Improved Techniques for Spring Protection
Developed by Rural Ecuadorian Communities

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Abstract

Naturally occurring springs often provide the water supply needed for rural Ecuadorian communities. Springs offer the advantages of a consistent flow rate, consistent water quality and sometimes an adequate elevation to provide water to the community by gravity flow without pumping. Many communities have used careful construction procedures to adequately protect water quality so that their water supply is potable quality water or close to that level of water quality. Although these practical techniques used by many Ecuadorian communities for spring protection vary from the spring box techniques advocated by many references, they are proven to be reliable, sustaining, and worthy of replicating.

Well-built spring protection structures normally last for decades without significant maintenance. Therefore this water supply approach can be more reliable, economical, and sustaining than water treatment.

This presentation elaborates the basic method used for successful spring protection. Several examples of spring protection design and construction are provided to illustrate these methods.

Advantages of using spring water sources

Often springs are used as a community water source prior to any interventions and hence already have a level of cultural acceptance for water use. Some communities are located close to springs purely for the convenience of being close to a water source. Thus, to improve their water source so that the water is acceptable drinking water quality has strong advantages.

Springs in Ecuador most often originate in free flowing aquifers and thus less likely to be affected with adverse taste and mineral issues than other water sources. The approximate water flow rate and water quality are normally evident prior to any protection of the spring; whereas these aspects are more difficult to accurately predict for wells.

Most often, the community residents are much more aware of the possible spring water sources than outsiders. This is especially true in areas where rainfall is limited and where heavy vegetation does not cover the terrain. Therefore, an important starting point is to ask the local people where they obtain water and whether they are aware of any springs in the area.

The next question that should be asked of the residents is which springs flow year-round. Intermittent springs are not normally worthy of incorporating into a water system due to their unreliable nature. Although in some cases, intermittent springs can be excavated to build a dug well serving year round. This is particularly true of so called “water holes”.

Analysis Prior to Construction

The production rate of flowing springs can normally be measured using a length of drain pipe and a bucket or other container of known volume. The spring flow rate should be evaluated for its adequacy to supply the anticipated water demand needed by the community.

It is difficult to exactly predict the water quality prior to protecting the spring, but in some cases it is possible to do preliminary testing. Bacteriological testing should be done after the spring protection structure is complete. A previous study presented at the 2012 IPWE conference which compared well protected springs with poorly protected springs showed an average reduction of coliform of two to three orders of magnitude. More often than not, well protected spring water sources are free of measureable amounts of coliform.

Constructing Spring Protection Structures

One of the significant advantages of the Ecuadorian method of spring protection is that work in the spring area can often be completed in a single day. This minimizes the difficulty of constantly removing mud and water from the construction area required by other approaches needing a longer time frame to build. Ecuadorian communities often mobilize the entire community for work days known as *mingas* enabling them to accomplish large projects quickly. Bucket brigades can quickly respond to the need to bail mud and water as well as conveying filter stone and concrete when needed. Moderately sized 8 liter flexible rubber construction buckets are used. When hundreds of people work together, *mingas* become an enjoyable social event as well as providing the manual labor needed.

Prior to excavation, preparation should be made by acquiring all of the needed building materials such as the pea gravel for the filter pack, slotted plastic drain pipe for the collection pipe, drain pipe fittings, concrete materials, and concrete formwork. Pea stone and concrete aggregates should be stock piled on plastic sheeting to protect them from mixing with topsoil or organic materials. Pea stone should be 1 cm or smaller average size so that the stone holds back the native soil in the spring area while also providing free draining characteristics. After gaining some experience with this approach, one can reasonably estimate the amount of materials needed prior to the start of construction.

Figure no. 1
Plan of Typical Spring Protection

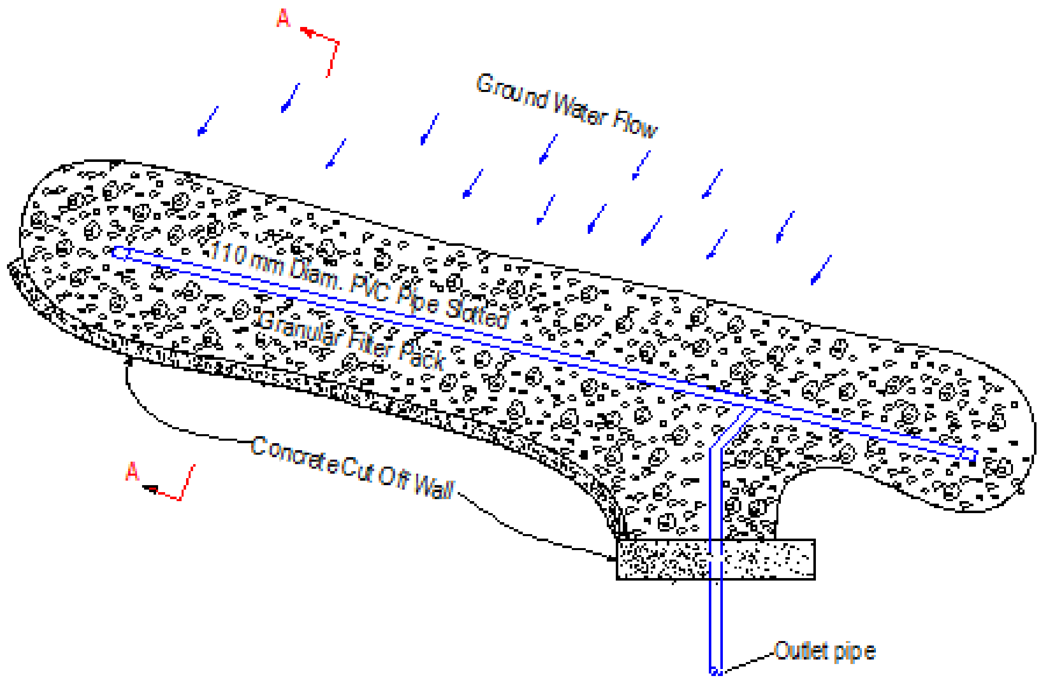
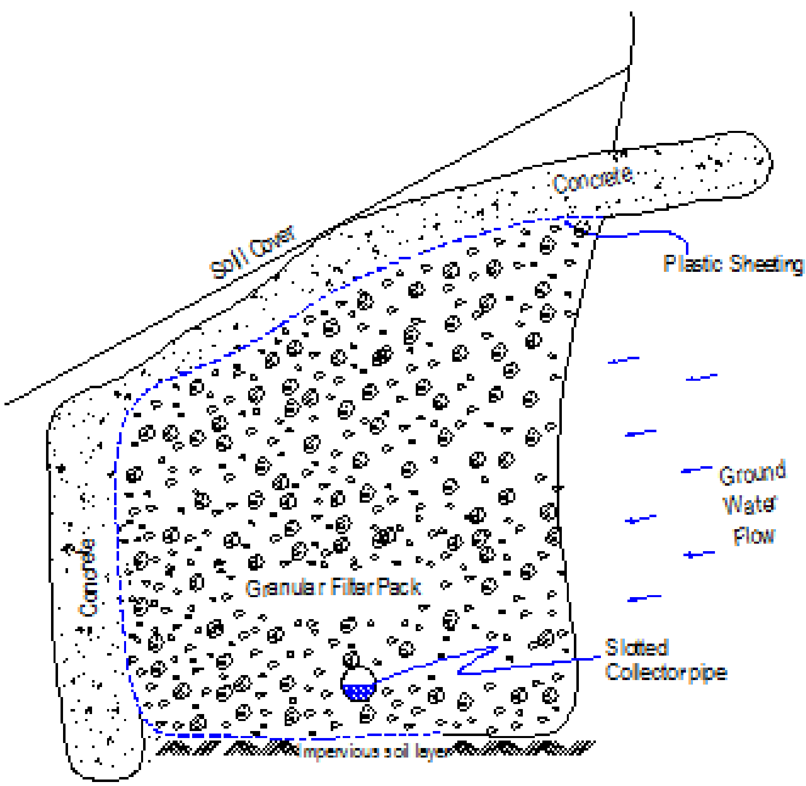


Figure no. 2
Cross-Section of Typical Spring Protection



The basic method of constructing the spring collection is to remove the topsoil, other soil strata necessary, loose stone, roots, and organic materials to expose the strata where the water is being produced. The area should be adequately cleared of all debris and extraneous materials which could contaminate or diminish the water quality. The slotted collector pipe is placed in or adjacent to the water bearing strata and then surrounded with filter pack.

Simultaneously, a cutoff wall is built to enclose the filter pack. The 25 cm thick cutoff wall is keyed into the less permeable strata underlying the water bearing layer about 30 cm or to the depth practical to prevent the spring flow from circumventing the collection structure. The cutoff wall must also be keyed into abutments so that the water production area is completely enclosed forcing the water to enter the collection pipe. Plastic sheeting is used as concrete formwork to form the inside of the concrete cutoff wall. Placement of the gravel filter pack and concrete for the cutoff wall should be coordinated to keep the levels similar balancing the pressure on the plastic sheeting on both sides. Figure no. 1 shows details of a typical spring protection structure in plan and Figure no. 2 shows a cross-section.

The cutoff wall should adequately penetrate the underlying impervious strata and abutments to prevent piping of fines that could allow progressive failure of the protection structure. The elevation of the collector pipe should allow the spring water to freely drain at a level not exceeding the elevation prior to building the protection structure. In cases where the protection structure ponds the spring water at an elevation higher than its previous state, there exists the risk that the water may eventually find an alternate route of escape causing failure of the structure.

The slotted plastic collector pipe can either be of the manufactured type or slotted in the field. Slots are normally cut into the pipe on two sides making about 90 degree cuts at one centimeter spacing. Cuts are made using a hacksaw or other type of saw depending on the width of cut required to keep fine material from entering the pipe. The collector pipe can be 75 mm, 110 mm or larger as required by the circumstances. The length and diameter of collector pipe should be sufficient to allow all of the spring water to freely enter the pipe without ponding water higher than the center of the pipe. Allowance should be made for the largest flows expected. Pipe should be placed so that slots are on the bottom of the pipe. The pipe should be solid without slots as it passes through the cutoff wall.

When the filter pack and concrete cutoff wall are built up to their full height, the filter pack should be rinsed with clean water to accelerate the removal of fine material. The rinsing should continue until the water discharged begins to run clear. In some circumstances the spring flow discharging from the collector pipe can be used to facilitate this step. When the water begins to flow reasonably clear, chlorine should be added to the rinse water to form a 100 to 250 ppm solution to shock dose and disinfect the filter pack.

After disinfecting the filter pack, plastic sheeting can be placed over the pea stone and then covered with 8 to 10 cm thickness of concrete. The concrete cover should be keyed into the surrounding soil structure so that neither rainwater nor surface water can penetrate the protection structure without being filtered by the natural soil structure. A period of up to several days may be required for the turbidity to more completely clear up.

The water users can either receive the clean spring water at the pipe end as it discharges through the cutoff wall or the flow can be directed to a collection-receiving tank. Even minor spring flows can accumulate in the tank allowing users to quickly fill their containers. Or alternatively, the tank can be used provide a stable water surface so that the clean water can be used for a water distribution system.

Rocky Spring Locations

Springs occurring in rocky locations provide more stable circumstances in the sense that piping or release of fine soil particles is not likely. Loose rock and organic material such as moss, roots, and lichens should be removed at the beginning of the work. Rock surfaces to be covered with the filter pack should be cleaned with a wire brush to remove growth. Possible rock fracture planes that could allow surface water to enter or roots to penetrate the filter pack and collection pipe should be grouted with cement or cement mortar.

Placement of the filter pack, collection pipe, cutoff wall, and concrete cover should be similar to the description previously described. Instead of keying the cutoff wall into the soil structure, the rock surfaces should be cleaned, roughened, and prepared so that the concrete fully adheres to those surfaces.

Disperse Springs

Experience in Ecuador indicates that the ideal type of spring that flows from a single point or even a compact area represents only a small percentage of all springs. Most springs are characterized by multiple points of water production or in some instances; water is produced over a wide area. In such cases it is necessary to adapt the above techniques as required. Rarely do communities have the luxury of only using the ideal point source springs. Hence significant creativity and resourcefulness are required to protect these challenging springs.

Where multiple points of spring water flow exist, the above method can merely be used repetitively to capture each point of water production. The advantage of the Ecuadorian approach is that multiple protection structures can direct each flow to an appropriately located receiving tank to develop the amount of water supply required.

Figure no. 3 – Picture of field slotting of pipe and cleaning out the cuttings.

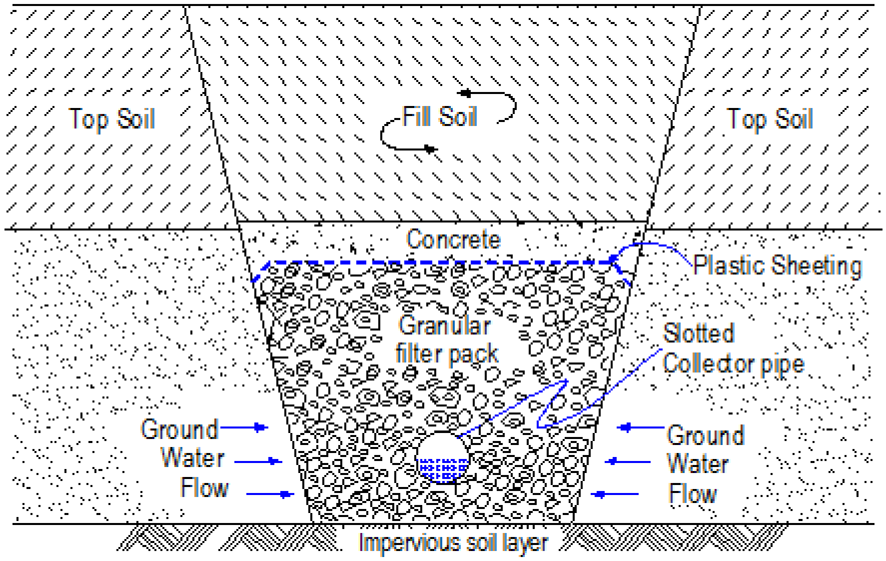


Figure no. 4
Cross-Section of a Typical Trench Spring Collector

Trench Spring Collectors

In some cases, where the groundwater flows in the permeable strata under the topsoil over a broad area, the water can be collected in a trench drain similar to a French drain. In steep slopes, it is possible to use geomembrane or plastic sheeting on the downhill side of the trench to insure that the groundwater enters the collector pipe.

The trench collector design can be applicable in some instances to collect groundwater parallel to a stream or river. Normally, the groundwater or river water collected in this manner is of higher quality than the adjacent surface water. Additionally, a collector of this nature has the advantage of being protected from the mud and debris which can be transported by the stream during flood events.

Traditionally, gallery spring collectors are used where groundwater is produced over a significant area. A trench spring/groundwater collector is normally quicker and less expensive to build than a gallery collector which can be used in these circumstances. A trench collector under construction is shown in Figure no. 5.

Figure no. 5 Trench Collector under construction

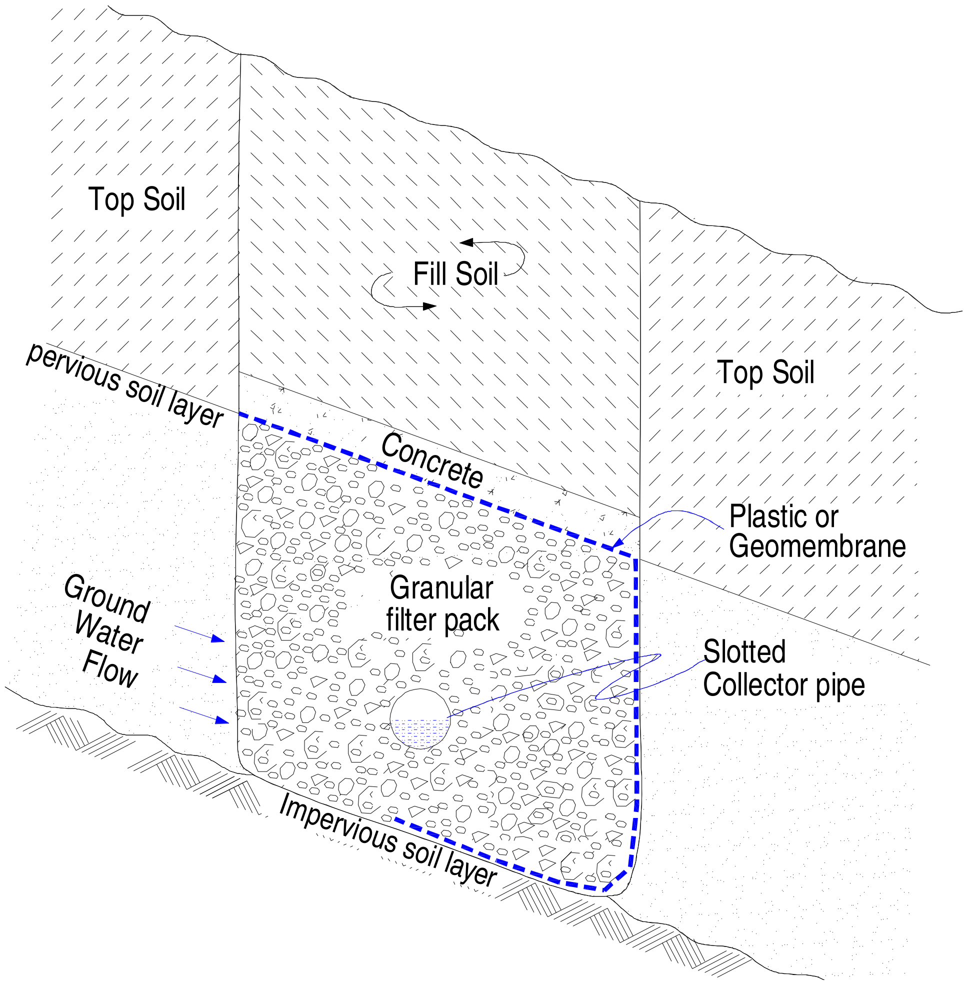


Figure no. 6 - Cross-Section of a Typical Hillside Trench Collector

Figure no. 7
Picture of a concrete gallery spring collector with the receiving tank in foreground.

Non-flowing Springs

Some so called springs or water holes are merely a pool of water where the groundwater table or freatic surface intersects a low depression in the topography. These water sources are often muddy low quality water due to the disturbance of collecting water and due to aquatic growth. These so-called water holes can often be improved by protecting them in a simple manner.

In cases where the water holes are larger than a few square meters and a strong groundwater flow exists, a spring protection structure can be built on the on the upstream side of the water body. In cases where the groundwater flow is weak, it is best to either build a dug well alongside of the water hole or in the case of a small water hole the dug well can be built into the water hole so that it is completely displaced by the new structure. There are numerous techniques for hand dug wells, such as the modified Chicago method.

Since the water produced does not generate a surface flow it is often helpful to install a manual or electric pump so that the protection structure can be fully sealed and water can be obtained without opening the water source to contamination. In this approach a collection receiving tank is not normally used or needed since the spring is non-flowing.

Collection Receiving Tanks

A key feature of the Ecuadorian spring protection approach is the use of a collection/receiving tank normally located remotely from the water production area. By constructing the tank a short distance from the water production area, the location of the structure can be carefully chosen to avoid soil stability issues and build the structure in drier conditions. The location of the tank should selected for ease of construction, ease of access, convenience of receiving the flow from all points of all of the spring protection structures, and an advantageous location allowing for a drain and overflow.

The water surface elevation in the tank should be below all of the spring water production points so that water freely flows to the tank without back pressuring any of the spring locations. The pipe from the spring protection to the tank must be generously sized to permit open channel flow not exceeding a depth of the radius of the pipe. This allows the receiving tank overflow to act as a breather for the spring protection and avoids installing the breather at the spring where it would be more susceptible to damage. Breather pipes can allow a possible entrance for contamination.

The tank overflow should be located at an elevation below the lowest spring from which the tank receives flow. The tank should also have a drain and a valved outlet to the feedline or water distribution fed from the tank. A covered access should be provided with a durable well designed sanitary cover which prevents the entrance of dust, dirt, rainwater, insects or animals.

A simplified design for a receiving tank using short lengths of vertical removable pipe lengths can be used instead of outlet and drain valves. The tank can be drained by opening the sanitary cover to drain the tank and removing the vertical overflow pipe from the pipe bend embedded in the tank floor. This design reduces costs and the maintenance liabilities of the additional valves and fittings.

Advantages over Spring Box Technique

Although spring boxes are commonly shown in technical literature, they are difficult to build under upwelling water conditions. Another disadvantage of spring boxes is that they can be circumvented by the groundwater flow and do not maximize the amount of groundwater collected. Simple spring collectors as described above are more economical, reliable, simpler and quicker to build.

Spring Protection Problem Issues

Spring protection is often challenging. Slope stability, floods, burrowing animals, roots and legal rights are some of the problem issues we have encountered.

Springs can occur on steep slopes where the soil characteristics, slope, and soil saturation adversely affect the slope stability. These factors make it necessary to locate the receiving tank where the slope is adequately stable. Gabbions or some other method of slope reinforcement can be used to enhance the slope stability for the collection structure where deemed necessary.

Some springs are located in stream beds, wash areas, or below the maximum flood levels of the adjacent stream. These spring collector structures require careful design consideration to avoid damage or contamination of the water source during wash or flood events. The receiving tank must be located sufficiently downstream to stay above the expected flood levels. If necessary, the tank overflow can be extended an additional distance downstream to avoid back flooding the tank.

Burrowing animals such as rodents or crayfish can sometimes burrow under or around the cutoff wall creating a path of escape for the spring water. In areas where this type of burrowing is known to occur, additional precaution should be taken to construct cutoff walls of adequate depth.

By far the most common issue faced in Ecuador is with roots growing into the spring collectors. Roots can clog the flow path reducing the effectiveness of the spring collector. Additionally, roots will eventually die and decay causing decreased water quality. It is not uncommon for native grass to extend roots of 2 to 3 meters in length.

La Pacifica spring prior to protection
Figure no. 8

Legal water rights should be obtained to use the spring water. Additionally, it is important to settle contested water rights issues on an adequate cultural and relational basis. Difficult and sometimes violent struggles over water rights are part of Ecuador's past where water is scarce. Our experience indicates that the importance of obtaining proper legal documentation and settling water rights issues before building should not be underestimated.

La Pacifica Spring

The pictures in figures no. 8 and no. 9 show the spring for the water supply to the community of La Pacifica. Figure no. 8 shows the spring prior to building a subterranean collection system as described in the previous discussion. Figure no. 9 shows the spring area completely covered with soil. Clean water is collected in the buried drainage system built with clean washed gravel and slotted pipe. The slotted collector pipe receives clean groundwater and transports the water to a receiving tank adjacent to the spring area.

La Pacifica spring after protection
Figure no. 9

Conclusions

Well-designed spring protection offers an advantageous sustainable method of producing high quality drinking water. This spring protection methodology fits well with community development principles and has demonstrated strong acceptance in more than 100 Ecuadorian communities over the past 25 years. We welcome feedback from others who have hands on learning in this area.

Acknowledgements

We are deeply indebted to scores of rural Ecuadorian communities which have patiently shared their learning with us and helped us to improve these techniques. The mutual accomplishments of protecting hundreds of springs which continue to provide thousands of cubic meters of clean water each day for rural communities has brought a sense of fulfillment which can never be expressed with mere words. Above all we are gratefully to the Almighty for his guidance and providence.

References

Rydbeck, Bruce and Yanez, Maritza. (2012). "Sustainable Water Quality for Rural Ecuadorian Communities." *International Perspective on Water Resources and the Environment Conference - January 2012.*

http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/ag473-15.html
http://www.rwsn.ch/documentation/skatdocumentation.2005-11-14.6529097230/file