

SIMPLE AND LOW COST MANUAL WATER WELL DRILLING

AN INSTRUCTION MANUAL FOR BAPTIST DRILLING

Written by Steven A. Bill

Simple Low-Cost Manual Water Well Drilling:
An Instruction Manual

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Acknowledgements

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Overview

The Baptist well drilling method was developed by Terry Waller of *Water for All International* in 1993. Having worked alongside Mr. Waller, Dr. Daniel Beams of *Agua Yaku* has since adopted the method, offering slight variations and adding an optional motorized component that alleviates the manual power required to drill. The following instruction manual details how to drill a well using the manual well drilling method only.

Keep in Mind…

Bold terms are found in the glossary at the back.

Whereas typical hand drilling techniques require a hand to be placed over the spout of the drill stem to act as the valve, the Baptist method uses a valve incorporated into the drill bit at the bottom of the **drill stem** (or elsewhere in the stem). The approach uses a combination of **sludging** and **percussion** methods. The sludging component consists of suspended **cuttings** in the **drilling fluid** that are pumped to the surface and spurted into a **settling pool**. The drill stem is lifted by volunteers pulling a rope through a pulley attached to a **derrick** and then dropped, thereby providing the percussion component of the drilling process. The width of the **borehole** is between 2-4" (≈5-10cm) with depths of over 300' (≈100m) possible depending on soil conditions.[1]

As of 2011, the Baptist method has been successfully used to drill over 2,000 wells throughout Latin America, Africa, and Asia and, at approximately 50 persons per well, has provided clean water to over 100,000 people throughout the world.[2]

The Drilling Process

The setup of the drilling rig consists of a custom-made drill bit and check-valve attached to one end of a 1¼" galvanized pipe and a spout attached to the opposite end. Using manual power and a rope and pulley system, the stem is continually lifted and dropped into the borehole. The repeated downward force of the rig into the borehole causes sediment and rocks to loosen. Water is poured into the hole so that as the hole deepens, the check valve on the drill bit allows cuttings and water to travel up through the drill stem and out the spout at the top. As the rig descends, PVC pieces are added to the stem until the desired depth is attained.

Once the desired aquifer has been reached, PVC well casing with a built-in filter is inserted into the borehole. The well is then conditioned and a hand pump is inserted into the casing, completing the well.

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[1] Baptist drilling. (n.d.). In *Rural Water Supply Network*. Retrieved from http://www.rwsn.ch/
[2] Forsyth, A.M., Ramudu, E., Hindal, H.L., & Lazarus, D.R. (2010). A manual well drilling pilot project: Implementing the Water for All International method. *International Journal for Service Learning in Engineering*, *5*(1), 128-147.

Advantages

i. **Simple**. Compared to other well drilling approaches, the Baptist method is considered simple and the knowledge easily transferable.

ii. **Local Materials**. There are no special materials or parts required. All the materials can be purchased through a local hardware store and manufactured in a welding shop.

iii. **Maintenance**. Because of the simplicity of the method and the materials used, maintenance to the hand pump is fairly easy, thus ensuring minimal down time.

iv. **Adaptable**. The technology is also adaptable to local contexts. Depending on availability, alternative materials can be substituted.

v. **Inexpensive**. The construction of the rig (including the drill stem, spout, pulley, drill bits, and tool kit) costs between $150-$300 US, depending on location and depth of well. The cost of a well (including well casing, filter, hand pump, and concrete sanitation pad) is approximately $50-$250 US, depending on location and depth of well.

vi. **Lightweight**. The materials required for drilling a well can be transported relatively easily, allowing for more remote wells to be drilled.

vii. **Fast**. Compared to other manual drilling methods, the Baptist method is considered a fast drilling procedure. Depending on soil conditions, rates of up to 100' (30m) per day can be attained.

viii. **Deep**. Wells have been reportedly drilled to depths of 345' (105m).[3]

Potential Limitations

i. **Cannot drill through rock**. The drilling method works best in **unconsolidated material** such as sand, loam, small gravel, and light rock. However, it will not penetrate hard rock or boulders. Accordingly, it is limited to non-mountainous regions.

ii. **Limited borehole**. The diameter of the borehole should be less than 4" (≈10cm) as it becomes increasingly difficult to insert the well casing into a wider borehole due to buoyancy and the amount of water to be displaced. This limited diameter of the borehole corresponds to less water production per pump.

iii. **Existing Water Supply**. The process requires 1500-2000L (≈400-550 Gallons) of water supply. This is usually not a limitation but should be considered when determining if the Baptist method should be used.

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3 Waller, T. (2010). *Water For All International*. Retrieved from http://www.waterforallinternational.org

iv. **High Risk**. The well drilling procedure is subject to several uncertainties, including: risk of poor water quality upon completion; uncertainty of soil conditions at a given depth (discovery of rocks or boulders results in having to abandon progress); potential for drill stem to snap or drill bit to break off; and potential to drop stem down borehole when adding or removing pieces.

In general, however, the Baptist method does not offer any limitations that are not also found in other manual well drilling procedures and, in fact, offers several significant advantages that other approaches do not. As such, the Baptist method is a preferred approach to other common manual well drilling techniques, particularly in non-mountainous areas. If great caution is applied throughout the entire process—from the choosing of the borehole location to the installation of the hand pump—a successful well can be drilled most of the time.

Special Note

- **Glossary** - The instructions in this manual have been written with the beginner well driller in mind. Terms that are in bold are referenced in the Glossary at the back of this book.
- **Units of Measurement** - Depending on the country in which the well is dug, units of measurements will differ. Accordingly, measurements are usually done in both metric and imperial units. However, where only one unit of measurement is provided, consult Appendix A for a conversion table. This manual switches between imperial and metric so caution must be taken in ensuring the proper measurements are consulted. In addition, most standard measurements used (e.g. width of PVC pipe, length of screws, etc.) are based on those used in Bolivia and as such may be slightly different elsewhere.
- ***Keep in Mind* Boxes** – Each section of the manual has a number of additional “knowledge boxes” that provide tips, optional variations, additional resources, and other useful information that should be consulted if possible in order to ensure a successful well.

Section I: Tools and Parts Assembly

A. Movable Point Drill Bit with Built-in Retention Valve

Materials:

- 2 - 1¼" galvanized coupling
- 1 - ¾"-1¼" galvanized reducer coupling
- 1 - ⅝" x 4" steel bolt
- 4 - 1" x ⅜" rebar (optional)
- 1 - Leaf-spring steel (cut into three triangles)
- 1 - Leaf-spring steel ring (optional)

Keep in Mind…

An instructional video detailing this section can be found at http://www.youtube.com/watch?v=orvSL8_e5ls.

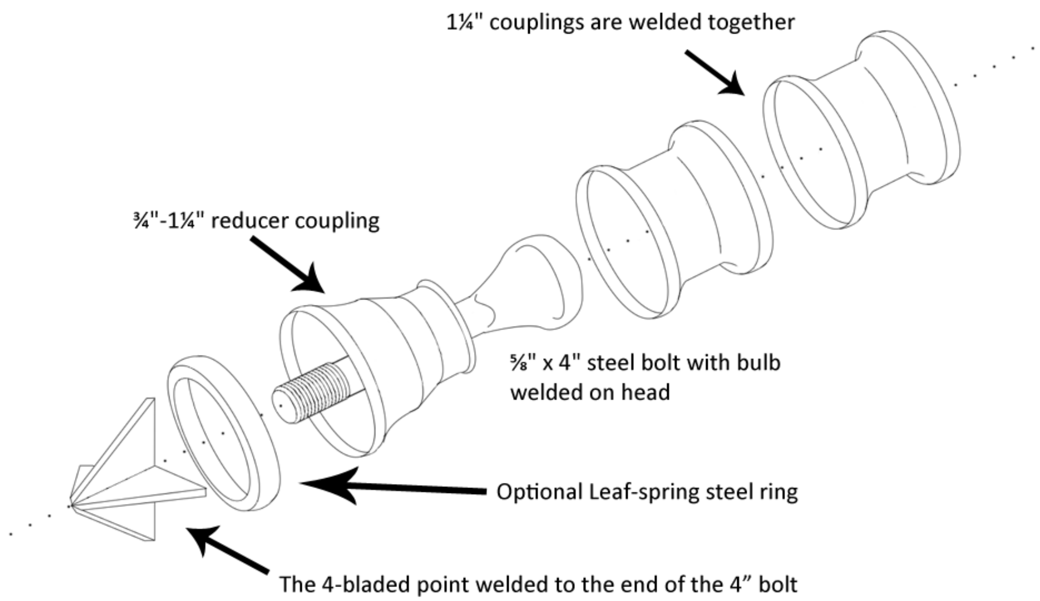

Figure 1 – Exploded view of movable point drill bit

i. Weld 1¼" galvanized couplings together (Figure 2, next page). Add ¼" ring of welding material around body. This will help widen the borehole.

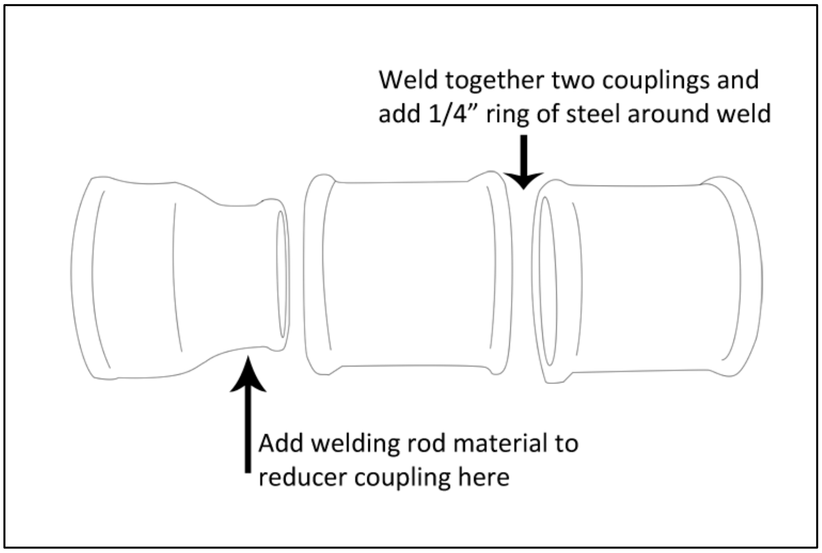

Figure 2 - Welding the valve-housing of the drill bit

ii. Add welding rod material to the outside of the ¾" end of the reducer coupling (Figure 2). Grind the material so that the reducer coupling will fit snugly into the coupling. This ensures that the reducer coupling does not flare out from the constant pounding of the bulb end of the valve, thus breaking the seal between the bulb and the reducer coupling.

iii. Weld reducer coupling to body.

iv. Weld ¼" ring of steel around valve-housing, which will aid in widening the borehole, allowing for a wider diameter well casing.

v. An optional addition is to weld (4) 1" x ⅜" rebar to the outside of the valve-housing to further aid in increasing the diameter of the borehole, allowing for a 2" PVC casing. (Adding Part iv. and v. is only effective in unconsolidated soil. In harder material, you may want to make a pilot hole with a smaller diameter bit and then ream the borehole using a reaming extension (See page 17).

vi. If available, weld a leaf-spring steel ring on to the top of the reducer coupling. The ring is harder than the coupling and will prolong the life of the bit.

vii. To create the valve, weld an approximate 1" diameter bulb/cone on to the head of the ⅝" x 4" bolt as shown in Figure 3 (next page). Shape the bulb with a grinder, ensuring that it fits snugly into the reducer coupling and that there is enough space around the bulb for the cuttings to flow up and through the

Keep in Mind…

IMPORTANT! Welding galvanized steel without removing galvanized coating will result in emissions of a heavy, noxious, yellow-green smoke that can envelope the welder. Continuous exposure to this smoke can result in galvanized poisoning. Where possible, use non-galvanized steel components when welding. If non-galvanized components are unavailable, de-galvanize the components using a wire brush or grinder prior to welding. Further, use a ventilation welding hood to reduce smoke inhalation.

bit. You may have to cut the bolt in order to limit the space between the body and the bit. However, if you have welded a leaf-spring ring, you should not have to cut the bolt.

viii. Cut parts A, B, and C from leaf-spring steel using a miter saw (Figure 4).

ix. Weld the 4-bladed point together and attach to bolt placed through the body of the bit as shown in Figure 1. When welding the 4-bladed point on to the valve-bolt, ensure that ½"-¾" is left between the bit body and the base of the point.

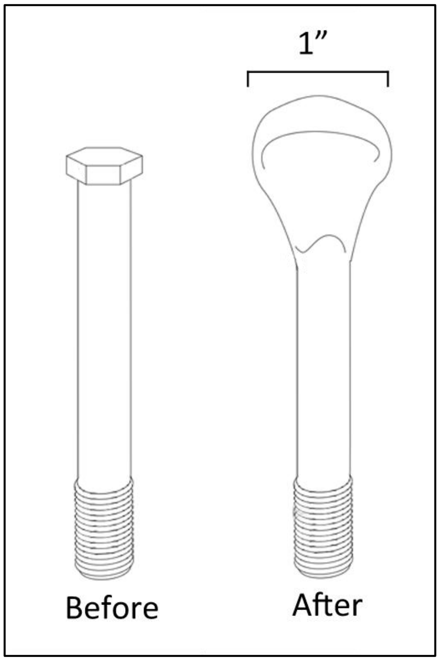

Figure 3 - 1" bulb welded on to head of 4" bolt

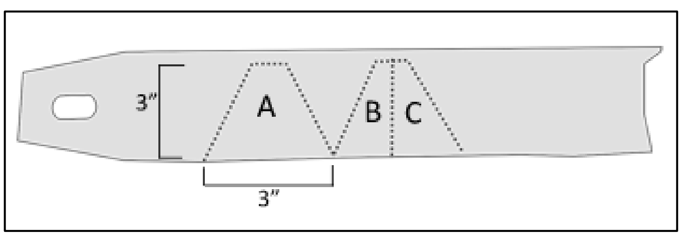

Figure 4 - 4-bladed point cut from leaf-spring steel

B. Fixed-Point Valve Drill Bit

Materials:
- 2 - 1¼" galvanized male-female reducer bushing
- 1 - ¾"-1¼" galvanized reducer coupling
- 1 - ⅝" x 4" steel bolt
- 1 - 1½" rebar
- 4 - 1" x ⅜" rebar (optional)
- 1 - Leaf-spring steel (cut into three triangles)

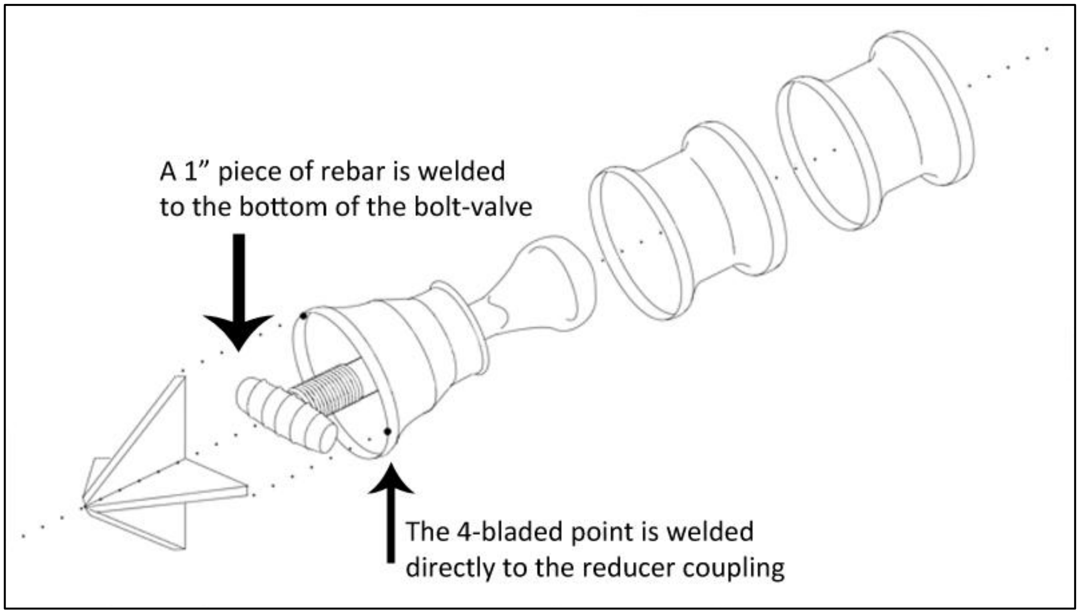

Figure 5 - Exploded view of fixed-point drill bit

The fixed-point valve drill bit provides extra impact to break through harder material.

i. Repeat **Section I; Subsection A; Steps i-vi**.

ii. Place the bolt into the reducer coupling and weld a piece of rebar across the end of the bolt, making a T (Figure 5). This will prevent the bolt-valve from slipping out the top of the bit.

iii. Cut parts A, B, and C from leaf-spring steel using a miter saw (Figure 4, page 12). The size of the blades should be slightly larger than the movable point drill bit. This is because the fixed-point bit is often used to widen the borehole.

iv. Weld the 4-bladed point together and then weld completed point to the reducer coupling.

C. Rock Drill Bit

Materials:
- 2 - 1¼" galvanized coupling
- 1 - ¾"-1¼" galvanized reducer coupling
- 1 - ⅝" x 4" steel bolt
- 1 - 1½" rebar
- 4 - 1" x ⅜" rebar (optional)
- 1 - Leaf-spring steel

The Rock Drill Bit is a variation of the fixed-point valve drill bit, specifically designed to penetrate through rock. Accordingly, the 4-point blade is designed to be more blunt.

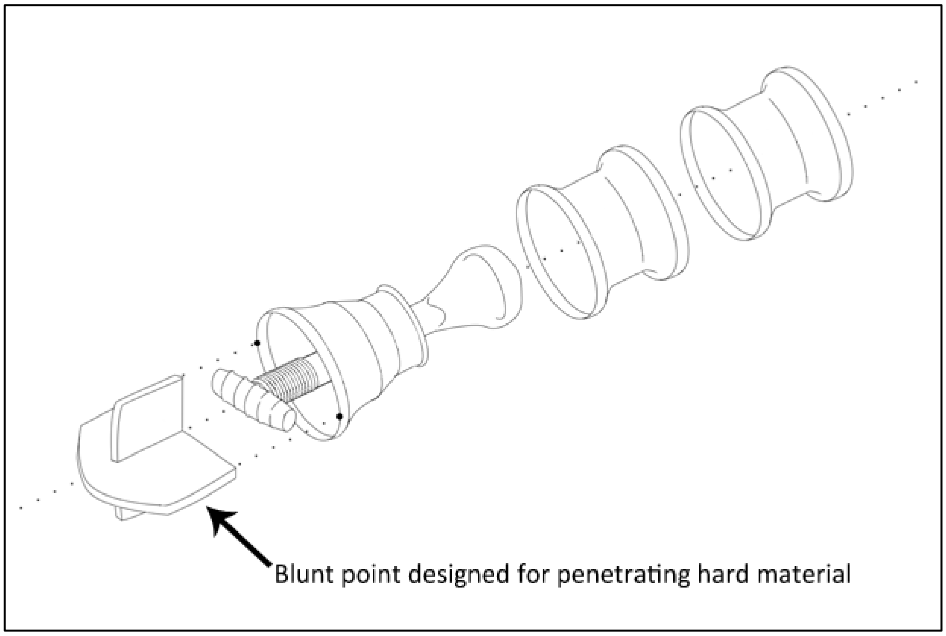

Figure 6 - Exploded view of rock drill bit

D. Open Drill Bit (Valve-less)

Materials:
- 2 - 1¼" galvanized coupling
- 1 - ¾"-1¼" galvanized reducer coupling
- 4 - 1" x ⅜" rebar (optional)

The open drill bit does not contain a valve at all. The valve-less bit depends on a valve placed elsewhere in the drill stem, generally near the spout of the stem (see Gate Valve below) or above the drill bit. An open drill bit would be used in material such as clay, in which there is a tendency for the clay to clog the bit, thus rendering the valve ineffective. Removing the valve decreases the probability of the bit from becoming plugged with viscid material such as clay. However, keep in mind that placing the valve at the top of the drill stem (near the spout) also decreases the efficiency of the valve's function.

The process for creating an open drill bit is identical to the processes noted above except that construction of the bolt-valve is not necessary.

E. Ball Valve

Materials:

- 2 - 1¼" galvanized coupling
- 1 - 2" x ⅜" steel bar
- 2 - 1½"-1¼" galvanized reducer coupling
- 4 - 1" x ⅜" rebar (optional)
- 1 -1 ¼" (32mm) ball bearing
- 1 - 1¼" diameter galvanized nipple

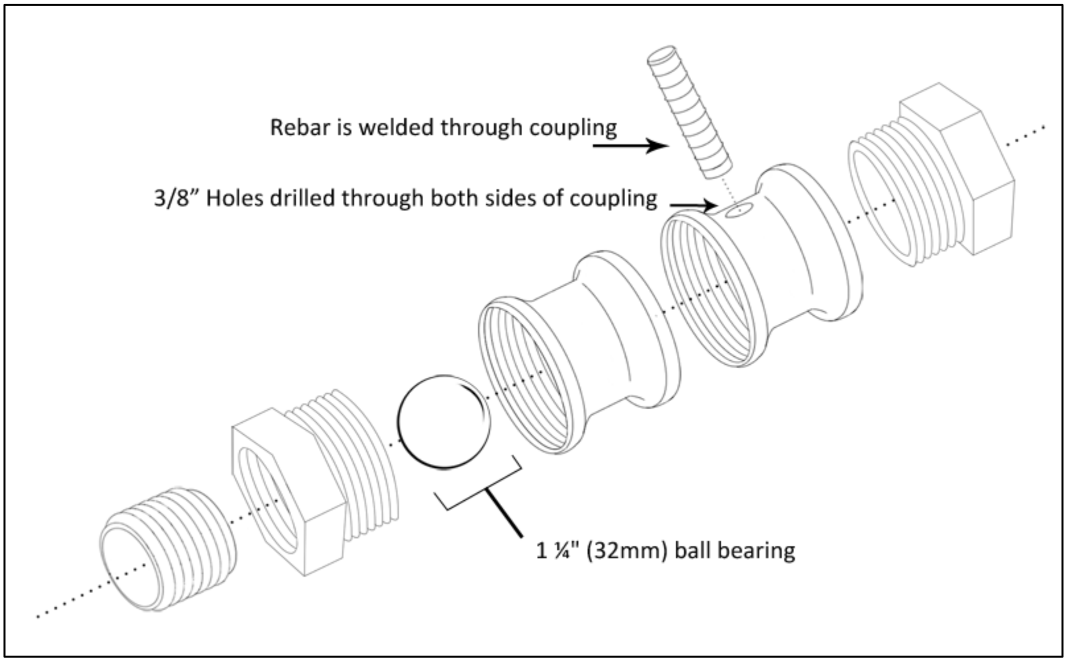

Figure 7 - Exploded view of ball valve

i. Weld 1¼" couplings together to form the valve housing. At the middle of the top coupling, drill a ⅜" hole. Weld steel bar through the hole.

ii. Attach male-female reducer couplings on to each end of the valve housing.

iii. Place the ball bearing into the valve housing.

iv. Attach nipple to bottom of valve housing. Ball bearing should fit snugly on to the nipple, ensuring that it does not get "jammed" or wedged inside.

F. Gate Valve

Materials:
- 2 - 1" steel nipple
- 1 - 45° elbow 1" coupling
- 1 - 1¼"-1" reducer coupling
- 1 - 1¼" diameter steel nipple
- 1 - 1¼" brass horizontal check valve

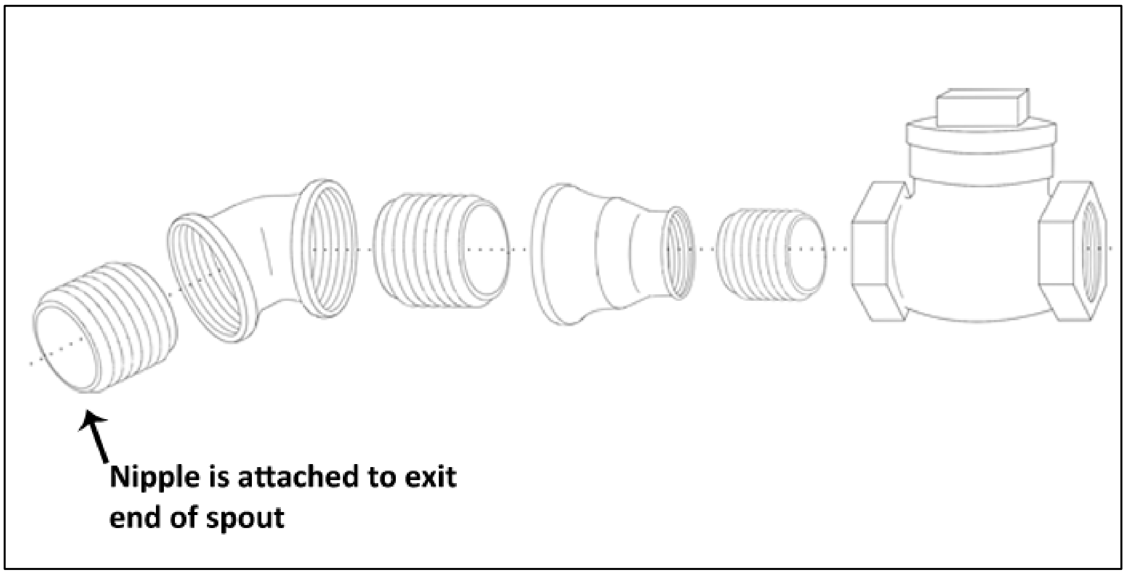

Figure 8 - Exploded view of gate valve

Used in conjunction with a valve-less open drill bit, the gate valve is attached to the end of the spout of the drill stem. It is used when a movable point or fixed-point drill bit continues to clog. This generally occurs in fine, compacted material such as clay.

i. Attach nipple to exit-end of spout.

ii. Attach elbow coupling to nipple.

iii. Attach nipple to elbow coupling.

iv. Attach reducer coupling to nipple.

v. Attach brass horizontal check valve to nipple.

G. Reaming Extension

Materials:

- 1 - 1¼" galvanized coupling
- 1 - automotive gear (approximately 3-4" in diameter)
- 1 – 1¼" galvanized nipple

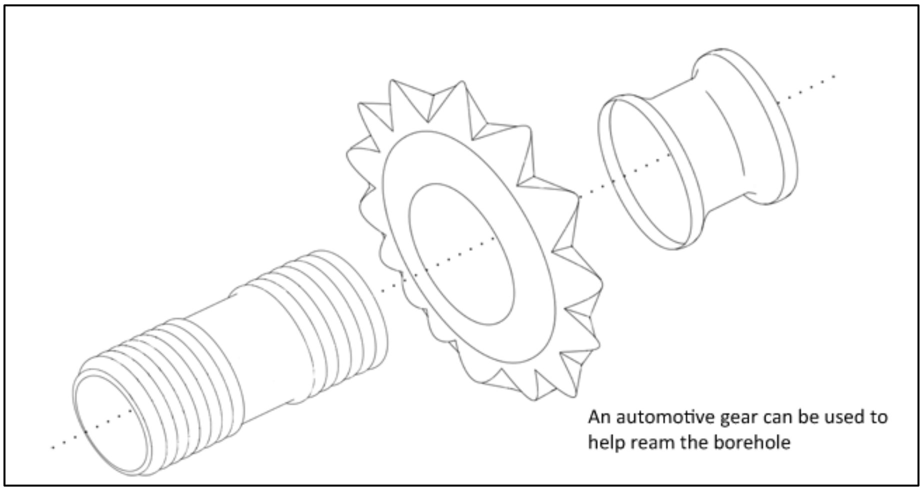

Figure 9 - Exploded view of reaming extension

The reaming extension is used in conjunction with a ball valve. It is used to widen the borehole, specifically for fitting a well casing 3-4" in diameter.

i. Weld the automotive gear to the end of the coupling.

ii. Weld the nipple to the other side of the automotive gear.

Figure 10 - Variation of reaming extension

H. Drill Stem and Spout

Materials:
- 1 - 1"x 9' (3m) steel pipe threaded on each end
- 2 - 1”-1¼" reducer coupling
- 1 - 1¼" x 18' (6m) galvanized pipe
- 1 - 1½" x 9' (3m) galvanized pipe (optional)
- 10 - 1" x 18' (6m) Schedule 40 PVC pipe
- 30 - 1" PVC coupling
- 2 - 1" galvanized 90° elbow coupling
- 2 - 16" (40cm) x ½" steel pipe
- 2 - 1" galvanized nipple

The following instructions refer to a 60m (≈200') well. Additional PVC pieces would be required for a deeper well.

Drill Stem

i. **Optional modification**: Divide the 1½" x 9' galvanized pipe into two pieces, length-wise, and weld on to one end of 18' pipe so that the bit, once screwed on, will fit snug against the 9' pieces. This modification is done so that extra weight is added to the drill stem near the bit as well as reduces the impact on the threads holding the bit (Figure 11 next page).

ii. On the opposite end of the 18' pipe (end without the additional attached piping), screw on a reducer coupling and then the steel nipple.

iii. Cut the PVC pipe into 19 x 9' sections and 2 x 4.5' (1.5m) sections. Each section is threaded on both ends with a PVC hand-threader.

iv. Screw 1" PVC coupling on to one end of each 9' piece and 4.5' piece. With seven threads, the coupling will be tight when the threads are no longer visible. Place the PVC pieces into a vice grip and use a pipe wrench to tighten the couplings. Additionally, grease can be smeared on to the threads, further aiding in tightening the couplings to the PVC pieces.

Keep in Mind…

When threading the PVC pipe, be careful not to create too few or too many threads. **The optimal number of threads is 7.**

Keep in Mind…

Both the 18' steel pipe and the 1" x 9' will require being threaded on both ends. Special tools are required to thread steel pipes, including a pipe vise, cutter, reamer and threading die to match the size of the pipe. Accordingly, this may have to be done in a machine shop by a professional machinist.

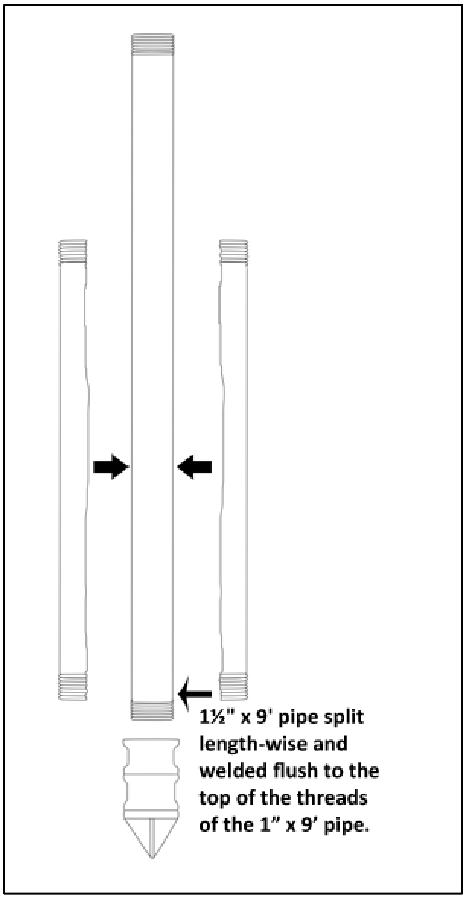

Figure 11 - Optional modification to stem

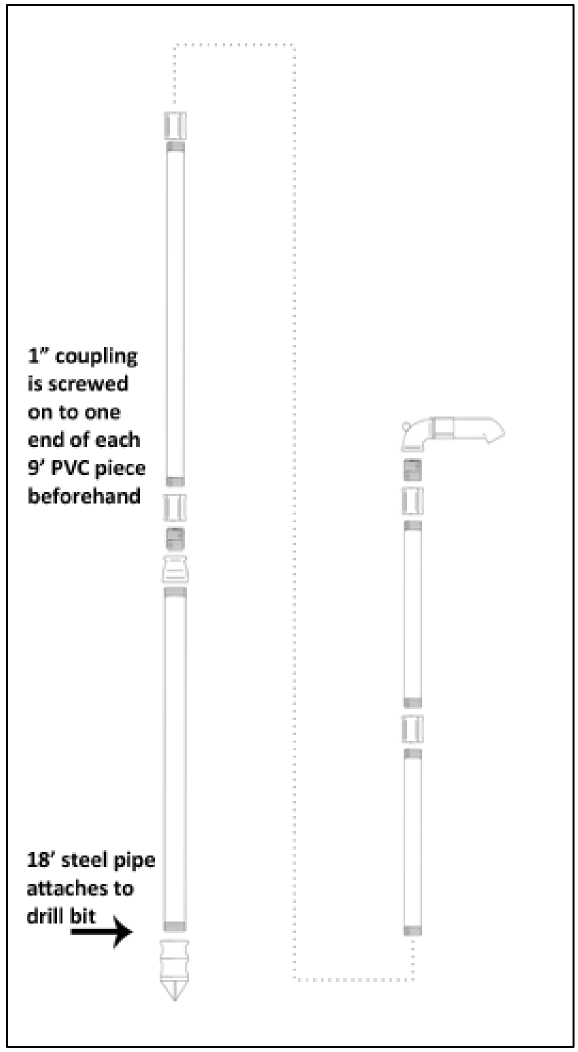

Figure 12 - Simple drill stem

Spout

i. The 16" steel pipe will act as the handle for the spout. Weld the middle of this pipe to the outer curve of the elbow coupling.

ii. Screw a 1" steel nipple into one end of the elbow coupling, and then tighten PVC coupling to the nipple.

> **Keep in Mind…**
>
> Ensure that the ends of the 16" steel pipe do not contain any sharp edges. Grind the ends if necessary.

iii. Cut a piece of 1" x 10" (≈25cm) piece of PVC pipe. Thread one end of this piece.

iv. Heat the last 3-4" of the PVC pipe, gently bending it downward (See Figure 13)

v. Screw the threaded end of the 10" PVC into the elbow coupling, ensuring that the pipe is pointing downward.

vi. Create a second spout using **Steps vi. – x**. Add a 1.5m PVC pipe to the PVC coupling. Having a second spout will greatly improving the efficiency of adding PVC pieces to the drill stem as required.

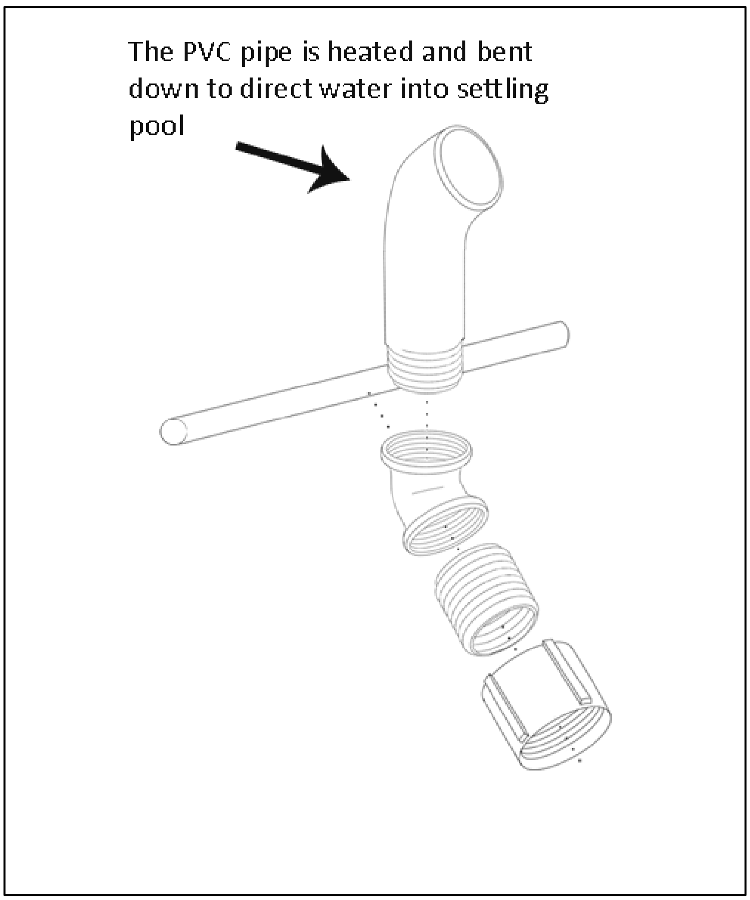

Figure 13 - Exploded view of spout

I. Well Casing and Filter

Materials:
- 11 - 2", 3", or 4" x 18' (6m) Class 9 PVC piping (depending on the diameter of the borehole) (11 pieces would be needed for a 60m well)
- 2 - Loose-woven nylon bags (rice or potato bag) (Alternatively, you can use specially manufactured material for well filter if available)
- 2 - Rolls of electrical tape
- Rubber cement
- PVC glue

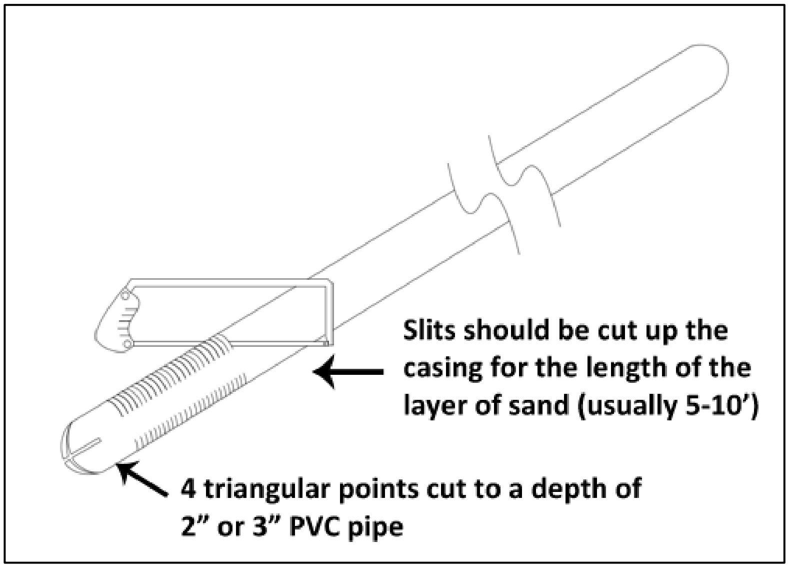

Figure 14 - Constructing the filter

> **Keep in Mind…**
>
> The length of the filter depends on the depth of the sand layer in which the filter will be placed. This is usually about 1.5-3m (≈5-7ft) in length.

i. Cut three triangular points to a depth of 2" on one end of a 2" PVC piece, or four triangular pieces on one end of a 3" PVC piece. Heat the ends over a flame until the triangular pieces become flexible. Fold the three (or four) tips to a point and hold until stiff.

ii. For a 2" casing, begin 4" (≈10cm) up from the folded point, cut two columns of width-wise slits, approximately ½" (≈1cm) apart for the determined length of the filter. (In a 3-4" casing, 3 columns of slits should be cut). Cuts should be made to a depth of the hacksaw blade (approximately 1.5" in length). To ensure columns are straight, use a marker to draw lines on opposite sides of the casing.

iii. Open up nylon bag(s). Beginning at the top of the filter (where the slits begin), liberally apply rubber cement in between the columns of slits, ensuring to avoid getting rubber cement in the slits). Let dry until tacky (approximately 10 minutes). Carefully stretch one edge of nylon bag and attach to rubber cement.

iv. Apply rubber cement to other side of casing. Let dry until tacky. Carefully stretch nylon bag around casing and attach to rubber cement.

v. Apply rubber cement on top of first seam (Step iii.) and let dry until tacky. Stretch bag around and attach on seam. When dry, cut excess away.

vi. Repeat Steps 3-5 moving down the filter, slightly overlapping, until all slits are covered with the nylon bag material.

vii. To ensure the nylon bags do not tear while descending down the borehole, wrap electrical tape around the nylon bag at the tip of the filter, as well as at sections where the nylon overlaps.

Figure 15 – Bottom of filter heated and bent

Figure 16 – Rice bags glued to filter

Figure 17 - Electrical tape around filter

J. Hand Pump

Materials:

- 1 - 40' x 1½" (≈13m x 4cm) Flexible coil plastic pipe (black polyethylene tubing)
- 1 - 35' (10½m) x ½" Flexible coil plastic pipe (black polyethylene tubing)
- 1 - 12" x 1¼" x 3⁄16" steel plate
- 1 - 1½" "T" galvanized or PVC coupling
- 2 - 1" x 2" angle iron (angular) (L-bracket)
- 1 - 1" PVC coupling
- 1 - 1" x 6" PVC pipe
- 1 - 1" PVC nipple
- 1 - ¾" PVC coupling
- 1 - 1" check valve
- 2 - ⅝" x 5" (≈10cm) steel rebar
- 4 - ⅜" x 3½" (≈9cm) bolt (6 nuts, 5 washers)
- 1 - ⅜" x 6" (≈15cm) bolt (1 nut, 2 washers)
- 1 - Foam sandal
- 1 - 5' x 5" x 3" (1.5m x 13cm x 8cm) board (to secure casing)
- 1 - 7½' x 5" x 3" (2.3m x 13cm x 8cm) board
- 1 - 6½' x 2" x 3" (2m x 5cm x 8cm) board
- 1 - 5-6½' (1.5-2m) wooden post (or 3" diameter steel pipe or larger if casing diameter is larger)
- Teflon® Tape

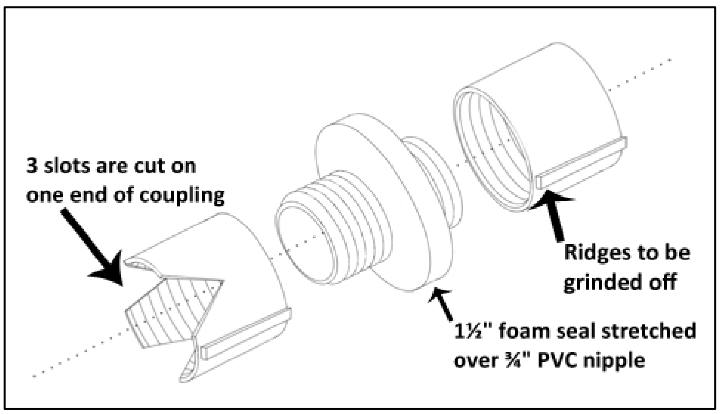

Figure 18 - Exploded view of coupling assembly for piston

Keep in Mind…

A step by step instruction video for creating the hand pump can be found here: http://www.youtube.com/watch?v=IHkEPx0hj4Y

Constructing the Piston

i. Saw the ¾" PVC coupling in half. Grind off the ridges around the coupling.

ii. Cut two foam circle seals from a sandal. The first seal should fit snugly inside 1½" diameter polyethylene tubing. Cut a ½" hole in the center of this seal. The second seal is approximately 1" in diameter, with a hole large enough to stretch over a ⅜" diameter bolt.

Keep in Mind…

This particular pump design is not efficient below approximately 50' (≈15m). For areas with a deeper water table, you may need to use a commercially available hand pump that functions at greater depths (up to 170' (50m)), such as the ***India Mark II***, commonly used throughout the world. For less initial investment, you can use a gasoline motor and air compressor. Keep in mind, however, that a submersible electric pump and the *India Mark II* require a minimum 4" casing size.

iii. Stretch the larger seal on to one end of the ¾" PVC nipple. Tighten the ¾" coupling halves on to both sides of the nipple using a vice and pipe wrench.

iv. Cut three triangular slots on one end of the coupling as shown in Figure 18 (previous page).

v. Weld head of ⅜" x 3½" bolt to one end of the steel bolt.

Keep in Mind…

You may need to grind or sand to ensure the foam seals are round. The seals should each be approximately ¾" thick, implying that a new sandal is ideal.

vi. Place a washer on the rod/bolt assembly. This washer will stop the piston from sliding too far down the shaft.

vii. Place the coupling assembly on to the rod/bolt assembly, with the triangular slots toward the washer.

viii. Screw on one nut above the coupling assembly.

ix. Add a washer above the nut.

x. Add the smaller foam seal.

xi. Add another washer above the seal.

xii. Tighten and secure the seal by screwing on two more nuts above the smaller seal.

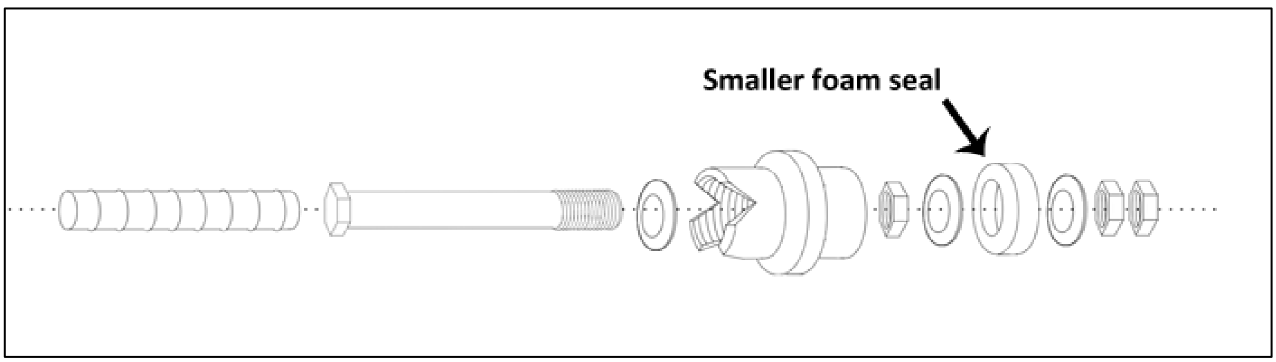

Figure 19 - Exploded view of piston assembly

Constructing the Piston Rod

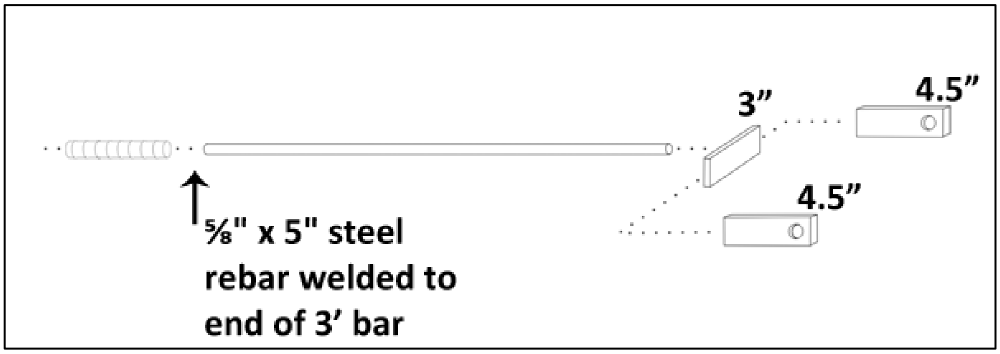

Figure 20 - Exploded view of piston rod

i. Cut the steel plate into three pieces with widths: 4.5", 4.5", and 3".

ii. Drill a ⅜" hole approximately ½" from the end of the two 4.5" pieces.

iii. Weld the three pieces together in a U-shape, with the 3" piece along the bottom.

iv. Weld the 3' x ⅜" steel bar to the middle of the 3" piece.

v. On the opposite end of the steel bar, weld a ⅝" x 5" steel rebar.

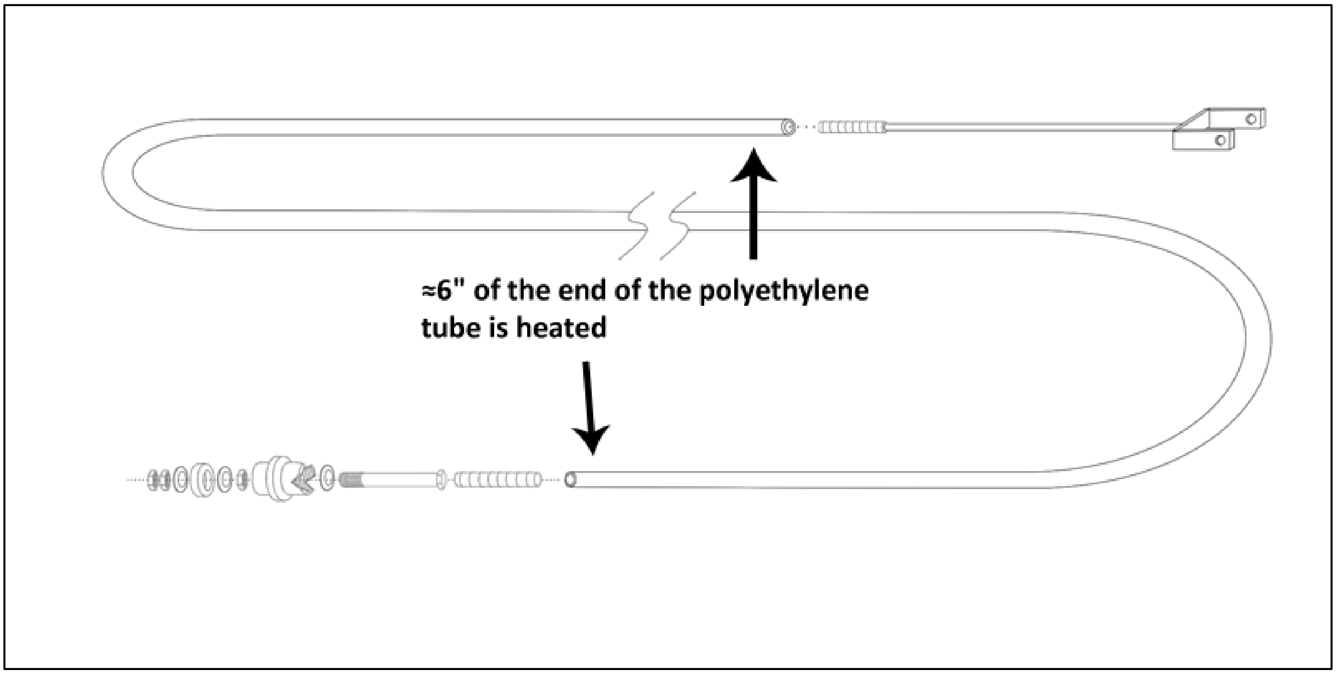

Figure 21 - Exploded view of piston rod assembly

Constructing the Piston Rod Assembly

i. Using a fire or gas burner, heat approximately 6" of the end of the ½" polyethylene tube.

ii. While the polyethylene tube is soft, force the free end of the piston down the tube.

iii. To firmly connect the piston to the tube, wrap rubber strapping tightly around the end of the polyethylene tube and use water to cool the end. Continue applying cold water for several minutes before unwrapping the rubber strapping.

iv. Using a fire or gas burner, heat approximately 6" of the other end of the ½" polyethylene tube.

v. While the polyethylene tube is soft, force the end of the piston rod down the tube, approximately 6".

vi. To firmly connect the piston rod to the tube, wrap rubber strapping tightly around the end of the polyethylene tube and use water to cool the end. Continue applying cold water for several minutes before unwrapping the rubber strapping.

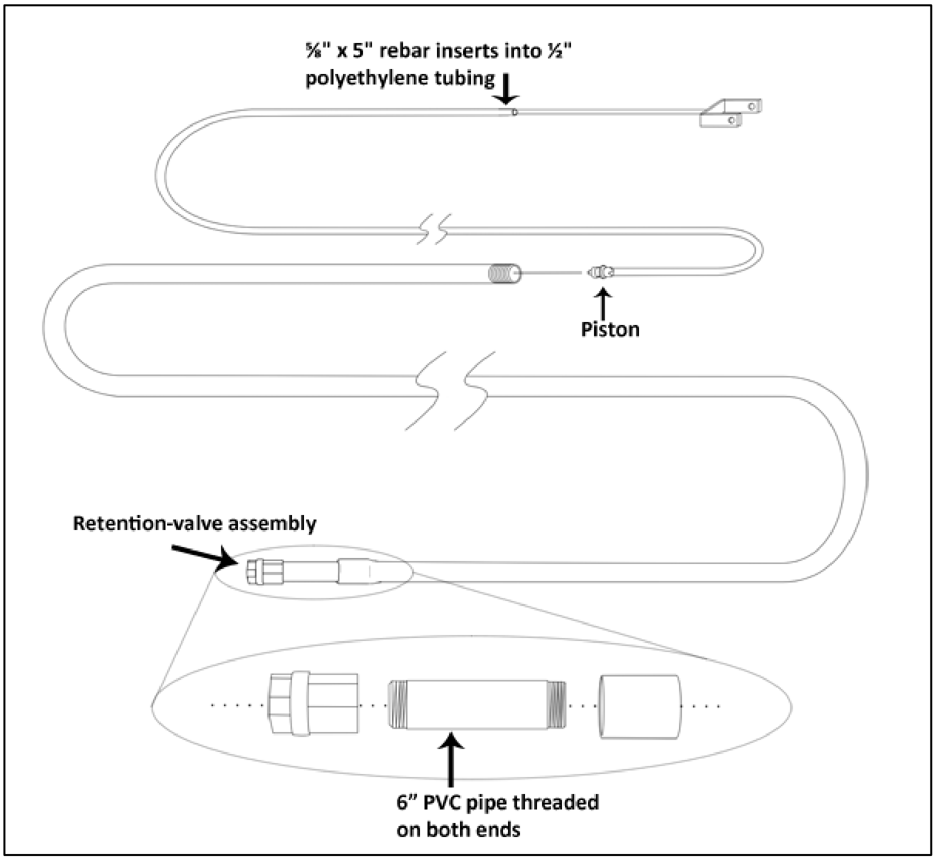

Figure 22 - Exploded view of pump housing

Assembling the Pump Housing

i. Cut a 9" (23cm) and a 12" (≈30cm) piece out of the 40' (≈13m) polyethylene tube and thread one end of each piece (approximately 7 threads).

ii. Thread one end of the remaining 40' polyethylene tube (approximately 7 threads).

iii. Thread both ends of the 1" x 6" PVC pipe and wrap threading with Teflon tape.

iv. Attach the 1" PVC coupling on to one end of the 6" PVC pipe.

v. Attach the check valve on to the other end of the 6" PVC pipe.

vi. To install the check valve assembly, heat the non-threaded end of the 40' polyethylene tube and then insert the coupling end of the check valve assembly into the heated tube. Wrap with rubber strapping tightly, and then cool with water to ensure check-valve assembly is securely fitted in the tube.

Installing the Completed Pump

Although the installation of the completed pump is described here, this is actually the last step in the drilling process. Accordingly, refer to **Section V, Subsection B** for the implementation of this step.

i. The 9" tube, followed by the T-coupling, is pushed on to the piston rod assembly.

ii. The piston rod is inserted into the open end of the 40' polyethylene tube.

iii. Screw the T-Coupling and the 9" piece of polyethylene tubing on to the end of the 40' tube.

iv. Screw the 12" piece of polyethylene tubing into the T-coupling (perpendicular to the rest of the tube).

v. Insert the pump assembly into the well casing.

vi. Move the piston rod up and down, ensuring that the piston is not too tight, nor too lose, and that water pumps out efficiently. If water does not pump out after several aggressive up and down motions, disassemble the pump assembly and ensure that the check valve and piston are working properly.

Note: The length of the hand pump assembly is determined by the level of the water table. The check-valve of the hand pump assembly (i.e. the bottom of the hand pump assembly) should be located at a minimum of 10-13' (≈2-4m). For example, in Bolivia, the water table is 13-26' (≈4-8m); therefore the length of the hand pump assembly is about 40' (≈12m).

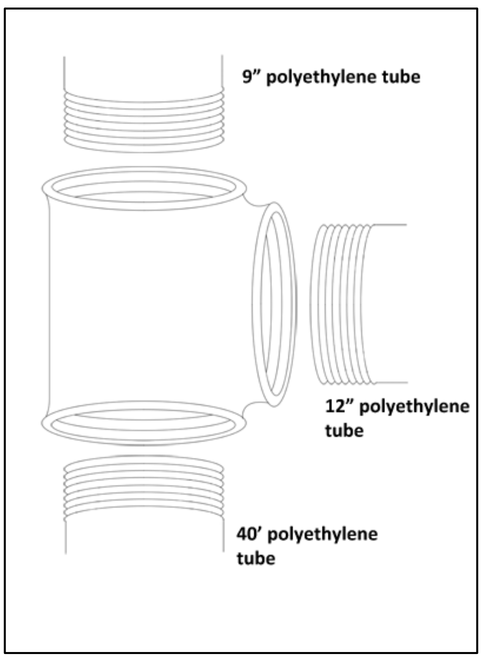

Figure 23 - T-coupling assembled on to pump

K. Manual Water Pump

Materials:

- 1 - ¾" x 25" (≈2cm x 64cm) steel pipe threaded on both ends
- 2 - ¾" x 6" (≈2cm x 15cm) steel pipe (threaded on one end)
- 1 - 6" x 1" (≈15cm x 2.5cm) galvanized pipe
- 1 - ¾" galvanized T-Coupling
- 1 - 1½"-1" steel reducer coupling
- 1 - 1½-1" steel reducer bushing
- 1 - ¾"-½" steel reducer coupling
- 1 - 10" x 2" x ½" piece of steel
- 1 - ½" x ½" polyethylene tubing (to be screwed into the ½" reducer coupling)
- 1 - marble (≈½" in diameter)
- 1 - Sandal
- 1 - 1½" steel elbow coupling
- 1 - ½" steel nipple
- 1 - ½" steel coupling
- 1 - 24" x 1½" PVC pipe threaded on both ends
- 1 - Roll of Teflon® tape
- 1 - ½" polyethylene tube (length depends on distance to water source from the well)

i. Screw in ¾" x 6" steel pipe into both ends of the T-coupling and weld the steel pipe to the coupling.

ii. Weld a ½" coupling to the end of one of the steel pipe ends and close off the other end using a hammer to flatten it and a weld to ensure it is airtight.

iii. Screw in the ¾" x 25" steel pipe into the T-coupling, using Teflon® tape around the threads.

iv. Weld a stopping ring around the piston end of the ¾" x 25" steel pipe.

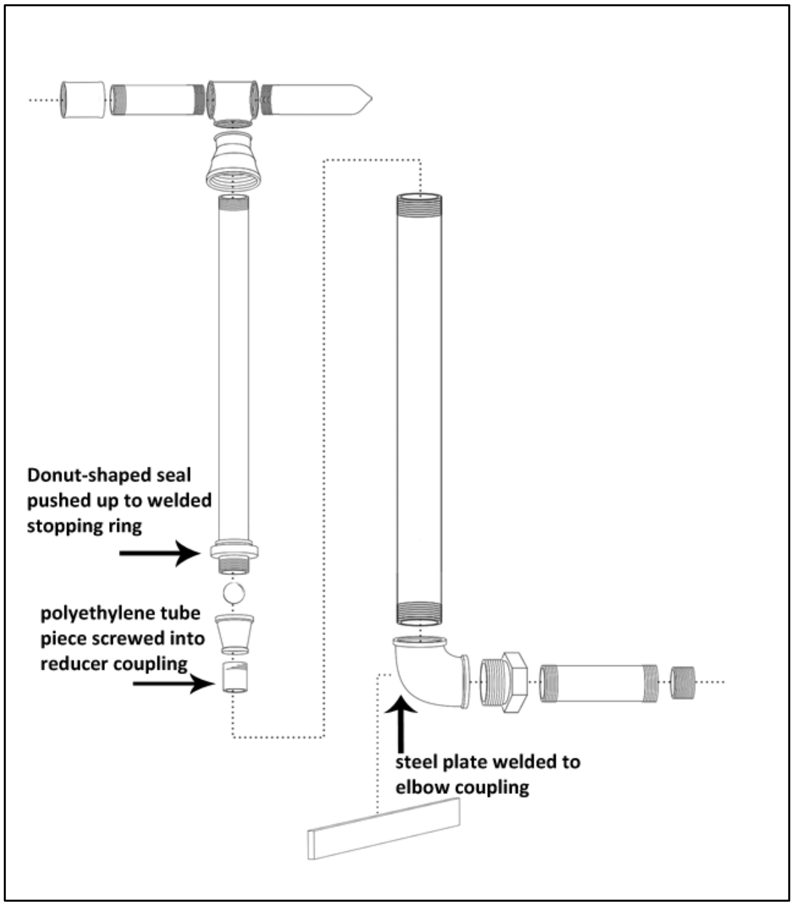

Figure 24 - Exploded view of manual water pump

v. Cut a donut-shaped seal out of the sandal: approximately 1½" in diameter with a ¾" diameter hole.

vi. Push the donut-shaped seal on to the end of the ¾" x 25" steel pipe, up to the welded stopping ring.

vii. Thread a short piece of ½" polyethylene tube and screw it into a ½"-¾" reducer coupling, cutting off the excess tubing to make it flush with the reducer coupling.

viii. Place the marble in the ¾" x 25" steel pipe.

ix. Screw on the ½"-¾" reducer coupling on to the end of ¾" x 25" steel pipe.

x. Screw the 1"-1½" reducer bushing into the end of the 1" x 6" steel pipe.

xi. Weld ½" nipple on to the other end of the 1" x 6" steel pipe.

xii. Screw ½" steel coupling on to the ½" nipple on the end of 1" x 6" steel pipe.

xiii. Screw elbow coupling on to end of 1"-1½" reducer bushel.

xiv. Weld the 10" x 2" piece of steel on to the back of the elbow coupling. This will serve as the footplate.

xv. Insert the ¾" x 25" steel pipe into the 24" x 1½" PVC pipe, screwing into the 1"-1½" reducer coupling.

xvi. Screw the elbow coupling of the base assembly into the 24" x 1½" PVC pipe.

xvii. Attach a hose or a threaded ½" polyethylene tube to the end of the base assembly, leading into the water source.

xviii. Attach a hose or a threaded ½" polyethylene tube to the handle end of the water pump, leading into the well.

Section II: Toolkit

The following is a checklist of tools and materials to have on site that will ensure the drilling procedure goes well.

- Ax/chainsaw
- Barrels (water containers)
- **Bentonite** (2 bags)
- Buckets (20L) - Used for carrying water and mixing bentonite
- Check valve (1")
- Electrical tape – several rolls
- Extra 1" couplings both PVC and steel (plastic couplings are less expensive but tend to crack more often)
- Gloves
- Hacksaw
- Hammer and nails
- Hand cable winch come along
- Hand drill/auger and bits
- Journal/note pad
- Knife
- Machete
- Magnifying glass
- Manual water pump (see page 29)
- Measuring tape
- Oil/grease
- Permanent marker
- Pick/hoe
- Pipe Vice
- Pipe wrenches (18") – a minimum of 4 is required
- Pliers
- Polyethylene tube (½") – 300'
- Post hole digger
- Pulley 4" (10cm) (extra)
- PVC cement
- PVC threader – various sizes include 1", 1.5", and ½"
- Rescue Tools
- Rope – 40-50' (12-15m) that is approximately ¾" in diameter (Ensure rope passes through pulley with ease)
- Rubber cement
- Rubber strapping
- Screen to catch cuttings
- Set of screwdrivers
- Set of wrenches
- Several tarps to build water holding tank
- Shovel
- Small sledge hammer
- Smaller rope
- Spout (extra)
- Steel brush
- Teflon® tape
- Various drill bits, including: movable-point; fixed-point; valve-less; rock bit; auger bit
- Vice grips
- Wire (10-20')
- Water testing kit
- Wood saw

Optional

- Gasoline motor with attached driveshaft pulley
- Belt-driven compressor and water pump
- Chassis to mount motor and air compressor
- Belts to drive water pump and air compressor

Section III: Preliminary Drilling Setup

A. Site Exploration

Site exploration is one of the most important steps in the drilling process. The success of the well is completely dependent on several factors, including the availability of ground water, whether the water is potable, and whether the well is easily accessible by the users. Accordingly, adhere to the following guidelines in determining the well placement.

> **Keep in Mind…**
>
> The best time of year to drill is during the dry season so that when groundwater is reached, you can be confident that this will be the lowest water level that will occur throughout the year, and even in the dry season, there will still be water available. If the well is drilled during the rainy season, it is difficult to determine how much the groundwater level could drop during the dry season and how deep the well would need to be drilled to ensure an adequate yield.*
>
> * Lassaline & Fitzgerald, (2010).

- If possible, conduct an inventory of existing wells in the area in order to estimate depth of water table, the quality of water at varying depths, and the geological strata that can be expected.
- Speak with the local community to determine if groundwater seeps into the bottom of pit latrines during the rainy season. This will indicate how deep the groundwater is.[4]
- Ensure that the well is placed in a location that is convenient to the people who will be using it. However, it may be necessary to compromise convenience in order to ensure the well is successful.
- Do not drill within 15-50m (≈50-165') down gradient from a latrine or other area in which human or animal waste is deposited. Bacteria and other contaminants from fecal waste can seep into the ground and travel through groundwater, and if a well is placed near a high concentration of contaminants, the well may become polluted.[5]

B. Well Site Preparation

Derrick Construction

Materials:
- Rope/Wire
- Nails
- Timbers/pipes x 3 (length = 12-15' (≈3.5-4m))
- Support beams x 4

> **Keep in Mind…**
>
> The construction of the **derrick** is dependent on local availability. Either pipes or a few pieces of timber will suffice.

i. Begin by using a posthole digger to dig two holes approximately 7' (≈2m) apart, with the desired borehole located mid-way between the two holes. Each

[4] Lassaline & Fitzgerald, 2010.

[5] Lassaline & Fitzgerald, 2010.

hole should be approximately 3' (≈1m) in order to ensure the timbers are secured.

ii. Place a timber down each hole. When determining the pieces of timber to use, locate pieces that are Y-shaped as this will ensure greater ease when securing the crossbeam (see Figure 25). After timbers are in place, pack in surrounding hole with earth, ensuring the timbers are aligned upright and firmly in place.

iii. Place a crossbeam timber across the two vertical timbers, approximately 8-10' (≈2.5-3m). Secure the crossbeam using rope, wire, or nails. It is important that the crossbeam does not shift during the drilling process so ensure that it is secured tightly, using extra rope and nails if necessary.

Keep in Mind…

It may be easier to secure the pulley to the crossbeam before raising the crossbeam.

iv. Stabilize the derrick structure using ropes and supporting beams as illustrated below.

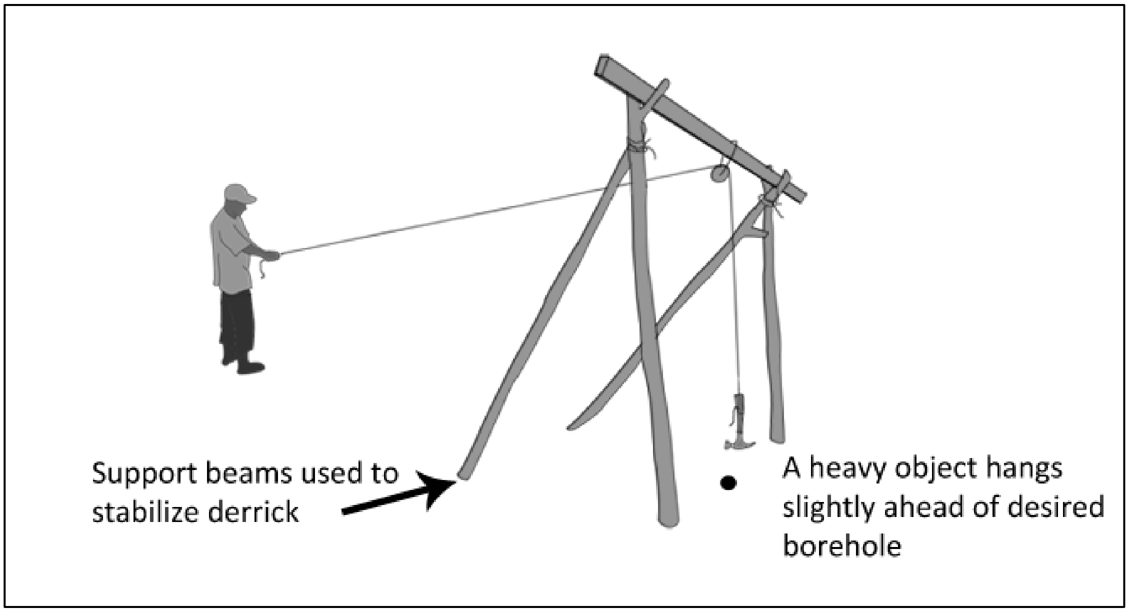

Figure 25 - Construction of Derrick Structure

Rope and Pulley Assembly

Materials:
- Pulley (4" (10cm))
- Rope (length = 50' (≈15m); thickness = 1" (2.5cm)
- Heavy object (hammer or pipe wrench)
- Wire, rope, or chain

vii. Secure the pulley to the center of the crossbeam, directly above the desired borehole location, using wire, rope, or a chain.

viii. Insert one end of the rope into the pulley and tie a heavy object such as a pipe wrench or hammer to it as demonstrated in Figure 25 (previous page). The tense rope will sit directly above where the borehole will be. As pulling begins, the pulley tends to swing forward as the rope is tensed. Therefore, locate the borehole 1-2" (3-5cm) forward from where the rope hangs.

ix. At the end of the rope, "rowing handles" made from locally available material are tied using a double-half hitch knot (See below).

Figure 26 - Rowing handles

Settling Pool

i. Dig a settling pool 3' x 3' x 1-2' deep (≈100cm x 100cm x 30-60cm deep). Make sure that the pool slopes away from the borehole. This ensures the cuttings will not fall down the hole once removed.

> **Keep in Mind…**
>
> In order to preserve the water supply, line the settling pool with **bentonite**. This prevents the water from seeping into the ground.

ii. Dig a 4" x 1' (≈10cm x 30cm) trench from the desired borehole to the settling pool.

Water Supply

Materials:
- Several barrels or cisterns to hold water
- Tarp
- Rope
- Stakes (3' (≈1m))
- Timbers (10-12' (≈4m))

Keep in Mind…

Approximately 500-1000L (≈132-264 gal.) of water is required for each day of drilling.

i. Because the water acts as the drilling fluid as well as mixes with the bentonite, it is **very important that a sufficient supply of water is available at all times**.

ii. If barrels or cisterns are not available, a makeshift holding structure can be constructed using a large tarp, wooden stakes, timbers, and rope.

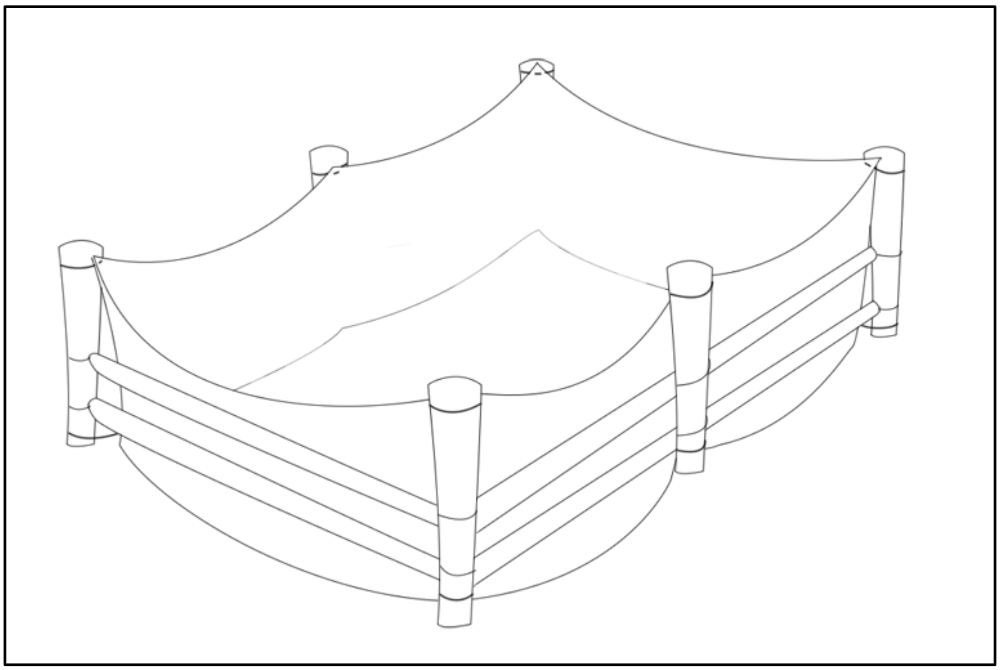

Figure 27 - Water holding structure

Section IV: Drilling Procedure

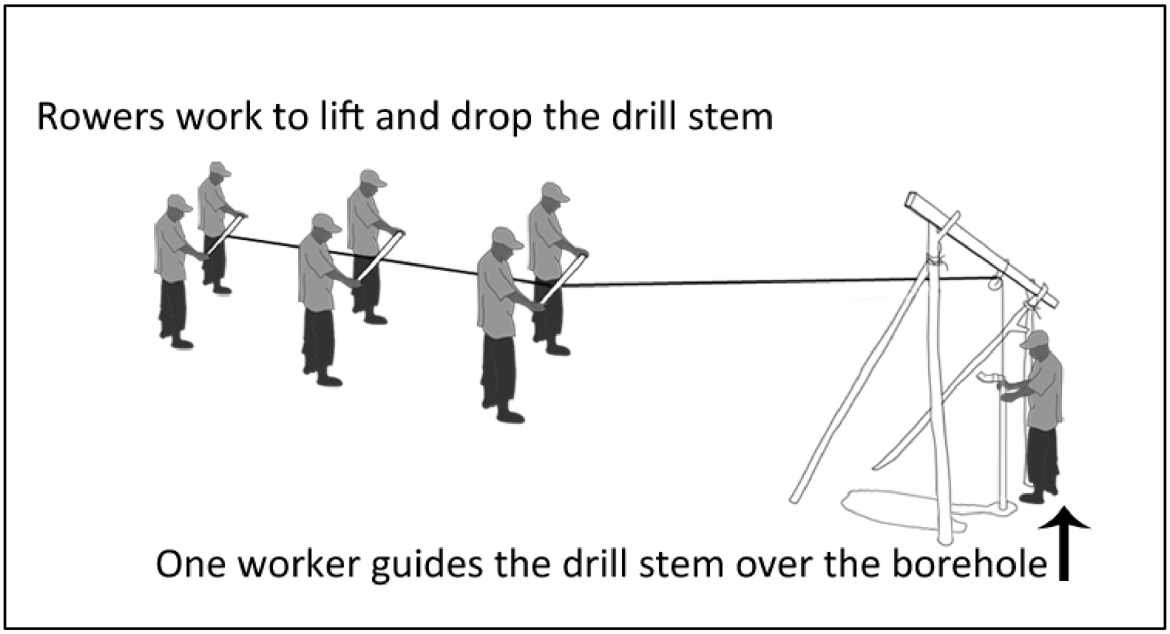

Figure 28 - Drilling procedure set up with rowers

Note: Measurements are provided as metric in this section due to the conventions used in Bolivia.

A. Handling the Stem

Before proceeding with drilling, consider the following points:

- **IMPORTANT:** It is critical that the drill stem is vertical (perpendicular to the horizon) at the outset of the drilling as this will ensure the borehole remains vertical later on in the drilling process.
- From the outset, an order for lifting the drill stem using pipe wrenches should be established. As the depth of the borehole increases, the drill stem becomes heavier, making it increasingly difficult to lift out. If the workers responsible for lifting the stem know when to attach their pipe wrench to the stem, the possibility of dropping the stem down the borehole greatly decreases.
- When lifting the PVC drill stem with the pipe wrenches, workers should be careful to ensure the angle at which the wrench attaches to the stem is not too severe, as this will cause the stem to snap (See Figure 29, next page). The PVC pipe is used primarily because of its lightness and low cost – not because of its durability.

- When adding pieces to the drill stem, it is important to ensure the drill bit does not sit on the bottom of the borehole as this will increase the likelihood of becoming clogged.

Figure 29 - Holding the drill stem with pipe wrenches

B. Commencement

i. Begin the borehole by using a posthole digger to descend as deep as possible. Ensure that the hole is placed several inches ahead of where the rope is hanging (see Page 34 for more information on this).

ii. Once the posthole digger has reached its maximum descent, fill the borehole and the settling pool with drilling fluid.

iii. Insert a 3m steel pipe with a movable bit attached to one end, and a spout attached to the other. Manually lift and drop the drilling rig into the borehole, drilling down as deep as possible. Ensure that the drill stem remains vertical while descending (have assistants help). With every down stroke, drilling fluid (mixed with cuttings) should begin to spurt from the spout into the settling pool.

> **Keep in Mind…**
>
> To ensure wrenches are not accidentally dropped down the borehole, use rubber strapping (tire tube rubber) to secure the wrenches to the derrick.

iv. In addition to the water in the borehole, a mixture of bentonite and water must be added as the well is being drilled in order to prevent the well from collapsing and to aid in lifting the cuttings out of the borehole.

C. Continuation

i. Once the 3m steel pipe has descended to its maximum depth, a 1.5m piece of 1½" PVC or steel is added. This piece should have a spout attached to it prior to attaching to the drill stem. To add the piece, several workers need to lift the existing drill stem several feet off the bottom of the borehole using pipe wrenches.

ii. Tie the spout to the rope that is hanging down. Use a slipknot to tie rope to spout as this will allow for easy removal when adding pieces. Sometimes a slipknot is difficult to remove so alternatively, a steel ring can be tied to the end of the rope, passing the rope through the ring to create the slipknot.

iii. With workers at the other end of the rope, a "rowing" motion ensues in which the drill stem is lifted and dropped. Begin with two people and as the drill stem becomes heavier, additional rowers are added. 4-6 persons are usually sufficient. A worker is stationed above the borehole to guide the drill stem, ensuring it remains vertical and to direct the spurting drilling fluid into the settling pool.

iv. Once 4.5m is reached, withdraw the drill stem and remove the drill bit, attaching it to the 6m steel pipe. The 6m pipe is used because it allows for correcting verticality due to its weight and straightness.

v. Once the 6m steel pipe has reached its maximum depth, a 1.5m PVC piece with an attached spout is added. Drilling resumes.

vi. At 7.5m, the 1.5m piece is removed and a 3m PVC piece is added, along with the spout. Drilling resumes.

vii. At 9m, the spout is removed and the 1.5m piece with attached spout is added. Drilling resumes.

viii. Steps v-vii are repeated until the desired aquifer is reached.

ix. When lifting the PVC drill stem with the pipe wrenches, workers should be careful to ensure the angle at which the wrench attaches to the stem is not too

Keep in Mind…

If water is not coming out from the spout, you may want to use the palm of your hand as a valve by cupping the end of the spout on the up stroke, and removing the palm on the down stroke. This may need to be repeated for 5-10 minutes in order to get the drilling fluid to recirculate in and out of the drill rig. If this does not work, you may need to remove the drill stem from the hole and unclog the drill bit.

Keep in Mind…

There is no "one size fits all" method for drilling. Accordingly, sometimes it is better to use more steel piping and other times it is better to use more plastic. Steel will go down faster and is better in clay, but it is much heavier and difficult to work with. Plastic is lighter but has a greater tendency to crack. A combination is determined as the drilling progresses.

severe, as this will cause the stem to snap. Remember that the PVC pipe is used primarily because of its lightness and low cost – not because of its durability.

D. Determining Depth and Filter Placement

i. Keep a logbook, recording cuttings that come out of the spout every 1.5m. To determine the type of sediment, catch a sample in a bucket as it spurts out from the spout and decant water off the top. Alternatively, you can use a small nylon screen that can catch the solid material as it comes out of the spout.

ii. Water is found in layers of sand called aquifers. The filter must be placed in at least 2m of an aquifer layer. Once the sediment is mostly sand and gravel, and the borehole seems to be recharging water naturally, the aquifer is most likely reached. However, it is important to continue drilling at this point in order to maximize exposure of the filter to the aquifer.[6] **Confined aquifers** are preferred over **unconfined aquifers**. Confined aquifers will usually follow a layer of clay. However, if rock is reached and the drill cannot descend further, than it is acceptable to place the filter in a shallow, unconfined aquifer.

iii. Thus, once sand is reached at a desirable depth, continue drilling until clay or rock is hit. This is where the filter should be placed.

iv. Sand quality – Coarse sand will contain more water than fine sand. Examine sand particles under a magnifying glass: rounded sand particles *may* indicate greater water volume compared to hard-edged sand particles.

Keep in Mind…

Cuttings include: topsoil, sand, clay, gravel/rock.

Sand usually passes through a nylon screen so a bucket must be used if passing through sand.

Keep in Mind…

WARNING: If the filter is placed in clay, there will be no water. If it is partially placed in clay, muddy water in reduced quantity will result.

E. Issues in Drilling

Rarely is a well drilled by simply adding PVC pieces and drilling until desired depth. Inevitably issues come up along the way that prevents a smooth process. However, if the well driller is prepared for these issues beforehand and ensures he or she has the right tools on site, as well as knows what action to take when issues arise, the drilling

[6] Lassaline & Fitzgerald, 2010.

procedure can usually continue with minimal interruption. The following list provides some tips for overcoming issues in drilling.

Hard material and Speed of Drilling

The Baptist method is not intended for drilling through thick layers of rock. However, if rock is hit, it is worth trying to pass through in order to avoid having to abandon the well. Certain action can be taken when drilling through tough material such as clay or rock.

- Use an all steel drilling stem attached to an auger bit or a rock bit. The added weight will provide increased force. Note: the steel drilling pipes will make the drilling rig much heavier than the PVC stem. 1" steel drill stem deeper than 30m becomes difficult to handle manually. Adding workers to the "rowing" crew will help alleviate this but it will still be a challenge. Once the hard material has been passed, you can switch back to the PVC stem or use a combination of steel and PVC.
- If the drill bit is in hard rock and ceases to make any progress after several hours, you will have to abandon the well and begin elsewhere. For a first well being dug in an area, several locations may need to be tested in order to determine the feasibility of drilling in the area.
- The speed of the drilling will vary. It is possible to descend 1.5m in 5 minutes or 1 hour, depending on the density of the layer. However, as long as progress is being made, regardless of the speed, do not be discouraged.

Flooding

- Because flooding is a common occurrence in many low level areas throughout the developing world, it is important to ensure that the top of the well casing will be well above the typical flood levels for that area.
- Once the drill has been completed and the well casing has been inserted, a platform of concrete can be placed around the well, thereby allowing the top of the well casing to be higher.

Drilling Fluid – Viscosity

- The proper thickness of the drilling fluid must be maintained. If it is too thin, it cannot suspend the cuttings. If it is too thick, it will not pump properly. The viscosity is determined by what material is being drilled through, as well as what is added to the water (i.e. bentonite).
- When drilling through sand, the viscosity of the drilling fluid needs to be increased as "thin" drilling fluid will not suspend the sand particles. Thus, if you are drilling through a layer of sand and not making any progress, add bentonite to the water.

- When drilling through clay, the drilling fluid may require "thinning." To do so, remove several buckets of drilling fluid from the settling pool and replace with water.

Collapsing Well

- To prevent a well from collapsing, ensure that bentonite is regularly added to the drilling fluid. The bentonite coats the walls of the borehole, preventing sand from caving in.

- Sand layers have a tendency to collapse, trapping the drill stem and bit. If this happens, do everything possible to extract the stem immediately. If the stem does not come out by hand, try using a hand cable winch come along or a motorized vehicular winch. Alternatively, a block and tackle pulley system can be used to increase the force required in removing the stem. Sometimes the drill stem is not removable and you may need to abandon the well and start elsewhere. It is important to have multiple bits and drill stem material on sight.

- Never leave the drill stem and bit at the bottom of a borehole as this greatly increases the chance of a collapsing well trapping the stem. If you stop for a few minutes, suspend the drill stem with the rope a few feet off the bottom. If you stop for a few hours or overnight, completely remove the drill stem.

Start and Stop Drilling

- Ideally, it is better to continuously drill as long as possible. This greatly reduces the chance of the well collapsing and is also more efficient as less time is spent removing and replacing the drill stem. Before drilling commences, you may decide on teams to work in shifts, running 24 hours, so that drilling does not have to stop.

- If continuous drilling is not possible, resuming drilling after stopping for a night must be done with care. Upon start up, be sure to slowly circulate the drilling fluid, as it tends to become too dense to pump at the bottom of the borehole. For example, if the well is 20m deep, begin pumping with a 6m-drill stem, adding 1.5m sections, and re-circulating the drilling fluid as the stem descends. In the last several meters, descend very slowly to avoid clogging the bit.

Drill Stem Rescue

- It is not uncommon for the drill stem to be lost down the well. Use the fabricated rescue tool (see below) to retrieve the stem. Begin by determining how deep the stem is by measuring the broken piece that was removed. Attach 3m pieces of PVC pipe to the rescue tool as it descends the borehole. When you have reached the top of the drill stem, attempt to “hook” the tool inside the stem or around the coupling (depending on the type of tool used) and gently extract the hooked drill stem.

Keep in Mind…

The most common reasons for losing the drill stem in the well:

1) Carelessness when lifting the stem to add or remove pieces.
2) PVC coupling breaks or unscrews.
3) PVC pieces break due to excessive flexing.
4) Well caves in.

- In the event that the drill bit breaks off or the movable drill bit tip breaks, the well will most likely have to be abandoned. Thus, before drilling begins, it is very important to inspect the drill bits, making sure they are well constructed, do not have any cracks, and are completely screwed on to the drill stem.

Rescue Tools

- If the drill stem drops down the hole, it is important to have a rescue tool readily available. The sooner action is taken to retrieving the stem, the better the chances of success are. The following is one variation of a rescue tool that has proved effective.

Materials:

- 3 x 5" pieces of rebar
- 1 x 1" galvanized coupling
- 1 x ¾" galvanized nipple
- 1 x ⅜" x 1m steel rod

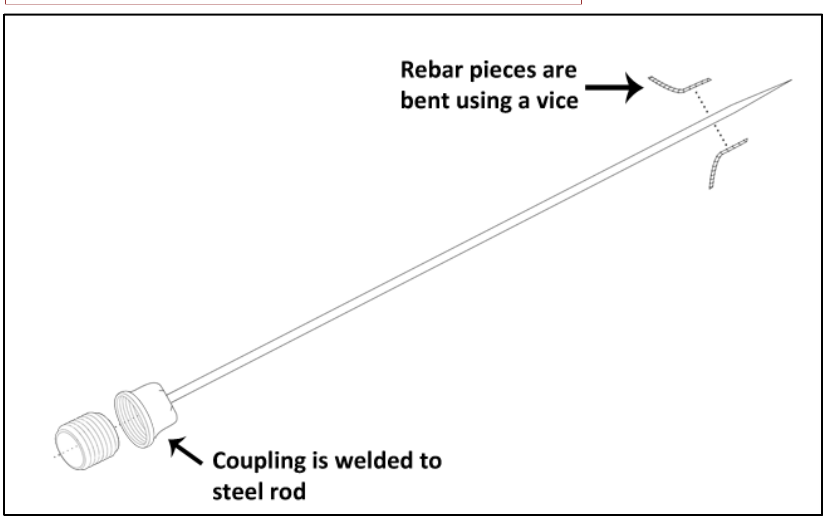

Figure 30 - Exploded view of rescue tool

i. Grind a point on the end of the steel rod.

ii. Each end of the rebar pieces is ground to a point.

iii. Weld the rebar pieces on to the steel rod, approximately 6" up from the grounded point.

iv. Weld a coupling on to opposite end of steel rod.

v. Insert nipple into coupling.

Repeated Clogging

- Drilling in consolidated material such as clay often results in the drill bit becoming clogged, thus preventing the removal of cuttings through the bit, and greatly decreasing the productivity of the drilling. Using a valve-less drill bit is the best action to take when confronted with continuous clogging.
  - The ball valve can be placed just above the bit or just below the spout at the top of the stem. It can also be placed at the 1.5m mark.
  - The gate valve can be placed at the exit spout. However, the off-centered weight of the gate valve causes the PVC pipe to flex excessively, which can cause threads to break in the stem. It is suggested that when using the gate valve, attach it to a steel 1.5m section.

Widening the Borehole

- The standard 1¼" diameter drill bit is usually sufficient for a 2" well casing. If the first part of the well casing (the filter) feels too tight when sliding down the borehole, remove it and widen the borehole.
- To widen the borehole, use the fixed-point drill bit.
- If a 3-4" well casing is to be used, a special reaming extension should be implemented (see Page 17).
- Bentonite should be used continuously while widening as the reaming process removes the existing bentonite, causing the walls and sand layers to cave in.

Section V: Inserting the Well Casing and Conditioning the Well

A. Well Casing

Casing Diameter and Material

- PVC plastic Class 9 (medium thickness) works sufficiently for the well casing. Generally, this comes in 6m (≈20') sections. However, for increased longevity of the well, steel casing can be used. This will increase the cost of the well substantially.

> **Keep in Mind…**
>
> Around the casing, clay or soil needs to be packed down to stabilize the well casing and to reduce water filtration around the well.

- 2" is the most common diameter used for wells that will be utilized by families and small communities. 3-4" diameter wells are ideal for increased volume such as irrigation and larger communities. Also, 4" is the minimum size for a submersible electric pump.

Installing Filter and Casing

i. Force the first piece of PVC pipe (with the filter) down the borehole. Depending on the diameter of the casing, it may take several people to assist in forcing it down and displacing the water. To counteract the buoyancy of the casing, the casing is filled with water after it is inserted in the borehole.

ii. Using PVC pipe glue, attach the next section of 6m casing. Once the piece has been attached, wait 10-20 seconds before thrusting the casing down the borehole. The casing is filled with water.

> **Keep in Mind…**
>
> The height of the well casing above ground will depend on how high the concrete sanitary pad will be, based on whether the area is prone to flooding. If flooding does not occur, usually 0.5-1m will suffice. However, for flood-prone areas, casing may have to be 1-2m above the ground.

iii. Continue adding 6m sections of PVC pipe as required, keeping track of the depth of the casing as it descends. Once the desired depth for the filter is reached, saw the casing off approximately 0.5-1.5m above the ground.

iv. Using a 3m section of 1" steel pipe along with rubber strapping (tire tube rubber), secure the well casing to a secured object such as the derrick or heavy timber. Lay the steel pipe on the ground, perpendicular to the well, using rubber strapping to tie to the casing and to the secured object. This will ensure the casing does not "pop" out of the borehole due to its buoyancy. Alternatively, rubber strapping attached to steaks or a piece of timber can help secure the casing as well (Figure 30).

v. After the case is inserted, fill the gap between the borehole and the casing with gravel.

Figure 31 - Holding the casing in place with rubber strapping
Image courtesy: Forsyth, Ramudu, Hindal, & Lazarus, 2010

Conditioning the Well

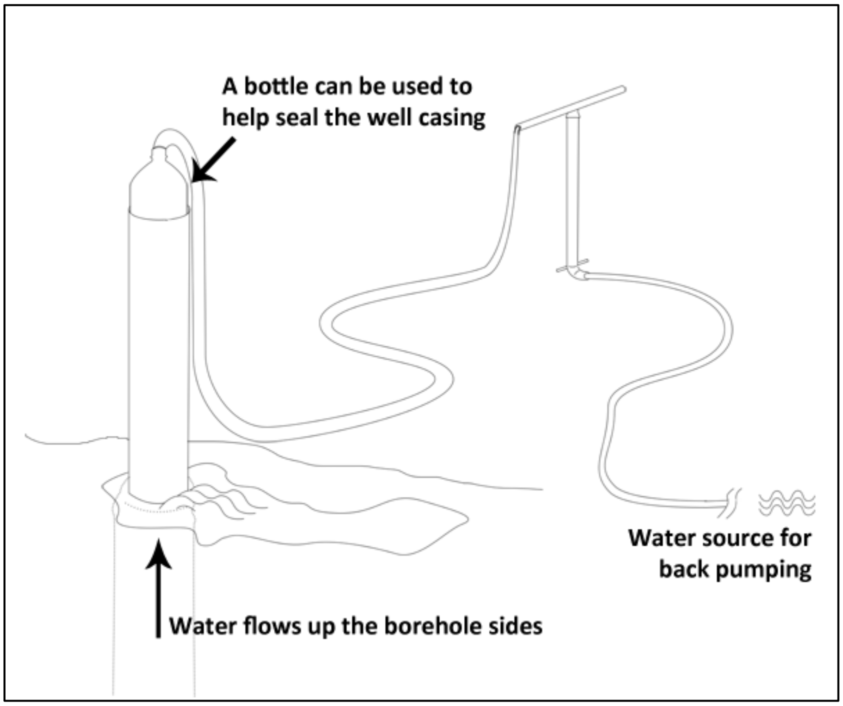

Figure 32 - Set up for back pumping into well casing

Water is “back pumped” into the casing and forced out of the filter. The back pumping is necessary as it flushes the drilling fluid, removes bentonite from the walls, and pushes the sediment out of the casing and lifts them to the surface, allowing water to flow freely from the aquifer into the filter.

i. The most inexpensive and manually intensive method for **back pumping** is to use the manual water pump (See page 29 for construction). Alternatively, a small gasoline-powered water pump can be used.

ii. Insert ½" polyethylene tube into the well casing and seal the casing using rubber strapping (tire tube rubber) and/or a 0.5L plastic soda bottle. Connect the other end of the polyethylene tube to the water pump.

iii. Begin pumping water into the casing until water runs clear from the ground around the outside of the casing. This generally takes between 15-30 minutes.

Keep in Mind…

In order to help dissolve bentonite, 2-4 kg of salt may be added to the water while it is being back-pumped into the well casing.

Keep in Mind…

Blocking the top of the spout (the top of the inertia pump) can enhance conditioning by forcing water to circulate around the retention valve. This process is known as **swabbing**.

iv. Once clean water flows around the casing, the well is ready for water to be pumped from inside the casing, using a makeshift inertia pump.[7]

v. To create the inertia pump, attach a 1" retention valve on to the end of a 3m PVC piece used in the drilling stem. In order to increase suction efficiency, wrap electrical tape around the retention valve such that the valve is slightly smaller than the diameter of the casing. Continue joining pieces of PVC piping, descending down the well until the retention valve is at the level of the filter. Note: Ensure that the top of the PVC piping is at least 1m above the top of the well casing in order to avoid the spout hitting the casing during the pumping.

Keep in Mind…

If after several cycles of back-pumping and inertia pumping, the recharge rate is still limited, it may take several days of conditioning and pumping for the recharge rate to increase.

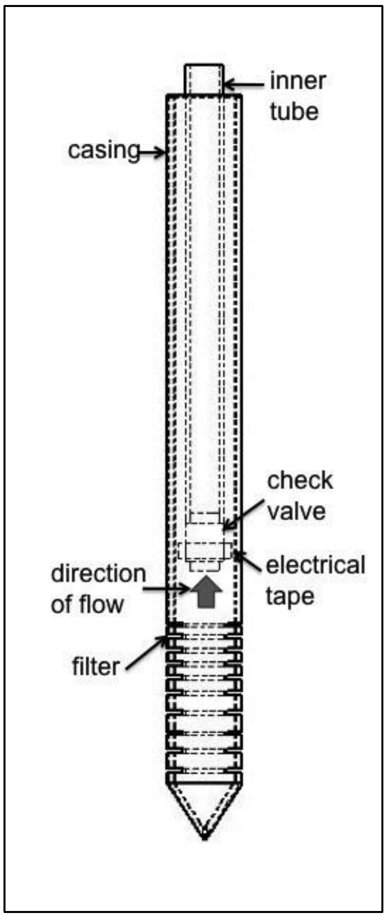

Figure 33 - Inertia pump
Image courtesy: Lassaline, & Fitzgerald, (2010).

[7] Forsyth, Ramudu, Hindal, & Lazarus, 2010.

vi. Begin pumping using the spout. If necessary, tie the spout to the rope through the pulley and use two workers to assist in pumping as is done in the drilling process. Pump continuously until the water is clear or until the casing has emptied. If the casing does not empty and the water runs clear, then the well is recharging adequately. If the casing empties, however, this means that the recharging rate is slower than the pumping rate. Repeating the back-pumping, inertia pumping, and swabbing several times will help condition the well, creating small pathways for water to flow toward the well, thereby increasing the recharge rate of the well.

Alternative Conditioning Method

i. An electric or gas-powered air compressor can be used to condition and pump the well. Attach a hose to the compressor and feed it to the bottom of the casing. Air will lift the water up the casing and blow it out the top. As the casing refills, the air compressor continues to blow out the water in spurts.

ii. To direct water away from the well area, attach a T-coupling to the top of the casing. Hose from the compressor (can be ½" polyethylene tube) can be forced down the top of the T-coupling while a second hose (of desired length) can be attached to the horizontal end. As air pushes down, water comes out of the horizontal piece, away from the well.

Keep in Mind…

After the well has been conditioned, water should be tested using a simple water testing kit to ensure it is free of bacteria. Further, shock chlorination should be conducted by adding chlorine to the well.*

*Lassaline & Fitzgerald, (2010).

B. Hand Pump Installation

Fulcrum and Lever

i. Install a support around the well casing. A piece of timber or a steel pipe (more durable) is hammered 2-3’ into the ground and tied securely to the well casing.

ii. 1.5-2.5' (½-¾m) from the casing, install a 5' (1½m) piece of timber with a U-top to act as the fulcrum. Drill a hole through both sides of the U (Figure 29).

iii. Insert pump assembly (see **Section I, Subsection J, Installing the Completed Pump**)

iv. Drill a hole approximately 2' up in a 6' timber (lever). Insert bolt through fulcrum and lever.

v. Connect pump assembly to lever using a ⅜” bolt.

Keep in Mind…

If there is a flooding potential for the area, a dirt platform should be constructed to raise the sanitation seal to a sufficient height.

Keep in Mind…

Alternative methods to a fulcrum and lever include a submersible electric pump, air compressor pump, and electric surface pump. The fulcrum and lever is the most inexpensive and readily available method.

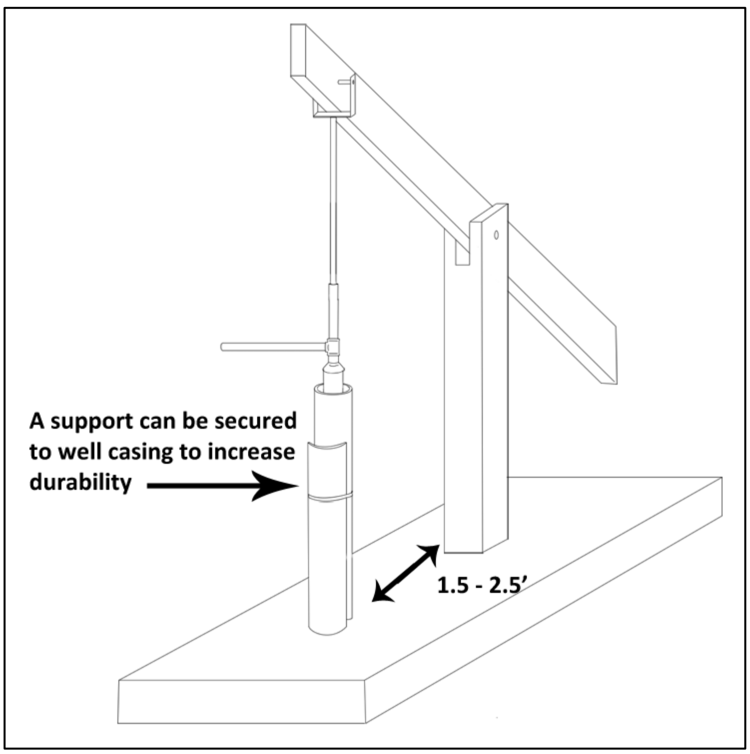

Figure 34 - Fulcrum and Sanitation Pad

Sanitation Seal (Pad)

i. A concrete pad should be constructed around the casing to eliminate water filtration. Ideally, the pad should be somewhere between 1-2m^2 (10-20 sq. ft.). At the very least, a 250cm^2 (3 sq. ft.) pad should be poured. The greater the size of the pad, the more convenient for keeping the pumping area mud-free. The pad should be built so that excess water is channeled away from the well, preventing water from pooling and becoming stagnant.

Congratulations on the successful completion of your new well!

Glossary

Term	Definition
Aquifer	An *aquifer* is an underground formation of permeable rock or loose material that can produce useful quantities of water when utilized by a well.
Back pump	*Back pumping* refers to forcing water down the well casing and out the filter. This action allows for water to flow more freely from the aquifer into the well casing.
Borehole	A *borehole* is a manually constructed hole in the ground used for extracting water, petroleum, or gas.
Confined Aquifer	A *confined aquifer* refers to an aquifer that is not open to receiving water from the surface. It is recharged from a distant, remote location. A confined aquifer is preferred over an unconfined because it will contain less contaminant.
Bentonite	*Bentonite* is an inexpensive, fine clay material used in well drilling that has the unique characteristic of swelling to several times its original volume when placed in water. It is most economical to buy bentonite in 50kg bags. A typical well requires 1-2 bags. If bentonite is not available, clay or manure can be used to thicken the drilling fluid and to line the borehole.
Consolidate material	*Consolidated material* refers to rock and other extremely hard to penetrate substances in the earth's surface.
Cuttings	*Cuttings* refer to the sediment that is lifted in the drilling fluid during the drilling process. The cuttings settle into the settling pool and are examined to determine the type of layer being drilled.
Derrick	A *derrick* is the framework over a well that supports the drill stem.
Drill Stem (drilling rig)	The *drill stem*, or drilling rig, refers to the drilling rig. In the Baptist method it is composed of the spout, PVC pipe, steel pipe, and the drill bit (and valve).
Drilling Fluid	*Drilling fluid* is composed of water, bentonite, and sediment and is responsible for carrying the cuttings from the bottom of the borehole out the spout.
Ground Water	*Ground water* refers to underground water that is found in the pore spaces of rocks. In general, ground water refers to any water below the earth's surface.
India Mark II	The *India Mark II* is a heavy-duty hand pump designed for communities up to 300 persons. The maximum lift of the India Mark II is 50m.
Percussion Drilling	*Percussion drilling* involves the lifting and dropping of a cutting tool suspended at the end of a rope. It is a dry technique, only adding a little water in order to remove the drill cuttings.
Recharge Rate	*Recharge rate* refers to the time required for the aquifer to be refilled which corresponds to the rate at which the well casing fills with water. Conditioning the well through back pumping opens up pathways for water to travel from the aquifer into the casing, thus increasing the recharge rate.

Sludging	*Sludging* (also known as Asian, or Indian sludging) involves reciprocating a steel pipe (of 25 to 40mm diameter) vertically in a shallow pit, which is kept full of water. The reciprocating action is achieved by a lever, which is attached to a bamboo frame. One operator operates the lever while the other uses his hand over the top like a flap valve. On the up-stroke the hand covers the pipe, while on the down stroke it lifts off. This action enables the cuttings to be carried up through the drill pipe and exit at the top.
Settling Pool	The *settling pool* refers to the dug hole in front of the borehole in which the drilling fluid empties and the cuttings settle.
Swabbing	*Swabbing* refers to a method in conditioning the well through blocking the top of the inertia pump which forces the water to circulate around the check valve.
Unconfined Aquifer	An *unconfined aquifer* is an aquifer that is open to receive water from the surface, and whose water table surface is free to fluctuate up and down, depending on the recharge rate.
Unconsolidated Material	Unconsolidated material refers to loose sediment such as sand or gravel.
Water Table	The level below which the ground is saturated with water. That is, all of the pore spaces in the ground are filled with water.

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Keep in Mind…

The Rural Water Supply Network (www.rwsn.ch) is a global knowledge network that provides information on many different methods of water well drilling, including the Baptist method. The site is an excellent resource.

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Appendix A: Inches to Millimeters Conversion Chart

The following chart provides fractions in inches with millimeter conversion. Common fractions are highlighted in bold for easy reference:

INCHES		METRIC	INCHES		METRIC	INCHES		METRIC	INCHES		METRIC
FRACTIONAL	DECIMAL	mm	FRACTIONAL	DECIMAL	mm	FRACTIONAL	DECIMAL	mm	FRACTIONAL	DECIMAL	mm
1/64	0.0156	0.3969	11/32	0.3438	8.7313	43/64	0.6719	17.0656	**1**	**1.0000**	**25.40**
1/32	0.0313	0.7938	23/64	0.3594	9.1281	11/16	0.6875	17.4625	**1 1/4**	**1.2500**	**31.75**
3/64	0.0469	1.1906	**3/8**	**0.3750**	**9.5250**	45/64	0.7031	17.8594	**1 1/2**	**1.5000**	**38.10**
1/16	0.0625	1.5875	25/64	0.3906	9.9219	23/32	0.7188	18.2563	**1 3/4**	**1.7500**	**44.45**
5/64	0.0781	1.9844	13/32	0.4063	10.3188	47/64	0.7344	18.6531	**2**	**2.0000**	**50.80**
3/32	0.0938	2.3813	27/64	0.4219	10.7156	**3/4**	**0.7500**	**19.0500**	**2 1/4**	**2.2500**	**57.15**
7/64	0.1094	2.7781	7/16	0.4375	11.1125	49/64	0.7656	19.4469	**2 1/2**	**2.5000**	**63.50**
1/8	**0.1250**	**3.1750**	29/64	0.4531	11.5094	25/32	0.7813	19.8438	**2 3/4**	**2.7500**	**69.85**
9/64	0.1406	3.5719	15/32	0.4688	11.9063	51/64	0.7969	20.2406	**3**	**3.0000**	**76.20**
5/32	0.1563	3.9688	31/64	0.4844	12.3031	13/16	0.8125	20.6375	**3 1/2**	**3.5000**	**88.90**
11/64	0.1719	4.3656	**1/2**	**0.5000**	**12.7000**	53/64	0.8281	21.0344	**4**	**4.0000**	**101.60**
3/16	0.1875	4.7625	33/64	0.5156	13.0969	27/32	0.8438	21.4313	**4 1/2**	**4.5000**	**114.30**
13/64	0.2031	5.1594	17/32	0.5313	13.4938	55/64	0.8594	21.8281	**5**	**5.0000**	**127.00**
7/32	0.2188	5.5563	35/64	0.5469	13.8906	**7/8**	**0.8750**	**22.2250**	**6**	**6.0000**	**152.40**
15/64	0.2344	5.9531	9/16	0.5625	14.2875	57/64	0.8906	22.6219	**8**	**8.0000**	**203.20**
1/4	**0.2500**	**6.3500**	37/64	0.5781	14.6844	29/32	0.9063	23.0188	**10**	**10.0000**	**254.00**
17/64	0.2656	6.7469	19/32	0.5938	15.0813	59/64	0.9219	23.4156	**20**	**20.0000**	**508.00**
9/32	0.2813	7.1438	39/64	0.6094	15.4781	15/16	0.9375	23.8125	**30**	**30.0000**	**762.00**
19/64	0.2969	7.5406	**5/8**	**0.6250**	**15.8750**	61/64	0.9531	24.2094	**40**	**40.0000**	**1016.00**
5/16	0.3125	7.9375	41/64	0.6406	16.2719	31/32	0.9688	24.6063	**60**	**60.0000**	**1524.00**
21/64	0.3281	8.3344	21/32	0.6563	16.6688	63/64	0.9844	25.0031	**80**	**80.0000**	**2032.00**
									100	**100.0000**	**2540.00**

Appendix B: Images of Parts

Name	Image	Name	Image
Angle iron		Steel Pipe	
Bronze horizontal check valve		Flexible coil plastic pipe (Polyethylene Tubing)	
Bushing (Reducer)		Nipple (steel)	
Check Valve		Nipple Coupling (PVC)	
Coupling (Steel)		PVC Piping (Class 9)	
Coupling (PVC)		Reducer Coupling	
Elbow Coupling (45°)		T-Shaped Coupling	

For more information on this simple well drilling, please contact:
Dr. Daniel Beams through email: beamsclan@yahoo.com or visit the Agua Yaku website: www.aguayaku.org or www.manualwelldrilling.org