6

Pump technology

IN THIS CHAPTER:

- An overview of pump technology
- Choice of pump technology – advantages and disadvantages of systems

Methods of raising water

Once water has passed through a screen and is free of sediment it can be moved to a supply point. Whether or not water can be pumped immediately on separation will depend on the screen system and pumping method.

Well-point system

Unless the well-screen has a diameter large enough to install a submersible pump, water will need to be drawn into a pump through connecting pipes that in larger systems may include a manifold and a priming tank.

Infiltration gallery and collector well

Water must first gravitate or percolate into a collector well, into which a pump may be installed.

Caisson and sand well

Water will already be at the base of a large diameter shaft to which a pump or water lifting device can be fitted.

Once there is a source of water of sufficient volume, a pump or lifting device can be selected.

Factors to consider and to which a pump must be matched are:

- volume and surface area of the supply – the pump used on a relatively large body of water in a well may not be appropriate for the small body of water in a well-point

- rate of inflow
- depth of water, depth to water below the surface and the diameter of the screen system
- height to which the water must be delivered
- power options
- physical security of equipment

Pumps have many designs and incorporate one or more of several operating principles so that not all pumps can be used in all water lifting situations.

Pump and water lifting systems

The categories by which water-lifting equipment may be classified vary substantially both in terminology and type. Any one or a combination of the following general principles may be used to convey water:

- Gravity systems – water flows downward under the influence of gravity but cannot be raised to a point higher than the source. The system can only be used to transfer water to a lower point.
- Direct lift systems – a fixed quantity of water is physically raised in a single or a number of containers.
- Displacement pumps – water cannot be compressed (unlike air) and when moved through a pump it draws further water behind it. The volume of water that is pumped is equal to the displacement of the piston when it is moved. This is effected immediately in a direct lift pump where the piston is generally in water, but in a suction pump where the piston is above the level of water, air must be evacuated before the system is able to be effective.
- Velocity pumps – when water is propelled with sufficient momentum in the absence of air further water is drawn through the pump.

Table 6.1 classifies four water transfer systems that can help determine the appropriate pump in relation to an abstraction system.

The selection of a suitable pump for a given system will also depend on whether the pump is to be hand or mechanically activated and the identification of an appropriate power source.

Table 6.1. Water lifting systems and their suitability for sand-abstraction use

Operating system		System / pump examples	Sand-abstraction application
Gravity devices		• Qanat • Syphon	Very limited possibility in offset sand well or infiltration gallery and collector well
Direct lift Pumps – Shallow well pumps	Reciprocating	• Rope and bucket – free or windlass • Blair bucket pump • Shadoof	Sand well, Infiltration gallery and collector well
	Rotary	• Rope and washer pump • Persian wheels	
Displacement Pumps – Well and borehole pumps	Suction – utilising atmospheric pressure	• Rod and piston – above water-level – pump • Rower pump • Treadle pump • Diaphragm pump	Offset sand well Infiltration gallery and collector well
	Reciprocating Rod – deep well/ borehole	• Rod and piston - below water-level – pump • Afridev • India • Direct Action pump	
	Rotary	• Progressive Cavity pump	
Velocity Pumps	Rotary Pump – High speed mechanical, surface pump	• Centrifugal pump • Submersible pump	Well-point Offset sand well Infiltration gallery and collector well
	Venturi pump – Deep well/ borehole	• Jet pump	Offset sand well Infiltration gallery and collector well

The suitability of water lifting devices in sand-abstraction systems

Gravity systems

The most basic method of moving water is by gravity. However, as sand-abstraction screens are generally placed deep within river sediment it is rarely possible to use this method.

Suitability — used to great effect in traditional qanat systems that draw water from hillside aquifers. Can be used to siphon water directly from an infiltration gallery or from an offset sand well where there is a gradient with an appropriate delivery point sufficiently below and away from the river channel to which water can be gravitated.

Direct lift devices

Buckets, scoops and water wheels are used to physically raise a fixed quantity of water. Although many of these methods are simple and easy to maintain, with the exception of the rope and washer pump, they can generally only be used on shallow open wells.

- **Buckets** (with or without a windlass) and mohtes can be used in infiltration gallery and collector wells and sand wells. Although generally hand operated, these can be can be animal-powered (with the exception of a windlass).

  Suitability — Generally reliable and easy to operate and repair. However, they are often slow and inefficient and provide only a limited yield.
- **Shadoofs** can also be used on collector wells and offset sand wells. They are slow hand operated systems.

  Suitability — Easy to operate and maintain but have a low yield and a limited lift.
- **Continuous rope and washer pumps** (Figure 6.1) (also called chain and washer, Paternoster or Yeddle pumps). These raise water through a series of close fitting washers on a rope or chain that move upward through a pipe. Water is discharged as the washers leave the top of the pipe with the rope continuing to circulate and return the empty washers to the bottom of the well to draw in further water. Such pumps are capable of providing a useful output and can be considered an appropriate and efficient option suitable for installation on any lined well of a diameter and depth typical of a sand-abstraction system. Such devices are generally hand or animal-powered and are capable of drawing water from as much as 20 metres.

  Suitability — Well suited for use on infiltration gallery and collector wells and offset sand wells.
- **Persian wheels and scoop wheels** are generally capable of raising larger quantities of water than other direct lift systems, but have a limited lift height depending on the diameter of the wheel. A large diameter well is required for a large diameter wheel. Typically such water-lifting wheels are animal-powered.

  Suitability — Generally not suitable except on shallow, open wells that are not within a river channel and where a sufficient depth of water can be maintained to fill the lift buckets

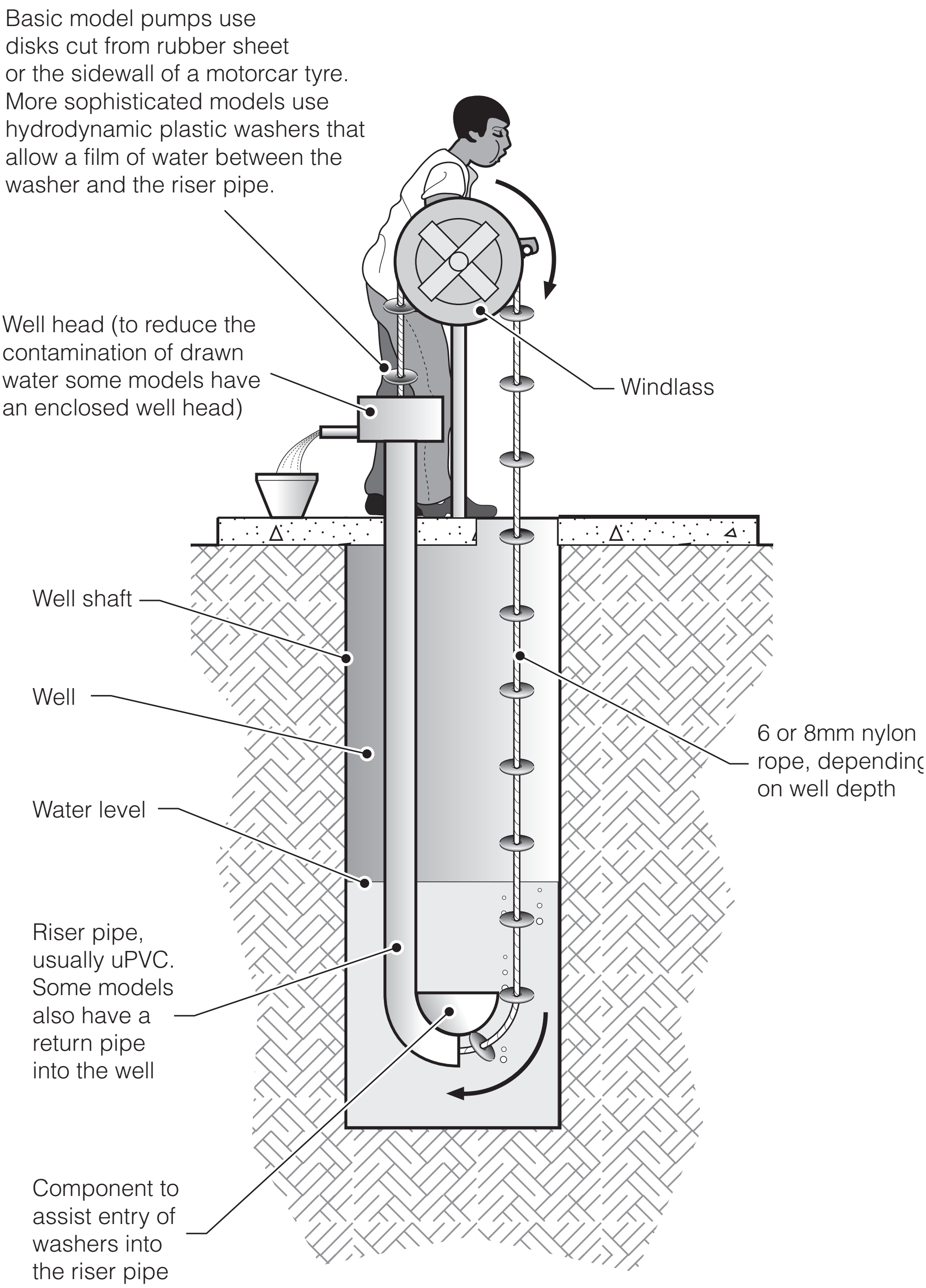

Figure 6.1. Rope and washer pump

Displacement pumps

There are variations in the principle of operation within this category that use either a reciprocating rod with a piston and valves to lift water, or a rotating rod and rotor that moves water through a screwing process. Within the lift category there is a further variation where water is either raised through direct lift or through suction. Figure 6.2 shows the principle of (a) a direct lift displacement pump with the pump piston operating in the water and (b) a suction pump with the piston operating out of water creating a vacuum within the pump cylinder that is filled with water by atmospheric pressure.

- **Direct lift pump – piston pumps.** On the upstroke a rod raises a piston that draws water into a cylinder through an open valve. On this stroke water is also discharged from the pump head. On the downstroke the lower valve closes and water flows through valves in the piston to the upper part of the cylinder for the process to be repeated. Typically rod and piston pumps are hand powered but are easily mechanized with an appropriate pump head. Mechanical pumps operate at ±30 strokes a minute.

  Suitability — Pumps with a reciprocating rod that is located within a riser pipe and attaches to a piston inside a cylinder are generally used on deep wells and boreholes where the piston can be installed below the residual water-level. Many rural communities utilize such pumps and have experience, spare part and service/maintenance systems to ensure their on-going use. Pumps of this type may be used on collector wells and offset sand wells but as they are primarily for deep water applications they are generally cumbersome and over-designed for such relatively shallow use.
- **Direct lift, direct action pumps.** These pumps have a piston designed to operate within water and have an internal pipe that acts both as a piston and as a pump rod. As this is raised the piston valve closes so that the water inside it is raised and it also draws further water into the pump body. When the pump handle is pushed down, the internal pipe displaces the water that is in the pump body so that it flows into the pump 'rod' and in so doing water is also discharged from the pump. The pumps use basic principles of operation with a simple tee-bar handle to raise and lower the pump 'rod' and piston rather than a more complicated pump head with a pivot or pitman rod.

  Suitability — Generally more suitable than deep well pumps as they are better matched to the shallow depth and yield of a collector well or offset sand well and are more easily serviced and maintained.

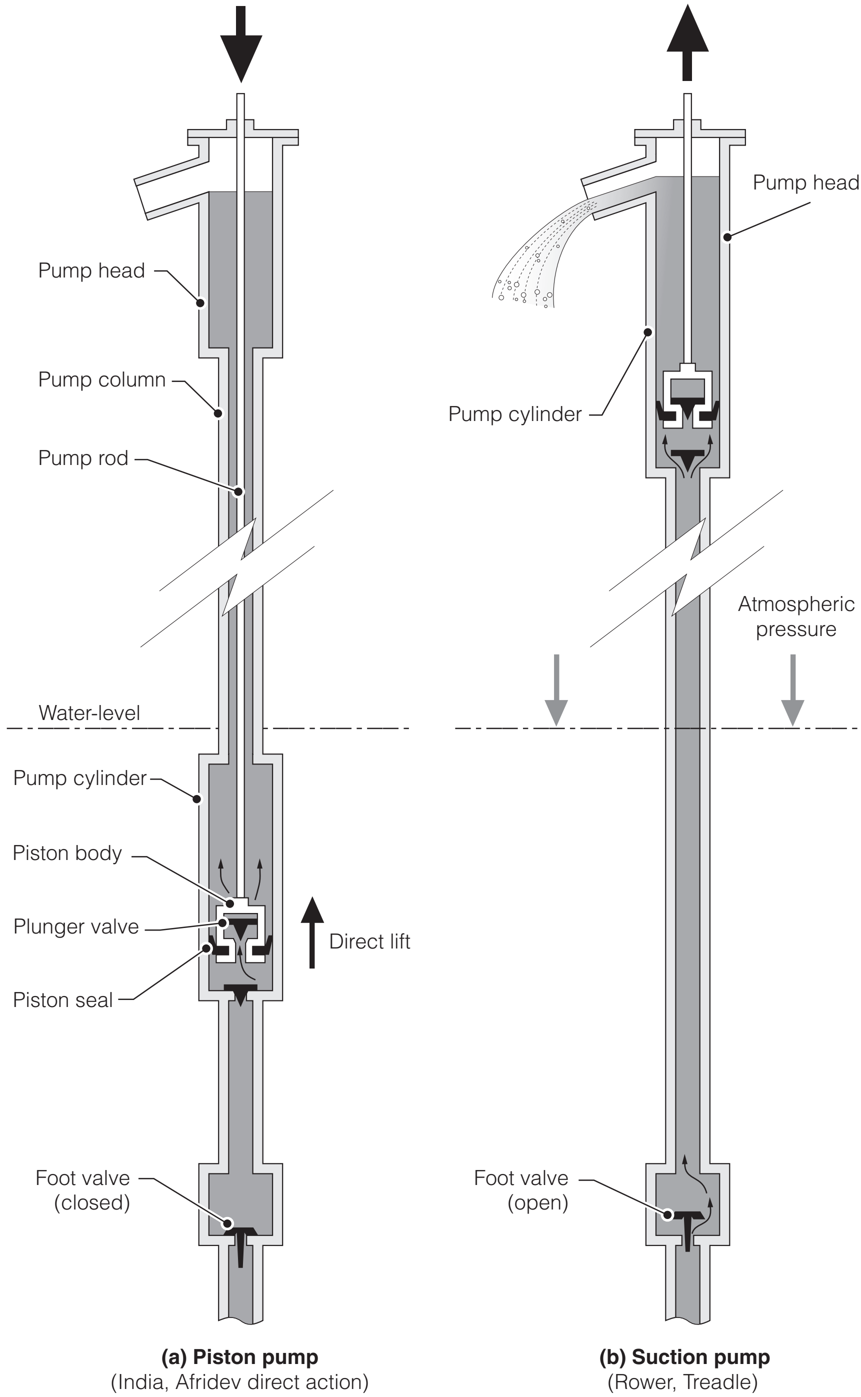

Figure 6.2. Principle of two types of displacement pump

Figure 6.3 shows the components and working action of a commercially available Tara direct action handpump.

- **Suction pump.** Although now rather outdated terminology this pump is sometimes referred to as a bucket pump because of the cup or bucket seals that are used on the piston. The operating principle is as a direct lift pump but the piston is situated above the water-level. The pump has to be primed to displace air from the pump cylinder, pump column or connecting pipes so that water is forced into the pump cylinder by atmospheric pressure. The principle of the pump is then that of the direct lift pump. The efficiency of a suction pump is dependent on its capacity to evacuate air and on the altitude at which it is installed. As the head requirements of a sand-abstraction system are generally comfortably within these specifications these pumps are highly suitable for installation either on a well or coupled to a connecting pipe and a well-point, which obviates the need for a well. Such pumps are generally low volume hand (or at least human) powered pumps.

  Suitability — Suited to use on well-point, sand well and infiltration gallery and collector well systems. Also very suitable for connecting to well-points where the pump can be installed on the riverbank (within the limitations of atmospheric pressure and further limitations of altitude and pump efficiency).

- **Suction pump – lift or force pump.** A suction pump with two valves, one foot valve and one side valve where water does not pass through the piston. Water is drawn into a cylinder by a piston, through a lower valve as the piston is raised. However in this pump the piston is solid so water does not pass through it. As the piston descends it closes the lower valve and forces water out of the pump through a valve and delivery pipe in the side of the pump.

  Suitability — As the principle of this type of pump is similar to other suction displacement type pumps it is also suitable for direct connection to well-points as well as installation on infiltration gallery and collector well and offset sand well systems.

- **Suction pump – diaphragm pump.** A flexible diaphragm can provide an alternative to a reciprocating piston to move water. An upward movement of a diaphragm increases the volume of a pump chamber. In the absence of air, water will flow into the chamber through an open valve. A downward movement of the diaphragm will reduce the volume of the pump chamber and consequently the valve closes and water will be expelled through another valve and a discharge pipe.

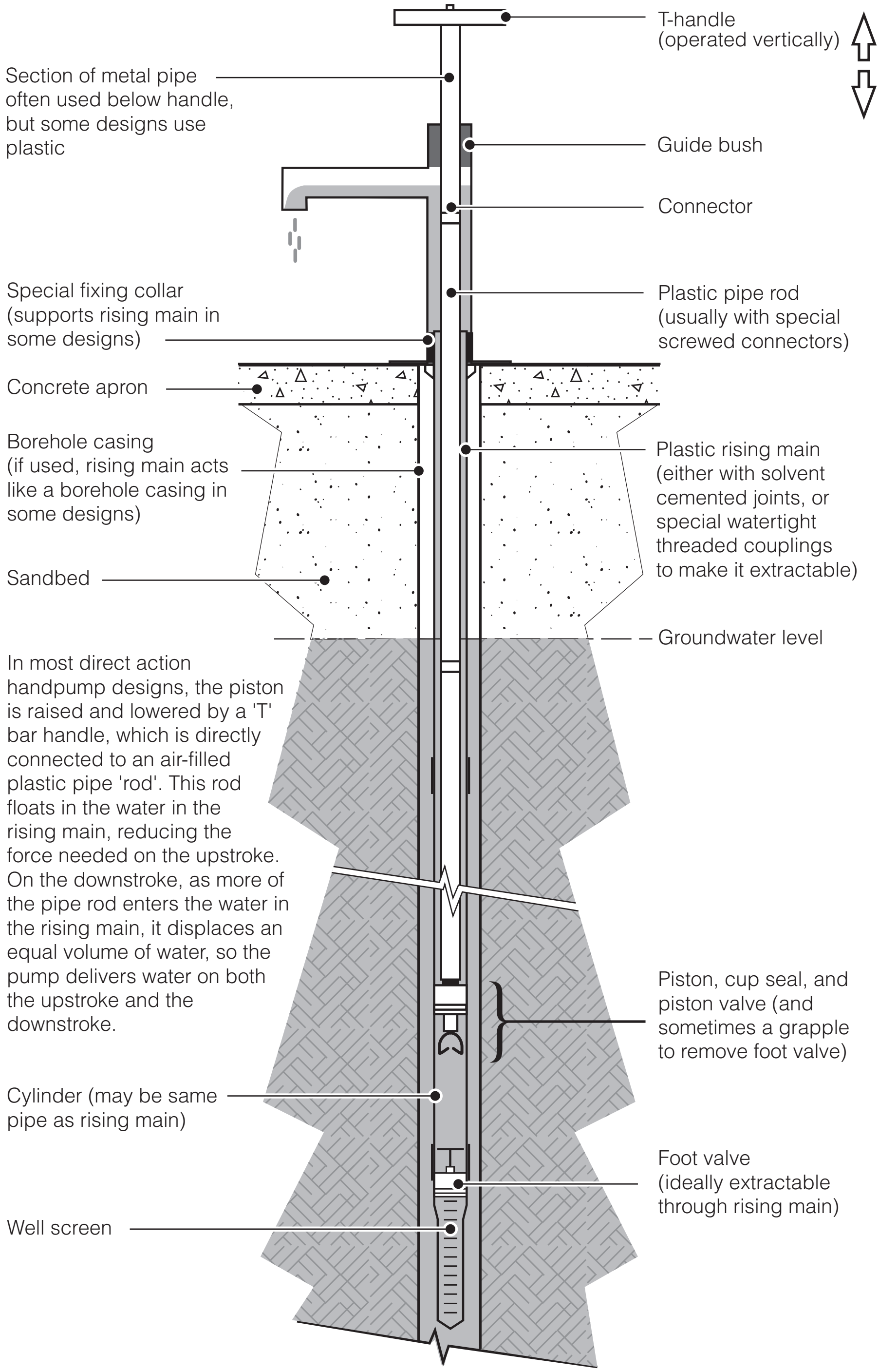

Figure 6.3. Direct action handpump

Suitability — The principle of the operating system is akin to the piston suction pump system and thus diaphragm pumps may be used in the same situations.

Figure 6.4 shows the principle of diaphragm handpump.

- **Progressive cavity pumps** are sometimes referred to as helical pumps or by their trade names, Mono or Orbit pumps. Such pumps effectively move water in a screw process in a cavity created between a rotating spiral shaft and a specially shaped pump body. They produce a continuous flow, unlike (single action) reciprocating pumps that only deliver water on one stroke. Progressive cavity pumps comprise a single helix rotor within a double helix stator. A rotor is the general shape of a single twist and can be likened to the thread on a screw, while the stator is a double twist. When placed together a cavity is created between the rotor and the stator. When the rotor is turned the cavity effectively moves along the rotor maintaining a space between it and the stator. Water within this space is moved as the rotor turns, until it is discharged from the pump.

  Suitability — Suitable for use on sand wells and infiltration gallery and collector well systems as well as direct coupling to well-points where the pump can be installed on the riverbank.

Figure 6.5 shows the method used by a progressive cavity pump to move water.

Velocity pumps

- **Centrifugal rotodynamic (volute and turbine) pumps.** These use a single spinning impellor to draw water into the pump and to propel it rapidly. The high velocity that the water attains causes it to be discharged from the pump by centrifugal force. When this occurs in the absence of air further water is drawn into the pump body.

  Suitability — High speed mechanical centrifugal surface pumps are suitable for use on sand wells and infiltration gallery and collector well systems. Although a centrifugal pump of an appropriate size can be used on a single well-point, centrifugal pumps are particularly suitable for multiple well-point schemes that use a manifold and where the pump can be installed on the riverbank with a priming tank.

Figure 6.6 indicates the operation of volute and turbine centrifugal pumps.

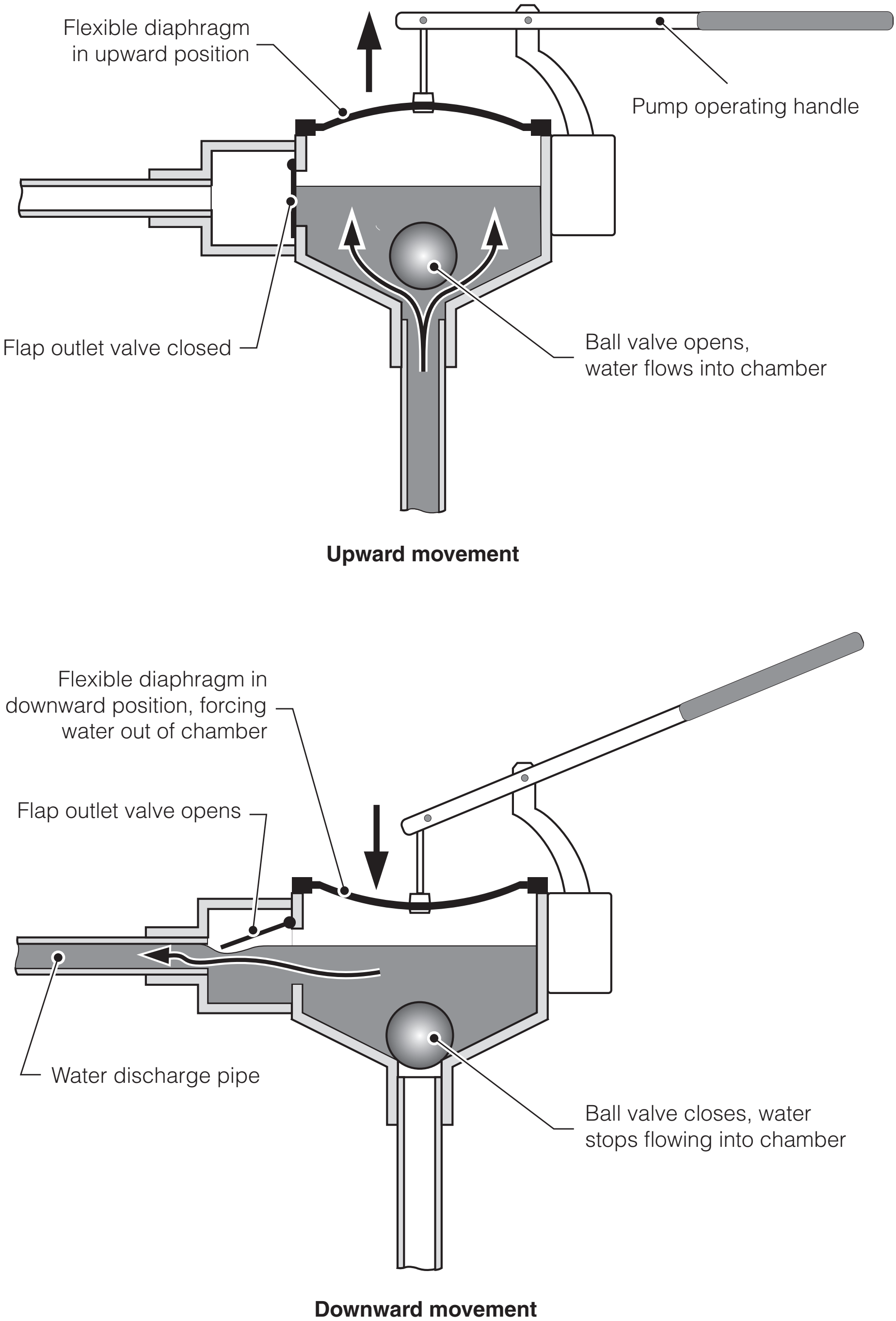

Figure 6.4. Diaphragm pump

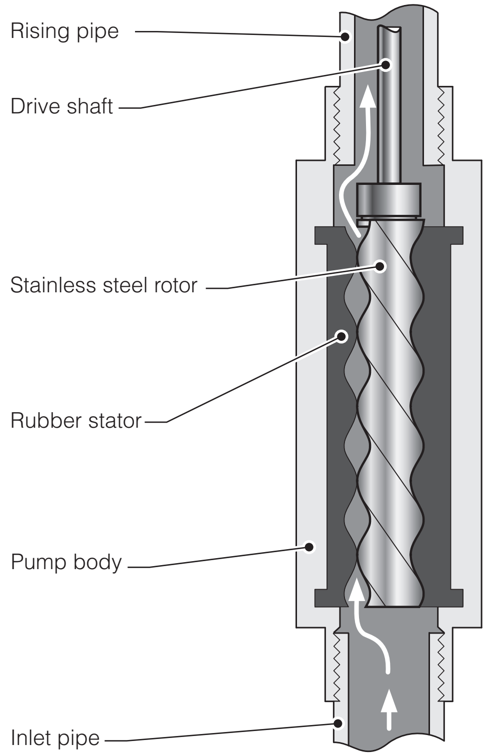

Figure 6.5. Progressive cavity pump

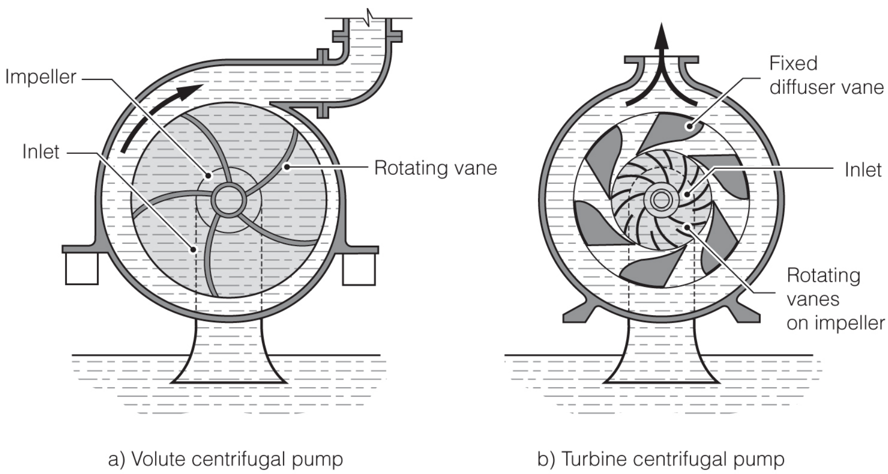

Figure 6.6. Centrifugal pumps

- **Centrifugal multi-stage pumps** – these use the same principle as the volute and turbine centrifugal pumps but use a series of impellors to achieve the same effect. By coupling together a number of impellors directly to a sealed electric motor a smaller diameter pump can be achieved that can be installed as a submersible pump in deep wells and boreholes.

  Suitability — A suitable pump for larger schemes where it can be installed below the residual water-level. It is thus suitable for installation in caissons and sand wells and well-points with a diameter sufficiently large to allow the pump to fit inside. It is also suited to installation on infiltration gallery and collector well and offset sand well systems.

Venturi pumps

Use a high speed jet of water to draw additional water to the surface. To achieve this, water is pumped down a well or borehole in a pipe to a fitting that has a jet which discharges into a venturi. The temporary rapid increase in the velocity of water through the jet and venturi draws additional water into the flow, which together with the already circulating water is then delivered to the surface.

- **Jet pumps** use a centrifugal pump to create a flow of water that will draw water to the surface from depths of 10 to 20 metres.

  Suitability — Jet pumps have a limited application but could be installed on infiltration gallery and collector well and offset sand well systems.

Pump systems not appropriate for sand-abstraction use

The foregoing is a list of pump systems that might be used in sand-abstraction applications and is by no means a comprehensive list. Other pump systems are:

Ram pumps

As a ram pump requires a continuous flow of water to provide the energy to raise a smaller volume of water it is thus inappropriate as a sand-abstraction pump system in a virtually motionless body of water.

Deep water displacement pumps

Deep water borehole pumps are typically high specification pumps designed to raise small volumes of water from depths in excess of 100 metres and as such are over-designed for use in low lift applications.

Table 6.2. Suitability of typical pump systems for sand-abstraction use		
Pump/Device	**Advantage**	**Disadvantage**
Gravity	• Basic • Low cost	• Generally unsuited to present-day applications
Direct lift – bucket and windlass	• Basic • Low initial cost • Low maintenance cost	• Limited yield. Suited only to sand well and infiltration gallery systems
Direct lift – rope and washer pump	• Basic • Low initial cost • Low maintenance cost	• Suited only to sand well and infiltration gallery systems
Displacement – suction - piston	• Versatile, general purpose pump • Ideal for small-scale schemes	• Best suited to small-scale applications
Displacement – direct lift, direct action	• Low initial cost • Low maintenance cost	• Suited only to wells
Displacement – diminishing cavity	• Efficient • Range of pumps available from handpumps to large-scale mechanized pumps • Best suited to large-scale mechanized schemes	• High initial cost • High maintenance cost • Intolerant of abrasive sediment
Displacement – suction - diaphragm	• Versatile, general purpose pump • Ideal for small-scale schemes	• High initial cost • Diaphragms liable to rupture
Velocity – centrifugal	• Efficient • Suited to large mechanized schemes	• High initial cost • Priming may be a problem • Not appropriate for small-scale schemes

Table 6.2 tabulates the advantages and disadvantages of typical and suitable pump systems.

Chapter summary

An overview of pumps and pump technology is provided as there is a vast array of pumps and pump operating systems that have been designed for particular applications. With the requirements of the various sand-abstraction systems it is apparent that not all pumps are suitable for use with all sand-abstraction systems. The suitability of a pump depends on a number of factors; the nature, size and location of the abstraction scheme, the volume of water to be pumped, the depths from, and the heights to which it has to be pumped; suitable power options and the resources of the end users. The physical dimension of apertures and access area of the chosen abstraction system will also affect the type of pump that can be used. A pump which is suitable for use with a well-point system will not necessarily be suitable on an open well shaft and a pump that can be used on a well shaft may not be suitable on a tube well shaft.

The selection of a suitable pump is crucial to the success and sustainability of a sand-abstraction system and requires careful planning.