Protective Structures For Springs: Spring Box Design, Construction and Maintenance

A newly completed spring box in the Dominican Republic. Note old spring box behind the new structure with open top to allow livestock a drink of water. Photo courtesy of Matt Niskanen, 2003.

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What is a spring?

A spring is a place where groundwater naturally seeps or gushes from the earth's surface. Spring water typically moves downhill through soils or through cracks and fissures in the bedrock until the ground's surface intersects the water table. There are many different types of springs falling under two categories: gravity springs and artesian springs.

Gravity springs include depression springs, contact springs, and fracture or tubular springs. Depression springs occur when the land's surface dips below the level of the water table. Yield from depression springs is highly variable, depending on the level of the water table. In areas that experience a pronounced dry season, depression springs may not be a suitable source of drinking water if the water table drops below the level of the depression, causing the spring to become seasonally dry. Gravity contact springs occur when an impervious layer beneath the earth's surface restricts surface water infiltration. Water is channeled along the impervious layer until it eventually comes in contact with the earth's surface. This type of spring typically has a very high yield and makes a good source of drinking water. Fracture and tubular springs are formed when water is forced upwards through cracks and fissures in rocks. The discharge is often concentrated at one point, thereby facilitating the process of protecting the source.

Artesian springs occur when water under pressure is trapped between two impervious layers. Because the water in these springs is under pressure, flow is generally greater than that of gravity springs. Artesian fissure springs are similar to fracture and tubular springs, in that water reaches the surface through cracks and fissures in rocks. These springs make excellent community water sources because of their relatively high flow rates and single discharge points. Another type of artesian spring that can be developed as a high quality water source is the artesian flow spring. These occur when water confined between two impervious layers emerges at a lower elevation. Artesian flow springs often occur on hillsides, making protection a fairly easy process.

Spring Water Protection

The main objective of spring development and protection is to provide improved water quantity and quality for human consumption. Before reaching the surface, spring water is generally considered high quality, depending on the composition of the surrounding soils and bedrock. However, groundwater can become contaminated as it exits the ground's surface. Contamination sources include livestock, wildlife, crop fields, forestry activities, septic systems and fuel tanks located upslope from the spring outlet. Therefore, spring water sources need to be protected at the source or *eye*. Just as there are many types of springs, there are also many different kinds of protective structures, such as spring boxes, seepage spring development structures, and horizontal wells. However, spring boxes are typically cheaper, require the least skill, and can be made with locally available materials. In contrast to the generally held belief that discharges decline if the springs are touched, the development of natural springs often leads to improved yields.

Benefits of Spring Development Structures

The obvious benefits of spring development structures include increased flow and reduced possibility of spring water contamination. However, there are other benefits that are less easily recognized. First of all, the cost associated with constructing a spring box is minimal, and the system is basically maintenance free, requiring only infrequent disinfections and sediment removal. Secondly, spring box technology is very simple and can be easily modified fit just about any situation. Although protective structures such as spring boxes do not necessarily improve accessibility of the source, they can be easily adapted to work in conjunction with other technologies such as gravity fed distribution systems. Small springs can be developed at low cost to augment an existing water supply or to provide a source of water should the main water supply experience seasonal fluctuations.

Basic Design Features

Although there are many different designs for spring boxes, they all share common features. Primarily, a spring box is a watertight collection box constructed of concrete, clay, or brick with one permeable side. The idea behind the spring box is to isolate spring water from surface contaminants such as rainwater or surface runoff. All spring boxes should be designed with a heavy, removable cover in order to prevent contamination from rainwater while providing access for disinfection and maintenance. Spring box design should include an overflow pipe that is screened for mosquito and small animal control. It is also important to provide some measure of erosion prevention at the overflow pipe. Approximately 8 meters upslope from the spring box, one needs to provide a diversion ditch capable of diverting surface runoff away from the spring box, and an animal fence should be constructed with a radius of at least 8 meters around the spring box. This protects the water source from livestock and wildlife contamination, as well as from soil compaction that could lead to reduced yields. Some sources argue that by removing vegetation from the area surrounding the spring, flow may increase due to reduced water use by vegetation, however, others maintain that shallow rooted grasses should be allowed to grow in the area due to their capacity for utilizing surface water before it is able to infiltrate and contaminate spring water. In either case, deep-rooted trees and plants should be avoided as their root systems could damage protective structures and reduce spring flow.

There are two basic spring box designs that could be modified to meet local conditions and requirements. The first is a spring box with a single permeable side for hillside collection, and the second design has a pervious bottom for collecting water flowing from a single opening on level ground (see Figures 1 and 2). The spring box with an open bottom is typically simpler and cheaper to construct because less digging and fewer materials are required.

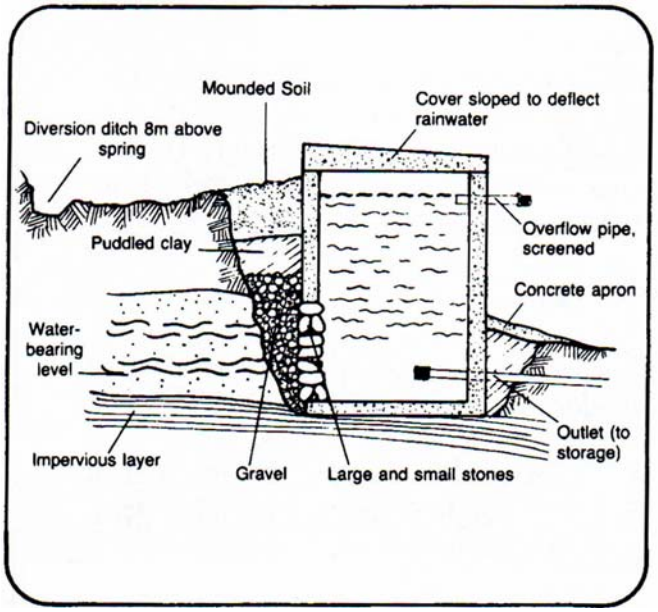

Figure 1: Spring box with single pervious side for hillside collection (Courtesy of USAID, 1982, available online at www.lifewater.org).

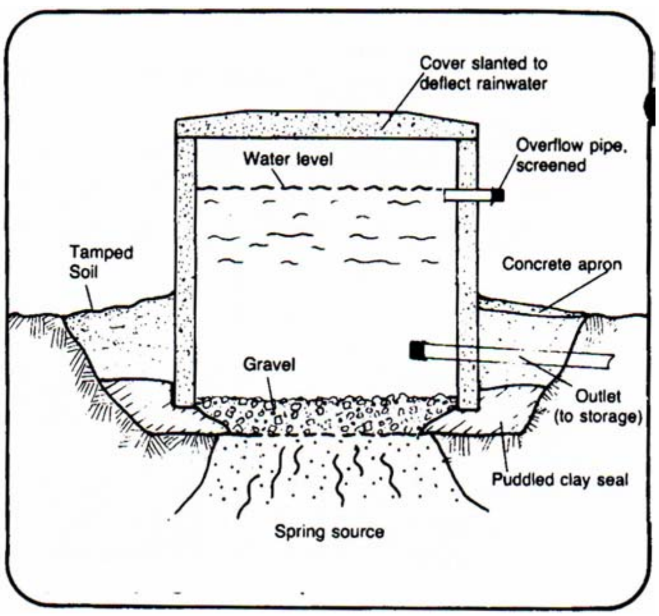

Figure 2: Spring box with permeable bottom for collecting spring water flowing from an opening on level ground (Courtesy of USAID, 1982, available online at www.lifewater.org).

If concrete is unavailable or if it's use is prohibitive due to cost, the spring box could be constructed using locally available materials, such as brick (see figure 3). This alternative is especially useful when protecting a single-source spring on level ground. If location and transportation are not prohibitive, large prefabricated concrete tubes can be used much like brick and cement spring boxes.

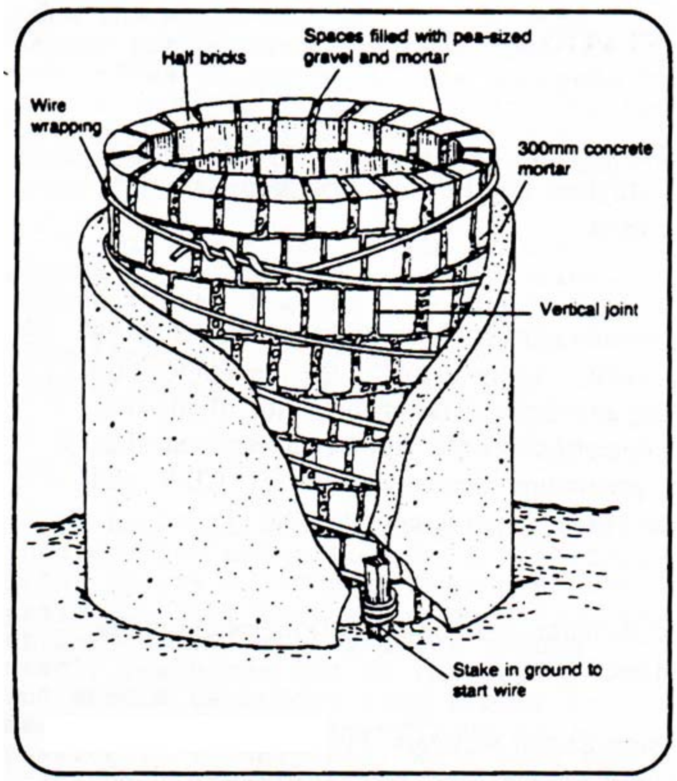

Figure 3: Spring box constructed with brick, wire and cement.
(Courtesy of USAID, 1982, available online at www.lifewater.org).

Designing the Structure

Because each spring site is unique and every community has individual water supply needs, there is not a particular spring box design that will fit all circumstances. It is up to the project manager and the community to decide what will work best depending on local conditions. For instance, if the spring is located at a higher elevation than the distribution area and the distance is not too great, it may be preferable to design a spring box that is large enough to also act as a storage structure large enough to supply the entire community, thereby eliminating the need to construct additional water storage tanks. It is also possible to design a spring box with a built in sedimentation tank if the source has high sediment loads.

The design chosen for any particular project will depend on local conditions, spring yield, available materials and community knowledge and requirements. The goal of the design process is to generate a dimensional plan of the spring box (see figure 4) and a map of the area, including the location of the spring, the location of houses in the community, distance from the spring to the community and elevation change as well as prominent features and landmarks (see figure 5). Another useful resource to produce during the design process is a list of all labor, materials, and tools needed, as well as those that are available on site. Such a list will help ensure that all necessary tools and materials are available on site in order to avoid delays and setbacks (see table1).

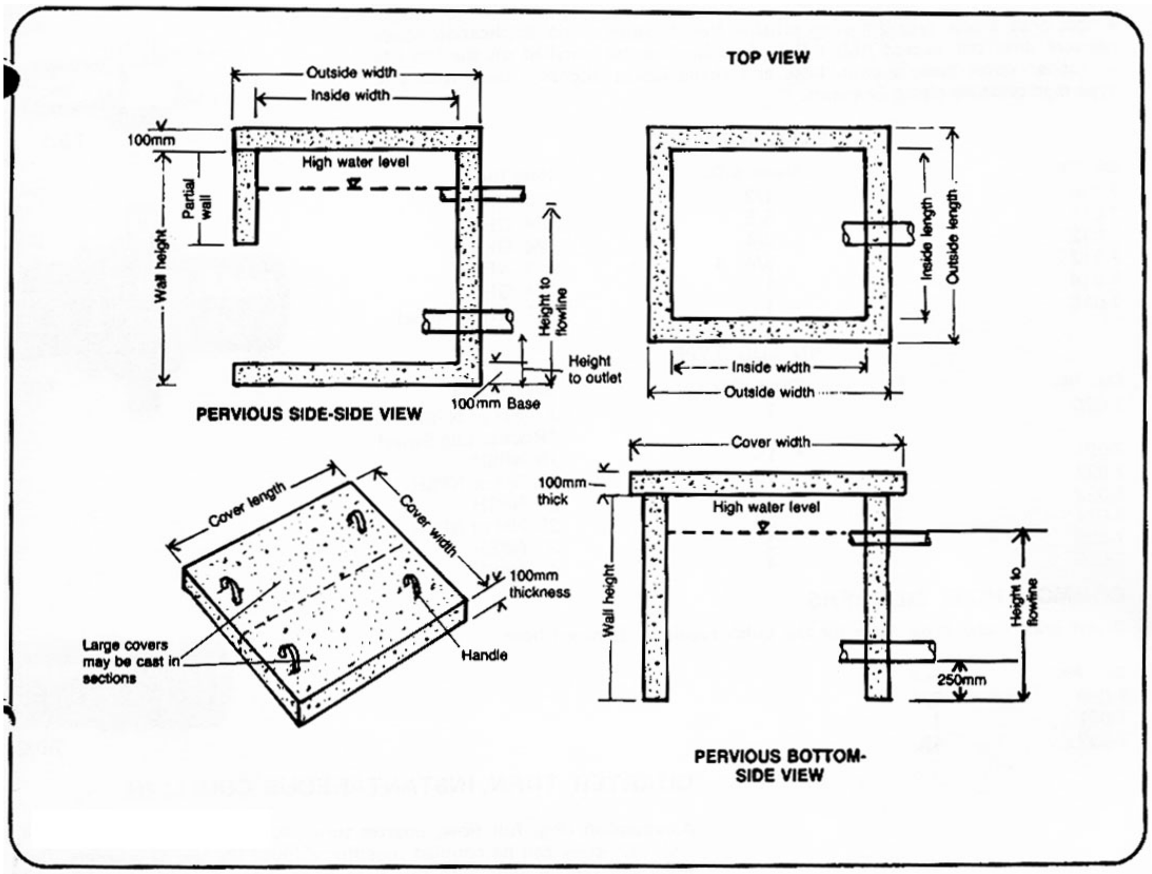

Figure 4: Dimensional plans of pervious side spring box and pervious bottom spring box (courtesy of USAID, 1982, available online at www.lifewater.org).

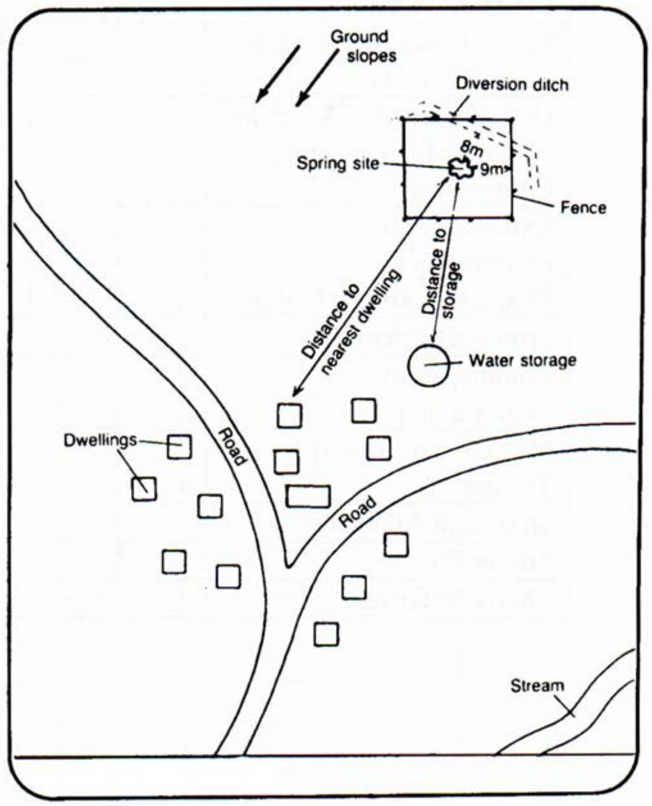

Figure 5: Location map showing spring location, distances to dwellings, and ground slope (courtesy of USAID, 1982, available online at www.lifewater.org).

Table 1: Materials, labor and tools list.

Item	Description	Quantity	Estimated Cost
Labor	Foreman	-	-
	Laborers	-	-
Supplies	Portland cement	-	-
	Clean sand and gravel	-	-
	Water	-	-
	Wire mesh or reinforcing rods	-	-
	Galvanized steel or plastic pipe	-	-
	Screening	-	-
	Boards and plywood	-	-
	Old motor oil or other lubricant	-	-
	Baling wire	-	-
	Nails	-	-
Tools	Shovels and picks	-	-
	Measuring tape	-	-
	Hammer	-	-
	Saw	-	-
	Buckets	-	-
	Carpenter's square	-	-
	Mixing bin	-	-
	Crowbar	-	-
	Pliers	-	-
	Pipe wrench	-	-
	Wheelbarrow	-	-
	Adjustable wrench	-	-
	Screwdriver	-	-
	Trowel	-	-
Transportation	Donkey (or other available transportation)	-	-

Preparing the Site

Once materials and labor are accounted for, the spring needs to be located and the site prepared (see figure 6). The site should be fenced off to protect the site from animals, and a diversion ditch needs to be dug approximately 8 meters upslope from the site to divert surface water runoff away from the spring.

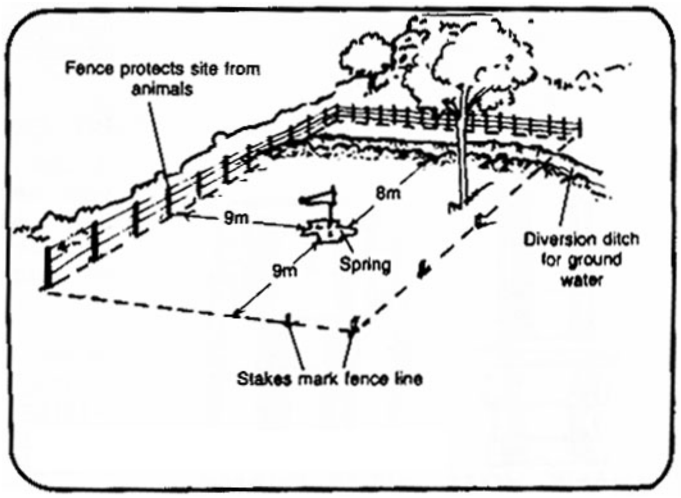

Figure 6: Preparation of spring box site (courtesy of USAID, 1982, available online at www.lifewater.org.)

Next, dig out the spring until the flow is concentrated from a single source. If the spring is located in a hillside, it may be necessary to dig into the hillside far enough to locate the eye of the spring. Look to see if flow from major openings increases, or if flow from minor openings decrease or stop. These are signs that the flow is becoming concentrated from a single eye. Remember that the objective is to collect as much water as possible from the spring and that it is generally easier to collect from a single opening than from many. If a single flow source cannot be located because of numerous, separated openings, it will probably be necessary to construct a seep collection system rather than a spring box (see *Alternatives*). Depending on the terrain of the site, it may be necessary to dig a temporary diversion ditch to drain spring water from the excavation site (see figure 7).

Once a single eye is located, dig down until you reach an impervious soil layer. This will make a good, waterproof foundation for the spring box. Before installing the spring box, pile stones and gravel against the spring. This will provide some capacity for sedimentation and will prevent erosion from around the spring eye. This will also support the impervious section of the back wall of a pervious-side spring box (see figure 1). If the spring is flowing from a single opening on level ground (pervious-bottom spring box), dig a basin around the spring eye until an impervious layer is reached. Line this basin with rocks and gravel, making sure to cover the spring eye so that water flows through the gravel before entering the spring box (see figure 2).

Figure 7: Excavating the spring site. Note temporary diversion ditch (Courtesy of USAID, 1982, available online at www. lifewater.org)

Constructing the Spring Box

Although concrete construction requires that the concrete remain moist for at least seven days, spring box construction should be done at the peak of the dry season, thereby ensuring that only the most reliable springs are protected. Since the strength of the concrete will increase with curing time, construction of the spring box should start as soon as the proper design for the particular spring is chosen, preferably on the first day of work. However, it is often necessary to excavate the spring before construction is initiated in order to determine the type of spring to be protected and the proper design to implement.

The first step in spring box construction is to ensure that all required materials and tools are available on site. This will help avoid construction delays. The next step is to build wooden forms. The dimensions of the forms will depend on the dimensions of the spring box, but a good rule of thumb is that the outside dimensions of the forms should be 0.1 meters larger than the dimensions of the spring box. When constructing a spring box for a spring flowing from a single source on level ground, a form with an open bottom should be built (see figure 8). If a pervious-side spring box is to be constructed, a form needs to be built for a box with an impervious bottom and one permeable side (see figure 9). In order to build a form for a box with a bottom, set the inside form 0.1 meters above the bottom for the floor. This can be done by nailing the inside form to the outside form so that it is left hanging 0.1 meters above the floor (see figure 8). Make holes in the forms to fit the diameter of your overflow and outflow pipes, and place small pieces of pipe in them to ensure that properly sized holes are left in the spring box when the concrete sets. Make sure temporary braces are installed on the outside of the forms and that wire bracing is used between the inside and outside forms. If the forms are not properly braced, the weight of the cement will cause the forms to separate. To brace with wire, drill small holes in the forms and place wire through them to tie them together. Tighten the braces by twisting the wire with a strong stick, thus pulling the forms together (see figures 8 and 9).

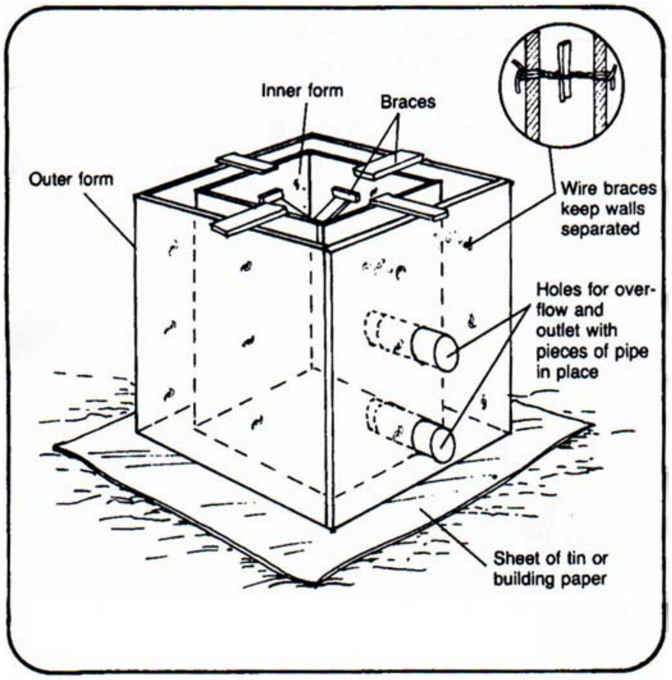

Figure 8: Form for a permeable-bottom spring box.
(Courtesy of USAID, 1982, available online at www.lifewater.org)

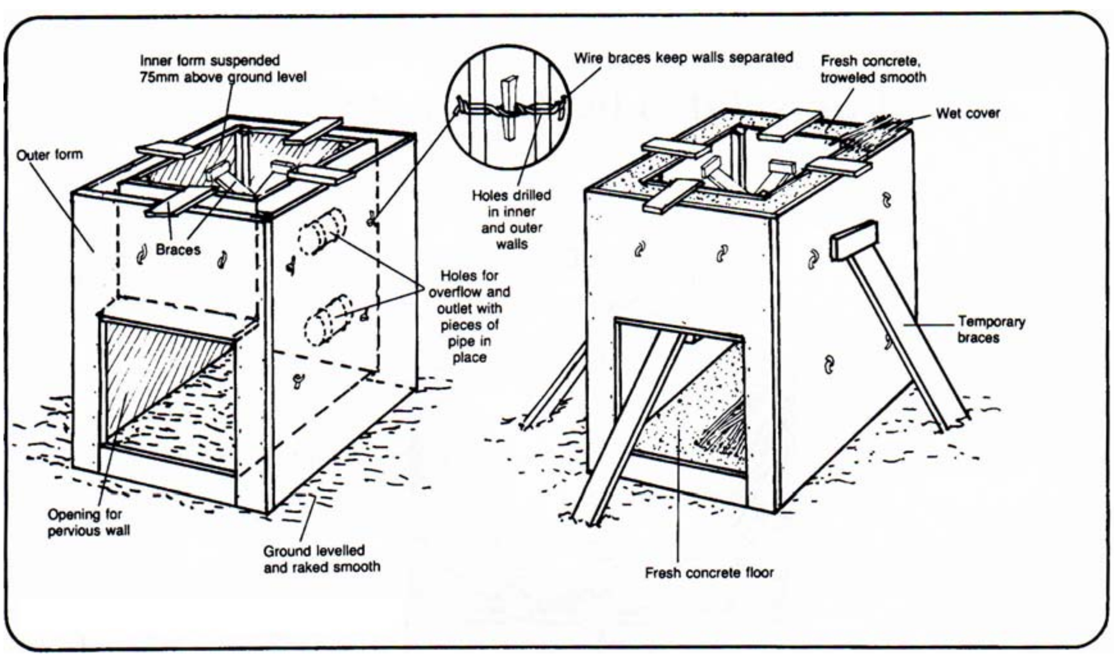

Figure 9: Form for a permeable-side spring box (courtesy of USAID, 1982, available online at www.lifewater.org).

Next, set the forms in place, either in the permanent site or nearby, depending on the size of the spring box. If the spring box is so large that installation will be difficult after the concrete has been placed and cured, the forms should be in its permanent site prior to placing the concrete. Make sure that your temporary diversion ditch is functioning properly while the concrete cures. Prior to placing cement in the forms, oil the insides with old motor oil so that the concrete won't stick to them. Keep in mind that although the spring box walls do not require major reinforcement, minor reinforcement around the perimeter of the box will prevent cracking of the cement. It is best to refer to concrete construction guides to determine the proper level of reinforcement for your particular spring box. In addition, the cover will require significant reinforcement, and handles will facilitate cleaning and inspection. Again, it is best to determine reinforcement guidelines based on your particular spring box design specifications. The cover should be sloped or concave so that water does not puddle on top of the cover. Concrete should be mixed in a proportion of one part cement, two parts sand, and three parts gravel. Only add enough water to make a thick paste, as too much water leads to weak cement. Finally, place the concrete into the forms, tamping as you go to ensure that there are no residual air pockets. This can be done by "vibrating the forms," which can be accomplished by pounding the outside form with a rock or hammer. Smooth out all concrete surfaces to ensure that the cover fits well, and cover with wet canvas, burlap or straw to prevent the concrete from losing moisture. This protective covering needs to be kept wet throughout the curing process, at least seven days, although longer curing will result in a stronger structure.

Installation

To minimize the possibility of contamination, it is important that the spring box be installed on a solid, impermeable base and that a seal is created between the ground and the spring box so that outside water is unable to infiltrate the box. Place the box so that the permeable section of the spring box collects the flow of the spring. When installing a hillside collection box, make sure that gravel and stones are piled at the back of the box to provide structural support for the structure while allowing water to enter the box (see figure 1). Next, create a seal with concrete or puddled clay, a mixture of clay and water, where the spring box comes into contact with the ground. This will ensure that water does not seep in under the box. For hillside spring boxes, backfill the area where the spring enters the box with gravel to the height where the permeable wall ends and the concrete wall begins. Place layers of puddled clay or concrete over the gravel backfill and sloping away from the spring box to divert surface water away from the water source (see figure 1), and then backfill with firmly tamped soil. If puddled clay or concrete is unavailable, soil alone may be used, although it should be at least 2 meters deep to prevent contaminated surface water from reaching the water source. For a level-ground spring box, puddled clay or cement should be placed around the spring box, sloping away from the water source to prevent infiltration.

Remove the pipe pieces used to form the pipe holes in the spring box and install the outflow and overflow pipes. Seal around the pipes on both sides of the wall to prevent leaks, and secure screening over the pipe openings. Make sure the screen size is small enough to prevent mosquito infestation, yet strong enough to deter small animals, and of a material durable enough to last a long time. Copper or plastic screening works best.

Before completely backfilling the spring box, disinfect the inside of the box and the cover with a chlorine solution and close the box. Remember that all backfill should slope away from the spring box to maximize runoff away from the box.

Maintenance

If properly installed, spring boxes require very little maintenance, however, it is recommended that the water quality be checked before being put into use, as well as on a yearly basis or as needed. It is also a good idea to check that the uphill diversion ditch is adequately diverting surface runoff away from the spring box and is not eroding. One maintenance item that is frequently overlooked is to ensure that the animal fence is in good repair. Although some grazing area may be lost, the loss in grazing area is preferable to a contaminated water source or compacted soil that could lead to decreased flow rates. For hillside collection boxes, it is important to check that the uphill wall is not eroding and is maintaining structural integrity. The cover should be checked frequently to ensure that it is in place and appears to be watertight. Make sure that water isn't seeping out from the sides or from underneath the spring box, and check that the screening is in place on the overflow pipe. Once a year, disinfect the system and remove sediment from the spring box. To do so, open the valve on the outlet pipe, allowing the spring box to drain. Remove any accumulated sediment from the box and wash the interior walls with a chlorine solution. It should be noted that chlorine and chlorine compounds might irritate eyes and skin; proper protective equipment such as gloves, safety glasses, and protective clothing should be worn if available when dealing with chlorine. The solution for washing the spring box should be mixed in a ration of 10 L water with 0.2 L chlorine bleach. After washing the interior of the spring box, chlorine should be added directly to the water in the spring box in a ration of 100 parts chlorine per million parts water, and allowed to sit for 24 hours. If it isn't possible to allow the chlorine to sit for 24 hours, two consecutive applications twelve hours apart should provide for adequate disinfection. If possible, water samples should be analyzed periodically for contamination.

Alternatives to Spring boxes

Spring boxes aren't the only method of protecting spring water sources. There are alternative structures that may suit the needs of the community better than a spring box. For example, if the distance from the spring eye to the primary distribution point isn't great, a stone-filled trench and headwall may be a preferable method of spring water protection. The design is much simpler, which may facilitate the dissemination of this technology from one community to the next, as the design is easier for local masons to copy. They are also quicker to construct and require less cement or local materials than a spring box, making them cheaper to build. The basic design of a stone-filled trench and headwall is to dig a trench from the distribution point to the spring eye. The trench should have a fairly impervious bottom to minimize water loss to infiltration. Two options exist for transporting water from the eye to the distribution point, the first is to simply fill the trench with clean stones and a layer of puddled clay approximately 100 mm thick over the stones in order to prevent surface water from infiltrating and contaminating the source. The second option is to pile clean stones over the eye, protect the source with a layer of puddled clay, and use a plastic pipe to convey water from the source to the distribution point. This method has several advantages over the stone-filled trench. First, if the topography allows, the pipe can be situated so that the outlet is above ground, eliminating the need to construct a large headwall. If this method is used, it is necessary to protect the above ground portion of the plastic pipe with a short length of steel pipe. With either method, a concrete headwall will need to be constructed at the outlet with a concrete apron below the outlet pipe to provide easy access and to prevent erosion.

A second alternative to a spring box is the development of a horizontal well (see figure 10). These are particularly useful where the water table is steeply sloped. In a horizontal well, a pipe with a screened or perforated driving point is driven into an aquifer horizontally at a higher elevation than the spring's natural discharge. Often, a headwall will need to be constructed in order to adequately seal the space outside the pipe. The only requirement of horizontal wells is that the water table be steeply sloped; flat water tables typically won't be under enough pressure to provide adequate flow.

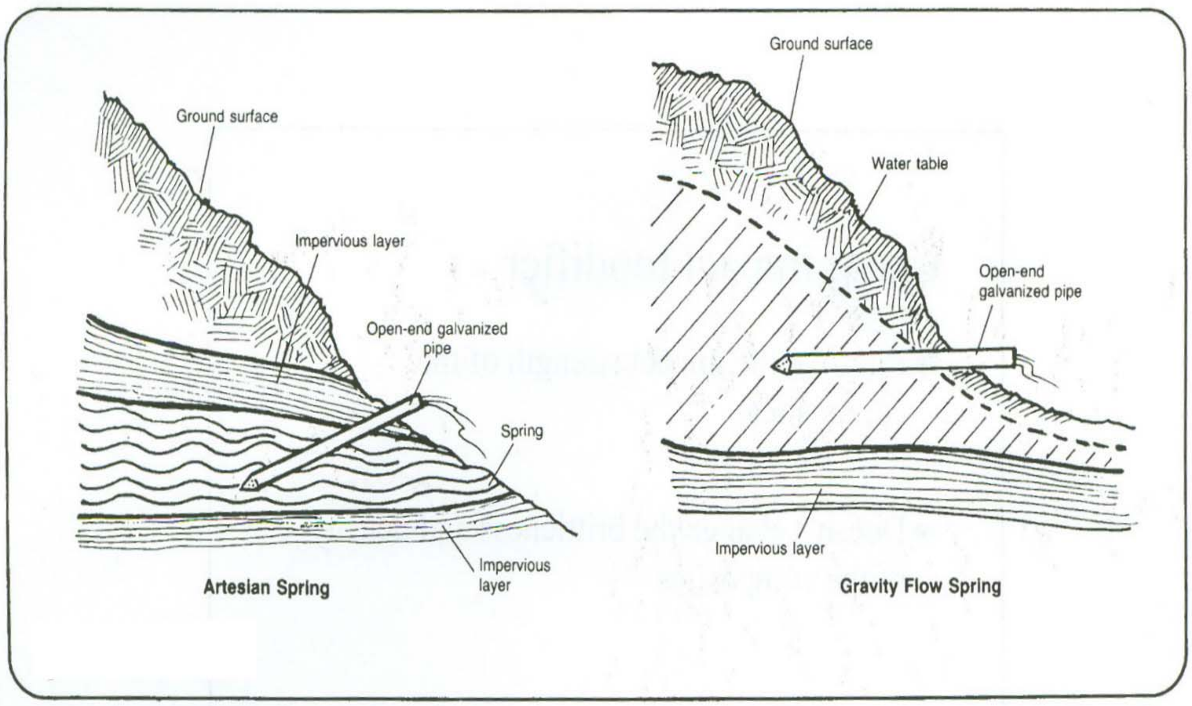

Figure 10: Horizontal well placement (courtesy of USAID, 1982, available online at www.lifewater.org).

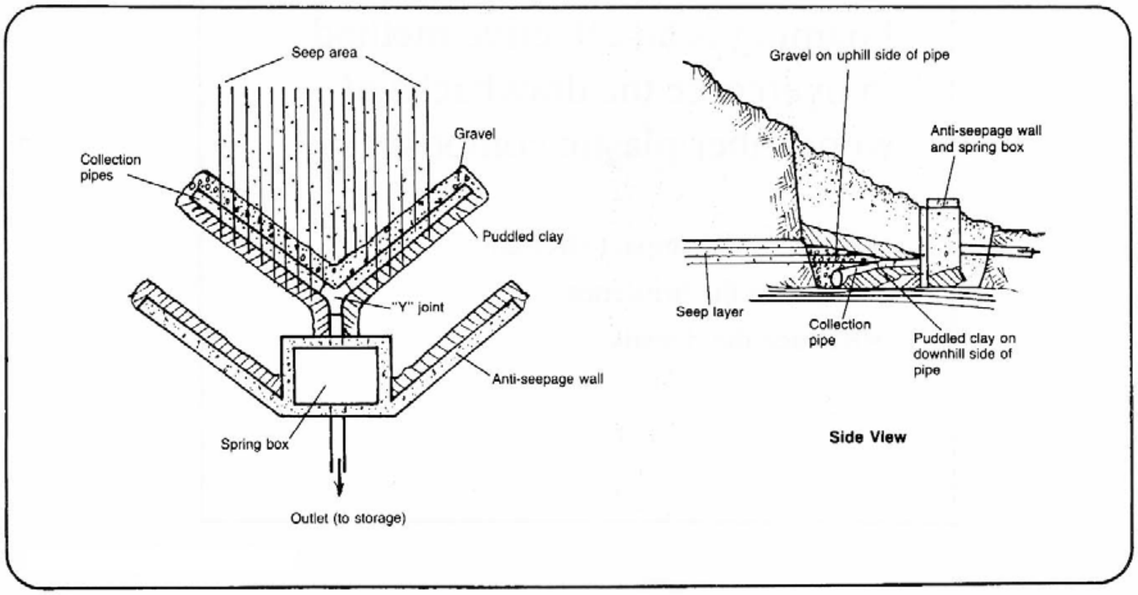

Figure 11: Seep collection system (courtesy of USAID, 1982, available online at www.lifewater.org).

If a single spring eye cannot be located, a seep collection system is a third alternative to a spring box (see figure 11). In a seep collection system, perforated collection pipes are laid in a "Y" shape perpendicular to the seep flow in order to collect and concentrate water, which is then diverted to a spring box or to a storage tank. Designing and constructing a seep collection system is much more difficult and typically more costly than other methods. In addition, collection pipes often clog with soil and rocks, making water collection less efficient and requiring more frequent and intensive maintenance.

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