# Water well

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A dug well in a village in Faryab Province, Afghanistan.

A **water well** is an excavation or structure created in the ground by digging, driving, boring, or drilling to access groundwater in underground aquifers. The well water is drawn by a pump, or using containers, such as buckets, that are raised mechanically or by hand. Wells were first constructed at least eight thousand years ago and historically vary in construction from a simple scoop in the sediment of a dry watercourse to the stepwells of India, the qanats of Iran, and the shadoofs and sakiehs of India. Placing a lining in the well shaft helps create stability and linings of wood or wickerwork date back at least as far as the Iron Age.

Wells have been traditionally sunk by hand digging as is the case in rural developing areas. These wells are inexpensive and low-tech as they use mostly manual labour and the structure can be lined with brick or stone as the excavation proceeds. A more modern method called caissoning uses pre-cast reinforced concrete well rings that are lowered into the hole. Driven wells can be created in unconsolidated material with a well hole structure, which consists of a hardened drive point and a screen of perforated pipe, after which a pump is installed to collect the water. Deeper wells can be excavated by hand drilling methods or machine drilling, using a bit in a borehole. Drilled wells are usually cased with a factory-made pipe composed of steel or plastic. Drilled wells can access water at much greater depths than dug wells.

Two broad classes of well are shallow or unconfined wells completed within the uppermost saturated aquifer at that location, and deep or confined wells, sunk through an impermeable stratum into an aquifer beneath. A collector well can be constructed adjacent to a freshwater lake or stream with water percolating through the intervening material. The site of a well can be selected by a hydrogeologist, or groundwater surveyor. Water may be pumped or hand drawn. Impurities from the surface can easily reach shallow sources and contamination of the supply by pathogens or chemical contaminants needs to be avoided. Well water typically contains more minerals in solution than surface water and may require treatment before being potable. Soil salination can occur as the water table falls and the surrounding soil begins to dry out. Another environmental problem is the potential for methane to seep into the water.

## Contents

# Types

## Dug wells


Leather bucket used for the water well.

Until recent centuries, all artificial wells were pumpless hand-dug wells of varying degrees of sophistication, and they remain a very important source of potable water in some rural developing areas where they are routinely dug and used today. Their indispensability has produced a number of literary references, literal and figurative, to them, including the reference to the incident of Jesus meeting a woman at Jacob's well (John 4:6) in the bible and the "Ding Dong Bell" nursery rhyme about a cat in a well.


A dug well, large shadoof (well sweep), and old barn in Markowa, Poland

Hand-dug wells are excavations with diameters large enough to accommodate one or more people with shovels digging down to below the water table. The excavation is braced horizontally to avoid landslide or erosion endangering the people digging. They can be lined with laid stones or brick; extending this lining upwards above the ground surface to form a wall around the well serves to reduce both contamination and injuries by falling into the well. A more modern method called caissoning uses reinforced concrete or plain concrete pre-cast well rings that are lowered into the hole. A well-digging team digs under a cutting ring and the well column slowly sinks into the aquifer, whilst protecting the team from collapse of the well bore.

Hand-dug wells are inexpensive and low tech (compared to drilling) as they use mostly manual labour to access groundwater in rural locations in developing countries. They may be built with a high degree of community participation, or by local entrepreneurs who specialize in hand-dug wells. They have been successfully excavated to 60 metres (200 ft). They have low operational and maintenance costs, in part because water can be extracted by hand bailing, without a pump. The water is often coming from an aquifer or groundwater, and can be easily deepened, which may be necessary if the ground water level drops, by telescoping the lining further down into the aquifer. The yield of existing hand dug wells may be improved by deepening or introducing vertical tunnels or perforated pipes.

Drawbacks to hand-dug wells are numerous. It can be impractical to hand dig wells in areas where hard rock is present, and they can be time-consuming to dig and line even in favourable areas. Because they exploit shallow aquifers, the well may be susceptible to yield fluctuations and possible contamination from surface water, including sewage. Hand dug well construction generally requires the use of a well trained construction team, and the capital investment for equipment such as concrete ring moulds, heavy lifting equipment, well shaft formwork, motorized de-watering pumps, and fuel can be large for people in developing countries. Construction of hand dug wells can be dangerous due to collapse of the well bore, falling objects and asphyxiation, including from dewatering pump exhaust fumes.

Well, Historical Village, Bhaini Sahib, Ludhiana, Punjab, India

Woodingdean well, hand-dug between 1858 and 1862, is claimed to be the world's deepest hand-dug well at 392 metres (1,285 ft).[1] The Big Well in Greensburg, Kansas is billed as the world's largest hand-dug well, at 109 feet (33 m) deep and 32 feet (9.8 m) in diameter. However, the *Well of Joseph* in the Cairo Citadel at 280 feet (85 m) deep and the Pozzo di S. Patrizio (St. Patrick's Well) built in 1527 in Orvieto, Italy, at 61 metres (200 ft) deep by 13 metres (43 ft) wide[2] are both larger by volume.

View into a hand-dug well cased with concrete rings; Ouelessebougou, Mali.

## Driven wells

Driven wells may be very simply created in unconsolidated material with a *well hole structure*, which consists of a hardened drive point and a screen (perforated pipe). The point is simply hammered into the ground, usually with a tripod and *driver*, with pipe sections added as needed. A driver is a weighted pipe that slides over the pipe being driven and is repeatedly dropped on it. When groundwater is encountered, the well is washed of sediment and a pump installed.[3]

A dug well in a village in Kerala, India.

## Drilled wells

Drilled wells are typically created using either top-head rotary style, table rotary, or cable tool drilling machines, all of which use drilling stems that are turned to create a cutting action in the formation, hence the term *drilling*.

Drilled wells can be excavated by simple hand drilling methods (augering, sludging, jetting, driving, hand percussion) or machine drilling (rotary, percussion, down the hole hammer). Deeprock rotary drilling method is most common. Rotary can be used in 90% of formation types.

Drilled wells can get water from a much deeper level than dug wells can—often down to several hundred metres.

Drilled wells with electric pumps are used throughout the world, typically in rural or sparsely populated areas, though many urban areas are supplied partly by municipal wells. Most shallow well drilling machines are mounted on large trucks, trailers, or tracked vehicle carriages. Water wells typically range from 3 to 18 metres

(10–60 ft) deep, but in some areas can go deeper than 900 metres (3,000 ft).

Cable tool water well drilling rig in Kimball, West Virginia, USA.

Rotary drilling machines use a segmented steel drilling string, typically made up of 6 metres (20 ft) sections of galvanized steel tubing that are threaded together, with a bit or other drilling device at the bottom end. Some rotary drilling machines are designed to install (by driving or drilling) a steel casing into the well in conjunction with the drilling of the actual bore hole. Air and/or water is used as a circulation fluid to displace cuttings and cool bits during the drilling. Another form of rotary style drilling, termed *mud rotary*, makes use of a specially made mud, or drilling fluid, which is constantly being altered during the drill so that it can consistently create enough hydraulic pressure to hold the side walls of the bore hole open, regardless of the presence of a casing in the well. Typically, boreholes drilled into solid rock are not cased until after the drilling process is completed, regardless of the machinery used.

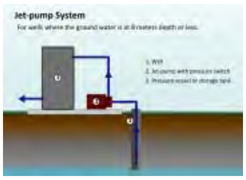
The oldest form of drilling machinery is the cable tool, still used today. Specifically designed to raise and lower a bit into the bore hole, the *spudding* of the drill causes the bit to be raised and dropped onto the bottom of the hole, and the design of the cable causes the bit to twist at approximately $^1/_4$ revolution per drop, thereby creating a drilling action. Unlike rotary drilling, cable tool drilling requires the drilling action to be stopped so that the bore hole can be bailed or emptied of drilled cuttings.

Water well drilling in Ein Hemed, near Jerusalem circa 1964

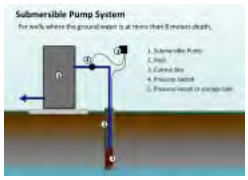
Drilled wells are usually cased with a factory-made pipe, typically steel (in air rotary or cable tool drilling) or plastic/PVC (in mud rotary wells, also present in wells drilled into solid rock). The casing is constructed by welding, either chemically or thermally, segments of casing together. If the casing is installed during the drilling, most drills will drive the casing into the ground as the bore hole advances, while some newer machines will actually allow for the casing to be rotated and drilled into the formation in a similar manner as the bit advancing just below. PVC or plastic is typically welded and then lowered into the drilled well, vertically stacked with their ends nested and either glued or splined together. The sections of casing are usually 6 metres (20 ft) or more in length, and 6 to 12 in (15 to 30 cm) in diameter, depending on the intended use of the well and local groundwater conditions.

Surface contamination of wells in the United States is typically controlled by the use of a *surface seal*. A large hole is drilled to a predetermined depth or to a confining formation (clay or bedrock, for example), and then a smaller hole for the well is completed from that point forward. The well is typically cased from the surface down into the smaller hole with a casing that is the same diameter as that hole. The annular space between the large bore hole and the smaller casing is filled with bentonite clay, concrete, or other sealant material. This creates an impermeable seal from the surface to the next confining layer that keeps contaminants from traveling down the outer sidewalls of the casing or borehole and into the aquifer. In addition, wells are typically capped with either an engineered well cap or seal that vents air through a screen into the well, but keeps insects, small animals, and unauthorized persons from accessing the well.

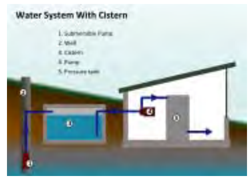
At the bottom of wells, based on formation, a screening device, filter pack, slotted casing, or open bore hole is left to allow the flow of water into the well. Constructed screens are typically used in unconsolidated formations (sands, gravels, etc.), allowing water and a percentage of the formation to pass through the screen. Allowing some material to pass through creates a large area filter out of the rest of the formation, as the amount of material present to pass into the well slowly decreases and is removed from the well. Rock wells are typically cased with a PVC liner/casing and screen or slotted casing at the bottom, this is mostly present just to keep rocks from entering the pump assembly. Some wells utilize a *filter pack* method, where an undersized screen or slotted casing is placed inside the well and a filter medium is packed around the screen, between the screen and the borehole or casing. This allows the water to be filtered of unwanted materials before entering the well and pumping zone.



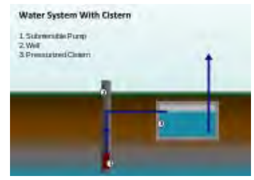

An automated water well system powered by a jet-pump.




An automated water well system powered by a submersible pump.




A water well system with a cistern.



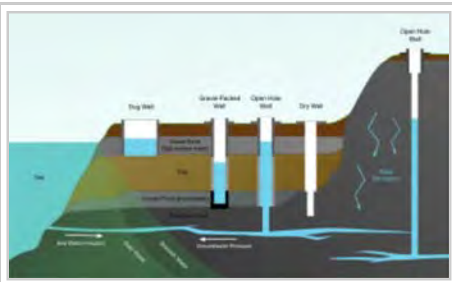

A water well system with a pressurized cistern.

A section of a stainless steel screen well.

# Classification

There are two broad classes of drilled-well types, based on the type of aquifer the well is in:

- *Shallow* or *unconfined wells* are completed in the uppermost saturated aquifer at that location (the upper unconfined aquifer).
- *Deep* or *confined wells* are sunk through an impermeable stratum into an aquifer that is sandwiched between two impermeable strata (aquitards or aquicludes). The majority of deep aquifers are classified as artesian because the hydraulic head in a confined well is higher than the level of the top of the aquifer. If the hydraulic head in a confined well is higher than the land surface it is a "flowing" artesian well (named after Artois in France).



Water well types.

A special type of water well may be constructed adjacent to freshwater lakes or streams. Commonly called a collector well but sometimes referred to by the trade name Ranney well or Ranney collector, this type of well involves sinking a caisson vertically below the top of the aquifer and then advancing lateral collectors out of the caisson and beneath the surface water body. Pumping from within the caisson induces infiltration of water from the surface water body into the aquifer, where it is collected by the collector well laterals and conveyed into the caisson where it can be pumped to the ground surface.

Two additional broad classes of well types may be distinguished, based on the use of the well:

- *production* or *pumping wells*, are large diameter (greater than 15 cm in diameter) cased (metal, plastic, or concrete) water wells, constructed for extracting water from the aquifer by a pump (if the well is not artesian).
- *monitoring wells* or *piezometers*, are often smaller diameter wells used to monitor the hydraulic head or sample the groundwater for chemical constituents. Piezometers are monitoring wells completed over a very short section of aquifer. Monitoring wells can also be completed at multiple levels, allowing discrete samples or measurements to be made at different vertical elevations at the same map location.

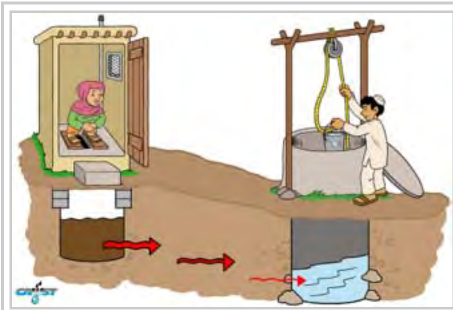
A well constructed for pumping groundwater can be used passively as a monitoring well and a small diameter well can be pumped, but this distinction by use is common.

# Siting

Before excavation, information about the geology, water table depth, seasonal fluctuations, recharge area and rate must be found. This work is typically done by a hydrogeologist, or a groundwater surveyor using a variety of tools including electro-seismic surveying,[4] any available information from nearby wells, geologic maps, and sometimes geophysical imaging.

# Contamination

Shallow pumping wells can often supply drinking water at a very low cost. However, impurities from the surface easily reach shallow sources, which leads to a greater risk of contamination for these wells compared to deeper wells. Contaminated wells can lead to the spread of various waterborne diseases. Dug and driven wells are relatively easy to contaminate; for instance, most dug wells are unreliable in the majority of the United States.[5]



Waterborne diseases can be spread via a well which is contaminated with fecal pathogens from pit latrines

## Pathogens

Most of the bacteria, viruses, parasites, and fungi that contaminate well water comes from fecal material from humans and other animals, for example from on-site sanitation systems (such as pit latrines and septic tanks). Common bacterial contaminants include *E. coli*, *Salmonella*, *Shigella*, and *Campylobacter jejuni*. Common viral contaminants include *norovirus*, *sapovirus*, *rotavirus*, enteroviruses, and hepatitis A and E. Parasites include *Giardia lamblia*, *Cryptosporidium*, *Cyclospora cayetanensis*, and microsporidia.[5]

## Chemical contamination

Chemical contamination is a common problem with groundwater. Nitrates from sewage, sewage sludge or fertilizer are a particular problem for babies and young children. Pollutant chemicals include pesticides and volatile organic compounds from gasoline, dry-cleaning, the fuel additive methyl tert-butyl ether (MTBE), and perchlorate from rocket fuel, airbag inflators, and other artificial and natural sources.


Man cleaning a well in Yaoundé, Cameroon.

Several minerals are also contaminants, including lead leached from brass fittings or old lead pipes, chromium VI from electroplating and other sources, naturally occurring arsenic, radon, and uranium—all of which can cause cancer—and naturally occurring fluoride, which is desirable in low quantities to prevent tooth decay, but can cause dental fluorosis in higher concentrations.[5]

Some chemicals are commonly present in water wells at levels that are not toxic, but can cause other problems. Calcium and magnesium cause what is known as hard water, which can precipitate and clog pipes or burn out water heaters. Iron and manganese can appear as dark flecks that stain clothing and plumbing, and can promote the growth of iron and manganese bacteria that can form slimy black colonies that clog pipes.[5]


Hand pump to pump water from a well in a village near Chennai in India, where the well water might be polluted by nearby pit latrines

## Prevention

The quality of the well water can be significantly increased by lining the well, sealing the well head, fitting a self-priming hand pump, constructing an apron, ensuring the area is kept clean and free from stagnant water and animals, moving sources of contamination (pit latrines, garbage pits, on-site sewer systems) and carrying out hygiene education. The well should be cleaned with 1% chlorine solution after construction and periodically every 6 months.

Well holes should be covered to prevent loose debris, animals, animal excrement, and wind-blown foreign matter from falling into the hole and decomposing. The cover should be able to be in place at all times, including when drawing water from the well. A suspended roof over an open hole helps to some degree, but ideally the cover should be tight fitting and fully enclosing, with only a screened air vent.

Minimum distances and soil percolation requirements between sewage disposal sites and water wells need to be observed. Rules regarding the design and installation of private and municipal septic systems take all these factors into account so that nearby drinking water sources are protected.

Education of the general population in society also plays an important role in protecting drinking water.

## Mitigation

Cleanup of contaminated groundwater tends to be very costly. Effective remediation of groundwater is generally very difficult. Contamination of groundwater from surface and subsurface sources can usually be dramatically reduced by correctly centering the casing during construction and filling the casing annulus with an appropriate sealing material. The sealing material (grout) should be placed from immediately above the production zone back to surface, because, in the absence of a correctly constructed casing seal, contaminated fluid can travel into the well through the casing annulus. Centering devices are important (usually 1 per length of casing or at maximum intervals of 9 m) to ensure that the grouted annular space is of even thickness. Upon the construction of a new test well, it is considered best practice to invest in a complete battery of chemical and biological tests on the well water in question. Point-of-use treatment is available for individual properties and treatment plants are often constructed for municipal water supplies that suffer from contamination. Most of these treatment methods involve the filtration of the contaminants of concern, and additional protection may be garnered by installing well-casing screens only at depths where contamination is not present.

Well water for personal use is often filtered with reverse osmosis water processors; this process can remove very small particles. A simple, effective way of killing microorganisms is to bring the water to a full boil for one to three minutes, depending on location. A household well contaminated by microorganisms can initially be treated by shock chlorination using bleach, generating concentrations hundreds of times greater than found in community water systems; however, this will not fix any structural problems that led to the contamination and generally requires some expertise and testing for effective application.[5]

After the filtration process, it is common to implement an Ultraviolet (UV) system to kill pathogens in the water. UV light effects the DNA of the pathogen by UV-C photons breaking through the cell wall. UV disinfection has been gaining popularity in the past decades as it is a chemical free method of water treatment.[6]

# Environmental problems

A risk with the placement of water wells is soil salination which occurs when the water table of the soil begins to drop and salt begins to accumulate as the soil begins to dry out.[7] Another environmental problem that is very prevalent in water well drilling is the potential for methane to seep through.

## Soil salination

The potential for soil salination is a large risk when choosing the placement of water wells. Soil salination is caused when the water table of the soil drops over time and salt begins to accumulate. In turn, the increased amount of salt begins to dry the soil out. This is a very detrimental problem because the increased level of salt in the soil can result in the degradation of soil and can be very harmful to vegetation.

## Methane

Methane, an asphyxiant, is a chemical compound that is the main component of natural gas. When methane is introduced into a confined space, it displaces oxygen, reducing oxygen concentration to a level low enough to pose a threat to humans and other aerobic organisms but still high enough for a risk of spontaneous or externally caused explosion. This potential for explosion is what poses such a danger in regards to the drilling and placement of water wells.

Low levels of methane in drinking water are not considered toxic. When methane seeps into a water supply, it is commonly referred to as "methane migration". This can be caused by old natural gas wells near water well systems becoming abandoned and no longer monitored.

Lately, however, the described wells/pumps are no longer very efficient and can be replaced by either handpumps or treadle pumps. Another alternative is the use of self-dug wells, electrical deep-well pumps (for higher depths). Appropriate technology organizations as Practical Action are now supplying information on how to build/set-up (DIY) handpumps and treadle pumps in practice.[8][9]

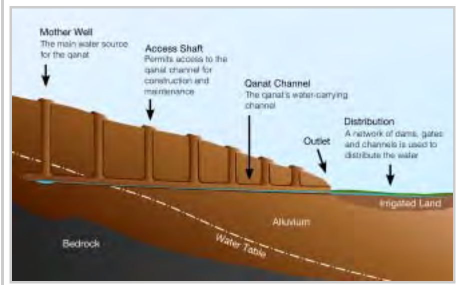
# History


Camel drawing water from a well, Djerba island, Tunisia

Wood-lined wells are known from the early Neolithic Linear Pottery culture, for example in Kückhoven (an outlying centre of Erkelenz), dated 5090 BC and Eythra, dated 5200 BC in Schletz (an outlying centre of Asparn an der Zaya) in Austria.[10]

Australian Aborigines relied on wells to survive the harsh Australian desert. They would dig down, scooping out sand and mud to reach clean water, then cover the source with spinifex to prevent spoilage. Non-Aborigines call these native wells, soaks or soakages.

Stepwells are common in the west of India. In these wells, the water may be reached by descending a set of steps. They may be covered and are often of architectural significance. Many stepwells were also used for leisure, providing relief from the daytime heat.



A qanat

A qanat is an ancient water collection system made up of a series of wells and linked underground water channels that collects flowing water from a source usually a distance away, stores it, and then brings the water to the surface using gravity. Much of the population of Iran and other arid countries in Asia and North Africa historically depended upon the water from qanats; the areas of population corresponded closely to the areas where qanats are possible.

In Egypt, shadoofs and sakiehs are used.[11][12] When compared to each other however, the Sakkieh is much more efficient, as it can bring up water from a depth of 10 metres (versus the 3 metres of the shadoof). The Sakieh is the Egyptian version of the Noria.

From the Iron Age onwards, wells are common archaeological features, both with wooden shafts and shaft linings made from wickerwork.

Some of the world's oldest known wells, located in Cyprus, date to 7000-8500 BC.[13] Two wells from the Neolithic period, around 6500 BC, have been discovered in Israel. One is in Atlit, on the northern coast of Israel, and the other is the Jezreel Valley.

# Society and culture


Water use, tacuinum sanitatis casanatensis (14th century)

Springs and wells have had cultural significance since prehistoric times, leading to the foundation of towns such as Wells and Bath in Somerset. Interest in health benefits led to the growth of spa towns including many with *wells* in their name, examples being Llandrindod Wells and Royal Tunbridge Wells.

Eratosthenes first calculated the radius of the Earth in about 230 BC by comparing shadows in wells during the summer solstice.

Many incidents in the bible take place around wells, such as the finding of a wife for Isaac in Genesis and Jesus's talk with the Samaritan woman in the Gospels.

# See also

- History of water supply and sanitation
- Baptist well drilling
- Brick-lined well
- Castle well
- Drainage by wells
- Spring supply
- Step well

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# External links

- Sustainable Groundwater Development theme of the Rural Water Supply Network (RWSN) (http://www.rural-water-supply.net/en/sustainable-groundwater-management)
- Water Portal - Akvopedia (http://akvopedia.org/wiki/Water_Portal)
- Sustainable Sanitation and Water Management Toolbox (http://www.sswm.info/)
- U.S. Centers for Disease Control and Prevention (CDC) Healthy

Wikimedia Commons has media related to ***Water wells***.

Wikisource has the text of the 1911 *Encyclopædia Britannica* article ***Well***.

Water - Water Wells (http://www.cdc.gov/healthywater/drinking/private/wells/index.html) Site covering well basics, guidelines for proper siting and location of wells to avoid contamination, well testing, diseases related to wells, emergency well treatment and other topics.
- US Geological Survey – Ground water: Wells (http://ga.water.usgs.gov/edu/earthgwwells.html)
- US Geological Survey – Water Science Pictures Flowing Artesian Well (http://ga.water.usgs.gov/edu/gwartesian.html)
- American Ground Water Trust (http://agwt.org/)
- Lifewater International Technical Library (http://www.lifewater.org/resources/ground_water.html#GW)
- Well Construction Technical Resources for NGOs (http://www.watersanitationhygiene.org/References/Technical%20Resources%20-%20Wells.htm)



Categories: Water wells | Water supply infrastructure | Archaeological features | Bodies of water

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