on date shown
- water inflow
- partial drill fluid loss
- complete drill fluid loss
- 25 water pressure test result (lugeons) for depth interval shown

Weathering/Alteration (W/A)

Fr	fresh
SW	slightly
MW	moderately
HW	highly
EW	extremely

Strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high
EH	extremely high

Defects

JT	joint
PT	parting
SM	seam
PL	planar
CV	curved
IR	irregular
RO	rough
SO	smooth
SL	slickensided

CORED BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

BOREHOLE BH2

shaw:urquhart

Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Borehole

Borehole No.	**BH3**
Sheet	1 of 3
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**9.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**9.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558693.00mE 6813312.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 19.178 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information | **Material Substance**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
AD				19.0	0.5		GM	Silty GRAVEL: fine to coarse grained, pale grey, low plasticity fines.	D	MD	FILL
				18.5	1.0		SP	Silty SAND: fine to medium grained, brown.	M	L	
			SPT 2,3,3 N*=6	18.0	1.5		CH	Silty CLAY: high plasticity, red brown, some fine to coarse grained gravel.		F-St	
WB/RR				17.5	2.0						
				17.0	2.5						
			SPT 3,3,3 N*=6	16.5	3.0		CH	Silty CLAY: high plasticity, dark grey, some fine to medium grained gravel, with root fibres.		S-F	
				16.0	3.5		SC	Clayey SAND: coarse grained, grey.		L	
			SPT 1,1,3 N*=4	15.5	4.0						
				15.0	4.5		CH	Silty CLAY: high plasticity, grey, some fine grained gravel.		S/F	NATURAL/COLLUVIUM
				14.5	5.0						

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

shaw:urquhart

Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Borehole

Borehole No.	**BH3**
Sheet	2 of 3
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**9.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**9.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558693.00mE 6813312.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 19.178 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information						Material Substance					
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
WB				14.0	5.5		OH	Silty CLAY: high plasticity, dark grey, some fine to coarse grained gravel, with high organic content and strong organic odour.	W	S/F	
			SPT 1,2,4 N*=6	13.5	6.0		CH	Silty CLAY: high plasticity, grey.	M	F	PP=50kPa
				13.0	6.5		GC	Clayey GRAVEL: fine to coarse grained, grey.	W	L	
				12.5	7.0		CH	Silty CLAY: high plasticity, red brown.	M	F-St	
			SPT 2,2,3 N*=5	12.0	7.5						PP=100kPa
				11.5	8.0						
				11.0	8.5		CH	Silty CLAY: high plasticity, brown and red brown.		VSt	
			U50	10.5	9.0						PP=300kPa
				10.0	9.5						
				9.5	10.0						

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

shaw:urquhart

Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Borehole

Borehole No.	**BH3**
Sheet	3 of 3
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**9.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**9.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558693.00mE 6813312.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 19.178 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information | **Material Substance**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
WB			SPT 5,8,12 N*=20	9.0	10.5		CH	Silty CLAY: high plasticity, grey brown, to orange brown and red brown mottled.	M	VSt	
				8.5	11.0						
				8.0	11.5						
			SPT 5,7,10 N*=17	7.5	12.0						
				7.0	12.5						
				6.5			GC	GRAVEL and COBBLES: fine to coarse grained, grey brown to brownish grey, with silty clay matrix.			
				6.0	13.0			Borehole BH3 continued as cored hole			
				5.5	13.5						
				5.0	14.0						
				4.5	14.5						
					15.0						

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

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Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Cored Borehole

Borehole No.	**BH3**
Sheet	1 of 1
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Borehole Location:	**REFER FIGURE 1**
Coordinates:	**558693.00mE 6813312.00mN**
Date started:	**9.2.2011**
Date completed:	**9.2.2011**
Logged by:	**WJB**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 19.178 m

Hole Diameter: 51 | Bearing: | Datum:

Drilling Information					Material Substance				Rock Mass Defects		
method	core-lift	water	RL	depth metres	graphic log / core recovery	material: rock type; grain characteristics, colour, structure, minor components	weathering alteration	estimated strength (EL VL L M H VH EH)	$Is_{(50)}$ MPa (D- diametral, A- axial)	RQD %	defect spacing mm (30 100 300 1000 3000)	defect description: type, inclination, planarity, roughness, coating, thickness (particular / general)
						Continued from non-cored borehole						
NMLC				13.0		BASALT: grey, vesicular, moderately to slightly weathered, high strength (COBBLE).	SW					COLLIVIUM: Interlayered sequence of clay, gravel and cobbles.
			6.0			Sandy Clayey SILT: mediun plasticity, dark brown to red brown mottled, fine grained sand, blocky, some fine to coarse grained gravel and cobbles, composed of high strength, slightly weathered basalt.				0		
				13.5								
			5.5									
				14.0						0		
			5.0			BH3 terminated at 14.15m						
				14.5								
			4.5									
				15.0								
			4.0									
				15.5								
			3.5									
				16.0								
			3.0									
				16.5								
			2.5									
				17.0								
			2.0									
				17.5								
			1.5									

Method

AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ, HQ, PQ	wireline core

Case-Lift

- casing used
- barrel withdrawn

Graphic Log/Core Recovery

- core recovered - hatching indicates material
- no core recovered

Water

- water level on date shown
- water inflow
- partial drill fluid loss
- complete drill fluid loss
- water pressure test result (lugeons) for depth interval shown (25)

Weathering/Alteration (W/A)

Fr	fresh
SW	slightly
MW	moderately
HW	highly
EW	extremely

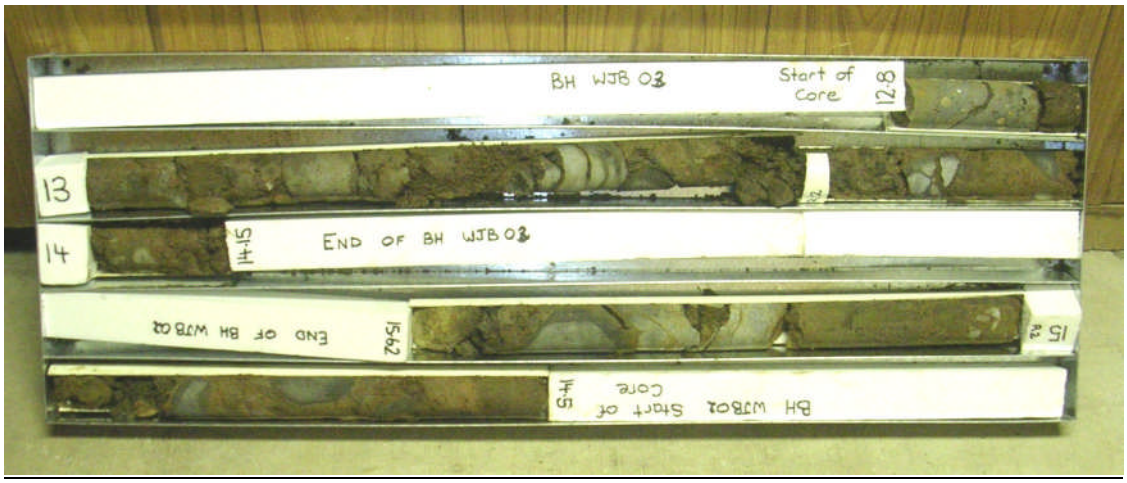
Strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high
EH	extremely high

Defects

JT	joint
PT	parting
SM	seam
PL	planar
CV	curved
IR	irregular
RO	rough
SO	smooth
SL	slickensided

CORED BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11



BOREHOLE BH3

shaw:urquhart

Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Borehole

Borehole No.	**BH4**
Sheet	1 of 2
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**10.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**10.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558660.00mE 6813347.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 15.802 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information						Material Substance					
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
AD				15.5	0.5		SP	Silty SAND: fine to medium grained, brown, with coarse grained gravel and boulders.	M	L	FILL
				15.0	1.0		CH	Gravelly CLAY: high plasticity, red brown.		St	
			SPT 6,8,5 N*=13	14.5	1.5						
				14.0	2.0		CH	Silty CLAY: high plasticity, dark brown, with some coarse grained gravel.	M/W	F/St	NATURAL/COLLUVIUM
			SPT 3,5,6 N*=11	13.5	2.5		CH	Sandy Gravelly CLAY: high plasticity, brown, fine to medium grained sand, fine grained gravel, with fine organic material.	M	St	
				13.0	3.0						PP=150-200kPa
				12.5	3.5						
				12.0	4.0						
			SPT 2,3,4 N*=7	11.5	4.5		CH	Silty CLAY: high plasticity, grey and brown.			PP=150kPa
				11.0	5.0						

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

shaw:urquhart

Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Borehole

Borehole No.	**BH4**
Sheet	2 of 2
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Date started:	**10.2.2011**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Date completed:	**10.2.2011**
Borehole Location:	**REFER FIGURE 1**
Logged by:	**WJB**
Coordinates:	**558660.00mE 6813347.00mN**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 15.802 m

Hole Diameter: 100 | Bearing: | Datum:

Drilling Information						Material Substance					
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
AD				10.5	5.5		CH	Silty CLAY: high plasticity, grey and brown. *(continued)*	M	St	
			SPT 3,5,8 N*=13	10.0	6.0		CH	Silty CLAY: high plasticity, grey brown mottled, some fine grained sand.			
				9.5	6.5						
				9.0	7.0			Borehole BH4 continued as cored hole			
				8.5	7.5						
				8.0	8.0						
				7.5	8.5						
				7.0	9.0						
				6.5	9.5						
				6.0	10.0						

Method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
HA	hand auger
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

Support

M mud N nil
C casing

Water

water level on date shown
water inflow
water outflow

Notes, Samples, Tests

U_{50}	undisturbed sample 50mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressure meter
Bs	bulk sample
R	refusal
E	environmental sample

Classification Symbols And Soil Description

based on unified classification system

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

Consistency/Density Index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

shaw:urquhart

Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Cored Borehole

Borehole No.	**BH4**
Sheet	1 of 2
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Borehole Location:	**REFER FIGURE 1**
Coordinates:	**558660.00mE 6813347.00mN**
Date started:	**10.2.2011**
Date completed:	**10.2.2011**
Logged by:	**WJB**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 15.802 m

Hole Diameter: 51 | Bearing: | Datum:

Drilling Information | **Material Substance** | **Rock Mass Defects**

method	core-lift	water	RL	depth metres	graphic log / core recovery	material: rock type; grain characteristics, colour, structure, minor components	weathering alteration	estimated strength (EL VL L M H VH EH)	$Is_{(50)}$ MPa D- diametral A- axial	RQD %	defect spacing mm (30 100 300 1000 3000)	defect description: type, inclination, planarity, roughness, coating, thickness (particular / general)
						Continued from non-cored borehole						
NMLC			8.5	7.0		Silty CLAY: high plasticity, brown to grey brown and orange brown mottled, trace of fine grained sand, occasional gravel fragments.				0		
			8.0	7.5								
			7.5	8.0								
			7.0	8.5								
			6.5	9.0		Silty CLAY: high plasticity, brown to grey brown and orange brown mottled, blocky, trace of fine grained sand, occasional Basalt gravel fragments becoming more numerous with depth.				0		
			6.0	9.5		CORE LOSS						
			5.5	10.0		Silty CLAY: high plasticity, brown to grey brown and orange brown mottled, blocky, trace of fine grained sand, occasional Basalt gravel fragments becoming more numerous with depth.				0		
			5.0	10.5		GRAVEL: coarse grained, dark brown to red brown and grey, rounded to sub-angular, composed of highly weathered Basalt.				0		
			4.5	11.0		SAND: fine to medium grained, dense, dark brown to browish grey, some clay fines, trace of coarse grained gravel.				0		
			4.0	11.5		CORE LOSS				0		

Method
AS auger screwing
AD auger drilling
RR roller/tricone
CB claw or blade bit
NMLC NMLC core
NQ, HQ, PQ wireline core

Case-Lift
casing used
barrel withdrawn

Graphic Log/Core Recovery
core recovered - hatching indicates material
no core recovered

Water
water level on date shown
water inflow
partial drill fluid loss
complete drill fluid loss
25 water pressure test result (lugeons) for depth interval shown

Weathering/Alteration (W/A)
Fr fresh
SW slightly
MW moderately
HW highly
EW extremely

Strength
EL extremely low
VL very low
L low
M medium
H high
VH very high
EH extremely high

Defects
JT joint
PT parting
SM seam
PL planar
CV curved
IR irregular
RO rough
SO smooth
SL slickensided

CORED BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

shaw:urquhart

Shaw Urquhart Pty Ltd ACN 108 592 623

Engineering Log - Cored Borehole

Borehole No.	**BH4**
Sheet	2 of 2
Job No.:	**10644/1**
Client:	**BALLINA SHIRE COUNCIL**
Project:	**COAST ROAD LANDSLIDE, LENNOX HEAD**
Borehole Location:	**REFER FIGURE 1**
Coordinates:	**558660.00mE 6813347.00mN**
Date started:	**10.2.2011**
Date completed:	**10.2.2011**
Logged by:	**WJB**
Checked by:	

Drill Model And Mounting: MD100 TRACKED | Slope: -90° | R.L. Surface: 15.802 m

Hole Diameter: 51 | Bearing: | Datum:

Drilling Information					Material Substance				Rock Mass Defects		
method	core-lift	water	RL	depth metres	graphic log / core recovery	material: rock type; grain characteristics, colour, structure, minor components	weathering alteration	estimated strength (EL VL L M H VH EH)	$Is_{(50)}$ MPa (D- diametral, A- axial)	RQD %	defect spacing mm (30 100 300 1000 3000)	defect description: type, inclination, planarity, roughness, coating, thickness (particular / general)
NMLC			3.5	12.0		CORE LOSS *(continued)*				0		
				12.5								
SPT			3.0			SAND: brown, medium grained (from SPT sample).				0		
WB				13.0		CORE LOSS				0		
			2.5	13.5		GRAVEL: fine to medium grained, some clay fines.						
NMLC			2.0			Silty CLAY: high plasticity, dark brown to orange brown and grey mottled, blocky, some coarse grained gravel (Basalt fragments).				0		
			1.5	14.0								
				14.5		BASALT: grey, fine grained (COBBLE).	SW			0		
			1.0			Gravelly Sandy CLAY: medium plasticity, brown to grey brown and orange brown mottled, fine to medium grained sand, fine to coarse grained gravel, occasional Basalt cobbles.						
			0.5	15.0						0		
				15.5		BASALT: grey to grey brown (BOULDER).	HW					
			0.0			BH4 terminated at 15.75m						COLLIVIUM: Interlayered sequence of clay, gravel and cobbles.
				16.0								
			-0.5									
				16.5								
			-1.0									

Method
AS auger screwing
AD auger drilling
RR roller/tricone
CB claw or blade bit
NMLC NMLC core
NQ, HQ, PQ wireline core

Case-Lift
casing used
barrel withdrawn

Graphic Log/Core Recovery
core recovered
- hatching indicates material
no core recovered

Water
water level on date shown
water inflow
partial drill fluid loss
complete drill fluid loss
25 water pressure test result (lugeons) for depth interval shown

Weathering/Alteration (W/A)
Fr fresh
SW slightly
MW moderately
HW highly
EW extremely

Strength
EL extremely low
VL very low
L low
M medium
H high
VH very high
EH extremely high

Defects
JT joint
PT parting
SM seam
PL planar
CV curved
IR irregular
RO rough
SO smooth
SL slickensided

CORED BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

10644/1-C
14 July 2011

BOREHOLE BH4 BOX 1 OF 2

BOREHOLE BH4 BOX 2 OF 2

10644/1-C
14 July 2011

shaw:urquhart

APPENDIX B
LABORATORY TEST RESULTS

Trilab Pty Ltd ABN: 25 065 630 506 PO Box 3317 Newmarket QLD 4051
test@trilab.com.au +61 7 3357 5535 www.trilab.com.au

ATTERBERG LIMITS TEST REPORT

Test Method: AS1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client:	Shaw Urquhart Pty Ltd	Report No.	11020651-AL
Project:	Coast Road, Lennox Head	Test Date:	10-16/03/11
		Report Date:	22/03/11

Client ID: BH2	Depth(m): 5.5	Sample No. 11020651	
Liquid Limit (%):	82	Linear Shrinkage (%):	15.0*
Plastic Limit (%):	45	Field Moisture Content (%):	63.2
Plasticity Index (%):	37		

Remarks: The sample/s were tested oven dried, dry sieved and in a 125 – 250mm mould.
*Crumbling occurred.
+Curling occurred

Sample/s supplied by the client

Authorised Signatory

J. Russell

Manager

N ATA Accredited Laboratory Number 9926
Form Number:GT004-5

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

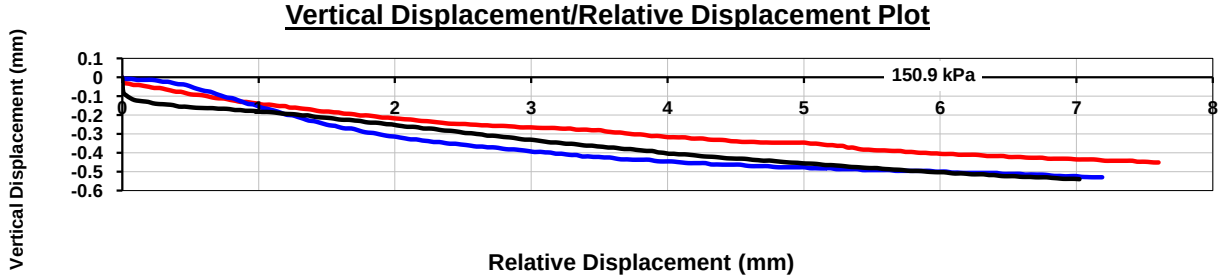
Trilab
+61 7 3357 5535 www.trilab.com.au 10/104 Newmarket Rd, Windsor QLD 4030

DIRECT SHEAR TEST REPORT

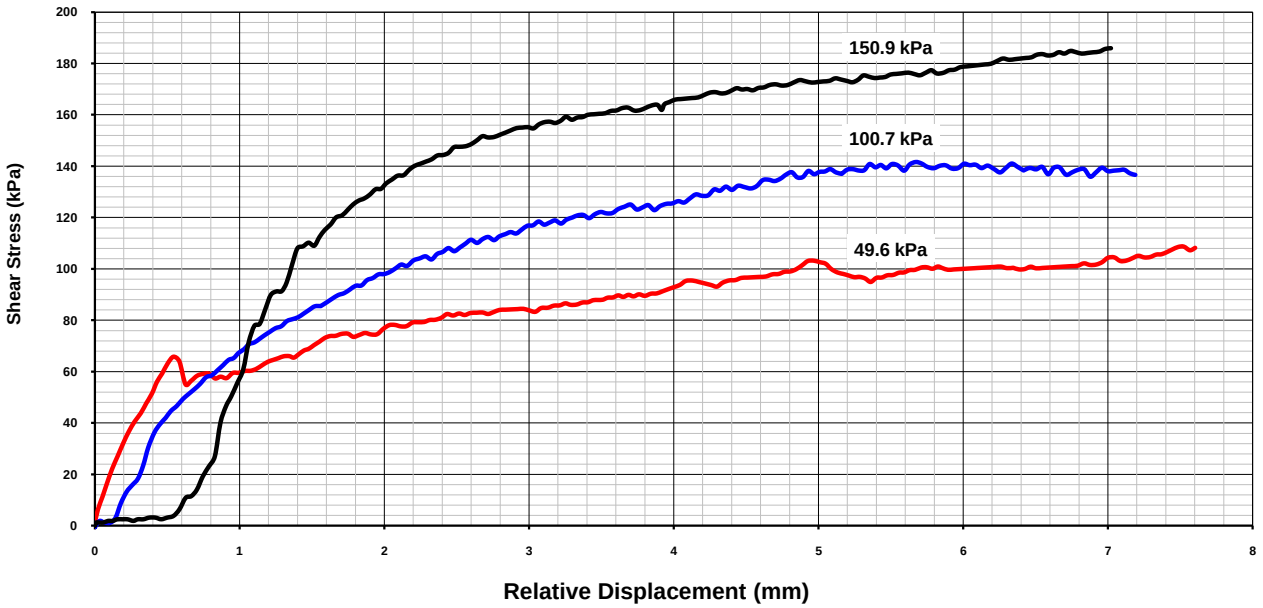
Test Method: AS 1289.6.2.2 / KH2 based on K.H. Head Vol. 2

Client	Shaw Urquhart Pty Ltd	**Report No.**	11020651- DS
Project	Coast Road, Lennox Head	**Test Date**	7/03/2011
		Report Date	21/03/2011
Client ID	BH2	**Depth (m)**	5.50
Description	CLAY-brown	**Sample Type**	Three Individual Undisturbed Soil Specimens
Failure Criteria	**Residual @ 5.5 mm Displacement**		

Vertical Displacement/Relative Displacement Plot



Shear Stress/Displacement Plot



Notes/Remarks: Please review the results if the Cohesion is above 2 kPa when plotted with a line of best fit

Graph not to scale

Sample/s supplied by the client

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IES 17025. The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Authorised Signatory

J. Russell

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

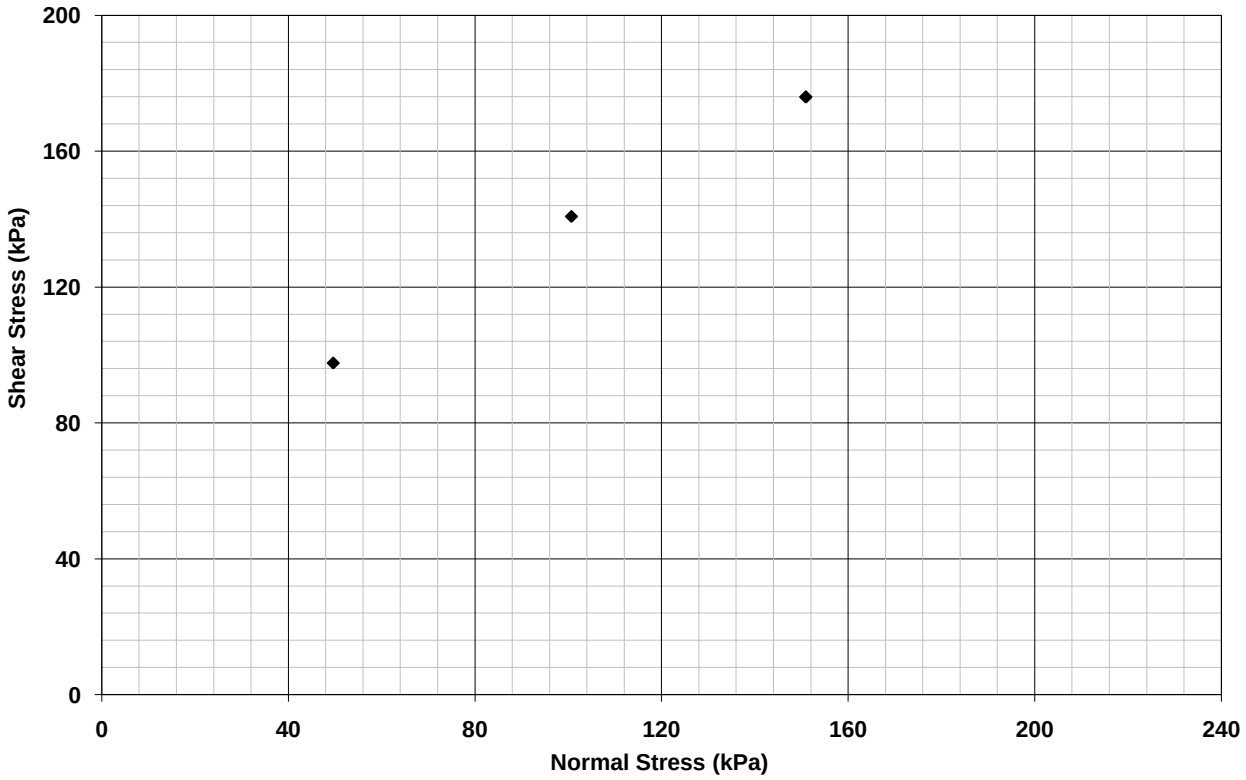
Trilab
+61 7 3357 5535 www.trilab.com.au 10/104 Newmarket Rd, Windsor QLD 4030

DIRECT SHEAR TEST REPORT

Test Method: AS 1289.6.2.2 / KH2 based on K.H. Head Vol. 2

Client	Shaw Urquhart Pty Ltd	**Report No.**	11020651- DS
Project	Coast Road, Lennox Head	**Test Date**	7/03/2011
		Report Date	21/03/2011
Client ID	BH2	**Depth (m)**	5.50
Description	CLAY-brown	**Sample Type**	Three Individual Undisturbed Soil Specimens
Failure Criteria	**Residual @ 5.5 mm Displacement**		

Residual - Normal Stress vs Shear Stress



Shear Angle (°)	**37.5**	**Cohesion (kPa)**	**60.9**	**R^2**	**0.999**
Specimen Dimensions (mm)	45*19	Normal Stress (kPa)		Shear Stress (kPa)	
Rate of Strain (mm/min)	0.008	Stage 1	49.6	97.6	
Initial Moisture Content (%)	63.2	Stage 2	100.7	140.8	
Initial Wet Density(t/m^3)	1.567, 1.562, 1.572	Stage 3	150.9	176.0	

Notes/Remarks: Please review the results if the Cohesion is above 2 kPa when plotted with a line of best fit

Graph not to scale Sample/s supplied by the client

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Authorised Signatory
J. Russell

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Laboratory No. 9926

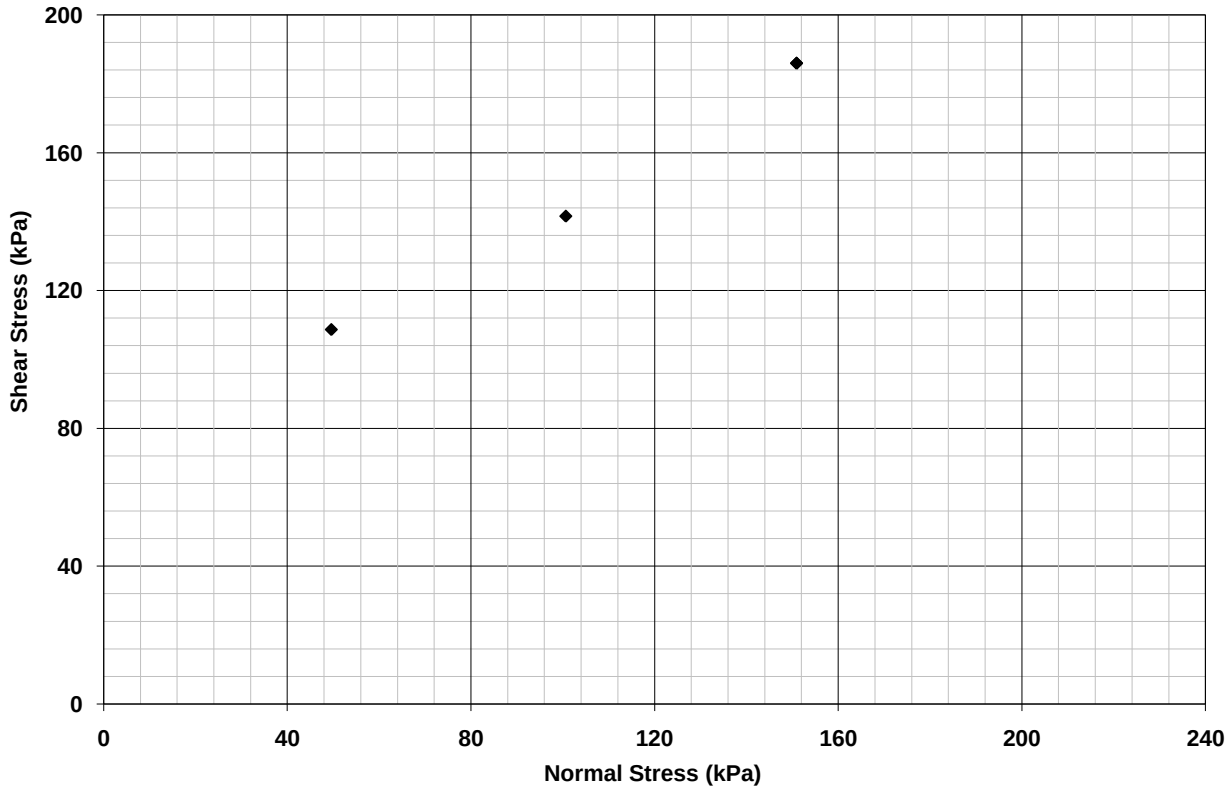
Trilab
+61 7 3357 5535 www.trilab.com.au 10/104 Newmarket Rd, Windsor QLD 4030

DIRECT SHEAR TEST REPORT

Test Method: AS 1289.6.2.2 / KH2 based on K.H. Head Vol. 2

Client	Shaw Urquhart Pty Ltd	**Report No.**	11020651- DS
Project	Coast Road, Lennox Head	**Test Date**	7/03/2011
		Report Date	21/03/2011
Client ID	BH2	**Depth (m)**	5.50
Description	CLAY-brown	**Sample Type**	Three Individual Undisturbed Soil Specimens
Failure Criteria		**Peak**	

Peak - Normal Stress vs Shear Stress



Shear Angle (°)	**37.7**	**Cohesion (kPa)**	**68.1**	**R^2**	**0.997**

Specimen Dimensions (mm)	45*19	Normal Stress (kPa)		Shear Stress (kPa)
Rate of Strain (mm/min)	0.008	Stage 1	49.6	108.6
Initial Moisture Content (%)	63.2	Stage 2	100.7	141.6
Initial Wet Density(t/m^3)	1.567, 1.562, 1.572	Stage 3	150.9	186.0

Notes/Remarks: Please review the results if the Cohesion is above 2 kPa when plotted with a line of best fit

Graph not to scale

Sample/s supplied by the client

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Authorised Signatory

J. Russell

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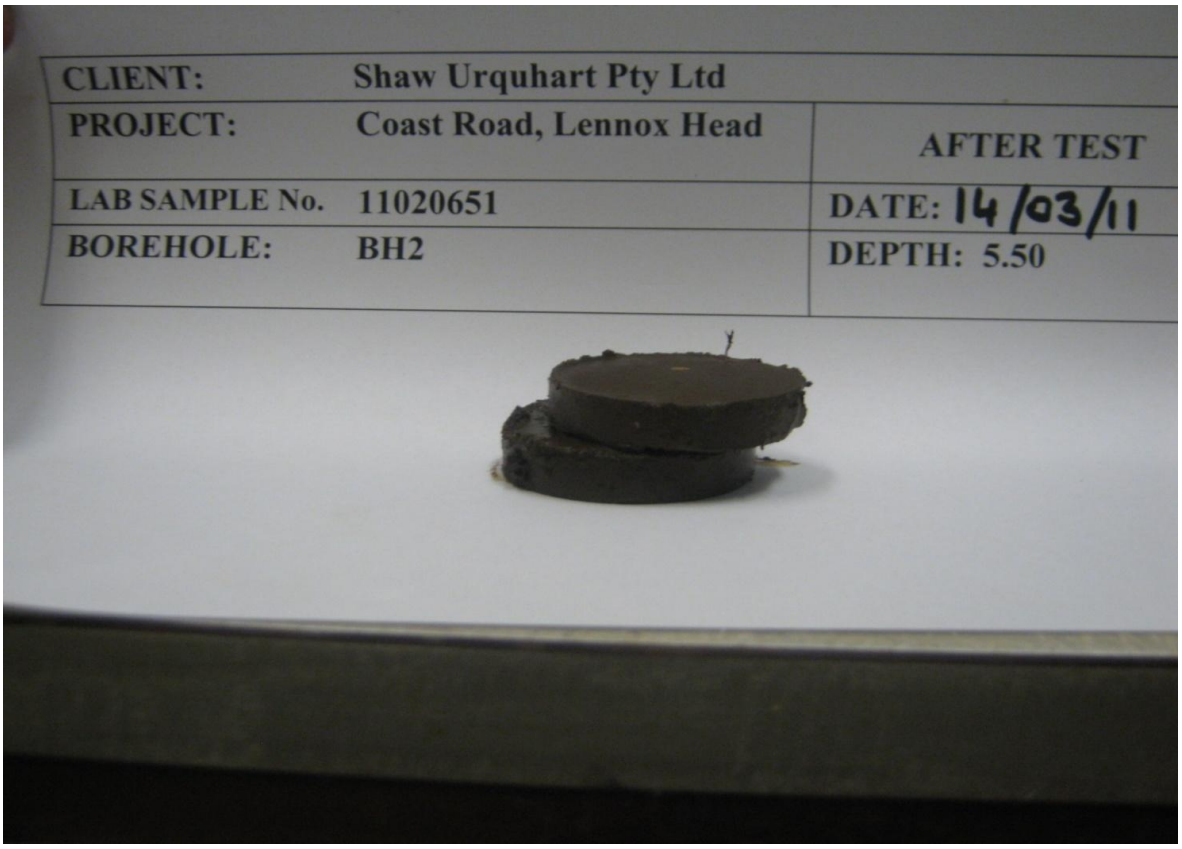
+61 7 3357 5535 www.trilab.com.au 10/104 Newmarket Rd, Windsor QLD 4030

DIRECT SHEAR TEST REPORT

Test Method: AS 1289.6.2.2 / KH2 based on K.H. Head Vol. 2

Client	Shaw Urquhart Pty Ltd	**Report No.**	11020651- DS
Project	Coast Road, Lennox Head	**Test Date**	7/03/2011
		Report Date	21/03/2011
Client ID	BH2	**Depth (m)**	5.50
Description	CLAY-brown	**Sample Type**	Three Individual Undisturbed Soil Specimens



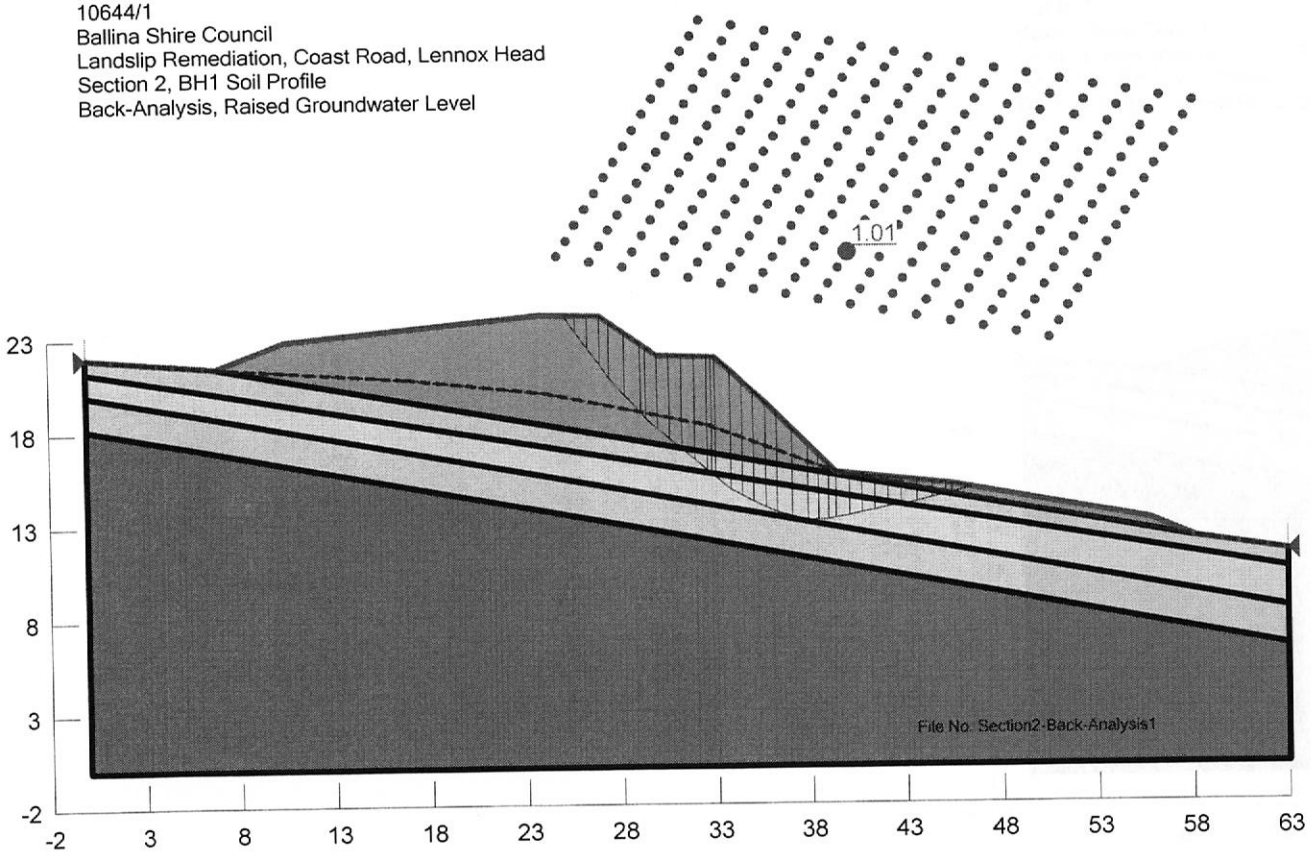
Notes/Remarks:

Photo not to scale Sample/s supplied by the client

APPENDIX C

COPIES OF TYPICAL COMPUTER STABILITY ANALYSIS PRINTOUTS

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1 Soil Profile
Back-Analysis, Raised Groundwater Level



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

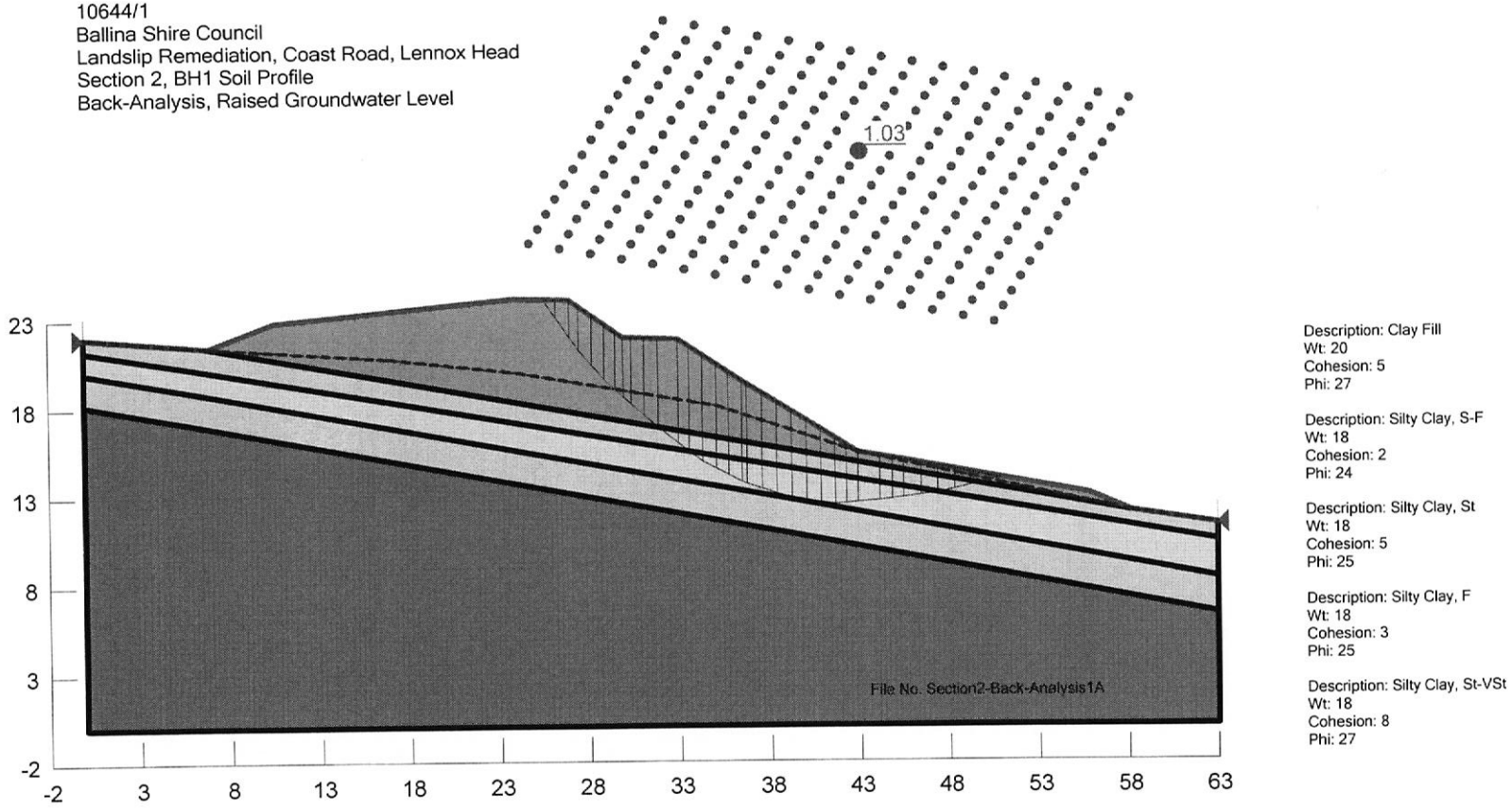
Description: Silty Clay, S-F
Wt: 18
Cohesion: 2
Phi: 24

Description: Stiff Clay
Wt: 18
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

Description: Stiff-Very Stiff Clay
Wt: 18
Cohesion: 8
Phi: 27

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1 Soil Profile
Back-Analysis, Raised Groundwater Level



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

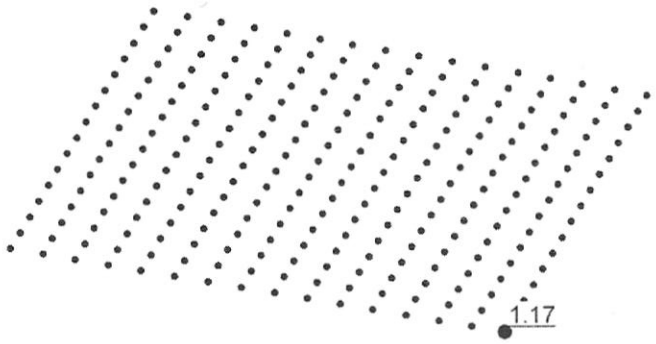
Description: Silty Clay, S-F
Wt: 18
Cohesion: 2
Phi: 24

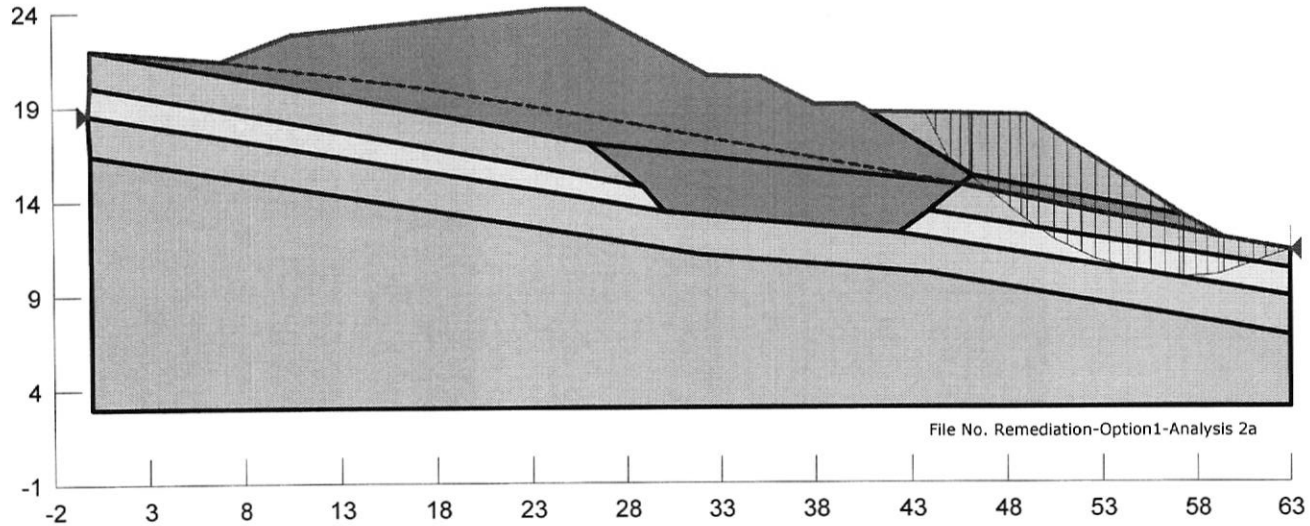
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level
Re-Profiled Batter, Fill Toe Berm
EXcavation and Replacement (Clay)





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

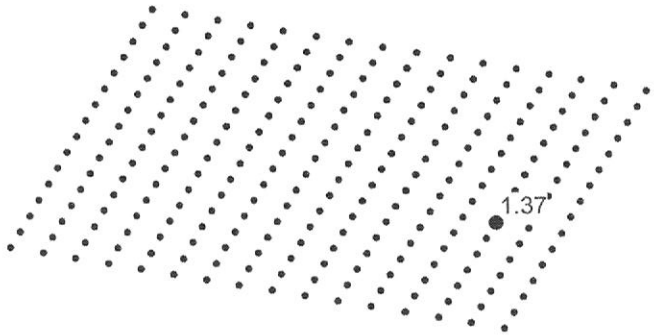
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

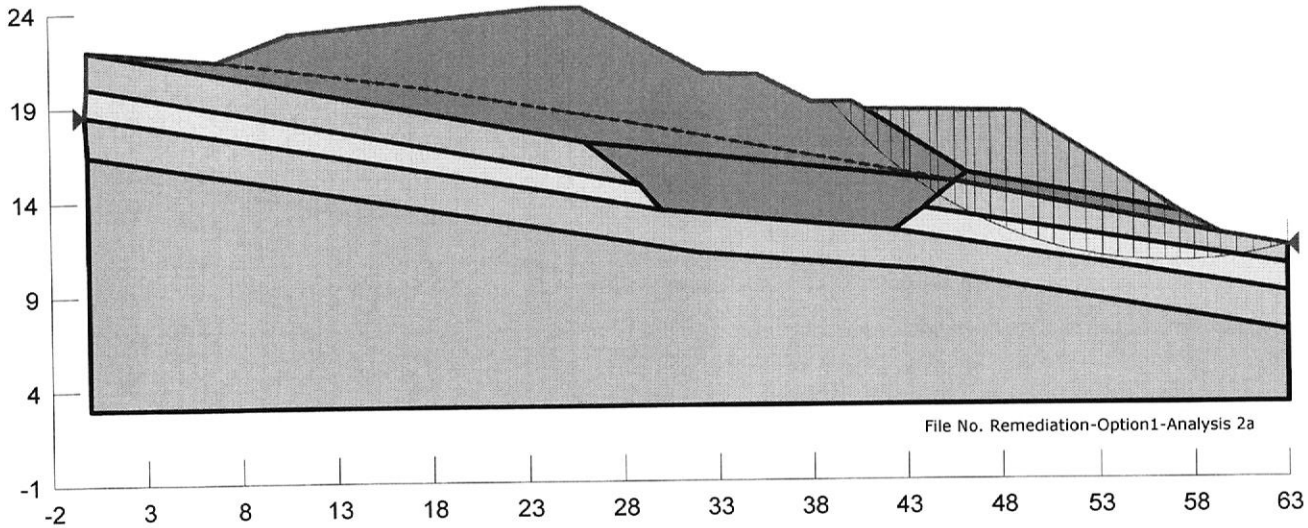
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strength
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level
Re-Profiled Batter, Fill Toe Berm
EXcavation and Replacement (Clay)





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

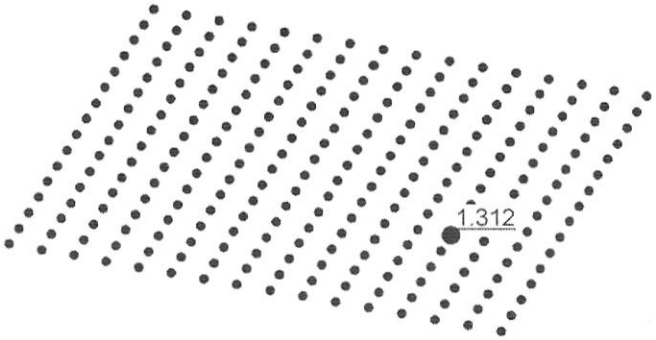
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

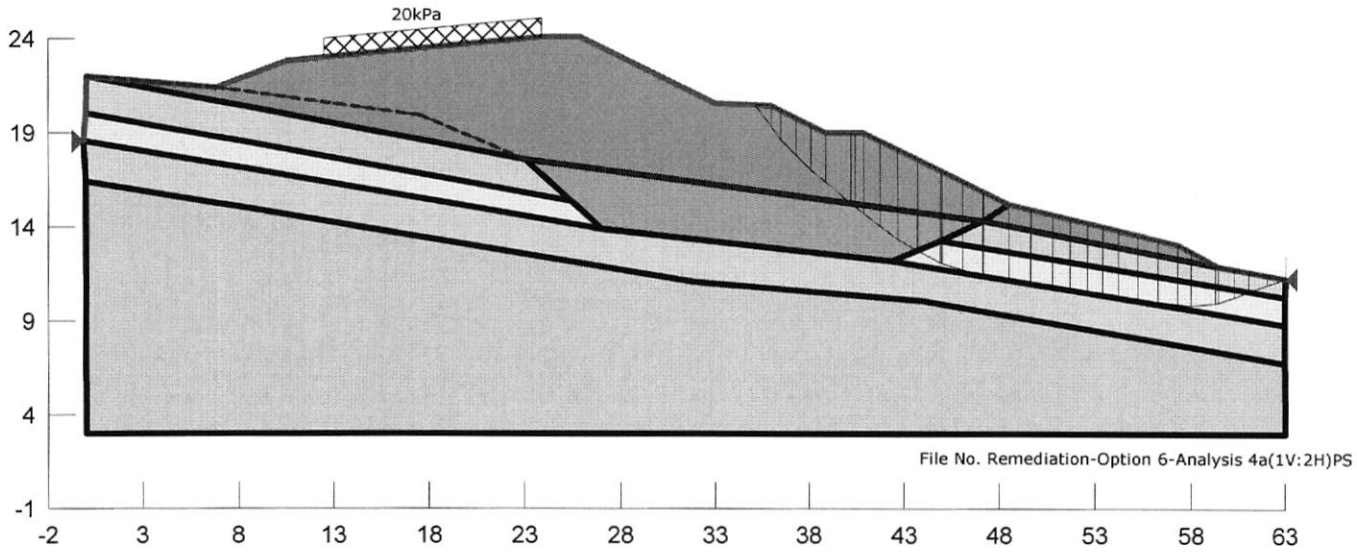
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strength
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level
Re-Profiled Batter,
Wider Excavation and Replacement (Clay Fill)





Description: Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

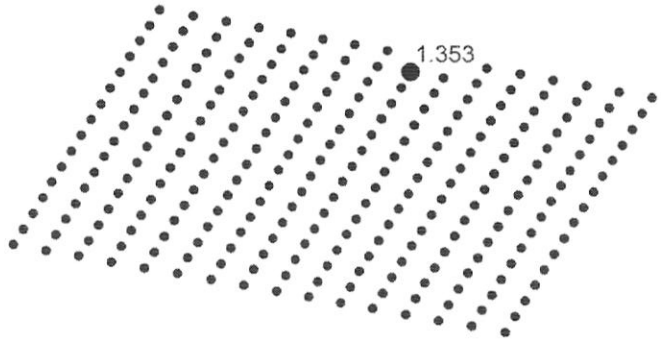
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

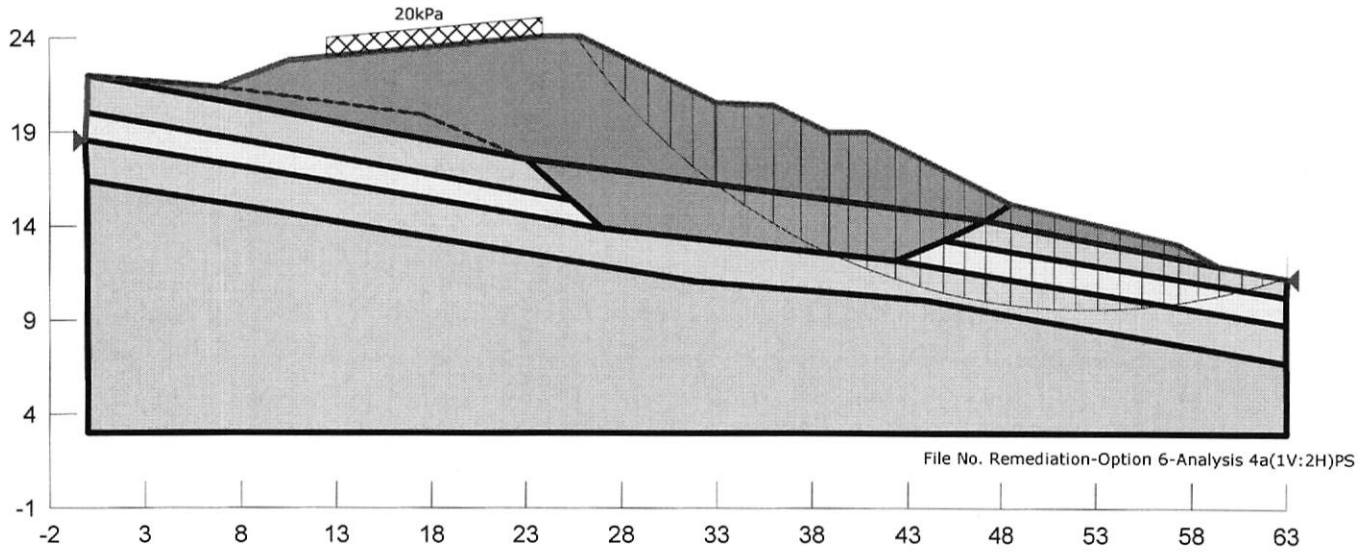
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Base Clay Fill
Wt: 20
Cohesion: 5
Phi: 25

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level
Re-Profiled Batter,
Wider Excavation and Replacement (Clay Fill)





Description: Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

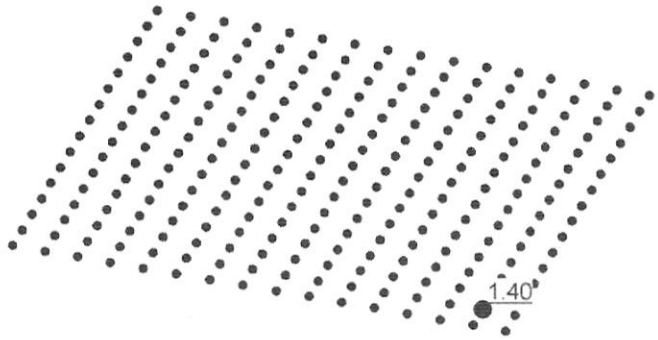
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

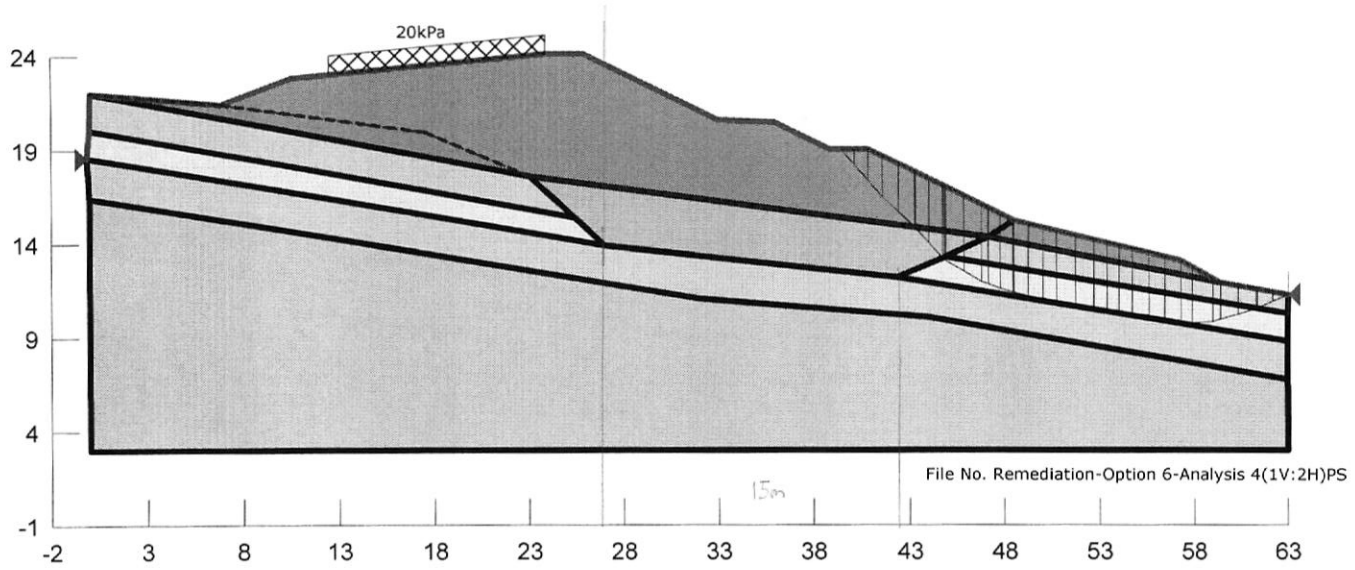
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Base Clay Fill
Wt: 20
Cohesion: 5
Phi: 25

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level
Re-Profiled Batter,
Wider Excavation and Replacement (Rock Fill)





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

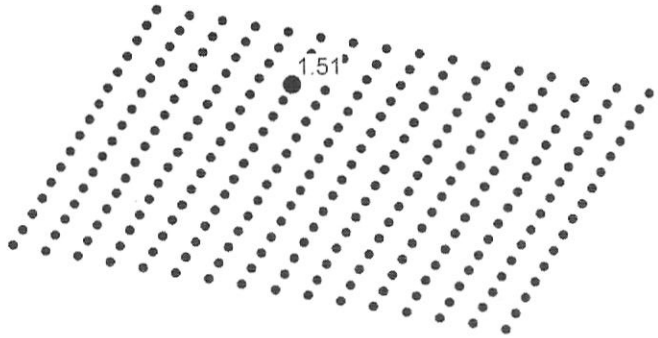
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

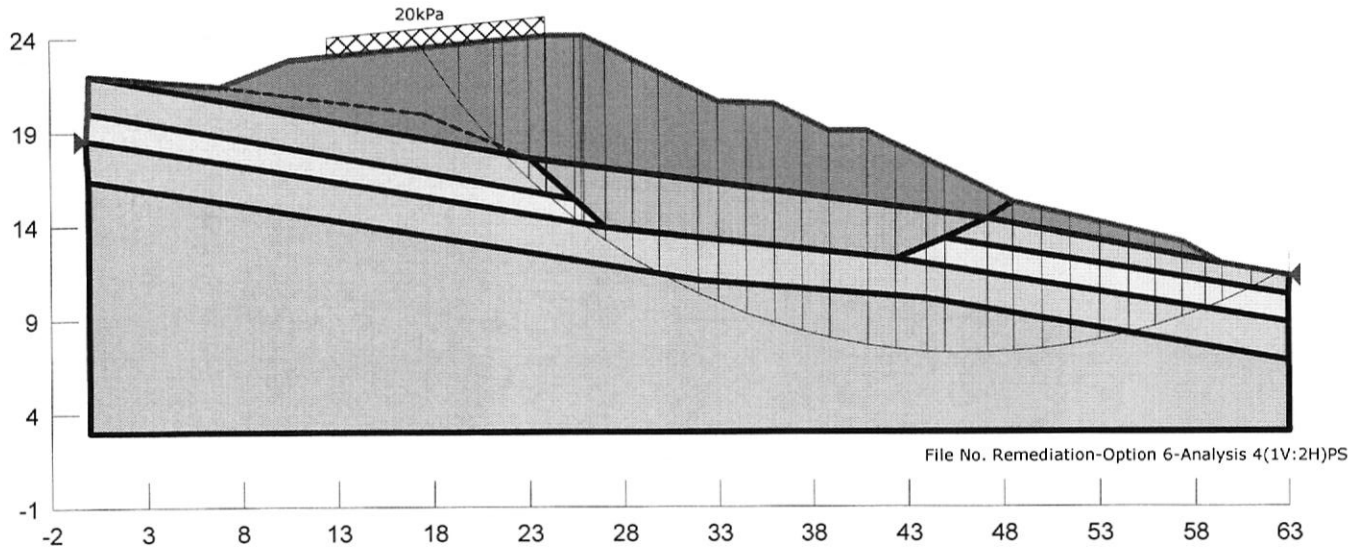
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level
Re-Profiled Batter,
Wider Excavation and Replacement (Rock Fill)





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

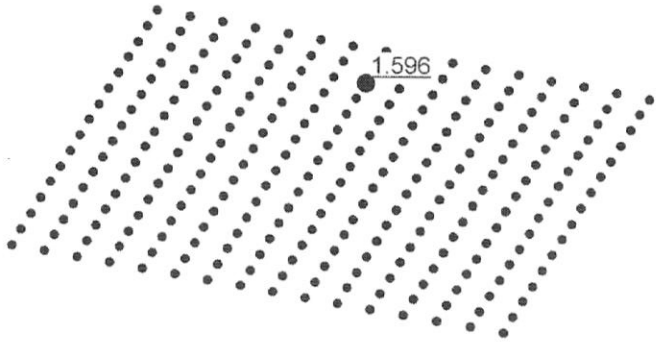
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

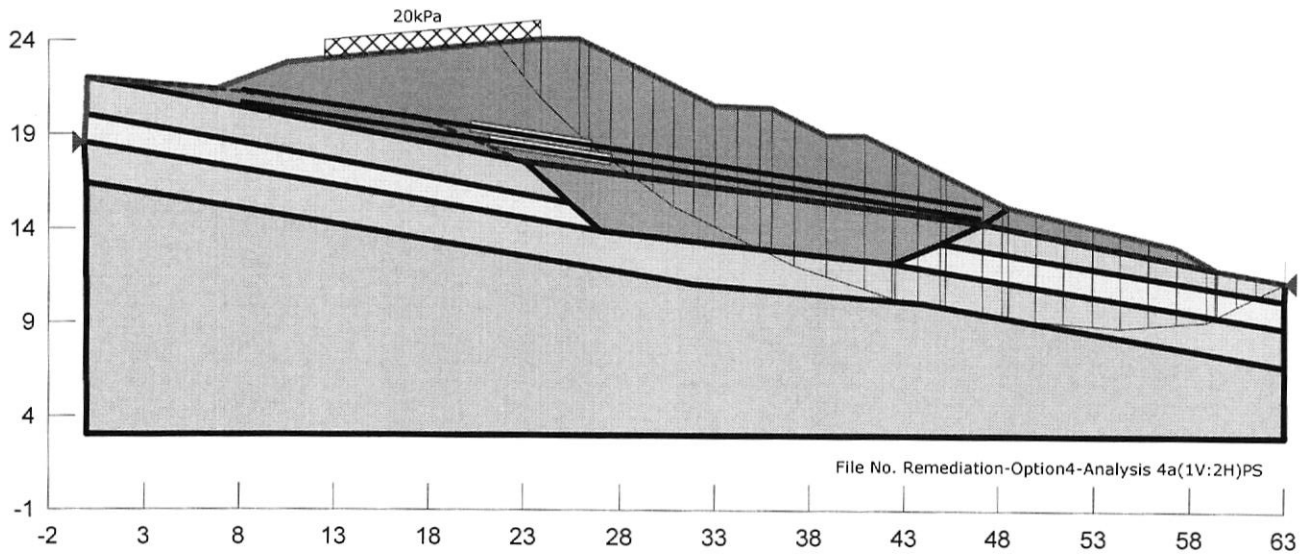
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level
Re-Profiled Batter,
Wider Excavation and Replacement (Clay Fill)
Two Layers of 200kN Geotextile





Description: Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

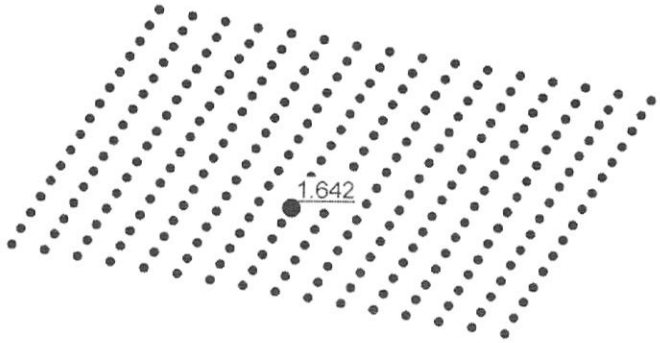
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

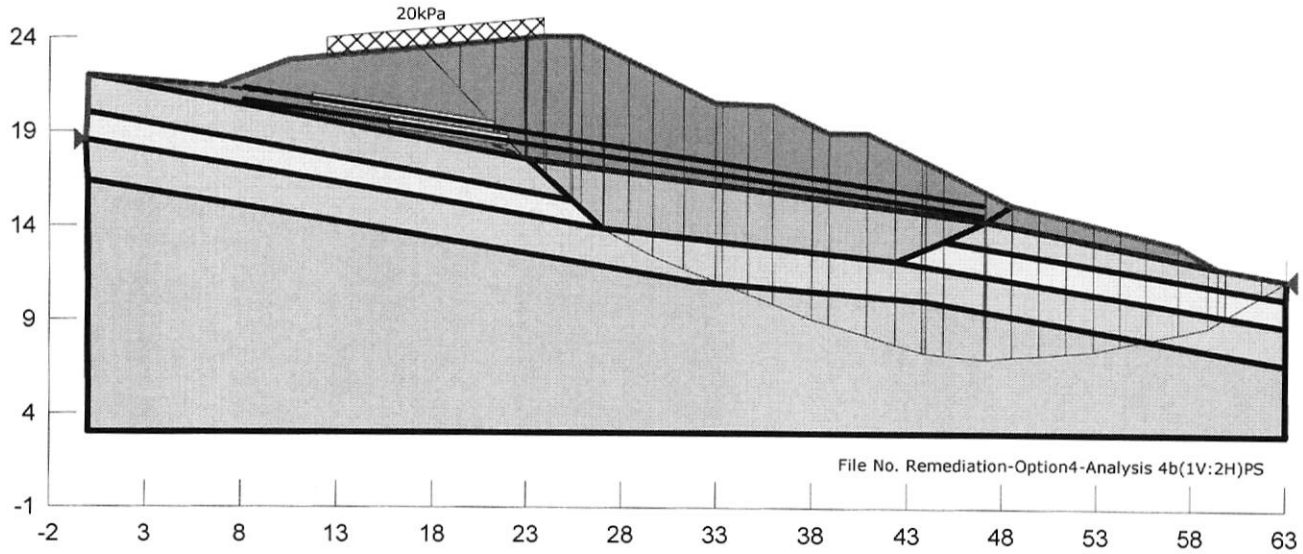
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Base Clay Fill
Wt: 20
Cohesion: 5
Phi: 25

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level
Re-Profiled Batter,
Wider Excavation and Replacement (Rock Fill)
Two Layers of 200kN Geotextile





Description: Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

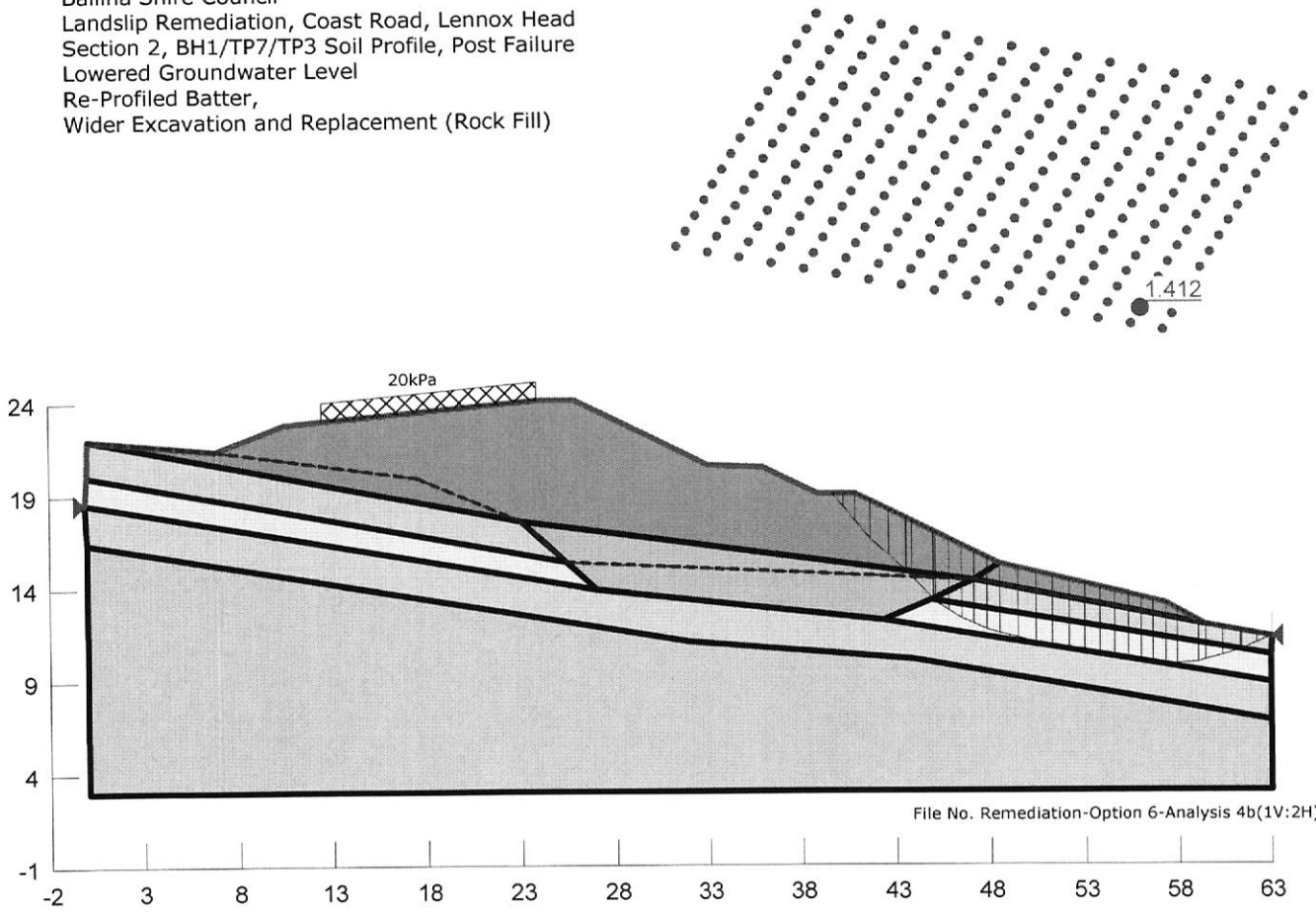
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Lowered Groundwater Level
Re-Profiled Batter,
Wider Excavation and Replacement (Rock Fill)



Description: Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

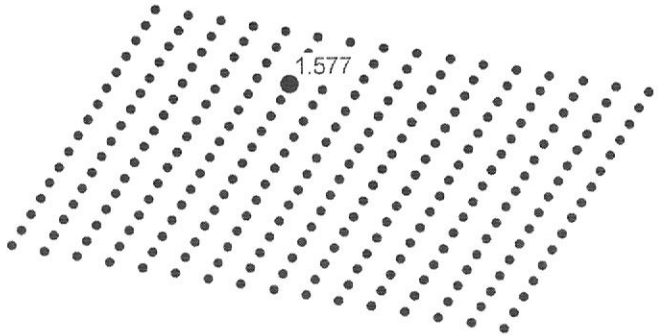
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

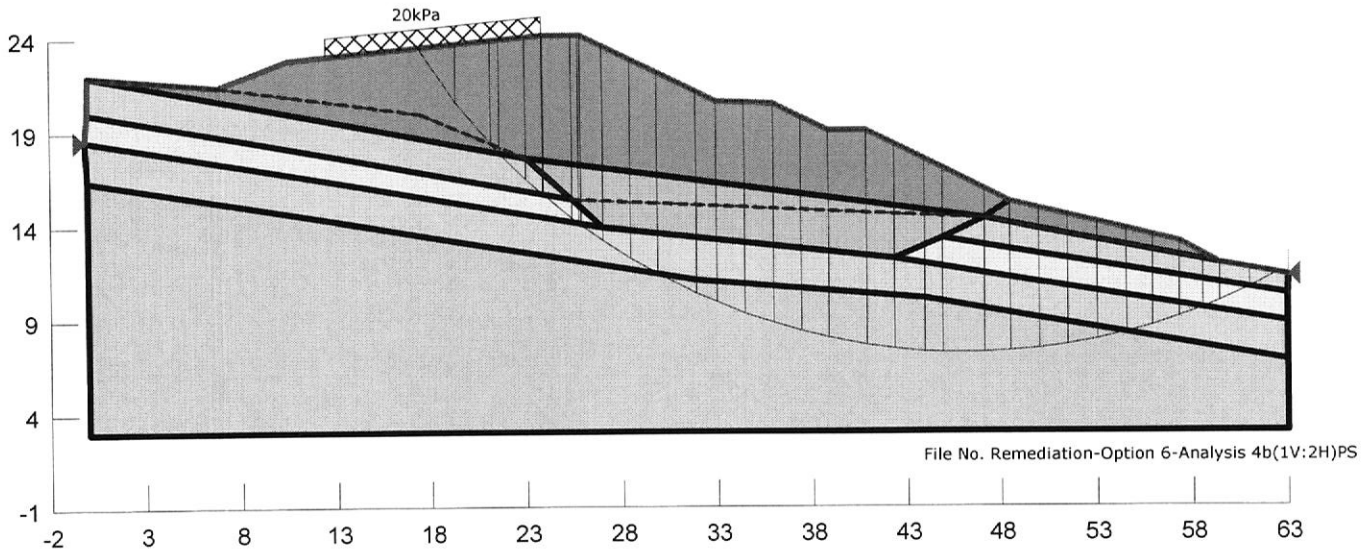
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Lowered Groundwater Level
Re-Profiled Batter,
Wider Excavation and Replacement (Rock Fill)





Description: Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

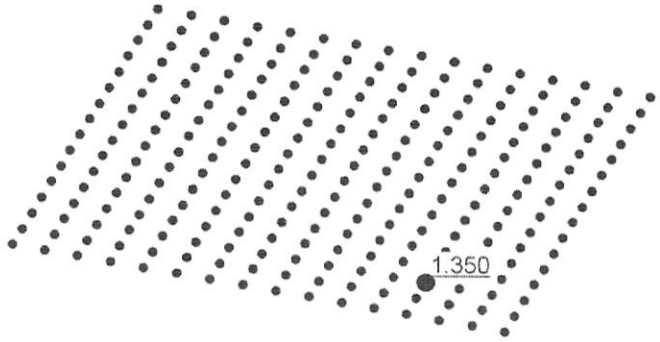
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

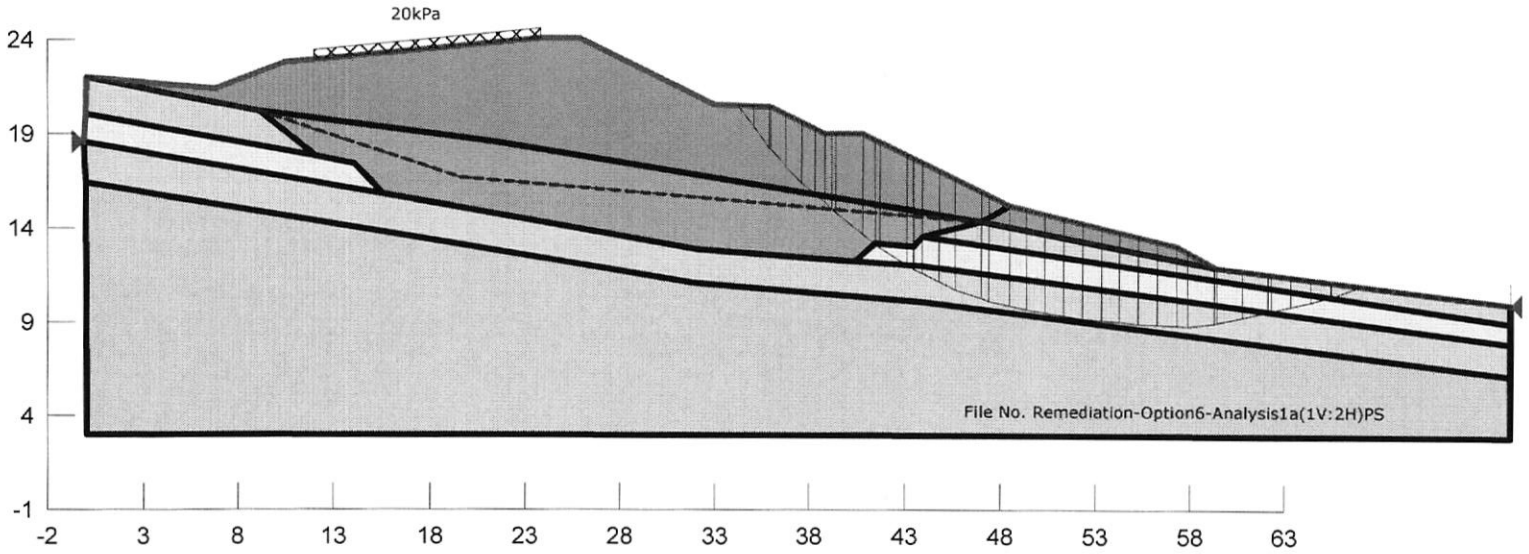
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level with Toe Drains
Re-Profiled Batter, Clay Fill Replacement





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

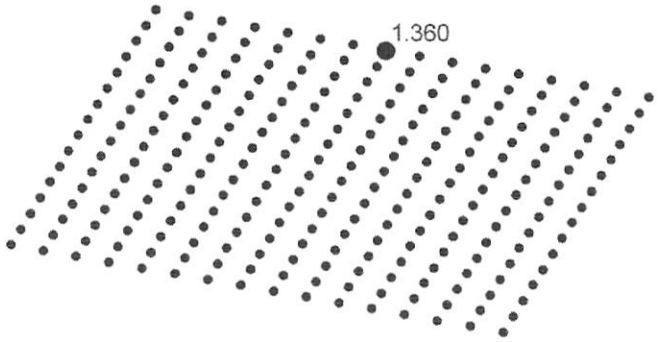
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

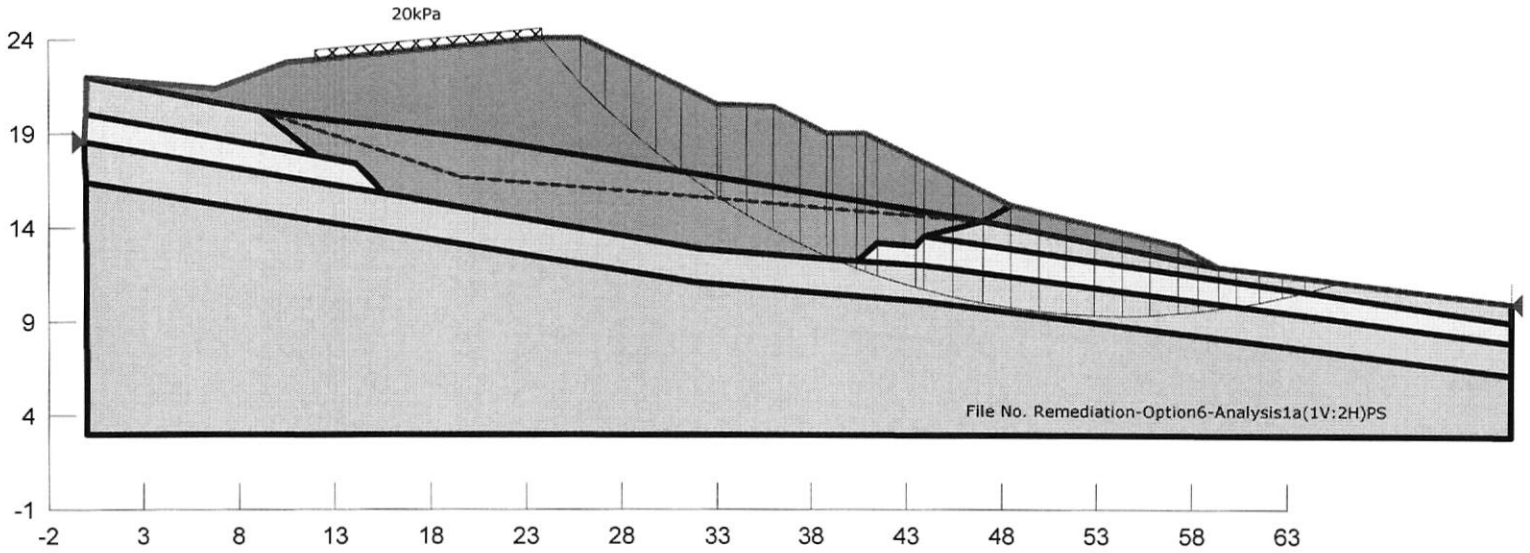
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Base Clay Fill
Wt: 20
Cohesion: 5
Phi: 25

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level with Toe Drains
Re-Profiled Batter, Clay Fill Replacement





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

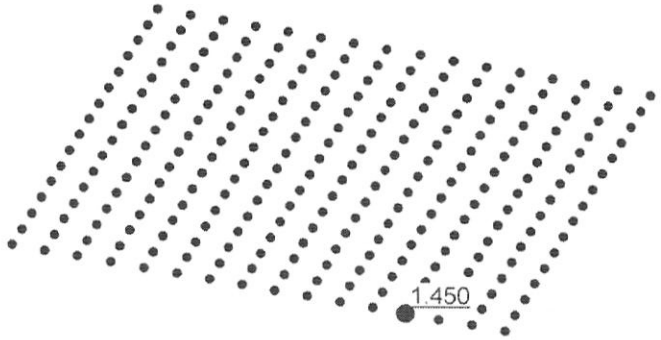
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

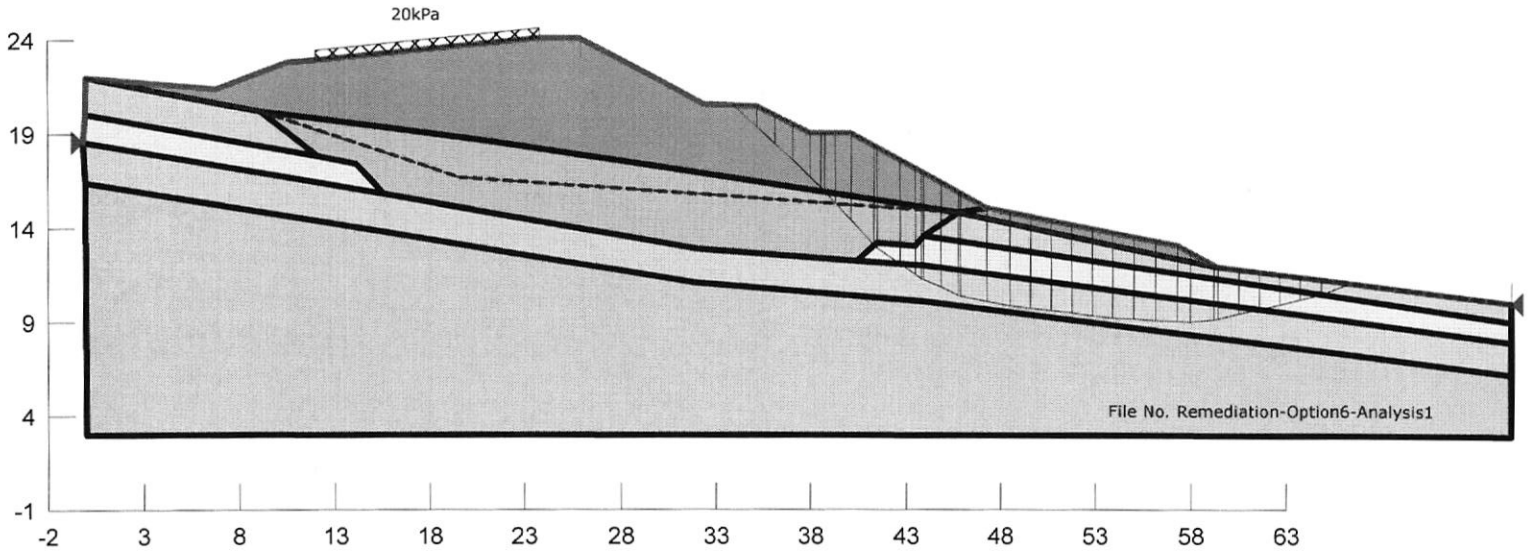
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Base Clay Fill
Wt: 20
Cohesion: 5
Phi: 25

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level with Toe Drains
Re-Profiled Batter, Rock Fill Replacement of Firm Clay





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

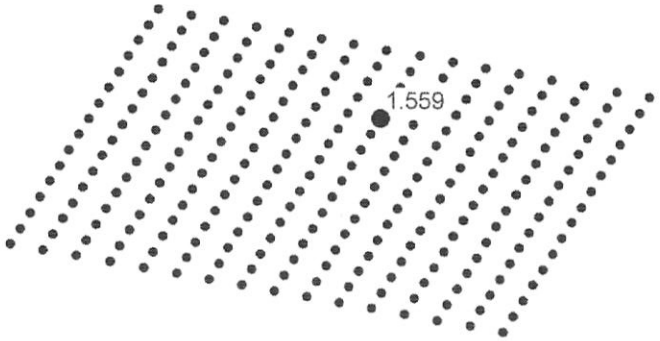
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

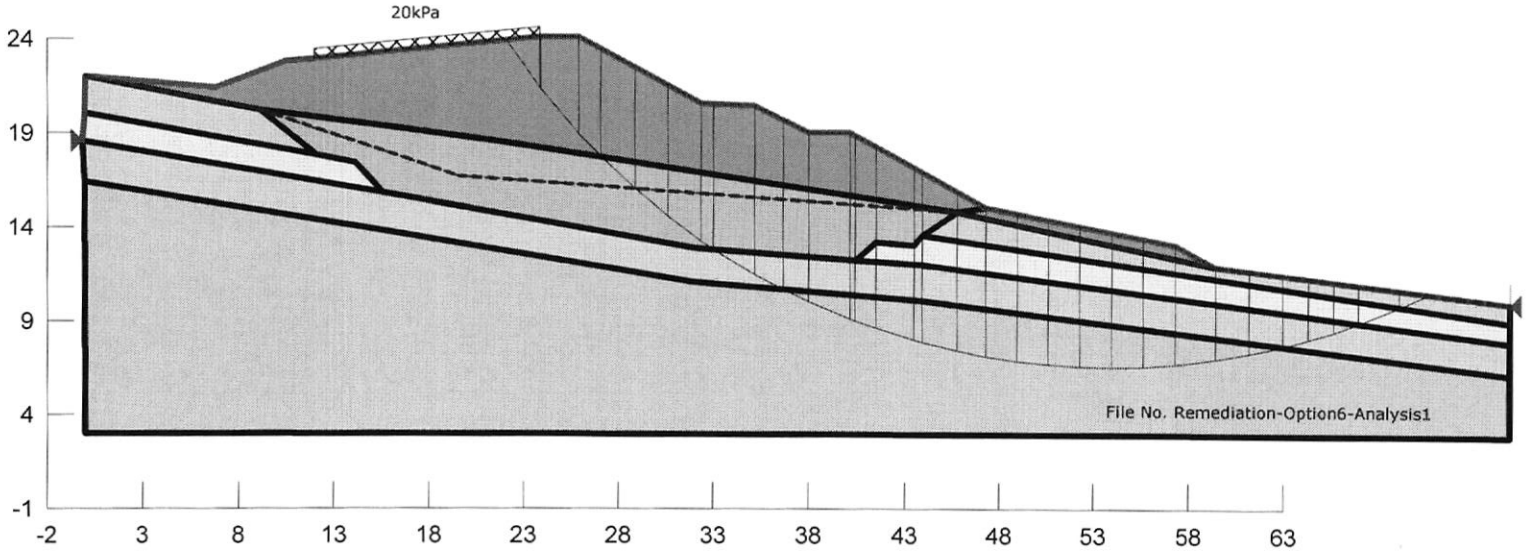
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level with Toe Drains
Re-Profiled Batter, Rock Fill Replacement of Firm Clay





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

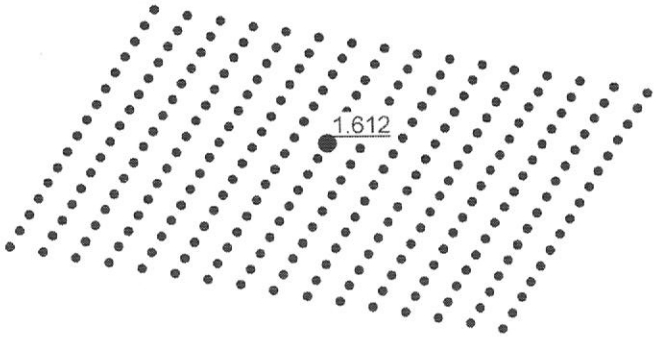
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

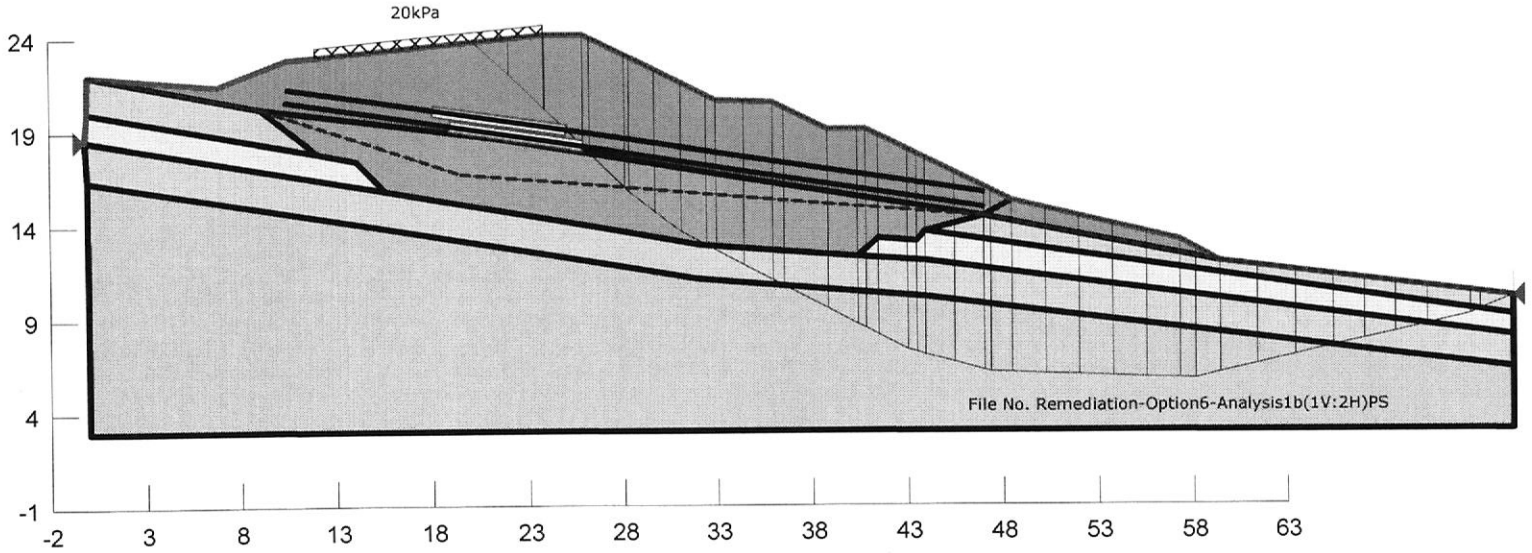
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengl
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level with Toe Drains
Re-Profiled Batter, Clay Fill Replacement
2 layers of 200kN Geotextile





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

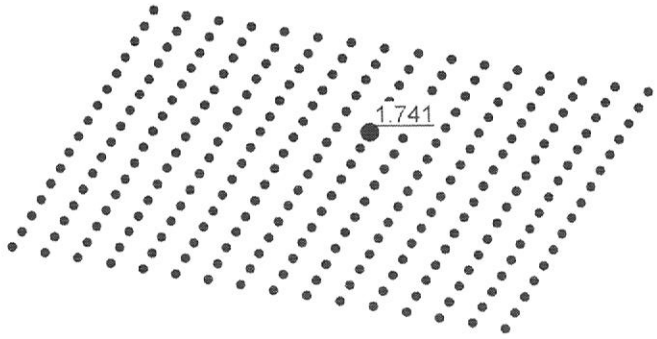
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

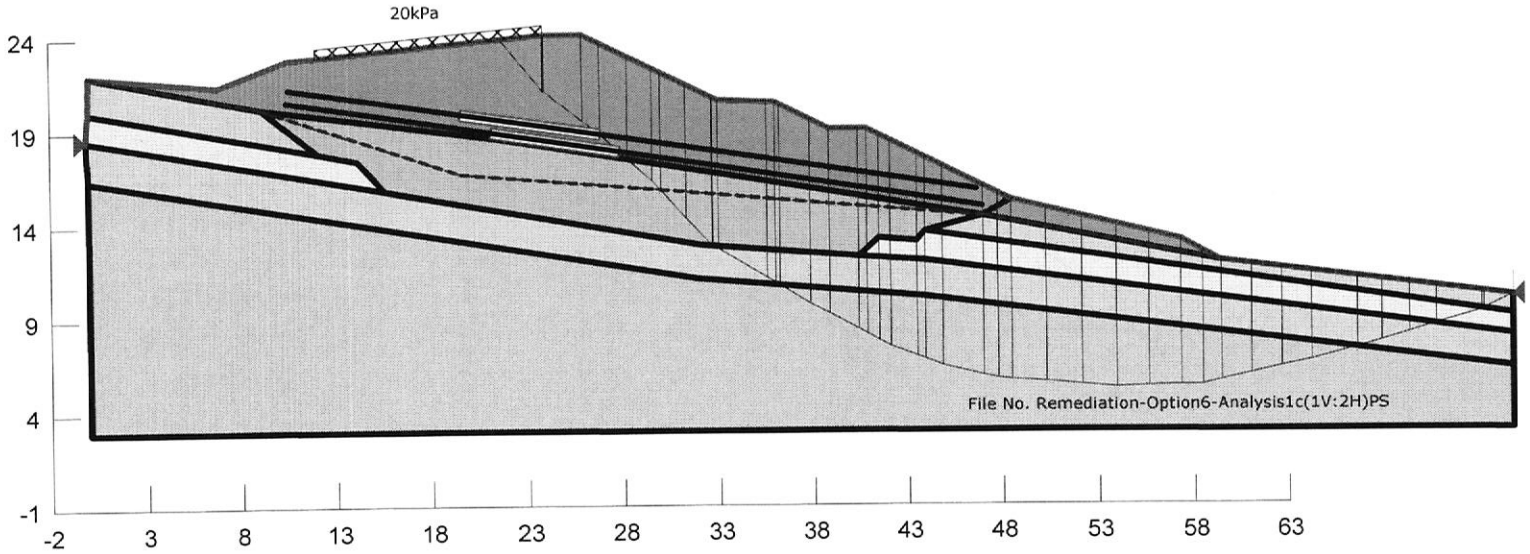
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Base Clay Fill
Wt: 20
Cohesion: 5
Phi: 25

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
Raised Groundwater Level with Toe Drains
Re-Profiled Batter, Rock Fill Replacement
2 layers of 200kN Geotextile





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

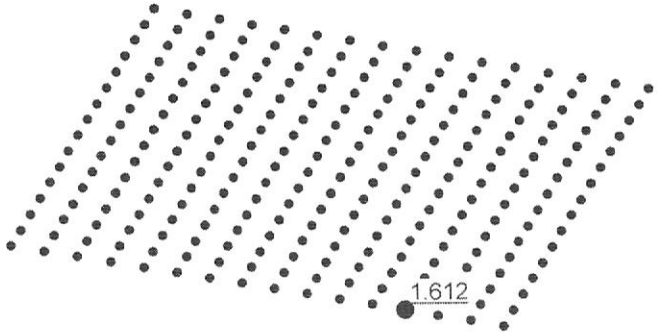
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

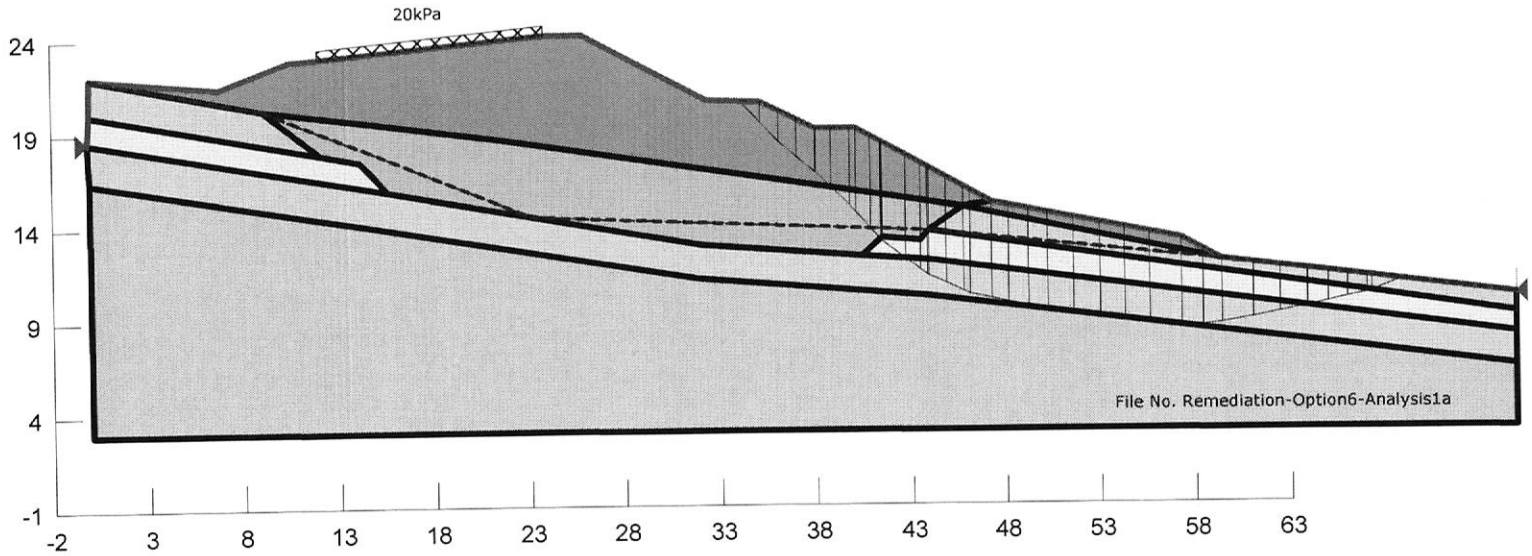
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengl
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
L0wered Groundwater Level with Toe Drains
Re-Profiled Batter, Rock Fill Replacement of Firm Clay





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

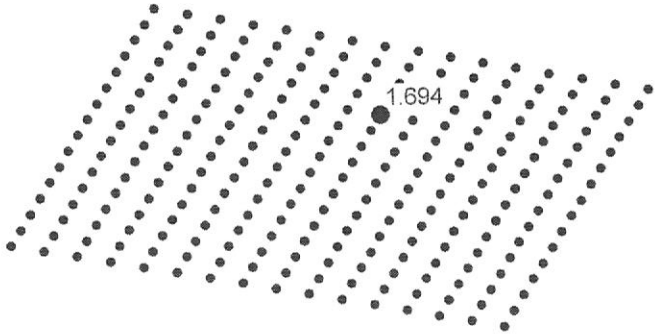
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

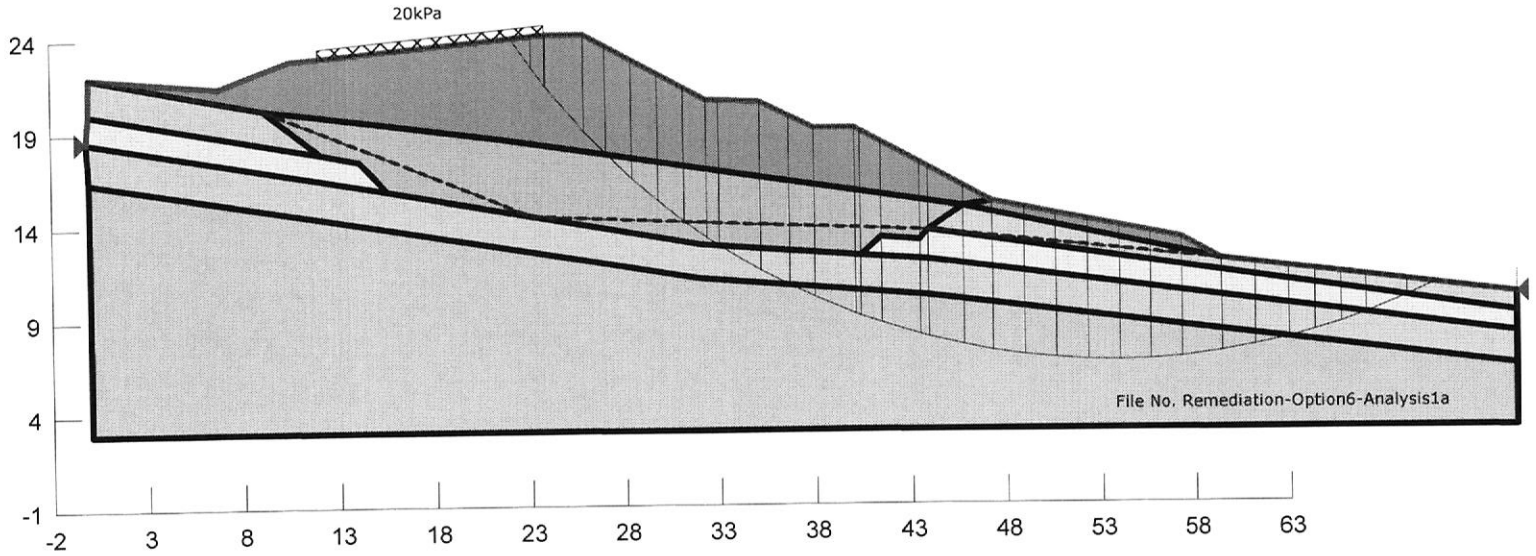
Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 2, BH1/TP7/TP3 Soil Profile, Post Failure
L0wered Groundwater Level with Toe Drains
Re-Profiled Batter, Rock Fill Replacement of Firm Clay





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: Silty Clay, F
Wt: 18
Cohesion: 3
Phi: 25

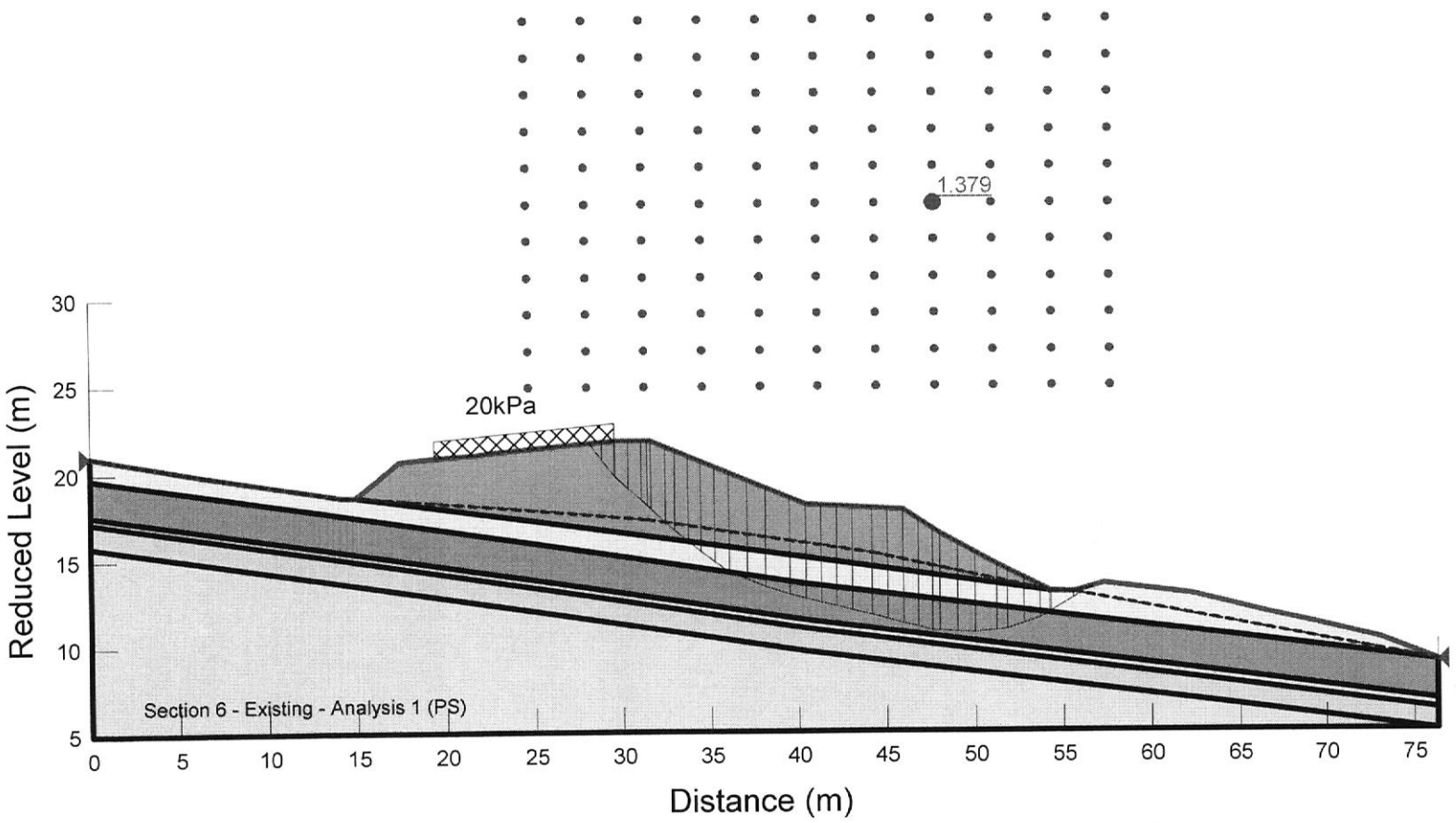
Description: Silty Clay, St-VSt
Wt: 18
Cohesion: 8
Phi: 27

Description: Silty Clay, St
Wt: 18
Cohesion: 5
Phi: 25

Description: Silty Clay, Reduced Strengt
Wt: 18
Cohesion: 0
Phi: 11

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Existing Geometry



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 2
Phi: 30

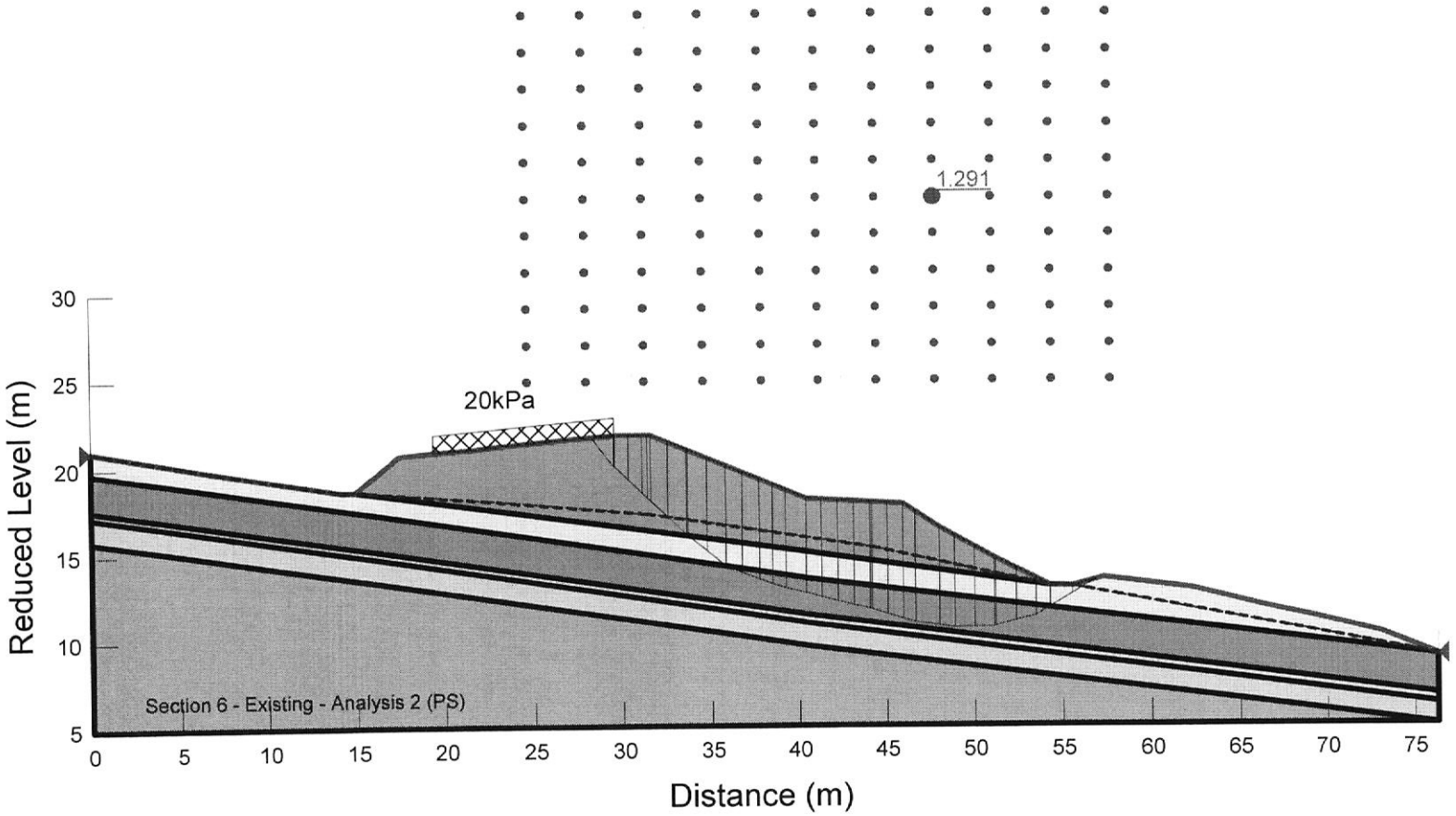
Description: soft to firm clay
Wt: 18
Cohesion: 3
Phi: 25

Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Existing Geometry



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 2
Phi: 30

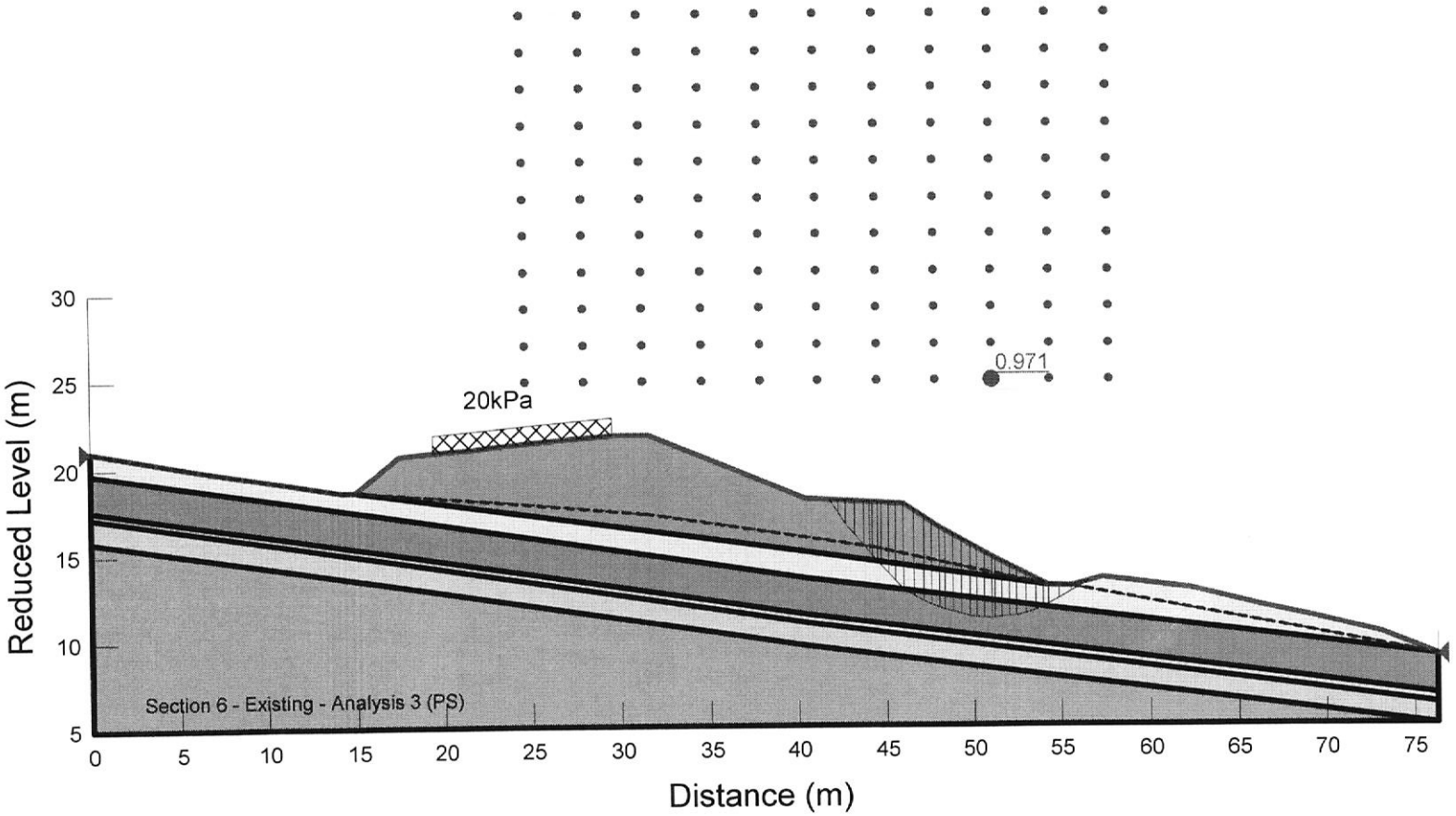
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 25

Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Existing Geometry



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 0
Phi: 28

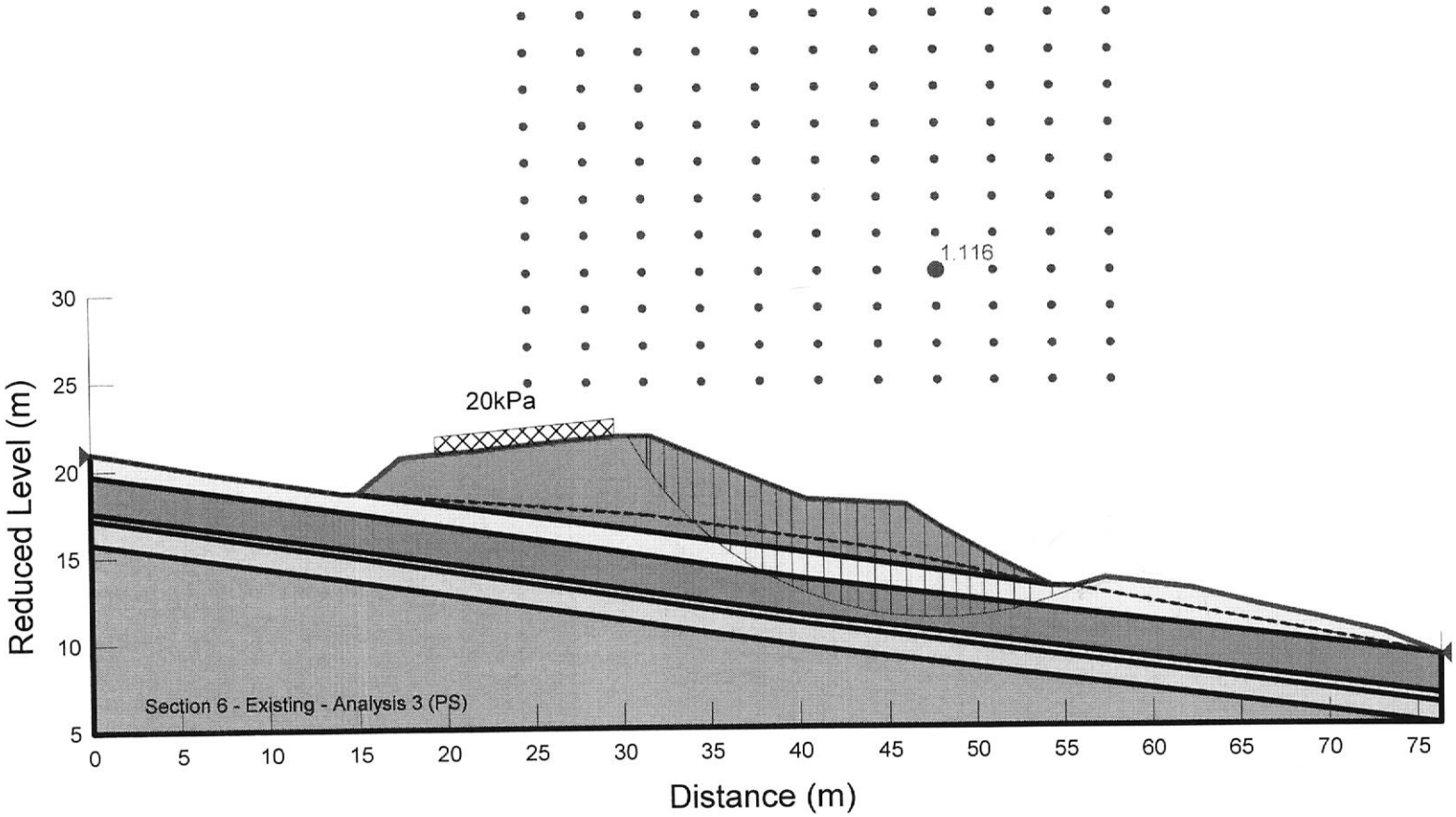
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Existing Geometry



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 0
Phi: 28

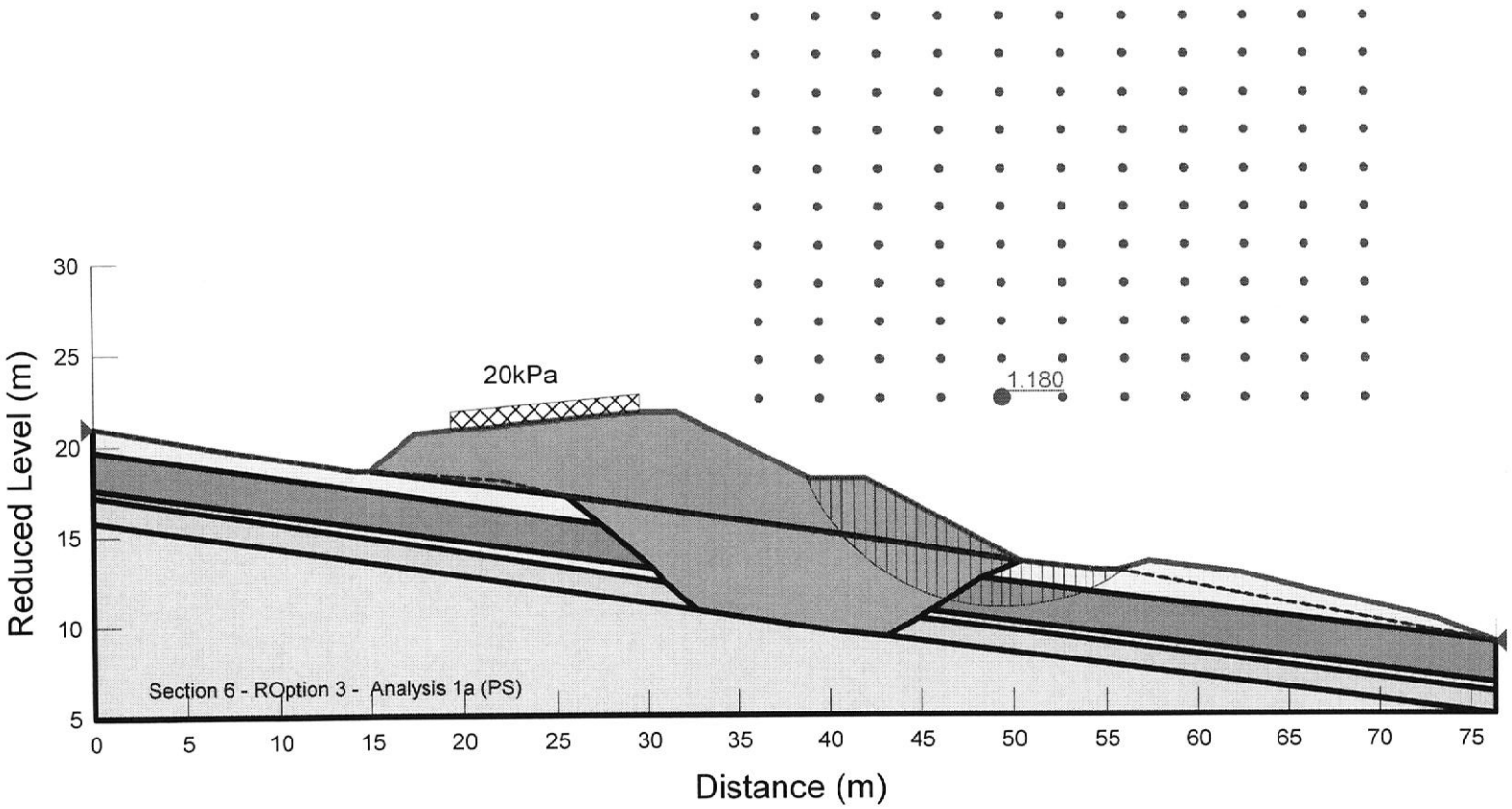
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Remedial Geometry 1V:2H
Clay Fill Excavation and Replacement



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 2
Phi: 30

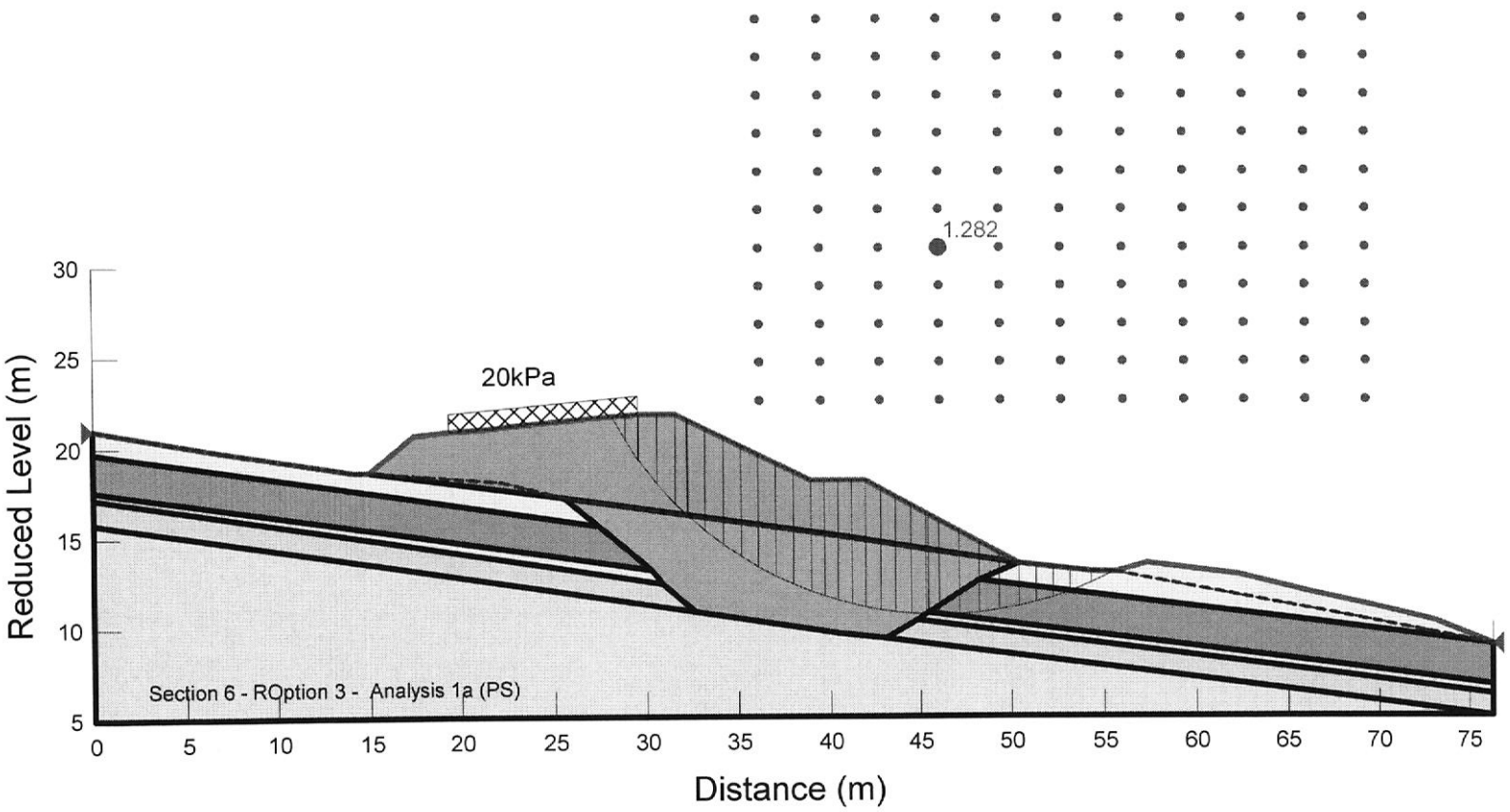
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Base Clay Fill
Wt: 20
Cohesion: 5
Phi: 25

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Remedial Geometry 1V:2H
Clay Fill Excavation and Replacement



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 2
Phi: 30

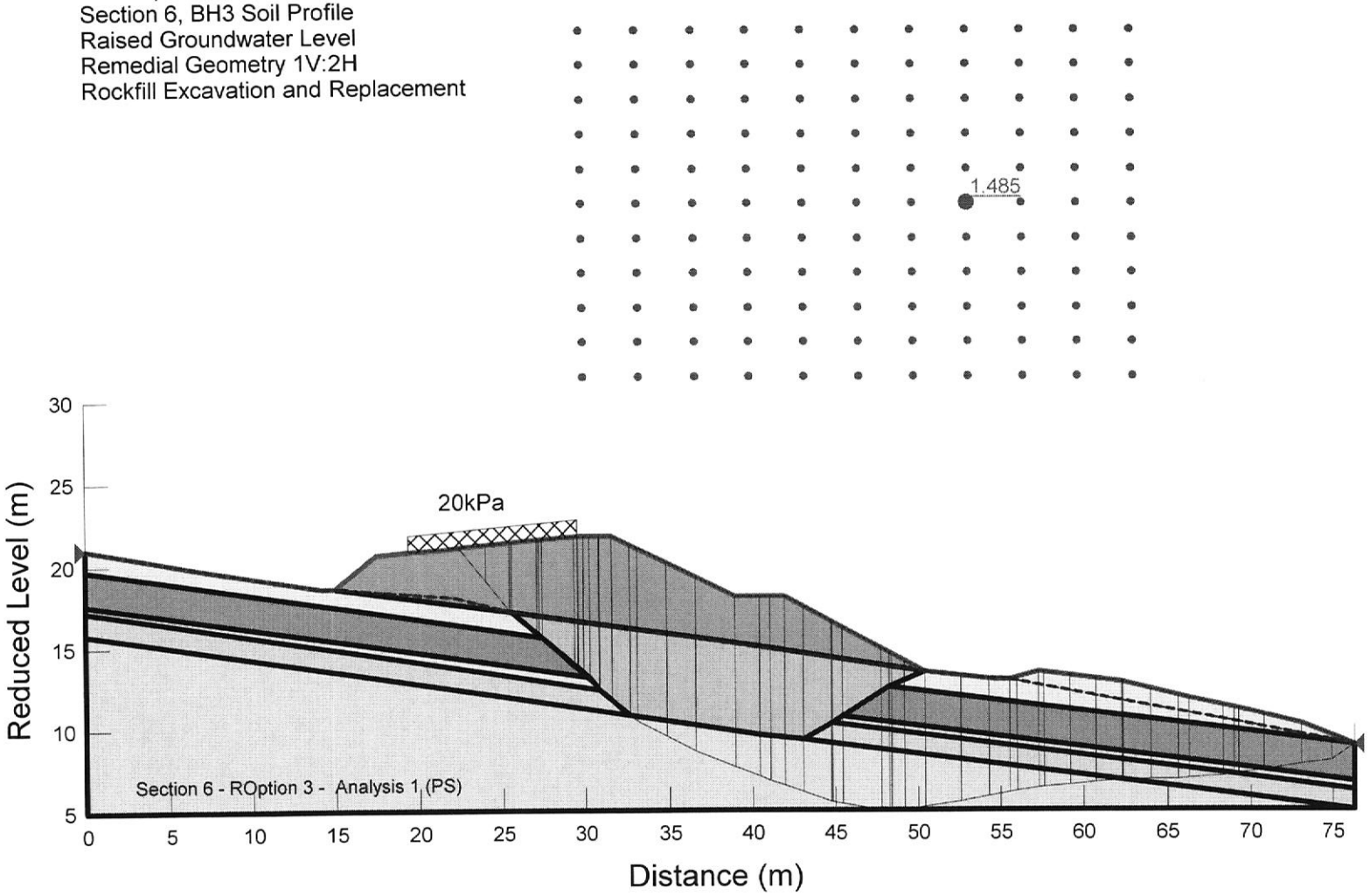
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Base Clay Fill
Wt: 20
Cohesion: 5
Phi: 25

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Remedial Geometry 1V:2H
Rockfill Excavation and Replacement



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 2
Phi: 30

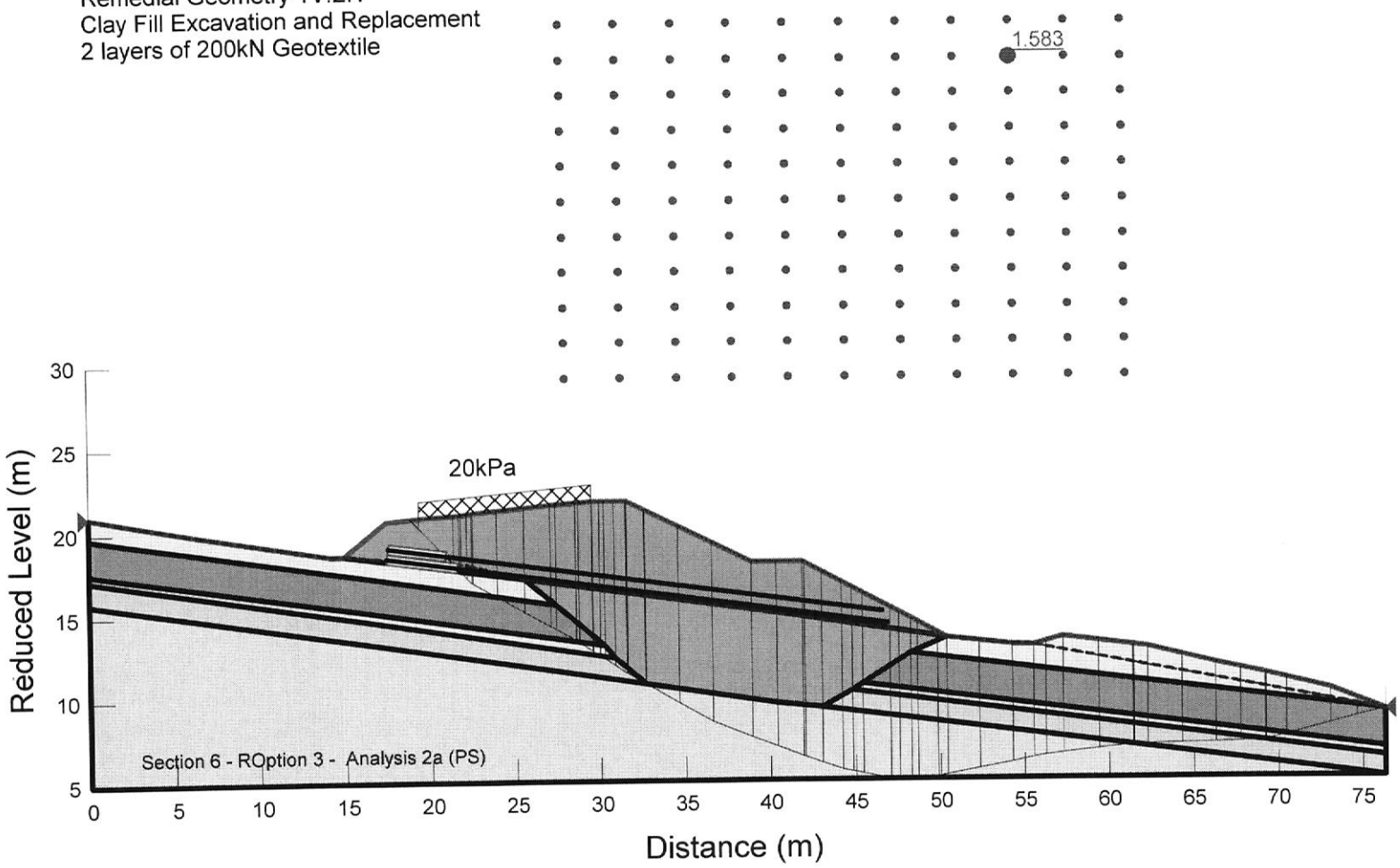
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Remedial Geometry 1V:2H
Clay Fill Excavation and Replacement
2 layers of 200kN Geotextile



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 2
Phi: 30

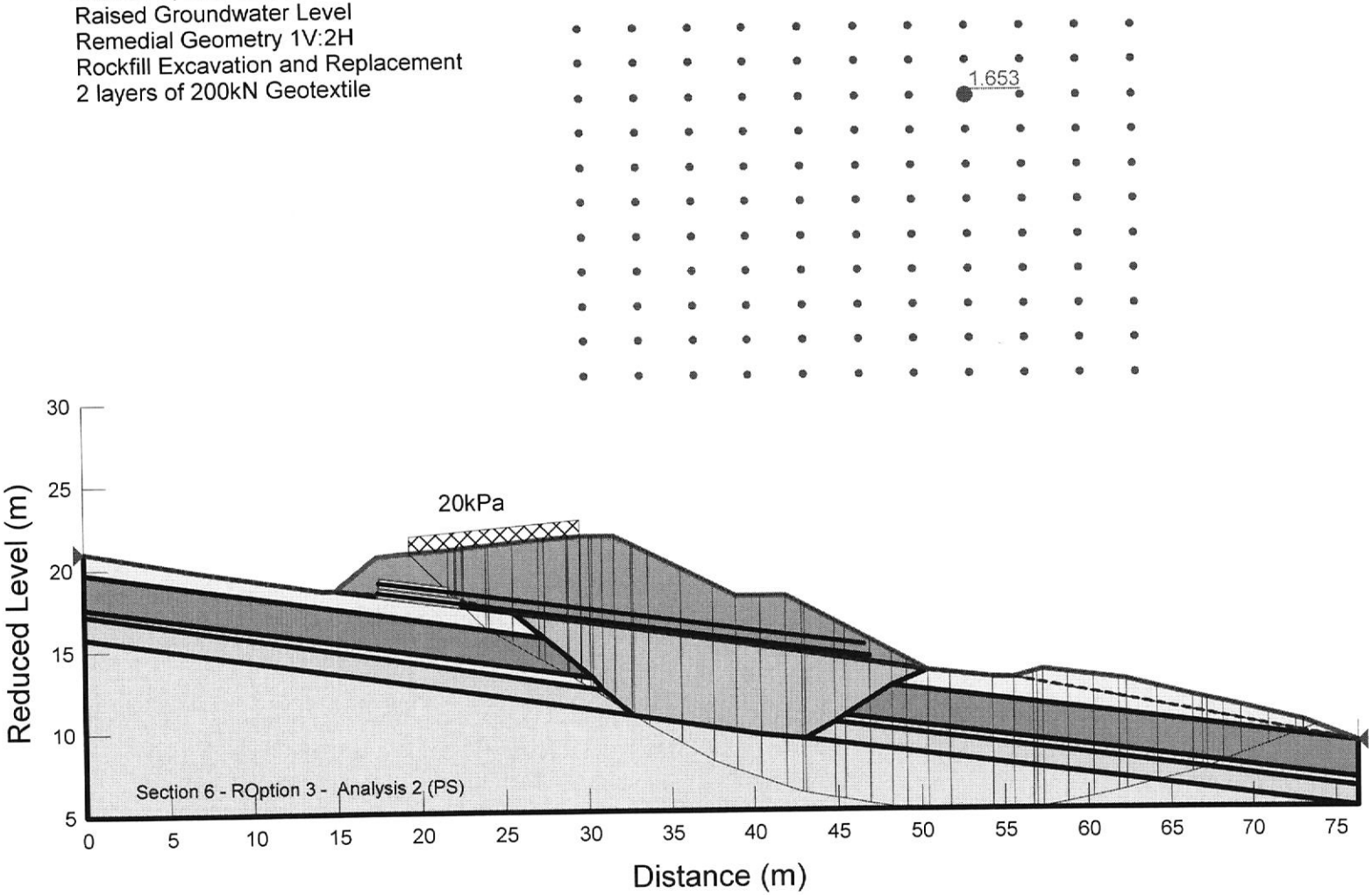
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Base Clay Fill
Wt: 20
Cohesion: 5
Phi: 25

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Remedial Geometry 1V:2H
Rockfill Excavation and Replacement
2 layers of 200kN Geotextile



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 2
Phi: 30

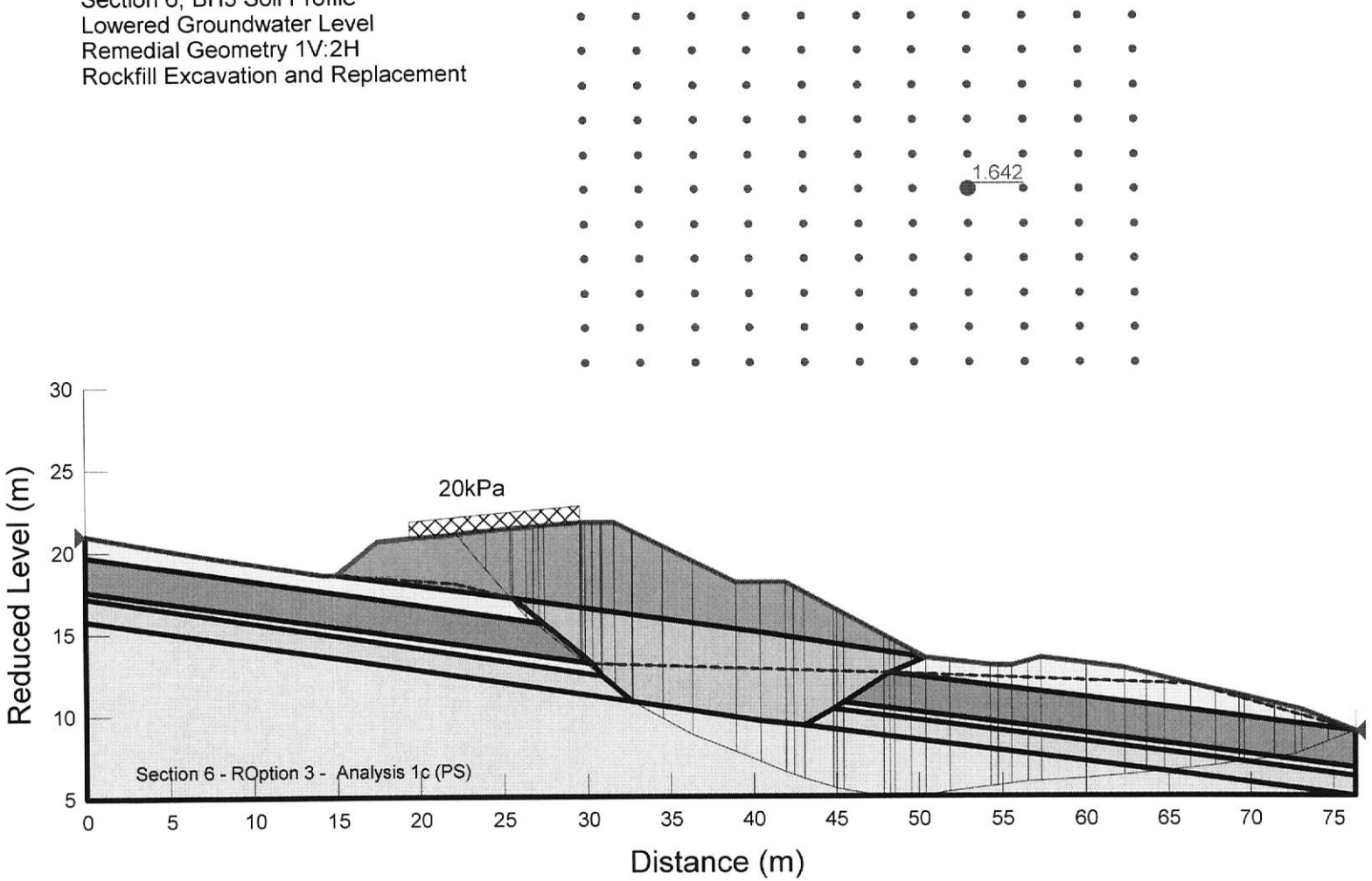
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Lowered Groundwater Level
Remedial Geometry 1V:2H
Rockfill Excavation and Replacement



Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 2
Phi: 30

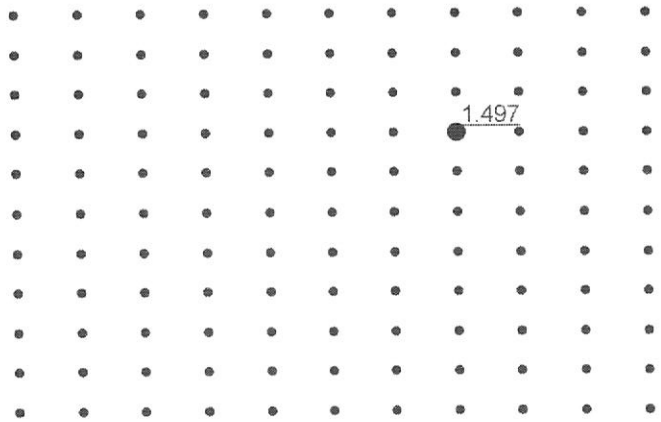
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

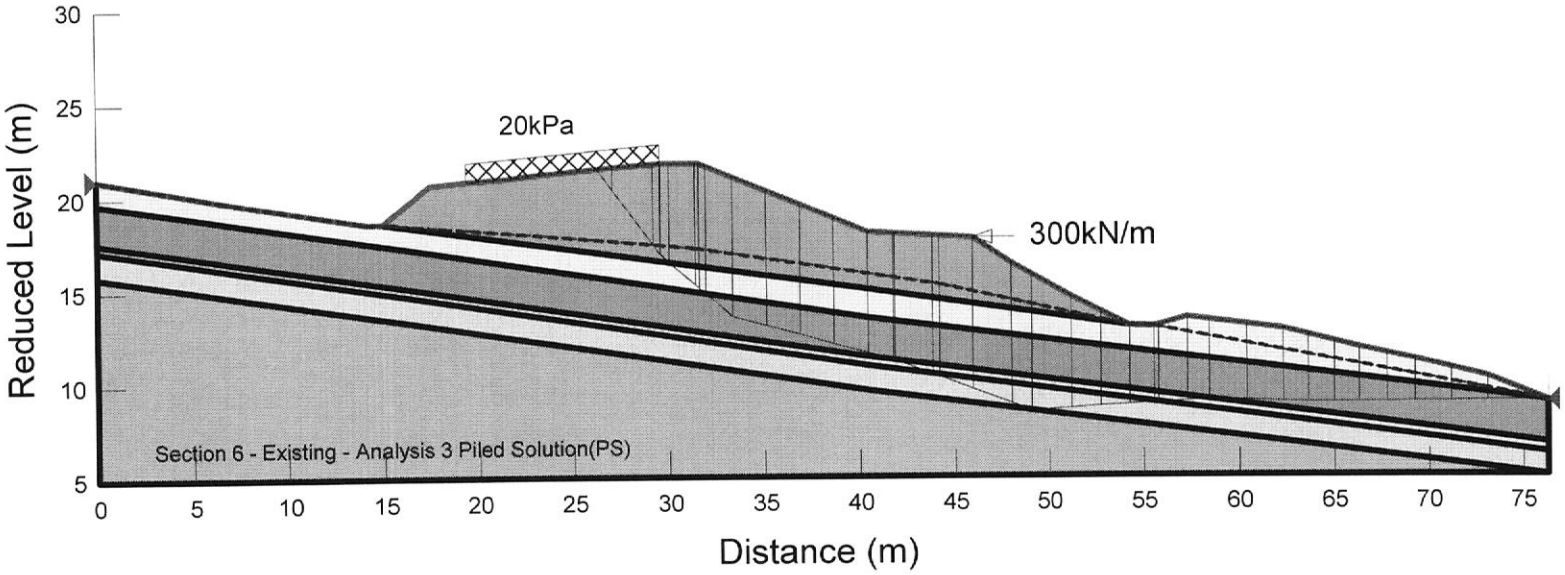
Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Existing Geometry
Piled Solution





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 0
Phi: 28

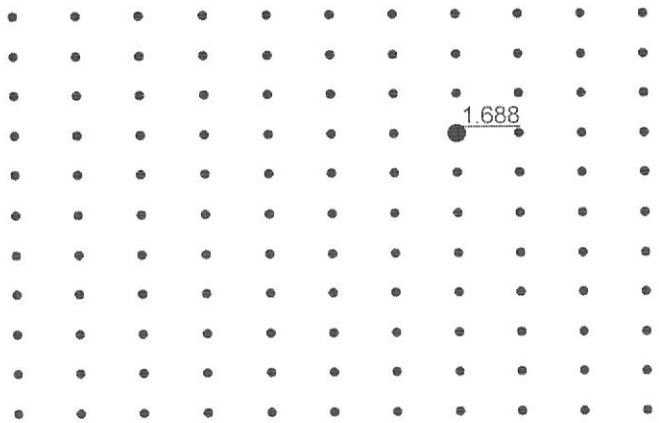
Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

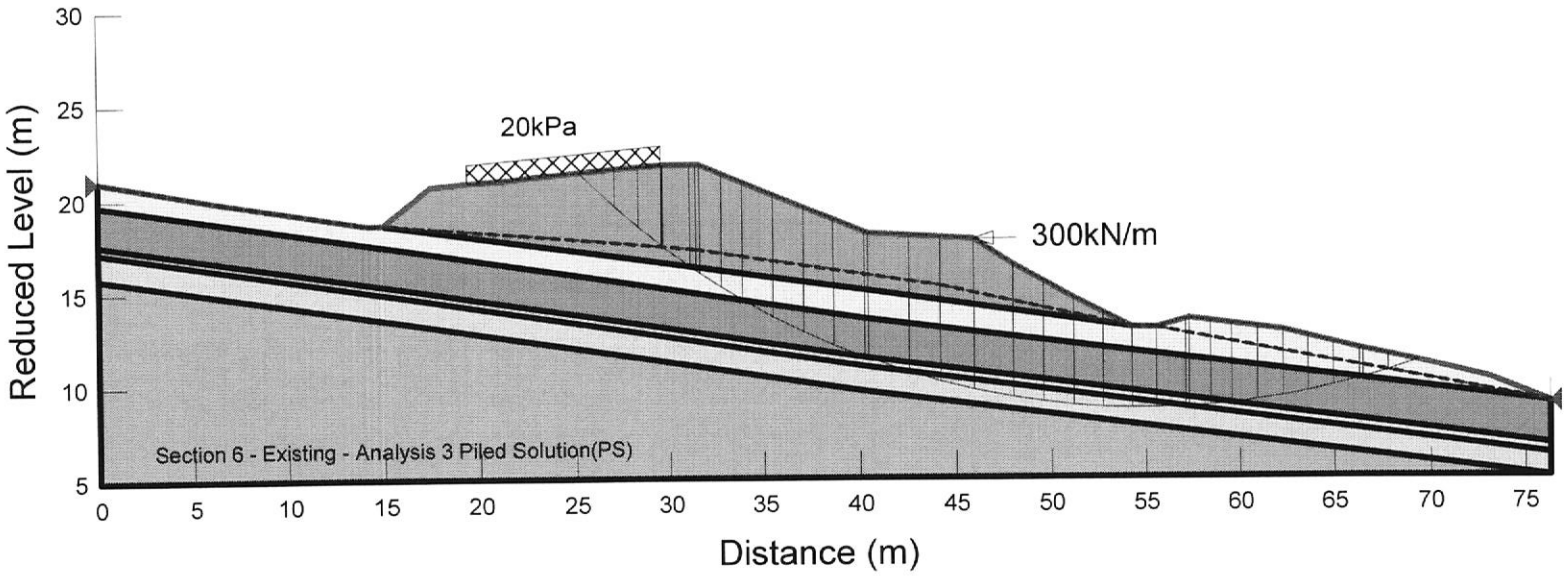
Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

10644/1
Ballina Shire Council
Landslip Remediation, Coast Road, Lennox Head
Section 6, BH3 Soil Profile
Raised Groundwater Level
Existing Geometry
Piled Solution





Description: Clay Fill
Wt: 20
Cohesion: 5
Phi: 27

Description: clayey sand loose
Wt: 17
Cohesion: 0
Phi: 28

Description: soft to firm clay
Wt: 18
Cohesion: 0
Phi: 20

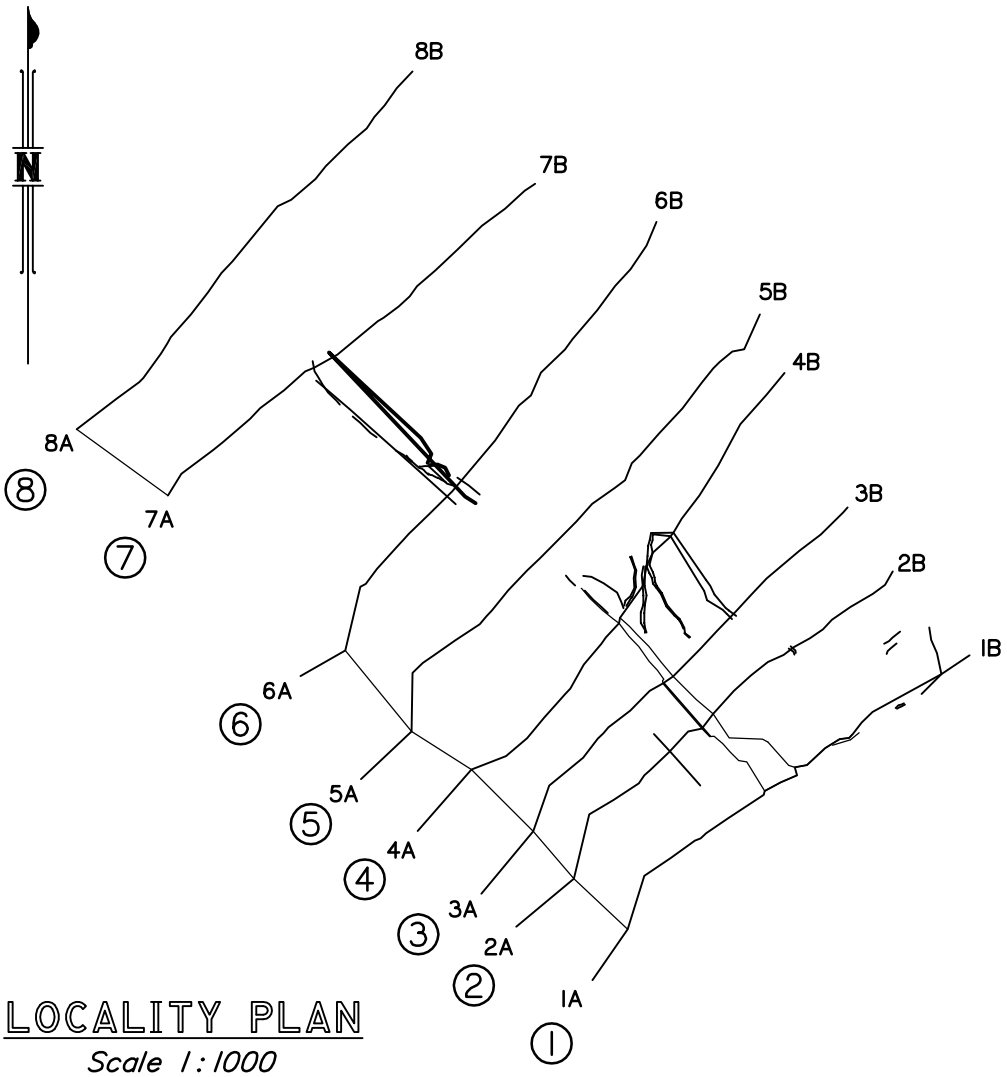
Description: firm to stiff clay
Wt: 18
Cohesion: 4
Phi: 25

Description: Very stiff clay
Wt: 18
Cohesion: 8
Phi: 27

Description: Rock Fill
Wt: 20
Cohesion: 0
Phi: 45

APPENDIX D

SITE SURVEY CROSS-SECTIONS

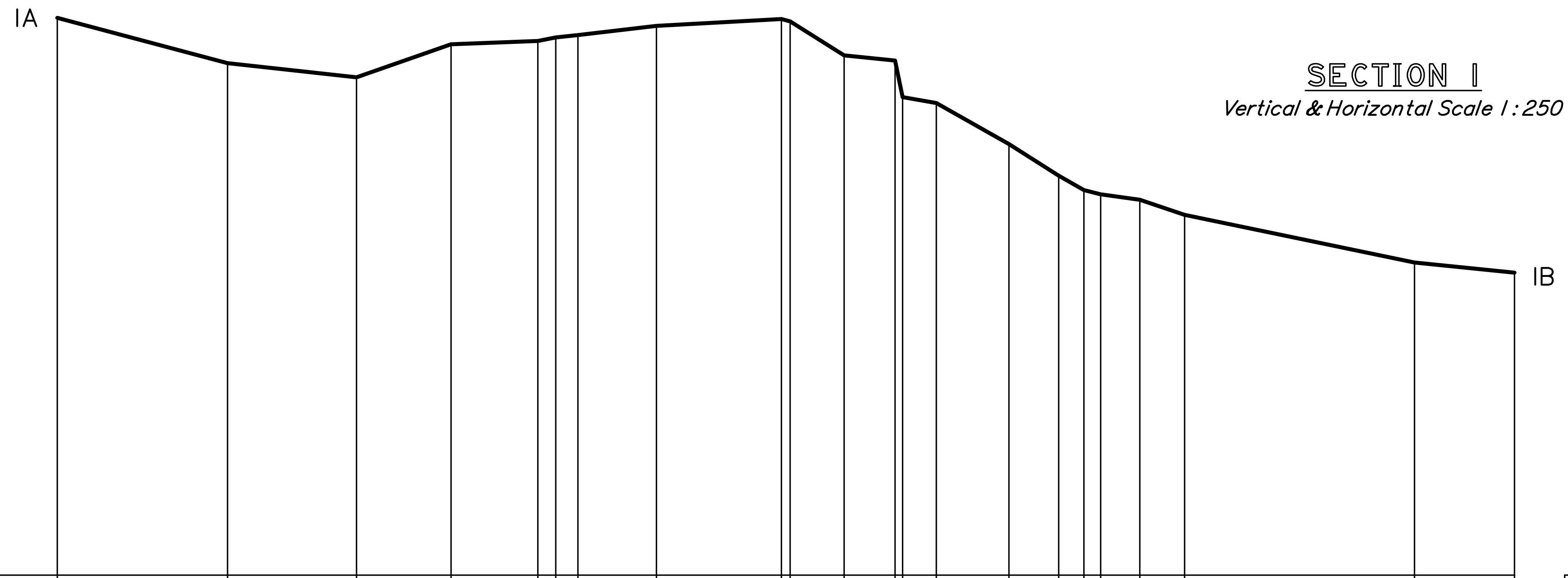


LOCALITY PLAN

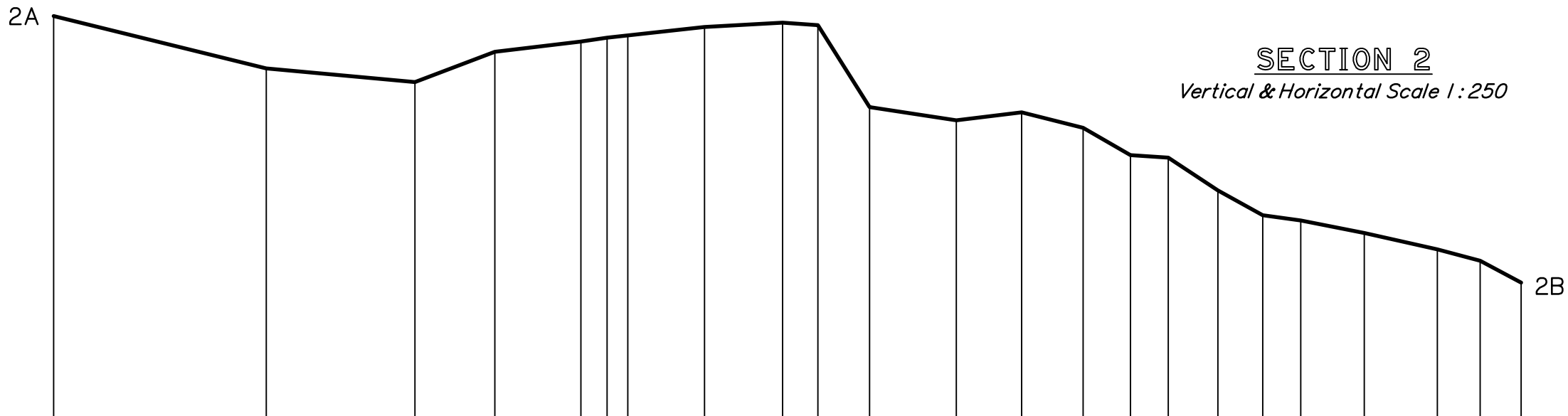
Scale 1 : 1000

SECTION I

Vertical & Horizontal Scale 1 : 250



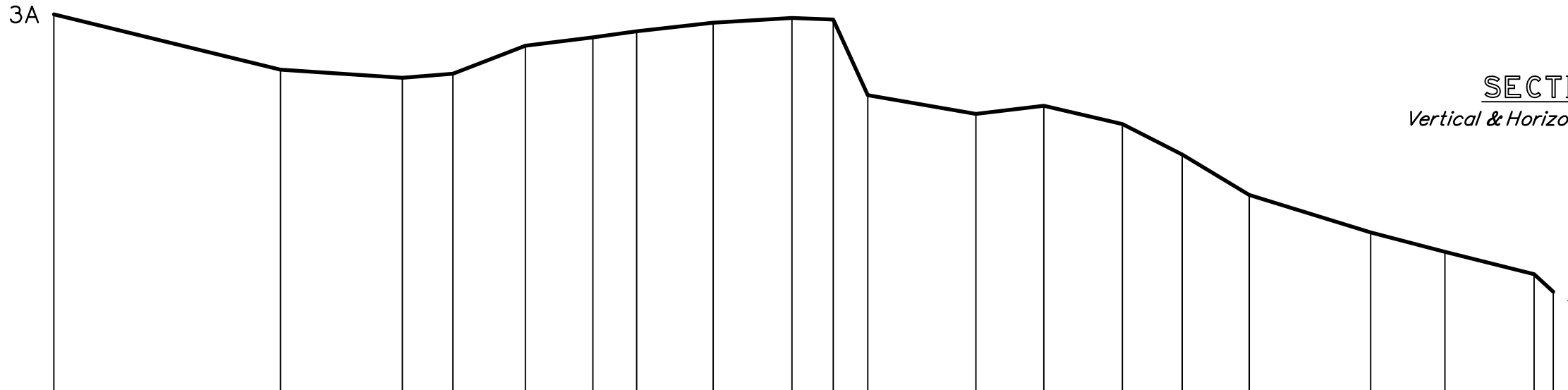
DATUM																					
CHAINAGE along section (A – B)	0·0	7·636	13·428	17·669	21·562	22·368	23·363	26·889	32·499	32·894	35·312	37·598	37·943	39·45	42·711	44·941	46·075	46·829	48·587	50·595	60·918	65·409
SURFACE RL	25·008	22·978	22·336	23·823	23·973	24·124	24·236	24·641	24·95	24·852	23·318	23·091	21·444	21·188	19·341	17·928	17·279	17·084	16·84	16·169	14·034	13·572



SECTION 2

Vertical & Horizontal Scale 1 : 250

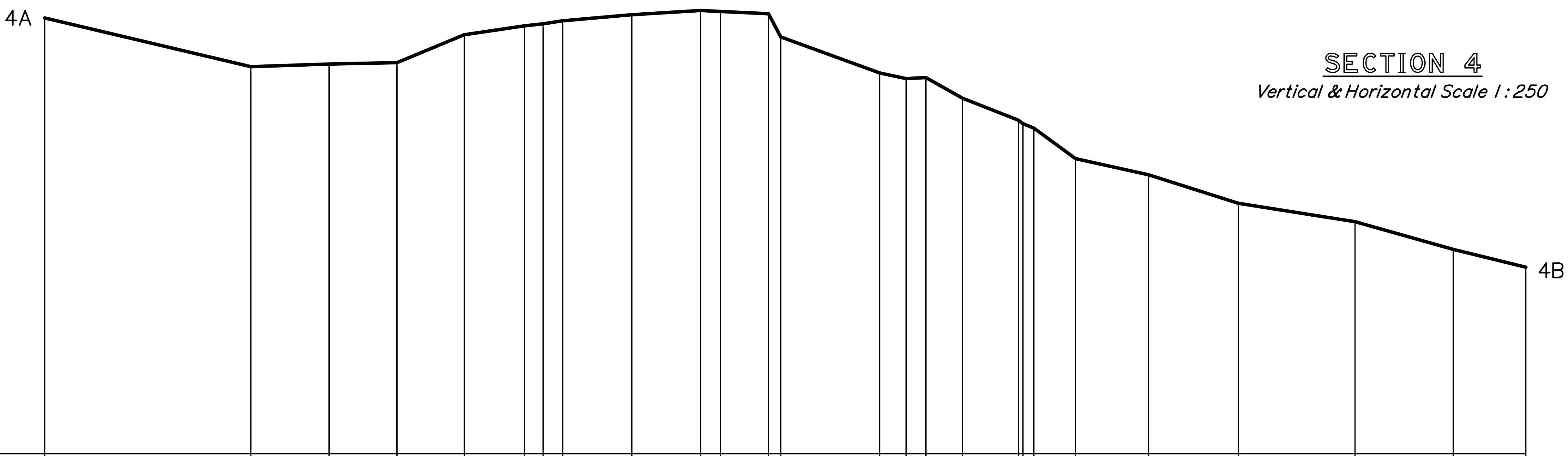
DATUM																							
CHAINAGE along section (A –B)	0·0	9·892	16·803	20·514	24·521	25·732		26·695	30·259	33·889	35·539	37·932	41·967	45·009	47·865	50·067	51·825	54·13	56·22	57·978	60·937	64·334	66·327	68·233
SURFACE RL	24·443	22·006	21·372	22·779	23·26	23·437		23·541	23·94	24·138	24·024	20·209	19·6	19·965	19·249	17·982	17·865	16·337	15·183	14·941	14·357	13·594	13·068	12·054



SECTION 3

Vertical & Horizontal Scale 1 : 250

DATUM																					
CHAINAGE along section (A –B)	0·0	10·633	16·35	18·713	22·118	25·28	27·33	30·918	34·613	36·548	38·166	43·241	46·428	50·103	52·914	56·058	61·744	65·227	69·414	70·308
SURFACE RL	23·869	21·281	20·895	21·088	22·393	22·792	23·075	23·479	23·7	23·629	20·077	19·204	19·588	18·728	17·292	15·4	13·645	12·734	11·688	10·857



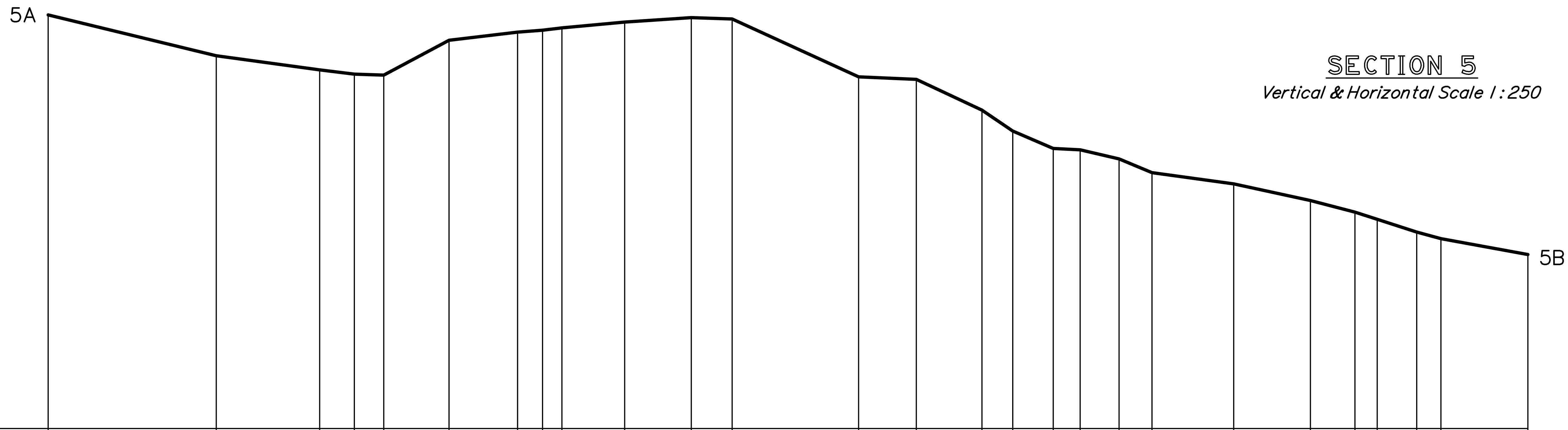
SECTION 4

Vertical & Horizontal Scale 1 : 250

DATUM																										
CHAINAGE along section (A –B)	0·0	10·802	14·892	18·456	21·975	25·127	26·107	27·134	30·753	34·352	35·391	37·903	38·554	43·723	45·115	46·148	48·06	50·995	51·232	51·804	53·98	57·809	62·512	68·619	73·76	77·56
SURFACE RL	22·827	20·273	20·411	20·48	21·946	22·408	22·517	22·672	22·997	23·213	23·162	23·048	21·831	19·942	19·643	19·696	18·625	17·466	17·298	17·051	15·453	14·607	13·119	12·149	10·708	9·774

SECTION 5

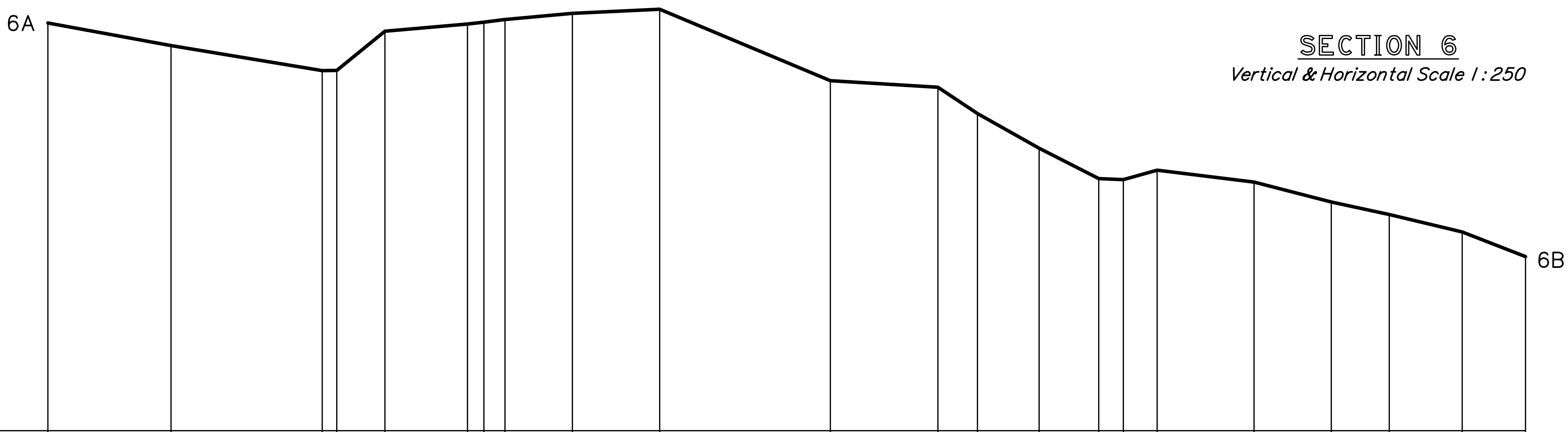
Vertical & Horizontal Scale 1 : 250



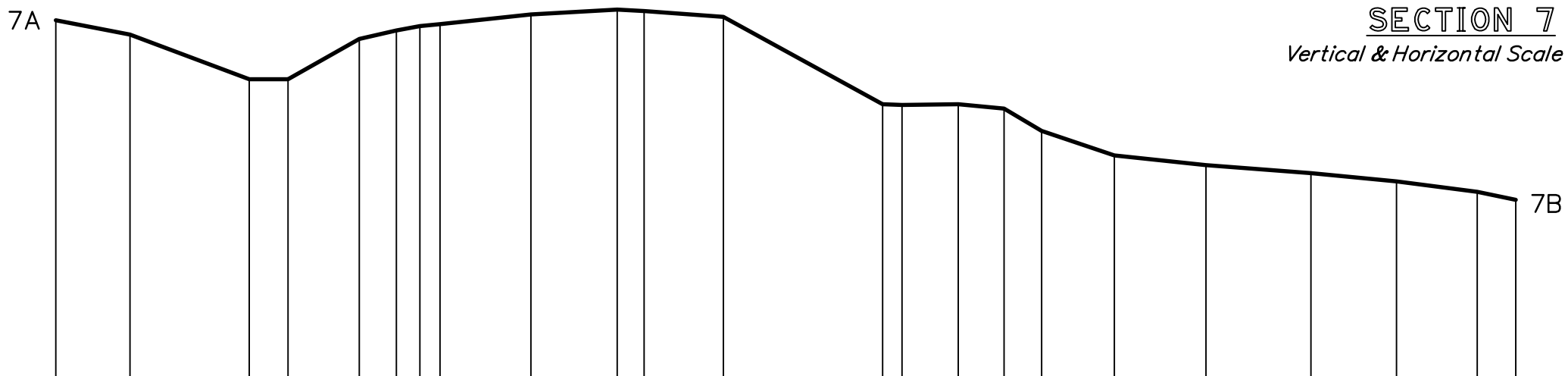
DATUM																												
CHAINAGE along section (A – B)	0·0	9·185	14·835	16·73	18·332	21·901	25·65	27·019		28·076 31·498	35·138	37·371	44·283	47·439	51·029	52·711	54·927	56·391	58·527	60·325	64·791	68·98	71·413	72·625	74·791	76·112	80·863
SURFACE RL	22·624	20·392	19·615	19·381	19·329	21·237	21·684	21·783		21·912 22·227	22·474	22·401	19·234	19·101	17·417	16·274	15·314	15·246	14·75	14·0	13·384	12·473	11·831	11·449	10·743	10·381	9·517

SECTION 6

Vertical & Horizontal Scale 1 : 250



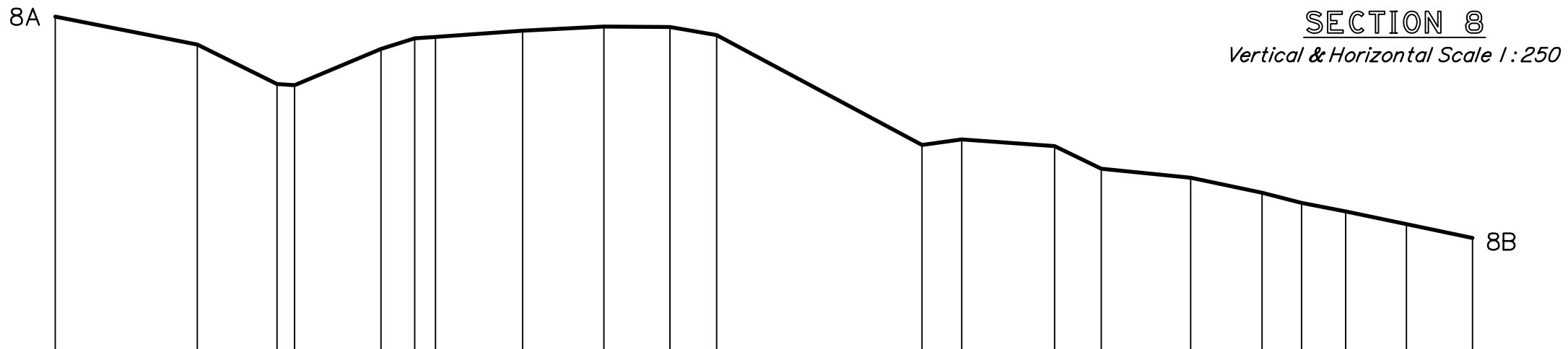
DATUM																										
CHAINAGE along section (A – B)	0·0	6·363	14·171	14·92	17·415	21·673	22·526	23·613	27·092	31·603	40·426	45·977	48·019	51·203	54·282	55·561	57·304	62·305	66·302	69·296	73·062	76·33				
SURFACE RL	21·019	19·857	18·573	18·574	20·598	20·972	21·071	21·206	21·517	21·733	18·047	17·715	16·36	14·563	13·001	12·948	13·439	12·816	11·796	11·147	10·253	8·974				



SECTION 7

Vertical & Horizontal Scale 1 : 250

DATUM																														
CHAINAGE along section (A –B)	0·0	3·24	8·453	10·147	13·255	14·878	15·895			16·78	20·75	24·517	25·685	29·154	36·102		36·95	39·41	41·408	43·044	46·221	50·226	54·802	58·545	62·062	63·754
SURFACE RL	20·334	19·707	17·76	17·764	19·521	19·883	20·074			20·167	20·587	20·803	20·735	20·484	16·673		16·638	16·673	16·478	15·505	14·441	14·014	13·667	13·302	12·845	12·503



SECTION 8

Vertical & Horizontal Scale 1 : 250

DATUM																							
CHAINAGE along section (A –B)	0·0	6·515	10·162		10·969	14·922	16·474		17·418	21·412	25·135	28·162	30·301	39·709	41·534	45·783	47·923	52·017	55·29	57·104	59·118	61·902	64·929
SURFACE RL	20·725	19·45	17·636		17·587	19·248	19·738		19·802	20·085	20·269	20·248	19·88	14·839	15·092	14·79	13·751	13·337	12·647	12·186	11·8	11·209	10·581

APPENDIX E

SITE PHOTOGRAPHS

Photo 1: Regional view of Coast Road and the landslide area, looking north west.

Photo 2: Regional view of Coast Road and the landslide area, looking west.

Photo 3: View of landslide head scarp and edge of road pavement, looking south east.

Photo 4: View of landslide head scarp and ground cracks on pedestrian path, looking north west.