Selecting and developing reliable bore sites in the eastern wheatbelt

Richard George
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By Richard George, Research Officer, Bunbury
Selecting the site

Introduction

In the Western Australian wheatbelt, groundwater supplies contribute about 40 per cent of the on-farm livestock requirements and occasionally domestic water supply systems.

The first part of this Bulletin comments on sites suitable for both high yielding bores and also those which yield water suitable for livestock. The second part outlines techniques for constructing and developing a bore.

Throughout this Bulletin livestock quality water, for adult sheep, is defined as groundwater of less than 12,000 mg/L (or 850 grains per gallon) which has not been subject to localized pollution. For other livestock, the maximum salinities range from 2,600 mg/L for poultry, to 8,500 mg/L for cattle (Table 1).

Water supplies from groundwater systems provided many of the historic watering points on which the wheatbelt regions were developed. However, the availability of improved heavy machinery for dam construction, the poor quality and supply rates of many bores and the early establishment of comprehensive water supply schemes, has contributed to the slow development of groundwater systems.

For example, at Corrigin, before the pipeline was connected, the town was serviced by groundwater used in conjunction with runoff from the granite outcrops. When in full use, water-tables below Corrigin were kept 10 to 20 metres below ground.

Today, with only a few users remaining, the water-table in the valley is near the surface and signs of salinity have appeared. The rise in the water-tables in recent years would have been accelerated by clearing within the catchment.

In the future, greater use will probably be made of groundwater resources as the available surface water supplies are redistributed between rural and urban users. Groundwater will supplement already established water harnessing schemes such as roaded catchments and other improved or natural catchments for dams and tanks.

Another reason for increasing the use of groundwater, apart from economic or logistic reasons, is to lessen the amount of land going saline. The Corrigin example is exceptional because of its scale, however, in smaller catchments, it is common sense to use livestock quality groundwater before it can migrate to saline areas. Local oversupply will be a problem in the short term, but in the long term the availability of additional water for agriculture will be an advantage.

A survey conducted in 1974 by the Department of Agriculture (Anon. 1974) in the Upper Great Southern and central and eastern wheatbelt found that 30 to 80 per cent of all farmers had sufficient groundwater for all stock needs. Average farms had one to three bores, producing 10 to 30 kl/day of stock quality water (1 kl = 1,000 L). The average success rate of drill holes ranged from one in two to one in ten, depending on regional and local conditions. For a farm with 5,000 sheep, only 25 kl per day is required in mid-summer to satisfy their water requirements.

More recently the Department of Primary Industries and Energy (Anon. 1985) published a report which suggests that the wheatbelt is only using 0.1 to 1.0 per cent of the available

| Table 1. Approximate upper limits of salinity for common farm animals and other uses |
|---------------------------------|-----------------|-----------------|
| Animal                        | Approximate upper limit | (mS/m)†          |
| Poultry                       | 2600 mg/L         | 470 mS/m         |
| Dairy cattle (milking)        | 3000 mg/L         | 550 mS/m         |
| Pigs                          | 3850 mg/L         | 700 mS/m         |
| Horses                        | 5500 mg/L         | 1000 mS/m        |
| Lambs, weaners and dairy cattle (dry) | 6050 mg/L         | 1100 mS/m        |
| Beef cattle                   | 8250 mg/L         | 1500 mS/m        |
| Adult sheep                   | 1650 - 2200 mg/L  | 9100 - 12000 mS/m|
| Other uses as a comparison    |                  |                 |
| Humans†                       | 1400 mg/L         | 250 mS/m         |
| Hot water systems             | 880 mg/L          | 160 mS/m         |
| Septic tanks                  | 8500 mg/L         | 1550 mS/m        |
| Nursery (trees)               | 280 mg/L          | 50 mS/m          |
| Garden plants                 | 550 mg/L          | 100 mS/m         |

† Conversions
mS/m (milliSiemens per metre at 25 °C) to mg/L (milligrams per litre) = multiply by 5.5
mS/m to g/g (grains per gallon) = multiply by 0.385

‡ For drinking water, World Health Organization standards suggest that the maximum salt level should be 1,500 mg/L, nitrate (N) 10 mg/L, chloride (Cl) 600 mg/L, sodium (Na) 400 mg/L, iron (Fe) (total) 1.0 mg/L.
water in local aquifer systems which is suitable for livestock. The results of both studies indicate that groundwater resources are under used.

In the period between 1985 and 1990, about 160 bores were drilled in the Merredin area by the Salinity and Hydrology Research Branch of the Department of Agriculture. The main aim of the drilling was to describe the processes responsible for dryland salinity; consequently most of the bores were located in areas unsuitable for successful water supplies. However, many of the bores, drilled well above saline areas, produced significant volumes of livestock quality groundwater.

ODriscoll (1973) and Bestow (1985) have previously described some of the geological factors which affect the location and development of a productive bore for livestock. However, little was said about where to drill and how to construct and develop a bore. This Bulletin broadly defines the most likely targets for drilling and highlights methods to maximize the life and efficiency of the bore.

Geology

Groundwater in the wheatbelt is usually stored in four different geologic materials. Each material has different hydraulic properties which affect their ability to store and transport water and salt. The four groundwater systems associated with these geologic materials are (from the surface downwards): sediments, deeply-weathered bedrock(pallid and transitional zones), coarse grained saprolite and the fresh or fractured bedrock aquifers (see Figures 1a and b).

• Sediments

The sediments vary in thickness from 0.5 to 20 m and are of greatest thickness below both the heavy and lighter textured flat valley-floor soils, east of the 450 mm annual rainfall line. The sediments range from highly permeable sands to lower permeability sandy clays and clays.

Aquifer yields range from 10 to 100 kL/day. They are normally saline (greater than 12,000 mg/L) because they occur in valley floors and the groundwater is not usually suitable for livestock. Occasionally, shallow soaks occur at the base of sandy rises, but their yield and longer-term use is often questionable.

• Deeply-weathered bedrock

The change from the sedimentary systems into the ancient and deeply-weathered bedrock zones can be clearly seen in large pits (mines) or in road and railway cuttings. Deeply-weathered bedrock materials (5 to 30 m thick) are typically pale grey to pink sandy clay, but locally, iron-rich (red-brown) zones are common and occasionally associated with the watertable.

The texture and permeability of the mottled, pallid (white clay) and decomposed bedrock zones depend on the properties of the local rock from which they are derived. In general, permeability gradually increases with depth towards bedrock. Only small supplies are found in these materials.

• Saprolite grits

The saprolite grits' zone is freshly-weathered bedrock in which the strength and structure of the original rock has been lost, leaving a coarse gritty-textured material. Saprolite 'grits' range in thickness from less than 1 to 20 m and are primarily comprised of fresh quartz and feldspar.

The saprolite grits form the major aquifer in the wheatbelt producing yields up to 250 kL/day. Groundwater salinities increase towards the valley floor, while flow rates increase. In areas of complex geology, where dolerite dykes and faults are common, saprolite grits can be considered as underground storages with the dykes acting as 'leaky' dam walls. Aquifer yield is directly related to the thickness of the saprolite and its areal extent.

• Fractured rock

Fractured rock aquifers are difficult to locate and require hard rock drilling equipment. Fractures in the fresh rock have been observed to depths of 5 to 10 m below the top of the bedrock interface. High permeability zones also sometimes occur, especially immediately adjacent to dykes and faults.
Flow rates and fracture permeability are highly variable. Major fracture systems often produce large flows following drilling, but regularly slow up as the fractures are drained at a quicker rate than they can be replenished.

Locating a bore for livestock water

Unless many positive factors coincide, bores seldom produce very high yields (more than 100 kL per day) and stock quality (less than 5,000 mg/L) water. Yield and quality becomes a trade-off related to the bores' position in the landscape. Upslope, bores often have the lowest salinity and yields, while downslope bores have higher yields and salinities.

Long-term bore yields are very dependent on the hydraulic properties of the area around the bore. Fractured rock aquifer systems are good examples of this condition. In areas where bedrock occurs on the surface nearby or when sites are near hill-tops, the long-

Figure 1a and b. Schematic cross-section of an example site
term pumping rate may only be a fraction of the driller’s prediction. The area around the bore site (1 to 10 ha) must be able to contribute flow to the proposed or existing production well.

When choosing the actual location for a site it is therefore more important to be in the right area than at an exact spot.

About 160 bores were drilled to bedrock in many catchments located throughout the eastern wheatbelt as a part of the salinity research programme (1985 to 1990). The results obtained can be used as a guide to the likely distribution of groundwater yield and quality. However, it must be stressed that the sites were not specifically chosen for livestock supplies. The results of the programme show that 92 of the bores produced less than 5 kl/day, 50 up to 50 kl/day and 12 produced flows of 50 to 250 kl/day. Groundwater quality was highly variable with the higher salinity waters occurring with the highest yields and vice versa.

A common pattern emerged from the drilling programme that indicated the most likely sites for locating productive, long-term and suitable livestock supplies. A schematic cross-section of an example site is shown in Figures 1a and b. The main visual indicators are as follows:

- small upslope valleys (200 to 2,000 ha);
- deep sandplain soils, and often in combination with areas of frequent or large granite outcrops and granite soils;
- catchments without clayey surface soils (e.g. white gum and salmon gum soils);
- upslope from saline areas;
- on fractures and quartz dykes;
- near creek lines.

### Predicting the depth of the water-table

In order to determine how deep a bore has to be drilled before water is encountered, it is useful to try to predict where the water-table will be. This is especially important when planning the amount of drilling to be done, and limiting the depth of unproductive and costly ‘dry’ work.

The water-table’s position is close to the surface (< 1 m) in saline areas, soaks, springs (or easy to find out from existing drill holes). However, predicting its location higher in the landscape, especially in rocky areas, is more difficult.

In most cases in ‘sandplain country’ the slope on the water-table will be less than one per cent (1 m rise in 100 m distance), although it may increase (up to 5%) in rocky or hilly areas.

To avoid extra drilling, try to locate the bore near creek-lines or in depressions.

### Locating a well for high yields

In most large valley systems bores have been drilled in sedimentary, saprolite and occasionally fractured rock aquifers. Flow rates are greatest where sand sediments (range 5 to 20 m) and deep saprolite zones (5 to 15 m) are found together (see Figure 1b). Yields from bores installed in sites with a deep saturated thickness (greater than 30 m) can produce flows from 30 to 250 kl/day.

The mean yield from 52 bores drilled in these conditions in the eastern wheatbelt was 50 kl/day. Salinities ranged from 5,000 to 100,000 mg/L (sea water = 35,000 mg/L). The greatest flow rates were obtained either in or adjacent to saline areas, because these bores had the maximum possible saturated thickness or depth of water to draw from.

In most situations, farmers will not consider the installation of a bore in an area where there is a high probability of finding poor water quality (greater than 2,200 mS/m). However, in some situations large volumes of water may be required. Examples include washing piggeries, mixing or shandying water to increase available stock supplies during droughts or for lowering saline groundwater tables. In these cases the following sites could be chosen:
The key elements in the selection of a suitable site for livestock supplies are noted above. But remember that the water resource being sought is stored in a highly variable aquifer, both in terms of its permeability and distribution. Appropriate drilling and bore construction techniques must be used to withdraw the water efficiently.

In the future, airborne remote sensing techniques may provide practical tools for locating highly productive, low salinity water supplies. However, until these techniques are proven, divining should be considered cautiously and guarantees sought. The preferable technique is to consult the Geological Survey, the Department of Agriculture or experienced local drillers for advice.

- broad valley floor locations;
- near or in saline areas in the valley;
- adjacent to geologic structures such as faults;
- adjacent to granitic rocks (not within 200 m);
- away from weathered dolerite.

**Diviners**

It is interesting to note that some of those diviners who are still practicing in the wheatbelt use the experience, often unknowingly, of previous successes and failures in the district and not the 'wire' to select sites. Most only drive to an area that 'looks good'. In other words, they only get out of their vehicle if the 'lay of the land' is such that they believe water may be found. In doing this, they use similar geographic factors (like those described above) to select a site. The art of then saying "it's here, drill on this mark on the ground and you find water" is where the scientific community and diviners part company.

Unless water is encountered in narrow, linear geologic structures such as shear zones, quartz veins or near dolerite dykes (often visible to hydrogeologists on air photos), the sustainable yield of any well is dependent on the permeability of the area (a hectare or more) around the well, and not the well itself.

In other words, it's no good drilling into a pocket of water with a small storage (if it exists!), since as soon as you pump on it, it will become dry. What is needed is a good supply, connected to a very large storage.

The 'age-old' debate over divining remains, and is not discussed further here. However, regardless of its use in the wheatbelt (which is reducing with time as better research data is available), farmers should seek advice from experienced people. Drilling for low salinity water is a difficult task. The best way to 'increase your odds' is by using all the available knowledge and resources at your disposal.

**Conclusions**

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Constructing and developing the bore

Bore construction

Suitable bore construction and development techniques are crucial for successful bore establishment. Many failures attributed to aquifer dewatering, well failure or pump intake of sediment, are often due to poor selection of casing, screen and filter pack. The following comments are directed at achieving maximum efficiency and life from saprolite aquifers, as these are the most often found and the most successfully harnessed. A cross-section of a standard bore is shown in Figure 2.
Drilling

Bores can be constructed with auger, percussion, rotary-air or mud-rotary drilling rigs. Rotary-air rigs are the most common. Bore diameters of above 200 mm are only necessary for large commercial bores. Diameters of 150 to 200 mm are adequate for yields of up to 500 kL/day. This yield is greater than any encountered in the wheatbelt to date.

Bores should be drilled to bedrock, and if site conditions are suitable and the driller is keen, continued a further 5 to 10 m into fractured bedrock in the search for fractured rock aquifers. Drilling further than 10 m is usually unrewarding, because by that depth the weight of soil and rock above has prevented the development of any fractures.

Casing choice is determined by expected bore yield, depth and cost. Corrosive waters with high iron, silica contents and low pH) can be effectively screened and cased with class 9 or 12 PVC. Stainless steel need not be used in most wheatbelt situations. However, for yields above 500 kL/day and from depths greater than 50 m, stainless steel casing and screens can be used. Class 18 PVC is not necessary for ordinary wheatbelt bores.

In most situations 125 mm PVC casing is all that is required, standard submersible and 'Airwell™ pumps fit into this diameter casing. Increasing the casing diameter by 25 mm, only produces an additional three to five per cent increase in yield. Rigid and strong casing (class 9 - 12) should be used for deep bores. Casing sections should be joined as per the manufacturer's recommendations to avoid lengths separating thus allowing sediment into the well.
Slotting or screens

Commercially slotted PVC screens are suitable for most situations. They are cheap ($20 to $60 per 6 m length of PVC, March 1991 price) and are available from most irrigation equipment suppliers. The slot size (width) chosen depends on the grain size of the materials in the aquifer. Slots for standard saprolite aquifers should not exceed 1.0 mm, although in coarse gritty materials it may be possible to use slots up to 1.5 mm. In nearly all situations, only one length of PVC screen is required to achieve flow rates of up to 500 l/d per day.

Slots should be chosen to allow some of the finer grains of the aquifer material to pass into the bore, this fine material will subsequently be removed by development. Development creates particle bridging in the filter pack and aquifer, which maximizes yield and minimizes sediment inflow (Figure 3). Do not use casing with large (for example, more than 5 mm) slots, as a large volume of sediment may fall into the bore or block the screen.

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**Figure 3a.** Cross-section through a standard stainless-steel screen. The open shape (to the right) allows sediment to be moved from the filter-pack (left), and away, out of bore, during development. Injections of water and/or compressed air through the screen juggle the filter pack, and eventually create 'bridges' so the fine grains are locked out. The open bore is to the right of the screen in both cases.

**Figure 3b.** Cross-section through a PVC screen. The upper 2 slots of the screen are blocked by sed from the filter pack. However, even without the special shape of the stainless-steel screen, development of the lower three slots has made the 'bridges', to keep out fine grains. Development is more important for PVC screens than stainless-steel.
**Filter packs**

Uniform and graded filter pack sands of 1.5 to 3.0 mm diameter are suitable for most of the situations described above. Filter packs with larger grain sizes (greater than 5 mm) should not be used as they allow too much fine grained material into the bore or pump. Standard bluemet should be avoided if possible because it is usually too coarse (more than 5 mm), but 3 mm is sometimes available and that is suitable.

Filter packs are placed around the slotted casing. A minimum annulus (distance between the screen and soil) of 25 mm is required. The filter pack should have a mean grain size such that only a small percentage of particles can move into the well (Figure 3a and b). Choose a filter pack which has the majority of the material above the minimum slot diameter. A cheap alternative to buying filter packs is to sieve some creek sand.

**Development**

Development of a bore is the term used to describe the process of removing unwanted fine materials in the aquifer and filter pack (Figure 3a and b). Developing the bore can also remove drilling contaminants (fluids and chemicals) that may have blocked the aquifer formation. Development is crucial and failure to do so can cause screen blockage, pump failure and low yields.

Drillers should use techniques such as overpumping, jetting, surging and air-circulation for periods of not less than two to eight hours, or until the effluent water is effectively free of suspended sediment (that is, less than 100 grams of sediment per 1,000 litres of water).

With rotary-air and mud-rotary drilling rigs it is often possible to inject air and/or water directly into the casing after it has been installed. By using couplings to the casing, or by direct pressure on the casing itself, it is possible to pump air and/or water down the PVC (casing) and out through the screen. By pumping for some time, mud and grit from down the hole can be washed to the surface. This makes it easier to add the filter pack and develops the hole.

Farmers often fail to develop wells as it seems expensive to have a driller sitting 'idle'. However, failure to properly develop the bore will mean it may not last as long as it should.
Pumps

Conventional windmills, electric submersibles and 'Airwell' pumps are commonly used. Conventional windmills are usually used for isolated bores which are not required to supply continuous or large volumes of water. Submersible pumps are efficient if power is nearby or large (10 to 1,000 kL/day) volumes are required.

Airwell pumps operate effectively in existing poorly constructed wells because of their ability to cope with sediment and low flows. Flows (less than 200 kL/day) can also be obtained at remote sites cheaper than with conventional submersibles. In most cases both submersible and Airwell pumps cannot economically be considered at a distance of 2 to 5 km from a power source. Solar systems are then feasible for small supplies where the total working head on the system is small (10 to 20 m).

Where the water-table is shallow, and the total head from the water-level when pumping to the pump inlet is less than 7 m, surface mounted petrol or diesel centrifugal pumps can be used.

Estimating aquifer yields

Estimates of the long-term or 'sustainable' aquifer yield of bores are difficult without the benefit of long-term test pumping. As a general rule, bores drilled low in the landscape (valley sites) will maintain their initial yield (from airlifting the bore) at about 50 to 100 per cent of the estimated rate. High in the landscape, especially when fractured rock bores are involved, long-term rates may only be between 10 to 50 per cent of rates established in tests. Overpumping is common in fractured rock aquifers.

Pumping tests are essential before expensive pump systems are established in any materials. Constant rate test pumping of new bores for periods from eight hours to three days is needed if continuous flow above a minimum rate is required. Drillers estimates of yield are often overestimates and should not be used as a substitute for test pumping in critical situations.

Legal requirements and lodging drilling records

At present there is a legal requirement in all areas under the Rights in Water and Irrigation Act, 1914, for landholders to register a bore. However, in the eastern wheatbelt no licence is required. It is an advantage to allow a central agency to collect records so that farmers have a database to draw on for local details and a method of monitoring the viability of supplies for water resources planning.

Bore details should be lodged with the Hydrogeological Section of the Geological Survey, who also issue report forms which the driller or owner can fill in and return for safekeeping.

There is a wide variety of information which can be kept, however the following points should be recorded.

- Owner's name and address.
- Location of bore (location number or grid reference).
- Supply of bore (in kilolitres per day).
- Quality of water (in mS/m as tested by Department of Agriculture or other agency).
- Depth of bore.
- Depth to watertable (water rest level).
- Description of materials drilled into.
Conclusions

The construction techniques used to install a reliable bore are almost as important as locating a suitable site. Poor drilling techniques and inexperienced drillers have been responsible for many of the problems associated with existing bores and often have required them to be re-drilled and equipped.

In recent times the introduction of PVC casing and screens has enabled establishment of low cost, efficient bores. However, the fundamental principles of bore construction, casing and screen selection and development techniques are well established. Professionally affiliated water-well drilling contractors should be used wherever possible.

References


Further detailed reading