Hand-Dug Water Wells: a Vanishing Technology

Puits creusés à la main : une technologie en voie de disparition

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Abstract

Many people who have heard the terms Bwater well drillere and awater well diggeru incorrectly believe they refer to the same profession. Well diggers, however, have been around much longer than well drillers, although both professions became established before the development of the science of hydrogeology. Today, the technology of digging water wells is almost a lost art in the Western world; however, it still is commonly employed in Africa and developing nations. Although modern text books and government publications give the impression that hand-dug wells are primitive, many of these early wells qualify as engineering marvels. It is unlikely that we have the skills or patience to duplicate many historical hand-dug wells. In Greece, many hand-dug wells from the fourth century B.C. were more than thirty meters deep. A well constructed in Italy in the mid-1500 s exceeded fifty meters in depth. In Algeria, hand-dug wells deeper than eighty meters were constructed in the 1860 s, and in the American West, large-diameter hand-dug water wells reaching deeper than seventy-five meters are recorded in the late 1880s. Materials used to case or line early hand-dug wells included wood, stone, brick, and mortar. In discussing hand-dug wells in Europe, the Middle East, Asia, and North America, this paper attempts to demonstrate that digging these early wells required a sophisticated technology.
Key words: Hand-dug water wells; qanats; railroad water supplyc

Résumé

Beaucoup ont entendu les termes « foreur » et « creuseur de puits », et beaucoup croient qu'il s'agit de la même profession. Il s'agit en fait de deux professions différentes. Les creuseurs de puits existent depuis beaucoup plus longtemps que les foreurs, et les deux professions ont commencé bien avant le développement la science de l'hydrogéologie. De nos jours, en Occident, les technologies de creusage de puits sont pratiquement un « art perdu », alors qu'elles sont toujours utilisées en Afrique ou d'autres pays en développement. Même si les manuels d'hydrogéologie moderne donnent l'impression que les puits creusés

manuellement sont primitifs, plusieurs anciens puits creusés manuellement peuvent être qualifiés de merveille d'ingénierie. Il est peu probable que nous possédions les techniques et la patience pour reconstruire plusieurs anciens puits creusés manuellement. En Grèce, plusieurs puits creusés manuellement durant le IV^{e} siècle avant J.-C., avaient plus de trente mètres de profondeur. En Italie, des puits creusés durant le XVI^{e} siècle ont plus de cinquante mètres de profondeur. En Algérie, des puits creusés manuellement autour de l'an 1860 dépassent des profondeurs de quatre-vingts mètres, et dans l'Ouest américain, des puits de grand diamètre, d'une profondeur excédant soixante-quinze mètres ont été construits à la fin des années 1880. Les matériaux utilisés pour soutenir les anciens puits incluent le bois, la pierre, les briques et le mortier. Ce document, discutant des premiers développements des puits d'eau potable creusés manuellement, inclut des exemples provenant de l'Europe, du Moyen-Orient et de l'Amérique du Nord coloniale, et démontre que le creusage des puits nécessitait la maîtrise de technologies sophistiquées.
Mot-clefs : Puits creusés manuellement, qanats, aqueduc ferroviaire

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1. Introduction

The first water well probably was a shallow, uncased hole in a dry streambed. Man is not the only creature to engage in this type of shallow well digging. Elephants and other animals have been observed to dig pits in dry riverbeds to reach underlying alluvial aquifers. For thousands of years, water well technology probably did not advance much beyond the primitive stage of excavating in dry streambeds. Because early men were nomadic, only temporary water supplies were required. Tools or materials to case or line a permanent well were neither available nor needed. At this early stage of well digging, wells probably were not much more than a few meters deep, and would have been big enough for a person to climb into to drink from. Walk-in wells have been documented in the Middle East and American West. Before groundwater usage could develop past this primitive stage, additional technology was needed to lift or carry water. With the development of pottery or bags made of animal skins, individuals could enter a well and hand or carry containers of soil or water up to the surface, allowing deeper wells to be dug. Eventually, ropes were tied to containers to lift dirt or water from greater depths, enabling even deeper wells to be dug.

Recent scientific literature characterizes hand-dug wells as shallow, low in yield, and generally unsatisfactory for extracting potable groundwater. The current concept of a dug well is one that is 6 to 10 meters deep, 2 to 3 meters in diameter, and used only by those who cannot afford a drilled well. This characterization, however, is contradicted by the engineering skills evident in many wells dug before the advent of drilling technology.

2. Early water-finding techniques

Exploration for groundwater has progressed to include regional hydrogeologic studies and modern techniques such as Landsat imagery and surface geophysical exploration. However, early water-finding techniques obviously were successful, and practitioners must have trusted their methods. Today if we drill a dry hole to a depth of 30 m, we lose less than a day's work. A 30-m hand-dug dry hole would have represented several months of lost time and labor, not to mention the prestige of the person who located the well.

Vitruvius, a Roman engineer, described how well locations were selected during the first century B.C.

> *"The method of trial is to fall on one,s face before sunrise in the place where the search is to take place, and placing and supporting onens chin on the ground, to look around the neighborhood.... Thereupon digging is to be carried out where moisture seems to curl upward and rise into the air; for this indication cannot arise on dry ground"* (Granger, 1934).

Once a spot was selected, Vitruvius recommended additional testing before making the effort to dig a well. Where groundwater was indicated, a shallow test pit was dug. The inside of a bronze or lead vessel was smeared with olive oil and the vessel turned upside down in the pit. The pit was covered with branches and dirt and left overnight. The next day the inside of the vessel was examined for water condensation. If water droplets were found, digging began (Granger, 1934).

In 1904, when Pedro Lopez wanted to dig a water well on his ranch in south Texas, he consulted with Don Pedrito Jaramillo, a local faith healer. Don Pedrito told Pedro to bury a tin can upside down and to check it the next day; if there was moisture inside, he should dig his well there. (UTSA) It would be interesting to know how the "faith healer" from south Texas knew about a technique described by a Roman engineer two thousand years before.

Vitruvius also suggested that specific plants, such as bullrush, alder, reeds, and ivy, indicated the presence of shallow groundwater (Granger, 1934). Early settlers and explorers of the American West also used cottonwood and sycamore trees as evidence of shallow subsurface water.

In 1859, Captain Randolph B. Macy, an early U.S. military explorer, wrote a handbook for overland expeditions that gave specific instructions on finding and obtaining water. Captain Macy recommended:

"...in searching for water along dry sandy beds of streams, it is well to try the earth with a stick or ramrod, and if this indicates moisture, water will generally be obtained by excavation...." (Macy, 1859).

Captain Macy also gave instructions for digging a well:

"...where it becomes necessary to sink a well in a stream bed of which is quicksand, a flour-barrel, perforated with small holes, should be used as a curb, to prevent the sand from caving in. The barrel must be forced down as the sand is removed; and when, as is often the case, there is an undercurrent through the sand, the well will be continually filled with water...."

No discussion of early water-finding techniques would be complete without mentioning "water witching", or dowsing. Although the scientific literature recognizes no basis for dowsing, and there is little or no support for dowsing among professional hydrogeologists, dowsing for water remains a worldwide practice. Some passages in the Bible have been interpreted to indicate that dowsing was practiced in biblical times. The use of a rod for locating underground water developed in the late 1500s to early 1600s in southern Europe. The practice spread to England in the 1700s and subsequently to the Americas. Scientific interest in the practice, which still continues, began in the 1800s (Ellis, 1938).

3. Dug wells of Europe and the Middle East

Both the Old and New Testaments discuss hand-dug wells. The Greek Papyri, 300 B.C. to 600 A.D., also discuss hand-dug wells. Archaeological excavations along the Mediterranean coast have uncovered numerous water wells that can be dated to about 1,000 years B.C. These wells, which were as much as twenty meters deep and one meter and forty centimeters in diameter, were lined with stone and cement plaster (Nir and Eldar, 1987).

3.1. Joseph's Well

Joseph's well, 89,9 m deep, is excavated into solid rock. The upper part of the well is 50,3 m deep and 7,3 m by 5,5 m in cross section. The lower part is 39,6 m deep and has a 4,57 m by 2,75 m cross section. The lower section is offset from the upper, which allowed the use of two bucket-and-chain pumps. Water was lifted from the lower section of the well and emptied into a pool at the base of the upper section, from which water was lifted to the surface by a second chain-and-bucket pump (Brantley, 1971).

3.2. Job's Well, Jerusalem

The City of Jerusalem is located on the edge of a limestone plateau. The limestone beds are fractured, and rainwater infiltrates rapidly into the subsurface. Surface and subsurface water flows across the plateau to the southeast toward Jobls Well, which was approximately thirty-eight meters deep. Water levels in the well fluctuated with the seasons; during wet years the well reportedly overflowed (Wilson, 1880).

3.3. Iran

Qanat (also known as *foggara, qarez, aflaj, or khettara*) water systems, dating to several thousand years ago, reflect one of the most unusual early technologies. Qanats are horizontal tunnels that transport water from aquifers in highland areas to a valley floor. Qanats began as a mother well (*Madar Chah*) dug vertically from the surface until it intersects the water table. In some cases the mother well may be 100 m deep. Near Tehran, Iran, these wells were dug in the Jaja Rud gravels at the base of the Elburz Mountains. From the mother well, a line of vertical wells, ranging from 20 to 150 m apart, were dug down the slope. Their depth decreased from as deep as 100 m near the mountains, to only 1 or 2 m at the valley floor (Clapp, 1930). A gently sloping tunnel is then dug to connect the wells. Qanat water systems remain in widespread use in Iran, Oman, and other Arabic countries. Figure 1 shows several *muzanni*, or qanat diggers, cleaning out a qanat in Tehran in 1994.

3.4. Algeria

An interesting account of well digging in the Sahara Desert was given in a report on artesian wells. The report, covering the period 1860 to 1864, was written by J. Duval to the governor general of Algeria.

> *"Before beginning their task they vigorously heat all of the members of their body around a big fire, they fill their ears with cotton that is impregnated with goat grease. They strip off all of their clothes except for some meager shorts and then group themselves around the chasm. There are no more songs and no more joyous cries. The scene has become solemn. The worker who has to start the work approaches the well slowly, deposits burning coals on the curb stone formed by the outer frame, and throws incense upon them. When the smoke begins to rise to the sky, he gives several blows with the palm of his hand to the timber casing. This is a call addressed to the guardian spirits of the suboceans so that they will be well informed that someone is coming to render the homage that is due them. After this religious ceremony, the diver descends and enters the water up to his shoulders. Fastened to this position by using his feet which are affixed to the wooden sides of the*

casing, he makes his ablutions, invokes Allah, then coughs, spits, sneezes, blows his nose, brings his lips to the level of the water, makes a series of aspirations and expirations to make sure that he has free movement of his lungs and then after all these preparations which lasts a good 10 minutes, he lets himself slide down the length of the rope to the bottom. There he fills with one hand the basket that preceded him and that can hold about 10 liters of sand. The operations finished, he re-takes the rope in his two hands and climbs back up. His time in the water last 2 to 6 minutes. The entire day consists of 4 trips for each one meaning therefore 40 liters, at the maximum, of sand extracted." (Paix, 1956)

According to Dr. Ghislain de Marsily (1986), some of these Algerian wells were more than eighty meters deep.

QuickTime™ et un décompresseur
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cette image.

Figure 1 – Cleaning of qanats.
Courtesy of: Bill Ambridge

4. Early wells in Europe

4.1. Greece

By the seventh century B.C., large villas in Greece boasted deep wells lined with stone. Public wells were constructed in the wider streets, then covered by stone slabs. Small openings cut through the stone allowed water jugs to be lowered by ropes. Recent excavations in Athens uncovered numerous early dug water wells up to 33 m deep (Lang, 1968). Many shallow wells were unlined; however, by the fourth century B.C., terra-cotta-lined wells were common (Figure 2). The well casings frequently had slots that may have served to hold the casing while it was lowered into the ground or as a ladder for entering and cleaning the well. Many early Greek wells were large enough to accommodate stairs reaching down to the water table.

Figure 2 - Terra-cotta-lined well, Greece.
Courtesy of:
American School of Classical Studies at Athens.

4.2. Roman Empire

Before 313 B.C., when the first Roman aqueduct was constructed, Rome's water came from the Tiber River, from wells or springs, or from cisterns that collected rain water. Springs were common in Rome, and productive wells could be dug almost anywhere.

By the third century A.D., the Roman Empire stretched from the present British Isles to the south coast of the Mediterranean Sea. As the boundaries of the Empire spread, so did the influence of the Roman engineers, who directed construction of water wells and water supply systems throughout the Empire. Although many early Roman wells were lined with wood, stone later was used to support the walls. In unconsolidated, loose soil, wells were excavated with larger openings at the top, and a diameter that decreased with depth. This cone shape prevented or minimized wall collapse. Once the desired depth was reached, the walls of the well were built up vertically from the bottom, and the void between the walls and the original face of the excavation was filled with previously excavated material (Gyorgy, 1980; Nahgrang, 1982). In some Roman wells, the walls below the water table were lined with logs instead of stone. These logs were set vertically in a configuration similar to driving piles.

4.3. The Middle Ages

One of the more complex water wells of the Middle Ages is located approximately 90 kilometers north of Rome in the City of Orvieto. The well, designed by Antonio da Sangallo the Younger, is known as Pozzo di San Patrizio. This cylindrical structure is illuminated by 72 arched windows. It is approximately 53,15 m deep and 12,21 m in outside diameter and had two spiral staircases constructed in a double helical arrangement. Pack animals could go down one staircase to the water, while animals loaded with full water skins could come up the other. The depth to water was approximately 50,45 m. Figure 3 is a cross section of the well showing this unique double helical staircase. More than 300 000 bricks were used to construct the well. After ten years of work, this well was completed in 1537 (Ludwig, 1972).

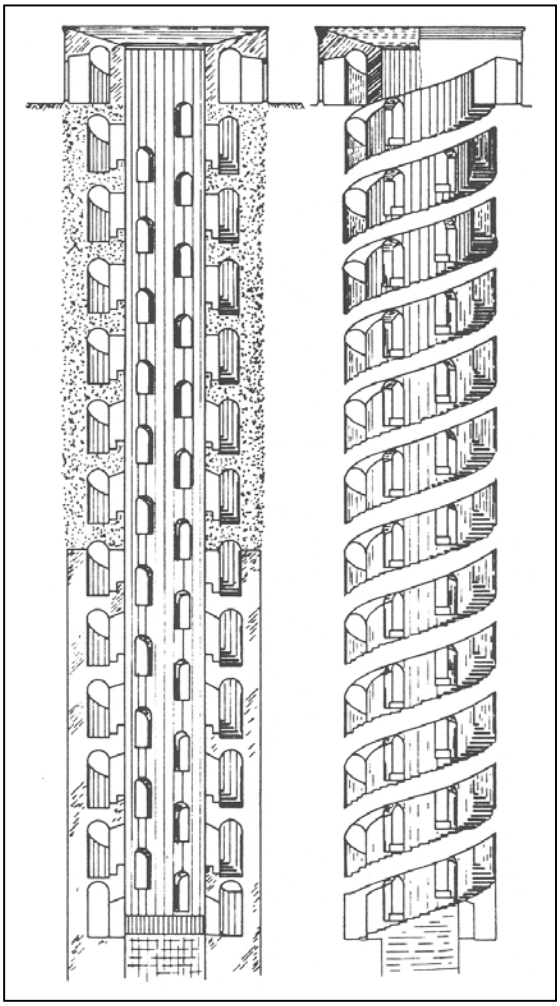

Figure 3 – The well of St. Patricius

5. Early wells in China

The Jiyi Temple, in the City of Yangwang, China, contains wall paintings honoring three gods. One of the gods, Boyi, was credited as the inventor of digging wells (China Virtual Tours). The "Sweet Spring" well, which is approximately 17 m deep, was dug in 1420 to supply the divine kitchen in a temple and today is a tourist attraction.

6. Dug wells in North America

Along the North American east coast, hand-dug water wells were abundant during the later 1700s to the late 1800s. In four years, one well digger, John Robert Shaw, dug more than 177 wells having a combined depth of 795 m. Shaw

also dug salt water wells and claimed to be able to locate both fresh and salt water by witching (Shaw, 1807).

One early American well still in use is on High Island, South Bristol, Maine. The well and summer home it supplies belong to Dr. John Archibald Wheeler. According to Dr. Wheeler, the well is approximately 8,64 m deep and 2,4 m by 3,65 m wide. The well, situated in the bottom of a glen between two hills, is about 45 m from the sea. Dr. Wheeler reports that the property at one time belonged to Captain Leander McFarland, who used the well to fill wooden casks with fresh water before making sailing voyages to China in the early 1800s.

Early American water wells were dug both into sand and gravel deposits and into hard rock formations, which required using explosives. The diameter of the well had to accommodate the digger using picks and shovels, which often were fitted with short handles. When rock was encountered, holes were drilled into the bottom of the excavation using a star drill and hammer. Black powder was packed into the holes and, before the development of safety fuses in 1831, was also used as a fuse. After lighting the fuse, the well digger had to exit the well quickly. Sparks from the burning powder frequently jumped ahead and set off the charge early. John Robert Shaw reportedly "blew himself up" at least four times while blasting wells into rock (Shaw, 1807). Because of the danger involved in lighting a fuse, hot coals frequently were dumped into the well to ignite the power after the digger exited the well (Jordan, 1979). Black powder was used exclusively for blasting rock until 1866, when Alfred Nobel mixed nitroglycerin with an absorbent to create dynamite (DuPont, 1942).

In areas where wells were excavated wholly or partly in sands and gravels, they were lined with cut stone or brick. Wood lining or cribbing also were common, although the wood had to be replaced frequently. During excavation, the well often was lined temporarily with wood, which was replaced with stone or brick from the bottom up when the desired well depth had been reached. A stone, brick, or wood curbing was constructed around the well to a height of 3 to 4 feet to prevent dirt or debris from entering the well and to provide a base for the windlass and bucket. Frequently, the aboveground curbing was mortared or plastered to a smooth finish.

6.1. American Southwest

The Cahuilla Indians in present-day California were experienced well diggers before the first Europeans arrived in the 1500s. They excavated large-diameter walk-in wells to depths of 10 m near dry streambeds (Bean, 1972). The Spanish explorers used springs and rivers for water supplies. Although early Spanish missions were established near springs or rivers, most missions also had hand-dug

water wells inside or near the mission walls. The water well at the Mission San Francisco de Espada (Figure 4) probably was constructed in 1730, at the same time as the mission.

Figure 4 – Water well at the Mission San Francisco de Espada.
Courtesy of: Barker History Center.

6.2. Western Frontier

In many frontier cities, water wells for public use were dug in the town square or near stores. The first well in Austin, Texas, reportedly was dug in 1839 by William A. A. "Big Foot" Wallace. Mr. H.L. Savoy, a saloonkeeper, whose business was located at Pine (now 6th Street) and Congress Street, paid Wallace $39 per meter for digging the well. When Wallace reportedly struck water at 5,79 m, the flow was so strong he yelled, "Draw me up, quick, before I drown in here" (Sowell). Figure 5 shows an early 1900s hand-dug public water well in Mason, Texas, complete with bucket and dipper. The U-shaped frame, pulley, bucket, and dipper were typical of early Texas hill country wells (Jordan, 1978).

Figure 5 – Public water supply well at Mason, Texas.
Courtesy of: University of Texas Barker Historv Center.

In the late 1800s, several wells deeper than 75 m were dug in West Texas. Picks and shovels were used to do the digging, and the dirt was windlassed out. The E.L. Whippo well, reportedly 76,8 m deep, was dug with great difficulty and perseverance. At a depth of 30,48 m, Mr. Whippo encountered a stratum of hard rock that required almost one year to pick through, no doubt because it was more than 31 m thick. Some days Mr. Whippo advanced less than nine centimeters (cm). He was so discouraged that he would have abandoned the well except for the insistence of his wife, whose duties included two trips per week to haul water from a spring 15 kilometers away. After digging through 2,44 m of sand and gravel (which required curbing), he again struck rock. When he punched a hole in this honeycombed rock with a crowbar, cool water rose to his armpits (Ochiltree County Historical Survey Committee, 1969). One Nebraska well digger, Joseph Grewe, also known as "Dutch Joe" or "the human badger," reportedly dug more than 1 829 m of

wells during a seven-year period in the 1880s and 1890s. These wells were between 30 and 60 meters deep. (Nebraska History)

6.3. Railroads

During the mid- to late-1800s, many wells were hand-dug to supply water for steam locomotives. Typically, the locomotives required water stops every 25 to 50 kilometers. A well at Selkirk, Kansas, was constructed in 1887 to supply water to the Chicago, Kansas and Western Railway, later renamed the Santa Fe Railroad. Digging the well took 15 men 90 days, during which time approximately 1 360 cubic meters of dirt was excavated using pulleys, wooden barrels, and mules to pull up the barrels as the diggers filled them. The completed well, 7,31 m in diameter and 31 m deep, was lined with quarried stone (Figure 6). A steam-powered pump was placed in the well on a concrete "shelf" just above the water table. The well could produce approximately 340 cubic meters of water in 24 hours. The well currently is being considered for listing on the National Register of Historical Places (Walk, 2000).

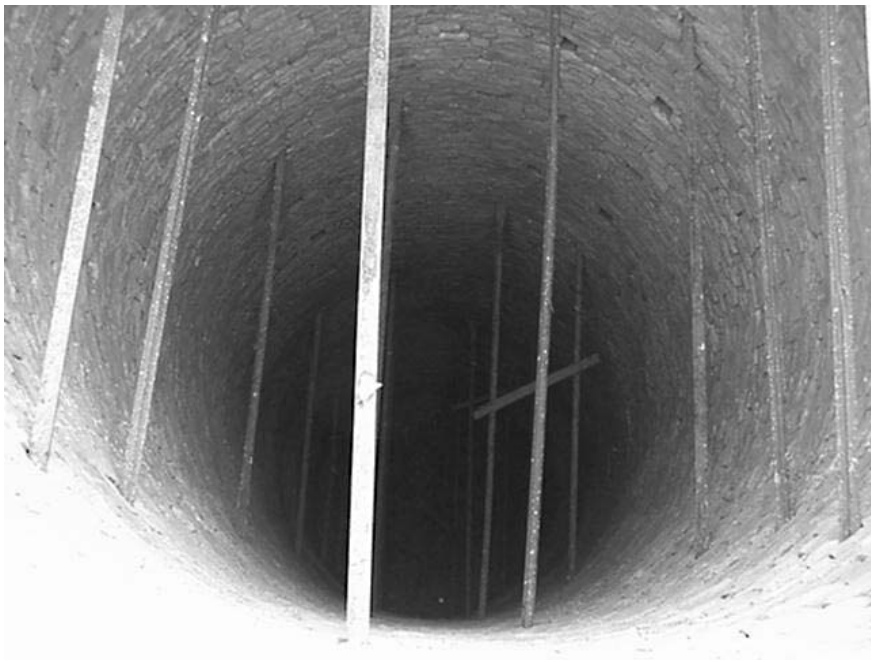

Figure 6 – Well. Railroad water supply well at Selkirk, Kansas.
Courtesy of: Karen Walk.

Another large hand-dug well remains as a tourist attraction in Greensburg, Kansas. Construction of the well began in 1887, with crews of 12 to 15 farmers and cowboys digging for 50 cents to $1.00 per day. Other crews quarried and hauled stone from a quarry approximately nineteen kilometers south of town; the same

crew hauled away the dirt excavated from the well. As dirt was removed, the excavation walls were cribbed with wood to prevent cave-ins. When the well reached the water table, a ring (or boot) of heavy oak timber was constructed. Stone curbing was added on top of the boot. As excavation continued approximately 6 m below the water table, additional stones were added to forced the boot through the water and sand. Perforated steel pipes reportedly were driven horizontally from the well bottom to increase yield (Schoenberger, 2001). Cross braces were removed as the cut stone wall was constructed from the bottom up. The well was completed in 1888 at an estimated cost of $45,000. The completed well was 33,22 m deep and 9,75 m in diameter. Water was brought to the surface using a steam-powered pump located on a shelf just above the water table. The Greensburg well was intended for use by the railroad, but the railroad bypassed the town (Greensburg Chamber of Commerce), and it served instead as a public supply well until 1932. Railroad water wells typically were enclosed in a building similar to the one at the train depot in Columbus, Nebraska (Figure 7).

Figure 7 - Well, windmill, and water storage tank, Columbus, Nebraska. *Courtesy of: Union Pacific Historical Collection (Image No. R0038).*

During the 1880s, Mr. Benjamin P. Hull of Sherman, Texas, constructed many water wells for the Denver, Katy, and T. and P. railroads. He also had a contract with the Fort Worth and Denver railroad to construct all of the wells from Fort Worth to Cheyenne, Texas. Some of Mr. Hullas wells were square, measuring 4,87 m by 4,87 m, and some of them went more than 30,48 m deep (genealogymagazine.com).

7. Safety issues

Most frontier domestic wells were dug by a digger and one helper. Large wells for the railroad or public water supplies utilized more diggers and helpers. On a frontier farm, one person may have worked alone on a well. He would have dug for a while, climbed to the top, and hauled the dirt or rock out of the excavation. In addition to cave-ins, which would have been fatal to a single digger, safety issues included objects falling from the surface, blasting problems, and lack of oxygen (or "bad air") in the well. Some well diggers lowered a kerosene lantern into a well to confirm adequate oxygen. Today when hand-dug wells are constructed by governments or charity organizations in developing nations, air frequently is pumped into a well that goes more than 9 m deep.

Abandoned hand-dug wells have long been a safety issue. In 1895, Mr. F. W. Carlin survived a fall into a 43,58 m deep well in Custer County, Nebraska. Using his pocket knife to cut footholds in the wooden lining, Mr. Carlin spent two days and nights crawling out of the well (Sheldon, undated). Mr. Joseph Grewe was killed in 1894 while cleaning a 68,88 m deep well. A bucket of sand and gravel tied at the top of the well came unfastened and fell to the bottom, striking Mr. Grewe on the head (Reese, undated). In 1907, Mr. Perry Bryant was killed by a falling rock while cleaning out a 38,40 m deep well (Reese, undated). In the early 1900s, it was estimated that more than 500 hand-dug wells and cisterns existed in the City of Austin, Texas. During the 1950s, several accidents occurred, some involving children and animals falling through rotten boards covering abandoned wells. Today, most states require landowners to fill any abandoned wells that are found.

8. Future use of hand-dug wells

Because hand-dug wells have fallen out of favor in industrial nations, the skills and patience required to dig a well are fast disappearing. Modern hydrogeology books and government publications have branded hand-dug wells as undependable and susceptible to pollution. Although an inadequately located or constructed hand-dug well can go dry or become polluted, the same is true for drilled or bored wells.

The technology has been kept alive primarily in developing nations. In Oman, for instance, more than 100 000 hand-dug wells remain in use (MWR, 1998) (Figure 8). Qanats and other similar tunnel systems are in widespread use in Iran, Oman, Morocco and other North African countries, and the technology is passed from generation to generation. The British Overseas Hydrogeology Group has also provided funding and technical assistance to several African nations in the construction of large diameter wells with radial screens, similar to the well constructed in Greensburg, Kansas in this late 1880s.

The technology of hand-dug wells has been lost in most of North America and Europe. However, self help organizations have kept the technology and practice alive in Africa and other underdeveloped areas of the world (Watt *et al.,* 1977, and Laver, 1987). Well digging is often a community project, which gives them an important advantage over bored wells, for which the villagers can only stand and watch while expatriate experts drill the well. Community participation engenders pride in the final project and increases incentives and opportunities for community maintenance.

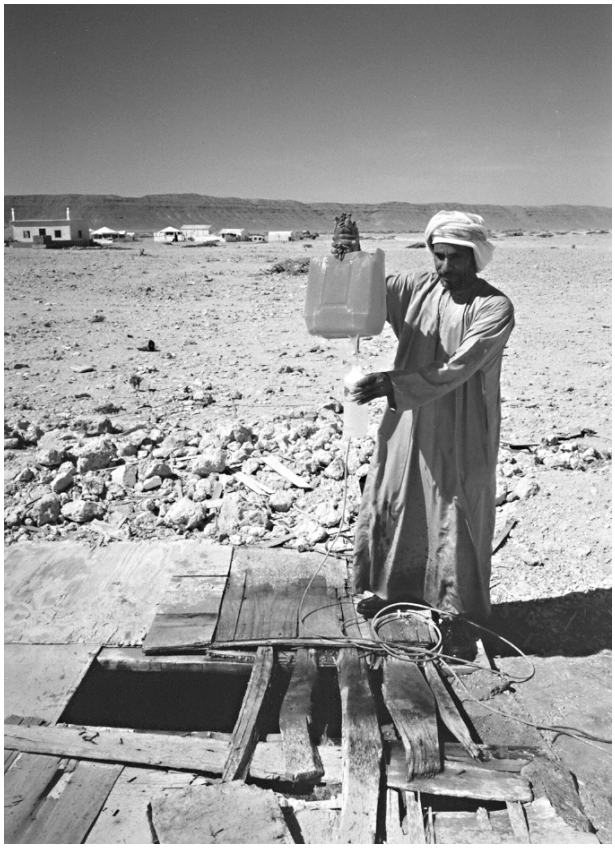

Figure 8 - Hand-dug well in Oman. *Photo by Author 1994.*

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