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Pump testing a confined coastal aquifer near Lady Barron, Flinders Island.

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Abstract

The unconsolidated coastal aquifer near Lady Barron on Flinders Island is confined by a partly cemented iron-stained B soil horizon. Analysis of drawdowns in seven observation bores monitoring a fourteen day pump test showed that *T* is in the range 68 - 105 m^2/day, *S* is probably about 5 x 10^{-3}, and that the data needed to be corrected for barometric fluctuations. The barometric efficiency of the aquifer is about 0.50. The existing array of bores will easily supply the township with 230 m^3/day, and although the aquifer's water balance is unknown, its reserves are probably sufficient to yield the required 23 000 m^3/year. The water will be objectionable in its raw state and will need to be treated.

INTRODUCTION

Following a request from the Rivers and Water Supply Commission, a regional groundwater investigation was made near Lady Barron (fig. 1) on Flinders Island towards the aim of eventually supplying the town's fifty houses and two factories with a reticulated groundwater supply. The survey included drilling and short pump testing of small-diameter bores, and in his subsequent report Matthews (1978) concluded that enough water was probably present in unconsolidated deposits north-west of Lady Barron, but that reserves should be more fully investigated by longer pump tests. The water quality is comparable to that used at Whitemark, but can be improved with treatment. The report also suggested long-term monitoring of water levels in the aquifer.

This report describes the results of a fourteen day pump test conducted on two of a group of four closely spaced bores [FR048494] installed and briefly tested by Matthews. The pair was pumped at an average rate of 155 m^3/day (108 *l*/min). Drawdowns were measured to the nearest millimetre in each of seven observation bores. Daily water samples were collected for chemical analysis and two bacterial analyses were made. In the plan of the test site (fig. 2) bore numbers correspond to those in Matthews (1978).

GEOLOGY

The lithology of the aquifer, based on over twenty drilled holes, is fairly constant over its outcrop area; about 10 m of brown coarse-medium grained quartz sand overlies grey clay believed to be weathered basalt. Near and east of the test site, the upper one or two metres of sand has been partly cemented with iron oxides and stained with humic material. This relatively impermeable layer is probably a strongly developed B soil horizon; west of the test site, however, the hardpan is replaced by clay. It is not certain whether this represents a facies change or is due to a topographic high in the weathered basalt basement.

RESULTS AND IMPLICATIONS OF THE PUMP TEST

Correcting drawdown readings for atmospheric and pumping rate fluctuations

Four observations indicate the aquifer is either confined or semi-confined:

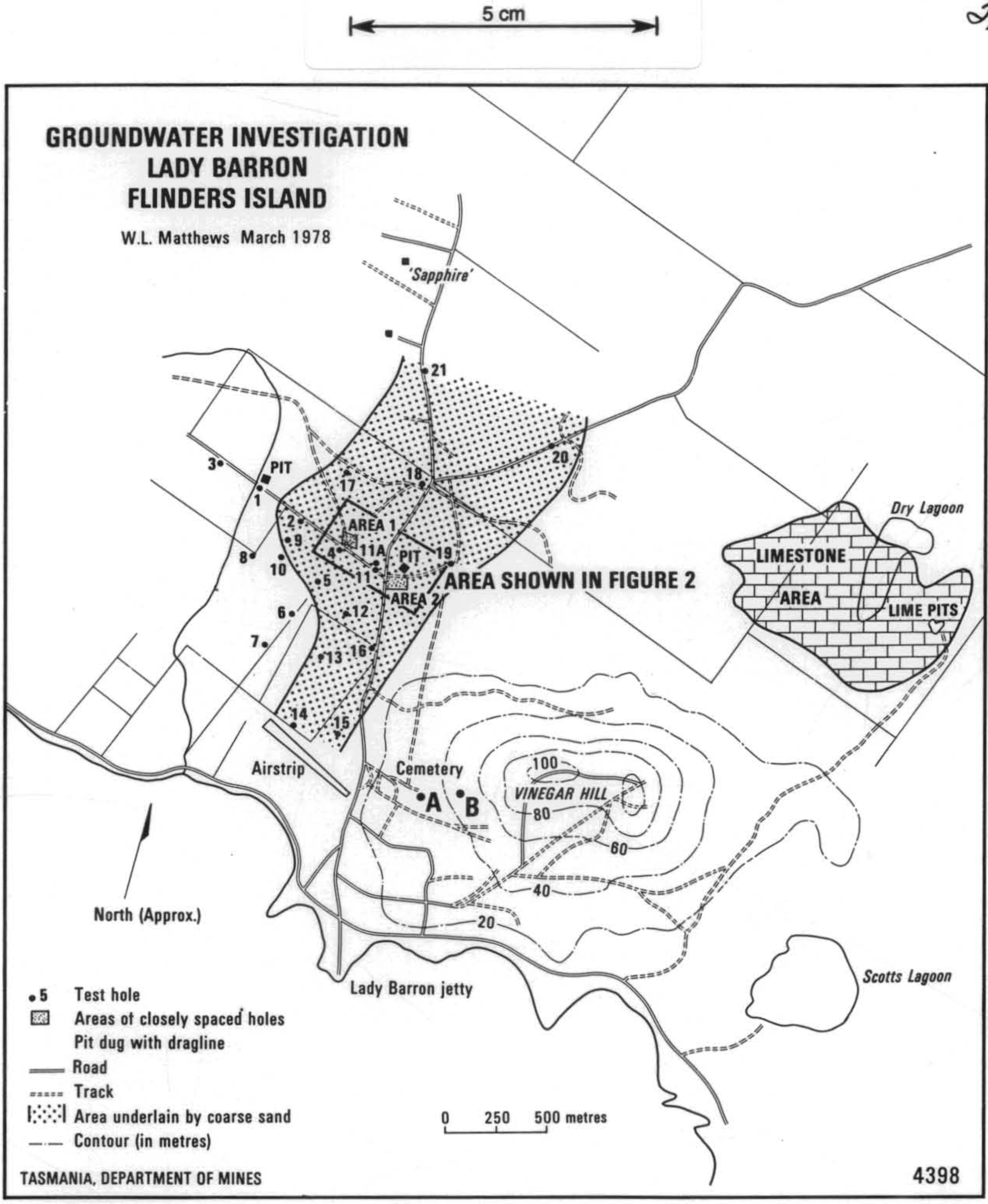


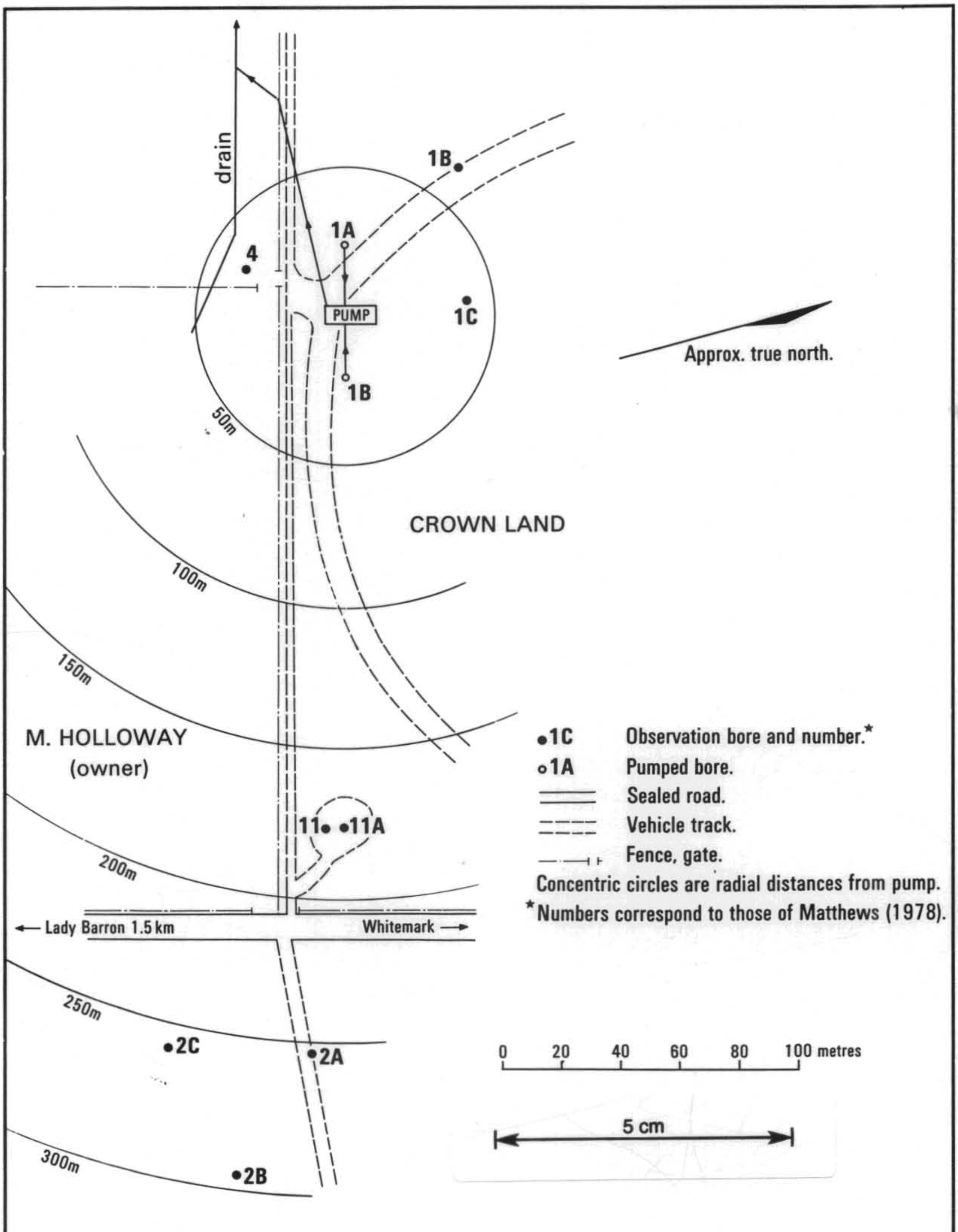
Figure 1.

(a) the partly cemented iron-stained upper zone is relatively impermeable and locally supports perched water tables

(b) drawdowns in all observation bores affected by pumping stabilised or tended towards equilibrium during the test

(c) the cone of depression expanded rapidly when pumping started; for example, bores 1B and 1C were affected almost instantaneously

(d) marked fluctuations in drawdown unrelated to changes in pumping rate bear a strong relationship to barometric changes (fig. 3) recorded on a continuous barograph at Pats River. Unconfined aquifers do not respond to atmospheric changes. Some of these effects are shown in the drawdown *vs* time graphs (fig. 4).



LOCATION OF PUMPED AND OBSERVATION BORES

Figure 2

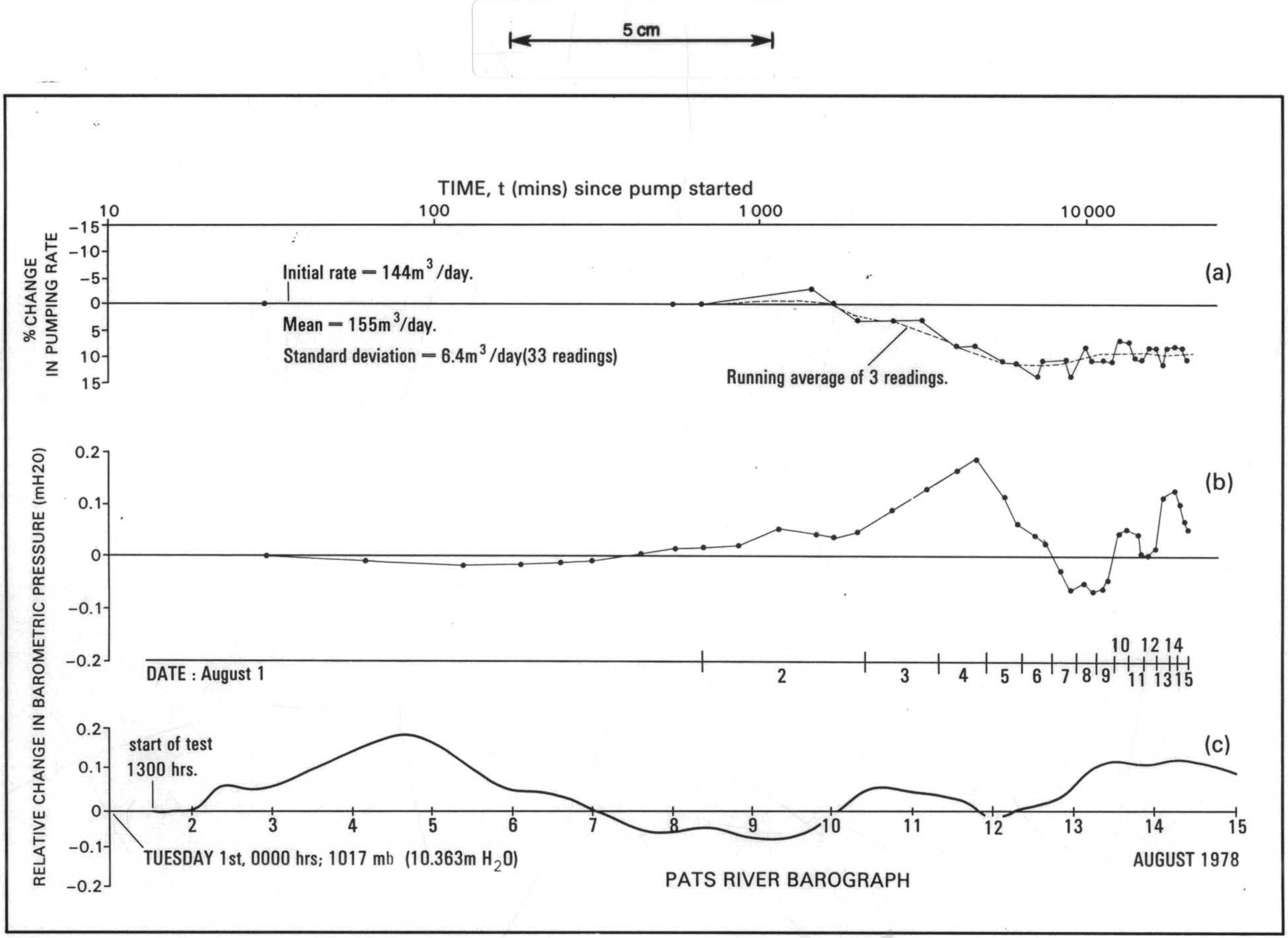

5 cm
TIME, t (mins) since pump started
10
100
1 000
10 000
% CHANGE IN PUMPING RATE
-15
-10
-5
0
5
10
15
Initial rate = 144m^3/day.
Mean = 155m^3/day.
Standard deviation = 6.4m^3/day(33 readings)
Running average of 3 readings.
(a)
RELATIVE CHANGE IN BAROMETRIC PRESSURE (mH20)
0.2
0.1
0
-0.1
-0.2
(b)
DATE : August 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
(c)
start of test
1300 hrs.
TUESDAY 1st, 0000 hrs; 1017 mb (10.363m H_2O)
AUGUST 1978
PATS RIVER BAROGRAPH

Figure 3

An increase in atmospheric pressure causes a corresponding decrease in water level (*i.e.* increase in drawdown) in an observation bore penetrating a confined aquifer. These fluctuations should be removed before analysing the results. Cromer (1978) has discussed correcting for barometric and other changes in confined aquifers. By plotting observed change in water level, Δh (= $-\Delta s$, where s is drawdown) against Δp, the corresponding change in pressure, both expressed in m H_2O, the barometric efficiency (BE) of the aquifer can be determined

$$BE = -\Delta h/\Delta p$$

which is the (negative) slope of the straight line of best fit through the points and is a measure of the aquifer's competency to reflect atmospheric pressure changes. BE for the Lady Barron aquifer is about 0.5, so that only half of the pressure change (expressed in m H_2O) is displayed in water level fluctuations in a bore. The fluctuations are then readily removed from drawdown readings by subtracting from any drawdown an amount ($\Delta p \cdot BE$), where Δp is the relative pressure difference at the time the drawdown reading was made. ($\Delta p \cdot BE$) may be positive or negative.

An increase or decrease in the pumping rate (Q) in a bore penetrating a confined aquifer produces respectively a linear increase or decrease in observed drawdown ($s_{obs.}$). Each drawdown reading is then corrected by a reduction of ($\Delta Q/Q_o$) $s_{obs.}$, where $\Delta Q = Q_o - Q_t$ is the difference between the initial rate and that at any time t.

The combined drawdown adjustment for both atmospheric and pumping rate changes is

$$s_{corr.} = [s_{obs.} - \Delta p \cdot BE][1 - \Delta Q/Q_o]$$

and Figure 5 shows graphically such a stepwise correction for bore 11. The curve in Figure 5(c) is more readily amenable to standard aquifer analysis. The effect of the barometric correction is to smooth out the graph; the rate correction tends to shift the curve vertically along the drawdown axis without obviously changing its shape. All the graphs shown in Figure 4 have been corrected for both effects, but it is apparent that other influences are still causing fluctuations in drawdown. There are two noteworthy aspects of the curves:

(a) drawdown in 1B, 1C and to a lesser extent 11 and 11A are stabilising and probably approaching equilibrium and

(b) there is a marked rise in water level (*i.e.* a negative drawdown) in 2A, 2B and to a lesser extent 1B, 1C, 11 and 11A, towards the end of the test.

The first of these effects indicates that continued pumping will probably produce a negligible change in drawdown in the system and the second may be partly accounted for by a regional rise in water levels. Ideally such a variation should be continuously monitored in a bore isolated from the influence of pumping, and drawdowns already adjusted for other influences should be further corrected to account for it. Since drawdowns were measured relative to the bore casing, another explanation for the rise in water level in 2A and 2B may also account for the almost instantaneous and marked increase in observed drawdown for 2B at about 7400 minutes; changes in atmospheric or artesian pressure may have caused the plastic casing to rise vertically in the hole (producing an apparent drawdown increase) and the subsequent slow sinking of the casing could explain the gradual apparent

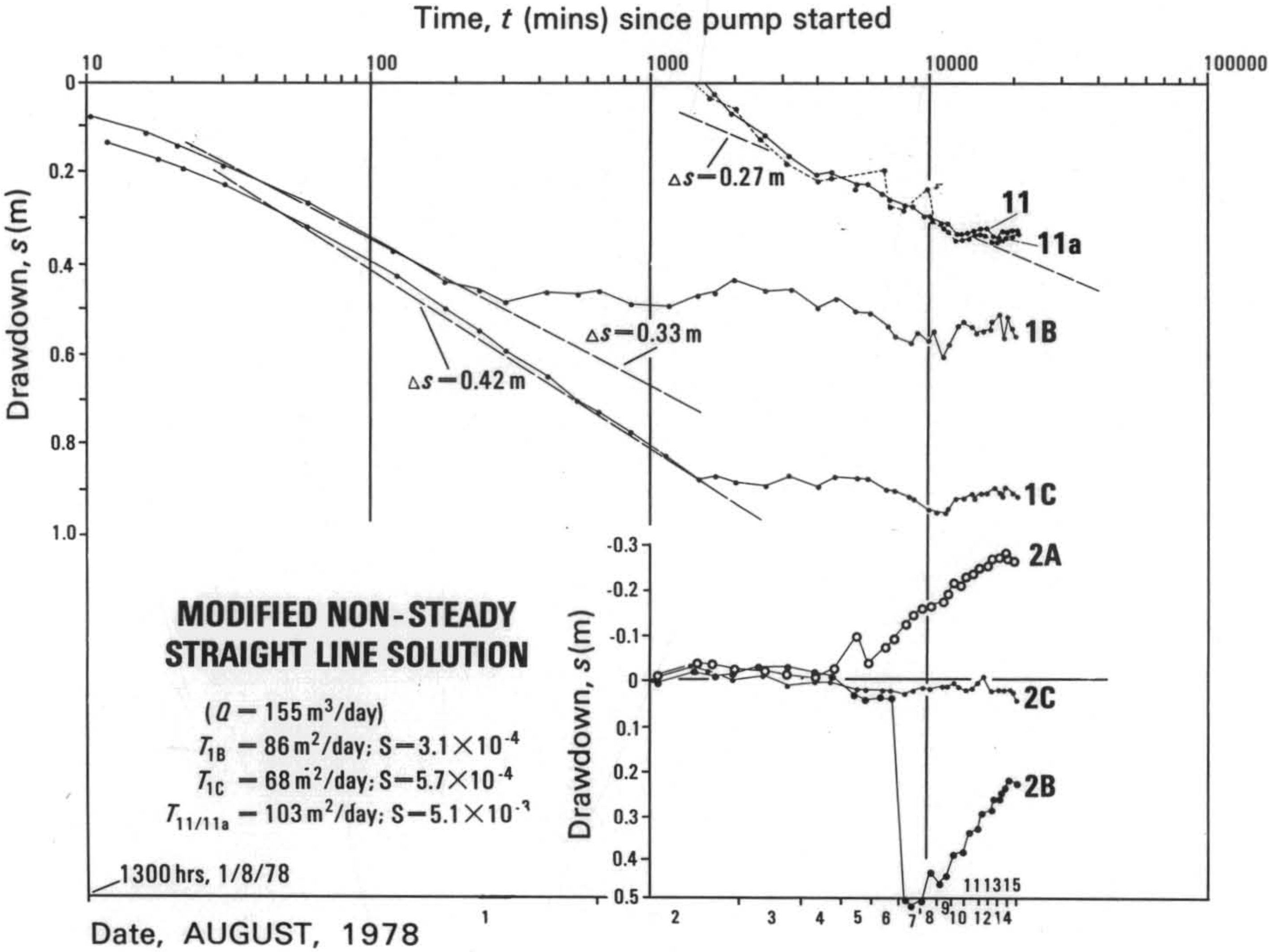

Time, t (mins) since pump started
10
100
1000
10000
100000
Drawdown, s (m)
0
0.2
0.4
0.6
0.8
1.0
Δs = 0.27 m
Δs = 0.33 m
Δs = 0.42 m
11
11a
1B
1C
2A
2C
2B
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
MODIFIED NON-STEADY STRAIGHT LINE SOLUTION
(Q = 155 m³/day)
T1B = 86 m²/day; S = 3.1×10⁻⁴
T1C = 68 m²/day; S = 5.7×10⁻⁴
T11/11a = 103 m²/day; S = 5.1×10⁻³
1300 hrs, 1/8/78
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Date, AUGUST, 1978

Figure 4

5 cm

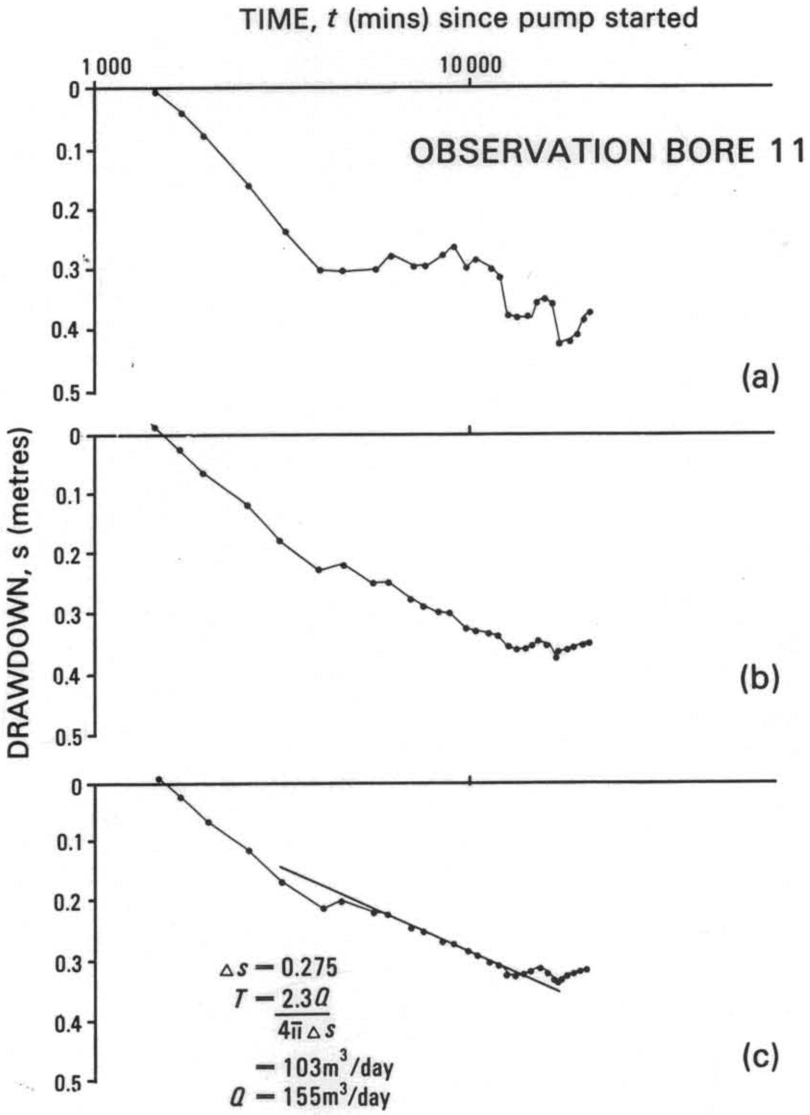

TIME, t (mins) since pump started
1 000
10 000
0
0.1
0.2
0.3
0.4
0.5
OBSERVATION BORE 11
(a)
DRAWDOWN, s (metres)
(b)
(c)
△s = 0.275
T = 2.3Q / 4π△s
= 103m³/day
Q = 155m³/day

Figure 5


5 cm

rise in water level. The graph for 2C is unaffected by these influences and it's almost constant water level indicates that both it and 2A and 2B lie outside the radius of influence of the pumped bores.

Transmissivity and storage co-efficient

Using the modified non-steady state equations applied to straight lines in Figure 4, transmissivity (*T*) ranges from 68 to 105 m^2/day [Matthews (1978) obtained a range of 36 to 55 m^2/day in a short pump test on bores 11 and 11A] and the storage coefficient (*S*) lies in the range 0.3 - 5.1 x 10^{-3}. Using the modified Hantush method (Lohman, 1972) which accounts for any vertical leakage from confining beds, values of *T* were 73 and 95 m^2/day and *S* was 2.3 - 7 x 10^{-3}. The higher values of *T* are probably more accurate and despite their wide range the values for *S* are typically those of a confined or slightly leaky aquifer.

T defines the rate at which water flows under unit gradient through a vertical strip of aquifer of unit width and extending its full saturated thickness; at Lady Barron the calculated value is somewhat lower than expected considering the coarse grained nature of the aquifer. Since the bores are not screened (they allow water through slotted plastic casing) but are nevertheless relatively high yielding, they are probably quite efficient.

Storage coefficient describes the volume of water an aquifer will discharge from, or take into, storage per unit surface area per unit change in head. As such, it defines the rate of lowering of the piezometric level in the aquifer, which is affected not only by pumping but by natural discharge and recharge. It should be the aim of any groundwater programme to reduce as much as possible the decline in piezometric head caused by pumping. The head in the Lady Barron aquifer is relatively small, standing only a metre or so above the base of the confining layer. It is possible that in dry periods, extensive pumping may reduce the head below the confining layer throughout the aquifer. Once this occurs and the combined cone of depression of the pumped bores intersects the recharge area of the aquifer, then the system will behave as an unconfined aquifer and gravity drainage of material will occur. (This is in contrast to thick extensive confined aquifers, where generally the pore spaces in the aquifer are saturated at all times). It is therefore difficult to estimate either the safe yield or reserve of the aquifer; in a confined situation the storage coefficient (probably about 10^{-3}) indicates the available volume of water. Once the material is drained, the specific yield* (unknown, but probably about 0.2 - 0.25) should be used in calculations. [For example, over a known outcrop area of at least 2 km^2, pumping of 2000 m^3 of water will lower the piezometric head one metre. If the cone of depression intersects the unconfined recharge area of the aquifer, gravity drainage will occur. With an average saturated depth of about 6 - 7 m and a specific yield of about 0.2, the aquifer contains at least (2 x 10^6)(6)(0.2) = 2.4 x 10^6 m^3 of recoverable water. Not all of this is usable with the present bores since they do not fully penetrate the aquifer and in any case, it would be undesirable to drain the aquifer to that extent]. Nevertheless, in view of the modest water needs of Lady Barron (about 23000 m^3/year with a daily peak of 230 m^3) it is obvious that the aquifer contains enough water to justify installation of a permanent groundwater supply. The fourteen day pump test established that the existing bore arrays are capable of supplying the required yield for long periods without excessive drawdowns.

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* The specific yield is the volume of water released by gravity drainage from an aquifer, compared to the total volume of the aquifer.

Table 1. ANALYSIS OF WATER SAMPLES, LADY BARRON PUMP TEST SITE

Bore Reg. No.	1 2A 773124	2 1A 773122	3 (1A + 1D) 782800	4 (1A + 1D) 782806	5 (1A + 1D) 782811
pH	6.6	6.0	4.5	5.0	5.0
Cond. (μS/cm at 25°C)	880	840	520	560	550
	(mg/*l*)	(mg/*l*)	(mg/*l*)	(mg/*l*)	(mg/*l*)
CO_3	nil	nil	nil	nil	nil
HCO_3	44	8.5	nil	7.4	6.7
Cl	200	180	150	170	170
SO_4	15	14	13	7.0	7.2
SiO_2	13	16	9	13	14
Ca	12	4	2.8	3.9	4.1
Mg	13	13	12	12	12
Fe	0.8	0.7	0.5	0.5	0.7
Al	0.8	0.3	0.7	0.2	0.2
K	3.3	2.5	2.5	2.5	2.5
Na	110	100	76	82	83
TDS	470	380	360	370	380
Hardness - permanent	53	59	61	55	57
- temporary	36	7.0	nil	6.0	5.5
Alkalinity (as $CaCO_3$)	36	7.0	nil	6.0	5.5
colour	230	20	90	50	50
turbidity	<5	<5	<5	<5	<5

1 and 2 from Matthews (1978)
3 Pump test, 1 August 1978, bores 1A and 1D pumped together
4 Pump test, 7 August 1978, bores 1A and 1D pumped together
5 Pump test, 12 August 1978, bores 1A and 1D pumped together

As Matthews (1978) suggested, a better understanding of the water balance in the aquifer will enable more accurate predictions of the effects of long term pumping. Rainfall figures should be collected from Lady Barron and regional changes in water levels in the aquifer should be monitored continuously by automatic equipment installed in open-ended cased bores near the test site.

WATER QUALITY

Water samples were collected daily during the pump test and alternate samples were later chemically analysed. Two samples, taken on 4 August and 10 August, were collected and tested for baterial contamination.

Chemical quality

The chemical quality of the water remained essentially constant during the test and representative analyses from the start, middle and end of the test period are very similar (table 1) to those analysed by Matthews (1978) from the same locality. The major difference is the drop in pH in the later samples; apart from this, the quality has improved slightly with a fall in Na and Cl and a subsequent lowering of conductivity.

The water compares favourably with that already used at Whitemark and it can be made more acceptable by appropriate treatment. In this regard, Wellington's comments (Matthews 1978, Appendix 3) remain valid. Aeration will be necessary to remove dissolved H_2S.

Bacterial quality

Both samples, collected 2.5 and 9 days after pumping started, were analysed by the State Health Laboratory and found to be free of faecal coliforms. This suggests that the water is biologically suitable for human consumption and, in view of the length of the pump test, further contamination is unlikely. Nevertheless it will be prudent to systematically and regularly analyse water samples if the bore water is reticulated to Lady Barron.

CONCLUSIONS AND RECOMMENDATIONS

The aquifer near Lady Barron is confined, with a transmissivity in the range 68 - 105 m^2/day and a storage coefficient of about 5 x 10^{-3}. The existing bores with slotted plastic casing are relatively efficient and their replacement with stainless steel screens is not yet warranted. The present installation (bores 1A, 1B, 1C, 1D) should be used for the town supply, and together they are easily capable of continuously pumping the required amounts of water to the town.

While the aquifer seems more than large enough to provide a permanent water supply, nothing is known of the water balance in it. A knowledge of long-term recharge to, and discharge from, the system will help in planning the most efficient pumping regime and possibly better spatial distributions of bores. It is therefore suggested that the regional water table be monitored continuously and coupled with rainfall and surface runoff values to compute the water budget for the area.

The water is too acidic to be used by consumers in its raw state. It may be made more suitable by treatment to raise the pH and partly remove Fe and Al. High chlorine levels may be a problem. Bacterially, the water seems suitable for human consumption; future biological sampling and analysis should be done on a regular basis.

REFERENCES

CROMER, W.C. 1978. Correcting drawdowns for atmospheric pressure changes: an example from a semi-confined aquifer on Flinders Island. *Unpubl. Rep.Dep.Mines Tasm.* 1978/34.

LOHMAN, S.W. 1972. Groundwater hydraulics. *Prof.Pap.U.S.geol.Surv.* 708

MATTHEWS, W.L. 1978. Groundwater at Lady Barron, Flinders Island. *Unpubl. Rep.Dep.Mines Tasm.* 1978/8.

[10 October 1978]