ASPI APPALACHIA
SCIENCE IN THE PUBLIC INTEREST
Route 5, Box 423 Livingston, KY 40445

CISTERNS

ASPI Technical Series

The following discussion is derived for Appalachia from hands-on experience at ASPI, but it is generalized to apply to water catchment systems in many parts of the world, especially the Third World. This is particularly applicable where water may be collected at plentiful times of the year and used in times of drought or low groundwater yield. Cisterns are also effective where aquifers are contaminated due to human waste disposal practices, lack of proper landfills, excessive land disturbance, and poor sewage disposal conditions.

For these reasons, it is apparent why water conservation is required in areas of relatively heavy rainfall. Many parts of the world are facing critical water shortages. Rural areas are better able to handle their own water problems, where cisterns are part of the water system and the people cannot expect massive infusions of outside assistance. Solutions will most likely be more individualistic, be at relatively low-cost, use native materials where possible, and be effective as means to conserve and preserve the quality of domestic water. Cisterns are good examples of an appropriate technology that is low cost, maintained at minimum expense, and easily serviced.

A cistern (Latin "Cisterna") is a receptacle for storing water, and is generally a tank, usually underground, in which rain water is collected for domestic use. However, some cisterns stand above ground or are partially buried and store spring or ground water as well as surface run-off. The water may be withdrawn manually or mechanically with the distribution system similar to that used for other water sources (see Diagram 1).

These devices have proven track records going back long before Jeremiah the Prophet was thrown into one. They have been popular in semi-arid regions where there is considerable rainfall during only one season of the year. Some cisterns built in this country continue to be of service to domestic households long after installment. Others have not been properly maintained and have lessened the popularity of cisterns among governmental water management and environmental officials. This is a problem with ease of control from a central office, not a deficiency of the cistern as such.

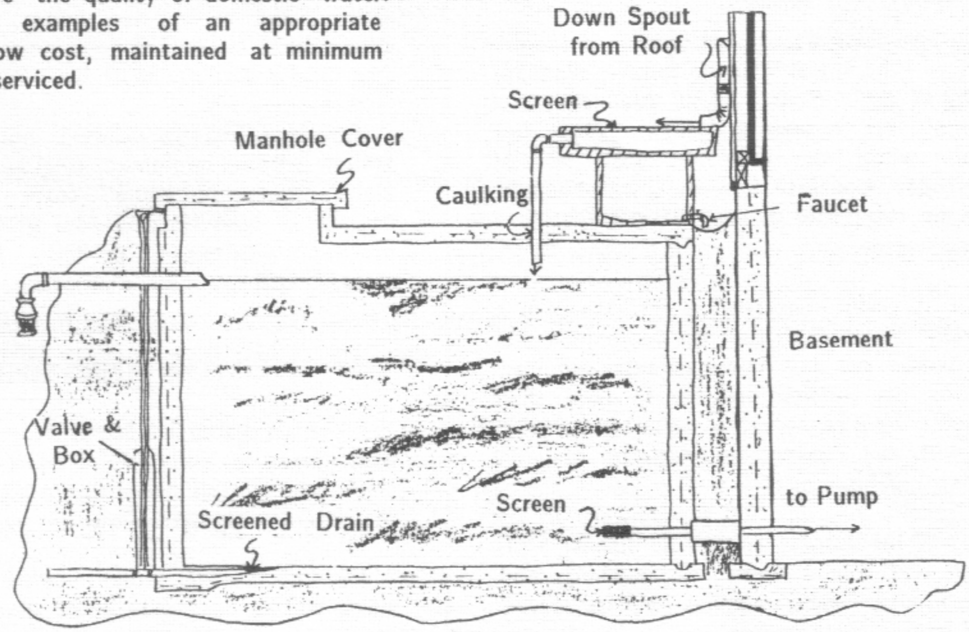

Diagram 1. CISTERN

CISTERN ADVANTAGES

* Can be built at a low-cost per unit and do not require expensive municipal water systems in rural areas;

* Are less risky than well-drilling gambles;

* Do not have the high salt or iron content, or other chemical contamination present in some groundwater;

* Are able to provide good quality water which is near-at-hand;

* Are under the homeowner's complete control;

* Have no water bills attached;

* Do not need chlorination;

* Are not subject to unexpected breakdowns and have low maintenance costs;

* Are a good way to conserve precious water.

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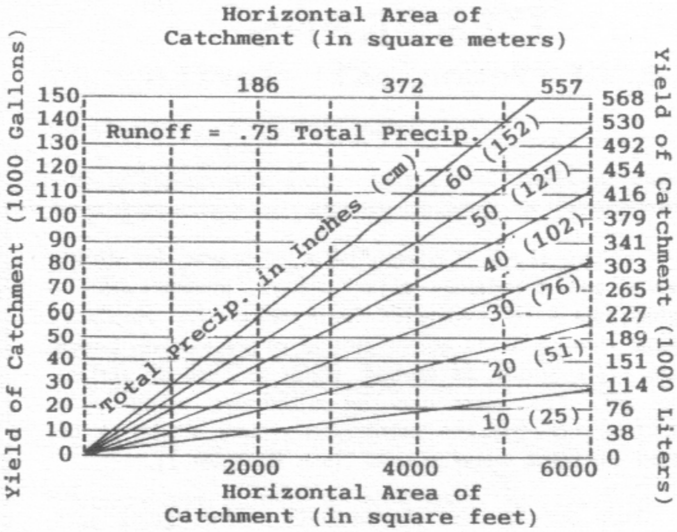


* Metric measurements have been rounded to the nearest whole number.

Diagram 2. CISTERN YIELD

CISTERN SIZE

Cisterns have the disadvantage of holding a limited amount of water —— the faucet running three–gallons for a tooth–brushing is out. Some might complain that cistern water won't last through a drought. True, but neither will ground water from wells that supply 90% of rural Americans today. Consider cisterns a water supply —— if not the only one, then a needed addition to a water–short environment.

Those who instill good conservation practices in a family are generally never short and do not require the 100 gallons per person per day American extravagance. In fact, 10 gallons per person per day is more than generous for families that conserve. A water–conserving family of four with dry composting toilet(s) and no automatic washing machine or dish washer could use at most about 75 gallons per day (20 for shower, 15 for food preparation, 20 for clothes, and 20 for dishes). It is assumed that pet and animal needs, car washing, and garden and greenhouse water supplies will be served from sources of lesser water quality.

Whatever the water consumption, the size of the cistern depends on the rainfall, when it occurs during the year, and the length of the dry season. (See Diagram 2). In areas with an average 43–inch annual rainfall, a household can collect about 20,000 gallons a year from a one–thousand square foot (average) house assuming 75% catchment. If the household needs more, collecting gutters can be added to nearby barns, sheds and other surfaces. Cisterns built on ground higher than a house can be gravity–fed and may require no pump or in–house storage system.

CONSTRUCTION MET

Cistern construction is a do–it–yourself project requiring digging and cementing tools. Building materials may be near at hand. In areas with accessible clay deposits, cisterns can be built without walls, but these may be susceptible (as are many waterwells) to contaminated seepage or water loss. It is better to construct cistern walls. Properly waterproofed concrete, stone, brick, or concrete block are recommended. Pre–fabricated light weight plastic or other types of cisterns may be referred in places where heavier building materials cannot be easily transported.

Pre–formed and plugged septic tanks can be used as can plastic water containers. An easy method for constructing cisterns is to convert two, 1,000–gallon septic tanks into cisterns. These are connected in series by pipes, and the holes are plugged. Plastic liners may be used but often these contain solvents and plasticizers which could enter and contaminate the water. In fact, swimming pool liners are no longer recommended

CISTERN COSTS

Cistern construction costs (for a somewhat skilled person utilizing native materials) could be as low as $400 (cement, sand and pump). For those hiring builders, labor–saving methods may be in order. Typical medium–sized cistern estimates: $500 for digging and backfilling; $400 for concrete block; $150 cement and sand; $50 re–bar and bolts; $700 labor; $100 for downspout, cut–off and opening cover; $100 for filter. The total is $2,000.

Masonry cisterns should not be exposed above ground without reinforced steel because, when filled, the water pressure could crack the walls. Even contractor–built cisterns cost less than municipal water systems with pipes, purifying plants, pumping and storage facilities, and maintenance.

CISTERN SITING SUGGESTIONS

* Although it is easier not to bury cisterns underground, water pressure on unreinforced exposed walls tends to crack and fracture the cistern. Completely surrounding the cistern with earth allows for lighter wall construction;

* Cisterns built on ground higher than the point where water will be used (faucet or shower outlet) will permit gravity–feed and make pumps unnecessary;

* Connecting a series of drainage pipes from the catchment areas may permit a greater potential for obtaining water. However, this method will require more care in keeping the water clean and well–filtered;

* If siting a cistern next to a house, place it as far as possible from sewer or septic lines, in an area where no seepage can occur. Secured this by running sewer lines lower and at a safe distance from the cistern.

[ME]DS AND MATERIALS

Don't use chemical sealants as the final inner lining. Instead use two coats of a one–to–three portland cement mortar on the inner walls for waterproofing. Use a plastering trowel and smooth with a thin slurry of cement just before drying to ensure that no small cracks occur.

Two able–bodied conscientious and skilled workers can complete a medium–sized cistern (12–foot diameter hole 10–foot deep) in several weeks, even when using hand tools. A 10–foot deep cistern need only be dug to a depth of six feet. The removed earth can serve as a bank or berm to the height of the constructed cistern. A cistern containing 9,000 gallons could last a water conservative family of four for three or more months without additional rainwater. This is provided a compost toilet is used, since flush toilets require about half the domestic water.

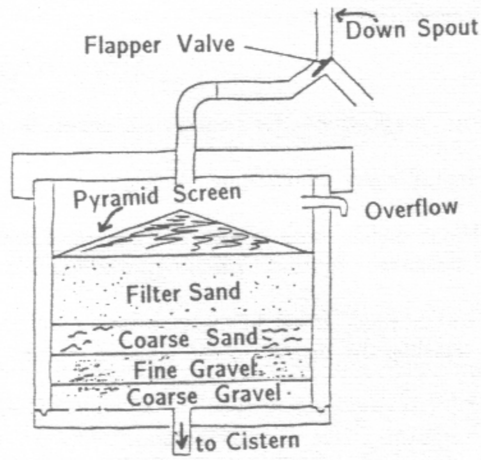


Diagram 3.
RAINWATER FILTER

IS THE WATER POTABLE?

Some complain that cisterns are risky. However, the risks are far less than those undertaken while drilling for water. In fact, the probability of catching and retaining good water in a cistern is greater than tapping into a plentiful supply of good groundwater. All drinking water systems are subject to contamination –– only larger ones affect more people. If individual cisterns are tightly sealed and located at least 50 feet from a sewage disposal system and on higher ground, there is no major source of bacteriological contamination.

Some recommend that cistern water be chlorinated. Much depends on the source and whether there is outside seepage into the cistern from cracks. If the catchment area is not contaminated, is cleaned before inserting water into the cistern, and the cistern is properly sealed, the water will be potable. Recently built cisterns may be disinfected with chlorine solutions.

While chlorination is a preferred low–cost water purification method, still other purification systems use ozone or other methods at the tap and in the kitchen. If in doubt about the purity of cistern water, test it on a periodic basis for bacteriological and chemical contamination. The presence of some iron in the water is not detrimental.

Another more worrisome aspect of collecting rainwater today is the growing concern about "acid rain". In some areas of heavy industrialization or downwind from coal–fired powerplants, water may get as low as a pH of four. Metal catchment surfaces cannot withstand such assault. While moderate acidity is not a threat to human health as such, acidic water tends to permit the introduction of harmful metals to water. The gravel in filters and the cement walls of the cistern are normally able to neutralize the slightly higher acidity.

MAINTENANCE OF CISTERNS

Cistern water can be soft, clear, and good–tasting if common sense and care are observed. Catchment and guttering must be free of leaves. The "soft" water does not have minerals and proves perfect for bathing, washing hair and laundering delicate clothing and other fabrics.

Cut–off outlets attached to the downspout will allow the first roof–washing to be used for garden watering. One Kentucky cistern was operated properly and had less than one half–inch of sediment after about fiftyyears of continuous operation. The operator always kept the cut–off in the "off" position until the rains were sufficiently heavy to wash off the roof and allow pure water to enter the container.

A filter system (either at the cistern inlet or at the point of use) requires proper maintenance (see Diagram 3). This is a basic filter mechanism, allowing water to pass through sand and gravel before entering the cistern proper. It is presumed that a mechanical cutoff will be used for preliminarily washing from the cistern dust or other airborne contamination.

One good cistern maintenance practice is to seal the top. The man hole cover is often the same block holding the mechanical pump. A light seal of cement may be added to reduce unwanted seepage and the lip of the cover hold may be slightly raised to discourage surface drainage. Also consider elevating the ceiling of the cistern above ground for the same reason. When making the cistern out of brick, consider a domed vault–type roof to effect a good seal.

Preservative–free wood shingles (e.g., cedar), lead–free clay tile and slate are excellent catchment roofing materials. Well–washed asphalt shingles are acceptable, but may still prove disadvantageous for some with chemical susceptibility since solvents are present. However, the use of a charcoal filtering system will remove any offensive impurities. Aluminum and galvanized roofing (without any lead–based paint) are also suitable materials. If uncertain as to types of materials, check with local health authorities.

TP-3 ADDITION (Concrete Roof)

One of the most vulnerable aspects of cistern construction is sealing the roof so that it does not leak. In the past builders have carved cisterns out of rock or dirt in such fashion that a natural ceiling is included. Others created arches and domes of superb crafting -- but today there are few who have this skill. As mentioned in Technical Paper 3, others have used pre-formed concrete containers. In cases when it is impossible to transport such heavy units to the property the cistern builder must resort to other alternatives.

ASPI recently completed the construction of a new 5,000 gallon cistern with a reenforced concrete roof. Building the roof was not exceptionally difficult as the wooden form was built to be removed from within the cistern. The design described here was developed by ASPIers Lewis VanWinkle and Jeff Cope. It is low-cost, practical and easily built.

The ASPI cistern is 10 feet in diameter and 8 feet in height. The walls of the cistern were laid using 4-inch solid block, except for 8 evenly spaced 4 inch standard blocks (with holes) placed on the top layer. (See Diagram 1.) Short pieces of rebar were cut and cemented in these open blocks with several inches extending above. After the walls of the cistern were finished, a center support column for the roof was built using 8-inch standard block (with holes). Two 10 ft sections of rebar were placed in the block holes (which were then filled almost to the top of the column with cement) for extra support. The unfilled space was left at the top of the blocks to allow the vertical support to be wired to the horizontal ones.

Three sheets of 3/4" (4' X 8') plywood were required to build the roof form. The crew used only two sheets by making use of some on-hand scrap materials. The frame was constructed so that during dismantling the pieces could be removed through a 2 ft. X 2 ft. opening (See Diagram 2). A 2 ft. by 2 ft. opening was left in the plywood form. A lip the thickness of the concrete to be poured was built around this opening. The sides of the roof form were made from scrap lumber cut the length of the concrete block forming the top layer of the cistern wall (See Diagram 3.)

Eight (8-foot) 2 X 4s were placed inside the perimeter of the cistern wall to support the form. About a dozen additional supports were placed at angle to the edge. Extreme angles were avoided so that the supports could be easily knocked down for removal from the cistern. Eight short (2 X 4s, 4 or 5 feet in length) were then used as cross-braces for the angled supports. (Diagram 2.)

After the roof form was placed over the cistern, 8 sections of 1/2 inch rebar were placed midway in the 3 inch deep form. This included two 10 ft. pieces crossing the diameters of the circular roof and six 5 ft. sections arranged a spoke pattern running from the center support to the rebar extending above the edges of the standard blocks on the cistern sides. The sections of rebar were wired together at the edges and in turn to the 10 ft. rebar section running through the center support column for added strength.

The concrete roof was poured in a single afternoon and allowed to stand a week before the form was removed. The drying concrete was checked for cracks which did not appear. After seven days the supports were dismantled and removed. See

Fastening Note. A cover block was made a little larger than the 2 ft. x 2 ft. opening (26 in. X 26 in.). This was poured on a mini-form box constructed from four 2 x 4s with a plywood bottom. This box was nailed loosely to two skids for ease of transfer.

Fastening Notes: 1/4 of an inch of the nail remained outside of the wood for ease of dismantling. No nailing was done where the nail heads would be unexposed (either inside or outside). The plywood strips were held in place by tight cuts and toe-nailing. Generally 8 penny nails were used except for the supports which were held by 16 penny nails.

DIAGRAM 1: Blocks and Rebar

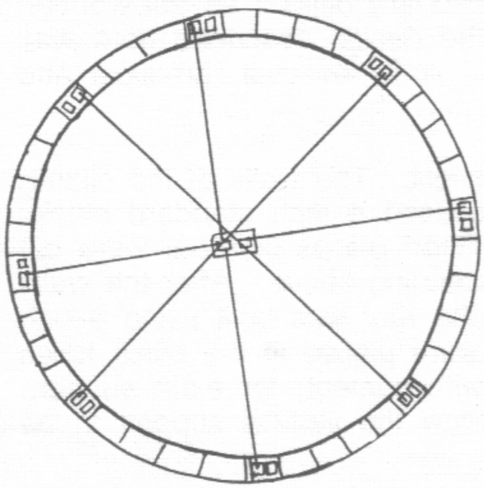
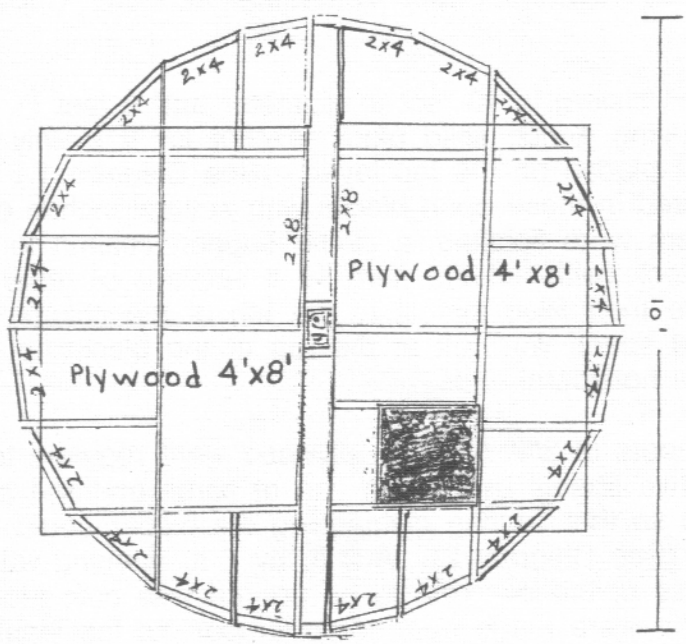


DIAGRAM 2: Top View



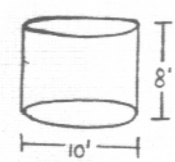
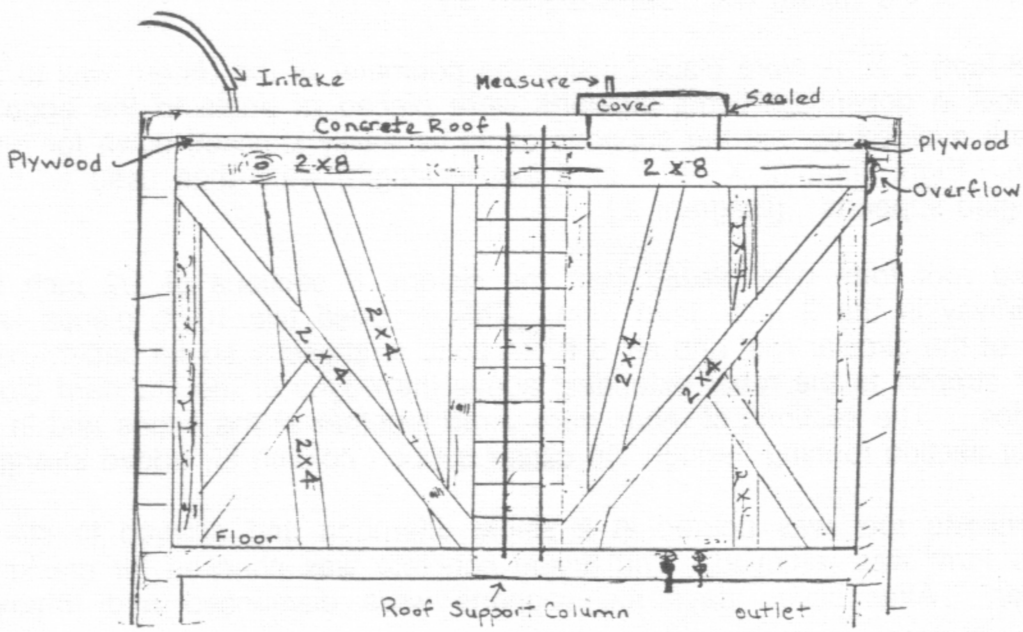


DIAGRAM 3: Side View



CONSERVING WATER WITH A CISTERN ECONOMY

Some suggestions for conserving water include:

* Install a dry composting toilet;
* Wash dishes once a day and use rinse water for other purposes (garden watering, washing floors, etc.);
* Catch rinse water in the sink or a pan rather than rinsing the dishes under running water;
* Do not pre-rinse dishes under running water for later washing. Use a small amount of "dip" water;
* Feed pets and water plants from other water sources;
* Don't irrigate gardens or water lawns from the cistern;
* Use cooking water for foods as soup stock.
* Save first run-off of catchment areas for plant watering or washing cars;
* Take showers by the "army" method --wet down, soap down and rinse off (or the 2-5 gallon shower);
* Limit bath water to a depth of 1/3 tubfull and small children can bathe together;
* Limit laundry at cistern site. Wash clothes less frequently and do heavier loads;
* Don't let the faucet run while brushing teeth;
* Utilize dehumidifier water for washing dishes.

PUBLIC INTEREST CONSIDERATIONS

If cisterns are again to become popular, they will need governmental incentives and sponsorship. Extension agencies could assist with hand-out information. The public needs to know more about these examples of appropriate technology, how to build them, and have access to low-cost loans and grants. Currently only large water systems have the advantage of access to governmental money. If the same amount were available in the form of loans or grants to independent builders, cisterns could flourish in this country --and reduce the need for extended municipal water systems.

A problem area must be addressed before one can popularize this appropriate technology method: What are the effects of acid rain on cistern water? When pH levels reach as low as four, the very catchment areas and gutter systems erode and some of this metal content enters the water. Research is needed to determine which materials are least susceptible to such erosion. We must obviously work to halt the acid rain as well.

STEPS TO GOOD CISTERN MAINTENANCE

* Ensure gutters are free of leaves
* Keep downspout lever in "off" position except during heavy rains.
* Keep filter materials replenished. (Check each season.)
* Don't allow water to enter cistern when using chimney of catchment area because of soot contamination.
* After earthquake or blasting operations, plaster any cracks using masonry cement.
* Keep mechanical pump oiled and repaired.

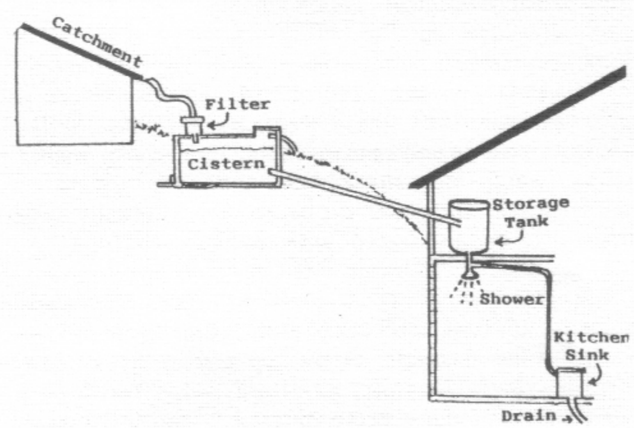


Diagram 4. IDEAL SYSTEM

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