GH 3174

THE GEOHYDROLOGY OF THE UPPER MOGALAKWENA VALLEY, NORTHWEST OF POTGIETERSRUS, TRANSVAAL

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Pretoria
30th June 1981

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ACKNOWLEDGEMENTS

I would like to thank Mr. W.R.G. Orpen for his overall supervision of this investigation, Mr. W. du Toit for undertaking the geophysical field work, Messrs. M. Jackson and C.J. Smith for supervising the pumping tests, Mr. P.S. Meyer for completing the borehole and groundwater abstraction survey and Messrs. E.A. and R. Whitehead for their assistance throughout the project.

Additionally I would like to express my appreciation to the N.P.R.L. for the opportunity to use the computer facilities at the C.S.I.R.

Hierdie koordinate is nie naastenby Potgietersrus nie !!

1 INTRODUCTION

1.1 Location of study area

The main area for this field investigation is situated to the northwest of Potgietersrus and covers approximately 30 km². It is located within lines of latitude 24°55' and 28°59' east, and is depicted on the 1:50 000 sheet 2428BB (Tinmyne). The studied area occupies the western portions of the farms Macalacaskop 243 KR and Turfspruit 241 KR which together constitute part of Mokerong administrative district of the Lebowa Homeland (see Fig. 1).

1.2 Background of investigation

This study forms the closing sequence of a long ranging investigation into the groundwater potential of the area surrounding Potgietersrus. The prime objective of this current investigation was to quantify the groundwater resources of the Upper Mogalakwena Valley using existing data and new data which was now obtainable thanks to the cooperation of the Lebowan government who gave permission for exploration drilling and geophysical fieldwork on land previously inaccessible. The results of this survey in conjunction with previously obtained information have enabled recommendations to be made to the Municipality of Potgietersr for the augmentation of existing water supplies.

1.3 Approach of investigation

As it was expected that the primary aquifer(s) would be arenaceous and rudaceous alluvial deposits of the Dorps and Rooisloot Rivers near their respective confluences with the Mogalakwena River these deposits were extensively investigated using the Schlumberger electrical resistivity technique. Curve forms obtained were carefully scrutinised but saturated coarse grained deposits did not possess a distinct character on the sounding curves. However the presence of weathered and fractured bedrock, the secondary aquifer, could be identified in many instances from the sounding curve when the thickness of fracturing and weathering was of the order of 10m plus. Calibration of sounding curves was achieved by exploratory drilling and limited downhole resistivity logging of the the uncased sections of some bores.

Production wells with complimentary observation boreholes were developed within promising formation. These holes were later test pumped to enable calculations of transmissivity (T) and storage coefficient (S) to be made.

A borehole survey was undertaken to allow estimates of groundwater abstraction to be made within the study area and to supplement water level observations made in existing specifically drilled boreholes. This information permitted the compilation of a water table contour map. Samples of groundwater from the investigated area were submitted for full chemical analysis, as were waters sampled from surface water present in the Dorps, Mogalakwena/Nile and Rooisloot Rivers. (see Fig. 1). Data was interpreted to determine the relationship between possible recharge water and local groundwater. Only limited geological mapping, magnetic and electromagnetic work was carried out.

All data obtained from previous investigations in this area were re-interpreted and utilised in this report when considered sufficiently accurate.

1.4 Previous work

The earliest available written record of investigations in this area was carried out by Graats (1960) who reported on the feasibility of a dam across the Mogalakwena River immediately upstream of its confluence with the Rooisloot.Although the construction of the dam was possible it was not recommended due to the strong possibility of bacteriological pollution from settlements on the eastern bank.

During the site investigation for the dam six boreholes were drilled on the farm Blinkwater 244 KR and their logs were re=corded by Van Rooyen (1960). It was found that up to 20m of alluvial material containing substantial sections of clay was present throughout the area studied. Van Rooyen discussed the nature of waterflow in the Dorps, Rooisloot and Mogalakwena Rivers and speculated that the course of the Mogalakwena River had been pushed westwards and been partly filled up by material deposited by the Dorps and Rooisloot River.

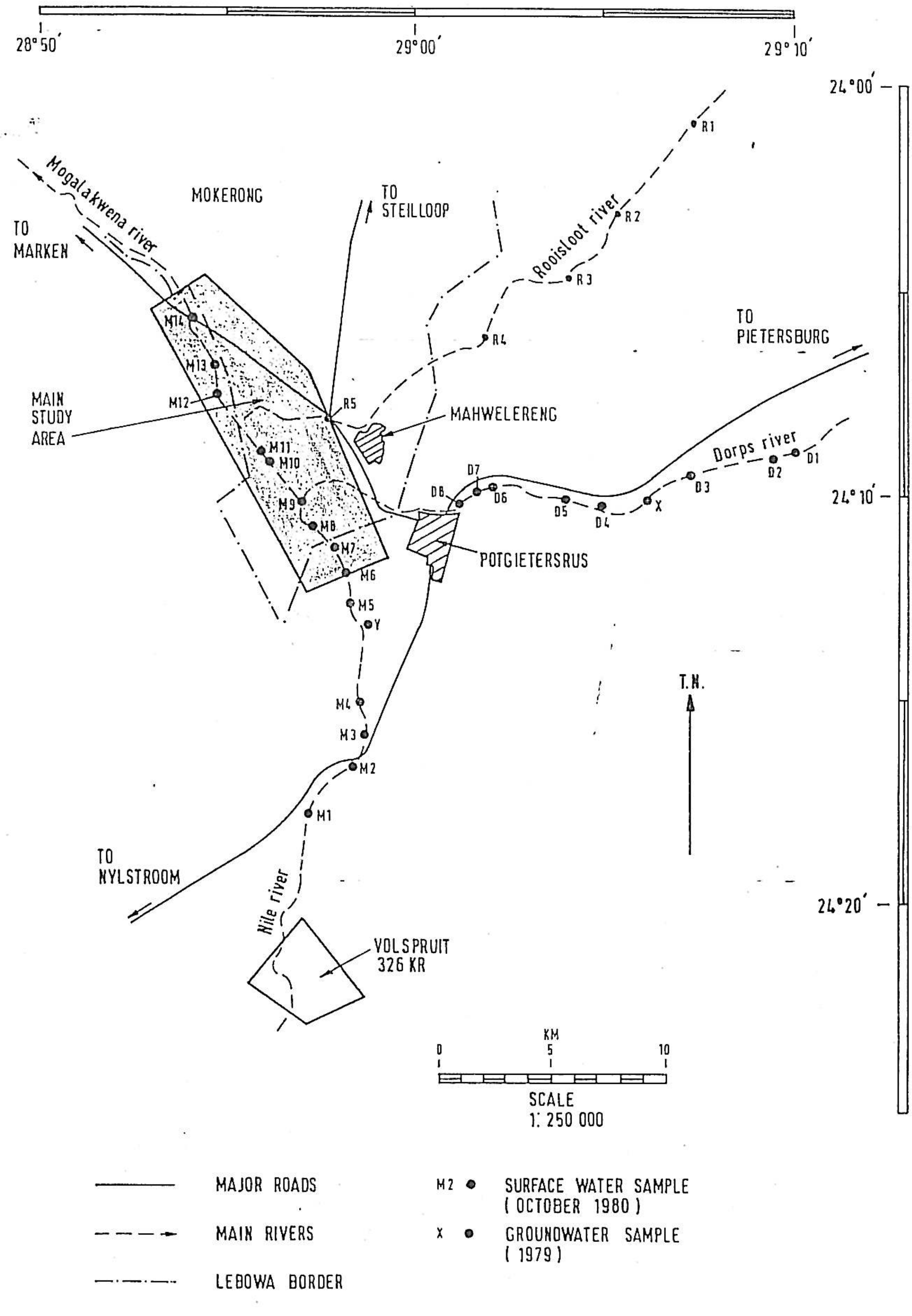
At a later stage (actual date and reference unknown, data presented in GH3012) fourteen boreholes were cored on the proposed dam wall site (refer to Enclosure 1) on Blinkwater 244 KR and the logs were described by S.B. de Villiers of the Geological Survey. These logs indicated that thin thicknesses of superficial material overlaid bedrock on the western bank and that the thickness of alluvial material increased to a promising 20m plus eastwards.

During 1973 the alluvial deposits on Blinkwater 244 KR were reconnoitred by Porszasz of the Dept. of Water Affairs. At least four exploratory boreholes were drilled and four monthly water level recorder stations were established along the course of the Mogalakwena River.

Kok and Venter (1978) published a report summarising the results obtained from a geohydrological examination of the farms Blink=water 244 KR, Rietfontein 240 KR and Turfspruit 241 KR. As part of this survey 437 Schlumberger electrical soundings were carried out and 37 boreholes were specifically drilled over the period 1975 to 1977. Borehole 5/28,5 was fitted with 6m of no. 40 Johnson sand screen and test pumped at a rate of 22 ℓ/sec for a period of $7^1/_2$ days. A map was prepared which indicated that the thickest development of alluvial material, some 25m plus, was present on Blinkwater 244 KR.

As part of the extensive investigation carried out by Lyness (1980) the deposits of the Nile River valley immediately west of Potgietersrus were examined by exploration drilling and test pumping. Geophysical work including Wenner and Schlumberger electrical soundings, electromagnetic and magnetic traverses were carried out across the Nile Valley. Lines 9 and 10 of Lyness were completed inside the area which is the subject of this investigation.

FIG. 1. LOCATION OF STUDY AREA AND SOME WATER SAMPLING POINTS.



2 PHYSIOGRAPHY

2.1 Topography

Reference to the topocadastral map 2428BB (Tinmyne) and Enclosure 3 reveals that the valley occupied by the Mogalakwena River has an elevation of some 1042m which declines extremely gradually northward. To the east a prominent gabbro hill, Lekalakala, rises some 175m above the surrounding countryside to a maximum height of 1242m, otherwise the land slopes gently with an average gradient of approximately 1 in 65 towards the river valley. A noticeable steepening in slope often occurs within a few hundred metres of the river valley. North of the Rooisloot River the gradient is somewhat shallower being in the order of 1 in 120 westwards.

West of the Mogalakwena River the granitic terrain rises abruptly some 600m plus above the valley floor and attains a maximum elevation of 1732m.

2.2 Drainage

2.2.1 Mogalakwena/Nile River

The main drainage feature is the Mogalakwena River, which known to the south as the Nile, this drains NNW with a very slack gradient of approximately 1 in 1000.

From Vaalkop 352 KR and Volspruit 326 KR (see Fig. 1) north=wards to Blinkwater 244 KR, a distance of some 30 km, the river channel consists of a series of shallow depressions, some of which are filled with water, generally only 1 to 2m deep while others being above the water table are dry. On the northern portion of Blinkwater the Mogalakwena forms a well-defined river channel incised some 1 to 2 metres into th unconsolidated depsots.

No surface water connections currently exists between lakes X, Y and Z refer to Enclosure 1, and the only surface flow in this river was observed in the well-defined channel but this declined to a trickle before the Marken-Potgietersrus road was reached.

Periodically heavy rainfall on the Nile River Catchment causes flood waters to travel downstream as far as Blinkwater 244 KR. The last flood occurred in 1976 (Kok 1978).

2.2.2 Dorps River

In the past surface water in the Dorps River joined the Mogalakwena valley from the east. This river has an average gradient of 1 in 70 and drains some 170 km² (Lyness 1980) of upland catchment composed mainly of carbonate and clastic sequences belonging to the Chuniespoort and Pretoria Groups respectively. The river channel is very clearly defined and even on the farm Macalacaskop 243 KR is still incised several meters deep before petering out some 500m east of the course of the Mogalakwena River. Since the construction of the Combrinck Dam in 1963 across the Dorps River no sustained flow has been observed in the channel south of Potgietersrus.

2.2.3 Rooisloot River:

The Rooisloot River drains an impressive upland catchment of some 280 km^2 before joining the Mogalakwena Valley. This river follows a well-defined channel with a gradient of approximately 1 in 100, from its origin in the S.W. Pietersburg District to a point some 1200m downstream of the present diversion channel on Turfspruit 241 KR. Upstream of Uitloop 3KS the catchment is composed of Arche granites while downstream for some 2,5 km the channel is incised into carbonate and clastic rocks of the Chuniespoort and Pretoria Groups, which are in turn succeeded to the west by gabbroic rocks of the Bushveld Igneous Complex.

Gently flowing surface water is found upstream for much of the year while surface flow through the unlined diversion canal to the Mogalakwena channel occurs only after heavy rainfall on the catchment in the middle and later parts of the rainy, season.

It was noticeable that heavy rainfall in early September 1980 caused the Rooisloot River to flow within the granitic are but that surface water flow virtually ceased over the are underlain by sand and dolomitic rocks on Uitloop. During t period only a small quantity of red coloured turbid water flowed over the weir immediately east of the Potgietersrus-Marken road. Heavy rainfall over a period of a few days in November caused run-off water to flow throughout the course of the Rooisloot River to a point some 600m north of the diversion channel where surface water apparently was lost to the sands flooring the channel. By early December similar high intensity rainfall caused surface flow throughout the Rooisloot River, through the diversion channel and into the valley of the Mogalakwena. Throughout December and January (the limit of field observations) even minor rain caused the Rooisloot River to flow throughout its length. The initial appearance of strong flowing water at the Potgietersrus-Marken road varied between 12 and 18 hours after the commencement of rainfall.

2.2.4 Minor Streams draining west

The Turfspruit has a well-defined valley before entering a marshy area just north of the Blinkwater track. A small flow was observed throughout December 1980 and January 1981.

Many of the other streams indicated on the topocadastral map have ceased to exist while others are ephemeral, acting only as conduits for local storm water.

Surface drainage within the built-up area west of the Potgietersrus-Marken is poor and when heavy rainfall occurs and a slight gradient is present sheet flow takes places towards the Mogalakwena River.

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2.2.5 Minor streams draining east

Several non-perennial streams drain into the Mogalakwena River from the rugged granitic escarpment to the west. After heavy rainfall run-off is high and waterfalls can be observed at several locations.

2.3 Climate

The area has a sub-humid climate with mild winters, hot summers and summer rainfall. For the period 1904 to 1980 rain fall station No. 633/881(A) now housed at Potgietersrus police station showed a mean annual rainfall of 605,1mm with an annual standard deviation of 143,4mm (see Fig. 2 and appendix 2).

3 GEOLOGY

3.1 Introduction

The formations in this area young from east to west and strike approximately northwest with a regional dip of some 20° to 25° to the southwest. These rocks form part of the northern limb of a major symmetrical syncline composed of Valium ar Mogolium aged formations which plunges at about 10° to the west.

Outcrops occur peripheral to the main study area and because of the considerable thickness of alluvial deposits they do not crop-out within the Mogalakwena Valley. Enclose 1 shows the distribution of the geological formations.

No major faults have been recognised with certainty during this study though evidence for some strike faulting is perhaps inferrable by the presence of altered sedimentary rocks within gabbro on geophysical line 16.

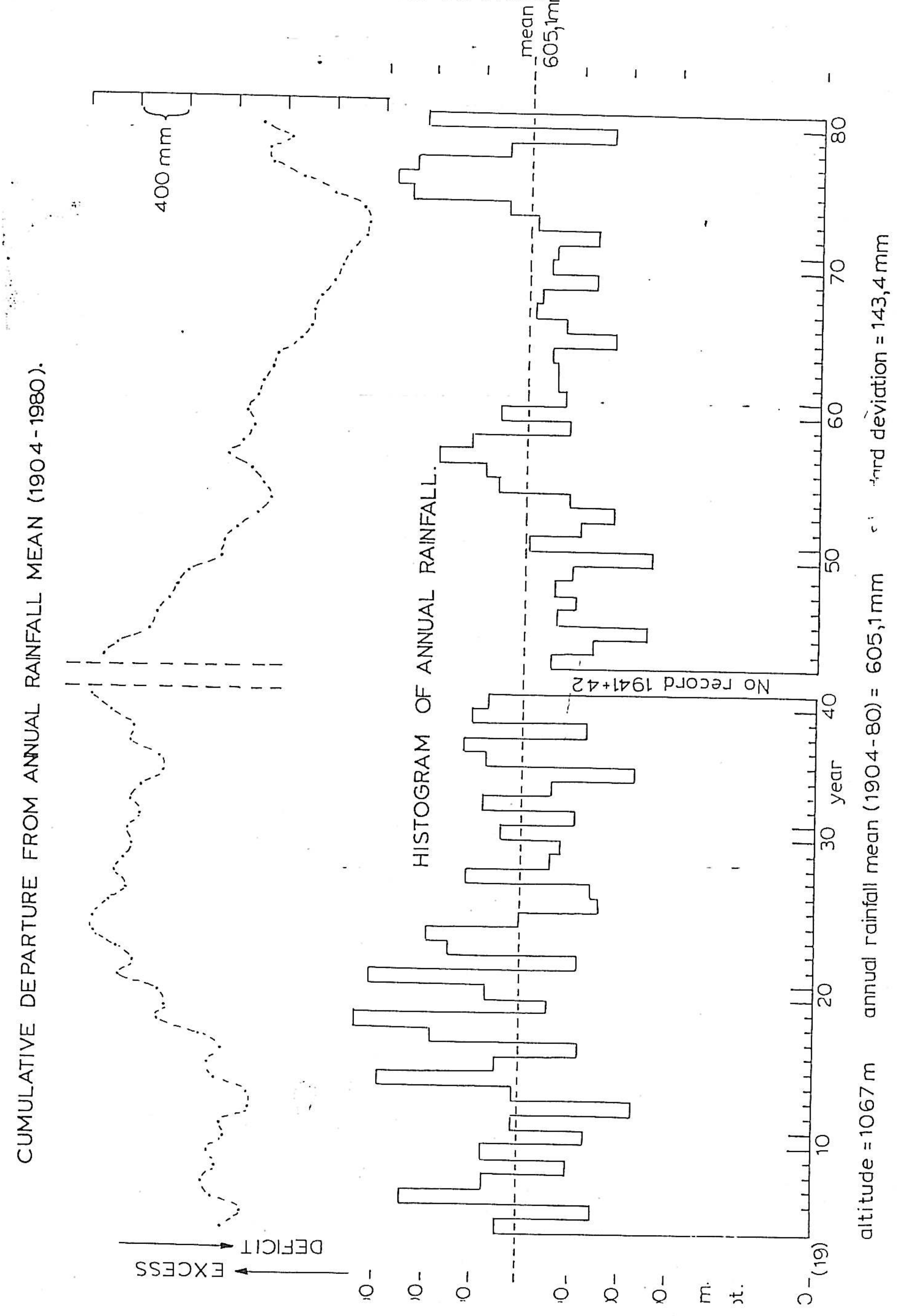
3.2 Metamorphosed Pretoria Group sediments

Formations of this group have been extensively metamorposed and partly metasomatised by the intrusive rocks of the Bushveld Igneous Complex thus individual formations are no longer distinguishable.

This group outcrops immediately west of the Mogalakwena River and subcrops partly beneath the valley. Similar rocks have also been encountered in boreholes G32701, G32705 and G32709 within the gabbro.

Argillaceous and arenaceous rocks have been altered to metaquartzite, hornfel, leptite, granulite and pseudogranophyre.

FIG 2 CHARACTERISTICS OF RAINFALL STATION No. 633/881 (A),
GHP 5400 POTGIETERSRUS POLICE STATION.



3.3 Rustenburg Layered Suite

Basic and ultrabasic igneous rocks occupy the flat land between the eastern upland area and the Mogalakwena Valley. This succession has been subdivided by the presence of distinct marker horizons and the following zones in younging order are recognised by the Geological Survey: lower zone; criticial zone; main zone and upper zone. Within the area studied only the two highest zones are present.

3.3.1 Main Zone

This zone outcrops in the east of the area investigated and forms the topographic high of Lekalakala. A gabbro with a fairly uniform appearance is the principal rock type developed. Minor layers of anorthosite can also be observed in the channel of the Rooisloot River west of Mahwelereng.

The depth of weathering and jointing appears to be very shallow within this rock type thus it is not expected that this zone would be of importance as an aquifer.

3.3.2 Upper Zone

Rocks of this zone are only known from drilling cuttings as they do not outcrop within the study area. Reference to the borehole logs indicates that rock types encountered have only been divided into gabbro and melagabbro, a pyroxene and/or olivine rich variety. It is probable that many of the drilling chips represent ferrogabbro but in the absence of a detailed petrographic study no attempt has been made to refine the rock inter pretation.

The presence of strongly conductive bands in certain magnetic profiles suggests the presence of distinct magne tite rich horizons.

This zone is thought to represent a fairly good secondary aquifer as weathering and jointing to an average depth of some 10m below the alluvial deposits has been indicated by drilling.

3.4 Lebowa Granite Suite

Coarsely crystalline grey and pink granite outcrop west of the Mogalakwena River stratigraphically above the altered Pretoria Group sediments, and also subcrop partly beneath the Mogalakwena Valley. When drilled they show some weathering and jointing and may be of minor importance as an aquifer when overlain by alluvial deposits.

Prominently exposed within the Rooisloot River are several dykes of pinkish aplite and microgranite which are intrusive within gabbroic rocks. These dykes strike roughly north-south and have a steep dip to the east.

9./........

3.5 Superficial deposits

A large part of this area is overlain by superficial deposits of varied lithology, thickness and origin. Sediment types include alluvial deposits, ferricrete, scree and soil.

Scree and a sandy loamy soil fringe the granitic uplands to the west of the Mogalakwena River, likewise gabbro scree and a heavy red clay occur peripheral to the residual hill Lekalakala.

Surface exposure adjacent to the Rooisloot River south of the Marken-Potgietersrus road clearly indicates that the gabbro weathers into semi-rounded boulders that are capped by a hard crust of ferricrete. Where products of decomposition are not readily removed a heavy red clay is formed. Areas that are affected by the major westwards draining rivers have had their natural soil types greatly altered by erosion and the deposit of sediments derived from upstream.

3.5.1 Alluvial deposits

These sediments are extremely important as an aquifer as they can attain a thickness in excess of 25m. The Dorps Rooisloot and Turfspruit have been the main contributors of detritus with presumably minor contributions coming down= stream within the Mogalakwena River and from the western highlands via swift flowing streams. Borehole information indicates that these deposits are thickest and contain the highest proportion of sorted coarse grained material to= wards the Mogalakwena River. Deposits downstream of the confluence of the Rooisloot and Mogalakwena River would also appear to contain a higher percentage of coarser material than those upstream.

A description of the alluvial deposits relies on an examination of the existing river banks, surface cover and the documented information obtained by drilling. When possible undisturbed formation has been cored with a sampler tube otherwise samples have been collected by bailer.

3.5.1.1 South of Lake Z

Alluvial material south of Lake Z to the Macalacaskop / Piet Potgietersrus boundary have been examined during this investigation.

The sediments show a large scale fining upwards cycle with unconsolidated gravelly sand being over= lain by clay and silty clay.

The logging of six boreholes, G32694 to G32698 and G32700 (Figs. 5 to 9 and 11 in appendix 1) indicates that between 4 and 8 metres of gravelly sand (Wentworth classification in Chapt. 3 of Pettijohn 1975) may be expected to be intercepted.

The composition of this gravelly sand is visually as= sessed to be:

10./.......

sand	≃ 65%
gravel, pebbles and cobbles	≃ 25%
clay and silt	≃ 10%

Sand grade material ranges from very fine to very coarse grained. It is composed predominantly of chert and quartz grains with some 5% pinkish feldspars and 5% of other lithic fragments.Individual grains are generally sub= angular and show a poor degree of sphericity and thus probably represent mainly first cycle sediment.

Rudaceous rocks are predominantly of gravel size though some pebbles and cobbles are also present. The following lithologies have been encountered and are listed in descending order of abundance:

chert (both bleached and fresh);
quartzite, white;
quartzite, black;
aplitic type rock,pink;
metashales and hornfels, blue-black;
vein quartz;
gabbro and
cemented cave earth deposits.

In form the gravel varies from subrounded to rounded and shows a low degree of sphericity with the metashales forming disc-shaped clasts.

Clay and silt occurs with the gravelly sand and con= stitutes around 10% of the bulk of the sample. From the method of sampling used it is unclear to what degree the gravels and sands are washed and sorted. It is possible that this argillaceous material is interstitial throughout the coarser sediment but it may also occur as distinct layering within the sands and gravels, or as a combination of both.

The thickness of clay and silty clay overlying the main coarse-grained fraction varies between 9 and 18m, the transition between lithologies is fairly abrupt. On line 14 the silty clay is red-brown in colour, loosely packed, and contains some 10% sand and gravel which may occur both scattered throughout and in distinct thin lenses. The clay is uncemented and apparently homogeneous throughout. The clay of line 12 is grey or black in colour and much more compact than that of line 14. It also contains some 10% sand with a similar mode of distribution. Coring indicates that this sediment has been thoroughly bioturbated and the activities of burrowing organisms has been confirmed by the recovery of calcified tube casts and valves of molluscs. A rootlet zone was also identified in G32695.

Borehole logging by Lyness (1980) suggests that in deposits to the south the sand and gravel is largely re= placed by silt.

3.5.1.2 Lake Z to Line 5

Sampling indicates that in an area north of the Blinkwater/Lebowa boundary a basic three fold subdivision of the alluvial deposits can be made i.e.:

1. sand; underlain by
2. silty clay; underlain by
3. gravelly sand

The logging of boreholes G32699, G32702 to 5 and G32708 (Figs. 10, 13 to 16 and 18 in Appendix 1) indicates that the basal layer varies from 1,5 to 4m in thickness, Visual examination shows that the clay content is variable. The estimate range in composition is;

sand	40 to 60%
gravel + pebbles	< 20%
clay	< 20 to 40%

Sand grade material is principally medium to very coarse grained and is somewhat different in composition to that found further south as it is consists of quartz grains with less than 10% orange-pink feldspar, chert and other lithic fragments. Grains are subangular and have a poor degree of sphericity.

Gravel and some pebbles occur and the following lithologies in an approximate descending order of abundance have been recognised;

quartzite, white;
aplitic type rock, pink;
granite, archean;
quartzite, blue;
metashale and hornfels, blue-black;
chert;
quartz and
gabbro.

Clasts are subrounded to rounded and show a low degree of sphericity.

Large quantities of clay and silt are present with the coarser sediments.

This layer is apparently poorly size sorted and uncemented.

12./........

A predominantly silty clay facies is developed above the gravelly sand with the junction between the two being somewhat transitional. The silty clay is generally red-brown in colour though some green-grey clay also occurs. River bank exposure indicates that sand and gravel occurs both scattered throughout the clay and also in distinct thin lenses. The silty clay is fairly compact and has often been indurated in its upper portion by cementation with ferruginous compounds.

Overlying the silty clay is an unconsolidated sand deposit. Where drilled this horizon varies between 2 and 6 metres in thickness. Excellent exposures occur in a working sand pit some 150m west of G32699.

Grade sizes ranges through fine sand to fine gravel with gravel being noticeably absent from some sections. The sand is composed principally of sub-angular and poorly spherical quartz grains, some of which are still cemented together by original matrix. Orange-pink feldspars and lithic fragments account for less than 8% of the sand. In some sections up to 10% quartzite and granite gravel is present. A few regular thin horizons of clay and silt impart a sense of stratification to an otherwise amorphous mass of poorly sorted sands and gravels.

Reference to borehole logs G32701, G32709 and G32710 (Figs. 12, 19 and 20 in Appendix 1) indicate that thick= nesses of alluvial deposits are considerably thinner and do not develop a basal gravelly sand layer. This is explained by the presence of a bedrock topographic high, see Enclosure 3.

The uppermost sand layer is not present in the vicinity of G32621 (Fig. 4) south of the Rooisloot diversion channel, nor in the environs of G32704 and G32705 (Figs. 15 and 16) as recent sand carrying flood waters of the Rooisloot have not inundated these areas.

Drillings data presented by Kok (1978) indicates that the three fold subdivision employed is not applicable from a line somewhere east of the Blinkwater/Lebowa boundary, here substantially larger thicknesses of coarser alluvial material are to be found.

3.5.1.3 <u>In the vicinity of borehole G32711</u>

Sampling of boreholes G32706, G32707, G32711 and G32712 (Figs. 17, 21 and 22) demonstrate that these depo= sits contain substantially less clay than those further south, e.g. G32708. These sediments can be roughly sub= divided into:

silty clays; underlain by
clayey gravelly sands; underlain by
gravelly sands.

The gravelly sands rest on weathered gabbroic bedrock and maintain a thickness of some 8,5m within this limited area, they consist of:

sand	≃ 70%
gravel and pebbles	≃20%
clay and silt	<10%

In appearance they are essentially similar to the gravelly sands described in section 3.4.1.2.

Three to six metres of clayey gravelly sands (clay up to 30% of the bulk) were recovered by G32706 and G32707 lying above the basal gravelly sands.

The topmost beds comprises 6 to 9m of loose packed orange-brown silty clay within which some scattered sand, gravel and pebbles occur.

3.5.1.4 <u>Mode of deposition</u>

The nature and distribution of the sediments indicate that deposition occurred in two major partly coalescing alluvial delta environments within and between which numerous subenvironments developed.

Sedimentation was presumably seasonal with detritus being brought down by strong surface flow events from the catchment of the major rivers. Run-off was intensified from these areas by the upland topography, scant vegetation and fairly steep river gradients.

Deposition of coarse sediments presumably occurred at a final slackening of gradient in the flood plain along the Mogalakwena River while finer material was carried into the river. Partial resorting and redistribution of these deposits was no doubt accomplished by flood waters of the Mogalakwena.

With time original river channels were blocked and coarser material was dumped further upstream which stimulated the cutting of fresh channels and the sedimentation of overbank deposits.

The presence of loosely packed clays with randonly scat= tered sand, gravel and pebbles suggests that much of the deposits may be termed mudflow deposits (Pettijohn, 1975, p. 548). These tend to be the product of severe but short-lived run-off events. Better stratified deposits may be the result of more sustained water flow. Black organic clays probably formed in a backswamp environment which was subjected to periodic inundation by flood waters.

The presence of widespread sand deposits resting on an eroded contact with the underlying cemented mudflow deposits suggest that a relatively recent change in depositional history has occurred within the RooiSloot delta. This may be related to changes in run-off con= ditions within the Rooisloot Catchment or the progressive building up of the delta.

Van Rooyen (1960) observed that the flood waters of the Rooisloot entering the flat land near the Mogalakwena channel advance over a front some 900m wide depositing sand rapidly and carrying fine material to the Mogalakwena River. He also noted that in 1960's the Dorps River brought down mainly silt.

Contouring of alluvial thicknesses indicates that the original channel of the Mogalakwena River had a gradient of some 1:200 (Enclosure 3) which was reduced by deposi= tion to the present 1:1000. The blocking of the courses of the Rooisloot and Dorps is also shown by contouring while the method indicates that the Turfspruit has managed to keep its channel fairly open.

Streams draining the granitic escarpment to the west bu[illegible] up minor alluvial fan deposits and contributed some gravel, sand, silt and clay to the Mogalkwena. The [illegible] contribution brought downstream by the then flowing Nile/Mogalakwena River is unknown.

At present no sediment is brought down by the Dorps River while the current diversion channel on the Rooisloot River has resulted in thicknesses of sand accumulating within this channel and spilling westwards out of the channel while suspended clay and silt are being carried into Lake Z.

4 GENERAL GEOHYDROLOGY

Information for this section was obtained from the following sources

- Kok and Venter (1978)
- Lyness (1980)
- Division of Works, Mahwelereng (Aug 1980)
- Borehole and groundwater abstraction survey conducted by Meyer (Sept.-Oct. 1980)
- logging of specifically drilled boreholes (Sept. 1980-Jan. 1981)

4.1 Borehole yields

Data presented by Kok (1978) indicates that boreholes yielding up to 25 ℓ/sec are present in this area with the strongest bore= holes have being drilled close to the Mogalakwena River and the irrigated land on Blinkwater 244 KR. Visual inspection has shown that substantial yields of 10 ℓ/sec are being obtained by the Lebowan government from a series of boreholes drilled adjacent to Lake Z. Information on wells drilled for this investigation is presented in Table 1 and shows that moderately yielding boreholes can be developed adjacent to Lake Y, e.g. G32697 and in the vicinity of G32709 and G32711.

TABLE 1 RELATIONSHIP OF WATER INTERCEPT TO GEOLOGY IN BOREHOLES DRILLED FOR THIS PROJECT

G/No.	B/No.	Latitude 24°S	Longitude 28°E	Depth m	Yield ℓ/sec	Water intercept (m)	Formation
32621	135987/6	09'19"	56'35"	25,9	> 2,1*	19 to 21	B
32694		09'40"	57'09"	31	> 3,1*	?	A+B
32695	135988/4	09'45"	56'54"	26	> 2,9*	?	A+B
32696	134922/4	10'39"	57'17"	51	0,13+	11-13	A
					> 6+	13 on	A
					2,6+	27	B
				Total	> 9		
32697	135935/5	10'39"	57'17"	45	17.	15 on	A+B
32698	137024/6	10'39"	57'17"	40	8,4+	15 on	A+B
32699		07'39"	55'50"	30,8	2,8*	?	A+B
32700	135956/7	10'31"	57'40"	51	> 6+	18 on	A+B
32701	135957/5	08'09"	56'12"	45	4,5+	34	C
32702	135958/3	07'39"	55'50"	35	1,5+	20-21	B
32703	135959/1	07'59"	56'06"	22	seepage	16	A
32704	135960/6	06'50"	55'17"	39	0,13	14	A
					3,2+	15-32	B
32705	135961/4	07'10"	55'29"	44	3,2+	32	B
32706	135962/2	06'49"	55'42"	15	> 5+	10	A
32707	137045/8	06'53"	55'44"	21	4,5+	17-18	A
32708	137046/6	07'03"	55'47"	32	4,2+	17	A
32709	137047/4	08'09"	56'12"	51	3,0+	31-32	C
					2,6+	35-36	C
					11.		
32710	137048/2	08'09"	56'12"	42	seepage	15-16	B
					0,5+	23	B
					2,5+	33	B
				total	3,0+		
32711		06'49"	55'40"	29	11,5.	14 on	A+B
32712		06'49"	55'40"	25	> 4,8*	13 on	A+B

* maximum of rotary pump
\+ measured by 90° 'V' notch
. test pump rate

A = alluvial deposits
B = weathered and fractured gabbro
C = fractured metaquartzite

16./.........

Comparisons of original delivery rate and present day pumpage indicates that the yield of the Lebowan Government boreholes by Lake Z has increased substantially since pumping commenced (see Appendix 3).

4.1.1 Relationship of borehole yield to geology

The strongest boreholes in this area eg 5/28,5 are present where the saturated gravelly sand or sand aquifer attain its maximum thickness and furthermore has been suitably developed as an aquifer by proper borehole construction and development. Wells in this material should be capable of yielding from 5 to over 25 ℓ/sec.

If sandy gravels are either not developed or are very thin or extremely clayey small quantities of water only are intercepted within this facies eg 0,13 ℓ/sec in G32704 (refer to Table 1).

Attention must then be paid to the weathered and fractured gabbroic bedrock which underlies much of the area. This formation provides between 2 and 10 ℓ/sec of water at a depth generally less than 33m and is thus an important aquifer. The highest yields are obtained by Lebowan government boreholes around Lake Z.

Most of the boreholes drilled on this project obtain water from both the alluvial deposits and the weathered bedrock.

G32701 and G32709 obtain moderate yields of groundwater, approximately 11 ℓ/sec from intensively fractured meta-quartzite.

The water-bearing properties of the granite and altered sedimentary rocks present on Blinkwater and west of the Mogalakwena river have not been examined.

Small yields obtained from wells and boreholes within the Mahwelereng town are due to the wells being hand dug through clayey deposits and thus having a limited degree of penetration into the weathered rock (results of borehole survey in Appendix 3).

4.2 Groundwater abstraction

4.2.1 Mokerong

Urban water for Mahwelereng east of the Marken-Potgieters=rus road is provided from boreholes adjacent to the Mogalakwena River, while untreated domestic water for the settlements west of the road is partly provided by a few Lebowan government borehole, with the remainder being obtained from several privately owned and equipped boreholes and numerous hand-dug wells (refer to Appendix 3).

The production boreholes T2809, T2810, T2811 and T2812 (and now L1017?) discharge into a common holding tank adjacent to T2809 (see Enclosure 1) where the water is chlorinated and pumped to a reservoir on Lekalakala. The water is then gravity fed to outlet points. Three stand-by boreholes; T2536, T2635 and T2636, are situated within Mahwelereng and are used when the supplied electric current is too low for pumping to the reservoir.

Only a limited amount of information is available for the important boreholes namely;

T2809 - pump cylinder at 20,5m, equipped with a Hartz diesel pump, used as stand-by for 3 hours a day.

T2810 - tested yield when drilled of 5,7 ℓ/sec,pump cylinder at 25m, English Electric pump, used nearly full time.

T2811 - initial yield 2,9 ℓ/sec, Filjo 4" with electric and stand-by diesel motor, used nearly continuously

T2812 - initial yield 4,4 ℓ/sec, Filjo 4" with electric and stand-by diesel motor, used nearly continously.

L1017 - drilled 1980 tested yield 6,7 ℓ/sec. Awaiting pump and linkage to holding reservoir in December 1980.

The yields of these boreholes can be visually assessed but not individually measured as they discharge under a concrete cover into a common holding tank. It was estimated that T2810, T2811 and T2812 are each pumped at a rate of approximately 10 ℓ/sec.

A flow meter installed on the main distribution pipe at the exit from the holding reservoir enables the rate of flow to be measured and would enable records of consumption to be kept if flow measurements were regularly made.

During this investigation the rate of flow was recorded and it was found to be consistently 31, 25 ℓ/sec. If this is the maximum flow rate of the pipe then continuous pumping for a period of one year would give a maximum possible annual groundwater abstraction of $0,986 \times 10^6 m^3$.

Flow meter readings at the start and finish of the investigation were made and were:

25/08/1980 at 0750 - 1495956 kℓ
23/12/1980 at 1500 - 1769774 kℓ

Thus 273818 kℓ of water was pumped during a period of 121 days. Extrapolation to an annual figure for 1980 gives an abstraction of approximately $0,826 \times 10^6 m^3$. When it is taken into account that water was only supplied by 3 main boreholes then this is the equivalent of a continuous rate of some 8,7 ℓ/sec per borehole.

The quantity of water withdrawn from other Government and private boreholes both east and west of the Marken-Potgietersrus road is highly speculative.

It is estimated that some $0.19 \times 10^6 m^3$ is pumped annually from the 8 government provided boreholes which is calculated using the following figures;

individual pumping rate of 1, 5 ℓ/sec
combined pumpage of 12 ℓ/sec
pumping period of 12 hours a day for 365 days

Withdrawal from privately owned boreholes is estimated to be approximately $0,1 \times 10^6 m^3$ annually. This is based on the premises that there are some 40 boreholes each delivering 1 ℓ/sec for 2 hours a day, 365 days a year.

The total quantity of groundwater abstracted in this portion of Mokerong, during 1980, was thus estimated to be approximately $1,116 \times 10^6 m^3$.

4.2.2 Blinkwater 244 KR

The results of a survey conducted by Meyer in 1980 indicate that $0,525 \times 10^6 m^3$ of water is withdrawn annually for irrigation.

A yearly consumption figure of $0,034 \times 10^6 m^3$ is estimated for the irrigation of about 32 hectares of maize, cotton and market vegetables on small holdings east of the Mogalakwena River.

Utilising strong boreholes to the west of the river du Plessis irrigates some 192 hectares with the abstraction of $0,491 \times 10^6 m^3$ of groundwater annually. Crops cultivated are citrus, tobacco and cotton.

Irrigation is mainly practised during the growing season of August to December.

4.3 Watertable contour pattern

A watertable map, refer to Enclosure 2, was compiled with 5m contour intervals from water level measurement made mainly in January 1981. Supplementary water-level data obtained in Mahwelereng in August 1980 was also incorporated. All existent government boreholes where measurements could be taken were accurately levelled, and the elevation of other boreholes were estimated from the topocadastral map. Information on levelled heights and waterlevels is tabulated in Appendix 4. Relevant geo=hydrological sections are presented in Enclosures 5 and 6.

Despite the poor spacing of measuring points and the lack of coverage west of the Mogalakwena River and north of the Rooisloot River several major conclusions can be made on groundwater conditions operative in January 1981, viz:

19./......

- generally the watertable contours mimic the topography
- conditions in the Mogalakwena channel are effluent i.e. it receives discharge from groundwater. Where the elevation of the watertable is above ground height surface water is present. The direction of groundwater and surface flow is towards the northwest
- east of the Mogalakwena groundwater flow is approximately W.by N. towards the river (contour directions changing northwestwards on Turfspruit due to the topography)
- west of the Mogalakwena groundwater flow is E.by N. towards the river
- the Rooisloot River is influent i.e. it recharges ground= water (see also Enclosure 6, Line 18)
- the Turfspruit is effluent (refer to enclosure 6 Line 18).
- the general lowering of the watertable eastwards around the southern tip of Lake Z may be due to the combined effects of topography and abstraction.

4.3.1 Changes in apparent transmissivity

Enclosure 2 shows that values of transmissivity are apparent= ly low in deposits fringing Lekalakala and the granitic escarpment to the west, e.g. a gradient of 1:22 on Line 1.

Contour intervals in the southwest portion of Macalacaskop 243 KR, gradient 1 in 80, which widen towards the Mogalakwena River indicate that a formation with a higher transmissivity value might occur close to the river.

Broad contour spacing, gradient 1 in 240 downstream of the Rooisloot diversion channel suggests the occurrence of formations with the highest apparent transmissivity values.

4.4 Hydrometry

4.4.1 Stream gauging

None of these rivers are currently being gauged. During 1979 (Lyness 1980) monthly flow measurements were made at two sites in the Rooisloot River on Uitloop 3 KS.

As suitable sites are available both the Rooisloot River (weir, immediately upstream of the Marken-Potgietersrus road) and the Mogalakwena River (downstream of the Marken-Potgietersrus road) should be fitted with gauging stations utilising a monthly chart. The intermittent flow found within the Rooisloot River makes it completely unsuitable for measurements only taken once monthly.

4.4.2 Rainfall measurements

A long term record is available for Potgietersrus (see section 2.3). Figure 2 illustrates that rainfall in the last few years has been above the mean in contrast to the long period of below mean rainfall recorded in the nineteen sixties and early seventies.

4.4.3 Groundwater recorder stations

Four recorders serviced on a monthly basis are currently in operation in this area they are:

A6N045 2428BB 5
A6N058 BB 10
A6N079 BB 1
A6N534 BB 4

Locations are shown in Enclosure 2, plotted data in Figure 3 and recorder details and raw data in Appendix 5.

Examination of the water level curves indicate that a marked seasonal fluctuation of the order of 0,5 to 1,: can be expected, with the groundwater high occurring generally through March, April and May. Measurement indicates that water levels are currently rising after the poor summer rainfall of 1979.

The recorder charts for A6N058 demonstrate a clear re= lationship between rainfall and water level changes the result of direct rainfall recharge influenced perhaps by surface water in the Mogalakwena River. Comparison of rainfall (plotted as a curve of cumulative departure from the mean) and water level changes, Fig. 3, indicate that rises in water level lag on average about 45 days behind corresponding rises of the C.D. curve. Similarily the water level reaches a peak some 27 days after a high on the C.D. curve. A maximum fluctuation in water level of 3,63m has been measured over the period 1973 to 1981, while seasonal fluctuations, excepting 1974 to 1975, are of the order of 1,4m.

A6N061 also shows well marked seasonal peaks and troughs but instead of a steady rise during the period 1975 to 1978 a general decline in the water-table has been measured. Pumping influences of the Lebowan Government boreholes to the south may be responsible for this phenomenon. Rises in water levels lag some 35 days behind corresponding rises of the C.D. curve. Since 1975 the recorded fluctuation of the water table has been 2,36m. Seasonal variations of up to 1,4m have been observed.

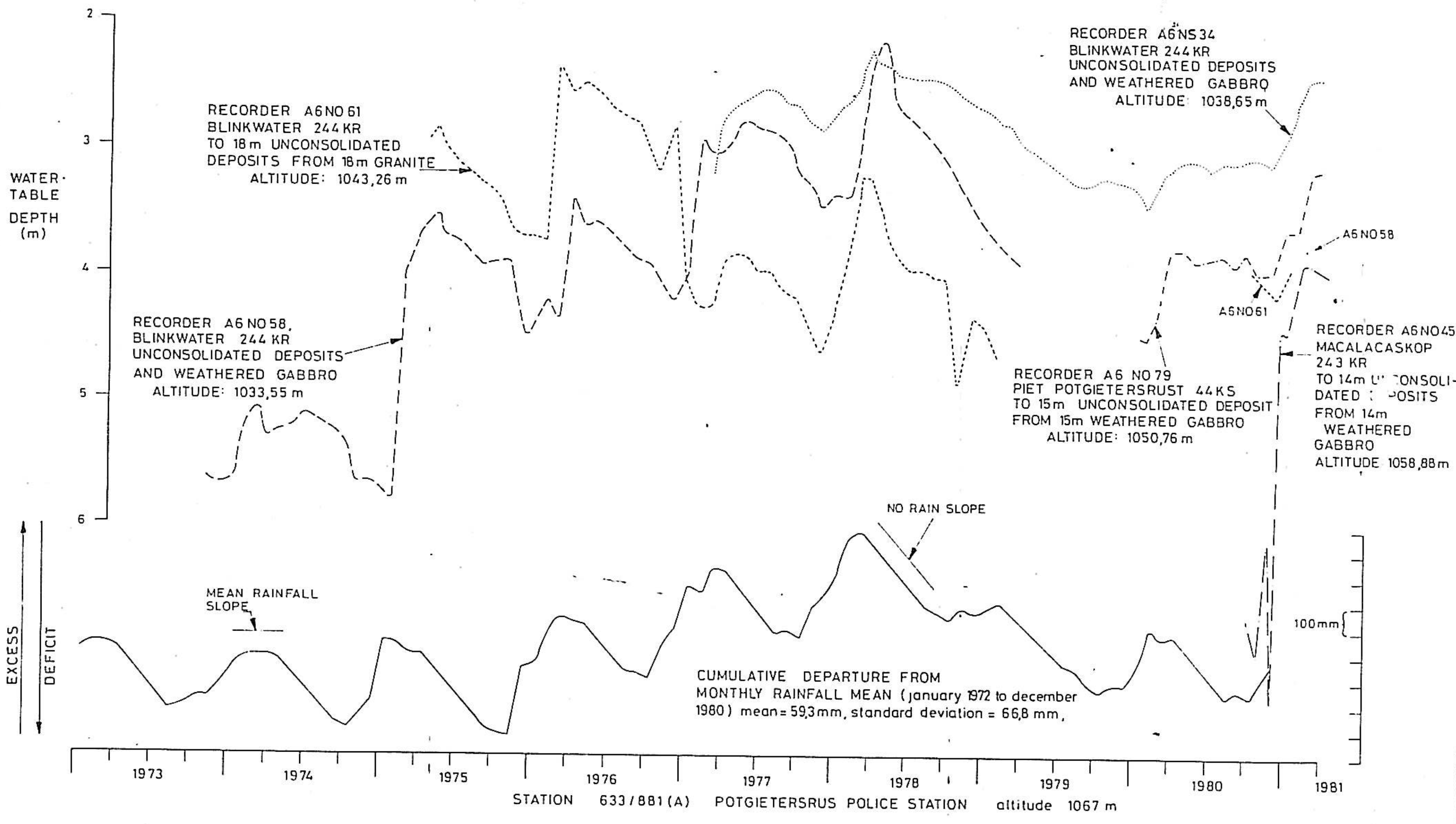


FIG.3 COMPARISON OF WATER TABLE RESPONSE AND C.D. CURVE IN THE MOKERONG DISTRICT
GHP 5401

Despite the very much smoother response displayed in A6N534 the same general trend in waterlevels is observable. Water level changes of 2,15m have been recorded from 1977 to 1981.

A rise in water levels is shown in the recently established recorders A6N045 and A6N079, the sudden increment of 4m in the former is attributed, to surface water recharge through the sandy bed of the Rooisloot River.

5 GEOPHYSICS

5.1 Introduction

Geophysical methods were extensively used to provide information on subsurface conditions. During the course of the investigation the following work was completed between August and December 1980 (refer to Enclosure 1 for locations).

- 210 Schlumberger electrical resistivity soundings
- 3 borehole resistivity logs
- 7 magnetometer traverses covering some 13 km
- 2 short electromagnetic lines.

The results of the geophysical work enabled sites to be selected for 20 exploration boreholes.

5.2 Schlumberger electrical resistivity soundings

5.2.1 Objectives

On certain previous investigations e.g. the Bree River valley, the Schlumberger resistivity technique has been successfully applied to provide information on the nature and distribution of alluvial aquifers.

It was hoped that from the interpretation of existing resistivity curves, produced by Kok (1978) and Lyness 1980, supplemented by additional soundings, information on the following would be produced:

- the extent and thickness of the alluvial deposits
- vertical and lateral facies changes within these deposits
- the geophysical nature of the alluvial deposits
- the depth to solid bedrock
- the nature and distribution of fractured and weathered rock between the alluvial deposits and the solid bedrock.

Information revealed by resistivity would influence the siting of potential production boreholes.

5.2.2 Distribution and choice of sounding centres

During previous investigations the north (refer to Enclosure 1, Lines 1 to 7) and the south of the studied area have been adequately covered. Thus the initial need was for an examination of the central area. Reconnaissance however revealed that much of this area was heavily built over and so completely unsuitable for geophysical work. Consequently lines had to be laid out peripheral to this development.

Sounding centres were aligned along traverse lines (see Enclosure 1 and Table 2) and a spacing of some 1000m was selected between lines to ensure that geophysical work would be completed within the time constraints of the investigation.

Initially lines were orientated approximately perpendicular to the regional N.W.-S.E strike, while lines 16 to 20 were placed parallel to the strike to reduce time delays caused by bush cutting. Electrode spreads were aligned parallel to the strike to minimise bedrock influence, the presence of the Rooisloot River south of line 8 necessitated an AB direction of N.E.-S.W.

Line 16 was located so that electrode spreads would not be affected by the deep channels of the Rooisloot River. A rigorous intra-sounding distance of 100m was not adhered to between stations 16/4 to 16/11 and 17/8 to 17/18 due to the presence of rapidly undulating mini-topography where vertical height difference of 1,5m were recorded between adjacent ridges and depressions. Instead soundings were centred such that the MN electrodes spacing up to at least MN 5m could be laid out on the flatter land in the intervening depressions.

24./.......

TABLE 2. GEOPHYSICAL LINES - NUMBER OF STATIONS AND SPACING INTERVAL

Line No.	No. of stations	Station interval(m)
8	23	50
9	9	"
10	10	"
11	11	"
12	23	"
13	11	100
14	14	"
15	6	irregular
16	38	100
17	20	"
18	17	200
19	4	150 and 200
20	5	100,150 and 200
21	1	

TOTAL NUMBER OF STATIONS = 192
TOTAL NUMBER OF SOUNDINGS = 210

5.2.3 Field procedure

The standard Schlumberger quadripole AMNB set-up was employed. An AB/2 distance of 400m was used, where terrain permitted, to allow clear resolution of bedrock. The following MN distance were used: 0,5m 2m, 5m, 20m and 80m (from station 12/13 only).

Throughout this investigation the Chemtron resistivity apparatus (G300 and G301) developed by the CSIR was used. This instrument emits direct current which is supplied by a separate power source . For the main features of the Chemtron refer to Jones (1979) and the users manual.

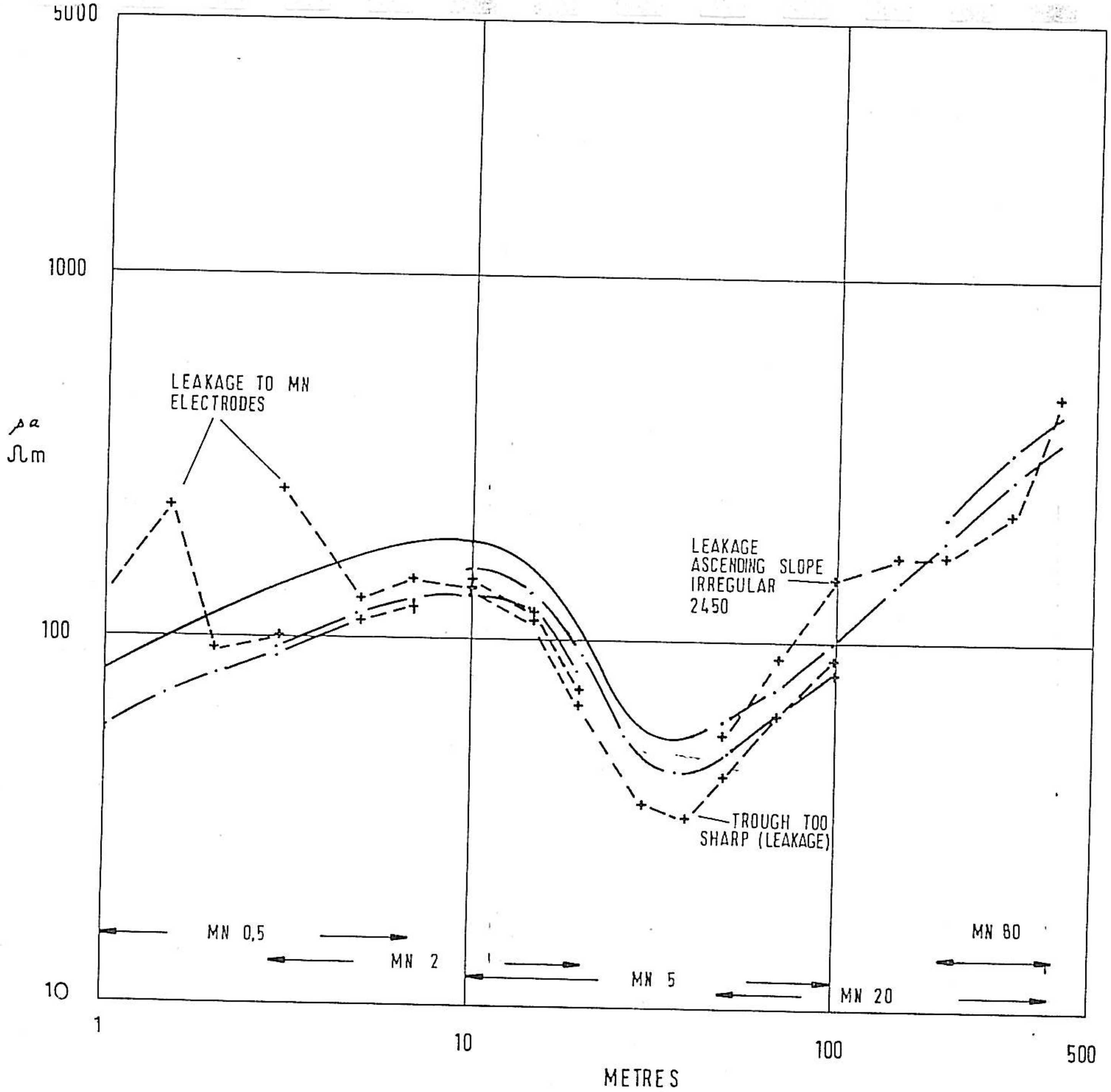
Sounding curves produced in the early part of the investigation were of poor to very poor quality being characterised by leakage cusps, crossed MN's, ascending slopes greater than 45° and a general irregular, unreliable appearance. In fact not at all the standard of curve that should be produced under the existing field conditions with the relatively sophisticated equipment.

A rigorous examination of field procedure and field equipment was instigated and adjustments made to bring field procedure into accord with that described by Van Zijl (1977). Unfortunately constraints were experienced on modification and replacement of field equipment.

Nevertheless a dramatic improvement in the quality of fieldwork was accomplished (refer to figures 23 and 24) by the simple adjustments detailed below.

- examination of all cables, in particularly the A-B emission line for leakage to earth. Cables were passed through a salt bath (see Van Zijl 1977, p.34) and breaks in the insulation were bound with insulation putty which was itself bound with insulating tape. Regular checking of field curves and cables was then instituted to maintain cables in good electrical con= dition. This simple procedure affected the most improve=

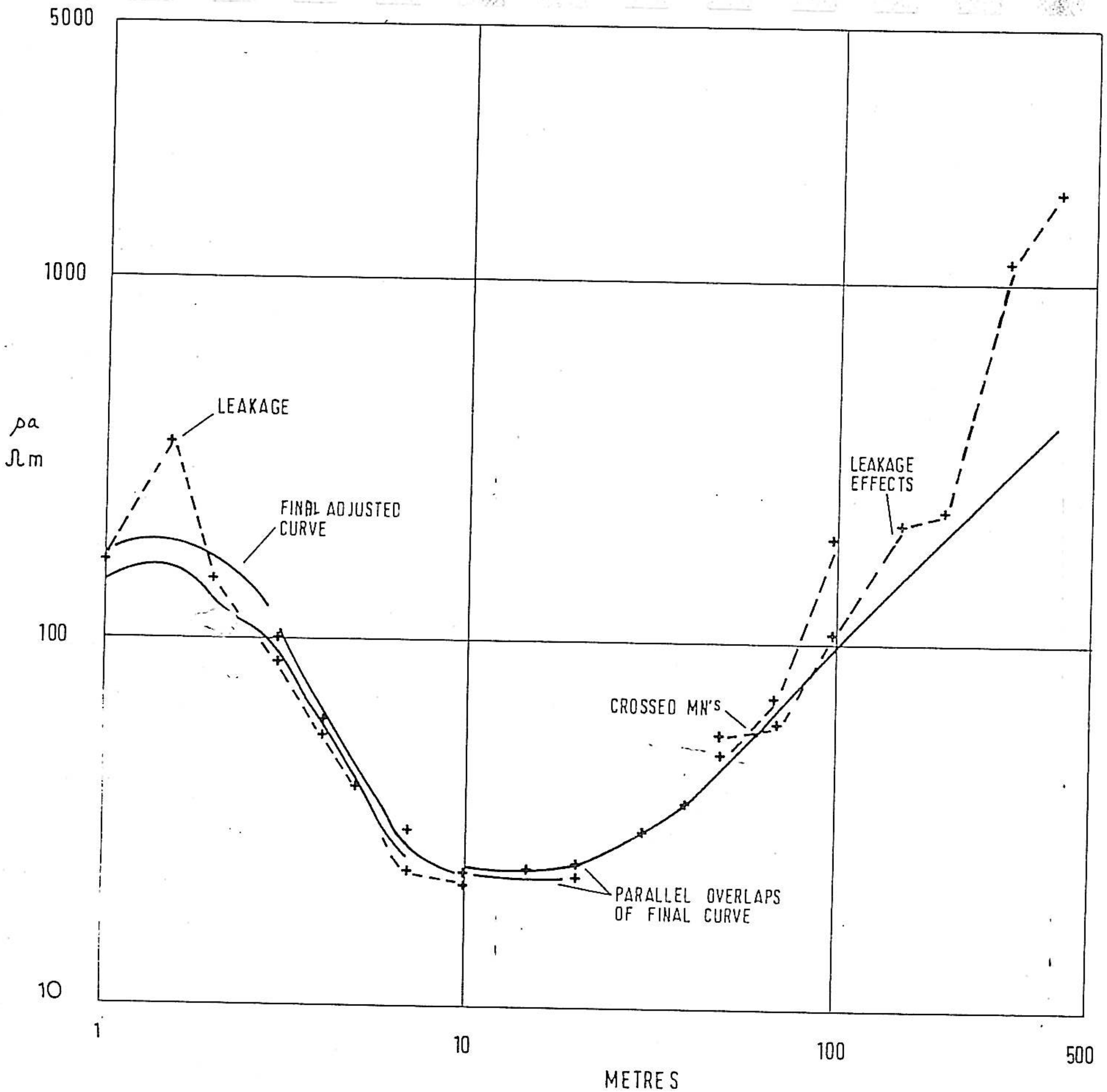
FIG 23 IMPROVEMENTS TO SCHLUMBERGE
G.H.P. 5421 SOUNDING 8/21



+ ρa BEFORE REPAIRS
· ρa AFTER REPAIRS
— FINAL SMOOTHED CURVE

NB. HETEROGENEOUS DEPOSITS CAUSING PARALLEL OVERLAPPING MN EFFECTS

FIG 24 IMPROVEMENTS TO SCHLUMBERG[ER]
G.H.P. 5422 SOUNDING 8/15



+ ρa BEFORE REPAIRS

—— CURVE PRODUCED AFTER REPAIRS

NB. LOCAL INHOMOGENEITIES IN NEAR SURFACE DEPOSITS, ONLY AFFECTING MN'S ment in curve form

- replacement of steel potential electrodes by those made of brass with consequential reduction in polarisation and potential drift

- proper emplacement of brass electrodes resulting in lower electrode resistance and lower noise levels

- correct relative placement of measuring apparatus, power source, A-B line and MN electrodes and cables to minimise e.m. coupling and leakage (Van Zijl 1977, p33)

- improved electrical connections throughout the circuits with wires soldered to electrodes (to reduce dirt on contacts) and then interlinked by snap plugs

- checking of marked measured electrode spacings on current cables so that cables can be remarked when original positions have altered by stretching of the poor quality cable.

- eventual replacement of unsatisfactory original cable drums by wooden drums which are at least partly insulated from the ground.

When these changes had been affected some 14 repeat measurements were undertaken.

At three sites comparative curves were obtained using the Gane-enslin a.c. instrument. A similar form (refer to Fig. 25) was developed for low AB/2 spacings but a marked detioration in quality of the Gane-enslin curve was observed when the AB/2 distance exceeded 100m.

Field values of apparent resistivity were plotted against AB/2 distance on standard modulus, semi-transparent bilogarithmic paper as readings were made.

5.2.4 Method of interpretation

Quantitative methods were used to determine the following parameters for each sounding:

- number of geo-electrical layers that could be identified
- thickness of each layer
- true resistivity of each layer
- longitudinal conductance of each layer
- transverse resistance of each layer (when applicable)
- total longitudinal conductance
- total transverse resistance.

When necessary MN effects were adjusted on field curves so that the final curve fitted to the longest MN segment (refer to Zohdy, 1974, p18 and Van Zijl 1977, p52 also see figures 23 and 24).

Initial interpretation of final curves were then made using standard 2, 3 and 4 layer master curves produced by the CSIR (Joubert 1977). A full explanation of the curve matching procedure is described by Orellana and Mooney (1966) and Van Zijl (1977).

Interpretations so made were then refined and adjusted with the aid of computer matching facilities of the CSIR.

The geological logging of 14 boreholes and the down-hole resistivity logging of 3 boreholes enabled some restraints to be placed on layer thicknesses and resistivities. Thus refinements could be made so that the final geo= electrical model more accurately reflected field conditions.

5.2.5 Results

The range of true resistivity values obtained are shown in Table 3. Enclosures 5 and 6 depict the interpreted geoelectrical profiles. Calibration boreholes with final sounding curve interpretations are shown with the relevant borehole log. Examples of typical sounding curves are presented in Figs. 23 to 30 (all other data can be examined in GHP envelope 618).

Caution must be exercised in the examination of the geoelectrical profiles as in many cases further refinement to sounding interpretation is possible.

As it was impossible to repeat all the initial soundings where leakage effects are apparent, mainly on Lines 8 to 11, a simplified interpretation had to be made due to the unclear development of curve form. Repeated soundings without exception enabled an additional layer to be inter= preted eg 9/2 (see Enclosure 5) which was identified as weathered and fractured bedrock. The presence of this extra conductive layer reduces the thickness of overlying alluvial and highly weathered gabbroic deposits.

TABLE 3 RESISTIVITY RANGE OF FORMATIONS

Formation		Ωm
Surface layer;	dry	40-870
	wet	2-8
Alluvial deposits;		
Sand and gravel with < 5% clay	dry	200-1700
	saturated	50-60
Clayey sand and gravel,	dry	100-200
	saturated	6,5-24
Unconsolidated clay with minor sand	dry	40-870
	saturated	3-8 (<5, brackish water)
Ferricrete	dry	40-280
	saturated	10-30
Bedrock;		
Clayey, weathered gabbro		1-16
Granular, weathered gabbro		7-90
Dry weathered gabbro		110-275
Fractured gabbro		15-150
Fractured metaquartzite		1-130, average 60
Fresh gabbro		300-20 000

As the field curves produced by earlier investigations had severe defects, noteably:

- an AB/2 distance not extended far enough to resolve bedrock and thus a value for total longitudinal conductance
- cable leakage, producing severly distorted curves with crossed MN effects

  it was not considered worthwhile to attempt an interpretation.

Reference to Line 11(Enclosure 5 and Fig. 4) clearly shows that the watertable often influences curve form.

The geophysical profiles may overestimate, but probably fairly accurately reflect the depth to solid bedrock eg Figs. 16 and 18.

Curve forms can indicate the presence of weathered and fractured bedrock and separate this geoelectric layer from more clayey weathered rock eg Figs. 12 and 15.

Crossed soundings undertaken on Line 12, Fig. 26, show that alluvial deposits are here homogeneous. While displaced parallel MN segments eg Figs. 23 and 25 indicate that elsewhere surface deposits are heterogeneous, refer also to Enclosures 5 and 6.

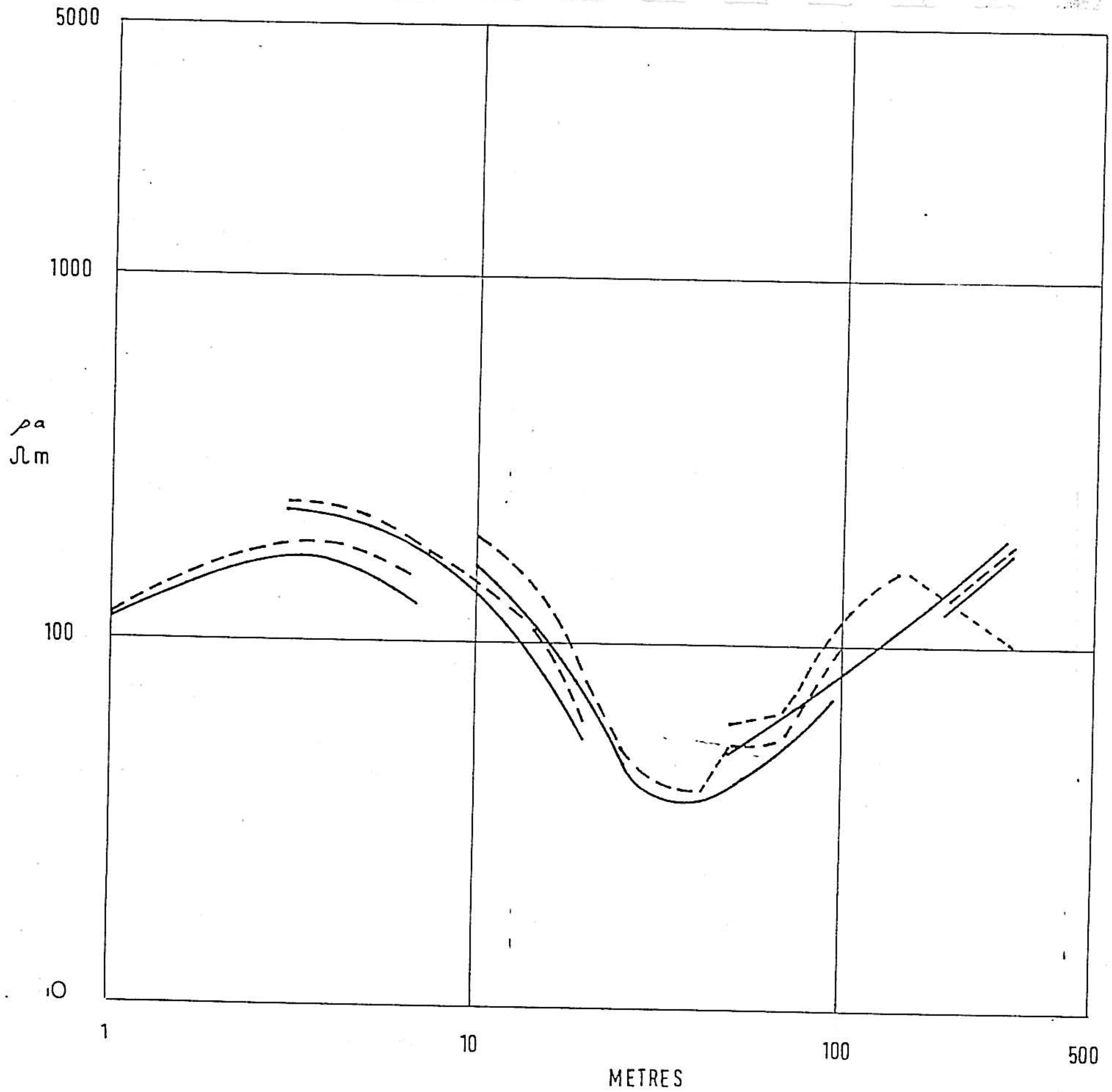


FIG 25 GHP 5423 COMPARISON OF SCHLUMBERGER FIELD CURVES PRODUCED AT SITE 16/2 WITH THE GANE-ENSLIN (----) AND THE CHEMTRON (——) RESISTIVITY EQUIPMENT.

NB. BOTH CURVES CARRIED OUT AFTER EQUIPMENT REPAIRS

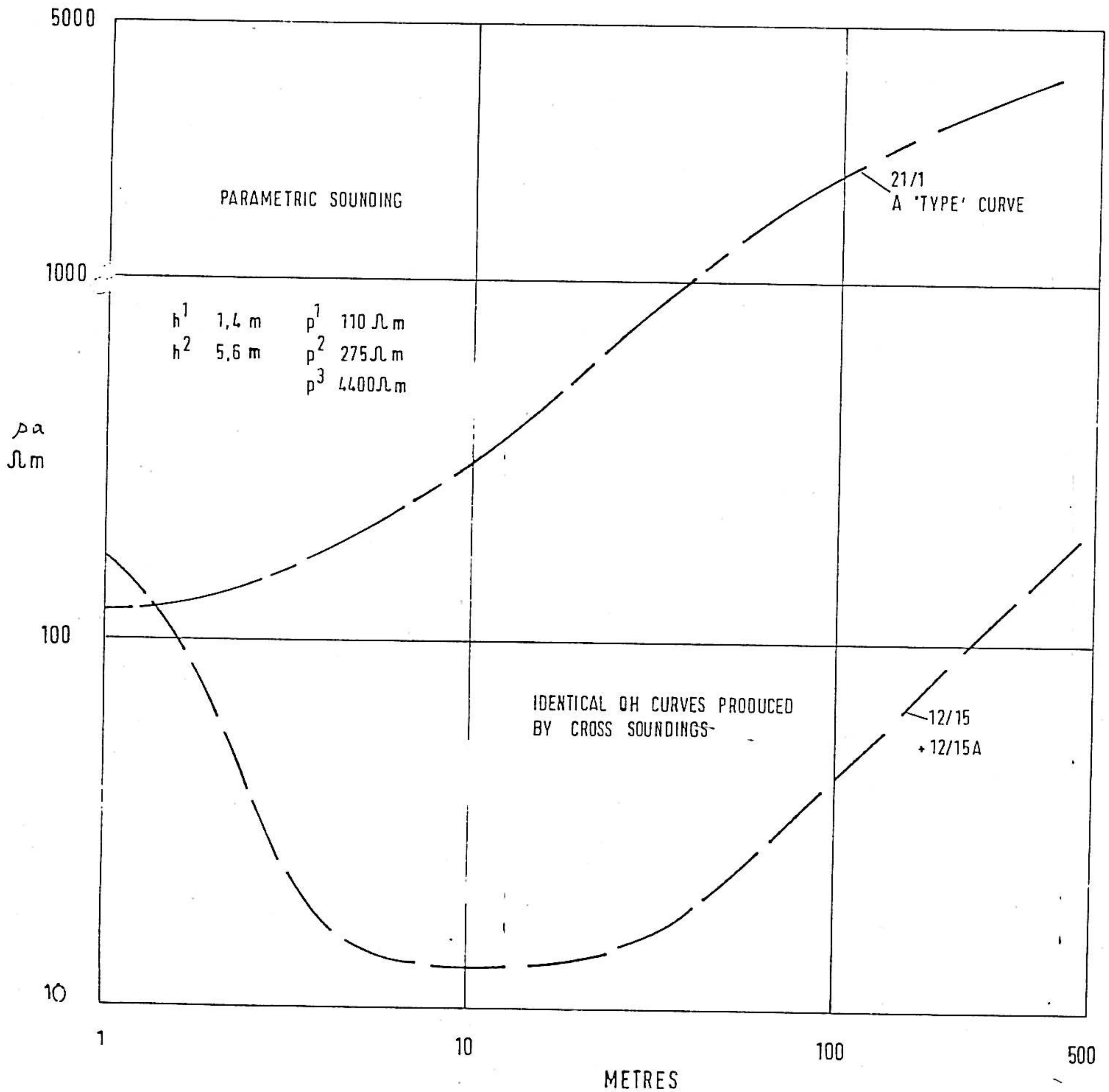


FIG. 26 SMOOTHED SCHLUMBERGER
GHP 5424 CURVES 12/15 AND 21/1

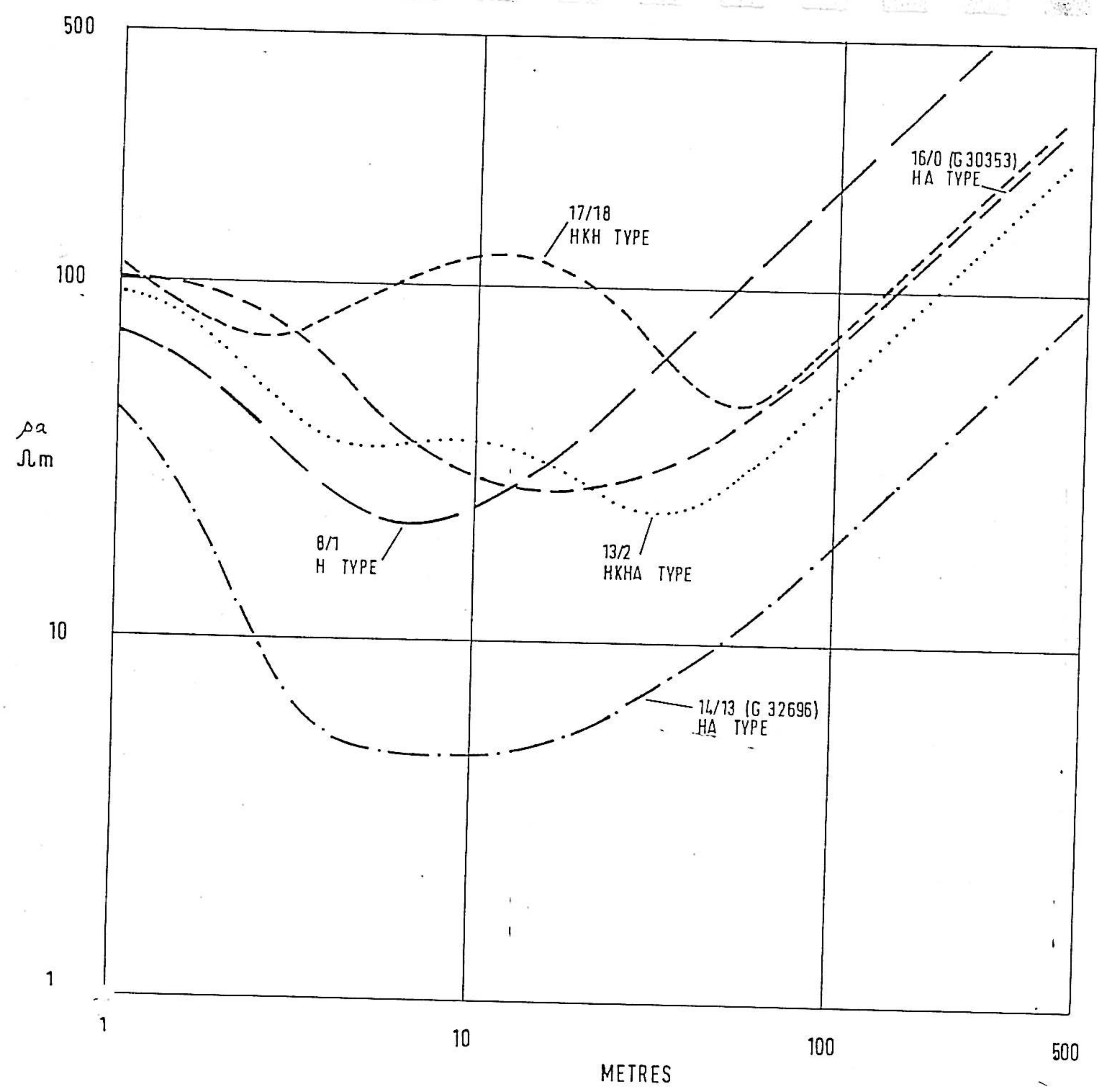


FIG. 27 . -- EXAMPLES OF TYPICAL
G.H.P. 5425 SOUNDING CURVES

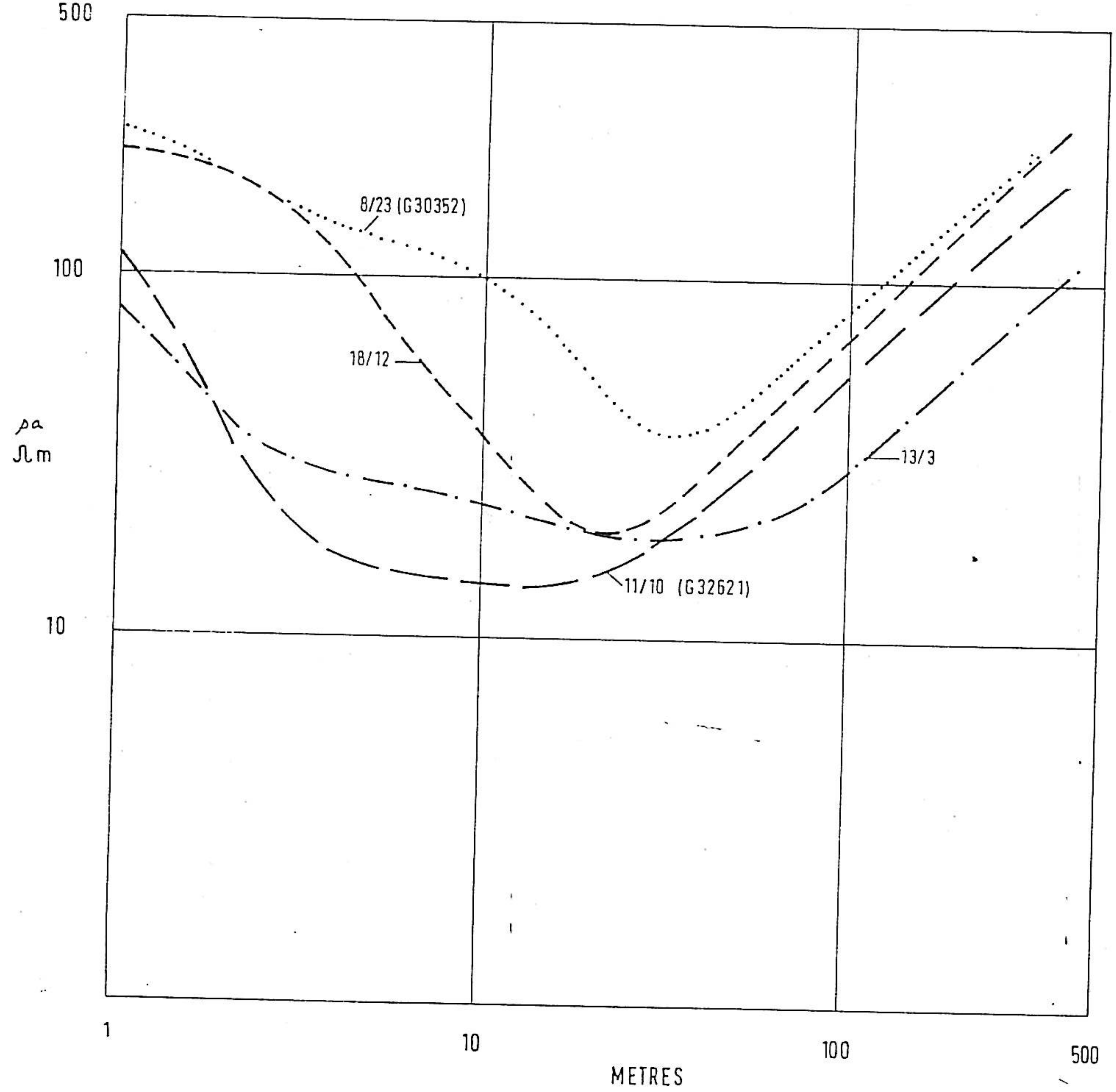


FIG. 28 EXAMPLES OF 4 LAYER
GHP 5426 QH TYPE SOUNDING CURVES

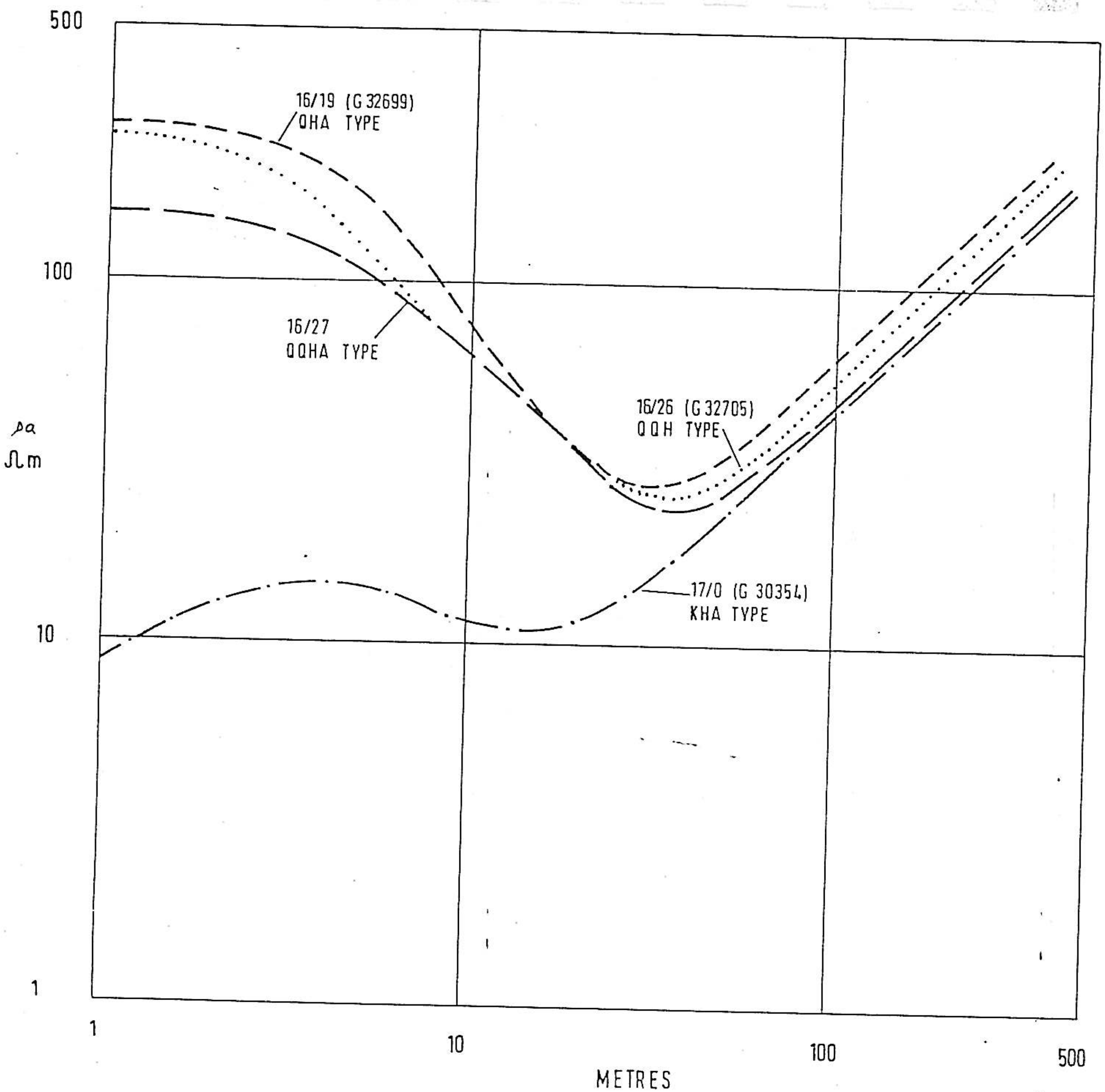


FIG 29. EXAMPLES OF TYPICAL G.H.P. 5427 SOUNDING CURVES

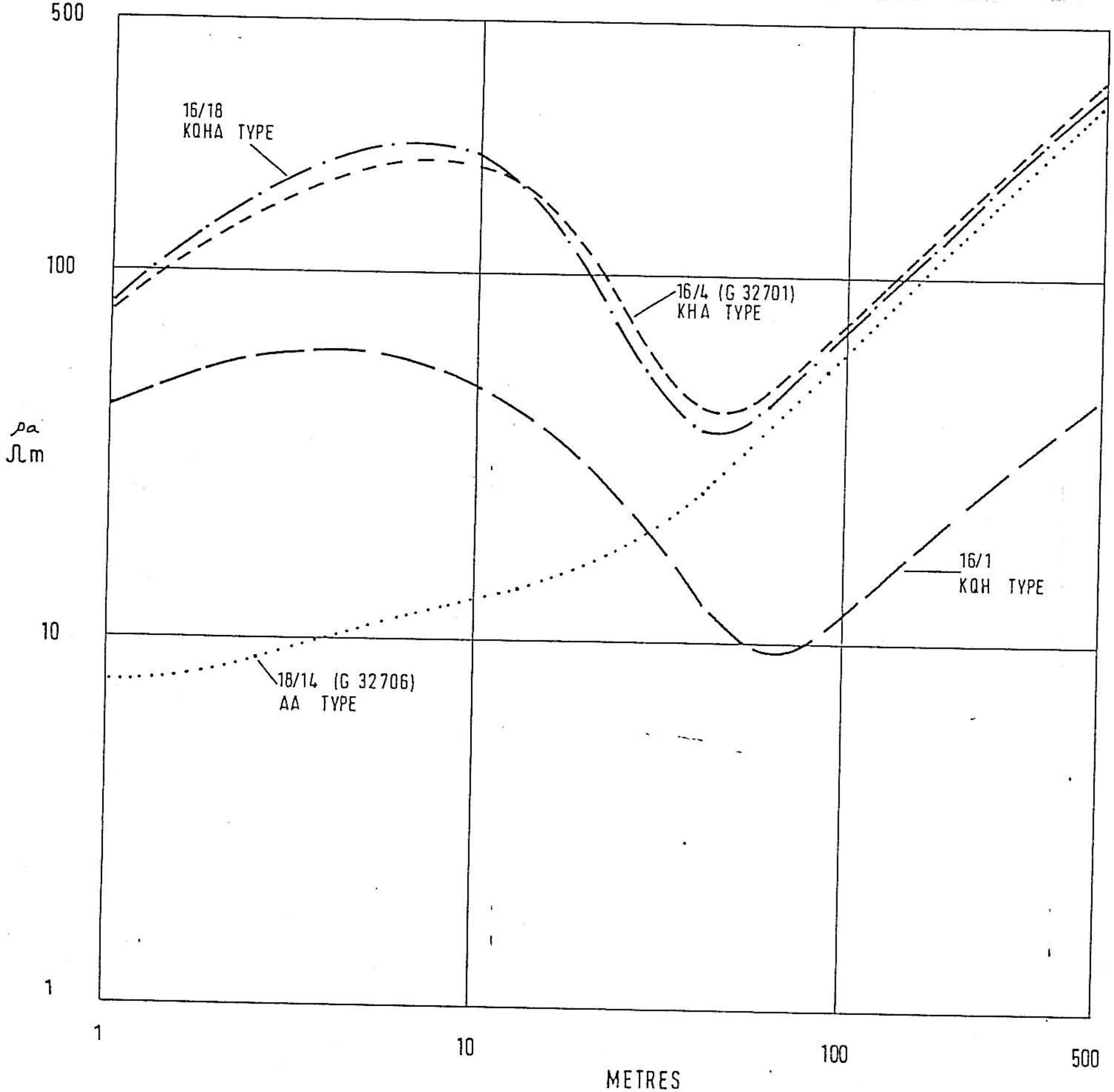


FIG 30 EXAMPLES OF TYPICAL
G.H.P. 5428 SOUNDING CURVES

Due to the principles of suppression and equivalence the alluvial gravelly sand aquifer does not appear on sounding curves as a distinct entity. Similarily it is generally not possible to distinguish saturated clay from saturated clayey weathered gabbro.

Above the phreatic zone the distribution of distinct geoelectrical layers is clearly demonstrated in the profiles, note in particular the resistive near-surface sandy facies shown on Line 16 in the vicinity of G32699.

High values of longitudinal conductance on Line 14, stations 12 to 14, are the results of alluvial deposits and weathered bedrock being saturated with brackish water.

5.3 Borehole geophysical logging

Due to the caving nature of the alluvial deposits and weathered rock steel casing had to be continually added as drilling continued. Hence conditions only permitted the resistivity logging of three boreholes, refer to Figs. 8, 12 and 13.

The apparent resistivity values obtained were used as a guide for Schlumberger interpretations.

5.4 Magnetic survey

The Scintrax magnetometer MF2 was used for the magnetic surveys which comprised 6 traverses, along the direction of dip and one along strike.

The profiles are shown in Enclosures 5 and 6. They repeat the main findings of Lyness (1980) that a large magnetic peak, presumably due to the presence of magnetite rich layers, is developed.

No distinct magnetic feature was developed over the suspected faulting around 16/4.

5.5 Electromagnetic survey

Two short traverses were undertaken parallel to the anticipated strata dip across stations 16/4 and 16/5 to try and prove the existence of a fault, however no conductive features were detected (refer to GHP envelope 618).

6 HYDROCHEMISTRY

6.1 Introduction

For this investigation 64 major element chemical analyses were undertaken on water samples obtained from 17 boreholes and 27 surface water stations (for locations and additional information see Fig. 1, Enclosure 2 and Appendix 6). Existing analyses presented by Kok (1978) and Lyness (1980) were re-evaluated.

Sampling was done to achieve the following objectives:

- assess general groundwater quality
- recognise areas with unpotable groundwater
- establish the recharge relationship, if any, between surface water and groundwater by identifying different water types and changes in composition.
- changes in water composition, if any, during pumping.

6.2 Procedure

Surface water samples were collected in early October after a period of slight rainfall. Where possible flowing water was sampled. Elsewhere samples had to be obtained from shallow water and thus may not be representative of the true composition of the standing water.

Groundwater samples were taken over the period October 1980 to February 1981 from boreholes that were either being pumped or blow-tested. Additional measurements of field conductivity were made on private borehole and are listed in Appendix 3.

At the time of sampling measurements were made of TDS, tempera= ture and ocassionally pH.

Final laboratory analyses in ppm were converted to meq/ℓ (see Appendix 6) using the conversion factors presented in Hem (1970,p83).

The reliability of the analyses were examined by the relationship (Hem, 1970, p233):

$$\frac{\text{difference between cation and anion in meq}/\ell}{\text{total of cations plus anions in meq}/\ell} \times 100$$

Correlations varied between excellent, eg G32709-0,2, and poor eg G32711-9,6. Nearly 80% of the samples had a variation of less than 6% (see Appendix 6). Samples outside this range were mainly obtained during pumping from the boreholes G32699, G32709 and G32711.

If the analysis of the sample was thought to represent the original sampled water composition it was plotted on the extended Durov diagrams (Figs. 32, 33 and 34) to enable comparisons of water chemistry to be made.

6.3 Water Quality

6.3.1 Total dissolved solids

Some TDS values are indicated on Enclosure 2 and are also listed in appendices 3 and 6. TDS figures in this area show that with the exception of groundwater found in the vicinity of G32697, all waters examined fall within the maximum permissable limit (< 2000 ppm) of the SABS for potable water.

In October 1980 the quantity of total dissolved solids in surface water was mainly between 200 and 500 ppm.

With two exceptions the Nile-Mogalakwena had values within the range 200 to 400 ppm. Considering the lack of surface water flow these values are low and must represent dilution by recent run-off.

The amount of total dissolved solids in the Dorps River varied between 340 and 450 ppm, while in the Rooisloot River figures of 180 to 260 ppm were representative. During times of flood TDS values for the Rooisloot River were as low as 35 ppm.

Groundwater to the south of the Rooisloot River has a fairly high content of total dissolved solids with figures generally ranging from 500 to 1400 ppm, groundwater inflow from the Dorps River catchment has values of approximately 500 ppm.

The lowest amounts of total dissolved solids are found in boreholes G32699 and G32701 where values of 260 ppm have been recorded. To the north TDS increase to some 360 ppm and is thus very similar to the values found in the Mogalakwena River on Blinkwater 244 KR.

6.3.2. Potability

As indicated in section 6.3.1. the groundwater in this area is of good quality.

Chemical analyses reveals that borehole water found northwest of the Rooisloot River is of particularly good quality for domestic supply as:

- low mineral content, TDS 260 to 360 ppm
- hard water, eg G32709 - hardness as $CaCO_3$, 178ppm
- suitable fluoride content, eg G32709, 1,0 ppm

The only clearly unpotable groundwater is present in the vicinity of G32697 where brackwater has been found see Table 4.

Nitrate concentrations are generally low (< 5 ppm). Higher values (> 15 ppm) associated with the urban development would indicate pollution. It is probable that the nitrate is oxidised organic compounds, present in human and animal faeces, which have locally polluted the aquifer through unprotected, open, unlined wells. Thus it is recommended that bacteriological analyses should be under= taken if any abstraction of groundwater is contemplated in the south of the area.

Major element analyses of surface water did not reveal any toxic quantities, in fact nitrate levels were surprisingly low being less than 2 ppm. Information supplied by Mr. Hendrikse of Potgietersrus Municipality indicated that surface water in Lake X and further down= stream were jointly polluted by organic contaminants from a piggery and the municipal sewerage works.

6.4 Classification and characterisation of local water

Fig. 31 demonstrates that surface water in the region (see Fig. 1) plots in distinct fields on a Piper diagram). The ratio between the fluoride concentration and the electrical conductivity is useful in distinguishing those waters which are recharged via the Dorps River valley (Fig. 32, 33 and 34).

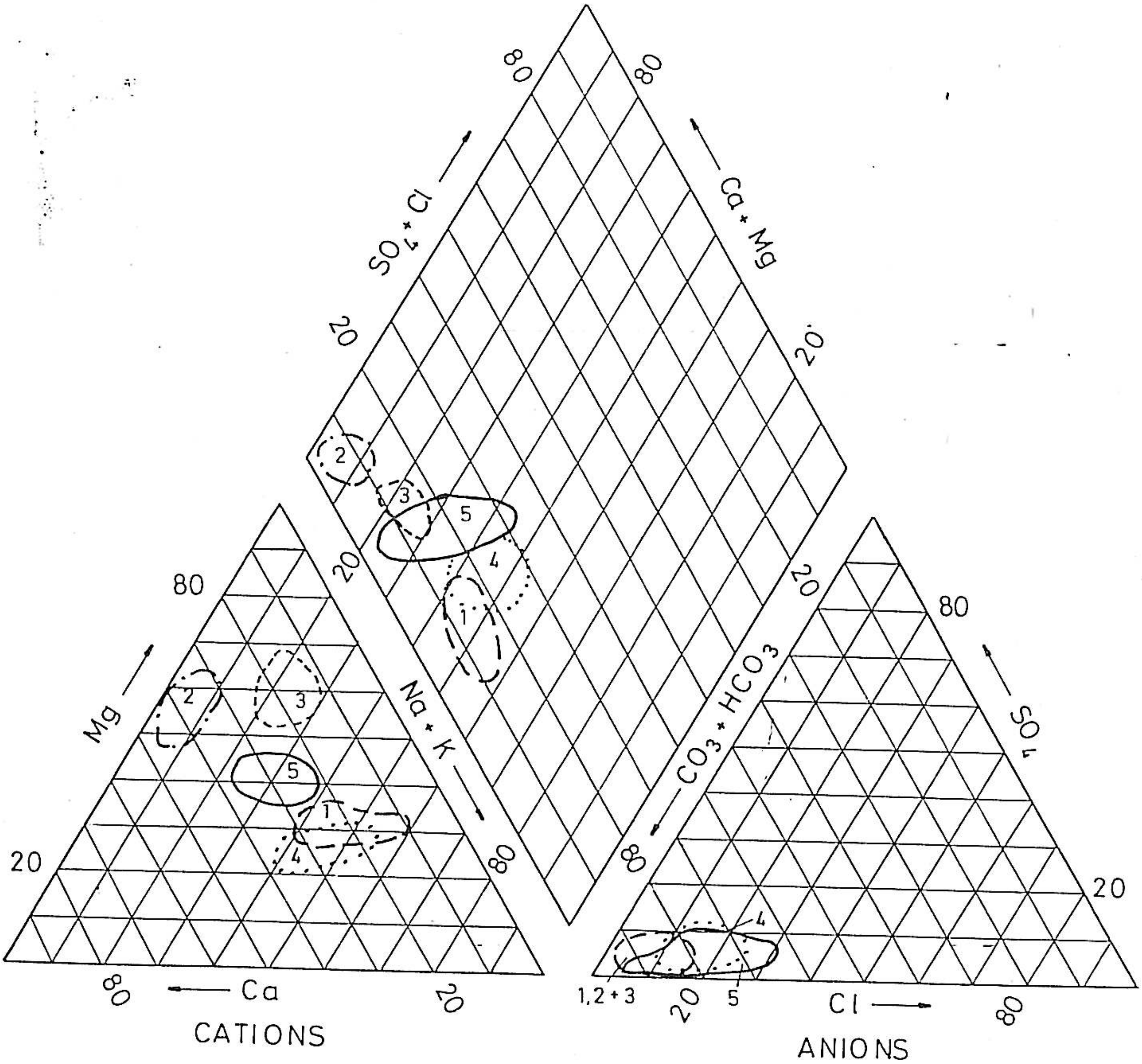
TABLE 4 UNPOTABLE BOREHOLE WATER

No. on diagram	Sampling point	parameter	ppm	SABS maximum permissible ppm
12	G32697	chloride	1540-1630	600
	"	magnesium	438-476	150
	"	TDS	5070-5200	2000
Polluted waters				
4	T2787B	nitrate	17,0	45
6	MP15	"	31,0	"
7	MP17	"	34,1	"
8	MP27	"	30,5	"
9	MP34	"	25,6	"

.40./........

FIG 31
GHP 5429

DIAGNOSTIC FIELDS OF SURFACE WATER ON THE PIPER DIAGRAM



1 SURFACE WATER IN THE NILE - MOGALAKWENA RIVER, UPSTREAM OF LAKE Y.
2 DORPS RIVER SURFACE WATER UPSTREAM OF COMBRINCK DAM.
3 DORPS RIVER SURFACE WATER DOWNSTREAM OF COMBRINCK DAM.
4. ROOISLOOT RIVER SURFACE WATER.
5 SURFACE WATER IN THE MOGALAKWENA RIVER, below 1.

Waters in the Nile-Mogalakwena River plot on a Durov diagram as a mixed cation HCO_3 facies, (refer to Enclosure 2) and the F/EC ratio generally decreases downstream. Upstream of Lake Z the fluoride content is presumably derived from the granitic catchment to the west.

The surface water in the Dorps River is a genuine $MgHCO_3$ type with a diagnostic low F/EC ratio. Groundwater from the Dorps River Valley and the Uitloop dolomitic area has a similar composition, regional contours (Lyness 1980) indicate that recharge south of Lekalakala is from these sources. This is confirmed by the low F/EC ratio of groundwater sampled south of Lake Z (refer to Enclosure 2). In this area groundwaters are of the $MgHCO_3$ type which has been modified in places to a mixed cation HCO_3 type by cation exchange. The highly mineralised water in G32697 is of a Na-mixed anion type and probably demonstrates the end result of cation exchange within the clayey deposits after a long residence period.

Between the Rooisloot River and Lake Z groundwater belongs to the $MgHCO_3$ field but is not recharged from the Dorps River Valley as a dramatic increase in the F/EC ratio is apparent.

Unfortunately the composition of the flood waters of the Rooisloot River are not known but reference to Figs. 33 indicate that upstream of Uitloop 3 KS sampled waters belong to the mixed cation HCO_3 facies in contrast to the $MgHCO_3$ water analysed at site R5. A similar large contrast was observed in F/EC ratios. In fact R5 with its $MgHCO_3$ composition and low F/EC ratio is very similar to the Uitloop dolomitic groundwater which according to regional groundwater contours also recharge the area north of the Rooisloot. Mixed cation HCO_3 groundwaters with distinctive F/EC ratios are found northwest of the Rooisloot diversion channel, these waters are fairly similar to the surface water in the Mogalakwena River. A distinct $NaHCO_3$ facies is developed at sites Brl and G32704 this may be due to modification through cation exchange in weathered clayey gabbro.

Cl/HCO_3 ratios (see Enclosure 2 and Appendix 6) may be a reflection on the relative ages of groundwater, if this is so the low values with a generally small range would indicate most groundwaters present are of fairly recent origin. The higher values recorded at G32697, T2811 and Mp27 would indicate that these waters are older.

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6.5 Changes in groundwater quality during pumping

Water samples were taken periodically from all boreholes pump tested. It is noteworthy that no significant changes in water composition occurred during pumping. As better quality water was not produced by G32697 this site cannot be considered for exploitation.

7 PUMPING TESTS

7.1 Introduction

During this investigation three of the tested borehole penetrated both the alluvial deposits and the weathered fractured gabbro thus pumping assessed the combined hydraulic properties of these two aquifers.

Two multirate and four constant rate pump tests were carried out on three boreholes penetrating the gravelly sands/weathered gabbro aquifer and one borehole penetrating the fractured metaquartzite.

Step-drawdown tests were undertaken to:

- calibrate the capacity of the potential production wells and to
- select a pumping rate for constant yield tests.

Constant rate tests were used to:

- determine the production status of individual boreholes,
- calculate the transmissivity and storage parameters, so that an average figure could be computed to allow estimates of regional groundwater storage to be made
- in the case of G32697 the quality of the groundwater was continually monitored to observe whether there was any improvement in quality.

All raw pumping data is presented in Appendix 7.

7.2 G32697 - Alluvial deposits/weathered gabbro aquifer - Macalacaskop 243 KR

7.2.1. Approach

As borehole G32696 (Fig. 7) intercepted a large thickness of water-bearing gravelly sands a production borehole, G32697 (Fig. 8) was sited 30m to the south (refer to Enclosure 1). A second observation borehole G32698 (Fig.9) was drilled 30m to the east of the production well. To explore the extent of the gravels G32700 (Fig. 11) was drilled some 700m to the east.

All boreholes penetrate through the gravelly sand into weathered and fractured gabbro , where additional water strikes were made. Drilling was terminated in solid bedrock.

Exploratory drilling and geophysical soundings indicate that fairly homogeneous conditions exist in an east-west and also north-south direction.

A potential recharge boundary is formed by Lake Y, which occurs some 120m to the south. The fact that the chemical composition of groundwater did not change during pumping presumably indicates that direct recharge did not take place from this potential source.

Due to the nature of the overlying alluvial deposits it was thought that the response to pumping would be of semi-unconfined type with delayed yield.

7.2.2 Step-drawdown test

At the second attempt a 5-stage multirate test was successfully completed. This test indicated that the maximum yield of the borehole was some 17 ℓ/sec and that a rapid recovery could be expected after the cessation of pumping (Fig. 35).

Well losses and formation losses were calculated using the Bierschenck and Wilson method and are presented in Table 5 and illustrated in Figs. 36 and 37.

G32697 is effectively developed, (development factor 0,065, Bierschenk 1964) and relatively efficient at a pumping rate less than 12,7 ℓ/sec.

7.2.3 Constant rate test

G32697 was pumped for 3300 minutes at a rate of 11,36 ℓ/sec (980 m^3/hr)

The response to pumping was that of a semi-unconfined aquifer with delayed yield.

Observation well responses closely matched type curves produced by Boulton for delayed yield (Fig. 38 and 39). Co-ordinates and calculated T and S values are presented in Table 6.

Comparitive data interpretation was undertaken using Jacob and Chow semi-logarithmic methods (Kruseman et al 1976) see Figs. 40 and 41. Reference to Table 7 indicate that similar values were calculated for long-term pumping conditions as were produced by the Bou ton method. The low values for G32698 are ascribable t the poor straight line fit.

TABLE 5 WELL CALIBRATION G32697

Step	Q ℓ/sec	* Δ SW (m)	Cumulative Δ SW (m)	$S_{W/Q}$	BQ	CQ^2	$BQ+CQ^2$	$\frac{BQ}{BQ+CQ^2} \times 100$ (%)
1	5,73	2,2	2,2	$4,44x10^{-3}$	1,75	0,57	2,32	75
2	8,22	1,5	3,7	$5,21x10^{-3}$	2,52	1,18	3,70	68
3	10,40	1,5	5,2	$5,75x10^{-3}$	3,21	1,91	5,12	63
4	12,83	1,6	6,8	$6,13x10^{-3}$	3,94	2,87	6,81	58
Constant Yield rate	11,36		(5,7)	$(5,82x10^{-3})$	(3,48)	(2,24)	(5,72)	(61) (interpolated)

Where $B = 3,55x10^{-3}$ and $C = 2,32x10^{-6}$

$^{SW}/Q$ = specific drawdown, BQ = formation loss, CQ^2 = well loss and $\frac{BQ}{BQ+CQ^2} \times 100$ = well efficiency

*increments of drawdown are taken at projected "steady state" conditions.

FIG 35 G 32697, STEP-DRAWDOWN TEST.
GHP 5433

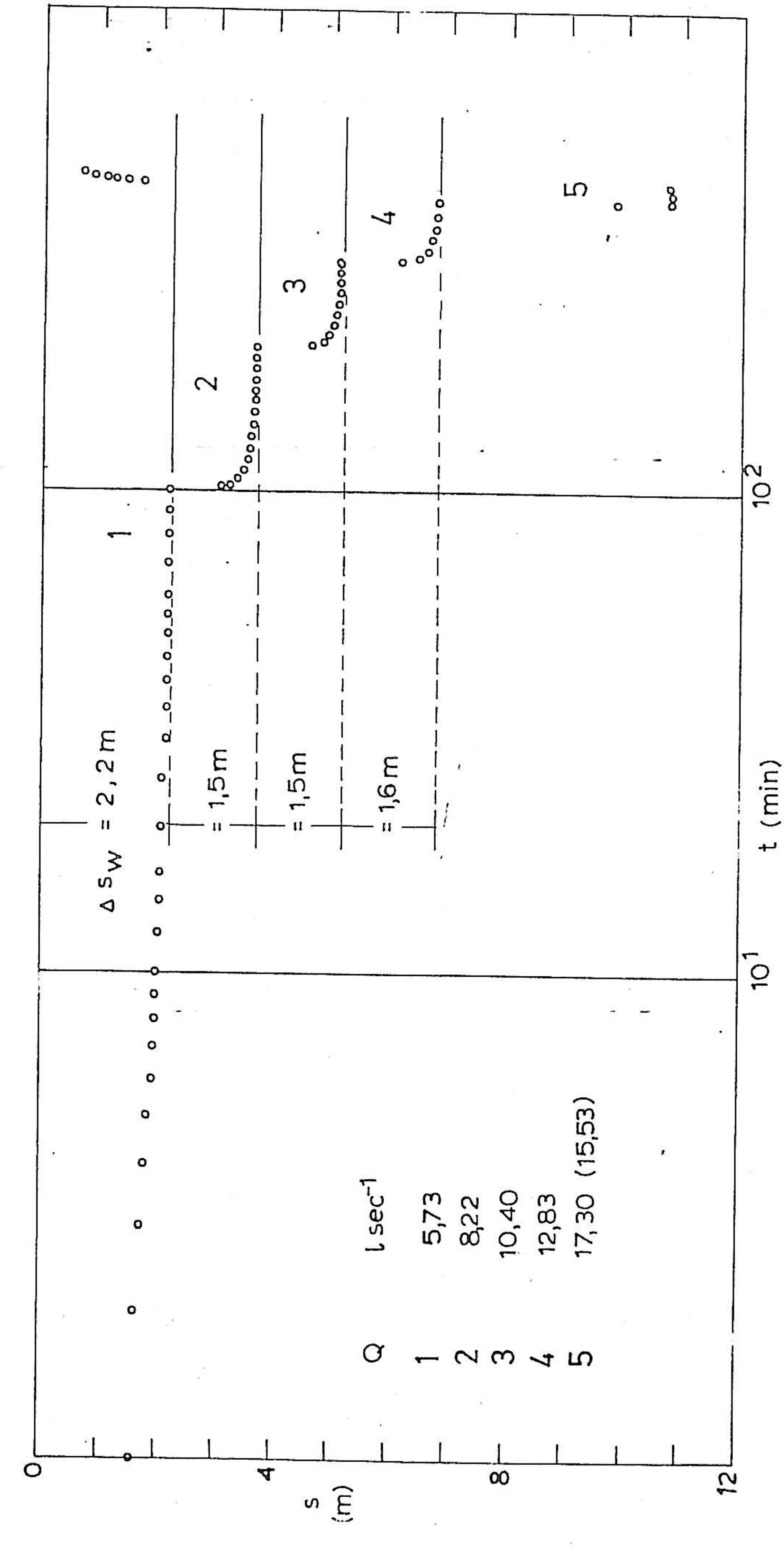


FIG 36 G32697, SPECIFIC DRAWDOWN-DISCHARGE. GHP 5434

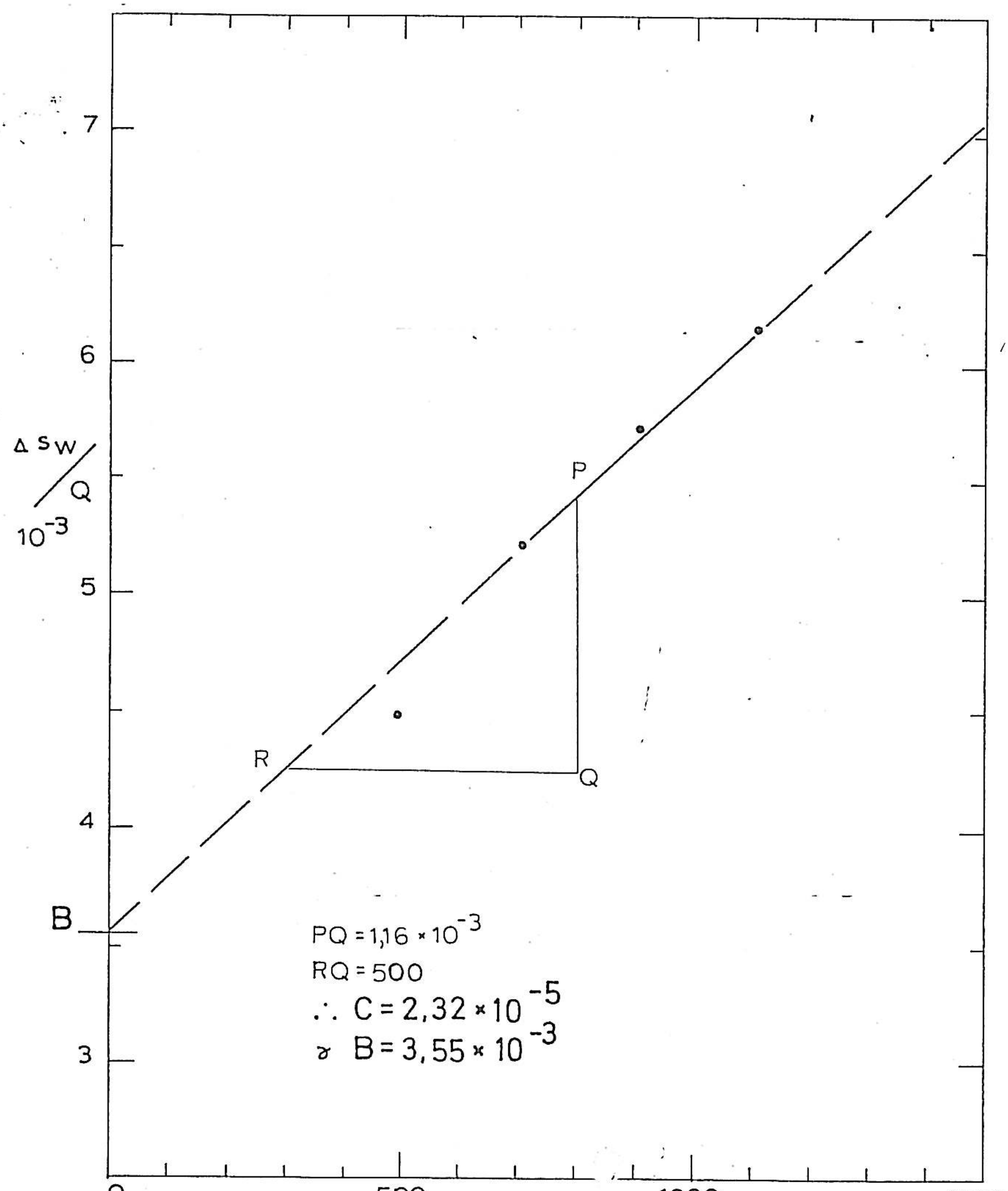


FIG 37 G32697, WELL EFFICIENCY DIAGRAM.
GHP 5435

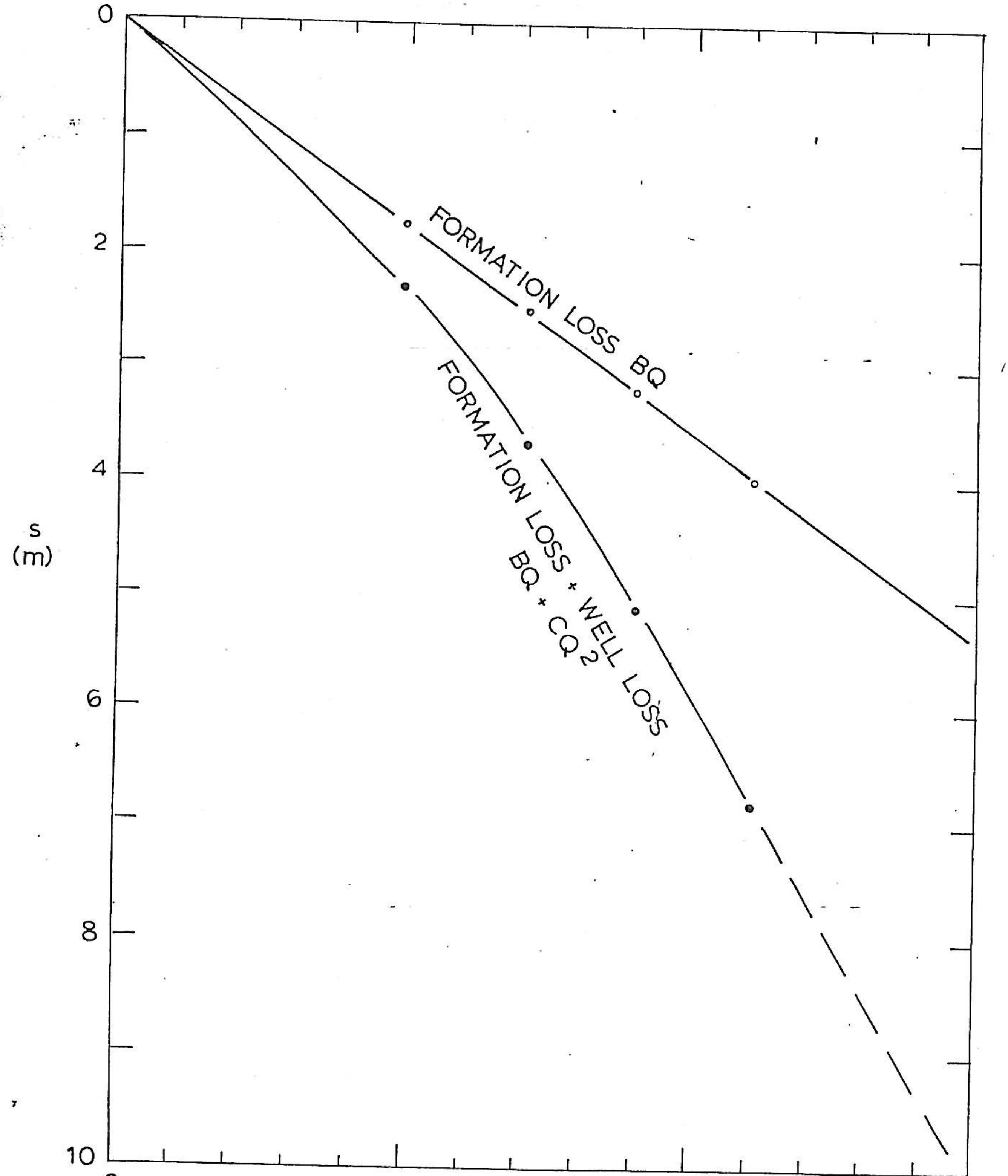


TABLE 6 MATCH POINT CO-ORDINATES WITH CALCULATED T AND S VALUES USING BOULTON TYPE-CURVE MATCHING, MOKERONG.

Observation well no.	$W_{(A-Y)}$, $^{r}/B$	1/UA-Y	s (m)	t (min)	Q m^3/d	($\frac{r}{m}$)	T m^2/d)	S_{A-Y}	S_{A+Y}	$^{r}/B$
G32696	1	1	0,33	2	980	30	236	$1,5\times10^{-3}$	$2,92\times10^{-2}$	0.8
"	1	1	0,33	38	"	"	236	$2,77\times10^{-2}$		"
G32698	1	1	0,29	1,9	"	"	269	$1,6\times10^{-3}$	$3,04\times10^{-2}$	0,6
"	1	1	0,31	37	"	"	252	$2,88\times10^{-2}$		"
G32701	1	10	1,3	4,4	848	30	52	$7,1\times10^{-5}$		0,316
"	no match									
G32710	1	1	1,02	5,2	848	30	66	$1,06\times10^{-2}$	$5,9\times10^{-1}$	1,0
"	1	1	1,10	3100	"	"	61	$5,8\times10^{-1}$		"
G32712	1	1	0,22	1,4	1000*	30,35	362	$1,5\times10^{-3}$	$1,11\times10^{-2}$	1,0
"	1	1	0,22	8,8	"	"	362	$9,6\times10^{-3}$		"

*averaged yield

NOTE S_{A+Y} = effective storage coefficient where 1. $T = \frac{Q}{4\pi s}(WU_{A-Y}\ ^{r}/B)$

and 2. $S_{A-Y} = \frac{4Tt}{r^2}(U_{A-Y})$

TABLE 7 G32697 - RESULTS OF PUMPING TEST ANALYSES

Obs.borehole	Method	T m^2/d	S	Remarks
G32696	Boulton A'	236	$1,5x10^{-3}$	Sy = $2,92x10^{-2}$
"	Boulton 'B'	236	$2,77x10^{-2}$	
"	Jacob	239	$2,95x10^{-2}$	0,01 2,76 days
"	Chow	237	$3,2x10^{-2}$	
"	Theis recovery	437		?
G32698	Boulton 'A'	269	$1,6x10^{-3}$	
	Boulton 'B'	252	$2,88x10^{-2}$	Sy = $3,04x10^{-2}$
	Jacob	204	$3,5x10^{-2}$	0,01 2,76 days poor fit
	Chow	190	$4x10^{-2}$	poor fit
	Theis recovery	437		?

Average T (excluding Theis method) = 233 m^2/d , and
average S (" " ") = $3,27 \times 10^{-2}$

Excluding Jacob and Chow values for G32698
Average T = 245 m^2/d, and
average S = 3×10^{-2}

FIG 38 G32696+G32697, TIME-DRAWDOWN.
GHP 5436

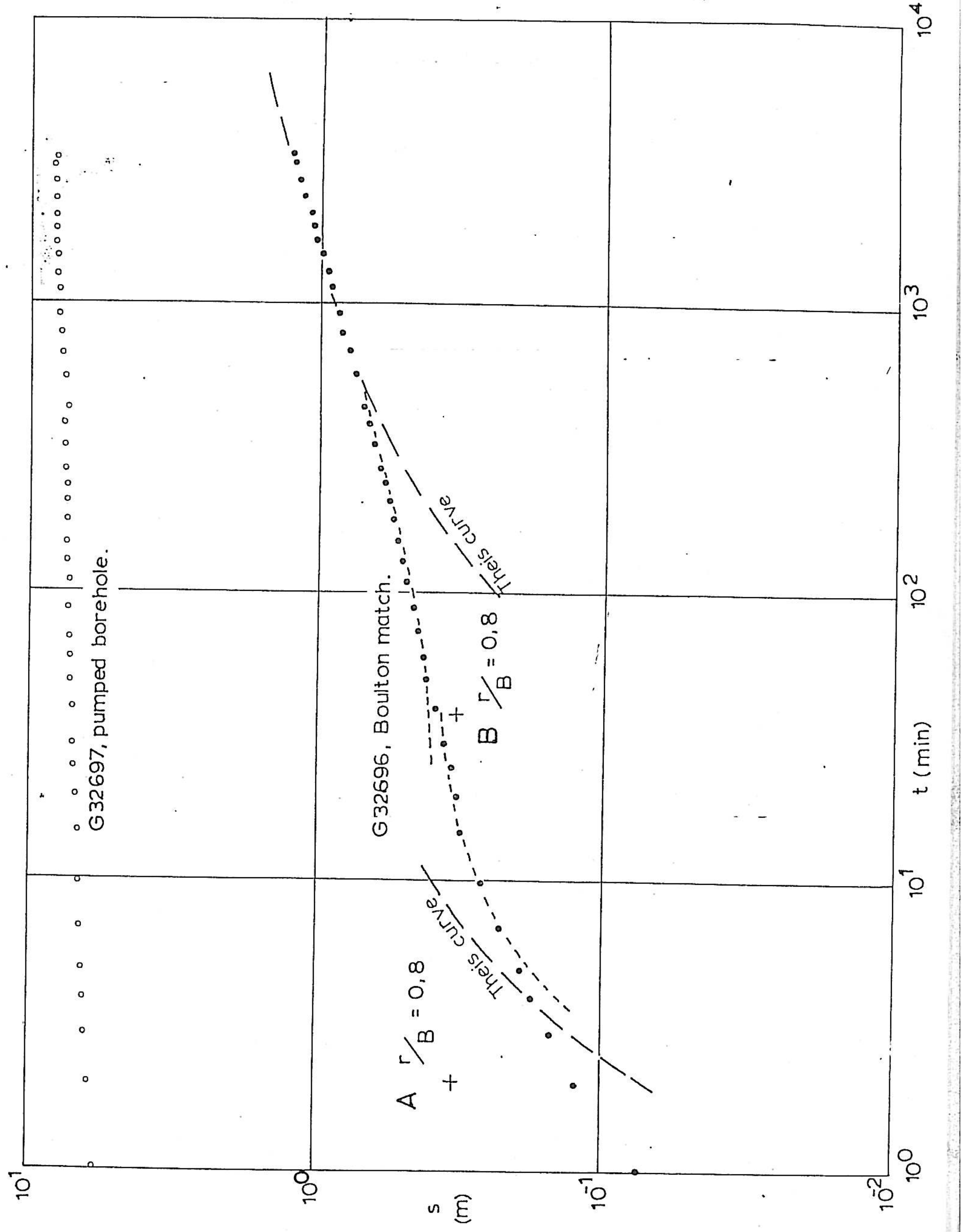


Fig 39 G 32698 TIME - DRAWDOWN, BOULTON MATCH

GHP 5437

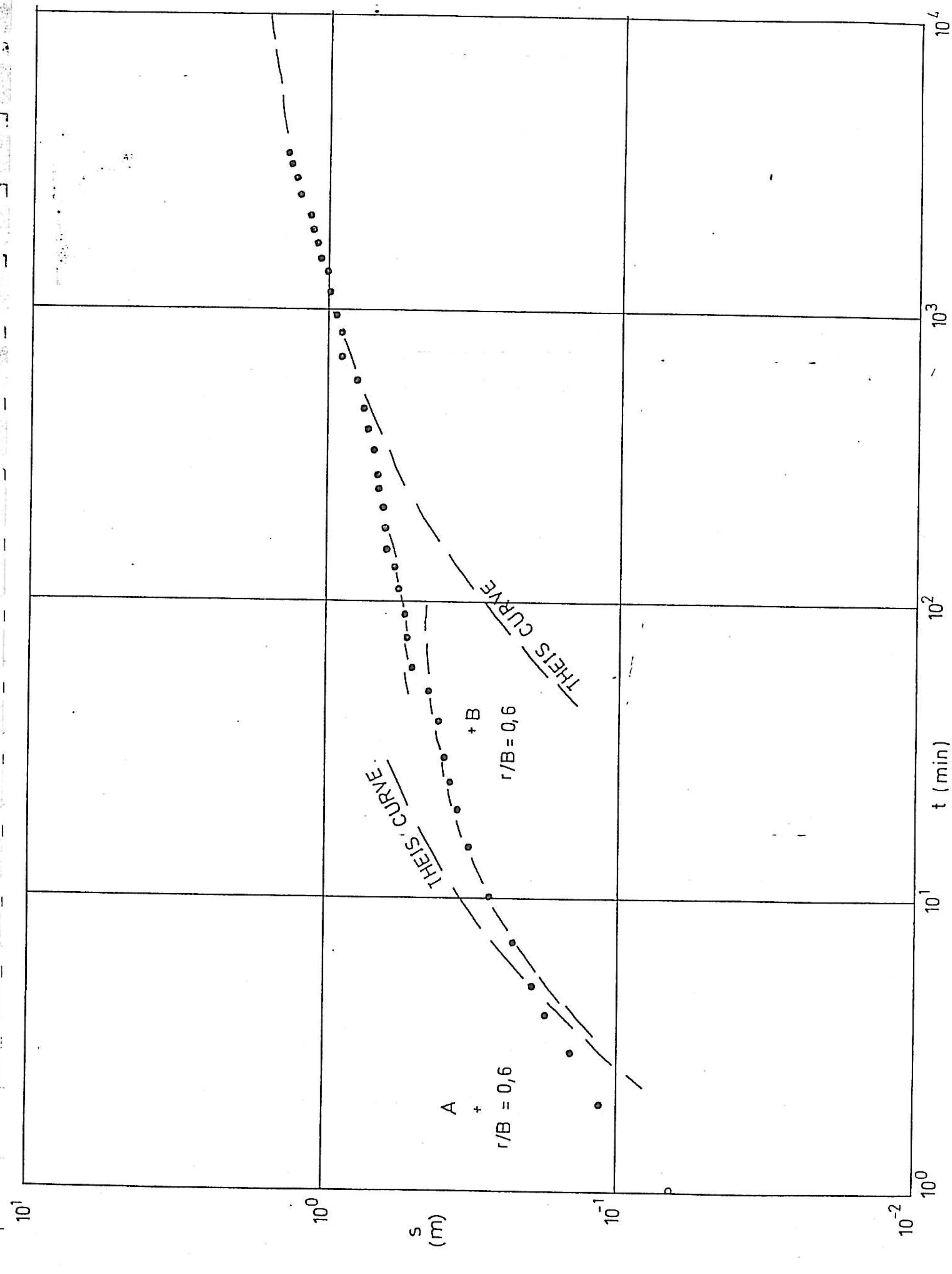


FIG 40 G32696, TIME-DRAWDOWN, JACOB+ CHOW ANALYSIS.
GHP 5438

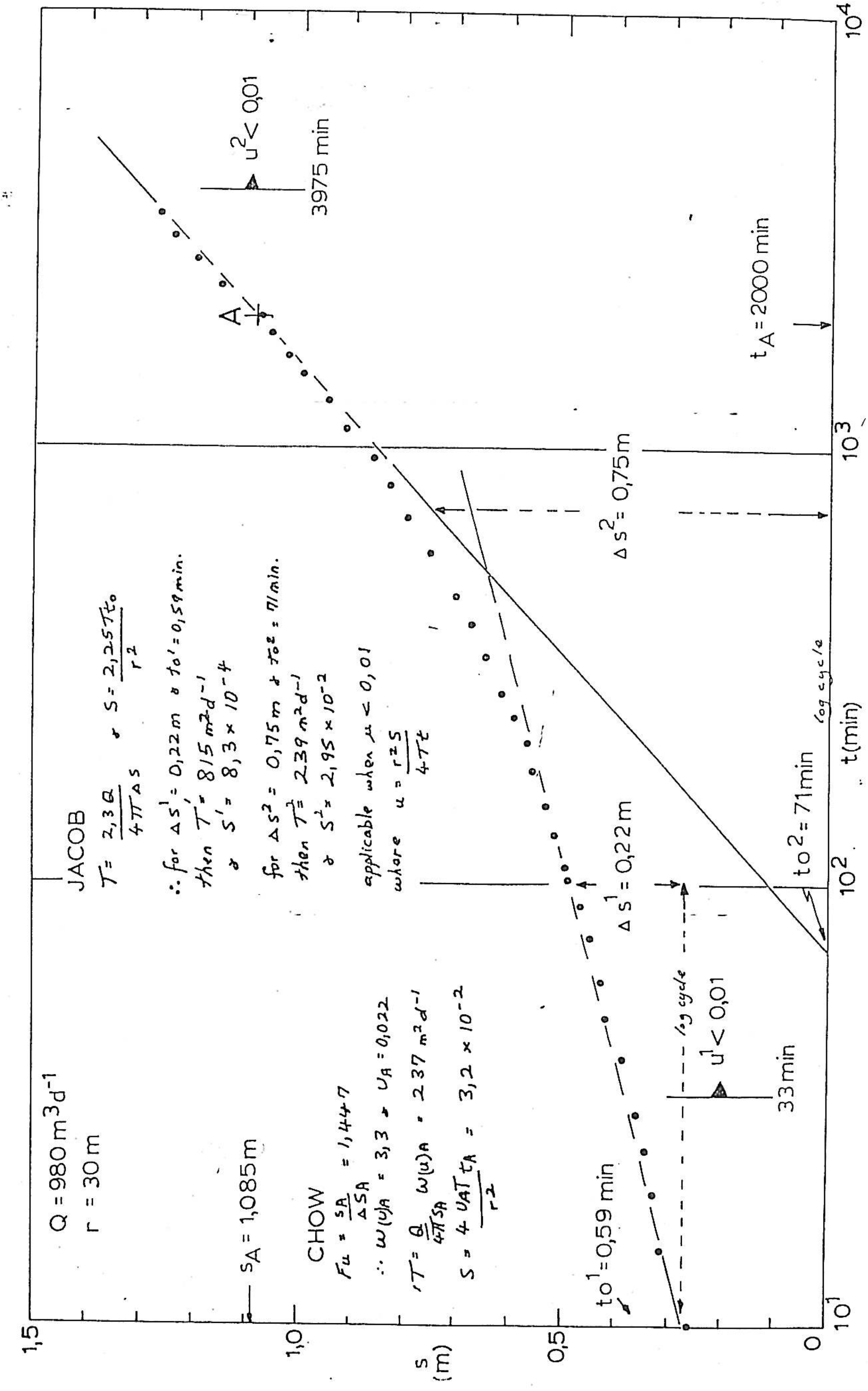


FIG 41 G32698, TIME - DRAWDOWN, JACOB+ CHOW ANALYSIS.

GHP 5439

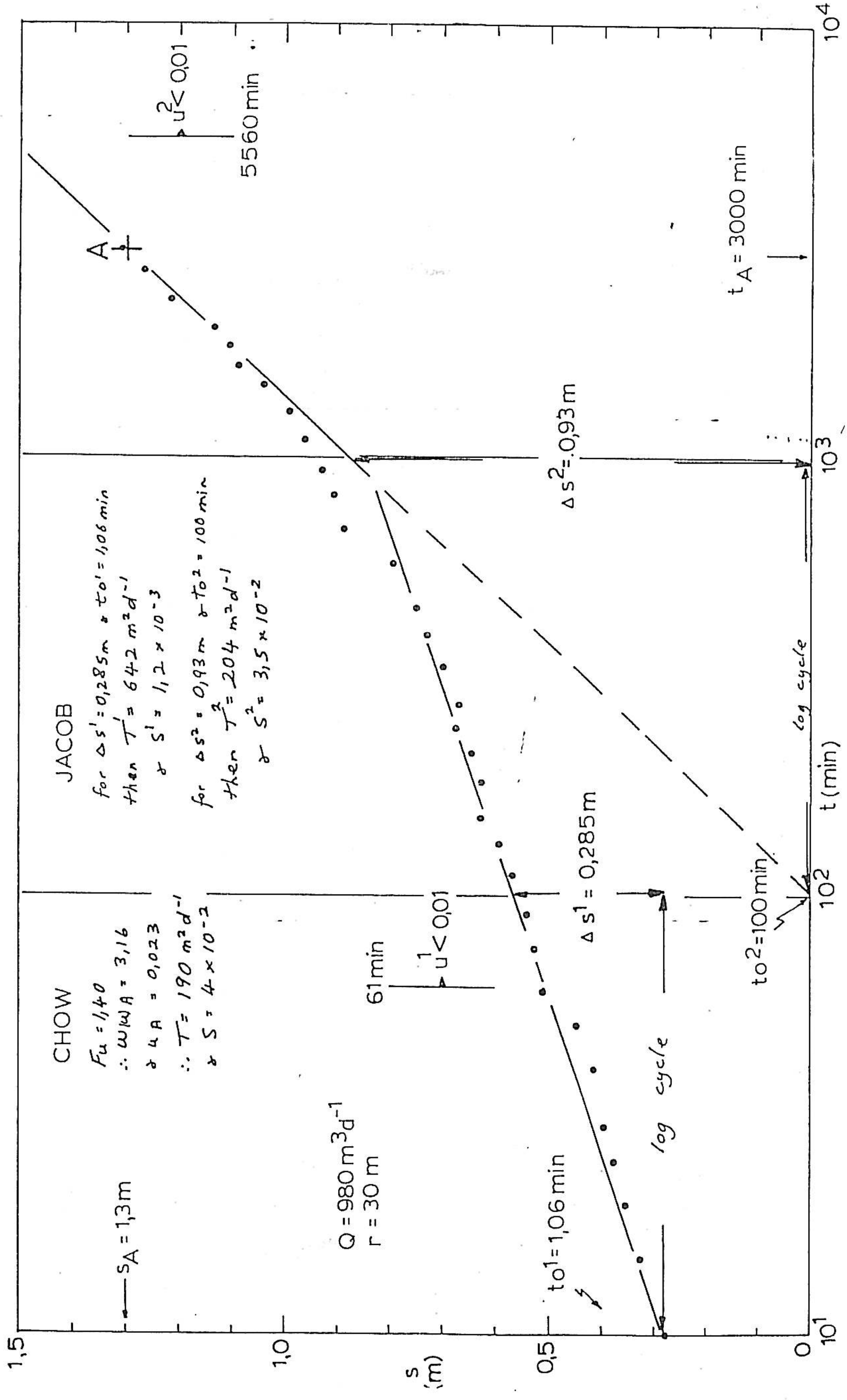


FIG 42 G32696 + G32697 THEIS RECOVERY ANALYSIS.
GHP 5440

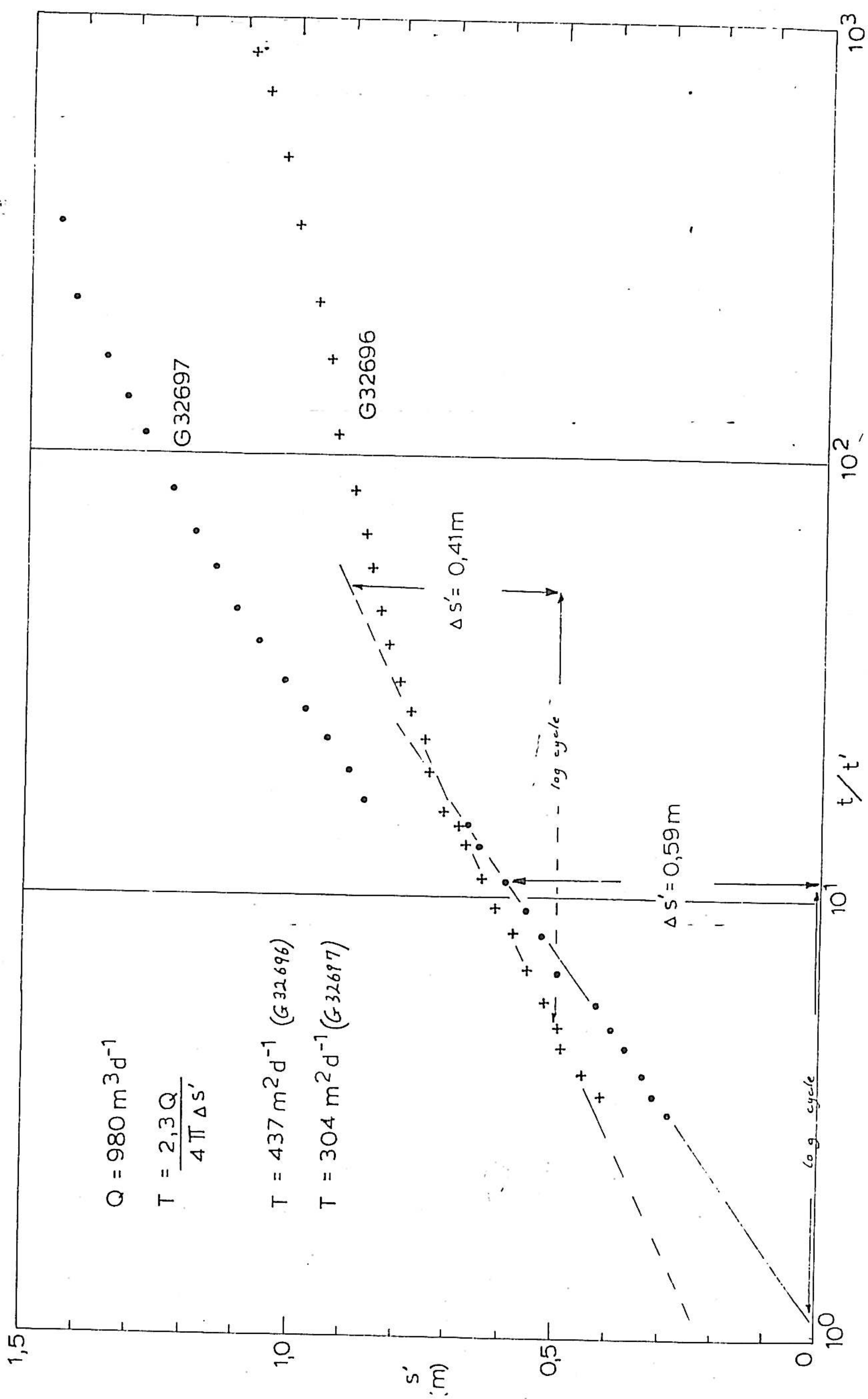


Fig. 43 G32698 THEIS RECOVERY ANALYSIS

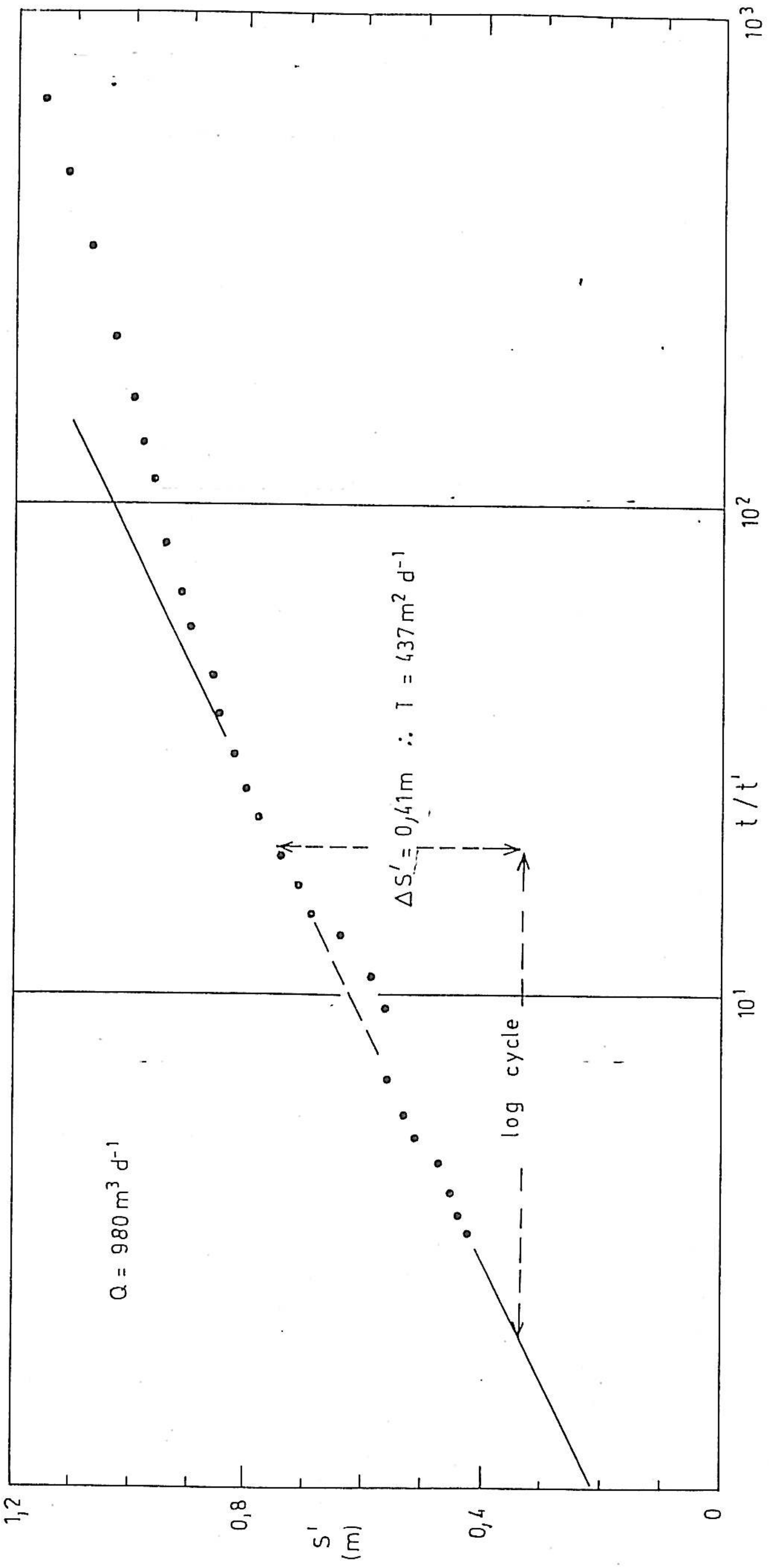
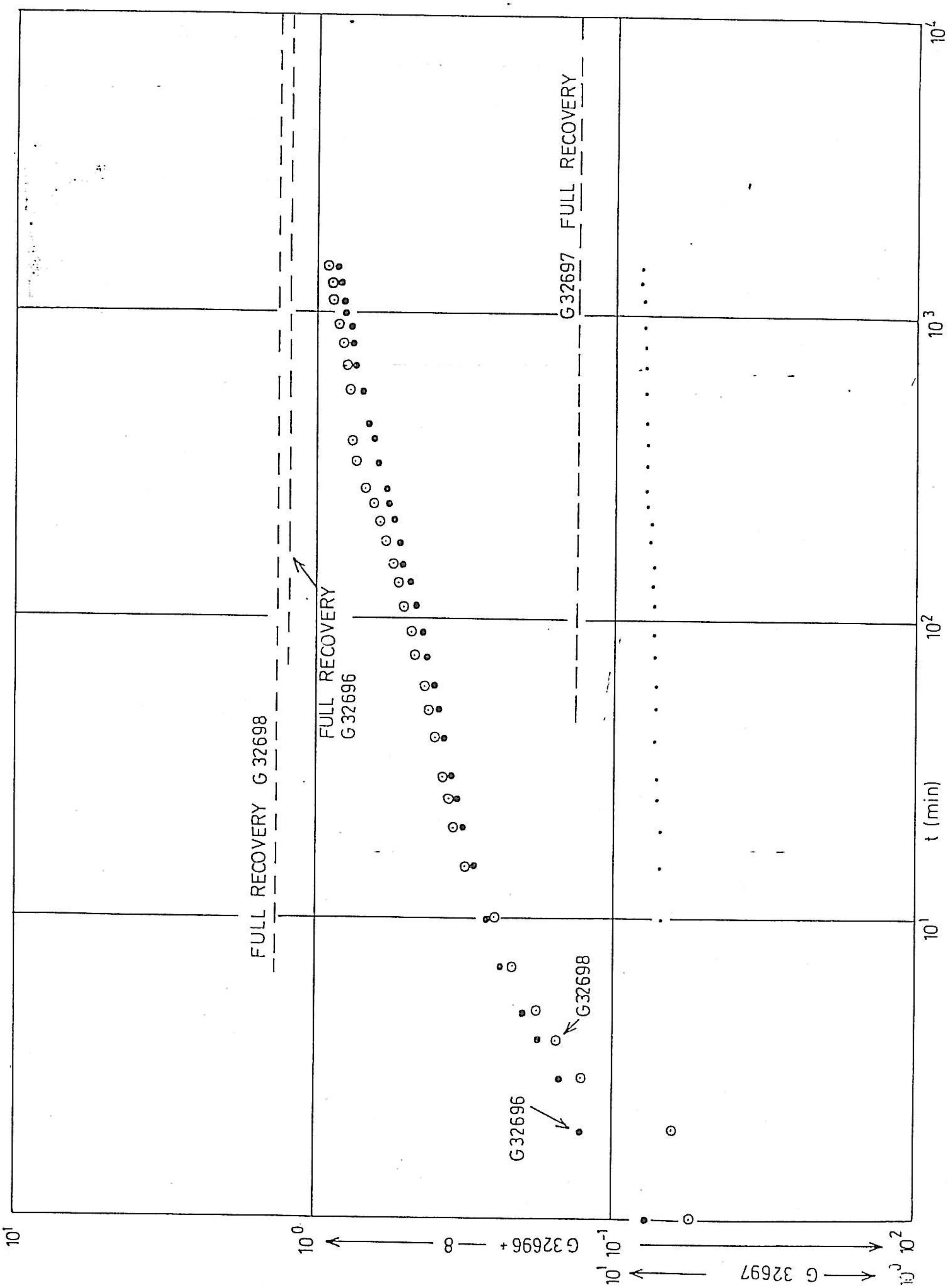


Fig. 44 RECOVERY FROM FINAL DYNAMIC PUMPING WATER LEVEL.

GHP 5442 G 32696, G 32697 and G 32698



Theis recovery analyses were made but reference to Figs. 42 and 43 and Table 7 indicate that this method was not really applicable. The mode of recovery is shown diagrammatically in Fig. 44.

An average transmissivity value of 245 m^2/day and an average effective storage of 3×10^{-2} was calculated.

7.3 G32699 - Alluvial deposits/weathered gabbro aquifer - Turfspruit 241 KR

7.3.1 Approach

Borehole G32699 (Fig. 10) was developed as a production well in an area where the gravelly sand facies is not well developed despite the thickness of alluvial deposits exceeding 20m. The piezometer G32702 (Fig. 13) was drilled some 40m to the SE and like G32699 fully penetrates the alluvial deposits and the weathered, fractured gabbro.

Geophysical and borehole information suggests that conditions are essentially homogeneous in the area likely to be affected by pumping.

A step-drawdown was attempted but had to be abandoned because of the low yield of this borehole, maximum 2,8 ℓ/sec.

7.3.2 Constant rate test

A 72 hour test was successfully completed at a pumping rate of 112 m^3/d. The maximum drawdown in the pumped well was 6,6m and the single piezometer showed a slow response to pumping.

The time-drawdown curve obtained could be fitted to the Theis curve for unsteady state flow in confined aquifers (see Fig. 45) which enabled T and S values to be calculated (Table 8).

The Chow nomograph method was also applied (Fig. 46) and the results were in close agreement to those obtained from the Theis curve.

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Fig. 45 G 32702. TIME-DRAWDOWN, THEIS METHOD
GHP 5443

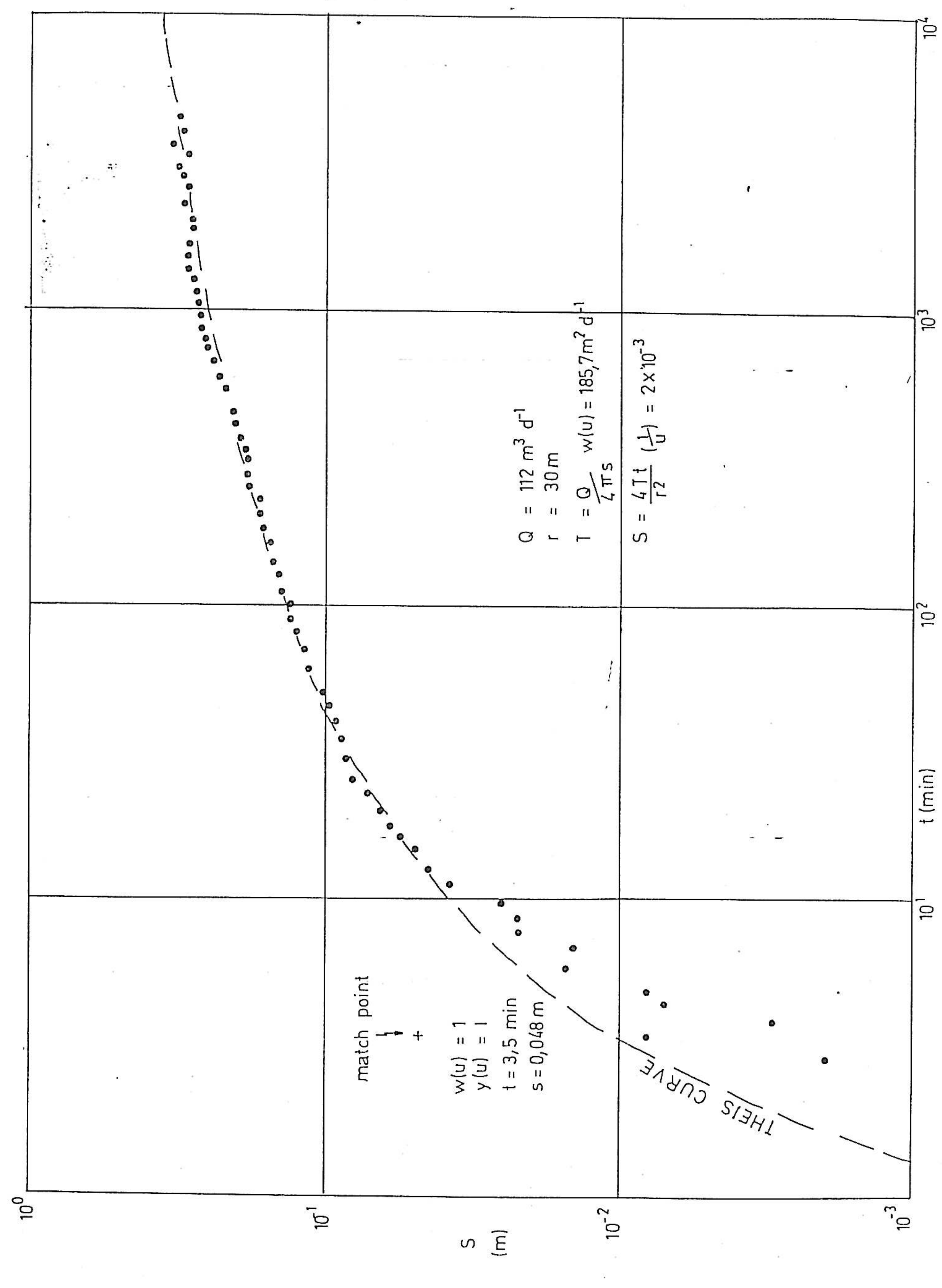


Fig. 46 G 32702 TIME - DRAWDOWN, JACOB + CHOW ANALYSIS.
GHP 5444

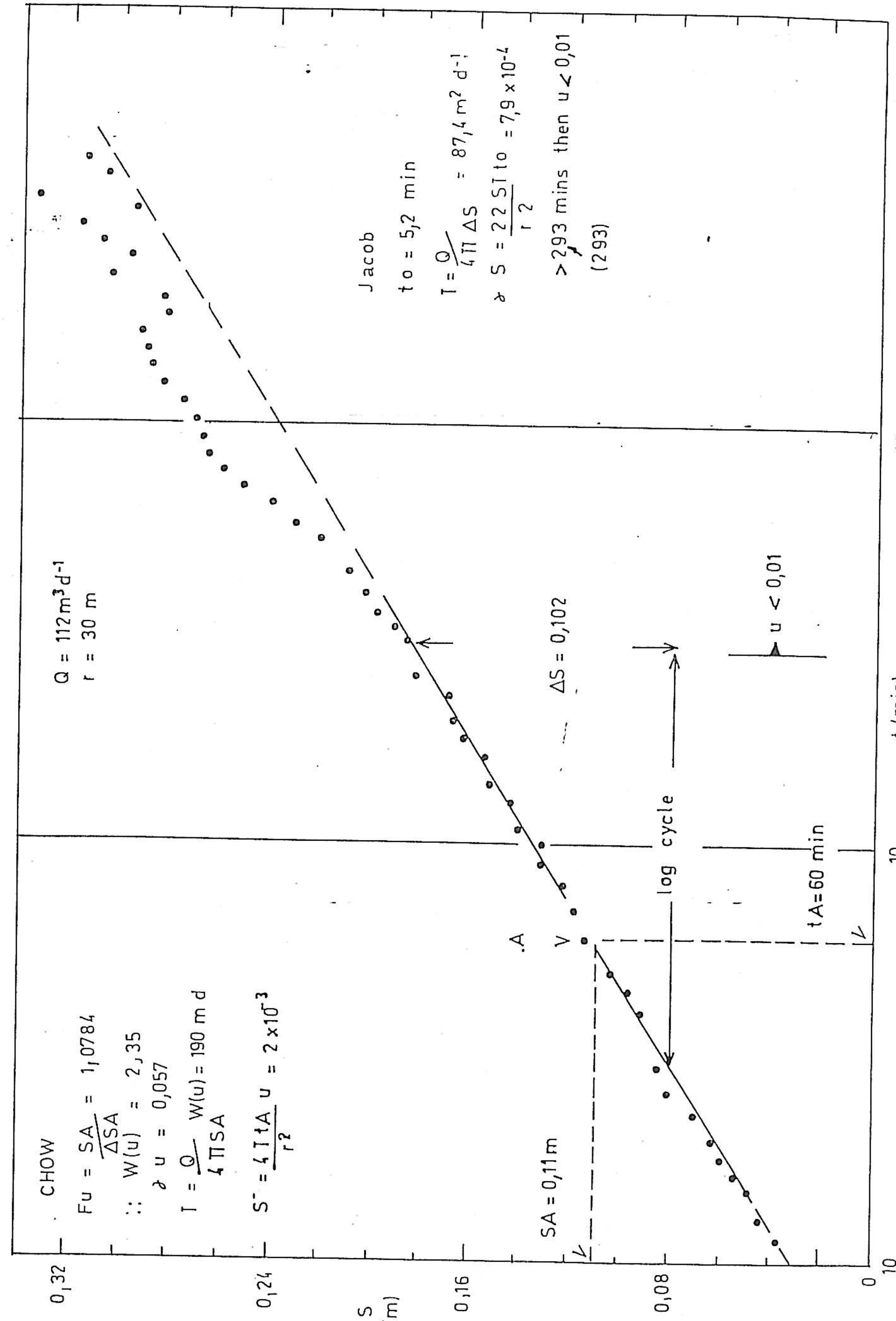


Fig. 47 G32699, THEIS RECOVERY ANALYSIS
GHP 5445

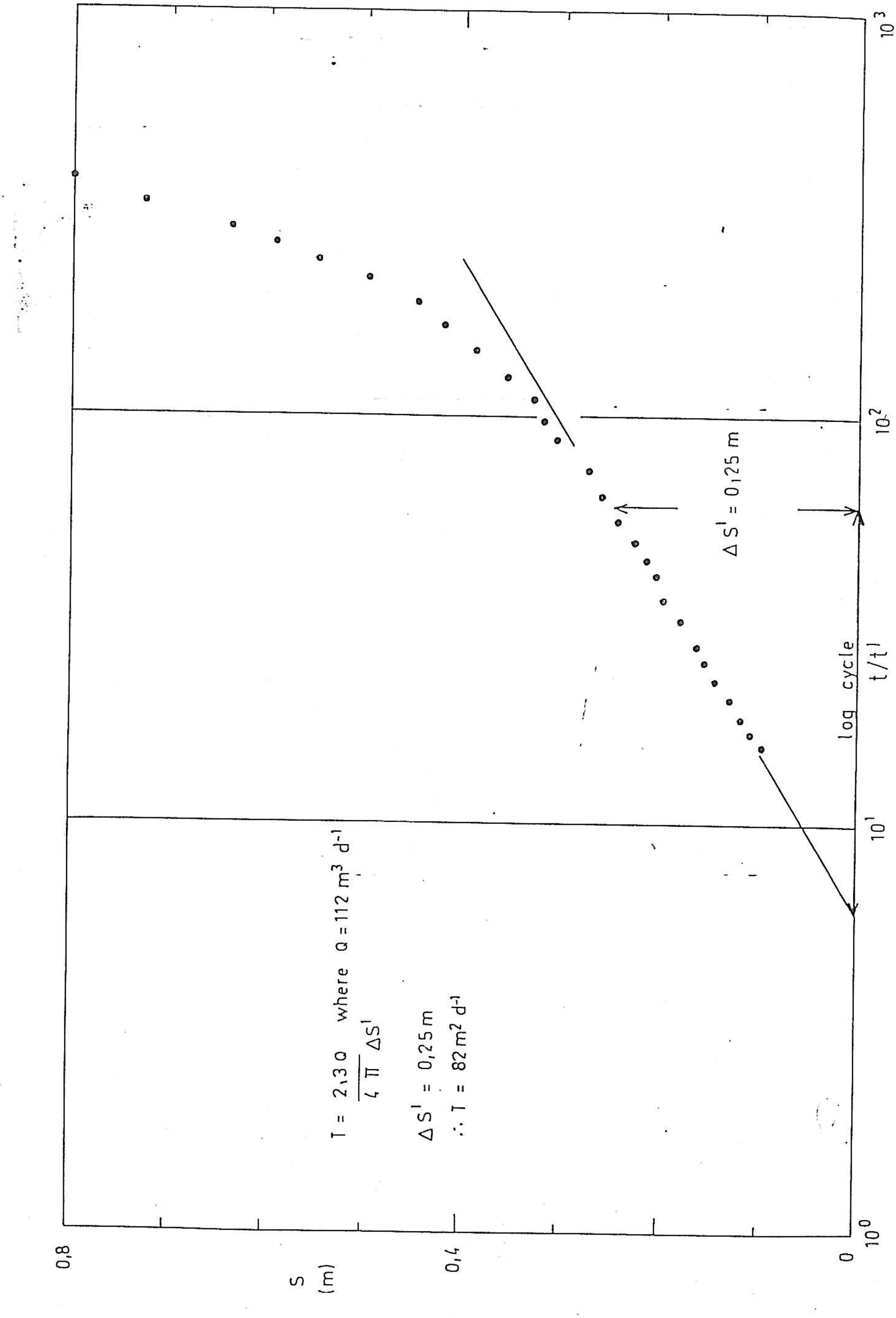


Fig. 48 G32702, THEIS RECOVERY ANALYSIS.
GHP 5446

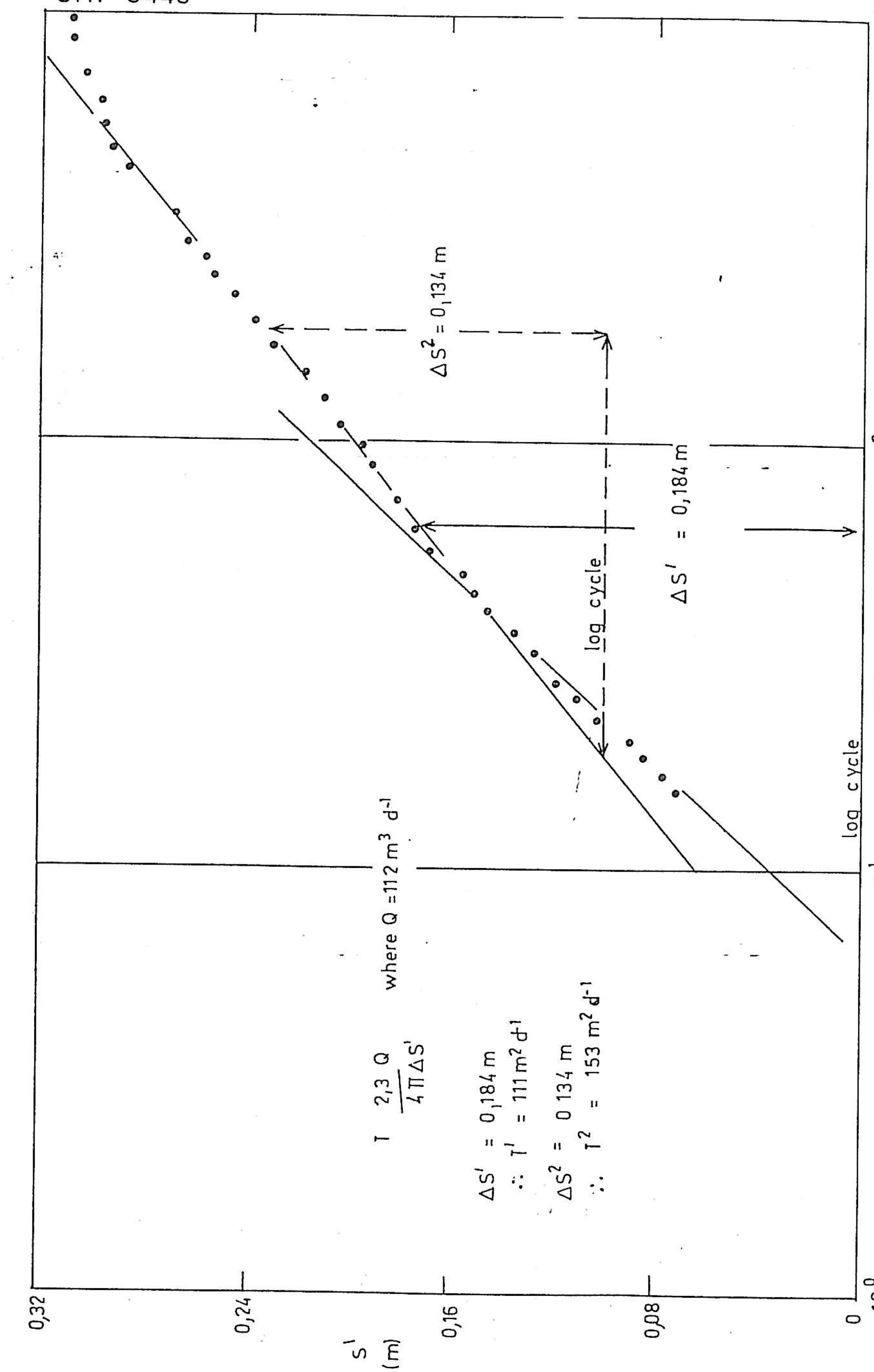
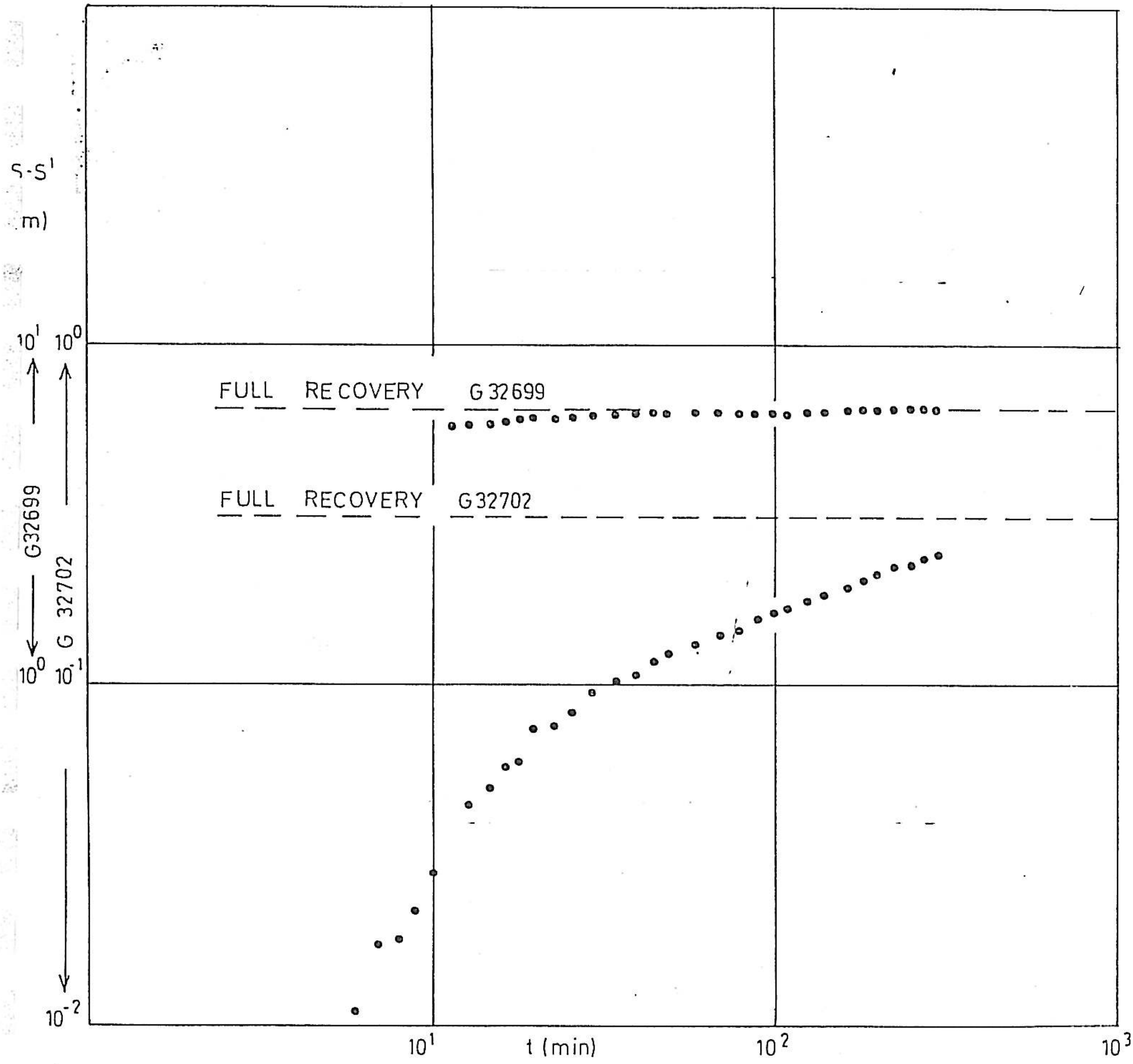


Fig.49 GHP 5447 RECOVERY FROM FINAL DYNAMIC PUMPING WATER LEVEL, G32699 and G32702.



Results obtained by the Jacob and the Theis recovery methods (Figs. 46, 47 and 48) were not considered applicable and thus were not used in determining average values of T and S.

Figure 49 shows that the recovery from final pumping water levels if fairly rapid

TABLE 8 G32699 Results of pumping test analyses

Borehole	Method	T	S	Remarks
G32699 (pumping)	Theis recovery	82		low $^t/t'$
G32702 (Obs.)	Theis	185,7	2×10^{-3}	ignoring early data
	Jacob	87,4	$7,9\times10^{-4}$	u 0,01, 293 min
	Chow	190	2×10^{-3}	
	Theis recovery	111,4 153		low $^t/t'$ high $^t/t'$

An average transmissivity value of 188 m^2/d^{-1} was calculated and a storage coefficient of 2×10^{-3}. This S value is high for a fully confined aquifer so conditions may probably be more accurately termed semi-confined.

7.4 G32709: Fractured rock aquifer - Turfspruit 241 KR

7.4.1 Approach

Exploration borehole G32701, Fig. 12, recorded a moderate blow yield which was intersected in heavily fractured metaquartzite. No water was encountered in the overlying alluvium and weathered gabbro.

Subsequently the production borehole G32709 (Fig. 19) was drilled 30m to the N.W. and similarily penetrated clayey, granular, weathered gabbro before striking water in fractured metaquartzite. Thirty metres NE of G32709 a second piezometer G32710 (Fig. 2), was drilled. This borehole encountered a greater thickness of alluvial deposits and encountered water within weathered and fractured gabbro formation, the hole was stopped at 42m without metaquartzite being drilled.

7.4.2 Step-drawdown test

A five stage test was successfully carried out and is illustrated in Fig. 50. Well calibration data using the Bierschenk and Wilson method is presented in Table 9 and Figs. 51 and 52. Information obtained revealed that:

- the maximum yield of G32709 was approximately 1020 m^3/d
- near steady-state conditions were attained rapidly
- the borehole was excellently developed ('development factor' 0,06)
- borehole is efficient below pumping rates of 11,56 ℓ/sec (1000 m^3/d) with only moderate well losses

67. ....

- recovery from pumping water levels is rapid.

7.4.3 Constant rate test

G32709 was pumped for 4200 minutes at a rate of 9,8 ℓ/sec (848 m^3/d) with an interpolated well efficiency of 66%.

Figures 53 and 54 clearly illustrate the difficulty of curve matching as the drawdown is rapid for the initial few minutes of pumping but subsequently attains apparent near steady-state conditions.

As can be seen from figures 55 a straight line fit is inapplicable after some 30 minutes, however an early T value of $79m^2d^{-1}$ has been calculated.

Comparisons of well geology and drawdown suggest that the Boulton delayed drainage type curves for unconfined and semi-unconfined aquifers are suitable for the determination of aquifer parameters (see Table 6).

For G32701 a Boulton 'A' match only can be produced thus no value of effective storage can be calculated.

The response in G32709 suggests that a tentative Y match can also be made, this match produces a high storage figure that must be considered as speculative.

The rapid mode of recovery is clearly shown in Figure 56.

Conditions in the fractured aquifer can probably be best be described as semi-unconfined with vertical gravity drainage from overlying weathered gabbro. An average value of transmissivity has been calculated as $65m^2d^{-1}$.

TABLE 9 WELL CALIBRATION G32709

STEP	Q ℓ/sec	*Δ Sw (m)	Cumulative Δ SW (m)	S_w/Q	BQ	CQ^2	$BQ+CQ^2$	$\frac{BQ}{BQ+CQ^2} \times 100$ (%)
1	6,22	10,90	10,90	$2,03\times10^{-2}$	8,18	2,66	10,84	75,5
2	7,29	2,40	13,30	$2,11\times10^{-2}$	9,59	3,66	13,25	72
3	8,68	3,25	16,55	$2,20\times10^{-2}$	11,42	5,19	16,61	69
4	9,63	2,45	19,00	$2,28\times10^{-2}$	12,66	6,38	19,04	66,5
5	10,68	3,00	22,00	$2,38\times10^{-2}$	14,04	7,85	21,89	64
6	11,79	(2,09)	(25,09)	$(2,46\times10^{-2})$	(15,50)	(9,57)	(25,07)	(62) interpolated
Constant yield rate	9,80		(19,4)	$(2,29\times10^{-2})$	(12,89)	(6,62)	(19,51)	(66) "

where $B = 1,52\times10^{-2}$ and $C = 9,2\times10^{-6}$

* increments of drawdown taken at projected "steady state" conditions

Fig.50 G 32709, STEP - DRAWDOWN TEST

GHP 5448

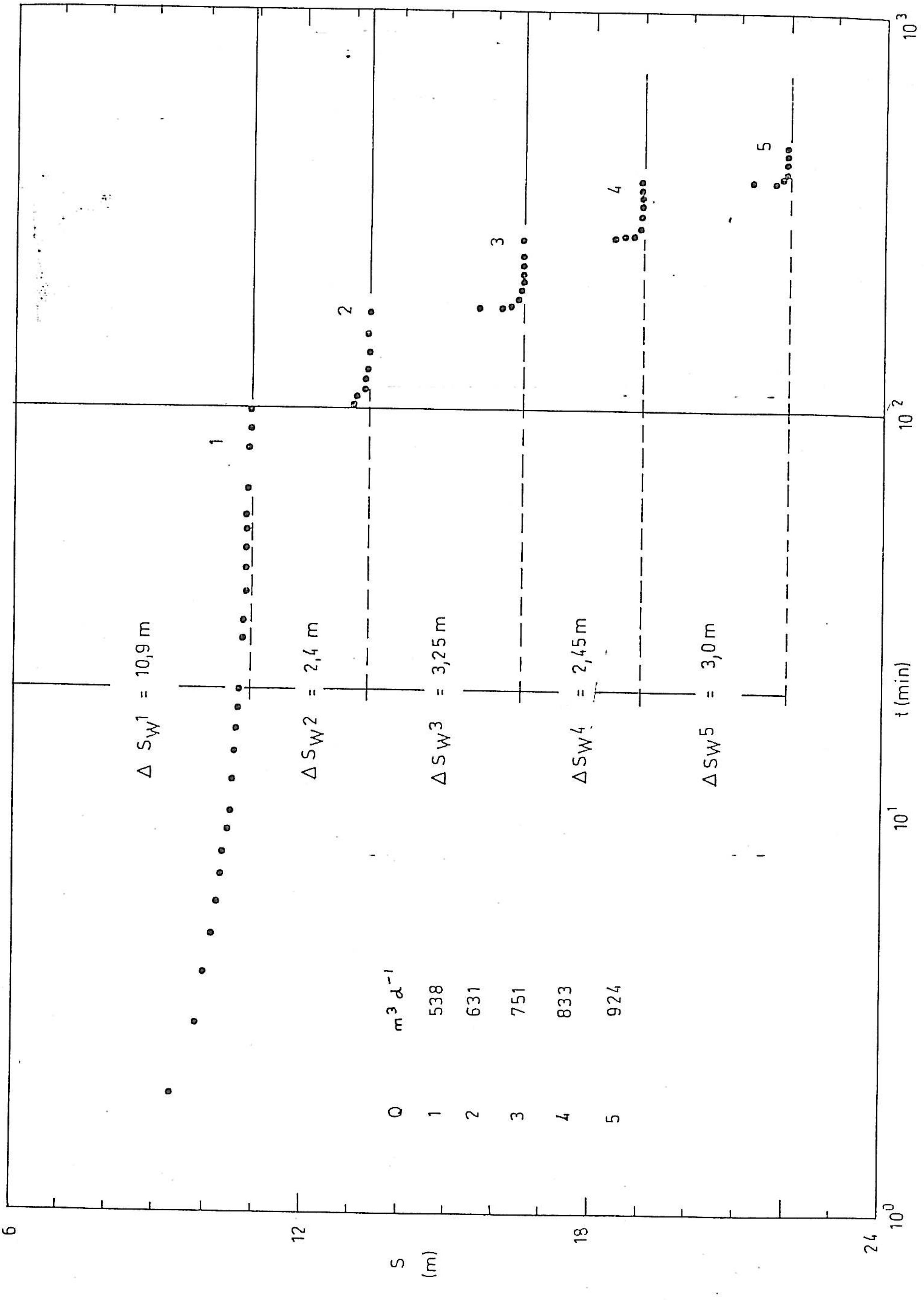


Fig. 51 G32709, SPECIFIC DRAWDOWN - DISCHARGE
GHP 5449

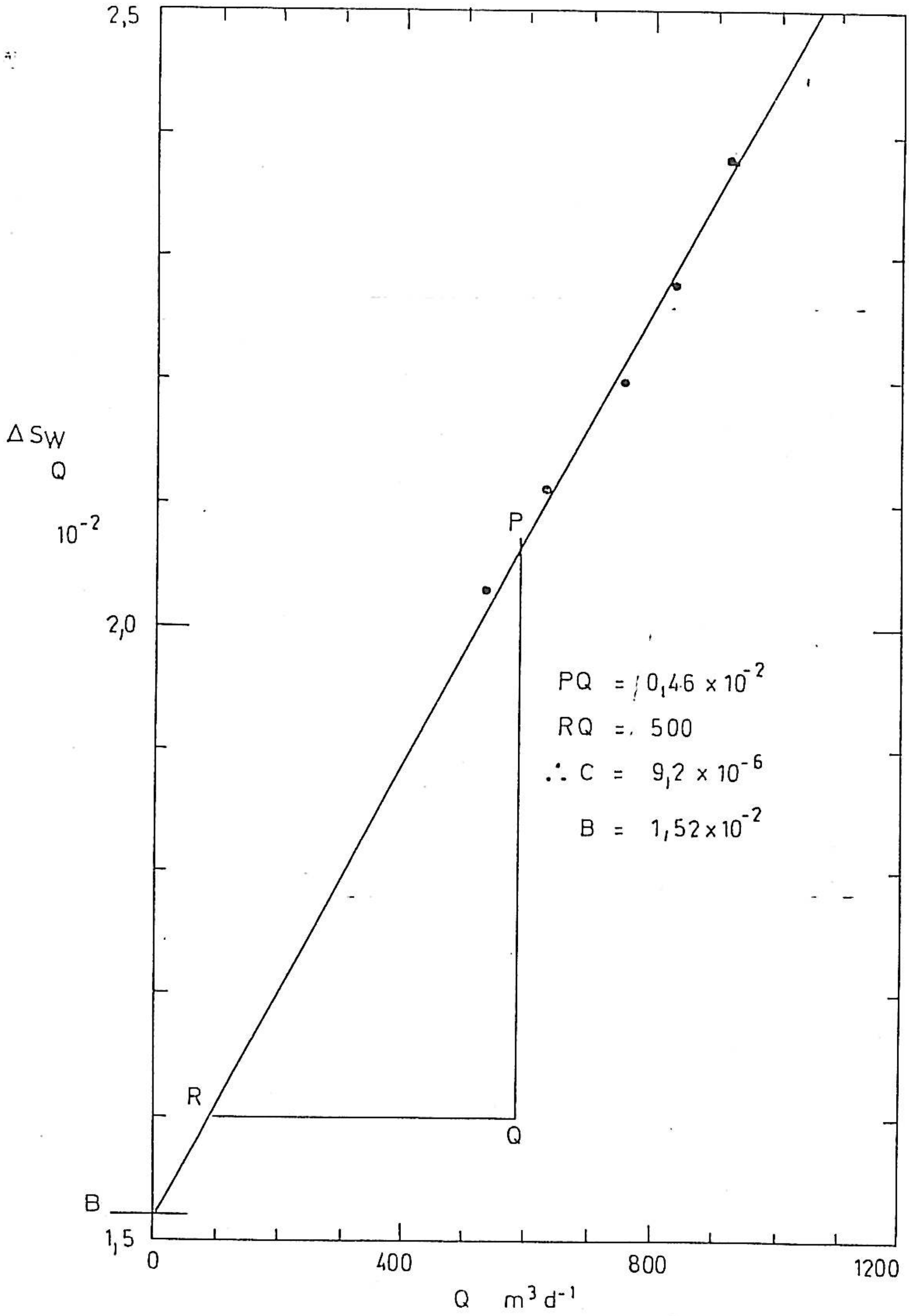


Fig. 52
GHP 5450

G 32709 WELL EFFICIENCY DIAGRAM

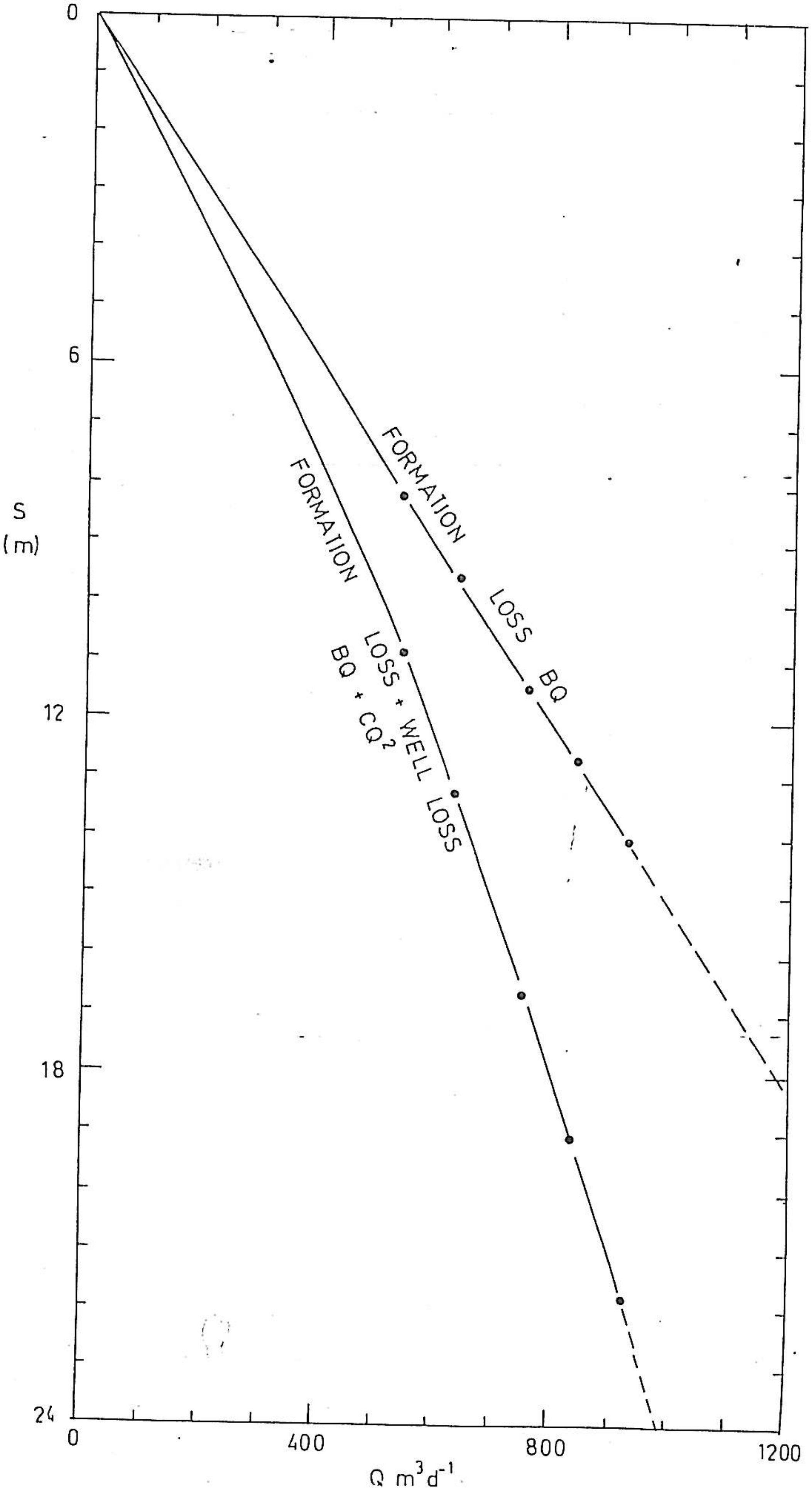


Fig. 53 G 32701 + G 32709, TIME - DRAWDOWN, BOULTON MATCH
GHP 5451

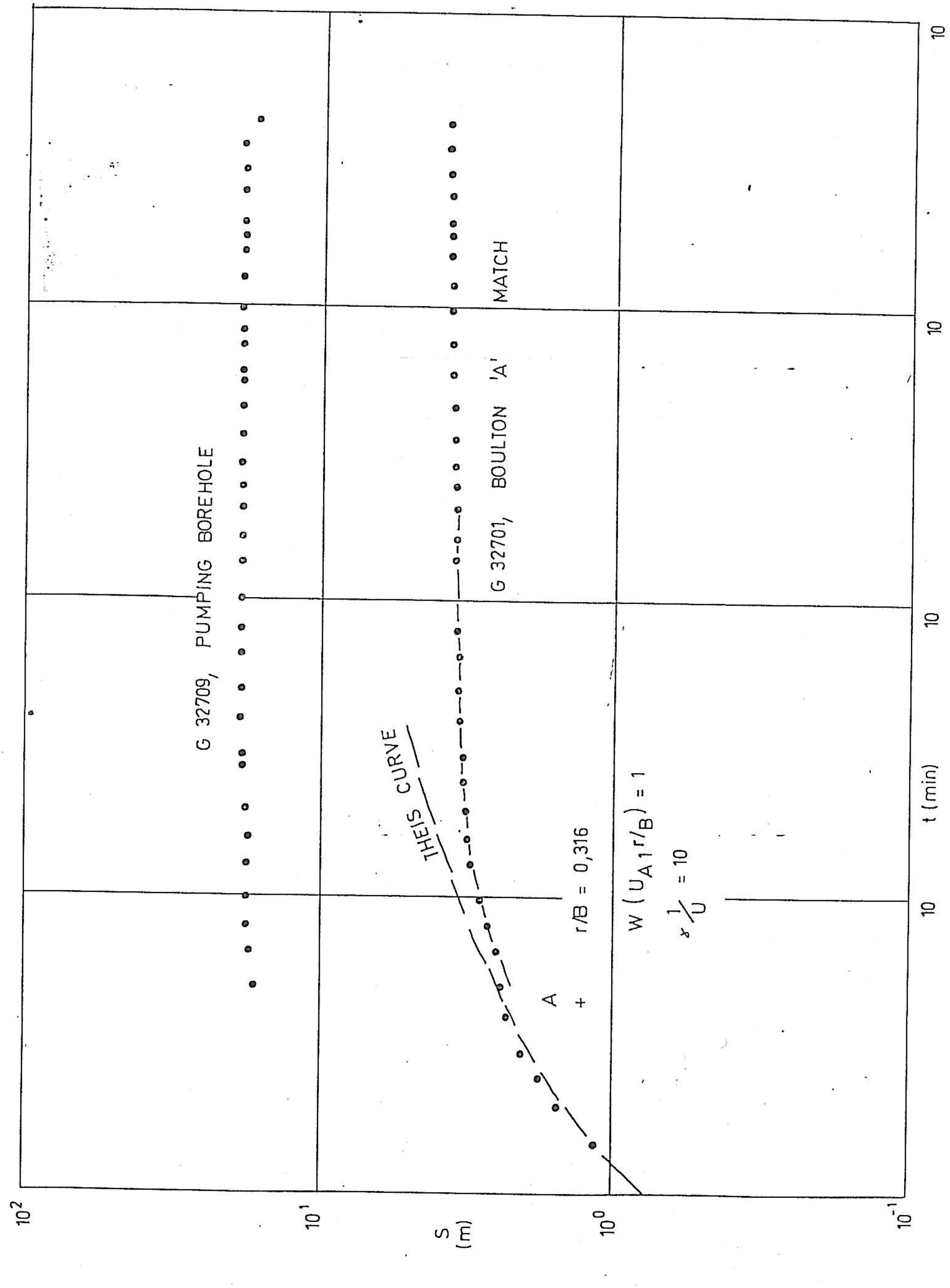


Fig 54 G 32710, TIME-DRAWDOWN, BOULTON MATCH.

GHP 5452

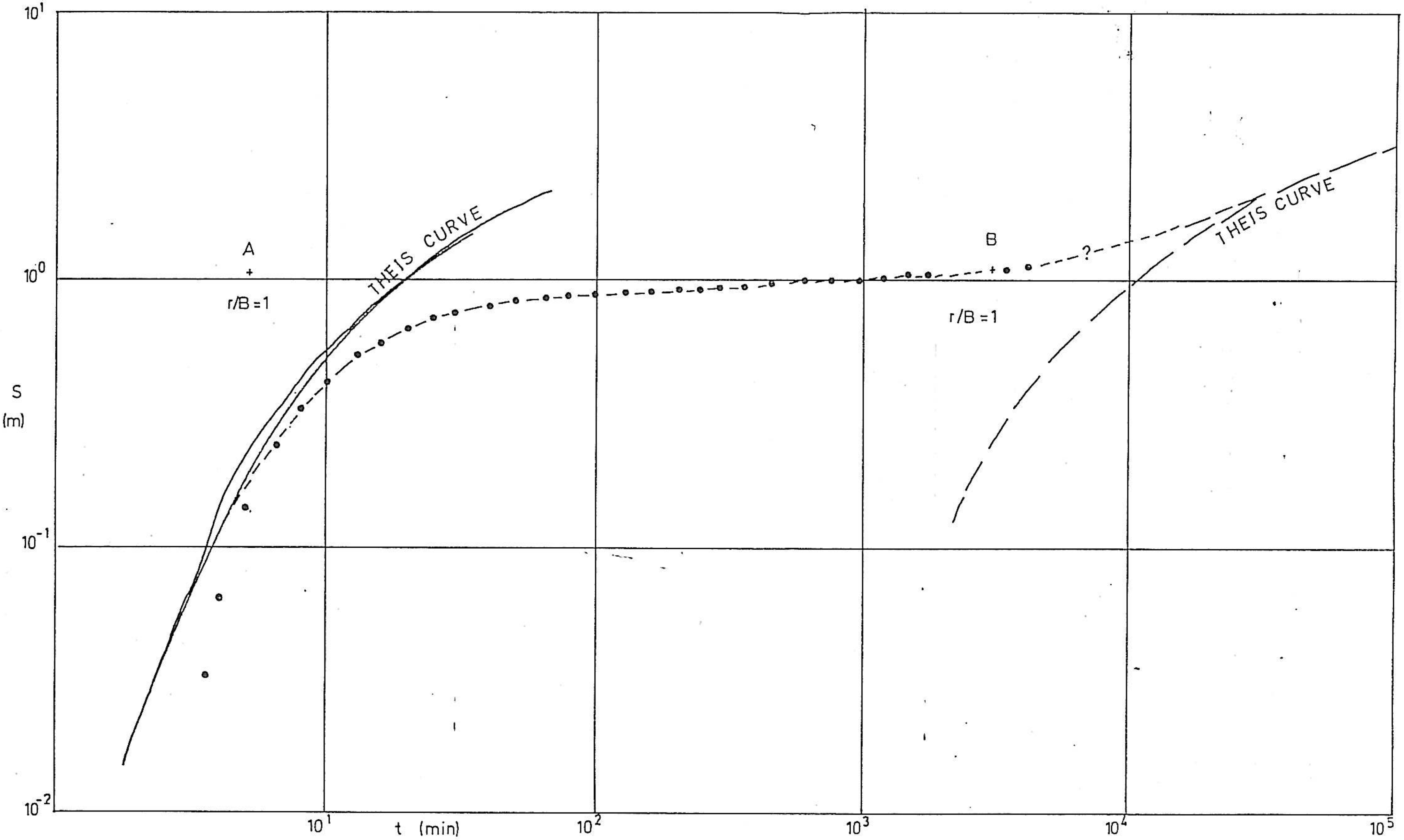


Fig. 55 G32710₁ JACOB STRAIGHT LINE ANALYSIS
GHP 5453

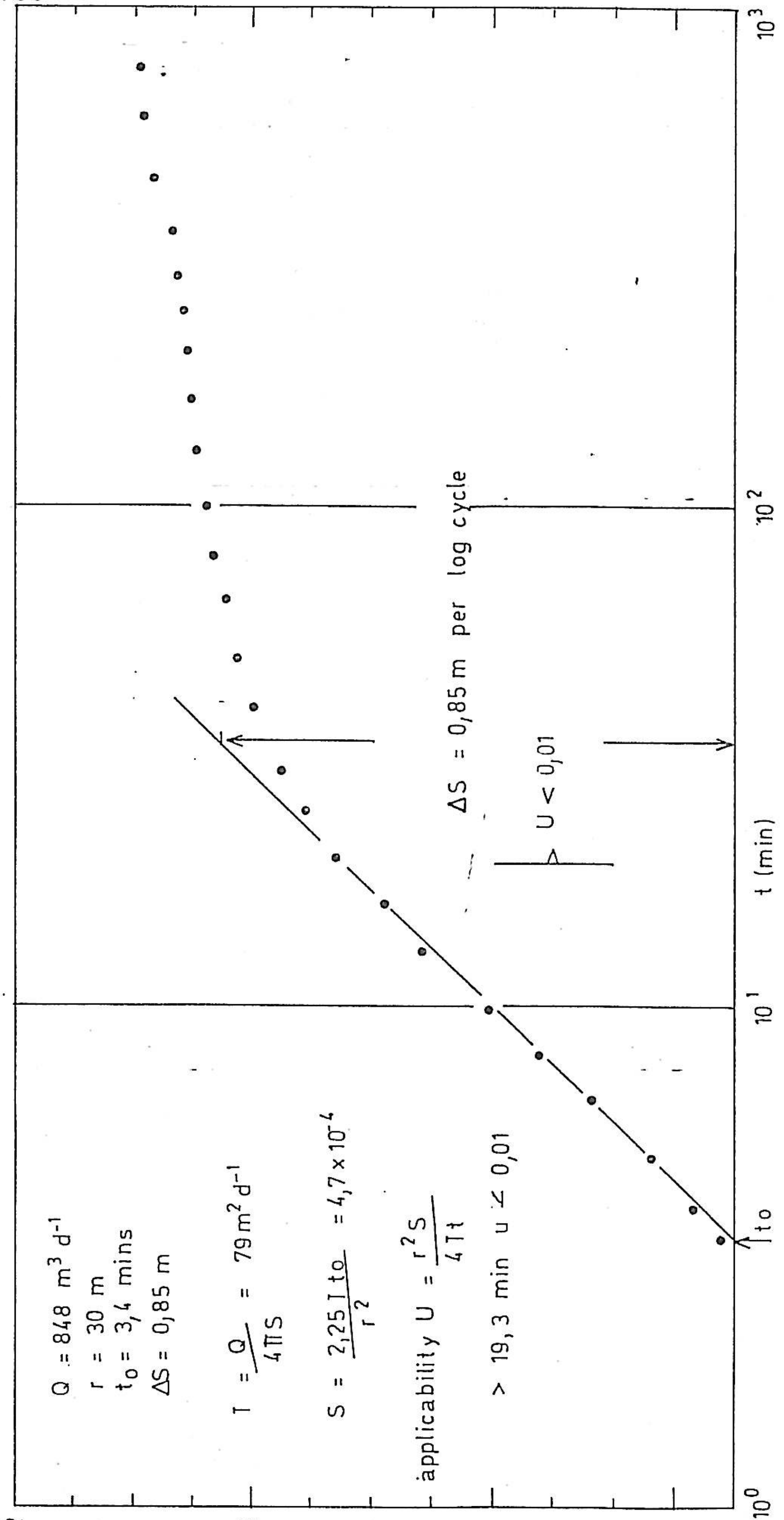
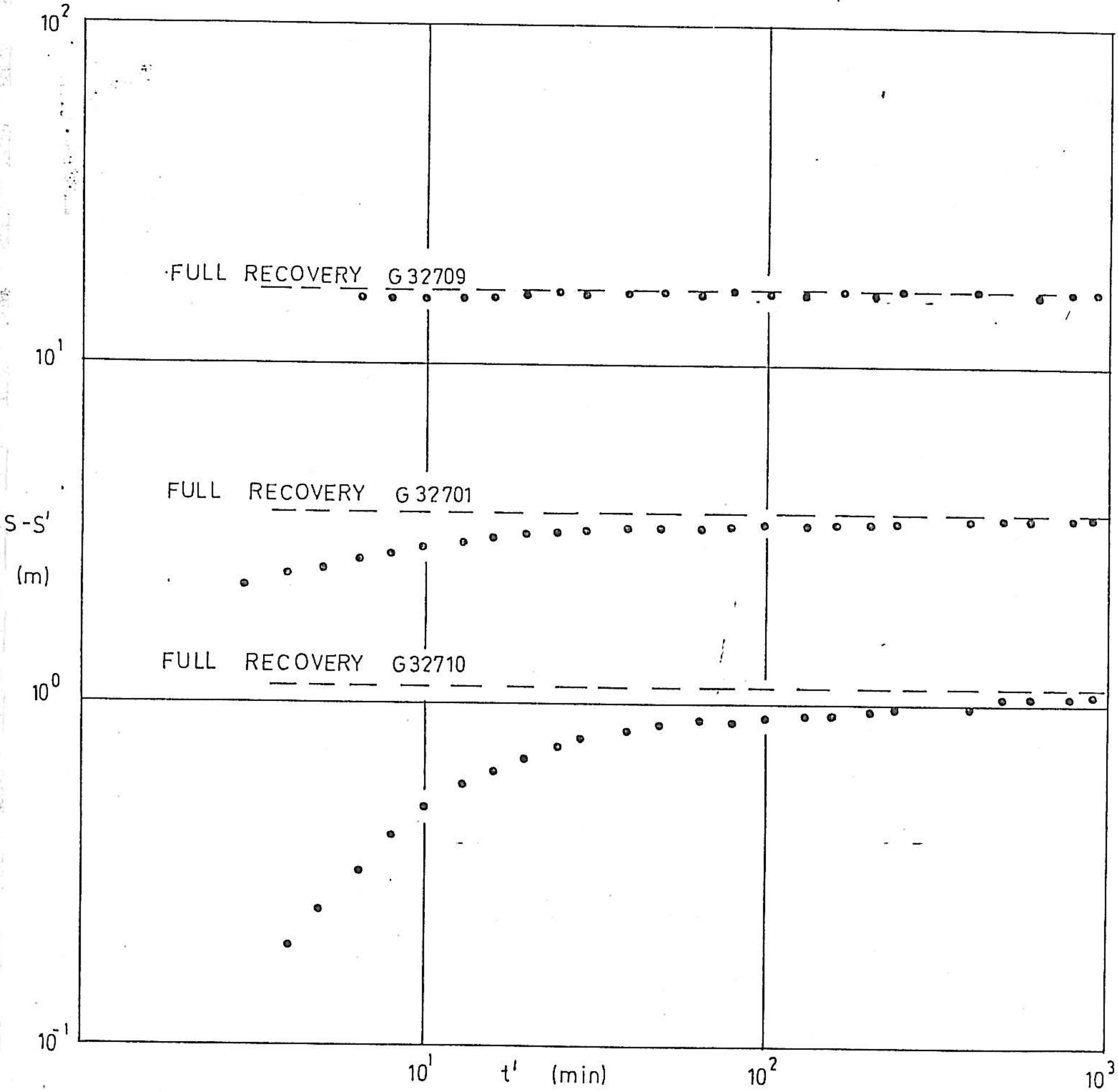


Fig. 56 RECOVERY FROM FINAL DYNAMIC PUMPING
GHP 5454 WATER LEVEL, G32701, G32709 and G32710



7.5 G32711-alluvial deposits/weathered gabbro aquifer - Turfspruit 241 KR (northern section)

7.5.1 Approach

G32706 (Fig. 17) was sited geophysically and encountered a considerable thickness of water-bearing gravelly sands. Further exploratory bore= holes G32707 (Fig. 17) and G32708 (Fig. 18) drilled respectively 100 and 300m to the south, encountered similar thicknesses of aquiferous gravelly sands.

A production borehole G32711 (Fig. 21) was sited some 40m N.W. of G32706, refer to Enclosure 1, and another piezometer G32712 (Fig. 22) was installed 30m to the west. All existing boreholes,-except G32707 fully penetrate the alluvial deposits and weathered gabbro.

Evidence accumulated from geophysical and borehole logging revealed that the area potentially affected by pumping was relatively homogeneous and isotropic.

Examination of the geological logs suggest that aquifer conditions would be unconfined or semi-unconfined with delayed yield.

7.5.2 Constant rate test

G32711 was pumped for 1695 minutes at a rate which fluctuated between 11,09 ℓ/sec and 12,23 ℓ/sec (see Appendix 6)

For the purpose of calculation an average discharge of 11,56 ℓ/sec (1000 m^3/d) was assumed. If a multirate test had been carried out prior to the constant rate test this unnecessary variation in pumping rate could have been avoided. Unfortunately the period of pumping was too short for all but the closest piezometer to give a satisfactory response.

Figure 57a illustrates that the time-drawdown curve for G32712 can be reasonably matched to a Boulton type curve despite poor test conditions. Co-ordinates and calculated T and S values are given in Tables 6.

Comparative analyses by the Jacob straight line and Chow nomograph methods (Figure 59 and Table 10) gave similar results to the Boulton matches for later pumping conditions.

TABLE 10 G32711 - RESULTS OF PUMPING TEST ANALYSES

Borehole	Method	T m^2/d	S	Remarks
G32712	Boulton 'A'	362*	$1,5 \times 10^{-3}$	
(obs)	Boulton 'B'	362*	$9,6 \times 10^{-3}$	$Sy = 1,11 \times 10^{-2}$*
	Jacob	327*	$1,33 \times 10^{-2}$*	$u' < 0,01$ after 1350 minutes
	Chow	314*	$1,5 \times 10^{-2}$*	late match
	Theis recovery	207		low $^t/t'$
		796		high $^t/t'$
G32707	Theis	637	2×10^{-2}	limited data
(obs)	Jacob	1017	$2,6 \times 10^{-2}$	not applicable
	Chow	711	$3,5 \times 10^{-2}$	early match
G32711	Theis recovery	149		low $^t/t'$
(pumped)		273		high $^t/t'$

*Values used for calculating aquifer parameters

FIG 57 G32707, TIME-DRAWDOWN, THEIS ANALYSIS.
GHP 5455

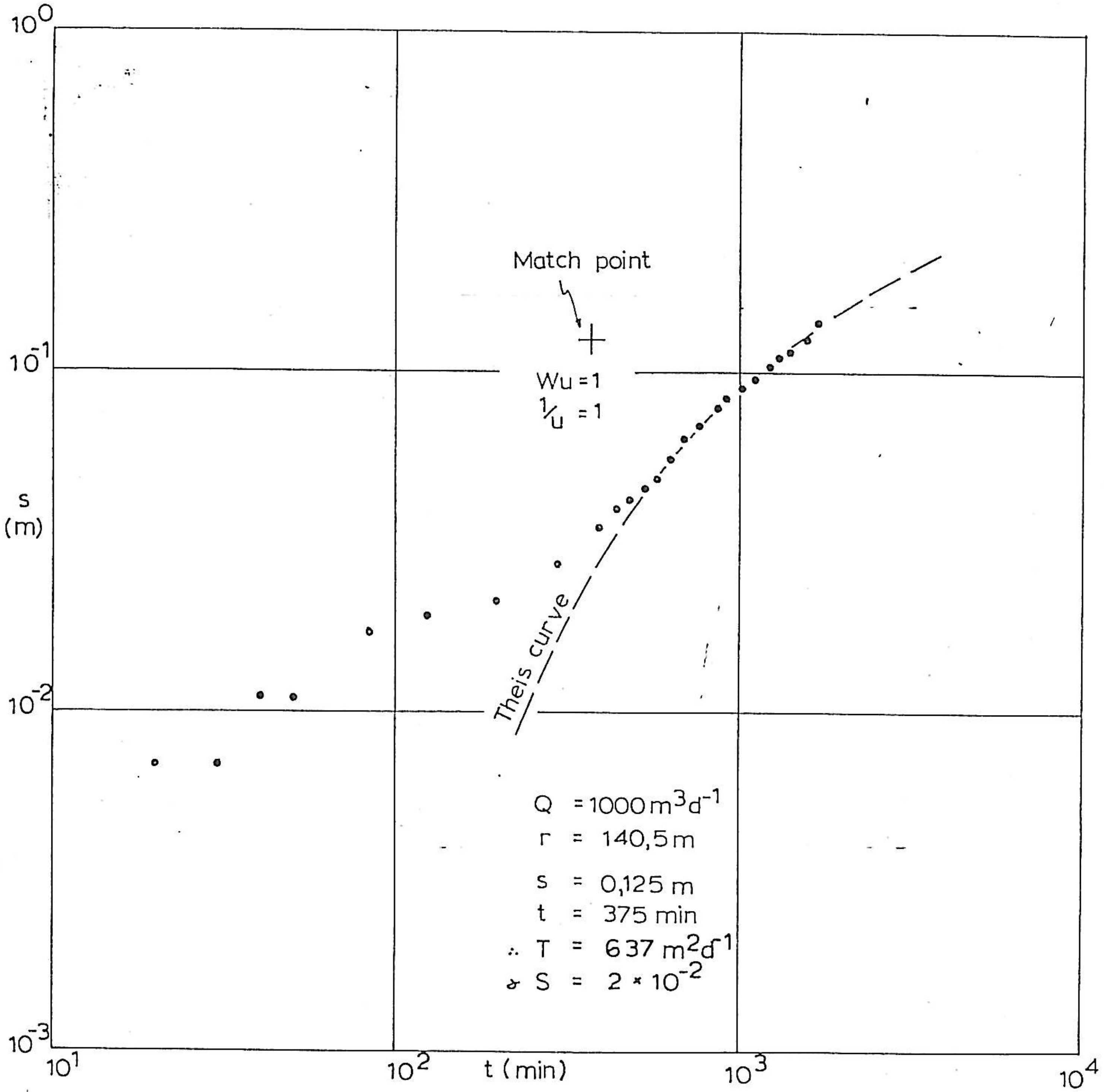


Fig 57a G32712, TIME-DRAWDOWN, BOULTON METHOD

GHP 5456

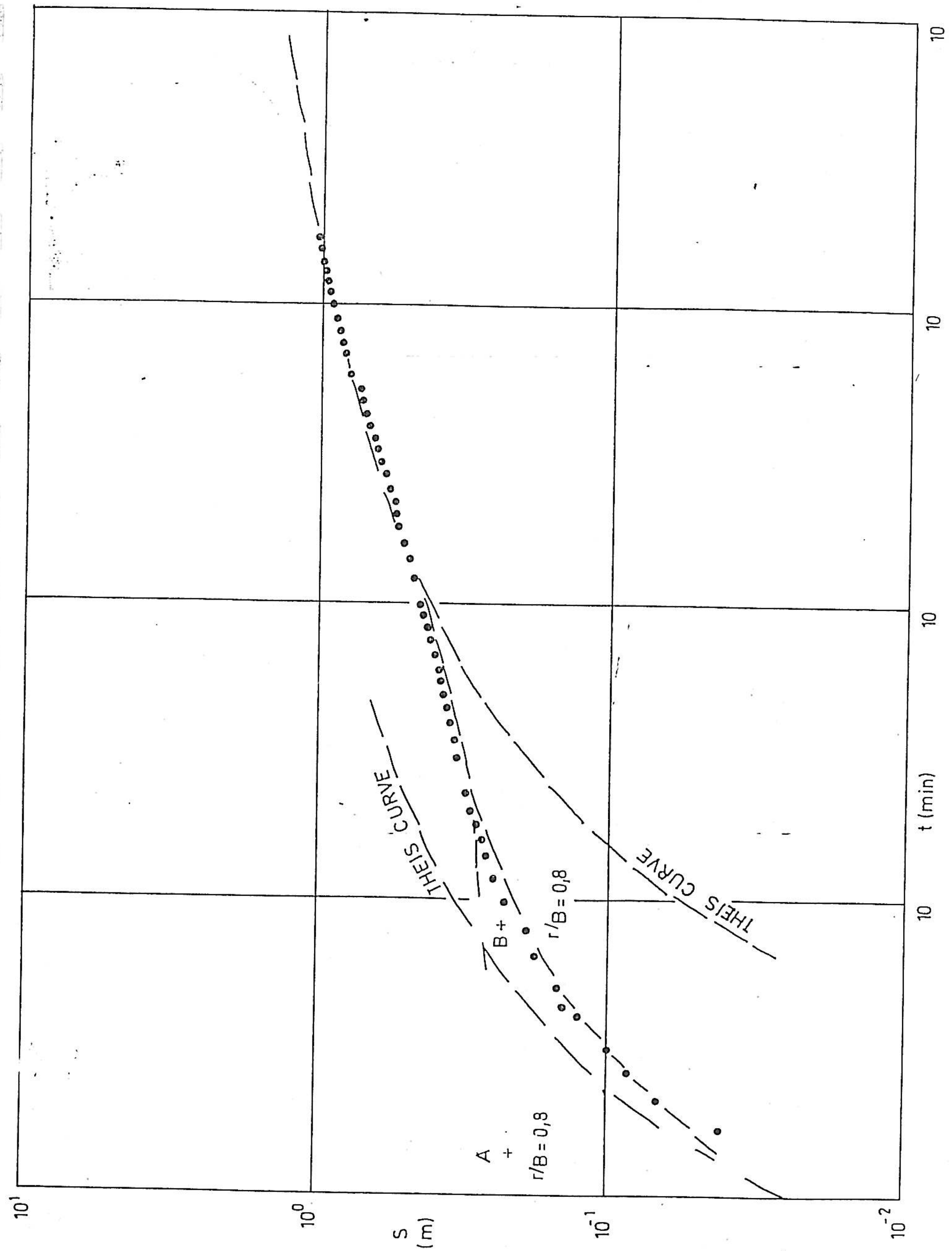


Fig 58 G 32707, : TIME DRAWDOWN, JACOB and CHOW METHODS
GHP 5457

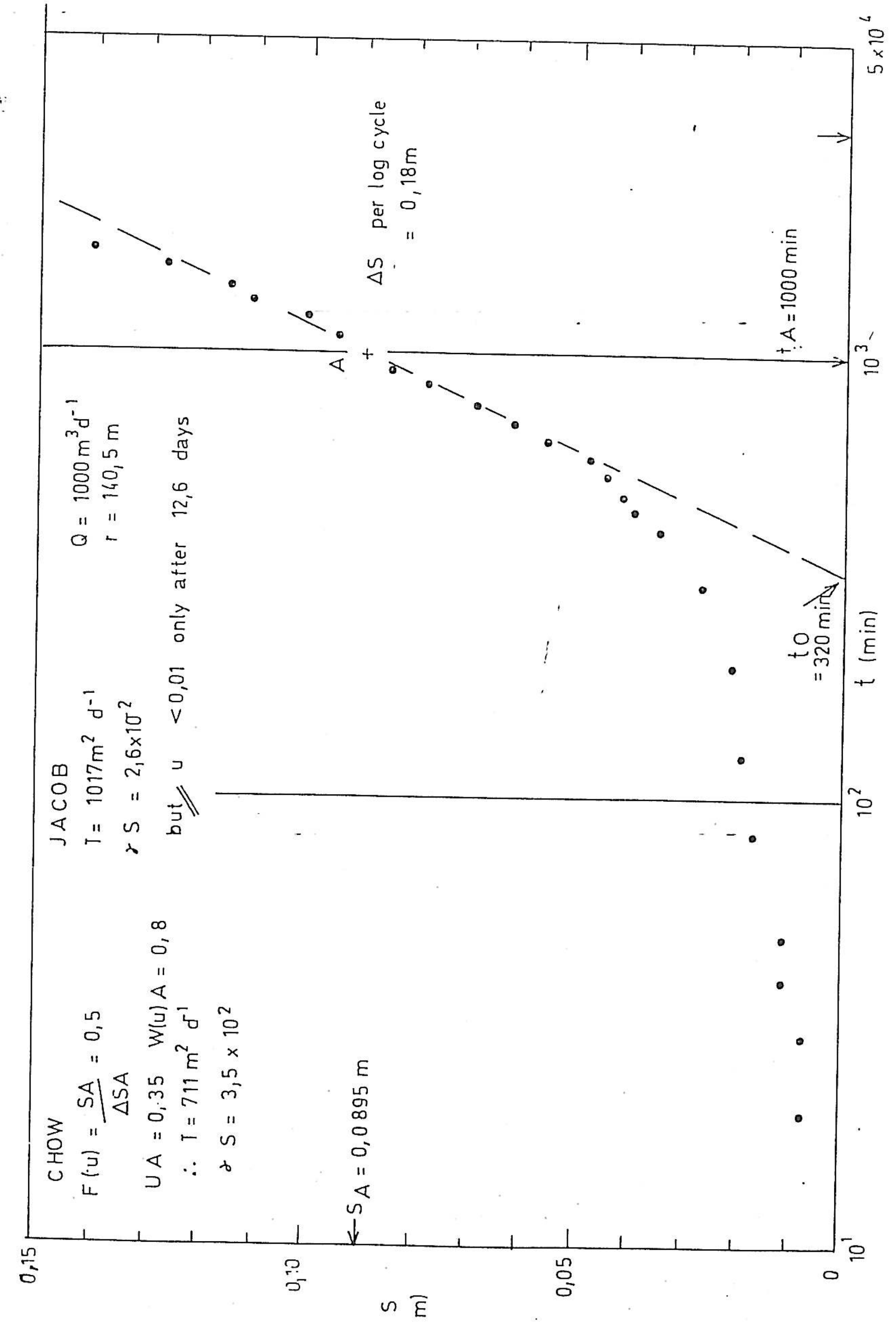


FIG 59 G32712, TIME - DRAWDOWN, JACOB + CHOW ANALYSIS
GHP 5458

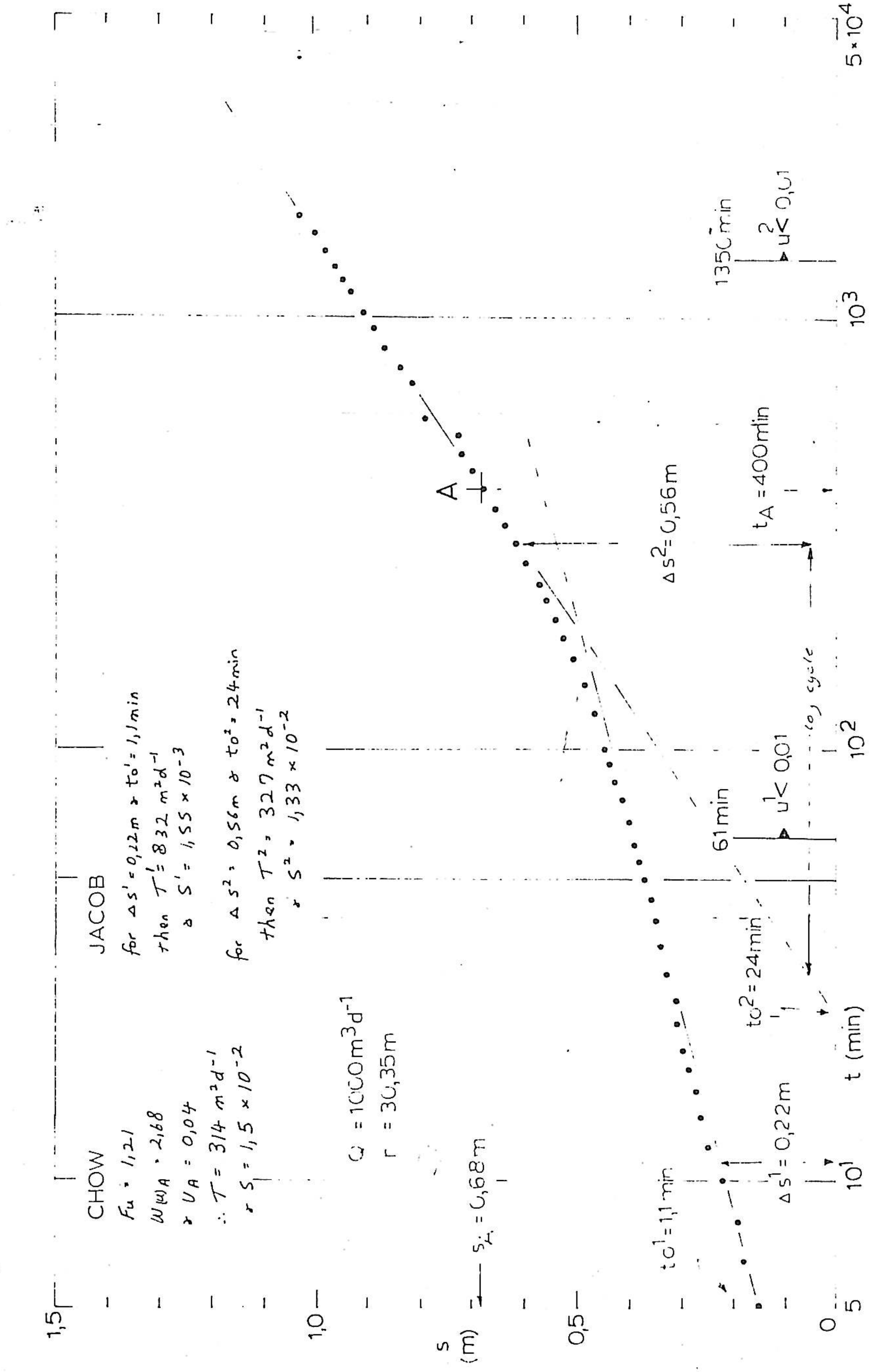


Fig. 60
GHP 5459

G 32711, THEIS RECOVERY ANALYSIS

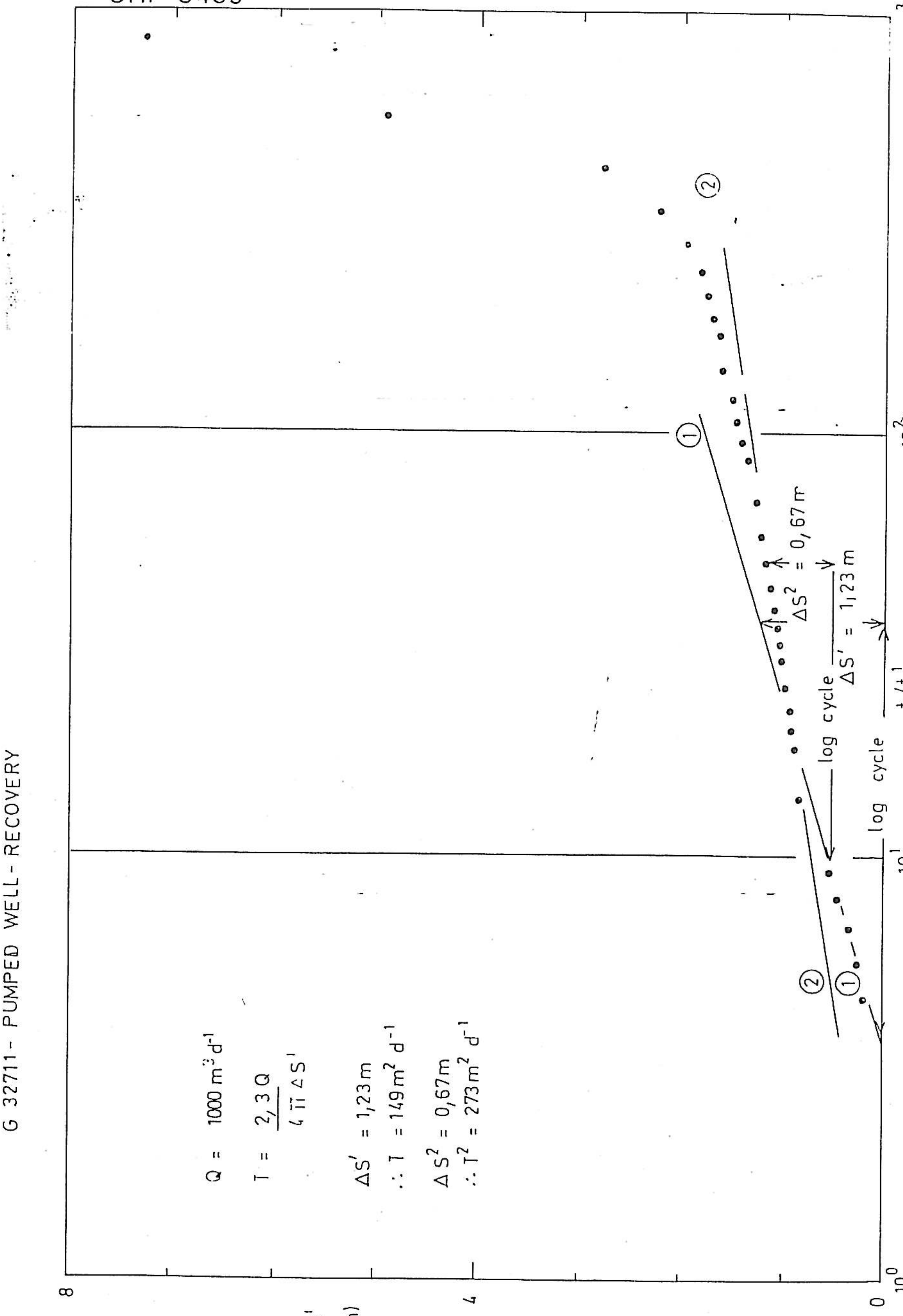


Fig 61
GHP 5460

G32712, THEIS RECOVERY ANALYSIS

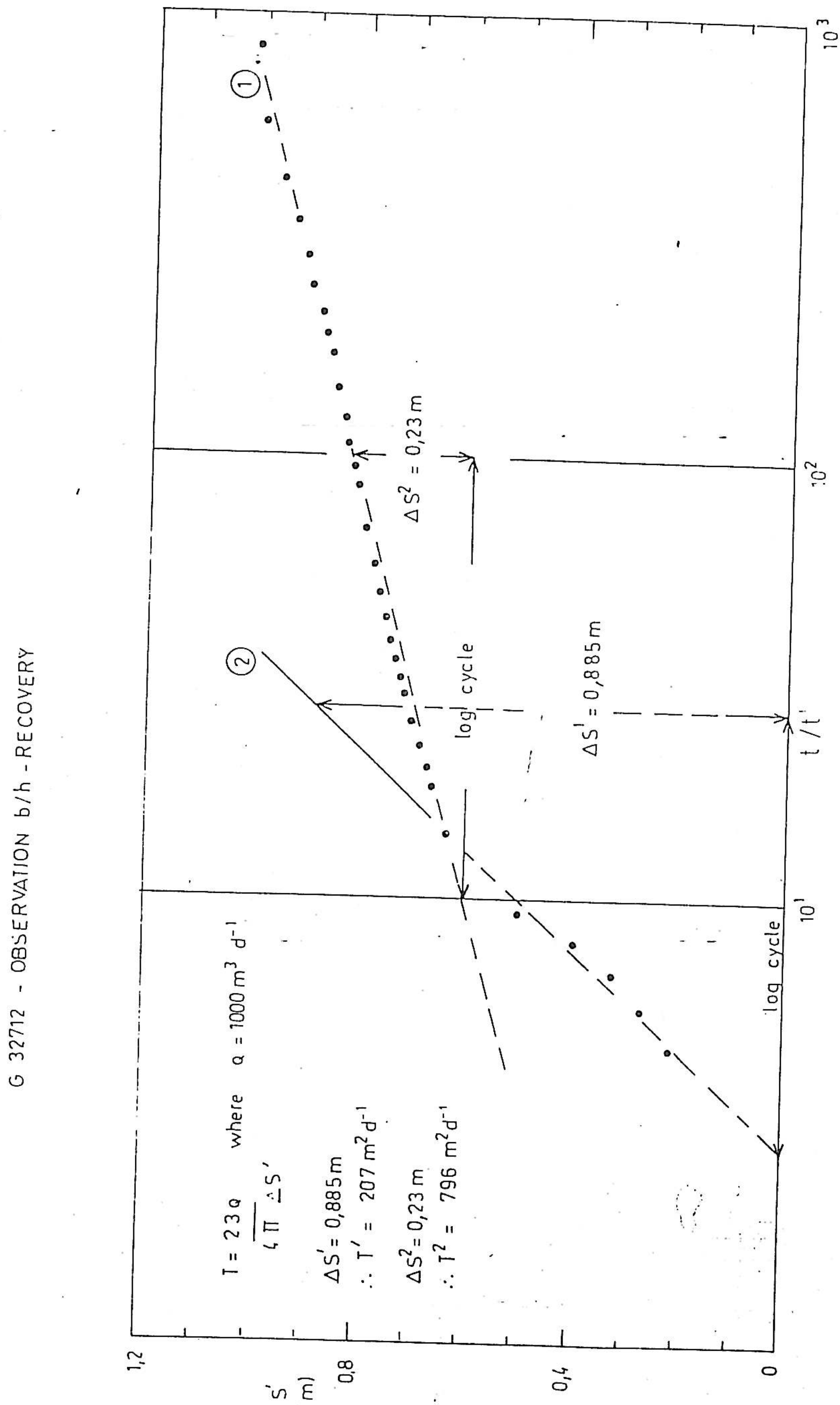
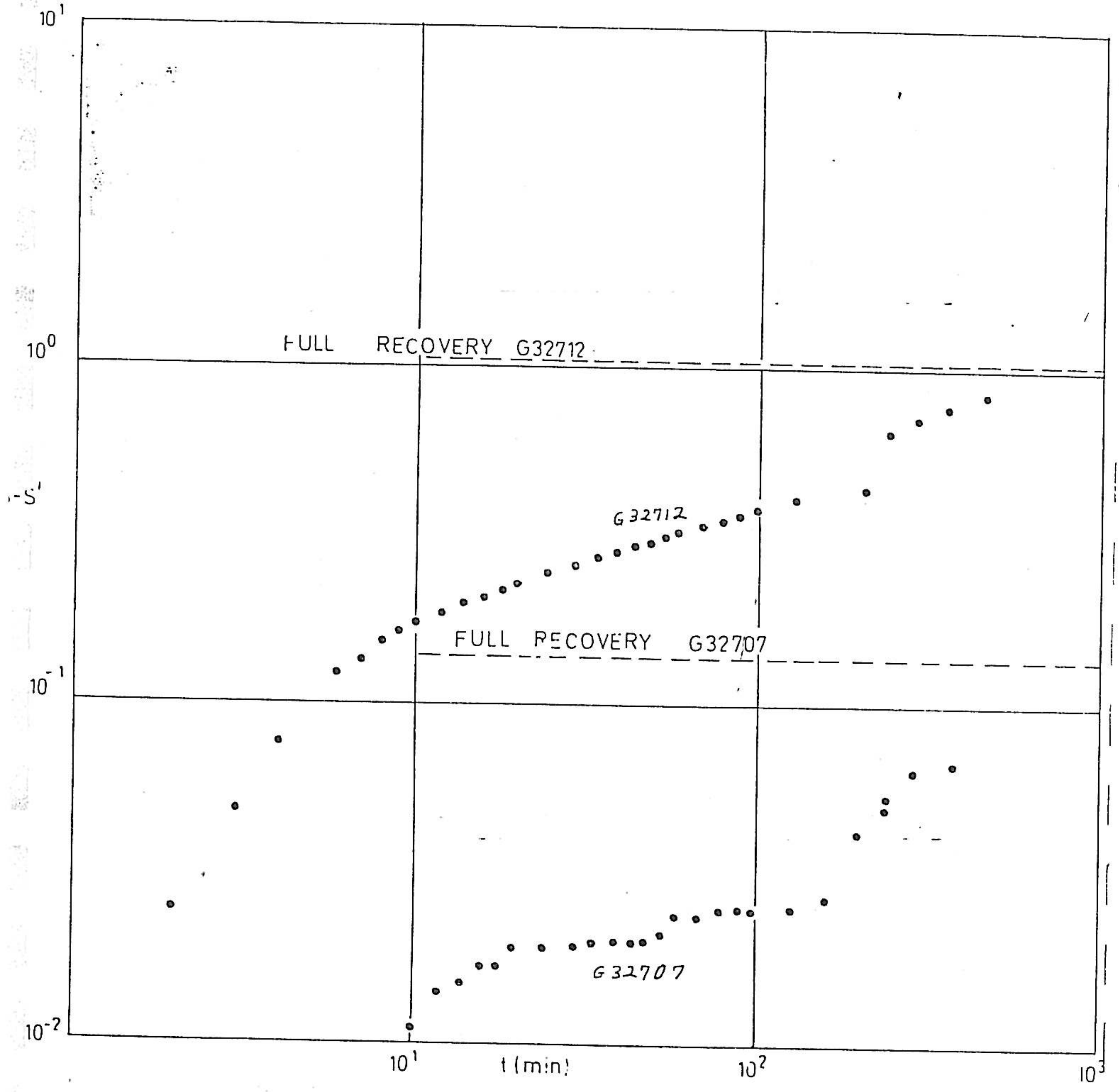


Fig. 62 RECOVERY FROM FINAL DYNAMIC PUMPING
GHP 5461 WATER LEVEL, G32707 and G32712



Early pumping conditions had higher T values and lower S values (Fig. 59). Figures for the distant observation borehole G32707 show similar T values and higher S figures, Table 10 and Figs. 57 and 58.

Appropriate Theis recovery values are shown for comparative purposes only, Figs. 60 and 61. The rather slow irregular nature of recovery is demonstrated by Fig. 62.

Aquifer conditions are considered to be unconfined to semi-unconfined with delayed yield. An average transmissivity value of 340 m^2d^{-1} and a storage coefficient of $1,3x10^{-2}$ has been calculated.

7.6 A reinterpretation of the constant rate test on borehole 5/28,5, Blinkwater 244 KR

The production borehole 5/28,5 penetrates the unconsolidated gravelly sand and weathered gabbro aquifer. It is complimented by four responsive observation wells.

During 1977 5/28,5 was pumped at a constant rate of 22,25 ℓ/sec (1925 m^3/d) for a period of 9300 minutes.

Time-drawdown curves produced were interpreted using the Jacob straight line method (Kok 1978). An early T value of 340 m^2d^{-1} was calculated while S values ranged between $4x10^{-3}$ and $5x10^{-4}$.

Geological evidence suggests that the response of the aquifer to pumping should be that of an unconfined or semi-unconfined aquifer with delayed yield.

Thus data presented in Kok (1978) was replotted on bilogarithmetric paper and matched with Boulton type curves. Good matches were found and are shown in figures 63 to 66, relevant figures are displayed in Table 11.

The results of reinterpretation show that the aquifer type is as was suspected and furthermore that an average transmissivity value of $172,8m^2d^{-1}$ has been calculated. The average effective storage coefficient is $8,5x10^{-2}$.

87./......

TABLE 11 MATCH POINT CO-ORDINATES WITH CALCULATED T AND S VALUES USING BOULTON TYPE-CURVE MATCHING, BLINKWATER (Aquifer-Unconsolidated gravelly sand and weathered gabbro)

Observation	$W(A-Y, {}^r/B)$	$^1/u_{A-Y}$	s (m)	t (min)	Q (m³/d)	r (m)	T (m²/d)	S_{A-Y}	S_{A+Y}	$^r/B$
'29	1(A)	1(A)	0,8	0,82	1930	25	192	$0,7\times10^{-3}$	4×10^{-2}	0,4
	1(Y)	1(Y)	0,82	47,5	1930	25	187	$3,95\times10^{-2}$		0,4
'30	1(A)	1(A)	1,15	8,3	1930	50	134	$1,2\times10^{-3}$	$8,7\times10^{-2}$	1,0
	1(Y)	1(Y)	1,1	550,0	1930	50	140	$8,6\times10^{-2}$		1,0
'31	1(A)	1(A)	1,18	18,3	1930	75	130	$1,2\times10^{-3}$	$6,4\times10^{-2}$	1,5
	1(Y)	1(Y)	1,18	980	1930	75	130	$6,3\times10^{-2}$		1,5
28124	1(A)	1(A)	0,64	27,5	1930	87,5	240	$2,4\times10^{-3}$	$1,47\times10^{-1}$	2,0
	1(Y)	1(Y)	0,70	1820	1930	87,5	230	$1,45\times10^{-1}$		2,0

S_{A+Y} effedive storage coefficient
(Kruseman et al, 1976, p.98)

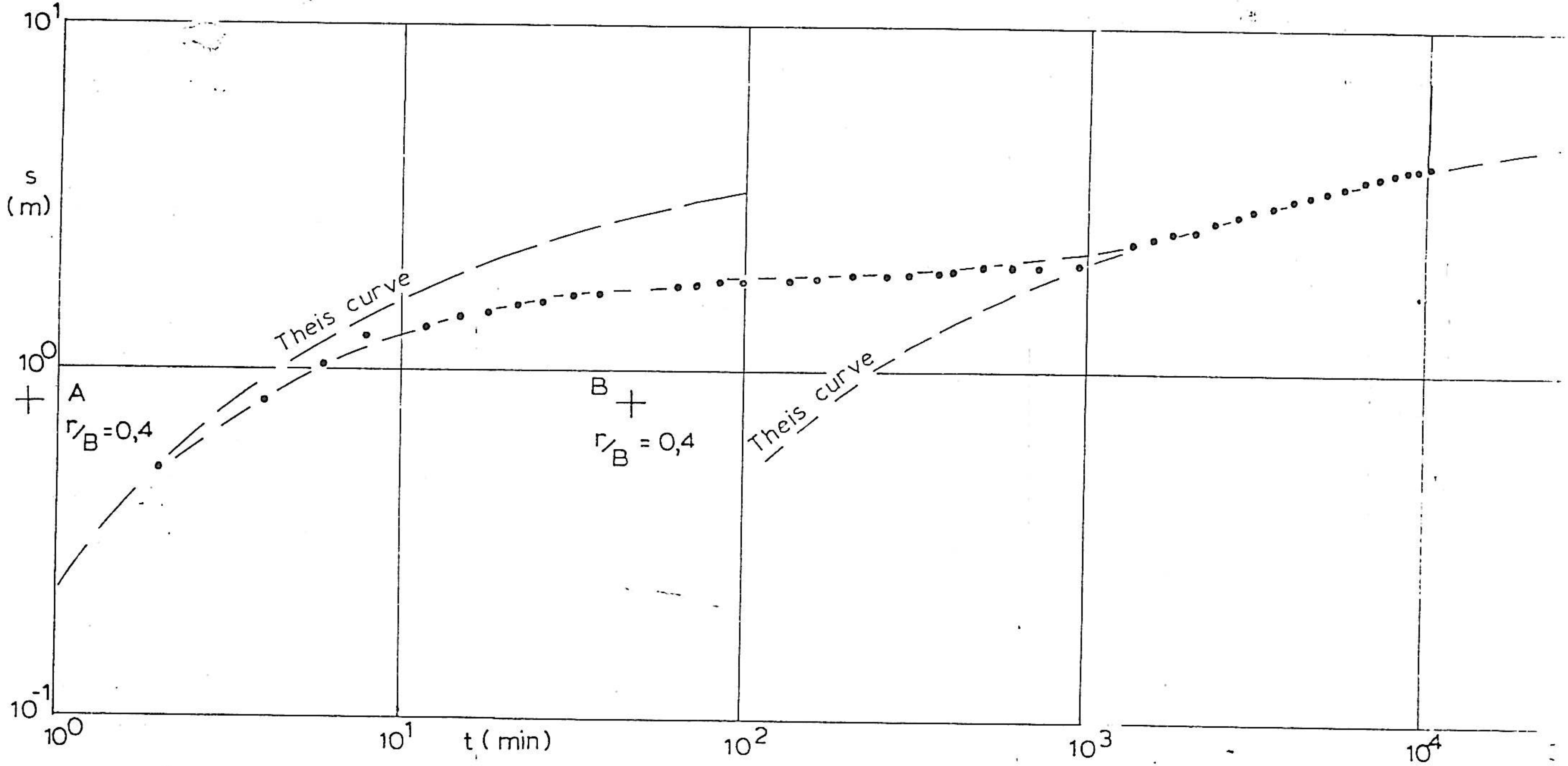


FIG 63 5/29 (B.no. 124911/0) , TIME - DRAWDOWN, BOULTON ANALYSIS.
GHP 5462

FIG 64 5/30 (B.no. 1249/3/8), TIME-DRAWDOWN,

BOULTON ANALYSIS.

GHP 5463

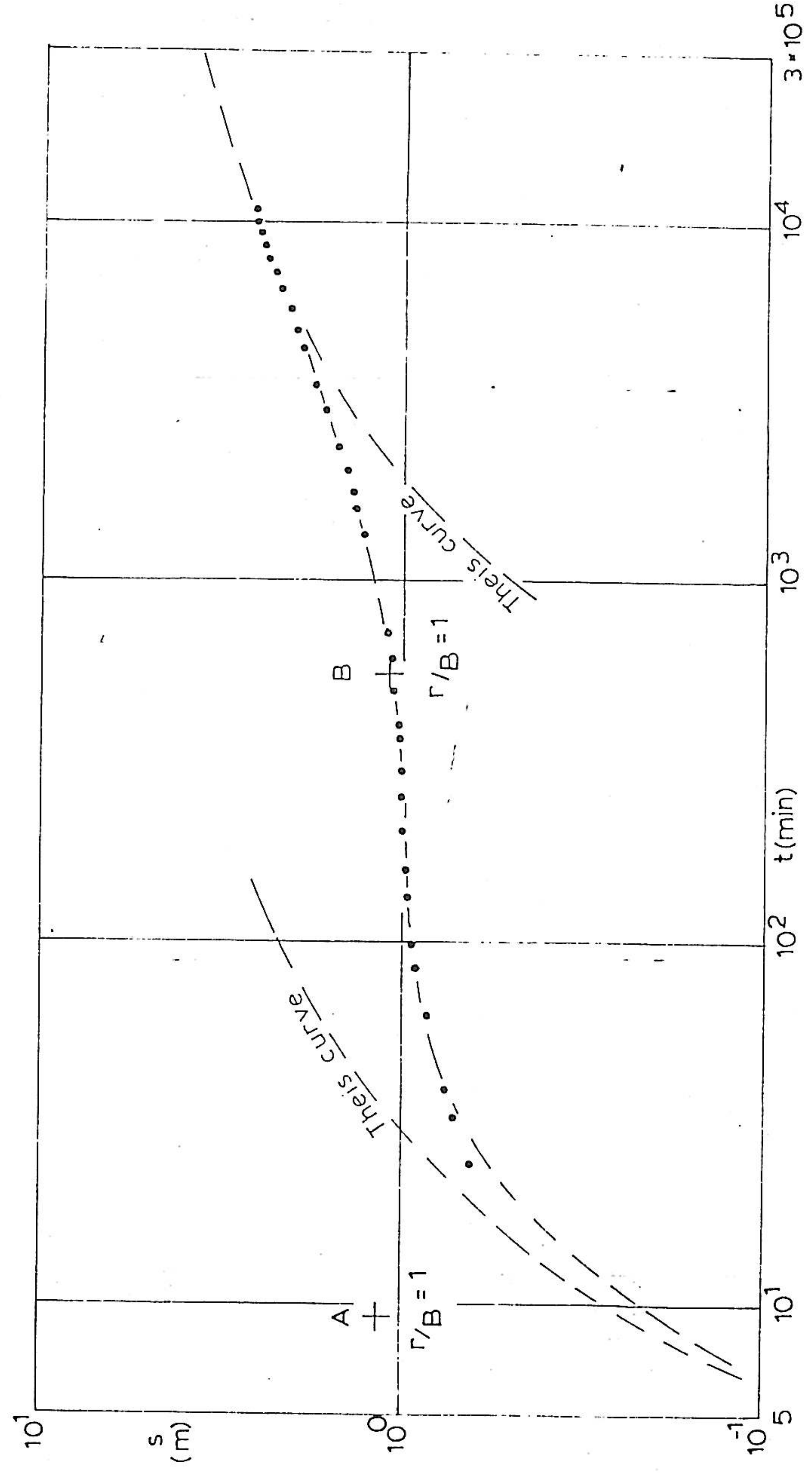


FIG 65 5731 (G30344), TIME-DRAWDOWN, BOULTON ANALYSIS.
GHP 5464

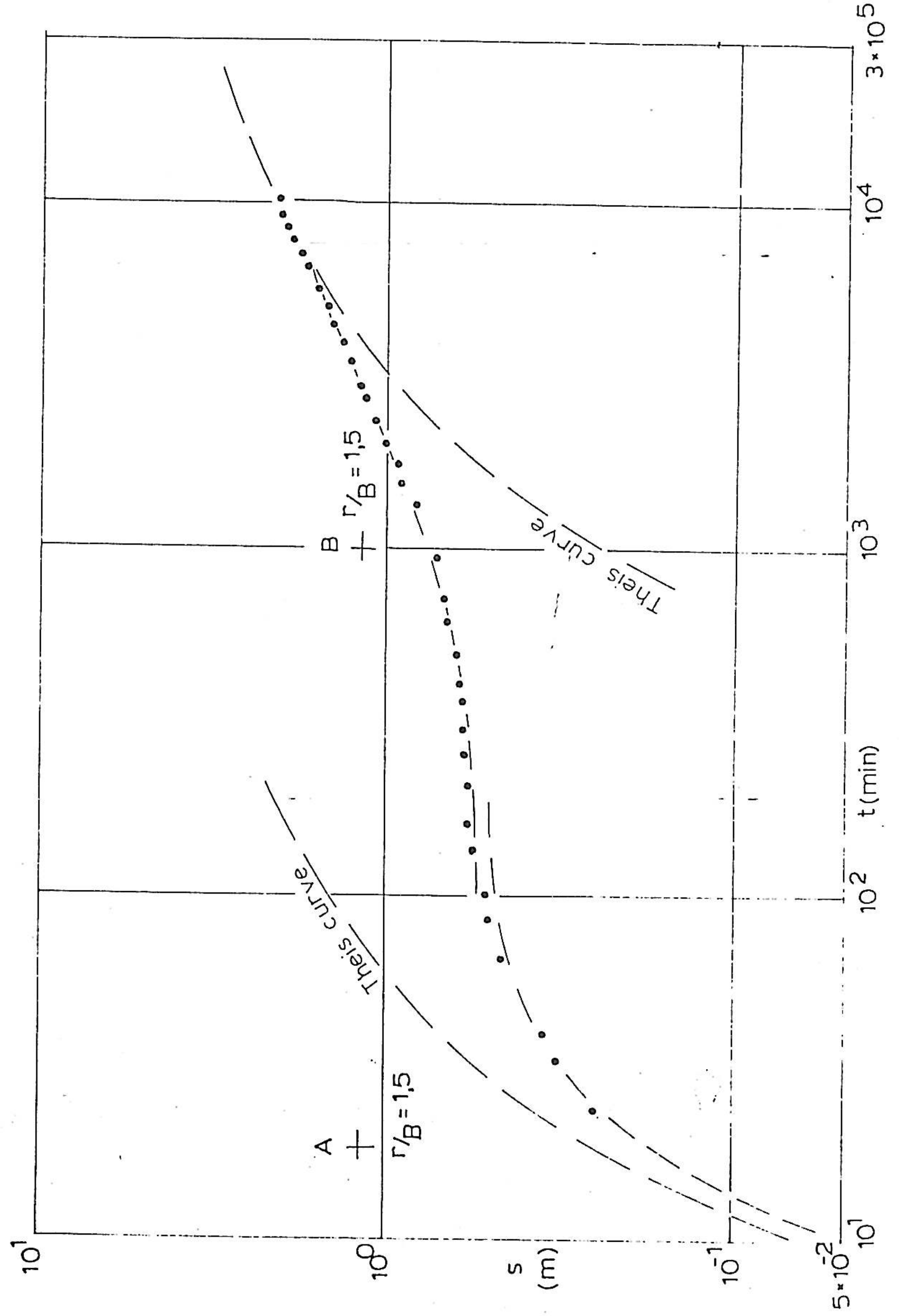
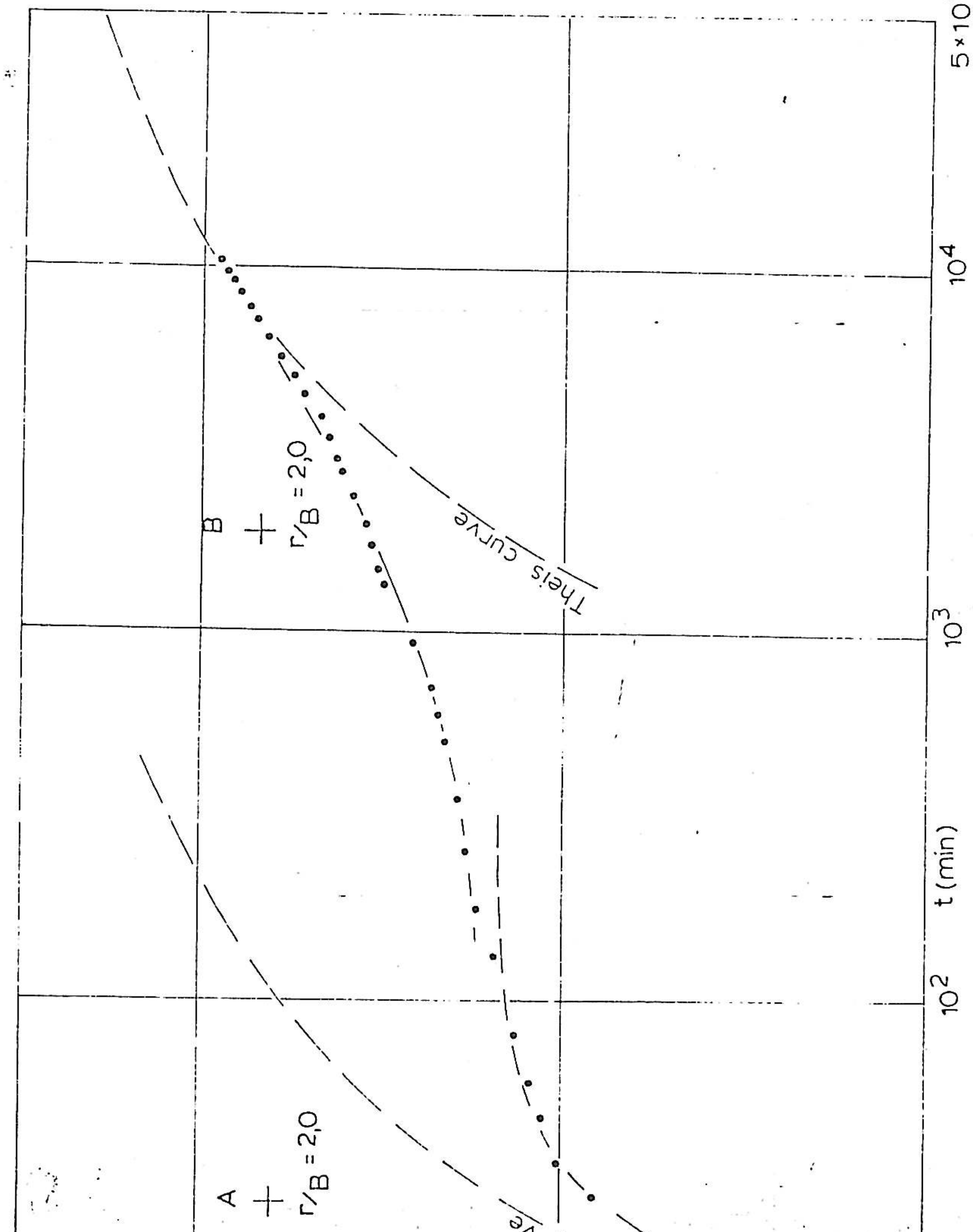


FIG 66
GHP 5.71

G28124 , TIME - DRAWDOWN, BOULTON ANALYSIS.



8. GROUNDWATER POTENTIAL

8.1 Introduction

The geohydrological investigation undertaken by Kok and Venter in 1978 was confined to the farms Blinkwater 244 KR and Turfspruit 241 KR between the latitudes 24°02' and 24°11' and the longitudes 28°50' and 29°00'. From observations made during the investigation it was stated that the general direction of groundwater movement through the area was westerly. The mean annual recharge of the alluvial aquifer was reported as $9,9 \times 10^6 m^3$ most of which originates in the Rooisloot River catchment. From a number of pumping tests undertaken it was concluded that the average transmissivity value of the aquifer was $340 m^2/d$ while the specific yield varied between 0,0005 and 0,02, an aquifer with characteristics lying between unconfined and semi-confined depending on the lithology. An effectively screened and developed production borehole was able to sustain a constant yield of about 22 ℓ/s for nearly 7,5 days. - Recharging of groundwater from the Magalakwena River was stated as being negligible.

In order to evaluate the groundwater potential of the alluvium with an improved degree of confidence it was imperative that the geohydrological investigation be extended through neighbouring Lebowa in the southeast and east, the direction from which the major portion of the groundwater recharge originates.

From the field data assembled and reported on in the previous chapters of this report an improved assessment can be made of the total storage of groundwater within the alluvial aquifer and the magnitude of the groundwater recharge, both within the studied area and the neighbouring farm Blinkwater.

8.2 Groundwater storage

As explained previously the alluvium which varies considerably in thickness and in composition is underlain by weathered gabbro which is fractured in parts. Because of the difficulty of separating the water-bearing properties of the alluvial de= posits and the weathered bedrock in places the formations are considered to constitute one single aquifer in subsequent calcu= lations.

From a number of pumping tests undertaken in the studied area the following average coefficients of storage have been determined as reported on in Chapter 7.

Borehole	5/28,5	$8,5 \times 10^{-2}$	
	G31522	$4,0 \times 10^{-3}$	(Lyness 1980)
	G32697	$3,0 \times 10^{-2}$	
	G32699	$2,0 \times 10^{-3}$	
	G32709	$6,0 \times 10^{-1}$	(suspect)
	G32712	$1,3 \times 10^{-2}$	

Coefficients of storage therefore vary from a low of 2×10^{-3} to a high of $8,5 \times 10^{-2}$ (disregarding the value for borehole G32709).

The mean of all these values is $2,7 \times 10^{-2}$. If the value for borehole 5/28,5 is also excluded from the mean a mean value of $\underline{1,2 \times 10^{-2}}$ is obtained which is considered acceptable for the subsequent calculation of aquifer storage. It is considered in view of experience gained from other areas of similar geohydrological conditions though that this mean coefficient of storage could be slightly under estimated.

The saturated thicknesses of the alluvial deposits, where they exceed 5m, are shown in Enclosure 4. The isopachytes were synthesised from the water table contour map (Enclosure 2) and the depth to bedrock map (Enclosure 3). The areas underlain by various thicknesses of saturated alluvial deposits were planimetered and the results are presented in Table 12.

Table 12: The areal distribution of saturated alluvial deposits with thicknesses greater than 5m ($10^6 m^2$)

Isopachyte interval (m)	5-10	10-15	15-20	> 20	Tota
Piet Potgietersrust 44 KS and Lisbon 288 KR	0,94	1,01	0,28	None	2,23
Mokerong	4,45	5,70	4,85	0,49	15,49
Blinkwater 244 KS	0,60	0,97	3,26	1,03	5,8
Total	5,99	7,68	8,39	1,52	23,5

Grand total: $\underline{23,6 \times 10^6 m^3}$

Table 13 shows the volume of the saturated alluvial deposits for various thicknesses. The total saturated volume of the alluvial deposits is estimated to be about $320 \times 10^6 m^3$.

Table 13: The volume of saturated alluvial deposits with thicknesses greater than 5m ($10^6 m^3$)

Average thickness(m)	7,5	12,5	17,6	21,0	Total
Piet Potgietersrust 44 KS and Lisbon 288 KR	7,05	12,63	4,90	None	24,58
Mokerong	33,38	71,25	84,88	10,29	199,80
Blinkwater 244 KS	4,50	12,13	57,05	21,63	95,31
Total	44,93	96,01	146,83	31,92	319,69

Grand total: $319,7 \times 10^6 m^3$

Geological logs from 60 exploration boreholes show that the alluvium is underlain by an average thickness of about 10m of weathered and fractured bedrock throughout the area. Therefore an additional $235,8 \times 10^6 m^3$ of secondary aquifer can therefore be included with the $319,7 \times 10^6 m^3$ of alluvial deposits giving a total volume of saturated primary and secondary aquifer of about $555,5 \times 10^6 m^3$.

Table 14 gives the values of groundwater storage for the alluvial deposits of weathered and fractured bedrock combined, and for each separately for different areas using the accepted mean coefficient of storage of $1,2 \times 10^{-2}$.

Table 14: Distribution of groundwater storage (assuming an S value of $1,2 \times 10^{-2}$) ($10^6 m^3$)

	Alluvial deposits	Weathered and fractured bedrock	Total aquifer
Piet Potgietersrust 44 KS and Lisbon 288 KR	0,29	0,27	0,56
Mokerong	2,40	1,86	4,26
Blinkwater 244 KS	1,14	0,70	1,84
Total	3,83	2,83	6,66

Grand total: $6,6 \times 10^6 m^3$

94./.....

The approximate volume of groundwater stored in the aquifer system at the time of the investigation is conservatively estimated to be about $6,6 \times 10^6 m^3$ of this total about $4,3 \times 10^6 m^3$ or 64% occurs in Lebowa. It should be stresssed that this estimate of the total groundwater storage depends heavily on the value of the mean coefficient of storage accepted for this area, a parameter which is shown to vary considerably from place to place within the studied area. The value of $6,6 \times 10^6 m^3$ is therefore a first approximation of the total storage of groundwater within the aquifer system but is likely to be of the right order of magnitude. In order to refine this value further pumping tests would have to be undertaken in the studied area at selected locations.

8.2. Groundwater recharge

The quantity of recharge of groundwater to the saturated aquifer is difficult to ascertain and is at best only a first approximation primarily because of a paucity of hydrological and geohydrological data available from the studied area. According to Report 2/69 of the Hydrological Research Unit of the University of the Witwatersrand 'Surface Water Resources of South Africa' the combined catchments of the Rooisloot and Dorps Rivers (combined area 560 km^2) yield an estimated mean annual runoff (MAR) of $16,8 \times 10^6 m^3$ at a point of entry into the Mogalakwena River based on a mean annual precipitation (MAP) of 660mm. This estimated is transposed from the measured MAR of a gauged catchment located within the same hydrological province but adjusted for differences in catchment area and MAP. It is important to note that differences in geological conditions are not considered. Because of the presence of Combrinck Dam and the geological nature of the catchment however it is adjudged that the Dorps River catchment contributes very little surface runoff between Combrinck Dam and the studied area. The Dorps River is therefore not considered a significant source of groundwater recharge of the alluvial deposits in Lebowa and on the farm Blinkwater. The Rooisloot River catchment on the other hand has favourable surface runoff properties influenced primarily by the geological nature of the catchment and as such is considered to be the primary source of recharge of the groundwater in the studied area. This is confirmed by the configuration of the groundwater table contours in the vicinity of the Rooisloot River delta area (Enclosure 2) and consideration of the groundwater quality which reflects a dynamic recharge situation in this area. Based on consideration of catchment area alone the MAR of the Rooisloot River is estimated to be about $8,4 \times 10^6 m^3$ which is equivalent to about 4,5% of the MAP over the catchment. Before entering the Mogalakwena River however this surface runoff must first pass over the alluvial deposits in the delta area of the Rooisloot River, an area considered to be very favourable for recharge of groundwater.

95./.....

Inspection of groundwater level fluctuations as partially recorded at several observation boreholes in the studied area (as depicted in Figure 3 for boreholes A6N058, A6N061, A6N534, A6N079 and A6N045) enable an estimate to be made of the annual recharge of the aquifer namely about $3,0 \times 10^6 m^3$ made up as follows;

- $1,7 \times 10^6 m^3$ from surface runoff in the Rooisloot River. This is equivalent to about 20% of the MAR of the Rooisloot River catchment.

- $0,7 \times 10^6 m^3$ from natural precipitation over the studied area. This is equivalent to about 5% of the MAP.

- $0,6 \times 10^6 m^3$ which enters the area as surface runoff from other surrounding areas such as the granitic escarpment to the west.

Additional groundwater that may enter the aquifer from outside of the studied area is not included as input to the aquifer because of a lack of sufficient data. This is not considered to add significantly to the local annual recharge however of $3,0 \times 10^6 m^3$ enumerated above.

At present only $1,6 \times 10^6 m^3$ of groundwater is abstracted from the area as detailed in Chapter 4 for irrigation purposes on the farm Blinkwater and for domestic purposes by the Lebowan authorities. The remaining $1,4 \times 10^6 m^3$ of the annual input to the groundwater system, provided the groundwater in storage remains relatively constant, drains from the groundwater system probably as seepage into the Mogalakwena River and associated pans and is ultimately lost through evaporation. This seepage can be ascribed as a loss from the aquifer system. Under conditions of average rainfall and average recharge therefore there is an unutilized portion of the annual recharge to groundwater of $1,4 \times 10^6 m^3$ which could be recovered for the benefit of local communities which at present represent a loss of groundwater from the aquifer system.

Examination of the groundwater table contour map (Enclosure 2) reveals that groundwater recharged in the vicinity of the Rooisloot River delta changes direction to the west and underflows the farm Blinkwater.

Some of the surface water in the Rooisloot River is diverted by means of a canal constructed on the recommendations of Graats (1960) to feed the proposed dam to be built in the Mogalakwena River. Because of the strong likelihood of water from this source recharging boreholes constructed by the Lebowan authorities along the Mogalakwena River the flow of surface water should not be inferred with in any way.

It should also be brought to the attention of planners that any diminution of the surface runoff of the Rooisloot River, for example by constructing a dam in the Rooisloot River catchment, will seriously influence the recharge of ground= water in the Rooisloot River delta area.

It needs to be reemphasised that the estimation of ground= water recharge in this area is only a first approximation and can only be refined by exploiting the groundwater under carefully controlled conditions and by monitoring the fluctuations in the groundwater levels.

9.0 RECOMMENDATIONS

The results obtained from a geohydrological investigation undertaken in this area have revealed that fairly substantial reserves of potable groundwater occur in the Upper Magalakwena Valley particularly in the alluvium associated with the deltaic areas of the Rooisloot and Dorps Rivers and which is supported by considerable periodic recharge originating primarily in the Rooisloot River catchment.

It is recommended that the most favourable site for developing a borehole field for the recovery of groundwater is to the northwest of the diverison canal in the Rooisloot Delta area and towards the farm Blinkwater. This area receives substantial recharge from the Rooisloot River, contains some of the most transmissive formations and is not directly down-gradient of any possible contamination that may be taking place in certain built-up areas in Mokerong resulting from the uncontrolled disposal of sewage waste. The water is of good quality and the formations are capable of yielding at least 8 ℓ/s on average from properly screened and developed boreholes.

From information presented in this report it is apparent that an additional approximate $1{,}0\times10^6 m^3$ of groundwater could safely be recovered from the Rooisloot delta area by the establishment of a borehole field consisting of 8-10 production boreholes in favourable areas. Although several boreholes have already been developed and pump tested in the investigated area they were originally sited as exploration boreholes and are thus not necessarily optimally sited for production purposes. However, the existing exploration boreholes and those previously drilled and developed on the farm Blinkwater could form the nucleus of a future borehole field.

In order to establish a borehole field it is not considered necessary to undertake any further geophysical exploration. Favourable sites for production boreholes could be selected on the information contained in this report. The required production boreholes could be drilled, screened and developed within a period of less than six months to recover $1{,}0\times10^6 m^3$ of groundwater.

97 ./.....

However, before a borehole field could be established in the studied area certain problems of a political nature would have to be resolved concerning the apportionment of the available groundwater resources. Firstly it is apparent that the major portion of the surface water recharging the alluvial deposits originates outside of Lebowa in the catchment of the Rooisloot River. Secondly this surface water is largely recharged within the boundaries of Lebowa and remains in Lebowa until it underflows the farm Blinkwater or dissipates into the Mogalakwena River. The alluvial aquifer underlies both the farm Blinkwater and that portion of Lebowa between the Potgietersrus-Marken road and the Mogalakwena River. 65% of the potential groundwater storage is located in the latter.

Further some protection should be given to existing production boreholes in the studied area e.g. those located along the Mogalakwena River. Finally aspects related to the potential contamination of the groundwater by indiscriminant sewage disposal should be investigated and controlled.

It is strongly recommended that high level discussions be initiated between interested parties at an early stage to negotiate a basis on which to apportion the available ground=water resources equitably. It is anticipated that with increased urban and industrial growth in this region the potential users of groundwater will inevitably compete for a greater share of its use. The groundwater is located conveniently to Makwelereng where at present the major portion of the groundwater abstracted in the investigated area is used for domestic purposes.

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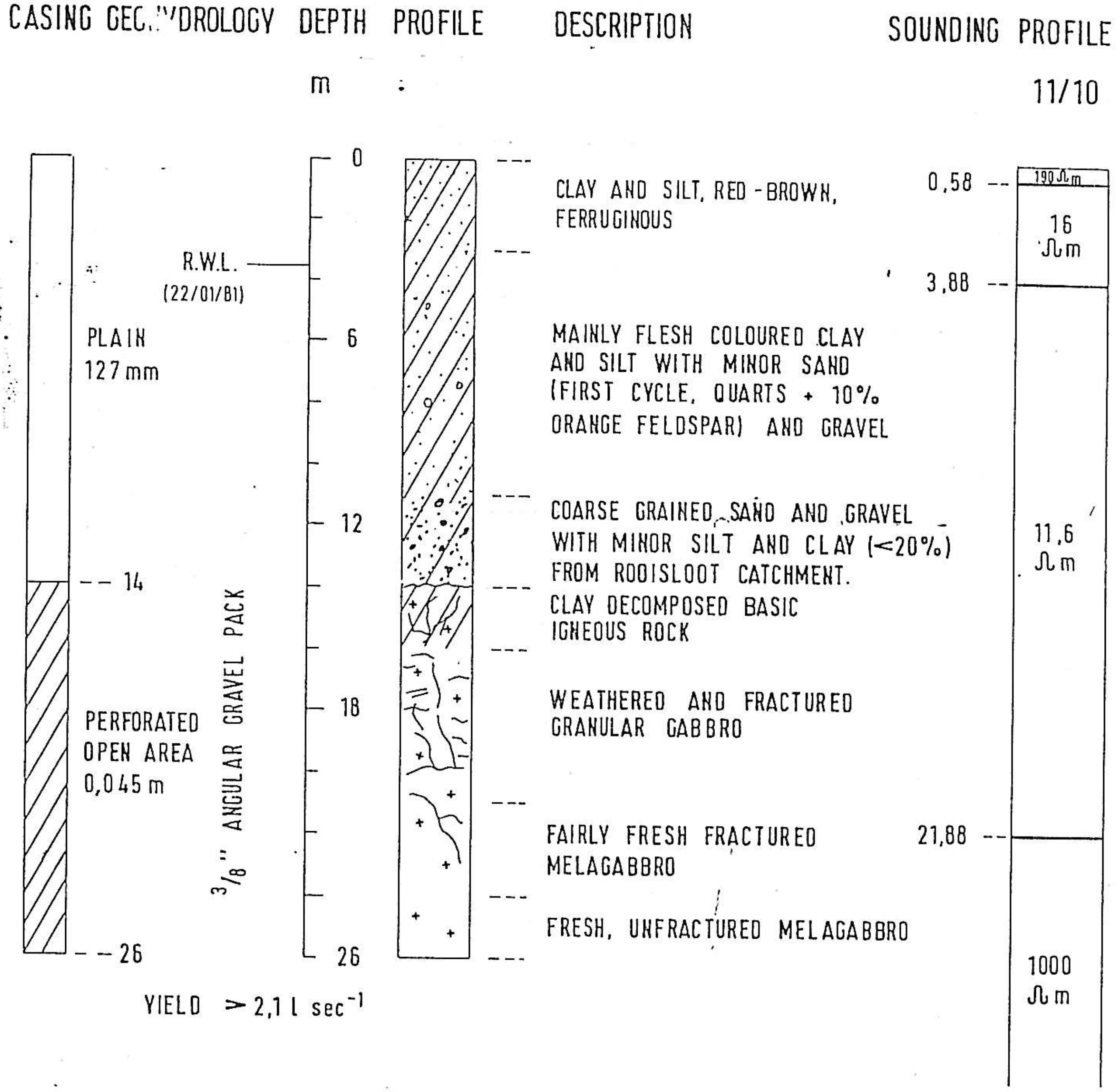
APPENDIX 1

Borehole logs

G32621 and G32694 to G32712

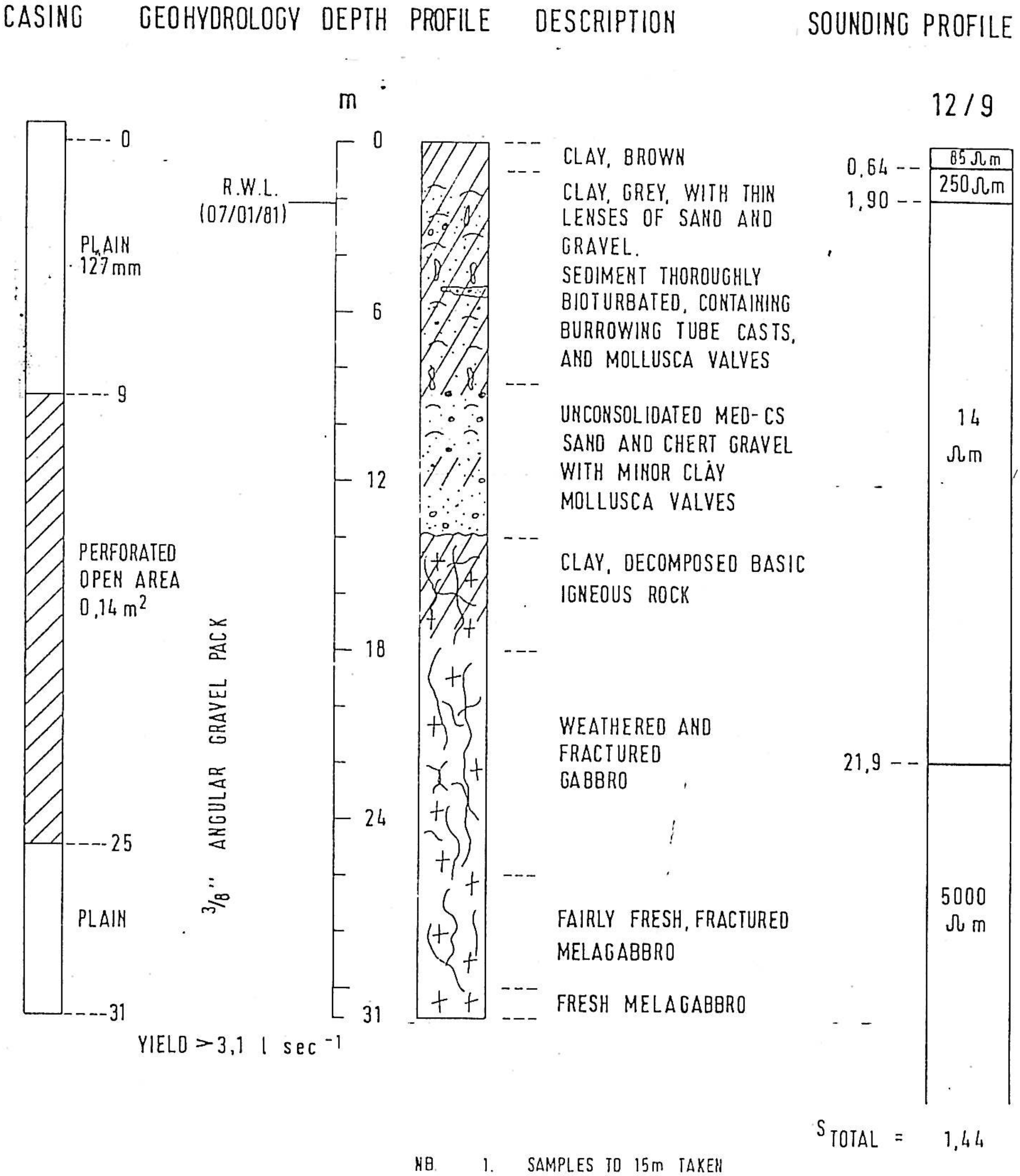
FIG 4 G-32621



NB. 1. SAMPLES TO 21m TAKEN BY SAMPLER TUBE.
2. REAMED AT 216 mm.
3. GRAVEL PACK DEVELOPED.

S_{TOTAL} 1,76

FIG 5 G - 32694



NB.
1. SAMPLES TO 15m TAKEN BY SAMPLER TUBE.
2. REAMED AT 216 mm.
3. GRAVEL PACK DEVELOPED.

FIG 6 G-32695

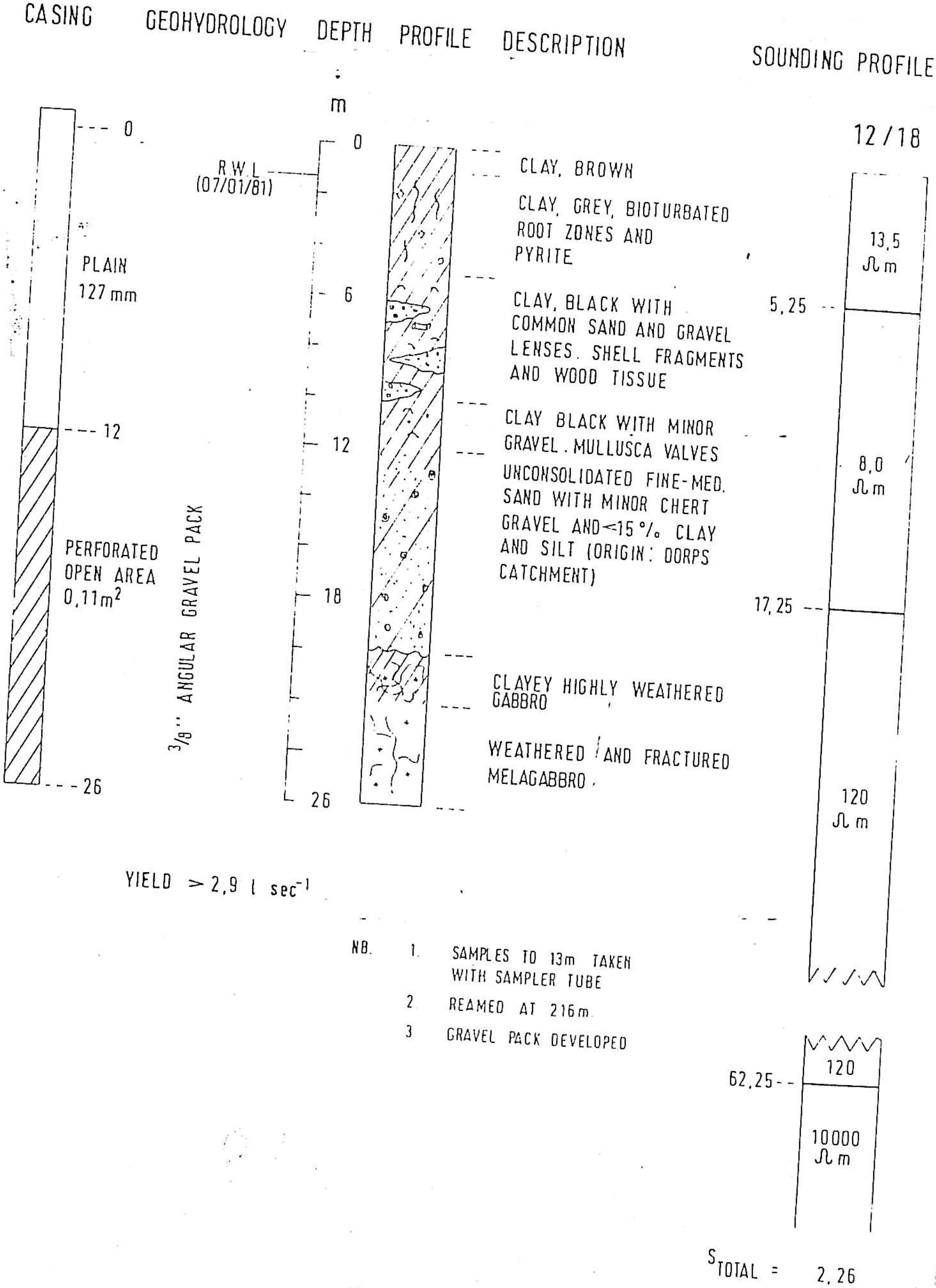
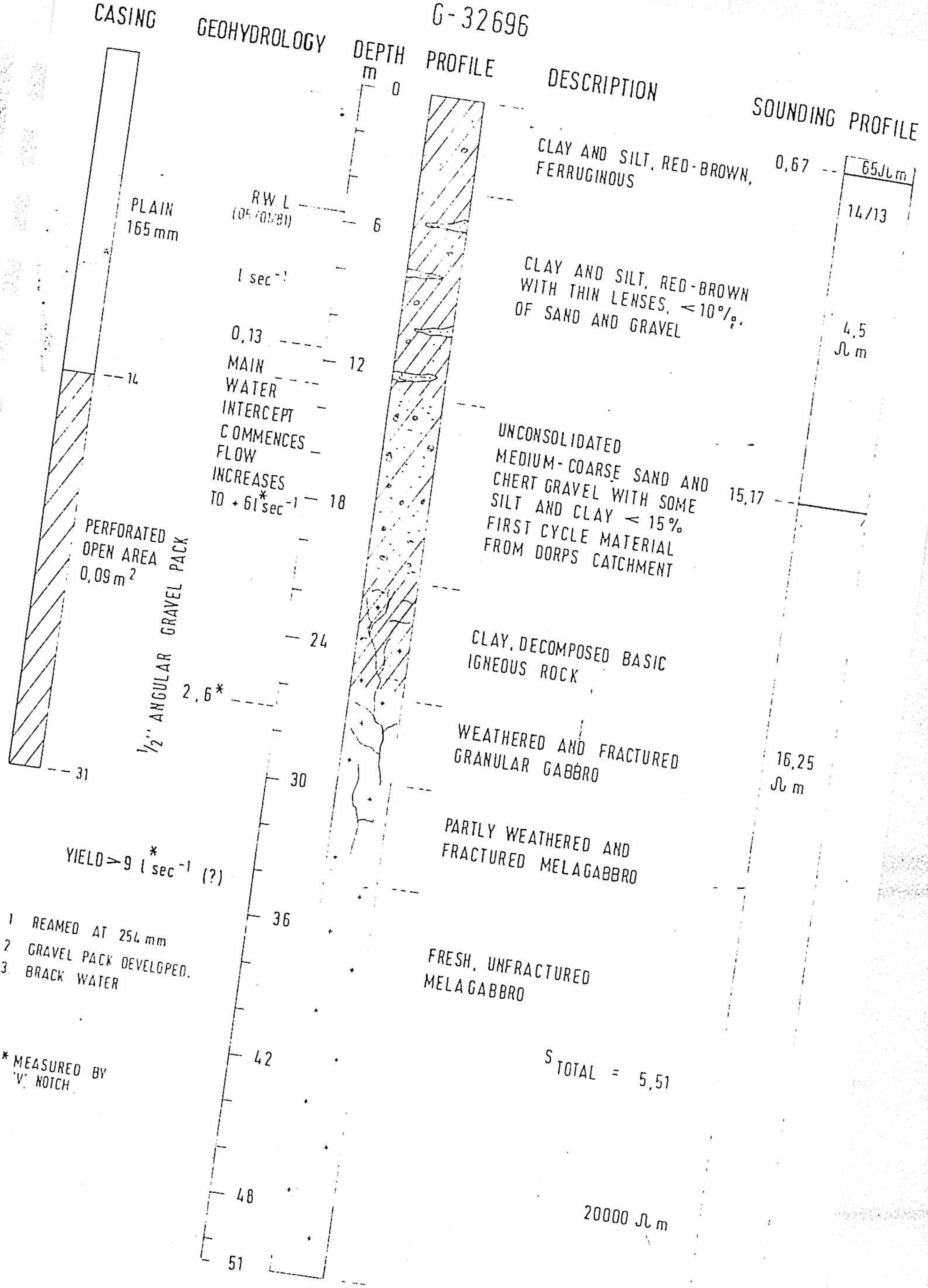

CASING
GEOHYDROLOGY
DEPTH
PROFILE
DESCRIPTION
SOUNDING PROFILE
m
0
12
26
PLAIN
127 mm
PERFORATED
OPEN AREA
0,11m²
R.W.L.
(07/01/81)
3/8" ANGULAR GRAVEL PACK
0
6
12
18
26
CLAY, BROWN
CLAY, GREY, BIOTURBATED
ROOT ZONES AND
PYRITE
CLAY, BLACK WITH
COMMON SAND AND GRAVEL
LENSES. SHELL FRAGMENTS
AND WOOD TISSUE
CLAY BLACK WITH MINOR
GRAVEL. MULLUSCA VALVES
UNCONSOLIDATED FINE-MED.
SAND WITH MINOR CHERT
GRAVEL AND <15 %. CLAY
AND SILT (ORIGIN: DORPS
CATCHMENT)
CLAYEY HIGHLY WEATHERED
GABBRO
WEATHERED AND FRACTURED
MELAGABBRO.
12/18
13,5
Ωm
5,25
8,0
Ωm
17,25
120
Ωm
120
62,25
10000
Ωm
YIELD > 2,9 l sec⁻¹
NB.
1. SAMPLES TO 13m TAKEN
WITH SAMPLER TUBE
2. REAMED AT 21.6m.
3. GRAVEL PACK DEVELOPED
S TOTAL = 2,26

FIG 7

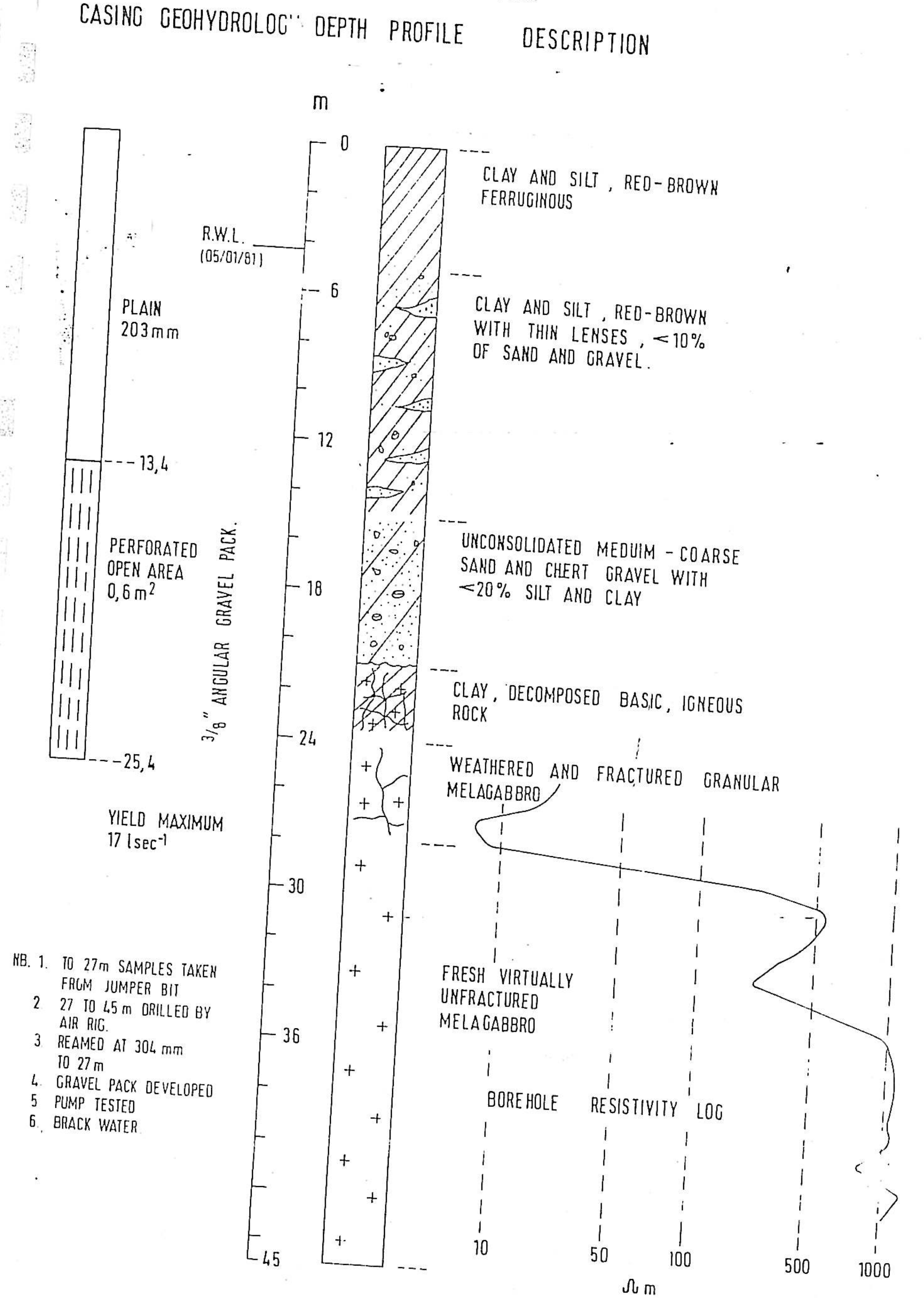


G-32696
CASING
GEOHYDROLOGY
DEPTH m
PROFILE
DESCRIPTION
SOUNDING PROFILE
0
6
12
18
24
30
36
42
48
51
PLAIN 165 mm
14
PERFORATED OPEN AREA 0,09 m²
31
1/2'' ANGULAR GRAVEL PACK
R.W.L. (05/01/81)
l sec⁻¹
0,13
MAIN WATER INTERCEPT COMMENCES
FLOW INCREASES TO + 6 l sec⁻¹ *
2,6*
YIELD > 9 l sec⁻¹ * (?)
B 1 REAMED AT 254 mm
2 GRAVEL PACK DEVELOPED.
3. BRACK WATER
* MEASURED BY 'V' NOTCH
CLAY AND SILT, RED-BROWN, FERRUGINOUS
CLAY AND SILT, RED-BROWN WITH THIN LENSES, < 10 % OF SAND AND GRAVEL
UNCONSOLIDATED MEDIUM-COARSE SAND AND CHERT GRAVEL WITH SOME SILT AND CLAY < 15 % FIRST CYCLE MATERIAL FROM DORPS CATCHMENT
CLAY, DECOMPOSED BASIC IGNEOUS ROCK
WEATHERED AND FRACTURED GRANULAR GABBRO
PARTLY WEATHERED AND FRACTURED MELAGABBRO
FRESH, UNFRACTURED MELAGABBRO
S TOTAL = 5,51
20000 Ω m
0,67
65 Ω m
14/13
4,5 Ω m
15,17
16,25 Ω m

V

FIG 8

G-32697

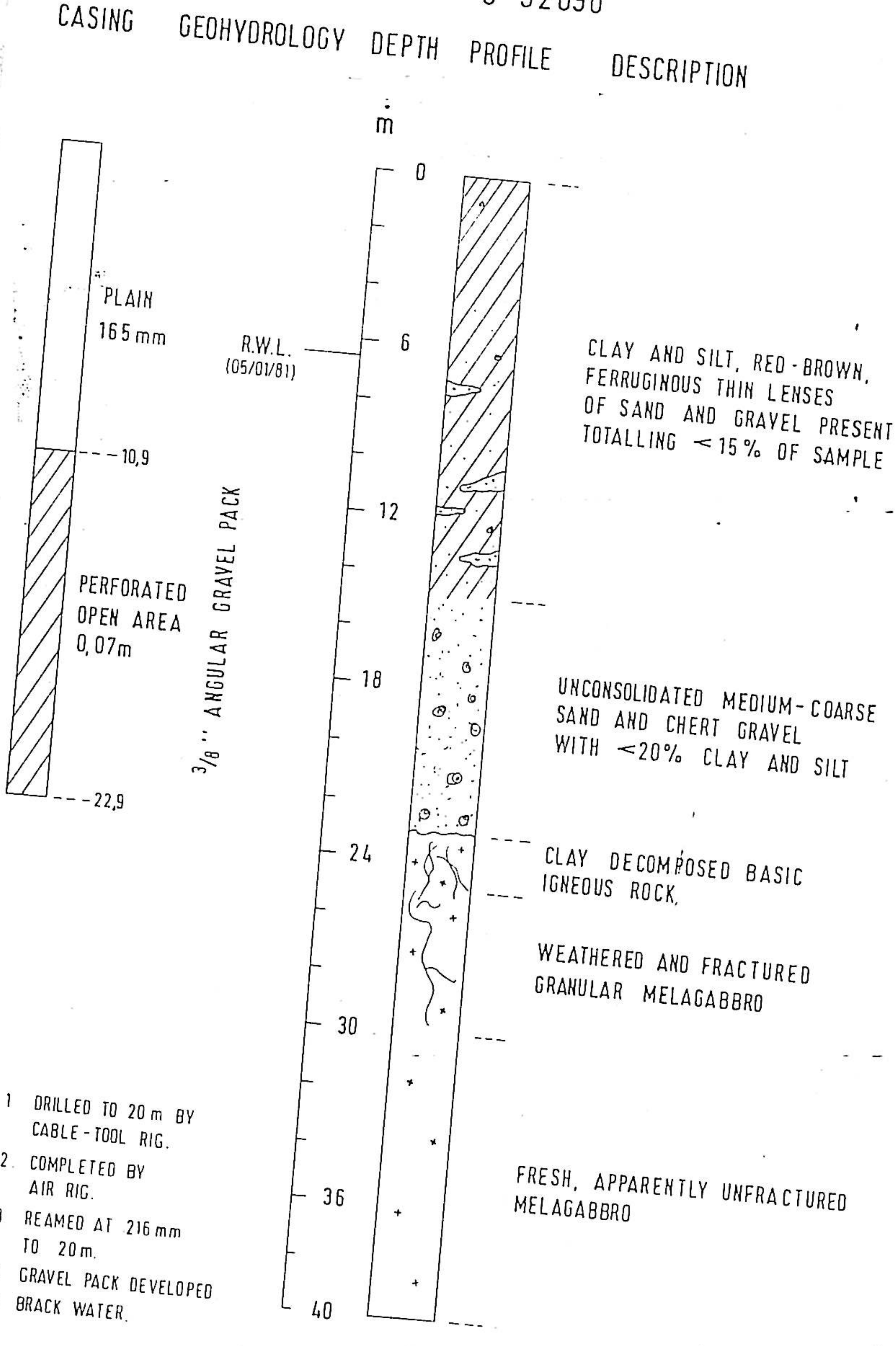


G.. P 5406

VI

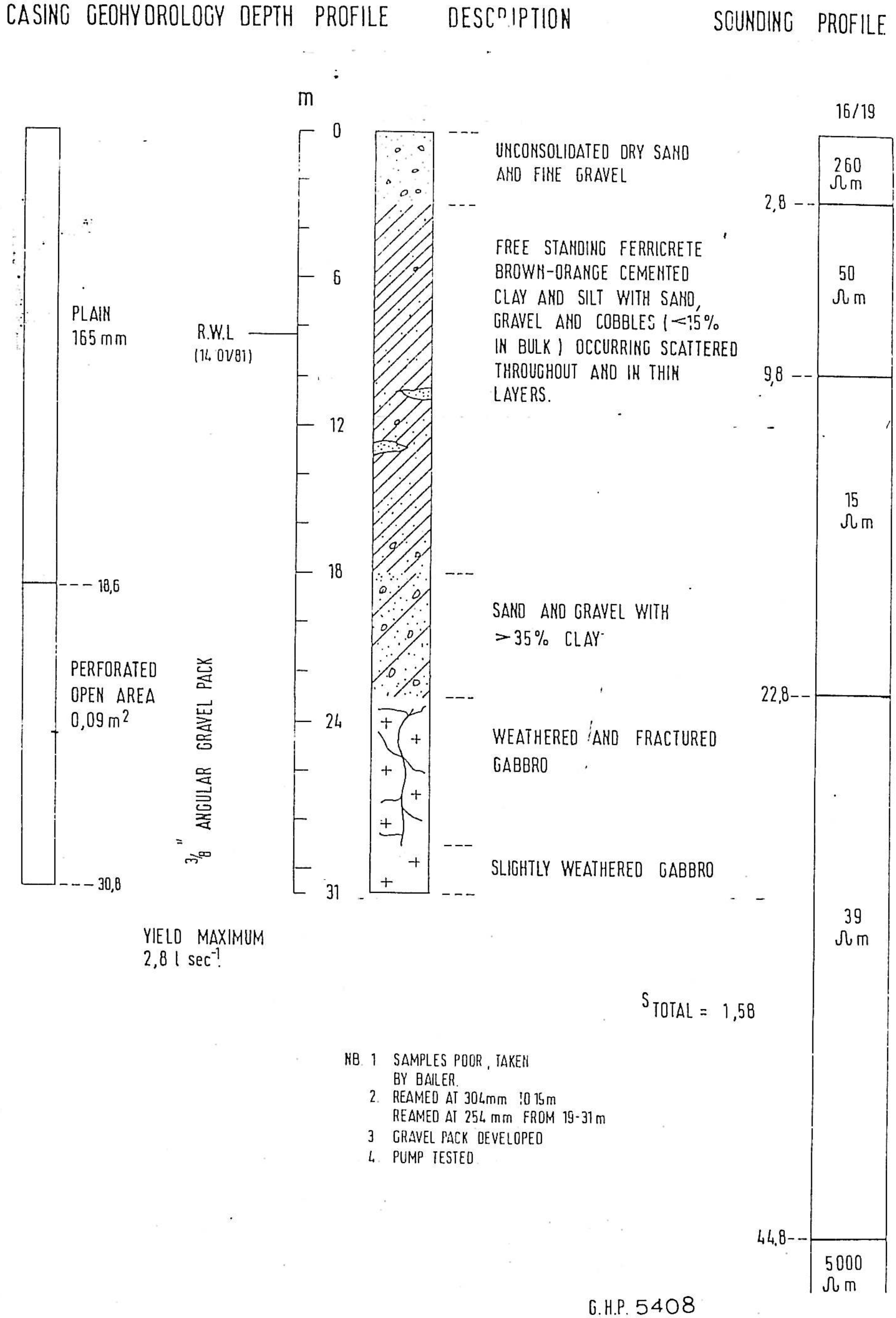
FIG 9

G-32698



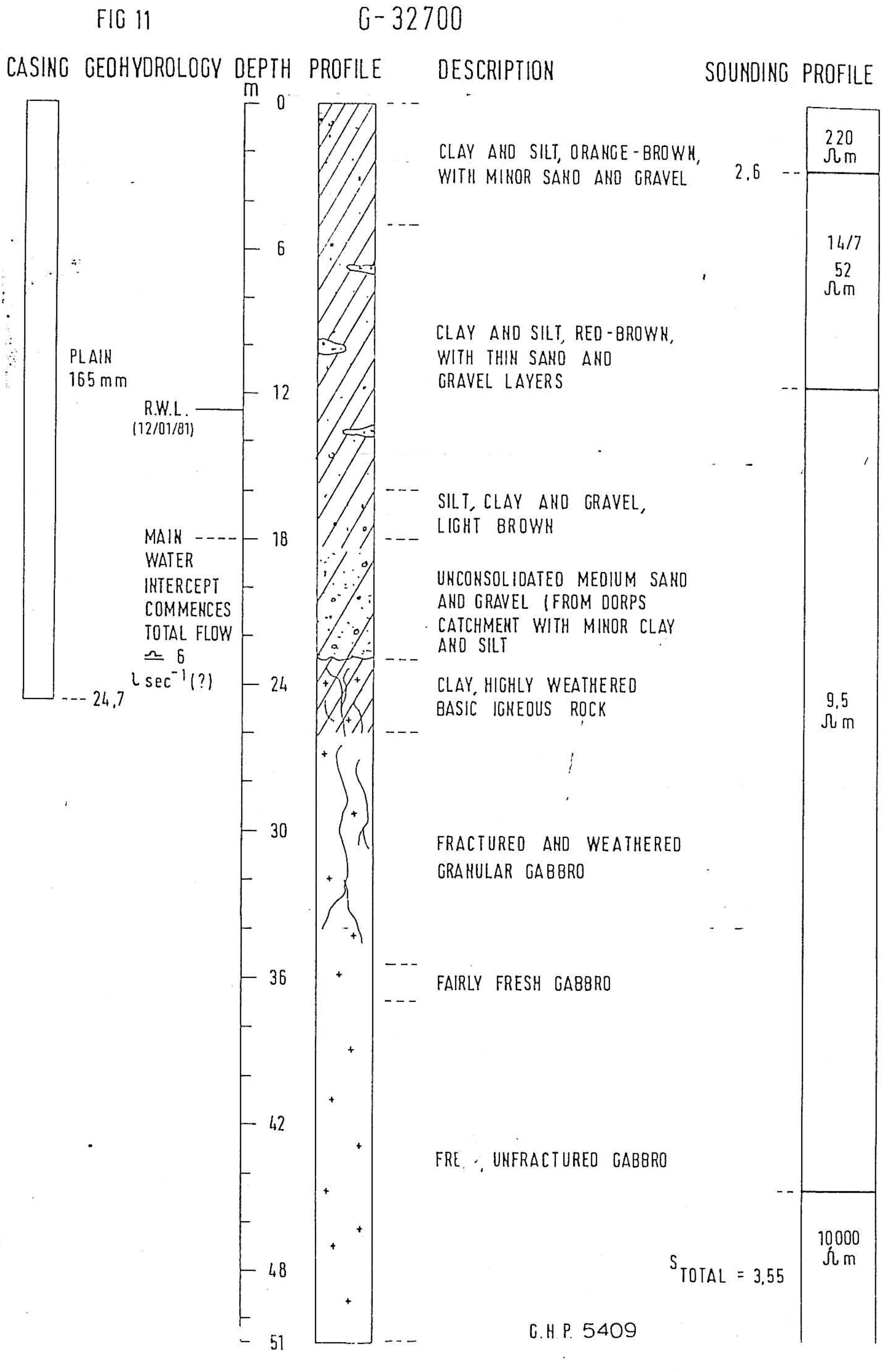
NB.
1. DRILLED TO 20 m BY CABLE-TOOL RIG.
2. COMPLETED BY AIR RIG.
3. REAMED AT 216 mm TO 20 m.
4. GRAVEL PACK DEVELOPED
5. BRACK WATER.

FIG 10 G-32699



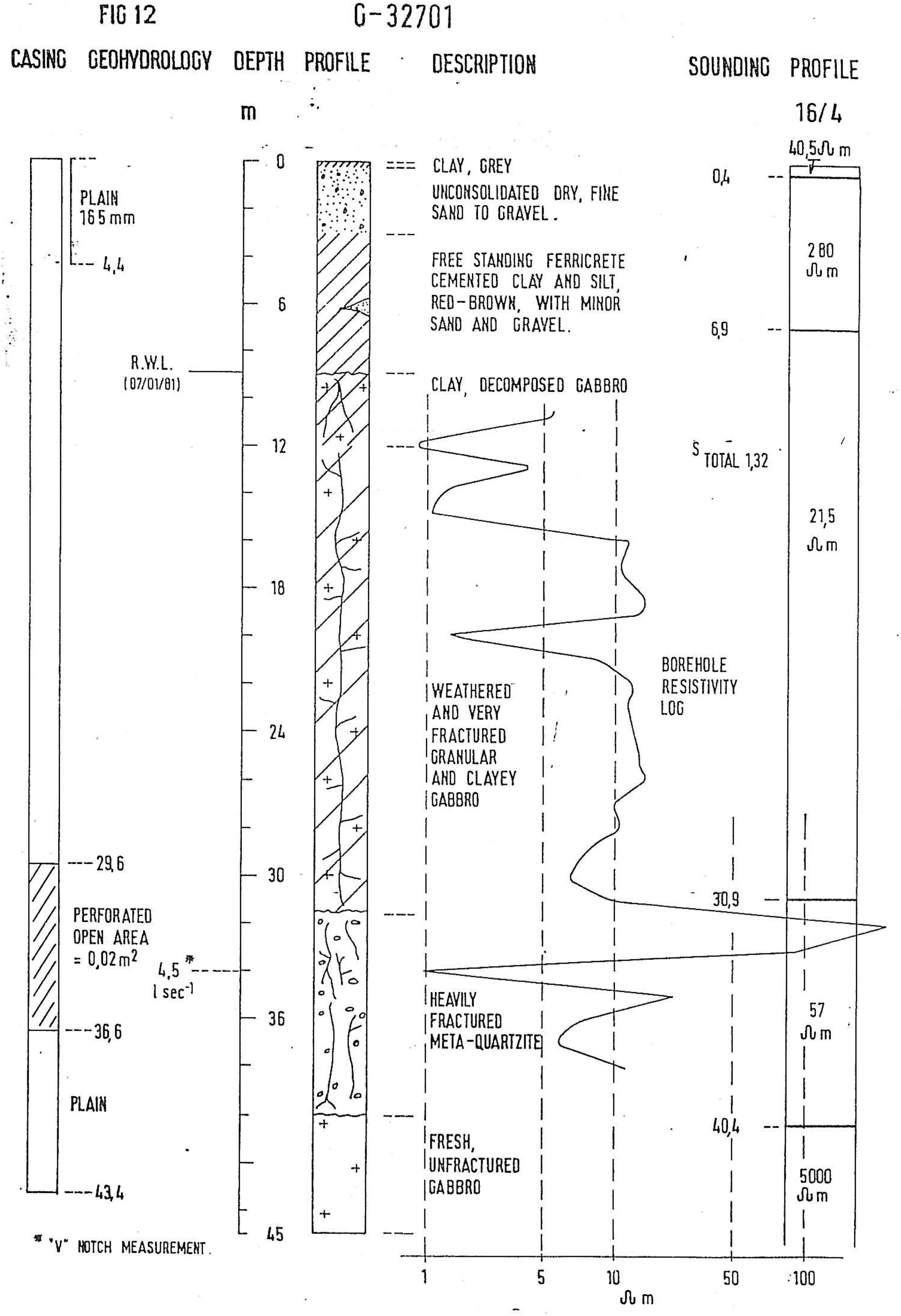
G.H.P. 5408

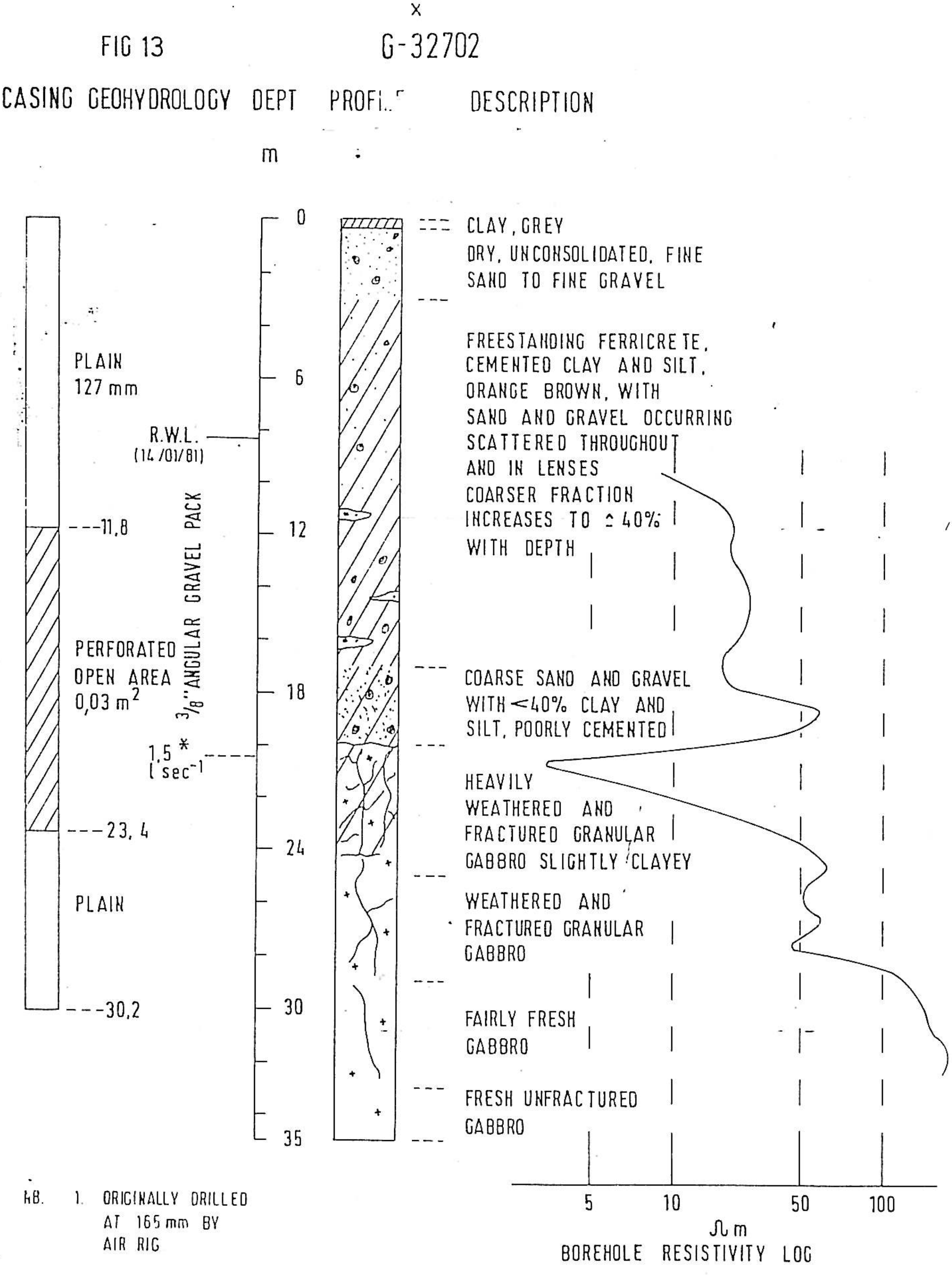
FIG 11



G.H.P. 5409

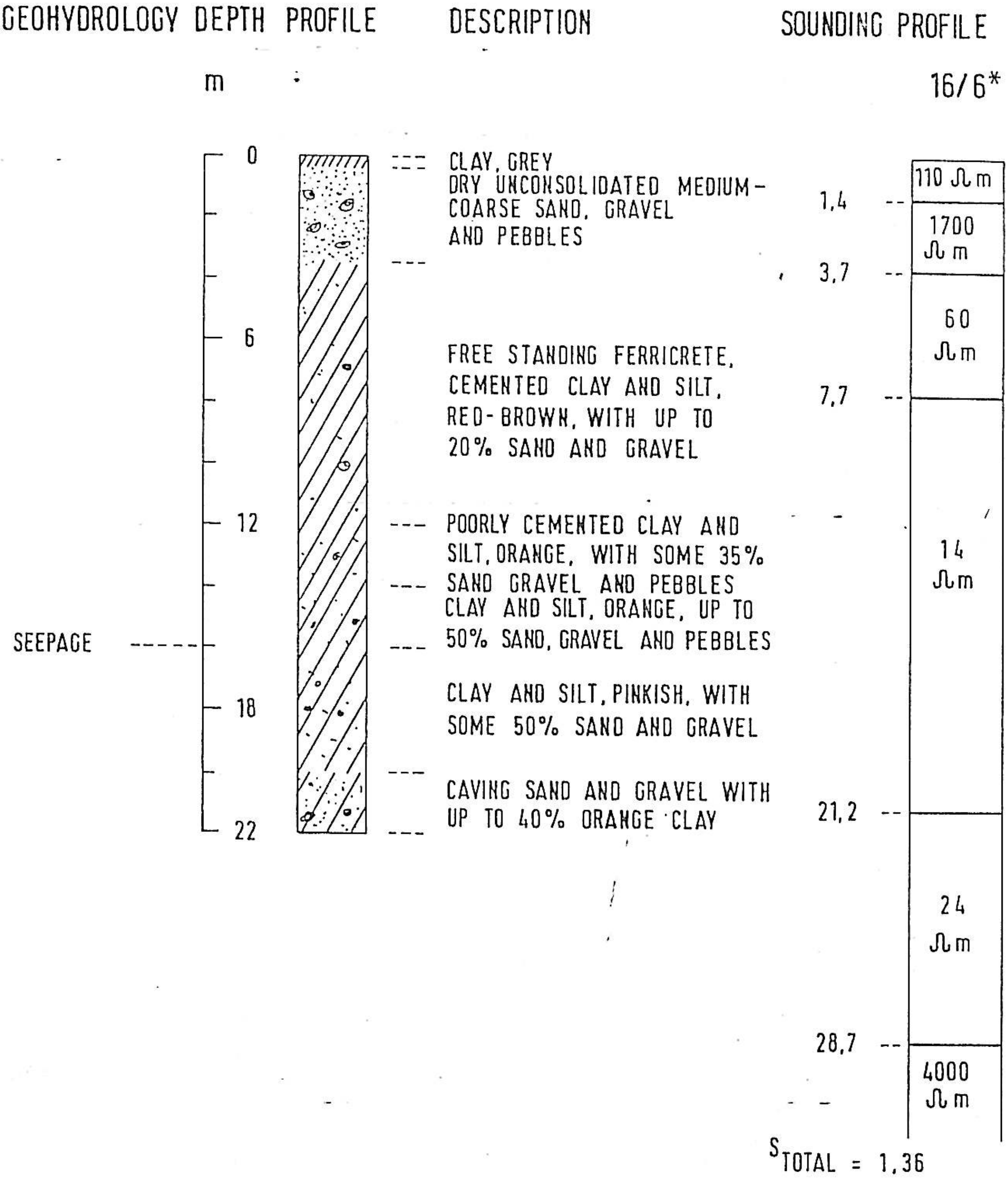
FIG 12


G-32701
CASING
GEOHYDROLOGY
DEPTH
m
PROFILE
DESCRIPTION
SOUNDING PROFILE
16/4
PLAIN
165 mm
4,4
R.W.L.
(07/01/81)
29,6
PERFORATED
OPEN AREA
= 0,02 m²
4,5*
l sec⁻¹
36,6
PLAIN
43,4
* "V" NOTCH MEASUREMENT.
0
6
12
18
24
30
36
45
CLAY, GREY
UNCONSOLIDATED DRY, FINE SAND TO GRAVEL.
FREE STANDING FERRICRETE CEMENTED CLAY AND SILT, RED-BROWN, WITH MINOR SAND AND GRAVEL.
CLAY, DECOMPOSED GABBRO
WEATHERED AND VERY FRACTURED GRANULAR AND CLAYEY GABBRO
HEAVILY FRACTURED META-QUARTZITE
FRESH, UNFRACTURED GABBRO
BOREHOLE RESISTIVITY LOG
40,5 Ωm
0,4
280 Ωm
6,9
S TOTAL 1,32
21,5 Ωm
30,9
57 Ωm
40,4
5000 Ωm
1
5
10
50
100
Ωm



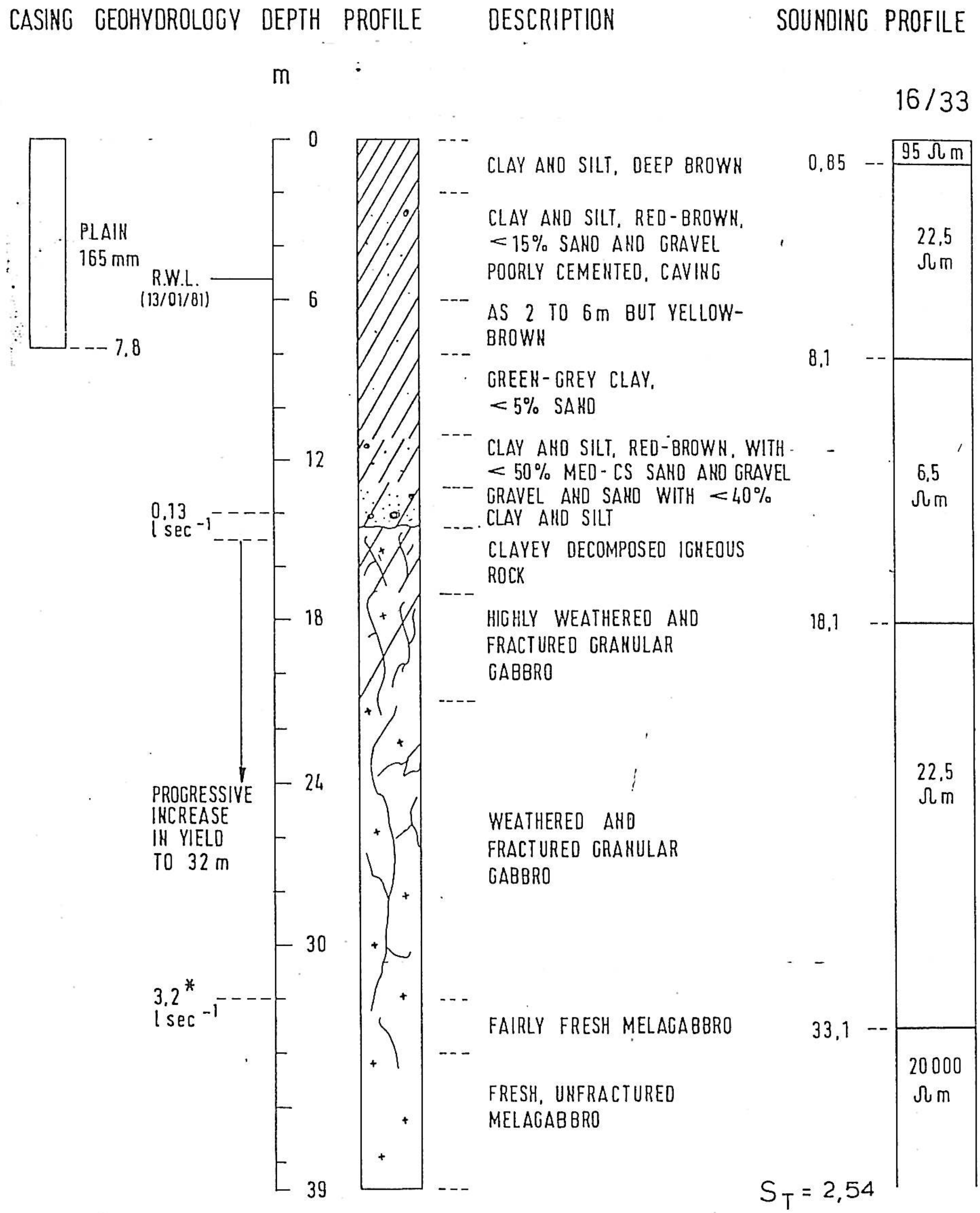
x
FIG 13
G-32702
CASING GEOHYDROLOGY DEPT PROFILE DESCRIPTION
m
PLAIN 127 mm
R.W.L. (14/01/81)
3/8" ANGULAR GRAVEL PACK
---11,8
PERFORATED OPEN AREA 0,03 m²
1,5 * l sec⁻¹
---23,4
PLAIN
---30,2
0
6
12
18
24
30
35
CLAY, GREY
DRY, UNCONSOLIDATED, FINE SAND TO FINE GRAVEL
FREESTANDING FERRICRETE, CEMENTED CLAY AND SILT, ORANGE BROWN, WITH SAND AND GRAVEL OCCURRING SCATTERED THROUGHOUT AND IN LENSES
COARSER FRACTION INCREASES TO ≃ 40% WITH DEPTH
COARSE SAND AND GRAVEL WITH <40% CLAY AND SILT, POORLY CEMENTED
HEAVILY WEATHERED AND FRACTURED GRANULAR GABBRO SLIGHTLY CLAYEY
WEATHERED AND FRACTURED GRANULAR GABBRO
FAIRLY FRESH GABBRO
FRESH UNFRACTURED GABBRO
5
10
50
100
Ωm
BOREHOLE RESISTIVITY LOG
NB. 1. ORIGINALLY DRILLED AT 165 mm BY AIR RIG

FIG 14 G-32703



* 53m TO S.W. OF B'HOLE

FIG 15 G- 32704



* MEASURED WITH 'V' NOTCH

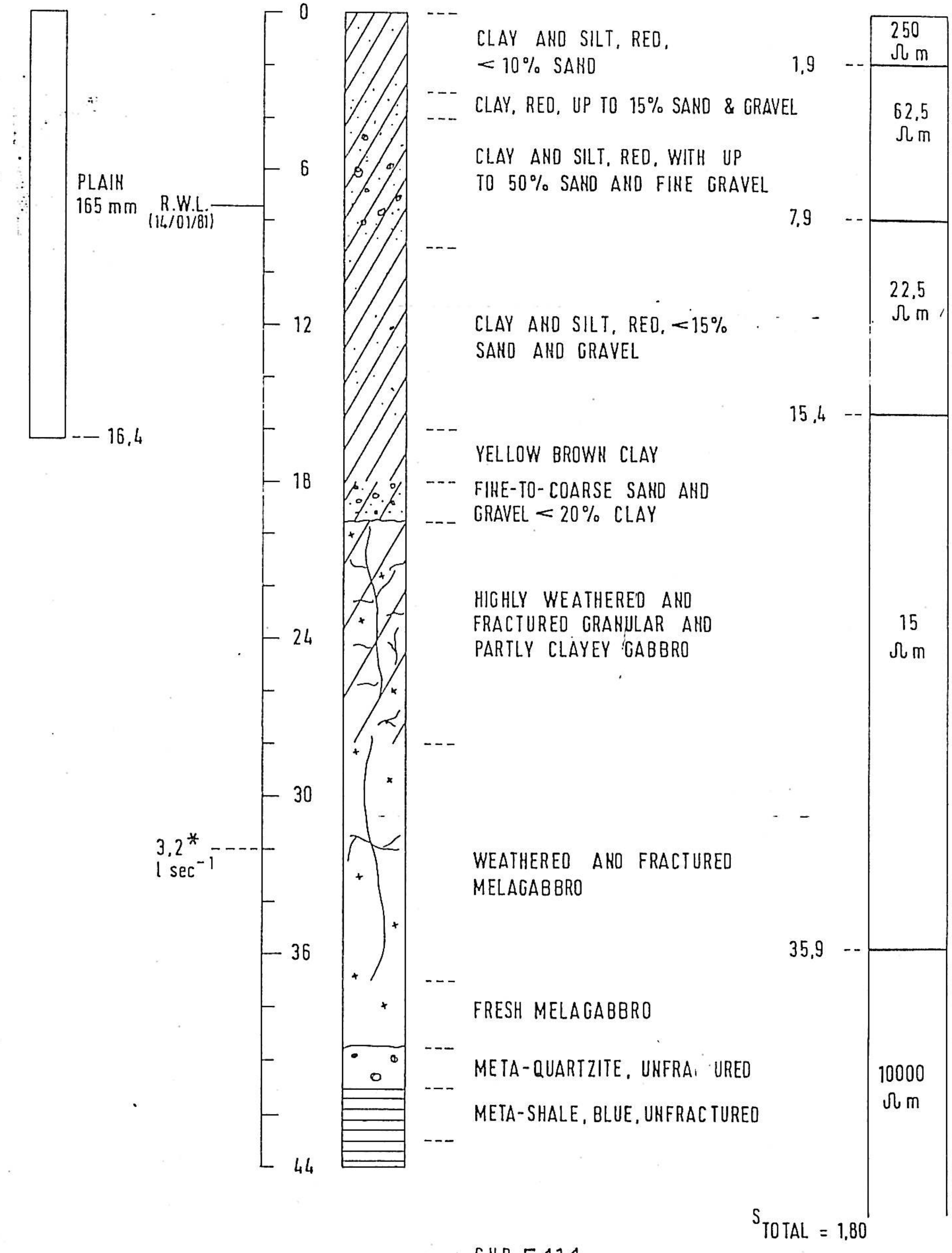
FIG 16

G-32705

CASING GEOHYDROLOGY DEPTH PROFILE DESCRIPTION SOUNDING PROFILE

m

16/26



S_{TOTAL} = 1,80

G.H.P. 5414

FIG 17

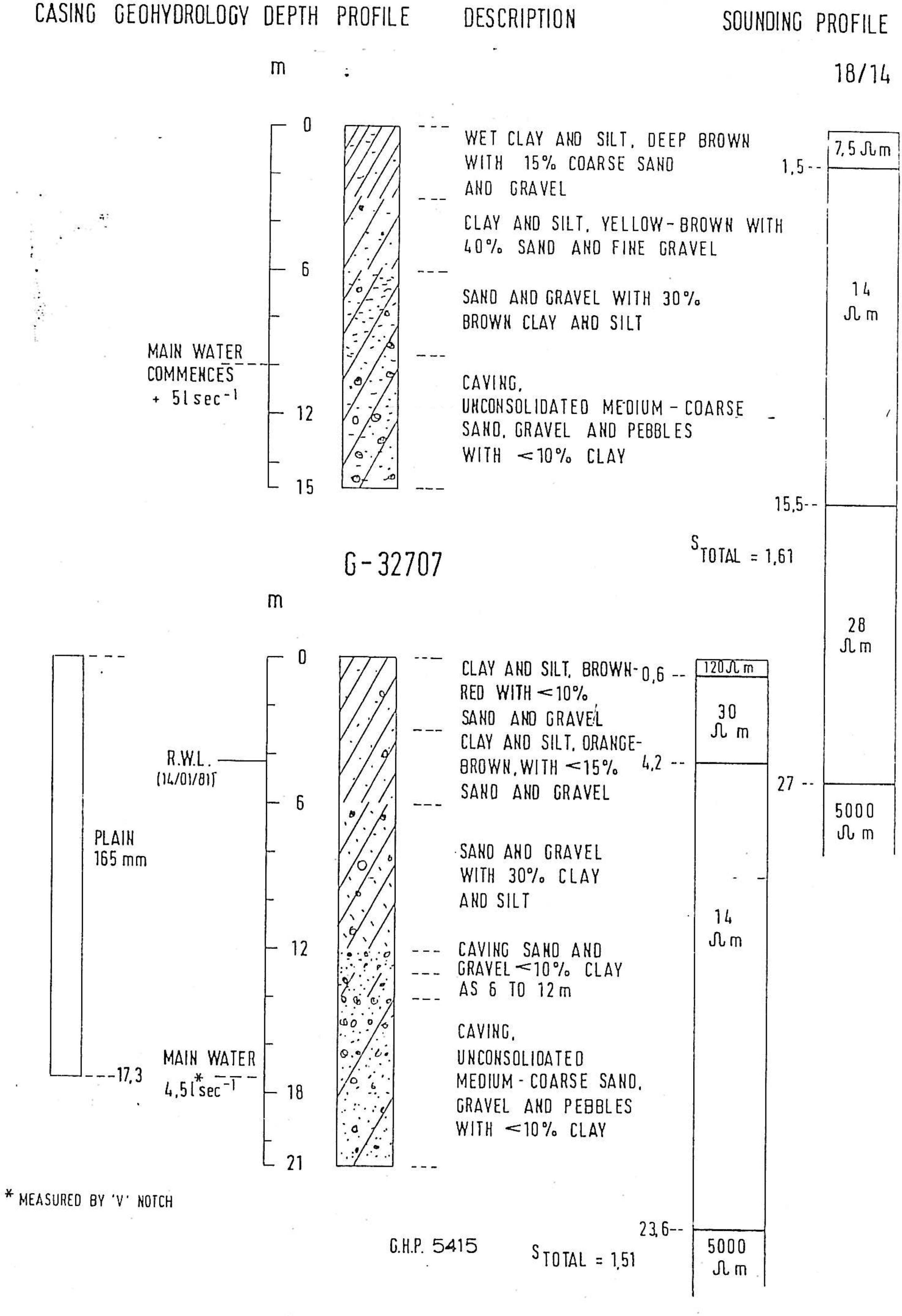
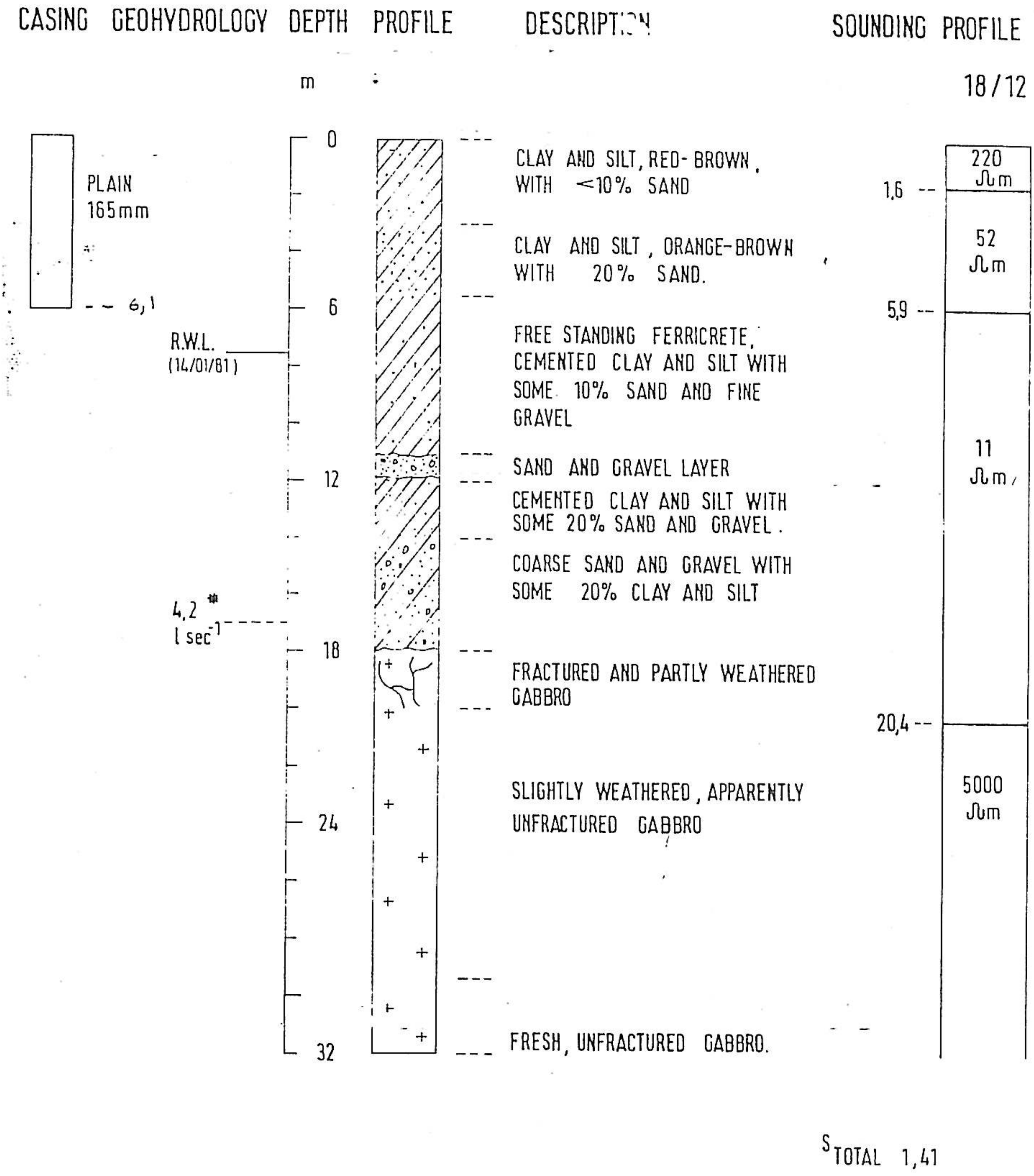

G-32706
CASING GEOHYDROLOGY DEPTH PROFILE DESCRIPTION
SOUNDING PROFILE
m
18/14
0
6
12
15
WET CLAY AND SILT, DEEP BROWN WITH 15% COARSE SAND AND GRAVEL
CLAY AND SILT, YELLOW-BROWN WITH 40% SAND AND FINE GRAVEL
SAND AND GRAVEL WITH 30% BROWN CLAY AND SILT
MAIN WATER COMMENCES + 5l sec-1
CAVING, UNCONSOLIDATED MEDIUM - COARSE SAND, GRAVEL AND PEBBLES WITH <10% CLAY
7,5 Ωm
1,5
14 Ωm
15,5
28 Ωm
27
5000 Ωm
S TOTAL = 1,61
G-32707
m
0
6
12
18
21
PLAIN 165 mm
17,3
R.W.L. (14/01/81)
MAIN WATER 4,5l sec-1 *
CLAY AND SILT, BROWN-RED WITH <10% SAND AND GRAVEL
CLAY AND SILT, ORANGE-BROWN, WITH <15% SAND AND GRAVEL
SAND AND GRAVEL WITH 30% CLAY AND SILT
CAVING SAND AND GRAVEL <10% CLAY AS 6 TO 12 m
CAVING, UNCONSOLIDATED MEDIUM - COARSE SAND, GRAVEL AND PEBBLES WITH <10% CLAY
0,6
120 Ωm
30 Ωm
4,2
14 Ωm
23,6
5000 Ωm
S TOTAL = 1,51
* MEASURED BY 'V' NOTCH
G.H.P. 5415

FIG 18

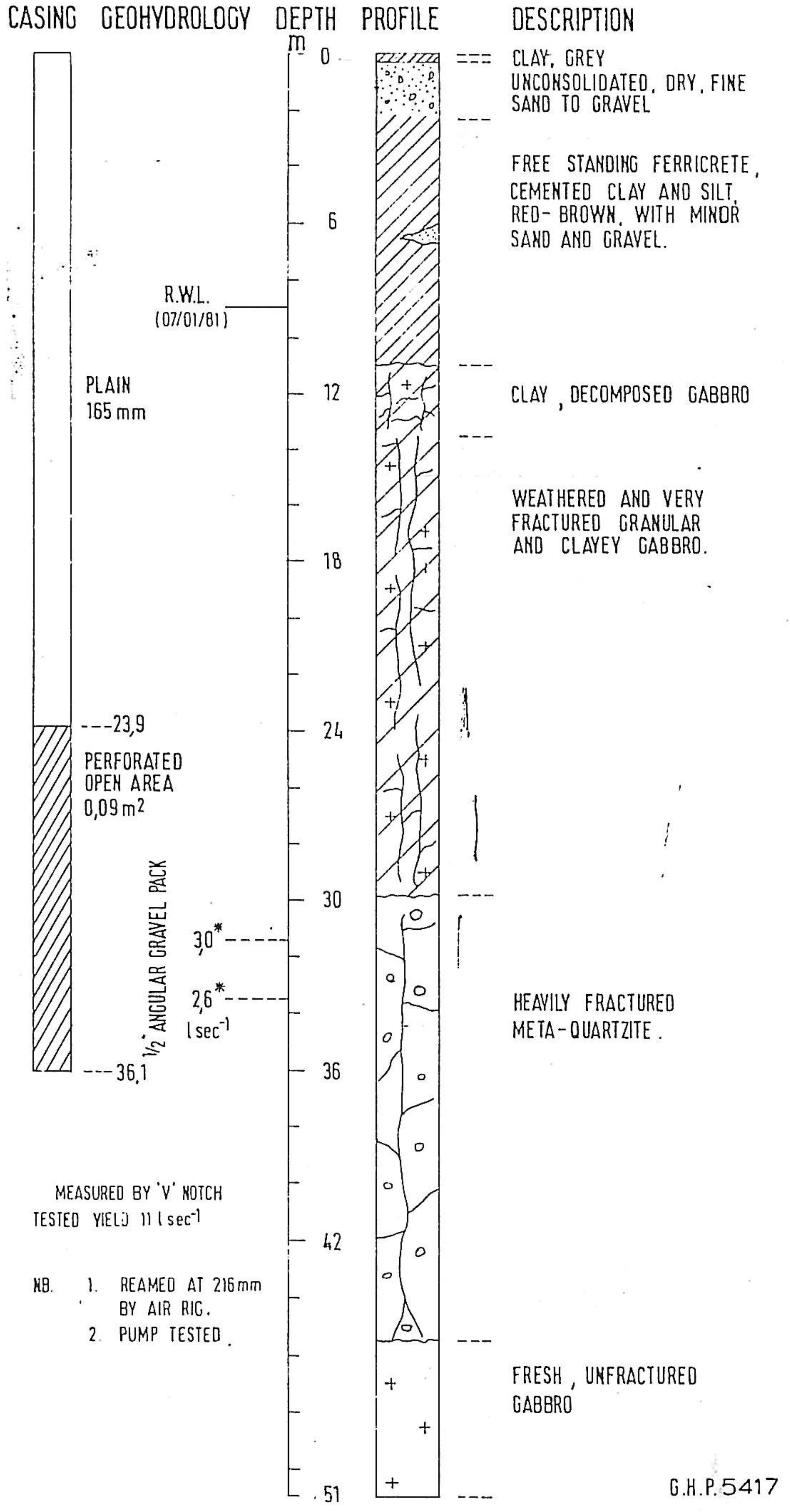
G-32708



* 'V' NOTCH MEASUREMENT

FIG 19

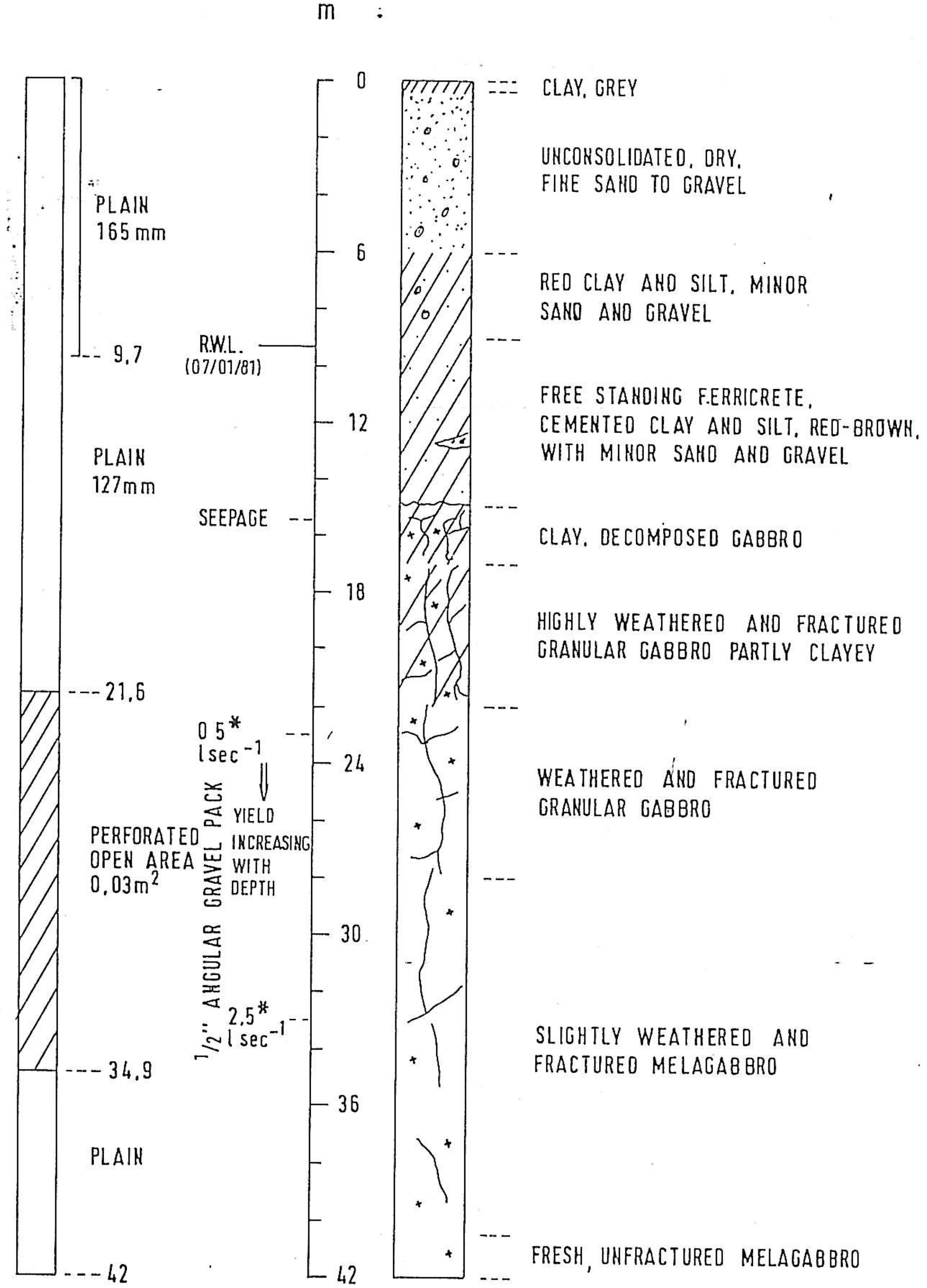
G-32709 2428 BB 155



G.H.P. 5417

FIG 20 G-32710 2428BB00006

CASING GEOHYDROLOGY DEPTH PROFILE DESCRIPTION

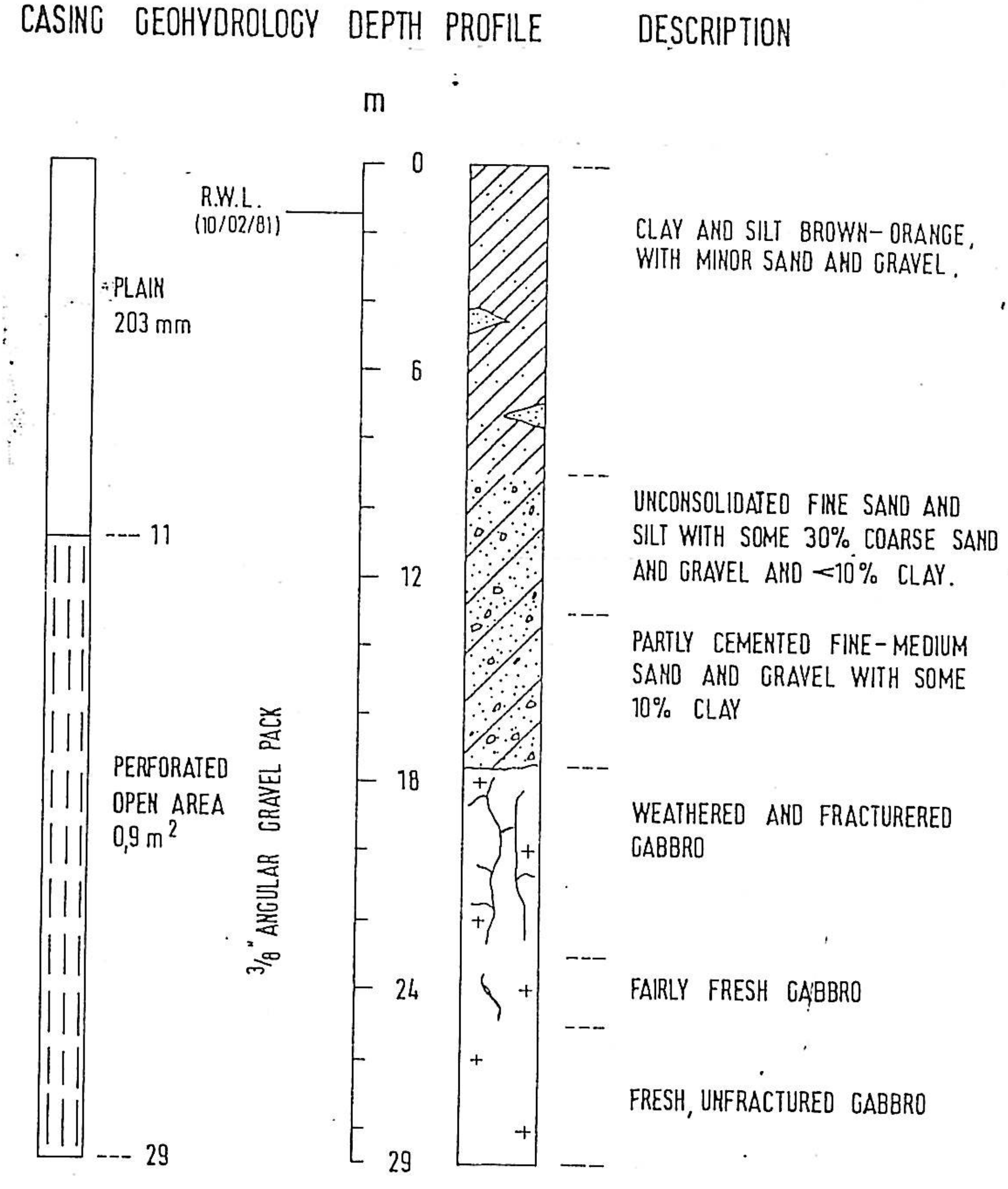


NB. REAMED AT 165 mm BY AIRRIG

* MEASURED BY 'V' NOTCH

G.H.P. 5418

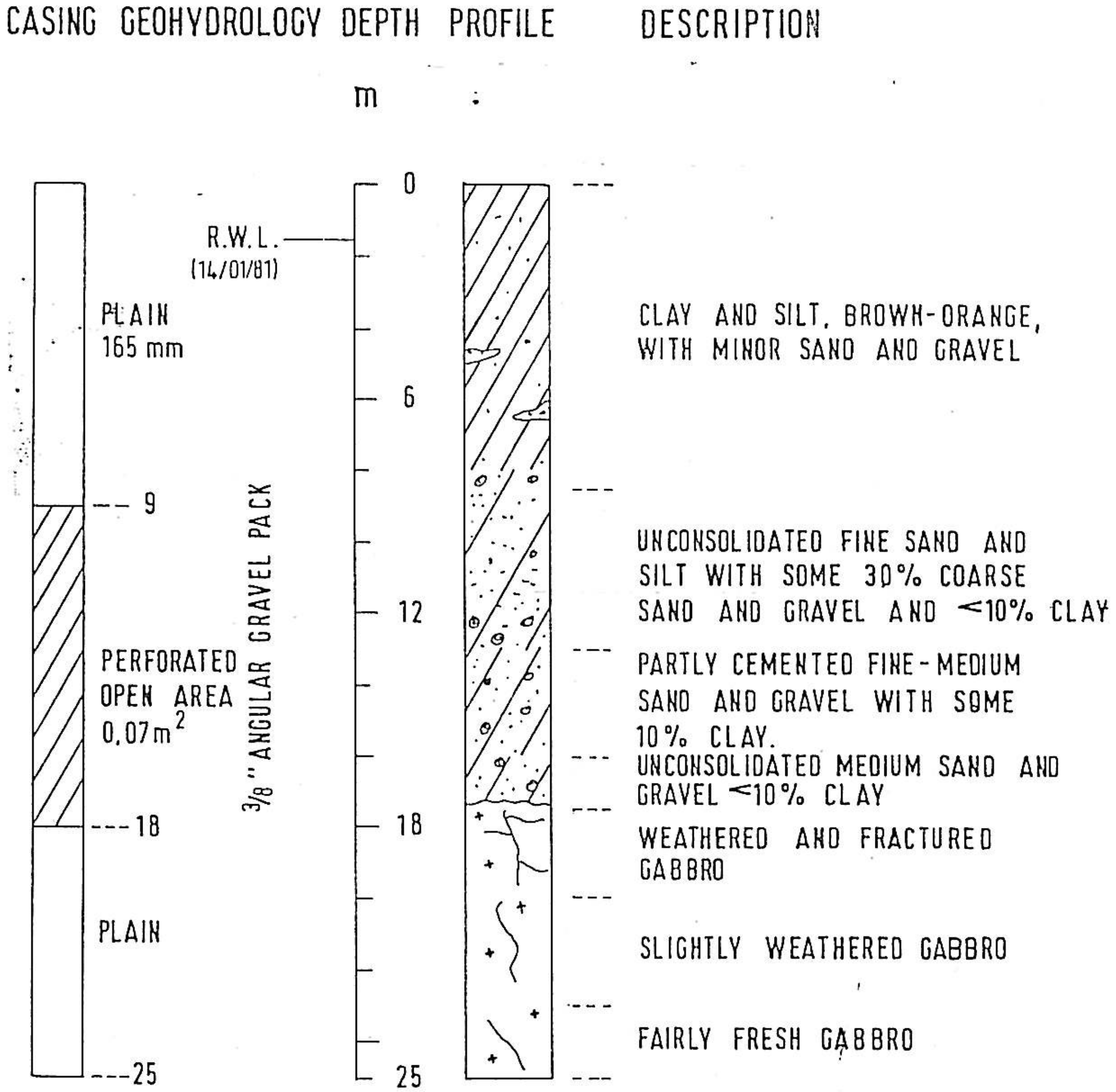
FIG 21 G-32711 Z 428BB156



TESTED YIELD 11,5 l sec^{-1}

NB.
1. SAMPLES TAKEN BAILER
2. REAMED AT 304 mm
3. GRAVEL PACK DEVELOPED, PRIOR TO
4. TEST PUMPED.

FIG 22 G-32712



YIELD $> 4,8 \ l \ sec^{-1}$

NB. 1 SAMPLES TAKEN BY BAILER.
2 REAMED AT 254 mm.
3 GRAVEL PACK DEVELOPED.

APPENDIX 2

Rainfall Data

Annual Rainfall measurements Station No. 633/881A, Potgietersrus, 1904-1980

Altitude 1067m   St. No. 633/881 (school, 1904-1960)
St. No. 633/881A (Police St. 1961-1980)

Year	Total rainfall (in mm)	Year	Total rainfall (in mm)	Year	Total rainfall (in mm)
1904	649,7	31	644,1	58	714,1
5	454,7	32	495,6	59	519,3
6	843,5	33	681,5	60	654,8
7	674,4	34	540,8	61	527,1
8	509,5	35	375,9	62	544,6
9	677,9	36	679,5	63	546,5
10	471,4	37	821,9	64	555,0
11	620,0	38	575,8	65	4240
12	372,4	39	807,0	66	528,2
13	610,9	40	776,0	67	586,2
14	894,6	41	no	68	571,3
15	650,0	42	record	69	466,7
16	487,4	43	550,2	70	555,5
17	786,4	44	466,3	71	544,0
18	944,1	45	352,0	72	461,3
19	548,6	46	539,5	73	589,5
20	675,9	47	500,1	74	647,5
21	911,4	48	543,1	75	842,8
22	490,2	49	508,5	76	875,5
23	751,6	50	342,6	77	837,2
24	796,5	51	595,9	78	645,8
25	609,3	52	496,1	79	433,4
26	447,5	53	425,6	80	817,1
27	464,8	54	514,5		
28	717,0	55	658,6		
29	548,1	56	684,2		
30	527,6	57	780,7		

mean annual rainfall = 605,05mm
standard deviation = 143,36mm
n = 75

MONTHLY RAINFALL MEASUREMENTS STATION NO. 633/881A, POTGIETERSRUS
Period Jan. 1973 to Dec. 1980, inclusive. mean monthly rainfall = 59,3mm
standard deviation = 66,8mm n=96

Rainfall in mm

Year / month	1973	1974	1975	1976	1977	1978	1979	1980
J	64,8	137,0	286,2	74,1	211,4	151,5	72,2	131,7
F	90,0	89,5	53,2	177,5	42,7	190,5	90,0	201,4
M	51,0	58,5	21,0	125,6	152,0	82,0	6,0	21,0
A	45,0	57,2	58,3	44,5	48,1	4,5	18,0	70,0
M	0,0	27,5	12,8	41,4	0,0	6,5	15,0	2,5
J	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
J	0,0	10,4	0,0	0,0	0,0	0,0	8,2	1,0
A	0,0	0,0	0,1	0,0	0,0	0,0	41,0	2,0
S	75,5	11,1	0,0	48,0	69,2	30,5	0,6	85,0
O	87,2	33,7	39,4	41,5	23,2	28,8	31,0	32,0
N	60,2	105,2	44,5	182,6	184,6	106,3	86,9	130,0
D	111,5	117,5	327,2	140,3	106,0	45,2	64,5	140,5

Survey of privately owned boreholes Maralaeaskop 243 KR

No. (Prefix MP)	Type	RWL (m) **	Estimated elevation (m. above M.S.L.)	T.D.S. (ppm)	T (°C)	Remarks
1	borehole			575*	25	Mageme school
2	"	11,98	1077,7	-	-	not in use
3	well	16,52	1071,1	640	25	
4	"	12,00	1076,1	705	25	Sekgakgapeng store, handpump, depth 16m.
5	"			770	26	handpump
6	"	9,12		705	24,5	"
7	"	11,16	1071,9	960	"	
8	"	3,47	1069,2	705	24	
9	"	9,90	1071,0	1215	24,5	
10	"	9,05	1068,3	1790	25	cement in well
11	"	10,81	1081,4	510	24,5	
12	"	7,23	1074,4	640	22	
13	"	11,78	1063,3	640	22,5	
14	"	8,45	1059,0	1345	"	
15	"	8,25	1055,7	830*	23	
16	"	14,07	1064,3	640	22	
17	Borehole			895*	23	
18	well	12,82	1057,4	640	"	
19	"	18,54	1061,1	895	24	
20	"	16,05	1089,7	400	25	
21	borehole			510	22	handpump
22	"			365	"	"
23	well	14,78	1060,1	1345	23	
24	"	12,65	1054,1	610	"	
25	borehole			545	"	Maroteng café
26	well	18,78	1065,3	1025	"	
27	"	13,91	1062,0	960*	"	
28	"	11,78	1054,0	1540	25	recently dug
29	"	14,86	1055,8	1090	"	" , depth 15,5m
30	"	19,39	1069,8	480	"	"
31	borehole			625	"	handpump, depth 19m
32	"					not in use
33	"			480	25	Nditho café
34	"			705*	"	
35	"			895	24	depth 20,4
36	"			610	"	
37	well	7,76	1105,0	575	23.5	
38	borehole	12,00	1100,3	960	24,5	depth 12,8m
39	"					windpump -
40	"					

*water sample submitted for full chemical analysis
** water level measurements August 1980.

INFORMATION ON LEBOWA GOVERNMENT BOREHOLES, MACALACASKOP 243 KR

No.	Yield when drilled ℓ/sec	Pump type	Pumpage rate	Remarks
T2534	2,53	windpump	1,5 ℓ/sec	Depth 36,3m
T2536		Niola 4"		stand-by
T2635	3,28	Filjo 4"		stand-by depth 24,4m
T2636		Mono spiralift 4"		stand-by
T2637				stand-by?
T2661	1,64		low	supplies area
T2719	1,52		low	" "
T2787B*	1,52	Filjo 2"?	low,12hr/day	"
T2788	1,52	windpump	low	" 705ppm at 27,5°C
T2809*		Hartz diesel	5 ℓ/sec ,3hrs/dy	pump cylinder at 20,5m
T2810	5,7	English electric	10 " 20 "	pump cylinder at 25m
T2811*	2,9	Filjo 4"	10 " 20 "	
T2812	4,4	Filjo 4"	10 " 20 "	
L930		windpump	low	supplies area
L975	3,78	windpump	low	"
L1017	6,67		expected to commence pumping 1981	

*water sample submitted for full chemical analysis

APPENDIX 4

GROUNDWATER LEVEL ELEVATIONS AND BOREHOLE COLLAR HEIGHTS

COLLAR ELEVATIONS, M. above M.S.L.

Borehole	Elevation
G30323	1065,24
G30325	1052,14
G30326	1047,62
G30327	1039,55
G30328	1026,97
G30329	1027,12
G30330	1038,48
G30332	1030,61
G30334	1031,38
G30336	1030,85
G30338	1033,62
G30340	1033,98
G30343	1037,81
G30345	1039,74
G30346	1040,59
G30347	1047,54
G30349	1054,73
G30351	1043,57
G30352	1058,88
G30353	1055,850
G30354	1045,19
G30355	1052,562
G31470	1050,617
G31474	1050,757
G31522	1050,391
G31524	1049,865
G31525	1052,272
G31545	1065,165

Borehole	Elevation
G32621	1048,062
G32694	1050,297
G32695	1047,252
G32696	1052,055
G32697	1051,740
G32698	1053,033
G32699	1048,294
G32700	1060,951
G32701	1055,120
G32702	1049,265
G32703	casing withdrawn
G32704	1040,538
G32705	1044,439
G32706	casing withdrawn
G32707	1041,428
G32708	1045,714
G32709	1054,995
G32710	1055,177
G32711	1038,374
G32712	1038,236
A6N045	1058,88
A6N058	1033,55
A6N061	1043,26
A6N062	1025,77
A6N079	1050,757
A6N534	1038,652
Br2	1044,136

Peg 11/1 1058,178 peg 14/1 1066,838
edge of Lake Y, Line 11 1044,083 (07/01/1981)
" " Lake 2, Line 14 1046,328 (05/01/1981)

WATER LEVEL ELEVATIONS

Borehole No.	R.W.L. (m)	Date	W.L. elevation m above MSL
G30323	11,33	06.01.81	1053,91
G30325	14,27	"	1037,87
G30326	13,245	14.01.81	1034,375
G30327	10,065	"	1029,485
G30328	2,385	"	1024,585
G30329	2,805	"	1024,315
G30330	7,46	06.01.81	1031,02
G30332	2,26	"	1028,35
G30334	3,120	14.01.81	1028,26
G30336	0,58	"	1030,27
G30338	2,86	06.01.81	1030,76
G30340	4,025	"	1029,955
G30343	2,695	14.01.81	1035,115
G30345	3,930	"	1035,810
G30346	5,23	06.01.81	1035;36
G30347	7,450	14.01.81	1040,090
G30349	11,740	06.01.81	1042,99
G30351	1,747	23.12.80	1041,823
G30352 2428BB5	4,438	02.01.81	1054,442
G30353	7,795	07.01.81	1048,055
G30354	2,50	06.01.81	1042,69
G30355	10,668	21.01.81	1041,894
G31470	2,450	02.01.81	1048,167
G31471	under water	"	
G31522 2428 DB 764	3,983	02.01.81	1046,408
G31525 2428 DB 756	3,073	"	1049,199
G31526 2428 BB 59	12,432	"	1046,422
G31545	14,716	"	1050,449
G32621	3,573	22.01.81	1044,489
G32694	2,165	07.01.81	1048,132
G32695	1,370	"	1045,882
G32696	5,580	05.01.81	1046,475
G32697	5,260	"	1046,480
G32698	6,530	"	1046,503
G32699	8,150	14.01.81	1040,144
G32700	12,659	12.01.81	1048,292
G32701	8,850	07.01.81	1046,270
G32702	8,340	14.01.81	1040,925
G32704	5,220	13.01.81	1035,318
G32705	7,410	14.01.81	1037,029
G32707	4,250	"	1037,178
G32708	7,455	"	1038,259
G32709	8,940	07.01.81	1046,055
G32710	9,225	"	1045,952
G32711	1,459	19.02.81	1036,915
G32712	1,595	14.01.81	1036,641
A6N058	3,815	"	1029,735
A6N061	3,900	"	1039,360
A6N062	3,535	"	1022,235
A6N079	2,162	25.02.81	1048,595
A6N534	2,638	21.01.81	1036,014
Br2	5,035	14.01.81	1039 ,101
Pt1			
	6,26	03.11.81	1089,66*

Edge of Lake Z Line 11 - 1044,1
Edge of Lake Y, Line 14 - 1046,3
* estimated from topocadastral map

APPENDIX 5
RECORDED GROUNDWATER LEVELS

A6N058 - Recorded water levels

Farm Blinkwater 244 KR, owner du Plessis
Latitude 24° 06'45" Longitude 28° 54' 46"
Collar elevation: 1033,55m Depth 18m? Formation: unconsolidated clay and sand?
Recorder established 26/10/1973 discontinued 03/07/1979
Request for re-establishment April 1981

Date	R.W.L. (m)	Date	R.W.L. (m)
26/10/1973	5,59	28/07/1977	2,93
04/12	5,67	31/08	3,19
03/01/1974	5,65	28/09	3,28
31/01	5,36	26/10	3,45
13/02	5,17	29/11	3,37
05/03	5,075	05/01/1978	3,38
2/04	5,30	07/02	2,94
29/04	5,25	02/03	2,30
06/06	5,21	30/03	2,16
03/07	5,11	25/04	2,36
01/08	5,19	24/05	2,65
13/08	5,43	28/06	2,75
06/09	5,22	25/07	2,87
17/09	5,47	23/08	2,96
04/10	5,36	26/09	3,09
06/11	5,65	30/10	3,29
02/12	5,64	06/12	3,48
31/12	5,70	02/01/1979	3,61
27/01/1975	5,78	02/02	3,75
03/03	3,97	26/02	3,80
02/04	3,68	27/03	3,90
15/05	3,53	23/05	2,10
03/06	3,69	28/06	2,09
02/07	3,74	14/01/1981	3,815
05/08/1975	3,84		
03/09	3,93		
29/09	3,90		
04/11	3,90		
01/12	4,47		
06/01/1976	4,20		
03/02	4,33		
02/03	3,41		
02/04	3,62		
04/05	3,58		
02/06	3,65		
02/07	3,77		
03/08	3,87		
02/09	3,90		
29/09	4,01		
27/10	4,19		
11/12	4,01		
05/01/1977	2,94		
03/02	3,05		
28/02	3,11		
30/03	2,86		
26/[illegible]	2,79		
27/0[illegible]	2,86		
30/06	2,87		

A6N061 - Recorded water levels

Boring No. 118050/0
Farm Blinkwater 244 KR, owner Du Plessis
Latitude 24°08'50" Longitude 28° 55' 59"
Collar elevation: 1043,26m
Depth 27,4m Formation: 0-18,3m, unconsolidated clay and sand
18,3-27,4m granite?

Recorder established 24/01/1975, discontinued 02/02/1979
re-established 08/10/1980, discontinued 14/01/1981

Date	R.W.L.(m)	Date	R.W.L.(m)
24/01/1975	5,50	06/12	4,33
21/04	2,94	02/01/1979	4,42
15/05	2,85	02/02	4,65
03/06	3,00	08/10/1980	3,95
02/07	3,12	05/11	4,032
05/08	3,20	05/12	4,145
03/09	3,29	14/01/1981	3,900
29/09	3,34		
04/11	3,56		
01/12	3,69		
06/01/1976	3,70		
03/02	3,73		
02/03	2,37		
02/04	2,56		
04/05	2,49		
02/06	2,57		
02/07	2,68		
03/08	2,75		
02/09	2,80		
29/09	2,95		
27/10	3,17		
01/12	2,83		
05/01/1977	4,06		
03/02	4,24		
02/03	4,25		
30/03	3,95		
26/04	3,83		
27/05	3,85		
30/06	3,96		
28/07	3,98		
31/08	4,12		
28/09	4,17		
26/10	4,39		
29/11	4,60		
05/01/1978	4,25		
07/02/	3,82		
2/03	3,25		
30/03	3,22		
25/04	3,50		
24/05	3.81		
28/06	3,95		
25/07	3,96		
23/08	4,00		
26/09	4,01		
30/10	4,86		

A6N079 - Recorded waterlevels

No. G31474
Farm: Piet Potgietersrust 44 KS, owner Municipality
Latititude 24º 12'04" Longitude 28º58'46"
Collar elevation: 1050,76m depth 30m
Formation 0-15 unconsolidated silty clay, 15-29 weathered gabbro
29-30 fresh gabbro
Recorder established 16/01/1980, to present

Date	R.W.L.(m)	Date	R.W.L.(m)
10/01.1980	4 47	25/08/1980	2,911
22/01	4,49	24/09	2,802
19/02	4,34	24/10	2,961
26/03	2,79	28/11	2,960
22/04	2,79	24/12	2,627
21/05	2,88	21/01/1981	2,627
24/06	2,861	25/02	2,162
22/07	2,831	24/03	2,152

A6N045 - Recorded water levels
No. G30352, B/No. 119973/9, 8/30 of Kok and Venter 1978.
Farm Turfspruit 241 KR or Macalacaskop 243 KR
Latitude 24º 08'05" Longitude 28º 56'42"
Collar elevation 1058,88m Depth 34m
Formation: 0-14m unconsolidated silty clay 14-34m weathered gabbro
Recorder established 6/10/1980 to present

Date	R.W.L.(m)	Date	R.W.L.(m)
16/10/1976	5,89	02/01/81	4,438
06/10/1980	6,732	25/02	3,890
03/11	7,002	27/03	3,947
05/12	7,342		

G32621 - Recorded water levels

Details given in Appendix 1
Fitted with temporary recorder 06/10/1980 to 14/01/1981

Date	RWL(m)
15/09/1980	3,27
06/10/	3,716
03/11	3,885
14/01/1981	3,573

A6N079 - Recorded waterlevels

No. G31474
Farm: Piet Potgietersrust 44 KS, owner Municipality
Latititude 24° 12'04" Longitude 28°58'46"
Collar elevation: 1050,76m depth 30m
Formation 0-15 unconsolidated silty clay, 15-29 weathered gabbro
29-30 fresh gabbro
Recorder established 16/01/1980, to present

Date	R.W.L.(m)	Date	R.W.L.(m)
10/01.1980	4 47	25/08/1980	2,911
22/01	4,49	24/09	2,802
19/02	4,34	24/10	2,961
26/03	2,79	28/11	2,960
22/04	2,79	24/12	2,627
21/05	2,88	21/01/1981	2,627
24/06	2,861	25/02	2,162
22/07	2,831	24/03	2,152

A6N045 - Recorded water levels
No. G30352, B/No. 119973/9, 8/30 of Kok and Venter 1978.
Farm Turfspruit 241 KR or Macalacaskop 243 KR
Latitude 24° 08'05" Longitude 28° 56'42"
Collar elevation 1058,88m Depth 34m
Formation: 0-14m unconsolidated silty clay 14-34m weathered gabbro
Recorder established 6/10/1980 to present

Date	R.W.L.(m)	Date	R.W.L.(m)
16/10/1976	5,89	02/01/81	4,438
06/10/1980	6,732	25/02	3,890
03/11	7,002	27/03	3,947
05/12	7,342		

G32621 - Recorded water levels

Details given in Appendix 1
Fitted with temporary recorder 06/10/1980 to 14/01/1981

Date	RWL(m)
15/09/1980	3,27
06/10/	3,716
03/11	3,885
14/01/1981	3,573

AGN534 - Recorded waterlevels

Boring No. 124975/4. No. 5/28,5 of Kok and Venter 1978
Farm - Blinkwater 244 KR, owner Landsberg
Latitude 24°07'18" Longitude 28°55'01"
Collar elevation: 1038,65m
Depth 22m? Formation: unconsolidated clay and gravelly sand
Casing: 0-16m, 203mm Rosslyn. 16-22m, 165mm Johnson No. 40 sandscreen
Recorder established 02/03/1977 to present

Date	RWL(m)
14/02/1977	2,70
02/03	3,20
30/03	2,77
26/04	2,66
27/05	2,61
30/06	2,55
28/07	2,54
31/08	2,64
28/09	2,66
26/10	2,80
29/11	2,85
05/01/1980	2,70
07/02	2,62
02/03	2,40
30/03	2,22
25/04	2,34
24/05	2,42
28/06	2,43
25/07	2,45
23/08	2,46
26/09	2,49
30/10	2,57
6/12	2,66
02/01/1979	2,70
02/02	2,80
26/02	2,81
27/03/1979	2,96
24/04	3,02
22/05	3,09
25/06	3,16
23/07	3,25
21/08	3,28
26/09	3,24
24/10	3,23
21/11	3,26
18/12	3,28
31/01/1980	3,46

Date	RWL(m)
11/03	3,18
26/03	3,15
24/04	3,09
21/05	3,09
25/06	3,148
22/07	3,098
27/08	3,100
24/09	3,070
22/10	3,075
19/11	3,111
24/12	2,922
21/1/1981	2,638
25/02	2,437
23/03	2,422

APPENDIX 6

CHEMICAL DATA

LOCATION OF SAMPLED SURFACE WATER

Sampling Point	Sampling Date	H-Number	Latitude 24°S		Longitude °E		
M1	801002	80314023	17'	05"	28°	57'	35"
M2	"	80314015	16'	41"	28°	58'	26"
M3	"	80314007	16'	18"	28°	58'	41"
M4	"	80313996	15'	44"	28°	58'	47"
M5	"	80313988	12'	19"	28°	58'	17"
M6	"	80313970	49'	11"	28°	58'	12"
M7	"	80313962	11'	10"	28°	57'	43"
D1xx	801003	80314104	08'	56"	29°	09'	56"
D2x	"	80314099	09'	24"	29°	09'	30"
D3xx	"	80314081	09'	25"	29°	07'	26"
D4xx	"	80314073	10'	12"	29°	04'	45"
D5x	"	80314065	10'	05"	29°	04'	01"
D6	"	80314057	09'	51"	29°	01'	55"
D7	"	80314049	09'	50"	29°	01'	44"
D7	810113	81400518					
D8	801003	80314049	10'	26"	29°	01'	00"
R1x	801001	80313831	00'	52"	29°	07'	16"
R2x	"	80313823	02'	40"	29°	05'	46"
R3x	"	80313815	04'	43"	29°	04'	00"
R4	"	80313849	06'	19"	29°	01'	40"
R5x	"	80313899	08'	10"	28°	57'	50"
M8	"	80313938	10'	40"	28°	57'	12"
M9	"	80313920	10'	13"	28°	57'	11"
M10	"	80313912	09'	21"	28°	56'	39"
M11	"	80313904	09'	03"	28°	50'	18"
M12	"	80313865	07'	26"	28°	54'	45"
M13x	"	80313857	06'	50"	28°	54'	43"
M14x	801219	80321737	05'	41"	28°	54'	07"
A, B	1977	Information in Kok, 1978					

Unmarked samples were obtained from standing water, those designated x were taken from flowing water and samples indicated xx were taken immediately downstream of flowing springs.

Prefix:

D Dorps River
R Rooisloot River
M Mogalakwena/Nile River
A and B from Mogalakwena River.

CONCENTRATIONS IN P.P.M.

Sample Location	Ca	Mg	Na	K	TAL	HCO_3	Cl	SO_4
M1	7,97	12,7	39,1	7,95	141	172	7,68	6,68
M 2	9,50	8,83	28,2	3,83	109	133	4,80	5,59
M3	16,2	10,1	26,3	7,70	118	144	8,42	6,14
M4	14,4	9,81	25,7	7,57	114	139	8,67	6,95
M5	21,5	17,5	45,8	8,33	150	183	43,3	5,59
M6	23,0	15,6	39,2	7,57	144	176	34,6	6,68
M7	23,3	19,4	43,8	7,44	186	227	15,2	5,60
D1	36,9	27,7	3,89	1,06	198	242	4,20	2,24
D3	28,4	34,4	7,40	0,69	200	244	6,20	1,52
D4	57,5	39,2	9,31	1,07	270	330	8,14	10,3
D5	37,7	42,5	10,5	0,40	244	300	8,14	10,5
D6	22,8	53,7	51,7	0,67	323	394	19,4	23,2
D7	22,8	54,4	21,3	0,54	274	334	16,6	7,74
D8	38,5	65,1	46,3	1,34	383	467	28,5	14,0
R1	29,1	14,7	40,7	1,20	181	221	19,4	5,32
R2	23,3	11,4	40,1	1,34	150	183	18,3	8,0
R3	32,0	17,9	60,5	1,47	200	244	37,9	17,9
R4	11,8	11,4	34,9	2,39	115	140	17,0	10,0
R5	27,5	52,8	43,9	3,05	297	362	404	16,0
M8	26,7	19,4	28,3	7,69	174	212	14,4	30,6
M9	44,9	56,6	139,0	11,0	381	465	179,0	5,32
M10	28,2	26,6	33,4	7,57	205	250	23,5	5,32
M11	38,4	89,6	68,9	6,42	444	542	85,7	25,0
M12	29,0	27,5	42,0	1,87	221	270	28,9	5,59
M13	37,0	29,4	34,2	1,20	247	301	14,2	5,32
M14	35,4	28,7	42,5	4,13	241	294	27,0	10,8

CONCENTRATIONS IN PPM

Sample Location	Si	NO_3	F	(lab) Ec	pH	(Field) Conductivity	T°C
M1	3,99	0,00	1,63	206	7,2	290	32
M2	4,43	0,00	1,32	155	7,4	230	25
M3	1,52	0,95	1,19	188	7,2	200	27
M4	0,80	0,00	1,23	175	7,3	235	27
M5	3,03	0,00	1,38	295	7,6	365	27
M6	4,51	0,00	1,34	274	7,5	285	21,5
M7	3,90	0,00	1,49	300	7,5	350	25
D1	6,44	0,55	0,09	270	6,8	375	22
D3	8,90	2,15	0,06	283	6,8	415	23
D4	8,79	1,95	0,19	378	7,8	420	22
D5	10,2	1,57	0,22	362	7,9	390	22
D6	6,79	0,80	0,56	446	8,2	450	23
D7	11,2	0,00	0,51	412	8,2	375	20,5
D8	10,5	0,00	0,63	520	8,0	485	22
R1	11,6	0,11	1,61	274	7,9	255	21
R2	8,92	0,09	1,39	240	7,8	210	18
R3	11,5	0,10	1,80	358	7,7	325	23
R4	4,85	0,00	1,18	196	7,4	180	22
R5	10,5	0,97	1,03	450	7,9	550	26
M8	6,69	0,00	1,47	262	7,5	350	23
M9	10,8	0,00	1,33	820	7,7	940	27
M10	4,61	0,00	1,40	314	7,7	370	27
M11	10,1	0,51	1,46	731	7,7	910	26
M12	4,82	0,00	1,11	340	8,0	325	25,5
M13	16,1	0,00	1,12	341	7,8	305	18
M14	13,9	0,00	0,99	378	6,6	350	22

CATIONS
Concentrations in meq ℓ^{-1}

Sample Location	Ca	Mg	Na	K	(Na+K)	Total Cations	Percentage Composition Ca : Mg : Na+K
M1	0,40	1,04	1,70	0,20	1,90	3,34	12 : 31 : 57
M2	0,47	0,73	1,23	0,10	1,33	2,53	18,5 : 29 : 52,5
M3	0,81	0,83	1,14	0,20	1,34	2,98	27 : 28 : 45
M4	0,72	0,81	1,12	0,19	1,31	2,84	25 : 29 : 46
M5	1,07	1,44	1,99	0,21	2,20	4,71	23 : 30 : 47
M6	1,15	1,28	1,70	0,19	1,89	4,32	26,5 : 29,5 : 44
M7	1,16	1,60	1,90	0,19	2,09	3,85	24 : 33 : 43
D1	1,84	2,28	0,17	0,03	0,20	4,32	42,5 : 53 : 4,5
D3	1,42	2,83	0,32	0,02	0,34	4,59	31 : 62 : 7
D4	2,87	3,22	0,40	0,03	0,43	6,52	44 : 49 : 7
D5	1,88	3,50	0,46	0,01	0,47	5,85	32 : 60 : 8
D6	1,14	4,42	2,25	0,02	2,27	7,83	15 : 56 : 29
D7	1,14	4,47	0,93	0,01	0,94	6,55	18 : 68 : 14
D8	1,92	5,35	2,01	0,03	2,04	9,31	21 : 57 : 22
R1	1,45	1,21	1,77	0,03	1,80	4,46	33 : 27 : 40
R2	1,16	0,94	1,74	0,03	1,77	3,87	30 : 24 : 46
R3	1,60	1,47	2,63	0,04	2,67	5,74	28 : 26 : 46
R4	0,59	0,94	1,52	0,06	1,58	3,11	19 : 30 : 51
R5	1,37	4,34	1,91	0,08	1,99	7,70	18 : 56 : 26
M8	1,33	1,60	1,23	0,20	1,43	4,36	30 : 37 : 33
M9	2,24	4,65	6,04	0,28	6,32	13,2	17 : 35 : 48
M10	1,41	2,19	1,45	0,19	1,64	5,24	27 : 42 : 31
M11	1,92	7,37	3,00	0,16	3,16	12,45	15,5 : 59 : 25,5
M12	1,45	2,26	1,83	0,05	1,88	5,59	26 : 40 : 34
M13	1,85	2,42	1,49	0,03	1,52	5,79	32 : 42 : 26
M14	1,77	2,36	1,85	0,11	1,96	6,09	29 : 39 : 32

ANIONS
CONCENTRATION IN meq/l

Sample Location	Cl	SO_4	HCO_3	Total Anions	Percentage composition Cl	SO_4	HCO_3
M1	0,22	0,14	2,82	3,18	7	: 4 :	89
M2	0,14	0,12	2,18	2,44	6	: 5 :	89
M3	0,24	0,13	2,36	2,73	9	: 5 :	86
M4	0,24	0,14	2,28	2,66	9	: 5 :	86
M5	1,22	0,12	3,00	4,34	28	: 3 :	69
M6	0,98	0,14	2,89	4,01	24	: 4 :	72
M7	0,43	0,12	3,72	4,27	10	: 3 :	87
D1	0,12	0,05	3,97	4,14	3	: 1 :	96
D3	0,17	0,03	4,00	4,20	4	: 1 :	95
D4	0,23	0,21	5,41	5,85	4	: 4 :	92
D5	0,23	0,22	4,92	5,37	4	: 4 :	92
D6	0,55	0,48	6,46	7,49	7,5	: 6,5 :	86
D7	0,47	0,16	5,48	6,11	7,5	: 3 :	89,5
D8	0,80	0,29	7,66	8,75	9	: 3 :	88
R1	0,55	0,11	3,62	4,28	13	: 2,5 :	84,5
R2	0,52	0,17	3,00	3,69	14	: 5 :	81
R3	1,07	0,37	4,00	5,44	20	: 7 :	73
R4	0,48	0,21	2,30	2,99	16	: 7 :	77
R5	1,14	0,33	5,93	7,40	15	: 5 :	80
M8	0,41	0,64	3,48	4,53	9	:14 :	77
M9	5,05	0,11	7,62	12,78	39,5	: 1 :	59,5
M10	0,66	0,11	4,10	4,87	14	: 2 :	84
M11	2,42	0,52	8,89	11,83	21	: 4 :	75
M12	0,82	0,12	4,43	5,37	15	: 2 :	83
M13	0,40	0,11	4,93	5,44	7	: 2 :	91
M14	0,76	0,22	4,82	5,80	13	: 4 :	83

INFORMATION ON SAMPLED BOREHOLES

Borehole number	Borehole depth(m)	Yield ℓ/sec	Formation main water struck in
Br1	n.k.*	< 1,5	alluvial deposits only?
T2811	n.k.	> 3	weathered gabbro ?
T2809	n.k.		" " ?
T2787B	n.k.	1,5	" " ?
Mp1	n.k.	≙ 1,5	" " ?
Mp 15	n.k.	well	superficial deposits only?
Mp17	n.k.	n.k.	weathered gabbro?
Mp27	n.k.	well	superficial deposits only?
Mp34	n.k.	n.k.	weathered gabbro?
G32694	31	> 3,1	unconsolidated alluvial sand and gravel and weathered gabbro
G32695	26	> 2,8	ditto
G32697	45	17	ditto
G32699	30,8	≙ 1,5	weathered gabbro?
G32700	51	+5	unconsolidated alluvial sand and gravel and weathered gabbro
G32704	38	3,2	weathered gabbro
G32709	51	11,5	fractured metaquartzite
G32711	29	11,3	unconsolidated alluvial sand and gravel and weathered gabbro

* n.k. = not known

LOCATION OF SAMPLED GROUNDWATER

Diagram No.	Sampling Point	Sampling Date	H-number	Latitude 24°S	Longitude 28°E
1	Brl	801001	80313873	07' 10"	55' 12"
2	T2811	801002	80313946	09' 24"	56' 39"
3	T2809	"	80313954	09' 06"	56' 19"
4	T2787B	801001	80313881	08' 05"	57' 09"
5	Mp1	800903	80314112	10' 20"	58' 48"
6	Mp15	"	80314120	09' 31"	57' 11"
7	Mp17	"	80314138	09' 05"	57' 30"
8	Mp27	800917	80314146	08' 40"	56' 49"
9	Mp34	"	80314154	08' 00"	58' 39"
10	G32694	801017	80318263	09' 40"	57' 09"
11	G32695	801016	80318271	09' 45"	56' 54"
	G32697	801202	80320430	10' 39"	57' 17"
	"	801203	80320448	"	
	"	801209-0500	80320456	"	
	"	" -1700	80320480	"	
	"	801210-0500	80320464	"	
12	"	" -1700	80320472	"	
13	G32699	801209	80320511	07' 39"	55' 50"
	"	810224-0920	81401124	"	
	"	" -2030	81401132	"	
	"	810225-0740	81401140	"	
	"	" -2145	81401019	"	
	"	810226-1040	81401027	"	
	"	2050	81401035	"	
	"	810227-0825	81401043	"	
14	G32700	801205	80320498	10' 31"	57' 40"
15	G32704	801119	80318298	06' 50"	55' 17"
	G32709	801205	80320503	08' 09"	56' 12"
	"	810116-0625	81400021	"	
	"	810116-1300	81400013	"	
	"	810121-0845	81400039	"	
	"	810128-0825	81400479	"	
16	"	810129-0805	81400487	"	
17	G32711	810211-0900	81401093	06' 49"	55' 40"
	"	810211-2030	81401108	"	
	"	810212-0815	81401116	"	
X	G31542				
Y	Ln24	1979	information in Lyness, 1980		
Z	A6N534		(location see Fig. 1)		

CONCENTRATIONS IN PPM

Sample Location	Ca	Mg	Na	K	TAL	HCO_3	Cl	SO_4
Br	12,4	16,9	103	1,60	282	344	14,7	16,7
T2811	27,4	108,0	92,2	1,87	384	468	172,0	30,6
T2809	36,5	48,1	41,8	5,26	284	346	53,2	7,74
T2787B	26,1	41,3	46,0	4,48	234	285	26,2	10,5
Mp1	20,1	79,1	42,8	0,27	381	465	21,2	16,0
Mp15	13,0	96,4	116,0	0,40	396	483	86,9	46,3
Mp17	50,3	80,5	72,1	0,67	237	289	164,0	26,9
Mp27	50,7	117,0	122,0	0,94	324	395	309,0	19,1
Mp34	50,7	84,6	96,5	0,67	460	561	50,3	27,5
G32694	56,0	72,7	24,9	0,70	386	471	56,0	17,6
G32695	53,2	65,6	13,0	1,23	357	436	38,4	10,3
G32697	96,8	438,0	1220,0	1,33	778	949	1540,0	1530,0
"	92,7	457,0	1210,0	1,33	769	938	1580,0	1510,0
"	92,4	457,0	1180,0	1,33	760	927	1630,0	1540,0
"	103,0	476,0	1200,0	1,33	761	928	1660,0	1550,0
"	99,8	473,0	1220,0	2,65	756	922	1690,0	1580,0
"	91,8	457,0	1190,0	2,65	772	942	1630,0	1520,0
G32699	23,5	26,2	25,1	4,40	184	224	16,7	5,65
"	21,1	22,1	32,5	5,91	161	196	12,7	4,65
"	21,8	23,2	32,1	5,64	164	200	12,6	5,98
"	21,8	23,2	32,6	5,56	166	203	12,5	5,53
"	22,1	23,5	31,8	5,62	168	205	15,5	5,09
"	21,8	23,3	31,4	5,61	169	206	13,9	4,65
"	21,8	23,7	32,2	5,60	167	204	13,8	4,21
"	23,1	23,9	31,9	5,59	168	205	13,7	5,53
G32700	25,1	71,9	149,0	1,84	532	650	68,9	32,4
G32704	23,0	25,2	72,1	1,37	280	342	27,0	7,21
G32709	23,1	25,9	22,7	1,71	178	217	20,2	7,77
"	24,4	25,2	26,2	1,33	165	201	21,4	6,78
"	24,0	25,5	26,3	1,20	165	196	22,0	8,24
"	24,4	24,8	26,2	1,33	167	204	21,4	6,66
"	23,0	25,5	25,1	1,40	168	204	23,0	8,31
"	22,9	24,6	25,1	1,54	166	203	22,2	7,70
G32711	35,2	37,0	55,3	1,53	246	300	34,0	5,53
"	34,4	36,3	54,1	1,18	246	300	30,7	5,93
"	34,7	36,7	55,0	1,17	244	298	32,1	5,98

CONCENTRATIONS IN PPM

Sample	Si	NO_3	F	Cc (lab)	pH	(Field) Conductivity	T°C
Br1	33,5	1,56	1,42	404	8,0	390	23
T2811	40,6	12,0	0,84	943	7,9	910	23
T2809	13,2	1,28	1,24	467	7,9	425	20
T2878 B	39,1	17,0	0,95	417	7,8	540	27
Mp1	21,2	3,16	0,38	546	8,2	585	25
Mp15	31,6	31,0	0,35	871	8,1	845	23
Mp17	36,4	34,1	0,04	852	8,0	910	23
Mp27	38,6	20,5	1,25	1092	8,0	975	23
Mp34	30,3	25,6	1,41	780	8,0	715	25
G32694	15,5	0,03	0,38	562	7,9	680	22
G32695	11,4	0,03	0,51	483	8,2	520	22
G32697	30,7	0,98	1,13	5030	8,0	5070	24
"	32,4	1,29	0,71	5020	8,0	5200	24
"	32,2	1,19	0,64	5090	7,9	5040	21
"	32,3	1,09	0,63	5170	7,8	5135	23,5
"	32,2	1,22	0,67	5250	7,8	5070	22,5
"	32,3	0,90	0,66	5090	7,8	5200	24
G32699	39,2	2,03	1,51	281	7,5	260	24
"	40,1	2,20	1,02	264	7,1	288	–
"	41,9	2,17	0,96	268	7,3	259	23
"	42,3	2,22	0,95	270	7,1	256	24
"	42,6	2,22	0,88	266	7,1	256	22,5
"	42,7	2,24	1,02	269	7,0	272	26,5
"	42,4	2,19	1,03	271	7,0	256	22
"	42,2	2,28	1,04	269	7,1	259	26
G32700	16,4	0,00	0,25	776	8,2	715	24
G32704	33,9	2,30	1,24	375	8,3	385	24
G32709	24,1	0,54	1,02	272	7,5	260	24
"	25,6	0,83	0,88	272	7,3	245	23
"	25,8	0,83	0,77	268	7,4	275	25
"	25,9	0,75	0,90	270	7,3	260	24
"	27,4	0,75	0,86	272	7,3	265	24
"	28,1	0,84	0,90	267	7,2	244	22,5
G32711	37,8	2,87	1,32	399	7,5	387	24
"	38,2	2,84	1,19	420	7,6	368	22
"	38,5	2,66	1,16	368	7,6	384	23,5

CATIONS
CONCENTRATIONS IN MEQ/ℓ

Sample Location	Ca	Mg	Na	K	(Na+K)	Total Cations	Percentage composition Ca : Mg : Na+K
Brl	0,62	1,39	4,48	0,04	4,52	6,53	10 : 21 : 69
T2811	1,37	8,88	4,01	0,05	4,06	14,31	10 : 62 : 28
T2809	1,82	3,98	1,82	0,13	1,95	7,75	24 ; 51 : 25
T2787B	1,30	3,40	2,00	0,11	2,11	6,81	19 : 50 : 31
Mp1	1,00	6,50	1,86	0,01	1,87	9,37	11 : 69 : 20
Mp15	0,65	7,93	5,04	0,01	5,05	13,63	5 : 58 : 37
Mp17	2,51	6,62	3,13	0,02	3,15	12,28	20 : 54 : 26
Mp27	2,53	9,62	5,30	0,02	5,32	17,47	14,5 : 55 : 30,5
Mp34	2,53	4,22	4,20	0,02	4,22	10,97	23 : 38,5 : 38,5
G32694	2,79	5,98	1,08	0,02	1,10	9,87	28 : 61 : 11
G32695	2,65	5,39	0,57	0,03	0,60	8,64	31 : 62 : 7
G32697	4,83	36,02	53,04	0,03	53,07	93,92	5 : 38,5 : 56,5
"	4,63	37,58	52,61	0,03	52,64	94.85	5 : 40 : 55
"	4,61	37,58	51,30	0,03	51,33	93,52	5 : 40 : 55
"	5,14	39,14	52,17	0,03	52,20	96,48	5 : 41 : 54
"	4,98	38,90	53,04	0,07	53,11	96,99	5 : 40 : 55
"	4,58	37,58	51,74	0,07	51,81	93,97	5 : 40 : 55
G32699	1,17	2,15	1,09	0,11	1,20	4,52	26 : 47,5 : 26,5
	1,05	1,82	1,41	0,11	1,52	4,39	24 : 41,5 : 34,5
"	1,09	1,91	1,40	0,15	1,55	4,55	24 : 42 : 34
"	1,09	1,91	1,42	0,14	1,56	4,56	24 : 42 : 34
"	1,10	1,93	1,38	0,14	1,52	4,55	24 : 42,5 : 33,5
"	1,09	1,92	1,37	0,14	1,51	4,52	24 : 42,5 : 33,5
"	1,09	1,95	1,40	0,14	1,54	4,58	24 : 42,5 : 33,5
"	1,15	1,97	1,39	0,14	1,53	4,65	25 : 42 : 33
G32700	1,25	5,91	6,48	0,05	6,53	13,69	9 : 43 : 48
G32704	1,15	2,07	3,13	0,04	3,17	6,39	18 : 32 : 50
G32709	1,15	2,13	0,99	0,04	1,03	4,31	26,5 : 49,5 : 24
"	1,22	2,07	1,14	0,03	1,17	4,46	27 : 47 : 26
"	1,20	2,10	1,14	0,03	1,17	4,47	27 : 47 : 26
"	1,22	2,04	1,14	0,03	1,17	4,43	27,5 : 46 : 26,5
"	1,15	2,10	1,09	0,04	1,13	4,38	26 : 48 : 26
"	1,14	2,02	1,09	0,04	1,13	4,29	27 : 47 : 26
G32711	1,76	3,04	2,40	0,04	2,44	7,24	24 : 42 : 34
"	1,72	2,99	2,35	0,03	2,38	7,09	24 : 42 : 34
"	1,73	3,02	2,39	0,03	2,42	7,17	24 : 42 : 34

ANIONS
CONCENTRATIONS IN MEQ/ℓ

Sample Location	Cl	SO_4	HCO_3	Total anions	Percentage composition Cl		SO_4		HCO_3
Br1	0,41	0,35	5,64	6,40	6,5	:	5,5	:	88
T2811	4,85	0,64	7,67	13,16	37	:	5	:	58
T2809	1,50	0,16	5,67	7,33	21	:	2	:	77
T2787B	0,74	0,22	4,67	5,63	13	:	4	:	83
Mp1	0,60	0,33	7,62	8,55	7	:	4	:	89
Mp15	2,45	0,96	7,92	11,33	21,5	:	8,5	:	70
Mp17	4.62	0,56	4,74	9,92	46,5	:	5,5	:	48
Mp27	8,71	0,40	6,48	15,59	56	:	2,5	:	41,5
Mp34	1,42	0,57	9,20	11,19	13	:	5	:	82
G32694	1,58	0,37	7,72	9,67	16	:	4	:	80
G32695	1,08	0,21	7,15	8,44	13	:	2	:	85
G32697	43,4	31,9	15,6	90,9	48	:	35	:	17
"	44,6	31,4	15,4	91,4	49	:	34	:	17
"	46,0	32,1	15,2	93,3	49	:	35	:	16
"	46,8	32,3	15,2	94,3	50	:	34	:	16
"	47,7	32,9	15,1	95,7	50	:	34	:	16
"	46,0	31,7	15,4	93,1	49,5	:	34	:	16,5
G32699	0,47	0,12	3,67	4,26	11	:	3	:	86
"	0,36	0,10	3,21	3,67	10	:	3	:	87
"	0,36	0,12	3,28	3,76	10	:	3	:	87
"	0,35	0,12	3,33	3,80	9	:	3	:	88
"	0,44	0,11	3,36	3,91	11	:	3	:	86
"	0,39	0,10	3,38	3,87	10	:	2,5	:	87,5
"	0,39	0,09	3,34	3,82	10	:	3	:	87
"	0,39	0,12	3,36	3,87	10	:	3	:	87
G32700	1,94	0,67	10,7	13,31	14	:	5	:	80
G32704	0,76	0,15	5,61	6,52	12	:	2	:	86
G32709	0,57	0,16	3,56	4,29	13	:	4	:	83
"	0,60	0,14	3,30	4,04	15	:	3,5	:	81,5
"	0,62	0,17	3,25	4,04	15	:	4	:	81
"	0,60	0,14	3,34	4,08	14,5	:	3,5	:	82
"	0,65	0,17	3,34	4,16	16	:	4	:	80
"	0,63	0,16	3,33	4,12	15	:	4	:	81
G32711	0,96	0,12	4,92	6,00	16	:	2	:	82
"	0,87	0,12	4,92	5,91	15	:	2	:	83
"	0,91	0,12	4,88	5,91	15	:	2	:	83

RATIOS

No. on Map	Sampling Point	F/E.C.lab.x10[4] (ppm)	$Cl_{meq/l}$ / HCO_3 meq/l x100	Diff. cation - anions / Total cation + anions x 100
1	Brl	35,1	7	1,0
2	T2811	8,9	63	4,2
3	T2809	26,6	20	2,8
4	T2787B	22,8	16	7,2
5	Mp1	7,0	8	4,6
6	Mp15	4,0	31	7,1
7	Mp17	0,5	97	8,0
8	Mp27	11,4	134	5,0
9	Mp34	18,1	15	2,8
10	G32694	6,8	20	1,0
11	G32695	10,6	15	1,2
	G32697		278	1,6
	"		290	1,9
	"		303	0,1
	"		308	1,1
	"		316	0,7
12	"	1,3	299	0,5
13	G32699	54	13	3,0
	"		11	8,9
	"		11	9,5
	"		11	9,1
	"		13	7,6
	"		12	7,7
	"		12	9,0
	"		12	9,2
14	G32700	3,2	18	1,4
15	G32704	33	14	1,0
	G32709		16	0,2
	"		18	4,9
	"		19	5,1
	"		18	3,9
	"		19	2,6
16	"	34	19	2,0
17	G32711	33	20	9,4
	"		18	9,1
	"		19	9,6
X	G31542	8,3	3	3,9
Y	Ln24	7,4	75	1,3
Z	A6N534	27,6	6	3,0

No. on Map	Sampling Point	F ppm/Ec lab x 10^4 ppm	Cl meq/ℓ / HCO_3 meq/ℓ x100	Diff. cations-anions / total cations+anions x100
Sampling Point and Map No.				
M1		79,1	8	2,5
M2		85,2	6	1,8
M3		63,3	10	4,4
M4		70,3	11	3,3
M5		46,8	41	4,1
M6		48,9	34	3,7
M7		49,7	12	6,4
M8		56,1	12	1,9
M9		16,2	66	1,6
M10		44,6	16	3,7
M11		20,0	27	2,6
M12		32,6	19	2,0
M13		32,8	8	3,1
M14		26,2	16	2,4
A		10,1	15	2,0
B		23	5	2,0
D1		3,3	3	2,1
D3		2,1	4	4,4
D4		5,0	4	5,4
D5		6,1	5	4,3
D6		12,6	9	2,2
D7		12,4	9	3,5
D8		12,1	10	3,1
R1		58,8	15	2,1
R2		57,9	17	2,4
R3		50,3	27	2,7
R4		60,2	21	2,0
R5		22,9	19	2,0

APPENDIX 7

PUMPING TEST DATA

MACALACASKOP 243 KR
G32697 Pumped borehole
Start 0830,03.12.1980 Shutdown 1550, 03.12.1980
R.W.L. 5,327m Pump intake 22m. Pumping period 440 min.

Step	1	2	3	4	5	Recovery
ℓ/sec	5,73	8,22	10,40	12,83	17,30	0
Mins. elapsed					* 15,53	Residual
from start of step	Drawdown (m)					drawdown (m)
1	1,600	3,047	4,662	6,185	9,853	1,694
2	1,677	3,215	4,735	–	10,958	1,400
3	1,737	3,265	4,764	6,378	11,340	1,188
4	1,792	3,296	4,801	5,413	10,778	1,114
5	1,838	3,335	4,836	6,443	10,793	1,034
6	1,901	3,375	4,863	–	10,760	0,975
7	1,924	3,410	4,883	6,490	10,493	0,934
8	1,945	3,437	4,894	–	10,773	0,893
9	1,962	3,465	4,910	6,511	10,770	0,865
10	1,987	3,481	4,930	6,526	10,778	0,837
12	2,008	3,511	4,958	6,543	10,781	0,787
14	2,027	3,518	4,967	6,565	10,768	0,756
16	2,032	3,533	4,984	–	10,778	0,708
18	–	3,544	4,999	6,605	10,780	0,695
20	2,050	3,552	5,019	6,621	–	0,666
25	2,081	3,568	5,038	6,630	*10,778	
30	2,110	3,588	5,039	6,648	–	
35	2,117	3,615	5,054	6,668	–	
40	2,119	3,631	5,064	6,690	10,773	
45	2,121	3,628	5,087	6,695	Shutdown	
50	2,130	3,636	5,105	6,715		
55	2,141	3,633	5,111	6,722		
60	2,150	3,643	5,119	6,736		
70	2,158	3,653	5.128	6,745		
80	2,175	3,671	5,142	6,759		
90	2,187	3,688	5,161	6,774		
100	2,191	3,692	5,169	6,785		

* pumping rate reduced as pump sucking air

G32697 Pumped borehole
Start 0730, 08.12.1980. Shutdown 1430, 10.12.1980
RWL 5,340m Pump intake 22m
Discharge 11,36 ℓ/sec   Constant Pumping Period 3300 min.

Time elapsed (min)	s(m)
1	5,842
2	6,192
3	6,317
4	6,408
5	6,497
7	6,606
10	6,687
15	6,778
20	6,877
25	7,017
30	7,102
40	7,157
50	7,227
60	7,245
75	7,292
90	7,337
110	7,381
130	7,427
150	7,441
180	7,499
210	7,523
240	7,574
270	7,607
330	7,649
390	7,672
450	7,581
570	7,668
690	7,880
810	7,995
930	8,076
1110	8,172
1290	8,205
1470	8,211
1650	8,273
1830	8,296
2010	8,342
2370	8,469
2730	8,503
3090	8,415
3300	8,326

OBSERVATION BOREHOLES FOR G32697

	G32696 RWL 5,536m r=30m	G32698 RWL 6,435m r=30m
Time elapsed	s(m)	s(m)
1	0,076	0,066
2	0,125	0,115
3	0,151	0,143
4	0,175	0,175
5	0,191	0,193
7	0,229	0,228
10	0,260	0,271
15	0,311	0,322
20	0,321	0,353
25	0,339	0,376
30	0,359	0,395
40	0,387	0,411
50	0,416	0,448
60	0,426	0,510
75	0,444	0,528
90	0,464	0,540
110	0,493	0,568
130	0,512	0,591
150	0,528	0,626
180	0,556	0,624
210	0,565	0,642
240	0,593	0,672
270	0,616	0,665
330	0,646	0,697
390	0,673	0,726
450	0,701	0,745
570	0,751	0,793
690	0,796	0,888
810	0,830	0,985
930	0,858	0,925
1110	0,912	0,961
1290	0,947	0,990
1470	0,991	1,040
1650	1,025	1,089
1830	1,057	1,103
2010	1,077	1,134
2370	1,153	1,216
2730	1,199	1,268
3090	1,240	1,307
3300	1,257	1,335

G32700 RWL 12,784m r= 700m
no response throughout pumping period.

G32697 Pumped borehole
RWL 5,340m
P.W.L. 13,666m s=8,326m

t' (min)	t/t'	s' (m)	Recovery from F.D.P.W.L.(m)
10	331	1,437	6,889
15	221	1,411	6,915
20	166	1,352	6,974
25	133	1,313	7,013
30	111	1,284	7,042
40	83,5	1,228	7,098
50	67	1,184	7,142
60	56	1,148	7,178
75	45	1,105	7,221
90	37,7	1,061	7,260
110	31	1,013	7,313
130	26,4	0,971	7,355
150	23	0,936	7,390
180	19,3	0,894	7,432
210	16,7	0,862	7,464
240	14,8	0,668	7,658
270	13,2	0,643	7,683
330	11	0,596	7,730
390	9,5	0,557	7,769
450	8,3	0,528	7,798
570	6,8	0,498	7,828
690	5,8	0,421	7,905
810	5,1	0,397	7,929
930	4,6	0,369	7 957
1110	4,0	0,332	7,994
1290	3,6	0,314	8,012
1445	3,3	0,284	8,042

G32696
RWL 5,536m
PWL 6,793m s=1,257

G32698
RWL 6,435m
PWL 7,770m s=1,335m

t' (min)	t/t'	s' (m)	Recovery from FDPWL(m)	s' (m)	Recovery from FDPWL(m)
1	3301	1,180	0,077	1,280	0,055
2	1651	1,130	0,127	1,272	0,063
3	1101	1,107	0,150	1,207	0,128
4	826	1,084	0,173	1,183	0,152
5	661	1,057	0,200	1,156	0,179
7	472	1,024	0,233	1,116	0,219
10	331	0,997	0,260	1,076	0,259
15	221	0,959	0,298	1,035	0,300
20	166	0,933	0,324	1,002	0,333
25	133	0,918	0,339	0,987	0,348
30	111	0,902	0,355	0,966	0,369
40	83,5	0,886	0,371	0,944	0,391
50	67	0,866	0,391	0,917	0,418
60	56	0,853	0,404	0,902	0,433
75	45	0,832	0,425	0,865	0,470
90	37,7	0,815	0,442	0,856	0,479
110	31	0,796	0,461	0,829	0,506
130	26,4	0,775	0,482	0,803	0,532
150	23	0,748	0,509	0,784	0,551
180	19,3	0,733	0,524	0,748	0,597
210	16,7	0,708	0,549	0,711	0,614
240	14,8	0,679	0,578	0,694	0,641
270	13,2	0,667	0,590	0,640	0,695
330	11	0,636	0,621	0,590	0,745
390	9,5	0,611	0,646	0,568	0,767
450	8,3	0,575	0,682	-	- -
570	6,8	0,550	0,707	0,565	0,770
690	5,8	0,515	0,742	0,536	0,799
810	5,1	0,496	0,761	0,519	0,816
930	4,6	0,488	0,769	0,477	0,858
1110	4,0	0,448	0,809	0,457	0,878
1290	3,6	0,416	0,841	0,441	0,894
1445	3,3	0,393	0,864	0,424	0,911

TURFSPRUIT 241 KR
G32699 Pumped borehole
Start 0830, 24.02.1981 Shutdown 0830, 27.02.1981
RWL 8,114m Pump intake 18,3m
Discharge 1,29 ℓ/sec , constant pumping period 4320 min.

Time elapsed (min)	s (m)	Time elapsed (min)	s (m)
0,5	0,024	140	5,145
1,0	0,781	160	5,201
1,5	2,248	180	5,225
2	2,641	200	5,249
2,5	2,976	225	5,265
3	3,161	254	5,270
3,5	3,338	275	5,291
4	3,509	302	5,296
4,5	3,657	333	5,327
5	3,794	365	5,739
6	4,016	402	5,738
7	4,200	444	5,750
8	4,317	537	5,795
9	4,433	584	5,782
10	4,502	654	5,744
11,5	4,577	717	5,721
13	4,636	774	5,720
15	4,698	844	5,678
16,5	4,731	923	5,801
18	4,761	1020	5,898
20	4,795	1122	5,950
23	4,851	1247	5,966
26	4,878	1380	5,950
30	4,903	1503	5,942
35	5,005	1663	6,191
40	5,016	1806	6,214
45	5,055	2004	6,248
50	5,096	2229	6,222
60	5,170	2537	6,165
70	5,203	2716	6,365
80	5,231	3005	6,427
90	5,244	3300	6,625
100	5,249	3600	6,535
110	5,249	3980	6.549
125	5,198	4320	6,590

G32702 observation borehole for G2699
RWL 8,259m
r=30m

Time elapsed (min)	s (m)	Time elapsed (min)	s (m)
3	0,002	200	0,165
3,5	0,008	225	0,168
4	0,003	250	0,182
4,5	0,007	275	0,183
5	0,008	304	0,185
6	0,015	330	0,189
7	0,014	360	0,197
8	0,022	400	0,202
9	0,022	442	0,208
10	0,025	534	0,220
11,5	0,037	580	0,230
13	0,044	651	0,240
15	0,049	713	0,251
16,5	0,055	771	0,259
18	0,060	842	0,265
20	0,064	920	0,269
23	0,071	1017	0,270
26	0,081	1119	0,275
30	0,086	1245	0,283
35	0,087	1378	0,297
40	0,092	1500	0,295
45	0,097	1653	0,291
50	0,103	1802	0,281
60	0,113	2000	0,282
70	0,118	2226	0,303
80	0,125	2533	0,295
90	0,131	2713	0,307
100	0,131	3000	0,316
110	0,140	3300	0,293
125	0,144	3608	0,333
140	0,151	3978	0,305
160	0,153	4320	0,314
180	0,162		

G32699
RWL 8,114m
PWL 14,704m s=6,590m

G32702
RWL 8,259m
PWL 8,573m s=0,314m

t' (min)	t/t'	s' (m)	Recovery from F.D.P.W.L.	s' (m)	recovery from F.D.P.W.L.
1	4321			0,311	0,003
1,5	2881			0,313	0,001
2	2161			0,314	0,000
2,5	1729			0,313	0,001
3	1441			0,313	0,001
3,5	1235			0,311	0,003
4	1081			0,311	0,003
4,5	961			0,308	0,006
5	865			0,309	0,007
6	721			0,303	0,011
7	618			0,297	0,017
8	541			0,296	0,018
9	481			0,292	0,022
10	433			0,286	0,028
11,5	377	0,799	5,791	–	–
13	333	0,727	5,863	0,269	0,045
15	289	0,638	5,952	0,264	0,050
16,5	265	0,595	5,995	0,257	0,057
18	241	0,551	6,039	0,254	0,060
20	217	0,500	6,090	0,240	0,074
23	189	0,448	6,142	0,238	0,076
26	167	0,421	6,169	0,231	0,083
30	145	0,388	6,202	0,219	0,095
35	124	0,355	6,235	0,211	0,103
40	109	0,328	6,262	0,205	0,109
45	97	0,319	6,271	0,196	0,118
50	87,4	0,305	6,285	0,192	0,122
60	73	0,273	6,317	0,182	0,132
70	62,7	0,259	6,331	0,174	0,140
80	55	0,243	6,347	0,169	0,145
90	49	0,227	6,363	0,156	0,158
100	44,2	0,215	6,375	0,151	0,163
110	40,3	0,206	6,384	0,146	0,168
125	35,6	0,197	6,393	0,135	0,179
140	31,9	0,181	6,409	0,128	0,186
164	27,3	0,164	6,426	0,119	0,195
180	25,0	0,156	6,434	0,111	0,203
200	22,6	0,144	6,446	0,103	0,211
225	20,2	0,129	6,461	0,091	0,223
250	18,3	0,119	6,471	0,085	0,229
275	16,7	0,109	6,481	0,078	0,236
300	15,4	0,087	6,503	0,073	0,241

TURFSPRUIT 291 KR
G32709 Pumped borehole
Start 0600, 16.01.1981 Shutdown 1450.16.01.1981
RWL 8,782m Pump intake 33,5m Pumping period 530 min.

Time elapsed from start of step (min)	Total elapsed time (min)	s (m)	Step no.	Q
1	1	7,772	1	6,22ℓ/sec
2	2	9,336		
3	3	9,836		538 m³/d
4	4	9,980		
5	5	10,130		
6	6	10,238		
7	7	10,330		
8	8	10,399		
9	9	10,457		
10	10	10,508		
12	12	10,555		
14	14	10,600		
16	16	10,642		
18	18	10,677		
20	20	10,716		
27	27	10,771		
30	30	10,785		
35	35	10,806		
40	40	10,830		
45	45	10,841		
50	50	10,851		
55	53	10,861		
63	63	10,873		
80	80	10,890		
90	90	10,904		
100	100	10,900		
1	101	12,526	2	7,30ℓ/sec
4,5	104,5	13,017		
6	106	13,038		631m³/d
8	108	13,065		
10	110	13,083		
13	113	13,242		
16	116	13,263		
18,5	118,5	13,275		
20	120	13,278		
28	128	13,296		
40	140	13,308		
55	155	13,312		
75	175	13,312		
80	180	13,312		

Time elapsed from start of step(min)	Total elapsed time (min)	s (m)	Step No.	Q
1	181	15,648	3	8,68 ℓ/sec
2	182	16,136		
3	183	16,266		751m³/d
5	185	16,357		
7,5	187,5	16,420		
10	190	16,440		
12,5	192,5	16,471		
15	195	16,475		
23	203	16,502		
30	210	16,520		
40	220	16,526		
50	230	16,531		
65	245	16,522		
90	270	16,532		
1,5	271,5	18,490	4	9,63 ℓ/sec
3	273	18,666		
4	274	18,829		
5,5	275,5	18,870		833m³/d
7	277	18,897		
10	280	18,908		
12,5	282,5	18,930		
15	285	18,934		
25	295	18,934		
41	311	18,975		
55	325	18,975		
70	340	18,995		
85	355	18,992		
105	375	18,951		
1,5	376,5	21,269	5	10,68ℓ/sec
3	378	21,700		
4	379	21,793		924 m³/d
7	382	21,867		
9	384	21,888		
13,5	388,5	21,940		
16	391	21,945		
25	400	21,965		
40	415	21,977		
75	450	21,975		
85	460	22,000		
1	461	no water level measurements possible	6	11,80 ℓ/sec
70	530			1020m³/d

G32709 Pumped borehole.
RWL 8,782m
PWL not known

t' (min)	t/t'	s' (m)
1	531	7,763
3	178	3,306
4	133,5	2,557
5	107	2,134
6	89	1,814
8	67	1,415
9	60	1,238
10	54	1,080
13	42	0,808
15	36	0,690
17	32	0,608
20	27,5	0,514
27,5	20	0,384
35	16	0,328
41	14	0,298
54	11	0,257
70	8,6	0,232
90	6,9	0,194

G32709 Pumped borehole
Start 0800, 28.01.1981 Shutdown 0600 , 31.01.1981
RWL 8,463m Pump intake 33,5m
Discharge 9,82 ℓ/sec Pumping period 4200 min.

Time elapsed (min)	s (m)
5	16,713
6,5	17,056
8	17,279
10	17,486
13	17,689
16	17,821
20	17,938
28	18,081
30	18,112
40	18,192
50	18,249
65	18,305
80	18,352
100	18,339
135	18,399
167	18,392
208	18,428
245	18,428
295	18,481
365	18,510
465	18,761
577	18,727
600	18,785
758	18,746
825	18,718
990	18,764
1210	18,742
1510	18,667
1775	18,688
1915	18,657
2410	18,716
2900	18,752
3460	18,949
4200	16,659

Lv

	G32701 RWL 8,281m r=30m	G32710 RWL 8,830m r=30m
Time elapsed (min)	s (m)	s (m)
1	0,809	0,000
1,5	1,149	"
2	1,528	"
2,5	1,780	"
3	2,008	"
3,5	-	0,033
4	2,249	0,064
5	2,379	0,137
6,5	2,487	0,234
8	2,667	0,322
10	2,834	0,407
13	3,006	0,517
16	3,107	0,576
20	3,179	0,657
25	3,247	0,707
30	3,287	0,750
40	3,323	0,799
50	3,360	0,826
65	3,384	0,845
80	3,404	0,865
100	3,411	0,876
130	-	0,891
138	3,449	-
162	3,461	0,900
204	3,479	0,910
245	3,493	0,915
290	3,512	0,922
360	3,530	0,933
460	3,588	0,966
600	3,618	0,981
755	3,625	0,990
980	3,641	0,997
1200	3,657	1,008
1500	3,666	1,029
1770	3,672	1,030
1910	3,673	1,038
2400	3,694	1,076
2855	3,719	1,081
3452	3,745	1,090
4200	3,711	1,103

G32709 Pumped borehole
RWL 8,463m
PWL 25,122m s=16,659m

t' (min)	t/t'	s' (m)	Recovery from FDPWL(m)
1	4201	1,763	14,896
6,5	647	1,243	15,416
8	526	1,106	15,553
10	421	0,974	15,685
13	324	0,835	15,824
16	263,5	0,740	15,919
20	211	0,655	16,004
25	169	0,592	16,067
30	141	0,550	16,109
40	106	0,505	16,154
50	85	0,470	16,189
65	65,6	0,447	16,212
80	53,5	0,425	16,234
101	42,6	0,397	16,262
130	33,3	0,369	16,290
166	26,3	0,341	16,318
204	21,6	0,317	16,342
244	18,2	0,298	16,361
406	11,3	0,231	16,428
510	9,2	0,200	16,459
607	7,9	0,175	16,484
798	6,3	0,145	16,514
906	5,6	0,134	16,525

		G32701 RWL 8,281m PWL 11,992m s=3,711m		G32710 RWL 8,830m PWL 9,933m s=1,103m	
t' (min)	t/t'	s' (m)	Recovery from FDPWL	s' (m)	Recovery from FDPWL
1	4201	2,759	0,952	-	-
2,5	1681	-	-	1,170	(+)0,067
3	1401	1,510	2,201	1,029	0,074
4	1051	1,309	2,402	0,908	0,195
5	841	1,219	2,492	0,853	0,250
6,5	647	1,077	2,634	0,776	0,327
8	526	0,974	2,737	0,694	0,409
10	421	0,860	2,851	0,604	0,499
13	342	0.734	2,977	0,523	0,580
16	264	0,658	3,053	0,475	0,628
20	211	0,578	3,133	0,410	0,693
25	169	0,532	3,179	0,362	0,741
30	141	0,504	3,207	0,313	0,790
40	106	0,470	3,241	0,273	0,830
50	85	0,440	3,271	0,240	0,863
65	65,6	0,417	3,294	0,221	0,882
80	53,5	0,396	3,315	0,214	0,889
100	42,6	0,377	3,334	0,199	0,904
130	33,3	0,352	3,359	0,188	0,915
160	27,3	0,349	3,362	0,176	0,927
200	22,0	0,319	3,392	0,163	0,940
240	18,6	0,299	3,412	0,147	0,956
400	11,5	0,205	3,506	0,110	0,993
500	9,4	0,205	3,506	0,088	1,015
600	8	0,182	3,529	0,073	1,030
790	6,3	0,155	3,556	0,062	1,041
900	5,7	0,134	3,577	0,060	1,043

TURFSPRUIT 241 KR

G32711 Pumped borehole
Start 0745 11.02.1981 Shutdown 1200 12.02.1981
RWL 1,536m Pump intake 26m
Discharge 12,22 ℓ/sec declining to 11,24 ℓ/sec at cessation pf pumping.

Pumping period 1695 min.

Time elapsed (min)	s (m)
0,25	3,134
1	7,141
1,5	7,911
2	8,071
2,5	8,215
3	8,370
3,5	8,579
4	8,792
5	9,039
6,5	11,160
8	11,195
10	12,732*(?)
12	13,003 (?)
14	13,091 (?)

* measurement discontinued after water level lowered into well screen due to erratic voltmeter readings (turbulence ?)

G32?11 - Discharge measurements

Average pumping rate taken as 11,55 ℓ/sec
Assuming discharge rate for the first 1000 minutes is 11,75 ℓ/sec
and that for the final 695 minutes is 11,24 ℓ/sec

Tank capacity 0,791m³

Time elapsed (min)	Q ℓ/sec
38	12,23
53	12,23
72	12,04
103	11,99
146	12,15
224	11,84
274	11,75
304	11,81
366	11,81
444	11,65
455	11,81*
561	11,56
584	11,56
592	11,86 *
643	11,68
651	12,03 *
704	11,81
764	11,72
802	11,93*
843	11,97
918	11,81
1011	11,76
1117	11,70
1208	11,68*
1217	11,22
1224	11,70*
1268	11,09*
1304	11,35
1345	11,21
1403	11,32
1465	11,10
1511	11,28
1575	11,38
1695	11,24

* Pump setting adjusted

G32712 Observation borehole for G32711
RWL 1,518m
r = 30,35m

Time elapsed (min)	s (m)	Time elapsed (min)	s (m)
1	0,029	100	0,442
1,7	0,042	120	0,464
2,15	0,068	140	0,481
2,65	0,086	160	0,505
3,15	0,100	180	0,523
4,15	0,128	200	0,538
4,50	0,141	220	0,551
5,15	0,147	240	0,568
6,5	0,175	270	0,591
8	0,188	300	0,611
10	0,221	330	0,631
12	0,243	360	0,650
14	0,259	400	0,673
16	0,268	440	0,696
18	0,281	480	0,715
20	0,293	530	0,723
23	0,303	580	0,785
26	0,304	700	0,812
30	0,323	760	0,834
35	0,335	840	0,863
40	0,345	920	0,885
45	0,356	1008	0,907
50	0,367	1113	0,932
55	0,378	1200	0,950
60	0,385	1300	0,968
68	0,398	1400	0,986
76	0,410	1550	1,005
84	0,423	1695	1,039
92	0,432		

G32707 Observation borehole for G32711
RWL 4,015m
r=140,5m

Time elapsed (min)	s (m)	Time elapsed (min)	s (m)
20	0,007	640	0,056
30	0,007	700	0,064
40	0,011	774	0,069
50	0,011	860	0,078
84	0,017	920	0,085
125	0,019	1007	0,089
200	0,021	1100	0,095
300	0,027	1202	0,104
400	0,035	1300	0,111
444	0,040	1400	0,115
480	0,042	1557	0,127
538	0,045	1695	0,141
580	0,048		

G32708
RWL 7,146m
R=440m

no response throughout pumping period.

t' (min)	t/t'	G32711 RWL 1,536m s' (m)	G32712 RWL 1,518m PWL 2,557m s=1,039m s' (m)	Recovery from F.D.P.W.L.(m)
1	1696	11,124	1,027	0,012
2	849	7,287	1,014	0,025
3	566	4,927	0,990	0,049
4	425	2,793	0,962	0,077
5	340	2,260	0,939	0,100
6	284	1,968	0,916	0,123
7	243	1,843	0,903	0,136
8	213	1,767	0,888	0,151
9	189	1,707	0,876	0,163
10	171	1,663	0,866	0,173
12	142	1,627	0,854	0,185
14	122	1,508	0,839	0,200
16	107	1,465	0,832	0,207
18	95,2	1,417	0,820	0,219
20	85,8	1,372	0,812	0,227
25	68,8	1,275	0,796	0,243
30	57,5	1,231	0,779	0,260
35	49,4	1,167	0,768	0,271
40	43,4	1,127	0,757	0,282
45	38,7	1,100	0,746	0,293
50	34,9	1,065	0,735	0,304
55	31,8	1,037	0,724	0,315
60	29,3	1,018	0,716	0,323
70	25,2	0,977	0,702	0,337
80	22,2	0,939	0,686	0,353
90	19,8	0,918	0,673	0,366
100	18,0	0,882	0,660	0,379
205	13,8	0,835	0,634	0,405
204	9,3	0,527	0,602	0,437
240	8,0	0,464	0,399	0,640
290	6,8	0,343	0,324	0,715
360	5,7	0,249	0,270	0,769
460	4,7	0,181	0,214	0,825
1160	2,5	(-0,061)	(-0,020)	(1,059)

G32707

RWL 4,015m
PWL 4,156m s=0,141m

t' (min)	t/t'	s' (m)	Recovery from FDPWL (m)
1	1696	0,140	0,001
2	894	0,135	0,006
3	566	0,135	0,006
4	425	0,134	0,007
5	340	0,132	0,009
6	284	0,132	0,009
7	243	0,132	0,009
8	213	0,131	0,010
9	189	0,131	0,010
10	171	0,130	0,011
12	142	0,127	0,014
14	122	0,126	0,015
16	107	0,124	0,017
18	95,2	0,124	0,017
20	85,8	0,122	0,019
25	68,8	0,122	0,019
30	57,7	0,122	0,019
35	49,4	0,121	0,020
40	43,4	0,121	0,020
45	38,7	0,121	0,020
50	34,9	0,121	0,020
55	31,8	0,120	0,021
60	29,3	0,117	0,024
70	25,2	0,117	0,025
80	22,2	0,116	0,025
90	19,8	0,116	0,025
100	18	0,116	0,025
130	14	0,116	0,025
160	12	0,114	0,027
200	9,5	0,099	0,042
240	8,1	0 087	0,054
290	6,8	0,076	0,065
375	5,5	0,073	0,068
1166	2,5	(-0,023)	(0,164)