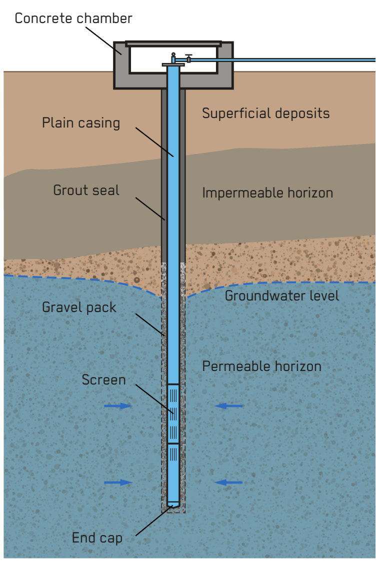
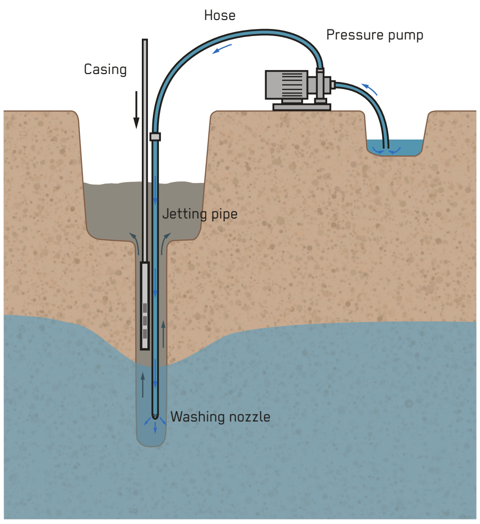
Protected Borehole

Response Phase	Application Level	Management Level	Objectives / Key Features
* Acute Response ** Stabilisation ** Recovery	* Household ** Neighbourhood ** City	* Household ** Shared ** Public	Extracting shallow/deep ground-water, drilled wells
Local Availability	**Technical Complexity**	**Maturity Level**	
** Medium	*** High	*** High	

PROTECTED BOREHOLE



JETTED WELL METHOD



A Protected Borehole is a small diameter drilled hole that is lined and covered, with water withdrawn using a pump. Existing boreholes can be equipped quickly to provide water in the acute response phase, but new boreholes, with the exception of jetted wells, are normally reserved for the stabilisation phase, as they can take several months to organise and complete.

Protected Boreholes can be drilled using various methods, both manually (e.g. augering, percussion, sludging, jetting) and mechanically (e.g. with a rotary mud flush drill rig or using compressed air to drive a down-the-hole hammer). The drill depth ranges widely from several metres up to 500 metres. The drilling diameter is usually between 100–250 mm. Borehole drilling is a specialist activity requiring proper siting, design, construction and testing for proper functioning.

Design Considerations: Well jetting is suited to shallow, weakly cohesive sandy/silty aquifers and can be done rapidly and with high success rates. For most boreholes, finding water in deeper aquifers can be more challenging. Even when drillers have experience in a particular area, the exact amount of water and its quality cannot be known in advance. Hydrogeological surveys (including geophysics) can help reduce failure rates in certain areas but do not guarantee success. Even if a borehole can deliver a certain yield in the short term and the aquifer is able to yield the water, if the groundwater is not replenished, then that yield will not be sustainable. It is therefore important (more so where high-production submersible pumps are installed) to evaluate this through a water balance calculation. In coastal areas, saltwater intrusion can also become a problem depending on withdrawal rates **(see I.9)**.
Boreholes should last for 20 to 50 years, and to achieve this proper design is essential, which considers thickness/depth/productivity of the aquifer, target yield, efficiency when in use and water quality. All these elements

should be considered at the outset and then checked during and after the drilling process, yet often this is not the case. Casing stabilises the well walls and prevents contamination from the surrounding soil, though is not always needed in stable rock with clean fractures. The screen serves a similar function, though is placed within the aquifer and contains holes/slots to allow water through. Screens come with slots of different widths (e.g. 0.5–1.5 mm), which are chosen based on the size of the material surrounding the screen to prevent finer material from entering in the long term. The required length of the screens depends on aquifer type/thickness, the demand, expected well productivity and the velocity of water entering the screen. The velocity should never exceed 0.03 m/s due to turbulence and resulting energy losses, as well as incrustation and sand particles being continually drawn in over time. Pumps should never be installed within the screens, and drawdown (the level of the water table during pumping) should never reach the screens. Pumps can be installed below a screen, but a shroud should be fitted in this case to ensure motor cooling. A sand trap with a plug is installed at the bottom of the screens to collect sand entering during borehole development and later use. In most aquifers, a gravel pack will be needed between the screen and the borehole walls, as the aquifer material is often smaller than the available screen slot size. The gravel pack is a mix of sieved coarse sand (usually between 1–6 mm) determined by a sieve analysis and is sized so that only 10 % of the grains in the aquifer pass through the slots. Its additional function is to increase the velocity of water entering the well.

After screens are in place, borehole development is essential to clean out any drilling mud or foam and to pull in finer material from the gravel pack to thereby increase water flow, a lengthy process that will vary according to the drilling technique (i.e. done until water is clear and free of any particles in suspension). A pumping test is also critical to investigate the well efficiency, safe yield and pump placement and may take several hours. Finished boreholes are protected by backfilling around the casing with clay, sealing the top five metres with a sanitary seal (e.g. cement grout) and installing a well head (usually metal and visible above ground) to prevent contamination of the well and protect against floods.

Materials: Materials include the casing/screen/sand trap (usually PVC or steel), gravel pack and a pump for abstracting the water.

Applicability: In the acute response phase, jetted wells can be made rapidly in sandy/silty alluvial aquifers, and existing boreholes can often be upgraded to provide water quickly, typically using a submersible pump and water distribution system. Deeper boreholes can be made in all types of ground and aquifers. While sometimes quick to drill, in practice it tends to take a few months to contract a driller to complete a well, so new boreholes are generally only considered for the stabilisation and recovery phases.

Operation and Maintenance: Includes ensuring that water from the surface cannot short-circuit into the well (e.g. preventing ponding of wastewater, checking the slab and apron for cracks) and using a fence to keep out grazing animals). Screens must be cleaned every few years. Most O & M will be related to pump function.

Health and Safety: Heavy drilling machinery with moving parts are always a risk, so good site management is needed, especially managing spectators. Overhead power lines are a risk factor when setting up drilling rigs. Care is needed to prevent collapse when installing jetted wells which are often started near the water table at the bottom of an excavated hole. In certain regions, there can also be health risks associated with levels of natural chemicals (e.g. arsenic, fluoride and nitrate). Where the pH is <5, the corrosion of metal pipes is a concern.

Costs: The cost for a typical drilled well varies from 125–300 USD per metre. Jetted wells tend to be cheaper (up to 150 USD per metre).

Social and Environmental Considerations: Boreholes are usually accepted if the water quality and taste are acceptable to users. Some aquifers though have significant levels of minerals that can affect taste and acceptability and cause users to search for alternative sources. For high abstraction requirements, the water taken from an aquifer should not exceed the water entering the aquifer **(see S.5)**.

Strengths and Weaknesses:

- (+) Safer and quicker to construct than dug wells
- (+) Good option for all soil types
- (+) Less susceptible to microbiological contamination compared to dug wells

- (−) High-technology option using specialised equipment and needing expertise
- (−) Water access not possible if pump breaks down
- (−) Higher overall cost for construction compared with dug wells, yet at times with more uncertain results
- (−) Chemical water quality can be variable
- (−) Difficult to assess water quality or quantity without existing boreholes as evidence

→ **References and further reading material for this technology can be found on page 215**