Attachment to ARC / WASH solutions for schools, version February 2012

Water Source options

Below is a series of examples, organized per water source.

If the option is available, the following priority sequence is the most likely, but exceptions are always possible. Except for the second and third solutions (link to existing water points), the solutions are elaborated in separate fact sheets. Lifting devices, tanks and treatment options are dealt with in later sections.

1.**Gravity systems.** Connection to a nearby spring and bring water to the school by gravity with pipes. Investment cost can be high 1.000 - 50.000 US$ but operational costs are very low and quality is mostly very reliable. Protection of the spring area (and feeding area) and seasonal variation are points to consider.

2. Connection to an **existing Piped Water scheme** in case this one is reliable. Cost is mostly at a very acceptable level (0.2-0.8 US$/m3), quality is reasonable and operation and maintenance is shared with others. Additional point of use treatment might be required and there is a risk the water maybe cut off in case of non payment.

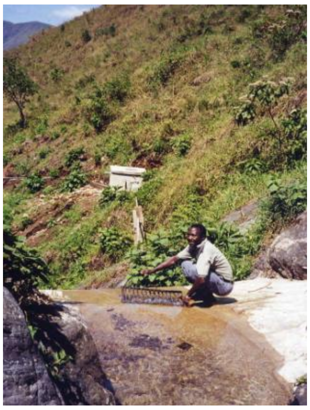
3. Use of an existing nearby **Public water point**. If this is far from the school the disadvantage is the walking distance with a heavy container, especially for small children, and may be the insecurity for small children and girls. A wheel-chart with containers might ease the supply to the school.

4. **Shallow well with cover**. Disadvantage is the maintenance of pumps and the risk of contamination. Making a shallow well is difficult or impossible where the soil is too rocky or in general where water levels are deeper than 15 meters. Depending on the type of hand pump a shallow hand dug well with hand pump costs € 500 - € 4.000 (Africa).

5. **Deep well/borehole**. Disadvantages are high investment cost, risk of failure to find water at or near the school and the maintenance of pumps. Cost of a borehole with a hand or electric pump depend on depth of the aquifer and geology. Drilling through rocks is expensive. In Africa, cost ranges from € 3.000 and € 12.000. New drilling methods and low cost and locally produced hand pumps can in some situations be an option. An example is in the South of Tanzania (Njombe). School water points there consist of a manually drilled borehole and a rope pump at 40 m deep. Total cost € 650 – 800. A good website for guidance on boreholes and handpumps is www.rwsn.ch

6. **Rain water harvesting**. Mostly applied where there is no alternative or as an add-on on other systems. In the examples below we distinguish roof top harvesting, run off collection, stream water collection, ponds and reservoirs, sand dams and subsurface dams.

Spring Intake and gravity

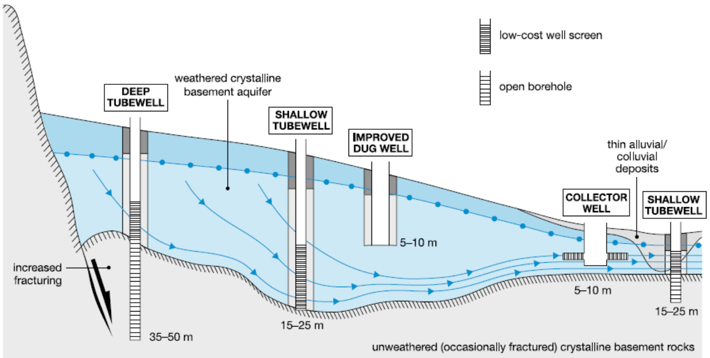


Spring intake and start gravity main SW Tanzania (Aqua for All)

Principle	Water from a permanently flowing natural spring is captured and brought to the school, mostly by gravity.
Factors	Minimum flow of the spring at the end of the dry season. * Chemical water quality (mind fluoride, hardness) For gravity, the spring needs to be higher than the school without higher hill tops in between Design capacity should include 20 years growth of school and might incorporate Multiple use (gardening) and inclusion of community ** A school/community of 500 people using 20 l/day needs 10.000 l/day, or 0,12 liters per second. The mimimum flow can be determined by measuring 3 times the flow during one dry season and extrapolation to the maximum length of dry season.*
Elements	• covered and protected spring chamber • collection chamber • gravity main (pipe) with wash out valves in lows and air release valves in highs • (raised) storage tank (capacity of half a day flow); mind overflow
Special features	• Be aware of 'false natural springs'; re-appearing surface water • Erosion and catchment protection • Deviate upstream drainage water • Break pressure tanks are required when too high differences in height are reached (each 60 meter difference in altitude) • Hydraulic calculation includes friction losses in pipe. Design flow, pipe type and available height difference determine the required pipe diameter. Let the hydraulic design be made by an engineer. • Poly pipes (HDPE) are the most economic and flexible, but need to be buried in 60 cm deep trenches. If pipe is at or above surface when crossing gullies or hard rock, steel pipes are required.
Optional:	Pump chamber and pump if spring is below school level or if pipe line has to pass a hill top
Treatment	Pretreatment by screen or strainer (large particles/dirt/frogs) . If well made and protected, no additional disinfection or treatment is required.
Main cost element	Pipe line is the most costly (€2 - €10 per meter, including labour). Tank might be a cost component. Capping of small springs mostly less than € 1.500. Mostly applied if a small spring is nearby; otherwise to be combined with community supply.
Maintenance	Bi-annual check/cleaning at spring and weekly check of pipe line. Funds for replacements.
Considera-tions	Ownership of source or user rights have to be arranged. Mind traditional rights. Depletion of spring yields by upstream land use changes and climate change. For hard water, pre-oxydation near the source is recommended (contact with air)
References	www.akvo.org (water portal), www.IRC.nl,

Groundwater by dug wells

Hand pump on shallow dug well



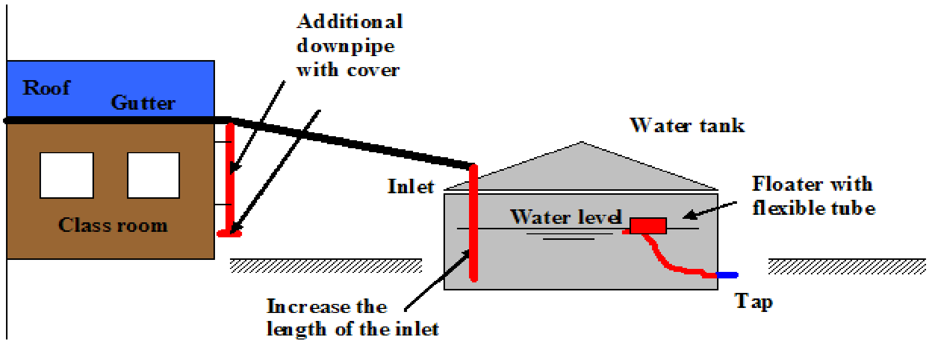
Positioning of dug wells and tube wells (source: Worldbank)

Principle	Shallow underground water is reached by digging a well. The well is protected by a cover. A lifting device is selected that prevents the entrance of dirt into the well.
Factors	The depth to water level should be less than 15 meter.* There should be a water bearing layer within less than 15 meter.* Chemical and biological water quality. Soil should be good to dig.** Distance to a sanitation unit, waste dump or other source of contamination at least 50 m. * in some countries wells are dug much deeper (examples of 70 m) ** in some regions, well diggers can easily dig into hard rock
Elements	• dug hole with lining of walls; mostly a filtering ring at depth and closed concrete rings above • a closed (and impermeable) cover on top • an impermeable (concrete) slab around the well and a drain to prevent re-entry of dirty drainage water and to avoid unhealthy muddy surroundings • a lifting device (see separate section)
Special features	• digging in hard rock and in fluid sand/silt requires special skills • pumps for schools are described in separate section . For shallow water levels, pump types can be cheaper and more maintenance friendly than for deep levels
Optional:	Pump to a raised tank (small electric pump (solar) or EMAS handpump). Use a simple but sturdy hand pump (soaking or direct action). Alternative to strong lining is the 'rooted reservoir well' of EMAS (see akvo)
Treatment	Generally, no additional disinfection or treatment is required if there is no chemical problem, wells are well made and sealed and water is collected in clean containers that are closed afterwards. For shallow groundwater, special consideration is to be given to chemical compounds, like iron, arsenic, salt and nitrates. Turbidity should not be a problem. Oxydation might be recommended if the water has no oxygen.
Main cost element	Digging and construction is the major cost component and largely dependent on depth, soil type and cost of labour. Cost vary between € 400 and € 4.000.
Maintenance	Regular greasing and maintenance of pump. Daily cleaning of surroundings.
Considera-tions	Digging preferably done in season with lowest water tables Best site for a successful well is depending on physical, economical and social factors. Physical siting techniques can save time and energy. Examples are manual test drilling and geophysical surveys. The latter can provide information on expected type of soil, depth of layers, salinity of water and sometimes depth of water table. Main principle of a dug well is the storage. Main principle of a drilled well is the yield.
References	www.akvo.org (water portal), www.IRC.nl, is www.rwsn.ch

Groundwater by drilled wells

Baptist drilling (left) light machine drilling (middle) and pumping(right)

Principle	Shallow or deep underground water is reached by drilling a well/borehole. The well is protected by a cover. A lifting device is selected that prevents the entrance of dirt into the well.
Factors	There should be a good water bearing layer * Chemical and biological water quality. Distance to a sanitation unit, waste dump or other source of contamination at least 50 m. * A drilled well has a much smaller diameter (mostly < 15 cm) than a dug well (mostly 100-150 cm), the stored volume in the drilled well is relatively small. Hence, the water transporting capacity of the water bearing layer should be much better than with dug wells. Minimum yield is about 750 liters per hour, otherwise the borehole is considered as ‘dry’.
Elements	• drilled hole with casing and filters at depth; filters are surrounded by a gravel pack; the upper part of the casing is surrounded by a clay seal. • a closed (and impermeable) cover on top • an impermeable (concrete) slab around the well and a drain to prevent re-entry of dirty drainage water • a lifting device (see separate section)
Special features	• there are many drilling technologies. Apart from the expensive machine driven technologies, there are several economic manual driven methods (see first column under http://www.akvo.org/wiki/index.php/Portal:Water).
Optional:	Pump to a raised tank (small electric pump (solar) or handpump).
Treatment	Generally, no additional disinfection or treatment is required if there is no chemical problem, wells are well made and sealed and water is collected in clean containers that are closed afterwards. For shallow groundwater, special consideration is to be given to chemical compounds, like iron, arsenic, salt and nitrates. Turbidity should not be a problem. Oxydation might be recommended if the water has no oxygen.
Main cost element	Drilling is the major cost component and largely dependent on depth, drilling technology, soil type, cost of labour and remoteness. Cost vary between € 10 and € 150 per meter depth.
Maintenance	Regular greasing and maintenance of pump. Daily cleaning of surroundings. Security.
Considera-tions	Best site for a successful well is depending on geological, physical, economical and social factors. Physical siting techniques can save time and energy. Geophysical surveys can provide information on expected type of soil, depth of layers, salinity of water and sometimes depth of water table.
References	www.akvo.org (water portal), www.IRC.nl, is www.rwsn.ch

Method	Rain Water Harvesting – Roof top
	*Roof top water harvesting in Kwale District, Kenya (Tende Pamoja). Mind First flush, deep inlet and floating tapping device*
Principle	Rain water falls on a (hardened) sloping roof. The water is collected in a gutter from which the water flows into a storage tank.
Factors	The volume of water that is drained from a roof in liters is the surface area A (m2) times the rainfall (in mm) times an efficiency factor. The efficiency factor for an iron roof is commonly around 0.75, but much lower if much water is spoiled when it overflows the gutter. Systems might be over dimensioned in case they need also to serve the neighboring community. If the tank is required to be full at the start of the dry season, the volume (in liters) is the surface area of the roof multiplied by the average rainfall in the wet season (in mm) times the efficiency factor minus the volume of water used during the wet season. Available water during dry season is calculated as follows. Assuming the tank with volume V (in liters) is full at the start of the dry season, then the daily volume per pupil in liters/day is Volume divided by number of pupils divided by maximum length of dry period (in school days). This should be at least 5 l/pupil per day. The best is to make these calculations for different drought scenarios.
Elements	• Inclined roof (clean and hard) • Gutters with sufficient slope (> 5 cm/meter) • Screen and first flush (several types) • Drainage pipes • Storage Tank (ground tank or underground tank)
Special features	• Efficiency can be increased with flush board over the gutter • Keep all openings closed for insects and animals • Avoid leakages and mind drainage at tap point • trap the tap water just below the water surface (floating device) • overflow can be guided into the subsoil for recharge
Optional:	Underground tank is cheaper, but needs water lifting. Other option: Pump and raised tank (small electric pump or EMAS handpump)
Treatment	Mostly some disinfection (chlorine, silver in tank; or ceramic filter at point of use). Carbon Filter if taste is an issue.
Main cost element	Covered water tank (many options: brick, ferro-cement, concrete, Plastic, sub-surface with foil) € 10 – 150 per m^3 storage volume.
Maintenance	Regular cleaning of gutter and first flush; annual cleaning tank; treatment
Considera-tions	Limited quantity during the dry season; sensitive for extreme dry spells. May be refilled from water tankers. If shared with surrounding community, strict regulations need to be in place.
References	www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl, www.agromisa.nl; www.rainwater-toolkit.net

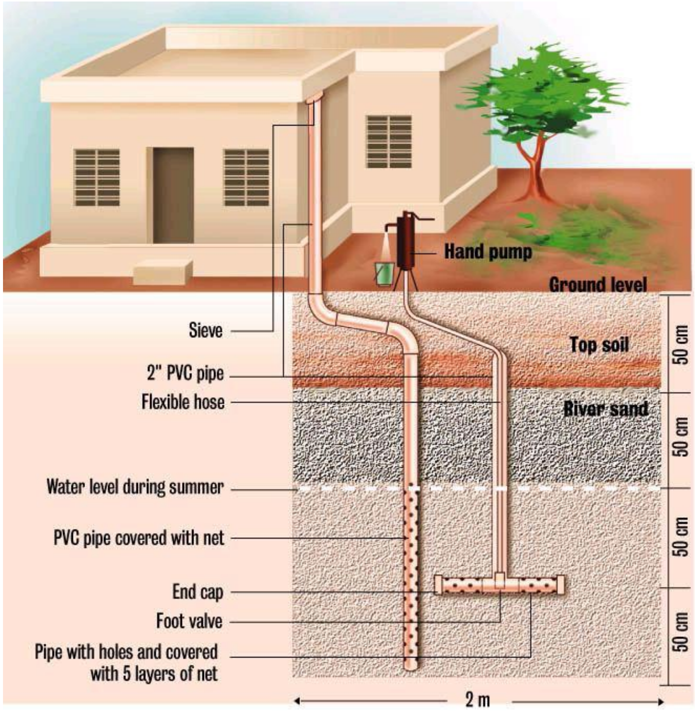
Rain Water Harvesting – Soil/Rock surface

Run off water collection
left: using foil (Tunesia);
right: in Borana, South Ethiopia (Rain Foundation). Mind sand traps and half circle reservoir

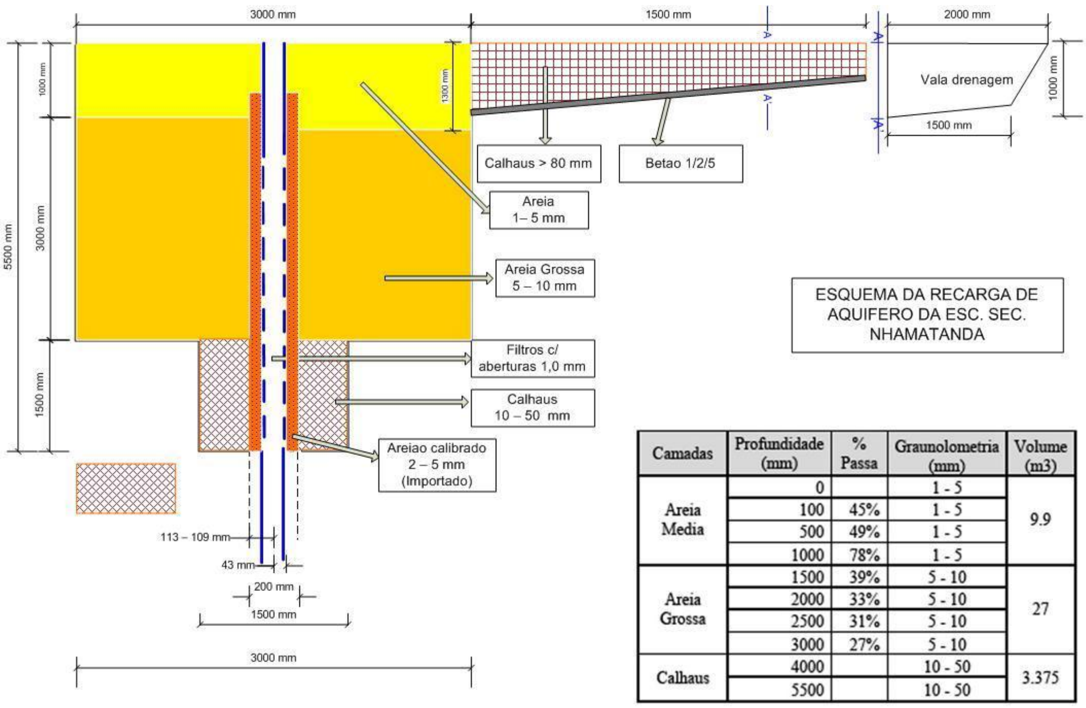
Principle	Rain water falls on a (hardened) soil surface. The water is collected in an underground tank, mostly after pre-filtration.
Factors	Q= Available water during dry season: (A*P*E)/(N*L_2) in liter per pupil per school day A = Surface area of (hardened) that can be used (in m2) P = Annual Rainfall (in mm/year) E = Collection efficiency factor (varying from 0.25 for grass to 0.8 for concrete or tarmic) N = Number of pupils L_1 = Maximum length of dry season (in days) L_2 = Maximum number of school days during L_1 (in days). Mind that this is an average; try to make the calculation for extreme years with 70% of mean annual rain fall and the once in 10 years long drought.
Elements	• (hardened) protected ground surface • Screen and sediment trap • Storage Tank (Minimum Volume L_2*N*Q in liters) • Treatment and pump
Special features	• Efficiency can be increased by hardening surface and cutting the vegetation • Erosion protection • Possibly protected surface • Overflow can be used
Optional:	Pump and raised tank (small electric pump (solar) or EMAS handpump). Use a simple hand pump (soaking or direct action).
Treatment	Pretreatment by screen (large particles/dirt) and sediment trap. Sediment trap is large device with less than 4 m/hour water velocity and at least 1 hour retention time. Before pumping, water can be lead through a sand bed in between pump and reservoir. Treatment/disinfection is essential before use
Main cost element	Covered water tank (many options: brick, ferro-cement, concrete, Plastic foil, crates); cover can be concrete, sheets, nets, grass. € 5 – 100 per m^3 storage volume.
Maintenance	Regular cleaning of surface area and repair of protection;; bi-annual cleaning tank; treatment
Considera-tions	Mainly applied when rainfall is too little for roof top water harvesting. Avoid inflow of human and animal excreta
References	www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl; www.practicalaction.org

Below some alternative examples of use of rainwater in which the underground is used to store the water instead of a tank. The underground has often a much larger storage capacity. There are many geological conditions, where the water is not ‘lost’, but remains accessible. Of course such solutions require higher investment costs.

Example 1: Nhamatanda/Mozambique – rain water used to infiltrate into the ground from where it is repumped (a) from roof top and (b) from soil surface (Unicef 2008).



Example 2: same source as example 1



Camadas	Profundidade (mm)	% Passa	Graunolometria (mm)	Volume (m3)
Areia Media	0		1 - 5	9.9
	100	45%	1 - 5	
	500	49%	1 - 5	
	1000	78%	1 - 5	
Areia Grossa	1500	39%	5 - 10	27
	2000	33%	5 - 10	
	2500	31%	5 - 10	
	3000	27%	5 - 10	
Calhaus	4000		10 - 50	3.375
	5500		10 - 50	

Stream Water Collection	
 *Bottom intake (SW Tanzania)*	
Principle	Water from a permanent stream is collected by an intake or pump and lead into a tank near the school. The water is to be treated. Water can be pumped straight from the river or can be pumped from a pump chamber after pre-sedimentation.
Factors	The system has comparable elements with the earlier described 'spring water collection' and 'run off water collection'. Water turbidity, flood/damage risks (including the flooding of chambers and pumps), upstream changes and pollution are important factors to consider. Maximum and minimum flows (and water levels) need to be estimated.
Elements	• intake structure including pre-screen • deviation structure, bringing the water beyond the flood zone • sediment trap or roughning filter • possible pump chamber and pump house • transport main • tank • Treatment and pump
Special features	• Point and design of water intake is very important to reduce sediment inflow and to guarantee continuous inflow (stilling basin/reservoir, bottom intake; side intakes). Smart designs are developed for small hydropower systems. • A gallery connecting the river to a protected pump well at the river bank might prevent many problems • Sediment trap is large device with less than 4 m/hour water velocity and at least 1 hour retention time. More sophisticated is the roughning filter.
Optional:	A pump at the river bank or on a pontoon can also pump water straight from the river. Beware flooding and risk of crocodiles.
Treatment	Pretreatment by screen (large particles/dirt). Turbidity reduction required (sediment trap or roughning filter) Before pumping, water can be lead through a sand bed in between pump and reservoir. Treatment/disinfection is essential before use Chemical treatment is rare, but mind upstream chemical pollution (mining, industry)
Main cost element	Intake and treatment structures If included: pump house
Maintenance	Regular cleaning of chambers. Daily operation. Repairs.
Considera-tions	Permits might be required to use surface water. Generally, this option is too complicated for a school.
References	www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl

Pond Water Collection

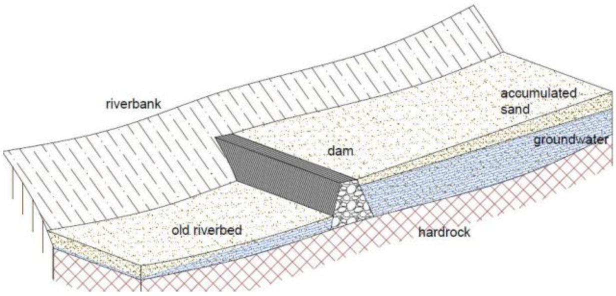
Picture still to be added.

Left: sand trap (Borana, Ethiopia)

Right: Spring pond near Arusha Tanzania

Principle	Water from a (seasonal) stream or temporary run off is collected in a pond or reservoir, from where it is pumped to a tank near the school. Or water is taken from a well near the pond. The water is to be treated.
Factors	The system has comparable elements with the earlier described 'spring water collection' and 'run off water collection' and stream collection. Water turbidity, flood/damage risks (including the flooding of chambers and pumps), upstream changes and pollution are important factors to consider. Maximum and minimum flows need to be estimated.
Elements	• a pre-sediment trap before the entrance; may also be a reed bed or vetiver grass strip • possibly a dam (earth, stone/masonry) • an overflow/spill way and a hardened dump • possibly a dug out • intake structure for water supply • sedimentation chamber • possible pump chamber and pump house • transport main • tank • Treatment and pump
Special features	• Pond or reservoir should be fenced. • Evaporation can be reduced by 'wind breakers' (shrubs, trees) or sheet covers/nets • A gallery connecting the pond to a protected pump well at the river bank might prevent many problems • Sediment trap is large device with less than 4 m/hour water velocity and at least 1 hour retention time. More sophisticated is the roughning filter.
Optional:	
Treatment	Pretreatment by screen (large particles/dirt). Turbidity reduction required (sediment trap or roughning filter) Before pumping, water can be lead through a sand bed in between pump and reservoir. Treatment/disinfection is essential before use Chemical treatment is rare, but mind upstream chemical pollution (mining, industry)
Main cost element	Intake and treatment structures If included: pump house
Maintenance	Emptying of sediments in pond/reservoir. Regular cleaning of chambers. Daily operation.
Considera-tions	Permanent standing water is a health risk. Ponds should be at some distance from schools. Fish might be used to fight mosquitos. Permits might be required to use surface water. Generally, this option is too complicated for a school.
References	www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl

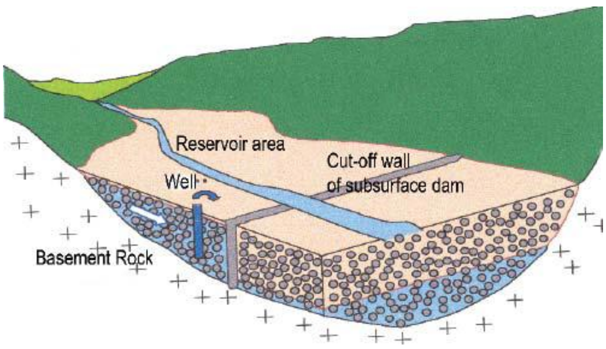
Sand Storage dams



Run off water collection in Borana, South Ethiopia (Rain Foundation). Mind sand traps and half circle reservoir

Principle	A low dam is placed in a stream bed with intermittent flow. When there is storm water, a sand body is created behind the dam. This sand body will keep groundwater.
Factors	This technology is only applicable in stream valleys with an impermeable base, a gradient of more than 3% and sufficient sand transport from upstream.
Elements	• a dam (mostly stone masonry), well anchored into the valley sides • a well connected to the main sand body (may be through a connecting drain)
Special features	• Part of the sand bottom needs to be fenced to avoid direct contamination of the shallow ground water. • In areas with less sand, the sand body might be developed by raising the wall every year with half a meter.
Optional:	Instead of a well, the water could also be tapped (by gravity) through a drain, leading to a lower tank with an automatic floating ball valve
Treatment	If well constructed and well protected, there is hrdly any need for treatment. Disinfection might be recommended, because of risk of short circuit in the sand body.
Main cost element	Dam (between € 5.000 and € 15.000). Dam can be for a school alone, or shared with the community.
Maintenance	Emptying of sediments in pond/reservoir. Regular cleaning of chambers. Daily operation.
Considera-tions	Maximum floods/stages are important to consider. Erosion is a risk at the side walls and at the spilling floor.
References	www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl; bebuffered.nl; www.waterforaridland.com

Subsurface dams and galleries



Sub-surface dams (from Belgina publication on Turkana case; www.bebuffered.com

Principle	A blocking wall is constructed in the river bed. The water in the river bed will remain and is available for use.
Factors	This technology is only applicable in stream valleys with an impermeable base and a sandy river bed. The river bed should not be too wide and rather stable.
Elements	• a wall (mostly stone masonry, but can also be compacted earth/clay or plastic sheets), • a well connected to the main sand body (may be through a connecting drain/gallery of filter pipe or even concrete)
Special features	• Part of the sand bottom needs to be fenced to avoid direct contamination of the shallow ground water. • In areas with less sand, the sand body might be developed by raising the wall every year with half a meter.
Optional:	If there is sufficient gradient, the water can also be drained through a tube to a downstream tank with a automatic floating ball valve. If the river bed has permanent water, the subsurface dam may not be required and a gallery could suffice.
Treatment	If well constructed and well protected, there is hardly any need for treatment. Disinfection might be recommended, because of risk of short circuit in the sand body.
Main cost element	Dam/wall. Depending depth of impermeable base and width of river bed.
Maintenance	Water collection device. Flood damage
Considera-tions	Maximum floods/stages are important to consider. Erosion is a risk at the side walls and at the spilling floor.
References	www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl; bebuffered.com; www.waterforaridland.com; Erik Nissen-Petersen