DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1977/51

CONTROL OF GROUND WATER SEEPAGE BY PUMPING FROM A BORE AT TORRES STREET, RED HILL, A.C.T.

by

P.D. HOHNEN

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SUMMARY

Block 16 and surrounding blocks at Torres Street, Red Hill, Australian Capital Territory, have a history of about 25 years of intermittent, and often prolonged, water-logging of the soils. Pumping from a bore that was drilled during investigations in 1958 and 1959 controlled the seepage until the abnormally wet years of 1974 and 1975. The Bureau of Mineral Resources, Geology and Geophysics (BMR) inspected the problem in 1975 and advised the drilling of a deeper, larger diameter bore to create a broader cone of depression, and the installation of an electric submersible pump. The bore and pump were installed in mid-1975 by a contractor under the supervision of BMR and the former Department of Housing and Construction (DHC).

Now the new pump is in operation, piezometers in soil on Blocks 14, 15 and 16 still show a rapid response to rainfall owing to the temporary saturation of perched aquifers in the soil. However, this water now infiltrates to the deeper, fractured-rock aquifer system in the area under the influence of the strong hydraulic gradient within the cone of depression of the pumping bore; the soils are now drained within a few days of the last rainfall.

INTRODUCTION

An area encompassing Block 14 Wickham Street and Blocks 15 and 16, Section 3, Torres Street (Fig. 1), has been recognised as an ephemeral swamp since 1951, when residents of the area complained of waterlogged ground. Buildings were erected in this area in the 1930s during a period of consecutive years with low rainfall that ended in 1949, and the intermittently swampy nature of the ground was not obvious (Noakes, 1958) . L.C. Noakes and N.H. Fisher of the Bureau of Mineral Resources (BMR) investigated the problem in 1953 at the request of the Department of Works (now Department of Construction). A system of deep drains was recommended, and these were completed by the leaseholder of Block 16 in 1954. The drains seemed to be effective until the end of 1955, but saturated ground became a problem again in the particularly wet year of 1956. The problem persisted throughout the relatively dry summer of 1956-57, and in places became worse.

In 1957 the Department of Works requested BMR to undertake another investigation. Results of this investigation were described by Noakes, (1958) who concluded that the soil profile beneath Block 16 was not readily drainable, and recommended drilling of a bore to determine the effectiveness of pumping for drainage of the soils.

Late in 1958 a bore (BMR no. 35) was drilled to a depth of 30 m on Block 15 near the boundary of Block 16. The bore intersected slightly weathered porphyry with several narrow extensively weathered zones and was pumped at 2.7 m^3/h. Wilson & Noakes (1959) concluded that pumping water from the bore at 2.7 m^3/h was sufficient to depress the potentiometric surface over Block 16, the eastern half of Block 15, and possibly over Block 14 as well. They recommended the permanent installation of pumping equipment as a cheaper and more effective alternative to a deep drainage system which would require pumping from a sump.

A jack pump was installed in the bore and intermittent pumping controlled the water-table until the unusually wet years of 1973-75, when extensive waterlogging initiated a call for reappraisal of the situation.

Record 1975/19 and 1977/51 Fig. 1 Map of catchment areas, Red Hill. 155/A16/1801

Representatives of BMR and DHC (now Department of Construction), visited the site in early 1975 and decided that the old bore and pump were inadequate and that further drainage investigations were necessary. The results of the investigation, BMR's recommendations, and the remedial works are described below.

INVESTIGATION AND RESULTS

Ten holes were hand-augered to refusal on Blocks 14, 15, and 16, to monitor the potentiometric surface of groundwater in the soil. Measurement of water-levels in piezometers and in the 30 m-deep bore indicated that the potentiometric surface of the deep, fractured-rock aquifer system coincided with the water-levels measured in the soil (Fig. 2). This leakage zone, or water-table, of the fractured-rock aquifer was at or above the ground surface over an area of about 400 m^2 - about 30% of the area of Block 16 - in June 1975 (Plate 1). Much of this area of vertical leakage towards a high potentiometric surface underlies the house on Block 16.

SOILS, GEOLOGY, AND GROUNDWATER

Recharge Zone

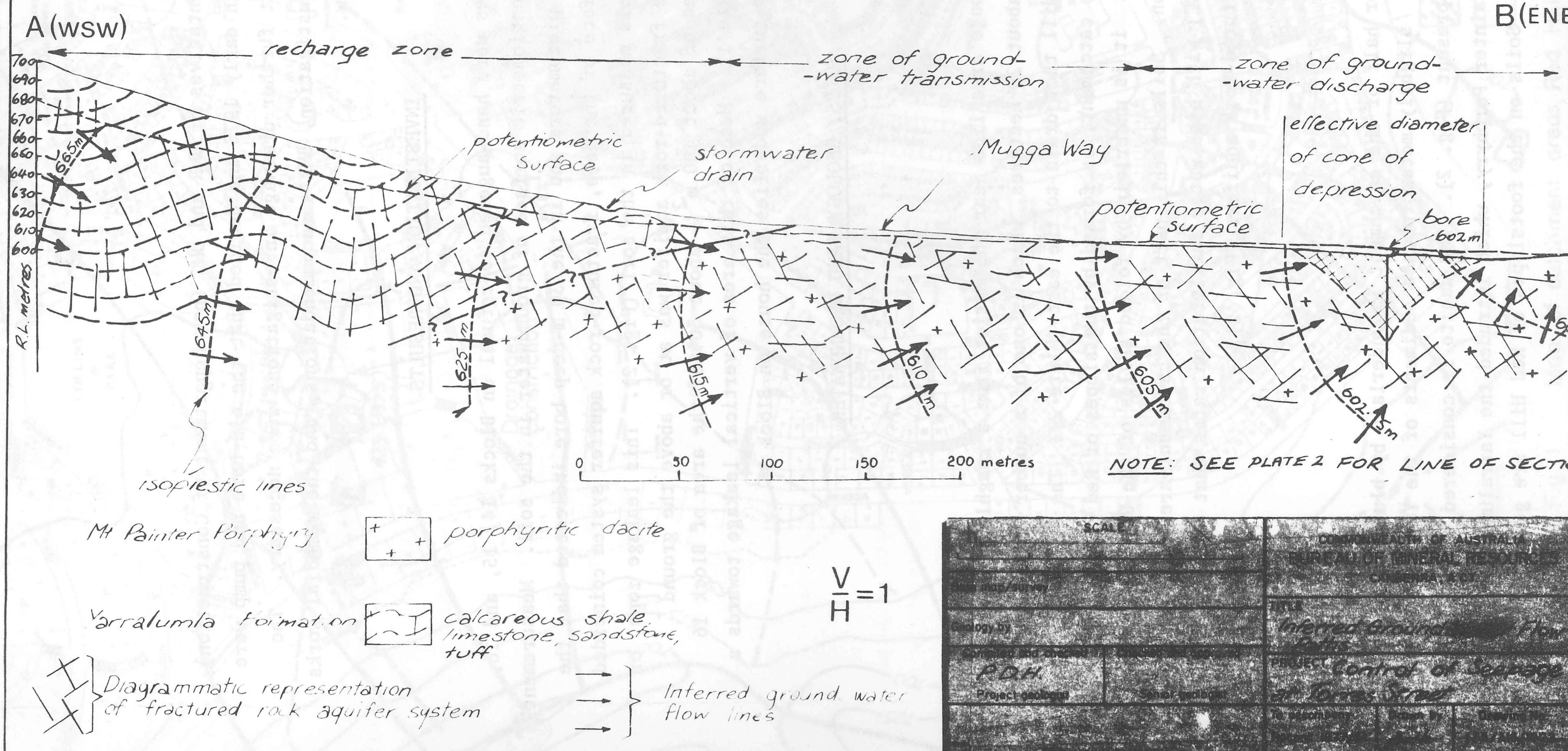
The seepage area lies near the outlet from a roughly rectangular catchment area of about 20 hectares, which is one of a number of such catchments in Red Hill that drain to the east (Plate 2). The steeper, south-western half of the catchment, is formed by the slopes of Red Hill from crest to footslope; it is underlain by folded shales of the Upper Silurian Yarralumla Formation. Soils in this part of the catchment are skeletal, stony clay soils (GC) with high water infiltration rates that aid recharge of the underlying fractured-rock aquifers (Fig. 2).

Transmission Zone

The lower half of the catchment is underlain by bluish grey porphyritic dacite; slightly metamorphosed sediments of the Yarralumla Formation are also present (Fig. 2). The dacite is considered to be part of a sill, the Mount Painter Porphyry, which intruded the Yarralumla Formation in the Upper Silurian. Soils on the footslopes of Red Hill are generally red

FIGURE 2

SECTION A-B SHOWING INFERRED GROUNDWATER FLOW PATHS



earths (SC) or minimal podzolics (CL), and are quite permeable to interflow. The footslopes thus act partly as a zone of transmission of some of the water to the saturated ground downslope in Torres Street, and partly as a recharge zone for deeper, fractured-rock aquifer system (Fig. 4).

Discharge Zone

The saturated soils on Block 16 are organic heavy clays (OH), which have very low permeability. The clayey soils overlie sand in places, which has been deposited on the surface of the dacite. These sands were probably deposited by hillwash and by former ephemeral streams draining east from Red Hill, and their distribution is probably like that of shoestring sands.

The fractured-rock aquifer system at depth below the catchment is constantly charged with water. This groundwater is periodically under sufficient pressure to reach the ground surface along leakage paths (Fig. 2) and, before a high-capacity bore and pump were installed, maintained saturation of the surficial clayey soils.

The dark grey humic gleys or gumbotils (OH clays) near Block 16 were formed from soil that was maintained in a saturated state for long periods of time by seepage from fractured-dacite aquifers below (Fig. 2). The dark grey colour of the soils is due to the accretion of organic matter, and is characteristic of marshy conditions.

The high groundwater potentials that supply water to the seepage zone are probably result of an abrupt decrease in the permeability of the fractured-rock aquifer system downslope; this may be due to the effect of weathering or to the incorporation of a raft of less permeable rocks of the Yarralumla Formation in the dacite.

REMEDIAL WORK

Conventional pipe-drain vs pumping bore

The BMR and DHC costed alternative methods of draining Block 16. For deep drains, it would have been necessary to blast through dacite bedrock on the eastern side of Block 16 in order to reach a sufficient depth to depress the potentiometric surface below the low-permeability soils. The high cost of excavation and the disruption caused by extensive trenching - combined with an element of uncertainty about the effectiveness of pipe-drains-led to a preference for the construction of a bore equipped with a high-capacity pump to alleviate the poor drainage.

Construction of the bore

A site for a deep bore was selected at a location accessible to an 18-tonne drilling rig as well as being reasonably central to the seepage area (Plates 1 and 2). The bore was drilled under contract in June 1975 by a rig equipped with a down-hole hammer operating on a bottom-of-hole air pressure of 700 kPa. The hole, with a 15-cm diameter, was drilled in one day to 62.5 m, and was reamed to 20.5-cm diameter over the next three days. Torch-slotted steel casing of 15 cm internal diameter was installed down the full depth of the hole. Lengths of casing were butt-welded together to obviate the need for collars. Two cubic metres of 5-6 mm diameter screened river gravel were vibrated in around the annulus to form a gravel pack (Fig. 3).

The bore was developed by air-lifting at 700 kPa until all gravel-pack material that could pass the 2-3-mm wide slots ceased to appear in the discharging water.

Pumping test

The newly drilled bore (BMR No. 423) was allowed to recover completely before the pumping test commenced. Water was flowing from the bore before the test started, and the levels in all piezometers had recovered to their pre-drilling levels, which were at or near the ground surface (Table 1). An eight-hour pumping test was carried out using the piezometers and the old (1958) bore for observations. Results of the test are shown in Figures 4, 5, and 6, and in Tables 1 and 2.

DETAILS OF PUMPING BORE AT BLOCK 16 — FIGURE 3

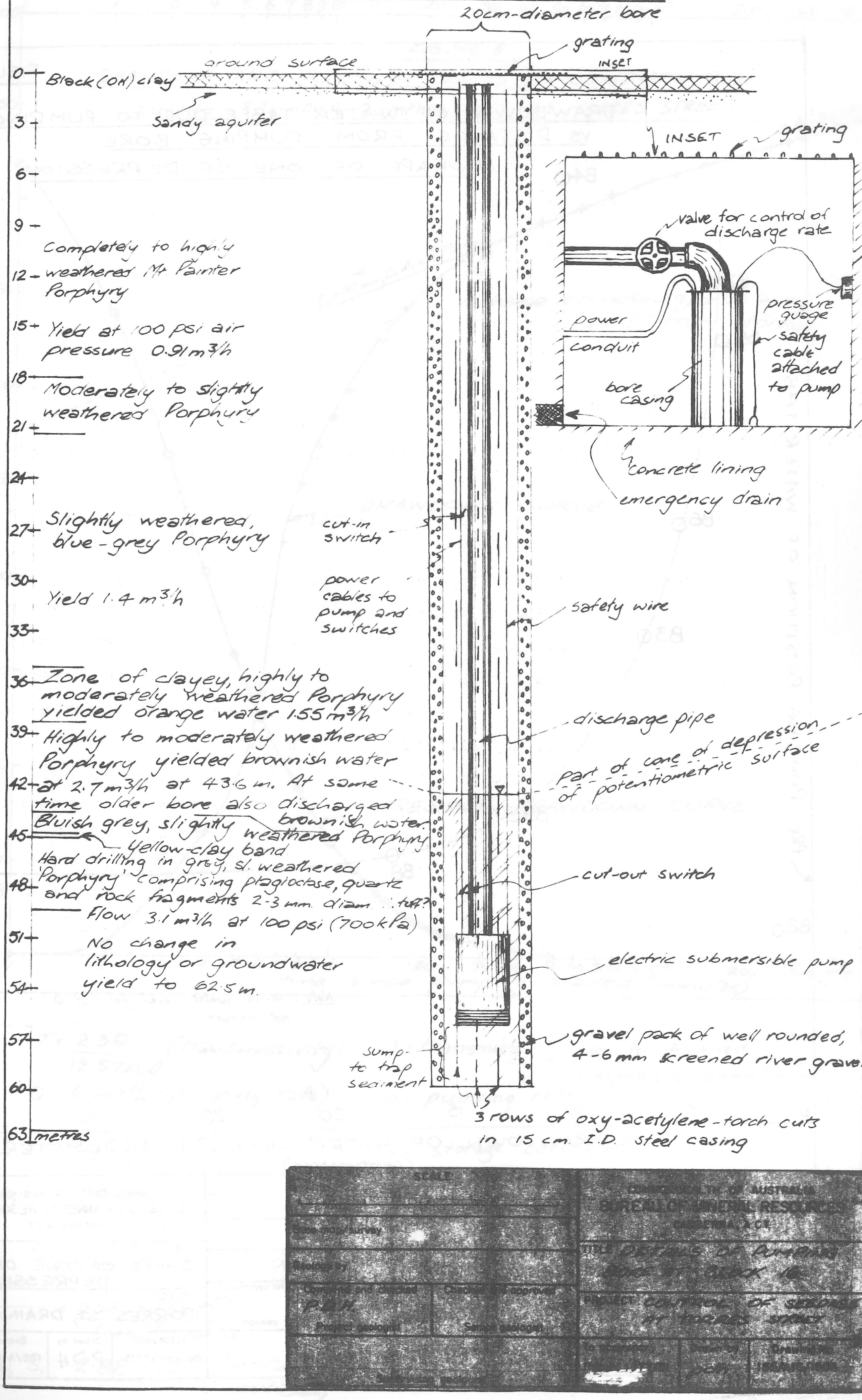
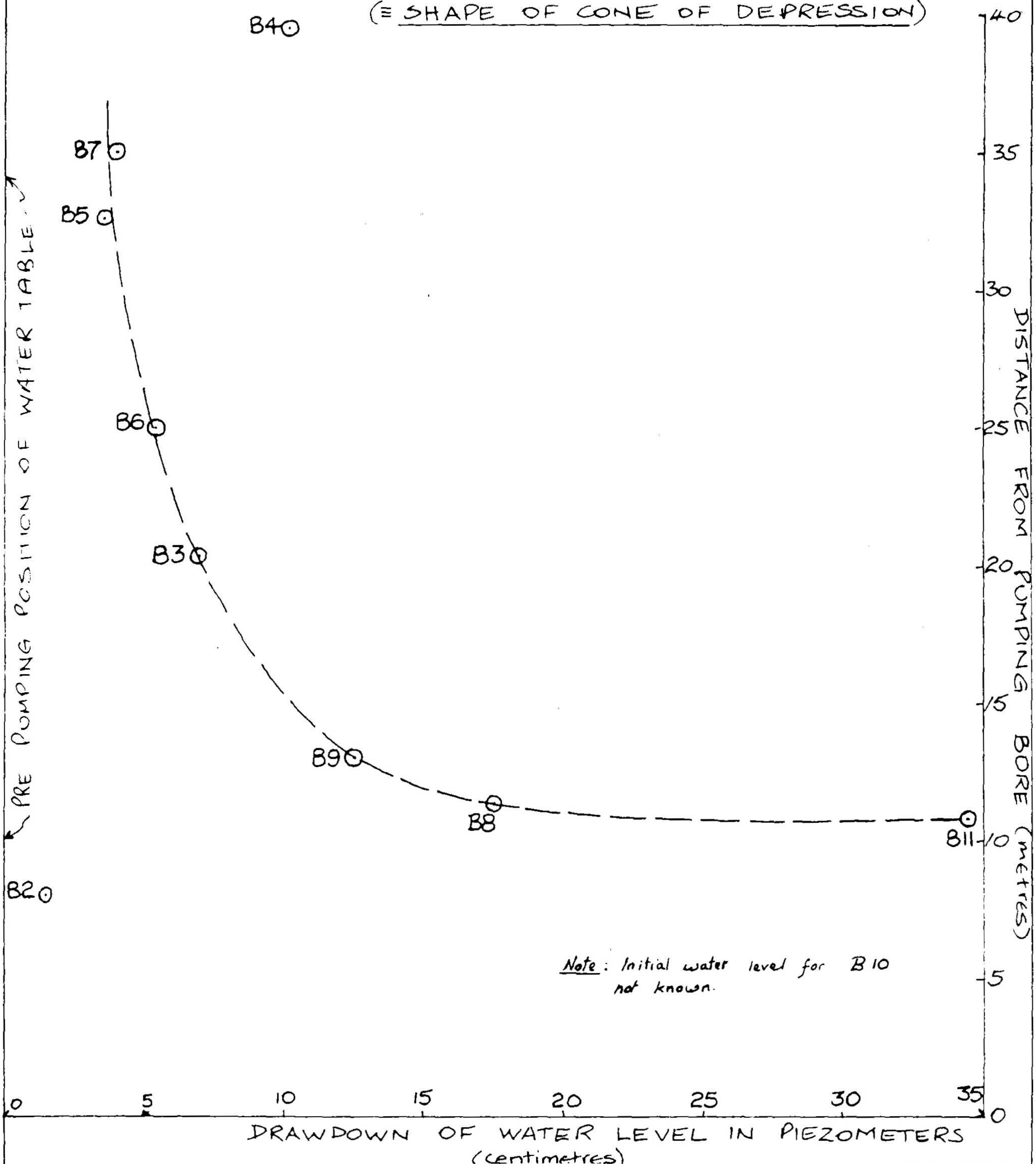


FIGURE 4

DRAWDOWN OF WATER TABLE DUE TO PUMPING VS DISTANCE FROM PUMPING BORE

(≡ SHAPE OF CONE OF DEPRESSION)



AMENDMENTS			
No.	Description	Author	Checked
A1			
A2			
A3			
A4			
A5			

SCALE

Base map/survey

Geology by P.D. HOHNEN

Compiled and checked: P.D.H. — Project geologist

Checked and approved: Senior geologist

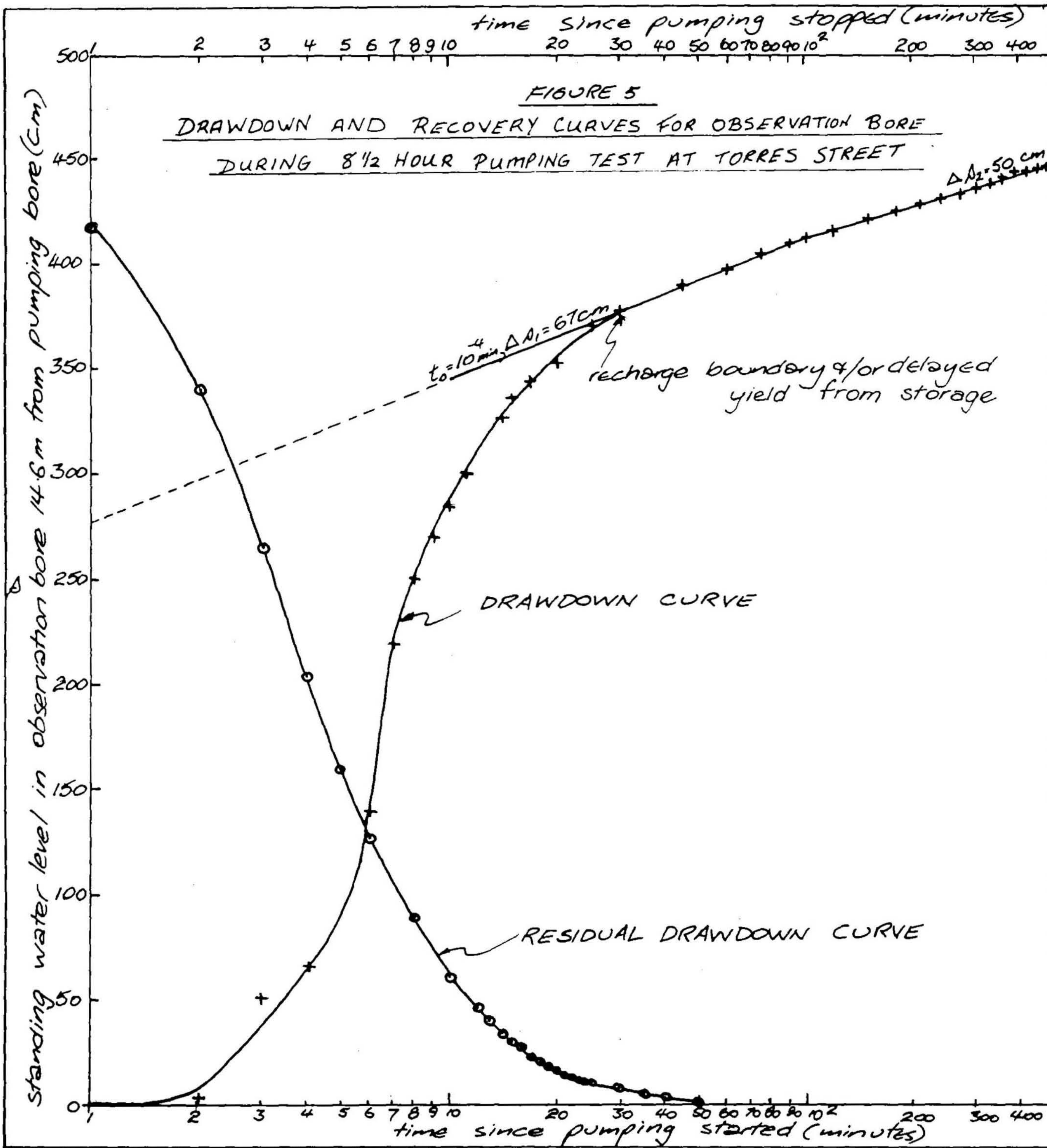
Supervising geologist

COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.

TITLE: SHAPE OF CONE OF DEPRESSION

PROJECT: TORRES ST, DRAINAGE

To accompany	Drawn by	Drawing No
Record 1977/51	P.D.H.	155/A16/1804



$T = \dfrac{2.3Q}{12.57\Delta s}$ (transmissivity)

$Q = 6\,m^3/h$ (pumping rate)

$\therefore T_1 = \dfrac{2.3 \times 6 \times 24}{12.57 \times 67}$

ie, $T = 39.3\ m^2/day$

$S_1 = \dfrac{2.25\,T_1 t_0}{r^2}$ .... $t_0 = 10^{-4}$, $r = 14.6m$

$= \dfrac{2.25 \times 39.3 \times 10^{-4}}{(14.6)^2 \times 1440}$

ie, $S_1 = 2.88 \times 10^{-8}$ (storage coefficient)

T = transmissivity = aquifer thickness x hydraulic conductivity

Q = pumping rate

S = storage coefficient

r = distance between pumping bore and observation bore.

t_0 extrapolation of linear part of drawdown curve to zero → t_0 = hypothetical time at zero drawdown.

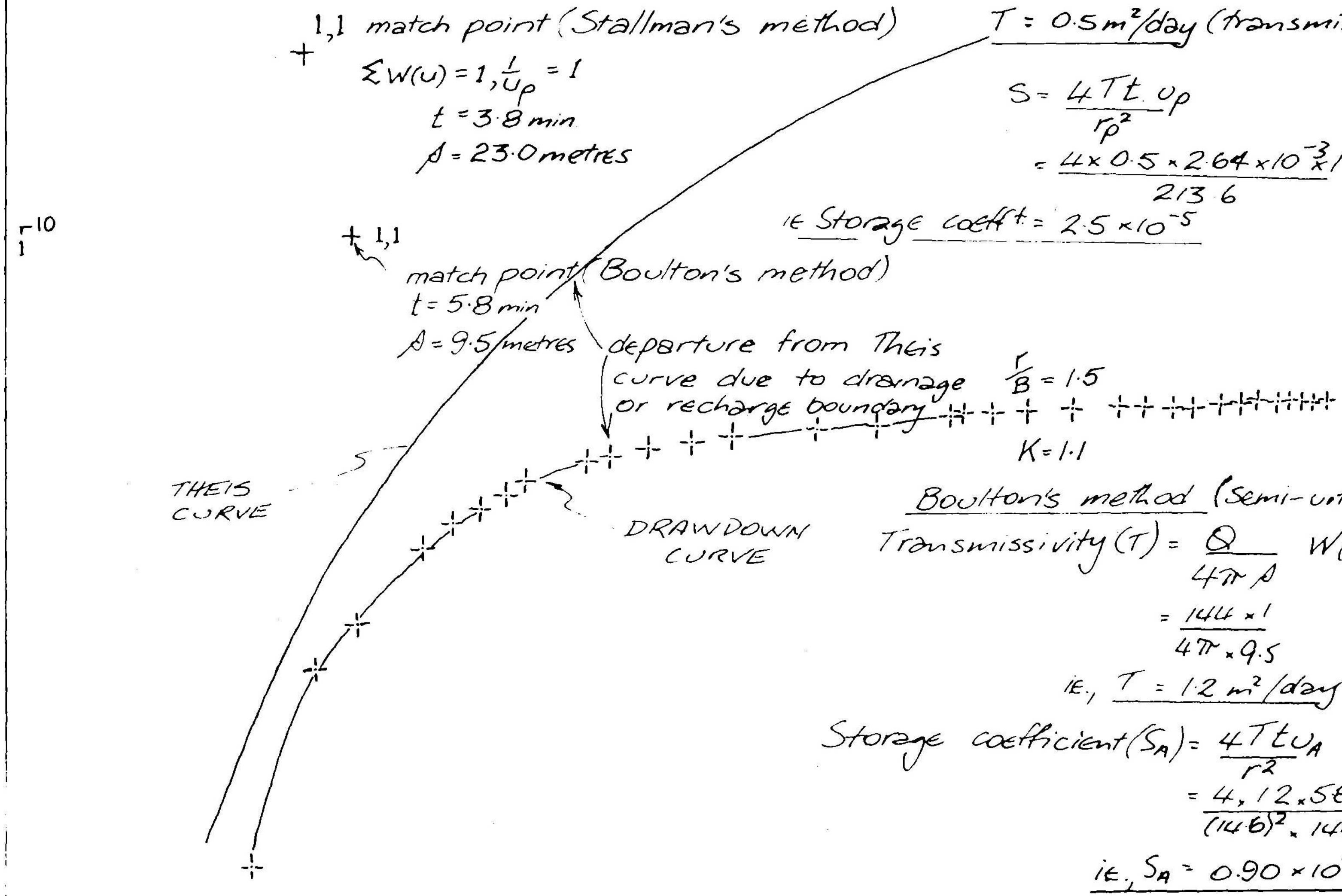
Δs = slope of linear part of drawdown curve

FIGURE 5

FIGURE 6

ANALYSIS of PUMPING TEST BY STALLMAN'S METHOD

and by BOULTON'S METHOD



Stallman's method (recharge boundary)

$$T = \frac{Q}{4\pi s_0}(W(u))$$

$$= \frac{144 \times 1}{12{\cdot}57 \times 23}$$

$Q = 144\ m^3/d$

$W(u) = 1$

$s_0 = 23\ m$

$T = 0{\cdot}5\ m^2/day$ (transmissivity = k × aquifer thickness)

$$S = \frac{4Tt\,u_p}{r_p^2}$$

$$= \frac{4 \times 0{\cdot}5 \times 2{\cdot}64 \times 10^{-3} \times 1}{213{\cdot}6}$$

$u_p = 1$

$r_p^2 = 213{\cdot}6\ m^2$

$t = \frac{3{\cdot}8}{1440}$ days

ie Storage coeff^t = $2{\cdot}5 \times 10^{-5}$

K = 1·1 (from type curve)

Boulton's method (Semi-unconfined aquifers with delayed yield)

$$\text{Transmissivity } (T) = \frac{Q}{4\pi s} W(u_A, r/B)$$

$$= \frac{144 \times 1}{4\pi \times 9{\cdot}5}$$

ie, $T = 1{\cdot}2\ m^2/day$

$$\text{Storage coefficient } (S_A) = \frac{4Ttu_A}{r^2}$$

$$= \frac{4 \times 1{\cdot}2 \times 5{\cdot}8 \times 1}{(14{\cdot}6)^2 \times 1440}$$

ie, $S_A = 0{\cdot}90 \times 10^{-4}$

$r = 14{\cdot}6$ metres

$Q = 144\ m^3/day$

from match point:

$t = \frac{5{\cdot}8}{1440}$ day

$s = 9{\cdot}5$ metres

$\pi = 3.14286$

$\frac{1}{u_A} = 1$

$W(u_A, r/B) = 1$

TABLE 1 - DRAWDOWN OF PIEZOMETERS DURING PUMPING TEST

Pumping rate: 6.5 m^3/h

time since pumping began (minutes) / height of piezometer above ground	Steel pipe	B2	B3	B4	B5	B6	B7	B8	B9	B10
	+9.0 cm	+68.0 cm	+64.0 cm	+66.0 cm	+31.5 cm	+31.0 cm	+34.0 cm	+36.0 cm	+32.0 cm	+8.5 cm
0	DRAWDOWN overflowing	- DEPTH BELOW TOP OF CASING (cm) 80.0	113.0	76.0	36.0	34.0	96.0	44.0	75.0	?
75	2.5									
80	2.6									
104	4.5									
111	5.15									
124	6.3									
137	7.4									
144	8.0									
154	9.1									
167	10.2									
175	11.4									
183	12.4									
186		80.0								
190	13.3							51.5		
196						36.5				
201	14.1							51.5		
203		80.0								
244	17.5	80.0						52.5		
285		81.0						54.0		
292	21.6									
307	22.8									
312						37.0				
321	23.8	81.5								
326								55.5	85.0	
344	25.7							56.0		
350								57.0	85.5	44.0
372	27.5	81.5								
376									86.0	
381						37.5				
398	29.0	81.5						58.0		
407									87.0	44.5
419			118.0	85.0	39.0	38.5				
426	30.8									
442	31.6								87.0	
446		81.5								
460	32.6							59.5		
475			119.0	86.0	39.5	39.0	100.0	60.5		
497	34.5					39.4			87.5	45.5
508		81.5	120.0	86.1				61.5		
DISTANCE FROM BORE	10.8 m	8 m	20.4 m	39.5 m	32.6 m	25.0 m	35.0 m	11.4 m	~13 m	>20 m
Drawdown	34.5 cm	1.5 cm	7.0 cm	10.1 cm	3.5 cm	5.4 cm	4.0 cm	17.5 cm	12.5 cm	?

TABLE 2 - SUMMARY OF INTERPRETATIONS OF AQUIFER TEST

METHOD OF ANALYSIS	TRANSMISSIVITY (m^2/day) Aquifer A (low values)	Aquifer B (intermediate values)	Aquifer C (high values)	STORAGE COEFFICIENT
1. Weathered, fractured Mt Painter Porphyry				
Stallman's (1963) method	0.5			2.5×10^{-5}
Boulton's (1963) method	1.2			9×10^{-5}
Recovery method (Hazel, 1973)	5.4	9.2	24*	(4.2×10^{-5}) (2×10^{-5}) (1.1×10^{-7})
Straight line approx. (Hazel, 1973)			39*	2.9×10^{-8}
Residual Drawdown (Hazel, 1973)	1.5,	3.4,	5.7	N/A
Average of low and intermediate values		3.8		4.4×10^{-5}
Average of high values (recharge boundary, see Fig. 4)		31.5		7×10^{-8}
2. Sandy soil at base of black (OH) clay				
Straight-line approx.	0.33			5.3×10^{-4}

Assuming that the thickness of aquifer A + B is 12 m (the total thickness of highly and completely weathered fractured dacite that yielded water, then the average hydraulic conductivity (or coefficient of permeability, k) for that interval is 0.32 m/day.

The low value of the storage coefficient indicates that the aquifer is confined or semiconfined. The organic clay of very low permeability that overlies the fractured-rock aquifer system is the confining layer.

The newly drilled bore was pumped at 6.5 m^3/h for eight and a half hours (Table 1; Fig. 5). Thirty minutes after the start of pumping, the water-level of the pumping bore had fallen to 7.85 m below ground surface and the drawdown of the observation bore at a distance of 14.7 m was 3.77 m at that time. The maximum drawdown of the pumping bore was achieved after 30 minutes, while the level of the observation bore fell over the eight and a half hour period to 4.48 m. When pumping stopped, the pumped bore recovered in less than eight minutes, the observation bore in 50 minutes (see residual drawdown curve, Fig. 5).

Analysis of pumping test

Several methods were used to analyse the pumping test results (Table 2). The shape of the drawdown curve (Figs 5 and 6) indicates that the aquifer system was recharged during pumping by one or both of the following processes:

a) drainage from weathered rock or soil above the aquifer;

b) intersection of a recharge boundary about 16 m from the observation bore.

The aquifer characteristics were analysed by Stallman's method and by Boulton's method (Fig. 6, Table 2). Analysis by the residual drawdown method and the recovery method was carried out for comparison.

The pumping test indicated that the bore could be pumped at rates up to a maximum of 11 m^3/h, with a much broader cone of depression resulting from high pumping rates than was achieved by the older bore with the jackpump installation. BMR recommended that an electric submersible pump capable of controllable, sustained yields of up to 11 m^3/h should be installed with the pump intake 3 m above the bottom of the bore.

EFFECTIVENESS OF REMEDIAL WORK

Pump installation

A 'Grundfos SP 10-18' electric-submersible pump capable of lifting water through a vertical height of 48 m at a rate of about 10.7 m^3/h was installed by a contractor at a depth of 56 m (Fig. 3). The pump is a multistage centrifugal type and is 1.68 m long and 9.5 cm in diameter. Initial tests of the pump at maximum delivery showed that the resultant drawdown depressed the water-level in the bore almost to the cut-out switch, 3 m above the pump, so the pump was throttled back by means of a valve on the discharge line. Groundwater discharge was again reduced in November, when conditions became much drier. The reduced delivery of 9 m^3/h resulted in a drawdown to within 3 m of the cut-out switch, and, with only minor fluctuations of drawdown in the bore, frequent operation of the cut-out was avoided. Manual switches were installed so that the pump could be turned off during dry periods, and a drain was constructed to divert flow from the bore to the stormwater drain during periods of high water-table when the pump is inoperative.

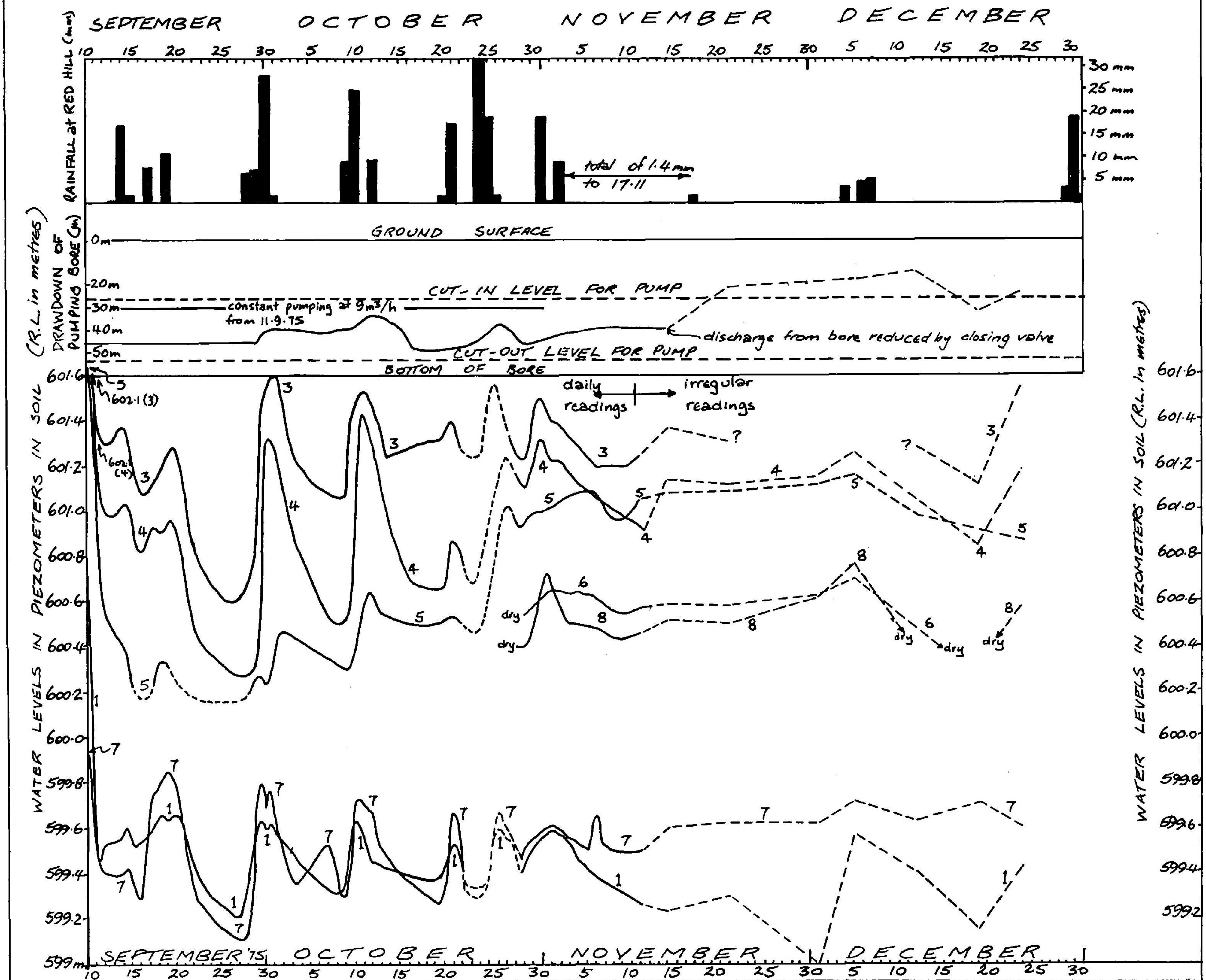
Pump operation and groundwater control

During the first three months of pumping the piezometric levels were monitored at first daily, then weekly (Fig. 7). The water-levels show a very close correlation with rainfall recorded at Red Hill, with a lag of less than 24 hours between peaks for rainfall and for groundwater levels in soil on Blocks 15 and 16.

After three months' operation of the new pump installation, there was no evidence of seepage on Blocks 14, 15, or 16, and a long-term resident of the area stated that Blocks 14, 15, 16, and 17 were in the driest condition that she had known over the last 25 years. At that time the operation of the pump was handed over to the lessees of Block 16.

FIGURE 7

RAINFALL/DRAWDOWN/WATER-LEVEL RELATIONS AT TORRES STREET



B1, B3, B4, B5, B6, B7, B8 are piezometers.
Piezometers B2, B9, B10 and B11 were either blocked or dry soon after pumping started.

AMENDMENTS			
No.	Description	Author	Checked
A1			
A2			
A3			
A4			
A5			

SCALE	
Base map/survey	
Geology by	P.D. HOHNEN
Compiled and checked: P.D.H. Project geologist	Checked and approved: Senior geologist
Supervising geologist	

COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.

TITLE: Rainfall-Drawdown-Water Table Relationship at Torres Street		
PROJECT: TORRES ST. DRAINAGE PROBLEM		
To accompany Record 1977/51	Drawn by P.D.H.	Drawing No: 155/A16/1807

APPROXIMATE WATER BALANCE OF TORRES STREET CATCHMENT

All the data that are required for these calculations are not available and so estimates, based on experience and data available for other areas, were used in the calculations. Calculations are believed to give results that have an order of accuracy of $\pm$ 100%, which though imprecise, give an idea of water balance at the urban level that is seldom given in literature on drainage problems.

Average infiltration from precipitation

Assuming 120 storms per annum, and that 2 mm of rainfall per storm infiltrates into the groundwater system, then the average daily infiltration is 0.7 mm.

Area of catchment = $2.9 \times 10^5 m^2$,

volume of infiltration from precipitation = 200 m^3 day ... (1)

Average infiltration from lawn watering

Assuming an average of two hours watering per diem for each house for half of year at a watering rate of 1 m^3/h per house; there are 25 houses within the catchment:

volume of infiltration from lawn watering = 25 x 1 x 2 x 0.5 = 25 m^3 /day ....(2)

Total average recharge, (1) + (2) = 225 m^3/day

Flow of groundwater beneath Torres Street catchment

Assuming that groundwater flows across the whole cross-section of the catchment through a saturated thickness of 30 m (the depth interval of the bore that contributed to groundwater yield), and that the transmissivity of the fractured-rock aquifer system that was calculated from the pumping test is representative of the cross-sectional area of 305 m x 30 m, then the average hydraulic conductivity for the saturated thickness of 30 m is $\frac{3.8}{30}$ m/day;

hydraulic conductivity k = $\frac{\text{transmissivity}}{\text{aquifer thickness}}$

$$\text{flow} = 305 \times 30 \times \frac{3.8}{30} \times 0.109$$

(Q) (A) (k) (i).... where

i.e. flow = 126 m^3/day

Q = flow
k = hydraulic conductivity
i = hydraulic gradient
A = cross-sectional area

The calculated average daily flow is about 100 m^3 less than the estimated average daily recharge. This indicates that a large volume of water is lost to the atmosphere by evapotranspiration, which seems reasonable considering the proximity of the water-table to the groundsurface.

The presumed average loss of groundwater to the atmosphere represents an average daily loss of 0.34 mm over the whole catchment.

WATER QUALITY

A chemical analysis of the groundwater is given in Table 3. It is quite suitable for garden watering, and was used for that purpose soon after initial operation of the pump.

TABLE 3. CHEMICAL ANALYSIS OF GROUNDWATER FROM BORE AT BLOCK 16, TORRES STREET, RED HILL

Sample No.: 75270003 Date of Collection: July 75

Chemical Composition

Cations		Milligrams per litre Mg/1	Milliequivalents per litre Me/1
Calcium	(Ca)	94	4.7
Magnesium	(mg)	29	2.4
Sodium	(Na)	43	1.9
Potassium	(K)	19	.5
Iron	(Fe)	-	-
Anions			
Hydroxide	(OH)	-	-
Carbonate	(CO_3)	-	-
Bicarbonate	(HCO_3)	407	6.7
Sulphate	(SO_4)	47	1.0
Chloride	(Cl)	63	1.8
Bromide	(Br)	-	-
Fluoride	(F)	0.65	0.03
Nitrate	(NO_3)	17	0.3
Phosphate	(PO_4)	-	-

TOTALS AND BALANCE

Cations	(Me/1)	9.5	DIFF = 0.3
Anions	(Me/1)	9.8	SUM = 19.3

Reaction - Ph 7.8

Sodium to total cation ratio (Me/1) 19.8%

Derived and Other Data

Conductivity (EC) Micro-s/cm at 25°C = 932	Milligrams per litre Mg/1
Total dissolved solids	
Calculated (HCO_3= CO_3)	513.
Total hardness as $CaCO_3$	354.
Carbonate hardness as $CaCO_3$	334.
Non-Carbonate hardness as $CaCO_3$	20.
Total alkalinity as $CaCO_3$	334.

CONCLUSIONS

1. Saturated soils on Blocks 15 and 16 are normally recharged from a deep, fractured-rock aquifer system.

2. Soils on Blocks 15 and 16 can be drained by pumping from a deep bore. The effect of the new pump is much greater than that of the old pump.

3. When the pump is operating, high water-levels in piezometers on Blocks 15 and 16 do not persist beyond 2-4 days after rainfall.

4. Transmissivities of the fractured-rock aquifers intersected by the bore range from 0.5 to 5.4 m^2/day, and there are indications that higher-transmissivity aquifers recharge the aquifer system. Storage coefficients are probably in the range 2.5×10^{-5} to 4.2×10^{-5}.

5. The approximate water balance indicates that, over a seasonal cycle, groundwater is being mined when it is extracted at a rate in excess of about 120 m^3/day. If high pumping rates are maintained for long periods, the soil beneath foundations could consolidate, with the risk of structural damage to the house on Block 16.

RECOMMENDATIONS

The pump should be used only intermittently :

(i) the pump need only be operated when the potentiometric surface is close to the ground surface on Block 16 - that is, when water appears in the shallow piezometer in the courtyard on the eastern side of the residence on Block 16;

(ii) groundwater extraction over a full year should not exceed an average of 120 m^3/day, or a continuous pumping rate of 5.2 m^3/hour. This pumping rate will cause a drawdown of about 27 m in the pumped bore, which should be sufficient to give a large cone of depression of the potentiometric surface and hence a widespread drainage effect.

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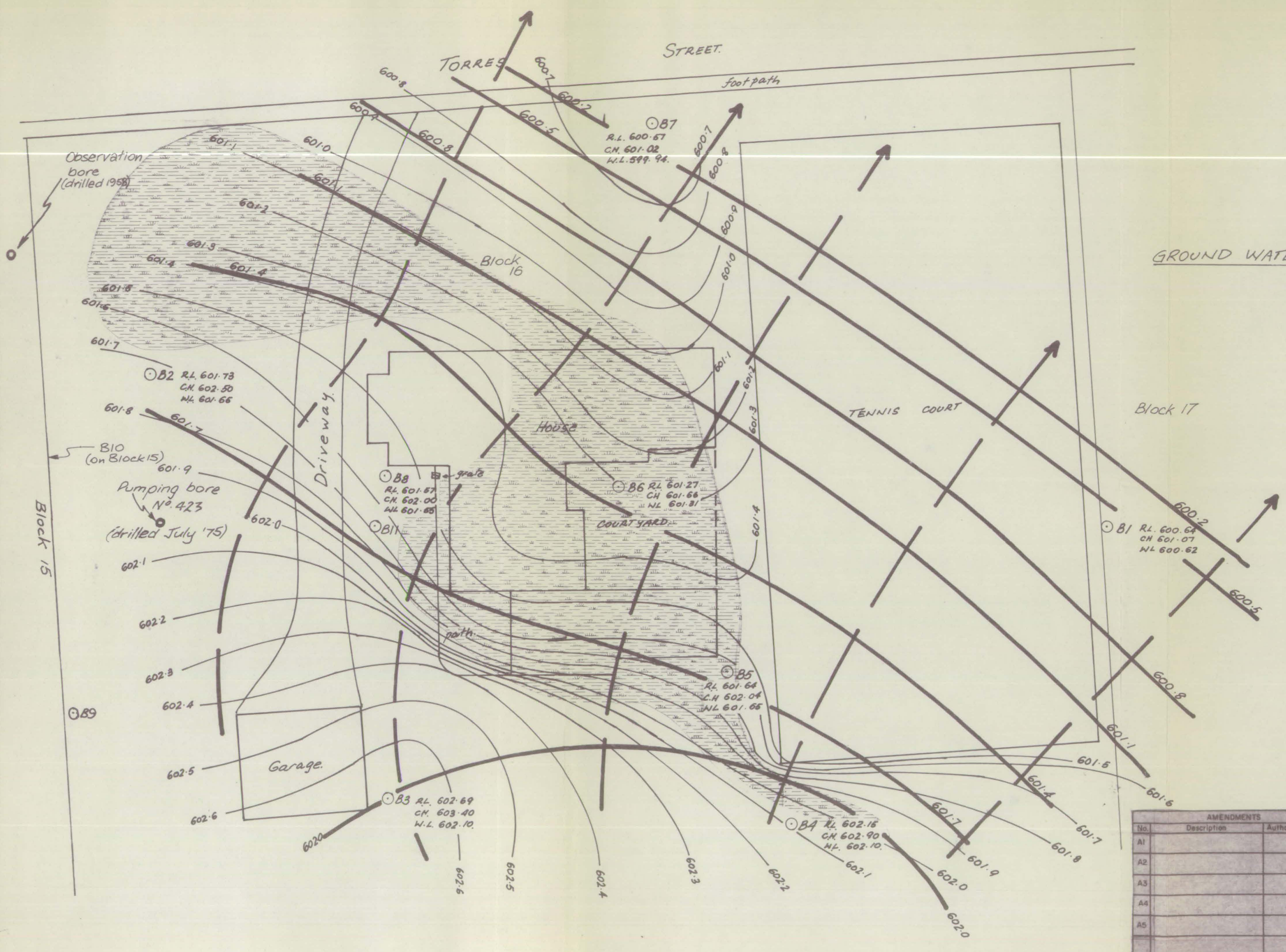
PLATE 1



GROUND WATER FLOW-NET, BLOCK 16, TORRES STREET

LEGEND

Topographic contours. — 602 —

Potentiometric-Surface Contours (for July, '75) — 602

Lines of groundwater flow (showing direction)

Piezometer ⊙ B1

Ground surface level R.L. 600·00

Height of casing. C.H. 601·07

Water level in piezometer. W.L. 600·62

Measurements in metres.

Area where water table was at or above ground surface in June, 1975 (despite pumping from 1958 bore at 2·7 m^3/h for 23 hrs/day)

AMENDMENTS			
No.	Description	Author	Checked
A1			
A2			
A3			
A4			
A5			

SCALE 1:200 — 2 0 2 4 6 8 m — Measurements in metres

Base map/survey

Geology by

Compiled and checked: P.D. HOHNEN, Project geologist

Checked and approved: Senior geologist

Supervising geologist

COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.

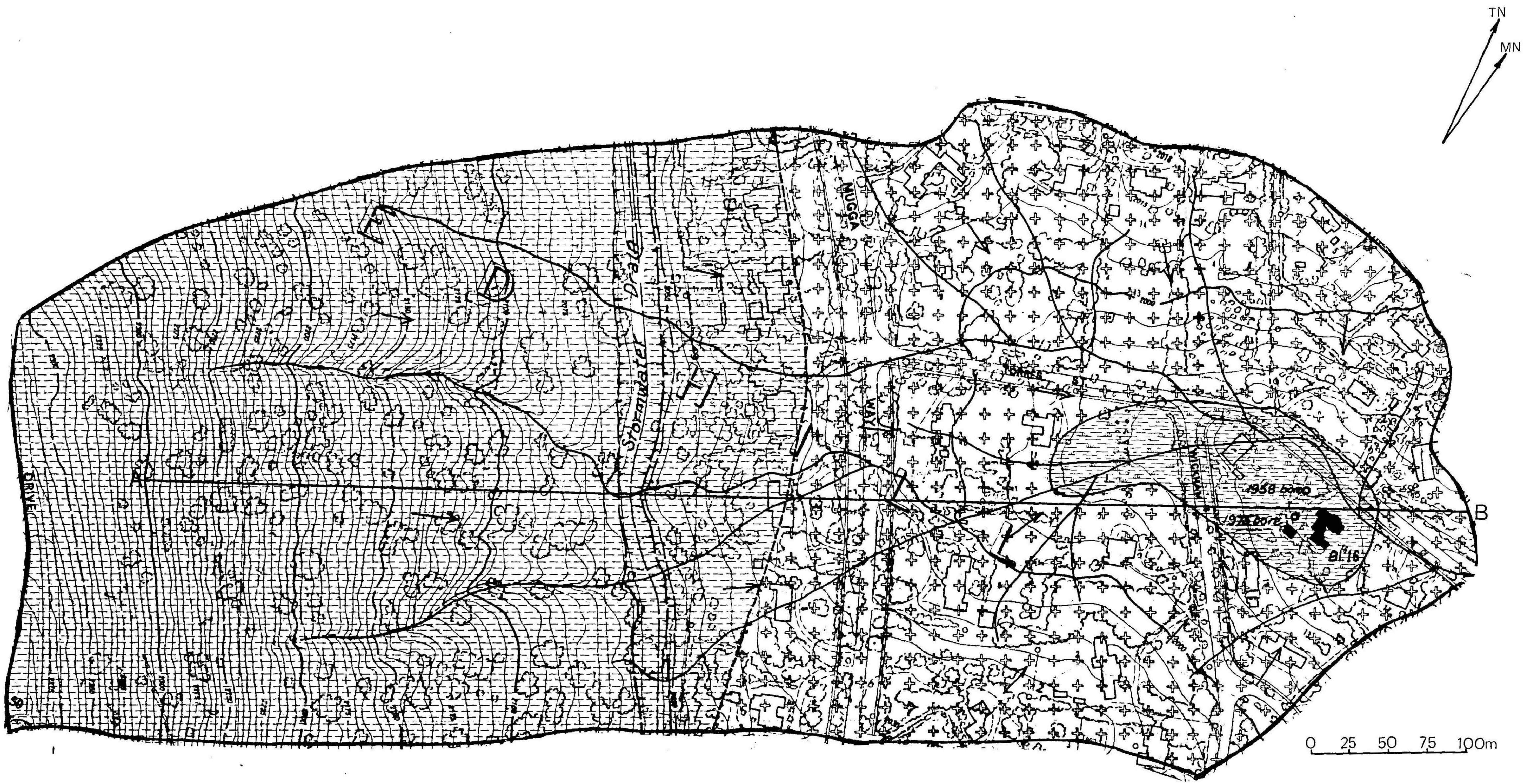
Project: Groundwater Investigation: Block 16 Torres St Red Hill

Title: Groundwater Flow-Net, Block 16, Torres Street

To accompany	Drawn by	Drawing No.
Record 1977/51	P. R.	155/A16/1809

PLATE 2

TORRES STREET CATCHMENT



Area of intermittent groundwater seepage

Ephemeral overland-flow paths
interflow

Mt Painter Porphyry

Yarralumla Formation

Geological boundary, position approximate

Record 1977/51

155/A16/1809