

GROUND WATER IN THE ROCKS OF THE PRETORIA AREA

BY

T.S. KOK

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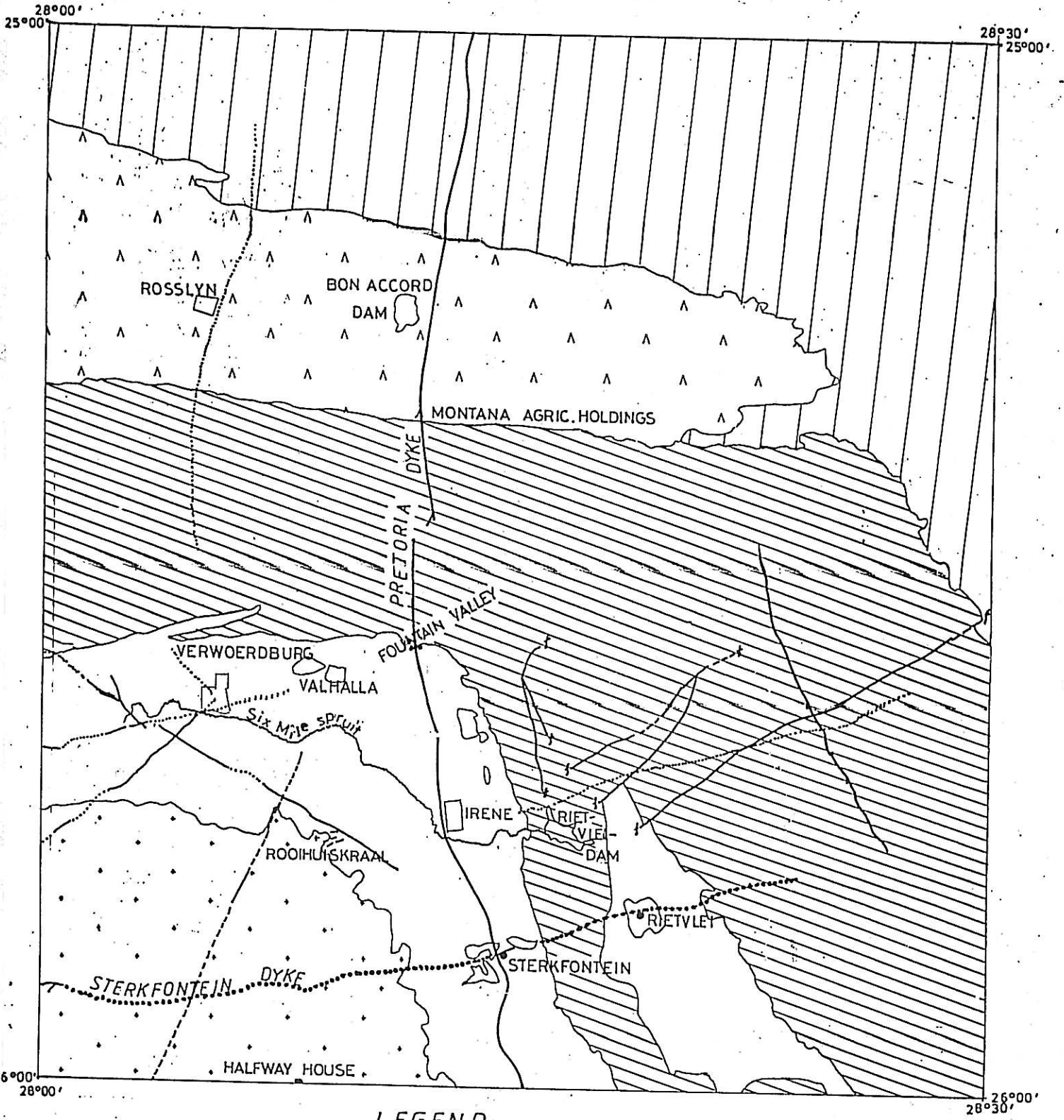
A. INTRODUCTION

It is generally accepted amongst the ground water fraternity that approximately 88 per cent of the ground water in SA occur in secondary aquifers, that is, in faults, fractures, contact planes, basins of decomposition and cavities. The other 12 per cent occur in primary aquifers consisting of unconsolidated Kalahari sediments (about 10 per cent) as well as coastal dunes and river alluvium.






In the Pretoria area, only secondary water-bearing structures occur. This area stretches from Halfway House in the south to just north of Bon Accord in the north.

Because of the difference in composition and modes of weathering of these rocks, their hydrogeological characteristics, and therefor their water-bearing and storing capacities, differ widely and this is clearly illustrated by drilling results which will be shown for every formation.

FIG. 1 SIMPLIFIED GEOLOGY of PRETORIA AREA



LEGEND

-  KAROO and other
-  NOVITE
-  PRETORIA GROUP
-  DOLOMITE
-  GRANITE

SCALE: 0 1 2 4 6 8 km

PRETORIA DYKE

STERKFONTEIN DYKE

Shales of the Eccca Group occur as outliers, mostly on the dolomite, but is of no significance as a water-bearing formation.

B. OCCURRENCE AND DEVELOPMENT

Refer to Fig. 1

1. The Halfway House granite

Constitutes the largest part of the northerly-draining catchment of the Crocodile River and its tributaries.

The main structural features which are important to ground water occurrence are shown on Fig. 1.

These are the north-east trending lineaments and fractures as well as several magnetic anomalies representing most probably diabase dykes.

Table 1 - Results of boreholes in the granite

Average total depth drilled	40 m
Average depth at which water was struck	28 m
Average depth to rest water level	14 m
Average yield	0,8 l/s
Percentage of failures (less than 0,1 l/s)	35%

None of the holes drilled deeper than 100 m penetrated any water-bearing structures.

These holes are situated on farms, small holdings and on erven in suburbs where their water is utilized for domestic, gardening and stock-watering purposes in the absence of, or additional to Rand Water Board supplies.

2. The dolomite

Follows unconformably on the Halfway House granite and outcrops (including the Black Reef Formation) mostly in the Verwoerdburg area between Rooihuiskraal and the Fountains Valley.

All four formations are represented, the chest-rich Eccles and Monte Christo being considered to be the best aquifers in SA, mainly because of -

- (a) It's high water-yielding capacity (100 l/s and more from boreholes);
- (b) it's high storage capacity (6 per cent in the Rietvlei dolomite); and
- (c) it's high recharge potential (10 to 20 per cent of the average annual rainfall).

Pretoria was founded on the dolomitic springs of the Fountains Valley where an eastern and western eye appear on both sides of the Pretoria dyke where it penetrates the more impervious Timeball Hill shales.

Other springs and boreholes also contribute to Pretoria's Water Supply.

Table 2 - Pretoria's dolomitic water supply

Two Fountain springs	305 l/s
Sterkfontein	75 "
Rietvlei springs	110 "
Rietvlei boreholes	360 "
Erasmia boreholes	100 "
Valhalla boreholes	<u>90</u> "
Total	1 040 l/s

This amounts to about 30 per cent of the city's water needs and make quite a difference to the eventual cost of water when compared to that of the Rand Water Board.

In addition to it's Rand Water Boards supply, Verwoerdburg also draws about 28 per cent of it's water needs from two boreholes in the Monte Christo Formation in the military area just north of the Six Mile Spruit.

During the drought period of the eighties when the Vaal Dam was down to 15 per cent of full capacity, the water-bearing possibilities of the Rietvlei, Verwoerdburg, Valhalla and Erasmia areas were explored by Geohydrology in order to prove additional water supplies for Pretoria and Verwoerdburg.

It was found that the Pretoria, Sterkfontein and other impervious

dykes and sills act as boundaries to the water-bearing dolomitic compartments, thereby controlling the movements of ground water in them and resulting in differences in water levels on either side of dykes.

These investigations also showed that the best results are obtained by drilling on or near gravity lows.

This is illustrated in Table 2 below in which privately selected boreholes are compared with those of boreholes selected by Geohydrology on gravity lows.

Table 3

Comparison of results of dolomitic borehole drilling in the Verwoerdburg area

Boreholes selected by Geohydrology		Census of boreholes not selected by Geohydrology		
Borehole No.	Tested yield ℓ/s	Suburb	Number of boreholes	Average pumping yield (ℓ/s)
G37818A	20	Doornkloof	18	0,6
G37819C	20	Clubview	29	1,6
G37820	35	The Reeds	68	0,8
G37821	45	Hennop's Park	7	0,9
G37823	35	Lyttleton	31	0,5
G37829A	88	Eldoraigue	49	1,1
G37831	70	Celtisdal	3	0,4
G37832	100	Rooihuiskraal	38	0,8
G37836	90	Bronberik	18	1,6
G37840	88	Pierre van Ryneveld	21	0,7
G37838	82	Irene	4	0,1
G37842	90	Wierda Park	52	0,8

752800 78

77

80

81

82

252800 16

18

19

23

252800 83

252800 26

29

3. The Rooihoogte and Timeball Hill Formations

Rooihoogte Formation consists mostly of very impervious unfractured shales and is not considered to be a water-bearer of any consequence. There are also no records of boreholes drilled into it.

The shales and magnetic quartzites of the Timeball Hill Formation have been explored for additional gardening water supplies in the Waterkloof, Groenkloof, Muckleneuk Hill and Iscor areas.

Pumping tests on boreholes selected by Geohydrology at the Pretoria Country Club and Unisa have shown that these sediments have secondary aquifer characteristics in that water is encountered in boreholes in fractures, joints and contact planes down to depths of 120 m. Yields from boreholes are generally low and ranges between 0,05 and 1 l/s, which is explained by the low transmissivity of $50 \text{ m}^2/\text{d}$ and storage coefficient of $0,02$ per cent obtained at pumping tests at the Country Club.

4. The Hekpoort andesite

Occupies large tracts of the central Pretoria, Arcadia, Menlo Park, Lynnwood and Faerie Glen areas. The upper weathered part (10 - 30 m) is clayey and very impervious ($k > 1 \times 10^6 \text{ cm/s}$). However, the fractured part below the weathering does store and yield water from boreholes drilled in the vicinity of faults, fractures and at the contacts with the over-lying Strubenkop shales and the underlying Timeball Hill shales.

which secondary aquifer conditions occur, sometimes resulting in high-yielding boreholes when correctly sited. The quartzites build the Magaliesberg Range where ground water in boreholes occurs in fractures and contacts with diabase sills at the foot of the northern slope of the mountain.

Results of drilling at Eersterus and Mamelodi by Geohydrology and a census of private boreholes by the Pretoria Municipality, are shown in Table 5.

Table 5

Drilling results in the Silverton shales and Magaliesberg quartzite

Depth drilled (range)	60 - 100 m
Depth water struck (range)	30 - 50 m
Water level depth range	20 - 50 m
Yield range	0,1 - 7 l/s
TDS range	70 - 240 mg/l
pH range	6,5 - 7,4
Weathering depth range	20 - 60 m

No pumping tests were carried out in water boreholes in these sediments to determine T & S values, but it is assumed that it would be very much the same as the values determined for the Strubenkop shales and Daspoort Quartzite shown in Table 4.

7. The norite and gabbro rocks

These basic rocks of the Bushveld Igneous Complex occur in an east-west belt about 8 km wide north of the Magaliesberg Mountains from Rosslyn in the west to Montana Smallholdings in the east. These

Borehole yields range from 0,05 to 2 l/s, but can deteriorate due to poor recharge conditions through the impervious weathered vadose zone.

5. The Strubenkop shales and Daspoort quartzite

Occupy the northern part of the valley stretching east and west of Pretoria from the CSIR in the east, past Colbyn, Brynterion, the Pretoria Zoo area to the military testing grounds north of Attridgeville in the west. These rocks are intruded by diabase sills and syenite dykes and their contacts, together with faults and fractures across the east-west strike, result in secondary aquifer conditions, giving rise to successful correctly selected boreholes.

Geological and geophysical investigations and exploration drilling at the CSIR, the Botanical Research Institute, the Presidency, the Union Buildings and the Rietondale Grass Research Station by the Ground Water Division of the Geological Survey resulted in the data in Table 4 below:

Depth drilled (range)	60 - 160 m
Depth water struck (range)	30 - 50 m
Water level depth range	20 - 50 m
Yield range	0,1 - 7 l/s
Transmissivity range	57 - 190 m ² /d
Storage coefficient	0,02 - 0,1
TDS range	70 - 240 mg/l
pH range	6,5 - 7 - 4
Weathering depth range	20 - 80 m

6. The Silverton shales and Magaliesberg Quartzite

The shales occupy die Moot Valley where they are intruded by east-west striking northdipping diabase sills, at the contacts of

rocks weather to a clayey mass which in places like Wonderboom, Bon Accord and Onderstepoort is represented by the well-known black turf.

The ground water section of the Geological Survey did considerable geophysical investigations (mainly electrical depthprobes and using the Wenner interpretation) for borehole site selection in the norites in the abovementioned areas. A success-rate of 75 per cent was recorded with boreholes yielding from 0,1 to 4 l/s.

Table 5 - Drilling results in the norites and gabbros

Average depth drilled	50 m
Average depth water struck	40 m
Average water level depth	30 m
Average yield	2 l/s
Percentage holes exceeding 100 m depth	1
Number holes yielding water beyond 100 m	none

C. Water quality

The quality of ground water from boreholes and springs in the Pretoria area is rarely a problem. Quality factors of most significance are potability, hardness and acidity.

Table 7 - Average concentrations in Pretoria area ground waters

Formation	Fluoride mg/l	Nitrate mg/l	TDS mg/l	Hardness as CaCO ₃ mg/l	pH
Halfway House granite	-	1	112	30	7,7
Dolomite springs	-	3	210	204	7,6
Dolomite borholes	0,1	-	215	181	7,1
All the quartzites	-	-	73	53	6,9
Timeball Hill shales	0,1	-	173	114	7,5
Strubenkop shales	0,2	1	100	68	7,4
Hekpoort andesite	0,2	-	209	50	7,5
Silverton shales	0,1	3,1	283	183	7,3
Norite	0,2	7,9	325	162	7,4

Table 7 shows that the fluoride content is far below the maximum allowable value of 1,5 mg/l and that dangerous nitrate pollution is unlikely in these waters (maximum concentration allowed is 45 mg/l). Even the total dissolved solids concentration is far below that of the potable limit of 2 000 mg/l.

Hardness is of more concern to the users of industrial water, as it causes an increase in the use of detergents and the deposition of scale in pipes, boilers and kettles. Table 7 shows that dolomite and Silverton shale waters have the highest hardness concentration, whereas Strubenkop shales and all the quartzite waters have the least.

In dolomite, Timeball Hill shales, quartzite and norite, hardness is mostly or entirely of a temporary nature, whereas in Strubenkop shales, Hekpoort andesite and Silverton shales it is mainly permanent.

The only slightly acidic waters are those in the Strubenkop shales and the quartzites.

D. Waste disposal sites

There are eleven waste disposal sites in the Pretoria area. Two of these, Irene and Kirkness, are closed down, the one at Chloorkop is about to receive toxic and non-toxic waste and the one at Rosslyn, although approved, is not yet in use by the Pretoria Municipality. The site at Bon Accord is still under investigation regarding ground water occurrence at and in the vicinity of the site in order to make a permit application. See Table 8.

Table 8 - Waste disposal sites in the Pretoria area

Site	Permit holder	Classification	Underlying formation	Pollution risk
Chloorkop	Waste Tech	Toxic	Halfway House granite	Negligible
Clayville	Waste Tech	Non-toxic	Ecca shales on dolomite	Negligible
Irene	Verwoerdburg	Non-toxic	Lyttleton dolomite	Negligible
Wingate Park	Pretoria Municipality	Non-toxic	Dolomite in graben	Doubtfull
Valhalla	Pretoria Municipality	Non-toxic	Lyttleton dolomite	Negligible
Quaggasrand	Pretoria Municipality	Non-toxic	Eccles dolomite	Doubtfull
Kirkness	Pretoria Municipality	Non-toxic	Timeball Hill shales on dolomite	Doubtfull
Pretoria North	Pretoria Municipality	Non-toxic	Weathered quartzite	Doubtfull

Site	Permit holder	Classification	Underlying formation	Pollution risk
Rosslyn	Pretoria Municipality	Non-toxic	Weathered norite	Negligible
Eersterus	Pretoria Municipality	Non-toxic	Diabase silt in Silverton shales	Negligible
Bon Accord	Mini waste	Toxic	Norite	Doubtfull

According to Act 73 of 1989, all solid waste disposal sites must have a permit, issued by the Department of Water Affairs. This Act makes provision for the prevention of ground water pollution by leachate from these waste disposal sites, which are classified according to the type of waste disposed of into two classes, namely, non-toxic waste, which consists of general urban waste and toxic waste which contain hazardous materials which are harmful to the environment.

The necessary investigations for ground water occurrences are carried out by ground water consultants under the supervision of the Directorate of Geohydrology, whose responsibility it is to approve or otherwise all applications from a ground water point of view.

All the sites in Table 8 indicated as doubtful under the heading of pollution risk, must still be investigated by ground water consultants before the issuing of permits can be considered.

E. Conclusion

Table 9 gives a summary of the hydrogeological characteristics of the rocks of the Pretoria area and are dealt with below:

1. Outcrop areas

Indicate the best-known places or suburbs where the particular formation crops out, or where it is indicated on the geological map, especially in built-up areas.

2. Water use

This varies considerably. In the suburbs about 50 per cent of the erven have boreholes which are used for garden-watering. On the small holdings surrounding Pretoria, Akasia, Verwoerdburg and Midrand, only borehole water is used for domestic, stock-watering and sometimes for gardening purposes.

Approximately 30 percent of the water supply of Verwoerdburg and Pretoria is derived from boreholes and springs in the dolomite.

3. Water strike depth

This depends on the water-bearing openings below the rest water level which are penetrated in the borehole. In the dolomite, cavities yielding water were penetrated at depths of 150 m below surface.

4. Water level depth

This depends on the topography and fluctuates because of draw-down by abstraction and a rise due to recharge.

Recharge in the Halfway House granite, the Pretoria Group sediments

and the norite is of the order of 5 per cent of the average annual rainfall, whereas in the dolomite, it varies between 10 and 15 per cent. See Fig. 2 for an illustration of recharge and abstraction in a fault zone in Pretoria Group sediments at the Rietondale Grass Research station.

5. Yield

Most of the boreholes selected on favourable sites in these rocks can yield from 1 to 7 l/s. Outstanding yields of 100 l/s and more are only derived from boreholes in the chert-rich Eccles and Monte Christo dolomite from which Pretoria and Verwoerdburg obtain their ground water supplies.

6. TDS concentration -

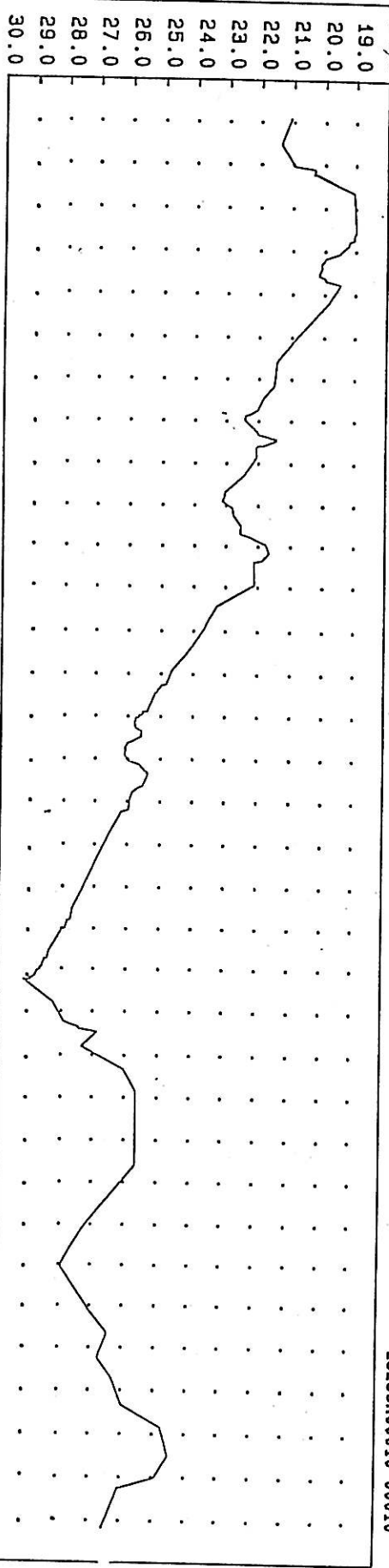
The highest concentrations are in the dolomite (590 mg/l, which is most probably due to pollution from the Six Mile Spruit south of the Rievlei Dam). Normally however, TDS concentrations of dolomite waters vary around 200 mg/l. Even the highest concentrations in the Hekpoort andesite (220 mg/l), the Silverton shales (310 mg/l), the norite (350 mg/l) and the Halfway House granite (210 mg/l), are far below the limit of potability of 2 000 mg/l.

7. k, S and T values -

These are determined from pumping and slug tests, amongst others.

WATER LEVEL [m below surface]

2528CA00010 00010



Monthly RAINFALL [mm]

000513/404A

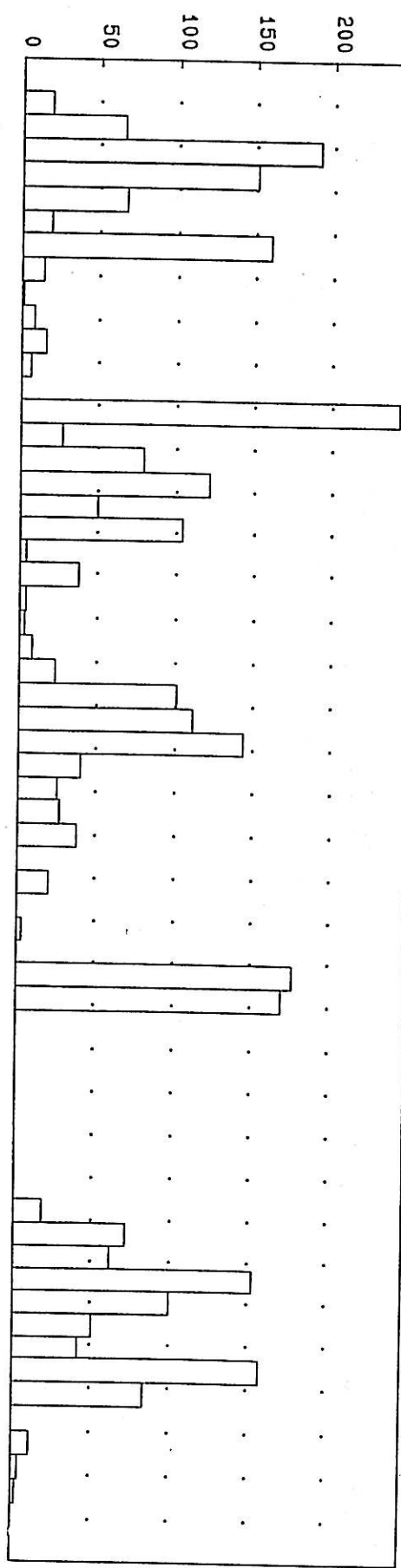


FIG. 2 - WATERLEVEL AND RAINFALL FLUCTUATIONS IN BOREHOLE A2N524 IN FAULT ZONE IN SHALE AT RIETONDALE, PRETORIA. AVERAGE ANNUAL RAINFALL = 690mm

Although there is doubt and speculation about the reliability of these values, especially in secondary aquifers, it is at least a means of comparison between the water-bearing capabilities of the rocks.

Again, in this respect the dolomite values are outstanding and indicate the superior water-bearing qualities of the chert-rich Eccles and Monte Christo dolomite.

Table 9 - Hydrogeological characteristics of the rock formations in the Pretoria area

Group, formation and lithology	Outcrop areas	Water use	Water strike depth range m	Water level level depth m	Yield range l/s	TDS range mg/l	Weathering K ₁₅ depth zone cm/s	S %	T m ² /d
Gabbro, norite	Rosslyn, Bon Accord, Montana	Smallholdings gardening water supply	20 - 60	20 - 40	0,1 - 4	300 - 330	20 - 50	Not determined	Not determined
Rayton shales, quartzite	Not present	Not applicable	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Magaliesberg quartzite	Magaliesberg range	Gardening and Smallholdings Water supply	30 - 50	20 - 50	0,1 - 4	60 - 80	20 - 60	Not determined	Not determined
Silverton shales	Die Moot Valley	Ditto	20 - 50	20 - 50	0,1 - 7	220 - 310	20 - 60	Not determined	Not determined
Daspoort quartzite	Meintjieskop and Daspoort tunnel areas	Ditto	30 - 50	20 - 50	0,1 - 4	60 - 80	20 - 80	Not determined	Not determined
Strubenkop shales	Constantia Park Colbyn Brynterion	Ditto	30 - 50	20 - 50	0,1 - 7	70 - 130	20 - 60	0,02	57 - 190
Hekpoort andesite	Central Pretoria	Ditto	30 - 50	20 - 40	0,05 - 2	190 - 220	10 - 30	Not determined	Not determined
Timeball Hill shales, quartzite en Rooihoogte shales, breccia	Waterkloof Groenkloof Iskor	Ditto	40 - 120	40 - 100	0,05 - 1	70 - 240	10 - 40	0,02	50
Dolomite & Black Reef quartzite	Verwoerdburg Rietvlei	Smallholding and Municipal Water Supply	0 - 150	0 - 100	1 - 180	220 - 590	20 - 150	10	180 - 13 000
Halfway House granite	South of Rooihuiskraal	Smallholding and Gardening Water Supply	20 - 40	10 - 20	- 1	110 - 210	10 - 40	Not determined	Not determined

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TITLE Ground water in the rocks of the Pretoria area

AUTHOR/AFFILIATION: T. S. KOK

LOCALITY: 2528

Refer to 1:50000 or 1:250000 map. ex. 2528CD

DRAINAGE: A, B & C

GH-PLANS: —

	KEYWORD	EQUIVALENT TERMS
	GAQ []	AQUIFER groundwater system, groundwater resource, storage parameters, characteristics, porosity, permeability
	GBC []	BOREHOLE CONSTRUCTION wellpoints, casing, screens, gravelpack
	GCO []	COMPUTER burroughs, pc
X	GDO []	DOLOMITE limestone, karst, carbonate
X	GDR []	DRILLING drilling machines, augering,
	GEO []	GEOLOGY
	GGP []	GEOPHYSICS magnetic, gravity, seismic, electrical, electromagnetic
	GIG []	IGNEOUS metamorphic granites, lavas, -
	GKA []	KAROO dykes, sedimentary
	GLE []	LEGAL law, control, permits
	GMA []	MANAGEMENT water resource mangement, monitoring, assessments
	GME []	METHOD techniques, manuals
	GMO []	MODEL simulation, finite element, finite difference
	GPR []	PROCESS precipitation, evapotranspiration, infiltration, recharge, groundwater flow, weathering, environmental factors, climate, vegetation, phreatophytes
X	GQU []	QUALITY pollution, geochemistry, analyses, contamination
	GST []	STATISTICS waterlevel, mathematics, borehole-survey
	GSY []	SYMPOSIUMS conference, workshops
	GUN []	UNCONSOLIDATED fluvial, aeolian, alluvial
X	GYI []	YIELD borehole development, rehabilitation, stimulation, hydraulics, hydrofracturing, pumpage, filters, blasting