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WaterSmart Pastoral Production™ Project Literature Reviews

Water Reticulation Equipment for Rangelands Pastoral Applications: A Review

Ralph Williams
David Pezzaniti

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University of South Australia
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WaterSmart Pastoral Production™ project participants

Australian Government Department of Agriculture, Fisheries and Forestry National Landcare Program	Gail Stevenson Manager National Landcare Program	www.daff.gov.au
desert channels QUEENSLAND	Colleen James Project Officer WaterSmart Pastoral Production™	www.dcq.org.au
Northern Territory Government	Andy Bubb Project Manager	www.primaryindustry.nt.gov.au
Government of South Australia South Australian Arid Lands Natural Resources Management Board	John Gavin General Manager	www.saalnrm.sa.gov.au
GREAT ARTESIAN BASIN COORDINATING COMMITTEE	Derek White Great Artesian Basin Coordinating Committee Australian Government Department of the Environment, Water, Heritage and the Arts	www.gabcc.org.au

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For additional information please contact

Desert Knowledge CRC
Publications Officer
PO Box 3971
Alice Springs NT 0871
Australia
Telephone +61 8 8959 6000 Fax +61 8 8959 6048
www.desertknowledgecrc.com.au

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1. Introduction

Traditional supply of water for stock in pastoral areas using bore drains has been the preferred method of pastoralists in Australia for more than 100 years. In this case water is typically fed to the open drains from bores (usually free flowing artesian bores from the Great Artesian Basin) and is distributed across the contours of the land (refer to Figure 1). This method of water distribution is highly inefficient, with more than 85 % of water lost through evaporation or seepage. It has been estimated that more than two-thirds of water extracted from the Great Artesian Basin (GAB) is currently wasted. Overuse or unnecessary use of this water will eventually reduce the water and pressure in the basin.

Figure 1: Open drain and reticulated watering systems

Source: Great Artesian Basin Coordinating Committee, QLD NR&M, 2005

Reticulation of water across pastoral areas is a key strategy in managing the use of underground water resources more efficiently. Improvements in plastic pipe technologies and methods of dealing with high temperature and pressure water, typical in the GAB, have enabled pastoralists to consider more seriously the use of reticulation instead of open channel delivery of water. By reticulating water, evaporation and seepage losses are eliminated and unnecessary wastage of water through free flowing bores is also prevented. Water reticulation also offers the pastoralists many advantages including:

- higher quality water for stock
- reduction in land degradation and erosion from water flowing through open channels
- a more flexible and reliable supply of water to stock
- reduction in pests and vermin that are attracted to water in open channels.

The following report has been produced to list and review reticulation equipment that is available to pastoralists. Specific issues related to extraction of water from the GAB, such as heat and pressure have also been addressed. Many of these issues were addressed during recent field workshops (June 2004) organised by the Department of Water, Land, and Biodiversity Conservation and the Arid Areas Catchment Water Management Board (South Australia). Some of the outcomes from these workshops are included in this report.

This report has been divided into sections addressing each of the main components that may be required for water reticulation. The main categories applicable for water reticulation include:

- Category 1 – Pipes
- Category 2 – Pumps
- Category 3 – Tanks and Troughs
- Category 4 – Valves
- Category 5 – Miscellaneous including drilling, bore casing, and bore capping; and telemetry systems.

Sections 2 to 6 of this report provide a brief description of issues to consider for each category and Section 7 provides tables of manufacturers together with specific information on product range and specifications.

In developing this report several key sources of information were used. These include:

- GAB Well Maintenance Field Guide for Artesian Wells (Government of SA 2006)
- On Farm Water Reticulation Guide (**GWM**Water 2005)
- Farm Water Supplies, Planning and Installation (Neil Southorn 1995)
- Minimum Construction Requirements for Water Bores in Australia, Edition 2 (National Minimum Bore Specifications Committee 2003)
- Individual manufacturer websites
- Personal communications with:
    - Lloyd Sampson (Hydrogeologist, Groundwater Group, Knowledge and Information Division, DWLBC, South Australia)
    - Kevin Dennis (Groundwater Group, Knowledge and Information Division, DWLBC, South Australia)
    - Neil Eigland (Cap and Pipe the Bores Program, DLWC, NSW)
    - Lynn Brake (Managing water resources projects for South Australian Arid Lands NRM and Desert Knowledge CRC)
    - Jade Defavari (Administration officer, South Australian Arid Areas NRM)
    - Zac Sibenaler (Senior Hydrogeologist, Australian Groundwater Technologies, South Australia; involved in the Water Allocation Plan for the Far North Prescribed Wells Area, South Australia)
    - Chris Blackmore (Blackmore's Power and Water, Laura, South Australia).

2. Category 1: Pipes

Polyethylene and polyvinyl chloride (PVC) pipes have replaced traditional galvanised iron, steel and ductile iron pipes due to their resistance to corrosion, ease and speed of installation and cost. Polyethylene is particularly popular in the farming community as it is:

- available in long lengths (typically 50 to 300 m coils for diameters up to 110 mm)
- flexible and easily transported
- easily laid and joined
- suitable for most flows and pressures required on farms.

Polyethylene pipe is also the most economical over long runs. PVC pipe is more appropriate for shorter runs and is rigid pipe that must be laid in a trench. Where pipe may be prone to damage or left above ground, such as at stock water points, pipe such as galvanised iron/steel may be preferred. Due to their wide use in the farming industry only polyethylene and PVC pipes are discussed.

Polyethylene and PVC pipes are generally suitable for working temperatures up to approximately 50 ^{o}C. In cases where groundwater is extracted at higher temperatures cooling ponds are typically used. Cooling ponds are typically designed to cool water to 40 ^{o}C. Alternatively cross linked polyethylene pipe, which has a higher temperature rating than normal plastic pipe, may be used in the initial length of the reticulation network from the bore until temperatures have cooled sufficiently.

2.1 Polyethylene pipe

Polyethylene pipe is available in various forms. The main types available include:

- Rural (or commonly known as Imperial or Rural B, class 6 or Economy)
- Metric (commonly made from high density polyethylene).

Roll lengths of 50 to 300 m are typically available for pipe diameters up to 110 mm with custom orders in longer lengths also available. Larger diameter pipes are typically available in 12 m lengths.

2.1.1 Rural pipe

Rural pipe is typically rated to 600 kPa (60 m) and is typically available in sizes from ½ to 2 inch (12 to 50 mm) diameters (internal). The Australian standard that applies to Rural pipe is *AS2698.2 – 1985 Polyethylene Rural Pipe.* Polymers used to manufacture Rural pipe should comply with *AS4131*. Pipe should be marked with Australian Standard number, pressure rating and diameter. Rural pipe is commonly used for stock and domestic purposes, particularly gravity systems.

2.1.2 Metric

Metric pipe is available in diameters (outside) from 16 to 1000 mm and a wide range of pressure ratings from 320 kPa (PN3.2) to 2000 kPa (PN20). The Australian standard that applies to Metric pipe is *AS4130-2003 Polyethylene Pressure Pipe*. Polymers used to manufacture Metric pipe should comply with *AS4131*. PE80 (B and C) and PE100 are the main materials used in the manufacture of polyethylene pipe. In general terms PE100 is stronger than PE80 and will thus withstand a greater pressure than a pipe with the same diameter and wall thickness made from PE80. Pipe should be marked with Australian Standard number, pressure rating and diameter. Metric pipe is most commonly used in applications where high reliability is essential, in pipes where high pressures may be experienced (including high pressures due to surges) and in pipes under heavy duty conditions.

2.1.3 Fittings and joining

Rural and Metric pipe fittings are not interchangeable, but conversion kits are available. A wide range of fittings is available varying in cost and quality. Fittings for Rural pipe are dictated by the internal diameter of the pipe with fittings inserted into the bore of the pipe. Metric pipe is dictated by outside diameters with fittings acting on the outside of the pipe. The main joining techniques available for polyethylene pipe include:

- compression couplings
- butt welding
- electrofusion
- stub flanges and backing plates.

Compression couplings

Typically used for joining smaller diameter pipes (e.g. Rural pipe), compression couplings allow an easy system for joining pipes and can be undone and re-used when altering pipe layout. The joint locks and seals pipe ends together using a threaded fitting. Figure 2 shows an example of a compression fitting.

Figure 2: Example of a compression fitting

Source: www.vinidex.com.au

Butt welding

Pipes are joined by heating both ends of the pipe to melting point and then pushing both ends together under pressure until both pipe ends are fused together. Thermal butt welding equipment is required to undertake the joining. Thermal butt welding is not generally recommended for joining Rural pipe due to the thin wall of the pipe and the potential premature failure of the joint. Figure 3 shows an example of thermal butt fusion of polyethylene pipe.

Figure 3: Fusion butt welding

Source: www.ritmoamerica.com

Electrofusion

Electrofusion is an alternative to butt welding where heating elements are imbedded into plastic fittings that are placed over the pipe. An electric current is passed through the fitting to produce a welded joint. An example of an electrofusion weld joint is shown in Figure 4.

Figure 4: Electrofusion weld

Source: http://users.skynet.be/fb045240/pex/vpec%20faq.pdf

Stub flanges and backing plates

Demountable flange joints can be provided using stub ends and metal backing plates together with rubber sealing gaskets. This can allow installation with pumps, valves etc. Figure 5 shows an example of a stub flange and backing plate for a polyethylene pipe.

Figure 5: Stub flange and backing plate

Source: www.vinidex.com.au

2.1.4 Installation

Polyethylene pipe should be laid below ground to avoid the effects of extreme temperature changes (both hot day time and cold night time temperatures), damage from stock and farm equipment. Below ground installation will also protect against damage from rodents and from fires. Generally pipes installed below ground will have a longer working life. Ripping and trenching are the two main techniques for installing pipe underground.

Ripping

Ripping is a common practice used on farms to lay pipe underground. The technique is easy and cost effective and uses a modified attachment on the back of a tractor ripper. This technique does not allow the final resting place of the pipe to be observed, and may also place stress on the pipe as it is being laid. Where soils are stony, this technique may not be suitable as pipe damage could occur if in contact with a sharp rock. Where the reliability of the pipeline is of high importance (e.g. water delivery to stock) then this technique would not be recommended.

Trenching

Trenching is more expensive than ripping, but this technique provides a high quality, reliable and long lasting system and may reduce future maintenance costs. Trenching allows the final resting place of the pipe to be observed, ensuring sharp objects, such as rocks, do not come in contact with the pipe. Sand can also be placed around pipes to protect them. Trenching also allows for pressure testing of pipelines prior to backfilling.

2.1.5 Effect of temperature

Polyethylene pipe is pressure rated at 20^{o}C. The minimum life of Metric pipe is 50 years and 20 years for Rural pipe at this temperature. Increases in temperature will reduce pressure ratings of pipelines as well as working life. This will depend on diameter and wall thickness. Typically maximum working temperatures in pipelines should not exceed 50 to 60 ^{o}C for Metric pipe and 45 ^{o}C for Rural pipe. For higher temperature applications cross linked polyethylene should be considered. Polyethylene pipe is suitable for sub zero temperatures. Pressure de-ratings for three types of polyethylene pipe are indicated in the tables below (DWLBC 2006).

Table 1: Pressure de-rating for Rural pipe

Temperature ^{o}C	Allowable Head m
20	63
25	55
30	50
35	45
40	40
45	35

Source: DWLBC 2006

Table 2: Pressure de-rating for Blueline PE-80B pipe

Temperature	Maximum Operating Pressure (kPa)				
	SDR9	SDR11	SDR13.6	SDR17	SDR21
^{o}C	PN16	PN12.5	PN10	PN8	PN6.3
20	1600	1250	1000	800	630
30	1504	1175	940	752	592
40	1296	1012	810	648	510
50	1104	862	690	552	434
60	1008	788	630	504	397
70	848	663	530	424	334

Source: DWLB 2006

Notes:

- Minimum of 50 years expected for water up to 45^{o}C
- Minimum of 28 years expected for water up to 50^{o}C
- Minimum of 9 years expected for water up to 60^{o}C
- Minimum of 1 year expected for water up to 70^{o}C

Table 3: Pressure de-rating for Vinidex PE-X100 pipe

Temperature	Maximum Operating Pressure (kPa)				
	SDR9	SDR11	SDR13.6	SDR17	SDR21
°C	PN16	PN12.5	PN10	PN8	PN6.3
20	1600	1250	1000	800	630
30	1410	1100	880	700	550
40	1260	980	790	630	500
50	1150	900	720	580	450
60	980	770	610	490	390
70	900	700	560	450	350
80	810	630	510	410	320
90	730	570	450	360	290

Source: DWLBC 2006

Notes:

- Minimum of 50 years expected for water up to 70 °C
- Minimum of 25 years expected for water up to 80 °C
- Minimum of 10 years expected for water up to 90 °C

Pressure de-ratings for elevated temperatures are also applicable for pipe joints. The following tables provide typical reduction factors for electrofusion and compression fittings (DWLBC, 2006).

Table 4: Pressure de-rating for electrofusion fittings (50 year lifespan)

Temperature	Pressure Reduction Factor	Maximum Operating Pressure (kPa)	
°C		PN16	PN12.5
20	1	1600	1250
25	0.9	1440	1130
30	0.81	1300	1010
35	0.72	1150	900
40	0.62	990	770
45	0.52	830	650
50	0.43	690	540

Source: DWLBC 2006

Table 5: Pressure de-rating for compression fittings (50 year lifespan)

Temperature	Pressure Reduction Factor	Maximum Operating Pressure (kPa)	
°C		PN16	PN12.5
20	1	1600	1250
25	0.9	1440	1120
30	0.8	1280	1000
35	0.72	1150	900
40	0.65	1040	810
45	0.54	860	670
50	0.45	720	560
60	0.3	480	370

Source: DWLBC 2006

2.1.6 Recent advancements

Cross linked polyethylene

Cross linked polyethylene (PEX) has similar characteristics to HDPE but with molecules cross linked to improve its ability to handle higher temperatures (up to 95 ^{o}C). Although mostly used in the plumbing industry, larger pipe diameters are available. The Australian standard related to PEX pipe is *AS2492-1994 "Cross linked polyethylene (PE-X) pipe for hot and cold water applications"*.

Cross linked polyethylene may be suitable for the initial run of reticulation pipework from an artesian bore where elevated temperatures may be a problem. As a guide a temperature drop of 8 ^{o}C/km can be expected in buried poly pipe (DWLBCq 2006). This may replace cooling ponds and will eliminate problems associated with cooling ponds such as algal build up and scaling of the copper pipes. Cooling ponds may still be preferable however, when several pipe offtakes from the wellhead make this option more expensive.

Cooling ponds

Cooling ponds allow hot bore water to be cooled sufficiently to allow water to be piped through polyethylene pipe. Ponds are typically designed to reduce bore water temperatures to 40 ^{o}C. Hot bore water is passed through a mesh of copper pipes placed in a pool of water. Cooling occurs through evaporative effects. A manifold at the end of the copper pipework mesh allows water to be passed to a single pipe. Care must be taken to avoid the affects of algal buildup and scaling on the copper pipes which can reduce the performance of the cooling ponds.

In NSW where water temperatures are usually less than 55 ^{o}C, a low cost cooling system is used where water is "dropped" into a tank. Some problems with algal growths have been experienced which allow scaling along the pipeline. Removal of built up algae and scale is via compressed air.

White co-extruded polyethylene

A white co-extruded polyethylene is designed for above ground pipelines in hot climates to significantly reduce the heating effect due to exposure to solar radiation which occurs in the normal black pigmented polyethylene. This allows the use of lower class pipes.

2.2 PVC pipe

PVC pipes for pressure applications have been used in Australia since the 1960s and are widely used in water supply, irrigation and sewerage rising mains. They have a high strength to weight ratio and exceptional resistance to corrosion and chemical attack. The most common PVC pipe available on the market is unplasticised PVC (uPVC). PVC pressure pipe is available in sizes from 15 to 450 mm and in lengths of generally 6 m but up to 12 m. PVC pressure pipe is available in a variety of pressure classes. Two designated diameter series are applicable to PVC pipe:

- Series 1: white colour with both rubber ring and solvent weld joints
- Series 2: blue in colour and comes with rubber ring deflection joints and is dimensionally compatible with cast iron, ductile iron and AC pipe.

The Australia standard that applies to unplasticised PVC pipe is AS1477-19996 "PVC pipes and fittings for pressure applications". A new standard AS4765-2000 "Modified PVC (PVC-M) pipes for pressure applications" has been developed for modified PVC.

2.2.1 Fittings and joining

Common joining methods used for PVC pipe includes:

- bell and spigot
- solvent cementing
- threaded couplings and adapters
- stub flanges and backing ring.

Bell and spigot

Each pipe length has a bell (larger diameter end) and a spigot (normal diameter end). The spigot is inserted into the bell with a rubber O-ring providing the necessary seal. Bell and spigot joints provide a watertight seal and allow for movements due to expansion and contraction. They are more appropriate for larger diameter pipes. Figure 6 shows an example of a bell and spigot joint for PVC pipe.

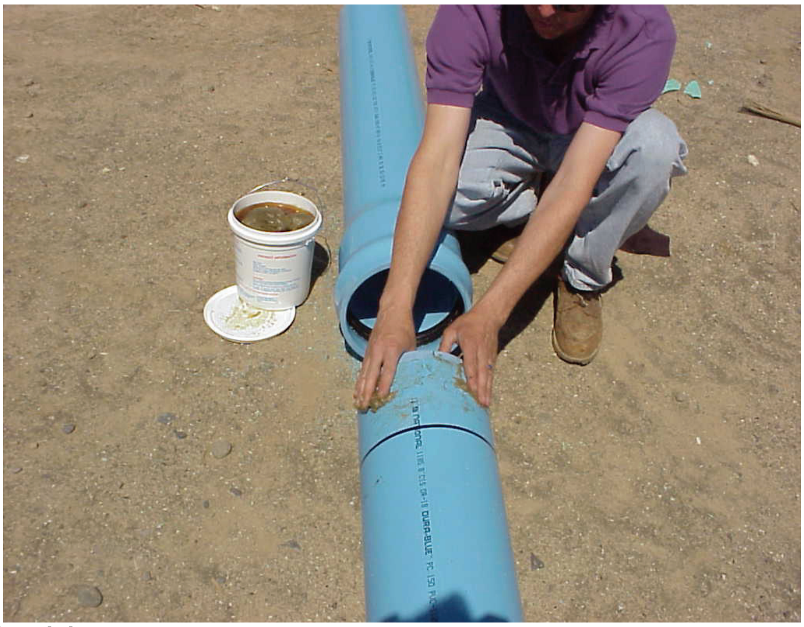

Figure 6: Bell and spigot joint

Source: www.nationalpipe.com

Solvent cementing

Pipes are bonded together by means of chemical fusion. A primer is used to clean surface to be bonded. Pipes to be connected consist of a pipe or tube end and a slightly tapered fitting socket. Solvent cement (Type P for pressure pipe) is applied to the outside of the pipe end and inside of the socket. The pipe is then pushed into the socket enabling the two surfaces to join via chemical fusion. Figure 7 shows an example of solvent cementing of PVC pipe.

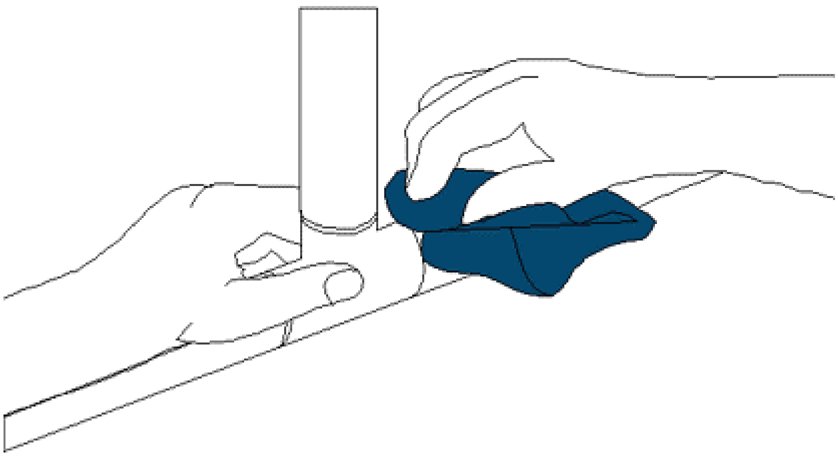

Figure 7: Solvent cementing PVC pipe

Source: www.lawngenie.com

Threaded couplings and adapters

Pipes with ends threaded are joined via a threaded coupling. PVC compatible threading tape or paste should be used. Threaded joints can allow for pipes to be dismantled, however joints may loosen over time. Figure 8 shows an example of a threaded adapter for joining PVC pipe.

Figure 8: Threaded adapter
Source: www.cepex.com

Stub flanges and backing rings

Demountable flange joints can be provided using stub ends and metal backing plates together with rubber sealing gaskets. This can allow installation with pumps, valves etc. Figure 9 shows an example of a stub flange and backing ring joint.

Figure 9: Stub flange with backing ring joint
Source: www.cepex.com

2.2.2 Installation

PVC pipe should be laid below ground to avoid the effects of temperature (both hot daytime and cold night time temperatures) and damage from stock and farm equipment. Due to the rigid nature of PVC pipe pipes must be laid in trenches. Care must be taken to prevent pipe from coming into contact with large rocks or stones. Sand bedding may be required

2.2.3 Effect of temperature

PVC pipe is pressure rated at 20 ^{o}C. The minimum life of PVC is 50 years, and it can have life expectancies greater than 100 years. Typically working temperatures in pipelines are 0^{o}C to 50 ^{o}C. Increases in temperature will reduce pressure ratings of pipelines. Pressure de-ratings at higher temperatures are indicated in the following table:

Table 6: Pressure de-rating for PVC pipe

Maximum service temperature (^{o}C)	Multiplication Factor for Pressure De-rating
20	1.0
30	0.9
40	0.7
50	0.5

Source: **GWM**Water 2005

2.2.4 Recent advancements

Modified PVC pressure pipe incorporates advanced technology and has superior physical characteristics over uPVC pipe. These include higher impact resistance, greater ductility, reduced weight and an increased hydraulic capacity. PVC-M is interchangeable with uPVC. A new standard *AS4765-2000 "Modified PVC (PVC-M) pipes for pressure applications"* has been developed for modified PVC.

3. Category 2: Pumps

Pumps may be required to draw water from the ground or deliver water to holding storages and drinking troughs. In areas where artesian pressure is sufficient pumps may not be required. Traditional pumping systems such as windmills require on-going maintenance and, due to distance, may be difficult to access on a regular basis to check performance. Many types of pumps are available on the market. The most common pumps available that will have application for farm reticulation include:

- centrifugal
- jet (shallow and deep well pumps)
- submersible borehole pumps
- helical rotor pumps
- piston pumps.

Ideally, water reticulation to troughs would be via gravity from a holding storage. This would eliminate the need for continuous pumping. Alternatively pumping directly to troughs can be undertaken using a pressure unit, with a gravity standby holding tank available in case of pump failure. This tank should be kept full and have sufficient water available (e.g. at least 1 day supply). If no gravity holding tank is available then a backup pump should be provided.

Pumps will be selected based on pressure required and discharge. These operating conditions will also dictate the power required. Some pumps will be more efficient than others for the same operating conditions. This will reduce energy costs.

3.1 Pump types

3.1.1 Centrifugal pumps

One of the most common pumps available, centrifugal pumps are efficient and easy to maintain. They are generally low cost with few moving or wearing parts. A motor rotates a propeller housed in a casing, imparting energy to the water. A partial vacuum is also created allowing atmospheric pressure to push the water into the vacuum. As water moves toward the outside of the impeller the energy increases. The greater the diameter and velocity of the impeller the faster the water will be moving. The maximum suction lift for a centrifugal pump is approximately 6 m. Figure 10 shows the details of a centrifugal pump.

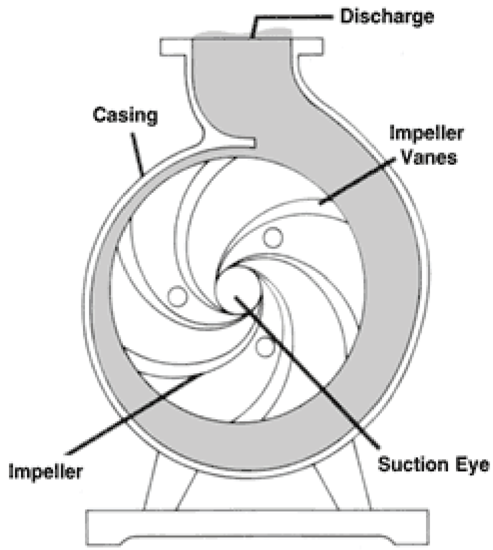

Figure 10: Centrifugal pump

Source: www.gouldspumps.com

Centrifugal pumps are suitable for a wide range of duties but are generally suitable for medium flows and pressures. They generally have lower efficiencies than other pumps. Centrifugal pumps generally require high rpm to operate and are most suited to direct coupling to electric motors, but can also be belt driven. Centrifugal pumps generally require priming before start-up. Self priming systems using priming tanks, foot valves or flooded inlets can eliminate the need for manual priming.

Multi-stage centrifugal pumps consist of a number of impellers mounted on the same shaft and are typically used in borehole applications (see submersible borehole pumps Section 3.1.3). This increases the pump pressure. In borehole applications these can be surface driven or have submersible electric motors.

3.1.2 Jet pumps (shallow and deep well pumps)

Jet pumps are generally surface mounted centrifugal pumps that are fitted with either shallow well or deep well injector kits. Jet pumps consist of a jet and venturi added to the suction side of a centrifugal pump. Part of the pumped water is returned through the jet and venturi which enhances suction lift. Jet pumps are common on farm properties and can produce greater suction and delivery heads than centrifugal pumps. Maximum suction heads for shallow wells are typically 7–8 m and for deep wells up to 50 m. Jet pumps may be considered appropriate where the depth of water in the well makes these pumps more economical than submersible pumps. Figure 11 shows an example of a deep well jet pump.

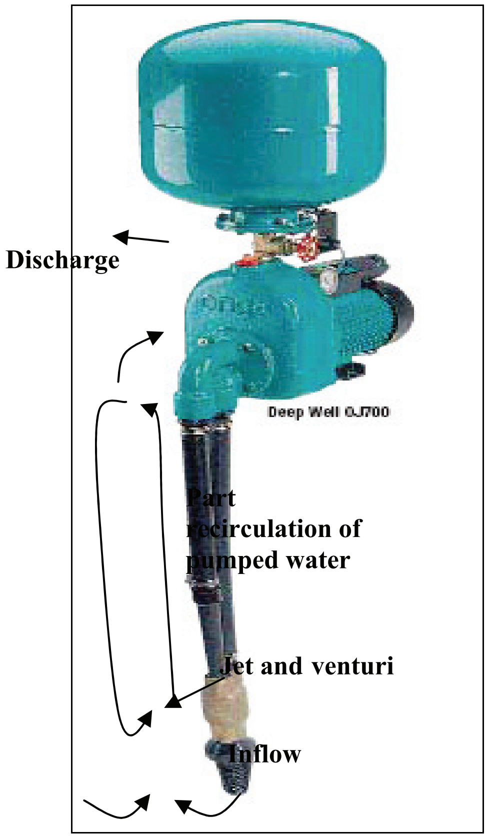

Figure 11: Deep well jet pump

Source: www.ongapumps.com.au

Jet pumps have superior self priming abilities compared with centrifugal pumps although the flow performance and pump efficiency are lower. Venturi and jet assemblies can be changed to alter the head and flow performance of the pump. This can allow for future changes and extensions to reticulation systems.

3.1.3 Submersible borehole pumps

Submersible borehole pumps are generally available for bore sizes from 75 mm up to 300 mm. Pump size and impeller combinations can be chosen for optimum performance. Submersible borehole pumps usually consist of submersible multi-stage centrifugal or mixed flow units, with the motor located directly under the pump. These pumps are electrically driven. Submersible borehole pumps are generally made of stainless steel, providing good protection against corrosion and abrasion. Submersible pumps are generally highly efficient, therefore lowering running costs. These pumps can also be coupled with solar power. Figure 12 shows an example of a submersible borehole pump.

Figure 12: Submersible borehole pump

Source: www.flygt.co.uk

3.1.4 Helical rotor pumps

A helical rotor pump is a positive displacement type pump that is inserted into a borehole. Water is moved up the rotor by being confined between the rotor and stator. There is only one moving pump part, and it is self cleansing – ensuring no algal or oxide deposits (refer to Figure 13 showing the components of a helical rotor pump vs a submersible multi-stage centrifugal pump). These pumps are mostly suitable for moderate to high pressures but low flows. They can also handle water with abrasive particles. A pressure relief valve is required to prevent damage from closure of the delivery line. Helical rotor pumps are highly efficient especially when compared to multi-stage and jet pumps. These pumps can have submersible motors, be surface driven (e.g. turbine pump) and can also be coupled with solar power.

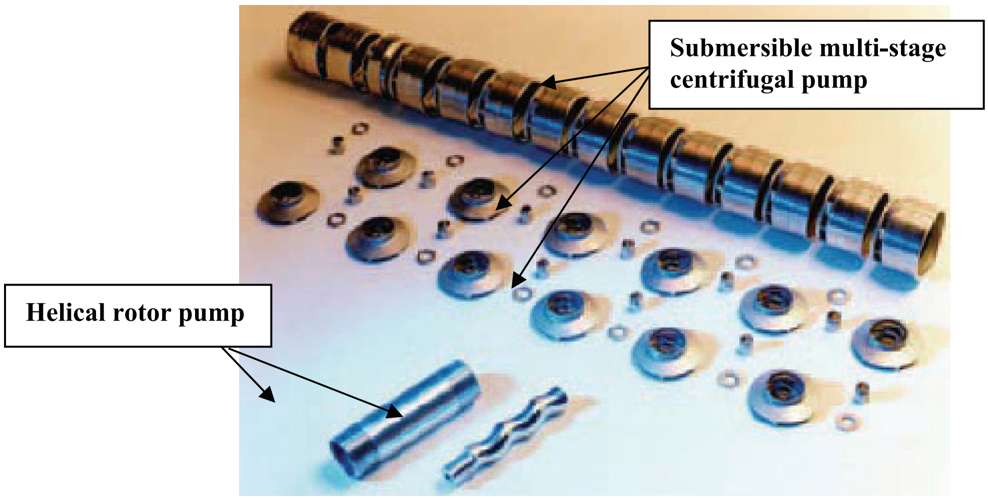

Figure 13: Helical rotor vs submersible multi-stage centrifugal pump components

Source: www.mono-pumps.com

3.1.5 Cylinder pumps

Cylinder pumps work by drawing water into a cylinder on the upstroke and expelling it on the return. Cylinder pumps are usually double acting to minimise fluctuations in delivery. An air chamber on the delivery line will help minimise fluctuations. Cylinder pumps generally require high maintenance. They can develop high pressures but only low flow. A pressure relief valve should be provided to prevent pump damage should the delivery line be closed. A common application of this type of pump is at windmills.

3.2 Pump power

The main forms of pump power available include:

- electric
- petrol/diesel
- wind
- solar.

3.2.1 Electric

Electric power is usually an ideal power source for running pumps and is usually the cheapest. Pumps can be easily automated to actuate for differing conditions. In cases where troughs are fed via gravity from holding tanks, tank filling can be undertaken in off-peak times, reducing pumping costs. It is usually cheaper to locate pumps near existing power sources rather than running power to a new pump location. In this case, the cost of installing new water pipes to the pump will often be cheaper, although where distances are large other power sources may be more appropriate. Pumps that run on electric power may be subject to power failures. Electric motor speeds are fixed which will influence the method of connecting the pump to the motor.

3.2.2 Petrol/diesel

Petrol engine driven pumps are mostly applicable for low use or mobile pumping units. Diesel engines are more appropriate for permanent and frequent use installations. Costs such as fuel, maintenance, ease of automation etc need to be considered when choosing between electric power supply and petrol/diesel engines. A diesel engine may be appropriate as a backup supply.

3.2.3 Wind

Installing wind powered pumps can be expensive and may involve regular maintenance. There may also be periods of low wind during particular times of the year. Back-up power supplies may be required. The power that can be derived from traditional windmill pumps are determined by the fan diameter. Typically windmills need to be placed in areas where turbulence is minimal and usually need to be located away from trees and high up on towers. This may also be a potential work hazard during maintenance. Traditional windmill driven pumps are increasingly being replaced with solar powered submersible pumps.

3.2.4 Solar

Solar powered pump systems may be more expensive to install, but are generally reliable and require little maintenance. They perform best in summer. They are particularly suited to remote site pumping. Solar powered submersible pumps are becoming more popular and can replace less reliable windmills at stock drinking points for only a small increase in cost (typical systems including solar panels, are in the order of $10 000). Backup supply such as a diesel generator may be also be required. Figure 14 shows an example of a solar powered pumping system.

Figure 14: Example of a solar powered pump system
Source: www.oksolar.com

3.3 Temperature

Typical operating ranges for most common farm reticulation pumps are up to 50°C. Increases in water temperature can affect the suction performance of a pump. It is thus desirable to reduce exposed suction pipeline lengths. For pumps powered by internal combustion engines loss of power occurs at higher temperatures. This generally equates to 1 percent for every 3 °C above 20 °C (Southorn 1995).

3.4 Pressure switches and tanks

Pump operation can be automated via the use of pressure switches on the discharge side of the pump. When the pressure falls below a predetermined level, due to a demand in the reticulation line, the pump is activated to deliver water. Pressure switches are set for cut in and cut out pressure, which are appropriate for the reticulation system.

Pressure switches may cause excessive pump cycling when small amounts of water are drawn off to supply stock troughs, for example. This can reduce the life of the pump. Also, should the holding storage empty, sufficient pressure cannot build up to switch off the pump, which could cause pump failure. A pressure tank can provide a stored volume of water that the system can draw from before the system pressure falls to the pump activation pressure. This will reduce pump cycling and help increase the life of the pump. Various sizes are available to suit particular applications.

3.5 Protection

Generally two types of motor enclosures are available for electric pumps:

- drip proof
- totally enclosed fan cooled (TEFC).

Drip proof will still allow dust, dirt and vermin to enter the motor through the cooling slots and may cause it to fail. A TEFC motor is more expensive but offers protection from dirt, dust and vermin. The motor is totally enclosed with an external fan blowing air over the outside to dissipate heat. The housing also offers some protection against weather exposure.

Pump motors need to be kept cool to protect electrical insulation. Operating temperatures should generally not exceed 40 ^{o}C for long periods. A pump house with adequate ventilation to the pump motor should be provided in areas exposed to extreme conditions.

4. Category 3: Tanks and troughs

A variety of holding tanks and troughs are available on the market. The size will be dictated by stock numbers and the reliability of the reticulation system. For electric pumps a 3 day back-up supply is recommended, for engine driven pumps 5 days and for windmills 7 to 10 days (Southorn 1995). Tanks will normally be located to enable gravity delivery to troughs.

4.1 Tanks

Various types of tanks are commercially available and include:

- steel
- concrete
- polyethylene
- fibreglass.

A less common timber tank is also available on the market. Tanks are available in a wide variety of sizes and can be prefabricated or constructed on site.

4.1.1 Steel

Corrugated galvanised steel or modular prefabricated steel tanks for larger volumes are two typical types of steel tanks available. Galvanised steel tanks, available with rust resitant linings such as Aquaplate and Zincalume, are generally available up to 27 000 litres. In corrugated, galvanised and prefabricated steel tanks which hold bore water or saline water, plastic liners such as polyethylene are often used to reduce corrosion. For large volumes, plastic lined modular steel kit tanks are generally more economical than multiple polyethylene tanks and are easy to deliver to site and construct (see Figure 15). The tanks must have a top cover to protect the plastic coating from UV radiation. Steel tanks can usually be easily moved or relocated.

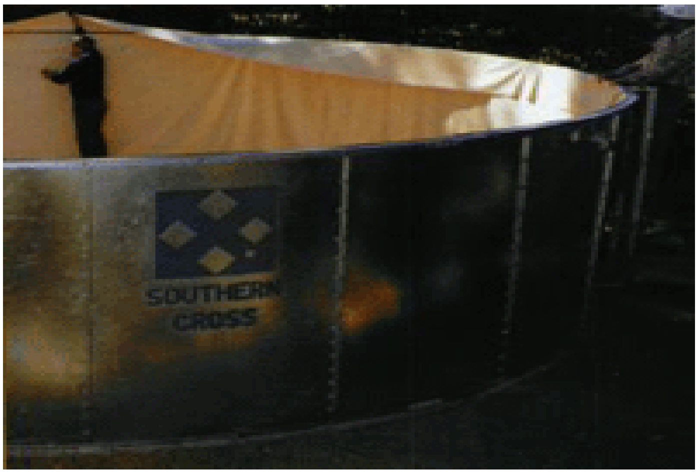

Figure 15: Example of a plastic lined modular steel tank

Source: www.southcross.com.au

4.1.2 Concrete

Concrete tanks are generally more expensive but have a long life expectancy against corrosion and damage. Prefabricated units up to approximately 35 kL are available, although they are more difficult to transport than lighter steel and plastic tanks. Larger tanks are usually cast in-situ. Concrete should be chosen for the exposure condition applicable (refer to *AS3735* and *AS3600*). Cast in-situ tanks should only be poured when maximum daily temperatures are less than approximately 34 ^{o}C. Tanks should be provided with roofs to prevent algal growth and minimise contamination. Concrete or steel roofs are available. Concrete tanks are difficult to construct in remote areas where delivery of materials and long construction times make them uneconomic. Concrete tanks are generally porous and prone to cracking and may develop leaks over time.

4.1.3 Polyethylene

Polyethylene tanks have become increasingly popular due to lower cost and corrosion resistance. Tanks are available in sizes up to approximately 32 000 litres although some manufacturers offer tanks as large as 45 500 litres. Tanks are usually molded in one piece with roofs and are UV stabilised. Tanks are usually molded with thicker walls at the bottom of the tank and corrugated for extra strength. Polypropylene tanks are generally light and can be easily relocated. Some problems have been experienced in tanks constructed with a vertical seam which, being the weak point in the tank, may cause splitting (see Figure 16). For larger tanks, a centre support post will help prevent collapse of the roof during hot days.

Figure 16: Splitting of poly tank with a vertical seam

Source: www.stockmanelectronics.com.au

4.1.4 Fibreglass tanks

Fibreglass tanks are usually more expensive than poly tanks. They resist corrosion and are generally not affected by chemicals or moisture. Fibreglass tanks may allow light to penetrate which may cause algal growth problems. Tanks should thus be painted on the outside or sealed with a black covering on the inside. Fibreglass can be brittle in nature and may crack and leak.

4.1.5 Timber

Timber tanks are uncommon in Australia but are an alternative to other tanks particularly for storages greater than 100 000 litres where costs are very competitive. In New Zealand these tanks have gained popularity in the last 10 years. On-site construction time for larger tanks is significantly less than that for concrete and they can be assembled easily in remote or difficult locations. Maintenance costs are also significantly less than concrete (can have leakage problems) and steel tanks (need painting every 5 to 10 years). Timber tanks have a longer life expectancy than other tanks (80 years) and are protected against termite attack. Timber tanks can be dismantled and relocated if necessary.

4.1.6 Fire resistance

Concrete, steel and to a lesser extent timber tanks provide good fire resistance, whereas plastic tanks offer the least resistance.

4.1.7 Tank roofs

Tank roofs should be provided to maintain water quality, eliminate light and minimise algal growths, which may block valves and fittings. They are also necessary for plastic lined tanks which are prone to UV degradation. For larger polyethylene tanks, a central support post should be provided to prevent roof collapse particularly during hot weather.

4.1.8 Tank stands

Tanks stands may be required to elevate tanks to enable gravity flow to troughs. Generally earth banks are the simplest and cheapest form of stand. Fabricated tank stands are usually more costly and may cause difficulties when placing the tank on the stand. Safety hazards may also exist with fabricated tank stands should climbing the stand be necessary for maintenance.

4.2 Troughs

Stock troughs are most commonly made from concrete or polyethylene. Galvanised steel, fibreglass, fibro cement and stainless steel troughs are also available. Home made tanks using steel and/or concrete (typically old pipe) are also common. Round and rectangular troughs are typically available. Larger round troughs are more stable and are more suitable for cattle. Rectangular troughs are usually made in sections and sit on pedestals, but are prone to leaks or overflowing if the soil underneath erodes.

Trough size will depend on the stock – it should be large enough to fit stock around the perimeter. Over sizing may cause water to become stagnant and unpalatable and may result in algal growth. Sheep troughs usually sit 300 mm high and cattle troughs 500 mm high. Combination troughs 400 mm high are available to suit both sheep and cattle.

4.2.1 Concrete

Concrete troughs are the most common type of trough. They are heavy and generally need to be lifted with a loader or forklift. They are generally better insulated and experience smaller temperature fluctuations. Due to their weight they are not easily damaged or moved by stock, passing floodwaters or wind. For cattle only concrete troughs are really appropriate as other material will be destroyed should cattle step in them. Figure 17 shows an example of a concrete stock trough.

Figure 17: Example of a rectangular concrete stock trough

4.2.2 Polyethylene

Polyethylene troughs are lightweight and are easily moved or relocated. Water temperature fluctuations are greater, with water cooling down at night and heating up in the day. This may induce algal growth. Due to their light weight they can be easily disturbed by stock. Polyethylene troughs are usually black, which absorbs more heat and can promote algal growth. Polyethylene tanks must be supported by a steel stand. Typically polyethylene troughs will only be appropriate for use by sheep. Figure 18 shows an example of a poly stock trough.

Figure 18: Example of a poly trough

Source: www.polymaster.com.au

4.2.3 Trough bases

A concrete apron or road base material under and around troughs is desirable to prevent erosion of soil around the trough, potentially causing troughs to spill or leak. A base will also provide a more hygienic environment for stock whilst drinking.

4.2.4 Trough float valves

A wide range of float valves for stock troughs is available on the market. For remote locations where failure of float valves may result in stock loss, high quality valves should be used. Quality is often reflected in the price, with plastic valves often the cheapest whereas stainless steel, brass or marine grade cast brass are more robust and durable and thus more expensive. Care must be taken when using float valves that are supplied with troughs. Typically cheaper plastic valves are used in these cases. Figure 19 shows an example of a brass float valve.

Figure 19: Brass float valve

Source: DWLBC 2006

Float valves are available for different supply pressures and the correct valve for the operating pressures should be chosen. Usually float valves in troughs should be designed for low pressure. High pressure float valves can restrict flow and are more likely to stick.

Large floats provide good water cut off and reduce float bounce, which can reduce the life of the valve and cause trough spillage. Conventional float valves are located at the upper edge of the trough and must be protected from stock damage with suitable covers. Dual level float valves can be used for troughs supplied by pumps. This allows a drop in water level before the valve opens, minimising pump stop and start. Armless trough valves that can be placed below water level are also available and can reduce damage of the valve and connecting pipe by stock.

4.2.5 Maintenance

Troughs will need periodic cleaning to remove algal growth, dust, dung, vermin etc. Shade structures can be placed over troughs to reduce sunlight and thus algal growth. This will also reduce evaporation and keep water cooler. Shade structures should not encourage stock to camp around the trough. Float valve and inlet pipework also require periodic maintenance including cleaning of built up scale and repair of damage caused by stock. Trough condition and operation in remote areas can be viewed through video telemetry.

5. Category 4: Valves

Many types and makes of valves are available on the market. Quality is usually reflected in the price of the valve. Typical valves appropriate for water reticulation systems include:

- Air valves or pressure relief valves
- Check or foot valves
- Gate or ball valves
- Float valves.

The quality required will depend on the intended use. For example high quality valves should be used for tanks and troughs in remote locations when inspection is infrequent, or for valves located in underground boxes where visual inspection of leaks is only possible when the valve box cover is removed. Increasingly, funding agencies for reticulation schemes will require stainless steel valves.

In areas where pressure and temperatures are high, only high quality material should be used. Typically stainless steel is used, although advances in epoxy coatings and electroplating may enable materials such as cast iron and bronze to be suitable.

5.1 Air valves or pressure relief valves

Air valves or pressure relief valves are usually installed at high points along pipeline routes to allow accumulated air to be released, thus preventing potential airlocks and interruptions to flow. Double acting air valves also can allow air entry should the pipe be drained. Caution is required for gravity lines where air valves may cause air to enter the pipe if negative heads are present in the pipeline, thus potentially causing flow problems. Accumulated air in pipelines may also be purged by simply installing a ball valve at high points along the pipeline and periodically opening these valves manually to bleed the line. This will avoid problems associated with blockage of air valves from scaling.

For positive displacement type pumps (e.g. helical rotor and piston pumps) pressure relief valves are necessary to prevent pump damage should the delivery line be closed. Air valves should not be located on the suction side of a pump, as air may enter and cause a loss of prime.

Air valves are commonly susceptible to deposition of calcium carbonate material and corrosion of metal fittings. Valves should be maintained periodically to remove built up deposits that could potentially block the valve. Figure 20 shows an example of carbonate deposition on an air valve.

Figure 20: Calcium carbonate deposits on an air valve

Source: DWLBC 2006

5.2 Check and foot valves

Check and foot valves allow flow in one direction only. Most modern pumps have check valves built into the suction port at the pump inlet. Foot valves are installed at the end of pump suction lines. This maintains the line primed event when the pump is not operating. Check valves also take the back pressure off pump valves and foot valves when the pump is idle. This prevents drainage of the line in case of the foot valve leaking. Check and foot valves are available in a variety of materials including plastic, glass fibre reinforced nylon, brass, cast iron, gunmetal bronze and stainless steel. Floating foot valves are also available.

5.3 Gate and ball valves

Gate and ball valves are commonly used on reticulation lines to allow maintenance (e.g. isolation valves) and control flow. Ball valves can also be used for monitoring pressure. Ball valves require a 90^{o} turn to fully open or close whereas a gate valve may require several turns of the hand wheel. Gate and ball valves are available in a variety of materials from plastic to stainless steel. The quality required will depend on the intended use. For example high quality valves should be used for tanks and troughs in remote locations when inspection is infrequent.

In areas where pressure and temperatures are high, only high quality material should be used. Typically stainless steel is used, although advances in epoxy coatings and electroplating may enable materials such as cast iron and bronze to be suitable.

Typically gate and ball valves are either threaded or flanged. For flanged fittings care must be taken to ensure gasket material is suitable for the operating temperature range. For example a neoprene rubber gasket may only be suitable for temperatures up to 50 ^{o}C, whereas an aramid fibre with nitrile binder can operate up to a continuous temperature of 205 ^{o}C. For threaded joints Teflon tape is usually used. Several wraps of tape may be required to seal threads. Typically four wraps are sufficient, although more may be required for poor quality or damaged threads. Teflon tape is suitable across a broad range of temperatures, is compatible with most liquids and gases as well as piping materials, and will act as a lubricant and anti-sieze material.

Care must be taken to prevent accidental closure of valves from stock or machinery. Valves may require protection in valve boxes to prevent damage. Valve handles can also be removed to prevent accidental closure.

5.4 Float valves

Float valves are typically used at stock troughs or in holding storages. The valve is attached to an arm with a float connected. Once water reaches a certain level the valve is shut. The quality of the valves varies and is usually reflected in the price. The type of valve chosen will depend on the use and the consequence of failure. Materials from plastic to stainless steel are available. Single lever, dual lever and submersible float valves are available. Float valves are also available for low and high pressures. More information on float valves is provided in Section 4.2.4 Trough float valves.

6. Category 5: Miscellaneous

6.1 Bores

The primary source of water for rangeland reticulation of water will be from groundwater bores. *Minimum Construction Requirements for Water Bores in Australia Edition 2* (NMBSC 2003) provides drillers in Australia with information and a technical standard for construction of water bores. The Australian Drilling Industry Association is the professional organisation for the drilling industry. Drilling contractors, suppliers and consultants can be accessed through the association website www.adia.com.au.

Depending on the location of the bore, either subartesian or artesian bores may be developed. Typically subartesian bores will not pose major problems with temperatures. Artesian bores may experience high temperature and pressures and require special consideration. Two components where problems may occur are:

- casing
- well head.

6.1.1 Casing

Casing is required to prevent bore collapse and to act as a safe housing for any pump installed in the bore. Casing materials include:

- steel
- PVC
- thermoplastic (ABS)
- fibreglass reinforced plastic (FRP).

Choice of material will depend on strength requirements, corrosion resistance, ease of handling, cost considerations, type of formation, method of drilling, bore design, construction techniques and licence or permit requirements. Table 7 provides a comparison of the casing material properties (NMBSC 2003).

Table 7: Casing material properties

Material	Specific Gravity	Tensile Strength (MPa)	Tensile Modulus (10^5 kPa)	Impact Strength (relative to PVC)	Upper Temp. Limits (°C)
Steel	7.85	350	2068	v.high	800-1000
Stainless Steel	8.0	517	2000	v.high	800-1000
PVC	1.4	55	28	x1	40
ABS	1.04	31	20	x6	50
FRP	1.89	115	158	x20	80

Source: NMBSC 2003

Steel

Steel casing typically consists of piping or tubing that is butt welded. Threaded or socketed casings are also available. Steel is stronger than other materials, can withstand rougher treatment and can be pressure cemented to greater depths. Steel however can have a reduced life span in corrosive environments. In South Australia steel casing is now not allowed for boreholes drilled through more than one aquifer (pers. comm. Kevin Dennis). Stainless steel is more resistant but is costly. Steel should not be used in bores where iron bacteria are present. Australian standards applicable include *AS1396-2000* and *AS1579-2001*.

Plastic

Plastic casings have a much lower strength to weight ratio than steel and require care in storage, handling and installation to prevent damage. Pressure de-ratings will also be applicable for higher temperature waters. Plastic pipes are resistant to corrosion and are usually light and easy to handle.

PVC

Only pressure rated PVC manufactured to *AS1477* is suitable for bore casing. The piping is swell jointed and solvent welded. The only solvent and primer to be used is Type "P" conforming to *AS3879*. Class 12 piping is the recommended casing for most bore construction applications. Modified PVC must not be used under any circumstances as a bore casing. Maximum temperatures are usually 40 ^{o}C. PVC is commonly used in shallower bores.

ABS (acrylonitrile butadiene styrene)

ABS is a low density material with a higher tensile strength and lower temperature de-rating than PVC. The only acceptable ABS piping to be used for casing must comply with *AS3518.1*. ABS can be jointed in a variety of ways, including threaded joints and tapered solvent weld joints. Maximum temperatures are usually 50 ^{o}C.

FRP (fibreglass reinforced plastic)

Inert FRP casing has excellent high temperature (up to 80 ^{o}C) and pressure qualities, which makes it ideal for use in corrosive environments. FRP has a higher strength to weight ratio than steel, and a higher collapse resistance than other plastic pipe. It can be used in deep bores. The higher initial cost may be offset with longer well life.

6.1.2 Well head

Well heads will protect the underlying aquifer from the ingress of surface water which may contain contaminants in subartesian wells and will allow flow to be controlled from artesian wells. For artesian wells special considerations will need to be made for pressure and flow testing without interfering with the pump or reticulation system. Headworks shall be of flanged jointed construction. Lead annular seals and screw jointed headworks are not acceptable.

In more corrosive environments, particularly the western side of the GAB where temperatures and pressures are higher, only first grade quality material should be used for the well head and valves, and it should be rated to handle the temperature and pressure of the bore. Typically stainless steel is used, although advances in epoxy coatings and electroplating have allowed materials such as cast iron and bronze to be considered. For temperatures exceeding 50 ^{o}C or flow exceeding 15 litres per second, a main isolating valve of equivalent diameter to the inner casing shall be incorporated in the headworks between the bore casing and the distribution outlets (NMBSC, 2003). Figure 21 shows an example of a well head.

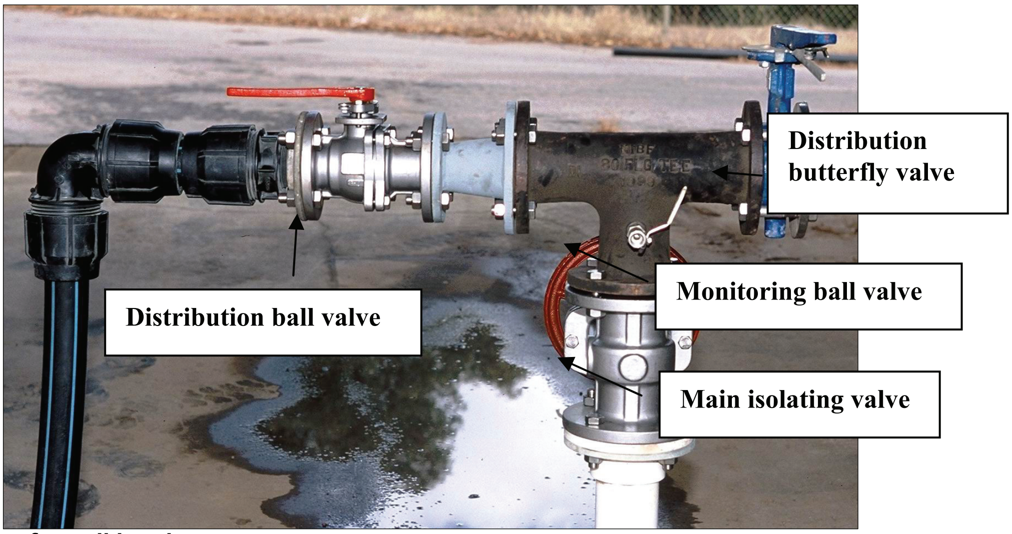

Figure 21: Example of a well head

Source: DWLBC 2006

For flanged joints use only 316SS bolts. All threaded bolts should have an anti-seize compound applied. Ensure gasket material is appropriate for temperature conditions. Table 8 indicates the temperature range for two types of gaskets.

Table 8: Temperature range for gaskets

	3000 Series Blueguard gasket	Neoprene Rubber gasket
Material	Aramid fibre with nitrile binder	Neoprene 50 or 60 duro
Temperature range	-40 ^{o}C to 370 ^{o}C	-18 ^{o}C to 93 ^{o}C
Continuous operating temperature	205 ^{o}C	76 ^{o}C. Note – Do not use when temperature exceeds 50 ^{o}C

Source: DWLBC 2006

6.2 Telemetry systems

Telemetry is remote monitoring and control through telecommunications. Advancements in telemetry technology will help pastoralists improve property management and overcome some of the maintenance issues associated with more efficient reticulation systems. This is particularly the case for remote areas where regular inspection of troughs, tanks, pumps etc is costly and time consuming, and failure to deliver water to stock can result in significant economic losses.

Early telemetry systems relied upon radio and fixed land line systems. With the rapid advancement in mobile phone, internet and satellite technology, telemetry and monitoring systems are increasingly becoming more affordable to the farming community. Now not only can tanks and trough water levels be controlled and monitored remotely but also visual images of reticulation components such as troughs can be transmitted back to the home computer without the need to travel and inspect such items. Figure 22 shows an example of a remote telemetry system for monitoring tank water levels and actuating a diesel driven pump.

Although telemetry systems offer many advantages to the landholder in automating and monitoring reticulation equipment, problems have been experienced with lightning strikes which may cause the system to fail. Protection against lightning strikes should be provided.

Figure 22: Examples of telemetry systems for tank water level monitoring (left) and pump actuation (right)

Source: www.stockmanelectronics.com.au

Table 9 provides an indication of the general uses of differing telemetry systems.

Table 9: Telemetry systems – general use

Technology	General use
Radio	Shorter distances: "line of sight applications"
Fixed telephone lines	Established sites: using existing infrastructure
Mobile phone networks	Unmanned sites: remote sites
Satellite	Remote areas: no mobile coverage

Source: **GWM**Water 2005

Radio

A radio controlled telemetry system will typically consist of a base station, field units and sensors. The base station regularly "talks" to the field units and checks the status of the sensor, battery level and signal strength to ensure the system is operating correctly. Radio systems use VHF/UHF radio for transmitting and receiving signals within a range of typically 10 to 100 km. Repeater stations can be installed to expand signal range. Signals received at the base station can be further transmitted to fixed or mobile phone lines to enable the landholder to be immediately notified of a problem. Radio telemetry systems can also be used to control as well as monitor, for example, by actuating pumps and monitoring tanks water levels. Licenced radio bands typically limit the amount of data that can be transmitted and may limit the use of radio telemetry systems for transmitting images back to the base station.

Internet, SMS, and satellite

The internet offers a low cost data transport system. Web cameras can be used at remote sites in order to upload images to the internet for viewing. Mobile phone access costs are much lower than fixed lines. Telecommunications companies offer numerous options to suit use. For example you only pay for data sent and not the time you are on-line (packet switching). SMS can be used for remote activation of pumps and alerting users when certain monitoring conditions are met. SMS messages can also be sent to and received from a personal computer via the internet. Satellite systems can be considered where there is no mobile coverage.

7. Summary of product manufacturers

The following tables provide a summary of the major manufacturers of equipment applicable for farm reticulation. Suppliers are too numerous to mention and will be location specific. Most suppliers can be found in the Yellow Pages or on the internet through industry specific sites such as the Rural Industries Research and Development Corporation www.rirdc.gov.au or product search sites such as www.hotfrog.com.au.

Table 10: Category 1 – Pipes

Only a few plastic pipe manufacturers in Australia produce polyethylene and PVC pipe. Recent advancements in cross linked polyethylene have enabled it to be used in pipe for high temperature applications. Only a select few manufacturers deal with this pipe.

Manufacturer Details	Products Available
Iplex Pipelines www.iplex.com.au	Formerly James Hardie Pipelines, manufacture a wide range of plastic pipe products including polyethylene (Metric and Rural), uPVC and modified PVC. Also manufactures white co-extruded polyethylene designed for above ground pipelines in hot climates. Products include: POLIplex (polyethylene pipe in PE80B, PE80C, PE100. Diameters DN16 to DN1000; pressure rating to 2 MPa; pipes to DN110 in rolls up to 300 m, larger diameters typically 12 m lengths). Thermapipe (white co-extruded PE for above ground installations in hot climates). Redline (Rural grade PE to 600 kPa; diameters 12 to 50 mm). uPVC pressure pipe (diameters 15 to 450 mm, series 1 (white) and series 2 (blue) available; available in a variety of pressure classes; maximum temperature 50 °C). Rhino Iplex, White Rhino and Blue Rhino (modified PVC pressure pipe; diameters 100 to 450 mm in series 1 and 2; superior physical characteristics to uPVC; Blue Rhino and White Rhino are calcium/zinc stabilised; maximum working temperature 50 °C). Hobas (centrifugally cast glass reinforced plastic pressure pipe; diameters up to 1200 mm; pressure classes 40 to 250 m; operating temperature for normal polyester based Hobas pipe is 35 °C, high temperature vinyl ester resins can be used). Future K2 (cross linked polyethylene; diameters up to 25 mm; temperatures up to 100 °C).
Vinidex www.vinidex.com.au	Australian made. Manufacturers of a wide variety of plastic pipe including PVC (modified and orientated) and polyethylene (types include PE80B, PE80C and PE100). Also manufactures white co-extruded polyethylene designed for above ground pipelines in hot climates. Products include: PE pressure pipe (polyethylene pipe in PE80B, PE80C, PE100; diameters DN16 to DN1000; pressure rating to 2 MPa; pipes to DN110 in rolls up to 300 m, larger diameters typically 12 m lengths, larger lengths up to 25 m can be supplied; co-extruded pipe in various colours including white also available). Supermain PVC-O (PVC orientated pressure pipe; diameters 100 to 300 mm; pressure to 1.6 MPa). Vinyl Iron (PVC pressure pipe; diameters (series2) compatible with ductile iron, cast iron and asbestos cement pipes; sizes 100 to 450 mm available; pressure to 2.0 MPa; available in blue, lilac and grey colours). Hydro PVC-M (modified PVC pressure pipe; diameters 100 to 450 available (series 1 and 2 available); pressure to 2.0 MPa; temperature to 50 °C).
PPI Corporation www.ppi.com.au	Australian owned. Manufactures a wide range of polyethylene pipe including Metric and Rural class. Also manufacture a variety of valves including float values, check valves and air relief valves. Products include: Polyethylene Metric pipe (PE80B, PE80C, PE100; diameters DN16 to DN450; pressure rating to 2 MPa; pipes to DN75 in rolls up to 300 m, DN90 and 100 in 100 m lengths, larger diameters typically 12 m lengths; colours available include black, blue, black with blue stripes or purple (up to DN63)). Rural Green (MDPE polyethylene pipe; diameters 18 to 50 mm; lengths up to 300 m; pressure up to 630 kPa; temperature to 40 °C).

Manufacturer Details	Products Available
Compco www.compco.com.au	Australian made. Manufactures cross linked polyethylene tubing suitable for high temperature and pressure applications. Manufacturing facility consists of twin screw co-rotating compounding extruders ranging from 53 to 123 mm.
Auspex www.auspex.com.au	Australian made. Manufactures small diameter cross linked polyethylene tubing typically for domestic hot and cold water uses.

Table 11: Category 2 – Pumps

A wide variety of models are available for each manufacturer. Only products applicable for pumping groundwater from bores are indicated. Additional information can be accessed from manufacturer websites.

Manufacturer Details	Products Available
Grundfos www.grundfos.com.au	Danish made. Widely used and proven in Australian conditions. Wide variety of pumps including submersible, centrifugal and solar/wind/battery powered submersible pumps. Products include: Submersible SQ/SQE (75 mm pump body; capacity up to 150 l/min; heads up to 210 m head, maximum temperature 40 °C; max installation depth 600 m; built in dry running protection). Submersible SQFlex. (Solar, wind or battery powered pump; 75 mm helical rotor and 100 mm centrifugal pumps available; capacity to 1500 l/min; heads to 120 m; maximum temperature 40 °C; voltage supply 30-300VDC or 1x90-240 V, 50/60Hz; maximum installation depth 150 m; built in dry running protection; built in electric Maximum Power Point Tracking (MPPT) to continuously optimise pump duty point according to input power available). Submersible SP (sizes 100 to 300 mm; capacity to 7,833 l/min; heads to 670 m head, max temperature 60 °C; maximum installation depth 600 m; built in dry running protection). Also manufacture pressure tanks to 400 litres. All pumps including motor and impellers are manufactured from stainless steel.
Mono Pumps www.monopumps.com	Australian made. Widely used and proven in Australian conditions. Wide variety of pumps including submersible, centrifugal and solar powered pumps. GPS tracking of solar arrays available. Products include: Subrotor (100 mm submersible helical rotor pump; stainless steel construction; capacity up to 150 l/min.; heads up to 150 m; maximum temperature 30 °C). Borehole lineshaft pumps (surface driven helical rotor borehole pump; can be used with electric, petrol or diesel motors; stainless steel construction available; special purpose corrosive water pumps available for special applications; capacity up to 836 l/min.; heads up to 300 m). Sun Buddy (solar powered submersible helical rotor pump; capacity up to 13.8 l/min.; heads up to 50 m; solar arrays up to 160W). Sun Sub (solar powered submersible helical rotor pump; 316 stainless steel construction; capacity up to 78 l/min.; heads up to 150 m; solar arrays up to 1200W). Sun Downer (solar powered helical rotor lineshaft borehole pump; suitable for bore 75 mm or greater; capacity up to 97 l/min.; heads up to 120 m; solar arrays up to 1575W).
Southern Cross www.southcross.com.au	Australian made. Manufacturers of centrifugal, submersible and deep well pumps. Also manufacture windmills. Products available include: E series (100 mm submersible borehole pump; stainless steel with polycarbonate pump element; capacity up to 360 l/min.; heads up to 320 m; maximum temperature 30 °C). W series (100 mm submersible borehole pump; 304 stainless steel; capacity up to 240 l/min.; heads up to 410 m; maximum temperature 30 °C). NA series (submersible borehole pump for boreholes 150 mm or greater; phosphor bronze and stainless steel construction; capacity to 3300 l/min.; heads up to 300 m). LA series (vertical shaft driven turbine pump for boreholes 150 mm or greater; phosphor bronze and stainless steel construction; capacity up to 3300 l/min.; heads up to 300 m). Borehole helical rotor pump (hard chrome plated and polished stainless steel helical rotor; surface motor driven; stainless steel; capacity up to 132 l/min.; heads up to 120 m).

Manufacturer Details	Products Available
Davey www.davey.com.au	Australian made. Manufacturers of a wide variety of pumps including centrifugal, jet, submersible pumps and shallow and deep well pumps. Products include: Deep well pressure pumps 95D, 125D and 165D (single stage centrifugal pump; marine grade aluminium pump body with rislan lining, glass filled polycarbonate impeller; maximum suction lift 30 to 42 m; maximum temperature 50 °C; output power 1.1 to 1.8 kW). Shallow well pressure pumps 95S, 125S and 165S (single stage centrifugal pump; marine grade aluminium pump body with rislan lining, glass filled polycarbonate impeller; maximum suction lift 7.5 m; maximum temperature 50 °C; output power 1.1 to 1.8 kW). Prime Jet 240 (single stage convertible jet assisted centrifugal pump; solid cast iron casing with cast bronze impeller; maximum shallow well capacity 238 l/min., maximum shallow well suction lift 7.5 m, maximum deep well capacity 194 l/min, maximum deep well suction lift 50 m; maximum temperature 50 °C; output power 2.3 to 2.6 kW). J and SR Series 100 mm submersible pump (304 stainless steel outer casing, either polyester with Teflon fill or glass filled polycarbonate impellers; capacity to 375 l/min.; head to 275 m; temperatures up to 30 °C, maximum temperature up to 55 °C; motors 0.37 kW to 7.5 kW). SS Series 150 mm submersible pump (316 stainless steel pump and impeller, capacity to 1,280 l/min.; head to 500 m; maximum temperature 50 °C; motors 4 kW to 37 kW). SS Series 200 mm submersible pump (316 stainless steel pump and impeller; capacity to 2,000 l/min.; head to 500 m; maximum temperature to 50 °C; motors 7.5 kW to 110 kW). Also manufacture pressure tanks up to 100 litres.
Onga www.onga.com.au	Australian made. Manufactures a wide variety of pumps including centrifugal, jet pumps, submersible and shallow and deep well pumps. Products include: JJ/OJ deep well pump (cast iron construction with thermoplastic internal components; suction lifts to 40 m (JJ) and 49 m (OJ); capacity to 205 l/min.; heads to 50 m (JJ) and 70 m (OJ)). JJ/OJ shallow well pump (cast iron construction with thermoplastic internal components; suction lift to 7.6 m; capacity to 140 l/min. (JJ) and 165 l/min. (OJ); head up to 60 m (JJ) and 120 m (OJ). Riva-flo SF 200 and SF300 shallow well pump (cast iron construction; capacity over 225 l/min.ute; head up to 43 m) Sta-rite Signature 2000 submersible borehole pumps (floating impeller design; capacity to 120 l/min; head up to 200 m; maximum temperature 40 °C) Sta-rite HighFlow submersible borehole pump (stainless steel with moulded polycarbonate and reinforced with glass impellers; capacity to 300 l/min; maximum head over 100 m; motors 1.5 to 5.5 kW; maximum temperature 40 °C) Also manufacture pressure tanks from 3 to 450 litres.
Lowara www.lowara.com	Italian made. Wide variety of pumps available including submersible and centrifugal pumps. Submersible pump products include: GS series 100 mm diameter pump (303 stainless steel with polycarbonate/fibreglass impellers; capacity to 350 l/min, head to 340 m, powers to 7.5kW; maximum immersion depth 150 m; maximum temperature 30 °C). SCUBA Series 125 mm diameter pump (304 stainless steel with tecnopolymer impellers; capacity to 130 l/min, head to 80 m, powers to 1.1 kW; maximum immersion depth 20 m; maximum temperature 40 °C). Z6-ZN6 Series 150 mm diameter (316 stainless steel construction; capacity to 1,533 l/min, head to 450 m, powers to 37 kW; maximum immersion depth 350 m; maximum temperature 40 °C). Z8-ZR8 Series 200 mm diameter Pump (304 stainless steel; capacity to 3,583 l/min, head to 550 m, powers to 185 kW; maximum immersion depth 350 m; maximum temperature 30 °C). S10-S12 series 250-300 mm diameter pumps (cast iron with bronze/cast iron impellers; capacity to 9,666 l/min, head to 340 m, powers to 400 kW; maximum temperature 25 °C (higher on request)). Also manufacture pressure tanks to 5000 litres.

Manufacturer Details	Products Available
Calpeda www.calpeda.it	Italian made. Wide variety of pumps available including centrifugal, jet and submersible bore pumps. Products include: Self priming jet pumps NG, NGC, NGX (NG/NGC cast iron casing, brass impeller, NGX stainless steel casing brass impeller; maximum suction lift NG 1m, NGC 9 m, NGX 9 m; maximum capacity NG 158 l/min, NGC 54 l/min NGX 83 l/min; max head 89 m NG/NGX 53 m NGC; max temp 40 °C NG, 35 °C NGC/NGX). Submersible borehole pumps 100 mm and 150 mm SD series (stainless steel external jacket, polycarbonate (100 mm) and PPO-GF20 (150 mm) impellers; capacity to 350 l/min (100 mm), 950 l/min (150 mm); maximum head to 298 m (100 mm), 354 m (150 mm); maximum temperature to 35°C; power output 0.37 to 7.5 kW (100 mm), 4 to 30 kW (150 mm)).
Caprari www.caprari.com	Italian made. Manufactures of submersible and centrifugal pumps. Products include: E4X series submersible 100 mm pump (316 stainless steel casting with thermoplastic resin impellers; capacity to 420 l/min; head to 425 m; max temperature 30 °C; power to 7.5 kW). E6X series submersible 150 mm pump (316 stainless steel casting with thermoplastic resin with stainless steel insert impellers; capacity up to 900 l/min; head up to 550 m; max temperature 30 °C; maximum power to 37 kW). ER/ES series submersible pumps for 150 to 600 mm (cast iron with either cast iron/thermoplastic resin/bronze impellers depending on size; maximum capacity up to 21 000 l/min; maximum head to 700 m; maximum temperature to 30 °C; max power to 370 kW).
Ebara www.ebara.it	Italian made. Manufacturers of centrifugal, jet and submersible pumps. Products include: 4BHS/A (100 mm multistage borehole pump made entirely of 304 stainless steel; maximum immersion 150 m; capacity to 300 l/min; heads to 260 m; maximum temperature 40 °C). 6BHE (150 mm 304 or 316 stainless steel submersible turbine pump; capacity up to 1,166 l/min; heads up to 500 m; maximum temperature 50 °C). 6BHS (150 mm 304 stainless steel borehole centrifugal pump; maximum immersion 100 m; capacity to 500 l/min; heads to 353 m; maximum temperature 30 °C). 8BHE (200 mm 316 stainless steel submersible turbine pump; capacity to 2,100 l/min; heads to 500 m; maximum temperature 50 °C). IDROGO (125 mm 304 stainless steel with tecnopolymer impeller, submersible centrifugal multistage pump; maximum immersion to 20 m; capacity to 120 l/min; heads to 75 m; maximum temperature 40 °C). SF6 (150 mmborehole centrifugal pump made from 304 stainless steel, discharge and suction made from spheroidal nickeled cast iron, tecnoploymer impellers; capacity to 1,000 l/min; heads to 372 m; maximum temperature to 30 °C). Winner (100 mm304 stainless steel with tecnopolymer impellers multistage centrifugal borehole pump; maximum immersion 100 m; capacity to 350 l/min; heads to 250 m; maximum temperature 30 °C).
Lorentz www.lorentzpumps.com	German made. Specialise in submersible solar or battery powered pumps for 100 mm boreholes or greater. Products include: PS150C (316 stainless steel submersible centrifugal pump; capacity up to 83 l/min; heads to 22 m; 12-24V DC; maximum temperature 40 °C). PS200 HR/C (stainless steel submersible helical rotor or centrifugal pump; capacity to 45 l/min; heads to 50 m; 24-48V DC; maximum temperature 40 °C). PS600 HR/C (316 stainless steel submersible helical rotor or centrifugal pump; capacity to 183 l/min; heads to 180 m; 48-72V DC solar, 48V DC battery; maximum temperature 40 °C). PS1200 HR/C (316 stainless steel submersible helical rotor or centrifugal pump; capacity to 183 l/min; heads to 240 m; 72–96V DC; maximum temperature 40 °C). PS1800 C (316 stainless steel submersible centrifugal pump; capacity up to 366 l/min; heads to 60 m; 72–96V DC; maximum temperature 40 °C). Solar park with Etatrack solar tracking panels increasing output by 20 to 40%).

Manufacturer Details	Products Available
Flygt www.flygt.com.au	Swedish made. Manufacturers of centrifugal and submersible pumps. Products include: F4FX (100 mm submersible borehole pump; 304 stainless steel with glass filled polycarbonate impellers; capacity to 350 l/min; heads to 340 m; maximum temperature 30 °C). F6FX (150 mm stainless steel submersible borehole pump; capacity to 1,300 l/min; heads to 410 m; maximum temperature 30 °C). HX (125 mmsubmersible borehole pump made of 304 stainless steel with tecnopolymer impellers; capacity to 120 l/min; heads to 80 m; maximum temperature 40 °C). TV (200, 250 and 300 mm submersible borehole pumps; material dependent on application; suitable for clear non aggressive water with options for sea and thermal water; capacity to 9,666 l/min; heads up to 450 m; temperatures normally 25 °C or up to 65 °C on request).
DAB www.dabpumps.com	Italian made. Manufacturers of a wide variety of centrifugal, jet, submersible, and shallow and deep well pumps for a variety of applications. Products available include: AS4/S4 (multistage centrifugal submersible pump for 100 mm wells or greater; stainless steel with tecnopolymer impellers; capacity to 400 l/min; heads to 320 m; maximum temperature 40 °C) CS4 (multistage centrifugal submersible pump for 100 mm wells or greater; tecnopolymer/stainless steel with tecnoploymer impellers; capacity to 100 l/min; heads to 230 m; maximum temperature 40 °C) S6 (multistage centrifugal submersible pump for 150 mm wells or greater; spheroidal graphite cast iron with tecnopolymer impellers; capacity up to 1,100 l/min; heads to 468 m; maximum temperature 30 °C) DP (deep suction centrifugal pump to 27 m; cast iron body, tecnopolymer impellers; capacity to 71.6 l/min.; heads to 80 m; maximum temperature 40 °C)

Table 12: Category 3 – Tanks and troughs

Numerous manufacturers provide tanks and troughs to the market, manufacturing in plastic, steel, concrete, etc. Only a select group for each is presented.

Manufacturer Details	Products Available
Southern Cross www.southcross.com.au	Manufacture steel water tanks. Products include: Liner tanks (prefabricated steel tanks for do-it-yourself on-site erection; sizes 26, 47, 90 and 146 kL available, larger tanks to 900 kL also available; diameters from 4.3 to 10 m, height 1.8 m; galvanised steel construction with food grade polyethylene liner; easily relocated; 20 year structural, 10 year liner guarantee). Prefabricated steel tanks (sizes 9 to 3040 kL available; tank height to 7.2 m, diameter to 25.4 m; elevated storage available up to 30 m for tanks 12.7 m in dia and up to 4.8 m high; galvanised steel construction, with options for PVC coated galvanised sheeting, painted framework and stainless steel nuts and bolts).
Aquaplate steel www.bluescopesteel.com.au	Aquaplate steel has been developed by BlueScope steel specifically for the water tank market. Water tanks made from Aquaplate are available in a galvanised steel finish or a selected range of pre-painted colours and has a food grade polymer skin bonded to the inner surface. 20 year warranty against corrosion to perforation. Tanks must be installed above ground, and copper pipe should not be connected to the tank. Waterpoint Classic traditional round corrugated tanks, manufactured by Bluescope Water has tank sizes up to 22 500 litres.
Team Poly www.teampoly.com.au	Manufacturer of a large range of poly tanks and troughs. All tanks are Ultra UV stabilised, food grade polyethylene to *AS4020.* Products include: Corrugated poly tanks (in sizes 545 to 27 000 litres with 25 year pro rata warranty; wide variety of colours available; larger tanks come with centre support pole to prevent collapse of roof during hot days). Stock troughs (including rectangular, round, linkable and fence; built in floats available. 5 year pro rata warranty).
Bushman Tanks www.bushmantanks.com	Manufacturer of a wide range of poly tanks for residential and rural applications. Products include: Rural tanks (up to 47 950 litres available; made from UV stabilised, food grade polyethylene with horizontal ribs; larger tanks come with centre support pole to prevent collapse of roof during hot days; available in a range of colours; 25 year guarantee against all manufacturing faults).
Clark Tanks www.clarktanks.com.au	Manufacture a range of poly tanks and troughs. Tanks up to 46 800 litres available, troughs up to 3500 litres available. Made from UV stabilised, food grade polyethylene. Available in a variety of colours. Also manufacture "cup and saucer" tanks.
Polyworld www.polyworld.com.au	Manufacture a range of poly tanks and troughs. Tanks up to 32 000 litres available, troughs up to 1500 litres available. Made from UV stabilised, food grade polyethylene. Available in a variety of colours.
Economy Concrete Tanks www.economytanks.com.au	Manufacturers of transportable and on-site concrete tanks. Transportable sizes up to 35 000 litres, on-site sizes up to 120 000 litres.
Concrete Tanks (Australia) www.concretetanks.com.au	On-site manufacturer and installation of large size concrete tanks. Sizes from 45 000 to 508 000 litres available.
Rocla www.rocla.com.au	Manufacturers of pre-cast concrete stock troughs. Rectangular and round sheep and cattle troughs available. Capacity to 1500 litres available. Concrete valve covers also provided.
Mid-West Concrete Stock Troughs www.midwestconcrete.com.au	Manufacturers of pre-cast concrete stock troughs. Rectangular and round sheep and cattle troughs available. Capacity to 1200 litres. Features include deep troughs to keep water cool, stock proof valve cover, 25 mm and 50 mm submerged float valve, brass fittings with low and high pressure.
Timber Tank Enterprises www.timbertanks.com	Timber Tank Enterprises manufacture on-site timber storage tanks and reservoirs from 500 to 3 000 000 litre capacity. Timber treated for termite attack. Life expectancy in excess of 80 years. Tanks require little maintenance and are earthquake and cyclone resistant. Tanks can be assembled in remote areas and can be relocated if necessary.

Table 13: Category 4 – Valves

Valve products, materials, sizes, specifications etc are too numerous to list. Valve selection should be made based on required performance and operating conditions such as temperature and pressure. Higher quality valves such as stainless steel should be used at well heads and locations where access is remote and failure of valve may result in stock losses etc. Epoxy coatings available for cast iron and bronze valves may enable use for high temperature conditions. Some of the main manufacturers include:

Manufacturer Details	Products Available
AVK www.avkvalves.com.au	Manufacturers of a variety of valves including: gate valves (ductile iron available with epoxy resin coatings for temperatures up to 70 °C; diameters to DN600 available, larger diameters also available). check valves (ductile and cast iron available with epoxy resin coatings for temperatures up to 70 °C; diameters up to DN 600 available). butterfly valves (cast iron, ductile iron, carbon steel, stainless steel bodies available, ductile iron, stainless steel aluminium bronze coated disks available; operating temperature depends on material; diameters to DN750 available;). air valves (double orifice “APEX” air valve, body ductile iron, floats and lever ABS plastic; temperature to 70 °C; diameters DN80 to 150).
Tyco Water and Tyco Flow Control www.tycoflowcontrol.com.au	Tyco Water manufacture a range of valves including: gate valves (ductile iron with rislan nylon 11 coating; range of diameters up to 900 mm; pressures to 1600 kPa; temperature to 40 °C). check valves (ductile iron with rislan nylon 11 coating; DN100 to DN150 available; pressure to 1600 kPa; temperature to 40 °C). Tyco flow control brings together worldwide manufacturers of flow control products and can specify products to suit individual needs, particularly for high temperature and pressure applications. Over 80 brands are offered through Tyco Flow Control. Products include: Ball valves (available brands Richards; temperatures -196 °C to 450 °C; pressures up to ANSI class 1500). Gate valves (available brands include Fasani, Keystone Controls, Raimondi; pressure ANSI class 150 to 4500; temperature to 650 °C). Butterfly valves (available brands Keystone, Neotecha, Winn; temperatures -40 °C to 120 °C; pressures up to 1600 kPa). Check valves (Brands include Fasani, FloCheck, Keystone valves, Neotecha, Raimondi; pressure to 1000 kPa; temperatures to 160°C). Pressure relief valves (Brands include Anderson Greenwood, Crosby, Kunkle, Sapag, Sempell).
OneSteel www.onesteel.com	One steel offers numerous brands of valves to suit a wide variety of applications. Brands include: Turnflo, Kitz, Audco, Sanders, Emico, SRI, Bonney, John, Stockham, YPPI, A-Sung, Vitaulic. Types of valves available include: Gate, globe, check, plug, ball, butterfly diaphragm, knifegate, regulating, safety relief, pressure and temperature control, actuators, strainers. Materials include: Brass, bronze, cast iron, ductile iron, stainless steel, alloy steel, PVC, urethane lined, rubber lined.
CMV-BVA Valves www.cmvvalves.com.au	Manufacturer of a wide variety of valves including: Ball valves (stainless steel, brass, PVC). Gate valves (stainless steel, brass). Butterfly valves (cast iron available with stainless steel disc). Knifegate (stainless steel). Check valves (stainless steel, bronze, brass, cast iron, PVC). Foot valves (PVC). Globe valves (stainless steel).

Manufacturer Details	Products Available
Crevet Pipelines www.crevet.com	One of Australia's largest manufacturers of valves and fittings. Products include: Gate valves (metal wedge valves; cast iron body with bronze seating and wedge face ring; diameters 80 to 300 mm; maximum working pressure 1400 kPa PN14, 2100 kPa PN21; maximum working temperature 65 °C; coatings available; knifegate valves to 1000 mm also available). Norcast resilient sealing sluice valves (ductile iron body with ductile iron or gunmetal wedge, coated with either Rislan Nylon 11 or fusion bonded epoxy; maximum operating pressure 1600 kPa; maximum operating temperature 60 °C). Metal wedge sluice valves (cast iron/ductile iron body with gunmetal/cast iron/ductile iron wedge; diameters 80 to 600 mm; maximum working pressures 1400 to 3500 kPa; coatings available). Non-return valves (body cast iron/ductile iron, disc and hinge gunmetal/cast iron; diameters 80 to 600 mm; maximum working pressures 1400/2100 kPa; maximum working temperature 95 °C). Air release valves (available in plastic and cast iron; single and double acting; diameters up to 80 mm).
Philmac www.philmac.com.au	Philmac manufacture a wide range of valves suitable for water distribution lines. Some of the products available include: Ball valves (glass reinforced plastic; diameters 15 to 50 mm; pressure to 1400 kPa at 20 °C). Foot valves and non-return valves (glass reinforced plastic; diameters 20 to 50 mm; pressure to 1400 kPa at 20 °C) Float valves (piston type float valves; available in plastic, brass, and stainless steel in sizes 12 to 50 mm; pressures up to 1600 kPa). Trough valves (submersible trough valve available in polypropylene or high quality brass; available in 18 to 37 mm). Air release valves (plastic 25 mm) Also manufacture and supply a range of fittings including mechanical compression and electrofusion fittings for joining polyethylene pipe.
Plasson www.plasson.com	Plasson manufacture a wide range of plastic valves and fittings. Products include: Ball valves (polypropylene, PVC; diameters up to 62 mm; pressure to 1600 kPa). Check valves (polypropylene, PVC; sizes up to 110 mm; pressure to 1600 kPa). Foot valves (PVC; sizes up to 63 mm; pressure to 1600 kPa). Air release valves (PVC; sizes to 63 mm; pressure to 1600 kPa). Also manufacture a range of fittings for joining plastic pipe including mechanical compression and electrofusion for polyethylene pipe; and solvent cement and threaded adapters for PVC.
PPI www.ppi.com.au	PPI manufacture a range of plastic valves. Products include: Ball valves (PVC and polypropylene; 12 to 50 mm diameters; pressures to 1600 kPa) Check valves (glass filled nylon; diameters 20 to 50 mm; pressure to 1600 kPa). Foot valves (glass filled nylon; diameters 20 to 50 mm; pressure to 1600 kPa). Air relief valves (glass filled nylon; single acting 25 mm and double entry air and vacuum release 25 mm and 50 mm; pressure to 1600 kPa). Float valves (plastic level and submersible cord valves; diameters 20 and 25 mm; pressure to 1170 kPa).
Alderdice Brassfounders www.alderdice.com.au	Alderdice Brassfounders manufacture a variety of valves. Products include: Check valves (diameters 20 to 50 mm; made from gunmetal bronze). Foot valves (diameters 20 to 75 mm; made from gunmetal bronze; also manufacture floating foot valves with diameters 32 to 50 mm). Float valves (made from gunmetal bronze with flap type valve to minimise valve blocking; diameters 20 to 50 mm; the 20 to 32 mm valves have a replaceable plastic seat to combat corrosion; available in low or high pressure; also available for underwater operation). Two level float valve (made from gunmetal bronze; water level drop of 400 mm before opening; suitable for pressures up to 700 kPa; maximum flow rate 230 l/min.; available in 32 mm diameter).

Manufacturer Details	Products Available
Apex www.apexvalves.co.nz	Manufacture a wide variety of float valves for tanks and troughs from piston to full flow sleeve valve design. Products include: Acetyl full flow (diameters 15 to 25 mm; pressure to 1200 kPa; also available in long tail allowing fitting through wall of trough or tank). Brass full flow (20 mm diameter; pressure to 1200 kPa). 69 and 72 full flow (brass valve; 20 and 25 mm diameter; pressure to 1000 kPa). 220 and 225 high/low (brass valve adjustable for high to low pressure; low pressure to 700 kPa, high pressure to 1000 kPa; diameters 15 and 20 mm). High flow (acetyl plastic valve; pressure to 850 kPa; diameters 15 to 20 mm). Xtraflo valve (armless submersible plastic float valve, also available with top entry lever; standard operating pressure 55 to 1000 kPa, also available low pressure/high flow for operating pressure 30 to 400 kPa; self cleaning valve mechanism; diameters 20 to 32 mm; 40 mm water level differential from open to close to reduce pump start/stop where pressure pumps are installed) Reservoir valve (high flow rate valve for controlling flow into large tanks; working pressure 1 float 0–550 kPa, 2 floats 0–850 kPa; diameters 32 to 50 mm) Dual lever valve (for pump applications; high flow rate for controlling water into large tanks; valve adjustable to allow water level to drop between 65 and 270 mm before opening; diameters 32 to 50 mm)

Table 14: Category 5 – Miscellaneous

The following table lists some of the companies providing telemetry services in Australia.

Manufacturer Details	Products Available
Standard Communications www.gme.net.au	Australian privately owned company that designs, manufactures and distributes radio frequency based products. Brands include GME Electrophone and GME Kingray. A range of simple, robust UHF telemetry systems are available, providing cost effective remote control and monitoring facilities. GME telemetry systems operate in the 450 to 520MHz UHF band, with ranges up to 100 km. Extended range available with repeaters.
Australian Satellite Communications www.ascs.com.au	Provides a wide range of satellite communications solutions to customers throughout Australia, including telemetry, monitoring and control of remote facilities. Operating on the L, Ku and C band transmissions as required.
Farm and Business Communications www.fbc.bizhosting.com	Farm and Business Communications specifically manufacture systems for remote starting of diesel pumps and the monitoring of tank levels via radio. Also an Electrophone and Uniden dealer.
Stockman Electronics www.stockmanelectronics.com.au	Specialising in computers and communications, radio telemetry products, custom designed microcontroller solutions with a large range of products to suit all applications. Telemetry systems using UHF, GSM and CDMA available. Stockman Electronics is a GME accredited telemetry dealer.

8. References

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Appendix 1: Metric conversion table

inches	millimetres
½	12
¾	18
1	25
1 ½	37
2	50
2 ½	62
3	75
4	100
5	125
6	150
8	200
10	250
12	300
24	600

gallons	litres
6000	27 000
7000	32 000
10 000	45 500

DKCRC Partners