7234e.05 - Godre'r Graig - Note on Governing Board of Godre’rgraig Primary School Letter (24th May 2023). Re: Future of Godre’rgraig Primary School

No representation on the stability of the hillside or the tip is made. It is unclear who the author/s are, their qualifications or experience is in South Wales. The key points being raised by the Governing Board/Tegwch appear to be:

1. **Material Parameters**: Over conservative parameter assumptions for the ‘Reasonable Case’ ground model, along with an underestimation of the positive contribution of large particles to soil shear strength.
2. **Method of Analysis**: Deemed unsuitability of limit equilibrium analysis and clarity on an acceptable factor of safety.
3. **Impact of Rainfall**: Clarity on the definition of a 1:100 year rainfall event, and how this might impact porewater pressures (correlation of rainfall to porewater pressures).
4. **Remediation Options**: Consideration of alternative remediation measures, including re-profiling.
5. **Material Volumes**: The estimated volume of the tipped material and the predicted volume of a failure.
6. **Instrumentation and Slope Angles**

ESP responded to the NPTCBC brief and associated time/budgetary constraints in a professional manner, considering industry standard practice and relevant guidance. Some key points that need to be considered:

- There is no such thing as perfect knowledge when it comes to geotechnical design.
- No design can have a zero probability of failure and the probability of failure increases with increasing uncertainty.
- Where the consequences of failure are significant, it is incumbent on the designer to adopt a cautious approach. The consequences of a single or chain of linked slope failures above an occupied primary school could be catastrophic. Some comments relating to the recent Coal Tip Safety (Wales) White Paper, May 2022: https://www.gov.wales/coal-tip-safety-wales-white-paper are included the end of this note for context.

Previous work included a risk management or mitigation options assessment, where different options were scored for effectiveness, durability, practicability, sustainability, and cost. The scoring system was given +1, for a positive impact, 0 (or zero) for a neither negative or positive impact and a -1 for a negative impact, all relative to the other options. The risk management or mitigation options that scored the highest were:

1. A combined approach of incorporating drainage to create betterment only, install monitoring points and produce warning system, 2 points; or
2. Close the school such that the tip no longer represents a risk to school users, 1 point.

The assessment showed that physically removing the tip or some combination of hard engineered structure(s) were unfavourable, with -1 point and -4 points respectively. These were the options ESP was asked to explore by NPTCBC in the remediation options report.

ESP Comments/Observations:

1. Material Parameters

We can never have ‘perfect’ knowledge when it comes to geotechnical design. There are two major sources of uncertainty: inherent variability due to the natural variability of geotechnical properties and a lack of knowledge; additional measurements or improved theories might assist in reducing the latter uncertainty. In all geotechnical assessments, the designer needs to deal with uncertainties, either implicitly or explicitly.

Section 2.4.5.2 of BS EN 1997-1:2004 discusses the selection of characteristic values of geotechnical parameters and includes numerous references to the need to be cautious. In practice this means that where reliance on ascribed values is required suitable statistical data is required for design. Adopted characteristic values can often be defined as less than the lowest measured value.

This may lead to a reasonable question; why hasn't more data been acquired? This may be linked to decisions taken within NPTCBC and the previous position of any risk is considered unacceptable to the school children and staff.

As previously mentioned in our reports and subsequent correspondence, additional assessment was recommended and discussed with NPTCBC to obtain further data on the ground model and materials so that more representative material parameters could be obtained, and to understand lateral and vertical variability. This was rejected by NPTCBC as they did not want to undertake any additional site investigation or assessment as a monitoring regime/early warning scenario was not acceptable to the authority because of:

- Site access difficulties;
- Site Topography;
- Time requirements for the results; and
- Cost.

The Governing Board's letter states that our parameter selection was based upon the 20mm and finer soils that were tested which is incorrect. Our parameter selection was based upon field observations, descriptions, lab data and empirical relationships. The selection of data for modelling was based upon the available information considering the uncertainties.

2. Method of Analysis

The suitability of adopting a limit equilibrium design approach is questioned in the Governing Board's letter, which suggests that they consider more advanced analytical methods should be adopted.

Limit equilibrium methods of analysing slope stability problems could be reasonably considered as the current 'industry standard' methodology in the UK. It is valid to consider more advanced analysis for a final design if the consequences of failure are significant, as would be the case if the school were to remain in place.

Given the volume and quality of available geotechnical data it is difficult to carry out a reliable Finite Element (FE) analysis. Significant assumptions would be required on the strain-dependent stiffness of the various materials identified, which would mean that any displacements predicated by an FE analysis would be subject to significant uncertainty.

It's worth noting that BS EN 1997-1:2004, 2.4.1 (2) states: *"It should be considered that knowledge of the ground conditions depends on the extent and quality of the geotechnical investigations. Such knowledge and the control of workmanship are usually more significant to fulfilling the fundamental requirements than is precision in the calculation models and partial factors."*

ESP and NPTCBC have discussed options for betterment, i.e., an improvement over the 'baseline' stability, rather than achieving a defined target FoS. The degree of betterment would normally be considered as part of a remediation options assessment and agreed criteria should be established that any design must satisfy involving the client in consultation with the designer and others. Minimum values should take account of both the uncertainties on parameter assessment, as well as the consequences of failure. The discussions with NPTCBC concluded that they were not willing to undertake any additional site investigations or assessments due to issues with:

- Site access difficulties;
- Site Topography;
- Time requirements for the results;

- Possibility for ongoing monitoring, or early warning system; and
- Cost.

Traditionally, for a limit equilibrium analysis, the Factor of Safety (FoS) against failure of a slope or earthworks has been considered as a target 'lump' factor, which should represent a minimum value that an analysis of failure can achieve.

When considering an acceptable FoS for the traditional 'lump' factor approach ICE (2012) [*ICE Manual of Geotechnical Engineering, Vol 2*, ICE Publishing, 2012], Section 69.4.1, pg. 1044, refers to Trenter (2001) [*Earthworks: a Guide*. London, Thomas Telford] who comments that the chosen FoS will depend on:

- Technical assessment of the geotechnical data collected.
- Judgement on the safety, environmental and economic costs of any failure.

ICE (2012) also refers to BS6031 (1981) [British Standards Institution. *Code of Practice for Earthworks.* BSI, BS6031], which gives minimum FoS of 1.3 - 1.4 for first time failures.

The probability of failure is never zero, and the probability of failure increases as the uncertainty increases.

3. Impact of Rainfall

In detailed design it is necessary to provide the definition of a 'trigger event'. This will then form part of a basis of a design statement so that it is clear what assumptions have been made in relation to destabilising actions.

The Governing Board's letter seems to suggest the slope may have experienced a rainfall event that exceeds the notional 1 in 100 year event, but that this has not initiated a large-scale failure. There are issues with this presumption because the properties within the spoil heap could be changing with time and there are hyper-local influences such as drainage pathways and ground permeability. For example, heavy rainfall events could result in the migration of fines within the spoil, which could lead to the formation of lower permeability zones or layers, which could result in the build-up of porewater pressures in confined or semi-confined zones (and subsequent slope failure).

Antecedent rainfall and groundwater conditions are likely to be a major factor in the reaction of the slope to more extreme weather events, as we have seen in other locations in the valley. If further design is to be carried out, and if rainfall is deemed to be a significant issue, it would be prudent for meteorologist input to be included. It would also be prudent to carry out further investigations into the hydrogeology of the area on and around the site.

4. Remediation Options

Previous work included a risk management or mitigation options assessment, where different options were scored for effectiveness, durability, practicability, sustainability, and cost. The scoring system was given +1, for a positive impact, 0 (or zero) for a neither negative or positive impact and a -1 for a negative impact, all relative to the other options. The risk management or mitigation options that scored the highest were:

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NPTCBC concluded that they were not willing to undertake any additional site investigations or assessments due to issues with:

- Site access difficulties;
- Site Topography;

- Waiting time for the result;
- Possibility for ongoing monitoring, or early warning system; and
- Cost.

As such, ESP received no further instruction to look at remedial options at the site.

Where slope re-profiling is discussed in the Residents' Report (Tegwch) it appears to be suggested that a cut is made at the current toe of the slope in preparation for creation of a berm. This kind of approach would need to be looked at carefully to avoid inducing a slope failure. There might also be a risk of 'shifting' the problem downslope. That is, placing fill at the toe of the current slope could be applying load to top of a notional down-slope landslide, particularly if a significant berm is formed at the current toe rather than aiming for an overall reduction in the slope angle. Consideration would also need to be given to increasing stresses on natural soils and changing their loading scenario.

The Governing Board's letter/Twgwch report is critical that ESPs assessments have not undergone a Category 3 check. Category 3 checks are commonly carried out in the later stages of engineering design for structures, but also for complex sites. They are not normally carried out on Site Investigation and Assessment reports at optioneering stages.

5. Material Volumes

There are discrepancies between the volumes of spoil estimated by ESP and those quoted in the Residents' Report/Tegwch.

In the ESP Remediation Options report (ESP.7234e.04.3564) the tip volume was estimated, and stated that additional work would be needed to confirm quantities. The volume was estimated by using the mapped area of the tip and an assumed thickness of 5m based on logs and geophysics. The mapped extents were defined through a review of LiDAR data, aerial photographs, site walkovers and topographic plans and is considered reasonable for estimation purposes.

It is likely that the volume will be updated with further information; for example, is it likely to be thinner toward the edges of the tip (unknown at present). There may also be other discard material included in the volumes present (e.g., from adjacent/nearby quarried or mined ground).

Nowak and Gilbert (2015) [*Earthworks: A Guide 2nd Edition*, ICE Publishing, Table 9.4] suggest a bulking factor of 40% to 75% for sedimentary rock. Once the volume of the quarry void has been determined the ratio of the 'useful' volume to the discard volume will be partially a function of the end use of the quarried rock. However, all estimates of spoil volume and quarry void volume will be dependent on having sufficient reliable information to define the boundary between *in situ* rock and all overlying materials, this will include a reliable identification of the differentiation between *in situ* weathered rock and *ex situ* quarry discards.

Considering the current amount of data available it is unlikely that any estimates of the volumes can be fully accurate. Volume estimates should be examined for consistency and reasons for differences considered further. This may have an influence on remediation options; for example, given the consequences of failure, the principle of adopting a cautious approach should also apply to the estimated volumes used as the 'input' to estimates of possible landslide volumes.

6. Instrumentation and Slope Angles

Three inclinometers were installed in the Quarry Spoil Tip, these were in BH01, BH04 and BH05. They were installed in general accordance with requirements of BS5930. The inclinometers are secured within the borehole with a cementitious grout annulus so that they mimic the surrounding ground conditions and thus be able to provide representation of ground movement.

Previous ESP reports and information issued has stated that the inclinometers from BH01 and BH05 have measured downward movement of the tip, in the region of 20mm and 15mm respectively.

The data obtained from BH04 is not as would be expected from a fully functioning inclinometer, in that there is movement being recorded at the base of the inclinometer. As previously stated in our reports, it is considered that this inclinometer base is possibly moving with the surrounding soils, which may explain the data being recorded. Due to this, the data from BH04 has not been used in our assessment. It is worth noting that the graph shows a relative downward movement of the upper horizons.

Previous comments received appeared to suggest that the tip generally measures some 27°. This is not accurate and is a simplification of the tip morphology. We have previously provided a geomorphological map of the tip in our report ref. 7234e.02.3302; the geomorphological mapping shows discrete areas of the tip that are steeper and shallower, as could be expected from a man-made topography.

Coal Tip Safety (Wales) White Paper (May 2022): https://www.gov.wales/coal-tip-safety-wales-white-paper

Welsh Government (WG) proposals aim to introduce a consistent approach to the management, monitoring, and oversight of disused coal tips in Wales. The aim being to create a new legislative management regime for monitoring and maintaining disused coal tips and the establishment of a new public body to ensure compliance and consistent delivery.

Proposals in the consultation document focus on disused coal tips; however, there is discussion of the extent of non-coal tips with a view to developing the framework to apply equally to both coal and non-coal tips, enabling the phasing in of other spoil tips into the regime over time.

It should be noted that the behaviours of non-coal tips are likely to differ to coal tips in terms of the geotechnical properties of the materials, the types of failures that could occur, event frequency and mass mobility.

Brief relevant excerpts of the white paper are presented below verbatim:

- *"4.18. It is proposed that receptors are classified under 5 key groups (1. people/communities, 2. property, 3. infrastructure, 4, ecosystems/environment, and 5. culturally sensitive/significant sites) with 4 Receptor Levels (1. low. 2. medium-low, 3. medium-high, 4. high), as detailed below and in Table 4.* ***We (WG) propose risk to life is always scored as a '4' – high priority, irrespective of receptor group.*** *Tiers 1 to 3 are to be considered where the consequence has the potential to cause injury or impact condition, safe operational performance or serviceability."*
- *"4.20. The hazard level is obtained by multiplying the likelihood of the hazard against the receptor level as outlined in Table 2. Table 3 provides a proposed hazard level key."*

Table 2: Hazard Level Matrices

		Likelihood				
		Highly Probable	Probable	Possible	Unlikely	Rare
		5	4	3	2	1
Receptor Level	4	20	16	12	8	4
	3	15	12	9	6	3
	2	10	8	6	4	2
	1	5	4	3	2	1

Table 3: Hazard Level Key

Hazard Level	
Severe	15–20
Major	7–14
Moderate	4–6
Minor	1–3

The Welsh Government approach will require development to refine understanding/meaning of the terms likelihood and hazard levels. We expect more guidance will be developed with example scenarios with refinement of the nomenclature and definition of terms (e.g., hazard, probability, and risk).

Initial consideration of the white paper approach is provided below:

- The risk-based approach discussed in the Hazard Assessment section of the document presents a rational framework for assessing the hazard level at Godre'r Graig. It is likely that this framework will be extended to non-coal tips in the future.
- The Coal Authority previously noted that *"A major failure of the quarry spoil could potentially reach Godre'r Graig School."* and this aligns with the ESP assessments carried out to date.
- If the school remains in place and occupied then the Receptor Level (Table 2, Hazard Level Matrices) could always be Level 4.
- With no changes/modification to the slope, the Likelihood is at best going to be Possible (but could conceivably be considered higher), meaning the Hazard Level (Table 3) is going to be at least 'Major Hazard'. This is also the case if a failure is considered 'unlikely' and perhaps underlines the sensitivity of the Godre'graig school scenario.
- If the Likelihood of the occurrence of a Ground Movement/Instability hazard could be reduced to 'Rare', a Moderate Hazard Level could be considered.

NPTCBC and stakeholders may view an engineered solution presents a Moderate Hazard level. This needs to be framed considering the potential impacts on the downslope school. As discussed earlier: *"Where the consequences of failure are significant, it is incumbent on the designer to adopt a cautious approach. The consequences of a single or chain of linked slope failures above an occupied primary school could be catastrophic."*