ON-SITE WATER SUPPLY OPTIONS

for

INDIVIDUAL AND NON-PUBLIC SYSTEMS

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Executive Summary

ON-SITE SUPPLY WATER FOR INDIVIDUAL AND NON-PUBLIC SYSTEMS

This research report about on-site water supply has been funded by a United States Housing and Urban Development Program grant; and written by TERRAFORMS for Panich, Noel and Associates Architects and Engineers, under contract from the Corporation for Ohio Appalachian Development. This report summarizes on-site supply water options for individual and non-public systems.

Technologies that have been selected for review consist of options available for low-income areas of Appalachia. The intent of presenting this information is to promote water supply systems that provide environmentally sound and cost effective on-site supply and treatment of residential water. The technologies discussed include both manufactured and owner-built systems for water collection, storage, treatment, and distribution.

One impetus for this resource guide is to provide options for water supply for utilization on affordable, rural land, which can be suitable for the development of low-cost cluster housing units. Affordable, rural land is often not serviced by conventional water supply infrastructure. Affordable, rural land is often marginal for commercial development and connection to municipal water supply. This land is frequently sloped, with soil types that are often not optimal for building homes. Technologies that can provide effective and affordable water supply on sloping rural land are given special consideration to provide resources for meeting development challenges of these sites.

Each technology or combination of technologies has benefits and limitations depending on site-specific factors such as climate, slope, soil structure, ground water level, and area available for collection and storage. Other factors include cost, appropriate system design and maintenance, perceptions of residents, and regulatory protocol of different state and county health departments. Technologies employed at each site must be selected based on consideration of multiple design factors in order to be effective and affordable.

This report can help residents and developers understand and access specific information on residential water supply. Manufacturers and distributors of water collection, testing, storage, treatment and distribution systems are summarized.

PREFACE

On-site water systems are a common method of water supply, and a serious public health concern. Groundwater is a source drinking water for about half of the North American population.[1] Approximately half of all know waterborne disease outbreaks in the United States are attributed to contaminated groundwater.[2] Adequate soils, proper site selection, system design, and maintenance are all factors that can influence the effectiveness of a residential water supply system. Even commonly approved systems can fail if they are not properly installed and maintained. Many individual and non-public systems have been built and operated which can provide high quality water for home use while costing less to maintain than conventional, commercially available technologies. This paper will review on-site water supply options that provide alternatives to large municipal water collection and treatment systems or commercially available water delivered from off the site.

DRINKING WATER SUPPLY

Definition

On-site water supply systems obtain water from the site where it is used, such as a well on home or subdivision property, pond water collected on the site, or from rainwater collected on buildings. Many on-site water supply options can provide potable drinking water with proper collection, storage, and treatment. Individual water supply systems provide water for a resident or family living in a single dwelling. Non-public water supply systems serve fewer than 15 households or fewer than 25 individual residents. Although the EPA does not regulate these small water systems, assistance is available from, local, state and federal agencies. Many residents do not have resources to develop information sources, monitor water quality, provide good system operation, and establish preventative maintenance programs. Information and public participation are vital to the effective operation of water supply systems, and information sharing can provide efficient and cost-effective water supply systems.

Water Quality Testing and Monitoring

Safe and high quality water can be insured for new and existing water supplies with proper analysis of the biological, physical and chemical substances in water. Local health departments, cooperative extension offices, or EPA drinking water offices are sources of information on water quality testing.[3] They may be able to help with selecting tests and locating testing laboratories. Some states certify testing laboratories and others provide testing. Test kits may also be available from dealers of water treatment equipment. It is important to carefully collect water samples to prevent contamination. Contaminants to be tested for include bacteria, iron, lead, manganese, nitrate, pH and hardness.[4] Annual testing for bacteria and nitrates is recommended for people on private well water systems.[5]

Drinking Water Contaminants

Contaminants of drinking water include pathogens, radionuclides, metals, chemicals and additives. Contaminants can cause diseases ranging from dysentery, hepatitis, and giardia, typhoid, cholera, cancer, birth defects, to other long-term negative health effects. These contaminants come from a variety of sources, and different methods are effective for treatment of specific contaminants.

Pathogens are microorganisms such as bacteria, protozoa, and viruses that can enter drinking water from human sewage or animal feces. Pathogen contamination of groundwater and surface water often results from failing and inadequate septic systems or feedlot runoff. Chlorine will kill many pathogens, but filtration is required to effectively kill viruses and protozoa such as giardia.[6]

Radionuclides include naturally occurring substances such as radium and uranium that admit radiation as they decay. Radon gas in groundwater can cause bone and kidney cancer, and a greater risk of lung cancer.[7] Radioactive fallout is a contaminant that occurs in atmospheric precipitation.[8]

Chemical and metal contaminants include lead that is leached by water from plumbing pipes, faucets, and well pumps. The primary source of lead in drinking water is from lead-lined plumbing pipes, still used by more than half of the cities in the US. Lead enters water through the atmosphere from the combustion of fossil fuels, leaded gasoline, and from ore smelting. Other inorganic chemical and metal contaminants include arsenic, mercury, cadmium, chromium, barium, antimony, beryllium, copper, nickel, thallium, asbestos, cyanide, nitrates and nitrites, and selenium.[9] Chemical contamination can also occur as a result of mine drainage, agricultural pesticide and fertilizer runoff, and leaking storage tanks, and landfill leakage.[10]

Additives include chlorine, fluoride, and flocculents. Chlorine is added to kill pathogens in water. Filtration prior to chlorination can prevent formation of carcinogenic, disinfection by-products (DBPs), such as trihalomethanes (THMS) formed when chlorine reacts with organic matter.[11]

Surface Water

Surface water includes ponds, lakes and streams. These water sources may be suitable for livestock or irrigation, but the cost and difficulty of treating the water for drinking purposes make this water source a last resort.[12] Surface water sources should only be used when groundwater sources are unavailable or inadequate.[13] Ponds are commonly used sources of surface water for domestic use. Existing ponds can be used, or specially constructed, and livestock should be excluded from the catchment area. Lakes and streams are often subject to pollution and there may be special water rights and restrictions in place that prevent the diversion of this water.[14] Turbidity caused by large quantities of suspended solids such as clay, silt, or organic matter can be conditioned by filtration. Sand filters are commonly used for treating pond water, with pretreatment provided by settling tanks to collect and settle particles.

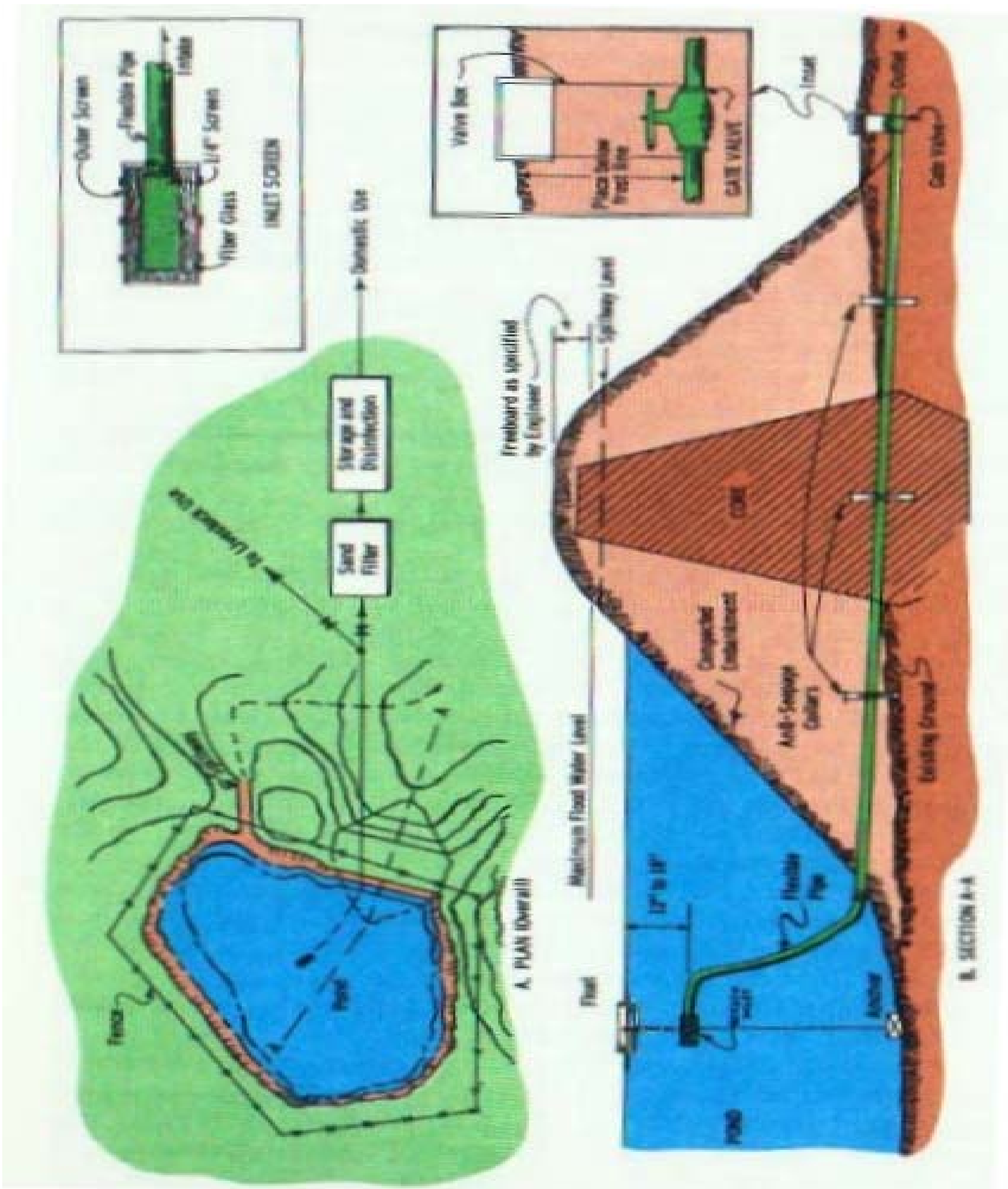

Diagram 1: Pond. From USEPA Manual of Individual Water Supply Systems

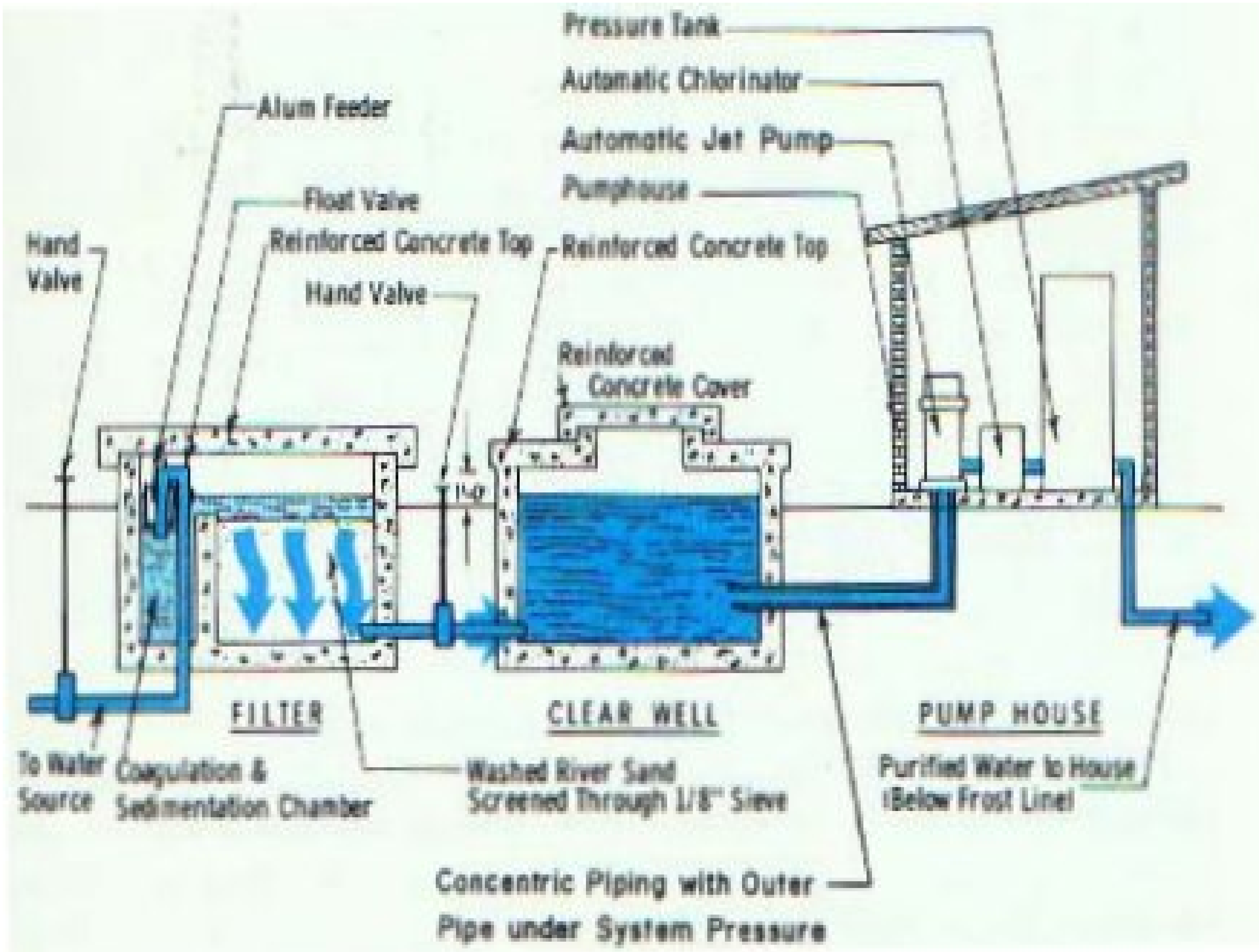

Diagram 2: Pond Filter - From USEPA Manual of individual Water Supply Systems

Rainwater
Rainwater catchments are often included in listings of surface water sources. Rainwater can provide safe drinking water if it is collected from a properly located and constructed catchment and cistern, with the addition of adequate filter and disinfection facilities. Catchments can be roofs or paved ground surfaces. Paved surfaces and shingled roofs can loose 10 percent of rainwater due to evaporation, while sheet metal roofs loose almost no water. Roof water collection cisterns should be located near a building and should be placed underground to prevent freezing in cold seasons, and to keep water cool during warm seasons. A cistern should be placed more than 50 feet from, and on higher ground than, a sewage disposal system. Cisterns should be water-tight with smooth interior surfaces and tightly sealed vents to prevent the entrance of light, surface water, and small animals. Cisterns should also have an access cover and bottom drain to facilitate regular cleaning. In rainwater supply systems, initial runoff is diverted to keep it from entering the cistern. Contaminants such as bird droppings, leaves, and dirt may enter the cistern if the first flush of rainwater is not completely diverted.[15] Roof washers are special screens or filters that separate out leaves and debris from roof water before it enters the cistern. Both owner-built designs and manufactured models are available.[16]

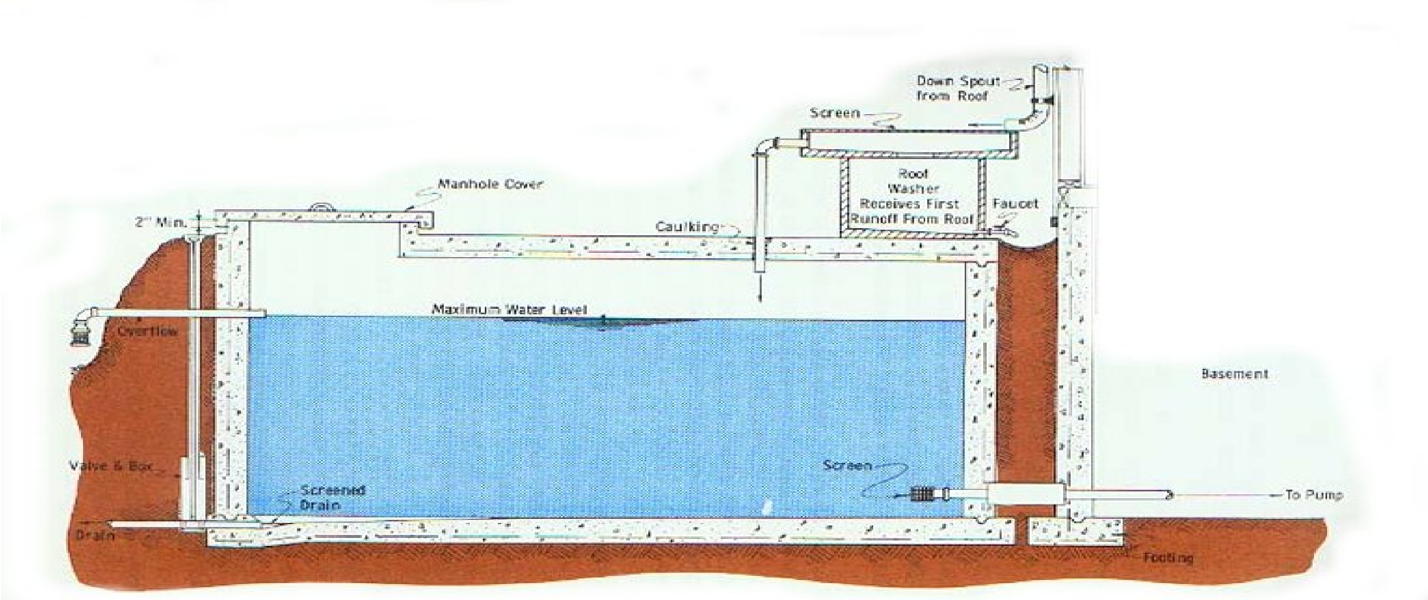

Diagram 3: Cistern and trap cross-section
From USEPA Manual of Small Public Water Supply Systems

Springs and Seeps
Springs and seeps are sites where water rises naturally to the surface. These water supply sources are subject to contamination from surface water and it is recommended to have health officials survey the area to determine suitability for drinking water purposes. Many of these water sources have been found to contain disease-causing bacteria that would classify them as surface water sources.[17] They may be developed as water supply sources with the installation of an infiltration gallery consisting of porous or perforated pipe that drains to a collection chamber. Surface runoff within 30 feet of a spring or seep should be diverted, and livestock should be excluded from areas at least 60 feet around these water sources. Although springs and seeps are seldom located in a convenient location for domestic use, they can be diverted via gravity flow to storage cisterns closer to the point of use.[18]

Groundwater
Groundwater is a source of drinking water for about half of the North American population.[19] Groundwater is defined as water beneath the surface of the ground that has drained down by gravity. This water may be close to the surface, or deep, depending on the topography and geology of a site. The level of groundwater may change seasonally depending on the weather. Groundwater may surface in springs, lakes, streams, rivers, or oceans, and is replenished by rain, snow, or irrigation. The subsoil stratum where groundwater occurs is called an aquifer. Some water can be confined to a layer above the main zone of saturation by impervious layers of rock, resulting in a "perched" water table. An aquifer may also be under pressure as a result of its location between two impervious strata. A well sunk into an aquifer under pressure will rise naturally and is referred to as an artesian well.

Well Water
Well water is a preferred source for domestic use because it is less likely to be contaminated than other sources. The proper location and construction of wells is vital to obtain pure water for domestic purposes. Improper construction is the primary cause of contamination of wells. To prevent surface water contamination, wells must be properly cased, grouted, and sealed. Information on properly constructing a well can be obtained form your local extension agent. Wells should be located far from sources of potential contamination including septic tanks and drain fields, outhouses, livestock or poultry yards. Minimum distances of more than 100 feet are often recommended. Well water may contain high concentrations of dissolved minerals such as iron and manganese. Dissolved minerals such as calcium and magnesium salts make water "hard" and render it less desirable for bathing, cooking or washing. Excessive amounts of minerals may also give well water a bad taste or odor. Manganese and iron bicarbonates, sulfates, or chlorides can also be a cause of hard water, resulting in scaly deposits in plumbing pipes, and insoluble soap residue on dishes and fabrics. Hard water also requires larger amounts of soap to be used in order to form suds.

Wells Types
The type of construction method for a well depends on factors such as site geology and depth of the aquifer, as well as the diameter of the well and supply needs such as the quantity of water required. Wells may be dug, bored, driven or jetted and such methods are suitable for a range of soils to a depth of 50-100 feet. However, these methods are unsuitable for dense igneous rock. Dug wells are usually at least 3 to 4 feet in diameter. These shallow wells may fail during periods of dry weather, but they can have an advantage over other wells in soils where water movement is slowed by sand mixed with clay and silt; because they have a larger storage area. Bored wells may be deeper and smaller in diameter than dug wells, and they are usually cased their entire length. These wells are simple to construct and may be dug by hand or with powered augers. Driven wells can be an appropriate and inexpensive option in areas with course sand. They consist of coupled pipe sections with a screened well point that is driven into the ground below the water table level. Jetted wells, or hydraulic wells, are most suitable for sandy soils. They are created using a high velocity stream of water. Cable tool or rotary-drilled wells are suitable for depths of up to 1000 feet as well as in situations where there is dense igneous rock.[20]

WATER PUMPS

Hand Pumps

Hand pumps, or cistern pumps, are positive displacement pumps that do not require electricity. These simple, low-cost, and reliable hand-operated pumps can lift water from depths of 150 feet. Capacity of hand pumps varies from 1.5 to 5 gal./per minute - up to 1,200 gallons of water per day. High lift hand pumps are able to lift water up to 150 feet, with intermediate lift lifting up to 80 feet, low lift hand pumps lift up to 40 feet, and suction pumps are able to lift water only up to 22 feet.[21] These hand operated pumps by themselves fail to supply on-demand pressure for the modern home. However, they can be used to fill a cistern up-slope of the home to provide on-demand pressure. Hand pumps can draw water even if there is some air that gets into the line.[22] The owner can perform regular maintenance, but an experienced mechanic should do repair of belowground parts. Lifetime of hand pumps is about 5 to 10 years depending on the amount of use and maintenance.

Jet Pumps

Shallow-well jet pumps are simple, low-cost, and reliable, but they do require electricity. Like the hand pumps, they are primarily designed for lifting water up to heights of only about 25 feet, but they do not function efficiently when a small amount of air gets into the line.

Solar Photovoltaic Pumps

Solar pump systems are powered by photovoltaic (solar electric) panels, which run a motor and a pump. The most common pumps used as part of photovoltaic systems are submersible centrifugal pumps, self-priming centrifugal pumps, and positive-displacement pumps, (also known as reciprocating piston pumps). Solar pumps require water storage tanks for supply of water during periods of reduced sunlight. Several solar pumping systems are reliable and available from a number of different manufacturers. Site suitability for solar pumps is determined by analysis of the record of daily irradiation at a site for at least one year. The month of lowest irradiation is used to determine the design for a solar pumping system appropriate for a site. Additional equipment such as tracking mechanisms and solar concentrating devices can be added to improve the performance of solar photovoltaic pumps. Analysis of equipment and operating costs indicates that solar pumps are likely to be cost effective in areas with high levels of solar irradiation.

Wind Pumps

Wind pumping systems, or windmills, harness wind energy to power a pump. The most common kind of wind pump is the horizontal-axis wind wheel, generally used with a reciprocating piston pump. Wind pumps should be built using a sturdy tower and a control device to withstand high winds. Occasional maintenance of these systems is needed and a complete overhaul is normally required every few years. As there is no guarantee of wind speed at a given site, a storage tank is needed for periods of reduced wind speed.

Hydraulic Ram Pumps

Hydraulic ram pumps are powered by water pressure and require no external power supply. Waterfalls or fast flowing creeks in hilly areas are harnessed to lift water to a storage tank. About 1/3 of the water supply diverted from the waterway is delivered to the storage tank for future use.

Pump Selection
Selection of a particular type of pump must be made using a number of factors including the capacity of a well or water source, daily needs and peak demand flows, quality of available water, cost and economy of operation, and reliability of the pumping equipment.[23] A typical household uses 1000 – 3000 gallons per day, this requires a pump capable of producing 600 gallons per day.[24] For solar, wind, or hydraulic ram pumps, sunlight strength, wind speed and tower height, and rate of water flow and fall respectively are all factors to evaluate before making a decision on a particular pump system.

A pumping test should be done to select the most suitable pumping equipment. This test should be done to after the well has been drilled determine the yield and draw down. Wells should be test pumped for more than 4 hours at a constant pumping rate not less than that planned for the final pumping installation. Testing is best done near the end of the dry season. Information regarding proper testing methods may be obtained from state or local health departments, the U.S. Geological Survey (USGS), or the manufacturers of pumping equipment and well screens. Manufacturers and authorized dealers of pumps are qualified to provide advice for finding a system that suits the needs and characteristics of a particular site.

Pump Housing
A heated pump house with a sloping concrete floor is standard for most well water supply systems. Proper construction requires the floor to slope away in all directions from pipe sleeve or casing.[25] (See Diagram 4, p 12).

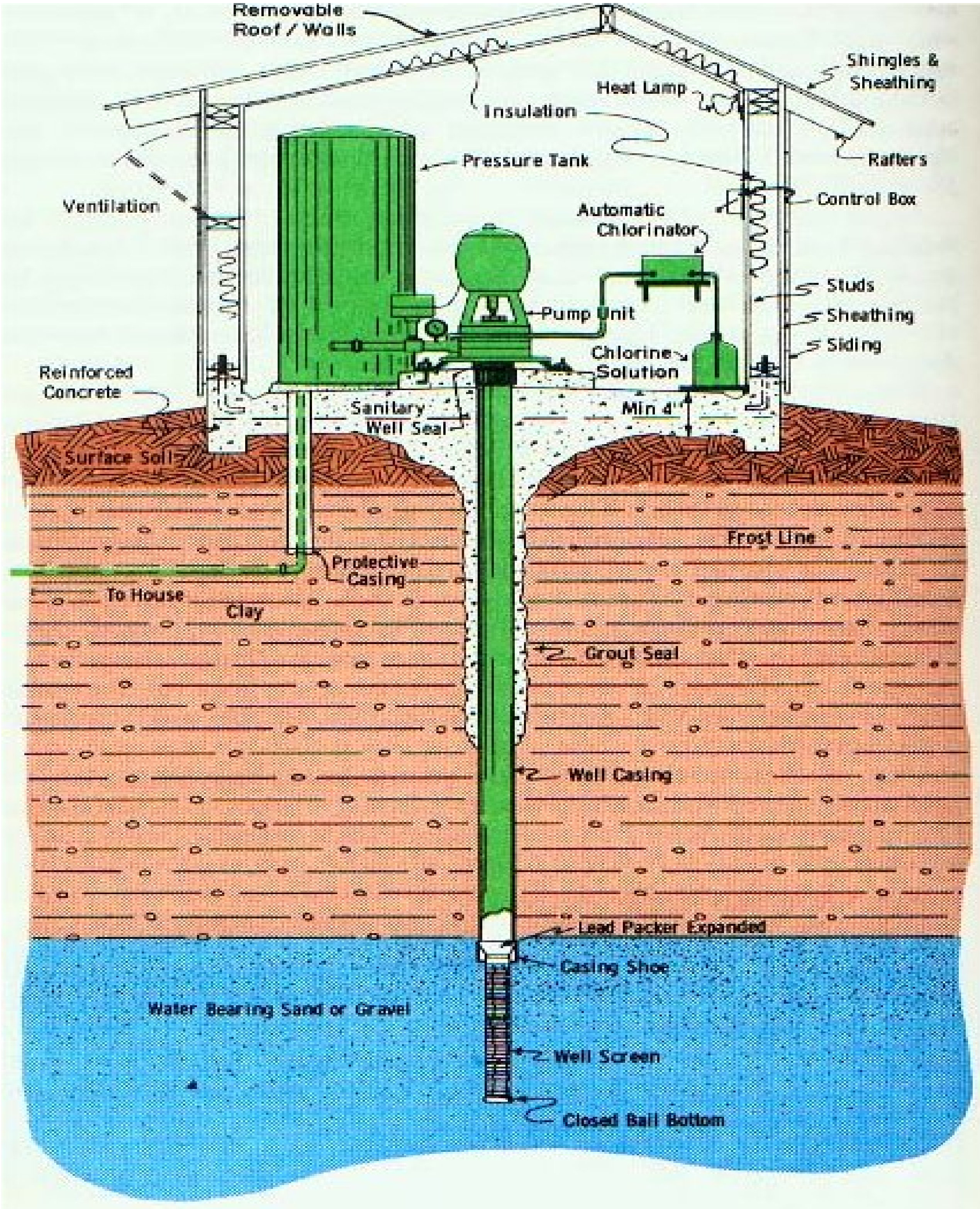

Diagram 4: Pump Housing **–** From **USEPA** Manual of Individual Water Supply Systems

WATER TREATMENT

Chlorination

The treatment of water to eliminate bacteriological pathogens is known as disinfection. Chlorine is the most common method of disinfection in small water systems. Systems for chlorination of water are often inexpensive and practical, and most frequently recommended by public health authorities. Ordinary bleach is commonly used for disinfecting small water systems. Chlorine can kill coliform bacteria and other disease organisms, and it can also oxidize sulfur, iron and other impurities to reduce the bad taste and odors. Chlorine requires "contact time" to disinfect water, and special equipment is needed to inject, mix, and retain water for treatment.[26] Chlorine must be in contact with water for about 20 minutes to be effective. Treatment effectiveness of is reduced by turbidity. A complete chlorination system, including a chemical feeder, reservoir, sediment tank, and carbon tank filter costs $3000-$4,000.[27]

Point of Entry Filters

Point of entry filters, sometimes call sediment filters, treat all water that enters the house. They are placed in the water distribution system at the point where the water enters the house, and are designed to trap large particles such as sand, dirt, or mineral contaminants. Prices for point of entry filters range from $50 to $200.

Activated Carbon Filters

Carbon filters, with a large and porous surface area, work by adsorption. Contaminants bind to the surface of the carbon as water passes through the filter. These filters are frequently faucet-mounted or used in pour-through carafes. Carbon filters are used to improve the taste of water by removing chlorine, and converts the chlorine into safer chloride and hydrogen ions. Some activated carbon filters can remove lead, asbestos, cysts, solvents, gasoline, and pesticides. Activated carbon filters are inexpensive, priced from $10 to $40, but you can expect to pay twice that much for filter replacements each year.

Distillation

Water is distilled in units that boil or vaporize water in a chamber, and then condense it back into liquid in a separate storage container. These units can remove nitrates, bacteria, microorganisms and metals such as iron and lead, and they have also been reported to remove salts and arsenic, as well as trichloroethylene, (a common dry-cleaning chemical). Distilling can remove more contaminants than activated carbon filters do. The U.S. Environmental Protection Agency says only reverse-osmosis systems and distillers may be called water "purifiers." All other systems are classified as water "treatment" devices. However, compounds such as benzene and toluene, which have a lower boiling point than water, are not removed in the boiling process. A distiller, paired with a carbon filter to remove residual chlorine and its byproducts, will provide low-cost clean drinking water.[28] or they can be made from plans.

Electric Distillers

Small countertop distillers produce about 1 gallon of distilled water in four to six hours. These distillers boil water, and can be connected directly to a water system to provide distilled water on demand. Electric distillers consume about 3 kilowatt-hours per gallon of water, and yield pure water at about 30 cents per gallon.[29] Countertop electric distillers cost $150 to $350.[30]

Passive Solar Distillers

Passive-solar distillation is an inexpensive, low-tech option for producing pure drinking water on-site. A passive-solar distiller does not require boiling for distillation and can produce water that is purer than boiled water because vigorous boiling can force unwanted residue into the distilled water. A passive-solar distiller can produce a gallon of pure water for every 1,000 sq. inches of cover surface or about 2-4 gallons per day with a 4 foot by 8 foot cover surface. Solar-distilled water has been shown to cost less than 7 cents per gallon, based on a 10-year distiller life span. These units have no mechanical parts and they are long lived. [31] Manufactured solar water distillers cost $400 to $800.[32]

Ultraviolet Light

Ultraviolet light (UV) has proven to be an effective disinfectant for groundwater, but because UV light does not work well with turbid water, it is not recommended for use with surface water unless an adequate filter is installed in the system prior to treatment. The main part of a UV system is an ultraviolet light bulb enclosed in a transparent sleeve, mounted so that water can pass by and be exposed to the light for treatment. Equipment for UV disinfection is readily available and easy to operate and maintain. However, one disadvantage of UV is that it does not provide a residual disinfectant for protection against recontamination, and another disinfectant such as chlorine is required to maintain a bacteria-controlling residual. Another disadvantage of UV is that it is not effective against some microorganisms such as *Giardia* cysts.[33]

Reverse Osmosis

Reverse osmosis (R.O.), or hyperfiltration, can remove the broadest spectrum of chemicals from water as well as give the highest removal rates.[34] R.O. is effective at removing contaminants such as organics, salts, metals, asbestos, and nitrates. It consists of a high-pressure pump, a semi-permeable membrane, and a control system to regulate pressure and flow. The membrane permits pure water to pass through under pressure while acting as a barrier to impurities. Normally some for of pretreatment is used, and post-treatment methods can include pH adjustment, aeration, and chlorination, as reverse osmosis does not provide a residual disinfectant for protection against recontamination. Water treated with R.O. systems is corrosive and may dissolve metal from plumbing or faucets.[35] The R.O. process consumes 2 to 4 gallons of water for every gallon of purified drinking water produced. R.O. systems require an incoming water pressure of 35-40 psi. If the home does not have this kind of pressure, then an auxiliary pump will need to be added which can substantially increase the cost.[36] R.O. units cost about $200-$400.

Water Conditioning

Treatment of water to improve chemical and physical water quality is known as conditioning. Hard water, resulting from minerals dissolved into groundwater from rock underground formations, is frequently “softened” in a unit connected into the water supply lines to kitchen, bath, and laundry, but not to toilets and lawn and garden lines. Water softeners consist of a tank containing ion-exchange material such as zeolite or resin beads. Some systems have a second tank containing salts for regeneration of the ion-exchange material. Homes can use 50 pounds of salt per month or about 600 pounds of salt per year, which can lead increased salt in the groundwater.[37] Softening may add salt to drinking water, and softening only the hot water will leave the cold drinking water untreated. Softening can also cause water to become more corrosive, increasing the levels of corrosion byproducts in drinking water and requiring more repairs and maintenance.[38]

Other Sources of Information:

American Consulting Engineers Council 1015 15th St. NW Suite 802, Washington, D.C. 20005.
Tel: (800) 548 2723. Email: acec@acec.org

American Rainwater Catchment Systems Association: P.O. Box 12521
Austin, TX 78711-2521 Website: www.arcsa-usa.org

American Water Works Association, 6666 West Quincy Ave. Denver, CO 80235.
Tel: (303) 794-7711

(ASPI) Appalachian Science in the Public Interest. Route 5, Box 423, Livingston, KY 40445
Tel: (606) 453 2105

Association of Plumbing and Mechanical Officials, 20001 Walnut Dr. South, Walnut CA 91789
Tel: (909) 595 8449 Fax: (909) 549 1537 Web: http://www.iapmo.org

Centre for Alternative Technology, Machynlleth, Powys SY20 9AZ UK
Tel: 01564 7024000 Fax: 01654 702782. Email: cat@gn.apc.org

Center for Maximum Potential Building Systems: www.cmpbs.org

Center for Minimum Cost Housing, School of Architecture, McGill University, 3480 University Street, Montreal, H3A 2A7, Canada

Energy Efficiency and Renewable Energy Clearinghouse. PO Box 3048, Merrifield, VA 22116
Tel: (800) 363 3732

National Rural Water Association. 2915 South 13th Street, P.O. Box 1428 Duncan, OK 73534
Tel: (405) 252 0629.

National Small Flows Clearinghouse, West VA University, PO Box 6064 Morgantown, WV 26506.
Tel: (800) 624 8301

Safe Drinking Water Act Hotline. Tel: (800) 426-4791

Texas Water Resources Institute Texas A&M University 301 Scoates Hall, MS 2118 College Station, TX 77843. Tel: (409) 845 1851 Fax: (409) 845 8554 Email: twri@twri.tamu.edu

Suppliers

Water test kits, rainwater collection systems, solar and wind pumps and filters can be purchased from:

GAIAM Real Goods - 360 Interlaken Blvd, Suite 300 Broomfield, CO 80021 (800) 919-2400.

Website: www.realgoods.com

Solar Distiller Dealers

Agua del Sol P.O. Box 651 Safford, AZ 85546 (928) 348-7512 www.aguadelsol.com
Products: ADS Flat Distiller; TSS Leaner Distiller

DMD Products P.O. Box 799 Longmont, CO 80501 (866) 253-7087
Products: Solar distiller subsystem components (pumps, solenoid valves, filters)

SolAqua P.O. Box 4976 El Paso,TX 79914 (877) 483-2980 www.solaqua.com
Products: *Rainmaker 550* single-basin distiller, SoAqua DlY Solar Distiller Kit

Sunwater Solar P.O. Box 64 Joseph City, AZ 86032 (928) 288-9267 atman@cybertrails.com
Products: Sunwater 5-L and 8-L solar distillers; Also sold through Gaiam Real Goods

Solar Distiller Plans

Ell Paso Solar Energy Association P.O. Box 26384 El Paso, Texas 79926 (915) 772-7657
Website: www.epsea.org/stills.html (solar distiller plans available for $15)

Solar Distiller Books

Pure Water Nature's Way by Dennis Lemon **DMD Products** P.O. Box 799 Longmont, CO 80501 Tel: (866) 253-7087

Solar Still by W.R. Breslin. Volunteers In Technical Assistance 815 N. Lynn St., Suite 200 Box 12438 Arlington, VA 22209 Tel: (703) 276-1800 Website: www.vita.org

Understanding Solar Distillers. Volunteers In Technical Assistance 815 N. Lynn St., Suite 200 Box 12438 Arlington, VA 22209 Tel: (703) 276-1800 Website: www.vita.org

Electric Distiller Dealers

Durastill Export Inc. (888) 434-7845 www.durastill.com

Glacier Water Systems (877) 717-5700 distilled-water.com

Polar Bear Water Group Limited (800) 363-7845 www.polarbearwater.com

Precision Water (877) 935-0505 www.precisionwater.com

University of Florida Dept. of Solar Energy Conversion Research and Development Laboratory
Website: http://seecl.mae.ufl.edu/solar/rch.htm

Waterwise (800) 874-9028 www.waterwise.com

West Bend Co. (262) 334-6949 www.westbend.com/water/product.html

Additional Resources

Jade Mountain. P.O. Box 4616 Boulder, CO 80306-4616 Tel: (800) 442 1972 or (303) 222 3500, Web: http://www.jademountain.com

Homestead Utilities. 17366 E. Meadow Lane, Mayer, AZ 86333-4119 Tel: (800) 292 5342.

NutriCycle Systems. Lewis Mill, 3205 Poffenberger, Jefferson, MD 21755 Tel: (301) 371 9172, Fax: (301) 371 9644, Web: http://www.nutricyclesystems.com

Oasis Design. 5 San Marcos Trout Club, Santa Barbara, CA 93105-9726 Tel: (805) 967 9956 Fax: (805) 967 3229, Web: http://www.graywater.net

ReWater Systems. 477 Marina Parkway, Chula Vista, CA 91910 888 Tel: (619) 585 1196, Fax: (619) 585 1919.

Solar Survival Architecture P.O. Box 1041 Taos, NM 87571 Tel: (505) 751 0462, Fax: (505) 751 1005 Email: earthship@taos.newmex.com Web: http://www.earthship.org

Sustainable Strategies 50 Beharrell Street P.O. Box 1313 Concord, MA 01742-1313 Fax: (978) 369 2484, Tel: (978) 369 9440, Email: info@ecologocal-engineering.com Web: http://www.ecologicalengineering.com

Symbiosystem. Round River Alternatives. 5879 Nikolai Road, Finland, Minnesota 55603 Tel: (877) 391 0888, Web: http://www.symbiosystem.com

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USDA. Water-Quality Improvements for Farmstead and Rural Home Water Systems. United States Department of Agriculture. Bulletin # 2274. 1984.

Numbered End Notes

1 Burns, *Cottage Water Systems*, 17.
2 Hagedorn, Groundwater Pollution, 192; and Macler, *Update on Groundwater Disinfection*, 14.
3 People with private wells can visit the EPA Safewater Website to locate state certified testing labs. Website: www.epa.gov/safewater
4 USEPA, *Manual of Small Public Water Supply*
5 Keiley, *Safe Drinking Water*
6 Lewis, safe Drinking Water, 2-7
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11 Lewis, *Safe Drinking Water*, 2-7
12 USDA, *Water Supply Sources for the Farmstead*
13 USEPA, *Manual of Small Public Water Supply*
14 USDA, *Water Supply Sources for the Farmstead*
15 USEPA, *Manual of Small Public Water Supply*
16 Roof Washer can be purchased from: Rainwater Systems, Inc. Website: www.rainwatersystem.com or Tank Town. Website: www.rainwatercollection.com
17 USEPA, *Manual of Small Public Water Supply*
18 USDA, *Water Supply Sources for the Farmstead*
19 Burns, *Cottage Water Systems*, 17.
20 USDA, *Water Supply Sources for the Farmstead*
21 USEPA, *Manual of Small Public Water Supply*
22 Burns, *Cottage Water Systems*, 28.
23 USEPA, *Manual of Small Public Water Supply*
24 Curtis, *Pump Selection and Installation*
25 USEPA, *Manual of Small Public Water Supply*

[26] USDA, *Water Supply Sources for the Farmstead*
[27] Burns, *Cottage Water Systems*, 74.
[28] Keiley, *Safe Drinking Water*
[29] SOLAR STILL WATER
[30] Keiley, *Safe Drinking Water*
[31] SOLAR STILL WATER
[32] Keiley, *Safe Drinking Water*
[33] USEPA, *Manual of Small Public Water Supply*
[34] Christian Daughton, Chief of USEPA Environmental Chemistry Branch, as cited in Keiley, *Safe Drinking Water*
[35] USEPA, *Manual of Small Public Water Supply*
[36] Burns, *Cottage Water Systems*, 73.
[37] USDA, *Water-Quality Improvements for Farmstead and Rural Home*
[38] USEPA, *Manual of Small Public Water Supply*