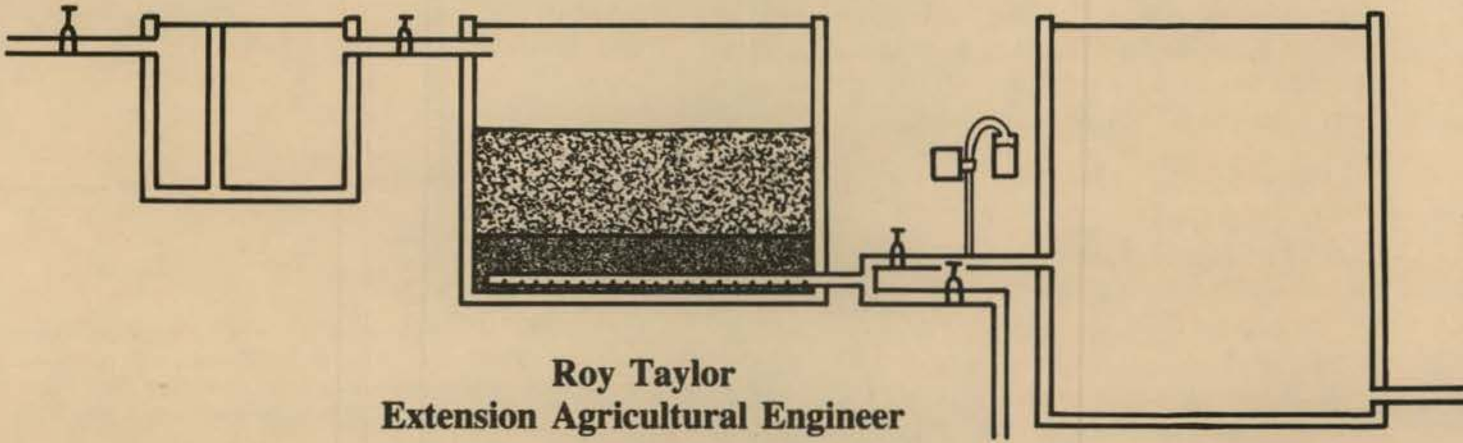
Bulletin No. 672

Slow Sand Filters for the Control Of Giardiasis in Private Water Supplies



Roy Taylor
Extension Agricultural Engineer

Cooperative Extension Service
University of Idaho
College of Agriculture

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The National Center for Disease Control reports that giardiasis, also known as back-packers disease, is now the most commonly documented cause of waterborne disease outbreaks. It is caused by the protozoan *Giardia lamblia*, which has a cyst form that resists the usual disinfection treatment of water. Conventional chlorination is not adequate to destroy Giardia cysts. Outbreaks are normally related to the ingestion of raw water from streams or lakes. Giardia cysts, however, are being found in increasing frequency in disinfected surface waters that have not been properly filtered, and even in water taken from protected springs.

Other Water Treatment Methods

Most water treatment methods that do destroy or remove Giardia cysts are considered too expensive, too slow, too dangerous or too unreliable to be acceptable.

Heat is the original disinfecting process, but heat-treatment is slow, expensive and energy intensive. Boiling or distillation processes are effective but are usually limited only to treating water for drinking and culinary uses. The threat of infection from water used for washing, bathing and other uses still exists.

Chlorine can kill the cysts, but only in a superchlorination process with high levels of free chlorine and long retention times. Dechlorination must then be performed to reduce chlorine content to a palatable level.

Ultraviolet irradiation is ineffective at killing cysts.

Charcoal filtration is effective in removing odors, tastes, chlorine and some water-borne minerals or salts, but is not a disinfectant.

Slow Sand Filters

Slow sand filtration is a physical/biological treatment system that, if properly managed, will effectively and consistently eliminate the threat of giardiasis caused by most surface waters.

A slow sand filter consists of a vault-like chamber containing layers of washed sand and gravel (Figs. 3, 7). The size of the sand grains and the depth of the filter bed need to provide several hours of retention time for the water as it slowly percolates through. A relatively large surface area is required to provide an adequate water supply. Recommended rate of flow through a slow sand filter is generally 50 to 100 gallons per

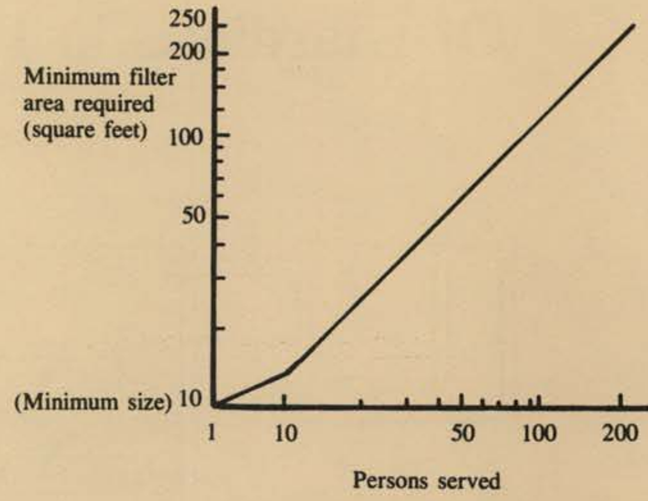


Fig. 1. Slow sand filter sizing for domestic water use. Based on a filtration rate of 60 gal/ft²/day and a usage rate of 75 gal/person/day (adapted from Slow Sand Filtration, Oregon Dept. of Human Resources, Health Div.).

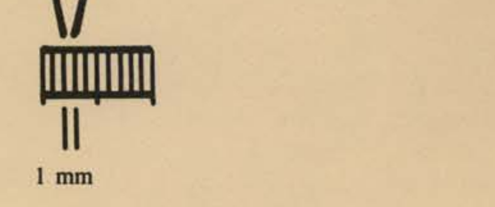


Fig. 2. Desirable range of grain size in filter sand.

The author gratefully acknowledges the assistance of the Idaho Department of Health and Welfare and two of the department's specialists, Stephen A. Tanner, senior water quality specialist, Division of Environment, Coeur d'Alene, and Richard G. Rogers, senior environmental engineer, Division of Environment, Boise.

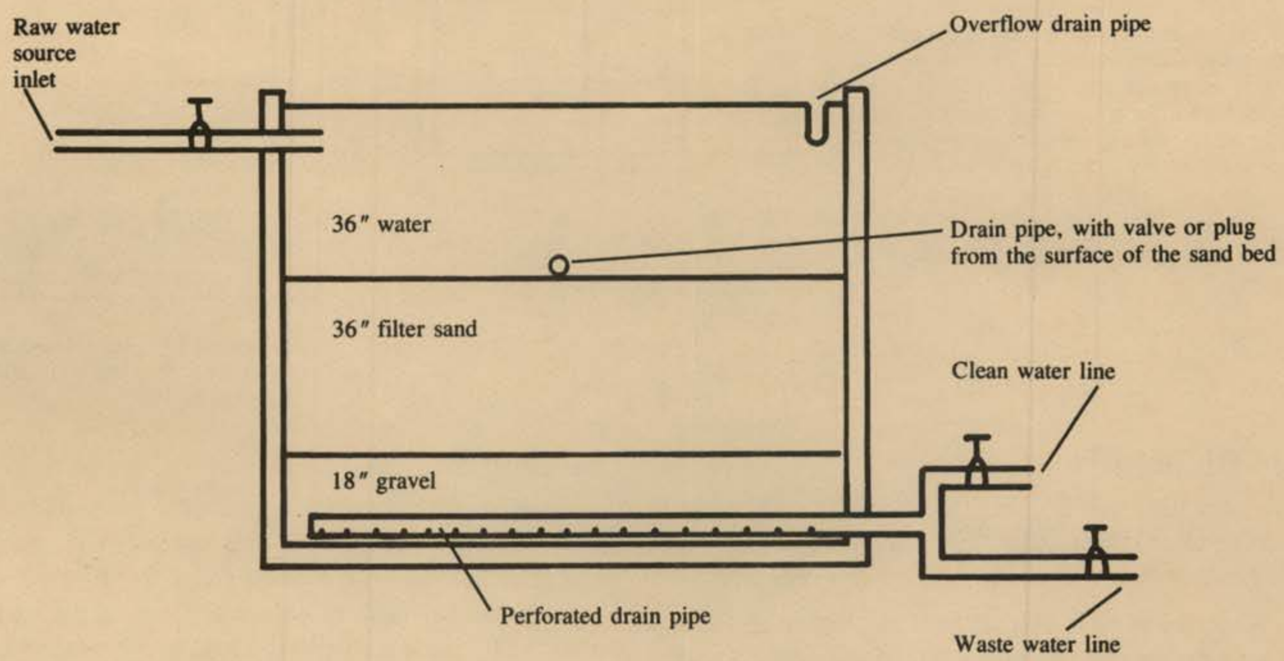


Fig. 3. The filter tank.

Notes: Size and uniformity of sand is very important (see Fig. 2). Overflow and drain pipes should have gravity flows to screened daylight outlets.

square feet of surface area per day. Some large community systems allow a slightly higher rate of flow. The outlet of the waste water line from the bottom of the tank can be used to determine the flow rate through the filter.

Waters carrying high amounts of clay, silt or algae will cause the filter to plug prematurely. It may be necessary under those conditions to pre-treat the water, as by the use of a settling basin.

Fig. 1 can be used to estimate the minimum filter area requirements for domestic water based on a usage rate of 75 gallons per person per day. A usage rate that includes water for livestock or for the irrigation of lawns and gardens could be many times higher.

The key to efficient Giardia control is the accumulation of biologically active, non-pathogenic microorganisms on the surfaces of the sand particles. This accumulation penetrates into the filter bed but is particularly dense on the bed surface. Silt, clay and other suspended particles also accumulate on the surface. This dense surface layer entraps Giardia cysts, which are then eaten by the microorganisms. A new slow sand filter usually will develop an effective biological population in 4 to 5 weeks. Rejuvenating an existing filter by adding new top sand does not appreciably reduce the filter's efficiency because the old sand is already populated.

The surface layer of microorganisms, silt, etc., must be removed periodically to maintain the filter's designed flow rate. This "cleaning" can be done by lowering the water level within the filter to several inches below the surface of the sand bed, then carefully removing the top ½ to 1 inch of sand with a scoop shovel or an improvised scraper blade (Fig. 6). This "cleaning" may need to be done every few weeks or perhaps only every few months depending on the quality of the raw water and the design of the filter.

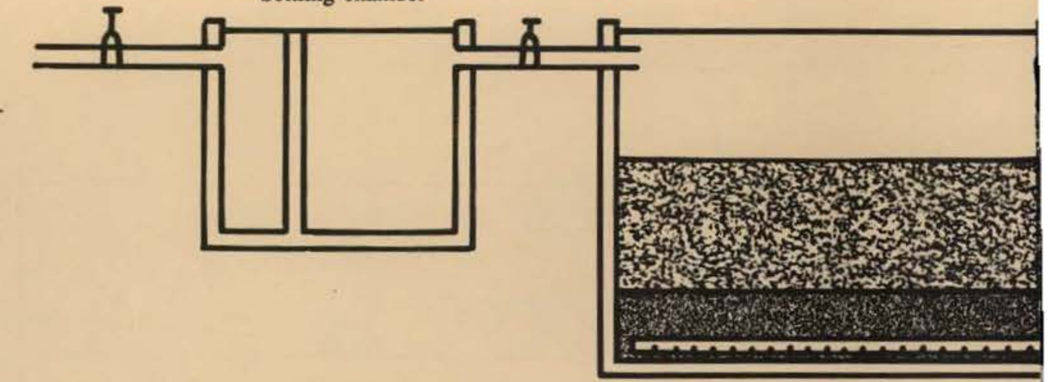
The "removed" sand is a potential contaminant. Spreading it in a thin layer for rapid air drying, in an area where it cannot leak or drain into water supplies, is an acceptable disposal method.

Filter Sand

Filter sand should have hard, durable grains and should be washed to remove dirt and organic matter. Fine river sand often can be used satisfactorily. The sand should be relatively uniform in size with a coefficient of uniformity below 3:

$$\frac{\text{Largest grain diameter}}{\text{Smallest grain diameter}} = \text{less than } 3$$

The most desirable range of size for filter sand grains is from 0.15 to 0.35 mm (Fig. 2) although both finer and coarser materials can be used satisfactorily. Maximum grain size should not exceed 0.50 mm (2 grains per mm).



Silt and surface debris can ruin the operation and effectiveness of the filter. A settling chamber and/or a trash screen is recommended for some water sources. Covering the settling chamber limits sunlight and controls algae growth.

Fig. 4. A complete sand filter system.

A slow sand filter should be used in conjunction with chlorinator (located after the filter). See Fig. 5.

Air Binding

A sand filter can become "air-bound" and require priming to establish water flow through the sand bed. Air binding is apt to occur under three situations:

1. When the filter is first put into use, either as a new tank or one that has been emptied and refilled with new filter material;
2. When the water level has been allowed to lower too much during normal maintenance; or
3. When the filtered water from the tank has been drawn off at a greater rate than that of the raw water supply entering the tank. Proper management of the sand filter can prevent situations 2 and 3 from occurring.

You can successfully prime an air-bound sand filter by allowing it to fill with water from the bottom of the filter bed upward. Allow water from the storage facility to flow back into the tank. When the water level reaches the top of the sand bed, shut off the reverse-flow water and use raw water to complete the filling. Then discharge normal filtration through the waste water line for several hours before diverting flow back into the water storage facility.

If the system has no water storage facility, you can prime the sand filter by pumping water of known purity back up into the filter through the clean water line. The pure water could come from the house or from a portable water tank of sufficient capacity to fill the tank to the top of the sand bed. Using raw water to prime the sand bed is not recommended because of the possibility of contaminating the entire filter media with Giardia cysts.

Settling Basins

Using a settling basin will reduce the amounts of soil and other water borne materials that might otherwise enter the sand filter and cause plugging. By their design, however, settling basins are conducive to the growth of algae which also can lead to premature plugging of the sand bed surface. A limited amount of algae growth in a settling basin may actually benefit the filter by contributing to the formation and sustenance of an effective biological layer. Algae growth in small, private sand filter systems can be controlled by providing a cover over the settling basin to block out sunlight.

Using copper sulfate as an algae control or chlorine as a disinfectant in settling basins is not recommended. Limiting application rates of such chemicals to levels that will not adversely affect the biological action of the filter is difficult in small, private filter systems.

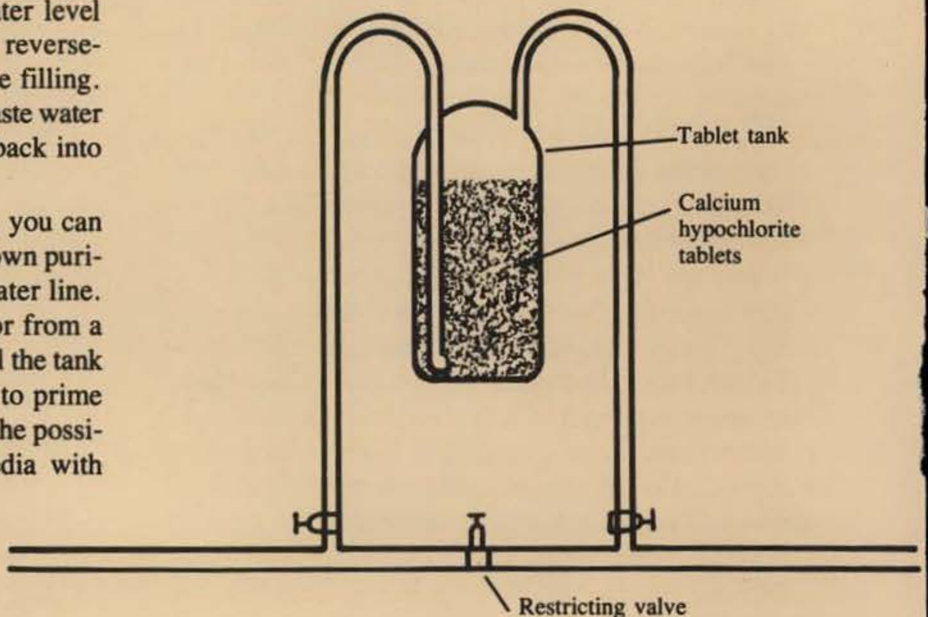
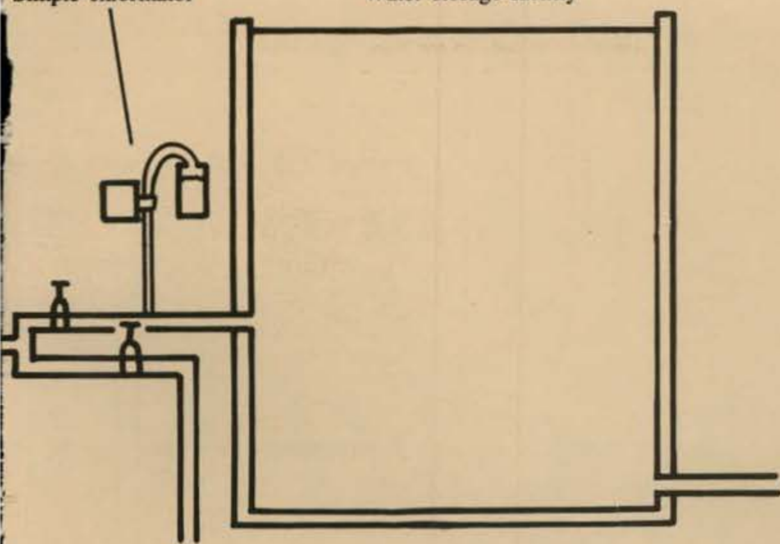


Fig. 5. Gravity flow chlorinator. (Note: This type of chlorinator may be subject to plugging and to injecting irregular rates of chlorine.)



Water storage provides retention time for the chlorination to become effective and provides an uninterrupted water supply while the filter is being serviced.

Chlorination

Add chlorine to the water after it passes the filter (see Figs. 4 and 5). Slow sand filters can remove the Giardia but may not be totally effective at removing pathogenic bacteria and viruses. Five minutes of "contact" time should be allowed after water has been chlorinated to assure effective treatment. A benefit of providing a water storage facility in the sand filter system (Fig. 4), in addition to providing an uninterrupted water supply, is that it allows ample retention time for the chlorine.

Adding chlorine or other disinfectant in front of the filter may inhibit development of the biological layer necessary for Giardia control.

Pilot Sand Filter Model

If you are considering a slow sand filter, you probably should construct and test a small pilot model for several months before investing in a full-scale system. This is particularly important if the water source is high in silt or clay content or other suspended material or if the intended filter sand is of questionable size and quality. One important thing to be learned from a pilot model is the length of time that the filter can operate between cleanings. Remember, however, that the amount of silt in a water supply can vary considerably because of seasonal influences and the occurrence of weather events.

The pilot filter should have about 1 square foot of surface area and be of full-scale vertical dimensions. It could be built of wood with joints securely sealed or lined with plastic. During operation, observe the clarity of the effluent (an indication of the cleanliness of the filter sand), the rate of accumulation of silt and debris on the sand surface (an indication of the cleanliness of the raw water), the development of a biological layer in the top ½ to 1 inch of sand (a slick, pasty accumulation on and among the sand grains) and the rate of water flow through the filter (ideally about 60 gallons per day per square feet of surface area).

Local public health officials could advise you how to collect and submit water samples for quality testing. Test the water, both before and after filtration, for coliform bacteria and Giardia cysts.

Slow Sand Filter Construction

Figs. 7 and 8 show the construction of a slow sand filter modified from one that has been in operation for over 6 years. It is the only treatment facility for creek water that supplies the Nick Plato farm near Bonners Ferry, Idaho. The filter box was designed by a professional engineer and could serve as a guide for others desiring a unit of similar size.

Slow sand filter systems to serve communities or municipalities can function as effectively as those for individual private water systems. Their design and construction must comply with specific regulations established by the State Department of Health and Welfare. Many community-sized systems do not have covers, and the resultant exposure to sunlight, to birds and animals and to freezing temperatures must be considered. The greater size of community systems necessitates particularly careful consideration of flow rates, effluent water quality and water storage.

Additional Reading

Disinfection Techniques, Article by W. H. Beauman, Chief Chemist, Everpure, Inc.

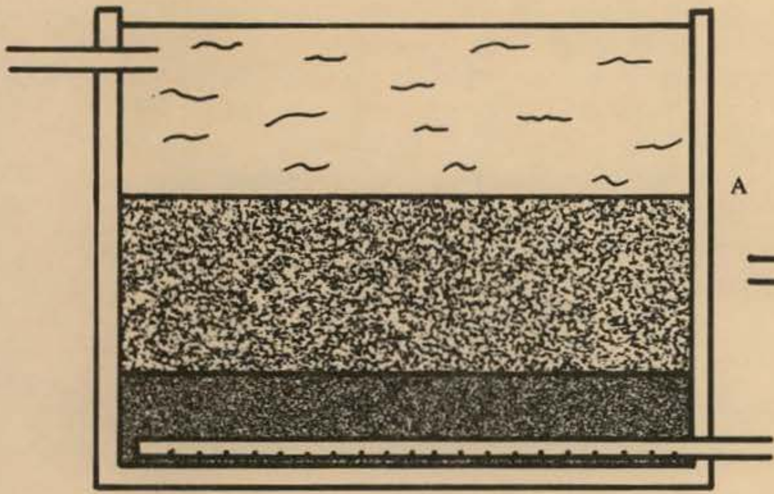
Idaho Clean Water, Issues of Fall, 1985 and Summer, 1986.

Idaho Water Quality Bureau, Division of Environment, Idaho Department of Health and Welfare.

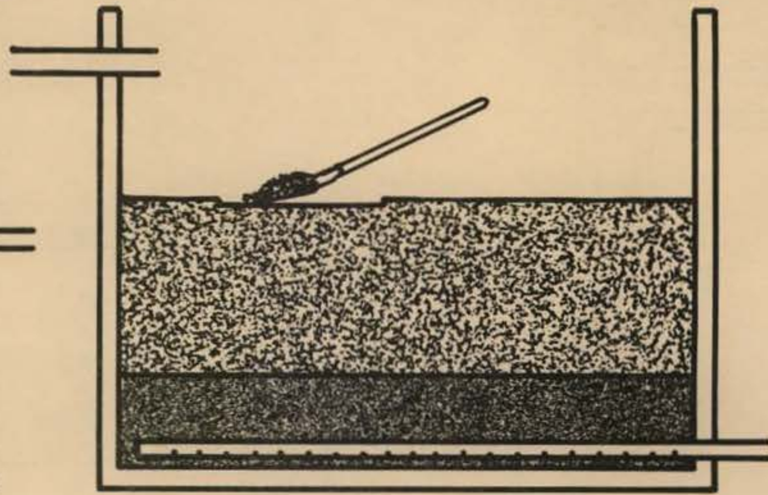
Private Water Systems Handbook, MWPS-14, Midwest Plan Service.

Slow Sand Filtration, Huisman and Wood. World Health Organization, Geneva, Switzerland.

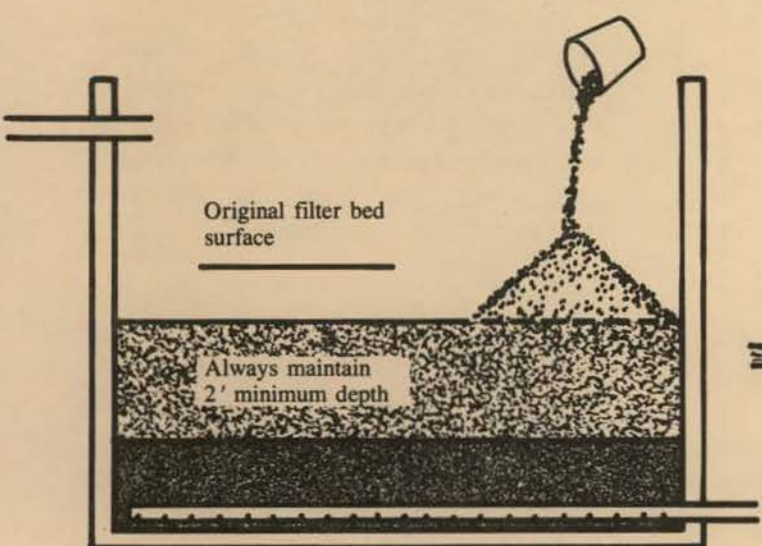
Slow Sand Filtration, State Health Division, Department of Human Resources, State of Oregon.



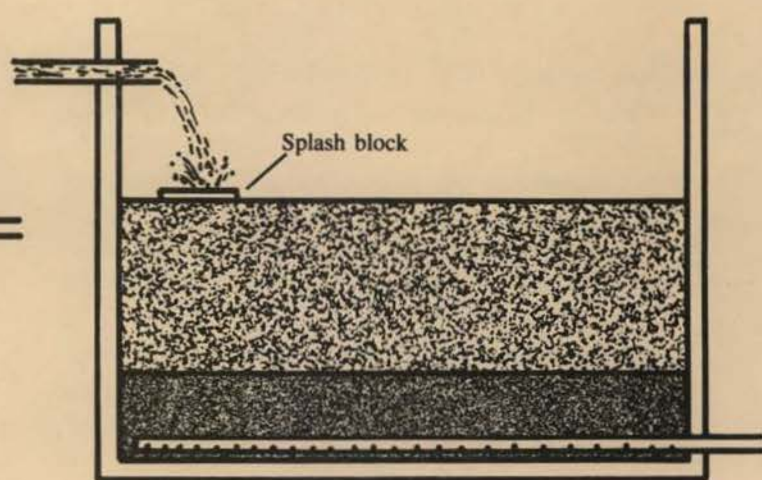
As filtering progresses, a biological layer "A" builds up on the surface of the sand bed. Surface debris (leaves, etc.) and silt also collect here. This retards flow through the filter and must be periodically removed. To remove this layer, close the valve on the inlet pipe and drain the water level inside the filter down to several inches below the filter bed surface. Do not drain the filter completely or it may become "air-bound" and have to be primed to reestablish flow.



Remove the top ½" to 1" of filter sand using a scoop shovel or scraper blade. The filter can then be returned to service. Refill the filter with water. For the first 30 minutes, let the filter water run out through the drain. This allows disturbed sediments to be washed out before the filtered water reenters the potable water supply.



Refill the filter bed to its original level either after each cleaning or after accumulative cleanings have removed sand to a remaining depth of 2 feet. Use washed filter sand.



Use a splash block when refilling the filter with water. This prevents the force of the water from cavitating the surface of the sand bed.

Fig. 6. Maintaining the slow sand filter.

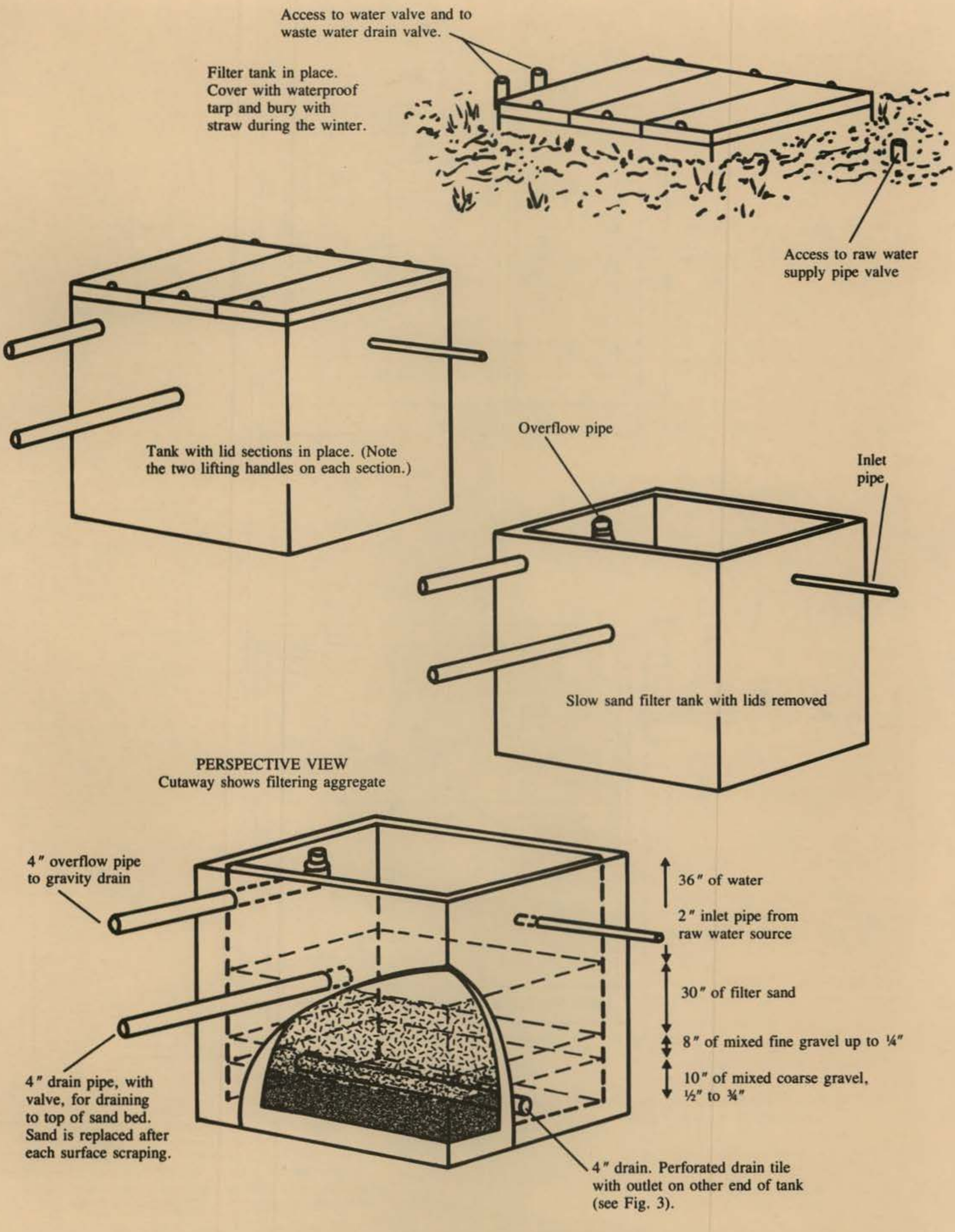


Fig. 7. A slow sand filter for single-family residence, modified from an existing facility in Boundary County, Idaho.

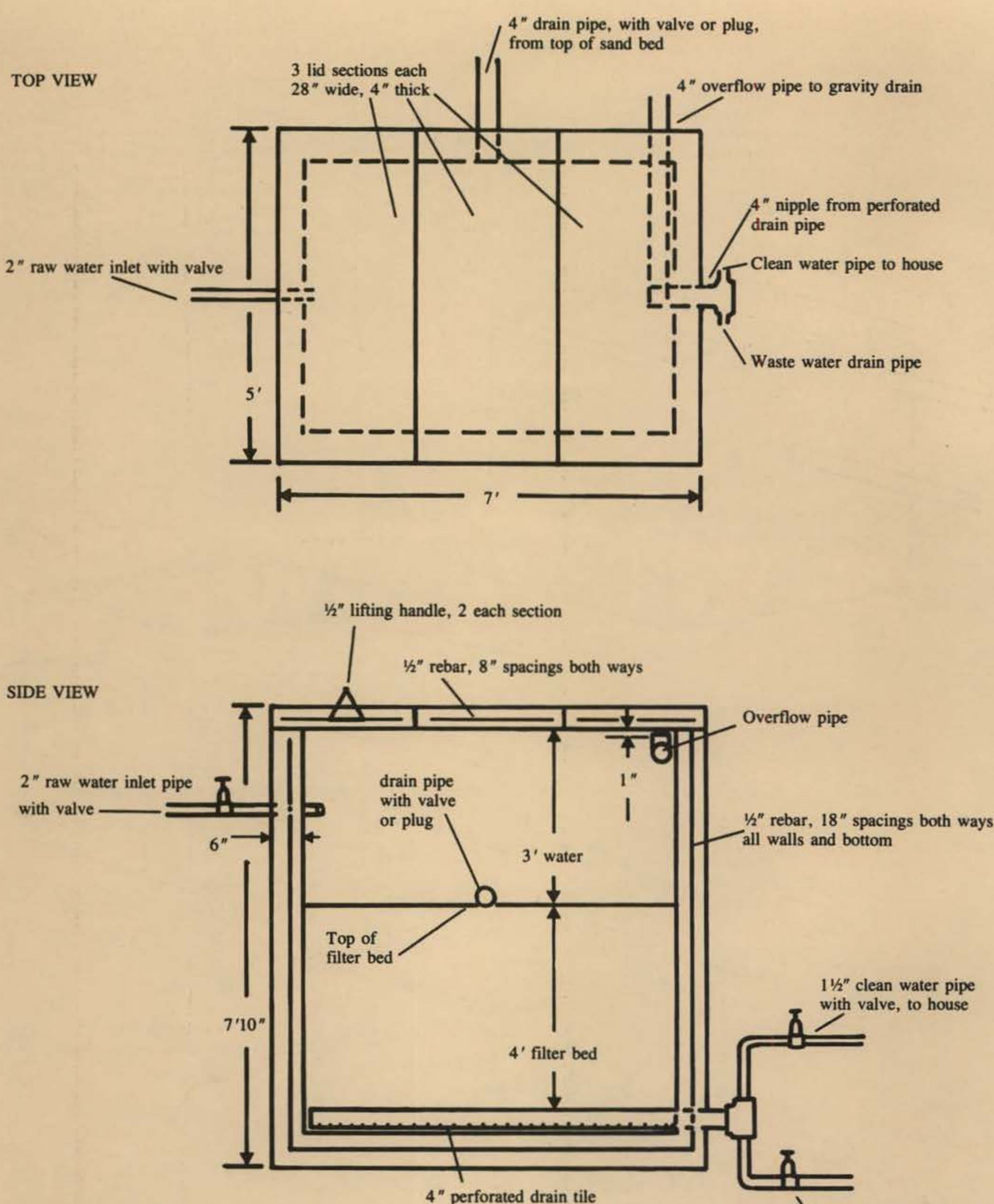


Fig. 8. Concrete tank constructions, modified from an existing facility in Boundary County, Idaho.

Note: All drains and overflows have gravity drains to screened, daylight outlets.

Note: Waste water from the waste water drain pipe can be used periodically to determine the flow rate through the filter (recommended rate is about 60 gallons per square foot of filter surface area per day).

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