CHAPTER 7

Wells

A WELL CONSTRUCTION

A well is usually dug manually to reach an aquifer situated at some depth below the ground. The depth and diameter of the well vary according to local conditions. Throughout history, people have dug wells to ensure a permanent water source.

1 Modern wells

Traditional wells are rarely lined, or only for part of the depth, usually with wood, so that the well must be regularly re-dug and rebuilt. As they are simple holes in the ground, these wells are rarely protected from surface pollution (contaminated water).

Some wells are constructed using stone or brick. The best examples are the pastoral wells constructed during colonial times in the Sahara, several dozen metres deep, and some 2 to 3 m across.

Wells of more modern type, which are the subject of this chapter, are lined in reinforced concrete for the whole of their depth, from the surface to the intake section. Construction techniques are tried and tested, and pastoral wells can reach 100 m in depth. They have a width of 2 m to be able to exploit Sahelian aquifers, and they are open and often equipped with several pulleys. Significant quantities of water are extracted (using animal power) to supply herds of animals.

Village wells are more modest, running to depths of 20 to 30 m, and equipped with manual water-drawing systems (scoops, pulleys, winches or handpumps).

Box 7.1
Combined well.

In certain sedimentary basins, there are captive aquifers covered by impermeable levels situated several dozens or even hundreds of metres in depth, but with static levels close to the surface. These aquifers, reached by boreholes, are exploited from wells whose depth varies with the static level. This facilitates drawing by hand. The intercalated continental aquifer levels of the Sahara (Mali, Niger) are often of this type, and do not need pumps, which would be difficult to manage in this context (nomadic population).

These wells act like underground, water-tight storage tanks. They are dug next to the borehole or around it, and connected to it with a horizontal tube welded to the casing, fitted with an open stop-valve to the well-cistern or with a ferrule strap.

This type of well provides a particularly useful water storage solution for the exploitation of aquifers with poor flows. An example of a combined well, constructed by ACF in Asia, is given in Chapter 8D.

The enormous advantage of the well in relation to the borehole is its storage capacity (related to its diameter) and the possibility of manual water drawing. Its permanence makes it very suitable for the conditions of the Sudan-Sahelian region, and other isolated or particularly remote regions. The cost of construction is considerable, so it should be well built and durable.

1.1 Surface works

The works at the surface of the well are an essential component in terms of water quality, because they protect the well from infiltration by surface water and facilitate access and water drawing. They are designed to drain surface water away from the well, to limit the risk of falling objects, and to prevent access by animals. Design details are given in Annex 14.

1.1.1 THE WELLHEAD

A low wall built around the top of the well, forming an extension of the well lining, secures and protects the well against mud and sand falling in from the surface.

On wells intended to be covered and fitted with a handpump, it is recommended that the wellhead should be lower (less than 0.5 m, thickness 0.2 m). A high wellhead (greater than 0.5 m, thickness 0.3 m) is more suitable for wells situated in the Sahelian region (protection against sandstorms).

1.1.2 APRON AND DRAINAGE

A slab of reinforced concrete directs wastewater towards a drainage channel (minimum slope 5% and minimum length 3 m). The channel is terminated by a toe at the outlet.

If no natural drainage is available (to low-lying land or a ditch), the construction of a soakaway should be considered (see Chapter 13). It will however quickly become blocked by contaminated water (mud, grease, soap etc.) and must be regularly maintained to remain efficient.

One solution is to drain the water to a small garden.

A clean area of stones can be laid around the apron.

The construction of a protective fence and troughs for animal watering may also be considered, depending on the context (Figure 7.1).

1.2 Manual water drawing

Water-drawing systems are of fundamental importance for the water quality. Their design must take account of the risk of contamination at the water point. A bucket and wet rope come into contact

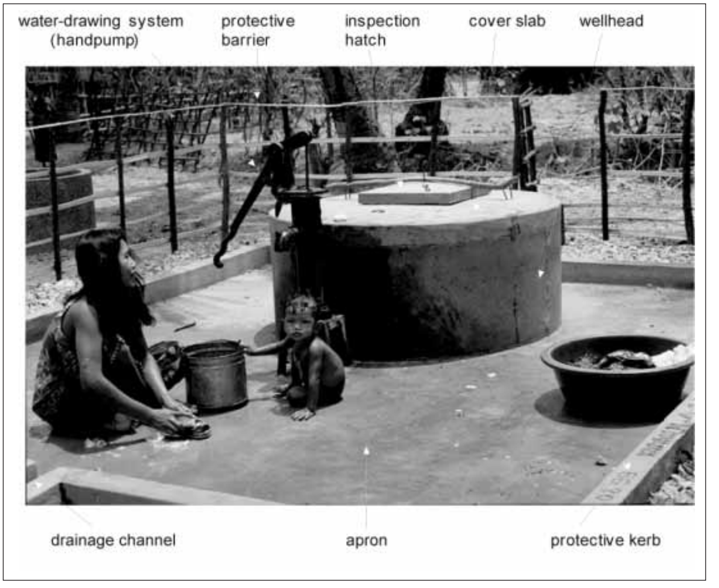


Figure 7.1: Well surface works (ACF, Cambodia, 1998).

with the ground and become contaminated with mud, faeces etc. every time water is drawn. With every immersion therefore, the bucket and rope contaminate the well water. Also, as all users have their own bucket, the risks of pollution are multiplied.

Water drawing by bucket or scoop is very frequent. Although the installation of a handpump is often the recommended solution, is not always suitable (heavy demand on pastoral wells, maintenance of the pump, large variation in water level etc.). Some examples of simple water-drawing systems are given below. These systems must fulfil the following criteria:

– ensure the necessary flow for the population being served, as well as easy and safe water drawing;
– designed so that containers and ropes are used only for water drawing and remain permanently at the well;
– prevent ropes and containers lying on the ground and risking contamination.

1.2.1 PULLEYS AND WINCHES

These (Figure 7.2) must be durable and appropriately designed (height and number of pulleys) for user satisfaction.

Pastoral wells are often equipped with several pulleys fixed to wooden forks arranged around the wellhead to allow several people to draw water simultaneously for herds (by animal traction).

The winch avoids the rope dragging on the ground and becoming contaminated, but this system is not always accepted by users, because it does not provide sufficient water flows for pastoral wells.

The ‘delou’ (pulley and animal traction) is used essentially for irrigation.

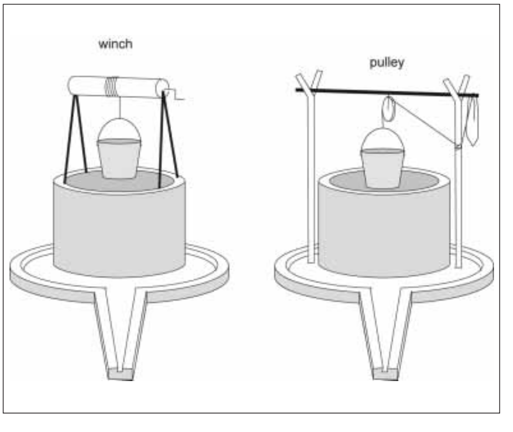


Figure 7.2: Manual water drawing.

1.2.2 THE 'SHADUF'

This system, used widely in Asia in shallow wells, protects the water from surface pollution transmitted by the bucket. It is also very convenient for the removal of spoil from excavations (Box 7.2).

Box 7.2
Working principle of the shaduf.

Define point A (Figure 1), the lowest level from which water is to be drawn (the dynamic water level during water drawing).

Ensure that the lift handle can be reached by the user.

The distance between the fulcrum of the shaduf and the well (OB) should be such that the arc defined by the counterbalance is large enough.

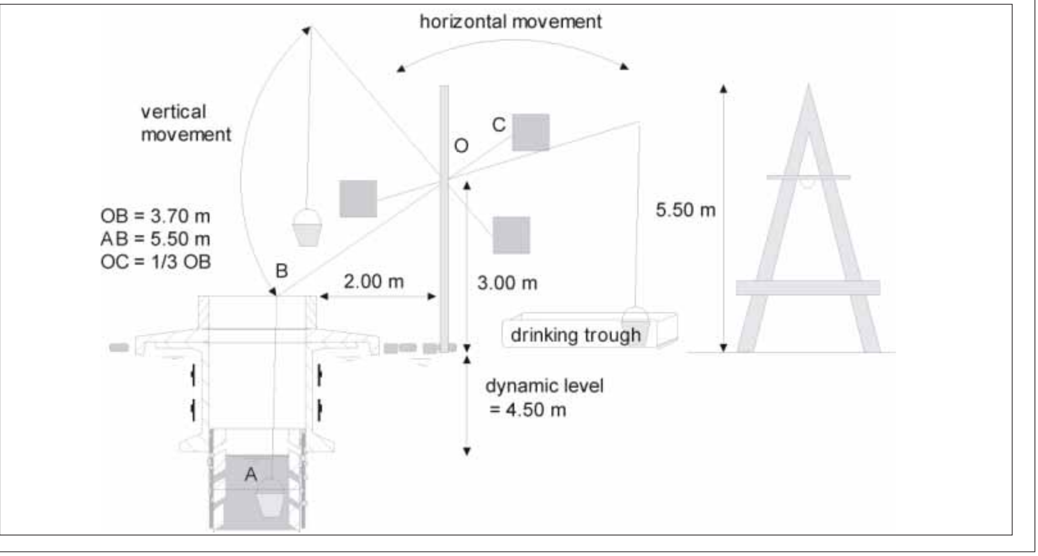
The lifting pole should be rigid (wood), and the flexible fixings at its extremities should be short.

The counterbalance should be located at the end of the lifting beam, one third of the length of OB from the fulcrum.

The counterweight is determined so that a container full of water can be raised without effort; the effort is exerted when lowering the scoop into the well.

The fulcrum must permit rotation in both vertical and horizontal planes (fixings of leather or rubber).

Figure 1: Shaduf.



1.3 Diameter

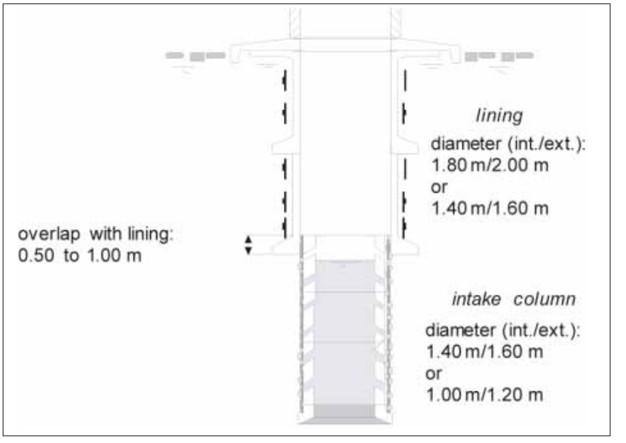
The diameter of a well varies depending on use, depth and flow. Larger diameters are used for pastoral wells (multiple users) or for shallow or poorly productive aquifers. The well has significant storage capacity and refills when not in use.

There are two construction techniques:

– independent intake: the intake column is telescoped into the well lining (Figure 7.3);

– intake lining: perforated well rings at the base of the well lining.

Figure 7.3: Lined well with independent intake.



Well diameters commonly used are 1 to 1.2 m inside diameter for wells with intake linings (less than 15 m deep).

For wells with independent intakes:

– lining 1.40 m and intake section 1 m internal diameter for village wells intended for drinking water;

– lining 1.80 m and intake section1.4 m internal diameter for pastoral wells, subject to much higher usage and allowing 6 people to draw water simultaneously. For wells wider than this, the volume of materials involved is enormous.

Wells of smaller diameter are too narrow to work easily inside.

1.4 Well lining

The lining extends from the surface down to the static level of the water table. Its function is to retain the earth and rock sides and to prevent infiltration of surface water or water from unwanted surface aquifers (polluted or saline water).

The most effective technique is lining *in situ* using metal shuttering during the construction of the well. The advantage of this technique is that it provides an integral, one-piece reinforced column, which is much stronger and more water-tight that a column of rings stacked one on top of another. Where rings are used, sealing of the column is poorer, and it is not unusual for lateral deflections of the column to occur because of ground movements.

1.5 Intake column

This is the immersed section of the well, and its role is to admit water while preventing ingress of fine solids (sand, silts etc.). It is made of perforated (or porous) rings and designed to provide a sufficient depth to ensure water supplies all year round, even during dry periods.

Ideally, this section of the well should be dug during a low-water period (lowest static level). If it is not done at this time, the water level in the well will be higher.

The height of water in the intake section of the well depends on annual groundwater variations and the water output from the well (see Chapter 6).

2 Construction techniques

2.1 Digging

Digging (or sinking) a well must be as close to the vertical as possible throughout the depth of the excavation. It is recommended to mark out on the ground a circle equal to the diameter of the excavation, and to mark the axis of the excavation with a plumb-line (Figure 7.4). The diameter of the excavation should be checked regularly using a gauge (Figure 7.5).

Digging takes place from the centre of the well and moves toward the wall. Excavated material is regularly lifted to the surface using a bucket or kibble.

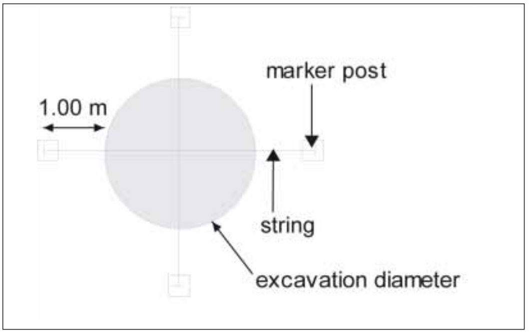


Figure 7.4: Marking the axis of excavation.

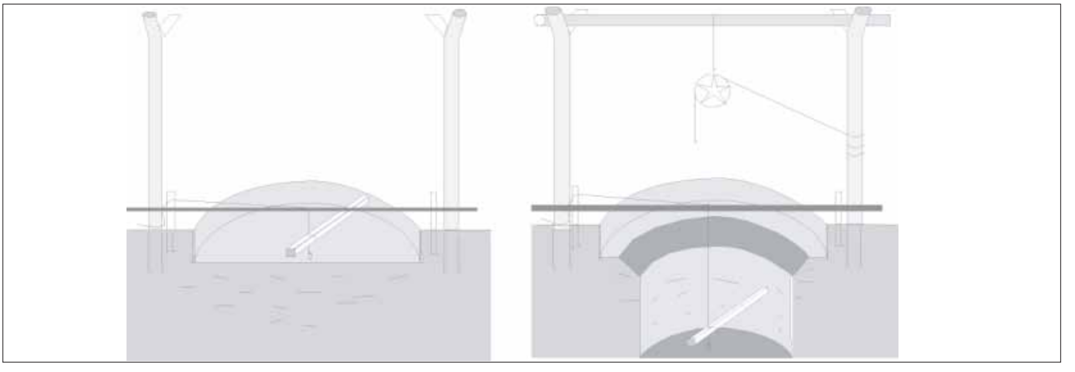


Figure 7.5: Use of a gauge.

Over the top of the excavation, a tripod fitted with either a motorised or manual winch is set up for raising or lowering men and materials. In shallow wells, this tripod can be replaced with a gantry carrying a pulley (for safety, it should have a locking and braking system for use when lowering the rope).

Digging can be done using a grab bucket, raised by a free-fall winch (motorised crane). This type of equipment is especially useful for dredging wells and for digging in loose ground or below the water table.

2.2 Lining

The techniques used for installing the lining and the intake section depend on the stability of the ground encountered during the excavation. There are three distinct techniques (Table 7.I).

Table 7.I: Techniques used for installing lining and intake section.

Nature of ground	Lining	Intake section
Stable ground	Bottom-up *in situ* lining	Independent intake with cutting rings
Ground unstable and/or well of more of 10 m depth	Top-down *in situ* lining	Independent intake with cutting rings
Loose ground and/or well of less than 15 m depth	Sunk lining on cutting ring	Intake lining with perforated rings below the lining

2.2.1 STABLE GROUND, BOTTOM-UP LINING

In ground that can be dug with a pick, and which does not present a risk of crumbling (some sandstones, clays etc.), the technique consists of lining the well from the bottom upwards. The excavation is open from surface to water level (Figure 7.6).

The first section of the lining is poured at the bottom of the excavation, at the same time as the base anchorage. The steel reinforcement is then put in place, its length being greater than the height of the shuttering, in order to tie it into the next section up (see Figure 7.8A).

The shuttering is lowered, centred using the plumb-line, and set vertical. Two or three shuttering sections are placed at a time, so that concrete sections two or three metres high can be poured in one go.

The concrete (350 kg cement per m^3) is poured, and vibrated with a jackhammer or a vibrator rod. Shuttering can be removed after 8 hours.

If the ground shows signs of instability during digging, the operation will have to be stopped, and the lining method changed to top-down, as described below.

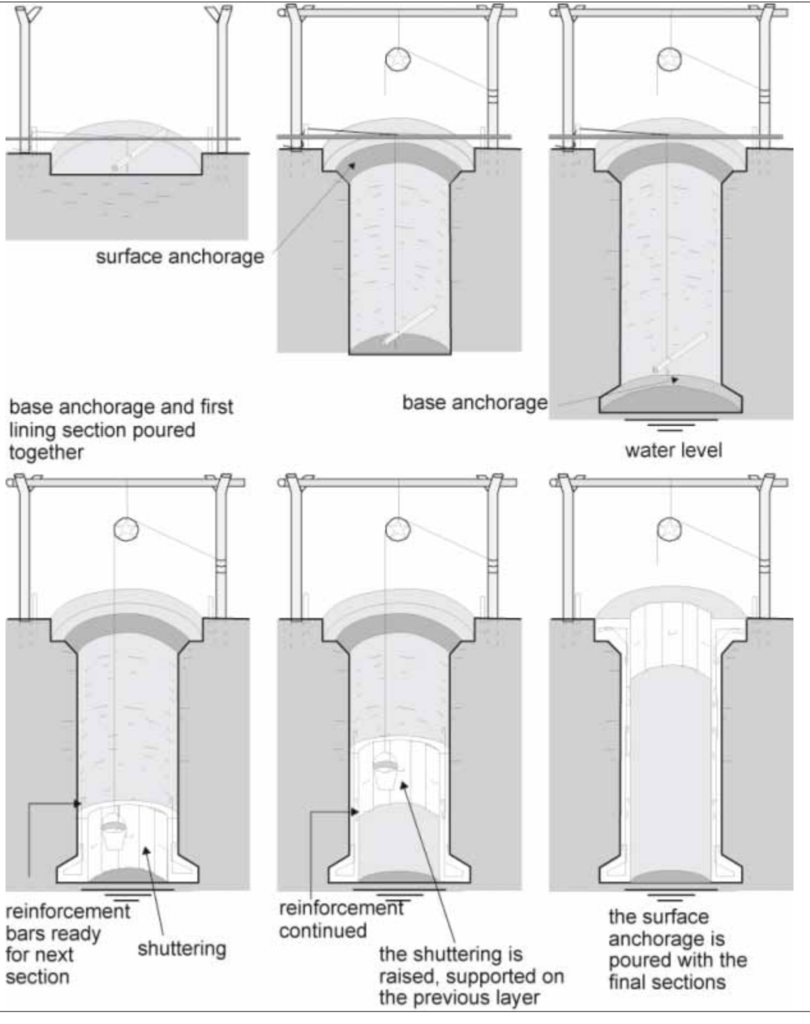


Figure 7.6: Bottom-up lining.

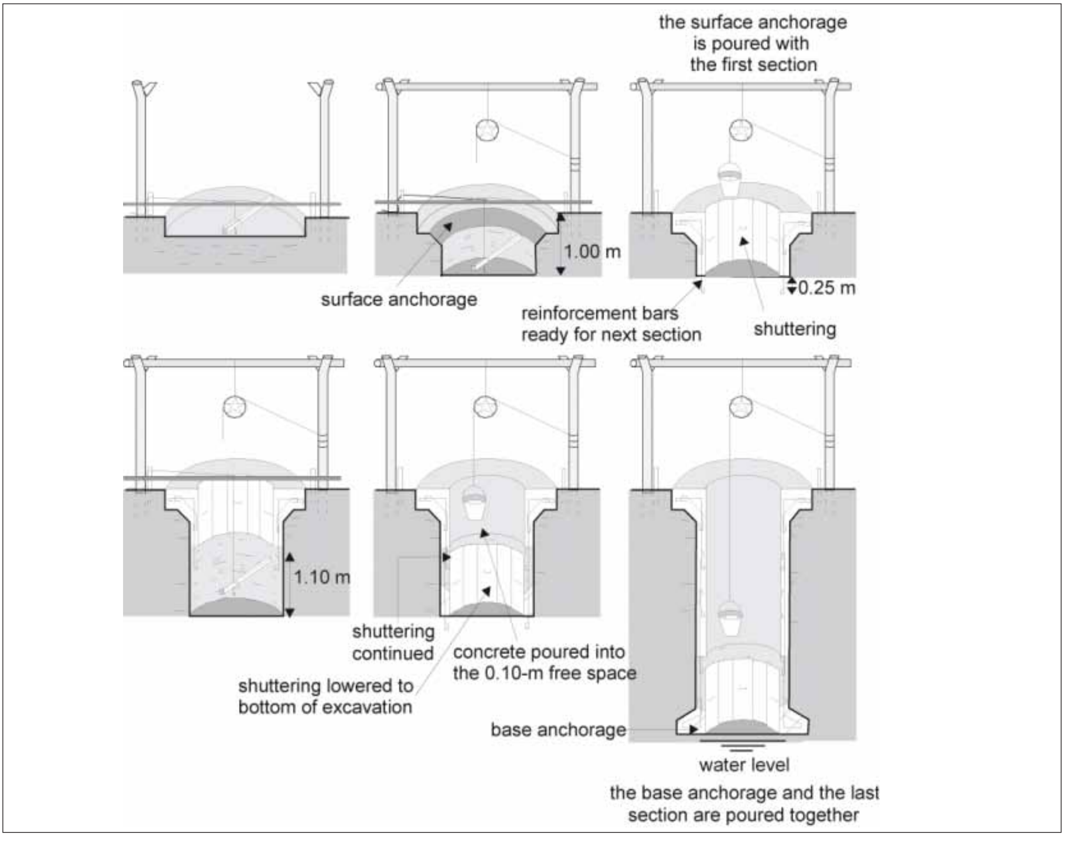


Figure 7.7: Top-down lining.

2.2.2 UNSTABLE GROUND, TOP-DOWN SHAFT LINING

In ground where there is a danger of collapse (sand, gravel etc.), it is essential to construct the lining in one-metre sections while the well is being dug (Figure 7.7).

In practice, when the first metre is dug, and the site of the surface anchorage has been cleared, the reinforcement is installed (Figure 7.8B) and the shuttering put in place. The process then involves:

– digging a section 1.10 m in depth;
– fixing reinforcement and fixing to the previous set of bars (vertical height of reinforcement 1.35 m);
– placing shuttering leaving 0.10 m clearance above it;
– pouring the concrete and filling the 0.10 m gap up to the lining section immediately above; removal of shuttering after 8 hours.

2.2.3 SOFT SANDS, SUNK INTAKE AND LINING

This technique is applied in soft sand, or with shallow wells (less than 15 m). It is currently used for the construction of village wells or for market gardening.

The base of the lining, made up of perforated rings, forms the intake column. The intake and lining form one continuous structure, which is installed by undercutting, as with an independent intake column (see Section 2.3).

This technique does not allow anchorage at the well bottom, and the column is suspended from the surface anchorage, which must be constructed with a maximum of care. Also, installing a gravel

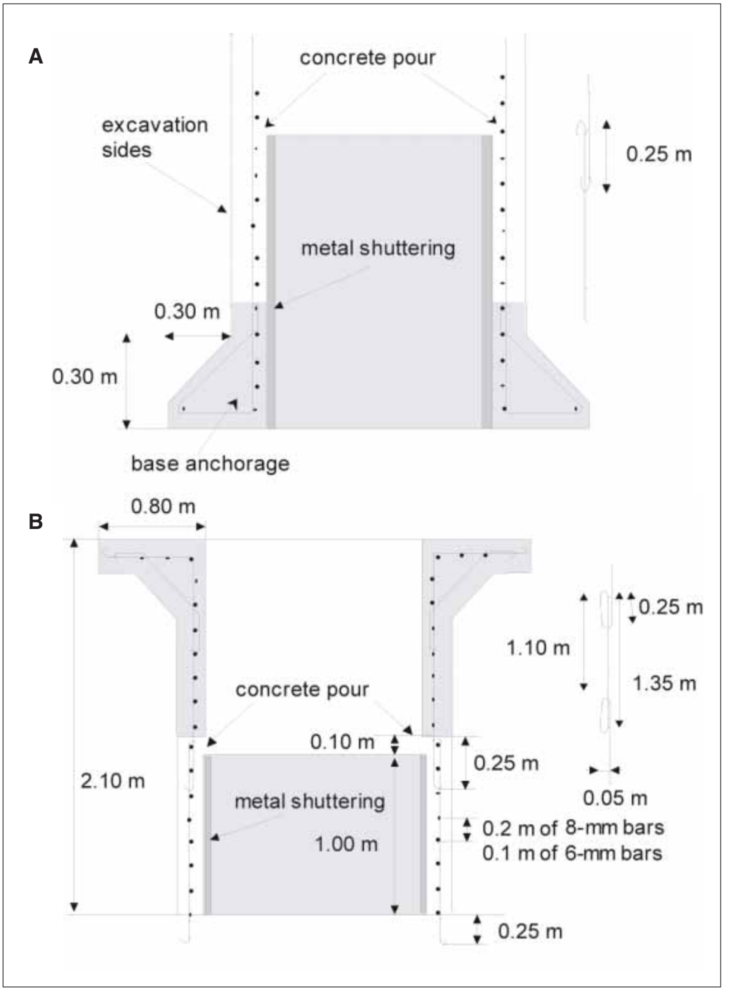


Figure 7.8: Reinforcement methods for bottom-up (A) and top-down (B) linings.

pack is difficult, and the intake level must be determined beforehand (the number of catchment-section rings being decided before reaching the aquifer).

For this kind of well, *filtering concrete rings* may be used. These rings are made of three bands (Figure 7.9), two impermeable and one porous. The rings are not reinforced and the porous concrete band is made exclusively with cement and gravel (1 volume of cement to 4 volumes of gravel). As these rings are not reinforced, the cement dosage and the time of drying have to be strictly respected. Moreover they are not recommended in places where the soil is unstable. The outside diameter should not exceed 1.30 m.

The advantage of this technique is to filter the water (to keep out sand) even if no gravel pack is installed. These rings are also cheaper and lighter than normal ones.

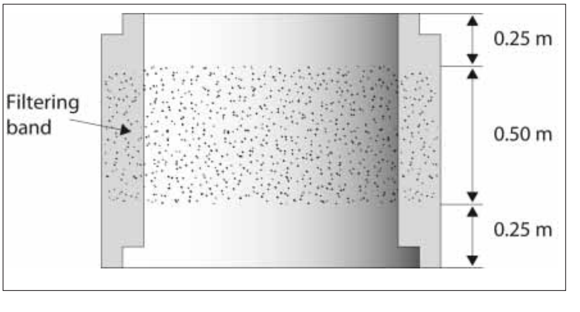


Figure 7.9: Filtering concrete ring.

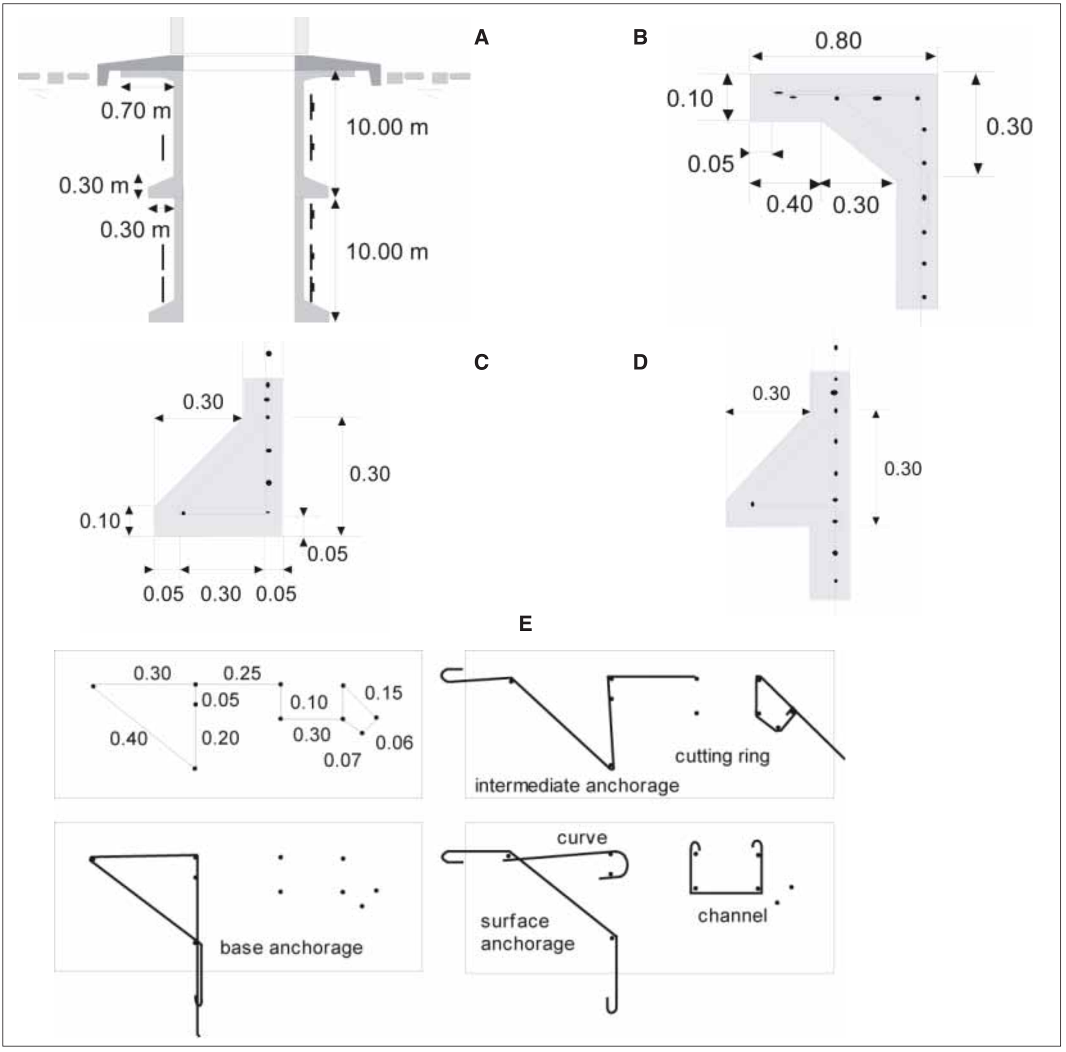


Figure 7.10: Reinforcement for lining anchorages.
A: general view. B: surface anchorage. C: base anchorage. D: immediate anchorage. E: pattern for making reinforcement elements, made of a thick plank, 1.1 m long and 0.5 m wide with short lengths of reinforcement bar inserted in it.

2.2.4 ANCHORAGES

Anchorages are essential and are cast at the top and bottom of the well, and every 10 m for wells of more than 20 m in depth. Their role is to absorb the vertical forces created by the weight of the column.

The surface anchorage is in the form of a crown 0.80 m in width at the top of the shaft lining; base and intermediate anchorages are 0.30 m wide (Figure 7.10).

2.2.5 LINING THICKNESS, CONCRETE MIXES AND REINFORCEMENT

The thickness of the lining and the mesh of the reinforcement are theoretically determined by on the forces to be resisted. However, the variation in forces imposed by the ground on the lining are small and difficult to measure precisely (the forces are compressive). Design is simplified by standardising the thickness of linings and reinforced concrete well rings to 10 cm and the steel reinforcement to 8 mm diameter with a mesh of 20 cm (or 6-mm bars with a mesh of 10 cm).

Concrete is made with 350 kg of cement per m^3 for the lining and 400 kg/m^3 for the intake section; mortars at 300 kg of cement per m^3.

2.3 Independent intake

This type of intake is independent of the well lining. It consists of a column of smaller-diameter perforated well rings telescoped into the well lining (Figure 7.3).

The excavation is taken down to the static level and is then pumped out. The column of well rings is then sunk by a cutting ring (see Section 2.3.3) to descend under its own weight: flooding with water is a critical stage in the construction of a well. The well is kept dry by pumping (see Chapter 9) or using a bailer operated by a motorised crane.

2.3.1 PRE-CAST WELL RINGS

The intake section is made up of perforated reinforced concrete rings, stacked up from the bottom of the well. There is a risk that they become destabilised and shift sideways during undercutting, which would jeopardise the process. To facilitate lowering the rings, their height is limited to 50 cm. They are lowered to the bottom of the well using a winch (see Figure 7.13 B & C).

The perforations, spaced at 10 cm intervals, are made using 8 or 10-mm reinforcement bars, protruding through holes in the mould. The bars should be smeared with oil and turned regularly to facilitate removal (Figure 7.11).

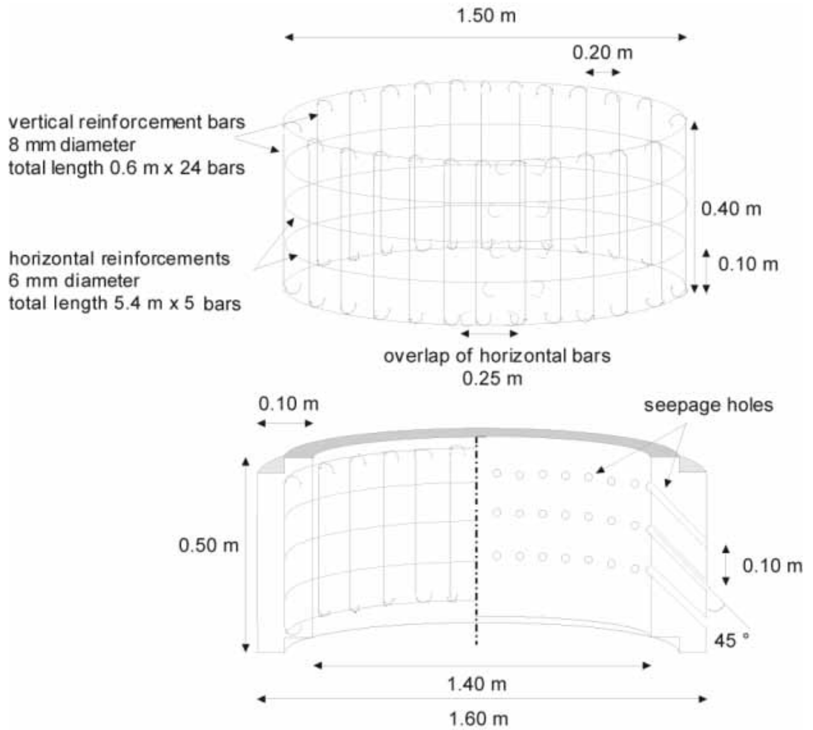


Figure 7.11: Reinforcement of perforated rings.

2.3.2 CASTING THE INTAKE COLUMN AT THE BOTTOM OF THE WELL

Prefabrication can save a week of total construction time. However, it is preferable to pour the column directly at the bottom of the well, locking the sections into one another by overlapping the reinforcement.

The mould is positioned at the bottom of the well. The reinforcement bars on the first intake ring are locked into bars protruding from the top of the cutting ring, and then the concrete is poured. The mould may be removed by the following day, and then a second section is poured.

2.3.3 THE CUTTING RING

This is a bevelled concrete ring, wider than the other rings, laid at the base of the intake column (Figure 7.12). Its role is to facilitate lowering the column into the ground, and to provide sufficient space to insert the gravel pack (see Section 2.3.5) between the rings and the ground around the well.

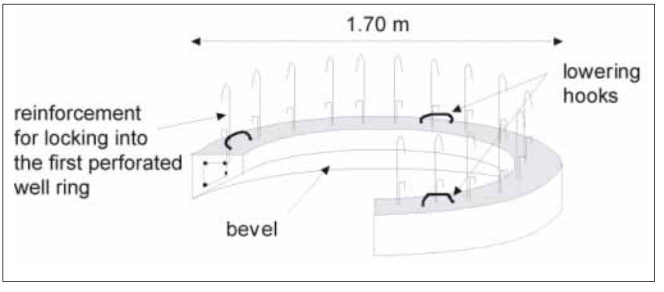


Figure 7.12: Cutting ring 1.4 / 1.6 m diameter.

2.3.4 SINKING THE INTAKE COLUMN UNDER ITS OWN WEIGHT

Four 4-cm thick wooden beams are inserted into the space between the lining and the intake column, extending about 10 cm above the top of the column, to act as reference markers and to check that the column is descending vertically (Figure 7.13. A-C).

The well is then dug inside the column, regularly clearing the bevel of the cutting ring around its perimeter so that it descends vertically. If a beam jams, earth is dug out from under the cutting ring on the side opposite the beam to straighten the column.

A gravel pack (see below) is forced into the space between the column and the surrounding earth as the digging proceeds.

Finally, if the earth is unstable and very fine grained, a concrete base consisting of two semi-circular slabs pierced with 10-mm holes spaced 15 cm apart is placed at the bottom of the well, on a bed of gravel.

2.3.5 GRAVEL PACK

This consists of 10 to 15-mm gravel, preferably siliceous and rounded (avoiding lateritic gravels and limestone), distributed evenly around the well intake column to a thickness of 5 cm. Its role is to keep out fine particles of earth while admitting water. It is therefore an essential part of the intake.

2.4 Developing the well

Once the work is finished, the well is developed. It is an important operation for removing fine particles and increasing permeability around the intake in order to increase the specific flow (sometimes considerably). It also allows complete cleaning of the well, and estimation of its yield (see Chapter 6). Two simple methods are used for this purpose:

– *surging with a bailer*. The method consists of agitating a 50-litre bailer (Figure 7.14) below the water surface in the well, plunging it up and down like a piston. These phases of surging alternate with phases of pumping, first at a low flow, then progressively increasing the flow until clear water is obtained;

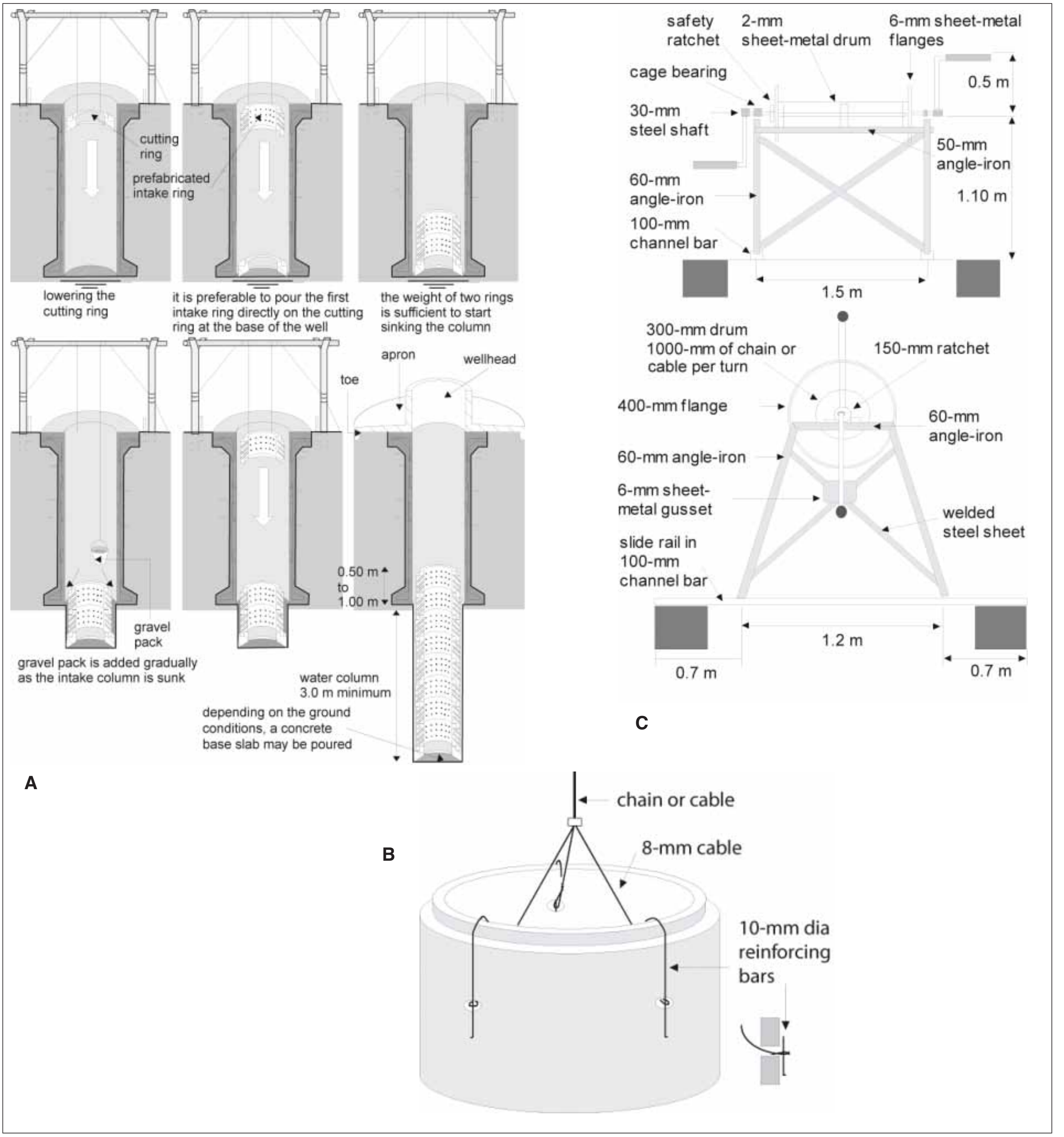


Figure 7.13: Sinking an independent intake.
A: sinking stages. B: lifting system for rings. C: winch for lowering rings.

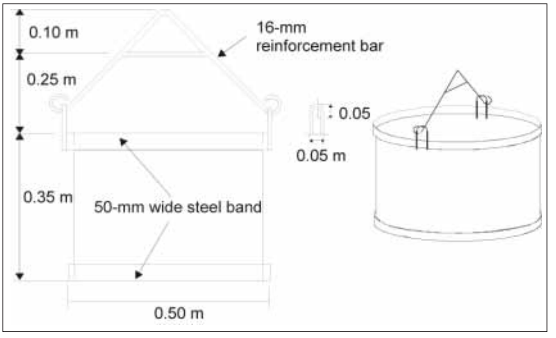


Figure 7.14: A bailer.

– *pumping*. By pumping in stages of increasing flow, the well is cleared of fine particles from around the lining. Ideally, a dewatering pump designed to handle turbid water should be used, but a submersible pump (see Chapter 9) can also be used.

2.5 Use of explosives

ACF teams dig wells in very different geological contexts around the world. Digging of hard formations may often be done with a jackhammer. However, in certain geological contexts (presence of hard rock that is only slightly weathered, or not at all), using a jackhammer is tedious, if not impossible (extremely slow progress, heavy wear of the tools and fatigue of the digging teams). Nevertheless, in some cases it might be necessary to get through layers of hard rock in order to reach an aquifer in fractured and weathered rock below.

On the Ifoghas massif in Mali, in 1998, the ACF teams overcame this type of problem using explosives.

After several years of experience, the results may be considered positive. The rates of progress in the unweathered or slightly weathered granite formations of the region are variable, around 25 cm per blast. Excavating a well using explosives costs about twice as much as digging by hand (excluding the cost of lining the well).

The methodology adopted can be summarised as follows:

– drilling the blasting holes (between 6 and 12, depending on the blasting plan), about 1 m deep;
– inserting the explosive packs with their detonating cords;
– packing clay in the blasting holes;
– connecting the detonating cords (6 to 12) to an electrical detonator;
– connecting the detonator to a battery or blaster;
– blasting;
– waiting for the evacuation of the blast gases;
– clearing the debris and then shaping the sides of the well with a pneumatic drill.

In order to perform such a technique a special set of equipment must be purchased: a pneumatic drill and air compressor, electrical detonator, dynamite packs, detonating cords, and electric cables and a battery (or blaster).

Note. – Due to the dangerous nature of the materials used, it is necessary to train the teams in mining techniques. In each country, specific legislation and regulations govern the use of explosives. Therefore, it is compulsory to involve the relevant government structures in the development of a training programme on the use of explosives before any intervention. Regulations (and hence the training) cover the purchase, transport, storage and use of explosives. It is essential to contact the appropriate technical service or ministry, to obtain the necessary permits to carry out this activity. In cases where a competent authority does not exist in the country, this kind of activity can only be performed if there is a specialist who ensures the security of the construction site.

2.6 Deep wells in Mali

The first so-called modern wells to be built in Mali date from the French colonial time. They are still in service and have the characteristics of a modern well of 180 cm diameter. Due to the hydrogeological conditions in northern Mali the depth of some these wells exceeds 100 m. In such a context, the well-digging technique does not change in itself, but the materials and equipment used must be adapted in order to facilitate the work of the well-digging teams.

ACF-Mali builds independent intake wells and cistern wells. The deepest such well that has been built has a total depth of 90 m and some of the cistern wells reach 70 m deep. It is clear that digging wells to these depths involves a number of difficulties. There are several points to be considered:

– *Safety of the teams*. The security rules are the same whatever the depth of the well (helmet, boots, safety rope, harness etc.), but the depth of the construction increases the need for the systematic application of the rules in order to prevent any person or object falling into well. During the construction phase the surroundings of the well must be kept free of all loose objects, and the tools must be lowered into the well very carefully.

– *Pumping equipment*. Beyond 40 m, ordinary dewatering pumps (type DOP 15 N) cannot be used, so it is difficult to remove the water. Initially, a 200-l bailer lifted with a derrick winch was used, but this caused too much strain on the winch motor (Hatz). Currently, the water is pumped with a high-head electric dewatering pump (brand FLYGT, model BIBO 2084 HT 250). This pump is able to extract 10 m^3/h from a depth of 80 m, and is powered by a 30 KVA generator (pump and parts cost 12 000 Euros, while the generator cost 10 000 Euros).

– *Installing the lining*. The diameter (180 cm), the digging technique and the characteristics of the reinforced concrete are conventional. At greater depths the quality of work needs to be very high at critical points, namely the anchorages (every 10 m), the steel reinforcement, particularly the covering of the steel and the quality of the joints between cast sections (top-down *in-situ* lining). Special care must be taken in the production of the concrete, since its quality ensures the long life of the construction. Concrete quality depends on the quality of the aggregates (cleanliness, hardness, shape and effective grain size) (and the cement (CPA 45 is a good guarantee), as well as the proportions of the materials used. The normal mix for 1 m^3 of concrete is 350 kg of cement (up to 400 kg), 800 l of gravel and 400 l of sand. The depth of the construction often means digging through intermediate aquifers that are not of interest (not perennial). The presence of this water disturbs the laying of the reinforced concrete. In these cases an accelerator and waterproofing compound such as SIKA 4A is used.

– *Disassembling old wells*. As part of the ACF project, old colonial wells are rehabilitated. This rehabilitation requires an initial disassembling phase. For this purpose a grab bucket such as the SECMIL / BP 55 is used. This is suspended from a derrick winch and allows the bottom of a well containing water to be cleaned out. For example, 25 m of sand was cleaned out from one well that was 120 m deep.

3 Rehabilitation of wells

3.1 Why rehabilitate?

Rehabilitation of a well is often more cost-effective that the construction of a new one, because less work is involved. Moreover, a well already in use by a village or community is governed by established rules which may have to be redefined for a new well.

Inspecting a well to be rehabilitated requires special attention to elements that protect the well from surface pollution during its use, and/or from infiltration of contaminated water (Table 7.II). A rehabilitated well is therefore one that is protected from pollution and that provides a satisfactory flow for its users (Figure 7.15).

Table 7.II: Routes of pollution to a well (see also Chapter 13).
A well must be situated at least 30 m from a source of contamination (latrines, domestic refuse tips etc.). In the majority of cases the distance of 30 m is quite sufficient (no more traces of faecal pollution beyond a few metres), except in fractured ground.

Route of pollution detected	Possible protection
Surface pollution Contamination by rope and bucket Contamination by surroundings of the well	Clean water-drawing system (pumps, winches, pulleys, shaduf) Wellhead, apron and drainage channel Protective fence against animals
Infiltration of polluted surface or underground water	Water-tight lining Slab Healthy environment (latrines situated more than 30 m away, no refuse, no wastewater drainage upstream of the well)

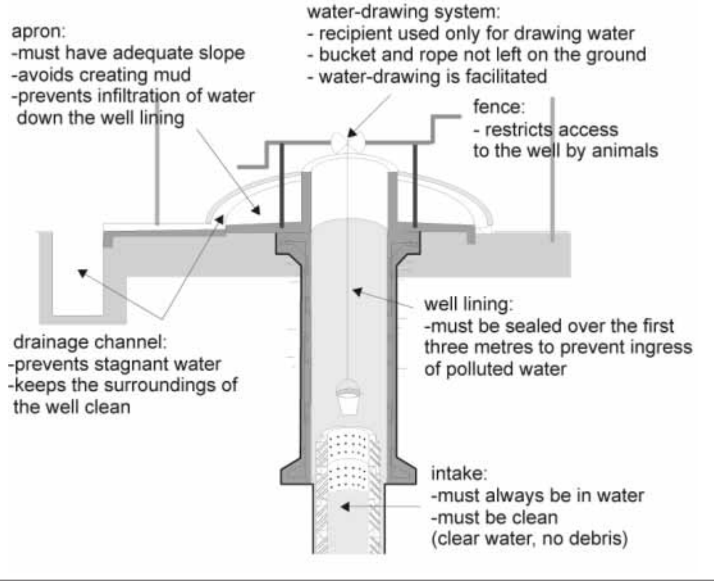


Figure 7.15: Protecting a well from pollution.

3.2 Rehabilitation of the well lining

3.2.1 REHABILITATION OF THE EXISTING LINING

Except in the rare cases where the concrete work is very poor, the linings of wells finished in reinforced concrete age well and any cracks can be simply repaired with mortar.

On the other hand, masonry linings must be carefully inspected, and the mortar joints always checked to ensure sealing of the lining, especially the upper part.

3.2.2 NEW LINING AND INTAKE

3.2.2.1 Narrow wells

If the well is unlined and of a smaller diameter than the diameter of the lining envisaged, it is best to rebore the well and fit a lining in an identical manner to that used in the construction of a well.

If the well to be rehabilitated includes an old lining (concrete and masonry) in poor repair and difficult to get at, it is possible to cast a new lining inside the old one, throughout its height. This is sometimes termed re-sheathing. However, the lining in place must have a diameter large enough to take a new lining and an intake column.

In the case of lateral displacement of the column, it will have to be demolished, at least partially. The time involved, the equipment needed (rock hammer) and the cost compared with constructing a new well must be carefully estimated before starting such a project.

3.2.2.2 Wide unlined wells

It is often the case that a traditional well collapses so that access becomes precarious.

The diameter of the excavation in place is too large for a lining, so the best solution is to build a column of well rings in reinforced concrete. Preferably, this column should be cast in place, or prefabricated and then assembled on site. Ain independent intake is then inserted.

It is not appropriate to install a top-down lining (too much excavation to do and too much concrete to be poured).

When the underlying ground is hard, for example if it is composed of limestone or sandstone, the base of the lining can be supported by the underlying rock, and there is no need to line the section of the well below water.

Repair or construction of a masonry lining is only done in large-diameter wells (especially for thin and relatively unproductive aquifers), where the well-ring moulds required for constructing a lining in reinforced concrete would be too cumbersome and the quantities of materials required would be excessive. Sinking a masonry column (bricks or stones) is almost impossible, because it does not take the strains involved, and disintegrates.

3.2.2.3 Backfilling the excavation

The space between the original excavation and the outside of the new lining must be filled with clay and rubble packing up to about 50 cm below ground level, where it is topped off with cement (see Chapter 8) to provide a seal.

It is very important to take special care over compaction of the packing, layer by layer. Water pumped during digging or development can be used to wet packing materials and obtain optimal compaction.

If this operation is not well done, the packing may compact naturally over the course of time (in the first rainy season, for example) and cause subsidence, creating cracks in the surface works, allowing infiltration of surface water.

3.3 Cleaning and deepening

Cleaning a well is often necessary in cases where it is blocked by objects and sediment that have fallen in or, more generally, by progressive silting. It is necessary to regain sufficient water depth so that the well does not dry up, and so it recovers its production capacity.

Well-cleaning is a yearly operation carried out by the communities that use the well. It is easier to carry it out in the dry period. Emptying the well, if it is not too productive, may be carried out by hand using a bucket. In the case of higher-yielding wells, pulleys and animal traction or a dewatering pump may be required. Public wells are unfortunately often no-one's responsibility and are not cleaned, which is evidently not the case with private wells, even those that are narrow and very deep.

Deepening a well increases its flow in most cases, except when the base of the aquifer has already been reached. It becomes necessary when the static level falls with the passage of the time, or in wells in which sufficient water depth was not given enough attention or could not be achieved because of lack of materials and equipment at the time the well was constructed.

Deepening wells near the sea can quickly become problematic because of saline water below the unconfined freshwater aquifer (as was the case in Mogadishu). Redigging beyond this level should not take place, therefore, to avoid all risk of contamination of the well by salt water (see Chapter 3).

There are several options for deepening techniques, depending on the nature of the well:

– for masonry intakes, a column of pre-cast well rings of a smaller diameter than those already existing in the well can be sunk, or the masonry lining can be extended as redigging progresses (shallow depths);

– for reinforced concrete intake-lining sections, an independent intake column is sunk inside t he old lining;

– for existing independent intakes, redigging is easy since it is sufficient to dig and add new well rings to deepen the intake column.

4 Disinfection

Disinfection is strongly recommended, both when rehabilitating a well and when digging a new one, and should always be done if the well is covered and equipped with a pump. There are various ways of proceeding using HTH (Box 7.3). Wells having significant occasional pollution, or those that are likely to be polluted, should be systematically disinfected.

Box 7.3
Methods for disinfecting wells.

Disinfection involving emptying the well

1) Dilute 200 ml of 1% solution of active chlorine in a 10-litre plastic bucket (solution of 200 mg/l of chlorine), i.e. 3 g HTH (70% active chlorine) or 50 ml bleach (4% active chlorine) in 10 l of water.

2) Empty the well and brush its walls with the chlorine solution (take care with chlorine vapour), then wait for 30 min and let the well refill itself again.

Disinfection without emptying the well

1) Prepare a solution of 200 mg/l of chlorine, as above.

2) Brush the walls of the well above the water level.

3) Calculate the volume of water contained in the well:

$$V = 3.14 \cdot r^2 \cdot h$$

where V is the volume of the well (m^3), r its radius (m), and h the height of water in the well (m).

4) Determine the quantity of chlorinated product to add to the water in the well to obtain a 100 mg/l chlorine solution: for each 1 000 l of water in the well, 100 mg/l of Cl = 140 mg HTH or 2.5 l of 4% bleach.

5) Make up the solution in 10-litre plastic buckets, with 250 g maximum of product per bucket (limit of solubility).

6) Pour the content of the buckets into the well, mix and wait 12 h, preventing access to the well.

7) Draw off water until it has only a slight chlorine smell.

Notes

– In zones where water is scarce, it is possible to treat the water in the well with only 50 mg/l of chlorine.

– If the well is equipped with a handpump, introduce the disinfecting solution into the well, then pump until chlorinated water is passing through the pump. Wait 12 hours, then pump until the water has only a slight chlorine smell.

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