Questions and Comments on Tip 2 Stability Reports

171 Graig Road, Godre'r Graig, Ystalyfera, Swansea (Formerly Godre'r Graig Infants School)

PRESENTED TO

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EXECUTIVE SUMMARY

Three historical tips were identified on the southeastern side of Mynydd Allt-y-grug by the Coal Authority and the tips locations were presented in the Coal Authority Report, L44.

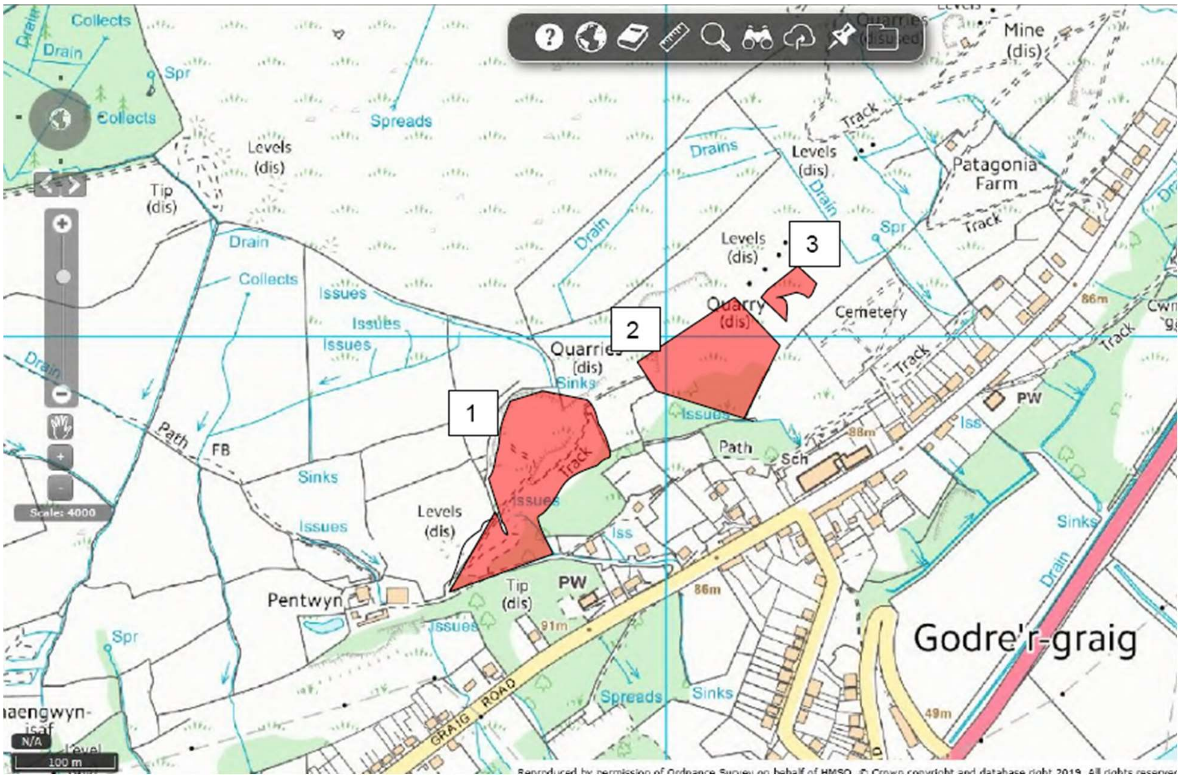

Figure copied from the Coal Authority L44 – Godre'r Graig Tips Site Inspection Report. Tip 2 is the subject tip. Neath Port Talbot Council (NPTC) identified Tip 2 as an asset requiring further exploration.

NPTC contracted Earth Science Partnership (ESP) through a competitive bid process to:

> *"develop further understanding of the historical and existing ground conditions of the Quarry Spoil Tip above the school and assess the hazards and risks that the Quarry Spoil poses to the school."*

ESP directed a series of explorative and intrusive investigations. These comprised walkover surveys, trial pit excavations, drilling boreholes, laboratory testing of material properties, and leading on to 2D limit equilibrium modelling of one plane through Tip 2. ESP then concluded that a 1:100 year rainfall event could mobilise a 500m^3 debris flow that could impact the school. This led NPTC to close the school and subsequently schedule the building for demolition.

The Godre'r Graig Residents (Tegwch) have some concerns about the process taken to arrive at these decisions. Over the past year a series of meetings were held, and questions were raised by Tegwch but some were not answered by NPTC or their consultant. These original questions have been copied into this document and some of the questions have been expanded following a partial response from NPTC and discovery of new information. Tegwch have proposed some additional questions following the new information.

One concern is that the properties used in the modelling are overly conservative and there has been an unsubstantiated 'leap of faith' that a given (unspecified) rainfall event can mobilise enough material to impact the school building. The remedial options presented comprised of demolition of the former school, installation of a barrier, or removal of the tipped material.

Geotechnical investigations produced geotechnical logs. Visual observations of the material arising from these pits noted particle size up to 700mm. Geotechnical testing was performed on particles less than 20mm in size and then conservatism was applied to these test results. The 20mm particle size appears to be a function of the limitations of ESP's testing laboratory. NPTC state that larger particle sizes can increase the phi angle (angle at which the material will move)

"*If there are many of them, they could interlock and indeed lead to an increase in phi.*".

Review of the trial pit logs show that the Coarse Discard particles:

"*generally comprises interlocking, angular and tabular boulders and cobbles of weak to medium strong sandstone*"

(quoted from the summary of Coarse Discard description). NPTC's consultant has provided a vague reference to one, two, or three British Standards / CIRIA guides was given for the selection of the conservatism towards these values, but nothing verifiable.

The conservative material parameters were used in the modelling of the slope in the naturally occurring Glacial Diamicton and the weathered bedrock layers. The "*realistic case*" parameters gave unrealistic Factors of Safety (Factors of Safety below 1) and was noted as such, but still were published in the report. A Factor of Safety below one means that the slope would have failed. An upper case set of parameters were used in the model and these gave a Factor of Safety. However, NPTC note that "*a minimum factor of safety of around 0.95 can be assumed when considering the current slope geometries*" which is still open to criticism as a Factor of Safety of 0.95 means the slope would have already failed (which is not the case). Additional modelling assessments were performed using an increasingly higher water table. The higher water table was used presumably to mimic the trigger event of a 1:100 rainfall event's water within the slope. Unsurprisingly the increase in water table decreased the Factor of Safety even lower than 0.95 Factor of Safety.

The modelling performed to date is limit equilibrium modelling. This is purely a ratio of the sum of restorative forces (friction and cohesion) over the sum of disturbing forces (gravity and water). It gives an instant in time of what the ratio is. Once the slope moves there are a new set of forces disturbing a new slope geometry and the model should be rerun. This modelling the slope after movement is observed in the model is effectively Finite Element modelling. This can add a temporal aspect to the model to see how the slope will deform over time and different material properties. If the slope was found to continue to deform over time rapid mass movement modelling could be performed to see if the risk level at the building or other soundings is acceptable given the trigger event. No alternative analysis of a debris movement path has been estimated other than the one section undertaken in the Limit Equilibrium modelling as this is the section between the quarry, Tip 2, and the former school building.

One confounding factor is neither NPTC nor ESP have proposed an acceptable Factor of Safety for the tip or the slope as a whole. This is similar to being given a speeding fine on a road without a published speed limit. It is curious that NPTC do not cite "Guidelines for Mine Waste Dump and Stockpile Design, 2017" in any of their reports. However, there are numerous references to "*modern engineering standards*" but do not state what these standards are or what Factors of Safety may be acceptable.

According to NPTC's consultant groundwater fluctuations are the key factor in the stability of the tip. However, there does not appear to have been any quantitative correlation between weather events and groundwater observations in the tip or on the hillside. No magnitude of rainfall other than a vague 1:100 year rainfall event has been proposed as a trigger for a mass movement event. No comment was provided at whether this magnitude of rainfall was likely observed over the life of the tip. (Note NPTC report published in

2016 "*Investigation Report into Flooding Incident of 3rd September 2016 Cilmaengwyn Road, Cilmaengwyn and Graig Road, Godre'r-graig. Godre'r Graig*". Which states that the slope was likely to have been exposed to a rainfall intensity greater than 50mm/h.

Instrumentation has been installed in the slope. Three slope movement indicators have been installed. One of which has provided results that suggest the inclinometer may be providing spurious readings. The other two are showing movement in the downhill direction that may be within the settling in tolerances provided by NPTC's consultant. These inclinometer readings have been used to demonstrate that the tip could be "*actively unstable*".

Only three options were provided work to address Tip 2. None of the remedial options included installation of on-slope drainage measures either through drilled drains or herringbone drainage systems. The most expensive option proposed by NPTC carried an estimate over £6M. This was to align with the hazard hierarchy where removal of the hazard is the highest priority option (removal>replace>engineering controls>administrative controls>personal protective equipment). However, this was based on Tip 2 comprising over 87,000m^3 of quarry waste. Rudimentary volume estimates of the quarry void in the rock escarpment at the crest or the area of tip extents as shown on publicly available LiDAR data suggest there could be a discrepancy between the two estimates. As the £6M tip removal costs are based on the 87,000m^3 volume the whole approach may need to be revisited and alternative removal strategies may be significantly less expensive than school demolition (Note: only the demolition costs have been provided, no estimate of price has been included for site reinstatement in this option).

There are continuous comments in the reports and responses from NPTC that:

- "*more data*",
- "*more testing*",
- "*more complex analysis*", and
- "*more stakeholder consultation*" would be required.

However, this appears to be not completed prior to taking the decision to demolish the former school building.

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APPENDIX SECTIONS

TABLES

ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
NPTC	Neath Port Talbot Council
ESP / The Consultant	Earth Science Partnership
Tegwch	Godre'r Graig Residents Committee
VWP	Vibrating Wire Piezometer

Table A – Particle Sizes with Engineering Descriptions

Soil Type	Particle Size	Lower Limit (mm)	Upper Limit (mm)
Boulders	Large	>630	-
	Boulders	200	630
Cobbles	Cobble	63	200
Gravel	Coarse	20	63
	Medium	6.3	20.0
	Fine	2.0	6.2
Sand	Coarse	0.63	2
	Medium	0.2	0.63
	Fine	0.063	0.2
Silt	Coarse	0.02	0.063
	Medium	0.0063	0.02
	Fine	0.002	0.0063
Clay	-	-	<0.002

1.0 INTRODUCTION

This document has been compiled on behalf of the Godre’r Graig Resident’s Committee (Tegwch). Tegwch have concerns that the decision to close the school and the decision for demolition of the building was potentially based on flawed modelling, unsubstantiated assumptions, incomplete remediation assessments, and inaccurate costing analysis.

2.0 PROJECT DOCUMENTATION

Neath Port Talbot Council (NPTC) instructed Earth Science Partnerships, Consulting Engineers, Geologists, and Environmental Scientists (ESP, Consultant) to undertake a landslide hazard and risk assessment on historical tips above 171 Graig Road (Former School building).

A number of reports, appendices and figures were produced by ESP. These documents have been listed in Table 2.0-1 below.

Table 2.0-1 – List of Documents Produced by Earth Science Partnership

NPTC Reference	ESP Report Reference	Report Title	Revision Number	Date	Notes
A - 7234e	7234e.3221	Godre’r Graig Primary School, Godre’r Graig Preliminary Landslide Hazard and Risk Assessment	1 - Final	2019-08	
B - 7234e.02	7234e.02.3302	Godre’r Graig Primary School Preliminary Investigation and Additional Assessment	0 - Draft 1 - Draft 2 - Final	2020-01 2020-02 2020-02	
	.7234e.02.3302	godrer-graig-final-combined-figures-and-plates-250220	-	-	
	7234e.3221	Godre’r Graig Primary School Preliminary Landslide Hazard and Risk Assessment	1 - Final	2019-08	
B2	7234e.02.3339	Godre’r Graig Primary School Executive Summary; Preliminary Investigation and Additional Assessment	0 - Draft 1 – Final	2020-03 2020-03	
C1	7372e.3331	Godre’r Graig Village Preliminary Landslide Hazard and Risk Assessment	0 - Draft 1 - Draft 2 - Final	2020-03 2020-03 2020-06	
		Figure 5			Engineering Geological Map
		Figure 12			Hazard Types
		Figure 14			Initial Risk Map
		24 No. Historical Maps – Large Scale			

NPTC Reference	ESP Report Reference	Report Title	Revision Number	Date	Notes
		5 No. Historical Maps – Small Scale			
C2	7372e.3394	Godre'r Graig Village Executive Summary; Preliminary Landslide Hazard and Risk Assessment	0 - Final	2020-08	
D	7234e.7372e.3451.Rev1	Godre'r Graig Village Land Stability Summary	1	No Date	Electronic file name suggests 2021-01-19
		Figure 2 - Investigation Point Plan			
		Figure 3: Initial Risk Map			
E	7234e.04.3564	Godre'r Graig Primary School, Godre'r Graig Tip Remediation Assessment	0 1 2 3 4 Draft 4 Final	2021-07 2021-07 2021-08 2021-08 2021-07 2021-09	
		Appendix			**Files Unable to download** ▪ Appendix A - GRG BH01 Inclo Graph 28.07.2021 ▪ Appendix A - GRG BH04 Inclo Graph 28.07.2021 ▪ Appendix A - GRG BH05 Inclo Graph 28.07.2021 ▪ Appendix B Access Routes (PDF 0 KB) ▪ Appendix C Preliminary Design Calculation ▪ Appendix D1 Retaining Structure Budget Cost Plan ▪ Appendix D2 Godre'r Graig Primary School Road ▪ Appendix E Demolition Programme (PDF 0 KB) ▪ ESP.311 General Notes

Some of the ESP reports are not true to their title, for instance, "Report Reference: ESP.7234e.04.3564 – Godre'r Graig Primary School Tip Remediation Assessment" also contains "updated monitoring results".

3.0 QUESTIONS PRESENTED TO NPTC

A set of questions relating to ESP's work was presented to NPTC and these questions solicited a partial response by NPTC (and presumably ESP). The questions have been reproduced below, in some sections additional comments were provided. The NPTC responses are shown in *Italic text*. More recent follow on questions or comments are provided.

Tegwch make no representation on the stability of the hillside or the tip, but believe that the assumptions, modelling and responses may not be accurate or are potentially flawed. Rendering the follow on decisions incorrect.

3.1 Material Properties

Tegwch Question 1

We note that there are six shear box test results. These tests have been compiled in Table 3.1-1 below.

Table 3.1-1 – Summary of Shearbox Test results

Pit	**TP101**	**TP101**	**TP102**	**TP102**	**TP102**	**TP104**
Depth	**0.6**	**2.9**	**1.0**	**2.6**	**3.8**	**1.0**
Phi (°)	26.5	33.5	44.5	42	47	39
c (kPa)	17	16	15	2	10	2

- The lab test reports state that the fraction greater than 20 mm was removed for the test.
- "Reasonable Case" Modelling Note 4 – "*In-situ testing used to guide parameter - value is considered conservative and allows for some variability/uncertainty*."

The results are shaded to provide ease of reference in Table 3.1-2 below.

Table 3.1-2 – Limit Equilibrium Modelling Parameters used by ESP

Strata Unit	Strata Unit	Reasonable Case			Upper Range Parameters		
		Bulk Density (Mg/m^3)	**Effective Cohesion (c') - kPa**	**Angle of Friction (ø') - Deg**	**Bulk Density (Mg/m^3)**	**Effective Cohesion (c') - kPa**	**Angle of Friction (ø') - Deg**
Made Ground – Coarse Discard - coarse	Variable	1.9	0	28 [4]	2.0	0	40 [4]
Made Ground – Coarse Discard – finer3	Variable	1.9	0	28[4]	2.0	27	33[4]
Glacial Diamicton	Variable	1.9	1	30[4]	2.0	2[7]	35[6]
Possible Weathered Rock Grade E / D	Mainly clay/gravel	1.8	1	32	1.9	3[7]	36
Bedrock	Mudstone, Siltstone, Sandstone 5, 8	Modelled as impenetrable					
		1. For full details of strata see Section 5.1. 2. Assume impermeable and hard boundary for assessment. 3. Material contains higher proportions of fine-grained material, modelled as cohesive strata. Ref. BS:8004. 4. In-situ testing used to guide parameter - value is considered conservative and allows for some variability/uncertainty. 5. Possible impact of coal seam/seat earth providing possible weak horizon ignored. 6. Bulk Densities in accordance with values within BS:8004.			1. For full details of strata see Section 5.1. 2. Assume impermeable and hard boundary for assessment. 3. Material contains higher proportions of fine-grained material, modelled as cohesive strata. Ref. BS:8004. 4. Laboratory test data used to guide parameter whilst considering in-situ tests results. 5. Possible impact of coal seam/seat earth providing possible weak horizon ignored. 6. CIRIA C504 used to estimate angle of friction. 7. Some soil suction assumed and modelled through cohesion.		

It is generally accepted that coarser particles (> 20 mm) would normally give a higher friction angle. We also note that the trial pit logs note that cobbles and boulders were also present. These would also increase the phi angle.

As such, what justification can ESP give to using a friction angle of 28° in the limit equilibrium analysis when the laboratory testing of the <20 mm fraction reported higher friction and the conservativeness was already built into the testing by not sampling the boulders and not testing the fraction 125mm to 20mm (or 700mm to 125mm)?

TP101 (0.6m depth) is logged as clayey, sandy GRAVEL with high cobble content and boulders and frequent rootlets. Cobbles and boulders were reported as interlocking. This suggests that even the 26.5° phi angle is conservative for the material observed in this pit. That sample also returned the highest cohesion (17 kPa). It may be considered somewhat disingenuous not to include cohesion this when the friction is so low.

There are 14 sieve test results which can be summarised in the Table 3.1-3 below. Apart from one TP104 sample taken at 1m depth are less than 125mm diameter particles. Note that this does not include the particles unable to be collected due to their size (larger cobbles and boulders). We note that no estimate of the frequency of these larger particles have been presented.

Table 3.1-3 Summary of Particle Sizes Collected During the Field Programmes

Particle Size	Average % composition in sieve tests
Cobbles	15
Gravel	56
Sand	12
Silt and Clay	18

3.1.1 Response from NPTC

Several queries relate to the use of reasonable case material parameters and discuss the use of higher values, in line with six shear box tests. Selection of suitable material parameters is difficult without extensive geotechnical testing; only a relatively limited data set is available. The report highlights that the lower/reasonable case parameters appear too low based on visual observations and higher parameters were considered in Section 6.4. Modelling using the higher parameters suggested that the quarry spoil tip is in a marginally stable state, with a FOS near 1, and an AF below 1.

The presence of cobbles and boulders does not necessarily mean an increase in phi angle. If there are many of them, they could interlock and indeed lead to an increase in phi. However, if the matrix is dominant and the larger particles do not interlock, their impact on the phi angle would be limited.

Justification for parameter selection is based on guidance in BS8004, BS5930 and EN1997-2:2007. Given the guidance, the size of the tip and the investigation carried out at this stage, parameter selection should be conservative until proven through additional testing; further investigation was recommended to consider this aspect further in the report.

The Atterberg test queried is from a sample of suspected Glacial Diamicton noted in the trial pit at base of tip. The results went into assessment of the stratum and more testing is recommended to fully characterise this stratum within the ground model and material parameters.

3.1.1.1 Follow up Questions by Tegwch

The Particle Size Distributions are presented in Table B appended to the back of this report. As per Note 1 in Table 3.1-1 the fraction greater than 20mm was removed. We assume this was due to the laboratory not possessing a large shear box to test larger particles. There was no commentary on why a large shear box test was not sought on obviously larger clast size samples. In addition to this there were no comments in the logs about what percentage of boulders were observed in the pits. However, it does state that the particles were interlocking.

Table 3.1.1.1 – Comparison of % of sample not tested and Phi and c properties

Trial Pit	Depth (m)	% passing 28mm sieve	% of Sample not tested due to oversize	Phi (°)	Cohesion (kPa)
TP101	0.6	62	38	26.5	17
	2.9	74	26	33.5	16
TP102	1.0	34	66	44.5	2
	2.6	82	18	42	2
	3.8	84	16	47	10
TP104	1	39	61	39	2
Average (Mean)			37.5	39	8

No commentary was provided to what size of material would have been produced in the quarry workings and what size would have been end tipped down the slope.

Pictorial representation of material testing limitations

Material Size Identified on site (mm)																																		Material size tested (mm)	
700	680	660	640	620	600	580	560	540	520	500	480	460	440	420	400	380	360	340	320	300	280	260	240	220	200	180	160	140	120	100	80	60	40	20	0.002

ESP provided a summary of the coarse discard in the report ESP.7234e.02.3302, Section 5.1.1 "*Made Ground Coarse Discard":*

> …"*Boulders up to 700mm diameter were noted throughout the upper portions of the strata. Gravels were fine to coarse, predominantly coarse, angular to subrounded sandstone. Cobbles and boulders were angular to subangular,* ***interlocking*** *medium strong to strong sandstone.*"…
>
> (Emphasis added through underlining and bold)

Guidelines for Mine Waste Dump and Stockpile Design, Section 5.3.3.2 "*Under low to medium confining pressures, angular particles are expected to result in greater interlocking among particles and, therefore, a stronger soil mass.*" (Hawley, 2017). Therefore, the angularity of the particles should be included in the material properties. The same book suggests that the density could be increased. The bulk density is a large factor in frictional stability analyses. (Hawley, 2017, p. 84)

We note that boulder deposits are notoriously difficult to sample due to the volume required to provide a representative sample (BS5930-2015, Table 4 – 1,000 kg required for boulders and 200 kg for cobbles), but the properties carried forward to the limit equilibrium modelling seem overly conservative. ("reasonable case" Phi = 28, c=0, "upper range" Phi = 40, c = 0, and Phi = 33, c = 2). We note there are inexpensive analyses available for coarse deposits (up to large boulders) based on mobile phone photographs such as Wipfrag (Wipware, 2022) or Split Desktop (Hexagon Engineering, 2022). These simple tests would potentially have given a better understanding of the particle sizes in the deposit. NPTC should confirm whether the sample sizes retrieved from the field programme met the requirements of BS5930-2015 Table 4.

Two shearbox tests (33% of the tests) reported over 60% of the sample sent to the laboratory was not tested due to size restraints. The average (mean) for the fraction too large to be tested was 37.5%. Although open to conjecture, it is not hyperbole to assume over 50% of the coarse discard deposit was not tested due to the sampling of larger particle sizes. ESP note that larger particle sizes generally give higher phi values (if the matrix is not governing stability). In this case it could be considered that the matrix was tested (shearbox) and the "*interlocking*" particles would have increased the phi angle further. NPTC should provide commentary on this.

The larger particle sized material in the deposit was reported by ESP to be "*interlocking and predominantly coarse*," therefore the material parameters would likely present higher phi angles than presented by ESP in the "*reasonable case*" limit equilibrium modelling. It may be that the "*upper range*" may be considered conservative for the slope.

NPTC state that "*Selection of suitable material parameters is difficult without extensive geotechnical testing; only a relatively limited data set is available.*" What additional testing is required to obtain more accurate material properties? What was the rationale for not collecting these data / performing these tests?

The lower material properties appears to be based on the uncertainty of whether the larger sized materials interlock due to the matrix potentially dominating the deposit. However, there appears to be a contradiction between the response to the questions {Response to Question 1 Paragraph 2 above} and the ESP report "*ESP.7234e.02.3302 - Godre'r Graig Primary School Preliminary Investigation and Additional Assessment.*" Section 5.1.1 quoted above, and described in Section 3.3 bullet 2, quoted below:

> "*Quarry spoil is visible across the site surface and generally comprises **interlocking**, angular and tabular boulders and cobbles of weak to medium strong sandstone. In the lower portions of the slopes, there is evidence on the site surface of groups of loose angular sandstone cobbles and boulders (Plate 13).*"
>
> Emphasis added in underlining and bold.

NPTC state that the selection of parameters is based on "*BS8004, BS5930 and EN1997-2:2007*" without specifying which section in these standards apply to these selections. These standards comprise 100s of pages and references. Please can NPTC provide which sections they are referring to for parameter selection other than the test parameters of the samples?

In NPTC's response it is stated that …"*more testing is recommended* [for the glacial diamicton] *to fully characterise this stratum within the ground model and material parameters*"… This seems to infer that the properties selected are not appropriate.

We note that Inserts 16 (FoS>0.99), 17 (FoS>1.30), and 18 (FoS>1.05) show failures occurring through the Diamicton strata. With this low Factor of Safety the properties of the Diamicton may be the critical element the whole hillside model. Therefore, the question was raised, what is the ambient condition of the hillside? i.e. is the rest of the hillside "acceptable" just out side the boundaries of Tip 2? Would the hillside fail in the 1:100 trigger rainfall event even if the tip was not on the hillside?

Why was modelling performed and reported using parameters that were obviously questionable or incomplete as this will skew the reader's (Council's) opinion on stability?

Summary on Material Properties

The material properties carried through to the modelling were based on the 20mm and finer portion of the samples collected, and an unreferenced level of conservatism was then applied to this finer fraction. A large portion of these samples were not tested due to the particles in the samples being over 20mm, and it is likely the "not tested" fraction of the material would have increased the friction angle of the material, potentially significantly.

NPTC's consultant states "*realistic case parameters are likely too low based on field observations.*" The "*upper case*" properties could also be considered conservative. It is perplexing as to why obviously low soil properties were chosen and report text generated when the properties used in the slope modelling show the slope should have failed.

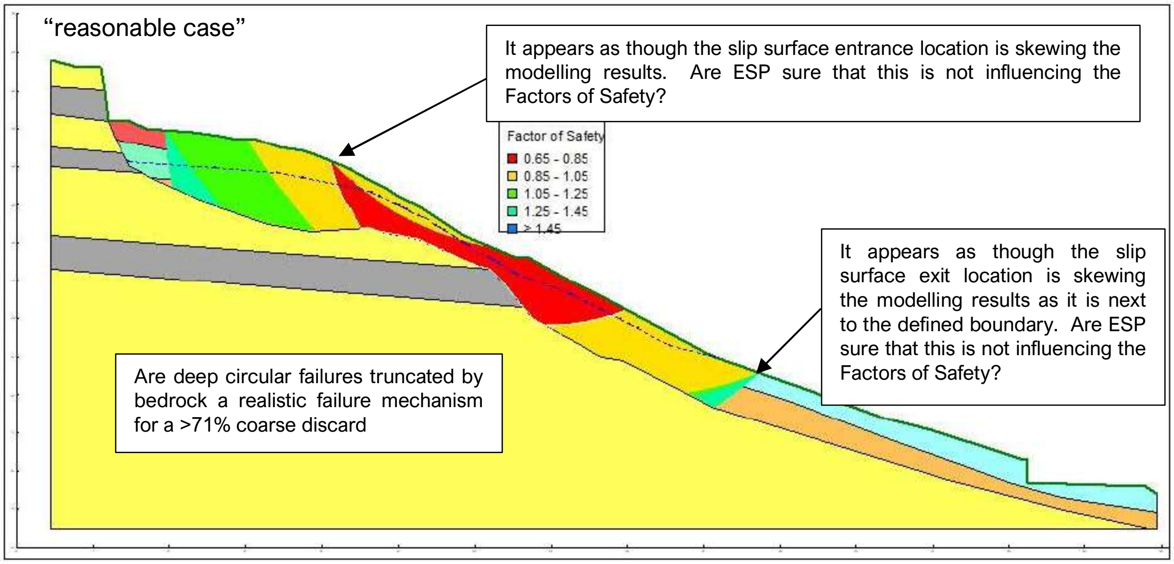
Please provide references and rationale for material properties carried forward to the Limit Equilibrium Modelling.

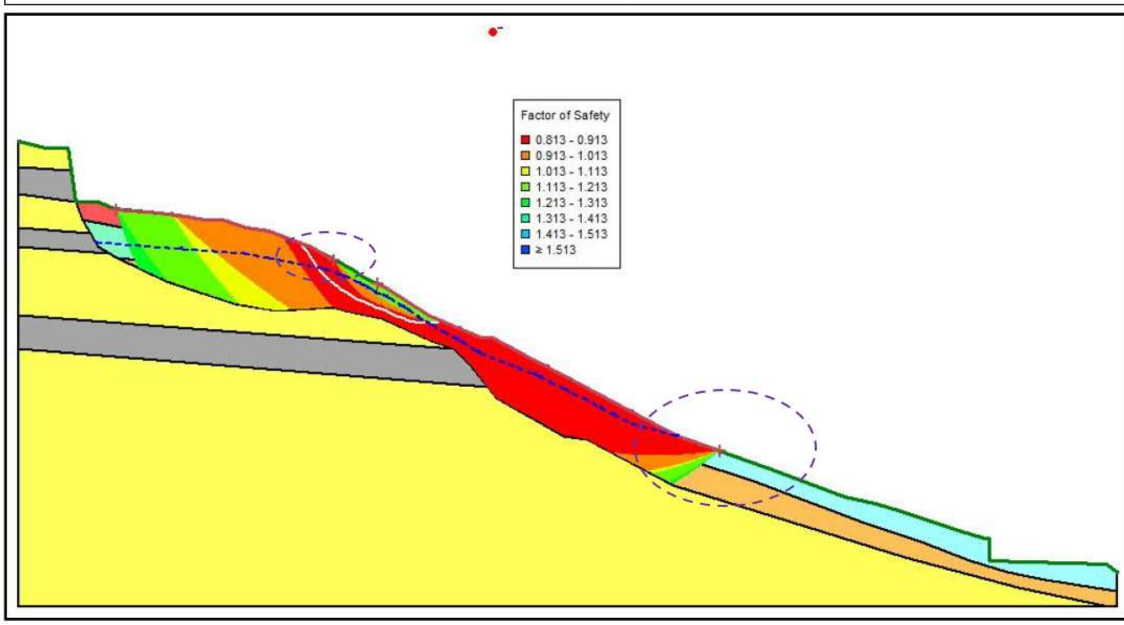
In the reports and the responses to Tegwch additional testing was recommended. What testing was required to complete the data set? Why was this testing not performed?

3.2 Limit Equilibrium Modelling

Tegwch Original Question 2

How sure are ESP that the Limit Equilibrium Modelling is correct for the slope?





The "*reasonable case*" model shows Factors of Safety as low as 0.65 to 0.85 (below 1.0). Are NPTC (and ESP) supporting this is not a realistic Factor of Safety as the slope would have failed if the Factors of Safety were that low. This supports the suggestion that the modelling material properties are overly conservative.

Note:

> *"The site walkover, historical mapping and aerial photographic review show no sign of instability predicted by the modelling. It is therefore likely that the Reasonable Case Material Parameters adopted are too low as signs of movement would likely be visible at the Quarry Spoil Tip."*

Question 2a
Would a stress dependent model (Leps, 1970) be more appropriate for a rock tip limit equilibrium model than an unsophisticated phi & c model?

Question 2b
Was back analysis undertaken to see what parameters (close to the laboratory data are most reasonable)?

Question 2c
What does ESP/NPTC use as an acceptable Factor of Safety for this tip? We don't think it is presented in the reports.

Question 2d
Will ESP/NPTC undertake 3D modelling of the tip?

Question 2e
We understand that the mechanism of the tip formation is end tipping. Would the velocity sorting of the difference in sizes of the discard affect the friction angles and drainage characteristics? {velocity sorting – usually larger rocks travel further than fine gravel or sands when end tipped}

Question 2f
What inferences do ESP/NPTC make from the Atterberg Limits data obtained from TP104 2.5m depth?

Moisture content 32%
Liquid Limit 49%
Plastic Limit 25%
Plasticity Index 26%
"Intermediate Clay"

Question 2g
Also, the shearbox tests suggest that there was minimal strain softening during shearing. What influences does this have on the models?

3.2.1 NPTC Responses

Slope angles measured on the tip (visually and via topographic survey) are provided in the report. Many slopes are steeper than 27° (Tegwch suggested maximum) with slopes as steep as 38°, see Figure 2 in ESP.7234.02.3302.

The limit equilibrium approach chosen considers stability of the tip based on the available information and the brief. It is stated that realistic case parameters are likely too low based on field observations; hence, higher parameters were also considered. Modelling included other iterations, considerations and assessments that were not included in the report for brevity. Modelling using favourable parameters yields a likely marginally stable scenario.

Back analysis is a method to obtain indictors of material properties/groundwater conditions for a known failure (i.e., where the FOS is just below 1) and when the slope morphology prior to failure is known.

Localised slope failures in the Tip material may have occurred (based on slope morphology); however, there is no mapped failure that can be modelled to allow a back analysis. Back analysis not considered suitable at this stage to provide a guide to parameters at Godre'r Graig.

The Leps, T (1970s) paper is informative. The assessment parameters were chosen with the aid of in-situ test data and values indicated within British Standards and Eurocodes (e.g. BS8004). Modelling has been used using two sets of parameters; the higher set is discussed in the report and shows a marginally stable slope. The model presented in the report is a contour graph of numerous possible failures, numerous other models of the tip were executed in the assessment, only one was presented in the report for clarity (limit equilibrium analysis is reasonable considering the available ground model information).

An allowable FoS has not been defined, stated by or agreed with NPTCBC to date and should be decided ahead of any future investigation, assessment or mitigation work as part of stakeholder/client engagement and consultation. The slope stability assessment includes consideration to Eurocodes which adopts partial factors of safety on different elements to the material parameters or loadings. Details of this can be seen in within BS EN 1997-1:2004.

Investigation has been generally limited to the quarry spoil tip and has yielded a relatively limited set of information when considering the land area, and volume of material within the tip. Limit equilibrium methods (e.g. SlopeW) are more appropriate when data is limited or it is necessary to make an initial stability estimate before undertaking more complex analysis.

If more data is obtained (as recommended in the reports). finite element analysis could be considered to allow analysis of any emerging heterogeneous ground conditions, geometries, seepage, consolidation and other possible hydrological and mechanical behaviours and more complex mechanical soil responses (e.g., post failure strain softening and progressive failure).

Groundwater sensitivity analysis was included in the assessment to understand implications of higher and lower levels. This helps understanding of this situation and possible variability, especially where the Ground Model is not fully understood. The slope stability sensitivity analysis/modelling shows a decreased stability with increased groundwater levels. Vibrating wire piezometers show variable pore water pressure, in response to rain and possibly from groundwater levels in the hillside. There will be contrasting increases in pressure/stability within the tip due to different martials/variabilities of that material. The vibrating wire piezometer graphs show the available information on sensitivity to rainfall.

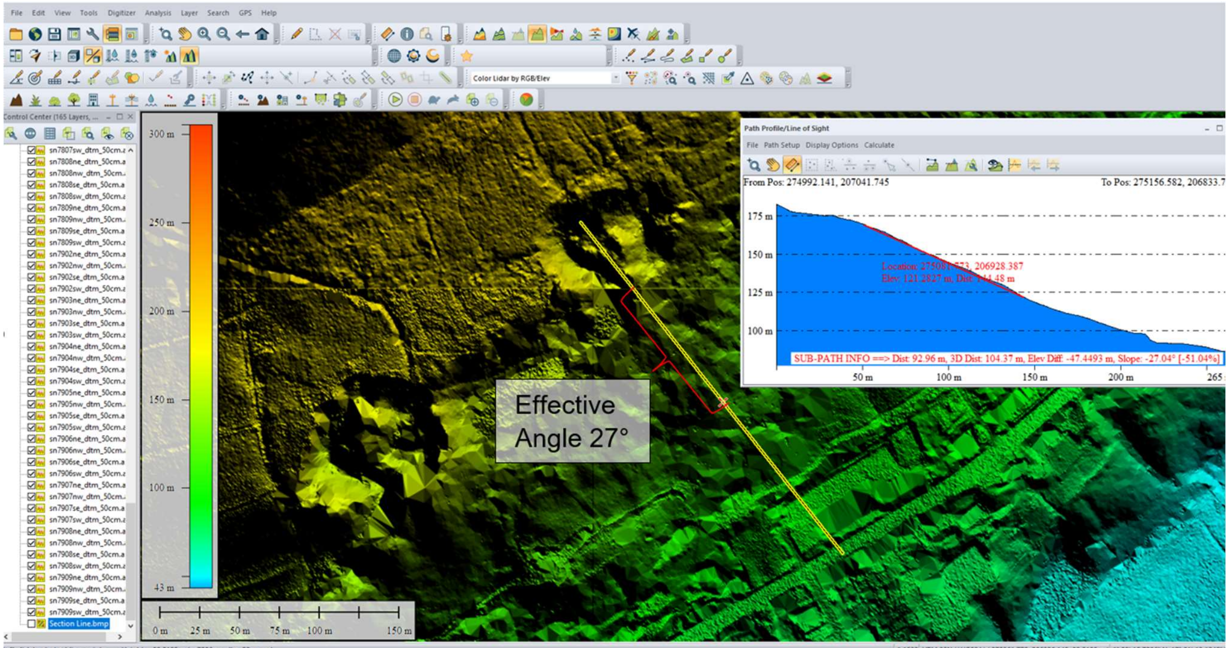
For the quarry spoil tip, the assessment progressed from AGS qualitative (prior to any physical works), to a quantitative method based on the available data. The assessment (Ref. 7234e.02.3302) shows that drainage, along with some slope modification, could increase stability to what might be considered acceptable by various stakeholders following consultation (e.g. NPTCBC, NRW, local community). Other options such as tip removal are also technically feasible but carry high costs, as reported in our Tip Remediation Assessment (ref. ESP.7234e.04.3564). Tip repair costs at Tylorstown are currently estimated by RCTCBC to be ***£82.5M.***

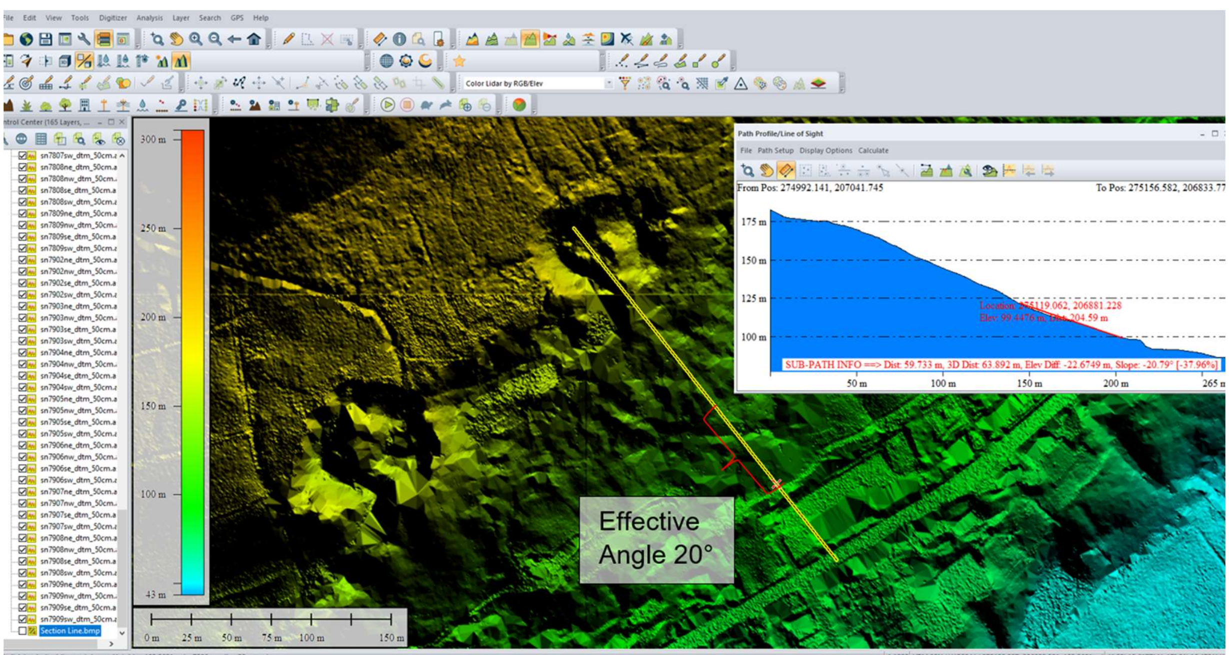
Earth Science Partnership is independent and work on this project has been carried out in accordance with current guidance and standards. Any future mitigation design should be independently checked and consultation with stakeholders enabled.

3.2.1.1 Response to NPTC

NPTC suggest that ESP.7234.02.3302 Figure 2 shows relatively short sections of slope steeper than 30° and some measurements taken on natural hillside (outside the mapped extents of Tip 2) to be 36° - presumably the angles on the natural hillside are not over steep and have an acceptable Factor of Safety. NPTC should confirm?

The effective slope angle (toe to crest) was estimated to be approximately 27°. The effective slope angle is usually the critical angle for analysis, especially when NPTC are suggesting volumes in excess of 500m^3 may be mobilised in a mass movement event. The angles presented in ESP's Figure 2 suggest that tens of cubic metres may be of concern based on the critical slip plane shown and not the 500m^3 reported as the volume of concern.





We note that there was no answer to what is an acceptable Factor of Safety for the Tip or Hillside. NPTC’s consultant states in Section 6 of the response document

> *“An allowable FoS has not been defined, stated by or agreed with NPTCBC to date and should be decided ahead of any future investigation, assessment or mitigation work as part of stakeholder/client engagement and consultation.”*

Until these Factors of Safety are provided the Factors of Safety mentioned, fallacious or not, are without merit. Without a published Factor of Safety, what was the justification for the decision to close the school and subsequent scheduling for demolition

As NPTC's consultant states that the "*reasonable case*" parameters were too low, what parameters were selected for the stability model on which the final decisions were based?

A shear normal approach for modelling the coarse discard was regarded as "*informative*", however, using the ESP density of 2.0 Mg/m^3 the corresponding phi angle could be between 48° and 54°, or more (2.0 Mg/m^3 x 5m thick layer = 0.1MPa which converting from Leps, 1970 contrasted with 28° for "*reasonable case"* and 33°/40° for "*upper case*") for about 5 m thick layer of *Coarse Discard*. The relationship referenced by ESP was "*Stroud, 1975*" but no paper, Standard, or reference was provided in the document to support this in ESP 7234e02.

We disagree about back analysis. Soil slopes usually start to deform with a Factor of Safety of approximately 1.1. If the field observations are replicated in the limit equilibrium models then the parameters start to become reasonable. In addition to this the slope deformation should represent the modelling and what the failure mechanism is thought to be.

NPTC have not provided any reasonable mechanism at which a 500m^3 of quarry tip may be mobilized and impact the building at the toe of the slope. As mentioned above, Limit Equilibrium Analyses are a summation of restorative forces over disturbing forces, i.e. a ratio of what is causing the slope instability and the properties keeping it up. Limit Equilibrium modelling does not show how the slope will deform over time.

In Section 6 of the response NPTC state that "*The assessment (Ref. 7234e.02.3302) shows that drainage, along with some slope modification, could increase stability to what might be considered acceptable by various stakeholders following consultation (e.g. NPTCBC, NRW, local community).*" This statement suggests that additional consultation will be forthcoming. However, the Council voted to close the school and subsequently mark the building for demolition without this phase of consultation. As stated above, this decision may be fallacious based on the material properties alone let the lack of viable modelling.

NPTC have mentioned the Tylorstown Tip remediation work is estimated to be £82M. Could NPTC comment on the volume differences between the two? It seems hyperbole to compare a Tylorstown tip some >330m in length and about 0.5km wide and considerably deeper with the subject tip's estimated volume (87,395 m^3).

Question 2f about the Index Properties of the Diamicton did not receive a response. However, with the Liquid Limit being 49% and moisture content at 32%, NPTC should confirm the water table seem reasonable for the modelling? If the Diamicton properties are low, and Diamicton forms the lower portion of the slope, the properties of the Diamicton will obviously affect the stability of the upslope materials. Contrast the properties of the Diamicton and the properties of the slope outside of the Tip 2 boundary that has been standing at a Factor of Safety likely greater than 1.1.

There is a vague reference to Eurocodes and partial Factors of Safety (BS EN 1997-1:2004 for example), but the investigation does not appear to have followed the guidance / standard set out as, for instance, in situ permeability tests were not performed.

ESP 7234e043564 Section 4.5 states that the "*Removal of the school structure would remove a barrier for any downward moving failed material from the tip.*" This seems to be a statement without engineering support as the original assessment has not modelled the impact on the school. Logically until the impact on the school has been justified all decision tree analysis may be fallacious. Notwithstanding, ESP continue with the "*Approx. Annual Probability*" quantitative analysis using assumptions which render the outputs simply numbers rather than actual probabilities.

We note that there is an absence of commentary on quality and health of vegetation on the slope. "*actively unstable*" slopes in the 50 years to 100 years range usually have trees with pistol butted trunks. Also, if slopes are around a nominal Factor of Safety of 1.1 the death of vegetation is sometimes noted due to root distress / damage.

3.3 Modelling Sophistication

Question 3

Could ESP provide a mechanism to show how the limit equilibrium model will deform over time and potentially become fluidised into a mass movement debris avalanche / flow / debris flood that has a propensity to impact the school building? We don't think the failure or fluidisation has been covered in the reports.

We have been unable to identify figures for finite element (or finite difference) models in the report(s). In addition to this if these time dependent deformation models do suggest this becomes mobilised there are mass movement modelling packages to estimate the forces and runout distances. At what stage will these models be completed?

This may be outside the current ESP scope, but finite element modelling and mass movement modelling (RAMMS or DAN/W) may be significantly cheaper than the lower end of the remedial work. Would more advanced modelling be the prudent next steps? (note that the "*reasonable case*" parameters may be considered overly conservative / simplistic.

3.3.1 Response from NPTC

None received.

3.3.1.1 Follow up Question to NPTC

Are NPTC certain the section line used for the Limit Equilibrium modelling may be the critical line for a landslide event? Or is it conceivable that a critical path of a mass movement event could not affect the building?

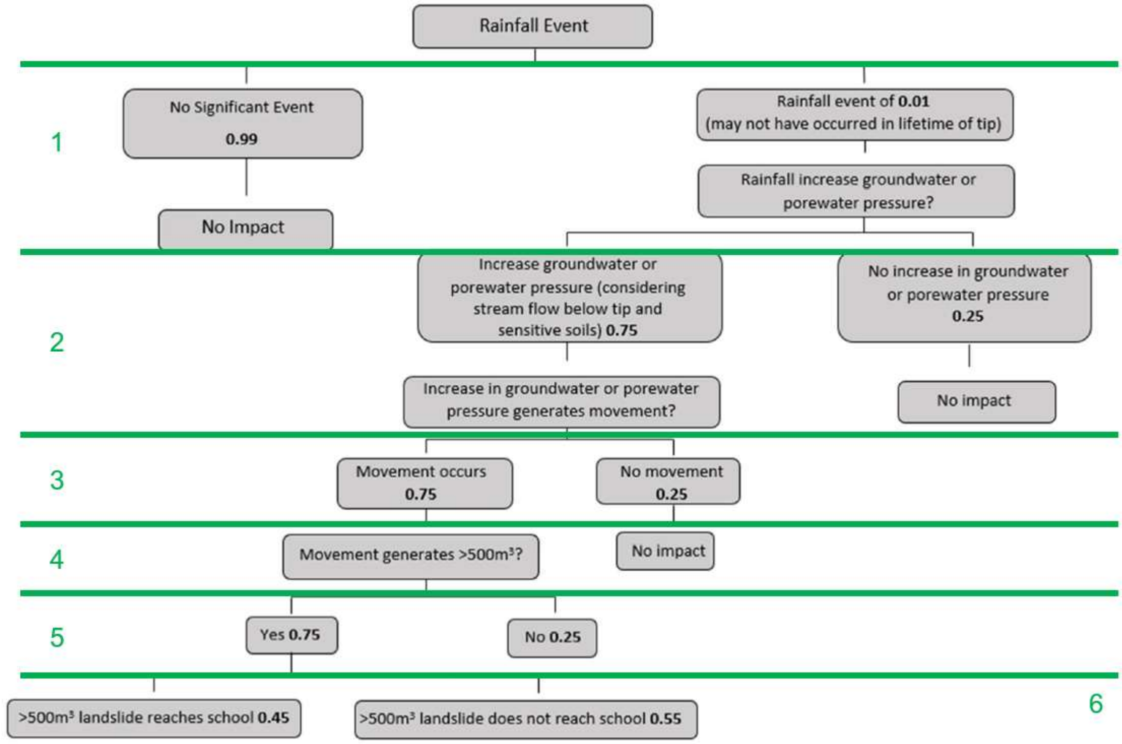
3.4 Event Tree

Question 4

The report states that there is a 1.9×10^{-3} probability of >500 m^3 could become mobilized in a 1:100 year event. The report does not state what magnitude of rainfall this is (mm of rain per hour or per 24 hours) or any other recognised metric. What was the estimation of rainfall intensity was used to cause the fluidisation of the tip?

Question 4a

What supporting references / published data / laboratory data / modelling results can ESP/NPTC provide for each level of the decision tree?



Question 4b

Decision Stage	Comment
1	▪ What is a 1:100 rainfall event? – Is this an annual probability? Or area lifetime probability? – How will the rest of the valley react to a 1:100 event? • Does this tip pose an elevated risk? ▪ Would anyone be using the school in that rainfall magnitude?
2	Stream below tip and "*sensitive soils*"? What are these? Would the stream have washed the fines away and then pore pressures not likely to increase? How was the case of P=0.75 developed to increase pore pressures? Would land drains help elevate the pore water pressures? Herringbone drainage? Horizontal drains (large diameter)?
3	No reference given for there is a 75% probability that movement occurs. What is the justification for this?
4	What justification for this movement will be over 500 cu m?
5	No justification given for 75%
6	No justification given

3.4.1 NPTC Response to the "Event Tree" questions

Event trees are useful for evaluation of probability of failure of a landslide, or consequence of failure, or risk. The logical sequence within the system is mapped as a branching network with conditional probabilities assigned to each branch of a node. The frequency of achieving a certain outcome is the product of the assumed probabilities leading to that outcome multiplied the frequency of the initiating 'trigger' such as rainfall.

An event tree analysis was used in the initial assessment as a graphical construct to show the logical sequence of events or considerations leading to a particular outcome; it is a qualitative approach. The first conclusion was similar to The

Coal Authority; a potential risk was identified and investigation/assessment was recommended (the ESP and CA reports were initial assessments).

Subsequent work has superseded the event tree which was not used in decision making and in making recommendations in the Preliminary Investigation and Additional Assessment report (Ref. 7234e.02.3302).

Hydrological assessment/design is required as part of any further investigation, assessment/modelling and mitigation work. Design requirements and parameters to control groundwater and surface water for defined rainfall intensities and frequencies (including potential climate change effects) will be a fundamental part of any future slope improvements.

Measures to prevent school occupation prior, during or following significant rainfall events will require suitable early warning systems and response plans. A detailed understanding of critical slope and drainage conditions will also be required. A discussion on how these measures could fit into a hierarchy of controls would be necessary as monitoring and reaction may be considered less effective/preferable

3.4.1.1 Follow up Questions / Comments

Not all the questions received responses, in particular the likelihood of an event of that magnitude occurring or whether it could trigger a mass movement (debris flow) event.

We are aware of how event trees can be used for the appropriation of risk based on certain data or probabilities. An event tree can become invalid if early data or assumptions are incorrect (fallacious outcome). However, we disagree with NPTC's statement that it is a qualitative assessment tool as probabilities were applied making it semi quantitative or fully quantitative and produced a "$1.9x10^{-3}$" probability that had follow on assumptions and decisions made.

Are NPTC still stating that the trigger of a debris event large enough to cause harm at the building will be a 1:100 year rainfall event?

What level of rainfall, mm/hour mm/day or other intensity data will mobilise the tip in a way that can impact the building?

ESP7234e02 Section 6.2.1 – 11th Bullet: "*Movement information from inclinometers (at present) not representative of large-scale instability.*" This suggests that the model has not replicated the other data suggesting the model needs additional refinement before it can be relied on to base decisions.

Can NPTC confirm that the "*reasonable case*" parameters have been rejected due to the egregiously low Factors of Safety? Therefore, the "*upper case*" parameters are considered reasonable (ESP7234e02 Section 6.4.1 Paragraph 2). Should a new set of upper case parameters be selected to carry on through the modelling as originally intended?

It is still unclear how BS:8004 (Code of Practice for Foundations) was used to select the material properties. Can NPTC provide references other than the entire 108-page document? NPTC's consultant states that the 260-page book has been used to estimate the phi value for Glacial Diamicton (CIRIA C504), again, this is a vague reference and cannot be verified as reasonable assumption.

ESP7234e02 suggests that the slope is Marginally Stable based on M.E. Popescu's 1994 paper ("A suggested method for Reporting Landslide Causes"). However, that paper shows that the marginally stable phase was instigated following preparatory causal factors and Popescu gave an example of erosion at the slope toe. It is our understanding that this has not occurred. In addition, Popescu states (Section 4 – Discussion) "*The need to properly recognize landslide causal conditions and processes in order to understand landslide mechanisms and to propose effective remedial measures is apparent.*" NPTC does not appear to have provided a cause apart from an unspecified rainfall event that would potentially cause the groundwater to rise 1m above a "simple arbitrary" level. In addition to this the mechanics behind the fluidisation of the tip material have not been postulated.

We note that numerous additional investigation / modelling / assessments were recommended by NPTC's consultant. Why were these not undertaken?

NPTC's consultant attempts to link the historical tip to current day practices but does not present a target Factor of Safety. Insert 13 and Insert 14 show critical failure surfaces relatively shallow.

NPTC's consultant attempted to understand the tip stability using partial factors and the results were published in ESP7234e02 Table 11 noting that the increase in groundwater height "*are simply arbitrary.*" It is perplexing that Factors of Safety below 1.0 are being proposed when it is obvious that a slope with a Factor of Safety less than 1.0 would have failed. No commentary has been proposed on how pore pressures will develop on the Coarse Discard strata.

ESP state that the potentially fallacious "*marginally stable*" state aligns with the "*Medium Risk*" from the ESP 7234E3221 Rev1 "*Medium Risk – May be tolerated in certain circumstances (subject to regulator approval) but requires investigation, planning and implementation of treatment options to reduce the risk to low. Treatment options to reduce the risk to low risk should be implemented as soon as practicable.*"

Even in the Remediation Options report (esp 7234e043564 Section 4.5.2) ESP are proposing (semi) quantitative assessments using the (potentially?) rejected Event Tree approach to suggest that properties opposite the current buildings will not be at risk if an engineered bund (2m to 3m tall) were to be present. A 500m^3 debris flow event is about 1/175th of the modelled tip volume (500m^3/87,395m^3). It appears to be counter intuitive that the assumption a 2m to 3m tall earthen bund would be sufficient to withstand the impact force required to damage an exceedingly well constructed masonry building. NPTC suggest that the 12 houses mentioned should accept this increase in risk based on zero engineering back up.

3.5 Tip Permeability

Question 5

Was any in situ permeability testing done as this appears to be the main mechanism for instability in this model? Can the coarse discard develop elevated pore water pressures that could mobilise the tip? Or other empirical estimations of permeability based on particle sizes, and then link these estimates through to the VWP data?

3.5.1 Potential NPTC Response

Response Section "2.0 Ground Model"

It is considered unlikely that end tipping would have occurred from the same location through time; therefore, it is unlikely that the tip spoil will be sorted as a natural scree or talus slope. Consequently, and based on current data, there is not likely to be predictable/homogenous layering within the tip.

Porosities and permeabilities will vary in the tip due to material heterogeneity. If present (not certain at present), persistent zones or layers of cobbles or boulders near the base of the tip may act as a preferential drainage pathway; however, more evidence and confidence in the Ground Model is needed to define this.

It is considered that groundwater in the tip is hydraulically linked to groundwater in the hillside. No in-situ permeability testing was carried out in the preliminary investigation. There are finer grained zones and layers within the tip that could result in higher pore water pressure generation relative to coarser grained layers.

3.5.1.1 Follow up Questions / Comments

It is quite likely that porosities will differ greatly in the Coase Discard strata. It seems like ESP's ground model comprises zones of coarse material and zones of finer grained material throughout the Coarse Discard strata.

However, could NPTC comment on the potential orders of magnitude difference and whether the more permeable layers will act as a drainage layer? (Hazen's Rule {$k=C(D_{10})^2$} could provide orders of magnitude permeability estimate) is it likely that the finer grained layers will be the critical layers as these finer layers are not proposed, by ESP, as continuous layers?

What is the critical permeability (order of magnitude) that will allow pore pressures to develop and to mobilize the tip?

There is no mention of the adit at NGR 274988E 206957N and how this links into the proposed water table model for the limit equilibrium analysis. Other adits are known to be on the slope. Adits significantly affect the water table (and slope stability analysis). As the water table fluctuations are "*simply arbitrary*" the instability noted as a consequence of them may not be applicable to the hillside.

Would an exploration programme to identify water pathways be a prudent step to take?

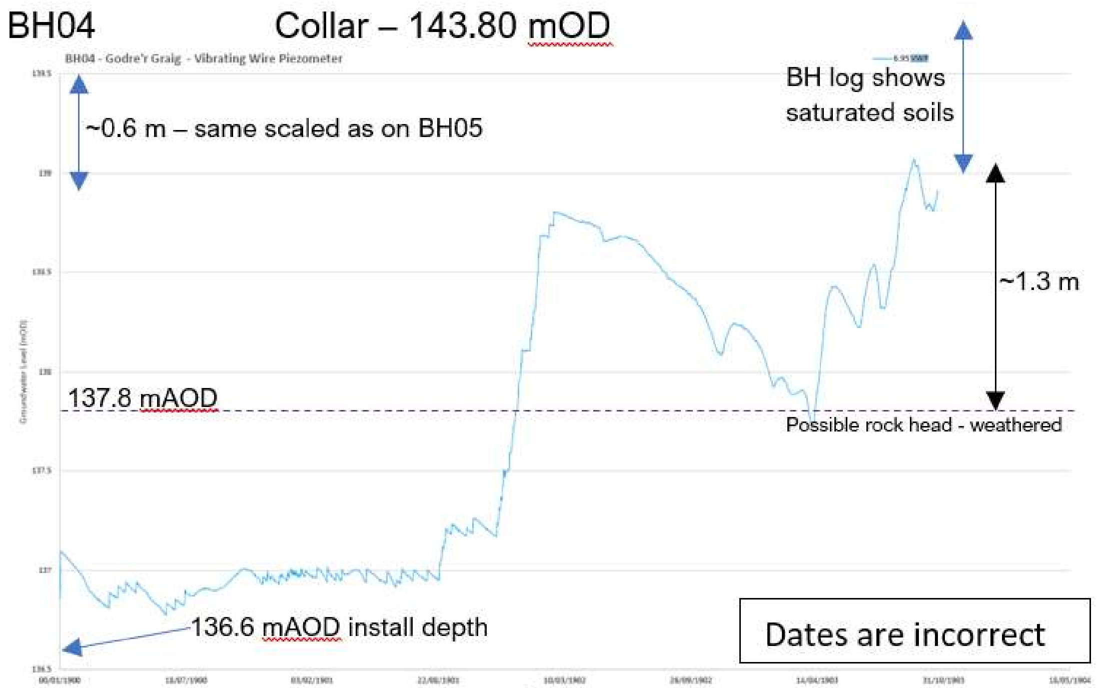
Have NPTC or the Consultant considered a tracer dye program to see the gross permeability of the tip? This could be undertaken at various rain fall events to characterise the transmissivity which is linked to the permeability.

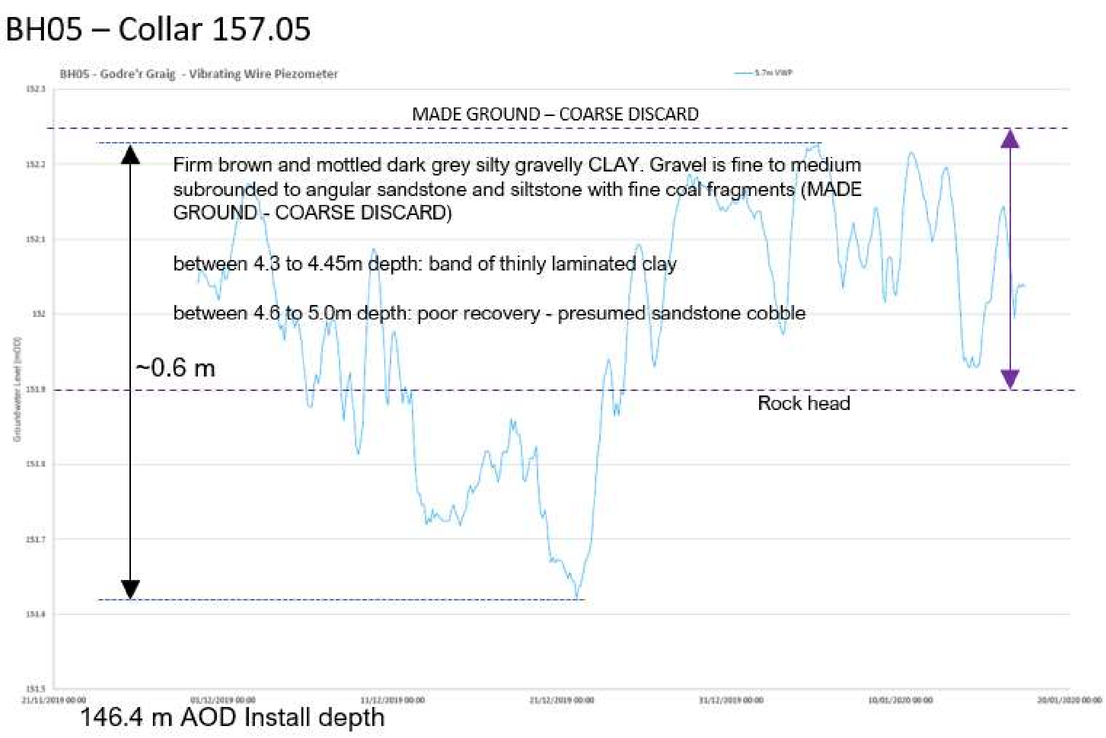
3.6 Monitoring Data

Question 6

The dates on the data logger for BH04 vibrating wire piezometer plot are incorrect. What inferences can be made on the gradient of the piezometric levels on the plots?

Would all the piezometric data presented (VWP and standpipe dips with notes on rainfall intensity) on one graphical representation of the data give with rain gauge data give a slope level understanding of the water table?





BH05 – appears to show rapid rise and fall of water but the fluctuations appear to be within the clay layer and have not reached the coarse discard. The figure above shows the elevation of rock head and where coarse discard starts. (scale and dates are difficult to read though)

Question 6a

Does the water table in the limit equilibrium model mimic the vibrating wire piezometer data with respect to elevations or depth?

Question 6b

What is the Factor of Safety of this tip compared to the adjacent hillsides in a 1:100 year rainfall event?

Question 6c

As intense rainfall events are usually predictable a few days out would the building likely be occupied at the time of the rainfall event (or for a given number of days following)? At least until water levels have subsided to within the project normals?

Question 6d

Does ESP/NPTC think that the BH05 400mm thick layer of sandstone cobble 4.6m to 5.0m depth may act as a drainage layer?

Question 6e

Limit Equilibrium Modelling assumptions state "*Assuming a constant groundwater level – as shown;*" is this realistic with the VWP data?

Question 6f

Limit Equilibrium Modelling assumptions state "*Smaller individual/impersistent layers of finer Made Ground within Spoil Tip ignored, lower phi angle adopted to allow for some variation; and*"…

How thick do these layers have to be to resist point to point contact of the coarse discard clasts punching through these "*Smaller individual/impersistent layers*"?

3.6.1 NPTC Response in "Section 4.0 – Monitoring Records"

The Ground Model and water level used in the assessment is based on various information sources, the vibrating wire piezometer data, geophysical information, visual observations at the surface and within exploratory holes. Further investigation locations within the tip and hillside are needed to fully define the Ground Model and understand the groundwater pressures in the hillside/spoil tip accurately.

The vibrating wire piezometer graphs show a relatively quick increase in porewater pressures, presumably a response from rainfall. The peaks have a shallower tail, or slower drop off in pressure suggesting a more gradual decrease in pressure or perhaps a masked secondary influence.

The most recent inclinometer data issued in the Design Remediations Options report shows clear downhill movement in BH01 and BH05 (~14mm and ~18mm respectively). Movement in BH01 and BH05 is not considered due to settling in of the inclinometer; the lower portions of the graph show no movement, indicating that the bottom section of the inclinometer pipe is static and the movement measured is the upper strata/tip moving downhill.

The installation in BH04 is different; it is likely that the base of this inclinometer is not fixed like BH01 and BH05. In this scenario, settlement of this installation/inclinometer can occur, so judgement was not based on the information from BH04. However, even with possible uncertainties, it is suggesting ~10mm downhill movement in the upper 3.8m, which is consistent with data from the other inclinometers.

The inclinometers data suggests that the quarry spoil tip may have become actively unstable. Investment in additional investigation, assessment, modelling and design will be required to fully assess the quarry spoil tip and to inform mitigation design.

The consideration presented of the vibrating wire piezometer graphs show some incorrect assumptions. We agree that the dates are incorrectly labelled on the vibrating wire piezometer graph for BH04, however, the scale is correct.

Slope stability modelling (using upper or best-case parameters) shows the slope to have a factor of safety at about 1, which aligns with the conditions noted. The slope may have become actively unstable based on the available monitoring data.

3.6.1.1 Response to NPTC's comments

Could NPTC elaborate on what is meant by a "masked secondary influence"?

With the response to the comment "*The vibrating wire piezometer graphs show a relatively quick increase in porewater pressures, presumably a response from rainfall. The peaks have a shallower tail, or slower drop off in pressure suggesting a more gradual decrease in pressure or perhaps a masked secondary influence*" As BH04 (the graph with a slower drop off rate) is located at a lower elevation noted near issues / spring; an alternative hypothesis for this could be a continuing recharge (rainfall or groundwater flow) into the slope causing the water level on the vibrating wire piezometers to drop less quickly rather than pore water pressure increase. A simple Falling Head Test would assist in resolving these questions.

The inclinometers moving less than 20 mm (see Inclinometer Section) suggests this movement being less than 20mm may be settling in.

3.7 Rainfall Events

Water tables are large features that can extend many hundreds of metres into the hillside in three dimensions. It is unusual to have the water table data plotted on different graphs using different scales and then make inferences from individual plots. As rainfall is implied to be the primary cause of instability of the tip by ESP not one rainfall intensity record was presented.

Question 7

How close to the "*1:100 rainfall event*" have the recent "*heavy rainfall*" events been?

3.7.1 NPTC Response

No response received from NPTC

Question 8

Does the ESP/NPTC consider the tip to be sensitive to rainfall with respect to pore water pressure increase? The blue shaded cells are reported to be taken following periods of unspecified "*heavy rainfall*". Note; no intensity or duration was provided.

Table 3.7-1 Summarising groundwater observations

Well ID	Collar Elv.	Response Zone Depth	Visit 1		Visit 2		Visit 3		Visit 4		Visit 5		Visit 6	
			2019-11-11		2019-11-25		2019-11-29		2009-12-09		2020-12-20		2019-01-17 Date in table, however, more likely to be 2020-01-17??)	
			(m BGL)	(m AOD)	(m BGL)	(m AOD)	(m BGL)	(m AOD)	(m BGL)	(m AOD)	(m BGL)	(m AOD)	(m BGL)	(m AOD)
TP102	159	2.0 to 5.0	4.7	154.3	4.95	154.05	4.7	154.3	4	155	4.7	154.3	4.66	154.34
TP104	120.8	3.5 to 5.5	2	118.8	2.1	118.7	1.9	118.9	1.9	118.9	1.8	119	1.81	118.99
BH02	157.9	2.0 to 3.0	2.6	155.3	2.82	155.08	2.9	155	2.6	155.3	2.6	155.3	2.6	155.3
BH03	157.6	3.2 to 4.2	2.6	155	2.75	154.85	2.9	154.7	2.6	155	2.9	154.7	2.6	155
			Following period of heavy rainfall		During period of heavy rainfall				Following period of heavy rainfall					

Table 3.7-2 – Processed Groundwater Depth Data

Well ID	Collar Elv.	Response Zone Depth	Visit 1 11/11/19	Visit 2 19/11/19	Visit 3 29/11/19	Visit 4 9/12/19	Visit 5 20/12/19	Visit 6 17/1/20
TP102	159.0	2.0 to 5.0	4.7	4.95	4.7	4	4.7	4.66
TP104	120.8	3.5 to 5.5	2.0	2.1	1.9	1.9	1.8	1.81
BH02	157.90	2.0 to 3.0	2.6	2.82	2.9	2.6	2.6	2.6
BH03	157.60	3.2 to 4.2	2.6	2.75	2.9	2.6	2.9	2.6

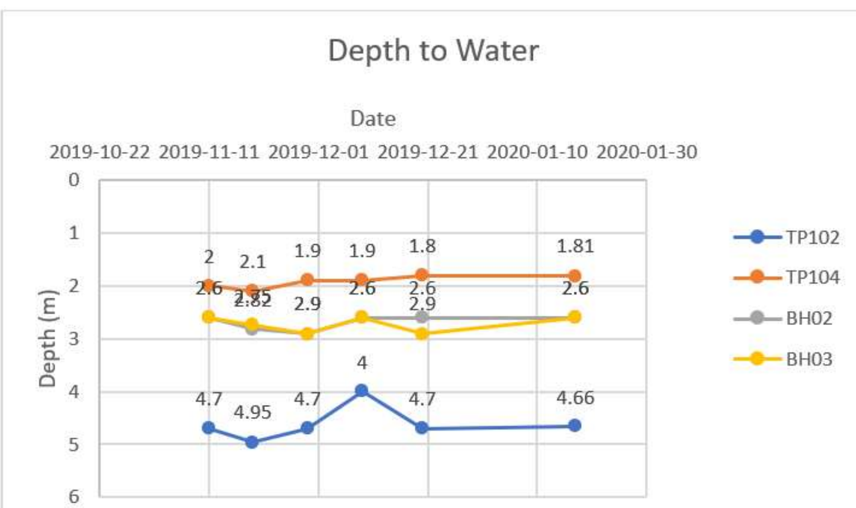
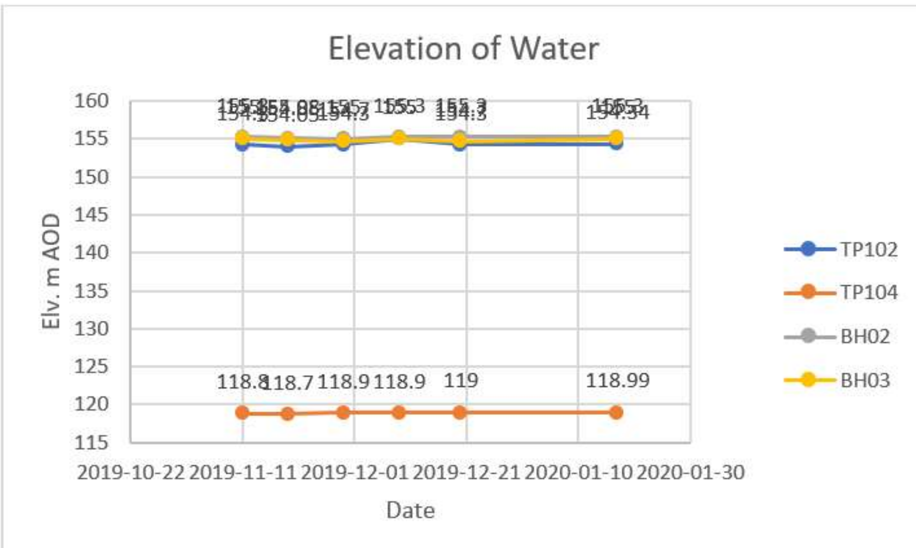


Table 3.7-3 – Summary of Water Elevations in standpipes

Well ID	Collar Elv.	Response Zone Depth	Visit 1 11/11/19	Visit 2 19/11/19	Visit 3 29/11/19	Visit 4 9/12/19	Visit 5 20/12/19	Visit 6 17/1/20
TP102	159.0	2.0 to 5.0	154.3	154.05	154.3	155	154.3	154.34
TP104	120.8	3.5 to 5.5	118.8	118.7	118.9	118.9	119	118.99
BH02	157.90	2.0 to 3.0	155.3	155.08	155	155.3	155.3	155.3
BH03	157.60	3.2 to 4.2	155	154.85	154.7	155	154.7	155



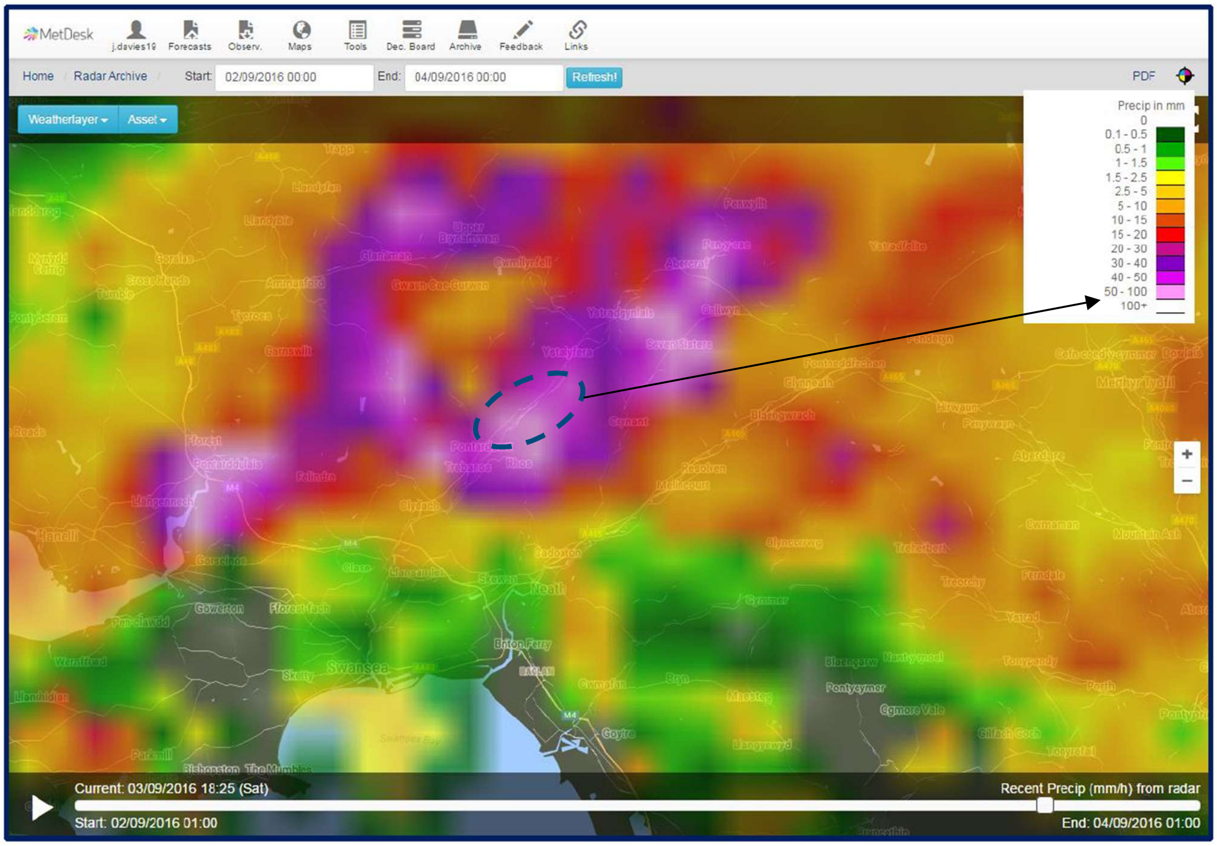


Figure 3.7-1 – Rainfall event at 18:25hrs 3 September 2016

The site was exposed to a significant magnitude rainfall event between 2016-09-02 and 2016-09-04 (NPTC, 2016). This occurred without a slope failure, deformation, or fluidization of the tip material. *Figure 2* is copied above as Figure 3.7-1.

This report (NPTC 2016 *Section 2.2*) states that there was 13 hours of continuous rainfall starting 08:00hrs on 3 September. Most of the rainfall was between 1mm/h and 5mm/h peaking at 18:00 hrs with 19.3mm for the hour, but the rainfall peaked above 50mm/h at 18:25hrs (Figure 3.7-1 above). Following this the northwest of the Country Borough began to suffer from surface water, ordinary watercourse, and river flooding.

We note that this report states that the magnitude of rainfall mobilised a great volume of debris in ordinary watercourses and the capacity of culverts were exceeded. The exceedance was exacerbated by "*a large amount of debris*" mobilised. NPTC 2016 *Figure 7* shows cobbles (and potentially boulders) mobilised onto the pavement beneath culvert CUL_318. Another Culvert CUL_0427 is about 350m away from Tip 2 and shows significant mobilisation of material and downcutting of the soil.

3.8 Inclinometer Data

An inclinometer casing is a circular plastic pipe with two sets of groves in it. A sensitive piece of equipment is lowered down the grooves that records movement relative to the distal end of the casing noted at given depths. It is essential for valid reasons that the distal end of the inclinometer casing is installed in unmovable ground as all measurements are taken relative to the distal end.

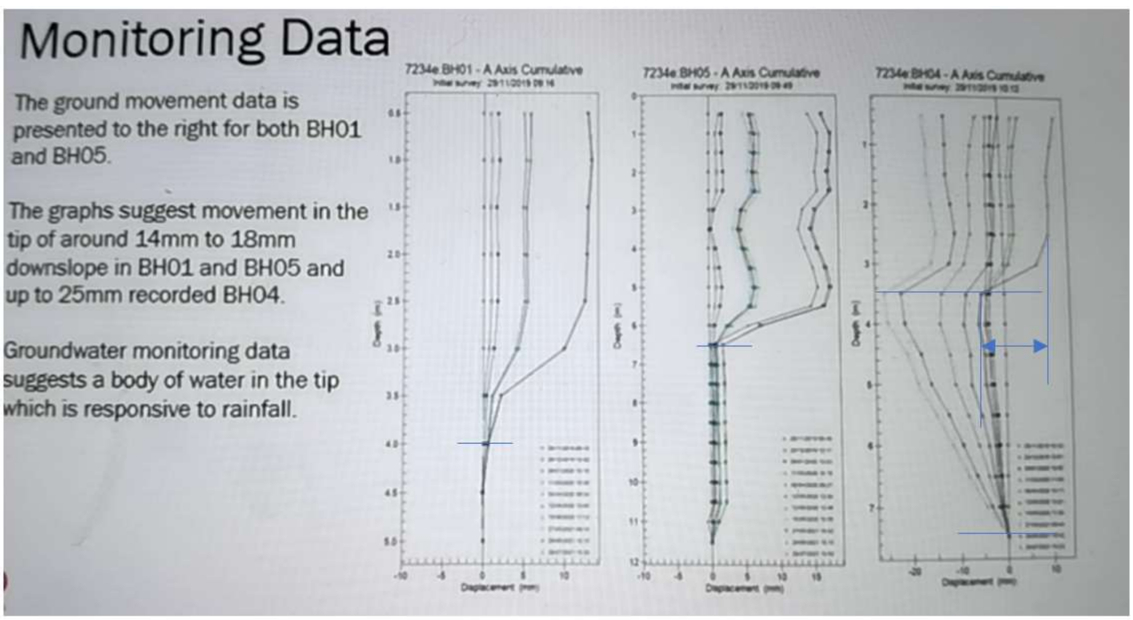
Question 9

What are the inclinometer readings showing? Do the deflections presented show consistent downslope movement? Is there any correlation with movement and Vibrating Wire Piezometers i.e. pore pressures build, slope moves, pore pressures dissipate (as an example)?

Section 5.4.3 – "*it is possible this initial 20mm of movement was some settling of the inclinometer installation which is common.*" The current movement appears to be within the 20mm, so is this still the inclinometer casings still bedding in?

BH01	~4.0 m depth	14 mm total movement
BH05	~6.4 m depth	16 mm total movement
BH04	~7.4 m depth ~3.6 m depth	~23 mm uphill total movement ~13 mm downhill total displacement
BH04 values greyed out due to the spurious readings and potentially not being effectively embedded in a non-moving stratum		

To put this into the context of the tip, a drill hole 150mm diameter was driven or hammered through the tip material ranging from clay to 700mm boulders. It is conceivable that a larger particle was pushed uphill slightly and through gravity is settling back. The backfill around the anulus of the inclinometer was noted to be "bentonite/cement surround" It is plausable that the bentontite cement slurry drained away into the tip in one of the more permeable layers.



Does BH04 (and other casings) inclinometer casing show movement as modelled in the Limit Equilibrium Models with the same water table??

Question 9a

How were the inclinometer casings fixed into the overburden / coarse discard before being anchored in the rock?

BH04 does seem to show some unusual movement.

Original Question 12

Is the contention that the tip is "*actively unstable*" based on the inclinometer data alone?

We note that the cable percussion rig would likely have formed nominal 150mm diameter holes and the inclinometer casing is 85mm (or 70mm). ESP's states that "*20mm of movement was some settling of the inclinometer installation which is common*" (ESP7234e02 Section 5.4.3). As shown in the Figure below, 85 mm casing may show more than 20mm of "settling" movement.

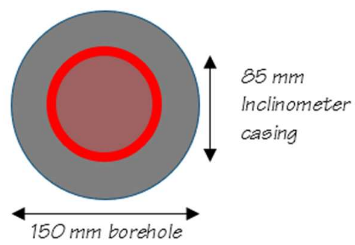


Figure showing borehole and inclinometer casing relative sizes.

3.8.1 Possible NPTC Response to Question 9a and Question 12

Copied from above: "*The installation in BH04 is different; it is likely that the base of this inclinometer is not fixed like BH01 and BH05. In this scenario, settlement of this installation/inclinometer can occur, so judgement was not based on the information from BH04*."

3.8.1.1 Follow on comment from Tegwch

The inclinometer reading in BH04 may not be reliable enough to make definitive decisions on, and BH01 and BH05 may be due to settling in as the readings are less than the 20mm of movement noted by ESP. The "movement" may be relaxing of the ground post drilling.

It is noted that the bentonite-cement grout mix proportions for fixing the inclinometer casing is not stated in the report. If a grout mix is too strong and does not replicate the surrounding ground conditions this can be shown as spurious movement.

Assuming a permeability from Hazen's rule, an alternative hypothesis may be that the grout body of the inclinometer casing may not be consistent over its full length/depth.

As the figure above shows, there can be about 70 mm of movement required before the inclinometer casing reaches the borehole wall.

3.9 Slope Angle

Question 10

A 27° slope is not as steep as contended by NPTC and ESP who refer to the slope as "*over steep*". The angle was estimated from ESP's Limit Equilibrium model (assumed to be natural scale X&Y direction)) and subsequently measured from LiDAR data provided by LLE GeoPortal For Wales.

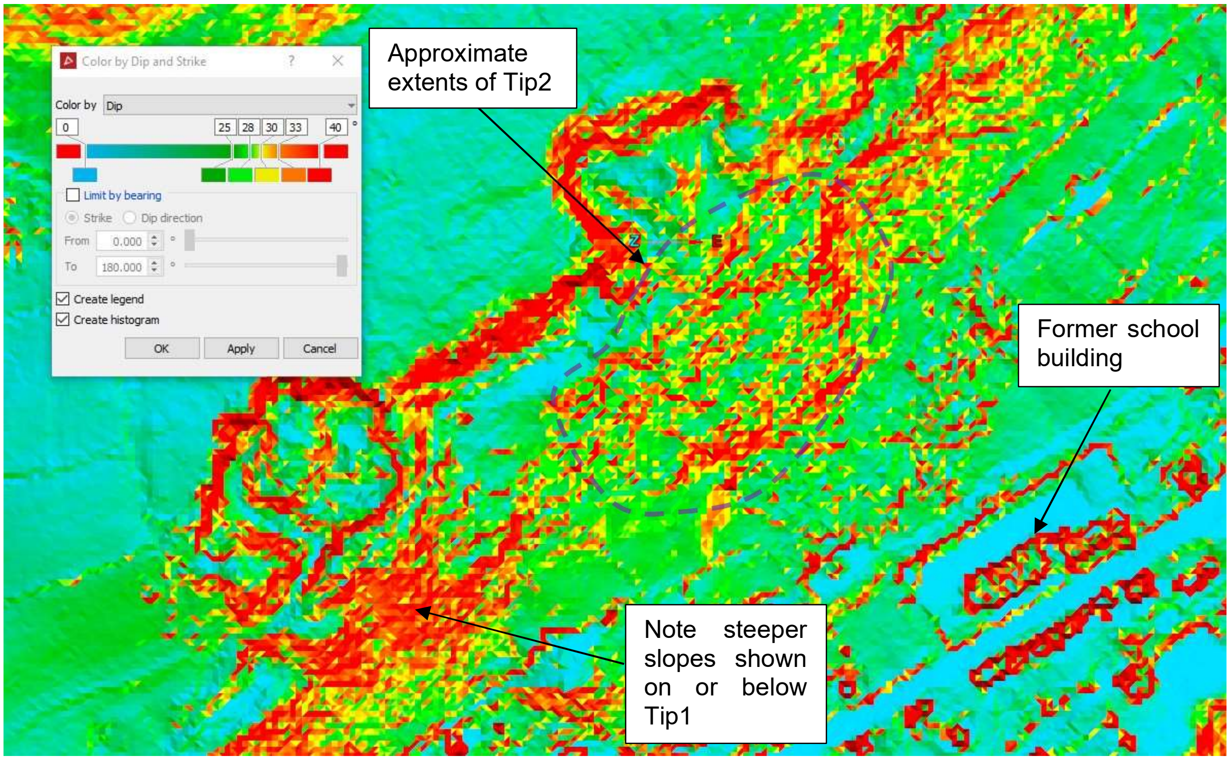


Figure 3.9-1 – Colourised slope angles from the Digital Surface Model

Figure 3.9-1 was developed from a grid created using lowest return values to provide a topographic ground surface to simulate vegetation removal. The steepness of each cell is represented by a colour. The angles can be seen in the key in the figure. The average dip of the approximate tip extents is 26° dipping towards 137° (southeast).

https://lle.gov.wales/GridProducts#data=LidarCompositeDataset 50cm DSM tiles were used and can be seen in Figure 3.1.1.1 above.

The AGS seems to suggest debris flows on this angle of slope would be a "*rare*" instance.

If the modelling is revisited, with potentially more realistic parameters, the remedial options may need to be revised. For instance, the soil nailing with Tecco netting as the requirement would need to retain the active layer not the whole tip.

The red slope(s) towards the lower extent of the tip suggest that there was 'velocity sorting' as mentioned above where the larger particles generally travel further down the slope due to them having more energy than the sands and gravels. The larger particles generally have a higher friction angle and therefore, when they are "*interlocking*" can form a steeper slope.

Note – A tip near Wattstown is substantially thicker - https://goo.gl/maps/Ze1CS16KMmxXizYQ7 and has been supported by soil nails and Maccaferri double twist netting.

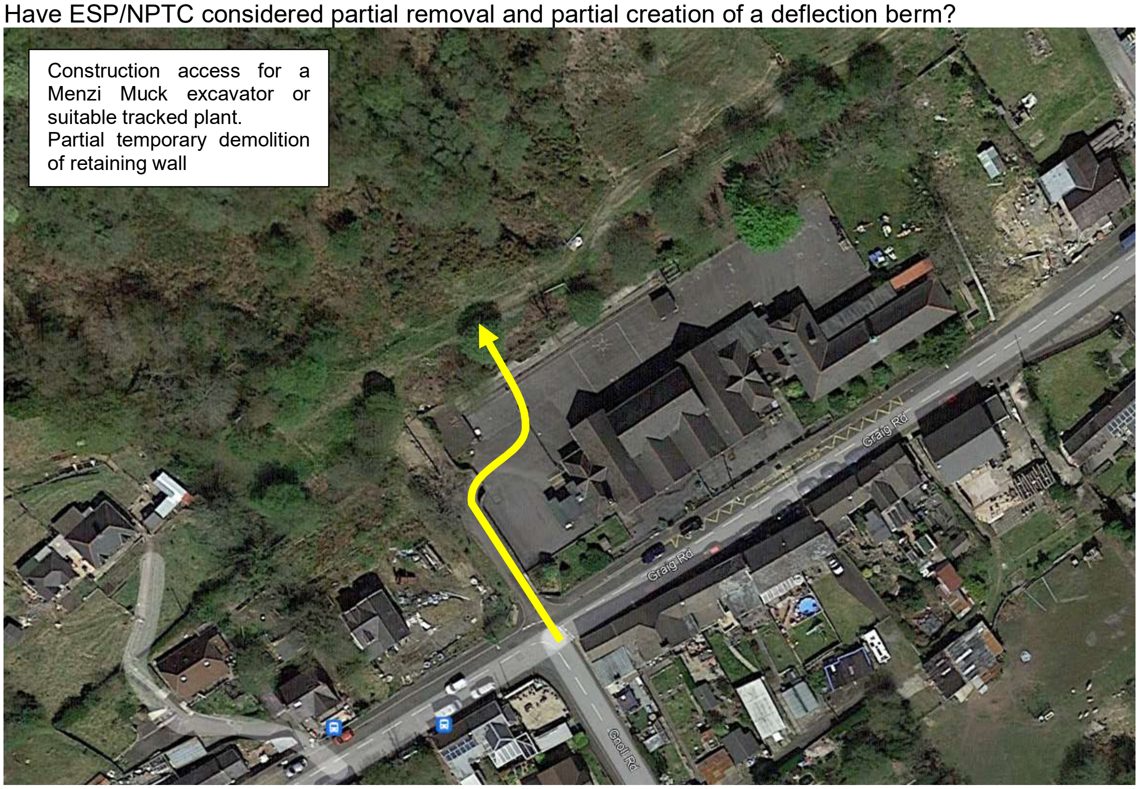
Geobrugg, Maccaferri, and Trumer all provide debris flow nets which are designed to retain debris flows. The structural netting can be infilled with finer aperture mesh and even 3D monofilament soil retention mats such as Greenax or Enkamat. However, to design these estimates of the impact energy would be required.

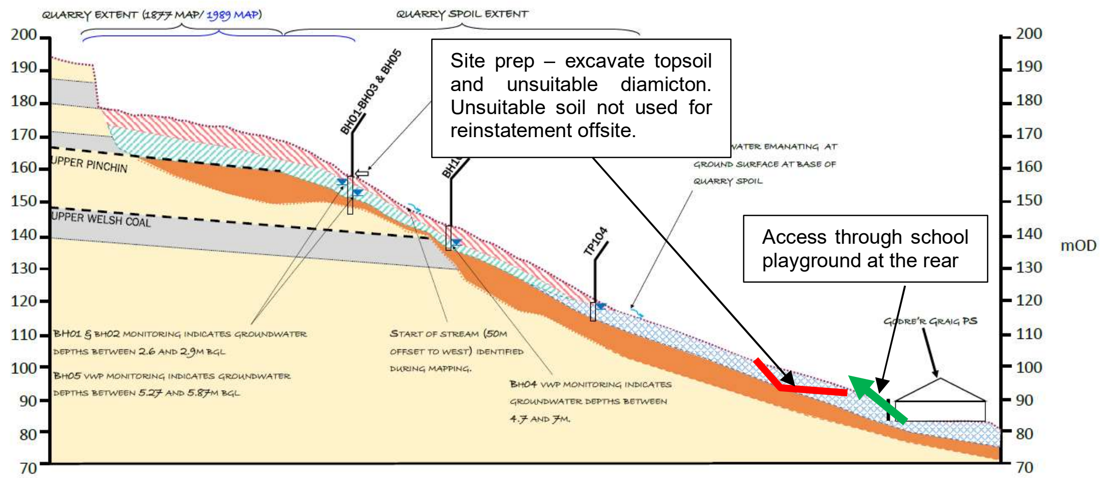
3.10 Possible Remediation Options

The options proposed by NPTC seem to be linear in thought and based around a 27° slope being "*over steep*", therefore have only proposed traditional construction. Rope access construction was not mentioned in the remedial options. Rope access technicians often work on vertical (or overhanging) slopes and structures. Many instances can be found working on slopes considerably steeper than the subject slope.

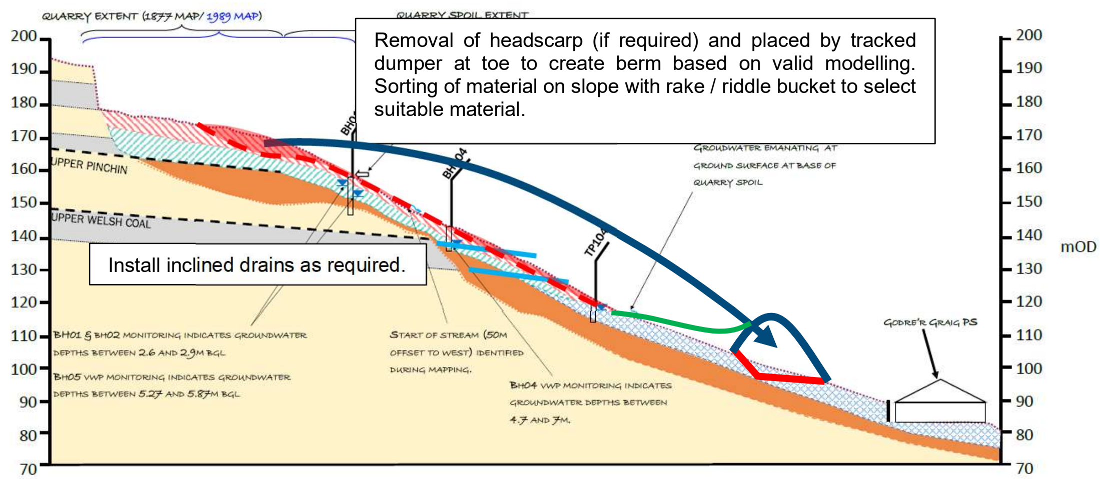
Original Question 11

Have ESP/NPTC considered partial removal and partial creation of a deflection berm?





https://www.menzimuck.com/en/areas-of-operation/special-civil-engineering/ could be used for early enabling work. However, with slope angles in the mid-twenties a bulldozer (D8) could be used to push the material downhill to create the bund and removal of the hazard satisfies the Hazard Hierarchy.



The former rear playground of school can be used as a staging area for unsuitable / offsite material.

The construction program could use an observational approach and adapt elements as required such as drainage pathways, herringbone drains, perforated pipes, and others.

As the limit equilibrium modelling would have a substantial amount of disturbing forces removed (head scarp and water) and if placed at the toe add to the restorative forces. The remaining tip stability assessments may suggest the building can be used for other purposes.

3.10.1 Response by NPTC

None Received

3.10.1.1 Follow on by Tegwch

Was a rope access drainage program considered? 103mm diameter drainage pipes can be installed using a symmetrix or odex rope access drilling system. These can be installed at depths up to 10m. These could lower the water table and therefore increase the Factor of Safety.

If a model is analysed and found to be valid, the extent and design of a barrier could be refined to be a more cost-effective remedial option that may need less of the length or a different configuration than the 110m length proposed by ESP. At the moment all the assumptions are based on a 2D plane from the disused quarry at the crest, through the deepest portion of the slope and then to the building. If a mass movement event is a viable outcome then the topography should be analysed to see where a mass movement event would flow.

The redevelopment of the site has not been factored into the cost estimate. This should be identified prior to the final decision being made.

Continuing with the traditional construction approach, has the use of a bulldozer (D8) been excluded? This could keep the material on site and a safety bund created at the toe of the slope. The D8 could work across the slope cutting across the unacceptable strata as required.

3.11 Independent Entity Checking ESP's Parameters and Findings

Original Question 13

A Category 3 check is an independent engineering firm using the same "factual" data as ESP, and comparing their own conclusion with ESP's.

There was intimation by NPTC that The Coal Authority was an independent checker. However, the Coal Authority's report has not performed any analyses to estimate slope stability and therefore cannot be considered an independent checking organisation.

CA Consequences, 2019:

- *A major failure of the quarry spoil <u>could potentially</u> reach Godre'r Graig School. <u>Although unlikely</u>, a slope stability analysis based on available information supported by ground investigation data would be beneficial to assess the extent and likelihood of such a failure.*
- *Blockages of the drainage infrastructure to the rear of Godre'r Graig Primary School would result in flooding and potential slope instability."*

Emphasis provided through underlining.

There is no definitive statement on stability from the Coal Authority and that report was issued prior to the investigation being completed. Although the Coal Authority do note that "*A major failure of the quarry spoil could potentially reach Godre'r Graig School. Although unlikely,*" ….

Since parameters used in the basic limit equilibrium modelling may be considered overly conservative an independent check would be significantly less than the £250k demolition option. This is routinely performed in engineering. Network Rail use Category 3 checks on earthworks projects.

3.11.1 NPTC Response to the Category 3 Check

Earth Science Partnership is independent and work on this project has been carried out in accordance with current guidance and standards. Any future mitigation design should be independently checked and consultation with stakeholders enabled.

3.11.1.1 Response to NPTC

Why is there such resistance to an independent geotechnical consultancy verifying Earth Science Partnership's assumptions and reports?

For clarity, the Parties involved in this discussion about Category 3 checks:

- Party 1 – Neath Port Talbot Council
- Party 2 – Earth Science Partnership
- **Party 3 – Independent Checking organization** (yet to be appointed)

The appointment of a Third-Party checking organisation may save hundreds of thousands of pounds if the modelling and assumptions published to date are not valid.

3.12 Failure / Debris Flow Mechanism

Question 14

See (original) Question 3 above. Please explain the mechanism of how the data provided in the ground investigation has been used to model a debris avalanche / flood / flow event impacting the school. As mentioned in NPTC's answer "*The FoS approach was adopted as it considers the ratio of disturbing forces against restoring forces and gives a simple indication to stability*" – this does not address how the slope is estimated to deform over time.

We do not believe that this has been satisfied for 2D let alone 3D.

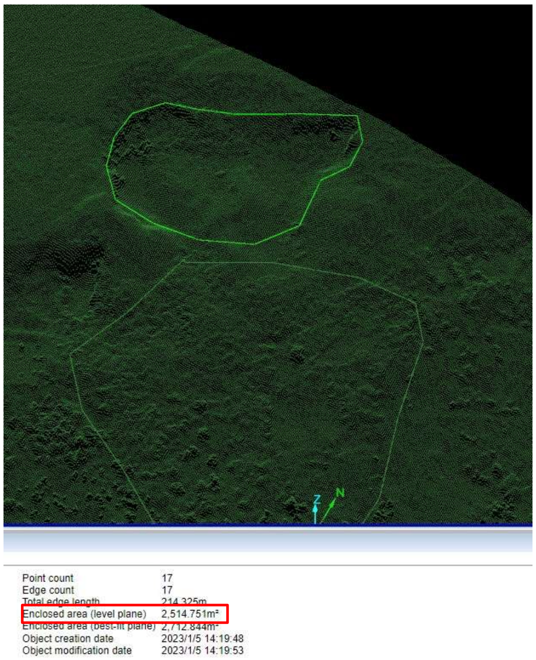
There has been no justification of the reduction of phi values from lab test data or the lack of inclusion of cohesion in the "*reasonable case*". The modelling of the critical slip surface has unusual Factor of Safety contours at the downslope boundaries (entrance and exit) which have not been explained.

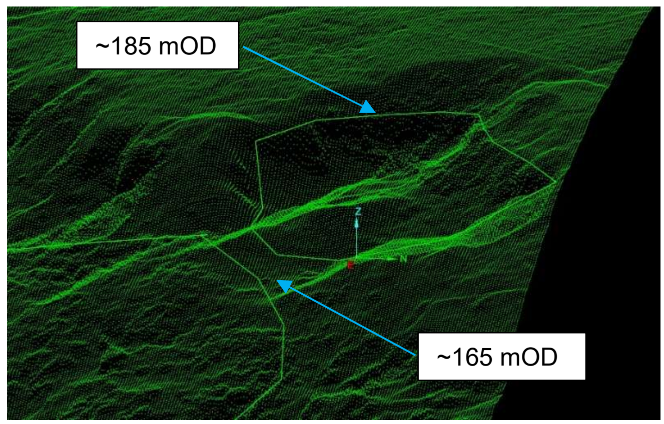
No higher order or mass movement modelling has been presented.

3.13 Original Quarry and Tip 2 Volume

Estimates of quarry volume were made using the LiDAR file. The crest of the rock slope was traced around the void above Tip 2.

The quarry directly above Tip 2 was estimated to have a 2D area of about 2,500m^2.





Figures 3.13-1a and -1b – Crest of highwall in quarry

Using a conservative approach assuming the rock was quarried leaving vertical slopes as highwalls, and rock was excavated from 185mOD to 165mOD this would give a highwall height of approximately 20m. Simple volume calculations of 2,500m^2 x 20m = 50,000m^3 (no allowance was made for the volume of tipped material currently in the quarry). This suggest that about 50,000m^3 of in situ rock was excavated. It is highly improbable that 100% of the rock was tipped on the slope.

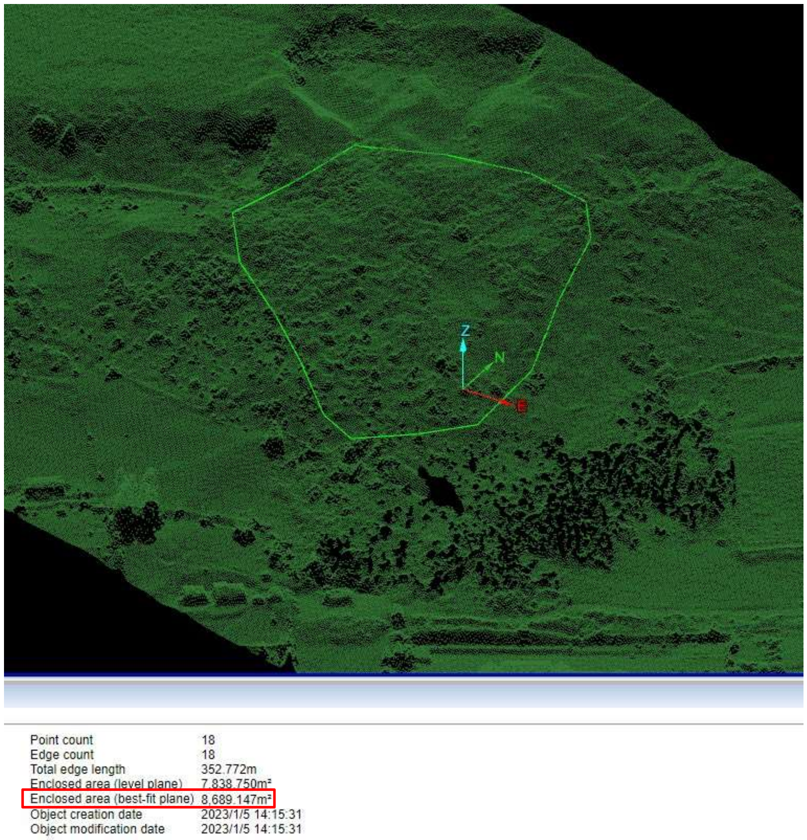


Figure 3.13-2 – Estimate of area occupied by Tip 2

The approximate boundary of Tip 2 was estimated to be 9,000m^2 (see Figure 3.13-2). Using NPTC's consultant's estimate of Tip 2's volume of 87,395m^3. 87,395m^3 ÷ 9,000m^2 = 9.71m thickness of end tipped coarse discard across the slope. The topography of the slope suggests that this is incorrect as the tipped material tapers into the hillside (See Figure 3.13-3 below). Especially as the thickest deposit as modelled is in the old quarry workings.

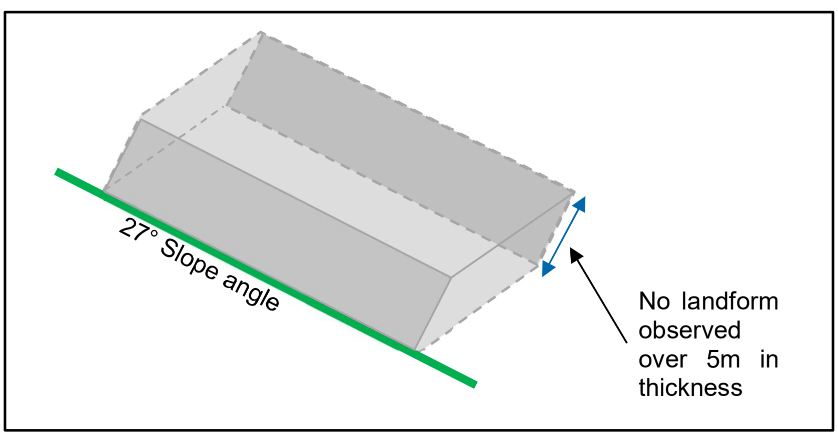


Figure 3.13-3 Pictorial representation of cross section through the Coarse Discard to satisfy 87,395m^3

Note no adjustment was made from vertical to normal to slope profile as shown in Figure 3.13-4 below.

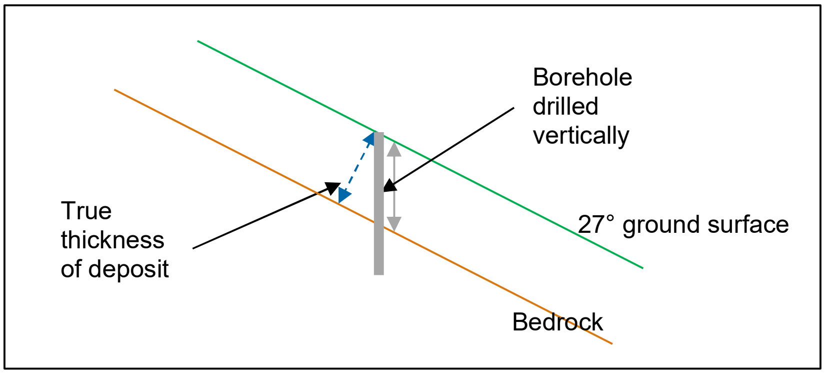


Figure 3.13-4 – Graphical Depiction of drilled depth versus thickness

The following three tables summarise the ground logged as anthropogenic deposits and natural deposits.

Table 3.13-1 – Summary of Trial Pit Records

Strata	TP01	TP02	TP03	TP04	TP05
Made Ground	0.4	0.2	-	0.9	0.1
Diamicton	1.8 (EoTP)	2.8 (EoTP)	2.8(EoTP)	2.9 (EoTP)	2.7(EoTP)

Notes:
- Shaded cells are trial pits excavated within the probable extents of Tip 2
- EoTP denotes end of trial pit. Termination criteria not included on the pit logs

Table 3.13-2 – Windowless Sample Records

Strata	WS01	WS02	WS03	WS04	WS05	WS06
Made Ground	1.7	1.6	1.1	0.1	0.1	0.2
Diamicton	4.0 (EoH)	5.0 (EoH)	3 (EoH)	3.7 (EoH)	2.7 (EoH)	5(EoH)

Note: No window sampler holes are thought to have been progressed through Tip 2 deposit.

Table 3.13-3 – Borehole Records

Strata	BH01	BH02	BH03	BH04	BH05
Made Ground	4.0	3.1 (EoH)	4.2 (EoH)	6.0	5.25
Weathered Rock	5.0			-	7.7
Rock	5.3 (EoH)			7.2 (EoH)	11.1 (EoH)

Notes:
- Strata divisions based on borehole logs and divided into natural strata and Made Ground and does not differentiate Upper Discard & Lower Discard
- EoH denotes End of Hole. Termination criteria not stated on logs.

If the bank volume of the quarry excavation is about 50,000m^3 there appears to be a discrepancy between the estimated volume of discard on the slope and what may have been discarded even if a bulking factor is applied. The percentage of useable quarry stone to quarry waste is not known.

However, if a depth of 5 m (average (mean) of borehole before rock was encountered was 4.5m) is applied uniformly across the tip area, then the volume of Tip 2 would be about 45,000m^3. This is still significantly larger volume than a conceivable percentage of discard from the quarry. Tegwch acknowledges there may have been some additional discard from the adits, but it is quite likely that the waste from the adits was discarded as close to the adit as practicable to reduce costs.

The estimated volume of the tip is a significant factor in the remedial options cost analysis.

4.0 CLOSURE

The Godre'r Graig Resident's Committee respectfully requests that the decision marking the building for demolition should be staved until responses to the all the questions raised above are received and verified.

At the moment, the ground model used in the modelling does not appear represent the properties of the slope nor the water table. In addition, a limit equilibrium model cannot be used to represent how the slope will deform over time or whether the slope may become fluidised generating a debris flow that may impact the building.

There appears to be a discrepancy between the volume of the rock excavated from the quarry and the volume of the material represented as Quarry Waste on the slope.

It appears that the approach to remedial options was fairly limited and only followed traditional construction practices. Tegwch would welcome a review of alternative options.

If it is easier for NPTC, Tegwch can produce a succinct series of questions for resolution.

5.0 REFERENCES

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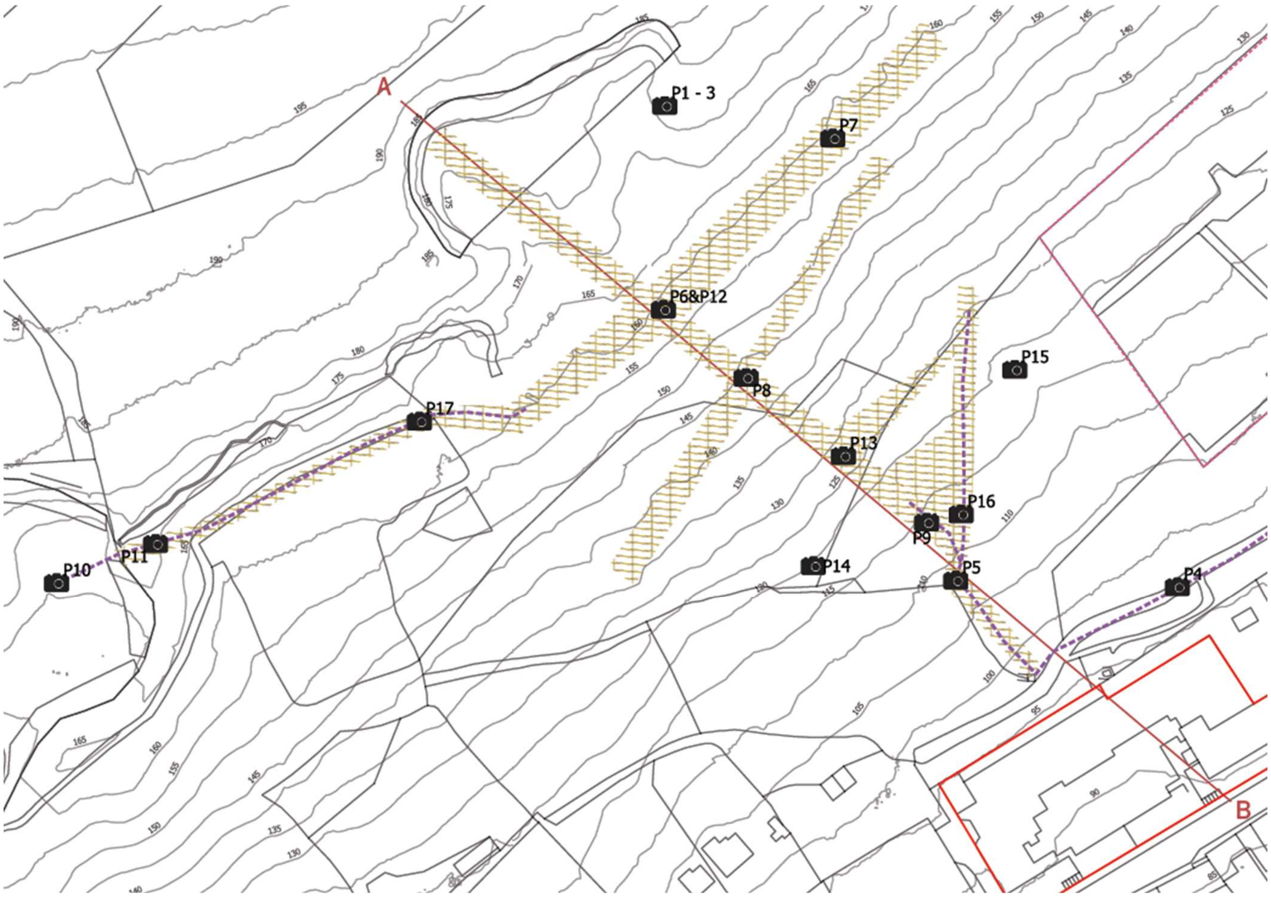
TABLES

Table B - Particle Size Distribution Summary

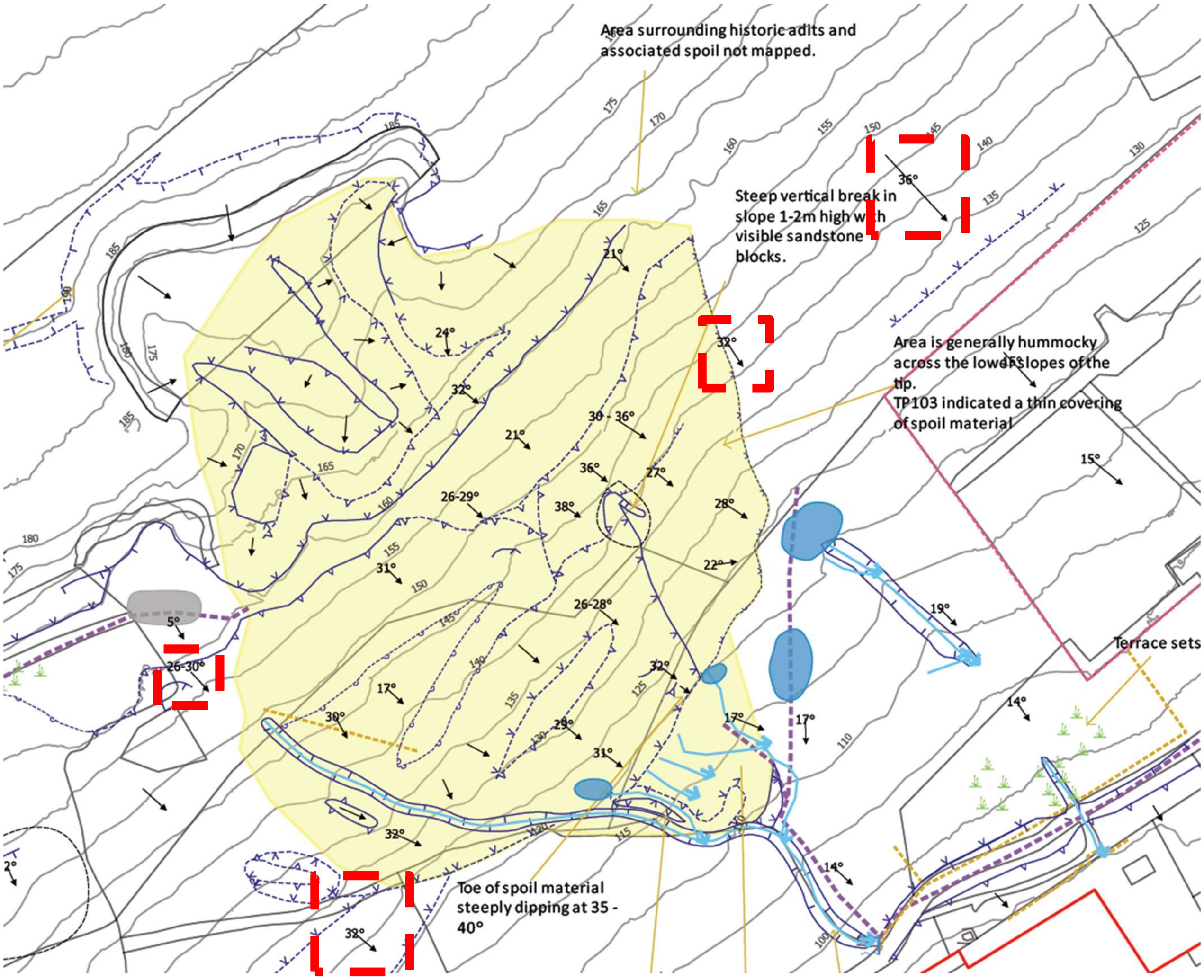
Pit	Soil Type	TP101	TP101	TP101	TP102	TP102	TP102	TP102	TP102	TP103	TP103	TP103	TP104	TP104	TP104
Size (mm) Depth (m)		0.6	1	2.9	1	2	2.6	2.9	3.8	0.3	0.6	1.5	1	3.3	4.5
		% passing sieve													
125	Cobbles	**100**	100	**100**	**100**	100	**100**	100	**100**	100	100	100	**92**	100	100
90		**93**	100	**100**	**77**	100	**100**	100	**100**	94	100	94	**89**	100	88
75		**83**	83	**100**	**65**	96	**100**	97	**100**	90	95	94	**84**	100	75
63	Gravel	**80**	72	**100**	**58**	90	**100**	93	**100**	87	85	80	**80**	100	70
50		**77**	40	**90**	**53**	79	**100**	92	**98**	76	69	73	**59**	100	60
37.5		**72**	22	**82**	**45**	62	**88**	84	**93**	71	62	61	**47**	100	56
28		**62**	13	**74**	**34**	47	**82**	77	**84**	65	59	52	**39**	100	53
20		55	9	58	25	33	72	69	77	59	52	43	33	97	49
14		51	7	53	19	27	69	61	67	56	48	40	28	96	46
10		47	6	43	15	22	62	53	59	51	44	37	24	95	43
6.3		41	5	34	12	17	57	42	49	46	37	34	20	93	39
5		37	5	30	11	16	55	36	46	44	34	32	18	92	37
3.35		33	4	27	10	15	52	30	41	42	30	30	17	91	34
2		29	4	23	9	13	49	25	36	40	26	27	16	90	31
1.18	Sand	22	3	21	9	12	47	22	29	37	24	26	14	86	28
0.6		18	3	19	8	11	44	19	25	34	21	23	14	82	27
0.425		17	3	18	8	11	44	18	23	33	21	22	13	80	26
0.3		16	3	18	7	10	42	18	21	31	19	21	13	79	25
0.212		15	3	17	7	10	41	17	20	30	18	18	12	77	24
0.15		15	2	16	7	9	38	16	19	29	17	16	11	76	22
0.063	Silt	13	2	13	5	6	32	15	16	25	15	12	8	70	20
0.02							25		12					62	
0.006							18		10					54	
0.002							12		8					45	
Cobbles		20	28	0	42	10	0	7	0	13	15	20	20	0	30
Gravel		51	68	77	49	77	51	68	64	47	59	53	64	10	39
Sand		16	2	10	4	7	17	10	20	15	11	15	8	20	11
Silt and Clay		13	2	13	5	6	-	15	-	25	15	12	8	-	20
Silt							20		8					25	
Clay							12		8					45	
Phi		26.5		33.5	44.5		42		47				39		
c		17		16	15		2		10				2		
Pit		TP101	TP101	TP101	TP102	TP102	TP102	TP102	TP102	TP103	TP103	TP103	TP104	TP104	TP104
Depth		0.6	1.0	2.9	1.0	2.0	2.6	2.9	3.8	0.3	0.6	1.5	1.0	3.3	4.5

Cells shaded tan show fraction of material not included in the shear box tests (bold text).

FIGURES



ESP Figure 1a: Site Plan – Plates Locations



ESP Figure 2 – Geomorphological Mapping

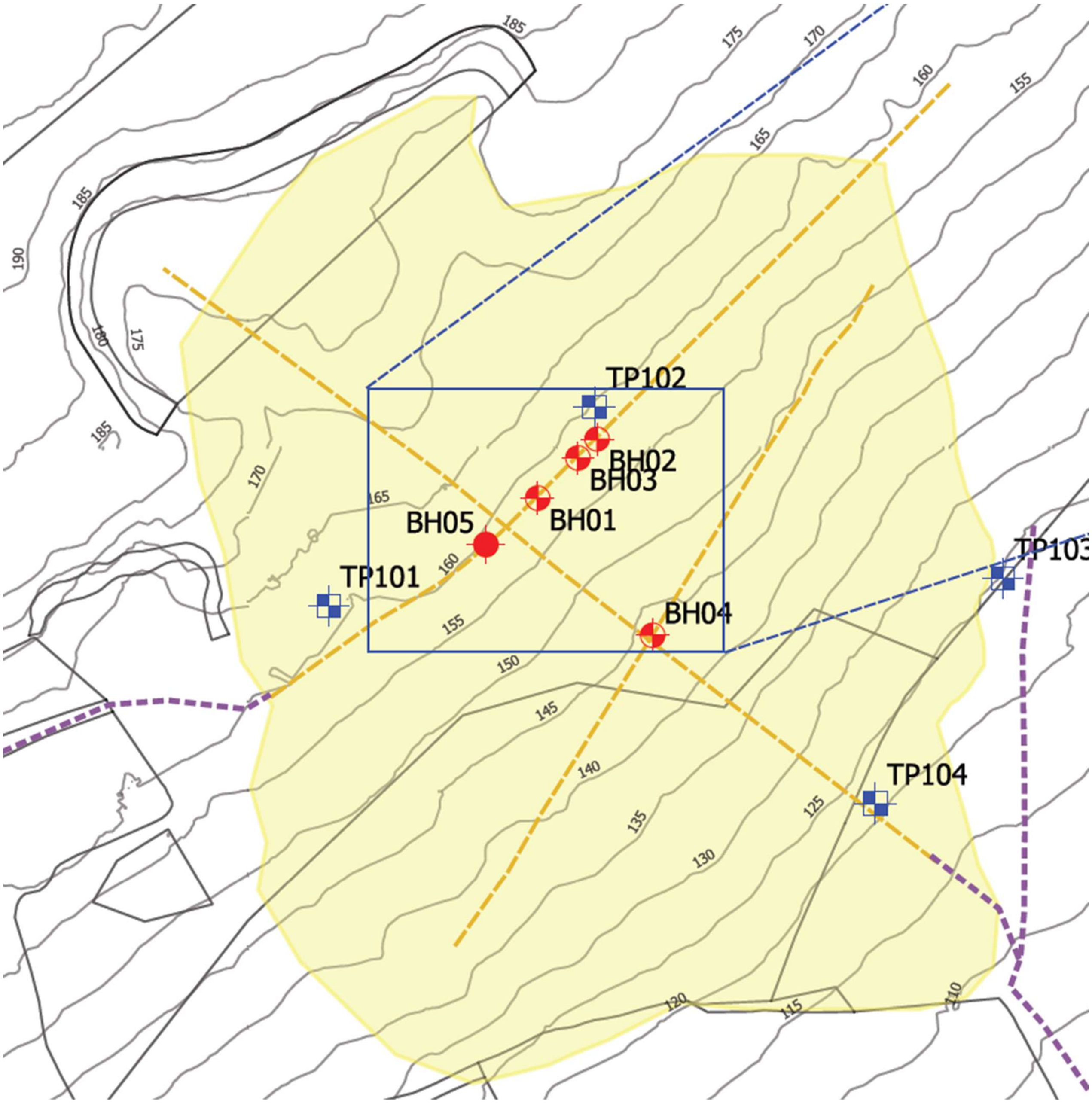


Figure 5: ESP Investigation Point Plan