Pumping Water from Remote Locations for Livestock Watering

Lori Marsh, Extension Engineer, Virginia Tech

Both intensive grazing and water quality protection programs are increasing the need for pumping water to livestock from locations where commercial electricity is not readily available. If electricity is available, it will generally be the most cost-effective method for pumping water. However, there may be instances where the distance from existing power lines to the desired pump location makes it cost-prohibitive to obtain electricity from the utility. A rule of thumb is that alternative energy sources may be economically justified if the distance to commercial power exceeds one-third of a mile. In this case, the livestock producer can select from a range of alternative power methods. The "best" alternative power option is generally site specific.

Prior to considering alternative power options, it is advisable to determine the cost of commercial electricity. This will allow comparison of the cost of commercial electricity to the cost of alternative systems such as solar or wind. If there is already electrical service within 1500 feet of the desired pumping location, it may be feasible to run a private electrical line to the site from the existing service. If the distance is greater, it is advisable to get a price quote from the local electrical utility regarding the cost.

How Much Water Do You Need?

Table 1 presents estimated water requirements for various livestock. Actual consumption will depend on many factors including air temperature, animal size, species, age, milk production, type of ration, dry matter consumed, and other variables.

It is not necessary to provide the entire daily requirement for dairy cows at pasture. Given the opportunity, milking cows will drink some water at the barn before and/or after milking. Provide at least 15 gal per hundred pounds of milk produced for each half day on pasture, especially if pastured during daylight hours.

Required Watering Space, Flow Rate, and Reserve Capacity

There are two issues involved in providing adequate water for animals. First, the total water requirement, as shown in Table 1, must be met. But there is another issue—the water must be available when the animals want to drink it. If an adequate flow rate is available, then water can be supplied on demand. If, however, the flow rate is low, then storage capacity must be pro-

Table 1. Livestock water consumption for various animals.

Livestock	Avg. Consumption (gal/day)	Hot Weather (gal/day)
Milking cow	20-25	25-40
Dry cow	10-15	20-25
Calves	4-5	9-10
Beef	8-12	20-25
Sheep	2-3	3-4
Horse	8-12	20-25

Virginia Tech
Invent the Future

Produced by Communications and Marketing, College of Agriculture and Life Sciences,
Virginia Polytechnic Institute and State University, 2009

VIRGINIA STATE UNIVERSITY

vided. In other words, providing a trickle of water over a 24-hour period requires storage capacity so that the water is available when the animal wants to drink.

The rate of water intake and herd drinking pattern is dependent on the location of the water. If water is located outside the fenced pasture or paddock, such that the animals must leave the pasture area through an opening in the fenced area, the entire herd will tend to go for a drink at the same time. Dominant animals will drink first, leaving the timid animals to drink last. If sufficient flow rate or water capacity isn't present, the last to drink will suffer thirst. This herd drinking behavior has been observed even if the water source is only a few feet outside the pasture.

If the water is some distance from the pasture, or if it is located in the shade, the herd will tend to congregate around the water source and not return to the pasture and grazing. Never locate water more than 500 feet from the nearest corner of the pasture paddock.

On the other hand, if animals do not have to leave the confines of the pasture to drink, they tend to drink one or two at a time as each animal becomes thirsty. In this case, a lower flow rate and fewer drinking spaces are required.

To assure access to water and, therefore, peak animal performance, adequate space should be available at the watering trough to allow for at least 5 % (one animal out of every 20) to drink simultaneously. If the water is outside the pasture area, provide as much drinking space as possible to reduce fighting and waiting time at the tank; at least one space for every 10 animals is recommended. For each animal drinking space, allow 20 inches of perimeter length around a circular tank and 30 inches of length for a tank with straight sides.

To assure that water is always available, a flow rate of 2 gallons per minute (gpm) per animal space is recommended for small tanks with little reserve capacity. For example, for a herd of 50 cattle with water located within the pasture area, it is recommended that a minimum of three drinking spaces (50 x 0.05, rounded up = 3) with a flow rate of 6 gpm (3 spaces x 2 gpm per space = 6) be provided. If there is not sufficient flow rate available to provide 2 gpm per animal served, then additional water storage should be provided. Reserve capacity should allow for at least 2 gallons of water for each cow or horse in the pasturing group and, ideally, the flow rate should allow for the reserve to be replenished within an hour. This information is summarized in Table 2.

Table 2. System flow rates and reservoir capacities.

A. System flow rates (gpm)

- 1-2 gpm per animal drinking space, if small reserve capacity.
- Flow rate should be the total daily water requirement divided by 1,440, if storage capacity of one or more days is provided. Note: 1,440 is the number of minutes in a day. Dividing the daily requirement by 1,440 yields the minimum continuous flow rate required for supply to meet demand.

B. Storage Recommendations (reservoir capacity)

- Not needed if flow rate equals instantaneous demand (2 gpm per animal space)
- Storage capacity of 2 gal/animal if sufficient flow rate is available to replenish in one hour.
- One day's water requirement if flow rate does not meet instantaneous demand or allow refilling of 2 gal/animal in one hour.
- At least two day's water requirement (three recommended) if intermittent power sources are used to pump water (e.g. wind or solar).

C. Water space minimums:

- Provide one space for every 20 animals—5% of herd (cup, bowl, or small tub) when water is available in each paddock and livestock generally drink one at a time
- Provide room for 10% of the animals (one animal out of every 10) to drink at one time at a trough or tank at centralized water supply. Allow 20 inches of perimeter length for circular tanks and 30 inches for straight side of a tank per animal.

Example: Assume a 75-head herd of beef cattle. For summer conditions, daily herd water requirement is 25x75 = 1,875 gal. This means a continuous flow rate of at least 1.3 gpm is required (1,875gal/1,440 min/day). Based on the 5% rule, a minimum of 4 cow drinking spaces should be provided. Ideally, a flow rate of 8 gpm would be provided to meet the instantaneous demand of the animals. If this flow rate is not available, reserve capacity of at least 150 gal (2 gal/animal x 75 animals) should be provided and a flow rate of 2.5 gpm (150 gal in 60 minutes) would be required to refill the storage in one hour. If 2.5 gpm is not available, reserve capacity should be at least 1,875 gal. Finally, if a solar system were used to pump water, reserve capacity should be at least 3,750 gal, to carry over days with little sunshine (see description of solar pumps below).

Sizing a Pump

A pump must be capable of both delivering the required flow rate and overcoming the resistance inherent in the distribution system. This resistance is referred to as total head and is generally expressed in terms of pounds per square inch (psi) or feet of head. One psi corresponds to a column of water 2.31 feet high. Put another way, a column of water 2.31 feet high exerts one psi of pressure at its base. To convert from feet of head to psi, multiply by 0.43. Conversely, to convert from psi to feet of head, multiply by 2.31.

The total head consists of the suction lift (vertical distance from water surface to pump), elevation head (vertical distance from the pump to the highest elevation of water in the system), friction loss (the pumping pressure lost in the system due to friction, which depends upon pipe length, size, material, number and type of pipe fittings, and water flow rate) and the outlet pressure required (the optimum working pressure for proper operation of the water outlet device.) See Figure 1.

Elevation changes can be measured using a surveying transit or a carpenter's level and a stick of known height. To do this, firmly attach the level to the stick. Next, starting with the stick and level at the water source, sight down the level toward the location for the pump (if you are determining suction lift) or the watering tank (if you are determining elevation head), until your line of sight hits the ground. Move the stick to the point sighted, and repeat the process. Remember to keep the device level as you site down it. The total vertical elevation change will be the number of times you moved the stick multiplied by the height of the stick. See Figure 2.

To aid in calculating the total pressure losses in the system due to friction, manufacturers provide friction loss tables for all pipe materials and pipe sizes. Table 3 is an example of a friction loss table for plastic (polyethylene) pipe. Friction losses for fittings can generally be ignored in designing livestock watering systems. The data provided in Table 3 are adequate for planning purposes if you plan to use flexible, polyethylene pipe. However, if possible, it is best to use data provided by the manufacturer of the product you plan to purchase.

Table 3. Friction loss in polyethylene pipe per 100' of pipe

	Nominal[1] Pipe Size					
Discharge GPM	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"
	Pressure Drop, PSI					
1	0.56	0.15	0.05	0.04	-	-
2	1.84	0.49	0.16	0.09	-	-
3	3.72	0.98	0.31	0.14	0.04	-
4	6.15	1.61	0.51	0.21	0.07	-
5	9.15	2.39	0.76	0.28	0.10	0.03
6	12.55	3.29	1.04	0.37	0.14	0.04
7	16.53	4.32	1.37	0.47	0.18	0.05
8	20.91	5.46	1.74	0.58	0.23	0.07
9	25.70	6.77	2.13	0.70	0.28	0.08
10	31.18	8.10	2.57	1.43	0.33	0.10
15	64.03	16.64	5.27	2.38	0.68	0.21

Notes:
1. Nominal pipe size refers to the name/size provided by the manufacturer, not the inside diameter of the pipe.
2. To determine friction loss for any length run, multiply table value times pipe length and divide by 100.
3. To convert from psi to ft, multiply by 2.31.

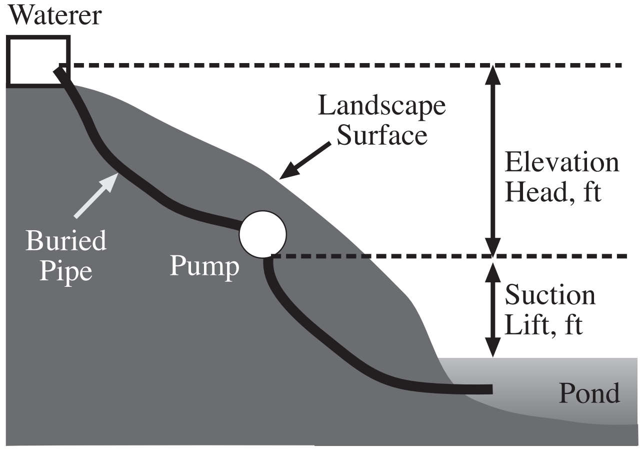

Figure 1. Suction lift and elevation head.

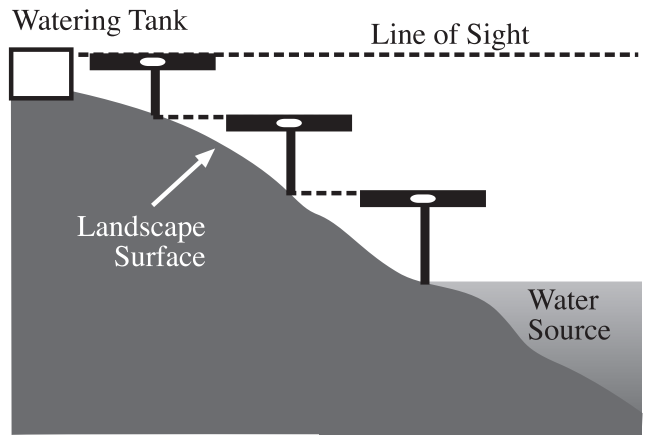

Figure 2. A method for measuring elevation changes.

Typically, friction losses are given per 100 feet of pipe. The longer the distance that water must travel, the greater the total friction loss. Also, as can be seen in Table 1, for a given flow rate, the smaller the pipe, the greater the friction losses. Finally, for a given pipe size, friction losses increase with flow rate.

In order to select a pump for your specific application, you need to specify the desired flow rate and the total head that the pump must overcome.

Total Head is calculated from the following equation:

$$TH = SL + EH + FL \qquad (1)$$

Where: TH = total head, ft
SL = suction lift, ft
EH = elevation head, ft
FL = friction losses, ft

Pumping Energy/Cost

The annual energy cost to pump water can be calculated from the following equation:

$$C = (DR/GPM) \times HP \times 4.5 \times 0.08^{*} \qquad (2)$$

Where: C = annual energy cost, dollars
DR = daily water requirement, gal
GPM = flow rate, gpm
HP = pump size, hp
4.5 = unit conversions

Piping

Galvanized steel, copper, and plastic are common pipe materials. Plastic pipe is made in flexible, semi-rigid, and rigid form. Flexible plastic pipe is commonly used in outdoor underground installations because of its ease and economy of installation. Also, for small diameters, flexible plastic pipe is the least expensive option.

The most important consideration in designing a piping system is proper pipe sizing. In general, the right pipe size is a trade-off between a diameter that is small enough to minimize pipe cost and large enough to not result in excessive friction losses, which will increase the pumping energy and therefore pumping costs. In other words, selecting a larger pipe size will result in greater pipe cost, but may allow for a smaller, and perhaps less expensive pump and will reduce the annual energy consumption.

To select a pipe size, the following information is needed:

- distance that the water will travel,
- flow rate required,
- vertical distance between the water source and the outlet of the stock tank, and
- required pressure at the outlet (determined by waterer type).

The steps involved in determining the best pipe size are the following:

1. Determine the minimum pipe size that could work. This is accomplished by assuring that the velocity of water in the pipe does not exceed 5 fps. The appropriate equation is:

   $$D = \sqrt{0.082 * Q} \qquad (3)$$

   Where: D = diameter, in
   Q = flow rate, gal/min
   NOTE: Round D up to the next manufactured pipe size
2. Call or visit your local pipe vendor and gather friction and cost data for the minimum size pipe determined above. Also, gather data for the next two larger commercially available sizes.
3. For each of the three sizes being considered, determine total system head from equation (1).
4. Convert the system head from ft to psi by dividing by 2.31.
5. Add the pressure required by the waterer (in psi) to the total system pressure. The pipe that you select must be rated to withstand the pressure calculated.
6. Call or visit your local pump vendor and determine the pump size needed for each of the three pipe sizes you are considering. The pump size for each pipe size will be determined by the total system head (which will be different for each pipe size) and the desired flow rate. For each pump size suggested by the vendor, there will be a corresponding flow rate at the given pressure. That is, for each system pressure (determined by the site and the pipe size you are considering), the vendor will suggest a pump that will meet or exceed the flow rate you require. For each pipe size, record the recommended pump size, the corresponding flow rate, and the pump cost.
7. Use equation (2) to determine the annual cost to operate the specified pump for each pipe size.
8. Generate a table containing the information you have gathered: pipe size, pipe cost, corresponding pump size, pump cost, and operating cost.

* 0.08 = assumed cost of electricity, $/kWh. This is a reasonable average cost of electricity. Use your actual electric rate if you know it.

9. Compare the initial costs for pipe and pump to the annual operating cost for each pipe size.
10. Look at the information you generated and decide which pipe size is most economical.

Example:
Assume a 100-cow herd on pasture. The water source is a pond and the water must be pumped a vertical distance of 30 feet and requires 1,000 feet of pipe. Electricity is available to pump the water. For summer conditions, 2000 gal/day of water will be provided. To allow 5% of the herd to drink at any one time, 5 watering spaces will be provided and a flow rate of 10 gal/min will accommodate the drinking rate of the animals.

Step 1: Determine the minimize size pipe:

$D = \sqrt{10*0.082} = 0.90$

Rounding up to the next available pipe size, a 1 inch pipe is the smallest size recommended.

Step 2: One thousand feet of pipe is required. Friction losses were determined from Table 3. One vendor was contacted to determine cost. (The prices were quoted February, 2001, and are provided for example only):

Pipe Size	Cost for 1,000 feet of pipe, $	Friction loss for 1,000 feet @ 10 gpm, ft
1 in	220	58.7
1.25 in	450	32.9
1.5 in	660	7.6

Step 3: Determine total system head for each pipe size:

From equation (1) TH = SH + EH + FL. For all three pipes SH + EH = 30 (vertical elevation from water source to watering point). For the 1-inch pipe, FL = 59 and TH=30+59=89. For the 1 1/4-inch pipe, TH =63 and for the 1 1/2-inch pipe, TH =38.

Pipe Size	TH (ft)	TH (psi)
1 inch	89	38.5
1.25 inch	63	27.3
1.5 inch	38	16.5

Step 4: Call the vendor and determine possible pump sizes, with corresponding flow rates and costs. The vendor will need to know the desired flow rate (10 gpm for this example) and the system pressure. The actual flow rate achieved from a pump depends on the system pressure. The vendor will help you select a pump that meets or exceeds the desired flow rate. Determine the flow rate that the pump is rated for at the system pressure you specify.

Pipe Size	Pump Size	Flow Rate	Pump Cost ($)*
1 inch	1/2 hp	15 gpm	280
1.25	1/4 hp	14 gpm	280
1.5	1/4 hp	18 gpm	280

*Note: In this case, the 1/4 hp and 1/2 hp pumps cost the same.

Step 5: Determine annual operating cost. For this example, it is assumed that electricity cost is $0.08/KWh.

For 1-inch pipe: C = (DR/GPM) x HP x 4.5 x 0.08* = 2000/15 x 1/2 x 4.5 x 0.08 = $24.00

For 1 1/4 inch pipe: C= $16.97

For the 1 1/2 inch pipe: C =$13.2

Step 6: Compare the options:

Pipe Size	Pipe + Pump Cost ($)	Annual Operating Cost ($)
1	500.00	24.00
1 1/4	730.00	16.97
1 1/2	940.00	13.20

From the data above, it appears that for this application, the 1-inch pipe is the most economical choice. Even though the 1-inch pipe requires a larger pump that costs about $7.00 more per year to operate, the initial cost for pipe is $230 less. It would take over 70 years to recover the difference in initial cost from the annual energy savings.

Options for Powering a Watering System

Several options are available when selecting a livestock watering system. The best system type for a particular producer will depend on many factors, including site layout, water requirement, availability and cost of water and electricity, and specifics of the water source, including type and location.

Gravity Systems

If the water source is above the desired watering location, a gravity flow system is most likely the best choice. Gravity systems are relatively simple and inexpensive, since no pump or power source is required. Remember, 1 psi is gained for every 2.31 feet in elevation drop. So if 5 psi of pressure is required to operate a livestock water-tank float valve, a minimum of 12 feet of vertical fall from the water source to the discharge point would be required.

Most gravity systems are simply tanks equipped with float valves that are located lower than the water source, which is usually a pond. The water pipe should be sized so that excessive friction losses are avoided and adequate flow is achieved. To do this, first determine the pressure available (the vertical elevation change in feet from water level to tank outlet, divided by 2.31). Next, for the pipe size chosen, use a pressure loss table from the pipe manufacturer to determine the pressure loss due to friction at the desired flow rate. Add to the losses the required pressure for the float valve. If the available pressure exceeds the losses plus pressure needed at the float valve, then the desired flow will be achieved. If the available pressure significantly exceeds the pressure required, then repeat the process for a smaller pipe and see if the required pressure is still exceeded. If the pressure remaining at the float valve is not adequate, increase the pipe size and try the calculation again.

If possible, with a pond source, the water delivery pipe should be installed during construction of the pond. It is difficult to install a pipe through a pond berm or levee after pond construction due to potential leak problems.

Gravity systems are limited to locations where the water is above the delivery point. This may be the case with ponds or springs, but is uncommon with streams, which tend to be the lowest point in the pasture. Steep streams may have enough elevation change to allow for gravity systems.

AC Electric Pumping Systems

From the basis of all-around convenience, dependability, and life-cycle cost, electricity from the electric utility is generally the best choice for small-scale water system pumping. As shown in the pipe-sizing example, the annual energy bill to pump water is typically low. However, most electric utilities have a minimum charge, or a metering charge, and if electricity is provided just for the water pump, the actual energy charge may be lower than the monthly bill. Even with a minimum monthly charge, the use of alternative energy systems generally cannot be economically justified based on energy costs alone. The distance to existing electrical service or the cost to bring in electrical service will determine which option is most economical.

Electrical alternating current submersible and standard (centrifical) pumps are available for pressurized water systems. Submersible pumps are commonly used in wells, but may also be installed in ponds or streams with proper pump selection. A submersible pump does not require priming and is freeze-proof because the pump is submerged below the water surface. A centrifical pump must be placed close enough to the water surface to ensure that the elevation difference between the water surface and pump does not exceed the suction lift capacity of the pump (approximately 15 to 20 feet). This type of pump must be protected from freezing in cold weather.

Ram Pumps

Ram pumps use the energy in flowing water to pump a portion of the water up hill. Ram pumps require no electrical power to operate and can offer a cost-effective solution to water system design. A ram pump requires a vertical drop between the intake of water and the location of the ram pump. The volume of water that can be pumped is directly proportional to the available elevation head from water intake to the ram pump and the volume of water available to the pump. A ram pump will pump from 2 to 20 % of the inflow volume to the delivery point. The remaining water is discharged at the pump site. The percentage of water pumped depends upon the pressure head between the water intake and the ram pump and the pressure head between the ram pump and the water delivery point.

Flow rates from ram pumps are typically low. However, the pump operates 24 hours per day, so with adequate storage volume, they can provide a significant amount of water. Ram pumps can be a cost-effective solution for appropriate sites. Generally, a ram pump is not a good choice for a pond, because a large percentage of the water input to the ram is lost. However, if the pond has sufficient out-flow, diverting the out-flow through a ram pump may be an effective option for pumping water to an up slope location.

Sling Pumps

Like Ram pumps, sling pumps do not require electricity to operate. A sling pump uses the energy of moving water to force water to a higher elevation. Sling pumps are available in different sizes, but require a minimum of 2.5 feet of water depth in the stream. They also require a minimum stream velocity of 1.5 feet per second. Streams meeting both these requirements are generally substantial in size.

Flow rates of 1-2 gpm, with lift capacity of about 50 feet, are common from sling pumps. Like ram pumps, they operate continuously, and with storage may be sufficient to meet the needs of some livestock producers.

Drawbacks of sling pumps are their limited application due to site requirements and also their high maintenance requirements. The pump is suspended in the stream, and debris such as leaves and sticks can prevent operation. The pump must be checked and cleaned routinely for dependable operation. Also, the pump must be well secured to prevent loss during high-water events.

Nose Pumps

Nose pumps, or animal-powered pumps deliver about a quart of water to a drinking bowl every time the animal pushes a paddle with its nose. The flow rate from these pumps is low, and therefore the pump only serves one animal at a time. This typically limits their use to small herds. Also, calves may not be able to operate the pump. Manufacturers suggest that the units be protected from freezing, which limits their application to warm months. Finally, their use is limited to situations where low-lift (typically 15 to 20 feet) is required.

Solar DC-Pumping Systems

Solar pumping systems provide a viable method to water livestock in locations where utility electricity is not available. They can be used to provide pressurized water from wells or low-lying ponds or streams to locations at higher elevations. Solar pumping systems typically provide a low flow rate. For this reason, and because the sun is not always shining, solar watering systems require storage of two to three days water supply.

A solar water pumping system consists of the following:

- photovoltaic (PV) panels to generate electricity
- mounting brackets for the panels
- a controller that conditions the output of the PV panels to meet the requirements of the pump
- a DC pump
- a float switch to turn the pump on or off.

Some solar systems include battery storage. Batteries increase the initial system cost and increase required system maintenance. They can increase the pumping capacity of the system by charging batteries and pumping water during high solar times, pumping from panels only during low solar times, and pumping from batteries when there is not sufficient solar to power the pump. In addition to the items listed above, solar water pumping systems with batteries include:

- batteries
- a charge controller, to control flow of electricity to the batteries
- instead of a float switch, a pressure tank and pressure switch are generally used to reduce cycling on and off of the pump.

Cost for a solar pumping system is highly dependent upon the required flow rate and the system head, as this will determine the number of solar panels required. A system designed to provide water for 50 cows, pumping against a total head of 35 feet, will cost between $2,500 and $3,000, plus labor to install. A system to provide water for a 100-cow herd, pumping against a total head of 150 feet, will cost approximately $10,000 plus labor to install.

Wind-Powered Systems

Wind-powered systems can either use the mechanical energy in wind to drive a piston pump or the energy can be used to generate electricity to power a DC electric pump. Either system can work, but both require a site where the wind blows frequently.

Windmills that power piston pumps can lift water 400 to 600 feet from a deep well to a tank. While they can be less costly to install than other systems, they require considerable maintenance.

Wind systems that generate electricity have a minimum wind speed at which they begin to generate power (typ-

Format:

Beaufort Number	**Miles/hour**	**Wind Speed in Description**
0	<1	Calm: Still: Smoke will rise vertically.
1	1-3	Light Air: Rising smoke drifts, weather vane is inactive.
2	4-7	Light Breeze: Leaves rustle, can feel wind on your face, weather vane is inactive.
3	8-12	Gentle Breeze: Leaves and twigs move around. Light-weight flags extend.
4	13-18	Moderate Breeze: Moves thin branches, raises dust and paper.
5	19-24	Fresh Breeze: Small trees sway.
6	25-31	Strong Breeze: Large tree branches move, open wires (such as telegraph wires) begin to "whistle," umbrellas are difficult to keep under control.
7-12	>32	Range from moderate gale to hurricane.

ically about 7 miles per hour wind) and many systems have a maximum wind speed that they can withstand without turning the blades out of the wind to prevent damage (and thus greatly reduce the power generated). While electric generation from wind is feasible and wind generators can be less expensive than photovoltaic panels for the same generation capacity, they are very site dependent. Hybrid systems, which use both wind and solar generation, are also possible.

Instrumentation to record the actual wind history of a site is available for about $300. The Beaufort Scale (see below), which was devised by rear-admiral Sir Francis Beaufort in 1805, can be used for a rough, visual evaluation of a site. Note that wind speed tends to increase with distance off the ground, so it is important to evaluate a site at the height where the wind generator would be mounted. Mounting a light flag at the proposed location will assist with evaluation. Use the following chart and record your observations over time. A site that frequently rates a 4 or above is a reasonable candidate for wind generation.

Selecting an Alternative Watering System

If you provide a water system supplier with the data for your application, most will design a system for you and give you a price quote. The following data are required to design a watering system:

- Daily water requirement for each month of the year
- Vertical distance between water source and watering tank
- Total distance between water source and watering tank (length of pipe required)
- Vertical distance from water source to pump (if applicable)

Description of water source: For a stream: depth and flow rate available. For a well: depth to water and water column depth. For a spring: flow rate. It is important to determine flow rates during low flow periods.

For a ram pump, you need vertical distance from water source to pump location (water source must be above pump location), and vertical distance from pump location to desired watering location.

A sketch showing location of water source and desired location of waterers, with distances marked, is helpful.
Useful References:

Private Water Systems Handbook Midwest Plan Service MWPS-14

Ponds—Planning, Design, Construction
United States Department of Agriculture
Agriculture Handbook Number 590

The following is a partial list of suppliers that can provide you with more information. The use of trade names, etc., in this publication does not imply an endorsement or guarantee by Virginia Cooperative Extension. Likewise, failure to mention a specific brand or company does not imply criticism of those products.

For information on ram, sling and nose pumps:
Rife Hydraulic Engine Manufacturing Company
P.O. Box 70
Wilkes-Barre, PA 18703
570-740-1100
www.riferam.com

For information on ram pumps and solar pumping systems:
The Ram Company
247 Llama Lane
Lowesville, Virginia
(In Virginia)
www.theramcompany.com

For information on solar pumping systems:
Solar Water Technologies, Inc.
426-B Elm Avenue
Portsmouth, Virginia 23706
1-800-952-7221
www.solarwater.com

Sunelco
P.O. Box 787
Hamilton, Montana 59840-0787
1-800-338-6844
www.sunelco.com

Sunelco produces a "Planning Guide and Product Catalog" that contains useful information for designing a solar or wind-powered system. Their catalog is marked $5.00, but if you call, they may send it to you at no cost. Even at $5.00, it is a useful resource for anyone considering purchasing a solar or wind-powered water pumping system.

Reviewed by Bobby Grisso, Extension specialist, Biological Systems Engineering