Water Storage For Off-Grid Living

H$_2$ Oh!
A look at what you have and what you need.

By Parker Abercrombie and Art Ludwig


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An ideal off-grid water system would draw water from an abundant, clean, year-round spring or creek. There would always be enough water to meet demand, and there would be no concerns about extra water for fire protection or emergencies. But since few of us are blessed in this way, nearly all water systems include some form of storage, most commonly a tank. Even if you get your water from a municipal water system, you may want to store water at your home for fire protection or emergency preparedness, or for any of the reasons mentioned below, some of which you've probably never thought of.

We're going to consider each of the following reasons to store water, then take a detailed look at water tanks, their design and construction, and a brief look at other ways to store water.

Cover peaks in demand. The most common function of water storage is to cover short-term use flows that are greater than the flow of the water source. For example, consider that a tiny, one-gallon-per-minute spring supplies 1,440 gallons a day. This is several times more than most homes use in a day. However, almost every fixture in the home consumes water at a faster rate than one gallon per minute (gpm) while it is turned on. Even a low-flow showerhead uses about 1.5 gpm.

By using water stored in a tank, you can supply water to the shower faster than it is flowing from the spring. At the end of a shower, the water will be coming in faster than it is going out, and the tank level will soon rise to its former level.

If you had a 10,000 gallon tank, you could run a 100-gpm fire hose—creating the kind of blast used to bowl over hostile crowds—for an hour and a half on the stored water from this tiny spring! With luck the fire would be out by then, as the tank would take several days to refill.

Smooth out variations in supply. In some circumstances, your storage needs will be affected by variations in the water supply. For instance, if the supply is rainwater, you will need enough storage to make it through the intervals between rainfalls. A six-month rainless dry season requires a heck of a lot more storage than the most common kind of variable supply—a well pump that cycles on and off. If you have a well that taps stored groundwater, a tank will save wear and tear on your pump, because the pump won't have to switch on and off every time you open a tap.

Provide water security during sup-

ply interruptions or disaster. In many places, the water supply chain from source to tap is long and made of many delicate links. If a cow steps on the supply line, a pump breaks, a wire works loose, the electricity goes out, the city misplaces your check, or there is a natural disaster, your water flow could stop. By locating your storage as few chain links away as possible from your use point, a large measure of security is added.

Save your home from fire. Designing a system to be effective for combating fire can change its specifications radically. To put out a fire, your stored water needs to be available at a flow rate many times greater than normal.

Meet legal requirements. Sometimes you may be required to install water storage simply to meet a legal requirement. But, you may be able to trade increased water storage for slack on a different legal requirement. For example, if you provide a large amount of water with good pressure that is reserved for fire emergency, a sprinkler system, and/or a hydrant, the fire department might allow you to build a narrower driveway with a smaller turnaround farther from the house than they would otherwise—thereby saving you considerable expense.

Improve water quality. The water coming out of a properly designed tank can be of significantly higher quality than the water that goes into it. This is mostly due to attrition and settling. Add an ozonator, and a tank becomes a substantial treatment step.

Provide thermal storage and freeze protection. Water has higher specific heat—stores more thermal energy per unit of weight—than any other common material. A large thermal mass of water stored within a solar greenhouse or home can help keep it cooler in the day and warmer at night.

Also, as water changes to ice, it radiates a tremendous amount of stored energy. Imagine how much gas it would take to melt a water-tank-sized ice cube; when water freezes, it releases this same amount of energy. This is why irrigating for frost protection is effective. The stored energy in water can prevent a water tank or nearby components from freezing (though in the coldest climates this may not be sufficient).

Evaporation consumes even more energy, which is why swamp coolers and cooling towers are effective. Water is also an effective heat-transfer medium. And, in rare instances, it can be economical to use elevated water storage as a "battery," from which electricity is extracted by running it through a hydroelectric turbine.

Enable a smaller pipe to serve for a distant source. If the flow of your source exceeds the peak demand, you can connect to it directly without storage. However, if the source is distant, it may be cheaper to run a small pipe to nearby storage and a big pipe from there to the use point. The small pipe would be sized to the average use, the big pipe to the peak use. The savings in materials and labor of running a smaller pipe over most of the distance can often pay for the storage.

Water Tanks 101

If you want to store water, there are several options open to you. They include the following:

Source direct (no storage). A rarely applicable but very desirable option if you have a clean source higher in elevation and flow than the end water uses.

Storage in soil. An inexpensive supplemental irrigation storage technique that uses water held naturally as a film over soil particles in the ground (not advisable in landslide areas).

Storage in aquifers. Free bulk storage safe from evaporative loss, but accessible only by pump, and subject to contamination and extraction by other users.

Storage in ponds. Inexpensive bulk storage of water, most appropriate where rainfall exceeds evaporation and the majority of water need is for nonpotable uses.

Storage in tanks. Most expensive, but offers the most flexibility in location and the best protection and control of the stored water.

Obviously, tanks are the most common way to store water. A well-designed tank offers nearly complete control of storage conditions, including security against leakage, protection from mosquitoes and vermin, shade so algae will not grow, minimal or no evaporation, and valve-controlled inlets and outlets.

Water tanks come in all shapes, sizes, and materials. Most tanks will have an inlet and outlet, a service access, a drain, an overflow mechanism, critter proofing, air venting, and some provision for sun screening. They can also have a host of optional features. Before installing your water tank you'll need to decide where to put it, whether it will be above- or belowground, how big it will be, and what material it will be made of. You may also need to meet local regulatory requirements.

The location of your water tank will largely determine which parts of your land can be supplied with tank water by gravity, the amount of pressure at

A temporary coffer dam is used to create a storage pond prior to permanent excavation work. Pond storage is relatively inexpensive due to the volume of water impounded, but rainfall must exceed evaporation rates.

every point in the system, the length and cost of pipe runs, the length of control wire runs, and line-of-sight for radio links. It will also establish how visually obtrusive your tank will be, the vulnerability of the tank and pipes to hazards such as falling trees, rocks, and landslides, the size of tank it is feasible to build, and ease of construction and service access.

To situate a water tank, you will need to first consider elevation. If you have a hill on your property, put the tank at an elevation that yields adequate pressure (230 feet of elevation produces 100 PSI, the maximum recommended pressure for a home).

In places where there is no hill available, you can make a water tower to artificially increase elevation, use a small pressure tank to pressurize water as it is needed (though this is dependent on power), build a huge pressure tank to store pressurized water at low elevation, or put a tank on your roof and live with low pressure, as do most people worldwide.

Stability of Soil and Slope

You don't want your tank to sink into the ground or slide down the hill. The load per unit of area from water tanks is actually quite low. A person walking can easily place much higher point loads on the soil. On the other hand, no one has feet as big as a water tank. It's the aggregate load from a water tank—all that area being pushed on at the same time—that can push your building pad down into the gully.

However, undisturbed native soil is sufficiently strong to support even large tanks. In the case of a tank on a slope, where you don't have a natural flat spot, put the tank on cut (newly exposed, undisturbed soil) rather than fill (freshly dumped, loose soil). For a really large tank or any tank on fill, it's a good idea to consult with an engineer.

Aesthetics, Security, and Buried Storage

Water tanks can be big, and although they can be beautiful, they are more often ugly. When locating a water tank, you should either put it where it doesn't matter, conceal it well, or make it attractive.

Ideally, you want your tank downstream from whatever hazards and weak links lie between you and your water source. Rivers that flood, gullies that wash out, landslides, falling trees, and rolling boulders—it's best if as few of these hazards as possible are between you and your tank.

Burying your water tank makes it less obtrusive, cooler, and more secure, as well as providing good protection from frost and sunlight. However, you probably won't be able to install a gravity drain, so you'll need a pump to get the water out, and cleaning it becomes more difficult. The design of buried storage is more structurally challenging, and inspection, repair, and replacement are more difficult. The buried tank will need to be protected from surface water leaking in, and protected from children and pets falling in and drowning.

Sizing Water Tanks

The size of your storage is one of the main factors that will determine under what circumstances you will find yourself short of water, and for how long. Will demand outstrip supply every morning? When there is a fire? A day after the well pump goes out? Size will also do a lot to determine what your system costs.

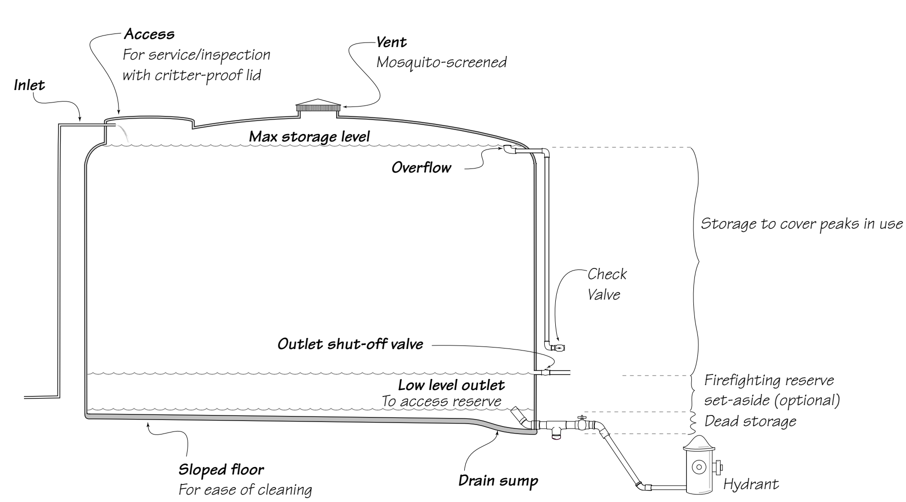
Sizing your tank is a matter of figuring out what degree of water security you want, then finding the tank volume that makes the most of your water supply within your budget and other limiting factors. This is a good time to remember the reasons you want storage, as they will drive the calculation of tank size.

The biggest variable by far is how much water security you're aiming for. In general, the more storage you have, the better your water security. Without storage, the security—the percentage of time you've got water—is equal to the security of the source. The more storage you've got, the longer an interruption to the source supply you can cover with stored water.

Is it possible to have too much storage? Yes. Too much storage can lead to freezing or water age problems. More likely, it simply constitutes a waste of the Earth's valuable resources. Because of the high up-front cost of storage, it is rare to see anyone except the superwealthy install too much storage volume.

Sizing a tank for demand peaks that exceed flow. Although water needs are usually expressed as a value-per-person for a 24-hour day, in actuality

COMMON TANK FEATURES



ILLUSTRATIONS COURTESY OF THE AUTHORS

just about all of this water will be used during a period of 10 to 12 hours. Over half of an entire day's water use may happen between dinnertime and bedtime, or in the morning, depending on the culture. Water provided by the source during low-demand periods (e.g., overnight) can be stored for use during high-demand periods.

Sizing a tank when you have limited water supply with scheduled use. This approach is the inverse of the approach above. It may be appropriate if the water supply is limited and there are known lengths of time without water use. Instead of sizing the tank to cover use, you size the tank to cover production of the source during the longest time without water use. If you store all the water that is produced during the longest time without usage, you'll have maximized your limited supply.

Sizing a tank to cover use during interruptions in supply. Most systems have at least a day's worth of storage to cover supply interruptions due to servicing, a fault within the system, or a disaster such as an earthquake or power outage. To size your tank for supply interruption, consider what is likely to jeopardize your supply and for how long.

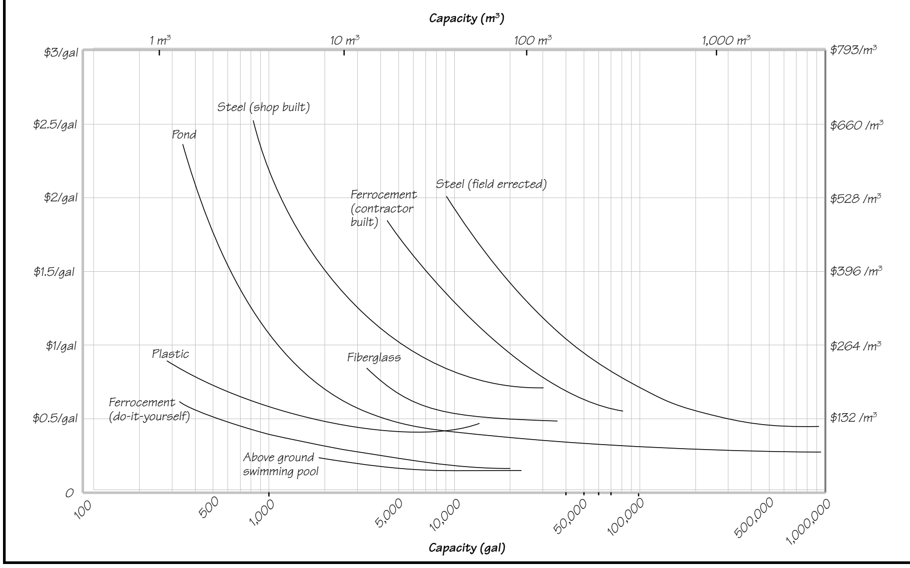
Sizing a tank when production is intermittent. If your water production is intermittent (for instance, from harvesting rainwater), your tank should cover the maximum cumulative deficit between production and consumption.

Sizing a tank for firefighting. If your system is part of a project that requires permits, there are most likely specific legal requirements for the system's firefighting capabilities, which you will have to research and fulfill. These probably include much more storage, bigger pipes, and higher pressure than you could otherwise imagine.

Size and Structural Integrity

As tanks get bigger, the structural engineering issues get much bigger. Tanks of 1,000 gallons are no great challenge. A 10,000-gallon tank requires serious consideration of the loads that will be operating on it. Any tank over 30,000 gallons should be professionally engineered.

Cost per Gallon



The tank shape determines how the material will resist the applied force and thus how easy it will be for the tank to resist a given load. This is something that you should consider carefully if you are making or modifying a tank.

Tank Materials

There are plenty of choices for water tank materials, each with advantages and disadvantages. Common materials include galvanized steel, various plastics, fiberglass, concrete, ferro-cement, brick, and rock and mortar. However, a few circumstances are unequivocally hazardous and to be avoided:

PVC exposed to sunlight. PVC breaks down in sunlight, reacting to form carcinogens, which leach into the water. It is a plumbing code violation to have potable water in unshaded PVC for this reason. You can see physical evidence of the change on the outside of the pipe; it darkens and becomes chalky and brittle. The reaction progresses from the outside in. To the extent PVC should be used at all, it should be buried or set indoors. If you have PVC that has already degraded, you should replace it.

Pre-1997 PVC. Earlier-generation PVC was made with more toxic plasticizers and should be avoided.

Flexible PVC. Water-bed bladders and trash cans both contain a high level of toxic plasticizers and should not be used for storage.

Pre-1980 tanks. Older tank coatings include coal tar and lead-based paint. These were great for corrosion resistance but they poison the water.

Lead pipe and pre-1987 lead-soldered copper pipe. Solders and flux currently contain less than 2 percent lead. Before 1987 they were typically half lead. As for plumbing, lead pipe can be recognized by its softness. Steer clear of both materials.

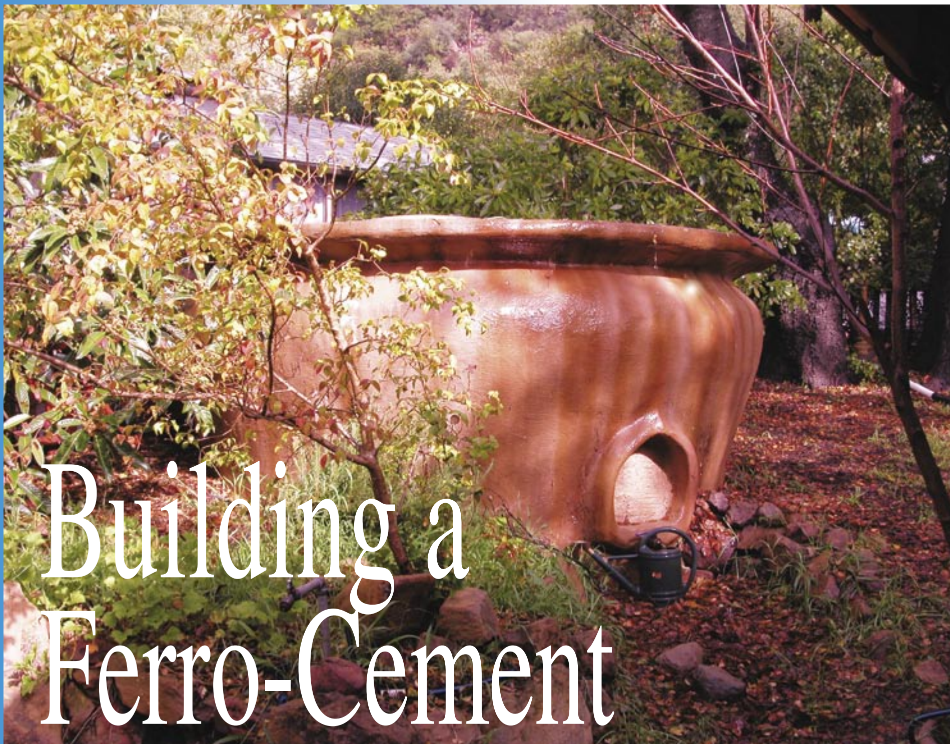
Western red cedar. The same elements that give this popular structural tank species its pleasant smell and inherent protection against rot and insect damage are toxic when ingested.

Fly ash in concrete. This is a noxious component in concrete and will leach out, especially when exposed to acidic water.

Often the worst hazards are not the base material, but solvents, additives, mold-release agents, fungicides, and so forth used in the construction. It pays to research all the materials you plan to use in a project, and a good place to start is by accessing the Materials Safety Data Sheets (MSDS) available from the manufacturers. You can usually request the information through the companies' toll-free numbers, or retrieve it from their Web sites.

For information on all types of water storage, examples of how to size water tanks, and extensive information on tank materials, see Water Storage, *Oasis Design Press 2005. http://www.waterstorage.ws*

Building a Ferro-Cement Tank



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One particularly flexible design from several standpoints is this 3,500-gallon (13-cubic-meter) urn-shaped ferro-cement tank. The construction technique is applicable to building tanks from 1,000 to 15,000 gallons, and it can be accomplished by moderately skilled workers or dedicated do-it-yourselfers. Especially attractive to many users is the fact that the wire-and-rebar framework can be bent to achieve unique shapes; too, the nature of ferro-cement allows it to be colored to blend with or complement the landscape.

The structural core of the tank is expanded metal lath over a rebar framework, wrapped externally with chicken wire. The No. 3 rebar (3/8") is formed in a grid about a foot on-center both ways. Everything needs to be tied off tightly and carefully, and it takes time. A moderately skilled mason can plaster the framework by hand, pushing through the wire onto the lath. After the structural coat dries, an additional coat is added on both sides, followed by a color-sealer coat.

The outside and inside of the tank are hand-plastered.

Beyond the appeal of its flexibility, the urn tank has several features that make it ideal for water catchment. It is designed with water-harvesting wings that catch rain and allow about 300 gallons of house roof wash water to be stored separately, on top of the tank, from the clean water within. Its sloped floor and drain sump make cleaning very easy, and it has a hidden inlet pipe that passes through the tank floor and roof. Also, the fact that it is partially buried reduces the visual mass of the structure. Aesthetically, though, nothing can beat its overflow performance: the water spills out in a wide, thin waterfall across several feet of wing, which looks extremely cool.

The excavation is graded for slope with a water level.

A rebar foundation grid and concrete-filled trenches reinforce the floor.

The floor is leveled to a 2 percent slope toward the drain.

The rings are set and leveled, then the verticals placed.

A lath and chicken-wire matrix are tied tightly to the rebar frame.