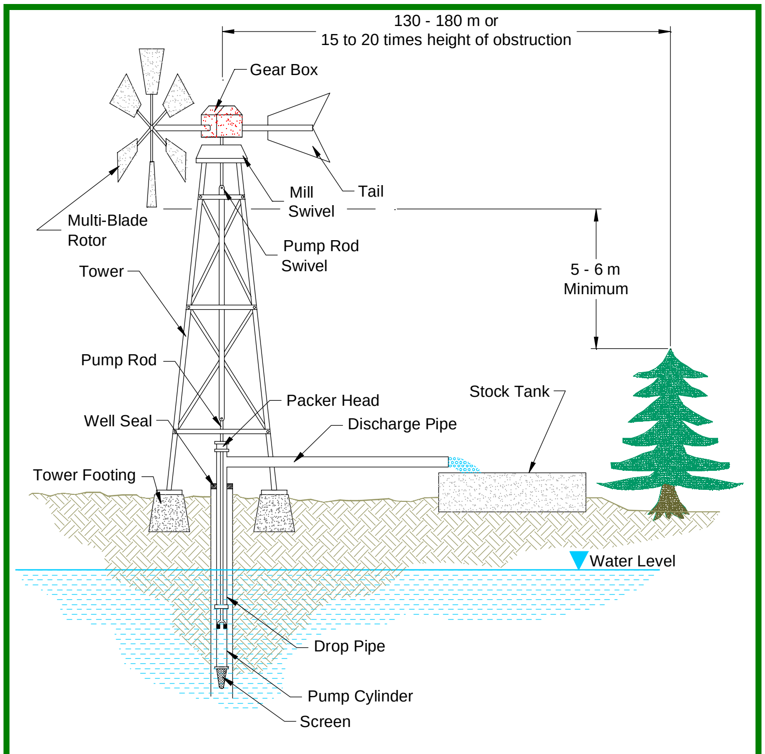
Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada | Canada

WIND-POWERED WATER PUMPING SYSTEMS FOR LIVESTOCK WATERING

Water supplies such as wells and dugouts can often be developed on the open range. However, the availability of power supplies on the open range is often limited, so some alternate form of energy is required to convey water from the source to a point of consumption. Wind energy is an abundant source of renewable energy that can be exploited for pumping water in remote locations, and windmills are one of the oldest methods of harnessing the energy of the wind to pump water.



Typical Windmill Water Pump

What kinds of windmills are there?

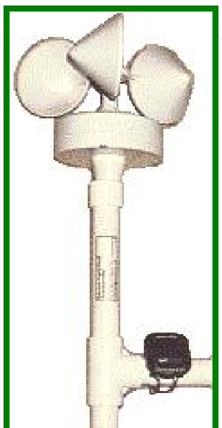
Windmills generally consist of two types, with the classification depending on the orientation of the axis of rotation of the rotor. Vertical-axis wind turbines are efficient and can obtain power from wind blowing in any direction, whereas horizontal-axis devices must be oriented facing the wind to extract power. Most windmills for water-pumping applications are of the horizontal-axis variety, and have multi-bladed rotors that can supply the high torque required to initiate operation of a mechanical pump. Windmills can also be used to generate electricity, but electricity-generating units usually consist of vertical-axis rotors or high-speed propellor rotors, due to the requirement for low starting torques. The following sketch illustrates a typical water-pumping windmill.

What should be considered in choosing a location for a windmill?

The primary consideration in choosing a site for a windmill is whether there is sufficient wind for such a device to be feasible. Although wind speed is monitored at a number of locations throughout Canada, this information is of limited usefulness because vegetation and other geographic characteristics can result in large variations in available wind power over short distances. Obtaining site-specific measurements of wind speed and duration during the period over which water pumping is required is the only reliable way of determining whether a wind-powered pumping unit will be a viable option.To take such measurements, an *anemometer* is required.

Economical hand-held anemometers are available, but their use requires that a considerable amount of time be spent on site to establish meaningful records. A better way of gathering wind data would be to mount an anemometer (with an automated data recording device) on a tower similar in height to the proposed windmill for the entire period of interest.

Hand-held anemometer



Tower-mount Anemometer

Portable trailer-mounted tower

Typical television or radio antenna towers can be used, and some are available as portable, trailer-mounted units. It may be possible to rent portable towers in some areas.

Windmills used to generate electricity to power an electrically-powered pump can be located away from the pumping unit, and windmills that power an air compressor which operates an air-lift pump can also be located away from the pump. However, most windmills are designed to operate a reciprocating piston-type pump and must be located directly over the water source (usually a well).

To ensure that the windmill receives a free flow of air from all directions, the rotor of a windmill should be located at least 5 to 6 m (15 to 20 feet) higher than any obstruction within about 130 to 180 m (450 to 600 ft.) of the windmill site. In fact, wind speed generally increases with altitude, so the tower should be as high as reasonably possible, regardless of the presence of obstructions. Topographic effects, such as confined draws and hills, should also be considered.

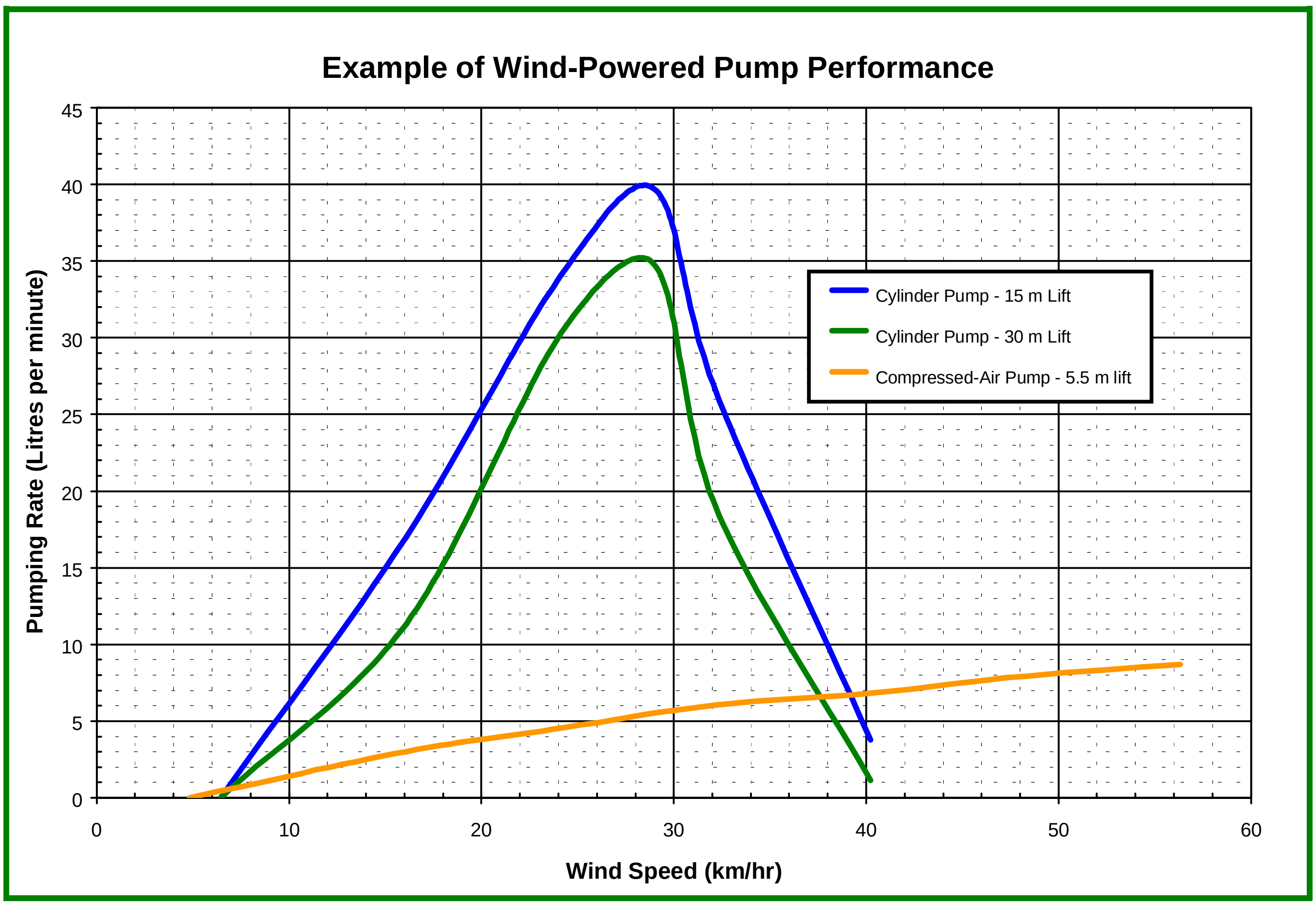
How much water can a wind-powered pump deliver?

The amount of water a wind-powered water pumping system can deliver depends on the speed and duration of the wind, the size and efficiency of the rotor, the efficiency of the pump being used, and how far the water has to be lifted. The power delivered by a windmill can be determined from the following equation:

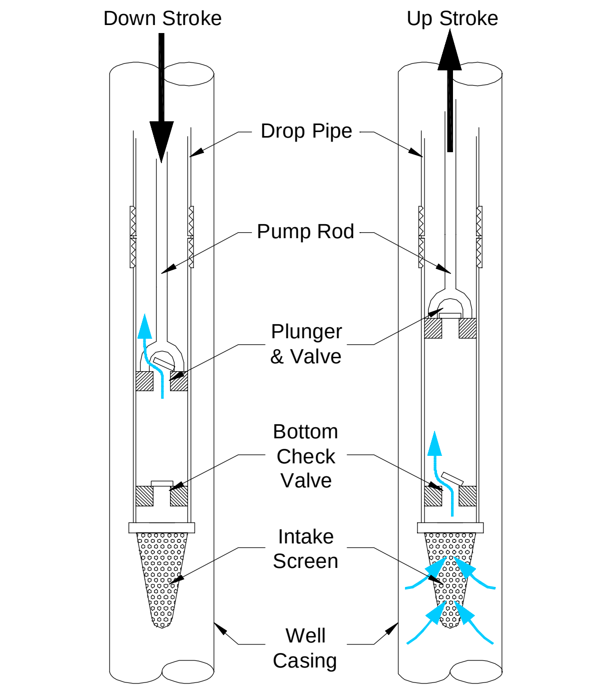
$$P = 0.0109 D^2 V^3 \eta$$

where P is power in watts, D is the rotor diameter in metres, V is the wind speed in kilometres per hour, and η is the efficiency of the wind turbine. As can be seen from this expression, relatively large increases in power result from comparatively small increases in the size of the rotor and the available wind speed; doubling the size of the rotor will result in a four-fold increase in power, while doubling the wind speed will result in an eight-fold increase in power. However, the efficiency of wind turbines decreases significantly in both low and high winds, so the result is that most commercially-available windmills operate best in a range of wind-speeds between about 15 km/hr and 50 km/hr. The following chart shows one way in which manufacturers present information relating to performance of their products:

What kinds of pumps are available for use with windmills?



If the windmill is used to generate electricity to power an electrically-powered pump, it will probably be necessary to store the electricity in batteries due to the variability in generation. Therefore, a pump powered by an electrical motor for use in conjunction with a windmill that generates electricity should have a Direct Current (DC) motor. For such systems, it is important to use good-quality deep-cycle batteries and to incorporate electrical controls such as blocking diodes and charge regulators to protect the batteries.

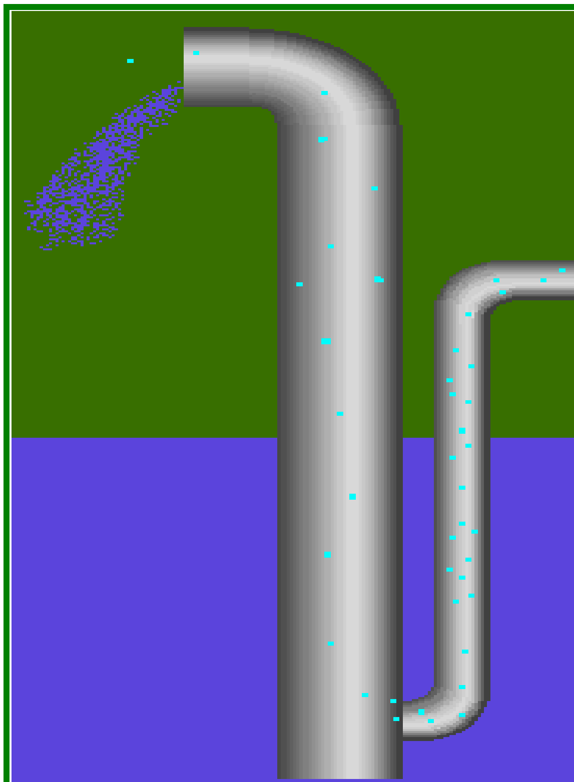


Typical Windmill Pump Cylinder

The most common type of pump used with windmills is the positive-displacement cylinder pump driven by a reciprocating rod connected to a gear box at the windmill rotor. The performance of these pumps can be enhanced through the addition of springs, cams and counterweights that alter the stroke cycle and off-set the weight of the drive rod, thereby reducing the starting torque and allowing the system to perform better in light winds.

An alternative to the traditional cylinder pump is the air-lift pump. The air-lift pump is a type of deep-well pump, sometimes used to remove water from mines. It can also be used to pump a slurry of sand and water or other "gritty" solutions. In its most basic form this pump has no moving parts, other than an air compressor driven by the windmill, and the efficiency of the air compressor is a prime factor in determining the overall efficiency of the pump. Compressed air is piped down the well to a foot piece attached to the discharge pipe. As air is discharged into the water column in the discharge pipe, a two-phase mixture of air and water is formed that is less dense than the surrounding water in the well. This apparent density difference is what causes water to rise in the discharge pipe.

Air-lift pumps can lift water at rates between 20 to 2000 gallons per minute, up to about 750 feet. The discharge pipe must be placed deep into the water, from 70% of the height of the pipe above the water level (for lifts to 20 feet) down to 40 percent for higher lifts. This is the most significant drawback to air-lift pumps, because many wells do not have the required depth of standing water. An advantage to this kind of pump is that the windmill can be located away from the well, and the windmill/air-compressor combination can also be used to aerate dugouts.



Air-Lift Pump

From The Internet Glossary of Pumps
http://www.animatedsoftware.com/pumpglos/air_lift.htm

What other considerations are there?

The availability of wind energy is highly variable and is likely to be intermittent. As a rule-of-thumb, expect an average of 6 to 8 hours per day of water pumping at a rate specified for a 25 km/hr (15 mph) wind. Hand pumping can be done on some windmill pumps in emergencies, but wind-powered pumping units should be used in conjunction with storage facilities capable of meeting three or four days water demand as a back-up supply during periods of low wind. For information on water requirements and storage, consult the fact sheets “Water Requirements for Pastured Livestock” and “Water Storage Facilities for Livestock Water Systems” in this series.

How much does a wind-powered pumping system cost?

The cost of a wind-powered pumping system will vary according to its capabilities, but the cost of most systems for stockwatering applications ranges between $1,000 for small compressed air systems to $6,000 for the larger well models.

What is required to maintain a wind-powered pumping system?

One of the attractions to wind-powered pumping systems is their simplicity and robustness. It is prudent to check all rubber diaphragms annually, and, on compressed-air models, to check all valves. The anchoring system for the windmill tower should also be checked to ensure that the windmill is not toppled during high winds. As with any pumping system, a wind-powered pumping system should be checked regularly to ensure that cattle have an adequate supply of water.

The Bigger Picture

Wind-powered water pumping systems are just one of many options available to producers interested in managing their rangelands, providing improved water quality for their livestock and protecting their water supplies. For additional information on other livestock watering systems, as well as solar-powered water pumping systems, contact your local PFRA office.

Sources of information for this fact sheet included: *The Stockman's Guide to Range Livestock Watering From Surface Water Sources*, available from the Prairie Agricultural Machinery Institute, P.O. Box 1060, 390 River Road, Portage la Prairie, Manitoba, R1N 3C5; *B.C. Livestock Watering Manual*, B.C. Ministry of Agriculture and Fisheries, Soils and Engineering Branch, Abbotsford, B.C.; *Water Wells that Last for Generations*, joint publication of AAFC/PFRA - AEP - AAFRD, *The Internet Glossary of Pumps*, http://www.animatedsoftware.com/pumpglos/air_lift.htm; *Wind Power - Uses and Potential*, joint publication of Alberta Agriculture - Engineering Services Branch and TransAlta Utilities Ltd., Summary of Wind and Solar Powered Pumping Units (1992 Test Season), Summary Report 703, joint publication of Alberta Farm Machinery Research Centre and Prairie Agricultural Machinery Institute.

UNIT ABBREVIATIONS

psi - pounds per square inch	kPa - kilopascal	gpm - gallon per minute
mm - millimetre	m - metre	ft - feet
in - inches	km - kilometre	L/s - litres per second

UNIT CONVERSIONS

1 US gallon = 3.785 litres	1 cubic metre (m^3) = 1,000 litres	1 metre (m) = 3.28 feet
1 Imp. Gallon = 4.546 litres	1 kilometre = 1,000 m = 0.62 miles	1 psi = 6.985 kPa
1 inch = 25.4 mm	1 psi = 2.307 ft. of water	1Hp = 746 Watts