Water for the World

Designing Hand Dug Wells
Technical Note No. RWS. 2.D.1

Proper design of hand dug wells is important to asure a year-round supply of water and to assure efficient use of personnel and materials. Designing involves determining the size and shape of the well; the method of lining the shaft; the type of intake; and the necessary personnel, materials, equipment, and tools. The products of the design process are drawings of the shaft and lining and a detailed materials list. These, along with a location map similar to Figure 1 ("Selecting a Well Site," RWS.2.P.3), should be given to the construction foreman before construction begins.

There are several good methods of designing and constructing hand dug wells; if you are familiar with a specific method, use it. This technical note describes one method of designing hand dug wells and arriving at the essential end-products. Read the entire technical note before beginning the design process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

KIBBLE - A large bucket for lifting materials when sinking a shaft; also called a hoppit or sinking bucket.

POROUS - Having tiny pores or spaces which can store water or allow water to pass through.

WATER TABLE - The top, or upper limit, of an aquifer.

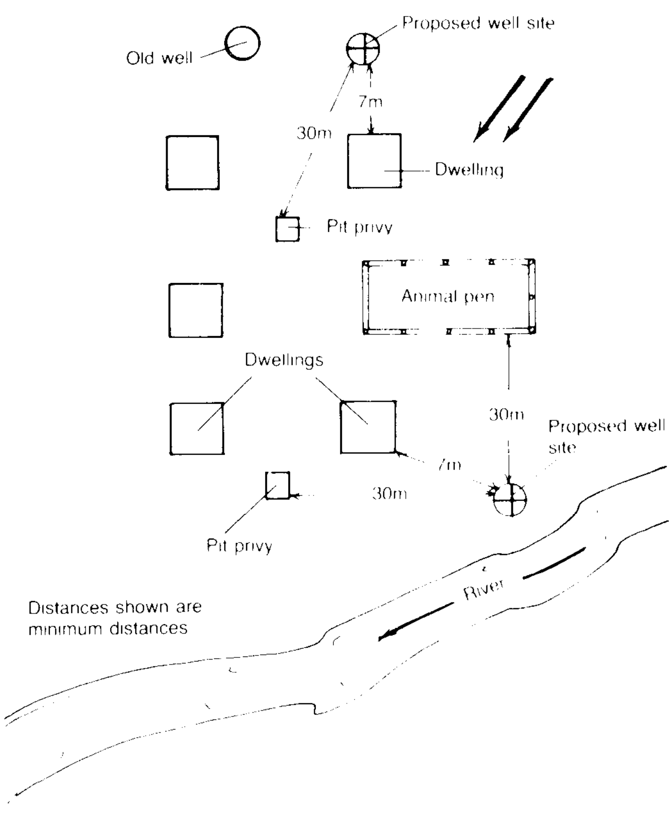

Figure 1. Location Map

Size and Shape

When viewed from the top, wells can be any shape but most of them are round. This is because a round well produces the greatest amount of water for the least amount of excavation, and a round lining is stronger than any other shape.

The size of the well refers to its depth and diameter. Although it is impossible to know the depth of a well before it is dug, an attempt should be made to estimate it. This will allow you to roughly calculate the quantities of materials needed for construction. Use information from test holes or existing wells in the area to estimate the depth of the water table.

For practical and economic reasons, well diameters are between 1.0m and 1.5m. The smaller diameter results in a savings in materials costs, and it requires less soil to be excavated. The larger diameter means a higher materials cost, but a more efficient work output, since two men rather than one can dig the shaft. A larger diameter provides a greater storage capacity and allows more water to enter the well. If pre-made forms or precast concrete rings are used, their size will determine the diameter of the well.

When the depth and diameter of the well shaft have been determined, write the dimensions on a design drawing similar to Figure 2.

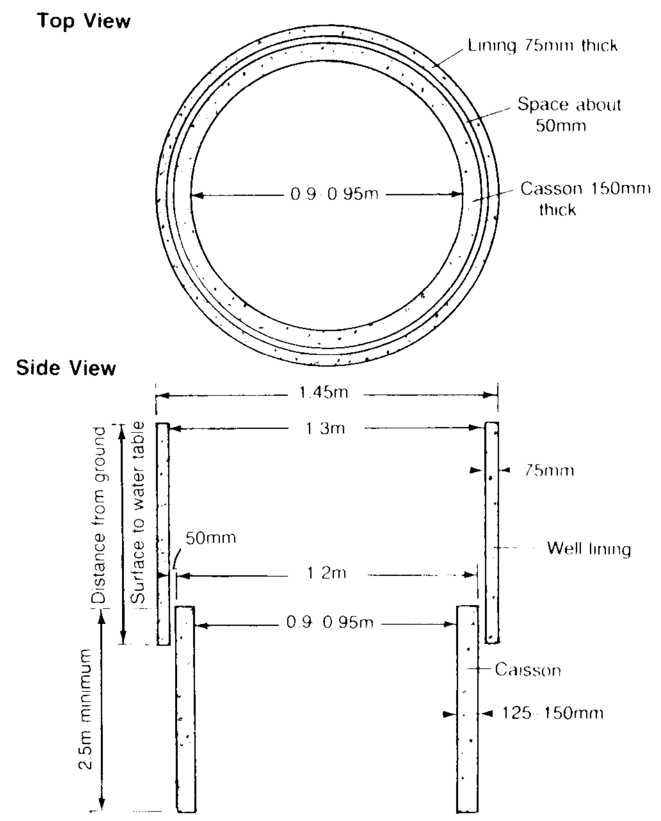

Figure 2. Design of Well Lining and Caisson

Lining the Shaft

Although various materials have been used to line well shafts, concrete is the best and most common lining. It is strong, long-lasting, and widely known.

The two basic methods of lining well shafts are dig-and-line and sink lining or caissoning. In dig-and-line, a portion of the shaft is excavated, shutters are set in place in the shaft, and concrete is poured behind the shutters. When the concrete hardens, the shutters are removed and the next portion of the shaft is excavated.

In sink lining, concrete rings called caissons are cast and cured in special molds at the surface. The rings are stacked on top of each other and attached together with bolts. As soil is excavated from beneath the rings, they sink into the earth and line the shaft.

Often, both methods are employed in a single well: dig-and-line is used until the water table is reached, then caissoning is used to sink the well into the aquifer. The lining is usually 75mm thick and the caisson rings are 125-150mm thick. The outside diameter of the rings is 50-100mm less than the inside diameter of the lining to allow the rings to freely move downward. Table 1 shows common dimensions of shaft, lining, and rings.

Write the dimensions that you determine are best for your well on the design drawing similar to Figure 2.

Intake

The caisson rings are sunk into the aquifer as far as possible; that is, until the water becomes too deep to

Table 1. Dimensions of Shaft, Lining and Caisson Rings

Feature	Dimension
Shaft diameter	1.45m
Lining, outside diameter	1.45m
Lining, inside diameter	1.30m
Lining, thickness	75mm
Caisson, outside diameter	1.20m
Caisson, inside diameter	0.90-0.95m
Caisson, thickness	125-150mm
Caisson, height	0.50m

continue the excavation. Ground water may then enter the well either (1) through the opening under the lowest caisson ring, or (2) through the rings themselves. In the first case, the rings are made of standard concrete which does not allow entry of water. In the second case, the rings are usually made of porous concrete which allows water to pass through. Another way to allow water to enter through the caisson rings is to build the rings from standard concrete and perforate them with seepage holes. For all types of intakes, the bottom of the shaft should be covered with a porous base plug made from porous concrete or layers of sand and gravel. The plug prevents aquifer material from rising into the well.

The type of caisson ring used depends on the nature of the aquifer. Normally, rings are made of porous concrete. However, if the aquifer is composed of fine sand, which would clog the pores or flow through the seepage holes, the rings should be made of standard concrete without perforations. It may not be possible to know which type of intake is needed until the aquifer is reached. But an attempt should be made to anticipate the necessary intake, based on test holes or other wells in the area.

When the type of intake has been determined, indicate it on the design drawing similar to Figure 2.

Personnel

The most important person involved with well construction is the foreman. He should have some experience. He must oversee all phases of construction, including excavating and lining the shaft, mixing concrete for the lining and caissons, and lowering the caissons into place. It is his responsibility to see that construction proceeds in a safe manner.

At least four workers are needed. One should have some experience with well digging and one should have experience with concrete construction. The workers must be reliable because the construction process may take several weeks or more.

Materials

The materials needed to line a hand dug well are concrete mix and reinforcing steel.

One common mix of concrete is one part cement to two parts sand to four parts gravel by volume and enough water to make a workable mix. The cement should be Portland cement, and it should be dry and free from hard lumps. Sand should be clean, and sized fine to 6mm. If porous concrete is used for the caisson rings, omit the sand. Gravel should be clean and sized 6-36mm (10-20mm for porous concrete). Water should be clean and clear.

Two sizes of reinforcing steel, called re-rods, are generally used: 8mm diameter for the lining and 15mm diameter for the caissons. The quantities of these materials needed can be roughly estimated.

For each meter of depth of the lining:

gravel = $0.5m^3$
sand = $0.25m^3$
cement = $0.125m^3$ (or about 190kg, assuming $0.00066m^3$ = 1.0kg)
8mm re-rod = 33m

For each meter of caisson rings:

gravel = $1.0m^3$ ($1.4m^3$ for porous concrete)
sand = $0.5m^3$ (none for porous concrete)
cement = $0.25m^3$ ($0.35m^3$ for porous concrete)
15mm re-rod = 4m

For example, suppose the estimated depth of the shaft and lining is 15m, the height of the caisson rings is 3m, and the rings are to be made from porous concrete. The quantities would be estimated in the following way.

For the lining:

gravel = $0.5m^3 \times 15 = 7.50m^3$
sand = $0.25m^3 \times 15 = 3.75m^3$
cement = $0.125m^3 \times 15 = 1.88m^3 = \frac{1.88m^3}{0.00066m^3/kg} = 2850kg$
8mm re-rod = 33m x 15 = 495m

For the porous concrete caissons:

gravel = $1.4m^3 \times 3 = 4.20m^3$
sand = none
cement = $0.35m^3 \times 3 = 1.05m^3 = \frac{1.05m^3}{0.00066m^3/kg} = 1590kg$
15mm re-rod = 4m x 3 = 12m

The total quantity of cement needed for the lining and the caisson rings = 2850kg + 1590kg = 4440kg. Cement is often packaged in 50kg sacks, so the number of sacks needed = $\frac{4440}{50}$ = 88.8 or 89 sacks. Worksheet A shows a further example of how to estimate quantities of materials needed for a hand dug well.

Other materials needed are those used to build a storage shed. Use locally available materials and traditional construction methods.

Equipment

The main piece of equipment needed is a headframe capable of lowering workers and caissons into the shaft and hoisting up excavated soil. The headframe must be able to support weights in excess of 350kg, the approximate weight of a concrete caisson. It should have a winch, a main pulley, and an auxiliary pulley.

At least three ropes are needed: one for lowering caissons, tensile strength of rope about $7kg/cm^2$, one for lowering and raising full kibbles and concrete buckets, and one for suspending trimming rods.

A heavy-duty stretcher with a U-bolt in the center is needed to lower caissons.

Steel shutters are needed to form the lining. For caissons, you will need steel molds and templates to position the re-rods.

Two kibbles are needed to hoist up water and excavated soil. The kibbles should be watertight and made of steel, with a safety latch on the handle to prevent them from tipping. They should be wider around the middle than around either end to prevent them from catching on any projections within the shaft.

Other equipment needed includes concrete buckets, a bosun's chair, top plumbing rod, long and short trimming rods, and hard hats.

Tools

The workers need tools for measuring, plumbing, excavating, and trimming the shaft; mixing, pouring, and finishing concrete; and positioning and securing re-rods. When you have determined all necessary personnel, materials, equipment, and tools, prepare a materials list similar to Table 2 and give it to the construction foreman. Give the construction foreman design drawings of the well, a detailed materials list, and a location map.

Worksheet A. Estimating Quantities of Materials for Hand Dug Wells

For the Lining:

1. Estimated depth of shaft = 15 m
2. Gravel = $0.50m^3$ x Line 1 = $0.50m^3$ x 15 = 7.50 m^3
3. Sand = $0.25m^3$ x Line 1 = $0.25m^3$ x 15 = 3.75 m^3
4. Cement (m^3) = $0.125m^3$ x Line 1 = $0.125m^3$ x 15 = 1.88 m^3
5. Cement (kg) = $\frac{\text{Line 4}}{0.00066m^3/kg}$ = $\frac{(1.88\ m^3)}{0.00066m^3/kg}$ = 2850 kg
6. 8mm re-rod = 33m x Line 1 = 33m x 15 = 495 m

For the Caisson Rings:

Type of concrete (check one): ☐ standard ☒ porous

Standard Concrete

7. Height of caisson rings = 3 m
8. Gravel = $1.0m^3$ x Line 7 = $1.0m^3$ x ____ = ____ m^3
9. Sand = $0.50m^3$ x Line 7 = $0.50m^3$ x ____ = ____ m^3
10. Cement (m^3) = $0.25m^3$ x Line 7 = $0.25m^3$ x ____ = ____ m^3
11. Cement (kg) = $\frac{\text{Line 10}}{0.00066m^3/kg}$ = $\frac{(\_\_\_\_\ m^3)}{0.00066m^3/kg}$ = ____ kg
12. 15mm re-rod = 4m x Line 7 = 4m x 3 = 12 m

Porous Concrete

13. Gravel = $1.40m^3$ x Line 7 = $1.40m^3$ x 3 = 4.20 m^3
14. Sand = none
15. Cement (m^3) = $0.35m^3$ x Line 7 = $0.35m^3$ x 3 = 1.05 m^3
16. Cement (kg) = $\frac{\text{Line 15}}{0.00066m^3/kg}$ = $\frac{(1.05\ m)}{0.00066m^3/kg}$ = 1590 kg

Total Amount of Cement for Lining and Caisson =

Line 5 + Line 11 + Line 16 = 2850 kg + – kg + 1590 kg = 4440 kg

Table 2. Sample Materials List

Item	Description	Quantity	Estimated Cost
Personnel	Foreman Worker, skilled in sinking well Worker, experienced with concrete Workers, unskilled	1 1 1 2-4	____ ____ ____ ____
Supplies	Cement (Portland) Sand (clean; fine to 6mm) Gravel (clean; 6-36mm) Water (clean and clear) Re-rod for lining: 8mm diameter Re-rod for caissons: 15mm diameter Materials for storage shed	____ kg ____ m^3 ____ m^3 ____ ____ m ____ m ____	____ ____ ____ ____ ____ ____ ____
Equipment	Headframe Rope for caissons; 100m x 12mm diameter, steel wire with fiber core tensil strength 7kg/cm^2 Rope for kibbles: 100 x 6mm diameter Rope for trimming rods: 100m x 3mm diameter Steel shutters (1.30m diameter x 0.5m high) with wedges and bolts Steel shutters (1.30m diameter x 1.0m high) with wedges and bolts Steel molds for caisson rings (1.20m outside diameter, 0.95m inside diameter, 0.5m high) Templates for molds Stretcher for caissons	____ ____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____ ____

Total Estimated Cost = ____