Design and Operation of Bores for Small Drinking-water Supplies

Resources for Drinking-water Assistance Programme

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1 Introduction

1.1 What this booklet covers

This booklet describes the design and operation of bores for small water supplies (serving fewer than 5000 people). It is intended to be used by small drinking-water suppliers who own or operate an existing bore, or those considering installing a new bore.

Bores are ideal for small drinking-water supplies because they are a fairly low-maintenance system producing a relatively constant water quality. A bore that has achieved ‘secure’ status is also a very safe water source in terms of contamination by pathogens. Nevertheless, there are a number of naturally occurring contaminants common in groundwater and human activity that can affect groundwater quality, particularly in shallow aquifers.

This booklet attempts to explain some of the issues the user of a groundwater source needs to know about.

1.2 Further guidance

This booklet is part of the Resources for Drinking-water Assistance Programme. Further guidance is available on other aspects of planning, developing and operating small drinking-water supplies, including:

- *Managing Projects for Small Drinking-water Supplies*
- *Operation and Maintenance of a Small Drinking -water Supply*
- *Pumps Pipes and Storage*
- *UV Disinfection and Cartridge Filtration*
- *Optimisation of Small Drinking-water Treatment Systems*
- *Sampling and Monitoring for Small Drinking-water Systems*
- *Treatment Options for Small Drinking-water Supplies*
- *Pathogens and Pathways and Small Drinking-water Supplies*
- *Sustainable Management of Small Drinking-water Supplies*.

These resources are all available from the Ministry of Health at: www.govt.moh.nz.

2 What is Groundwater?

2.1 Groundwater basics

In New Zealand, groundwater comprises approximately 80 percent of our freshwater resource.

When rain falls to the land's surface, some renews surface waters such as lakes, rivers and the ocean, some evaporates back into the atmosphere, and some percolates downward into the ground and forms natural underground reservoirs, called aquifers. Most groundwater in these aquifers flows from one place to another, just like a river. The layering of different materials under the surface (ie, rock, clay and sand) can trap and change the direction of the underground flows.

When water flows downwards through the soil and rock it will eventually reach a point where all the air voids are filled by water. This is called the saturated zone. The area above is the unsaturated zone.

Groundwater aquifers are either 'confined' or 'unconfined'. If the water-carrying layer of rock or sand has a layer of impermeable material above it, the aquifer is called a confined aquifer. Confined aquifer status is usually granted by a drinking-water assessor. Where there is no impermeable layer above the aquifer it is called unconfined.

The top water level in an unconfined aquifer is often called the 'water table'. This is water that has percolated into the soil and has been trapped between the impermeable layer and the ground surface.

Water trapped under confining layers can sometimes be put under enough pressure to allow it to flow to the surface without pumping. In these cases the bore is described as 'artesian'.

Definitions

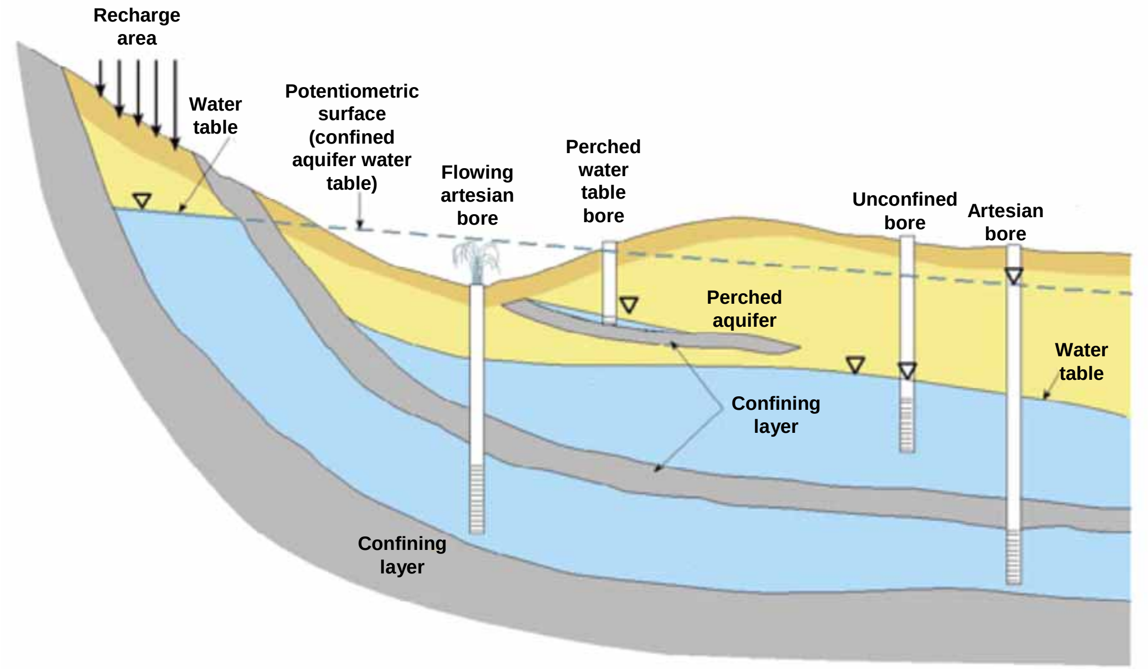
Bore: A hole in the ground that intersects the water table, causing water to pond in the bottom. Bores are usually drilled by mechanical means.

Well: The same as a bore but usually dug by hand and therefore shallower.

Spring: Point at which the water table meets the surface, causing a flow of groundwater out of the ground.

The composition of the water may change while underground. Small particles and some micro-organisms may be filtered out. This filtration can be very effective where the soil consists of thick layers of fine particles. On the other hand, substances in the soil and rocks can be dissolved into the water. These may do no harm, they may affect the taste or hardness of the water, or they may even make the water hazardous to drink.

Figure 1: Components of an aquifer



2.2 Microbiological quality

Micro-organisms are filtered out and die off as the water travels through the ground. Very often, because it travels slowly the water in a deep unconfined aquifer or a confined aquifer has been there for many years and is free of harmful organisms.

Shallow, unconfined aquifers are not much safer than surface water sources because the water has had very little filtration or storage time before it is collected for drinking. *Campylobacte*r, *Escherichia coli* (*E. coli*), *Cryptosporidium*, *Giardia* and viruses have all been found in groundwater supplies. These microbes are carried into the aquifer from the surface.

The vulnerability of aquifers to microbial contamination is increased by:

- shallow aquifer depth
- microbial contamination in the surface water catchment
- water flowing quickly through the aquifer via particularly porous material or fractured rock
- the absence of a confining layer.

2.3 Chemical quality

The chemical quality of groundwater is influenced by the quality of the water entering the aquifer as well as by the minerals in the ground. Minerals in the soil and rocks dissolve into the water as time passes. In limestone country, for example, the water can become very ‘hard’ as the lime dissolves. In some regions, arsenic is present in volcanic rocks and can be found in groundwater taken from particular aquifers.

Often, because a deep aquifer is devoid of oxygen, the form of the chemicals will change as they pass through it. As a result it is common for groundwater to contain ammonia, sulphides and the soluble forms of many metals such as manganese and iron. These and other compounds can cause problems with the taste, smell or colour of the water.

A number of common chemical contaminants that are a particular issue in groundwater are described in Table 1 below.

Table 1: Common contaminants in groundwater

Arsenic and boron	Arsenic and boron often occur at potentially harmful levels in groundwater, particularly in geothermal and hydrothermal areas. The concentration of arsenic can vary significantly in shallower bores between summer and winter.
Calcium and magnesium	High calcium and magnesium concentrations can cause water to be 'hard', which can lead to problems of scale formation on hot surfaces and difficulty in getting soap to lather. This often happens in areas where limestone is part of the land formation.
Fluoride	Fluoride has not been commonly found at levels that are of concern to health in New Zealand. However, if fluoride is being dosed, the concentration in the source water should be taken into account when deciding the dose rate.
Iron and manganese	Iron in drinking-water in high enough concentrations can cause an unpleasant metallic taste and a rusty colour, which can stain fixtures and clothing. Manganese can also affect the taste of the water and has potential health effects when present in the water at higher levels. When oxidised, manganese can be deposited in pipes. It also causes staining of laundry. Iron and manganese are often found together in groundwater. The conditions that lead to the presence of iron and manganese can be localised and may change over time.
Nitrate	High nitrate concentrations can occur in drinking-water sources due to contamination from farming, septic tank systems and solid waste disposal. A high nitrate concentration can be toxic to bottle-fed infants.
Pesticides	In some bores pesticides may be present. Testing should be undertaken if it is suspected that pesticides may be present, particularly in shallow unconfined aquifers.
Radioactive elements	Groundwater can contain naturally occurring radioactive elements, such as radon. Water from new underground sources must be tested for radon before they are connected to a reticulated drinking-water supply.
Salinity	Some aquifers are naturally saline (salty). Bores located near the coast may be affected by seawater flowing into the aquifer if excessive water abstraction causes seawater to be drawn into the aquifer to replace the fresh water.

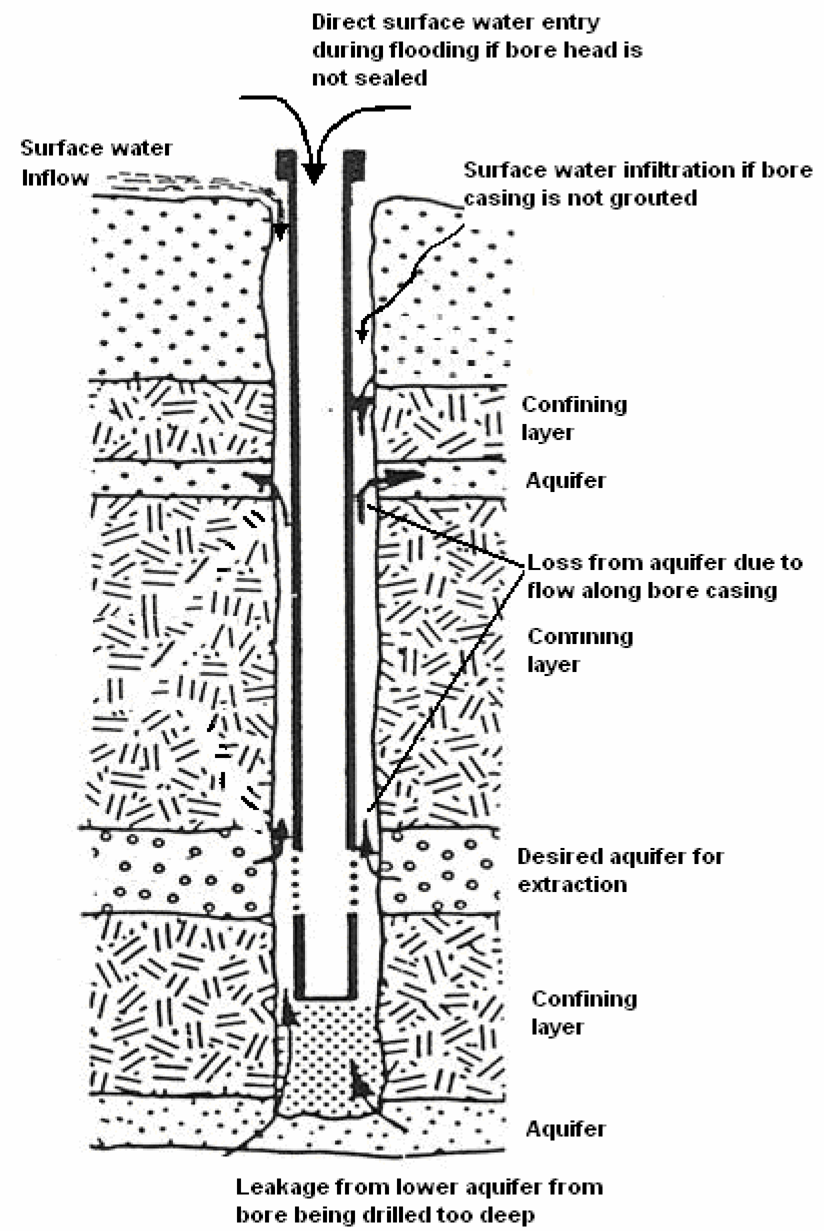
2.4 Pollution of groundwater

A bore that has been producing water of good quality can sometimes become polluted. Pollutants can enter the aquifer with the water as it percolates from the surface, or directly via the bore shaft itself. Precautions need to be taken to protect the groundwater supply from contamination.

Sources of contamination include seepage from underground fuel storage tanks, effluent discharges, septic tanks, waste ponds, offal pits, industrial areas, leaking sewers and landfills. If possible, new bores should be located away from potential sources of contamination. Disused bores are a special pollution hazard because contaminants can find their way directly into the aquifer. Because there is not a net flow of water out of the bore, any water entering the bore from above will tend to end up in the aquifer. Disused bores should be made safe according to the requirements of the local regional council.

Figure 2 shows some of the sources of bore contamination.

Figure 2: Routes for bore contamination



There are recommended design features for bores to help prevent pollutants reaching the aquifer through the bore. These measures are described in section 3.2.

3 Water Supply Bore Design

Drilled wells, or bores, are one of the most common methods for collecting water in New Zealand. They are drilled into an aquifer using a vertical drilling rig. The basic components of a bore water supply are shown in Figure 3 and described in Table 2.

Figure 3: Typical bore

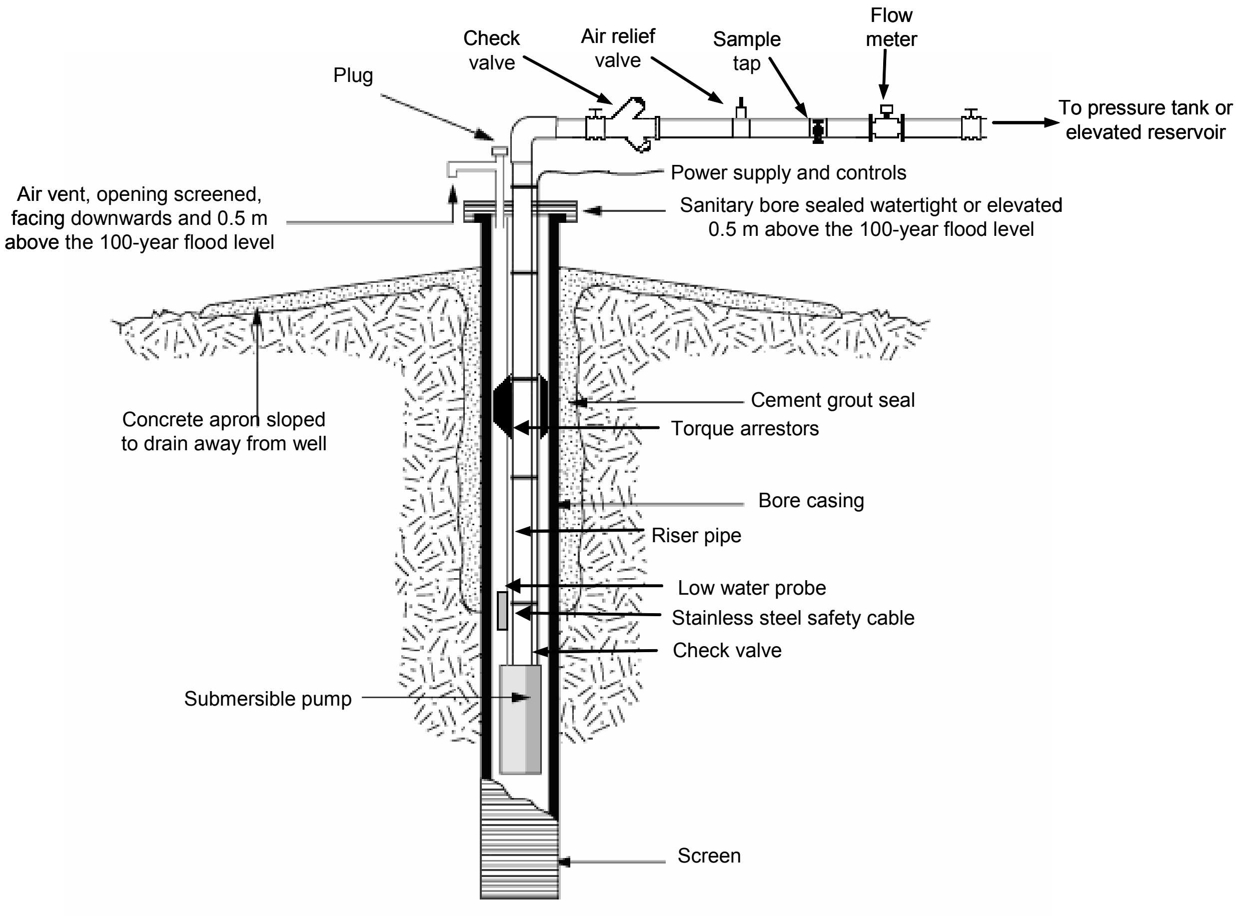


Table 2: Components of a bore system

Bore casing	A bore casing supports the sides of the hole and also protects the aquifer from contamination by water in the upper soil layers. Most bores are between 50 and 300 mm in diameter. The diameter needs to be large enough to accommodate the pump and any other equipment that must go down the hole. The bore casing can be made of either steel or plastic (usually polyvinyl chloride, PVC). Steel casings are stronger but they can corrode in some environments. Stainless steel casings can be used but are expensive. Plastic pipes are the usual alternative to steel. They may be PVC, ABS or FRP (fibreglass).
Pump	Most groundwater supplies need to be pumped. Bore pumps are powered by an electric motor that is designed to be submerged.
Riser pipe	The pump is connected to a riser pipe that delivers the water to the surface. This riser pipe can either be a series of lengths of plastic or steel pipe, or a flexible tube.
Screen	A screen is often fitted at the depth of the target aquifer to allow water into the bore while preventing the walls from collapsing inward. If an aquifer is in fractured rock then a screen may not be needed. The screen materials don't have to be the same as the casing. There is often a layer of packing material around a screen, which increases the 'open' area around the bore to increase water flows. This is called a gravel pack.
Check valves	There should be a check valve on the pump and also at the surface to stop water running back down into the well when the pump stops. This helps to protect the well from damage and contamination. It also means the pump starts with a column of water above it.
Vent	Because of changes in water level in the well there needs to be a vent to allow air into the well when the pump starts, and to allow the air out again when it stops. Otherwise the pressure fluctuations could cause contamination to enter the well.
Air relief valve	Pipework leaving the bore site may include an air relief valve to vent off any air that accumulates in the pipe. If air is trapped in the pipe then the flow expected from the pump could be reduced.
Pressure tank	There may also be a pressure tank in some systems to maintain the water pressure when the bore pump is turned off. Alternatively, the water may be pumped to a tank (in an elevated position) and then distributed either by gravity or by another pump to the properties served by the supply.
Controls	Bore pumps usually run automatically, based on the need for water or the level in a storage tank. Electrical controls for the pump should also include an on/off override switch so that the pump can be tested and turned off if there is a problem. Pumps often have an emergency cut-out so that the pump will stop if the water level in the bore drops below the pump level, preventing pump damage.
Sample tap	A sample tap at the bore head allows the operator to take samples of the raw water before it can be contaminated by any other sources. This is particularly important for supplies seeking 'secure' status. The sample tap should be appropriate for flaming (heating using a small gas cooker to disinfect the tap), and located to be free draining and to minimise the amount of contamination that may occur, such as from stock effluent, mud, etc.

3.1 Equipment for monitoring bore water

It is important to collect information about the bore performance and the quality of the water so that problems can be identified.

A sampling tap should be installed as close to the bore head as possible but after the check valve. Locating it close to the bore head means the sample will closely represent the water in the bore. This can be important if bacteria are found in the water supply and the source of the contamination needs to be traced.

A flow meter may need to be installed on the pipework as part of the resource consent conditions (bore permit). Flow meter manufacturers often have requirements for the length of straight pipe before and after the flow meter so that it operates accurately.

It may sometimes be necessary to measure the water level in the bore. This can be done by installing a level transducer (or similar device) at the bottom of the bore. Otherwise the level can be measured manually using a depth indicator on a cable. If the water level is to be measured manually, the depth indicator and cable must be clean and care must be exercised so as not to introduce contaminants into the bore during the measurement process. It is best to take advice from a specialist if water-level measurements are required.

Minimum sampling requirements are defined in the Drinking-water Standards.[1]

3.2 Designing a bore to protect water quality

The bore should be constructed so that water cannot seep into the bore from the surface or from relatively contaminated layers along the length of the casing. This not only protects the bore but also other water supplies that are drawn from the same aquifer. Figure 3 (above) shows how a bore can be constructed to protect groundwater from surface water contamination. Correct bore construction is essential if the bore is to achieve secure status.

There are a number of other protective measures shown in the diagram that help to protect the aquifer from contamination (these are also needed to achieve secure status):

- a concrete pad around the bore head (see Figure 3) − it is recommended that the apron be at least 100 mm thick and 1 m square
- a cement grout seal extending below the ground surface to whatever depth is necessary to prevent contamination getting in − a bore driller could advise on the required depth
- screening all openings in the top of the casing to prevent the entry of foreign material − these should be at least 0.5 m above the 100-year flood level (this is the level that surface flooding at the bore site could rise to in a 100-year storm event)

[1] *Drinking-water Standards for New Zealand 2005* (revised 2008).

- protection at the bore head to prevent stock or other interference – this may be achieved by constructing a pump shed over the bore or erecting fencing (the Drinking-water Standards require that stock be excluded to a minimum distance of 5 m from the bore head)
- a backflow prevention device to prevent the flow of water back into the bore unless the bore is under positive pressure (artesian).

4 Secure Groundwater

The *Drinking-water Standards for New Zealand 2005 (revised 2008)* give special consideration to water sourced from bores that meet certain criteria indicating that there is a very low risk of microbiological contamination. Bore waters that meet these criteria are described as ‘secure’. Because of their low risk of contamination, the requirements for treatment and monitoring are much less stringent for secure waters than for other sources.

Sources in shallow, unconfined aquifers less than 10 m below ground level cannot achieve secure status.

4.1 Rules for establishing secure status for a bore

To achieve secure status the water supplier must demonstrate that the water is not affected by surface or climate influences and the bore head is designed to prevent contamination of the aquifer. The specific requirements are listed in this section.

4.1.1 Establish adequate bore head protection

The design requirements described in section 3 need to be adhered to in order to prevent contamination of the bore. The bore construction must also comply with the environmental standard for drilling soil and rock (NZS 4411), unless agreed by the local drinking-water assessor. The bore must then be inspected and approved by a person deemed appropriately qualified by the Ministry of Health.

The bore head protection needs to be reviewed every five years. If any changes are made to the bore protection, these need to be reported to the drinking-water assessor.

4.1.2 Demonstrate groundwater residence time

The length of time the water is in the ground before it is extracted out of a bore is called the ‘residence time’. If the water has been in the ground for a very long time, the risk of microbiological contamination is much reduced. Therefore the age of the water is tested to show that it is sufficiently old for the likelihood of live pathogenic micro-organisms being present to be very low.

This can be done using one of the following three methods (summarised from the Drinking-water Standards):

- scientific testing (residence time) to show that less than 0.005 percent of the water has been present in the aquifer for under one year − the test is sensitive to contamination, even from the influence of luminous watches, and care needs to be exercised when obtaining the water sample from the bore
- water quality monitoring over a period if time to show that the concentrations of conductivity, chloride or nitrate do not vary by more than the allowable percentage
- where neither of the options above can be used, a verified hydro-geological model demonstrating that the bore is pumping from a secure aquifer.

4.1.3 Proving the microbiological quality of the water

The purpose of proving that bore water is secure is to show that it is free of pathogenic micro-organisms. Clearly, if *E. coli* is present then the source is not secure. As a result, the Drinking-water Standards include requirements for monitoring the source over a period of time to show that there is no intermittent contamination of the water.

Five years of *E. coli* monitoring (with none detected) is required to prove secure status for bores in unconfined aquifers between 10 and 30 m deep. Only 12 months of data is required to prove secure status for bore water drawn from confined aquifers and bore water drawn from unconfined aquifers greater than 30 m deep.

As stated earlier, water from unconfined aquifers shallower than 10 m below ground level cannot achieve secure status.

After the bore water has been given secure status, the monitoring of *E. coli* can occur as infrequently as once a year for supplies complying under section 10 of the Drinking-water Standards.

4.2 Changes in security status

Care is needed to maintain secure status, as the Drinking-water Standards state that it only takes two positive tests within a 12-month period for the secure status to be lost.

As described earlier in the report, a great many things need to be correct in order to prevent contamination. There are obvious changes to a bore supply that can affect its secure status. These include damage to the bore head, and events such as flooding. There are also some less obvious issues that can cast the security of the supply into doubt. These include mistakes with sampling and failure to disinfect equipment installed in the bore. Clearly, simple mistakes like lying a bore pump in a cow pat during maintenance could easily lead to a positive *E. coli* result if it is not disinfected afterwards.

5 Planning a New Bore Water Supply

5.1 Collecting background information

Regional councils hold data on the aquifers in their region being used as water sources. The type and amount of data that councils hold varies by region. This data can be very useful for determining the likely location and quality of water sources in an area.

The regional councils also control the amount of water that can be taken from underground aquifers and will therefore be able to indicate whether a resource consent will be needed and whether the water in an aquifer is already fully allocated to existing users.

Existing groundwater users in an area will also have useful practical information about what can be expected from a local bore. It is important to bear in mind that groundwater yield and quality can vary substantially over short distances and depths. More than one attempt may be needed to achieve a suitable result. There is a large element of luck with bore construction!

5.2 Bore permits

Permission is generally required both to drill a bore and to use the water. Both consents are granted by regional councils. Taking too much groundwater can affect other bore water supplies in the area, reduce water levels at the surface and even cause salt water to be drawn into an aquifer from the ocean. For the same reasons, permission is needed to increase the amount taken beyond what has been consented.

In many areas there is a lower limit below which water abstraction is a ‘permitted activity’ and no consent is needed. This depends on the local circumstances. The local regional council can advise on their specific requirements. Be ready to tell them how much water is required and the location it will be drawn from.

5.3 Installing a bore

5.3.1 Selecting a driller

The skill and experience of a bore driller are important to ensure the bore is properly constructed. Drilling a bore can be expensive and the results achieved are very uncertain, so it will probably be useful to seek help with the contractual arrangements. Drinking Water Assistance Programme (DWAP) facilitators can give advice on this, as can staff at the regional council.

5.3.2 Selecting a site

Ground conditions and aquifers are unpredictable, and bores only a short distance away from each other can behave quite differently.

Bore sites are generally chosen based on local knowledge and regional council records. Drillers with experience of drilling in a particular area can often judge better than anyone which sites and depths have the best chance of success. A driller may sometimes drill a smaller-diameter test bore adjacent to the proposed bore location. This will give information on the ground conditions and the depth that water can be taken from.

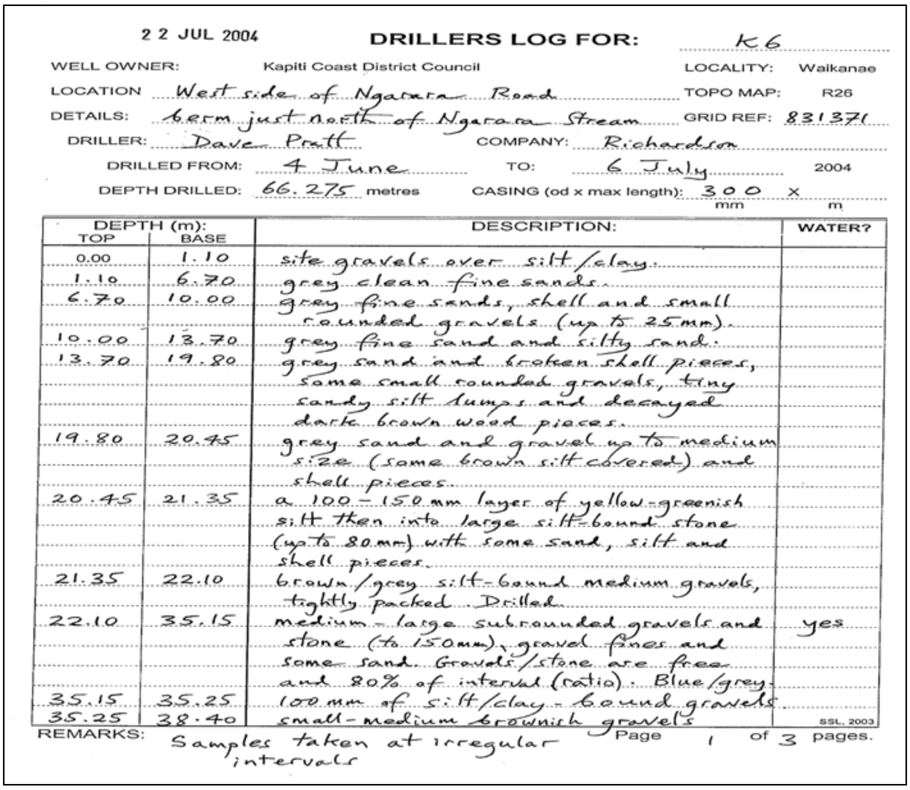
If possible the bore should be positioned away from likely sources of contamination. The shallower the bore, the more important this is.

5.3.3 Drilling the bore

The specific method for drilling the bore will normally be decided by the drilling contractor. However, they will need some direction on the eventual design of the bore. They will want to know what the requirements are for the casing, screen, grouting and capping of the bore.

Generally the contractor must keep a record for the local regional council of the soil layers that are found as the bore is drilled. The driller will record these, and the owner of the bore is generally expected to send them in to the regional council. See Figure 4 below for an example of a bore log.

Figure 4: An example of a bore log



2 2 JUL 2004

DRILLERS LOG FOR: K6

WELL OWNER: Kapiti Coast District Council LOCALITY: Waikanae

LOCATION West side of Ngarara Road TOPO MAP: R26

DETAILS: berm just north of Ngarara Stream GRID REF: 831371

DRILLER: Dave Pratt COMPANY: Richardson

DRILLED FROM: 4 June TO: 6 July 2004

DEPTH DRILLED: 66.275 metres CASING (od x max length): 300 mm x m

DEPTH (m): TOP	BASE	DESCRIPTION:	WATER?
0.00	1.10	site gravels over silt/clay.	
1.10	6.70	grey clean fine sands.	
6.70	10.00	grey fine sands, shell and small rounded gravels (up to 25mm).	
10.00	13.70	grey fine sand and silty sand.	
13.70	19.80	grey sand and broken shell pieces, some small rounded gravels, tiny sandy silt lumps and decayed dark brown wood pieces.	
19.80	20.45	grey sand and gravel up to medium size (some brown silt covered) and shell pieces.	
20.45	21.35	a 100–150 mm layer of yellow-greenish silt then into large silt-bound stone (up to 80mm) with some sand, silt and shell pieces.	
21.35	22.10	brown/grey silt-bound medium gravels, tightly packed. Drilled.	
22.10	35.15	medium – large subrounded gravels and stone (to 150mm), gravel fines and some sand. Gravels/stone are free and 80% of interval (ratio). Blue/grey.	yes
35.15	35.25	100 mm of silt/clay-bound gravels.	
35.25	38.40	small-medium brownish gravels	

SSL, 2003

REMARKS: Samples taken at irregular intervals

Page 1 of 3 pages.

5.3.4 Bore development and testing

Bore development is the process of establishing and optimising the amount of water the bore can supply once it has been drilled. It also stabilises the aquifer structure by flushing out loose material. The methods used may include agitating the water in the bore and pumping the bore at high flow rates.

The local regional council may have guidelines or requirements for developing and testing a bore. This may include testing to demonstrate that other users of the aquifer are not going to be negatively affected by the bore. One test used is to measure the draw down of the aquifer level while the bore is pumped for an extended period of time.

The drilling contractor and DWAP facilitator will be able to advise on the best way to develop and test a particular bore.

5.3.5 Selecting and installing a pump

Calculating the requirements for a pump can be a complex job, and advice will need to be sought from a suitably qualified pumping specialist. However, as a guide, the following information sets out a number of factors that need to be taken into consideration.

The selection of a pump to draw water from a bore needs to ensure the best flow and pressure performance is met for the system at the lowest capital and operational cost. In other words, if the right pump is selected for the job it will deliver the right amount of water for the community and will do so for the best operational cost.

These considerations will also help with determining the best type of pump to use, with submersible bore pumps and surface-mounted jet pumps being the most common. Other pumps can be used, such as positive displacement pumps driven by electric motors or even wind mills, but these are generally associated with specific limitations, such as power supply availability or restricted water flow availability.

Submersible bore pumps are the most common pump type for bores due to their high flow and high head (pressure) characteristics, meaning no other pumping is required in the system. Surface-mounted pumps have the advantage of easy access for servicing, but they generally cannot provide the same high flow and high head options that a multi-stage borehole pump can provide. For systems that have very low flow demand but require water to be lifted to a high elevation, a positive displacement pump may be a good alternative.

The maximum pressure or head a pump needs to provide is the sum of a number of requirements and is most often referred to in units of head in metres. The pump must be capable of lifting the water from the lowest level the water table will reach in the bore. This level is affected by ‘draw down’, which is the lowering of the water table near the bore due to the flow out of the bore. This level may also be affected by the seasonal change in static water levels, meaning the water table may be much lower in summer than in winter.

The required head for the pump output must also allow for the lift to the highest point in the system, which may be a tank or a customer at the top of a hill.

Where the pump is to be connected to a pipe network to supply water directly to a number of consumers without allowance for storage, you will need to select an appropriate method to control the discharge flow and head produced by the pump as the demand varies during the day. It is very inefficient and ultimately costly (due to excessive wear and high power demand) to select a pump that is too big for normal duties. Using pressure- and flow-regulating valves at the well head is one way to regulate flow, but this introduces the risk of the mechanical parts in these valves failing. It may be appropriate to select a pump fitted with a variable speed drive. These pump sets are able to ramp the speed of the motor up and down to adjust the flow and pressure to varying levels of demand as customers turn taps on and off. Variable speed drives are often fitted with additional pump motor protection functions, such as overloading, overheating and phase reversal.

Providing storage tanks in a system helps buffer against any risk associated with loss of supply to consumers in the event of a bore or pump failure. The control of a pump supplying a storage reservoir is generally straightforward, as the pump is only required to provide a fixed flow rate at a constant head, and so a simple motor starter is normally sufficient. Advice should be sought from a qualified electrician or the local power supplier because there may be requirements for particular motor control devices to be fitted depending on the size of the pump motor to be installed.

Refer to *Pumps, Pipes and Storage*[2] for more information on pumping, and contact the local DWAP facilitator for technical assistance.

The pump will need to be installed by an electrician or other qualified person. The well driller may be able to arrange this. The installer should also be able to test the pump and control system as part of a preventive maintenance plan to avoid the risk of unforeseen failure leading to loss of supply. The installer should complete a checklist when installing and commissioning the pump so that factors such as the maximum pressure and electrical loads at various flow rates can be re-checked at a later date. These test results, including a test of maximum pressure delivered in a no-flow situation, will give a good indication of whether the pump is still functioning according to its original specification or is showing signs of deterioration.

Surface-mounted pumps must be adequately secured to a strong base to prevent damage through vibration or movement. Pipework leading to the pump should be self-supporting or braced to the floor or walls of the pump enclosure to prevent mechanical load being transferred to the pump casing. Surface-mounted pumps, and sometimes the pipes connected to them, will be damaged if they run for extended periods without adequate water flow. A no-flow or low-pressure cut-out should be fitted to the motor controller.

5.4 Water treatment

After the bore is completed, water testing may show that the quality is not adequate without treatment. For example, if the bore cannot achieve secure status (as described in section 4 above), the water will have to be treated to remove or inactivate microbial

[2] Ministry of Health Resources for Drinking-water Assistance Programme.

contaminants. Chemical contaminants may also have to be removed. Treatment is very common for turbidity, iron and manganese. The pH of the water may also have to be corrected.

Common chemical and microbiological contaminants are referred to in section 2. *Treatment Options for Small Supplies*[3] describes methods for treating these contaminants.

5.5 Abandoning a bore

Bores eventually reach the end of their useful life and have to be replaced. Sometimes they are simply no longer needed. A disused bores represents a hazard to water quality.

Regional councils often have guidelines on how to abandon bores safely. A specialist contractor should do this work. The guidelines may ask for the removal of the casing and back-filling the hole to prevent the flow of water between the surface and the aquifer. The regional council will require a record of how the bore has been sealed and made safe.

[3] Ministry of Health Resources for Drinking-water Assistance Programme.

6 Operating and Maintaining a Bore

Once installed, bores are very reliable and need little maintenance. This can mean they are largely forgotten until problems develop.

6.1 Water quality monitoring

There are basic monitoring requirements outlined in the Drinking-water Standards. In many cases the quality of the groundwater can change. Monitoring should be designed to alert the water supplier to these changes, particularly where they affect the safety of the water.

Where water quality is influenced by water entering from the surface, turbidity can increase sharply after rain. This is likely to be accompanied by an increase in microbiological contamination. Of course the microbiological contamination may increase independently of turbidity, and sampling needs to be sufficient to detect changes that could affect the safety of the water.

Most aquifers release minerals of some kind into the water. The concentration can change depending on how the aquifer is being used. For example, heavy pumping may mean that water is drawn from another part of the aquifer with other mineral influences. This heavy pumping may be by other users of the aquifer, so a change in quality could happen unexpectedly.

6.2 Operations and maintenance planning

Information on how to develop an operations and maintenance plan is provided in *A Guide to Operations and Maintenance Planning for your Water Supply.*[4]

In general, only limited preventive maintenance can be done on the bore itself as most of the structure is inaccessible. However, regular preventive maintenance should be carried out on mechanical components such as the pumps and valves. In addition, operators should check the condition of the above-ground structure, including the concrete apron and fence, to ensure it is in good condition.

A troubleshooting guide specific to bore water supplies is included in section 7 of this booklet.

6.3 Bore deterioration

It is not unusual for the yield from a bore to decline over time. A number of causes for this are outlined below.

[4] Ministry of Health Resources for Drinking-water Assistance Programme.

6.3.1 Mechanical failure

Obviously mechanical equipment such as pumps will fail from time to time. Bore pumps are often left in the ground until this happens. Given the practical difficulties involved in lifting pumps and checking screens, this is not entirely unreasonable, as long as there is an alternative source of drinking-water available while any problems are resolved.

6.3.2 Chemical encrustation

Bore screens can become encrusted with minerals from the groundwater. Chemical encrustation is most often associated with calcium carbonate and insoluble iron and manganese hydroxides. Warm groundwater can deposit silica.

Mechanical methods such as wire brushing or scraping can be used to remove encrustation. The most effective method is the application of strong acid, such as hydrochloric acid. This requires careful handling and flushing.

6.3.3 Bio-fouling

Bio-fouling is any form of bacterial activity that interferes with the efficient operation of a bore. It is not commonly realised that large numbers of bacteria live in underground aquifers. These bacteria specialise in living in this environment, and often use compounds such as iron, manganese, sulphate and nitrate for their growth. These activities can change the nature of the water and can also lead to gradual clogging of the bore. Bio-fouling can also lead to corrosion of steel and concrete, which is potentially very damaging for a well.

Bio-fouling by iron bacteria can produce rust-coloured deposits and slime. These can affect bore capacity by blocking the screen and other water supply components. Other side-effects include slight and intermittent sulphide odour and occasional breakthrough of red water. Iron bacteria may also cause pitting-type corrosion of steel and iron.

6.3.4 Corrosion

Corrosion of pumps and bore structural materials, such as the casing, can be a consequence of the chemistry of the water or bio-fouling. High rates of corrosion can be associated with acidic water and elevated levels of chemicals such as carbon dioxide, hydrogen sulphide, chloride and total dissolved solids.

Corrosion along the length of the bore casing has the potential to allow poor-quality water from shallower depths into the bore. As a result, a secure groundwater source may quickly become unsafe. Corrosion of the well screen has obvious consequences for the stability of the bore structure.

Generally, corrosion is easily controlled by selecting appropriate materials for the construction of the bore. This needs to be thought about at the planning stage. Thorough water quality testing will provide a good indication of the characteristics of the water and is essential for accurate selection of the materials to be used in the bore.

6.3.5 Sand intrusion

Excessive amounts of sand can be drawn into a bore if it is pumped at too high a rate or there is too much surging in the flows, such as where a check valve has failed. The problem may also be related to problems with the screen or the packing material around it. Sand can add significantly to pump wear, so this issue should not be ignored for too long.

6.3.6 Rehabilitation techniques

There are rehabilitation techniques that are used to boost the performance of an ailing bore. These include forcing air or water into the bore, brushing, over-pumping, and treating the bore with chemicals. This work is undertaken by specialist companies. Note that the local regional council may place conditions on how a bore can be rehabilitated in order to protect the aquifer for other users.

7 Troubleshooting Guide

Indicator	Possible problem	Solution
E. coli detected in bore water that has been assessed to have secure status	Water contaminated by poor sampling technique	Take more samples to see if further positives are detected. Positive results must be reported to the drinking-water assessor.
	Contaminated water is entering the well from the surface or a shallow depth	Check the bore to make sure water is not getting in from the surface or through the casing.
	Contamination of the aquifer	Seek advice from the regional council. Check for activities in the area that could affect the water quality.
Change in turbidity or colour	Damaged screen, bore head or casing	Check bore head security. In some cases a drilling contractor may be able to replace the screen or repair the casing.
	Drawing in water from a different part of the aquifer	Seek advice from the regional council.
Change in turbidity or colour after rainfall	Surface water intrusion into bore	Check bore head security. Can the intrusion be prevented? Is it necessary to take water when the quality is poor?
Water is turbid during the first stages of pumping	The rising main within the bore is corroding	Can the first flush of water be diverted to waste? Inspect the rising main in the bore. Examine the inlet screen, check valve and pipe connections. Replace badly corroded pipes.
Sand in well discharge and/or excessive pump impeller wear	Damaged well screen or gravel envelope	In some cases a drilling contractor may be able to replace or repair the screen or gravel envelope.
	Flow is drawing sand into the well	Throttle back the flow rate to reduce the problem. A drilling contractor may also need to redevelop the bore to flush out the sand around the bore screen (or take other measures as appropriate).
	Rapid stop/start pumping agitating the bore and not flushing out the sand	Look at the pump controls. Install storage or a variable speed drive (not always appropriate).
Pump vibration	Cavitation caused by inadequate pump submergence	The flow rate should be throttled back to reduce the draw down.
	Unbalanced pump or worn pump components	Have the pump serviced.
Pump cutting out on high temperature or high amps	Pump needs repairing	Have the pump serviced.
	Pump cycling too quickly between start and stop	Look at pump controls. Install storage or variable speed drive (not always appropriate).

Indicator	Possible problem	Solution
Sudden change in flow rate	The position of a flow-restricting valve has been changed A leaking pipe A damaged pump	Find the problem and fix as appropriate.
Gradual decline in pump flow rate	Pump wear or flow constriction in delivery pipework	Check pump shut-off pressure against previous values to see if this is falling. Do not run a bore pump for any longer than necessary against a closed valve (check manufacturer's instructions). Have the pump serviced.
The bore draw down increases	Water demand is increasing in relation to the capacity of the bore	Is another bore needed?
	The aquifer is becoming depleted	Are other bore users in the area noticing increased draw down? Investigate water extraction in the local area and consider the effect of recent weather.
	Plugging of bore screen	Consider screen corrosion, chemical encrustation, biological fouling and fine material build-up. A drilling contractor would normally undertake any remedial action.
	Gradual blockage of the area around the bore is affecting water recharge	A drilling contractor may be able to re-develop the bore.