Agricultural Extension Service
The University of Tennessee

PB 1640

Solar-Powered Livestock Watering Systems

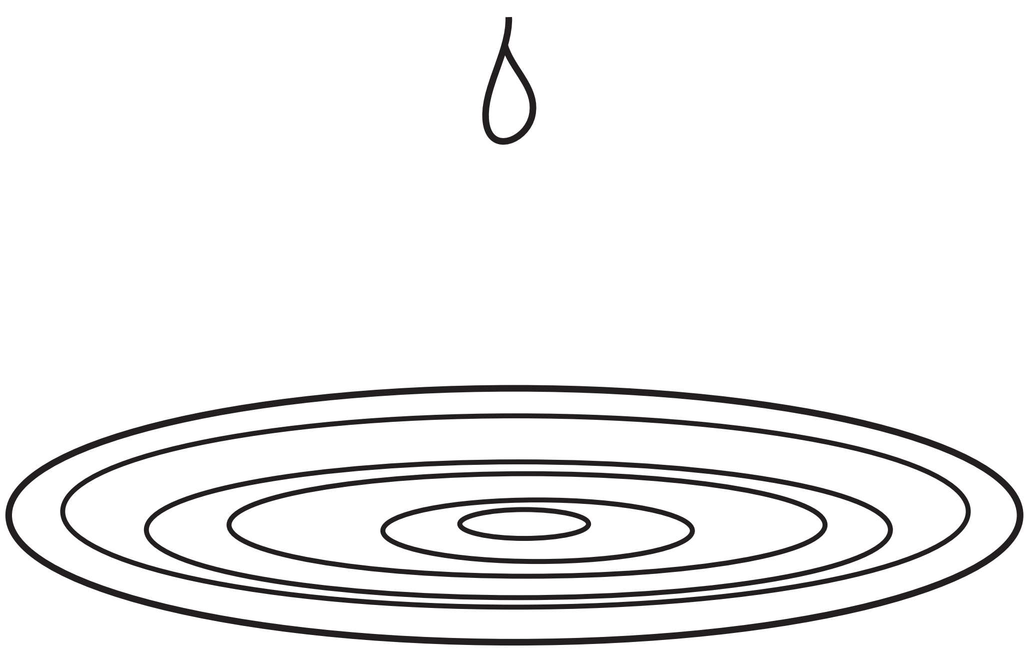

Table of Contents

Water

Solar-Powered Livestock Watering Systems

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Introduction

Many livestock producers allow their animals free access to the rivers, streams and creeks that run through rural Tennessee. Along these surface water sources are areas commonly referred to as riparian zones. A well-vegetated riparian zone establishes a buffer between agricultural land and surface water sources. These buffer strips filter and purify water as it moves across the riparian zone, reduce sediment loads and support soil stability while providing additional benefits such as improved wildlife and fisheries habitat. Over time, allowing livestock access to these buffer areas can lead to poorly vegetated riparian zones with unstable, erosion-prone stream banks.

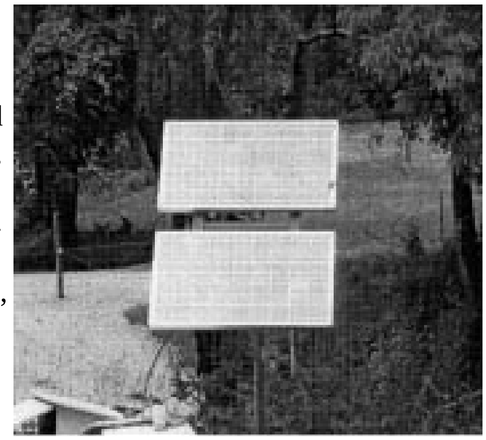

Figure 1. Photovoltaic Panels

Livestock producers are hearing more these days about the need to protect water quality through riparian zone management. Allowing the riparian zone to revegetate by removing or limiting livestock access to these buffer areas is one method of protecting water quality. However, the major problem most livestock producers face when considering limiting cattle access to riparian zones is that these rivers, streams and creeks are the only water source for their livestock.

Fencing livestock out of these streams dictates the need for an alternative watering system. In areas where AC electric power is readily available, an AC-powered pump is by far the best choice for pumping water from the stream. More often than not, AC power is not available. Since the stream is generally lower in elevation than the fields bordering the riparian zone, gravity systems are usually not an option. Several alternative pumping systems are available, including ram, sling and solar-powered pumps. While ram and sling pumps require specific conditions to operate (i.e., adequate elevation head or stream velocity), solar pumps can be operated at any sunny location within reasonable elevation limits between the watering tank and water supply. For more information about alternative livestock watering options, see PB 1641, *Selection of Alternative Livestock Watering Systems*.

How Does a Solar Water Pumping System Work?

Photovoltaic Panels

A solar-powered water pumping system is made up of two basic components. The first component is the power supply consisting of photovoltaic (PV) panels (Figure 1). The smallest element of a PV panel is the solar cell. Each solar cell has two or more specially prepared layers of semiconductor material that produce direct current (DC) electricity when exposed to light. This DC current is collected by the wiring in the panel. It is then supplied either to a DC pump, which in turn pumps water whenever the sun shines, or stored in batteries for later use by the pump.

Manufacturers normally rate voltage (volts) and current (amps) output from PV panels under peak power conditions. Peak power (watts=volts x amps) is the maximum power available from the PV panel at 1000 W/m^2 solar irradiance (amount of sunshine) and a specified temperature, usually 25C (77 F). Typical output from a 60-watt PV panel is shown in Table 1. The amount of DC current produced by a PV panel is much more sensitive to light intensity striking the panel than is voltage generated. Roughly speaking, if you halve the light intensity, you halve the DC current output, but the voltage output is reduced only slightly.

Table 1. Typical output from a 60-watt, 12-volt photovoltaic panel.

Maximum Power	60 Watts
Maximum Power Voltage	16.9 Volts
Maximum Power Current	3.55 Amps

Individual PV panels can be wired in series or parallel to obtain the required voltage or current needed to run the pump. The voltage output from panels wired in series is the sum of all the voltages from the panels. For example, the maximum voltage output from two of the 12-volt PV panels shown in Table 1 wired in series is 33.8 volts. Thus, a 24-volt DC pump requires a minimum of two, 12-volt panels wired in series. The current (amps) output from these same panels wired in series is equal to the current (amps) output from an individual panel, 3.55 amps.

The voltage and current output from panels wired in parallel is the exact opposite of series-wired panels. For panels wired in parallel, the current (amps) output is the sum of all the currents (amps) from the panels and the voltage is equal to the voltage output from an individual panel.

Solar (DC) Water Pumps

The other major component of these systems is the pump. Solar water pumps are specially designed to use solar power efficiently. Conventional pumps require steady AC current that utility lines or generators supply. Solar pumps use DC current from batteries and/or PV panels. Also, they are designed to work effectively during low-light conditions, at reduced voltage, without stalling or overheating.

Although a wide range of sizes are available, most pumps used in livestock-watering applications are low volume, yielding two to four gallons of water per minute. Low-volume pumping keeps the cost of the system down by using a minimum number of solar panels and using the entire daylight period to pump water or charge batteries. Some solar pumps are fully submersible, while others are not. The use of submersible pumps eliminates potential priming and freezing problems. Most solar water pumps are designed to use solar power most efficiently and operate on 12 to 36 volts DC.

Many solar pumping systems use positive displacement pumps that seal water in cavities inside the pump and force it upward. Their design enables them to maintain their lift capacity all through the solar day at the slow, varying speeds that result from varying light conditions. Positive displacement pumps include piston and jack pumps, diaphragm, vane and screw pumps.

Centrifugal-type pumps that impart energy to the water using a rotating impeller are typically used for low-lift or high-volume systems. Centrifugal pumps start gradually and their flow output increases with the amount of current. For this reason, they can be tied directly to the PV array without including a battery or controls. However, because their output drops off at reduced speeds, a good match between the pump and PV array is necessary to achieve efficient operation.

Pumps, because of their mechanical nature, have certain well-defined operating properties. These properties vary between types of pumps, manufacturers and models. The amount of water that a solar pumping system will deliver over a given period of time (usually measured in gallons per minute (GPM) or gallons per hour (GPH)) depends upon the pressure against which the pump has to work. The system pressure is largely determined by the total vertical pumping distance (the vertical distance between the water source and the watering tank) referred to simply as elevation head. It is roughly equal to an increase of 1 PSI (Pound per Square Inch) for every 2.31 feet of elevation head. Simply put, as the vertical pumping distance increases, the amount of water pumped over a given period of time decreases. When system friction losses and discharge pressure requirements (if any) are added to elevation head, the total system head can be determined. Pump manufacturers publish information that describes how each pump will perform under varying operating conditions. The expected flow rates and minimum recommended solar panel sizes for a typical 24-volt, positive-displacement, diaphragm-type submersible pump are shown in Table 2. The choice of pump depends on water volume needed, efficiency, price and reliability.

Table 2. Estimated flow rates in gallons per minute for a typical positive-displacement, 24-volt diaphragm type pump.

Total Head Feet	Flow Rate GPM	Current Amps
0	3.7	1.6
10	3.5	1.7
20	3.4	2.0
30	3.3	2.2
40	3.2	2.4
50	3.1	2.6
60	3	2.9
70	2.9	3.1

Non shaded areas - Two 53-watt panels in series
Shaded areas - Two 70-watt panels in series

Solar-Powered Water Pumping System Configurations

There are two basic types of solar-powered water pumping systems, battery-coupled and direct-coupled. A variety of factors must be considered in determining the optimum system for a particular application.

Battery-Coupled Solar Pumping Systems

Battery-coupled water pumping systems consist of photovoltaic (PV) panels, charge control regulator, batteries, pump controller, pressure switch and tank and DC water pump (Figure 2). The electric current produced by PV panels during daylight hours charges the batteries, and the batteries in turn supply power to the pump anytime water is needed. The use of batteries spreads the pumping over a longer period of time by providing a steady operating voltage to the DC motor of the pump. Thus, during the night and low light periods, the system can still deliver a constant source of water for livestock.

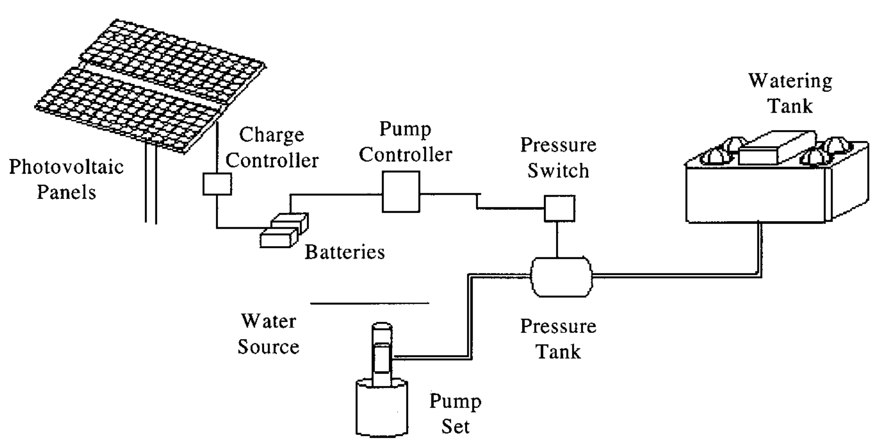

Figure 2. Battery-coupled solar water pumping system.

The use of batteries has its drawbacks. First, batteries can reduce the efficiency of the overall system because the operating voltage is dictated by the batteries and not the PV panels. Depending on their temperature and how well the batteries are charged, the voltage supplied by the batteries can be one to four volts lower than the voltage produced by the panels during maximum sunlight conditions. This reduced efficiency can be minimized with the use of an appropriate pump controller that boosts the battery voltage supplied to the pump.

System Components

Pump Controller**:** The primary function of a pump controller in a battery-coupled pumping system is to boost the voltage of the battery bank to match the desired input voltage of the pump. Without a pump controller, the PV panels' operating voltage is dictated by the battery bank and is reduced from levels which are achieved by operating the pump directly off the solar panels. For example, under load, two PV panels wired in series produce between 30 to 34 volts, while two fully charged batteries wired in series produce just over 26 volts. A pump with an optimum operating voltage of 30 volts would pump more water tied directly to the PV panels than if connected to the batteries. In the case of this particular pump, a pump controller with a 24-volt input would step the voltage up to 30 volts, which would increase the amount of water pumped by the system.

Charge Control Regulators: Solar panels that are wired directly to a set of batteries can produce voltage levels sufficient enough to overcharge the batteries. A charge control regulator should be installed between the PV panels and the batteries to prevent excessive charging. Charge controllers allow the full current produced by the PV panels to flow into the batteries until they are nearly fully charged. The charge controller then lowers the current, which trickle charges the battery until fully charged. The regulator installed should be rated at the appropriate system voltage (i.e., 12-volt, 24-volt, etc.) and the maximum number of amperes the solar panels can produce. The regulator should be installed near the batteries, in accordance with the manufacturer's instructions. This usually requires only four connections: the PV panel "POS" and "NEG" terminals and the battery "POS" and "NEG" terminals.

In addition to overcharging protection, a low-voltage or battery state-of-charge control is required to prevent deep-discharge damage to batteries. The low-voltage relay acts as an automatic switch to disconnect the pump before the battery voltage gets too low. The relay is activated and switches when battery voltage drops to "low-voltage" threshold, and de-activates and switches back when the battery voltage rises to "reconnect" threshold. Most suppliers of PV equipment offer a charge control regulator that combines both overcharge protection and low-voltage disconnect to protect the batteries.

Batteries: The most common batteries used in stand-alone PV systems are lead-acid batteries. The familiar deep-cycle, marine-grade battery is a good example. They are rechargeable, easily maintained, relatively inexpensive, available in a variety of sizes and most will withstand daily discharges of up to 80 percent of their rated capacity.

A new type of lead-acid battery "gel cell" uses an additive that turns the electrolyte into a non-spillable gel. These batteries can be mounted sideways or even upside down if needed because they are sealed. Another type of battery using nickel cadmium (NiCd) plates can be used in PV systems. Their initial cost is much higher than lead-acid batteries, but for some applications the life-cycle cost may be lower. Some advantages of NiCd batteries include their long-life expectancy, low maintenance requirements and their ability to withstand extreme conditions. Also, the NiCd battery is more tolerant to complete discharge. It is important to choose a quality battery rated at a minimum of 100 amp-hour storage capacity.

Shallow-cycle (car batteries) should not be used for PV applications. These batteries are lighter, less expensive and are designed to produce a high-current cold-cranking amps for a short period. The battery is then quickly recharged. Generally, shallow-cycle batteries should not be discharged more than 25 percent of the rated battery capacity.

Battery banks are often used in PV systems. These banks are set up by connecting individual batteries in series or parallel to get the desired operating voltage or current. The voltage achieved in a series connection is the sum of the voltages of all the batteries, while the current (amps) achieved in series-connected batteries is equal to that of the smallest battery. For example, two 12-volt batteries connected in series produce the equivalent voltage of a 24-volt battery with the same amount of current (amps) output as a single battery. When wiring batteries in parallel, the current (amps) is the sum of the currents (amps) from all the batteries and the voltage remains the same as that of a single battery.

Batteries must be protected from the elements. Batteries should be buried below the frost line in a water-tight enclosure or placed in a building where the temperature will remain above freezing. If the batteries are buried, select a well-drained location. Batteries should never be set directly on concrete surfaces, as self discharge will increase, especially if the concrete surface gets damp.

Direct-Coupled Solar Pumping System

In direct-coupled pumping systems, electricity from the PV modules is sent directly to the pump, which in turn pumps water through a pipe to where it is needed (Figure 3). This system is designed to pump water only during the day. The amount of water pumped is totally dependent on the amount of sunlight hitting the PV panels and the type of pump. Because the intensity of the sun and the angle at which it strikes the PV panel changes throughout the day, the amount of water pumped by this system also changes throughout the day. For instance, during optimum sunlight periods (late morning to late afternoon on bright sunny days) the pump operates at or near 100 percent efficiency with maximum water flow. However, during early morning and late afternoon, pump efficiency may drop by as much as 25 percent or more under these low-light conditions. During cloudy days, pump efficiency will drop off even more. To compensate for these variable flow rates, a good match between the pump and PV module(s) is necessary to achieve efficient operation of the system.

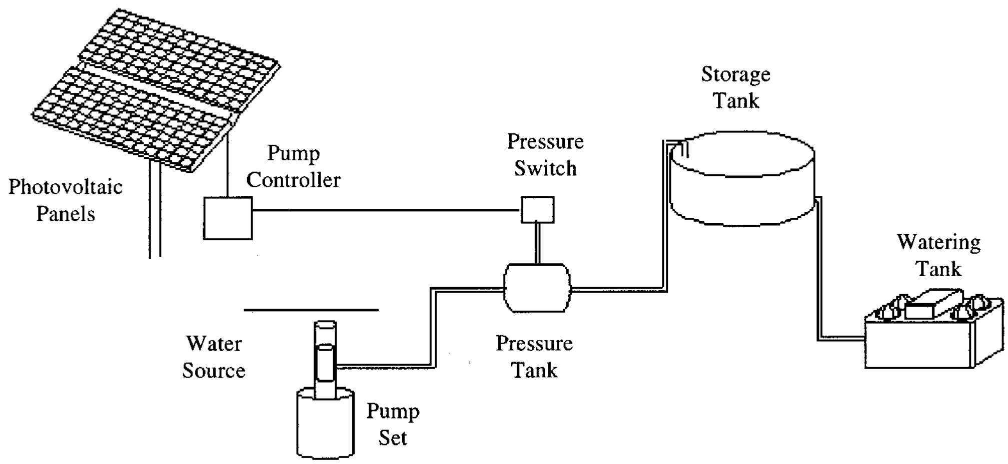

Figure 3. Direct-coupled solar pumping system.

Direct-coupled pumping systems are sized to store extra water on sunny days so it is available on cloudy days and at night. Water can be stored in a larger-than-needed watering tank or in a separate storage tank and then gravity-fed to smaller watering tanks. Water-storage capacity is important in this pumping system. Two to five days' storage may be required, depending on climate and pattern of water usage.

Storing water in tanks has its drawbacks. Considerable evaporation losses can occur if the water is stored in open tanks, while closed tanks big enough to store several days water supply can be expensive. Also, water in the storage tank may freeze during cold weather.

System Component

Power Controllers: The efficiency of a direct-coupled water pumping system is sensitive to the match between the pump and the PV system. PV panels produce a fairly constant voltage as the light intensity changes throughout the day; however, amperage changes dramatically with light intensity. During low-light levels, such as early morning and late evening, the PV array may be producing 30 volts at 1 amp. The pump motor needs current to start; however, it can run on a lower voltage. A pump controller's circuitry trades voltage for current, which allows the pump to start and run at reduced output in weak-sunlight periods. Matching pump motor performance to the available sunlight with a properly sized controller can increase the amount of water pumped in a day by 10 to 15 percent.

Selecting a Solar-Powered Water Pumping System

Cost

Cost is a factor that must be considered when selecting a solar pumping system. Total cost depends on many factors, such as the type of system (direct-coupled or battery-coupled), daily water requirements, pressure the pump must work against to supply the required water flow, complexity of the water delivery system, etc. For example, low-volume solar pumping systems keep costs down, when compared to higher-output solar pumping systems, by using a minimum number of solar panels and by using the entire daylight period to charge batteries or pump water. Producers who participate in cost-sharing programs offered by the USDA Natural Resources Conservation Service and the Tennessee Department of Agriculture can greatly reduce their portion of the system cost.

Livestock Water Requirements

The daily livestock water requirement is one of the key factors in the design of the solar water pumping system. Size of the herd, pregnancy, lactation, animal weight, type of feed, physical activity and time of year all have to be considered when determining the minimum volume of water the solar pumping system must supply each day. The daily water intake by various types of beef cattle for each month of the year, shown in Table 3, gives a good estimate of the daily water needs that must be met by the solar pumping system. For example, an average cow/calf operation in Tennessee may need to water 30 cows and one bull year round. If the cows have nursing calves from February through June and the calves are sold in October for finishing, the pumping system must be designed to supply a maximum of roughly 740 gallons per day during July, the hottest month of the year (Table 3.)

Sizing the System

Many reputable solar equipment dealers (Appendix A) provide technical assistance free of charge. The dealer will combine the information you provide about your water requirements and livestock operation with the information on solar energy available in your area, and help you select the solar pumping system that best fits your livestock watering needs and budget. The type of information you will need to supply to the vendor to have your system designed or to solicit a price quote includes:

- The maximum number of gallons of water needed daily for each month of the year.
- Description of water source.
- Total vertical distance that water is to be pumped, as measured from the lowest level from the water source to the highest level of the watering tank, including the pipe outlet.
- Quality of water. Is it clear, silty, high in mineral content or does it contain a lot of algae growth?
- Solar access: Is unobstructed sunlight available near the water source? If not, how far away?
- Information on any water-pumping equipment, distribution system and storage capacity presently being used.
- A sketch of how you want to lay out your watering system. Include the distances from the solar panels to the pump and from the pump to the watering tank(s).

Table 3. Estimated daily water intake of cattle

Month	Cows		Bulls	Growing Cattle			Finishing Cattle			
	Nursing Cows	Bred Dry Cows & Heifers		400 lbs.	600 lbs.	800 lbs.	400 lbs.	600 lbs.	800 lbs.	1200 lbs
	gal./day	gal./day	gal./day	gal./day	gal./day	gal./day	gal./day	gal./day	gal./day	gal./day
Jan.	11	6	7	3.5	5	6	5.5	7	8.5	9.5
Feb.	11.5	6	8	4	5.5	6.5	6	7.5	9	10
Mar.	12.5	6.5	8.6	4.5	6	7	6.5	8	9.5	10.5
April	15.5	8	10.5	5.5	7	8.5	8	9.5	11	12.5
May	16.5	9	12	6	8	9.5	9	11	13	14.5
June	17	10	13	6.5	8.5	10	9.5	12	14	16
July	17.5	14.5	19	9.5	13	15	14.5	17.5	20.5	23
Aug.	17.5	14	18	9	12	14	14	17	20	22.5
Sept.	16.5	10	13	6.5	8.5	10	9.5	12	14	16
Oct.	16.5	8.5	11.5	5.5	7.5	9	8.5	10	12	14
Nov.	13	6.5	9	4.5	6	7	6.5	8	10	10.5
Dec.	11	6	7.5	4	5	6	6	7	8.5	9.5

Table prepared by Paul Q. Guyer, University of Nebraska, G77-372-A

Installing the System

Mounting PV Panels

The PV panels should be mounted facing due south in a location where they receive maximum sunlight throughout the year. Panels facing 30 degrees away from south will lose approximately 10 to 15 percent of their power output. When choosing a site, it is essential to avoid trees or other obstructions that could cast shadows on the solar panels and reduce their output. This is especially true during the winter when the arc of the sun is lowest over the horizon.

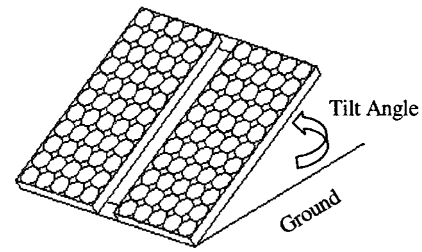

Figure 4. Solar panel tilt angle.

Solar panels produce the most power when they are pointed directly at the sun. The tilt angle is the angle between the plane of the solar panel surface and the ground. For maximum energy collection, the panel surface should be perpendicular to the sun. The desired tilt angle can be selected using the following general rules for optimum summer or winter use:

Summer Use: tilt angle = 25 degrees   Winter Use: tilt angle = 45 degrees

For installations where the solar panels are permanently mounted, they should be tilted for maximum winter output. As a rule, if the power output is sufficient in the winter, it will be totally satisfactory during the rest of the year.

Most manufacturers and distributors sell mounting hardware specifically designed for their panels. This hardware is intended for multiple applications so parameters such as wind loading have been considered in the design. Using this mounting hardware is the simplest and often the most cost effective.

Locating the PV modules close to the water source is important to keep voltage loss in the system wiring to a minimum. A fence around the PV modules is required to protect the PV panels from damage due to animals. After installation, the area inside the fence must be maintained. Shading from weeds or a single tree branch can limit power output.

Wiring

Selecting the correct size and type of wire when connecting the pump to the batteries or solar panels increases the performance and reliability of the system. If possible, keep the PV panel and pump sets within 100 feet of each other. At this distance, a # 12 gauge wire is sufficient to keep the voltage loss in most 24-volt systems to roughly 3 percent. Larger diameter wires will be required at distances greater than 100 feet to keep the voltage loss in the system to a minimum. A voltage drop of only 5 percent translates to a 7.5 percent power loss at the pump. The use of direct-burial wire (UF) simplifies installation, since the wire can be buried under the water pipe in the same trench without conduit. Make all connections in water-tight junction boxes and attach all wires to support structures with wire ties. Use PVC conduit to protect the wires anytime they are above ground.

Solar water pumping systems attract lightning because of the excellent ground they provide. If possible, do not locate the pump system, which includes the PV array, wiring and pump, on high ground. Ground the PV panel frame and all equipment boxes to metal well casings or to a driven ground rod. You might have to install lightning rods on higher terrain around the pump if lightning is a problem.

Water Delivery System

The pump can be operated using either a standard pressure switch and recharged pressure tank commonly used with home well pumps or an electronic float switch. The recharged pressure tank prevents the continuous on/off cycling of the pump when cattle drink from a nearly full watering tank. When the float valve closes in a recharged pressure tank system, the pump continues to run until the pressure tank is charged with water at the preset off-pressure. As the level in a near-full tank fluctuates when animals are drinking and the float valve opens and closes, water is supplied from the charged pressure tank and the pump does not cycle. When animals drink enough to lower the water level and the float valve remains open, the pressure tank water charge is exhausted and the pressure switch then turns on the pump. A check valve placed in line upstream from the pressure switch location prevents the water line from draining when the pump is not operating.

Electronic float switches can be used to turn the pump on and off when the livestock watering and/or storage tank is low or full. Control wires from the livestock watering tank and/or storage to the pump controller must be run to make the system operate.

In most applications, the flows associated with low-volume pumping systems can be handled in 3/4-inch, schedule 40 PVC pipe; however, the use of 1-inch, schedule 40 PVC pipe is recommended to keep friction losses negligible. Friction losses throughout the system can significantly increase the total head and thus reduce the amount of water that can be pumped. Cattle watering tanks should be installed on heavy use areas to prevent erosion and mud problems from developing around the watering tank. For more information on installing heavy use areas, see Agricultural Engineering and Biosystems Engineering publication WE-01-99 *Construction of Farm Heavy-Use Areas Using Geotextile*.

Pump Sets

The use of submersible pumps requires some method of securing the pump in the stream. For pump sets where the low-flow water depth exceeds 3 feet, a low-cost pump mount can be constructed from 6-inch PVC pipe and a 5-gallon plastic bucket (Figure 5). This pump set mirrors a well bore. This works quite well, since the pump is designed as a well pump and is intended to be housed in a vertical well pipe.

First, place a 36-inch length of 6-inch, schedule 40 PVC pipe vertically in a 5-gallon bucket and then fill the bucket and pipe with concrete to the full depth of the bucket. Drill a series of 1-inch holes in the pipe extending above the bucket up to the bottom of the pump to allow water to enter the pipe. Holes should not be drilled in line or near the pump intake or the pump motor may not be adequately cooled. The motor depends on flow past the pump body to keep it cool. A piece of stainless steel mesh banded around the pipe helps keep debris from clogging the pump inlet. A hole dug into the stream bottom allows the bottom of the bucket to be set 8 to 10 inches below the stream bed. Although the weight of the concrete keeps this unit in place, attach a cable from a post or other secure anchor to the unit for additional security.

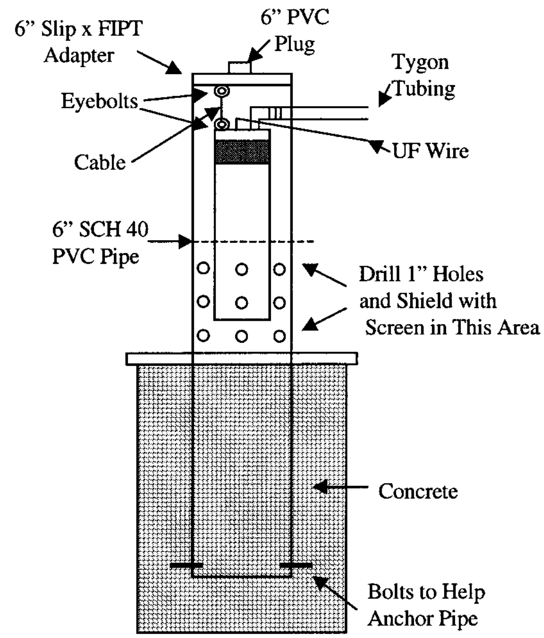

Figure 5. Pump set for submersible pump.

Maintenance

Most failures of solar pumping systems are caused by pump problems. Sand and silt pulled in by the pump are the primary cause of failure. Filtering out silt or sand at the pump intake with fine mesh screen will prolong the life of the pump.

The amount of maintenance required by solar pumping systems depends on the type and complexity of the system. PV panels generally require very little maintenance; however, pumps, batteries and other components require periodic routine maintenance. Solar pumping systems failures can be avoided with the following preventative maintenance:

- Check the tightness of all electrical connections in the system. Battery connections should be cleaned and treated with a corrosion inhibitor available from any auto parts store.

- Follow the manufacturer's recommended maintenance procedures for all batteries. Check the electrolyte level and specific gravity of each cell in the battery. Do not overfill batteries.

- Check system wiring. Look for cracks in the insulation of exposed wires. Inspect wires entering and exiting junction boxes for cracks or breaks in the insulation. Replace as necessary.

- Check all junction boxes for water damage or corrosion. Check the tightness of the terminal screws and the general condition of the wiring. After inspection, make sure covers on junction boxes are closed and sealed.

- Inspect the array-mounting frame to be sure that all mounting hardware is tight. Loose bolts could result in a damaged panel. Maintain any tie-down anchors. Remove any weeds, tree branches or any other objects that may be shading the PV panel.

- Check to see if the panel glass is clean. If it is dirty, simply clean it with a soft cloth, mild detergent and water. Rinse with clean water to prevent the detergent from forming a film on the panel.

- Check the operation of switches. Make sure the switch movement is solid. Look for corrosion or charring around contacts. Check fuses with ohmmeter after removing; look for discoloration at their ends.

Demonstration Systems

Solar water pumping systems have been installed across Tennessee to determine their capability and reliability under actual field conditions. On one demonstration farm, a battery-coupled, solar pumping system was installed to provide water to 50 beef cows that had been fenced out of a stream. The system pumped water from the stream to a Mirafount™ watering tank located approximately 300 linear feet from and 30 feet above the stream. The watering tank was placed on an heavy use area to prevent erosion and mud problems. This system provided the sole source of water for the animals.

The power generated by two, 51-watt solar panels wired in series was stored in two deep-cycle marine batteries also wired in series to produce a 24-volt system. A 24-volt submersible pump that supplies approximately three gallons per minute pumps water from the stream up to the watering tank in the pasture. These solar-pumping systems have proved to be quite reliable and trouble-free when properly installed. A breakdown of the cost for this system is shown in Table 4.

Table 4. Typical cost for a direct-coupled solar pumping system

Item	Cost ($)
Solar pumping system	
24-volt submersible pump	500
2, 51-watt PV panels	525
Mounting bracket	150
Pump controller	150
Charge controller	35
2 deep-cycle batteries	125
100 ft., #12 UF wire	20
Watertight enclosure for batteries, system circuitry and pressure tank	100
Water Lines	
300 ft., 1-in PVC pipe	60
Fittings/glue	35
Check valve	15
Trenching	75
Pressure tank and switch	125
Watering Tank	
Freeze proof stock tank	500
Concrete	30
Geotextile fabric	65
Crushed stone	200
Site preparation	150
Total	$2860

Appendix A: Solar Water-pumping Equipment Suppliers

This is a partial list of suppliers that sell solar pumping equipment. The use of trade names, etc. in this publication does not imply an endorsement or guarantee by The University of Tennessee of the products or criticism of similar ones not mentioned.

Golden Genesis Company
7812 East Acoma
Scottsdale, AZ 85260
(800) 223-9580
Web Site: **http://www.goldengenesis.com**

SHURflo
Unit 5 Sterling Park Gatwick Road
Crawley, West Sussex United Kingdom RH10 2QT
44 (0) 1293 424000
Web Site: **http://www.shurflo.com**

Solar Water Technologies
426-B Elm Ave.
Portsmouth, VA 23704
(800) 952-7221
Web Site: **http://solarwater.com**

Solar Pumping Products
325 E. Main Street
Safford, AZ 85546
(602) 428-1092

Visit the Agricultural Extension Service Web site at:
http://www.utextension.utk.edu/

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COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
The University of Tennessee Institute of Agriculture, U.S. Department of Agriculture,
and county governments cooperating in furtherance of Acts of May 8 and June 30, 1914.
Agricultural Extension Service
Charles L. Norman, Dean