INTERNATIONAL STANDARD

# ISO 14686

First edition
2003-07-15

# Hydrometric determinations — Pumping tests for water wells — Considerations and guidelines for design, performance and use

*Déterminations hydrométriques — Essais de pompage pour puits d'eau — Considérations et lignes directrices pour la conception, l'exécution et l'utilisation*

Reference number
ISO 14686:2003(E)

**PDF disclaimer**

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO 14686:2003
https://standards.iteh.ai/catalog/standards/sist/7f894c5e-be22-4b75-b416-0ed9f2db2ef3/iso-14686-2003

© ISO 2003

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

# Contents

Page

# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14686 was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 8, *Ground water*.

# Introduction

Pumping tests are normally carried out to obtain data with which to:

a) assess the hydraulic behaviour of a well and so determine its ability to yield water, predict its performance under different pumping regimes, select the most suitable pump for long-term use and give some estimate of probable pumping costs;

b) determine the hydraulic properties of the aquifer or aquifers which yield water to the well; these properties include the transmissivity and related hydraulic conductivities, storage coefficient, and the presence, type and distance of any hydraulic boundaries; and

c) determine the effects of pumping upon neighbouring wells, watercourses or spring discharges.

A pumping test also provides a good opportunity to obtain information on water quality and its variation with time and perhaps with discharge rate. These matters are not dealt with in detail in this International Standard.

When water is pumped from a well, the head in the well is lowered, creating a drawdown or head loss and setting up a localized hydraulic gradient that causes water to flow to the well from the surrounding aquifer. The head in the aquifer is also reduced and the effect spreads outwards from the well. A cone of depression of the potentiometric surface is thus formed around the well and the shape and the manner of expansion of this cone depend on the pumping rate and on the hydraulic properties of the aquifer. By recording the changes in the position of the potentiometric surface in observation wells located around the pumping well, it is possible to monitor the growth of the cone of depression and determine these hydraulic characteristics. The form of the cone of depression immediately around the well will generally be modified because additional head losses are incurred as the water crosses the well face. The drawdown may be considered to consist of two components:

a) head loss through the aquifer; and

b) head loss in the well.

Consequently, there are two test objectives: an understanding of the characteristics of the well and those of the aquifer.

A test may be performed to serve either of these two main objectives. If they are satisfied, it may be said that the hydraulic regime of the well and aquifer has been evaluated. However, it needs to be understood that other information, particularly about other factors affecting recharge, will be required to predict the long-term effects of abstraction.

It needs to be recognized that there are inherent difficulties involved in carrying out a pumping test, e.g. making many physical measurements. In part, these arise from the tendency of the measurement process or equipment to change the quantity being measured. For example, the drilling of boreholes to investigate the hydraulic regime of an aquifer may disturb that hydraulic regime by providing vertical communication between aquifer levels containing water at different heads. A second difficulty involves sampling. Only rarely will a cone of depression be circular and symmetrical; the relatively few observation boreholes that are usually available in effect provide a limited number of sampling points with which to determine the form of the cone. It is important that these limitations and difficulties are kept clearly in mind when designing and analysing a pumping test and, in particular, when using the results.

Figure 1 indicates the normal sequence of events in a pumping test.

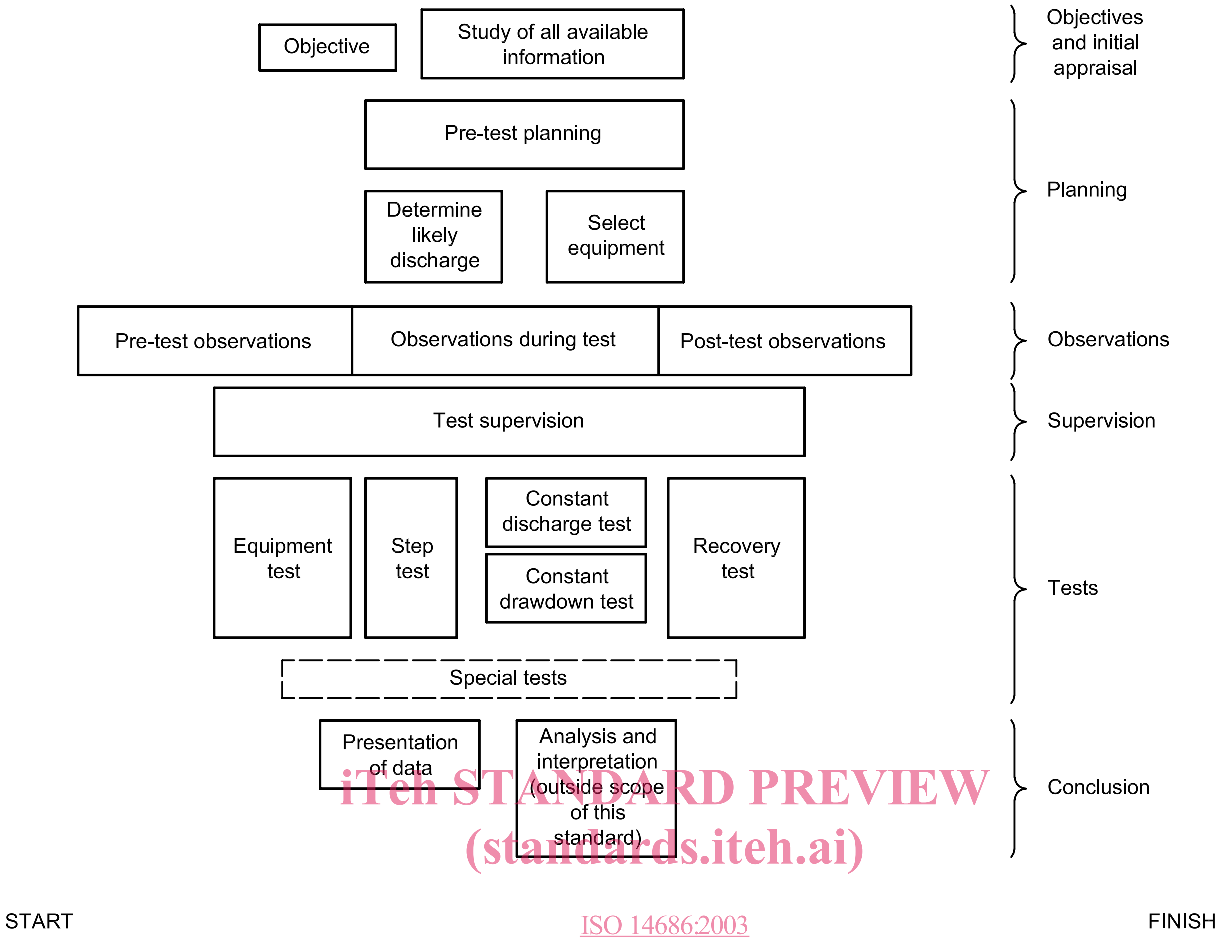

**Figure 1 — Typical pumping-test procedure**

# Hydrometric determinations — Pumping tests for water wells — Considerations and guidelines for design, performance and use

## 1 Scope

This International Standard describes the factors to be considered and the measurements to be made when designing and performing a pumping test, in addition to a set of guidelines for field practice to take account of the diversity of objectives, aquifers, groundwater conditions, available technology and legal contexts. The standard specifies the fundamental components required of any pumping test. It also indicates how they may be varied to take account of particular local conditions. It deals with the usual types of pumping test carried out for water-supply purposes, in which water is abstracted from the entire screened, perforated or unlined interval(s) of a well.

Interpretation of the data collected during a pumping test is referred to in this International Standard only in a general way. For full details of the analysis and interpretation of test data, reference should be made to specialized texts. Examples of such texts are included in a selected bibliography.

## 2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

**2.1**
**abstraction**
removal of water from a borehole or well

**2.2**
**access tube**
pipe inserted into a well to permit installation of instruments, and safeguarding them from touching or becoming entangled with the pump or other equipment in the well

**2.3**
**aquifer**
lithological unit, group of lithological units, or part of a lithological unit containing sufficient saturated permeable material to yield significant quantities of water to wells, boreholes or springs

**2.4**
**aquifer loss**
head loss at a pumped or overflowing well associated with groundwater flow through the aquifer to the well face

**2.5**
**aquifer properties**
properties of an aquifer that determine its hydraulic behaviour and its response to abstraction

**2.6**
**borehole**
a hole, usually vertical, bored to determine ground conditions, for extraction of water or measurement of groundwater level

**2.7**
**casing**
tubular retaining structure, which is installed in a drilled borehole or excavated well, to maintain the borehole opening

NOTE Plain casing prevents the entry of water.

**2.8**
**column pipe**
that part of the rising main within the well

**2.9**
**cone of depression**
that portion of the potentiometric surface that is perceptibly lowered as a result of abstraction of groundwater from a well

**2.10**
**confining bed**
bed or body of impermeable material stratigraphically adjacent to an aquifer and restricting or reducing natural flow of groundwater to or from the aquifer

**2.11**
**discharge**
volumetric flow rate

**2.12**
**drawdown**
reduction in static head within the aquifer resulting from abstraction

**2.13**
**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 well

**2.14**
**flow, steady**
flow in which parameters such as velocity, pressure, density and temperature do not vary sufficiently with time to affect the required accuracy of measurement

**2.15**
**flow, uniform**
flow in which the magnitude and direction of flow at a given moment are constant with respect to distance

**2.16**
**foot valve**
non-return valve fitted at the bottom of a suction pipe of a pump

**2.17**
**groundwater**
water within the saturated zone

**2.18**
**hydraulic conductivity**
volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow

NOTE This definition assumes an isotropic medium in which the pores are completely filled with water.

**2.19**
**hydraulic gradient**
change in static head per unit of distance in a given direction

**2.20**
**hydrogeology**
study of subsurface water in its geological context

**2.21**
**impermeable material**
material that does not permit water to move through it at perceptible rates under the hydraulic gradients normally present

**2.22**
**incompetent stratum**
stratum unable to stand without support

**2.23**
**isotropic**
having the same properties in all directions

**2.24**
**lining**
tube or wall used to support the sides of a well, and sometimes to prevent the entry of water

**2.25**
**lining tube**
preformed tube used as the lining for a well

NOTE See also casing (2.7) and screen (2.39)

**2.26**
**lithology**
physical character and mineralogical composition that give rise to the appearance and properties of a rock

**2.27**
**observation well**
well used for observing groundwater head or quality

**2.28**
**overflowing well**
well from which groundwater is discharged at the ground surface without the aid of pumping

NOTE A deprecated term for this type of well is an artesian well.

**2.29**
**permeability**
characteristic of a material that determines the rate at which fluids pass through it under the influence of differential pressure

**2.30**
**permeable material**
material that permits water to move through it at perceptible rates under the hydraulic gradients normally present

**2.31**
**phreatic surface**
upper boundary of an unconfined groundwater body, at which the water pressure is equal to atmospheric

**2.32**
**potentiometric surface**
surface that represents the static head of groundwater

**2.33**
**radius of influence**
radius of the cone of depression

**2.34**
**rest water level**
water level in the pumped well observed under equilibrium conditions when the pump is off

**2.35**
**rising main**
pipe carrying water from within a well to a point of discharge

**2.36**
**rock**
natural mass of one or more minerals that may be consolidated or loose (excluding top soil)

**2.37**
**running plot**
graph of a variable against elapsed time continually updated as measurements are taken

**2.38**
**saturated zone**
that part of the earthen material, normally beneath the water table, in which all voids are filled with water

**2.39**
**screen**
type of lining tube, with apertures designed to permit the flow of water into a well while preventing the entry of aquifer or filter pack material

**2.40**
**slurry**
mixture of fluid and rock fragments formed when drilling or developing a borehole

**2.41**
**specific capacity**
rate of discharge of water from a well divided by the drawdown within the well

**2.42**
**specific yield**
ratio of the volume of water which can be drained by gravity from an initially saturated porous medium to the total volume of the porous medium

**2.43**
**static head**
height, relative to an arbitrary reference level, of a column of water that can be supported by the static pressure at a given point

**2.44**
**storage coefficient**
volume of water an aquifer releases from storage or takes into storage per unit surface area of the aquifer per unit change of head

**2.45**
**transmissivity**
rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the saturated aquifer under a unit hydraulic gradient

**2.46**
**unconsolidated rock**
rock that lacks natural cementation

**2.47**
**unsaturated zone**
that part of the earthen material between the land surface and the water table

**2.48**
**water table**
surface of the saturated zone at which the water pressure is atmospheric

**2.49**
**well**
hole sunk into the ground for abstraction of water or for observation purposes

NOTE See also Annex A.

**2.50**
**well bore storage**
volume of water released from within the well itself during a decline in head

**2.51**
**well development**
physical and chemical treatment of a well to achieve minimum resistance to movement of water between well and aquifer

**2.52**
**well efficiency**
measure of the performance of a production well

**2.53**
**well loss**
head loss resulting from flow of groundwater across the well face, including any part of the aquifer affected by drilling, and any filter pack or lining tube, into the well and up or down the well to the pump

# 3 Hydrogeological considerations

## 3.1 General

Before a pumping test is planned, a full assessment of the hydrogeological conditions at and around the test site should be carried out. A survey of existing wells is necessary and, in areas where the hydrogeological data are inadequate, it may be desirable to expand these by a field survey.

Pumping tests might be contemplated in a wide range of circumstances. There is also the probability that the aquifer will be partly and perhaps nearly fully developed already. Therefore a search for and analysis of existing borehole operational and test data and associated surface water levels and flows should be considered as prerequisites to such tests.

## 3.2 Aquifer response characteristics

Two parameters define the quantitative hydrogeological properties of an aquifer, namely permeability and storage. Permeability is concerned with the ability of an aquifer to permit groundwater flow under a hydraulic gradient. Storage concerns the volume of water available within the aquifer and subsequently released when water levels are depressed around a discharging well. Together these two parameters can be taken to control the response time for pumping effects in an aquifer. A consideration of the aquifer response time is necessary when locating sites for observation wells. With a low permeability and a large storage coefficient, the radius of influence will increase slowly. An aquifer with a high permeability and a small storage coefficient would exhibit a rapid increase in the growth of the radius of influence.

The first non-equilibrium pumping-test formula was developed by C.V. Theis in 1935 for use in confined aquifers which are always fully saturated and in which the water is at a pressure greater than atmospheric. Removing water from a confined aquifer is rather like removing air from a motor car tyre: the pressure drops, but the aquifer is still filled with water, in the same way that the tyre is still filled with air. In an unconfined aquifer, or in a confined aquifer that becomes unconfined as a result of the potentiometric surface being drawn down below the top of the aquifer, the saturated thickness (and therefore the transmissivity) decreases as the drawdown increases. A second complication that occurs in unconfined aquifers is the phenomenon of delayed yield. After an initial period during which the cone of depression expands rapidly, there follows an interval where the rate of expansion decreases, on occasion approaching an apparently steady state. This interval may be as short as 1 hour, or may extend to several weeks. Thereafter, the cone of depression resumes its previous rate of expansion. As illustrated by a time-drawdown plot, the curve initially follows the normal Theis prediction, then tends to level out, and finally moves upward again to approach the Theis curve although the latter is now displaced some distance along the time axis. Several explanations of delayed yield have been offered, but none has full general acceptance at the present time.

## 3.3 Groundwater conditions (see also Annex B)

The storage coefficient in a confined aquifer may be at least 100 times less than in the same aquifer in an unconfined state. This reduction is reflected in a much more rapid aquifer response time.

When the confining bed is not wholly impermeable, the storage coefficient varies between the totally unconfined and the totally confined values and the aquifer response time will vary accordingly.

The presence of overlying impermeable strata does not necessarily imply a confined aquifer. The presence of an unsaturated zone beneath an impermeable stratum may permit the aquifer to demonstrate an unconfined response.

It is possible for confined and unconfined conditions to occur in different parts of the same aquifer, or in the same part of the aquifer, as a result of seasonal or other movements of the potentiometric surface.

## 3.4 Multi-layered aquifers

Many aquifers comprise sedimentary strata and these are deposited as a series of superimposed layers. Successive layers could have different lithological characteristics from the adjacent layers and consequently the hydraulic conductivity in the horizontal plane tends to be greater than that in the vertical plane. In extreme cases, intervening layers may be impermeable, resulting in a multi-layered aquifer. Wells penetrating such an aquifer may intersect an unconfined layer near the surface and one or more confined layers at depth. Failure to recognize this possibility may lead to inadequate monitoring of groundwater levels and to misleading data being obtained in a pumping test. The analysis of data from fractured-rock aquifers may be particularly difficult. The response to pumping may be asymmetric, depending on the number, location, orientation and size of fractures encountered by the well. Some fractured-rock groundwater systems may be acceptably represented as an equivalent porous media conceptual model, and standard analysis methods would then apply. However, certain advanced analysis techniques may dictate pumping and observation well placement.

### 3.5 Boundary conditions

Barrier boundaries are normally presented by geological discontinuities caused by faulting of the aquifer or by the aquifer itself having a rapid diminution in thickness or saturated thickness. Occasionally, aquifers show a rapid, lateral, lithological change with a consequent severe reduction in the aquifer properties. Deep channels scoured in an aquifer and later filled with impermeable deposits may also form barriers. Barrier boundaries have the effect of increasing the drawdown. The pumping of another well in the same aquifer will have the same effect as a boundary if the cones of influence of the two wells intersect.

Recharge boundaries occur when water other than from groundwater storage effectively contributes to an aquifer drawn on by a pumping well. Surface watercourses, by lakes, or by the sea, may provide such boundaries when these lie within the radius of influence of the well.

All these may be regarded as discrete recharge boundaries and often are definable as point or line recharge sources for the purpose of analysis. Recharge boundaries have the effect of decreasing the rate of drawdown, or checking the drawdown altogether. Downward leakage from overlying strata or the interception of natural flow through the aquifer may simulate a recharge boundary by decelerating the drawdown, but the effects cannot necessarily be identified with a localized source.

### 3.6 Other hydrogeological factors

There are several factors that may significantly affect the analysis of pumping-test data although they may not affect the test itself.

The thickness of the aquifer should be ascertained, at least approximately, including spatial trends. Corrections are necessary in the analysis for partial penetration by the pumping wells. The degree of penetration of the observation wells is also important to ensure the measurement of realistic water levels.

Unconfined aquifers may demonstrate the phenomenon of delayed yield from storage. The rate of drawdown during the early stages of the test may be temporarily reduced for a period ranging from an hour to several weeks before again increasing. It may be necessary in these circumstances to prolong the pumping test to obtain sufficient drawdown data after the effects of the delayed yield have ceased.

During the period of a pumping test in a confined aquifer, water levels in the pumping well (and possibly in the observation wells) may fall below the confining bed. If this possibility exists, the depth of the base of the confining bed needs to be determined in all the wells to permit proper analysis of the test data.

## 4 Pre-test planning

### 4.1 Statutory requirements

Attention is drawn to local acts, byelaws, regulations and any other statutory requirements relating to matters dealt with in this International Standard. Work should be carried out in accordance with, and the equipment in use should comply with, the appropriate regulations.

Sites within designated areas such as national parks, areas of outstanding natural beauty, areas of special scientific interest, or those close to or within residential areas, may have special constraints imposed on test operations and these should be ascertained before any drilling or test-pumping operations commence.

Persons planning to sink and/or test-pump a well are advised and may be required to discuss their proposals in advance with appropriate regulatory authorities. Unless specifically exempted by the regulations, it is essential that they ensure that procedures for obtaining permissions or consents are followed before any works are carried out.

## 4.2 Site facilities and organization

### 4.2.1 General

Guidance is given on general matters that affect the organization and activities of the test-pumping site. The actual details will vary from site to site and may include matters not described in this clause that therefore should not be assumed to be exhaustive in its coverage.

Before any drilling or test pumping commences, a preliminary survey should be carried out bearing in mind these recommendations for site facilities and organization.

### 4.2.2 Space and headroom

At the outset, it is necessary to ensure that sufficient space is available for any test equipment and pumping plant required on the site as well as lagoons for disposal of acid sludge, etc., where necessary. Parking space for vehicles should be designated, and overhead obstructions such as power cables, guy lines, trees and so forth should be noted and clearly marked if necessary.

### 4.2.3 Safety of personnel on site

Every care should be taken to reduce the risks to personnel working at the test-pumping site. First-aid kits should be provided on site as a part of the normal safety arrangements and should be additionally equipped with soda for the neutralization of acid when acid is to be handled during the development of a well; an adequate supply of flowing fresh water should be available for washing acid from the eyes or sluicing it from the skin or clothing.

Paths between the site hut, the test well, the observation wells, etc., should be clearly marked, as should hazards such as fences, cables, mud pits and spoil heaps. Sites that on initial inspection appear to be firm and dry often degenerate to a slippery morass around the wellhead. The nature of the ground therefore should be carefully inspected beforehand and, if necessary, arrangements made to provide duckboards and walkways for the working team.

If the test is prolonged through the hours of darkness, adequate lighting should be provided.

The site inspection should have revealed the presence of any overhead electric cables likely to be a hazard. Unless details are already available, a check should be made for the presence of any underground electric cables or other services under the site, such as gas mains, telecommunication cables, etc., and the route of these should be temporarily marked. In the case of overhead cables, a vehicle route beneath them should be established and clearly marked giving also the minimum overhead clearance.

NOTE The presence of either overhead or underground power lines may also affect certain types of electronic equipment, notably pH and ion-selective meters and down-hole logging equipment.

### 4.2.4 Utility services

If electrically powered equipment is to be used, the possibility of making available a supply from the mains will need to be investigated. This should be done well ahead of mobilization to site since a temporary incoming switchboard and metering point will be required and the precise requirements for this are likely to vary between different electricity supply authorities. At the same time, earthing arrangements should be settled. In many cases, the supply authorities will be able to provide an earth terminal either from a continuous earth wire system or from a protective multiple earthing system. It is important to ascertain which form of earthing any electricity supply authority will provide, as the requirements imposed on the customer are different. If there is any doubt about the mains earthing arrangements, it is essential to provide an earth leakage circuit breaker of suitable capacity.

If a mains supply is not available, it will be necessary to supply a generator of suitable capacity (see 4.5.3). In this case, electrical earthing requirements can be met by cross-bonding the lifting rig, pump pipework and generator and providing an earth probe. The earth loop impedance of the complete system should not be greater than 2 W.

All electrical installations on the site should comply with the requirements and recommendations, as appropriate. Surface power cables between generator and wellhead should be armoured. Flexible-braid-armoured cable is more suitable and easier to handle in this application than single-wire-armoured cable. Single-wire-armoured cable should comply with local standards. A watertight emergency stop lockout button should be mounted within easy reach.

Special tests, such as certain types of packer test, will require a water supply. There may be constraints on the type of water which can be used; tankers may be required, and possibly storage on site need to be arranged. If the site is residential, it will be necessary to provide a supply of potable water as well as water for general use. Where this is provided in containers, these should be marked to distinguish potable from non-potable water.

If a telephone is required, it should be installed prior to the test commencing.

### 4.2.5 Site accommodation

A suitable hut or shelter should be erected on the site, adequately lit and, if necessary, heated. Such accommodation should include tables and seating for the partaking of meals and facilities for boiling water and heating food.

The accommodation should be sufficiently secure to store first-aid and fire-fighting equipment, test equipment, records, etc. If the test is to continue for one or more nights, sleeping accommodation should be arranged for off-duty personnel.

Latrines and washing facilities should be made available on site; if the operation is of a long-term nature, consideration should be given to the provision of shower facilities.

### 4.2.6 Site communications

Signalling between the observation and pumping wells during the test can be carried out by visual or audible means, appropriate to the circumstances, e.g. by radio. Under some conditions, visual signals may be inadequate.

### 4.2.7 Avoidance of pollution and disposal of wastes

Care should be taken to dispose of liquid or solid wastes carefully and safely and in a manner that will not pollute the wells or the surrounding area and is consistent with environmental regulations. If it is not possible to dispose of contaminated waste water directly into the sewerage system, it should be collected and removed from site for treatment and disposal. Disposal of contaminated waste waters to a soakway, albeit remote from the well head, ditches and watercourses, should not be undertaken without the consent of the regulatory authority. Solid wastes should be removed from the site for disposal at a licensed waste facility. Requirements to treat the pumped water or to tanker it for disposal may constrain pumping rate and duration.

If an internal-combustion engine is to be employed, either for power supply or direct drive, precautions should be taken to ensure that any oil or fuel spillages are contained. This point needs particular attention when an internal-combustion engine is connected through a right-angle gearbox to a long-shaft turbine pump at the well head. The engine should be mounted on a firm platform with means to ensure that any fuel or oil spillage can be contained. Adequate storage of fuel will also need to be provided, with suitable precautions taken against leakage and fire.

In addition to the prevention of pollution by oil and fuel, precautions should be taken to prevent the well being infected by pathogenic and non-pathogenic organisms. The most likely source of pathogenic organisms is from latrine accommodation, which should therefore be sited as far as possible from the well. Sterilization of any equipment to be placed in the well will reduce the risk of introducing infections from other sources (see 4.2.10).