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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

English Version

Wells for water extraction - Part 1: Design

Forages pour l'extraction de l'eau - Partie 1 :
Conception

Brunnen zur Wassergewinnung - Teil 1: Design

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 451.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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European foreword

This document (prEN 18049-1:2024) has been prepared by Technical Committee CEN/TC 451 “Water wells and borehole heat exchangers”, the secretariat of which is held by AFNOR.

This document is currently submitted to the CEN Enquiry.

Within its program of work, Technical Committee CEN/TC 451 requested CEN/TC 451/WG 1 “*water wells*” to prepare the following standard:

EN 18049-1, Wells for water extraction — Part 1: design.

The EN 18049 series under the main title Wells for water extraction will consist of the following parts:

- *Part 1: design;*
- *Part 2: XXX;*
- *Part 3: XXX;*

1 Scope

This document covers all types of water wells, whether for public or private use, abstracting from or injecting water to the groundwater, in a variety of applications. These include potable water abstraction, industrial use, irrigation, dewatering, infiltration or recharge, and geothermal applications, or for groundwater observation (see Clause 13).

This document does not apply to horizontal wells and closed loop geothermal systems.

The document defines design requirements of water wells for public and private users in accordance with groundwater protection goals. It gives guidelines for all planning steps from preliminary to final executive project design.

A sequential method for designing and dimensioning a well is specified. Based on the hydrogeological conditions and the objectives of the well, a step-by-step process for dimensioning the well is defined. This methodology includes dimensioning for the drilling, filter packs, sealing and a screen. Furthermore, selection of appropriate materials, the pump and all other additional well equipment is outlined. With regard to the planning process references are provided for drilling methods, geophysical well logging, well development and pumping tests.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 14396, *Fixed ladders for manholes*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp/>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

abandoned well

also called decommissioned a term used when a well's use is permanently discontinued or if it is in a condition that makes it uneconomic to repair

3.2

alignment of the well

measure of the straightness of adjacent sections of a well

Note 1 to entry: Often tested by running a dummy tool into the well.

3.3

annular space (annulus)

space between a drilled hole and the well casing

3.4

aquifer

water-bearing geological layer comprising permeable rock, fractures or unconsolidated materials (gravel, sand, or silt)

3.5

aquifer stimulation

type of development that is carried out to alter the formation physically to improve its hydraulic properties

3.6

aquifer test

special case of a pumping test using additional observation wells to obtain information about the characteristics of a aquifer

3.7

aquitard

geologic formation having very low permeability

3.8

artesian aquifer

confined aquifer in which the piezometric surface is above the ground level

3.9

artesian well

wells (bore holes) that penetrate artesian aquifers

3.10

auger

machine having a rotating helical shaft for boring into the earth

3.11

bailer

cylindrical, bucket-like device with a footvalve used to collect or remove mud and rock cuttings from, the borehole

3.12

borehole

hole created by drilling into the ground

3.13

bottom hole assembly

lower portion of the drill string, which may consist of (from the bottom up) the bit, bit sub, a mud motor (in certain cases), stabilizers, drill collars, heavyweight drill pipe, jarring devices (jar) and crossovers for various thread forms

3.14

cable tool

group of machines for drilling by the breaking and crushing action of heavy drilling tools suspended on a cable which are repeatedly lifted and dropped

3.15

casing

tube (usually steel or plastic) that is installed in a well to maintain the well opening and to provide a seal

3.16

cementing

specific case of grouting where only cement and water are used

3.17

centralisers

devices used to ensure that casing or riser tubes are installed centrally within the borehole

3.18

confined aquifer

aquifer whose upper and lower boundaries are low permeability layers which confine the groundwater under greater than atmospheric pressure

3.19

unconfined aquifer

aquifer with an upper surface as a water table, whose piezometric surface is at atmospheric pressure (an unconfined surface)

Note 1 to entry: The level of this groundwater can fluctuate, creating a saturated zone and an unsaturated zone

3.20

core

continuous cylinder of rock, cut from the bottom of a borehole as a sample of an underground formation

3.21

cuttings

small pieces of rock or broken material derived from the drilling process, which can be used for sampling

3.22

Down-the-hole hammer

DTH

self-rotating air-activated percussive drilling bit

3.23

drawdown

decrease in ground water level caused by pumping, measured as the difference between the static and the dynamic water level at a particular time

3.24

drill bit

cutting tool used in well drilling

3.25

drilling additives

specific components of the drilling fluid that can be used to restore the drilling mud properties or to act in a particular way as required

3.26

drill collar

component of a drill string that provides weight on the bit for drilling

3.27

drill pipe

steel pipe used to carry and rotate the drilling tools in a well, and to permit the circulation of drilling fluid

3.28

drilling fluid drilling mud

water or air-based fluid used in the water well drilling operation to remove cuttings from the hole, to clean and cool the bit, to reduce friction between the drill string and the sides of the hole, and to seal the borehole

3.29

dynamic water level cf. static water level

piezometric surface influenced by drawdown or injection, as opposed to the natural water level at rest at the same point;

Note 1 to entry: More specifically, drawn down or raised water level, whether or not stabilized, in a pumping well or injection structure

Note 2 to entry: Static level (natural groundwater level): the piezometric surface in a borehole not influenced by pumping, sampling or by injection of water

3.30

filter cake

suspended solids that are deposited on a porous medium during the process of filtration

3.31

free flowing well (see artesian well)

3.32

formation

general term for the geological units surrounding the borehole

3.33

formation stabiliser

sand or gravel placed in the annulus of the well between the borehole wall and the well screen to provide temporary or long-term support for the borehole

3.34

geophysical well logging

generic name for a suite of technologies that indicate absolute or relative properties of geological formations, aquifers and wells

3.35

filter pack gravel pack

coarse sand, fine gravel, glass beads, or other suitable materials, that is placed between the borehole wall and screen

Note 1 to entry: Filter packs are used to retain the formation and improve the hydraulic condition around the well.

3.36

grout

cement- and/or clay-based sealing material (e.g. swelling clay) used to create a sanitary seal in the annular space to prevent crossflow between aquifers and/or contaminants from entering the well

3.37**head**

for the purpose of this standard means hydraulic head

3.38**head loss**

energy which is lost due to friction as water moves from an aquifer through the well (filter pack, screen, pump, riser pipes) to the surface

3.39**hydraulic conductivity**

capacity of subsurface materials (sand, rock etc.) to allow a fluid (i.e. water) to flow through it. For an isotropic porous medium and homogenous fluid, the volume of water that moves in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow

Note 1 to entry: In the SI System, the units are $\text{m}^3/\text{s}/\text{m}^2$ or m/s .

3.40**hydraulic head [m]**

height above a datum plane (such as sea level) of the top of the column of water that can be supported by the hydraulic pressure at a given point in a ground water system. For a well, the hydraulic head is equal to the distance between the water level in the well and the datum plane

3.41**impermeable**

resistant to flow of or penetration by water or other liquids

3.42**injection well**

well constructed for the purpose of injecting water directly into the aquifer

3.43**kelly**

long square or hexagonal steel bar connecting the rotary table with the drill string enabling rotary motion, while allowing the drill string to be lowered or raised during rotation

3.44**Managed Aquifer Recharge****MAR**

Managed Aquifer Recharge (MAR) is the deliberate recharge of water to aquifers for subsequent recovery or environmental benefit e.g. achieved through injection wells

3.45**monitoring well**

well constructed or used for the purposes of water level or water quality data collection

Note 1 to entry: Monitoring wells are often installed to provide an early warning of contamination occurring down gradient from a landfill or industrial facility. See also Observation wells.

3.46

observation well

well constructed in a specific location for the purpose of observing(measuring) changes in water level

Note 1 to entry: An existing well perhaps drilled for a different purpose may also be used to observe water level changes. Observation wells are typically used for short duration data collection such as before, during and after an aquifer test. Wells that are used to collect data on a long term basis are usually referred to as monitoring wells.

3.47

packer

device used to isolate particular portions of the aquifer in a borehole

3.48

partial penetration

when the depth of the intake portion of the well is less than the full thickness of the aquifer

3.49

piezometer

(see monitoring well)

3.50

polymer mud

water based drilling fluid with polymers

3.51

production well

water well designed to meet a particular demand of groundwater

3.52

pumping test

controlled pumping with associated measurements of water level changes that are used to determine aquifer characteristics and the hydraulic properties of wells

3.53

rig

machine used to drill a well

3.54

rising main

drop pipe

pump column

pipe connecting the submersible pump to the wellhead

3.55

rotary table

revolving or spinning section of the drill floor that provides 3. power to turn the drill string in a clockwise direction

Note 1 to entry: The rotary motion and power are transmitted through the kelly bushing and the kelly to the drill string

3.56

saline intrusion

entry of sea water into a coastal aquifer

3.57**saline water (salt water)**

water that contains significant amounts of dissolved solids (usually more than 1 000 parts per million (ppm))

3.58**screen****well screen**

cylinder usually made of steel or plastic material used to allow water to enter a well while preventing sediment or rock particles from entering the well

3.59**sieve analysis**

determination of the particle-size distribution of a soil, sediment, or rock by measuring the percentage of the particles that will pass through each sieve in a standard set of sieves

3.60**sinkhole**

depression in the land surface caused by collapse of overlying soils or rock into pre-existing cave systems, usually in areas of limestone geology

3.61**slurry**

thin mixture of liquid, especially water, and any of several finely divided substances, such as cement or clay particles, but capable of pumping

3.62**specific capacity**

rate of discharge of a well per unit depth of drawdown. It is used as a measure of well efficiency. The ideal for a well is high discharge and low drawdown

Note 1 to entry Units are $\text{m}^3/\text{s}/\text{m}$ or m^2/s .

3.63**static water level**

static or rest water level is the level at which water stands in a well when the water level is at equilibrium with atmospheric pressures when it is not under the influence of a pumping nor an injection

Note 1 to entry: It is a measure of the depth from the ground surface or from a known reference point to the water level. The water level may also be measured relative to a datum such as sea level (see also, dynamic water level)

3.64**subsidence**

dropping of the land surface as a result of over-pumping ground water. Cracks and fissures can appear in the land

Note 1 to entry: Subsidence is usually an irreversible process.

3.65

suspended sediment/particles

soil particles that remain in suspension in water for a considerable period of time without falling to the bottom under the force of gravity

Note 1 to entry: Such material remains in suspension due to the upward components of turbulence and currents and/or by suspension.

3.66

test well

reconnaissance borehole

pilot borehole

exploratory borehole

well used to assess and/or test the geologic and hydraulic properties of an aquifer. A series of test wells may be drilled in order to determine the most effective location for a (much more expensive) production well

Note 1 to entry: Test wells are usually of a smaller diameter than production wells.

3.67

top drive drilling

drilling rotary method in which the rotary motion is provided by a mechanical device (hydraulic pressure head) located at the swivel and which moves vertically up and down the mast. It is a recent alternative to the rotary table and kelly drive

3.68

transmissivity

rate at which groundwater can flow through an aquifer section of unit width under a unit hydraulic gradient. It is the average hydraulic conductivity of a section of the entire aquifer at a given location multiplied by the thickness of the producing formation

Note 1 to entry: Units are m²/day.

3.69

tremie pipe

pipe used to carry materials (usually grout) to a specific depth in a drilled hole. Tremie pipes are slowly withdrawn as the grout is placed in the well

3.70

unconfined aquifer

aquifer with an upper surface as a water table whose piezometric surface is at atmospheric pressure (an unconfined surface)

Note 1 to entry: The level of this groundwater can fluctuate, creating a saturated zone and an unsaturated zone

3.71

uniformity coefficient

d_{40}/d_{90}

ratio used to characterise a sediment using a plotted grain-size distribution curve, derived from sieving. It is the 40 % retained size divided by the 90 % retained size

3.72**verticality**

deviation from an imaginary vertical line from the ground surface to the centre of the earth

Note 1 to entry: Usually measured in meters or centimeters.

3.73**water table**

surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere. The static water level in a well in an unconfined aquifer

3.74**well development**

application of techniques after and during the drilling process that bring the well to its maximum yield capacity and achieve maximum well efficiency

3.75**well yield**

volume of water discharged from a well usually expressed in cubic meters per day (m³/day)

3.76**wellhead**

equipment/installation used to maintain surface control of a well

4 Project objectives**4.1 Background**

Before starting the design of a well or well field, there needs to be a common understanding between the commissioning party and the designing party with respect to the objectives of the project.

These objectives form a framework for the entire design process, including the evaluation of the design at the end of the design process to check whether the design meets the project objectives (as explained in Clause 21) and the construction of the work. Secondly, the requirements form the basis of a contract between the commissioning party and the designing party. Thus, they also serve as protection for the customer, especially those that are not very familiar with the design of wells. Finally, the requirements may also be used for communication with third parties who depend on the design of the well. For example, the well discharge may be the important input for a company that is responsible for the transmission of pumped water above ground surface.

4.2 Requirement

Identification of the location and objectives of the well as well as for the timeframe of the project.

4.3 Compliance

These following aspects shall be formulated in a document, such as a specification sheet or tender document. Both design and commissioning party shall go through the document and agree consensually on it.

- The location of the well. This shall either be defined in the form of georeferenced discrete point or as an area for the project defined as a polygon of georeferenced points.
- The purpose of well: for the pumping, injection, infiltration or as an observation well.

- The required flowrate and/or required water level. This shall be defined as a discrete number or as a range.
- The theoretical minimum technical life span for the well.
- The minimum required water quality properties of the abstracted water. These shall be in line with the purpose of the well and other requirements of the commissioning party.¹
- Interface with the above-ground installation. For example the water pressure and pipe diameter at the well head.
- Check if additional requirements arise from an existing legal framework
- Check if there are additional requirements, depending on the purpose of the well (see examples in Annex A).
- A concrete time schedule or at least a timeframe. The time schedule shall at least indicate when the wells need to be drilled and when they need to be operational, and address both the dimension and complexity of the project.

5 Site conditions

5.1 Background

Encountering unanticipated site conditions leads to increasing risk to the later construction work and therefore such uncertainty has to be considered during project planning. Existing surface and subsurface structures, general accessibility, storage space, compliance with existing regulation on access, environmental, health and safety issues have to be investigated and identified before starting construction work.

5.2 Requirements

5.2.1 Requirement 1

Appraisal of legal feasibility with the relevant authorities.

5.2.2 Requirement 2

Collation of available information on potential obstacles to the planned project.

5.3 Compliance

The information collected should contain but is not limited to:

- legal position concerning the location (ownership, rights of way etc.);
- current and future status of location in the land utilization or land development plan;
- special regulations e.g. environmental restrictions;
- legal limitations on abstraction or infiltration;
- site-specific health and safety issues e.g. overhead cables, unexploded ordnance, contaminated land;

¹ Local regulations can apply.

- site-specific risks for natural hazards e.g. flooding;
- information on underground infrastructure e.g. cables, sewers, pipes;
- accessibility for heavy machinery;
- power and water supply;
- waste management and disposal during construction;
- a preliminary site inspection should be undertaken; if it is not undertaken, justification shall be reported in the designing document.

6 Geological and hydrogeological characterization

6.1 Background

Prior to the design process phase all available information regarding geology, hydrogeology and hydrochemistry of the target aquifer and traversed geological strata needs to be collated, evaluated and if necessary investigated.

Depending on the type and the specific purpose of the well, the following requirements need to be fulfilled:

6.2 Requirements

6.2.1 Assessment of the geology

The lithological description of the rock or soil sequence to be drilled and the structural characterization of the site area are both compulsory in order to provide sufficient information for the preparation of a good quality well design and provision of adequate drilling machinery and ancillary equipment for efficient construction works. Provision and analysis of these data on the other hand avoids, minimizes and helps to reduce any potential geological risks occurred during drilling:

- in order to be able to evaluate the geological situation, information on the following geological aspects are essential: Occurrence and description of the regional geologic structure(s) – sedimentary basin, folded structures and/or faults;
- the vertical geological structure of the ground through which the well is to be constructed (e.g. occurrence of multiple separate aquifers);
- occurrence and characterization of local tectonic (structural) discontinuities, joints - faults, fissures, fractures (particularly in the case of hard rocks);
- occurrence and characterization of dissolution voids and channels (in the case of carbonate and evaporate rocks);
- geological description of the soil or rock (e.g. grain size, type of deposit, type of rock);
- the lithological (specific) description (from bottom to top or reverse) of the litho-stratigraphic units (formations, beds, layers, or horizons and their thicknesses) to be drilled through.

6.2.2 Characterization of the hydrogeological units

Identifying the target aquifer which is likely to yield a sufficient amount of water of an adequate quality for the project and considering the possible interferences with adjacent hydrogeological units is a prerequisite for any water well design and construction works. Information on the hydrogeological conditions is also required during the drilling phase (e.g. hydraulic heads to ensure borehole stability, use of salt/fresh working water).

A summary of aspects to be investigated and evaluated in a quantitative manner are listed as follows:

- aquifer type (confined or unconfined);
- aquifer thickness and depth;
- Depth to water table level, and/or the level of piezometric/pressure heads for deeper confined groundwater bodies, at the drilling location itself, as well as assessment of their spatial and temporal variations in the surrounding region.
- hydrodynamic parameters such as porosity and hydraulic conductivity/permeability with varying depth;
- specific capacity of neighbouring wells, as available;
- direction of regional and local groundwater flow;
- influence of surface water (influent or effluent).

Special requirements: For drinking water abstraction or dewatering wells, which can induce later infiltration, potential sources of pollution, such as landfills, shall be identified and evaluated at an early planning stage.

6.2.3 Characterization of groundwater quality

An understanding of the physical and chemical quality of the abstracted water is essential during the design process in order to be able to determine the most efficient type of drilling operation as well as the appropriate choice of materials for the well.

6.3 Compliance

A report that shall contain a prediction (forecast) of the following hydrogeological aspects:

- physical parameters of the groundwater (e.g. temperature);
- *in situ* parameters of the groundwater (e.g. electrical conductivity);
- chemical parameters depending on the purpose and use of the water (e.g. Iron, manganese, nitrate and chloride concentration, pH).

The means of gathering information (informative for all requirements) include:

- geological maps (at different scales) and reports;
- databases (geology, hydrology, hydrogeology);
- information and results from neighbouring boreholes and wells and/or water-supply projects;
- governmental and local administration bodies (entities);

- local experience (e.g. based on experience with groundwater wells in locations in the vicinity of the project site with similar hydrogeological conditions).

In case of insufficient knowledge or depending on the specific purpose of the project, additional information is to be obtained through:

- exploratory (pilot) boreholes;
- geo-hydrological surveys at project scale;
- surface or airborne geophysics;
- remote sensing particularly in the case of hard rocks.

7 Qualitative risk assessment

7.1 Background

Regional or local conditions may cause a well to fail (e.g. collapse of bore hole due to artesian conditions, clogging). Also, drilling and operation of the well may have an impact on the environment and other users of the subsurface (e.g. interaction with neighbouring wells, subsidence). These types of failure mechanisms shall be anticipated in the design phase.

Note that it may be necessary to calculate the hydrological influence of abstracting and/or injecting water including secondary effects (such as settlement and depression of agricultural yield depression). Such assessment is in order to establish risks for other users and/or for applying for permits. These calculations are not covered by this standard.

7.2 Requirements

Risk analysis for the construction and operation of the well.

7.3 Compliance

The risk analysis shall involve the following steps:

- 1) *Characterize environmental conditions and other uses in the surrounding area.* The designing party shall define and confirm substantiate the “surrounding area”. The size may, for example, be determined by the area where within which the well causes a net displacement of water or change of heads above a certain threshold.

The following information shall be used to characterize the environmental conditions (if available from a desktop study) and is necessary to perform the risk assessment:

- other wells, including abandoned wells, abstraction wells and geothermal energy systems in the surrounding areas;
- (mobile) soil pollution in the surrounding area;
- terrain and buildings sensitive to settlement or collapse (e.g. via sinkholes);
- groundwater-dependent ecosystems;
- hydraulic structures such as dikes and sluices.

2) *List failure mechanisms.*

Consider at least the non-limiting list of failure mechanisms and how to recognize them as described in Annex B.

3) *Evaluate the likelihood that these failure mechanisms will occur, the severity of the consequence for the well and the environment/other users.*

4) *Verify whether the available data are sufficient for proper assessment of failure mechanisms and risks. If not, then additional field investigation or quantitative risk assessment shall be proposed.*

The need for additional investigation depends on the quality of the available information and the likelihood of failure mechanisms with high consequences. Proposals for additional investigation shall include the purpose of the investigation and a description of the methodology.

5) *Determine how risks can be controlled or mitigated.*

Possible mitigating measures are mentioned in Annex B.

8 Estimation of yield

8.1 Background

The estimation of the anticipated yield of a well depends on:

- the prognosis of the demand (i.e. the project goal);
- the availability and choice of a suitable aquifer;
- constraints related to groundwater management imposed by administrative bodies;
- technical aspects imposed by well design and operation.

The anticipated (estimated) well yield is an important parameter, as it defines the likely success of the project in meeting the required production capacity.

The sustainable well yield depends on the transmissivity of the target aquifer and its longterm recharge. It is therefore important that these parameters are predicted in order to be able to estimate the sustainable yield.

An estimated specific capacity is an important parameter enable determination of the design characteristics for the planned well, such as:

- the length of the production screen;
- the diameter of the drill hole and the completed well;
- in the case of a production well, the depth at which a submersible pump may be installed (or the suction pipe in case of a vacuum pump), so that the water level in the well will always remain above the pump (or the end of the suction pipe);
- in the case of an infiltration well, the maximum pressure overhead tolerated in the well.

By obtaining a sufficiently reliable figure for the specific capacity, it is straightforward to estimate the well yield.

The anticipated well yield can also be estimated from a variety of sources including local experience, expert knowledge, databases or an exploratory well. Each method will have a different level of uncertainty which shall be matched with the scale of the project and the level of risk acceptable to the developer. Note that it is never possible to be 100 % certain of the estimate.

8.2 Requirement 1

Select the target aquifer.

8.3 Compliance

- The aquifer has a sufficient (anticipated) transmissivity.
- The aquifer is well protected against anthropogenic influences.
- The (presumed) water quality meets the objective of the well in the longterm.

8.4 Requirement 2

Estimate of the anticipated well yield (Q_{well}) with sufficient confidence to allow design of the production well or test well.

8.5 Compliance

- Check whether the anticipated well yield meets the project objectives.
- If more than one well is required then the mutual interaction between the wells shall be taken into account.
- Document the sources that are consulted.
- Describe the analysis method.
- Establish the criteria which the well design will be undertaken (such as maximum allowable draw down, flow velocity and discharge, see Clause 10 for details).
- Indicate a range of possible outcomes.
- State and justify an expected value for the yield.

9 Pump selection

9.1 Background

Before designing or drilling a water well, it shall be clear how the water will be abstracted. If the pumping water level in the well is likely to drop further than 8 m below ground level (mbgl), the use of a conventional suction pump will not be possible and a submersible pump will be required. The inside diameter of the well shall be sufficient to allow the submersible pump to be installed below the lowest dynamic water level.

It is critical that the well is designed to accommodate the correctly sized submersible pump (refer to Annex C, Table C.1 for an indication of submersible pump diameter for a required flow rate). Also the space should be designed to allow sufficient flow past the pump for cooling. In some cases it will also be necessary to fit a pump shroud to facilitate motor cooling when a portion of the pumped water comes from above the pump suction intake. The manufacturer will advise on the shroud diameter required and this shall be allowed for in the well lining design. Some borehole operators may require additional equipment such as pressure transducers or CCTV inspection access tubes which will add to the diameter requirements. The diameter of the pump power cable, cable joint and rising main couplings should be checked to ensure there is adequate clearance. Detailed specification of the final production pump and rising main should be undertaken once the well performance has been established by a pumping test. Final selection of the pump should take account of cooling and energy efficiency requirements.

9.2 Requirement

Establishment of the diameter and position of the submersible pump, based on the yield and pumping rates.

9.3 Compliance

The pump diameter shall be established based on the likely well yield or abstraction rate requirement (whichever is the smaller), together with an estimate of the total pumping head.

The positioning of the submersible pump should be in a blank section of the casing/screen string unless a pump shroud over the submersible pump motor and intake is used. The submersible pump shall be positioned below the lowest dynamic water level, with sufficient depth of water above the submersible pump to prevent cavitation.

In addition, the depth of the submersible pump positioning may be limited by the top of the screened casing, to ensure that the screen is kept under water; and by the depth of the highest productive aquifer, or contributing layer in the case of a heterogeneous aquifer, since dewatering of the contributing layers will reduce the transmissivity and may allow air to enter the formation.

Document the natural variation in water levels in the aquifer, to assess the deepest likely natural water level in the production aquifer (**a meters below ground level, mbgl**).

- Estimate the well drawdown (**b meters**) and effects on it from adjacent wells (**c meters**).
- Estimate the total pumping head required, including static head above and below ground level, pipe friction losses and secondary losses in pipe fittings (including the pump non-return valve). (**d meters**).
- Select the submersible pump diameter from manufacturers Information based on total pumping head (**d**) and expected yield.
- Document the required minimum residual water column while the submersible pump is in operation, based on the submersible pump specification (**e meters**).

- Allowances shall be made for uncertainty in the aquifer properties, clogging and future trends in the water level. **(f meters)**.
- The installation depth of the submersible pump shall be:

Depth > a + b + c + e + f (mbgl)
- Installation position shall take account of the other potential constraints such as the position of the uppermost screen and depth of the highest productive layer.
- Document the selection process.

During determination of pump specifications, the planner should consider the physical and chemical characteristics of the water to be abstracted, as this may have adverse effects on the material, performance and lifespan of the pump.

When designing a pump head, requirements downstream shall also be considered including use of a booster pump when downstream total head losses may be significant.

10 Dimensioning of the well

10.1 General background

The well dimensioning addressed in this section presumes that information regarding the hydrogeological setting has previously been collected from reliable sources, such as from exploratory boreholes or local experience.

The aim of well dimensioning is to attain an optimal balance among the technical dimensions of the well itself within its hydrogeological setting. The dimensioning of the well can be considered as an iterative process taking into account information on aquifer thickness and yield.

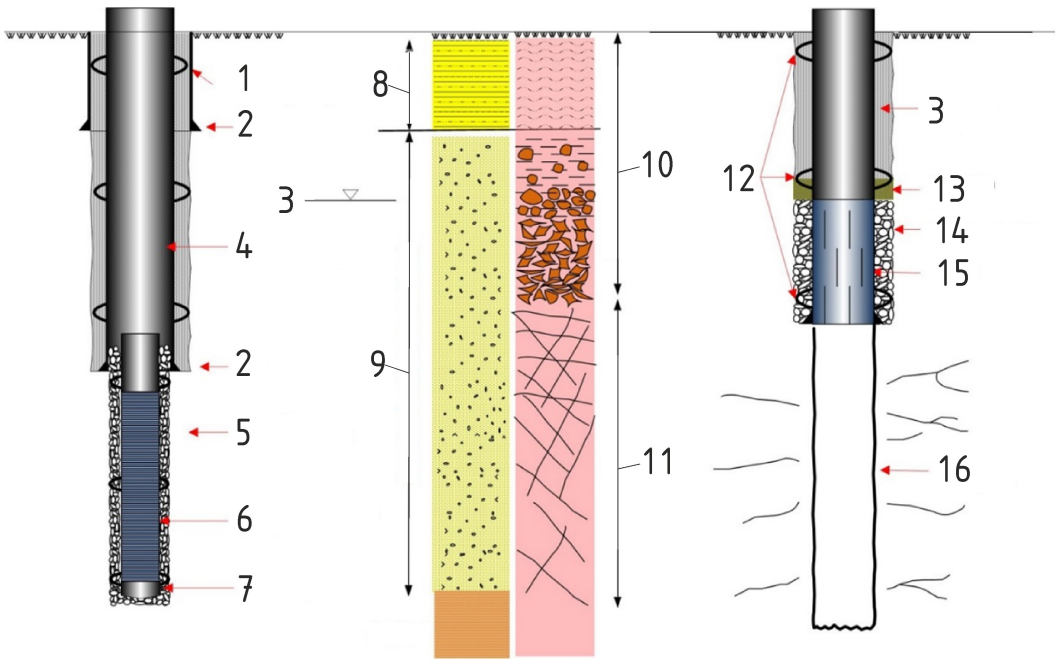
The minimum dimensions of the well depend on the estimation of the pump dimensions in combination with its position within the well, which both define all remaining parameters for well dimensioning.

Selection of the well diameters is also related to available drilling tools, starting at the targeted aquifer level.

Dimensioning the well depends on the following aquifer equipment options related to the production section:

- Open borehole. i.e. without screen or casing;
- Screened but without filter pack;
- Naturally developed filter pack in heterogeneous coarse material (typical criteria being 80 % of grain size larger than 0,5 mm and the uniformity coefficient $U > 3$);
- Artificial gravel (filter) pack when aquifer cannot be naturally filtered (typical value $U < 3$);
- Stabilizer pack when filtering is not required but gravel is necessary to maintain borehole stability and to support the separation filter and sealing material.

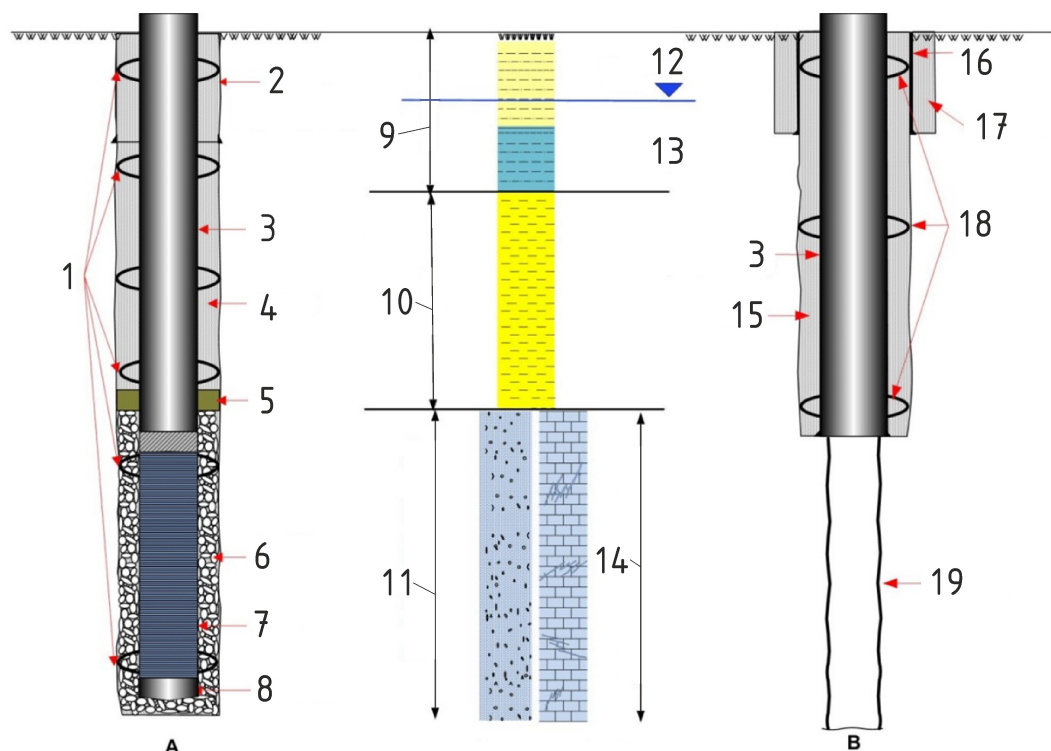
The borehole may either consist of a single diameter drilling to depth or of various drilling diameters in the form of a telescopic borehole (see Figure 1 and Figure 2).



Key

1	9
2	10
3	11
4	12
5	13
6	14
7	15
8	16

Figure 1 — Borehole components in an unconfined aquifer



Key

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	

Figure 2 — Borehole components in a confined aquifer

Well completion may comprise one or several casings.

In the case of a single casing, the production section, the conductor casing and the pump chamber have a unique diameter from the bottom to the top, but with different backfilling materials between the casing and the geological formations, usually: filter pack, clay seal and cement seal (see Clause 11).

The use of two or more casing diameters (telescopic wells) may be dictated by the complexity of the geological formations (unconsolidated materials at the top or within the upper layers, excluded aquifer layers, zones of expected drilling fluid losses), critical drilling depth and economical optimization of the drilling costs. Whatever the complexity of the well, its principal dimension (diameter) will be chosen technically in order to fulfil its objective (usually, to produce a certain yield of water). The drilling diameters will be chosen to correspond to the casing diameters, respecting the annular space required to protect against cementation failure.