GEO Technical Guidance Note No. 3 (TGN 3)
Use of Downhole Geophysical Methods in Identification of Weak Layers in the Ground

Issue No. 1	Revision: A	Date: 1.7.2004	Page 1 of 6

1. SCOPE

1.1 This Technical Guidance Note (TGN) provides technical guidelines on the use of downhole geophysical investigation techniques in the identification of weak layers in the ground, wh ch could affect slope stability. The technical recommendations contained in this TGN supplement the information given in Chapter 33 of Geoguide 2 (GCO, 1987).

1.2. The guidelines contained in this TGN are based on the findings of the Site Characterisation Study recently completed by the GEO. In the Study, a number of downhole geophysical techniques were examined to evaluate the practicality and performance of their use in identifying weak layers. These included the Gamma Density method, Spectral Gamma Ray method, Neutron Porosity method, Self Potential method, Acoustic Borehole Televiewer method, 4-arm Dipmeter method, 3-arm Caliper method and Electrical Cylinder method.

1.3 Any feedback on this TGN should be directed to Chief Geotechnical Engineer/Planning of the GEO.

2. TECHNICAL POLICY

2.1 The technical recommendations promulgated in this TGN were agreed by GEO Geotechnical Control Conference on 1 November 2000.

3. RELATED DOCUMENTS

3.1 Geotechnical Control Office (1987). *Guide to Site Investigation, Geoguide 2*. Geotechnical Control Office, Civil Engineering Services Department, Hong Kong Government, 362 p.

3.2 Lau, K.C. (1998). *A Review of Downhole Geophysical Methods for Ground Investigatio*n. Technical Note No. TN 4/98, Geotechnical Engineering Office, Hong Kong, 67 p.

3.3 Lau, K.C. & Franks, C.A.M. (2000). *Phase 3 Site Characterisation Study - Stage 3: Evaluation of Downhole Geophysical Methods for Ground Investigation at the Calibration Site*. Technical Note No. TN 3/2000, Geotechnical Engineering Office, Hong Kong, 72 p.

3.4 Lau, K.C. & Franks, C.A.M. (2000). *Phase 3 Site Characterisation Study - Stage 4: Evaluation of Downhole Geophysical Methods for Ground Investigation at the Field Trial Sites.* Technical Note No. TN 6/2000, Geotechnical Engineering Office, Hong Kong,114 p.

4. DEFINITIONS

4.1 Nil.

5. TECHNICAL RECOMMENDATIONS

5.1 The Gamma Density and Spectral Gamma Ray methods [Notes (1) & (2)] are recommended for use as supplementary ground investigation techniques to help to identify weak layers in the ground. These methods have been included in CEDD's ground investigation term contracts to facilitate their use in government projects.

5.2 Useful results may be obtained from the Neutron Porosity method [Note (3)] in identifying weak layers in ground that is saturated with water. However, in unsaturated ground, the method can give misleading results.

5.3 The Self Potential method, Acoustic Borehole Televiewer method, 4-arm Dipmeter method, 3-arm Caliper method and Electrical Cylinder method did not give consistent and reliable results in the identification of weak layers.

5.4 The Explanatory Notes in Annex TGN3 A1 provide further details on the methods and their application.

6. ANNEX

6.1 TGN3 A1 – Explanatory Notes.

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EXPLANATORY NOTES

1. THE GAMMA DENSITY METHOD

1.1 The principle of the Gamma Density method is to irradiate the target material with medium-high energy collimated gamma rays and to measure their attenuation between the tool source and the detectors. The attenuation is a function of the electron density of the target material, which in turn is closely related to its mass density.

1.2 Based on the relative density contrast between target materials, the technique can be used, within a drillhole, to identify weak layers in the ground at a practical logging speed of 1 m/min. Such weak layers include clay-rich layers, weathered seams and disturbed zones that are of comparatively lower mass density. The resolution of the method increases with the increase in relative density contrast between the target and the adjacent materials. The resolution decreases if casing is used and as the dip angle of the weak layer becomes aligned with the drillhole axis (i.e. sub-vertical in a vertical drillhole).

1.3 Two examples are shown in Figures 1 and 2. Figure 1 shows strong signatures for the weak clay-rich layers at locations A to D where the density contrast is high between the weak layers and the adjacent materials. In this case the method was able to identify weak layers as thin as in the centimeter range. The clay-rich layers at E to I as a whole give a strong signature in the log, but the individual layers cannot be clearly distinguished. Figure 2 shows poor correlation for those weak clay-rich layers at locations A to H where the density contrast between the weak layers and the adjacent materials is low.

1.4 The method is most suitable for use in uncased or plastic-cased drillholes and where the relative density contrast between the target (weak layers) and adjacent materials is high. However, caution needs to be exercised in interpreting the data as the absence of a strong signature does not necessarily confirm the absence of weak layers in the ground.

2. THE SPECTRAL GAMMA RAY METHOD

2.1 The Spectral Gamma Ray method is based on the principle that decomposition of potassium-bearing minerals leads to a progressive loss of potassium ions (K). Naturally occurring potassium contains radiogenic K. Thus the amount of radiogenic K present in the material is related to the degree of decomposition of potassium-bearing minerals in the parent rock and hence the degree of weathering of the rock mass. The Spectral Gamma Ray method produces a log of the potassium count rate along the drillhole.

2.2 The location along the drillhole where the count rate shows a significant reduction compared to the adjacent materials can be interpreted as a more weathered, weak layer. However, interpretation of the data is dependent on the origin of the target material, which may significantly affect the potassium count rate. For instance, where a clay layer does not originate directly from the decomposition of the adjacent materials, the potassium count rate of the layer may not necessarily be lower than those of the adjacent materials. Also, if thin layers are to be identified, a slow logging speed will be required, e.g. 0.05 m/min for a resolution of 50 mm.

2.3 This method does not require the use of any radioactive source and it can be used in drillholes lined with different types of casing. Also it is much cheaper than the Gamma Density method (about half the price based on term contract rates in 1999/2000). The Spectral Gamma Ray method, when applied to materials of the same origin and preferably backed up by site-specific calibration, can give an indication of the degree of weathering. Although the method is not as good as the Gamma Density method in identifying thin weak clay-rich layers, there is potential for it to be used in verifying ground conditions, especially in the case of a large number of drillholes without the need for sampling, e.g. drillholes for installing soil nails, raking drains, observation wells and piezometers, etc.

2.4 The example in Figure 1 shows that the potassium count rate log gives signatures for the weak clay-rich layers at locations A, B and C. The potassium count rate log in Figure 2 is unable to identify any of the weak layers (A to H). However, the trend of increasing potassium count rate in less weathered material is evident.

3. THE NEUTRON POROSITY METHOD

3.1 The principle of the Neutron Porosity method is to irradiate the target materials with fast neutrons. The neutrons collide with particles having similar mass as the neutrons in the target material, reducing their speed and becoming thermal neutrons. Within the ground, those particles that would normally have similar mass as the neutrons are mainly hydrogen nuclei. If the ground is saturated, the hydrogen content equates with water content and that in turn is related to porosity. So the neutron porosity log gives an indication of porosity if the target material is saturated.

3.2 Based on the relative moisture content contrast between the target materials, the technique can be used in open and steel-cased drillholes to identify weak layers in saturated ground at a practical logging speed of 1 m/min. However, in unsaturated ground, the relative moisture content between target materials does not truly reflect the porosity and misleading results will be given by the method.

3.3 The method does not work where plastic casing is used because the hydrogen molecules in the plastic absorb the neutrons and affect the results.

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Issue No. 1	Revision: A	Date: 1.7.2004	Page 5 of 6

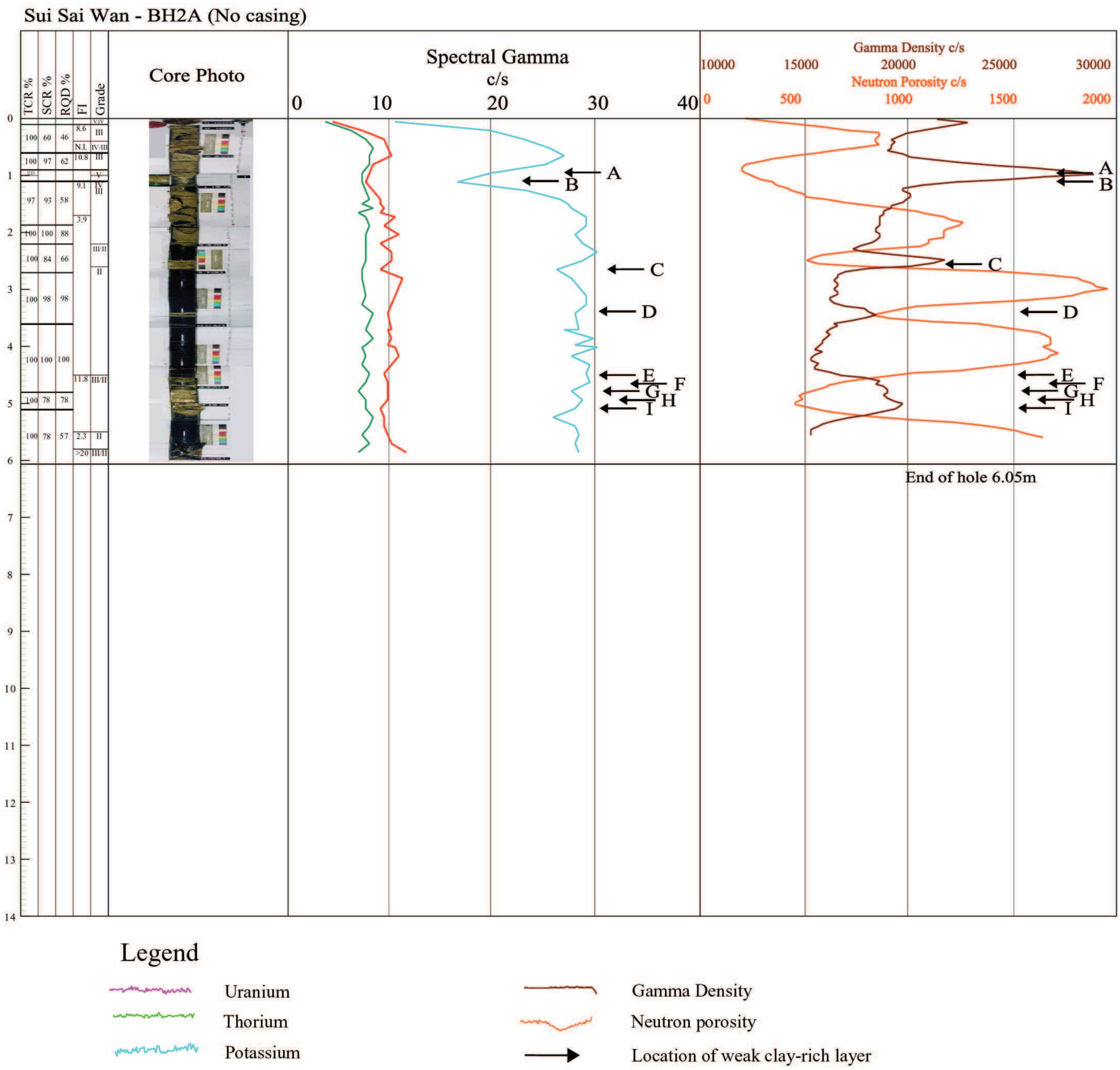

Figure 1 – Geophysical Logs – Siu Sai Wan – BH2A

Shum Wan - BH1A (Slotted plastic casing to 7.7m depth)

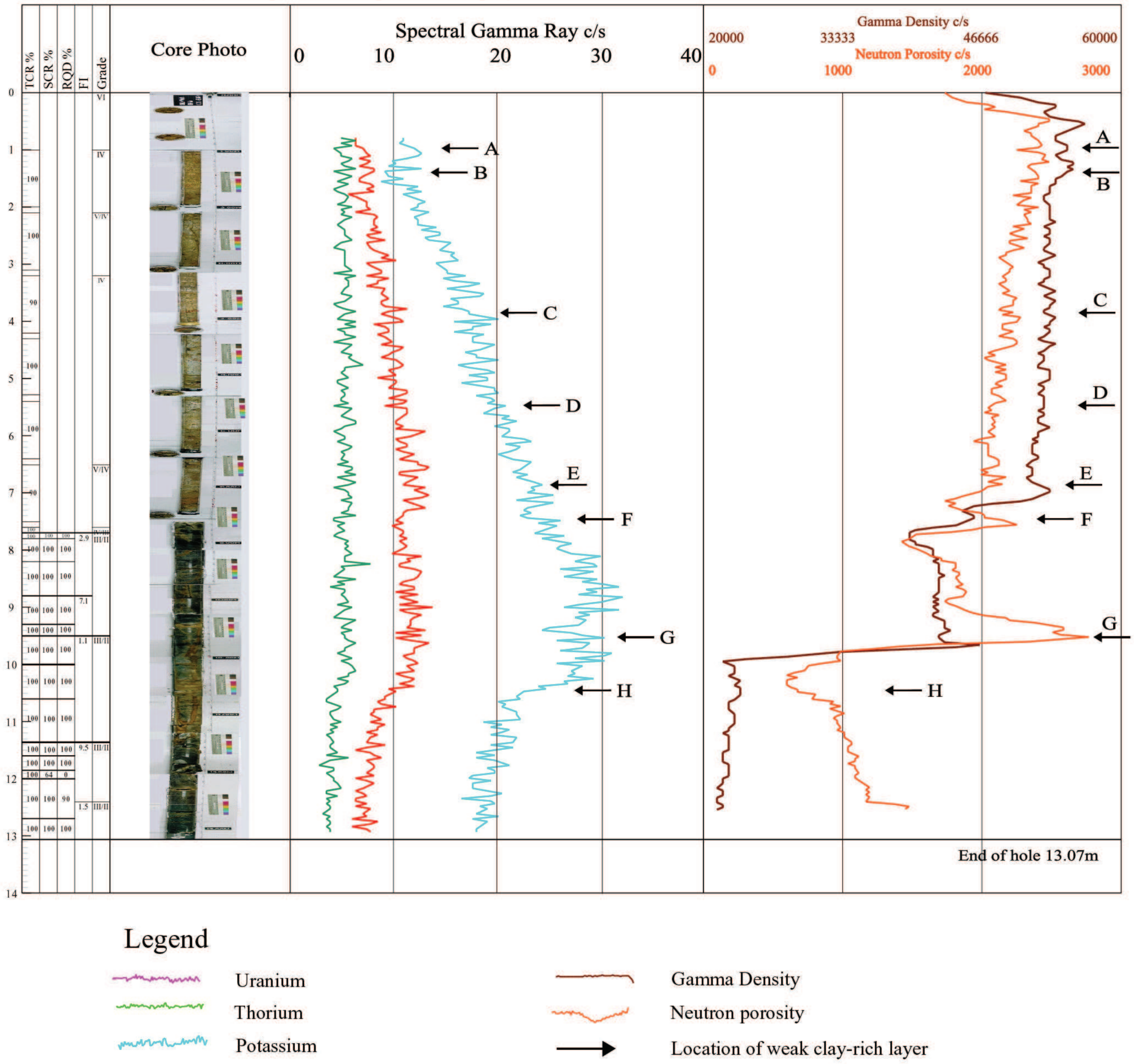

Figure 2 – Geophysical Logs – Shum Wan – BH1A