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Standard Operating Procedures for the Measurement of Soil Depth and Resistance to Penetration using a Knocking-pole Penetrometer

EPS SOP.05
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Dynamac Corporation:
Signature indicates that this standard operating procedure is approved and will be implemented in providing technical support under Contract 68-D-01-005.

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1 Scope and Application

This standard operating procedure (SOP) describes a method for measuring soil depth and incremental soil resistance using a knocking-pole penetrometer. It explains how to conduct knocking-pole measurements in a systematic and repeatable way to ensure accurate and comparable results. The SOP does not, however, identify sampling scheme or address how to interpret or scale data to make inferences regarding soil depth or resistance outside of the finite area of the actual measurement, in this case, the soil column directly beneath the tip of the penetrometer.

2 Summary of Method

These procedures follow the method used by Onda *et al*., 2004; Burns *et al*., 2001; Zumbuhl, 1999; and Yoshinaga *et al*. 1995. The knocking-pole penetrometer is a graduated steel rod with a cone-shaped tip that is driven into the ground with repeated blows of consistent force utilizing a striking platform/sliding weight apparatus. The apparatus is threaded on to the uppermost section of the pole. The 5 kg weight can be lifted vertically and fall freely but is kept centered via a spindle through a hole in the weight. The number of knocks required to penetrate a given soil increment are recorded, usually every 10 cm. The resistance to penetration is quantified as the number of knocks needed to penetrate 10 cm of soil. Thus, for each soil increment measured, a soil resistance value is calculated by dividing the number of knocks by distance penetrated then multiplying by ten. When the resistance becomes very large or infinite (i.e., each blow has little or no affect on penetration), the bedrock has been reached and the total distance penetrated equals the soil depth.

3 Definitions

Knock - one knock is the act of dropping the 5 kg weight onto the pole from a height of 20 cm.
Nc - number of knocks required to penetrate 10 cm of soil. [Nc = (number of knocks/distance penetrated in cm) x 10].

Soil depth – vertical distance (cm) from the soil surface to the bedrock.

Bedrock – interface of soil and parent material below, **defined here as Nc >100.**

4 Health and Safety Warnings

Conducting knocking pole soil depth measures may occur in remote field areas, which presents some health and safety concerns. Consult the field safety plan "Ecological Processes Field Safety Plan for the Oregon Cascade and Coast Ranges (HASP 03-05)" and follow the procedures therein to address health and safety considerations related to working at remote field sites. There are no hazardous materials used in this procedure

5 Cautions

NA – Refer to Health and Safety Warnings section.

6 Interferences

Objects other than soil or bedrock encountered by the penetrometer may result in false bedrock indication. The penetrometer may encounter items such as large roots or rocks within the soil column that stop penetration but are not actually bedrock. If this is suspected, another measure should be taken in close proximity (within 1m) of the original location. When large roots are encountered, the sound and movement associated with the knock is very distinctive and noticeable. By taking corrective action the likelihood of roots resulting in error is small. Large rocks imbedded in the soil column are the most likely cause of an erroneous soil depth measure. The possibility of this error should be recognized and accounted for in the sampling scheme and interpretation of results.

7 Personnel Qualifications

The Work Plan Manager and/or task leader will review the contents of this SOP with personnel assigned to complete the task or activity for which this SOP is relevant; orientation will be provided before beginning any task or activity. This SOP assumes that a qualified technician

with appropriate training and background will be conducting the procedures described in this document.

8 Equipment and Supplies

- *Knocking-pole penetrometer: Including 5 kg weight, sliding weight shaft, Doken-type cone tip (2-cm dia.) and several 50-cm pole sections (each graduated in 5 cm increments).*
- *Wrenches: two, 9/16" open end style and one large "vise-grip" type.*
- *Field data sheets*
- *Pen*
- *Black felt-tip pen*

9 Procedure

1. Bring all the equipment and supplies to the measurement location.
2. Assemble the penetrometer including at least two sections of pole. Screw two pole sections together, then screw the cone tip into one end and the knocking apparatus onto the other. Be sure to wrench-tighten all connections.
3. Check to make sure that the mark indicating the 20 cm height is clearly visible, re-mark with felt pen if necessary.
4. Stand the knocking-pole vertically over the measurement location (even if the ground is sloped), hold the pole steady with one hand and raise the weight to 20 cm with the other.
5. Drop the weight freely.
6. Record on the data sheet (Appendix 1) the depth to which the penetrometer reached in cm (using the graduated marks on the pole at the soils surface) and the number of knocks (1).
7. Apply knocks until the next 10-cm increment is reached. Record the total depth of penetration and the number of knocks applied since the last recording.
8. Repeat step 7, attaching more pole sections as needed.
9. Continue applying knocks until 10 knocks results in less than 1 cm of penetration (Nc>100). Record depth and # of knocks.

10. Knock ten additional times and again record depth and knocks (10) on data sheet to clearly document that Nc>100 is achieved.
11. Remove the pole from the soil by pulling vertically. Some clockwise twisting may help, but **never twist the pole counterclockwise while it is in the ground** because the sections would be loosened and possibly separated underground.
12. After the completion of the field measures, enter the data electronically into a spreadsheet and calculate the Nc value for each measurement. For each plot identify the soil depth (depth where Nc>100). Additionally, a profile of soil resistance with depth can then be plotted as shown in Appendix 2.

10 Data Records and Management

Data sheets are photocopied upon return from the field. The data from the field data sheets is entered into an electronic spreadsheet and verified by a second person for accuracy. The electronic file is then stored on the appropriate network storage drive.

11 QA/QC Application and Documentation

Quality control primarily rests on conducting systematic, consistent, measures because it is assumed that differences between measurements are solely due to actual physical differences in soil properties. Some particular areas of emphasis are:

- Start with and maintain the knocking pole in a vertical position.
- Check the tightness of all fittings. A loose fitting may result in a loss of penetrating force consequently overestimating resistance.
- Dropping the weight from the same height (20 cm). Keep the 20-cm indicating mark clearly labeled.
- Record soil depth to the nearest 1cm. Because the pole is graduated in 5-cm increments, interpolate to the nearest 1 cm as accurately as possible.

- Do not use bent poles. Also, avoid bending poles by not "knocking" any more than necessary when resistance is high and by removing the pole as vertically as possible.

12 References

Burns D.A., J.J. McDonnell, R.P. Hooper, N.E. Peters, J.E. Freer, C. Kendall, and K. Beven. 2001. Quantifying contributions to storm runoff through end-member mixing analysis and hydrological measurements at the Panola Mountain Research Watershed (Georgia, USA). *Hydrological Processes* 15:1903-1924.

Onda Y., M. Tsujimura and H. Tabuchi. 2004. The role of subsurface water flow paths on hillslpe hydrological processes, landslides and landform development in steep mountains in Japan. *Hydrological Processes* 18: 637-650.

Yoshinaga S. and Y. Ohnuki. 1995. Estimation of soil physical properties from a handy dynamic cone penetrometer test. *Journal of the Japan Society of Erosion Control Engin*eers 48: 22-28.

Zumbuhl A. 1999. The relationship between soil depth and terrain attributes in a headwater Piedmont catchment. M.S. Thesis, State University of New York College of Environmental Sciences and Forestry, Syracuse, NY.

13 Appendices

Appendix 1. Knocking-pole field data sheet

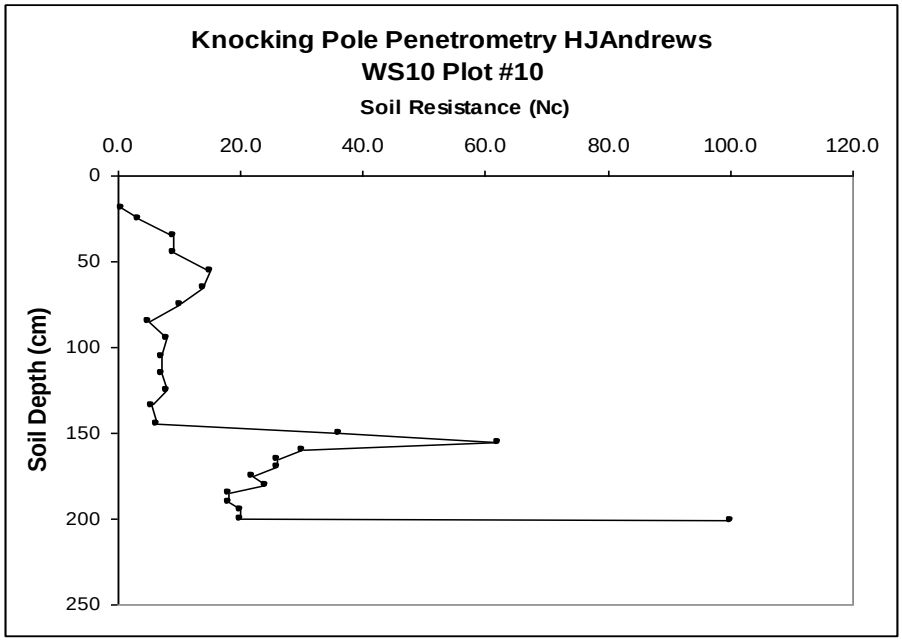
Knocking-pole field data sheet Date:_____

Crew:_____

PLOT #:_____

Soil Depth (cm)	Number of Knocks	Notes

Appendix 2. Soil resistance profile chart and calculated data



Study: HJ Andrews WS10 Tree Xylem $\delta^{18}O$
Plot: 10
Date: 7/20/2004
Crew: R. Coulombe, G. Heine

Soildepth	Knocks	Resistance
19	1	0.5
25	2	3.3
35	9	9.0
45	9	9.0
55	15	15.0
65	14	14.0
75	10	10.0
85	5	5.0
95	8	8.0
105	7	7.0
115	7	7.0
125	8	8.0
134	5	5.6
145	7	6.4
150	18	36.0
155	31	62.0
160	15	30.0
165	13	26.0
170	13	26.0
175	11	22.0
180	12	24.0
185	9	18.0
190	9	18.0
195	10	20.0
200	10	20.0
201	10	100.0
201	10	bedrock