74/81.

RECORDS

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Engineering Division

Depot

PRODUCTION TESTS OF THE UPPER KNIGHT GROUP AQUIFER
AT MOUNT GAMBIER

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and

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Department of Mines
South Australia

74/81

DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
ENGINEERING DIVISION

PRODUCTION TESTS OF THE UPPER KNIGHT GROUP AQUIFER AT MOUNT GAMBIER

by

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GEOLOGISTS
HYDROGEOLOGY SECTION

Rept.Bk.No. 74/81
G.S. No. 5400
Hyd. No. 2645
D.M. No. 299/72

25th March, 1974

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PLANS

DEPARTMENT OF MINES
SOUTH AUSTRALIA

Rept.Bk.No. 74/81
G.S. No. 5400
Hyd. No. 2645
D.M. No. 299/72

PRODUCTION TESTS OF THE UPPER KNIGHT GROUP AQUIFER AT MOUNT GAMBIER

LOCATION

General : Commercial Street West, Mount Gambier

Region : 1

County : Grey

Hundred: Blanche

Section: 364

ABSTRACT

Analyses of two pumping tests conducted on the Knight Formation water supply bore on the property of Wattie Pict Ltd. at Mt. Gambier suggest transmissivities of 1,600 metres^3/day/metre and 180 metres^3/day/metre respectively for the early and late stages of pumping. An early stage value of storage coefficient of 10^{-4} was determined from a later test which utilized an observation bore drilled for that purpose. The bore from which the determinations were made is currently being pumped intermittently at about three times the calculated safe rate.

INTRODUCTION

A 24 hour pumping test was conducted in May, 1972 on the Wattie Pict factory bore which draws its supply from the Knight Group sand aquifer, (Bowering, 1973), and which was constructed due to extreme contamination of water in the overlying Gambier Limestone water table aquifer.

Subsequently, an observation bore (BLA88) was drilled to allow an aquifer test with determination of storage coefficient, and to act as an observation bore for the upper Knight Group aquifer. The geological logs of the supply bore and observation bore BLA 88 are included in appendices A & B respectively.

An intended 72 hour aquifer test was conducted in late October, 1973 thanks to the co-operation of the factory management, but the test was terminated after 51 hours by an electrical failure. Recovery measurements were not taken immediately because the pump shutdown occurred when drawdown measurements were required only every 500 minutes, and consequently officers were not in full-time attendance. Recovery measurements for a later period of 60 hours were derived from the readings of a Lea water level recorder which was subsequently installed on the observation bore.

Water from the bore was discharged into the nearby Mt. Gambier sewerage outfall line. Figure 1 shows details of the discharge system and Figure 2 the relative locations of pumped and observation bores.

Geology and hydrogeology are summarised in Bowering (1973). Table 1 (below) summarises tests carried out to date.

TABLE 1

SUMMARY OF TESTS AT WATTIE PICT

PUMPING RATE l/sec	m^3/day	DURATION Hours	REMARKS
45	3900	24	Original test of production bore. No observation bore. (Bowering, 1973).
22	1892	50	Drawdown measured in observation bore BLA 88 only.
22	1892	60	Recovery measurements in observation bore BLA 88 obtained with Lea Recorder.

AQUIFER TEST ANALYSIS AND RESULTS

The test results were analysed in two ways, using plots of drawdown vs. log time and log drawdown vs. log time for drawdowns measured in the observation bore (ELA 88), as shown in Figures 3 and 5. Figure 6 also shows a plot of the recovery data obtained from the Lea recorder. Figure 4 shows the drawdown vs. log time plot from Bowering (1973) for the production bore.

The mathematics involved is detailed in Hazel (1973). Water salinities have not varied significantly since the bore was drilled, and a full analysis is included in Appendix C.

1. Straight Line Solution (Figures 3 and 4)

The plot of s (drawdown) vs. log t (logarithm to the base 10 of time) in the period of time from 1 to 10 minutes (Figure 3), and the values of S and T obtained, must be regarded as questionable early stage values only. The last few measurements exhibited a straight line relationship, but the mathematical assumptions for the straight line solution require that $\frac{s}{\Delta s}$ be greater than 1.75, and this requirement was not met.

One approximate straight line solution was therefore used for analysis at an early stage of pumping, where quite a good relationship was apparent.

Trnasmissivity is determined by this method by use of the formula:-

$$T = \frac{0.183Q}{\Delta s}$$

where T is transmissivity in metres^3/day/metre

Q is pumping rate in metres^3/day

Δs is the slope of the straight line per log cycle in metres.

Storage Coefficient is determined using the Zero Drawdown Intercept Method. The drawdown - log time line is extrapolated back to zero drawdown, and the time (t_o) recorded.

Then $$S = \frac{2.25Tt_0}{r^2}$$

where S is the storage coefficient (dimensionless)

T is the transmissivity (metres^3/day/metre)

t_o is the zero drawdown intercept (days)

r is the distance from the pumped bore to the observation bore (metres).

The calculations are shown on Figures 3 and 4 and the results tabulated on page 6 in Table 2.

Data in Bowering (1973) are for the pumped well only (Storage Coefficient cannot therefore be determined) and only give an early stage transmissivity. A late stage straight line relationship can be seen in the time period 500-1500 minutes on Figure 4, giving another value of transmissivity, which is also presented in Table 2.

2. Match Point Solution

The plot of log s vs. log t is shown on Figure 5. The curve is mathematically of the same form as a type curve plot of L (U, V) vs. 1 / u (Hazel, 1973).

A match point was obtained at values of s = 1.0 m,

t = 5.5 min.,

L(U,V) = W(U) = 10, $l/u = 10^2$.

Values of S and T were then calculated using the formulae

$$T = \frac{Q.W(u)}{4\ \ s} \qquad S = \frac{4Tut}{r^2}$$

where T is transmissivity in metres^3/day/metre

Q is pumping rate in metres^3/day

s is the drawdown in metres (from match point) u is dimensionless (from the match point)

t is the time in minutes (from the match point)

W(u) is dimensionless (from the match point)

r is the distance in metres from pumped bore to observation bore (52 m)

S is the storage coefficient (dimensionless)

The calculations are shown on Figure 5, values being derived from the early stage only because the plotted data deviated from the type curve after about 20 minutes pumping time. The results are shown on Table 2.

3. Recovery Method

The recovery data which is plotted on Figure 3 was interpolated from the chart of a Lea Recorder, installed while repairs were being made to the pump system. Readings for a period of approximately 60 hours were obtained, beginning 335 minutes after the electrical failure and ceasing when the factory resumed pumping.

The actual, linear scale recovery curve is shown on Figure 6, together with a typical Lea Recorder chart illustrating well the intermittent pumping to which the aquifer is submitted.

The plot is that of log t/to vs. residual drawdown in metres, t is the time since pumping began and to is the time since pumping stopped. A good straight-line relationship was obtained until the pump had been idle for 1 775 minutes, at which point deviation in the direction of decreasing drawdown was observed.

Transmissivity is determined by this method using the formula

$$T = \frac{2.30}{4\pi\Delta S} \text{(residual drawdown)}$$

and values of transmissivity were obtained fro the early and late stages of recovery. Results are tabulated overleaf in Table 2.

TABLE 2

SOURCE OF VALUE	TRANSMISSIVITY m^3/day/m	STORAGE COEFFICIENT
Pumped Bore - Early stage (Bowering, 1973)	630	
Pumped Bore - Late stage (from Bowering, 1973)	179	
Observation Bore - Straight Line Solution - Early stage	1649	9.2×10^{-5}
Observation Bore - Match Point Solution - Early stage	1500	8.0×10^{-5}
Recovery in observation bore Early stage	326	-
Recovery in observation bore Late Stage	160	-

DISCUSSION OF RESULTS

1. General

The values of transmissivity and storage coefficient which resulted from treatment of drawdown data from the observation bore by the straight line and match point methods were in good agreement for the early stages of pumping and can be compared with the results obtained from the pumped bore in 1972.

There is an apparent increase in the early stage Transmissivity (i.e. the Transmissivity of the material near the borehole) from 630 m^3/day/m to about 1500 m^3/day/m over the 18 month period. As the bore is being pumped at a rate somewhat greater than would be considered advisable (see page 9) the increase in Transmissivity is likely to be the result of continued development of the aquifer near the bore. Drilling mud used in the construction of the bore may well have been only partially removed during the initial development of the bore, and completely removed since. It is understood that the bore is still producing small amounts of sand.

After approximately 20 minutes pumping the plotted data deviated, in the direction of increasing drawdown, from the early stage straight lines from pumped and observation bores and from the Log-Log plot for the observation bore. The plotted recovery data also deviated, and the most marked steepening of slope for both the drawdown and residual drawdown plots occurred when the water level in the observation bore was 1 to 1.5 metres below the non-pumping level.

This is interpreted as the result of a zone of reduced aquifer Transmissivity at some distance from the borehole. As distance drawdown measurements are not available (it was not possible to measure drawdown in the pumped bore after the initial 1972 test due to the pump installation) the distance of this inferred boundary from the pumped bore cannot be determined.

The reduced Transmissivity may be the result of variations in permeability (due to variations in grain size distribution), or aquifer thickness, or a combination of both. The environment of deposition of the Knight Formation (marginal marine with some quite active sedimentation) is such that these variations are to be expected.

There is not good agreement between the two values of Transmissivity obtained from the recovery measurements and the four values from drawdown measurements. This may be a function of inaccuracies involved with the Lea Recorder interpretation, or the lack of early time Recovery data.

The late stage recovery Transmissivity value obtained is lower than that from the early stage recovery - the reverse of the results obtained from drawdown measurements. As the Lea Recorder was not installed until 355 minutes after the failure of the pumps, there is no data for the earliest part of the recovery cycle. This unmeasured period may well be the equivalent of the early stage drawdown, but without the data there is little to be gained from further discussion of the recovery data.

The transposition of the recovery data from the Lea recorder chart is worthy of note, and the method may well be valuable for measuring long term recoveries of reasonable magnitude.

At this stage the respective values of 1575 m^3/day/m (average of 2 values from the observation bore) and 179 m^3/day/m for Transmissivities of the aquifer near the boreholes and at some indeterminate distance from them are regarded as representative. A trial calculation from the plot of drawdown vs. log time for the late stage of drawdown for the observation bore (Fig.3) gave a value of 130 m^3/day/m. Although this is not valid mathematically, it is a useful confirmatory value for comparison with the late stage Transmissivity from the 1972 test, and suggests that development of the aquifer since 1972 has only occurred in the higher Transmissivity zone near the bore, as would be expected.

2. <u>Prediction of Long Term Drawdown</u>

As variable discharge tests have not been carried out on the production bore, it is not possible to evaluate the drawdown due to turbulent head loss. As this component of drawdown is proportional to the square of rate of discharge, long term drawdown predictions can only be made for the pumping rate at which the test was conducted.

The boundary conditions indicated by the drawdown plots suggest that the (Late stage) steeper of the two straight lines should be used for longer term drawdown prediction.

Figure 7 shows the predicted time - drawdown relationship obtained by extending the line obtained in the 1972 test. This prediction can only be regarded as approximate as the other boundaries may well be encountered by the extending cone of drawdown.

3. Safe Yield Determination

There is a maximum safe yield for any bore employing a sand-screen based on the entrance velocity of water into the screen.

Excessive entrance velocities tend to accelerate corrosion of the screen, and may be responsible for carrying fine material into the bore, increasing pump wear.

Walton (1970) gives the following formula for calculating entrance velocities, and tabulates optimum entrance velocities for difference aquifer permeabilities.

$$S_L = \frac{Q}{7.48\ AoVc}$$

where S_L = optimum length of screen in feet (40 feet in this case)

Q = discharge in gallons per minute

Ao = effective open area of screen in square feet/foot

Vc = optimum screen entrance velocity in feet per minute.

A safe pumping rate can therefore be determined from:-

$$Q = S_L \times 7.48 \times Ao \times Vc$$

The average coefficient of permeability is given by transmissivity divided by aquifer thickness and is equal to:-

$$\frac{1575}{20}\ m^3/day/m^2$$

$$= \frac{1575}{20 \times 8031 \times 3.28}\ ft^3/sec/ft^2$$

$$= \frac{1575 \times 86,400 \times 6.25}{20 \times 8031 \times 3.28}\ gpd/ft^2$$

$$= 1614\ gpd/ft^2$$

(where 1575 m^3/day/m is the Transmissivity of the aquifer near the bore)

20 m is the aquifer thickness

8031 m^3/day/m = 1 ft^3/sec/ft

3.28 ft = 1 m

6.25 gallons = 1 ft^3

86,400 sec = 1 day

From the table 5.1 (Walton 1970, p. 297) Vc = 3 f.p.m.

Surface area of 6" screen = 2 x 0.25 sq. feet/foot

For a Surescreen with 0.035" openings, actual open area is 32% of the total

∴ Actual open area = $\frac{32}{100}$ x 2 x 0.25 sq. feet/foot

Allowing for 50% of the screen being blocked by aquifer material as suggested in Walton (1970), Ao (Actual open area) = $\frac{32}{100} \times 2 \times \frac{0.25 \times}{0.50}$

= 0.25 ft^2/ft

The optimum safe yield can now be calculated

Q = 40 x 7.48 x 0.25 x 3 g.p.m.

= 224 g.p.m. or 17 litres/sec or approx. 13,500 g.p.h.

The bore is pumped at 650 g.p.m. during periods of heavy demand (information supplied by factory management) which is a little less than three times calculated safe rate.

CONCLUSIONS

1. The top aquifer of the Knight Group is inhomogeneous, with a transmissivity of 1600 m^3/day/m near the boreholes, and 180 m^3/day/m at some indeterminate distance away. This is to be expected from the environment in which the sediments were deposited.
2. A storage coefficient of 9.0 x 10^{-5} can be applied for the high transmissivity zone of the aquifer near the production bore.
3. The aquifer has been developed considerably by irregular pumping

since it was first tested in 1972, shown by the increase in Transmissivity near the bores from 630 to 1575 m^3/day/m.

4. The production bore is currently being pumped at about three times the safe maximum rate.

RECOMMENDATIONS

To avoid future trouble with the sandscreen it is recommended that the pumping rate of the bore be reduced to less than 20 l/sec. This will presumably require the installation of larger storage tanks.

At this stage data is inadequate for reliable predictions of safe withdrawals from the aquifer, and further testing is recommended before the inevitable increased development takes place.

ACKNOWLEDGEMENTS

We are most grateful to Mr. Colin Cameron and his staff for their limitless co-operation in allowing us to perform the tests.

Thanks are also due to the E. & W.S., Mt. Gambier for assistance in rectification of a fault in the discharge system.

J.T. Valentine & J.D. Waterhouse
per JDW

JTV/JDW:JS
25th March, 1974.

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HYDROGEOLOGY SECTION

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Hazel, C.P., 1973. Lecture Notes on Groundwater Hydraulics. Presented at the Australian Water Resources Council, 1973 Groundwater School, Adelaide, by the Irrigation and Water Supply Commission, Queensland.

Walton, W.C., 1970. Groundwater Resources Evaluation. McGraw-Hill

Series in Hydroscience and Hydrosystems Engineering,
664 pp.

APPENDIX A

Geological Log of Production Bore

DEPARTMENT OF MINES — SOUTH AUSTRALIA

BORE LOG · HYDROGEOLOGY

Purpose of Bore Water supply
State No. 246036403
Hundred Blanche
Section 364
Bore Serial No. 28/72
Owner A.P.D. Ltd.
Address Commercial Street
Mt. Gambier
Project No.
Driller H. James
Docket No. 100/72
Commenced 6.3.72
Completed 13.5.72
R.L. Collar (M.S.L.)
Depth 120 metres
Drill type Percussion
Circulation
R.L. Surface
Co-ords E
Logged by J. Bowering
Date 7.12.72
Casing 50.6m x 10" & 91mx8"
A.M.G. Zone
N

WATERS CUT

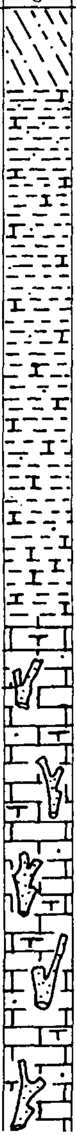
DEPTH (m)	WATER LEVEL (m)	SUPPLY-G.P.H.	HOW TESTED	TOTAL SALTS mg/l	ANALYSIS No.
28 m	26.0 m	-		470	W 1753/72
98.0m	19.02m	36,000	pump	620	/
				585	W 2291/72

REMARKS

CASING 1	WATERS CUT 2	WATER LEVEL 3	DEPTH (m) 4	CORE 5	GRAPHIC LOG 6	AGE 7	UNIT 8	PENETRATION RATE 9	DESCRIPTION

Casing: 91m of 8", and 50·64m of 10" casing cemented to surface.

Depth: 0, 5, 10, 15

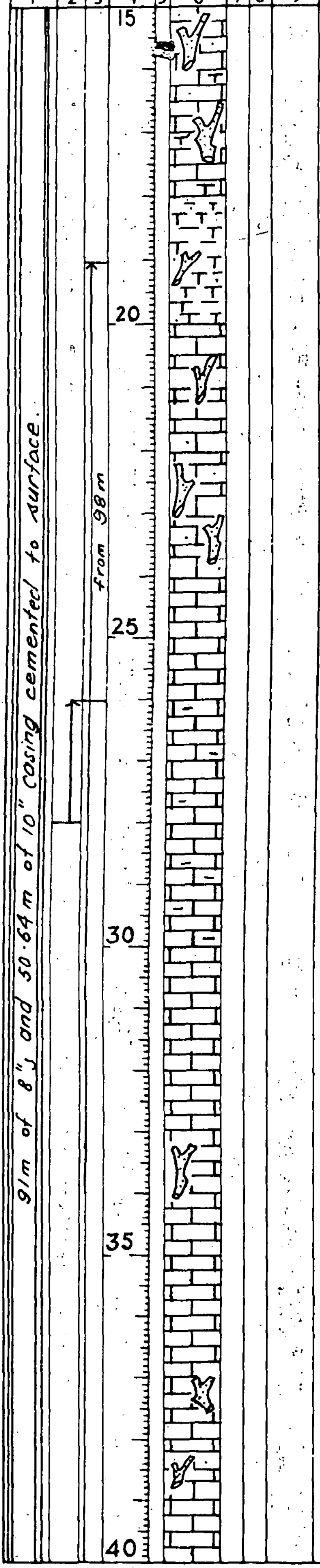


0–1 m: SOIL : dark brown sandy loam, organic

1–2 m: SILT : pale brown, argillaceous to sandy, strongly calcareous.

2–8 m: SILT : cream, argillaceous, slightly sandy with occasional coarse sand grains, strongly calcareous. Becoming more calcareous toward 8 m.

8–18 m: CALCARENITE : Cream, marly, poorly sorted. Consists essentially of bryozoal fragments with occasional quartzose grains & occasional silicified claystone fragments.



18-20 : MARL : pale cream - off white, silty with very fine bryozoal fragments & common coarse fragments of hard cemented marl & sandy quartz grains.

20-22 : LIMESTONE : dark cream-pale brown, fine sandy, bryozoal, some fine to medium quartzitic sandy grains.

22-24m: LIMESTONE : pale cream-off white, coarser bryozoal fragments. Common hard fragments of cemented marl.

24-30m: CALCARENITE : Off white, becoming finer grained & silty. Generally more even grained with few calcareous chips & fragments.

30-38m: CALCARENITE : pale brown-buff, moderately to well sorted, weakly cemented to friable, slightly silty in part. Occasional bryozoal fragments.

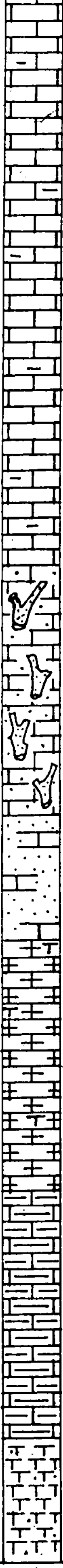
38-39m: LIMESTONE : Deep yellow-pale brown, hard, massive. Consists of hard fragments of possibly partly silicified limestone. Common coarse sandy grains & bryozoal fragments.

1	2	3	4	5	6	7	8	9	State No. 246036403 Bore Serial No. 28/72 SHEET 3 OF 6

50.64m of 10" casing cemented to surface

91m of 8" casing

Depth (m): 40, 45, 50, 55, 60, 65



39-47m: CALCARENITE : Medium yellow, medium-coarse grained mod. to well sorted, silty in pt. Comm. hard argillaceous fragments.

47-49m: As above, becoming more buff coloured.

49-53m: CALCARENITE : pale brown, medium-coarse grained. Dominantly quartzose with abundant bryozoal fragments, moderately sorted. Some pink ferruginous staining.

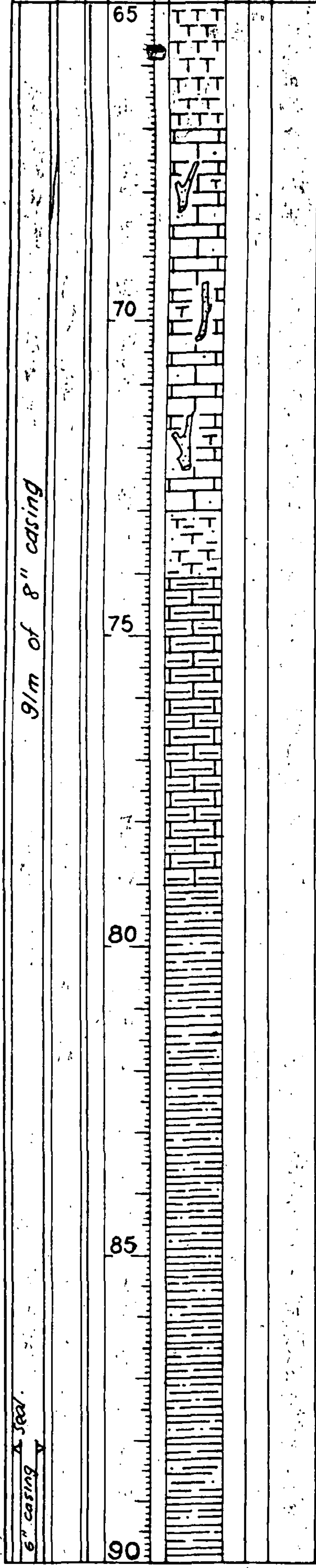
53-55m: CALCARENITE : yellow, 70% quartz, 30% calcite.

55-59m: CALCISILTITE : pale brown, marly in part. Some orange Fe staining.

59-63 : CALCILUTITE : Med. grey, marly, occasional hard siliceous fragments.

63-67 : MARL : pale grey, soft & puggy, sandy in part.

1	2	3	4	5	6	7	8	9	State No. 246036403 Bore Serial No. 28/72 SHEET 4 OF 6



67-73 : LIMESTONE : off white-pale grey, bryozoal, sandy & marly in part

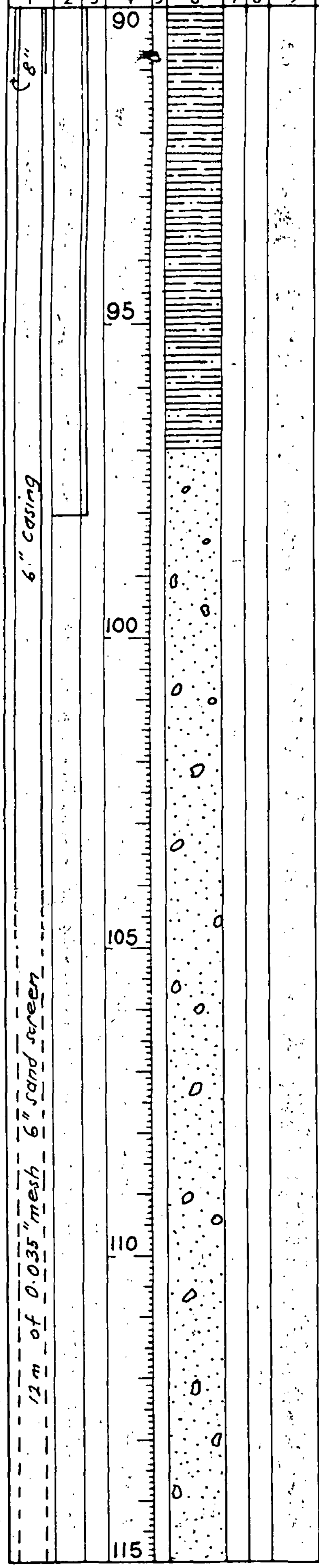
73-74 : MARL : Buff, soft, silty & sandy

74-79 : CALCILUTITE : Med-dark brown, becoming less silty.

79-95 : CLAY : dark-v. dark brown, soft & puggy. Generally slightly sandy throughout & finely micaceous. Becoming lignitic in part. Occasional pale brown calcareous inclusions.

State No. 246036403 Bore Serial No. 28/72 SHEET 5 OF 6

1	2	3	4	5	6	7	8	9



95-97m : CLAY : as above but becoming firmer & more blocky & sl. more sandy.

97-99 : SANDSTONE : pale-med. grey, poorly sorted, medium-v. coarse grained. Conglomeratic, subangular to subrounded, clear to cloudy quartz, occasional felspar. Common lithic fragments.

99-115m: SANDSTONE : As above but generally medium brown. Conglomeratic, unconsolidated & friable.

115

bail down shoe and plug

115-117 : SANDSTONE : As above but becoming dark grey and dirtier with increasing argillaceous matter.

117-120m: CLAY : Dark-v. dark brown, soft & puggy, moderately sandy with fine to medium grained quartz. Trace very fine mica.

120

END OF HOLE 120m

APPENDIX B

Geological Log of Observation Bore BLA 26

DEPARTMENT OF MINES — SOUTH AUSTRALIA

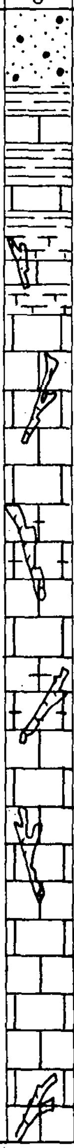
BORE LOG · HYDROGEOLOGY

Purpose of Bore: Observation
State No.: 264036409
Hundred: Blanche
Section: 364
Bore Serial No.: 114/73
Owner: Dept. of Mines
Address: Adelaide
Project No.: BLA 88
Driller: R.B. Toohey, L. Housler
Docket No.: 231/69
Commenced: 11.9.72
Completed: 27.11.72
R.L. Collar (M.S.L.):
Depth: 118.5 m
Drill type: Cable Tool
Circulation: Water
R.L. Surface:
Co-ords E:
Logged by: Fred W. Aslin
Date: 4.3.73
Casing:
A.M.G. Zone:
N:

WATERS CUT

DEPTH (m)	WATER LEVEL (m)	SUPPLY-	HOW TESTED	TOTAL SALTS mg/ℓ	ANALYSIS No.
27.0	26.0		SEE SUMMARY SHEET		
96.5	18.80				

REMARKS: Bit samples at 74 m, 76 m, 79 m, 83 m, 84 m, 86 m, 88 m, 89 m, 90 m, 92 m, 94 m, 96 m

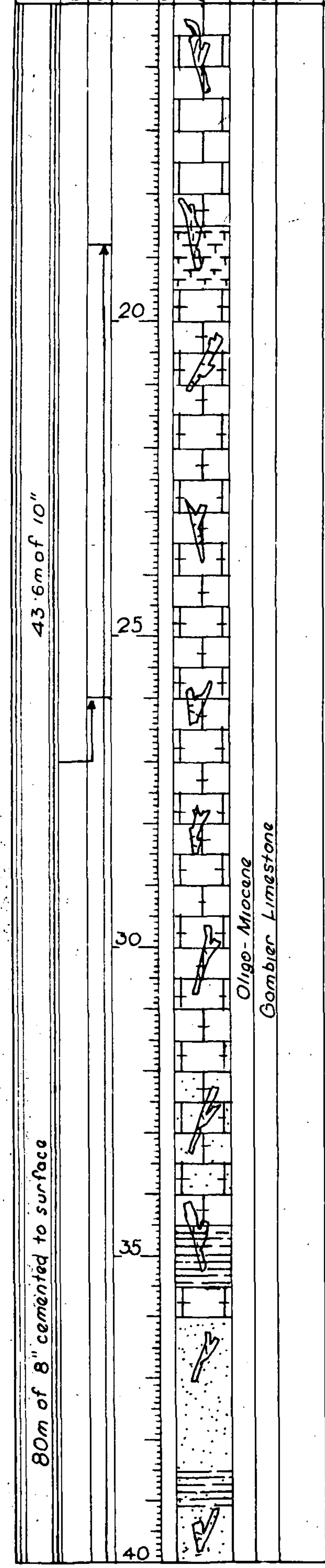
1 CASING	2 WATERS CUT	3 WATER LEVEL	4 DEPTH (m)	5 CORE	6 GRAPHIC LOG	7 AGE	8 UNIT	9 PENETRATION RATE	DESCRIPTION
80m of 8" cemented to surface; 43.6m of 10"			5, 10, 15			Recent; Oligo-Miocene	Volcanics; Gambier Limestone		see below

0 - 1 m Volcanic ash, dark brown, slightly silty, minor organic matter, minor quartz arenite <0.1 - 0.4 mm (Av. 0.2 mm) sub angular - subrounded.

1 - 3 m Clay, mid brown, minor marl.
20-30% Calcareous fragments, finely disseminated <1 mm, and minor slightly calcareous sub angular fragments to 1 cm (Av. 2 mm).

3 - 4 m 50% Clayey marl, cream-grey
50% Calcarenite, partially fossiliferous. Moderate to strong cementation. Minor red and black grains.

4 - 18 m Fossiliferous Calcarenite, dull cream moderate to strong cementation, silty.
6 - 8 m 30-40% calcisiltite, white
8 -10 m off white, minor calcisiltite, white
16 -18 m fossil fragments to 8 mm.



18 - 20 m Marly calcisiltite, light grey,
Approx. 40% calcarenite, partially fossiliferous
moderate to strong cementation, portion massive
and less calcareous, light grey.

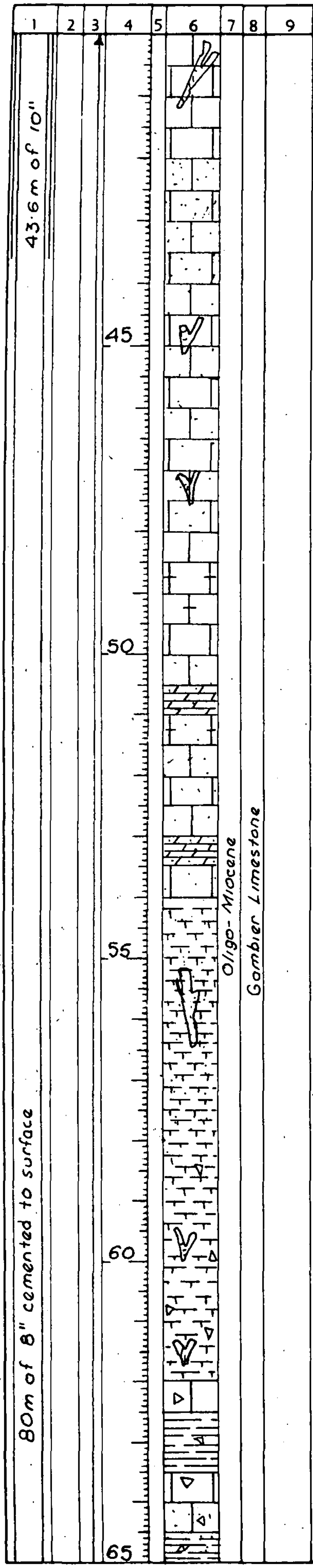
20 - 32 m Calcisiltite, off white - light grey
20 - 22 m 30% calcarenite, mainly bryozoa
fragments odd massive fragments.

22 - 24 m 20% calcarenite, weakly cemented,
mainly bryozoa fragments
odd massive fragments (decreasing)

24 - 28 m 50% Calcarenite, weak to moderate
cementation, mainly bryozoa.

28 - 32 m Marly off white
40% fossiliferous calcarenite, weakly
cemented bryozoa.

32 - 40 m Quartz arenite, <0.1 - 0.4 mm (Av. 0.15 mm) well
sorted, clear, sub angular-subrounded
32 - 34 m 40% calcisiltite, off white.
10% calcarenite, weakly cemented
bryozoa overall colour light
brown.
34 - 36 m 20% clay, yellow-brown with red mottle
10% calcareous sandstone weak to
moderate cementation light to
mid brown.
10% fossiliferous calcarenite, off-
white weak to strong cementation.
36 - 38 m 20% calcareous sandstone as above.
20% fossiliferous calcarenite as
above, minor silt and clay
38 - 40 m as for 34 - 36 m.



40 - 42 m Fossiliferous calcarenite, off white, weak to strong cementation.
5 - 10% sandstone, weakly cemented quartz, light mid brown. Minor quartz arenite clear, fine.

42 - 54 m Calcarenite, off white, cream (other colours in part) wide range of cementation.
42 - 44 m full range of cementation, odd massiv
5 - 10% sandstone, light brown, dull yellow strongly cemented near massive minor silt, mino quartz arenite.
44 - 48 m weakly cemented, minor fossils, minor silt, minor quartz arenite.

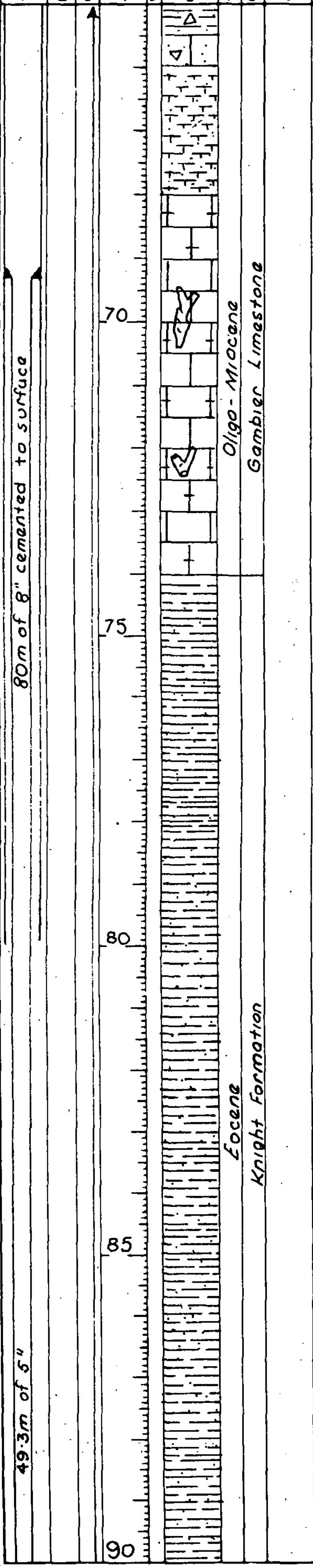
48 - 50 m cream-grey
Approx. 40% calcisitite, cream grey.

50 - 52 m pink, cream (dolomitic in part) weakly cemented
30% calcisiltite cream-grey
20% Quartz arenite, clear, <0.1 - 0.2 (Av. 0.1 mm).
52 - 54 m wide colour range but with each grou distinct cream, grey, dull pink, dull yellow cementation weak (odd fragments probably dolomitic
5 - 10% quartz arenite as above.

54 - 62 m Marl, grey
54 - 58 m 10% calcareous sandstone, moderately cemented off white, cream, light grey.
10% quartz arenite as above.
Minor fossil fragments to 1 cm.

58 - 60 m Mid dark grey
5% Bryozoa fragments to 5 mm
5% calcareous and slightly calcareou fragments to 1 cm, odd massive, grey flecked with black
Trace fine quartz arenite
60 - 62 m Mid grey
10% Bryozoa fragments to 5 mm
10% Massive angular fragments gradin from calcarenite to pure flint. Grey to black (some grey flecked with black).

62 - 66 m Calcisiltite, off white, light grey
10% calcarenite, off white, strongly cemented, partially fossiliferous.
5% flint, angular fragments to 5 mm.
64 - 66 m as above plus 5% quartz arenite ~~<0.1 - 0.4 mm (Av. 0.2 mm) clear, sub~~ angular.



66 - 68 m Marl, light grey, slightly silty
15% Quartz arenite as above
Minor fossil fragments. Trace fine flint.

68 - 74 m Calcisiltite, light grey
40 - 50% fossiliferous calcarenite, off white (trace of light green) weakly cemented fossil fragments to 2 mm.
Minor marl, light grey
Trace quartz arenite as above.

72 - 74 m decreasing calcarenite ? 30%

74 - 97 m Clay dark brown - black, sticky. Quartz arenite percentage variable, clear and opaque and rare black, red, pink and green grains. Sub angular to rounded

74 - 76 m 10 - 15% quartz arenite <0.1 - 6.0 mm (Av. 0.4 mm) minor fossil fragments to 3.5 mm.

76 - 78 m 5% quartz arenite <0.1 - 5.0 mm (Av. 0.4 mm) minor glauconite
Trace fine fossil fragments

78 - 79 m No sample

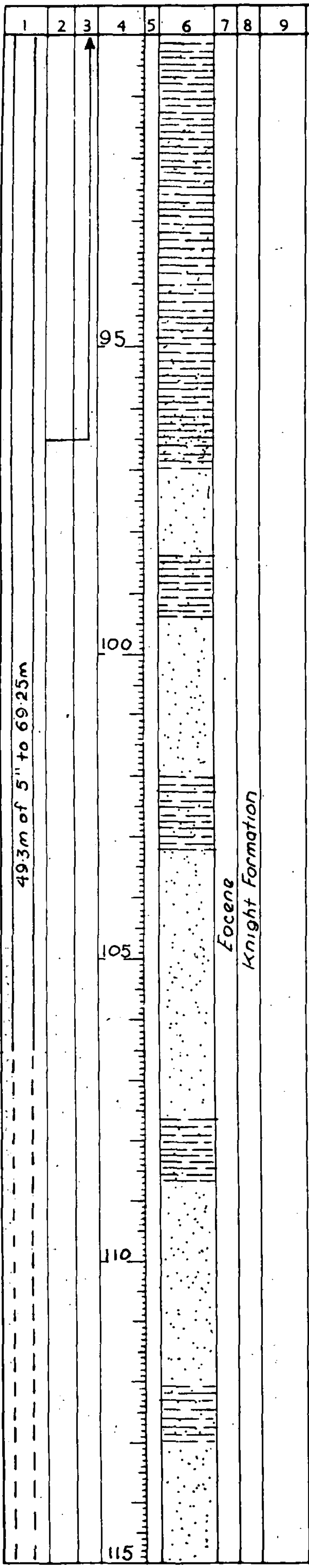
79 - 84 m Trace silt, trace fine quartz arenite (<0.1 - 0.1 mm)

84 - 86 m No quartz

86 - 88 m Trace fine quartz arenite

88 - 89 m Trace fine quartz arenite and ?glauconite nodule

89 - 90 m 5% quartz arenite. Part as <0.1 - 0.1 mm) and part as 1.0 - 5.0 mm (Av. 2.5 mm) grains opague, sub angular - sub rounded.



90 - 92 m <5% quartz arenite, part as <0.1 - 0.1 mm clear and part as 1.0 - 3.0 mm (Av. 1.5 mm) opaque, sub angular-sub rounded.

92 - 96 m Trace quartz arenite, very fine. Rare grains to 3 mm subrounded.

96 - 97 m 30% quartz arenite, <0.1 - 4.0 mm (Av. 0.8 mm) clear and opaque, sub angular - sub rounded.

97 - 117 m <u>Quartz arenite</u>, trace of dark brown-black silty clay (except at 108 - 109 where there was minor cream silt and no clay and at 113 - 114, and 116 - 117 where there was no clay).
Quartz was poorly sorted, clear and opaque with rare coloured grains, angular to sub rounded.

113 - 114 m minor fine mica flakes, rare to 3 mm

116 - 117 m minor fine mica.

Size range and averages

97 - 100	<0.1 - 5.0 mm	Av. 0.7 mm
100 - 101	<0.1 -15.0 mm	Av. 2.0 mm
101 - 104	<0.1 -10.0 mm	Av. 1.0 mm
104 - 105	<0.1 - 5.0 mm	Av. 0.7 mm
105 - 108	<0.1 - 8.0 mm	Av. 0.7 mm
108 - 109	<0.1 - 6.0 mm	Av. 0.4 mm
109 - 110	<0.1 -14.0 mm	Av. 0.7 mm
110 - 111	<0.1 - 5.0 mm	Av. 0.5 mm
111 - 112	<0.1 - 9.0 mm	Av. 0.8 mm
112 - 113	<0.1 - 8.0 mm	Av. 0.7 mm
113 - 114	<0.1 - 9.0 mm	Av. 0.6 mm
114 - 116	<0.1 - 7.0 mm	Av. 0.6 mm
116 - 117	<0.1 -10.0 mm	Av. 0.8 mm

1	2	3	4	5	6	7	8	9	State No. 264036409	Bore Serial No. 114/73	SHEET 6 OF 6
5" slotted			120						117 - 118.5 m	Clay, dark brown-black, slightly silty. 5% quartz arenite <0.1 - 4.0 mm (Av. 0.8 mm) as above End of hole 118.5 m.	

APPENDIX C

Water analysis

WATER ANALYSIS REPORT

SAMPLE NO. W4643/72 JOB NO. 2886/73

CHEMICAL COMPOSITION

		Milligrams per litre mg/l	Milliequivalents per litre me/l
Cations			
Calcium	(Ca)	53	2.6
Magnesium	(Mg)	24	2.0
Sodium	(Na)	80	3.5
Potassium	(K)	7	0.2
Iron	(Fe)		
Anions			
Carbonate	(CO_3)		
Bicarbonate	(HCO_3)	265	4.3
Sulphate	(SO_4)	20	0.4
Chloride	(Cl)	120	3.4
Fluoride	(F)		
Nitrate	(NO_3)	0.5	-
Phosphate	(PO_4)		

TOTALS and BALANCE

Cations me/l	Anion me/l
8.3	8.1

diff Δ 0.2 sum Σ 16.4 % $\left(\frac{\Delta \times 100}{\Sigma}\right)$ 1.2

DERIVED AND OTHER DATA

Conductivity (E.C.) µS/cm at 25°C 870

	Milligrams per litre mg/l
Total Dissolved Solids:	
a. Based on E.C.	
b. Calculated (HCO_3=CO_3)	434
c. Residue on evaporation at 180°C	
Total Hardness as $CaCO_3$	230
Carbonate Hardness as $CaCO_3$	220
Non-carbonate Hardness as $CaCO_3$	10
Total Alkalinity as $CaCO_3$	220
Free Carbon Dioxide (CO_2)	
Suspended Solids	
Silica (SiO_2)	
Boron (B)	
	Units
Reaction–pH	
Turbidity (Jackson)	
Colour (Hazen)	
Sodium Absorption Ratio	42.2

Name: Dept. of Mines

Address: Mt Gambier

Hundred: Blanche

Section: Adj 364

Hole No.: 1

Water Cut: 96.50M

Water Level: 25.80M

Supply:

Depth Hole: 118.50M

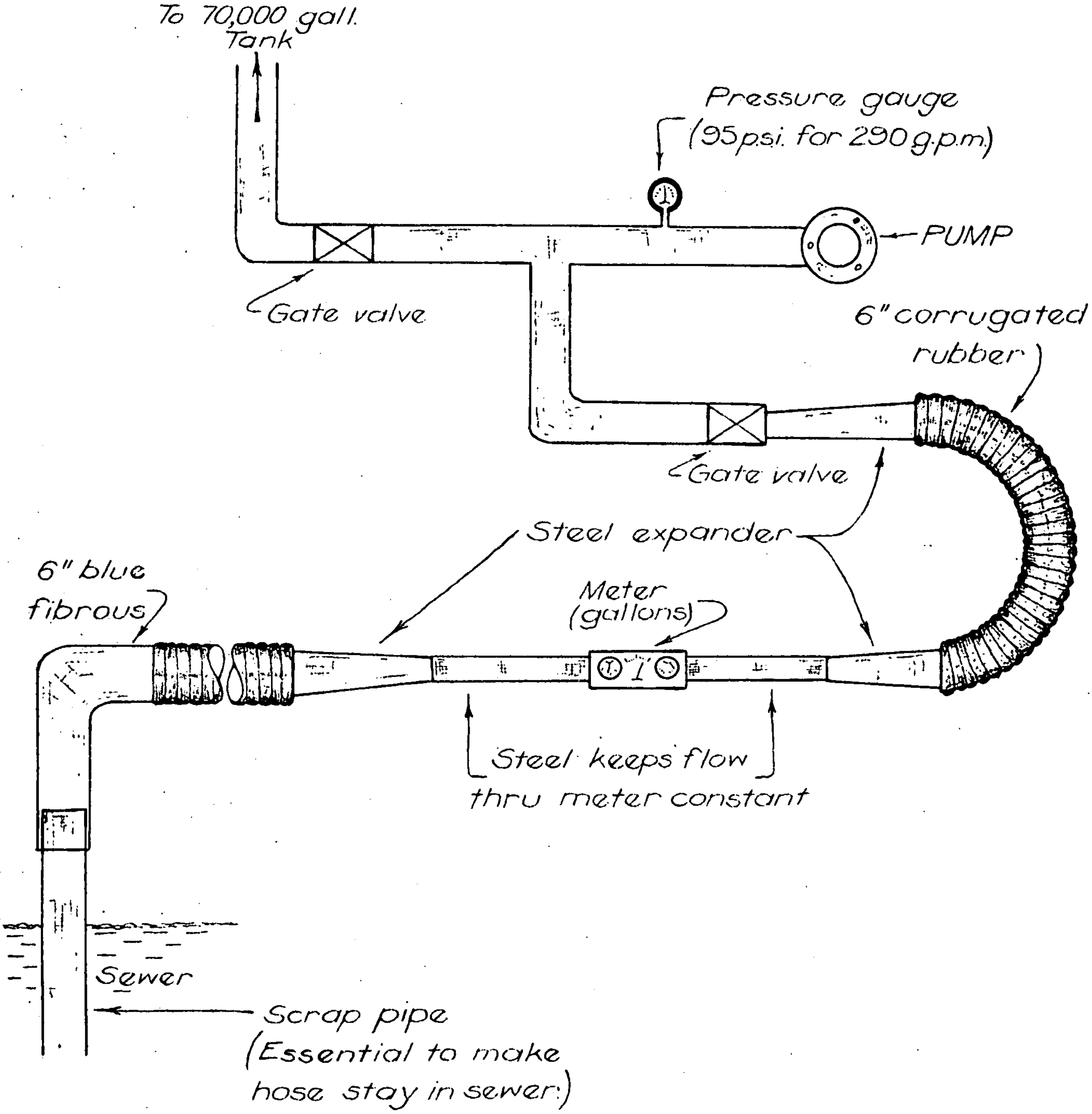
Date Collected: 26.11.72

Sample Collected by: R. Toohey

Date Received:

REMARKS:

for Director



TESTED 23/10/73 – 25/10/73

FIG.1

	DEPARTMENT OF MINES — SOUTH AUSTRALIA	Scale : DIAGRAMMATIC
Compiled J.VALENTINE	WATTIE – PICT LTD.	Date : 6TH MARCH 1974
Drn. A.R. Ckd A.F.	DISCHARGE LINE FOR PUMP TEST	Drg No.
	DISCHARGE SYSTEM	S10742 Kd17

IM - 270 A'810

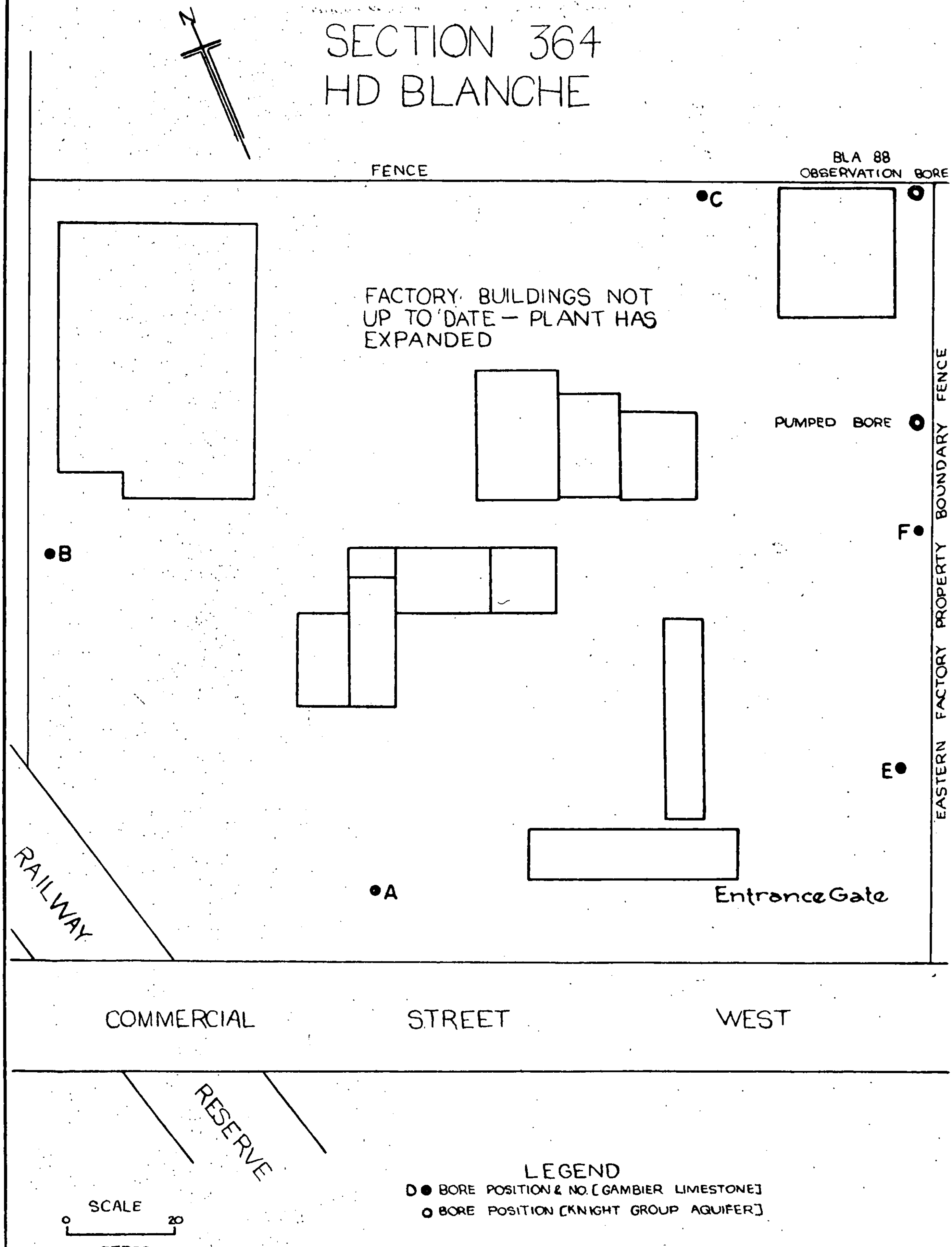
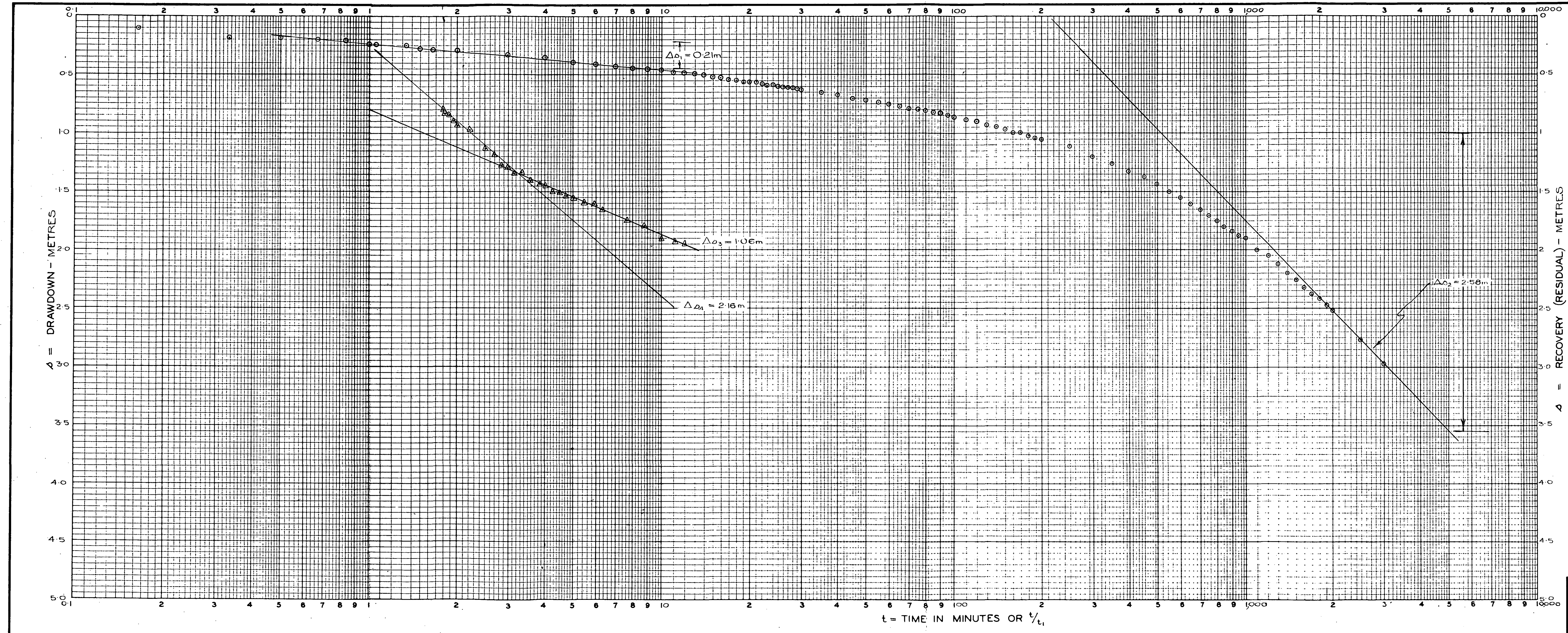


FIG. 2

	DEPARTMENT OF MINES — SOUTH AUSTRALIA	Scale : AS SHOWN
Compiled : J.D.W.	WATTI PICT FROZEN FOODS SEC. 364 H.D. BLANCHE BORE LOCATION PLAN	Date : 19·3·74
Drn. L.P.R. Ckd A.F.		Drg. No. S 10762 Kd 17

1M—2.70 A1810



BOREHOLE STATE No. 246036403
DEPTH TO WATER LEVEL AT TEST START (ℓ_2) 18m (approx) (L) **
PUMP INTAKE DEPTH (ℓ_1) 33·5m (L)
*AVAILABLE DRAWDOWN 15·5m (L)

TYPE OF PUMP PEERLESS 5HH
DISCHARGE STARTED AT 0800 ON 23/10/73
" STOPPED AT 1040 ON 25/10/73
AQUIFER FROM 97m TO 117m (L)
HOLE DEPTH 120m (L)

EQUATIONS

$$T = \frac{0{\cdot}183 \times Q}{\Delta_s} \qquad S = \frac{2{\cdot}25 \times T t_0}{r^2}$$

In which
T = Transmissivity ($L^3/t/L$)
Q = Pumping Rate (L^3/t)
Δ_s = Drawdown per log cycle. (L)

S = Storage Coefficient
t_0 = Zero drawdown time - (t)
r = Distance to Observation Bore - (L)
1 day = $8{\cdot}64 \times 10^4$ secs.
$r^2 = 2862$

DATA

Q		Δ_s		t_0
289 g.p.m = 1892 m³ day		0·21 m	DRAWDOWN	0·1 mins. = $6{\cdot}94 \times 10^{-5}$ days
		Δs^2 2·58 m.	DRAWDOWN	
		Δs^3 1·06 m	RECOVERY	
		Δs^4 2·16 m	RECOVERY	

CALCULATIONS

$$T_1 = \frac{0{\cdot}183 \times 1892}{0{\cdot}21} = 1649\ m^3/day/m$$

$$S_1 = \frac{2{\cdot}25 \times 1649 \times 6{\cdot}94}{2862 \times 10^5} = 9{\cdot}00 \times 10^{-5}$$

T_2 NOT CALCULATED

S_2 NOT CALCULATED

$$T_3 = \frac{0{\cdot}183 \times 1892}{1{\cdot}06} = 327\ m^3/day/m$$

$$T_4 = \frac{0{\cdot}183 \times 1892}{2{\cdot}16} = 160\ m^3/day/m$$

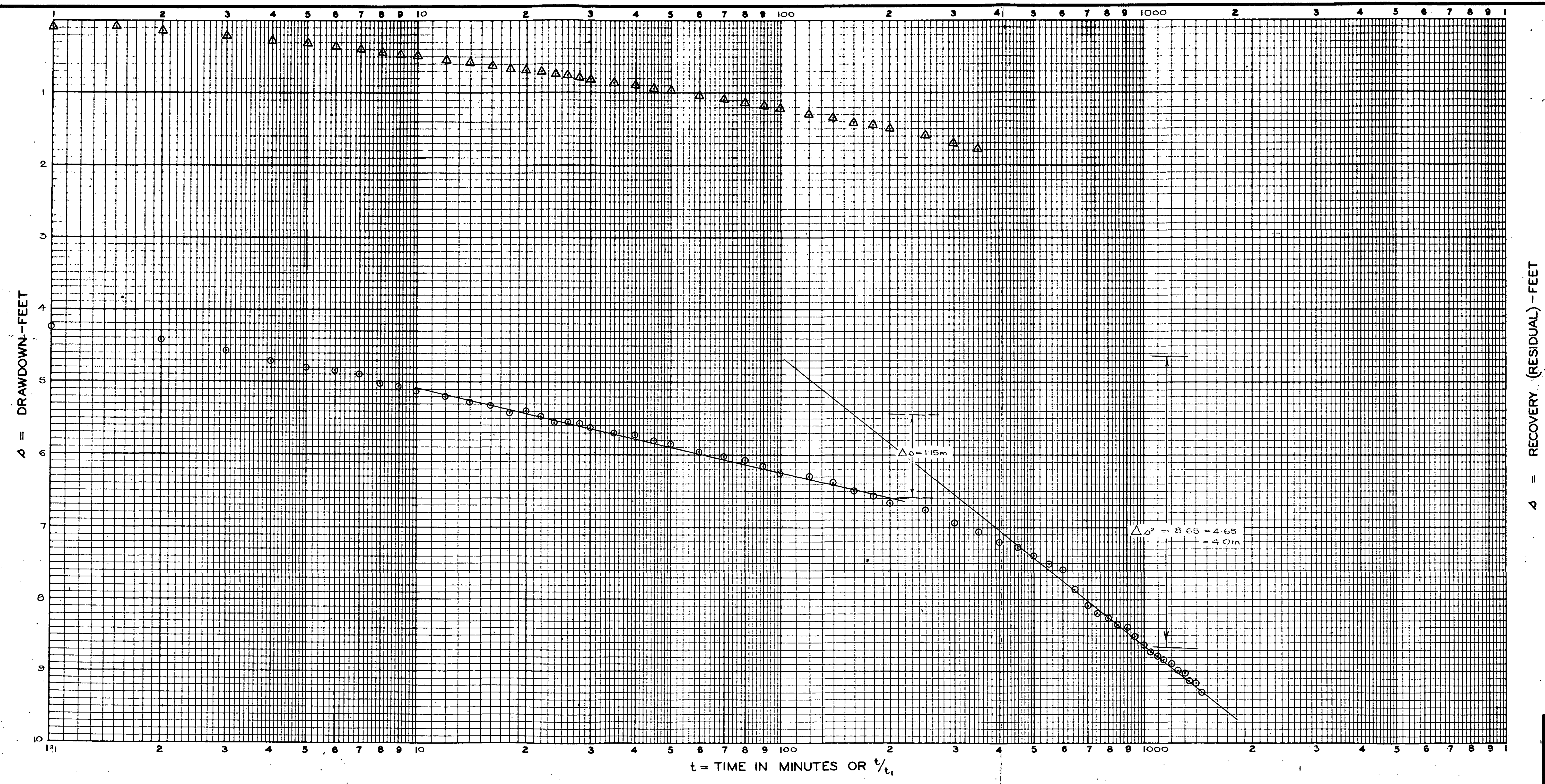
* Available drawdown = $\ell_1 - (\ell_2 + \text{-----})$

** L = unit of length.
t = time unit.

FIG.3

HYDROGEOLOGY SECTION		DEPARTMENT OF MINES—SOUTH AUSTRALIA	D.M. /
COMPILED: J. VALENTINE		WATTIE — PICT LTD.	DATE: 5TH MARCH 1974
DRN. A.R.	CHD. A.F.	PLOT OF DRAWDOWN VS LOG TIME	DRG. No.
		FOR OBSERVATION BORE BLA.BB	74-214a Kd17

P.F. No. 69-953 MH



BOREHOLE STATE Nº 246036403	TYPE OF PUMP POMONA
DEPTH TO WATER LEVEL 19·0m	DISCHARGE STARTED AT 10·15 ON 11-5-72
AT TEST START (ℓ_2) ______ (L) **	" STOPPED AT 10·25 ON 12-5-72
PUMP INTAKE DEPTH (ℓ_1) ______ (L)	AQUIFER FROM 97·0m TO 117·0m (L)
*AVAILABLE DRAWDOWN 5m (L)	HOLE DEPTH 120m (L)

EQUATIONS

$$T = \frac{0{\cdot}183 \times Q}{\Delta_o} \qquad S = \frac{2{\cdot}25 \times T t_o}{r^2}$$

In which

- T = Transmissivity $(L^3/t/L)$
- Q = Pumping Rate (L^3/t)
- Δ_o = Drawdown per log cycle. (L)
- S = Storage Coefficient
- t_o = Zero drawdown time- (t)
- r = Distance to Observation Bore- (L)

1 day = $8{\cdot}64 \times 10^4$ secs.

DATA

Q	Δ_o	t_o
1.600 Cusec	5.06 ft = 1·15m Δ_o^2 13·12 ft = 4·0m	

CALCULATIONS

$$T_1 = \frac{0{\cdot}183 \times 1{\cdot}600}{3{\cdot}78} = 7{\cdot}74 \times 10^{-2}\ ft^3/sec./ft. = 630\ m^3/day/m$$

$$T_2 = \frac{0{\cdot}183 \times 1{\cdot}600}{13{\cdot}12} = 2{\cdot}2 \times 10^{-2}\ ft^3/sec./ft. = 179\ m^3/day/m$$

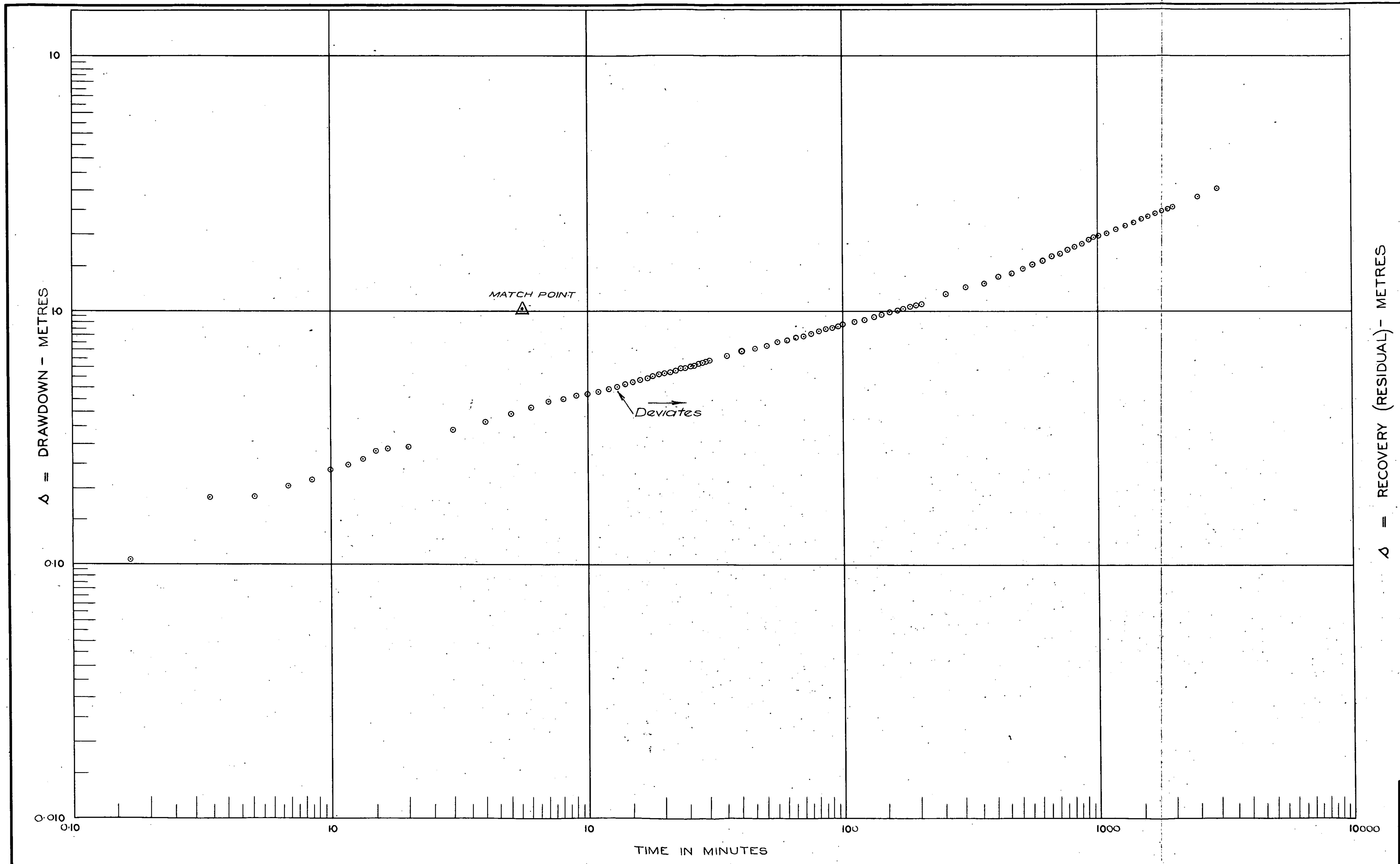
* Available drawdown = $\ell_1 - (\ell_2 + \_\_\_\_\_)$

** L = unit of length.
t = time unit.

FIG.4

HYDROGEOLOGY SECTION	DEPARTMENT OF MINES—SOUTH AUSTRALIA	D.M. 23 / 69
COMPILED: J.W.B.	WATTIE − PICT LTD.	DATE: 4th MARCH 1974.
DRN. A.R. / CHD. A.F.	PLOT OF DRAWDOWN VS LOG TIME FOR PUMPED BORE (11/5/72 − 12/5/72	DRG. No. 74-213 Kd17

P.F. No. 69−953 MH



BOREHOLE STATE N° 246036403
DEPTH TO WATER LEVEL
AT TEST START 16m (Approx.) (L) *
PUMP INTAKE DEPTH 33·5m (L)
AVAILABLE DRAWDOWN 15·5m (L)

TYPE OF PUMP PEERLESS 5HH
DISCHARGE STARTED AT 0800 ON 23/10/73
" STOPPED AT 1040 ON 25/10/73
AQUIFER FROM 97m TO 117m (L)
HOLE DEPTH 120m (L)

BASIC EQUATIONS

$$T = \frac{Q}{4\pi\Delta} Wu \qquad S = \frac{4Tut}{r^2}$$

In which
T = Transmissivity ($L^3/t/L$)
Q = Pumping Rate (L^3/t)
Δ = Drawdown (L)
Wu = function of u

S = Storage Coefficient (dimensionless)
t = time (t)
r = Distance to observation hole (L)

DATA

Q	Δ	t	Wu	u	1 day
1892 m³/day	1·0m	5·5min =3·82 X 10^{-3} days	10	10^{-2}	8·64 X 10^4 SEC.

CALCULATIONS

$$T = \frac{1892 \times 10}{4\pi} = 1505 \ m^3/day/m$$

$$S = \frac{4 \times 1505 \times 3\cdot82}{10^2 \times 2862 \times 10^3} = 8\cdot04 \times 10^{-5}$$

* L = unit of Length
t = time unit

FIG.5

HYDROGEOLOGY SECTION		DEPARTMENT OF MINES - SOUTH AUSTRALIA	D.M. /
COMPILED: J.VALENTINE		WATTIE PICT LTD PLOT OF LOG DRAWDOWN VS. LOG TIME FOR OBSERVATION BORE BLA 68	DATE: 4TH MARCH 1974
DRN: A.R.	CHD: A.F.		DRG.NO. 74-214 Kd17

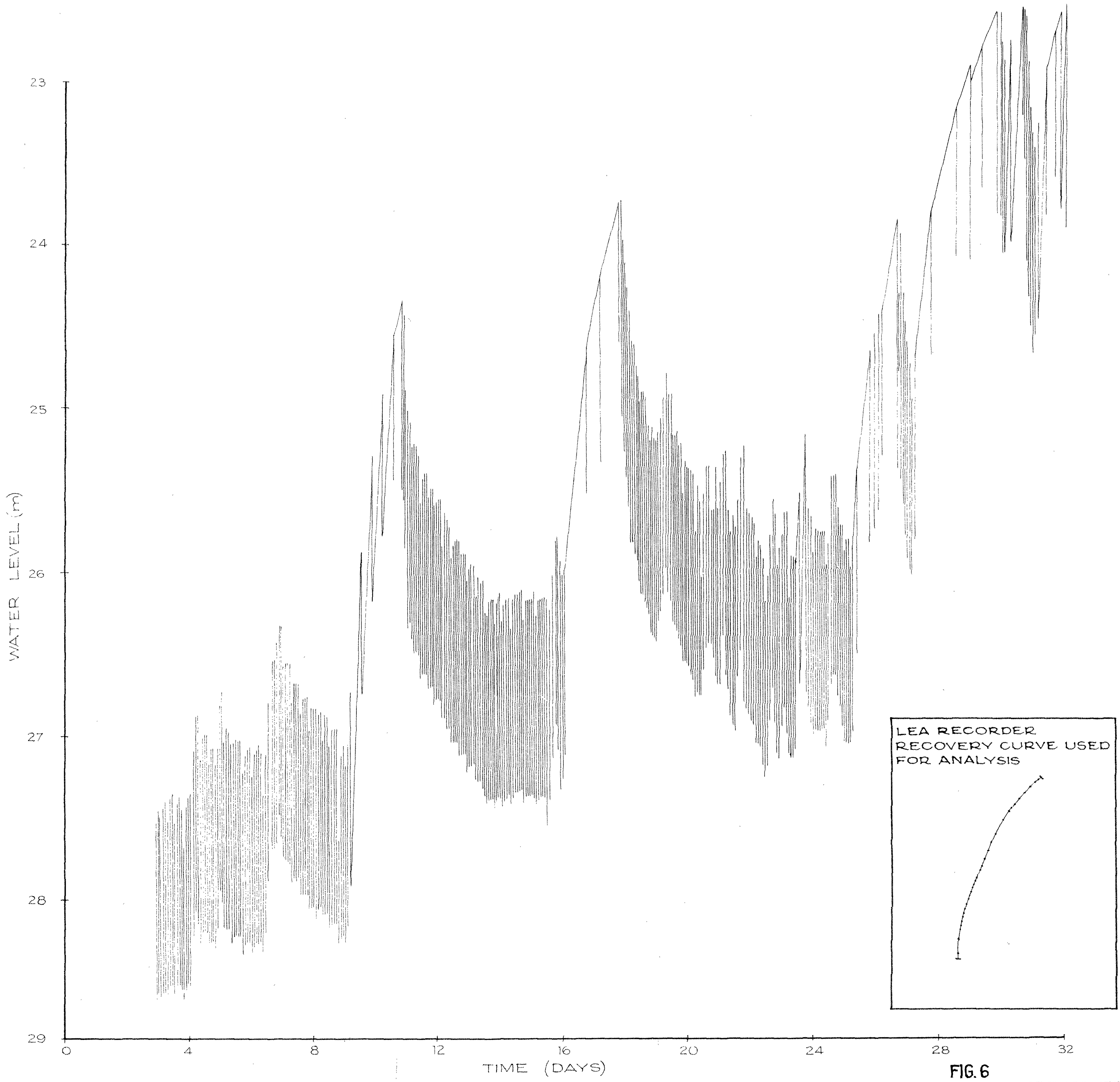
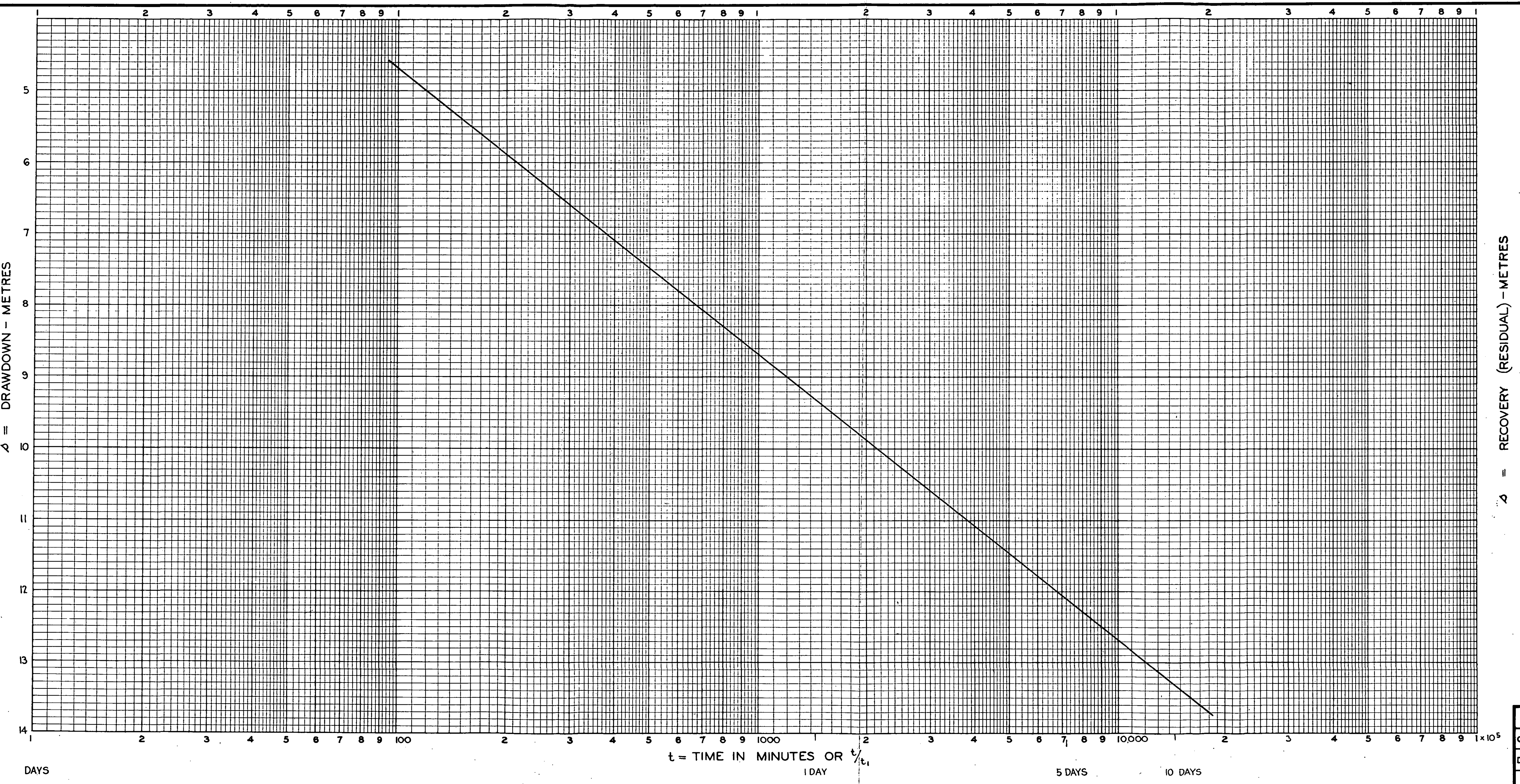


FIG. 6

DEPARTMENT OF MINES — SOUTH AUSTRALIA

SOUTH EAST WATER RESOURCES
MOUNT GAMBIER AREA INVESTIGATION
TYPICAL LEA RECORDER CHART FOR OBSERVATION BORE
BLA 88 (DEC. 1973 - JAN. 1974)
AND RECOVERY CURVE USED FOR ANALYSIS

HYDROGEOLOGY SECTION	J.D. WATERHOUSE *Geologist*	Compiled J.W.	Scale: Graph Date: 8th Feb. 1974
Director of Mines		Drn. G.M. Ckd. A.F.	Drg. No. 74-106 Ka 17



BOREHOLE STATE Nº 246036403
DEPTH TO WATER LEVEL
AT TEST START (ℓ_2)______(L) **
PUMP INTAKE DEPTH (ℓ_1)______(L)
*AVAILABLE DRAWDOWN______(L)

TYPE OF PUMP______
DISCHARGE STARTED AT____ON____
" STOPPED AT____ON____
AQUIFER FROM____TO____(L)
HOLE DEPTH____(L)

EQUATIONS

$$T = \frac{0{\cdot}183 \times Q}{\Delta_s} \qquad S = \frac{2{\cdot}25 \times T t_0}{r^2}$$

In which
T = Transmissivity ($L^3/t/L$)
Q = Pumping Rate. (L^3/t)
Δ_s = Drawdown per log cycle. (L)

S = Storage Coefficient
t_0 = Zero drawdown time- (t)
r = Distance to Observation Bore- (L)
1 day = $8{\cdot}64 \times 10^4$ secs.

DATA

Q Δ_s t_0

CALCULATIONS

T = 0·183×______ =

S = 2·25×______ =

** L = unit of length.
t = time unit.

* Available drawdown = $\ell_1 - (\ell_2 +$ ____)

FIG. 7

HYDROGEOLOGY SECTION		DEPARTMENT OF MINES—SOUTH AUSTRALIA	D.M. 299/72
COMPILED: J.D.W.		WATTIE - PICT LTD. PREDICTED TIME-DRAWDOWN RELATIONSHIP PUMPING RATE 45 LITRES/SEC.	DATE:
DRN. L.V.W.	CHD.		DRG. No. 74-269 Ke9

P.F. No. 69—953 MH