

HUMAN & ANIMAL POWERED WATER-LIFTING DEVICES FOR IRRIGATION



technical brief

Introduction

This technical brief outlines the main types of human and animal water-lifting devices used for irrigation. A separate technical brief is available on human powered water lifting for domestic and community water supply.

Human and animal powered water lifting devices have been traditionally used in irrigation in a number of places around the world. Many of the technologies applied today have been used for thousands of years. Recent developments have concentrated on increasing the efficiency of water lifting by combining ease of use with higher water delivery.



Figure 1: Traditional surface water lifter in Bangladesh
Photo: Practical Action.

Human physical power output is between 0.08 – 0.10 horsepower (hp) or 0.06 - 0.075 kW whereas traction animals have a physical power output of between five and ten times this amount. For example, a pair of bullocks has a physical power output of around 0.8 hp or 0.6 kW and can lift water from depths of 30 metres or more. Hence, animals can pump more water in a shorter time, making irrigation more efficient and more productive.

This technical brief provides guidance on the key criteria that needs to be taken into account when selecting a human or animal powered water lifter and discusses the applicability of the different types of water lifter to specific local conditions.

Selection Criteria for Human- or Animal- Powered Water Lifters for Irrigation

Table 1 provides a summary of the technical, financial, economic, institutional and social questions that need to be answered when selecting a human or animal powered lifting device for irrigation:

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Criteria	Key Questions	Important Points to Note
Technical Aspects :		
Lift height and yield	How much water is required for irrigation purposes? How high does the lifter have to raise the water?	Water lifting requirements depends amongst other things upon the climate, the crop and the area to be irrigated. The capacity of water lifter varies from around 0.5 m to more than 100 m.
Soil Conditions	What are the local soil conditions? Can you access water the water easily i.e. surface water or hand-dug well or is drilling required?	Where there is very rocky soil a borehole will usually need to be drilled to reach the groundwater.
Operators	Is the lifter suitable and acceptable to the people who will operate it? Is the operation ergonomic (comfortable to use) and realistic for the group responsible for irrigation? Are there health and safety considerations, such as dangerous machinery?	The choice of water lifter should take into account which group of people are tasked with water lifting for irrigation. It is important to determine if average and maximum handle forces required are realistic for the proposed user.
Financial and Economic Aspects :		
Capital Cost	What is the initial cost of the water lifter? Does the village have sufficient funds or is a loan required? How soon will the community be able to pay back the loan/ recover this investment?	Using a water lifter for irrigation increases efficiency and productivity and can ensure the generation of additional income. For instance families that introduced a treadle pump for irrigation were able to generate between US\$100 and 500 additional income each year.
Material and Manufacturing Costs	Can the lifter be manufactured using local skills and materials?	
Operating Costs	What is the operating cost of the lifter? Does the village have sufficient manpower/animal power to operate the lifter for all the time it is needed?	It should be noted that although it may only be necessary to irrigate crops for some of the year, traction animals will need to be maintained all year round. It is therefore important to determine other tasks that will be undertaken by the animal and ensure that the timing of these task do not conflict.
Maintenance Costs	What is the cost of maintaining/ repairing the lifter? Are the skills to maintain/ repair the water lifter available locally? Are spare parts available and affordable? How often is the lifter likely to need maintenance and/or repair? How long will repairs take and what will the villagers do in the meantime?	Maintenance is an integral part of lifter management. For more complicated designs, it is important to carry out preventative maintenance. Serious problems can be avoided by undertaking regular inspections and servicing of the mechanical parts. Wear and tear will be less severe this way and any problems will be solved before they cause major damage.
Life expectancy	How long is the lifter expected to last before it has to be replaced? How resistant is the lifter to vandalism or abuse?	
Institutional and Social Aspects :		
Household/ Community	Is there a community organisation capable of overseeing operation, maintenance and management of the device and the water? Will the users be instructed how to use and look after the device?	The lifter should be suitable for Village Level Operation and Maintenance (VLOM) or Management of Maintenance (VLOMM). This reduces the reliance of villagers upon large institutions to sustain the water supply.

Table 1: Checklist for Water Lifting Device Selection

Types of Human- and Animal-Powered Water Lifters

Human and Animal Powered Water Lifters can be split into two categories: those designed to lift surface water and those designed to raise groundwater.

- **Surface Water** is present in depressions, lakes, rivers, reservoirs, and oceans.
- **Groundwater** flows or seeps downward through the earth filling up the spaces between soil, sand and rock to form a saturated zone. The upper surface of this saturated zone is called the “water table.” The “water table” may be just below the surface like a spring or oasis or it may be over 100 metres down. The only way to get access to this water is by digging and/or drilling.

Surface Water Lifters

Surface water lifters are generally the simplest form of human and animal water lifters because the water is readily accessible and does not need to be raised more than a few metres.

Swing basket

The swing basket is made from cheap materials like woven bamboo strips, leather, or iron sheet to which four ropes are attached. Two people hold the basket facing each other, they dip the basket into the surface water and the basket is lifted by swinging it and emptied into an irrigation channel from which point the water flows to the fields. This lifter can be used at depths of up to 1.2 m. Typical flow rates of 60 to 80 l/min are obtained at depths of 0.75 m.

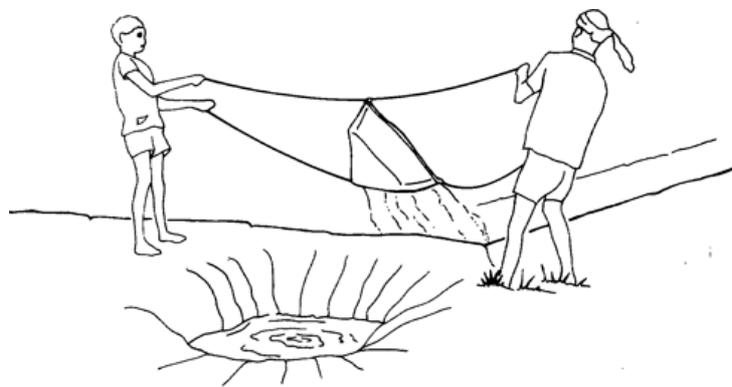


Figure 2: Swing Basket Irrigation
Source: [Water Pumping Devices](#)

Advantages	Disadvantages
Simple, inexpensive technology which can be locally made and maintained.	Limited to lifts of less than 1.2 m
Easy to operate by both adults and children	Limited water yield 60-80 l/min suitable for small fields
	Low efficiency (10-15%) big human effort with significant water spillage

Shadouf (Picottah)

The basic **shadouf** consists of a rope, pole, bucket and counterweight and is capable of lifting water up to 4 metres.

The counterweight can be just a heavy rock, but in the more advanced **picottah** design, one person guides the bucket while the other acts as a moving counterweight (Figure 3). It is generally used for lifting water from unlined wells, streams or ponds for irrigating small fields. Approximately 60 litres/ min can be lifted from a depth of 2 to 3 metres.

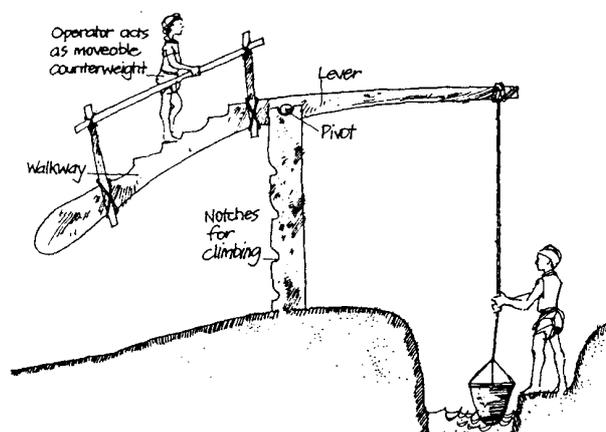


Figure 3: Shadouf (Picottah)

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Advantages	Disadvantages
A relatively inexpensive traditional technology which can be locally made and maintained. Easy to operate Relatively efficient (30-60%)	Limited to lifts of less than 4 m Limited water yield, 60 l/min suitable for small fields

Dhone

The **dhone** consists of a trough made from a wooden log or iron sheet; closed at one end and open at the other. The trough is mounted on a suspended pivoted lever to produce a see-sawing gutter or dhone which operates at relatively low lifts of up to 1.5 m. The trough is lowered into the water by exerting pressure using a rope or the foot of the operator until the closed end is submerged in water. Upon releasing pressure the trough comes to its original position and the water is delivered to the irrigation channel. Typical yields of 80-160 l/min can be obtained from the dhone between 0.3-1.0 m.

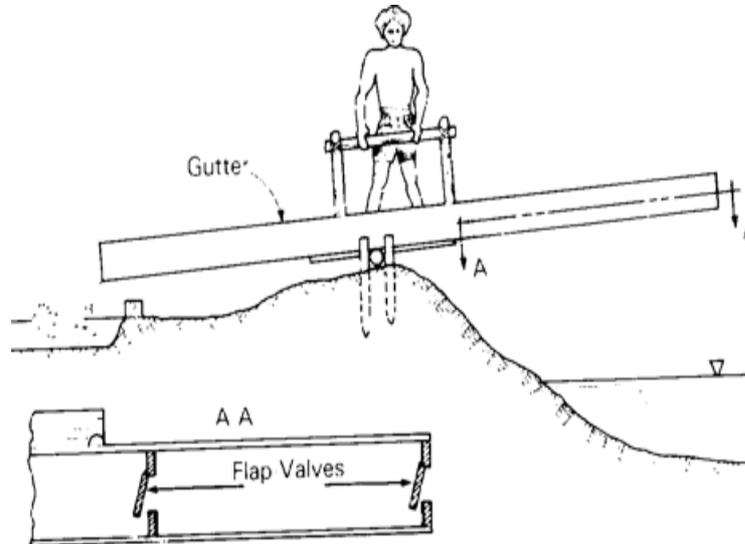


Figure 4: Dhone
Source: [Water Pumping Devices](#)

Advantages	Disadvantages
A relatively inexpensive traditional technology which can be locally made and maintained. Easy to operate Water yields of approximately 160 l/min for lifts of less than 1 m	Limited to lifts of less than 1.5 m Low to medium efficiency (20-50%)

Paddle wheel (Chakram)

The paddle wheel is only suitable for low water lifts of up to 0.5 metres and it is mostly used in coastal regions to irrigate paddy fields.

Small paddles are mounted on a horizontal shaft, which rotates in a close fitting concave trough, pushing water upwards. The operator walks directly on the rim of the paddle wheel, turning it so that it continuously and steadily scoops up water and deposits it into the irrigation channel.

The paddle wheel is not particularly efficient because a lot of water lifted flows back around the edges of the blades and hence it is not used extensively. However it is simple to build and install in situations where a lot of water needs to be lifted through a small height. A paddle wheel with 12 blades can lift 300 litres/ min at depths of 0.5 metres.

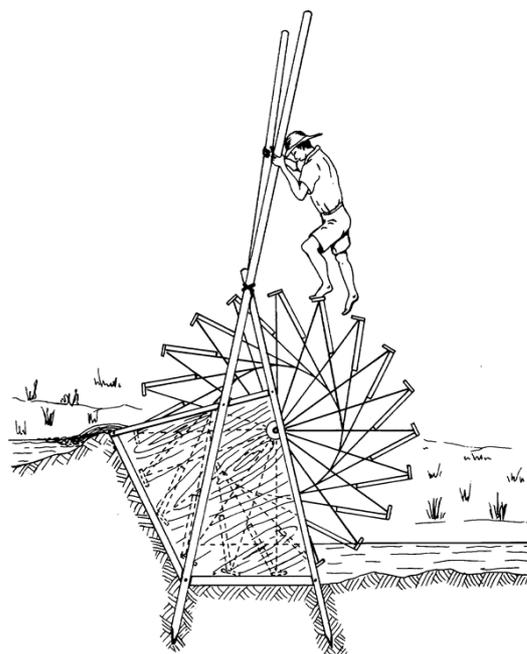


Figure 5: Paddle Wheel
Source: [Water Pumping Devi](#)

Advantages	Disadvantages
Traditional technology which can be locally made and maintained. Water yields of approximately 300 l/min for lifts of 0.5 m	Limited to lifts of less than 0.5m Not very efficient (20-50%), lots of backflow

Persian Wheel (Raha)

This device consists of an endless chain of buckets typically with an individual capacity of 8-15 litres mounted upon a drum and submerged in water to the required depth. The drum is connected to a toothed wheel held in a vertical plane by a long shaft usually kept below ground level. The vertical toothed wheel is geared with a large toothed horizontal wheel connected to a horizontal beam. This beam is yoked to a pair of animals. The animals move in a circle to turn the drum and raise the water. Water is released when the bucket reaches the top.

The average discharge rate from a Persian wheel is about 160-170 litres/min from a depth of 9m with one pair of bullocks. The Persian wheel can be used to raise water from a depth of up to 20 m but its efficiency is reduced at depths below 7.5 metres.

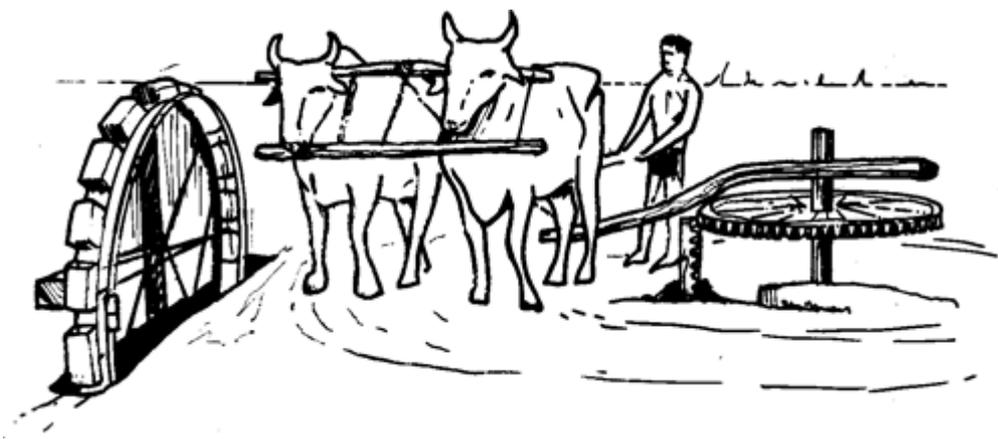


Figure 6: Animal Driven Persian Wheel
Source: [Water Pumping Devices](#)

A variety of all-metal improved Persian wheels have been built. Their smaller diameter reduces the extra height the water needs to be lifted before it is tipped out of the containers, and also reduces the well diameter that is necessary.

Advantages	Disadvantages
A relatively inexpensive traditional technology which can be locally made and maintained. Easy to operate Lifts water up to 20 m but most efficient at depths of less than 7.5 m. Water yields of approximately 160-170 l/min for lifts of 9 m Medium efficiency (40-70%)	The design means that water is raised above the point of discharge before falling into the collection channel. Animals need to be maintained all year even when irrigation is not necessary.

Archimedean screw

The Archimedean screw consists of a helical screw mounted on a spindle which is rotated inside a wooden or metallic cylinder. One end of the cylinder is placed at an angle of 30 degrees and submerged in the surface water source. When the handle is turned water is trapped in the cavities and raised to the level of the irrigation channel as shown in Figure 7.

Although this design looks quite complicated, it is fairly easy to build using local materials and is readily transportable. It can also be adapted to be driven by animals as shown in Figure 8. The Archimedean screw typically raises water from depths of 0.2 - 1.0 metres at a rate of 250-500 litres/ min.

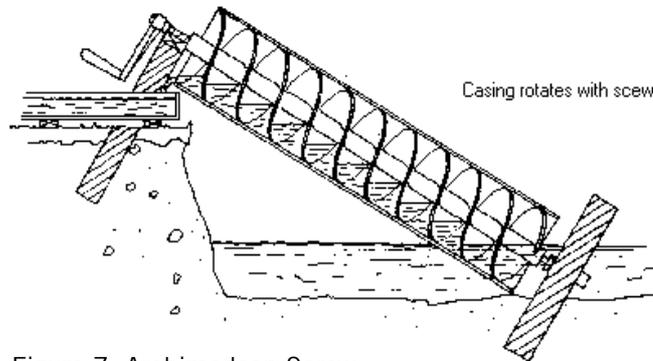


Figure 7: Archimedean Screw
Source: [Water Pumping Devices](#)

Advantages	Disadvantages
A relatively inexpensive traditional technology which can be locally made and maintained.	Limited to lifts of up to 1.2 m.
Transportable and easy to operate	
Low to Medium efficiency (30-60%)	
Water Delivery of 250-500 l/min for lifts of 0.2-1.0 m	

Groundwater Lifters

The following section presents the main types of human and animal powered devices used for lifting water from shallow and deep wells for irrigation purposes.

Rope and Bucket (Mohte, Charsa, Pur)

The simplest and cheapest method of lifting groundwater remains a rope and bucket in a wide, shallow well. This type of well can operate up to a depth of 100 metres, although they rarely exceed 45 metres. The rope and bucket lifter can be operated by humans or animals. Human operated rope and bucket lifters typically raise 10-15 litres/min from depths of 10-15 metres whereas an animal water lifter can raise 150 litres/ min from 15 metres. In the animal driven rope and bucket lifter, the rope attached to the bucket is passed over a pulley and fixed to the animal. The animal is driven down on an earthen ramp sloped at an angle of 5-10 degrees in order to lift the water.

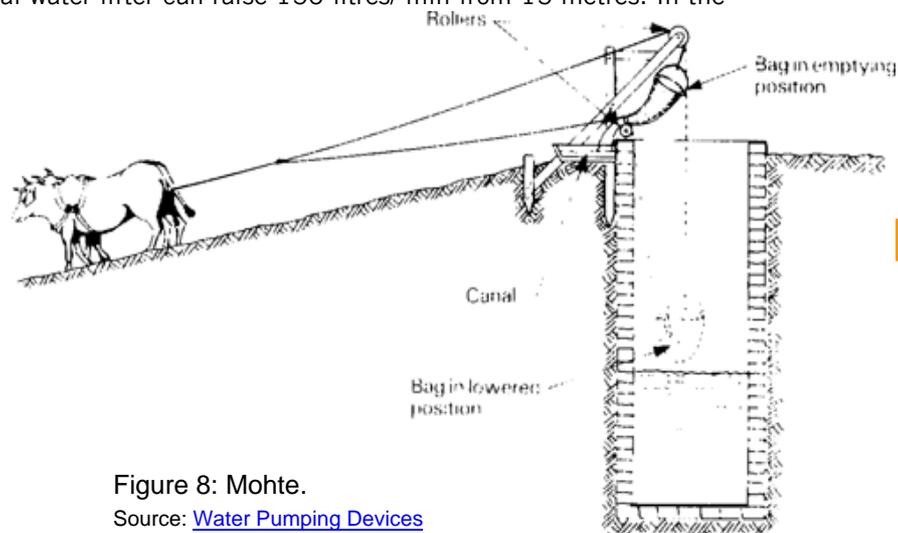


Figure 8: Mohte.
Source: [Water Pumping Devices](#)

A self-emptying container or **mohte** can be used in place of the bucket as shown in Figure 8. The system consists of a leather container, shaped like a funnel. The container can typically hold between 100 to 150 litres. This arrangement can discharge about 130 litres/ min at depths of up to 9 metres.

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The rope and bucket lifter can also be adapted to include two buckets which are raised and lowered alternately. In this case the pulling animal moves in a circular path and with the help of central rotating lever, rope and pulley arrangement the buckets move up and down. Each bucket has a carrying capacity of up to 70 litres. The buckets have a hinged flap at the bottom, which acts as a valve. Guide rods are provided in the well to control the movement of the buckets. The buckets are automatically filled and emptied during operation. This device can lift about 230 litres /min from depths of up to 5 metres.

Advantages	Disadvantages
Simple technology which is inexpensive to build and maintain.	Water Delivery from Human Operated Rope and Bucket Water Lifter is limited to 15 l/min.
Can be operated at depths of up to 100 m.	Animals need to be maintained all year even when irrigation is not necessary.
Water Delivery from Animal Operated Rope and Bucket Water Lifter of over 200 l/min for double bucket system	Relatively low efficiency for traditional human and animal operated designs (10-40%)

Shallow-Well Piston Pump

A **reciprocating suction pump** has a plunger or piston which moves up and down in a two-valve closed cylinder. As the plunger moves upward it forces water out through the outlet valve and at the same time draws water into the cylinder through the inlet valve. Moving the plunger down brings it back to its starting position.

The reciprocating suction pump has the pump cylinder situated above ground or near the surface. Pulling up the plunger lowers the atmospheric pressure in the cylinder (creates suction) causing the atmospheric pressure outside the cylinder to push the water upwards. The main limitation of this pumping method is that the atmospheric pressure difference between the inside and outside of the cylinder is only large enough to raise water up to a maximum of 7m from the water table.

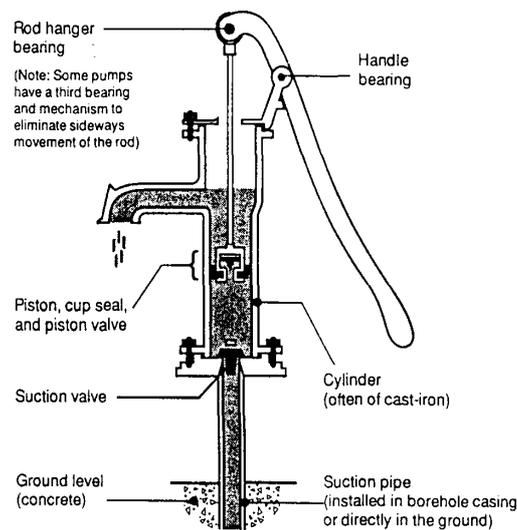


Figure 9: Shallow-Well Piston Pump

A large piston diameter will give water delivery of 24-36 litres/min at a depth of 7 metres. Most designs have a maximum usage of around 50 people/day, which makes them less appropriate for irrigation purposes than for household water supply.

Advantages	Disadvantages
Relatively simple maintenance (main pump components positioned above ground)	More expensive than most basic/traditional irrigation methods.
Large piston diameter gives water delivery of 24-36 litres/min at 7 m depth	Limited to wells of less than 7 metres in depth
Medium to high efficiency (60-85%)	

Treadle pump

A type of suction pump designed to lift water from a depth of 7 metres or less. The treadle pump has a lever pushed by the foot to drive the pump. Because leg muscles are stronger than arm muscles, this design is less tiring to use than other human powered water lifters.

Most of the parts can be manufactured locally hence the treadle pump is relatively simple and inexpensive to build. The treadle pump can lift up to 100 litres/ min at depths of around 4 m.

The introduction of the treadle pump for irrigation has been shown to have a positive impact on household income. In Bangladesh, a simple treadle pump costs around US\$20 but this investment allows families to generate US\$100 additional income annually. In Africa where treadle pumps cost between US\$50-80 additional income rises to between US\$200 – 500 each year.

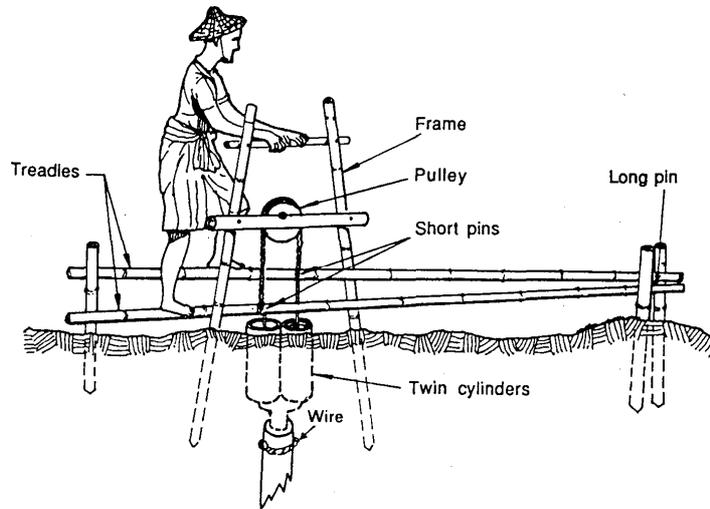


Figure 10: Treadle Pump

Advantages	Disadvantages
<ul style="list-style-type: none"> Simple and inexpensive construction Less intensive operation (foot operated) Maintenance uses local skills and materials Water delivery of up to 100 litres/min at 4 metres depth Use leads to generation of US\$100-500 additional income per year for rural households in Africa and Asia 	<ul style="list-style-type: none"> Limited to wells of less than 7 metres in depth

Rower

The rower pump is a simpler and cheaper version of the traditional reciprocating suction pump. The pump is set at an angle of 30° and water is lifted through a rowing action. The long piston stroke ensures fast water delivery of up to 90 litres/min at 4 m depth.

Its simple design means it can be easily manufactured and maintained using locally available skills and materials.

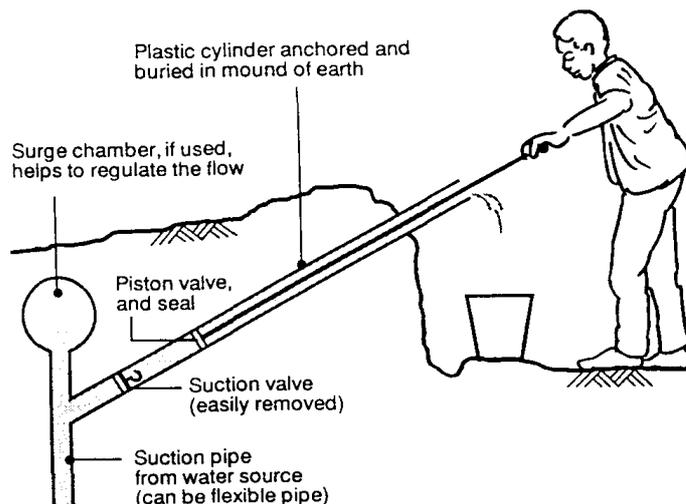


Figure 11: Rower Pump

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Advantages	Disadvantages
<p>Cheaper construction than most reciprocating suction and lift pumps</p> <p>Maintenance using local skills and materials</p> <p>Long piston stroke gives water delivery of up to 90 litres/min at 4 metres depth</p>	<p>Limited to wells of less than 7 metres in depth</p>

Chain / Rope and Washer Pump ('Pater noster')

These pumps have been used in China and Europe for many centuries. The pump consists of an endless chain or rope on which washers are mounted at intervals. The endless chain usually passes over two drums. The upper drum is above the top of well to which axle and handle is attached for operation. The chain with disc passes through a pipe which extends downward from the top of well to about 0.6 to 0.9m below the surface of water. As the chain rotates the discs trap the water in the pipe and carry it to the surface where it is discharged in a trough.

Although in theory it is possible to construct a vertical chain and washer pump to raise water to any height, most do not exceed 35 metres. At this depth the average yield is calculated as 10 litres/ min. However, rope pumps more commonly operate at depths of up to 10 m with a water yield of 40 litres/ min. The rope pump can be adapted to be operated by a horse and will raise 60 litres/min from a 20 m well.

Chain/Rope and washer pumps require less maintenance than other equivalent pumps. Their simple design means that repairs can often be done by users and require few spare parts. Models can use parts that incorporate commonly available materials such as PVC pipe, rope, and old car parts.

The main disadvantage of this type of pump for irrigation is that since this is not a pressurised system it may take time to receive water from the well with the water falling back to the level of the bottom of the well when not in use.

A variation of this design is called the "dragon-spine" pump, which lies at a shallow angle to the horizontal. In this case, lifting height is rarely more than 6 metres. However, the design is very flexible and can easily be adapted to circumstances.

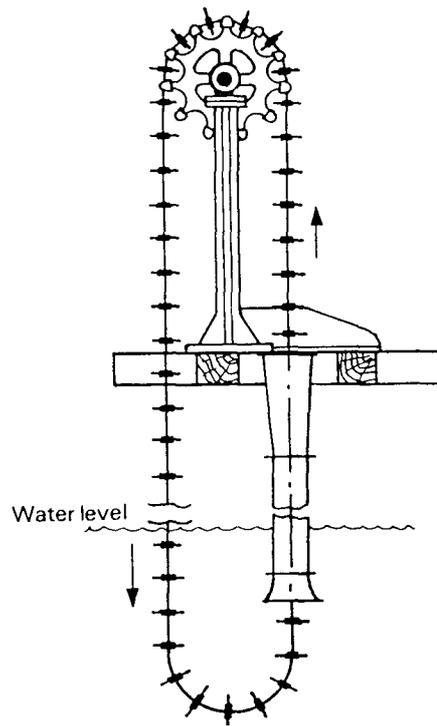


Figure 12: Chain and Washer Pump

Advantages	Disadvantages
<p>Relatively cheap, and easy to manufacture (for wells down to 35 m rope pumps are five times cheaper than piston lift pumps.)</p> <p>Maintenance uses local skills and materials</p>	<p>Operation limited to depths of up to 35 m.</p> <p>Initial water delivery is relatively slow at greater depths.</p> <p>Frequent simple maintenance required</p> <p>Medium to high efficiency (50-80%)</p>

Comparison of human- and animal- surface water and groundwater lifting devices

Table 2 provides an assessment of the different technologies considered in this technical brief.

Type	Power Source	Manufacture	Investment Cost	Maximum Lift (m)	Typical Flow Rate (litres/min)	Typical Lift (m)
SURFACE WATER						
Swing Basket	Human	Basic	Low	1.20	60-80	0.75
Shadouf / Picottah	Human	Basic/ Traditional	Low-Medium	4.00	60	2-3
Dhone	Human	Basic/ Traditional	Low-Medium	1.5 0	80-60	0.30- 1.00
Paddle Wheel	Human	Basic/ Traditional	Low-Medium	0.50	300	0.50
Persian Wheel	Animal	Traditional	Low-Medium	20	250-280 160-170	3 9
Archimedean Screw	Human	Traditional/ Industrial	Medium-High	1.5	250-500	0.2-1.0
SURFACE WATER AND GROUNDWATER						
Rope and Bucket	Human	Basic	Low	100	15	10
	Animal	Basic	Low	100	150	15
Mohte	Animal	Basic/ Traditional	Low - Medium	100	130	9
Double Bucket	Animal	Basic/ Traditional	Low - Medium	100	230	5
Suction piston	Human	Industrial	Low - Medium	7	24-36	7
Treadle	Human	Basic/ Traditional	Low - Medium	7	100	4
Rower	Human	Traditional	Low - Medium	7	50	4
Chain & Washer Pump	Human	Basic/ Traditional	Low to Medium	35	40 10	10 35
	Animal	Basic/ Traditional	Low to Medium	35	60	20

Table 2: Comparison of Different Types of Human- & Animal- Powered Water Lifting Devices

References and resources

- [Human-Powered Handpumps for Water Lifting](#) Technical Brief Practical Action
- [Treadle Pumps](#) Technical Brief Practical Action
- [Low Lift Irrigation Pumps](#) Technical Brief Waterline
- [Maintaining Handpumps](#) Technical Brief Waterline
- [Handpumps](#) Technology Note WaterAid
- [VLOM pumps](#) Technical Brief Waterline
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by W. K. Kennedy & T. A. Rolgers. Practical Action Publishing, 1985.
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- *The Treadle Pump: Manual Irrigation for Small Farmers in Bangladesh* by Alastair Orr, A. S. M. Nazrul Islam, & Gunner Barnes, Rangpur Dinajpur Rural Service – RDRS
- [Tools for Agriculture - a buyer's guide to appropriate equipment](#)
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- [Water Lifting Devices](#), FAO Irrigation and Drainage Paper 43, PL Fraenkel, 1986
- [Water Pumping Devices - A Handbook 3rd Edition](#)
by Peter Fraenkel & Jeremy Thake, Practical Action Publishing, 2006.

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Organisations

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The IRC International Water and Sanitation Centre (IRC) facilitates the sharing, promotion and use of knowledge so that governments, professionals and organisations can better support poor men, women and children in developing countries to obtain water and sanitation services they will use and maintain.

Netherlands Water Partnership (NWP)

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Website: <http://www.nwp.nl/>

The Netherlands Water Partnership (NWP) is an independent body set up by the Dutch private and public sectors. They nationally coordinate water activities overseas and provide relevant information regarding these activities.

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 Producers of helical rotor and piston lift device

Steelman Industries

Shanti Dham, Kankarbagh Main Road, Patna (Bihar) - 800 020, India
 Tel: +91-612-352530
 Fax: +91-612-352872
 E-mail: manraw@hotmail.com
 Website: <http://www.geocities.com/Eureka/park/4967/>
 Produce the following handpumps: India Mark II, India Mark III, India Mark IV, Rawman shallow & force handpump, Rawman special Lift & force VLOM handpump

Van Reekum Materials bv

P. O. Box 98, 7300 AB Apeldoorn, The Netherlands
 Tel: +31 55 533 54 66
 Fax: +31 55 533 54 88
 E-mail: info@reekum.nl
 Website: www.reekum.nl
 Producers of a range of pumping equipment

This technical brief was produced by Jane Olley for Practical Action, November 2008.

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technical brief