

Guide for

Geophysical logging of boreholes for hydrogeological purposes

UDC 628.112:528:624.131.32:624.131.38:620.1.08:(683.71)

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW



Document Sharing Hub

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Industrial-process Measurement and Control Standards Committee (PCL/-) to Technical Committee PCL/3, upon which the following bodies were represented:

- Department of the Environment for Northern Ireland
- Department of the Environment (Welsh Office)
- Institute of Measurement and Control
- Institution of Civil Engineers
- Institution of Water and Environmental Management (IWEM)
- Scottish Development Department
- Water Authorities Association

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- British Geological Survey
- North West Water Authority
- Northern Ireland Geological Survey
- Severn Trent Water Authority
- Southern Water Authority
- Thames Water Authority
- University of Birmingham (Department of Geological Science)
- Wessex Water Authority

This British Standard, having been prepared under the direction of the Industrial-process Measurement and Control Standards Committee, was published under the authority of the Board of BSI and comes into effect on 28 February 1989

© BSI 06-1999

The following BSI references relate to the work on this standard:
Committee reference PCL/3
Draft for comment 87/23397 DC

ISBN 0 580 16871 9

Amendments issued since publication

Amd. No.	Date	Comments

Contents

	Page
Committees responsible	Inside front cover
Foreword	iii
1 Introduction	1
2 Scope	2
3 Definitions	2
4 Units of measurement	4
5 Purpose of geophysical logging	4
5.1 General	4
5.2 Formation logging	5
5.3 Fluid logging	8
5.4 Construction logging	9
5.5 Selection of logs	9
6 Planning	12
6.1 Statutory obligations	12
6.2 General considerations	12
6.3 Safety around wells, borehole and shafts	12
6.4 Site access	13
6.5 Access within a borehole	13
6.6 Equipment	13
6.7 Borehole details	13
6.8 Logging sequence	14
7 Formation logging	14
7.1 General	14
7.2 Electric logs	14
7.3 Natural gamma ray logs	15
7.4 Neutron-neutron (porosity) logs	16
7.5 Gamma-gamma (density) logs	16
7.6 Sonic logs	17
8 Fluid logging	17
8.1 General	17
8.2 Temperature	17
8.3 Conductivity	17
8.4 Flow	18
9 Construction logging	19
9.1 General	19
9.2 Caliper	19
9.3 Casing collar locator	19
9.4 Cement bond	19
9.5 Closed circuit television log	20
10 Log presentation	20
10.1 General	20
10.2 Log headers	20
10.3 Track layout	21
10.4 Log parameter scales	21
10.5 Depth scales	21
10.6 Composite logs	21
10.7 Differential logs	21
Appendix A Selected bibliography	24

	Page
Figure 1 — Basic geophysical logging system	1
Figure 2 — A composite suite of geophysical logs	6
Figure 3 — Correlation between boreholes using natural gamma-ray logs	7
Figure 4 — Example of the effect of flow mixing in a borehole	10
Figure 5 — Electrically equivalent concentrations of a sodium chloride solution as a function of conductivity and temperature	18
Figure 6 — Site and logging information sheets: header section	22
Figure 7 — Site and logging information sheets: tail section	23
Table 1 — Parameters and units of measurement	5
Table 2 — Application and limitation of geophysical logs	11

Foreword

This British Standard has been prepared under the direction of the Industrial-process Measurement and Control Standards Committee.

The standard is based on a draft produced by PCL/3/-/1, Geophysical Logging of Boreholes.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 24 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Introduction

Geophysical logging of boreholes, wells and/or shafts (hereafter described as boreholes) provides a measurement of various physical and chemical properties of formations penetrated by a borehole and of its contained fluids. Sondes measuring different parameters are lowered into the borehole and the continuous change in a measured property is presented graphically as a geophysical log.

Geophysical logging of boreholes is carried out to obtain information on:

- the geological formations through which the borehole is drilled;
- the presence, quantity, location and quality of fluid (usually water) within the borehole;
- the dimensions, construction and physical condition of the borehole.

The logging equipment consists essentially of four units: downhole instrument probe or tool (hereafter described as a sonde); cable and winch; power and processing modules; data recording unit (see Figure 1).

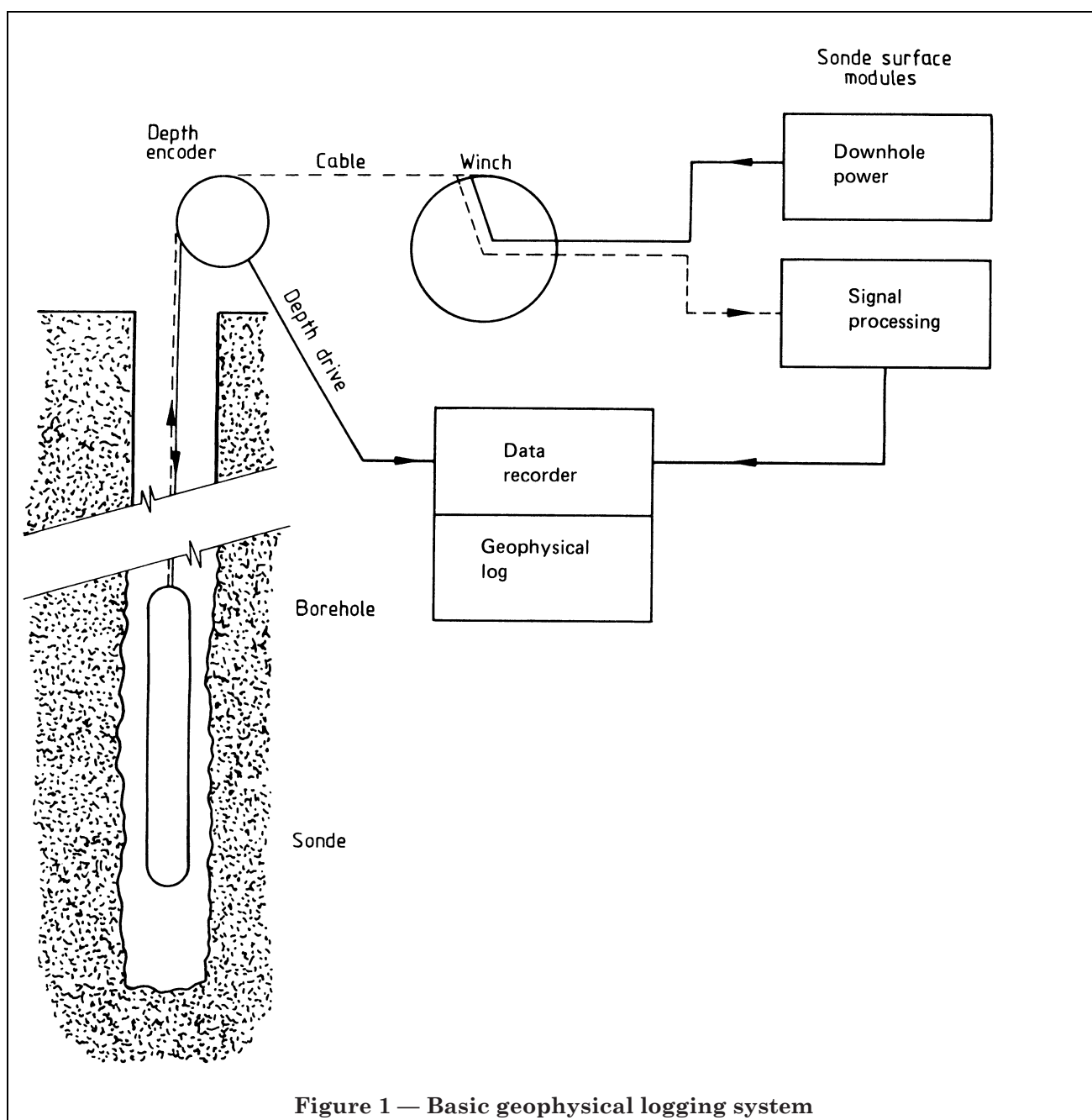


Figure 1 — Basic geophysical logging system

The various sondes contain appropriate sensors to enable specific properties to be measured. Output from the sondes is in the form of electronic signals, either analogue or digital. These signals are transmitted to the surface instruments via the cable and winch.

The cable serves the dual purpose of supporting the sonde and conveying electrical power and signals to and from the sonde. To this end it has a double outer layer of high tensile steel or polyurethane/kevlar.

The winch serves to raise or lower the sonde and to measure its precise depth. This is achieved by passing the cable round a measuring sheave of known diameter linked to an accurate depth measuring system.

The surface instrumentation typically consist of two sections to provide power and process the electronic signals from each of the sondes for recording purposes.

Data recorder units are often dedicated computers, encoding the signal data from the sonde or surface modules, formatting them and storing them on magnetic tape, and driving the plotter to produce field logs. Data recording can be either depth or time based.

2 Scope

This guide describes the factors which need to be considered and the measurements which need to be made when logging boreholes. There can, however, be no definitive “standard” logging procedure because of the great diversity of objectives, aquifers, groundwater conditions, available technology and legal contexts. Geophysical logging of water boreholes is an evolving science, continually adapting new and different techniques. Every application poses a range of problems and is likely to require a particular set of logs to gain the maximum information. This guide therefore provides information on field practice, with an indication of how variations may be made to take account of particular local conditions. It deals with the usual types of logging carried out for: water resources assessment; water supply purposes; groundwater quality studies including saline intrusion; landfill investigations and aquifer contamination; well or borehole construction and condition; geological (formation) information.

Applications not considered include mineral and hydrocarbon evaluation, and geotechnical and structural engineering investigations.

NOTE Interpretation of the data collected during logging is referred to in this guide only in a general way. For full details of the analysis and interpretation of geophysical logs, reference should be made to specialized texts. Examples of such texts are included in Appendix A.

3 Definitions

For the purposes of this British Standard the following definitions apply.

3.1

abstraction

removal of water from a borehole or aquifer

3.2

access tube

a pipe inserted into a borehole to permit safe installation of instruments, thus safeguarding them from touching or becoming entangled with the pump or other equipment in the borehole

3.3

air lifting

a method of producing a discharge of water from a borehole by the injection of compressed air

3.4

aquifer

a lithological unit, group of lithological units, or part of a lithological unit containing sufficient permeable material to yield significant quantities of water to boreholes or springs

3.5

aquifer properties

the properties of an aquifer that determine its hydraulic behaviour

3.6

argillaceous

containing clay minerals

3.7

bed resolution

minimum detectable bed thickness

3.8

bonding

the seal between a borehole lining and the geological formation

3.9

cable boom

rigid support from which the geophysical sonde and cable are suspended

3.10

calibration tail

section of field log carrying information on sonde calibration

3.11**casing**

a tubular retaining structure, which is installed in a drilled borehole or excavated well, to maintain the borehole opening. Plain casing prevents the entry of water

3.12**casing string**

a set of lengths of casing assembled for lowering into a borehole

3.13**core**

a section of geological formation obtained from a borehole by drilling

3.14**curve matching**

comparison of individual borehole data in graphical form with standard or control data

3.15**dip tube**

(see access tube)

3.16**drawdown**

the reduction in head within the aquifer resulting from abstraction

3.17**drilling circulation**

the movement of drilling fluid (air foam or liquid) used to clear the borehole during drilling

3.18**filter pack**

granular material introduced into a borehole between the aquifer and a screen or perforated lining to prevent or control the movement of particles from the aquifer into the borehole

3.19**fishing tool**

grappling equipment used to locate and recover items from within a borehole

3.20**fluid column**

that part of a borehole filled by water

3.21**formation**

a geological unit or series of units

3.22**geophysical log**

the continuous record of a physical or chemical property, plotted against depth or time

3.23**grain size**

the principal dimension of the basic particle making up an aquifer or geological unit

3.24**grout**

a cement/water slurry

3.25**header information**

description of type of data required for inclusion in a table or as input to a computer program

3.26**invaded zone**

the portion of formation surrounding a borehole into which drilling fluid has penetrated

3.27**jig**

calibrating device for logging sondes

3.28**leachate**

percolating liquor

3.29**lining**

(see casing)

3.30**lithology**

the physical character and chemical composition that gives rise to the appearance and properties of a rock

3.31**logging**

recording of data

3.32**mud cake**

a residue deposited on the borehole wall during drilling

3.33**open borehole**

an unlined borehole

3.34**packer**

a device placed in a borehole to seal or plug it at a specific point

3.35**permeability**

the ability of a material to allow the passage of a fluid

3.36**photomultiplier**

an electronic device for amplifying and converting light pulses into measurable electrical signals

3.37**plummet**

a plumb bob used for determining the apparent depth of a borehole

3.38**porosity**

the ratio of the volume of open pore space in a sample to the bulk volume of that sample

3.39**rising main**

the pipe carrying water from within a borehole to a point of discharge

3.40**rugosity**

degree of roughness (of the borehole wall)

3.41**saline interface**

the boundary between waters of differing salt content

3.42**saturated zone**

that part of an aquifer, beneath the water table, in which all voids are filled with water

3.43**screen**

a type of lining tube, with apertures designed to permit the flow of water into a borehole while preventing the entry of aquifer or filter pack material

3.44**sonde**

a cable-suspended probe or tool containing a sensor

3.45**unconfined aquifer**

water bearing formation with a free water surface

3.46**unconsolidated rock**

rock that lacks natural cementation

3.47**unsaturated zone**

that part of an aquifer between the land surface and the water table

3.48**washout**

a cavity formed by the action of drilling

3.49**water table**

the surface in an unconfined aquifer at which the water pressure is atmospheric

3.50**API unit**

a unit or counting rate used for scaling gamma-ray logs and neutron logs

4 Units of measurement

Table 1 gives a list of parameters and units of measurement in common use. Historically there has been a mix of units, many from the oil industry and the United States.

5 Purpose of geophysical logging**5.1 General**

Ideally, every borehole drilled for hydrogeological purposes should be geophysically logged. For a small percentage (typically 2 % to 10 % of the cost of drilling a borehole), the return of information derived from geophysical logs can far exceed that derived from drilling samples. Logging costs are an even smaller percentage of total costs for developing a groundwater source. Even when a borehole is totally cored and 100 % recovery is achieved, most geophysical logs will continuously sample perhaps 100 times the volume of the cores.

Not only are coring and subsequent laboratory analysis very expensive, they are also time consuming. Long term storage of cores presents problems but digital data of geophysical logs can be stored and recalled easily. Whilst there can be no substitute for high quality geological samples for determining for example strata classification, lithology, mineral content and grain size, the geophysical log provides data on the hydrogeological regime around the borehole.

Boreholes drilled for hydrogeological investigation are not often cored and good sample collection techniques are often difficult to achieve. Sample quality is unpredictable in these circumstances and sampling will not be possible where drilling circulation is lost. It is in such situations that geophysical logging provides a continuous quantitative set of data when compared with the drilling samples, which are always subjective. Furthermore geophysical logging can be used in old boreholes where geological records are uncertain or even unknown.

In addition to geological interpretation, a number of physical and chemical properties of the surrounding rock and fluids contained therein can be investigated.