Aquarius

Technical Issue Paper 4

Appraisal and monitoring of spring catchments and gravity fed systems

The purpose of *Technical issue papers* is to provide an easy and up-to-date point of reference on technical issues relevant for humanitarian interventions through the consolidation of field experience and current research.

They aim at providing information to assist in funding decisions and monitoring of humanitarian projects and not at providing definitive answers.

Technical issue papers are developed for internal use only and do not represent an official position of DG ECHO or the European Commission.

* * *

This *Aquarius technical issue paper* has been prepared by the Aquarius group of Watsan Technical Advisors of DG ECHO. It has been compiled by Benoit Collin and Alvaro de Vicente, and edited by Robin Lloyd and DenisHeidebroek.

Last update: 27/11/2008

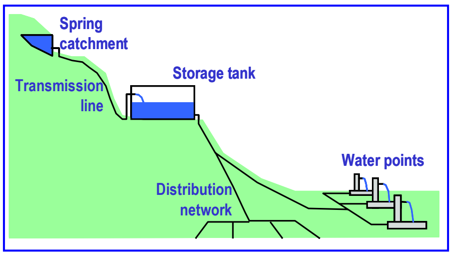
In post emergency situations but also in emergencies, most of the activities funded by DG ECHO in the sub sector of Rehabilitation, Development and Operation of Water Supply and Treatment Systems are dealing with wells, boreholes, spring catchments and water networks. Therefore, the purpose of this TIP is to cover specific technical issues to help you assess the conceptual soundness and functioning of Gravity Fed Systems at the different stages of a project (proposal, monitoring and evaluation). This paper does not address issues related to pumping systems and/or management of the water point, but provides an overview of specific technical issues to look at. Keep in mind that the quality of the design and of the construction is a prerequisite for the sustainability of the projects.

Overview of the Issue

Basics on springs and GFS:

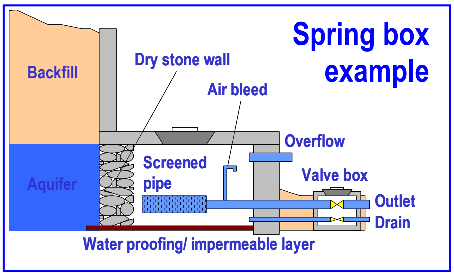
- Springs are locations where underground water rises naturally to the surface.
- The quality of the water and the relative ease to extract it are the main reasons why springs are often considered ideal water sources for villages and small to middle sized towns.
- A spring can be exploited either to supply a fully developed Gravity Fed System (GFS) or to provide water at a single outlet (fountain), which is set at a sufficient height to allow a bucket or container to be placed below it.
- The main conditions that should be fulfilled to implement a GFS are:
  - The source must be higher than the place where one plans to locate the water points (normally in the village/town). In order to avoid problems with air and sediments in the pipes, it is advisable to have a transmission slope greater than 1%.
  - The daily flow of the spring must be greater than the daily needs of the population served by the system.
  - The distance between the spring and the village/town may vary, but the cost of the system per beneficiary should not be excessive (Example: some agencies in Myanmar set a maximum of 60 meters of transmission line/beneficiary).
  - Considering the amount of work that goes into the construction of a GFS and the need for the community to eventually manage the system on its own, beneficiaries should be involved as early as possible. For that reason they are often requested to participate during the construction of the system (trench digging, cleaning, etc.). Assessing the demand and community willingness to participate is therefore an important precondition to assess the sustainability of the project.
- Except for emergency GFS, gravity fed systems are conceived to last for at least 20 years.
- GFS should be designed and constructed by professionals to ensure that they are technologically and socially adapted to the local context, functional, cost-efficient and sustainable.

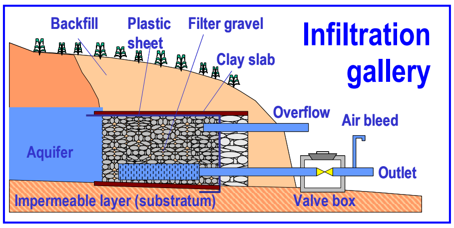
Parts of a Gravity Fed System (GFS)



1. Spring catchment

It is the most delicate and important part of the system. Spring catchments should be designed and built so that they are protected from contamination sources and able to collect the maximum yield of the spring. Every catchment is different, and its design mostly depends on hydrogeological characteristics. Nevertheless, catchments are generally classified as “spring box” or “infiltration gallery” (see drawings below).





Sometimes springs are not directly exploitable (too small, too far…) so the alternative is to catch water from its incoming stream. In this case one should check that there are no possibilities of contamination upstream of the intake (human settlement, livestock, arable areas, etc.). The construction of a sedimentation chamber just after the intake is sometimes recommended to reduce the water turbidity in times of heavy rains.

Experience shows that:

- Open spring catchments require regular maintenance and increase the risks of debris entering in the transmission lines and blocking the system.
- Deforestation around catchment areas may lead to a substantial decrease in the yield of springs. Fencing and limited reforestation with native plants is often recommended.
- Heavy rains can provoke the collapse of spring catchments without overflow (or badly designed ones).
- Private ownership of the land where the spring is located has often been a source of conflicts once the catchment is built. Prior agreements between the beneficiaries and land owners are recommended.

2. <u>Transmission line</u>
This is the pipeline which goes from the spring to the storage tank. Depending on the design, the transmission line may include elements such as break pressure tanks, air valves and wash-out valves (please refer to key definitions below). The most common materials for pipes are:

- HDPE (polyethylene): Usually the best technical option.
- PVC: generally easier to find in local markets
- GI (Galvanised iron/steel): appropriate for exposed pipes.

Experience shows that:

- Caution should be exercised when water lines go through villages or agricultural lands with no (or poor) water services. In such cases, the possibilities of "illegal" connections are high, as people will be tempted to make holes in the pipes. If necessary, the design of the GFS and its management should be reviewed and agreed upon will all stakeholders.
- River crossings are highly vulnerable to floods, and should be built considering DRR criteria.
- Road and elevated crossings are also vulnerable component of GFS (metallic pipe properly anchored is recommended).
- Pipes are often laid at inappropriately low depth, which increases their vulnerability.
- Anchorages should be installed in changes of direction or diameter, steep slopes, etc.
- DRR criteria should be considered when selecting pipe material (E.g. in seismic areas the use of metallic pipes is not recommended).

3. <u>Storage tank & Treatment</u>
The natural spring flow may be insufficient to satisfy the water demand of the population during peak hours. In this case a tank (or reservoir) should store the excess water during the hours of low demand (E.g. night) in order to cover the needs in the peak hours. The capacity of the storage tank should be calculated in such way that it guarantees uninterrupted supply throughout the day.

The tank is usually the place where water may be treated through chlorination. A drip chlorinator should be installed when disinfection of the water is considered necessary.

Experience shows that:

- A badly built tank can represent a risk for the population (the soil where tank is placed should be firm and not exposed to erosion).
- Bacteriological testing of the water may be necessary to detect potential contamination sources, and decide if chlorination is required or not.

4. <u>Distribution network</u>
This is the pipe system which carries water from the storage tank to the water points. In humanitarian settings it is usually a "branched" system. Valve boxes are usually found at every junction (intersection of several lines) and at the entrance of the buildings the network serves.

5. <u>Water point(s)</u>
This is where the water comes out of the system. Water points can be:

- Public tap stands: this is the usual case in less developed areas and in emergencies.
- Household connections: Taps are usually inside private yards or inside the houses. This option is of course more expensive but reduces the possibilities of pollution that often occurs in the process of fetching-transporting-storing water. In some contexts beneficiaries will only accept this option. As the water point is family owned, its maintenance is easier.

Experience shows that:

- Availability of affordable taps in the local market is sometimes more important for sustainability than the quality of the taps installed.
- Creation of separated water points for livestock in rural areas increases the sustainability of the system. The use of mixed GFS (for potable water and agricultural/irrigation purposes) should be discouraged.
- In some specific settings, water meters may exist at water points. These can be used to prevent the misuse & wastage of water, and eventually facilitate the sustainability of GFS.

6. <u>Drainage - Disposal of waste water</u>
Although often overlooked, safe disposal of waste water should be considered in the project. This is not usually a problem in rural areas where waste water can be easily disposed of through soak pits, infiltration trenches or irrigation of small vegetable gardens. On the other hand it can pose serious difficulties in urban settlements where the availability of space to evacuate waste water is limited. Storm water drains and/or sewerage systems are not always present in peri-urban or low-income areas, or do no longer function because of a lack of maintenance.

Key definitions:

- Flow/ yield: Volume of water flowing per unit of time. Usually expressed in litres per second (lts/sec).
- Head Loss: Loss of pressure caused by the friction between the pipes and the water. It increases with the flow and decreases as the diameter of the pipe increases.
- Residual pressure: Pressure of the water when delivered at the water point.
- Peak hour: Hour of maximum water consumption in the day.
- Break pressure tank: Small tank allowing water to return to atmospheric pressure. It is used when the difference of elevation between two points is too high for the pipes to resist rupture.
- Air valve: Valve allowing air to be released from the pipe. They are usually installed in the high points of the trajectory.
- Wash-out valve: Valves used to empty the flush out the system. They are installed in the lowest parts of the system and usually required when water carries sediments or when the speed of the water is too low.
- Overflow: Pipe allowing excess water to safely exit spring catchments or tanks when the maximum level is reached. They are especially important in catchments, where they should not be higher than the natural level of the water found in the source.

Implementation steps

1. Feasibility study
This step allows us to know whether the conditions to build a GFS are met. It should be done at the end of the dry season. Conditions are:
- Water quality OK.
- Daily source flow > daily water needs
- Elevation source > elevation village
- Reasonable distance source-village
- Community & land owners agree.

2. Topographic and detailed survey
This survey is done (in agreement with the beneficiaries) with more precise instruments, and its purpose is to define the routes and layout of pipes (transmission line & distribution network) as well as the location of the other system components (storage tanks, water points, etc.)

3. Design and calculation
Once the required technical data has been collected, one needs to calculate if and how water should be treated, the diameter of the pipes in each sector, the capacity of the tanks, the valves to be installed, etc. The hydraulic calculation is compulsory in the case of permanent systems and can be done manually (using abacus), excel files or specific software (e.g. Epanet). The design of the system should take into account the expected population growth rate for the next 20 years.

GFS should be designed on the basis of national norms and standards, although it is possible to apply the "Sphere Standards" in case of emergencies.

4. Construction
The construction of a GFS is a long process that usually requires the involvement and participation of the beneficiaries. Construction plans should be adapted to calendar and preferences of the community. Logistic constraints are also to be considered, as the process of tendering, procurement, transport and delivery of pipes and fittings usually takes time. Work often starts with the masonry (water points, catchment and reservoirs) and concludes with the laying of pipes and the plumbing. Once the parts of the system are connected and before pipes are covered with compacted soil, a pressure test should be carried out by a technician, in order to verify that the system functions correctly and to localise eventual leaks.

5. Ensuring operation and maintenance:
It is extremely important to ensure that the beneficiaries have the capacity to operate, maintain and/or improve the water system. Good practices are:
- Early definition of the management model by the community and approval of the design.
- Provision of tools and spare parts.
- Training of technicians and of the water committees.
- It is recommended to establish a "hand over period" after which the partner will come back to the village in order to verify whether everything works well and replace/fix eventual failures.

Specific cases:

Emergency GFS
In cases of acute emergencies, simpler (but safe) systems may be temporally constructed. Civil works are limited and portable prefabricated elements can be used:
- Water catchment can be a small and simple dam done with sand bags. Sometimes water is taken from streams and not from springs. In this case water should be chlorinated.
- Pipes are frequently not buried, as installation must be quick. This allows also a quick localisation of the leaks.
- Tapstands are often set up without any masonry work and are pre-fabricated.
- Reservoirs are also prefabricated: rigid plastic, Oxfam type, flexible (bladders, onion, etc.).
- Pipes used can be of the "heliflex" type or even fire hoses, although one should consider that these are not very appropriate due to the high head losses.
- Measurements of height and length, as well as calculations do not need to be as precise as in case of permanent GFS. Elevation can be measured with an altimeter and length with a GPS.
- At a first stage, management of the system can be done by the staff of the implementing agency.

Rehabilitation
Most existing GFS systems will require a certain level of fixing up in order to meet the water needs of the population at risks. If major rehabilitation or an extension is foreseen (not just replacement of small parts), a thorough technical assessment should always be done ahead of any work in order to verify:
- How the system was designed and built (It is usually better to build new systems than to rehabilitate poorly designed systems that will give problems in the future).
- How old and how damaged the system is (old systems or those with extensive damage are better replaced than repaired).

References

- *ACF – Water, Sanitation and Hygiene for population at risk.*
- *RedR – Engineering in Emergencies*
- *Field Engineering. Peter Stern and F. Longland, Intermediate Technology Publications, London, 1983.*
- *Small Community Water Supplies. From IRC, WHO Collaborating Center, Intermediate Technology Publications, London, 1981.*
- *A Handbook of Gravity-Flow Water Systems. Thomas D. Jordan Jr., UNICEF, 1980. Reprinted by Intermediate Technology Publications, London, 1992, 1996.*
- *Practical Hydraulics Handbook. Barbara A. Hauser, Lewis Publishers Inc., Chelsea, Michigan, 1991.*
- *Developing and Managing Community Water Supplies. Jan Davis & Gerry Garvey, Oxfam, Oxford, 1993.*

Web

- *http://www.cee.mtu.edu/peacecorps/documents_july03/Visualizing_Gravity_Fed_Water_System_FINAL.pdf*
- *Water for the World. From USAID (1982) (http://www.lifewater.org)*
  - *i. Designing a System of Gravity Flow*
  - *ii. Methods of Water Treatment*
  - *iii. Selecting Pipe Materials*
  - *iv. Installing Pipes*
  - *v. Selecting a Source of Surface Water*
- *Water Aid: http://www.wateraid.org/international/what_we_do/how_we_work/sustainable_technologies/technology_notes/2058.asp*

Checklist for appraisal/monitoring of ECHO funded operations:

1. Appraisal of the proposal:

Steps already undertaken

- ❒ Has the partner worked before in the area?
- ❒ Is the feasibility study done?
- ❒ If yes, verify list of locations and data.
- ❒ If no, verify if it is to be done at the end of the dry season.
- ❒ Is hazard risk analysis done or foreseen?

Costs

- ❒ Try to ensure that no "massive" works are planned (remember that long distances between spring and village reduce the effectiveness and increase the technical difficulties).

Human resources

- ❒ Engineers with skills in GFS design.
- ❒ Plumbers.
- ❒ Masons.

Equipment/ material,

- ❒ Measurement equipment:
  - GPS, altimeter, clinometer/ theodolite.
  - Water testing kit.
- ❒ Pipes and fittings.
- ❒ Cement, iron.

Time schedule and delay

- ❒ Verify that all steps are in the time frame.
- ❒ Will the feasibility study be done in time?
- ❒ Is the community calendar considered?

Technical capacity of the partner

- ❒ Are experienced engineers foreseen in the proposal?
- ❒ Has the assessment been done by somebody technically knowledgeable?

---

2. Monitoring/ evaluation

Monitoring visits will be more relevant while the construction works are being done (e.g. pipe installation) or when they have been recently finished.

In case of non-emergency interventions, evaluations done several years after the conclusion of the project are useful to evaluate the sustainability of the works carried out.

Assessment done

- ❒ Feasibility study
- ❒ Topographic survey
- ❒ Community involvement in assessments

Design

- ❒ Verify that there is a plan of the system. Try to understand it before visiting it.
- ❒ Verify hydraulic calculation sheets, or at least be sure that hydraulic calculation has been done properly. In order to know about whether the design was done by skilled personnel, ask about:
  - Residual pressure in taps
  - Method used for hydraulic calculation
  - Method used for calculating tank capacity
- ❒ Involvement of community in water point location.
- ❒ Integration of DRR measures in the design

Construction

- ❒ Visit the spring catchment and verify:
  - Catchment is sealed and closed to external contamination.
  - Catchment area protected against floods, landslides, animals, etc.
  - Cut-off drain to divert surface water
  - Absence of cracks and leaks.
  - Overflow placed lower than the initial level of the water.
  - Cleanliness.
  - Frequency of the maintenance.

- ❒ In the case of stream catchment:
  - System to reduce turbidity in the rainy season (filter, sedimentation tank?)
  - Intake protected against increase of stream level and heavy current.
- ❒ Visit some points of the transmission line and check:
  - Pipe is appropriately buried (minimum 60-80 cm deep)
  - Wash-out valves in lower points and air valves in higher points of the route.
  - Risks of natural hazards have been considered.
  - Critical points (river crossings, exposed segments, change of diameter/direction) have been reinforced/ anchored.
  - No plastic pipes are exposed.
- ❒ Visit the storage tank and verify:
  - It looks strong and impermeable (liner, plastering or water-proofed treatment of inside walls)
  - Has a concrete test been done? Has the construction been supervised by a technical person?
  - Absence of leaks and cracks.
  - Overflow, wash out and valve chamber at the outlet.
  - Protected against external pollution.
  - Could the tank represent any risk towards the population if it collapses?
- ❒ In the distribution network, visit a couple of valve boxes and verify that:
  - Valves seem to be properly installed
  - Absence of leaks in junctions (no water in the box)
  - There are unions in order to remove/ replace the valves if necessary
  - It is protected, there is a locked cover that opens and closes properly.
- ❒ Visit a few water points and verify:
  - Reasonable number of people per tap (Key indicator Sphere Standard is 250 people/tap)
  - Reasonable distance to dwellings (Key indicator sphere is 500 m)
  - The tap looks strong.
  - Cleanliness of the surroundings
  - The water comes out with enough pressure.
  - Is it properly isolated against freezing (in cold areas)
  - Water quality (check residual chlorine and turbidity).
  - There is a drainage and appropriate evacuation of waste water.
  - It is protected against animals. There are alternative water points for livestock.

Questions for the beneficiaries (user feedback):

- ❒ Has the system worked properly since it was finished? Do they have any complaint?
- ❒ Who is responsible for the maintenance of the system (water committee, private, administration, etc.)?
- ❒ Is there a system to cover the expenses of the maintenance (e.g. collection of fees) Do they obtain any benefit from that?
- ❒ Has the implementing partner provided training for the management of the system?
- ❒ Has the partner handed over the system officially? To whom?
- ❒ Has the partner given a set of tools and spare parts? Are spare parts available in the local market?
- ❒ Are there “illegal” connections in the system? (individuals connecting by themselves to the system without authorisation, this would be a negative point)
- ❒ How are new connections granted/ regulated?
- ❒ Who is responsible (and how often is it done):
  - Replace the taps
  - Clean the reservoirs and sedimentation chambers
  - Clean the filters (if any)
  - Empty air from pipes (when air valves are not automatic)
  - Empty sediments from pipes

The purpose of the above monitoring tools is to ensure that GFS function correctly (technically speaking), and to a lesser extent, are well managed. The next step of the monitoring process should look at whether the facilities are utilized correctly by the beneficiaries.