SA Water

TG 10e

SOUTH AUSTRALIAN WATER CORPORATION

TECHNICAL GUIDELINE

GENERAL TECHNICAL INFORMATION FOR GEOTECHNICAL DESIGN

~ Part E ~
Hydrogeology

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of South Australia

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No Changes Required In the January 2007 Edition

The following lists the major changes to the November 2004 edition of TG 10e:

1. Nil

Contents

Tables & Figures

Referenced Documents

Report: "Aldinga Waste Water Treatment Plant - Summary Report on the Geotechnical and Hydrogeological Aspects of a Potential Treatment Plant Site and Irrigated Vine Effluent Disposal Area on Sections 426, 432 and 438 at Aldinga", docket EWS 2695/94, EB Collingham, Principal Engineer Geotechnical, July 1994.

Section 1: Scope

Section 2: Groundwater Monitoring Wells – Spec & Comments

The Contractor shall install three monitoring wells. One groundwater monitoring well shall be installed under each of the two centre-pivot circles. The third monitoring well shall be installed east of the irrigation site on Section 128. The exact locations of the monitoring wells shall be determined on-site with the Superintendent's Representative.

A well construction design shall be submitted by the Contractor for approval by the Superintendent's Representative, but shall comply with the following minimum criteria:

- The drill hole to extend a minimum of 3 m below the static groundwater level observed during drilling.
- The well screen to extend from 50 mm above the base of the drill hole to a minimum of 1 m and a maximum of 1.5 m above the groundwater level encountered during drilling
- The well screen to have no sump or dead space at the bottom and to be sleeved with geotextile. Watertight casing to extend from the top of the screen to the ground surface;
- Minimum screen and casing diameter to be 75 mm.
- Appropriate filter sand to extend from the base of the drill hole to a minimum of 0.5 and a maximum of 1 m above t he top of the screen.
- The drill hole above the sand filter to be backfilled with bentonite mud to the surface.
- The top of the well to be finished with an appropriate protective cap and marker post.

Note: The above was prepared (in some haste) as part of the design spec for Millicent WWTP Reuse scheme.

It sets out the basic requirements for the design/construction of a well, but does not address the function or philosophy behind such wells. So-called monitoring wells are an ongoing expensive waste of resources use unless someone has:

- Thought about / studied the local hydrogeology.

- Decided for the particular site and the particular local hydrogeology what impacts the irrigation might have on the quality of the water in the aquifer.

- Decided what levels of impacts would be acceptable/unacceptable.

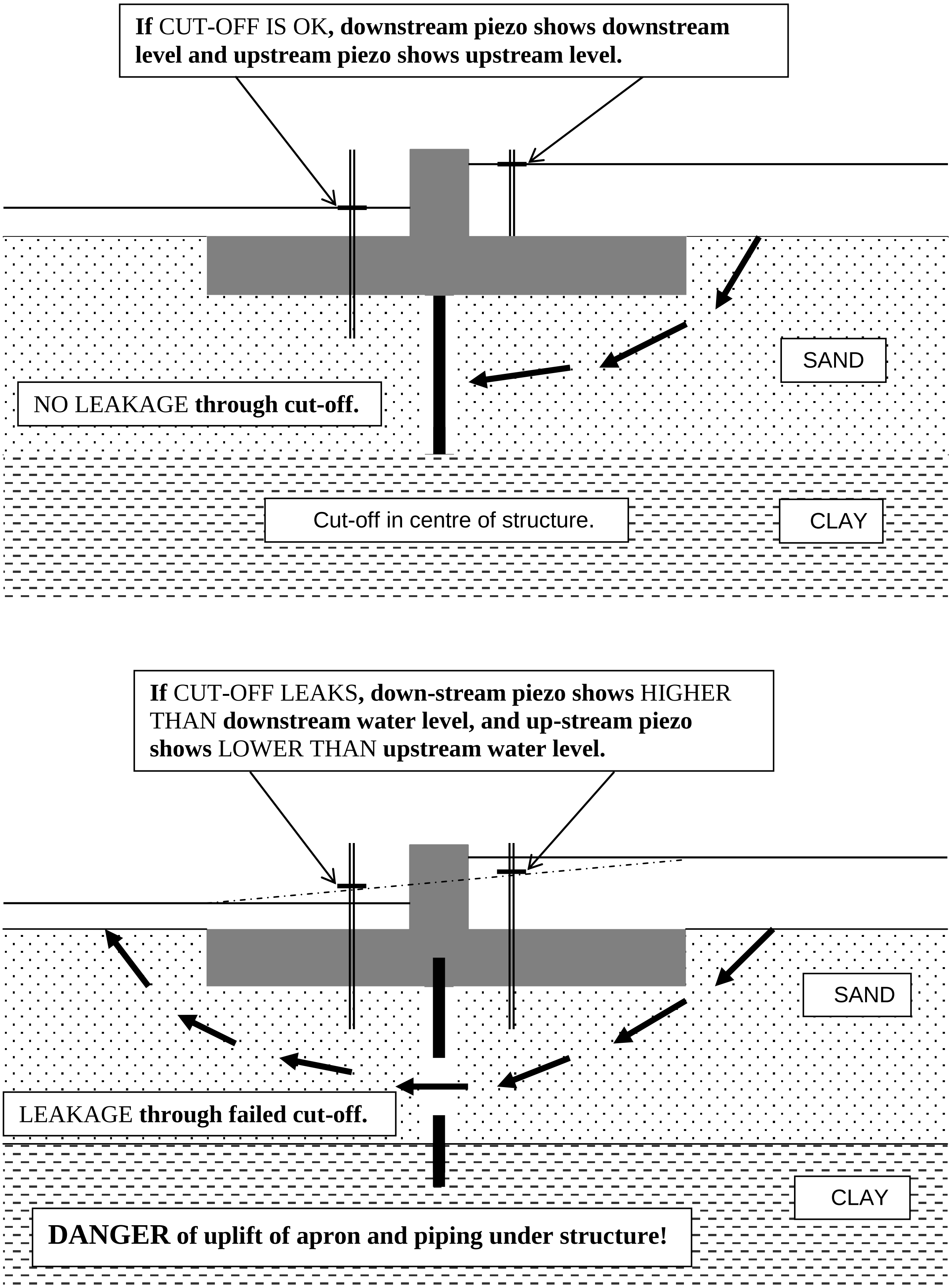
- Worked out a sampling and testing protocol to measure those impacts.

- Thought about what the response might be if the observed impacts were unacceptable (eg changed irrigation operation).

It is a concern if these things as installed simply to "comply" with ill-thought-through EPA requirements.

This “Technical Note” was prepared by Ed Collingham, 06/12/2000
(Ex Principal Engineer Geotechnical)

Section 3: Piezometer Under River Murray (MDBC) Structures



If CUT-OFF IS OK**, downstream piezo shows downstream level and upstream piezo shows upstream level.**

NO LEAKAGE **through cut-off.**

Cut-off in centre of structure.

If CUT-OFF LEAKS**, down-stream piezo shows** HIGHER THAN **downstream water level, and up-stream piezo shows** LOWER THAN **upstream water level.**

LEAKAGE **through failed cut-off.**

DANGER of uplift of apron and piping under structure!

Figure 3.1 - Illustration of Centre Cut-off Effectiveness.

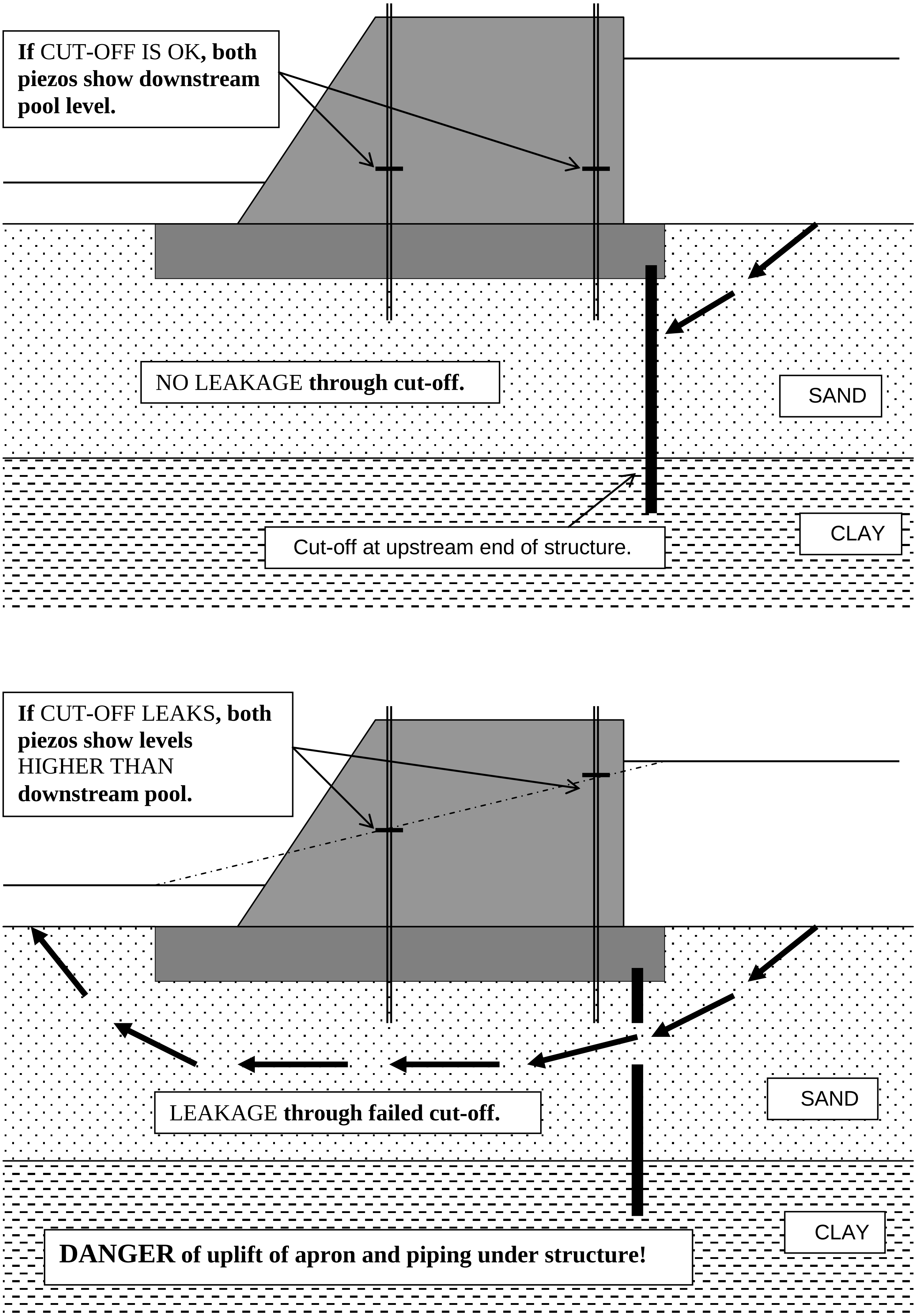


Figure 3.2 - Illustration of Upstream Cut-off Effectiveness.

Section 4: Groundwater Recharge in the SA Mallee – The Impact of Irrigation Drainage in Perspective

4.1 TYPICAL RECHARGE RATES IN SA

How does the Rate of Recharge beneath irrigation compare to other sources of Recharge in the SA Riverlands and Mallee Country?

Table 4.1 - Typical Recharge Rates in SA

SOURCE OF RECHARGE	TYPICAL RECHARGE RATE
Native Mallee	0.1 mm/a
Cleared Mallee / Arable Land	10 mm/a
Blanchetown Clay Aquitard (With a perched watertable on top and a vertical permeability in the range 1 to 5×10^{-9} m/s)	30 to 160 mm/a
Irrigation Drainage	300 to 600 mm/a
Disposal Basin Leakage	<<100 mm/a over good Blanchetown Clay <500 mm/a for a gradient controlled “leaky” design

4.2 WHAT DO THESE FIGURES IMPLY?

a. That irrigation recharge is several thousands of times greater than that beneath native mallee.

b. That irrigation recharge is 30 to 60 times greater than that beneath cleared mallee / arable land.

c. That the Blanchetown Clay is "transparent" to recharge beneath native mallee and arable land, and so no perched watertable will form beneath these areas.

d. That the Blanchetown Clay has a lower vertical hydraulic conductivity than typical irrigation recharge rates and therefore a perched watertable will always form on the clay beneath irrigation.

e. That the recharge rate beneath Blanchetown Clay with irrigation above is still several times greater than that beneath cleared mallee.

f. That disposal basins have a similar recharge rate to irrigation areas.

4.3 WHAT ARE THE IMPACTS OF MALLEE CLEARANCE AND CAN THEY BE MITIGATED?

a. Both Barnett and Goode have shown that mallee clearance recharge rates will, in a century or so, bring the regional watertable beneath the mallee to the surface in many new areas, and will cause a several-fold increase in saline groundwater inflows to the River Murray. This will render the quality of water in much of the SA reach of the River Murray unsuitable for irrigation even if the quality does not continue to deteriorate as it comes over the border.

b. Because of the one-hundredfold increase in recharge when mallee is cleared, revegetation of only a portion of the mallee will not significantly change the outcome discussed above. It would be a futile and expensive gesture.

4.4 WHAT ARE THE IMPACTS OF IRRIGATION DRAINAGE AND CAN THEY BE MITIGATED?

a. The impacts of recharge from irrigation are similar to, but much worse than those caused by mallee clearance. This is because of the very much higher rate of recharge beneath irrigation compared to cleared mallee (eg 30 to 60 times). If, as discussed in 3(b) above, revegetation of only part of the mallee is futile without irrigation then it would make even less sense if there any irrigation is present in the area. It is common knowledge (by observation) that irrigation on high ground above the Blanchetown Clay or similar aquitard creates a perched watertable that cuts the surface within ten years or so. (This is totally predictable - 500 mm/a draining into a soil with a porosity of 50% will fill it up at a rate of 1 m/a, so if it is ten metres down to the perching aquitard then it will take ten years to hit the surface - no magic in that calculation!) This causes problems for the irrigator, drowning and salinisation of adjacent land, cliff seepage and collapse etc. The irrigator’s problems have traditionally been controlled by installing drainage bores. But these simply transfer the impacts to the regional aquifer (see below), and are usually only temporary – ultimately requiring the installation of a comprehensive drainage system and some form of "permanent" disposal.

b. It is also a matter of observation that irrigation drainage entering the regional aquifer beneath highland irrigation areas in SA (either directly of via drainage bores) will "fill" these aquifers to the surface within 30 to 60 years. This leads to well known problems of high watertables for the irrigator, degradation of the floodplain fronting the irrigation area and salt displacement into the river. Mitigation involves CDS installation, interception works and some form of permanent disposal.

4.5 "SUSTAINABLE" IRRIGATION IN SA

It is clear that truly sustainable irrigation along the River Murray in SA is not possible:

a) The quality of River Murray water entering SA, and its further degradation within SA due to mallee clearance and irrigation drainage impacts, will render it unusable without costly treatment.

b) The impacts on the river and parts of the floodplain may become no longer acceptable to the community.

c) If the irrigator were required to pay his own pollution mitigation costs, rather than "externalising" them onto the wider community as at present, then this could make much irrigation uneconomic.

d) We have just about run out of cheap and acceptable sites for disposal basins, yet more and more current irrigation areas will soon require them.

e) The current disposal basins all have limited lives - say 50 to 100 years.

f) As the river water quality drops, the fraction of the applied water going to drainage must increase to maintain the root-zone soil water salinity within the tolerance of the crop. This will increase drainage volumes, impacts and disposal costs.

4.6 ZONING OF THE RIVER FOR MEDIUM-TERM SUSTAINABILITY

With considerable effort and cost, and the tightening of water allocation/transfer policies, irrigation drainage problems might be able to be controlled sufficiently to ensure that irrigation from the River Murray in SA can be sustained for some decades. There are no truly "safe" areas for irrigation in SA, but some ideas to minimise irrigation drainage and its impacts are given below.

a. Prohibit all ribbon development of irrigation areas.

b. Ensure that all irrigation allocations/transfer licences include proper plans for the minimisation, control and disposal of drainage.

c. Retirement of irrigation in locations where the problems far outweigh the benefits. (Non-food crops such as wine grapes should go first - alcohol can be produced quite satisfactorily from dry land crops!)

d. Consolidation of irrigation - to areas where drainage problems for the irrigator, the river and the environment can be controlled at reasonable cost. (Eg away from the river, "behind" existing irrigation areas, and where there is a suitable disposal site/system.)

This “Technical Note” was prepared by Ed Collingham, 12/11/2003
(Ex Principal Engineer Geotechnical)

Section 5: Irrigation – Sustainability & Salt Balance

The sustainability of irrigation salt balance aspects

With Particular Reference to the Hydrogeology of the Willunga Basin and Aldinga Scrub in South Australia

First Prepared January 1996 – Edited March 2002

5.1 THE GENERAL REQUIREMENT FOR FLUSHING THE ROOT ZONE

For an irrigation system to be sustainable it is necessary that the salt added to the soil with the irrigation water is removed frequently and permanently from the root zone.

The salt is removed by ensuring that some water, in addition to that demanded by the crop and surface evaporation, is allowed to pass down through, and then away from, the root zone. This water is generally referred to as the "leaching fraction". It may come from either irrigation or natural rainfall.

The amount of water required for leaching will depend mainly on the soil, the crop, the rainfall, and the salinity of the irrigation water, as well as the way the irrigation water is applied and the timing of irrigation and rainfall events. In the very simplest terms however, the leaching fraction needs to be about the same as the ratio between the salinity of the irrigation water and the root zone salinity tolerance of the crop. For example, if the irrigation water has a salinity of 1 000 mg/L and the root zone salinity tolerance of the crop is 3 000 mg/L then the leaching fraction needs to be about 30% of the applied irrigation water. Ie for an irrigation application of 1 500 mm/a the water required for leaching is 500 mm/a.

That the leaching water is able to drain away from the root zone is crucial.

On ***favourable sites*** "natural deep drainage" suffices to remove the leaching water from the root zone. For this to be the case, the vertical permeability of the deeper soil profile must be high enough that water can pass relatively freely down to the regional groundwater aquifers. The regional groundwater aquifers in turn must have sufficient transmissivity to carry the water away laterally to wherever they ultimately discharge (such as the sea).

On ***unfavourable sites*** the deeper soil profile is not sufficiently permeable and/or the regional groundwater aquifers are not sufficiently transmissive to remove the leaching water from the root zone. On some unfavourable sites it may be feasible to overcome this drawback by installing engineered sub-surface drainage systems.

5.2 PERMEABILITY VS ANNUAL DRAINAGE POTENTIAL

The rate at which an aquitard will let water pass down through it (usually expressed in millimetres per year) is equal to the vertical permeability of the aquitard material "k_v" (usually expressed in metres per second), multiplied by the hydraulic gradient across the aquitard "i" (metres per metre or "dimensionless").

Note that "i" is the hydraulic head difference between the top and the bottom of the aquitard (h) divided by the thickness of the aquitard (t).

This is illustrated below for the specific case where there is perched groundwater being held up by an aquitard some way down below the ground surface, and where the regional watertable is in another aquifer some way below the aquitard.

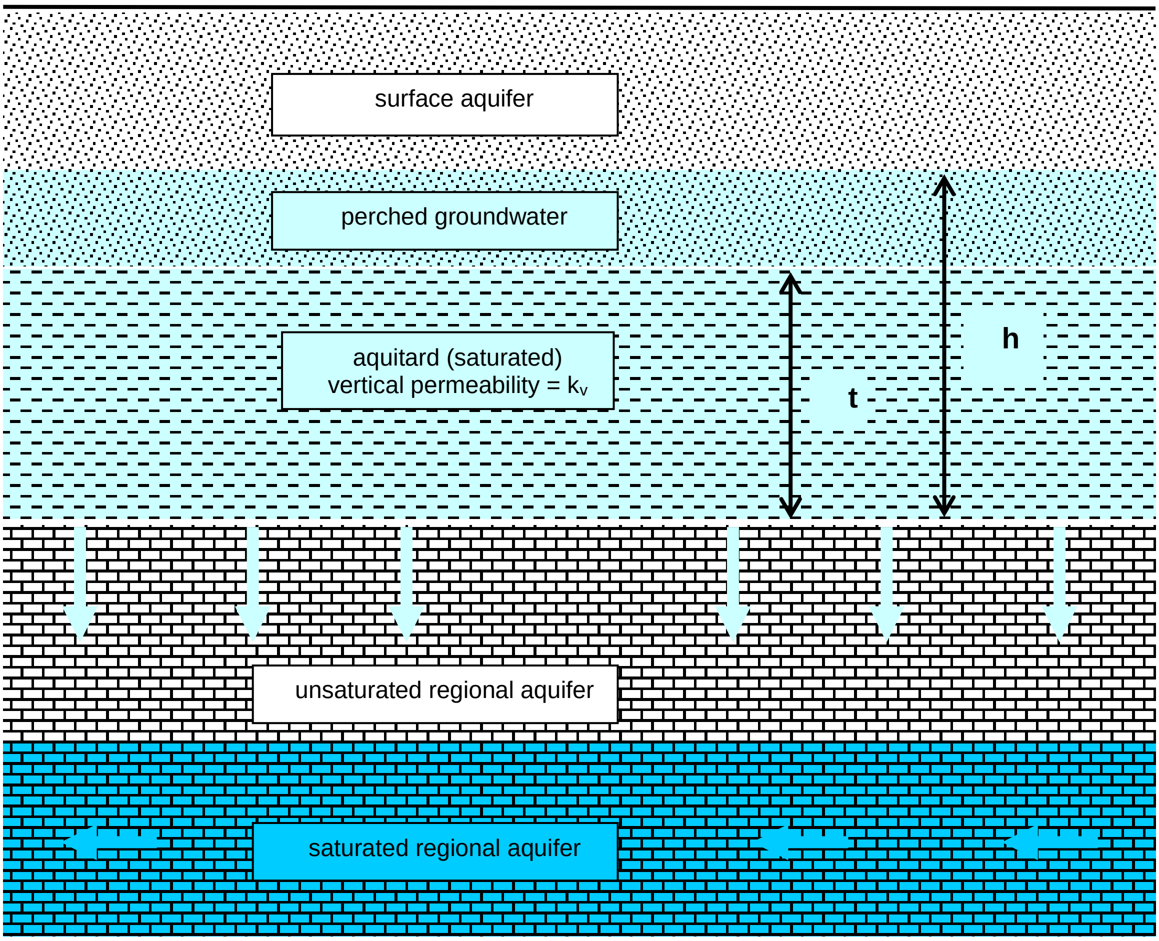


Figure 5.1 Permeability and Drainage Potential

The downward leakage through the aquitard = k_v x h/t

Note that for the particular case where the aquitard extends to the ground surface (as in much of the Willunga Basin) h/t is equal to 1, because there is no possibility of building up a “driving head” on top of the aquitard. In this case the maximum downward leakage rate is equal to the vertical permeability.

5.3 DEEP DRAINAGE IN THE WILLUNGA BASIN

A high percentage of the area of the Willunga Basin may be considered ***unfavourable*** as far as natural deep drainage is concerned, due to the presence beneath the area of the clays of the Hindmarsh Formation, which form a very effective aquitard.

The clays are up to 15 m thick, and are typically grey with a red-brown mottle, stiff to very stiff, and have no visible structure at depth other than slickensides. They display a very low permeability in laboratory-scale samples (of the order of 1×10^{-11} m/s or 0.2 mm/a). The recommended design range for their vertical permeability on the larger scale in the field is 5 to 50 mm/a, with a most likely value being about 20 mm/a. (Reference 1.)

The clays of the Hindmarsh Formation are geologically contemporary with and similar in properties to those of the Blanchetown Clay Formation in the Murray-Darling Basin. The Blanchetown Clay is the aquitard that leads to the perched groundwater mounds and associated “drainage problems” in most of the Riverland irrigation areas. Fortunately, in the Riverland the clay is usually covered by some 10 m of sandy soils in which it is possible to install effective drainage systems.

Unfortunately, over much of the Willunga Basin the clays extend up to the ground surface. This means that the maximum rate of downward leakage is limited to the large-scale vertical permeability of the aquitard (ie 5 to 50 mm/a) – which is well below the 500 mm/a required for effective leaching in the scenario outlined in Section 1. Also it would be technically difficult, and possibly economically unfeasible, to install effective subsoil drainage in areas where the clay extends up to the ground surface because of the low lateral permeability of the clay.

It can therefore be appreciated that even if the available downward leakage through the clays of the Hindmarsh Formation in the Willunga Basin were close to the upper bound value of 50 mm/a, irrigation applications with treated wastewater would still need to be frugal and managed extremely carefully to ensure no long term build up of salt in the root zone.

If the lower bound value of 5 mm/a applies (and if it was not technically and/or economically feasible to install subsurface drainage) then it would probably not be possible to sustain irrigation using treated wastewater in much of the Willunga Basin.

REFERENCES

1. Report: "Aldinga Waste Water Treatment Plant - Summary Report on the Geotechnical and Hydrogeological Aspects of a Potential Treatment Plant Site and Irrigated Vine Effluent Disposal Area on Sections 426, 432 and 438 at Aldinga", docket EWS 2695/94, EB Collingham, Principal Engineer Geotechnical, July 1994.

This “Technical Note” was prepared by Ed Collingham, 18/03/2002
(Ex Principal Engineer Geotechnical)

Section 6: Vacuum Assisted Tube Well and Water Levels

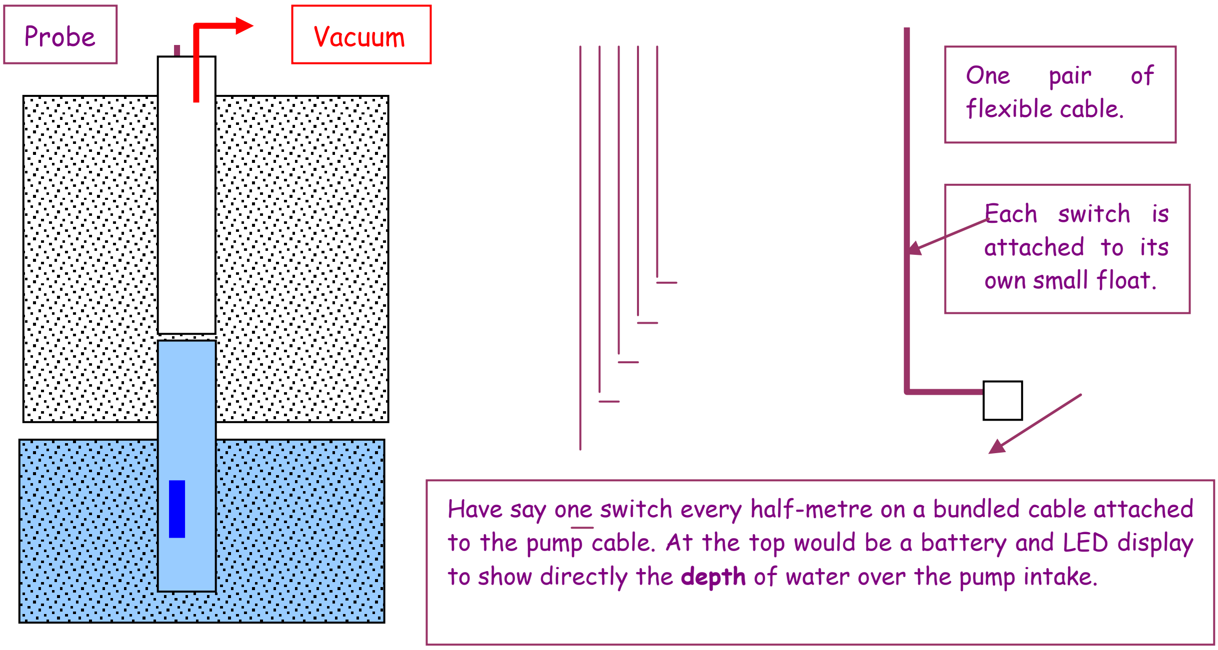
This “Technical Note” was prepared by Ed Collingham, 12/06/2003
(Ex Principal Engineer Geotechnical)

Glass encapsulated 125V 3 amp AC.
SPST.
Size glass 18(L)mm x 5.5mm dia.

	Qty 1+	Qty 10+	Qty 25+
Cat. SM-1035	$2.80	$2.45	$2.15

Figure 6.1 - Illustration of Mercury Switch

A pressure transducer or obs tube would not directly indicate the level of the water surface in a vacuum assisted well. It would also be necessary to measure the vacuum and do a calculation. Suggest instead using a probe consisting of a string of mercury switches each with its own little float. A mercury switch simply works by the mercury shorting two contacts when the switch is tilted. The contacts and mercury are sealed in an evacuated glass tube, so the whole string could be made robust and watertight. **This probe could also be used to control the pump to get maximum yield without risking dry-running.**

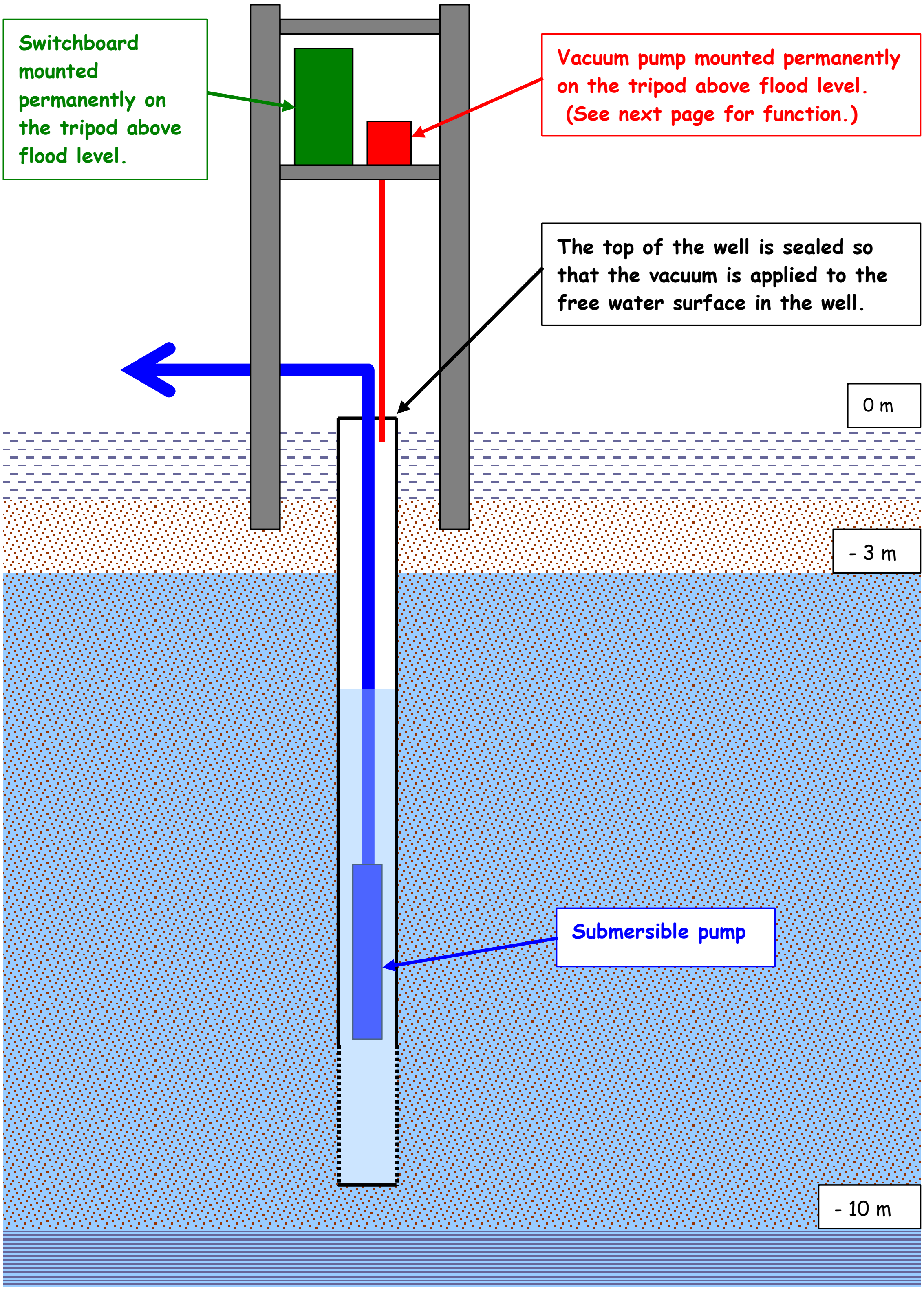


One pair of flexible cable.

Each switch is attached to its own small float.

Have say one switch every half-metre on a bundled cable attached to the pump cable. At the top would be a battery and LED display to show directly the **depth** of water over the pump intake.

Figure 6.2 - Illustration of Probe with Multiple Mercury Switches


Switchboard mounted permanently on the tripod above flood level.

Vacuum pump mounted permanently on the tripod above flood level. (See next page for function.)

The top of the well is sealed so that the vacuum is applied to the free water surface in the well.

Submersible pump

A Discussion of the Use of Tubewells on the River Murray Floodplain including:

- **Vacuum Assist to Increase Well Yield**
- **Tripod Tower Mounting of Electrical Gear for Flood Immunity**

Figure 6.3 - Illustration of Vacuum Pump Arrangement

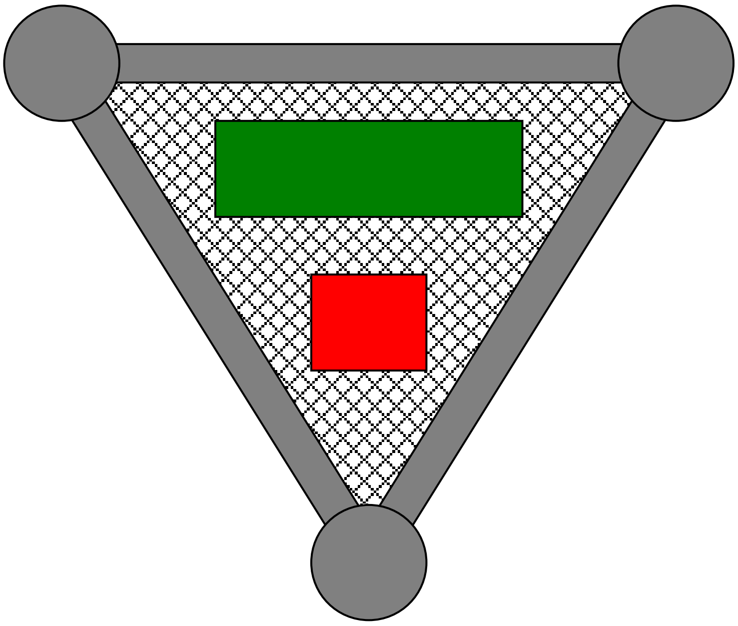


Figure 6.4 - Plan view of the tripod tower showing the suggested layout of the switchboard and the vacuum pump

When is Vacuum Assist Desirable and how does it Work?

Where the watertable is within a few metres of the ground surface (such as beneath the River Murray Floodplain) it is possible to extract groundwater using **either** a vacuum wellpoint (typically with a surface pump) **or** a tubewell (typically with a submersible pump in the well).

The main factor limiting the flow that can be extracted from a **wellpoint** (apart from aquifer properties) is the difference between the depth to the watertable from the pump and the suction capability of the pumping system. For example, if the depth to the watertable is 3 m and the available suction head is 7 m, then the **net suction head** on the aquifer is 4 m. Fortunately, wellpoints are cheap to install and so several can be connected to one pump to compensate for low individual yield. For this reason, and because wellpoints also work well in thin and variable aquifers, a floodplain interception scheme based on wellpoints will normally be far cheaper and more effective than one based on any other pumping system.

The main factor limiting the flow that can be extracted from a **tubewell** is the difference between the depth to the watertable and the depth to the pump intake. For example, if the well is 10 m deep (because the base of the aquifer is only 10 m down), the watertable is 3 m below the surface, the lowest position for the pump intake is 2 m above the bottom of the well, and the pump needs a 2-metre positive head on its suction, then the maximum available drawdown in the well is only about 3 m. This means that it would only yield about the same flow as the wellpoint in the example above. But if, for example, a 60 kPa vacuum is applied to the top of the tubewell, the well screen will experience an additional 6 metres of suction head (for the same water level in the well), which should triple the yield.

If the aquifer could not sustain triple the yield from the one spot (because the watertable drawdown was too high), then several wellpoint spears could be connected into the vacuum-assisted pumped tubewell to give a hybrid tubewell/wellpoint arrangement.

Section 7: Types of Wells

The most appropriate and economical type of well for extracting groundwater depends on (a) the depth to the aquifer, (b) the thickness of the aquifer, (c) the depth to the watertable (confined or phreatic) and (d) the required yield.

Where the watertable is deep (>20 m say), there would be little choice but to use a conventional drilled bore with a submersible or line-shaft pump in the bore. Most water bores fall into this category.

Where the watertable is shallow (< 6 m), there would be the opportunity to use a vacuum pumping system – with a single centrifugal pump at ground level drawing water from a group of simple, small-diameter wellpoints. Such an arrangement is typically used for construction dewatering. Permanent installations are used for groundwater control in, for example, the Mildura Irrigation Area and also the Rufus River Salt Interception Scheme at Lake Victoria.

Where the watertable is very shallow (less than say 2 m), extremely simple surface trenches can be used - as is done by SA Water in the Polda Basin on the Eyre Peninsula.

Arrangements such as the “Horizontal Water Collector” would be only be technically appropriate and competitive on cost where the watertable was too deep for wellpoints and the aquifer too thin or poor yielding (low permeability) for conventional bores. Also the aquifer must not be too deep to caisson down to (between say 5 m and 15 m).

As a technology, the collection of groundwater using horizontal screens is well established. The “Horizontal Water Collector” is, in effect, the same as the many hundreds of “drainage caissons” used in the irrigation areas along River Murray. In these, a local network of agricultural drains feeds into a concrete caisson from which the groundwater is pumped to final disposal.

Other than in the River Murray Irrigation Areas, to my knowledge similar horizontal gravity-drained bore arrangements have mostly been used in alluvial aquifers alongside rivers in which the water quality or the seasonal variation in flow are such as to render direct extraction from the river unattractive. The alluvium acts both as a filter for the river water (which is in effect “pulled through” the alluvium by the well), and also as a reservoir when the river is low.

Where caisson based systems can be used, they do have the advantage of being “low tech” once installed. Flow into the caisson from the laterals is by gravity. The pumps are simple and accessible. The large volume of the caisson provides a buffer storage allowing peak pumping rates to be greater than average inflow (although it could be argued that it would be cheaper to build a surface storage of the same volume as the caisson). The

large screen area and low hydraulic gradients across the screens reduces the risk of both clogging and passage of fines.

However, the claim in the brochure that the drawdown in the aquifer is less than with other extraction techniques is overstated (one diagram shows the watertable sloping *up* to the water level in the caisson). While the drawdown in the caisson itself is low, and while the *local* drawdown in the aquifer close to the caisson might be less than with some other extraction systems, the regional drawdown in the aquifer is a function of the overall extraction rate and the aquifer parameters, and will not change with different extraction systems.

Also overstated is the claim that such as system promises “abundant water”. The maximum yield from an aquifer in any given location is a limited by the aquifer parameters. Any appropriate extraction system could be designed to extract this amount.

7.1 SUMMARY

a. The gathering of water from horizontal screens is neither a new or unique technology. The “horizontal water collector” system promoted in the brochure is simply a packaged application of established techniques.

b. It would not always be either feasible or appropriate to use such a system. Each site would need to be assessed to determine which water extraction technique would be best.

c. Where it is feasible and appropriate to use a “horizontal water collector” system, it does bring with it some specific benefits.

Please contact Ed Collingham if you would like further discussion on this response, or would like me to take the research further.

This “Technical Note” was prepared by Ed Collingham, 21/01/1999
(Ex Principal Engineer Geotechnical)