GH 3502

HYDROGEOLOGY OF THE VERWOERDBURG DOLOMITE AQUIFER

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SUMMARY

This study forms part of the groundwater investigation programme undertaken by the Department of Water Affairs and aimed at evaluating the emergency urban water supply potential of dolomite aquifers in the PWV area. The integration of geological and hydrogeological information with residual gravity data aided the siting of 26 exploration boreholes and the definition of groundwater flow systems in the study area. The contract drilling programme, completed at a cost of some R1,47 million, established 14 potential production boreholes validated as such during the course of a contract test pumping programme costing some R71 000. The theoretical optimum yield potential of these boreholes in a one-year emergency water supply context is calculated at some $52,7.10^6$ m^3 (1 623 l/s). However, pump capacity limitations reduce this volume to some $24,9.10^6$ m^3 (790 l/s) if no additional boreholes are drilled, and satisfaction of the mean annual historic water supply from the Pretoria Fountains further reduces the net benefit from an emergency water supply scheme to some $15,3.10^6$ m^3 (485 l/s). Groundwater balance calculations for the study area indicate that groundwater recharge from rainfall could amount to some 11% of the mean annual rainfall, and that subsurface groundwater outflow from the study area in a westerly direction could amount to some $4,0.10^6$ m^3 per year.

OPSOMMING

Hierdie studie maak deel uit van die grondwaterondersoeke onderneem deur die Departement van Waterwese met die doel om die noodwatervoorsieningspotensiaal van die dolomiet grondwaterdraers in die PWV-gebied te evalueer. Die integrasie van geologiese en hidrogeologiese inligting met residuele gravitasie data het die aanwys van 26 eksplorasie boorgate en die omlyning van grondwatervloeisisteme in die studiegebied vergemaklik. Die kontrakboorprogram, voltooi teen 'n koste van sowat R1,47 miljoen, het gelei tot die daarstelling van 14 potensiële produksieboorgate as sodanig bevestig gedurende die uitvoer van pomptoetse op kontrak teen 'n koste van R71 000. Die teoretiese optimum leweringsvermoë van hierdie boorgate vir noodwatervoorsieningsdoeleindes vir 'n tydperk van 1 jaar word beraam op sowat $52,7.10^6$ m^3 (1 623 l/s). Beperkings opgelê deur pompkapasiteite verminder hierdie hoeveelheid na $24,9.10^6$ m^3 (790 l/s) indien geen addisionele boorgate geboor word nie. Bevrediging van die gemiddelde jaarlikse watervoorsiening vanuit die Pretoria Fonteine verminder die netto voordeel van 'n noodwatervoorsieningskema verder tot sowat $15,3.10^6$ m^3 (485 l/s). Grondwaterbalansberekenings vir die studiegebied dui daarop dat grondwateraanvulling afkomstig uit reënval moontlik 11% van die gemiddelde jaarlikse reënval bedra, en dat ondergrondse grondwatervloeiverliese in 'n westelike rigting sowat $4,0.10^6$ m^3 per jaar kan bedra.

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1. INTRODUCTION

1.1 Background

The dolomite aquifers in the Pretoria-Witwatersrand-Vereeniging (PWV) area are presently the subject of intensive hydrogeological investigations undertaken mainly by the Directorate of Geohydrology of the Department of Water Affairs. The inability of the Vaal Dam to safely provide adequate surface water supplies for urban use in the PWV area in recent years, and the consequent recognition of the potential contribution of the dolomite aquifers mainly as a source of emergency urban water supply (Vegter, 1983), precipitated these investigations. This study continues the programme of dolomite aquifer investigations in the PWV area initiated in November 1983.

1.2 Location

The study area is located immediately south-west of Pretoria, and is framed by lines of latitude 25°47' and 25°56'S, and lines of longitude 28°05' and 28°16'E. It covers a surface area of some 300 km^2, fully encompassing the Municipality of Verwoerdburg (Figure 1.1) with a surface area of some 20 000 ha (200 km^2) and a total population in November 1986 of 71 990. The northern and eastern portions of the study area fall within the Pretoria Municipal area, the southern portion within that of Midrand, and the south-eastern portion under the control of the Transvaal Board for the Development of Peri-urban Areas.

1.3 Geographical/geological boundaries

The dolomite formations of the Chuniespoort Group represent the aquifer under study. The Chuniespoort Group in the study area has clearly defined geological contacts (boundaries) with the underlying Black Reef Formation in the south-west and Pretoria Group rocks in the north, north-east and east. The east-west striking Sterkfontein dyke at Clayville forms the geological boundary of the aquifer in the south, and line of longitude 28°05'E the geographical boundary in the west.

1.4 Objectives

The objective of this investigation was to evaluate the water-bearing potential and general hydrogeology of the dolomite aquifer as an augmentative source of water for urban supply through the regional service network of the Rand Water Board. Similar use of this water by the Municipality of Verwoerdburg enjoyed secondary consideration.

1.5 Methodology

The study was carried out in two phases.

Phase 1 commenced in June 1986, and was completed in December 1986. It entailed an initial desk study to assimilate all available and relevant information from previous investigations (section 1.6), and the fieldwork summarised below.

A selective yet comprehensive survey of boreholes was undertaken to collect relevant data for a hydrogeological evaluation of the study area. The selection was made from existing borehole census data collected and provided by the Municipality of Verwoerdburg. The measurement of groundwater levels in these boreholes permitted the compilation of groundwater level contour maps for the study area. Groundwater samples were collected from these boreholes for full chemical analysis to determine the general quality of groundwater in the study area. Reconnaisance-type field mapping (geological) was carried out in an attempt to better define the surface extent of the various formations of the Malmani Subgroup dolomite. A geophysical exploration programme was carried out to further investigate structures of possible hydrogeological significance. This programme entailed a gravity survey to delineate zones of possible greater water-bearing potential in the dolomite aquifer, and magnetic surveys to locate and/or better define dykes and fault/fracture zones influencing the groundwater regime in the study area.

Phase 2 commenced in March 1987 and was completed in May 1988. It entailed an exploration/production borehole drilling programme during which 26 boreholes were drilled, 24 of which were subsequently subjected to test pumping. The drilling programme provided invaluable new hydrogeological data, especially water levels in those areas where none previously were obtainable. The borehole tests served to identify production status boreholes, and the aquifer tests yielded information on the behaviour of the dolomite aquifer at each bore.

1.6 Previous investigations

The study area lies in a region that has witnessed numerous regional geology and site-specific engineering geological investigations. Unfortunately groundwater has received relatively minor attention except as it relates to engineering geological considerations, which in most instances only regard near-surface hydrogeological conditions.

However, noteworthy recent contributions to a better understanding of the hydrogeology of the study area are those of Temperley (1978) and the consulting firm of Steffen, Robertson and Kirsten (1985).

The subjects (and authors) of the more important contributions to the geology and hydrogeology of the study area (and environs) from which much valuable information was obtained are documented in Table 1.1. Complete reference to these and other references in the text are provided in the bibliography.

TABLE 1.1: Subjects of the more important references consulted

Subject	Author
Geology of the Fountains Valley	Le R. Cilliers (1953)
Geology of the country around Pretoria	Jansen (1977)
Groundwater in Pretoria and surrounding areas	Temperley (1978)
Groundwater supply potential of the Pretoria Dolomites	SRK (1985)

2. PHYSIOGRAPHY

2.1 Morphology and drainage

The topography of the study area generally reveals a weak to moderate gradient rising away from and normal to the course of the Hennops River. Low hills with a maximum elevation of some 1 540 m and shallow valleys with a minimum elevation of some 1 400 m further characterise the gently undulating topography of the greater portion of the study area. Slightly more rugged topography is observed south-east of Irene, where the Hennops River has incised the dolomite and flows through a steep-sided valley some 60 m deep immediately downstream of Rietvlei Dam.

The main drainage through the study area is the Hennops River. It enters the study area in the south-east at an elevation of some 1 460 m and normal to the north-south geological strike in this vicinity. South of Irene the direction of flow changes to coincide with the curved regional geological strike of the dolomite formations, eventually leaving the study area in the west at an elevation of some 1 360 m and parallel to the geological strike.

Only two noteworthy tributeries of the Hennops River, the Olifantspruit in the south and the Rietspruit in the south-west, conceivably contribute significantly to the surface runoff component of flow in the Hennops River. The greater majority of other, more minor, surface drainages are also confined to the south-western quadrant of the study area.

2.2 Climate and rainfall

The region experiences a sub-humid warm climate after the classification of Thornthwaite (Schulze, 1947). The mean daily maximum temperature recorded at Station 513/382 (Irene) is 24,1°C, and the mean daily minimum is 7,6°C. The summers are warm and the winters cool with moderate to severe frost.

The long-term rainfall records for Stations 513/382 (1916 to 1985) and 513/350 (Verwoerdburg Municipality) (1906 to 1985) reveal a mean annual rainfall of 689 mm and 667 mm respectively. Most of the rainfall occurs as afternoon thundershowers between November and March. The mean annual evaporation varies around 1 700 mm (Middleton et. al., 1981).

The potential evapotranspiration (PET) has been calculated for Station 513/382 (Irene) following the Thornthwaite method (Gray, 1970 p. 3.86). The data used in this calculation are presented in Table 2.1 together with the results. The latter are graphically compared with the mean long-term monthly rainfall record of the same station in Figure 2.1. It appears that the annual potential evapotranspiration of 742 mm only slightly exceeds the mean annual rainfall (675 mm) in the study area.

TABLE 2.1: Calculation of potential evaportanspiration for Station 513/382 (Irene)

Month	J	F	M	A	M	J	J	A	S	O	N	D	Total
Mean monthly temp. (°C)	20,9	20,2	18,6	15,6	11,9	8,9	8,7	11,5	15,1	18,8	19,4	20,5	
Heat index $i=(t/5)^{1,514}$	8,7	8,3	7,3	5,6	3,7	2,4	2,3	3,5	5,3	7,4	7,8	8,5	70,8
Unadjusted PET (mm)	90	85	73	54	33	20	20	32	51	74	79	87	
Adjusted PET (mm)	105	86	77	52	31	18	19	31	51	81	88	103	742

2.3 Vegetation and soils

The greater portion of the study area comprises built-up urban areas, small-holdings and cultivated lands where the natural vegetation has either been removed or is strongly disguised. There is, however, sufficient exposure of the natural vegetation in the remaining portions to indicate that the particularly sour wiry grassveld dotted with trees is typical of the Central Variation of the Bankenveld veld type, a false grassveld type described by Acocks (1975).

The sour Bushveld vegetation that characterises the rocky hills and chert ridges comprises trees and shrubs such as the suikerbos (Protea caffra), Kaffer-wag-'n-bietjie (Acacia caffra) and Camdeboo stinkwood (Celtis africana). The occurrence of species such as White Olive (Halleria lucida) and Natal Mahogany (Kiggelaria africana) in sheltered valleys and sinkholes represent remaining traces of temperate or transitional forest.

The general characteristics of dominant soils in the study area as described on the published 1:50 000 soil map (2528CC, Lyttelton) can be summarised as follows. Shallow stoney soils and red apedal sandy loam, sandy clay loam and sandy clay characterise the overburden of the Chuniespoort Group dolomite. The latter soils show a broad correlation with the occurrence of intrusive rocks in the dolomite. Yellow ferruginous sandy loam or sandy clay loam and grey ferruginous sand or loamy sand characterise the soil cover of the granite. Vertic, melanic, hydromorphic and weakly developed soils occur on bottomland along streams and water channels, and represent a gully-eroded phase of soil development.

3. GEOLOGY

3.1 Regional setting

Following the SACS (1980) lithostratigraphic subdivision of the Transvaal Sequence in the Central Transvaal, all three major rock units of this Sequence are recognized in the study area. In decreasing age these are the Black Reef Quartzite Formation, the Chuniespoort Group (mainly dolomite) and the Pretoria Group (mainly quartzite and shale).

The basal unit of the Transvaal Sequence i.e. the Black Reef Quartzite Formation, rests uncomformably on the domical intrusive granitic basement informaly termed the Halfway House Granite. The latter is an intrusive of Swazian age (SACS, 1980) dated at 3 200 $\pm$ 65 Ma by Allsopp (1961). However, Jansen (1977) points out that these determinations were probably made on younger-phase rocks (granodiorites) of this intrusive, in which case the granitic basement itself may be older.

The rocks of the Transvaal Sequence in the study area assume an arcuate occurrence around the north-eastern quadrant of the granitic basement. SACS (1980, p. 192) reports a maximum age for the Transvaal Sequence that varies from 2 318 $\pm$ 17 Ma in the North-western Transvaal to 2 460 $\pm$ 120 Ma in the Eastern Transvaal. It is, however, the dolomite formations of the Chuniespoort Group of this Sequence that form the aquifer of main interest in this investigation.

The following lithostratigraphic/geological description of the hydrogeologically relevant rock units exposed in the study area largely represents a summary of information compiled by Jansen (1977), and attempts to lay a geological foundation for the later discussion (section 8) of the hydrogeology of the study area especially with regard to the dolomite formations of the Chuniespoort Group.

3.2 Relevant lithostratigraphy

Figure 3.1 represents a generalised geological map of the study area for reference with the following text.

3.2.1 Black Reef Quartzite Formation

As already mentioned, this Formation unconformably overlies the granitic basement. The succession is generally composed of an impersistent basal conglomerate followed by alternating quartzite and shale horizons characterised as follows:

- the lower quartzite horizons are gritty and feldspathic with sparsely distributed well-rounded quartz pebbles;

- the lower shale horizons are grey, red and black in colour;

- the upper quartzite horizons are coarse-grained but seldom feldspathic or pebbly;

- the upper shale horizons are generally black and carbonaceous.

The total thickness of the Formation averages 14 m, and probably does not exceed 21 m anywhere in the study area. The regional dip varies from 10° to the east in the southern portion to 30° to the north in the western portion of the study area.

3.2.2 Chuniespoort Group

SACS (1980, p. 192) describes the Chuniespoort Group as consisting of the Malmani Subgroup and two overlying formations where it attains maximum development, with the Malmani Subgroup comprising five formations. In the Central Transvaal however, the uppermost Frisco Formation of the Malmani Subgroup and both the overlying Penge and Duidschland Formations are absent, and the stratigraphic term Malmani Subgroup is dropped from the lithostratigraphic nomenclature. This scenario holds true for the study area, prompting the author to adopt the same policy in this report.

Much of the study area is soil covered. However, where outcrops of the Chuniespoort Group formations do occur, it is generally possible to distinguish between these on the basis of their chert content.

The contact relationship of the Chuniespoort Group with the underlying Black Reef Quartzite Formation is transitional and conformable. The upper boundary with the Pretoria Group sediments is very irregular especially along the eastern margin. This can probably be attributed to a combination of the following:

- an irregular Chuniespoort Group erosion surface on which the younger formations were deposited;

- subsidence in the residual dolomite overburden carrying these younger formations subsequent to their deposition;

- the influence of local minor transverse faulting across the contact.

The Chuniespoort Group attains its maximum width on outcrop (12 000 m) in the central portion of the study area, narrowing westwards to some 9 000 m and southwards to some 7 000 m. The general dip of the Chuniespoort Group in the latter vicinity is some 10° to the east. The dip of the Lyttelton Formation exposed in the open-cast Lyttelton Dolomite Mine immediately north of Irene confirms this observation. If this dip is regarded to be the norm for the whole of the Chuniespoort Group in the study area, then the stratigraphic thickness of the succession varies from 1 560 m in the west through 2 080 m in the central portion to 1 215 m in the south of the study area. SACS (1980, p. 204) reports the stratigraphic thickness of the succession in the Central Transvaal as 1 430 m.

3.2.2.1 Oaktree Formation

Kaffri et. al. (1986) describe this rock unit as an often hard and generally highly siliceous blueish or dark drey dolomicrite. They further report the presence (in exploration boreholes) of light grey siliceous or calcitic patches and thin shale horizons, the latter increasing in abundance towards the base of the formation.

3.2.2.2 Monte Christo Formation

This formation is typically a light-coloured recrystallised chert banded dolomite. It is heavily intruded by sills (mainly syenite), and as a result detailed surface geological mapping of this rock unit is severely complicated. An abandoned Departmental exploration borehole located on the northern portion of Centurion Park (Verwoerdburg Sportsground) revealed the chert to vary from black through grey to white in colour. The lighter-coloured chert, often showing brown staining from oxides and hydroxides of iron and manganese, characterises the appearance of weathered chert on surface.

3.2.2.3 Lyttelton Formation

This formation is recognized as a dark chocolate-coloured dolomite generally devoid of chert. Extensive outcrops thereof are visible immediately east of the Olifantspruit on the SAMANCOR-owned portion of the farm Doornkloof 391 JR. Large stromatolitic mounds in this formation can be seen in the sidewall of the open-cast Lyttelton Dolomite Mine. The highly irregular and eroded sub-surface topography, and some large-scale fractures in-filled with soil, dolomite residuum and wad, are also clearly visible at this location.

Diamond-drill exploration boreholes located on the eastern-most outcrop of this formation and started just below the clearly visible contact with the overlying Eccles Formation on the SAMANCOR property (Doornkloof 391 JR) confirm the SACS (1980) stratigraphic thickness for this formation of some 150 m. Further, that this formation can be divided into two siliceous horizons and two "clean dolomite" horizons.

3.2.2.4 Eccles Formation

The Eccles Formation is recognized as a chert-rich dolomite with hard, well-cemented chert breccia in a siliceous matrix, with the lower portion resembling the Monte Christo Formation in that stromatolites are present.

3.2.3 Pretoria Group

The Pretoria Group rests unconformably on the post-Chuniespoort Group erosion surface. The rocks of this group outcrop on the higher ridges to the north, north-east and east, realising a marked change in the topographic elevation especially towards the east and north-east. The basal unit of this group comprises the chert breccias, quartz arenites, conglomerates and shales of the Rooihoogte Formation deposited during the first marine transgression of the Pretoria Group.

3.2.4 Karoo Sequence

Occurrences of Karoo sediments in the study area are generally associated with in-filled palaeokarst features concentrated within the chert-rich dolomite of the Eccles Formation (Wilkins et. al., 1987). These features take the form of large valleys, dolines and sinkholes formed by preferential groundwater movement promoting karst-forming solution processes along lithological and/or structural weaknesses.

The Karoo sediments generally comprise diamictites, carbonaceous shales, mudstones, mudclast conglomerates, fossil-bearing shales and sandstones (Wilkins et. al, 1987). The depth and extent of these sediments varies considerably. Wilkins et. al. (1987) report dimensions of up to 90 m deep, 800 m wide and 3 300 m long for a karst-fill feature north-east of Irene. The contact relationship of the consolidated Karoo sediments with the underlying dolomite varies from gentle to steep gradients but always unconformable. Chert breccia and chert residua have been found to underly these sediments (Wilkins et. al., 1987 and Jansen, 1977).

3.2.5 Tertiary/Quaternary deposits

Wilkins et. al (1987) report on unconsolidated Late Tertiary to Middle Quarternary clayey and sandy silt soils that partly and unconformably overlie the older Karoo sediments, and partly fill a second generation of palaeokarst features recognized in their study area north-east of Irene. They further report thicknesses of up to 48 m for these sediments, and ascribe their presence to a period of post-Karoo karst formation that appears to have occurred possibly as a result of episodic uplift of the land surface.

The alluvium adjoining the main drainage courses in the study area represents the deposition of Late Quarternary sediments. In this regard the sand, silt and clay adjoining the Hennops River represent by far the most significant occurrence, and also provide the most fertile soils for small-scale but intensive agriculture especially in the vicinity of Irene. The lateral extent of these deposits reaches a maximum of some 800 m in the vicinity of Zwartkop Country Club. Little information on the maximum thickness of these is available, but probably does not exceed 15 m anywhere in the study area.

3.2.6 Intrusive rocks

Intrusive rocks in the study area comprise both dykes and sills of varying age, composition and strike. For clarity, these intrusives are discussed in the respective subsections below. Their influence on the groundwater regime is discussed fully in section 8.

3.2.6.1 Dykes

Day (1980) recognizes three dyke systems in the Southern Transvaal based on magnetic signature, direction of strike and age relative to the Karoo Sequence. On this basis he identifies

- a negative magnetic signature, pre-Karoo Sequence, Pilanesberg dyke system;
- a positive magnetic signature, pre-Karoo Sequence and north-south trending East Rand dyke system;
- a positive magnetic signature, post-Karoo Sequence, east-west (striking) dyke system.

Examples of the latter two systems are represented in the study area. The most prominent of these is the 100 to 130 m wide north-south striking and generally vertical to subvertical Pretoria dyke. Jansen (1977) reports a dip of 20° to 25° to the west just south of the study area (east of Clayville). Borehole 105 (Figure 8.1, map grid reference E9) located some 30 m west of this dyke in the suburb of Doringkloof (erf 511) reportedly struck dyke material at a depth of some 60 m, indicating a dip of some 26° to the west at this locality.

Anomalous water levels (Figure 8.1) and subsequent ground magnetic surveys (section 4) have revealed the presence of what must be considered an off-shoot of this dyke located immediately west of Lyttelton Dolomite Mine. The general composition of the Pretoria dyke is described by Le R. Cilliers (1953) as a slightly granophyric gabbro. Although Jansen (1977) classifies this dyke as part of the Pilanesberg dyke system, it's positive magnetic signature indicates an affinity with the East Rand dyke system of Day (1980).

A second prominent dyke in the study area is the NW-SE striking Pinedene dyke. This dyke intersects the Pretoria dyke, and outcrops near this intersection in the vicinity of Pinedene railway station as a medium - grained dolerite (Le R. Cilliers, 1953). On the published 1:50 000 geological map (2528CC Lyttelton) it is indicated to be of diabase composition to the north-west, and is not mapped across the grounds of the Animal and Dairy Science Research Institute south of Irene. However, ground magnetic surveys on this property (section 4) provide evidence for it's existence, and substantiate the regional continuity of this dyke as indicated by Day (1980, Fig. 3.1.).

Two other dykes of hydrogeological significance in the study area are the E-W striking Irene and Sterkfontein dykes. These consist mainly of an equigranular and fine-grained to medium-grained olivine dolerite, although outcrops of both dykes are very scarce.

Day (1980) reports that both dolerite and diabase exposures have been mapped along the trace of the Sterkfontein dyke, and suggests that these dykes are of post-Karoo Sequence age conforming with his

East-West dyke system. Ground magnetic surveys on the dolomites to the east and west of Irene (section 4, Figs.) provide evidence for the continuity of the Irene dyke across the Chuniespoort Group, as substantiated by water level contours (Figure 5.1, section 5).

3.2.6.2 Sills

Numerous syenite sills are widely distributed in the Chuniespoort Group. These sills attain widths of up to several hundreds of metres on outcrop. Jansen (1977) postulates that these sills "may have intruded during the operation of tensional stresses which were dominant during the updoming of the granite core and the initial stages of the formation of the Bushveld Igneous Complex". Undoubtedly their occurrence bears some relationship to the structural features of the study area, specifically the concentric strikes and centrifugal dips of the Chuniespoort Group rocks around the dome-shaped Halfway House Granite. It is further interesting to note that the extent of occurrence of these sills as portrayed on the published 1:50 000 geological map (2528CC Lyttelton) is limited roughly to south and south-west of the Hennops River and west of the Olifantspruit.

4. GEOPHYSICS

4.1 General

The geophysical investigations carried out during the course of this study entailed ground magnetic and gravity surveys. The gravity survey far exceeded the magnetic surveys both in scope and area covered. It was carried out for the DWA by the consulting firm Southern Geophysical Exploration. The ground magnetic surveys were carried out by staff of the DWA.

4.2 Magnetic surveys

A Chemtron model G3 proton-precession magnetometer was used. This instrument measures directly the strength of the total magnetic field at a given locality. A total of 36 traverses were completed covering a total distance of some 22 line km at a station interval of 10 m. The position of these traverses are indicated on Figure 4.1, and graphs of the field data are presented in Appendix 4. A breakdown of the logistics of these surveys is presented in Table 4.1.

TABLE 4.1: Magnetic survey traverse logistics

Magnetic traverse no.	Map grid reference	No. of stations	Station interval (m)	Length of traverse (m)
1.	F12	61	10	600
2.	F10	56	10	550
3.	F8	71	10	700
4.	F9	51	10	500
5.	F7	51	10	500
6.	G5	27	10	260
7.	G5	25	10	240
8.	G1	20	10	190
9.	G1	30	10	290
10.	H8	60	10	590
11.	H9	65	10	640
12.	I9	54	10	530
12A.	H10	115	10	1 140
13.	G7	41	10	400
14.	I10	100	10	990
14A.	H10	113	10	1 120
15.	D9	41	10	400
16.	G1	56	10	550

TABLE 4.1: (Continued)

Magnetic traverse no.	Map grid reference	No. of stations	Station interval (m)	Length of traverse (m)
17.	H9	71	10	700
18.	D9	61	10	600
19.	D9	52	10	510
20.	D9	21	10	200
21.	D9	16	10	150
22.	D9	79	10	780
23.	E9	41	10	400
24.	E9	40	10	390
24A.	E10	49	10	480
25.	E10	15	10	140
26.	E10	61	10	600
26A.	E10	61	10	600
27.	D9	61	10	600
28.	E8	90	10	890
28A.	E8	94	10	930
29.	E4	47	10	460
30.	D5	24	10	230
31.	D4	33	10	320
32.	F6	31	10	300
33.	E10	62	10	610
34.	H11	27	10	260
35.	H11	51	10	500
36.	H11	110	10	1 140
Total		2 234		21 980

4.2.1 Objectives

The magnetic surveys attempted to investigate and qualify the following geological and hydrogeological aspects.

- The accurate location of existing dykes shown on the published 1:50 000 scale geological maps.
- The possible cause of anomalous adjacent water levels revealed by the groundwater elevation contour map (Figure 8.1, section 8).
- The accurate position of major faults shown on the published 1:50 000 scale geological maps.
- The accurate position of geological contact zones between Formations of the Chuniespoort Group where these are thought to be governed by faulting.

4.2.2 Results

The magnetic surveys proved generally successful in determining the position of known dykes in the study area. Magnetic traverses 1, 2, 3, 4 and 5 confirmed the continuity of the Irene dyke, and traverses 10, 11, 12A, 13, 14A, and 17 that of the Pinedene dyke, across the dolomite in those localities where these dykes are not indicated on the published 1:50 000 geological maps. The Irene dyke revealed a negative magnetic signature and the Pinedene dyke a positive magnetic signature.

Magnetic traverses 15, 18, 19, 20, 21, 22 and 27 successfully investigated the possible occurrence of an intrusive that could explain the anomalous adjacent water levels in grid D9 of Figure 8.1. These surveys revealed the presence of a dyke with a positive magnetic signature amounting to some 2 000 nanoTesla. It is hypothesised that this dyke is an off-shoot of the Pretoria dyke. The hydrogeological signature of this dyke is discussed in section 8.2. Traverses 23, 24, 24A, 25, 26, 26A and 33 attempted to trace the strike of this dyke toward the south-east, but restrictive accessibility, unsuitable terrain (urban areas) and a high level of industrial noise from pipelines, powerlines and an electrified railway foiled this exercise. However, a characteristic 3 000 nanoTesla, double-peaked positive anomaly some 100 m wide on magnetic traverse 24 did confirm the presence of the Pretoria dyke west of Irene.

Magnetic traverses 28 and 28A were run along Lenchen Street in an attempt to identify the magnetic signature produced by the numerous sills indicated in this vicinity on the published 1: 50 000 scale geological map. The high noise level along this traverse, however, negates sensible interpretation of this data.

Magnetic traverses 29, 30, 31 and 32 attempted to accurately locate the position of two major faults in the study area (Figure 4.1). The absence of a magnetic signature across these features rendered this exercise unsuccessful.

Magnetic traverse 34 investigated a possible geological cause for the difference in groundwater elevation of 17 m between boreholes 136 and 156 (map grid reference H11, Figure 8.1). Although the data indicates a 300 nanoTesla positive anomaly some 30 m from the start (southern end) of this traverse, the lack of other substantiating magnetic data in this vicinity renders it precocious to regard this as proof of the presence of a dyke that could cause the observed anomalous groundwater elevations.

Magnetic traverse 35 investigated the geological contact between the Lyttelton and Eccles Formations on the SAMANCOR-owned property east of the Olifantspruit (map grid reference H11). The 200 nanoTesla positive anomaly at 230 m on this traverse is located immediately east of the surmised geological contact revealed by field observations. It is possible however, that this anomaly represents the signature of a carbonaceous shale horizon near the base of the Lyttelton Formation. Surface manganese enrichment of the dolomite at this locality is also observed.

Magnetic traverse 36 investigated the magnetic signature across the Lyttelton/Eccles Formation geological contact north of traverse 35. No exceptional anomalies were observed. However, a striking feature of this traverse is the difference in noise level of the magnetic readings over the Lyttelton and Eccles Formations. The latter reveals much more "quiet" readings than that obtained over the Lyttelton Formation, indicating the "cleaner" nature of the chert-rich dolomite with regard to magnetically susceptible contaminating material such as iron and manganese oxides and carbonaceous shale horizons.

4.3 Gravity survey

The gravity survey was carried out by the consulting firm Southern Geophysical Exploration (SGE) using Warden and Sodin gravimetric instruments. A total of 3 305 stations were surveyed at an average cost of R 19,24 per station. All data pertaining to this survey are referenced in Contract Report 2.2(58).

4.3.1 Objectives and methodology

The objectives of this survey were primarily to locate zones of low density in the dolomite. These zones are generally associated with leached dolomite and/or in-filled paleokarst features over dolomite terrain. Linear trending gravity low zones can indicate the presence of fault zones along which preferential leaching has taken place. In any event, low density zones revealed by gravimetric data are generally associated with well-developed aquifers, and constitute prime target areas for the location of groundwater supplies.

The gravity survey was conducted both on a grid basis and along selected routes deviating from the grid pattern. The grid pattern generally adhered to the dimensions 250 x 100 m i.e. 250 m between lines, with a station interval of 100 m along each line. A continuous grid pattern was not feasible due to urban infrastructure. Without exception, the lines of the grid follow a NE-SW strike normal to the geological strike in order to maximize the value of the survey data with regard to the probable orientation of gravity features in the dolomite. The Pretoria Group rocks form the north-eastern boundary of the grid, while the Oaktree/Monte Christo Formation geological contact can generally be regarded to form the south-western boundary as only local coverage of the Oaktree Formation was realised.

The gravity surveys conducted at 100 m station intervals along selected routes served not only as a regional gravimetric investigation, but also facilitated control over the denser grid survey data and, more importantly, the determination of the regional gravity field in the study area.

In essence, the survey represents an absolute gravity survey. For the reduction of the gravity values to absolute values, six absolute base stations were established (and cemented) in the survey area with tie-ins to the Voortrekker Monument base station.

A Bouguer density of 2,670 kg/m^3 was used, yielding a combined free-air and Bouguer correction factor of 0,196854 mgal/m. A Bouguer contour map was compiled by the consultant. A critical examination of this map allowed the visual construction of the regional gravity field. This was done by staff of the DWA. A concerted attempt was made to obtain both a "smooth" regional field and an eventual residual value ranging from 0 to a maximum of 0,5 mgal for outcropping chert-free dolomite and the Pretoria Group rocks. The regional gravity field was digitized, and a 3 rd order polynomial function fitted to the digitized values with a goodness of fit better than 0,9995. The equation generating this surface was then used to interpolate a regional gravity value at each observation station, subtraction of which from the Bouguer data yielded residual gravity values from which a residual contour map was compiled with a contour interval of 0,1 mgal.

A secondary but nonetheless important facet of the regional gravity survey was the visual description of the surface geology at each station. Although very cursory and generalised, these descriptions identified areas of outcrop and overburden that facilitated the construction of the regional gravity field.

In addition to the regional gravity survey, localized supplementary gravity surveys were carried out in instances where greater resolution of anomalies was required. Three such surveys were carried out over the anomalies on which boreholes G37836 and G37837 were sited and after these boreholes were drilled. The reason for this was to emulate the great success of borehole G37836 after the failure of G37837, it being felt that the gravity data in the case of G37837 required greater resolution to more accurately site a successful borehole in this locality, as well as further south along the anomaly on which G37836 was drilled.

4.3.2 Interpretation

Bredenkamp et. al. (1986), in their study of the groundwater supply potential of dolomite compartments west of Krugersdorp, identified both lateral and linear gravity lows. The former were ascribed to dissolution of dolomite formations, infilled paleo-valleys probably associated with underlying leached dolomite, or intersection of two or more fracture and/or fault zones susceptible to leaching. The linear gravity lows were mainly ascribed to dissolution along zones of faulting or fracturing. These authors further report that where dykes intersect prominent gravity lows, they usually do not act as groundwater barriers. Interpretation of the gravity survey of the present study area supports many of the above observations, as described below.

The residual gravity contour map of the study area (Figure 4.2) reveals a number of positive (gravity high) and negative (gravity low) anomalies that differ in size and magnitude. Lesser regard is afforded the smaller and generally isolated anomalies, as these require more critical appraisal regarding the number and distribution of data points used in the construction of their defining contours. These factors bias the data-inferred dimensions of these anomalies, which therefore do not necessarily represent the real geometry of the features.

Greater significance is attached to the larger anomalies as these correlate remarkably well with both known geologic and hypothesized hydrogeologic features in the study area. These anomalies are alphabetically referenced and indicated on Figure 4.1:

- a north-south trending 'positive' anomaly (A) that coincides with the strike and position of the Pretoria dyke;
- a less well-defined NW-SE trending 'positive' anomaly (B) that coincides with the strike and position of the Pinedene dyke;
- a north-south trending 'negative' anomaly (C) coincident with the hypothesized zone of high transmissivity located west of the Pretoria dyke in the West Doornkloof subcatchment;
- an east-west trending 'negative' anomaly (D) coincident with the hypothesized zone of high transmissivity located south of the Irene dyke and linking the East and West Doornkloof subcatchments;
- a NW-SE trending 'negative' anomaly (E) indicating hydrogeological continuity across the Irene dyke east of Irene;

Further, 'positive' anomalies that coincide with the outcrop of the Pretoria Group rocks are observed along the eastern margin of the study area, and the association of observed extensive outcrops of chert with the position of the stronger negative anomalies i.e. those smaller than -2 mgal, shows good agreement.

4.3.3 Borehole siting criteria

Initial exploratory drilling in the dolomite compartments west of Krugersdorp revealed that boreholes sited in the centre of prominent gravity lows encountered highly leached dolomite that gave rise to adverse drilling conditions and associated increased borehole construction costs (Bredenkamp et. al., 1986). Subsequent drilling sites were therefore selected at the foot or edge rather than the centre of a gravity low. A similar approach was followed in the present study.

The residual gravity contour map (Figure 4.2) afforded the initial siting of boreholes. The siting criteria did not rest only with the magnitude of the specific residual gravity anomalies considered, but also took cognizance of how the geology (formation, strike and dip) and hydrogeology (depth to water level where known, need for additional data) related to the geometry of these anomalies. Boreholes were therefore generally sited at the foot of gravity gradients emerging on the geologically determined down-dip side of negative gravity anomalies.

As drilling proceeded and results were obtained, a revision of initial siting criteria necessitated the relocation of some of the boreholes. Such revision was based mainly on the observation that boreholes sited at a topographically higher elevation on the same gravity low anomaly were generally unsuccessful. Examples are boreholes G37822, G37824, G37827, G37833 and G37835A. The positions of the 26 boreholes eventually drilled are indicated on Figure 4.1.

Figures 4.3 and 4.4 illustrate the magnitude of the residual gravity anomalies along four profiles referenced on Figure 4.2, and further attempt to relate these anomalies to geological/hydrogeological features along these profiles.

The data obtained from the localized supplementary gravity surveys are presented in Tables 4.2.1, 4.2.2 and 4.2.3. The gravity profiles and other relevant information are presented in Figure 4.5. Unfortunately both boreholes G37837A and G37841 were unsuccessful. This result reflects somewhat poorly on the use of the gravity method for borehole siting, and unfairly so, for in this instance the occurrence of the highly productive aquifer intercepted in G37836 appears to be tightly controlled by localized structural features, probably faults.

5. DRILLING

5.1 Introduction

The contract drilling programme under Tender W9541 commenced in March 1987 and was completed in November 1987 at a cost of R1 469 829. During this period 26 boreholes were drilled by the 3 contractors employed. A summary of each contractors involvement with the programme is presented in Table 5.1. A DWA drilling rig was used to deepen 4 of the boreholes.

TABLE 5.1: Summary of drilling contractors involvement with the contract drilling programme

Contractor's name and address	No. of rigs employed	No. of boreholes drilled	Total metreage	Period engaged (weeks)
Boart Exploration Services, Contract Drilling Division, P.O. Box 51, Welkom 9400	2	13	1 749	8
W. Prinsloo Drilling (Pty) Limited, P.O. Box 6579, Bloemfontein 9300	1	6	1 187	18
Interdrills (Pty) Ltd P.O. Box 11296, Brooklyn 0011	1	7	1 324	20
Boring Division Dept. of Water Affairs	1	*4	686	
TOTAL		26	4 946	

* Existing boreholes drilled deeper.

The aim of the drilling programme was to establish large-diameter production-status boreholes. For the purposes of the PWV dolomite aquifer investigations, a final blow yield >25 l/s identified a possible production-status borehole. Further, the programme was initiated without the benefit of prior knowledge regarding subterranean drilling conditions that is to be gained from an exploration drilling phase. Each borehole therefore had to be approached as a potential production borehole, with the exploration facet enjoying secondary importance.

The target areas were identified following the interpretation of residual gravity data and geological and hydrogeological considerations where known. Terrain-influenced logistical considerations determined the actual drill sites.

5.2 Methods and approach

The basic drilling method applied by all three the contractors was the air rotary percussion method. This was supplemented with the use of a water-based surfactant (soap) added to the airstream to create an air-foam drilling system yielding the following advantages:

- capacity to carry more and larger cuttings;
- ability to lift greater volumes of water;
- increased borehole stability;
- reduced 'erosion' of poorly consolidated formations;
- proper flushing and cleansing of the hole following final construction.

The basic approach was to start each borehole at as large a diameter as the contractor was capable of drilling till first water strike, refusal due to caving/instability, or excessive depths (usually approaching 100 m) causing significantly reduced penetration rates. Appropriately sized casing was then installed in the bore to the specifications of the hydrogeologist, and drilling continued at a diameter nominally smaller than the inside diameter (ID) of the installed casing. This process was repeated till the hydrogeologist considered the borehole acceptable (required depth and/or maximum possible yield achieved) or, under extremely difficult drilling conditions, refusal occurred at a bore diameter of 203 mm. Further, it was at all times attempted to complete each borehole at as large a diameter as possible and to as great a depth as warranted or difficult drilling conditions allowed.

The cuttings brought to the surface by the air-foam return from the bore were collected, described, bagged and labelled for each metre drilled. The lithologic description of each borehole is presented in Appendix, Volume 2, together with all other relevant information pertaining to and obtained from every borehole. No lithologic descriptions are available for those horizons from which no returns were obtained due to loss of the air-foam circulation. Such horizons generally indicated extremely cavernous conditions.

Water intersections were recorded, and blow yields measured with a 90° V-notch weir. However, excessive air-foam returns obtained ironically from both very low-yielding and extremely high-yielding boreholes often hindered these observations to the extent of discounting their accuracy and value.

5.2.1 Boart Exploration Services

This contractor started each borehole at a diameter of 381 mm. This allowed the contractor the option of reducing the bore diameter twice before having to install 207 mm ID casing if deemed necessary. This contractor was further suitably equipped with high-capacity air compressors (2413 kPa x 24 m^3/min) to cope with large volumes of water, and a full complement of drill collars and stabilizers for each bit size to maintain a straight borehole.

5.2.2 W. Prinsloo Drilling (Pty) Limited

This contractor started each borehole at a diameter of 445 mm, allowing the option of reducing the bore diameter three times before having to install 207 mm ID casing. This contractor was also suitably equipped with high-capacity air compressors and a full complement of drill collars and stabilizers for each bit size.

After having experienced extremely difficult drilling conditions requiring a laborious standard "drill-and-drive" approach to advance the casing in two of their first three boreholes (boreholes G37827 and G37818A), this contractor purchased and put into operation a drill-through casing driver to minimize this problem. The drilling procedure followed when using the casing driver was to advance the bit some 30 to 50 cm beyond the casing before withdrawing it back into the casing, which was then driven by the pneumatically operated casing driver whilst the air-foam was still applied to the borehole through the drill pipe. The advantages to the contractor of using the drill-through casing driver included the following:

- casing advance was more rapid, as full lengths (6,1 m) of casing were driven instead of the shorter (± 2 m) lengths allowed by the standard "drill-and-drive" approach;

- the longer lengths of casing so driven reduced the number of times air-foam circulation needed to be restored, as with the standard approach the drill string needs to be broken each time a short length of casing is added.

The main advantage to the client was the advance of casing to greater depths than was possible with the standard approach, thereby postponing the undesirable action of untimely reducing the bore diameter in unstable horizons.

5.2.3 Interdrills (Pty) Limited

The approach followed by this contractor differed significantly from that of the other two as follows:

- first a 165 mm diameter pilot borehole was drilled as deep as possible with the aim of reconnoitering drilling conditions at each site;

- the pilot borehole was then reamed to a diameter of 330 mm and, if possible, drilled deeper before building in 305 mm ID casing and proceeding with the "normal" approach (subsection 5.2).

This particular approach realised numerous problems, the more significant of which are elaborated upon below.

Firstly, the pilot boreholes were drilled by the air rotary percussion method without the addition of a surfactant to the airstream. This exacerbated the technical difficulties encountered in leached and unstable horizons, resulting in one or more of the following scenarios:

- the drill string becoming irretrievably stuck in the bore;
- inability to attain a reasonable depth;
- recourse to more than one attempt.

Secondly, no drill collars and stabilizers were used in the drilling of the pilot boreholes to ensure their straightness. Resulting deviations were therefore unwittingly translated to the reamed bore.

The dire consequences of the above approach are appreciated when the following is considered.

- Borehole G37818 was not accepted as a production borehole after failing the straightness test. This was the direct result of the 261 mm ID casing separating at a welding joint due to excessive deviation of the bore below a depth of 80 m. Although the subsequent 207 mm ID casing was eventually, after much time and effort, forced through this division, the deviation was of such magnitude that it was transmitted to the casing resulting in a failed straightness test.

- Borehole G37819C represents the fourth and only successful attempt to drill and complete a borehole at this site. The first attempt (G37819) was abandoned at 62 m with the drill string stuck in the pilot borehole. The second attempt (G37819A) was abandoned at 20 m after the bit had lost tungsten carbide buttons in the bore. The third attempt (G37819B) was abandoned at 28 m after being reamed to a diameter of 445 mm only to have the bore refusing the passage of 343 mm ID casing due to a deviation.

- Borehole G37825A represents the second and successful attempt at this site. Borehole G37825 was abandoned after the 343 mm ID casing had separated at a welding joint and refused the 330 mm drill bit access to the bore below 98 m. The separation of the casing at 98 m is also attributed to excessive deviation of the bore inherited from the pilot borehole.

- Borehole G37835A also represents the second and successful attempt at this site. Borehole G37835 was abandoned at a depth of 61 m after being reamed to a diameter of 432 mm only to have the bore refusing the passage of 343 mm ID casing due to a deviation again inherited from the pilot borehole.

An equally important factor contributing to the less than satisfactory performance of this contractor was the nonuse of appropriate drill collars and stabilizers for each bit size. This was partly remedied after the third successfully completed borehole when the contractor acquired a drill collar/stabilizer unit for the 330 mm drill bit. However, without similar equipment for the other sizes of drill bit, this was inadequate to overcome the problem of deviation.

This contractor was taken off the project after completing the sixth "successful" borehole as it was considered that very little effort was being made to complete the boreholes at as large a final diameter as possible despite repeated requests in this regard.

5.3 Relative performance of contractors

Some measure of the relative performance of the contractors with regard to the number of rigs employed, number of boreholes drilled, total metreage drilled and period engaged has already been summarised in Table 5.1. However, an objective analysis of relative performance based on the above factors must consider the length and/or number of shifts employed by each contractor. In this regard, Boart Exploration Services ran a double shift, working 144 hours (6 days) per week on each of the two drill rigs employed. W. Prinsloo Drilling ran an 18 hour shift, working 108 hours (4.5 days) per week. Interdrills initially employed a 16 hour shift working 96 hours (4 days) per week whilst drilling the first borehole. This schedule was subsequently extended to a double shift, working 135 hours (5.6 days) per week.

A more subjective method of performance analysis compares the final cased diameters of the boreholes completed by each contractor. Such an analysis is presented in Table 5.2.

TABLE 5.2: Relative performance of contractors with regard to the final cased diameters of boreholes

Contractor	Final cased diameters of boreholes							
	394 mm		343 mm		261 mm		207 mm	
	No	% of total	No	% of total	No	% of total	No	% of total
Boart Exploration			4	31%	8	62%	1	7%
W. Prinsloo Drilling	1	17%	2	33%	2	33%	1	17%
Interdrills			2	29%	3	42%	2	29%
TOTAL	1		8		13		4	

In the above analysis, due regard must be afforded the number of boreholes drilled by each contractor that penetrated highly leached and cavernous formations. Such drilling conditions favour a higher incidence of forced bore diameter reductions influencing the diameter at which a borehole is finally cased. The lithologic descriptions presented in Appendix 2 identify these boreholes. In this regard, 67% of the boreholes drilled by W. Prinsloo Drilling, 54% of those drilled by Boart Exploration Services and 29% of those drilled by Interdrills presented difficult to extremely difficult drilling conditions.

From the above analyses it is clear that both Boart Exploration Services and W. Prinsloo Drilling performed well in comparison to Interdrills. This is ascribed to better organisation, strict adherence to a proven methodology and approach, the use of proper equipment, and a proper understanding and application of the sophisticated drilling techniques required.

5.4 Results

Salient information relating to the exploration/production borehole drilling programme is summarised in Table 5.3. Detailed borehole and lithological records are presented in Appendix 2.

The results of the drilling programme are summarised as follows:

- Eight of the 26 boreholes drilled produced airlift yields of greater than 25 l/s.
- A further 7 boreholes penetrated highly leached chert-rich dolomite exhibiting the potential to produce high yields.
- One of the above 15 boreholes (G37818) failed the straightness test and must be discounted as a potential production borehole.
- The remaining 11 boreholes produced airlift yields less than 5 l/s.
- Eight of the 15 "successful" boreholes (G37818, G37818A, G37819C, G37820, G37821, G37823, G37825A and G37840) penetrated the chert-rich Eccles Formation.
- Six of these boreholes (G37829A, G37831, G37832, G37834, G37838 and G37842) penetrated the chert-rich Monte Christo Formation.
- The remaining "successful" borehole (G37836) penetrated a fault-controlled contact zone between the Monte Christo and Lyttelton Formations.
- The drilling programme identified 3 types of highly productive aquifer identified as follows:
    - highly leached dolomite extending from the near-surface to sometimes considerable depths (G37829A was stopped at

a depth of 89 m without penetrating "fresh" dolomite), and representing phreatic aquifers characterised by shallow water levels (<30 m from surface);

- highly leached dolomite underlying relatively "fresh" dolomite and Karoo Sequence deposits, with the aquifer zone occurring at depths below 80 m, extending to depths of some 160 m below furface, and representing semi-unconfined to semi-confined aquifers characterized by deep water levels (>70 m from surface);

- deep-lying zones of highly fractured dolomite often showing calcite growth, and representing confined aquifers characterized by "intermediate" piezometric water levels (30 m to 50 m from surface).

. Gravity survey data were used to site all the exploration/production boreholes drilled, and the mixed success of the drilling programme therefore reflects the ambiguity inherent in using this method to site high-yielding boreholes in the study area. The following observations serve to qualify this statement.

- The gravity method proved most successful where integrated with available geological and hydrogeological information to better assess the aquifer regime in the target drilling areas.

- Although serving to identify areas encompassing low-density material, the interpreted data did not adequately define the vertical extent of this material, and the elevation of the rest water level could not be related to that of the base of the low-density material. This "deficiency" resulted in a number of boreholes (G37824, G37827, G37833, G37835A, G37837, G37837A and G37841) penetrating potentially high - yielding aquifers but located above the ambient groundwater level elevation.

- The gravity method was not able to detect the deep-lying fractured dolomite aquifers, these only being detected following exploration drilling of overlying shallower aquifers exhibiting negative gravity signatures of sufficient magnitude to warrant investigation.

TABLE 5.3: Summary of salient exploration/production borehole information

Borehole no.	Co-ordinates X	Co-ordinates Y	Drilling contractor	Final cased diameter mm	Total cost R c	Total depth m	Cost per metre R c	Collar elevation m.a.m.s.l.	Depth to rest water level m	Rest water level elevation m.a.m.s.l.	Final blow yield l/s	Water quality EC mS/m	Water quality Temp. °C
G37818	+2863780	+74840	Interdrills (Pty) Ltd	207	17 640,14	125	141,12	± 1 460	79,6	± 1 380	-	-	-
G37818A	+2863810	+74880	W. Prinsloo Drilling (Pty) Ltd	207	93 493,69	200	467,68	± 1 460	80,3	± 1 380	± 10	41	21
G37819C	+2864160	+74790	Interdrills (Pty) Ltd	207	53 276,71	177	300,49	± 1 475	95,3	± 1 380	± 13	-	-
G37820	+2862350	+74540	Interdrills (Pty) Ltd	261	53 449,30	211	253,31	± 1 477	97,3	± 1 380	-	-	-
G37821	+2862460	+75090	W. Prinsloo Drilling (Pty) Ltd	261	70 150,50	140	501,07	± 1 468	90,3	± 1 378	14	42	21
G37822	+2863090	+75280	W. Prinsloo Drilling (Pty) Ltd	343	86 918,75	191	455,07	± 1 466	87,8	± 1 378	-	-	-
G37823	+2863300	+75025	W. Prinsloo Drilling (Pty) Ltd	343	81 760,75	204	400,79	± 1 455	73,9	± 1 381	-	-	-
G37824	+2861240	+77590	Interdrills (Pty) Ltd	343	56 797,40	246	230,88	± 1 513	139,7	± 1 373	< 5	-	-
G37825A	+2861010	+77875	Interdrills (Pty) Ltd	261	64 519,62	206	313,20	± 1 494	119,1	± 1 375	-	-	-
G37827	+2863075	+76775	W. Prinsloo Drilling (Pty) Ltd	261	104 132,73	252	413,22	± 1 493	69,6	± 1 423	< 5	-	-
G37828	+2862115	+77570	W. Prinsloo Drilling (Pty) Ltd	394	68 890,08	200	334,45	± 1 473	56,6	± 1 416	< 5	-	-
G37829A	+2864570	+79240	Boart Exploration Services	261	40 605,35	89	456,24	± 1 458	35,3	± 1 423	± 50	48	19
G37830	+2864150	+79535	Boart Exploration Services	261	61 315,38	180	340,64	± 1 463	36,9	± 1 426	< 5	-	-
G37831	+2864915	+79130	Interdrills (Pty) Ltd	261	38 971,00	159	245,10	± 1 467	45,0	± 1 422	> 70	78	20
G37832	+2863415	+80340	Boart Exploration Services	261	32 813,65	68	482,55	± 1 453	28,4	± 1 425	> 60	48	16
G37833	+2863540	+80630	Boart Exploration Services	343	51 454,30	348[1]	343,03	± 1 463	38,6	± 1 424	< 5	-	-
G37834	+2863575	+79950	Boart Exploration Services	207	31 684,50	55	576,08	± 1 434	11,8	± 1 422	> 60	49	19
G37835A	+2865660	+79035	Interdrills (Pty) Ltd	343	40 240,51	349[2]	201,20	± 1 491	70,2	± 1 421	< 5	-	-
G37836	+2866450	+76255	Boart Exploration Services	261	61 233,76	150	406,87	± 1 470	27,9	± 1 442	> 80	39	20
G37837	+2867115	+75660	Boart Exploration Services	261	70 818,06	250	283,27	± 1 498	61,3	± 1 437	< 5	-	-
G37837A	+2867115	+75705	Boart Exploration Services	343	50 625,07	285[3]	339,77	± 1 495	57,6	± 1 437	< 5	-	-
G37838	+2868830	+78160	Boart Exploration Services	261	49 209,13	150	328,06	± 1 475	20,7	± 1 454	> 30	75	19
G37839	+2869680	+77010	Boart Exploration Services	343	60 484,77	200	302,42	± 1 491	38,8	± 1 452	< 5	-	-
G37840	+2868330	+74390	Boart Exploration Services	261	59 457,64	122	487,36	± 1 497	40,6	± 1 456	> 30	41	20
G37841	+2867115	+76335	Boart Exploration Services	343	50 786,89	402[4]	338,58	± 1 472	30,0	± 1 442	< 5	-	-
G37842	+2858205	+88560	Boart Exploration Services	261	21 099,51	36	586,10	± 1 383	8,1	± 1 375	> 40	59	19

6. TEST PUMPING

6.1 Introduction

The test pumping programme commenced in November 1987 and was completed in May 1988 at a cost of R71 302. During this period 24 of the 26 boreholes drilled (section 5.1) were tested. The programme was carried out under contract W9706LQ by Groundwater Practitioners (Pty) Ltd, who tested 14 boreholes, and Spray-Mor Irrigation (Pty) Ltd, who tested 10 boreholes.

The aim of the test pumping programme was to assess the performance characteristics and productivity of each exploration/production borehole drilled and aquifer locally penetrated. The tests further served to identify and/or confirm high-capacity boreholes and their short-term potential as augmentative sources of emergency water supply. A final airlift yield >25 l/s recorded during drilling operations initially identified such possible production-status boreholes.

6.2 Equipment

6.2.1 Spray-Mor Irrigation

This contractor mobilised a test pumping unit comprising the models BH150D and BH250D Mono borehole pumps driven by a 3 cylinder Perkins marine diesel engine. These units allowed the contractor to pump at yields <25 l/s at depths of up to 180 m, the pump selected for each test being determined by such site-specific factors as depth to rest water level and estimated probable yield of the borehole.

6.2.2 Groundwater Practitioners

This contractor had at his disposal a Mono BP250M pump driven by a 164 kW Detroit diesel engine and capable of producing yields up to 90 l/s, but was limited by insufficient pumping column to a maximum depth of some 120 m.

The contractor also employed a Mono BH250D pump driven by a 74 kW Atlantis diesel engine and capable of producing yields up to 20 l/s. This unit was used to test 207 mm ID cased boreholes suspected of having potential yields >25 l/s.

6.3 Methods and approach

Both multi-rate tests, by which the performance characteristics of a borehole, and constant rate tests, by which aquifer behaviour and, in the absence of observation boreholes, at least the transmissivity (T) of the aquifer can be evaluated, were employed.

The basic approach followed with the test pumping programme is summarised below.

- Identification of the test pumping unit to be used based on the final airlift yield (subsection 6.1).

- Execution of a calibration test of not longer than 40 minutes duration to assess the yield/drawdown limits in order to facilitate the planning of a multi-rate test. The calibration tests took the form of a multi-rate test, and often served to indicate that execution of a full multi-rate test was unwarranted. Conditions dictating such action relate to the following:

  - insignificant drawdown at maximum pumping rate;

  - excessive drawdown approaching exhaustion of available drawdown at very low yields;

  - cavitation of the pump at yields up to 50% less than the potential maximum pumping rate.

- Execution of a multi-rate test of constant step duration (generally 4 steps of 100 minutes duration each), the individual pumping rates being pre-determined from the calibration test. No recovery was allowed between steps, with recovery measurements only being conducted following cessation of pumping. Where possible, recovery of water level to within 10% of the pre-test rest water level was considered sufficient before execution of a constant rate test. In 14 cases a recovery better than 95% was realised within 2 hours of pump shutdown.

- Execution of a constant rate test generally of 8 hours duration at a yield pre-determined from the multi-rate test (or the calibration test in those instances where no multi-rate test was performed), and again followed by measurement of recovery after pump shutdown.

In all instances the pump intake depth was selected so as to maximize available drawdown within the constraints of depth to rest water level, estimated probable drawdown, depth of casing emplacement and, where relevant, the depth and nature of major water-intercept horizons.

A circular orifice weir was used to measure the discharge rate of the high-capacity BP250M pump, while the time taken to fill a 220 l container provided sufficient accuracy for the determination of the lower yields (< 20 l/s) obtained from the weaker boreholes. Every attempt was made to discharge the pumped water as far from the pumped borehole as possible (generally further than 100 m away), and every precaution taken to prevent the possible occurrence of recharge to the aquifer by this water.

6.4 Data analysis

The multi-rate test data were analysed following the method of Jacob (1946b), enabling the productive capacity of a borehole to be assessed in terms of

- the fall-off (or otherwise) in specific capacity with increasing yield, and

- the percentage of the total head loss (drawdown) attributable to laminar flow, which percentage does not necessarily reflect the true hydraulic efficiency of the borehole (Driscoll, 1986).

The constant rate test data were analysed following the applicable methods developed for transient flow conditions in homogeneous and isotropic aquifers of infinite areal extent. In the absence of observation boreholes, these methods provided determination of aquifer transmissivity only, but their applicability suggests that the aquifer regime within the radius of influence of the tested boreholes generally satisfied the assumptions conditional on the application of these methods of analysis. In many instances the time - drawdown data obtained for the first step of the multi-rate tests were also used to determine a transmissivity value.

6.5 Results

The logistics of the multi-rate tests are presented in Appendix 3.1, of the constant rate tests in Appendix 3.2, and the results obtained from the analysis of these tests in Appendix 3.3.

In general terms, the test pumping programme identified at least 11 of the 24 boreholes tested (and 26 boreholes drilled) as potential production boreholes (yield >25 l/s). A further 3 boreholes could not be tested according to their true potential, but nevertheless revealed the potential to support yields >25 l/s. All but one of the remaining 10 boreholes yielded <5 l/s when tested, the exception yielding some 12 l/s. Analysis of the test pumping data also revealed a variation in transmissivity ranging through 5 orders of magnitude (<1 m^2/day to 13 700 m^2/day) which, together with the great variation in yield (from <1 l/s to 100 l/s), reflects the heterogeneous water-bearing properties of the dolomite aquifer in the study area.

Considering that, for the purpose of the dolomite aquifer investigations of which this study forms part, a yield of 25 l/s represents the cut-off yield below which a borehole is not regarded to be a potential production borehole, the boreholes presently under discussion can be grouped as either non-production or potential production boreholes and further discussed accordingly.

6.5.1 Non-production (weak) boreholes

As these boreholes are only of hydrogeological interest, the results obtained from the test pumping of these boreholes (more fully documented in Appendices 3.1, 3.2 and 3.3) are best summarised in Table 6.1 below.

TABLE 6.1: Summarised test pumping results of non-production (weak) boreholes

Borehole No.	Yield at which tested (l/s)	Aquifer trans-missivity (m^2/day)	Worst specific capacity (m^3/h/m	Worst specific drawdown (m/m^3/h)	% recovery/ duration (mins)
G37822	12,2	73	2,13	0,47	95%/180 mins
G37824	0,3	–	0,03	33,75	9%/300 mins
G37827	0,7	1	0,05	20,12	43%/60 mins
G37828	1,3	0,7	0,07	14,96	40%/80 mins
G37830	1,5	–	0,07	15,17	57%/600 mins
G37835A	3,0	9	0,56	1,77	99%/120 mins
G37837	2,5	0,5	0,14	7,11	52%/170 mins
G37837A	2,9	–	0,18	5,71	51%/155 mins
G37839	0,7	0,2	0,03	31,33	27%/120 mins
G37841	3,3	0,7	0,13	7,79	75%/205 mins

The poor yields obtained from these boreholes is a direct function of the poor water-bearing properties of the aquifer penetrated by these boreholes. This is best reflected in the very low computed transmissivities (<1 m^2/day) and related slow rates of recovery. Notable exceptions are boreholes G37822 and G37835A with aquifer transmissivities of 73 and 9 m^2/day respectively, and associated improved rates of recovery.

6.5.2 Production boreholes

Although the results obtained from the test pumping of these boreholes are also fully documented in Appendices 3.1, 3.2 and 3.3, their potential use as production boreholes for emergency urban water supply warrants more detailed discussion. Table 6.2 summarises the results presented in the above-mentioned Appendices.

TABLE 6.2: Summarised test pumping results of potential production boreholes

Borehole No.	Yield at which tested (l/s)	Aquifer trans-missivity (m^2/day)	One-day specific capacity (m^3/h/m)	% recovery/ duration (mins)
G37818A	20	1 262	51	98%/100 mins
G37819C	20	800	–	64%/160 mins
G37820	35	592	16	98%/250 mins
G37821	45	770	38	91%/35 mins
G37823	30	570	13	99%/30 mins
G37825A	19*	–	–	100%/0,5 mins
G37829A	88	–	817	100%/4 mins
G37831	70	186	9	100%/0,5 mins
G37832	100	10 900	732	94%/60 mins
G37834	85**	2 108	90	100%/50 mins
G37836	90	161		80%/480 mins
G37838	82	2 400	97	98%/160 mins
G37840	88	694	24	91%/200 mins
G37842	90	13 678	410	83%/60 mins

* Highest calibration test yield in absence of multi-rate and constant rate tests

** Highest multi-rate test yield in absence of constant rate test.

Attention is drawn to the fact that boreholes G37818A, G37819C and G37825A, which were each tested at a yield of some 20 l/s, have been included as potential production boreholes in Table 6.2 for the following reasons.

. The yields at which these boreholes were tested represents only the maximum pumping rate of the BH250D pump used to test these boreholes. The excessive depth to water level (>80 m), in conjunction with the small borehole cased diameter (203 mm ID), necessitated the use of this pump in boreholes G37818A and G37819C. The extreme depth to rest water level (120 m) accounted for the use of the same pump in borehole G37825A.

- The insignificant drawdowns created at the test pumping rates (Appendices 6.1 and 6.2) unequivocally suggest that all three boreholes are capable of yields considerably greater than 25 l/s.

Attention is further drawn to the observation that all yields greater than 80 l/s represent the maximum pumping rate, under individual site-specific conditions, of the high-capacity BP250M pump used.

6.5.2.1 Borehole and aquifer performance

The performance of all the potential production boreholes except G37825A are graphed as yield versus drawdown curves in Figure 6.1, and as yield versus specific capacity curves in Figure 6.2.

The performance of a borehole is most commonly evaluated following the Jacob (1946b) equation that equates the efficiency of a borehole to the ratio (expressed as a percentage) of the head loss attributable to laminar flow (aquifer losses) to the total head loss (aquifer plus borehole losses). Therefore, the smaller the borehole losses, the more efficient the borehole, and the graphic representation of this scenario approaches a straight-line yield versus drawdown graph. However, Driscoll (1986) points out that this percentaged ratio (termed L_p) does not necessarily represent the true efficiency of the borehole as both aquifer and borehole losses are to some or other degree represented in respectively the turbulent and laminar components of the Jacob equation. It follows that L_p merely indicates the percentage of total head loss attributable to laminar flow, and due regard is afforded this premise where referred to in the following text.

The performance of an aquifer is not only reflected in the behaviour thereof during an aquifer test and by the transmissivity and storativity parameters thereby determined, but also in the nature of water-level recovery following such a test. Reference thereto is therefore considered integral to the following discussion.

Finally, as one of the main objectives of this investigation was to establish potential production boreholes for emergency urban water supply purposes, it would be gross neglect not to evaluate in some detail the performance of individual potential production boreholes so established and, where possible, the performance of the aquifer(s) penetrated by these boreholes. This is attempted in the following text/discussion.

*G37818A: Subject to the limitations imposed on the test pumping of this borehole (subsection 6.5.2), it was observed that the head loss attributable to laminar flow (L_p) decreases from 13% at 5 l/s to 3% at 20 l/s with a reciprocate five-fold decrease in specific capacity from 100 l/s/m to 18 l/s/m (Appendix 3.1). The relatively rapid water level recovery of 90% within 30 minutes following the 8 hour constant rate test suggests that borehole losses are indeed significant. This observation is supported by the strongly curved nature of the yield/drawdown graph (Figure 6.1a), and it is concluded that this borehole could be as inefficient as the value for L_p indicates.

*G37819C: Subject to the same limitations as for G37818A and the additional limitation that the borehole performance evaluation is based on calibration test data, this borehole reveals a decrease in L_p from 36% at 15 l/s to 30% at 20 l/s with a reciprocate 17% decrease in specific capacity from 300 l/s/m to 250 l/s/m (Appendix 3.1). However, the observation that only 64% water level recovery occurred within 160 minutes following the 8 hour constant rate test (Appendix 3.2) suggests that turbulent flow in the aquifer contributes significantly to the apparent inefficiency of the borehole. This observation is supported by the straight-line nature of the yield/drawdown graph (Figure 6.1a). It is concluded that, although this borehole appears inefficient based on the values of L_p, it may in fact be acceptably efficient.

*G37820: The calibration test data proved uninterpretable for borehole performance evaluation purposes. However, the test did reveal the deleterious effect on the potential yield of the borehole caused by the loss of carbon dioxide from the pumped water. This phenonemon necessitated that the constant rate test be performed at a yield of 35 l/s in order to prevent cavitation of the pump. The curved nature of the yield/drawdown graph (Figure 6.1c) suggests mediocre "efficiency", while the 250 minutes taken to achieve 98% water level recovery following the 450 minute constant rate test suggests that the aquifer performance at this site is not entirely satisfactory.

*G37821: An analysis of the calibration test data, although seemingly interpretable, returned a negative laminar loss constant that discounts the value of the analysis. The test did, however, reveal cavitation of the pump at yields >50 l/s that must be attributed to the "inefficiency" of the pump operating at the deep pump setting of $\geq$100 m, especially as insignificant loss of carbon dioxide from the pumped water was observed. A disconcerting aspect of the aquifer behaviour at this site was the nature of the water level recovery following the 400 minute constant rate test. Having recovered 99% within 0,5 minutes, the water level declined to 0,38 m below the initial rest water level within 6 minutes, at which level it remained for the remaining 29 minutes of recorded recovery. The initial recovery is attributed to the inability of either the aquifer, the casing or both of these to allow rapid dissipation of the return-flow of water from the pumping column. The incomplete recovery possibly indicates dewatering of the aquifer to have occurred, although the period of recorded recovery is too short to unequivocally support this statement.

*G37823: Both the yield/drawdown (Figure 6.1C) and yield/specific capacity (Figure 6.2) graphs reveal an improved specific capacity for this borehole at successively higher yields. An analysis of the multi-rate test data therefore returned a negative turbulent loss constant that discounts the value of the analysis. Cavitation of the pump at a yield of 46 l/s was experienced, but this is attributed to an insufficient ($\pm$ 7m) dynamic head of water remaining above the pump following a drawdown of some 11 m. A deeper pump setting would have remedied this situation. The water level recovery following the 8 hour constant rate test to a lesser degree emulates that of G37821. Having recovered to above the initial rest water level within 2,5 minutes, the water level declined to and remained at -0,11 m for the remaining 26 minutes of recorded recovery.

*G37829A: The multi-rate test revealed a 41% decrease in L_p from 80% at 20 l/s to 47% at 82 l/s with a reciprocate 63% decrease in specific capacity from 667 l/s/m to 248 l/s/m (Appendix 3.1). This analysis suggests a relatively inefficient borehole. However, the observed 100% recovery within 4 minutes of the 3 hour constant rate test (Appendix 3.2), and the straight-line nature of the yield/drawdown graph (Figure 6.1b) indicates that the borehole losses are possibly not as severe as suggested, and that the borehole in fact may be quite efficient. Steady-state conditions were achieved in this borehole 40 minutes after the start of the constant rate test.

*G37831: The multi-rate test revealed a 13% decrease in L_p from 94% at 20 l/s to 81% at 70 l/s, with an equally insignificant fall-off of 27% in the specific capacity from 4,4 l/s/m to 3,2 l/s/m. The relatively high efficiency of this borehole is also reflected in the straight-line nature of the yield/drawdown graph (Figure 6.1d). The extremely rapid water level recovery of 100% within 0,5 minutes following the 30 minute constant rate test reflects the excellent performance of the aquifer penetrated by this borehole. The short duration of the constant rate test was caused by a major pump break-down.

*G37832: The calibration test data proved uninterpretable for borehole performance evaluation purposes, but did reveal a 24% fall-off in specific capacity from 500 l/s/m at 40 l/s to 378 l/s/m at 68 l/s. The shape of the yield/drawdown graph (Figure 6.1b) suggests that the efficiency of the borehole does suffer, although not severely, from borehole losses. The relatively rapid water level recovery of 94% within 1 hour following the 230 minute constant rate test supports this observation.

The performance of the aquifer at this site reveals no shortcomings.

*G37834: The multi-rate test revealed a 20% decrease in L_p from 88% at 20 l/s to 70% at 60 l/s with a reciprocate 31% fall-off in specific capacity from 32 l/s/m to 22 l/s/m (Appendix 3.1). The straight-line nature of the yield/drawdown graph (Figure 6.1c) supports the relatively high efficiency rating of this borehole. The observed 100% water level recovery within 50 minutes following the multi-rate test reflects the equally satisfying performance of the aquifer at this site.

*G37836: The calibration test data proved uninterpretable for borehole performance evaluation purposes, but did reveal a disconcertingly large (88%) fall-off in specific capacity from 118 l/s/m at 20 l/s to 14 l/s/m at 80 l/s (Appendix 3.1). This is clearly illustrated in the yield/specific capacity graph (Figure 6.2). The yield/drawdown graph (Figure 6.1c) indicates that the severest fall-off occurs at yields above some 60 l/s, and it must be concluded that the "efficiency" of this borehole is only acceptable at yields <60 l/s. The relatively poor water level recovery of 80% within 480 minutes following the 8 hour constant rate test also reflects the relatively poor performance of the aquifer at the tested yield of 90 l/s. Whether this observation holds true for yields <60 l/s can only be ascertained by conducting a second appropriate constant rate test.

*G37838: The multi-rate test revealed a 30% decrease in L_p from 88% at 20 l/s to 62% at 83 l/s with a reciprocate 37% fall-off in specific capacity from 51 l/s/m to 32 l/s/m (Appendix 3.1). This analysis again seemingly reflects significant inefficiency of the borehole that is not wholly supported by the straight-line nature of the yield/drawdown graph (Figure 6.1c), and it is concluded that the performance of the borehole shows no significant shortcomings. However, the same cannot be said for aquifer performance at this site, as a relatively slow water level recovery amounting to 86% within 160 minutes following the 8 hour constant rate test was observed.

*G37840: The multi-rate test revealed a 55% decrease in L_p from 58% at 20 l/s to 26% at 80 l/s with a reciprocate 74% fall-off in specific capacity from 34 l/s/m to 9 l/s/m (Appendix 3.1). The apparently high borehole loss contribution to the "inefficiency" of this borehole is supported by the form of the yield/drawdown graph (Figure 6.1c). Further, the relatively slow water level recovery amounting to 91% within 200 minutes following the 5 hour constant rate test reveals a disconcerting shortcoming of aquifer performance at this site.

*G37842: Only the first 3 steps of the 4-step calibration test proved interpretable, and revealed a 31% decrease in L_p from 75% at 20 l/s to 52% at 60 l/s. A reciprocate 57% fall-off in specific capacity from 2000 l/s/m to 857 l/s/m was observed (Appendix 3.1). However, an even greater fall-off in specific capacity of 75% occurred between the 3rd and 4th calibration steps, the specific capacity at 90 l/s amounting to 214 l/s/m following a six-fold increase in drawdown from 0,07 m at 60 l/s. This indicates a significant deterioration in the "efficiency" of the borehole at yields >60 l/s.

This is also reflected in the yield/drawdown graph (Figure 6.1b). The relatively slow water level recovery amounting to 83% within 1 hour following the 330 minute constant rate test reflects a shortcoming in the performance of the aquifer even though a 100% recovery was observed within 15 hours following the test.

6.5.5.2 Production potential

The augmentation of urban water supply under whatever circumstances from the boreholes established and aquifers explored as part of this investigation requires quantification of the production potential of these sources. Table 6.3 represents an attempt at such a quantification based on the Cooper and Jacob (1946) modification of the Theis non-equilibrium equation

$$s = \frac{0,183Q}{T} \log \frac{2,25\ Tt}{r^2\ S} \qquad 6.1$$

where

s = drawdown, in metres, at any point in the vicinity of a borehole discharging at a constant rate
Q = pumping rate, in m^3/day
T = transmissivity of the aquifer, in m^2/day
t = time since pumping started, in days
r = distance, in metres, from the centre of a pumped borehole to a point where the drawdown is measured
S = storativity of the aquifer (dimensionless)

Rearranging equation 6.1 allows determination of the rate at which a borehole must be pumped in order to satisfy a specified drawdown at a specified distance from the pumped borehole after a specified time, provided that the transmissivity and storativity of the aquifer are known.

The choice of values for the variables s, t and r for each potential production borehole (Table 6.3) represents the maximum permissible drawdown at the radius of the pumped borehole after 1 year of continuous pumping. Although arbitrary, the maximum permissible drawdown was selected as

- 5 m where shallow (<30 m) water levels occur in association with highly-leached phreatic dolomite aquifers;

TABLE 6.3: Calculated one-year production (yield) potential of the production boreholes

Borehole no.	Equation parameters for calculating optimum pumping rate					Theoretical optimum pumping rate			Specific capacity		
	Transmis-sivity (m^2/day)	Storativity	Time (days)	Distance from borehole (m)	Maximum allowable drawdown (m)	(l/s)	(m^3/day)	(m^3/year)	one-day (m^3/h/m)	one-year (m^3/h/m)	% ratio
G37818A	1 262	0,03	365	0,102	10	83,8	7 243	$2,6 \times 10^6$	51	30	59%
G37819C	800	0,03	365	0,102	10	54,3	4 689	$1,7 \times 10^6$	-	20	-
G37820	592	0,03	365	0,127	10	41,6	3 593	$1,3 \times 10^6$	16	15	94%
G37821	770	0,03	365	0,127	10	53,4	4 615	$1,7 \times 10^6$	38	19	50%
G37823	570	0,03	365	0,165	10	41,2	3 556	$1,3 \times 10^6$	13	15	115%
G37825A	500*	0,03	365	0,127	10	35,4	3 060	$1,1 \times 10^6$	-	13	-
G37829A	10 000*	0,10	365	0,127	5	325,8	28 147	$10,3 \times 10^6$	817	235	29%
G37831	186	0,01	365	0,127	20	26,2	2 264	$0,8 \times 10^6$	9	5	52%
G37832	10 900	0,10	365	0,127	5	353,7	30 563	$11,1 \times 10^6$	732	255	35%
G37834	2 108	0,10	365	0,102	5	72,3	6 246	$2,3 \times 10^6$	90	52	58%
G37836	161	0,01	365	0,127	20	22,9	1 974	$0,7 \times 10^6$	-	4	-
G37838	2 400	0,03	365	0,127	5	79,0	6 824	$2,5 \times 10^6$	97	57	59%
G37840	694	0,03	365	0,127	10	48,4	4 180	$1,5 \times 10^6$	24	17	71%
G37842	13 678	0,10	365	0,127	5	439,5	37 968	$13,8 \times 10^6$	410	316	77%
					Total	1 623,2	140 233	$52,7 \times 10^6$			

* Conservative estimate of transmissivity for the aquifer zone penetrated by this borehole.

- 10 m where deep (>50 m) water levels occur in association with deep-lying (>80 m) highly-leached semi-unconfined to semi-confined dolomite aquifers;

- 20 m where intermediate water levels (25 m to 50 m) represent the piesometric head associated with deep-lying (>100 m) leached or fractured confined dolomite aquifers.

The transmissivity values used in Table 6.3 were obtained from the test pumping results of the potential production boreholes (Table 6.2, subsection 6.5.2).

The values of the final parameter required i.e. storativity, again represents a subjective estimate based on the observed aquifer regime, yet remaining well within the limits of estimated storativity values for dolomite aquifers given by Bredenkamp (1988).

Reality dictates that the very high calculated optimum pumping rates of boreholes G37829A (326 l/s), G37832 (354 l/s) and G37842 (440 l/s) presented in Table 6.3 can never be realised by a single pump. However, these yields merely reflect the pumping rates required to obtain the specified maximum permissible drawdowns after one year of continuous pumping. Lower pumping rates would necessarily result in smaller drawdowns after one year.

A comparative analysis of the calculated optimum pumping rates presented in Table 6.3 with the yields at which these boreholes were tested (Table 6.2) and the resulting performance characteristics of each borehole as discussed in detail in subsection 6.5.5.1 confirms that these pumping rates are acceptably realistic and feasible.

6.5.3 Transmissivity and specific capacity

Hobbs (1988) reports a strong correlation between aquifer transmissivity and borehole specific capacity obtained from an analysis of 86 dolomite aquifer pumping tests. Figure 6.3 represents a similar analysis of these data for the potential production boreholes tested as part of this investigation, and again reveals a strong correlation between these two parameters. This correlation is embodied in the equation

$$T = 37{,}83 \; SC^{0{,}91} \qquad 6.2$$

where

T = transmissivity of the aquifer in m^2/day
SC = one-day specific capacity of a borehole, in m^3/h/m

The observation that equation 6.2 above differs significantly from that reported by Hobbs (1988) is ascribed to the fact that this equation is based on data obtained for high-yielding boreholes only, that the data is further representative of that for a specific region, and also that the specific capacity data represents one-day rather than 8-hour specific capacities.

If it is accepted that the specific capacity of a borehole is detrimentally influenced by such factors as period of pumping, pumping rate, partial penetration of the aquifer by the borehole, and the magnitude of the turbulent flow head loss component of drawdown, then equation 6.2 should only be regarded as a rule of thumb criteria for judging transmissivity from specific capacity data in the study area.

7. HYDROCHEMISTRY

7.1 General

A total of 127 groundwater samples were collected throughout the study area during the first two weeks of October 1988. The samples were analysed for their major-ion chemistry at the Hydrological Research Institute. The final laboratory analyses expressed in mg/ l are presented in Appendix 5.1. These analyses were converted to meq/ l using the conversion factors presented in Hem (1970, p.83) in order to determine the various analytical parameters by which groundwater quality in the study area could be evaluated. These data are presented in Appendix 5.2.

In order to correlate the groundwater chemistry with known hydrogeological data, it was possible in all but seven instances to collect groundwater samples from boreholes in which groundwater levels had previously been measured. In the case of the seven exceptions, the nearest active borehole was sampled. These boreholes therefore carry the same identifying number as the nearest hydrogeological data point, but are suffixed by a C.

The representativeness of the groundwater samples was assured by sampling only active boreholes. In instances where pumps had to be started, the sample was taken after 15 minutes of pumping. Both the electrical conductivity (EC) and pH of each sample was determined in the field. A WTW model LF 90 portable conductivity meter and Whatman pH indicator paper were used for this purpose. The field temperature of each sample was also measured, and the temperature compensation facility of the EC meter adjusted accordingly to produce an EC value referenced to a temperature of 25°C.

The percentage error on analysis varies from 0,1% to 16,9% (Appendix 5.2). However, the average percentage error of 4,2% is only marginally greater than the suggested 3% acceptable for groundwater of moderate TDS (Miles et. al., 1981). The field determined EC values vary (in exceptional cases) by up to 18% from the reported laboratory values, but in general are less than 10% lower than the latter values. A much more serious discrepancy is observed between the field and laboratory determined pH values. The "roughly" determined field pH values in no instance exceed a value of 6.5, whereas 89% (111) of the laboratory determined pH values lie between 7,0 and 8,0 i.e. neutral to slightly alkaline. The lowest reported laboratory pH value of the remaining 14 samples is 6,1.

7.2 Groundwater quality

The general quality of groundwater in the study area, as illustrated in Table 7.1 below, is excellent.

TABLE 7.1: Range of EC and TDS values of groundwater.

SOURCE AQUIFER	EC (mS/m)	TDS (mg/ 1)
Granite	10 - 20	100 - 180
Black Reef Quartzite Fm.	15 - 30	100 - 200
Chuniespoort Group (dolomite)	35 - 70 *60 - 80	250 - 550 *450 - 600
Pretoria Group (quartzite/shale)	5 - 15	40 - 100

*Dolomite groundwater from boreholes within 1 000 m of the Hennops River.

The apparent difference in dolomite groundwater quality from that of the other aquifers in the study area is more clearly illustrated in Figure 7.1. Here it has been possible to construct lines (as indicated) demarcating this difference not only on the basis of TDS values but also following the chemical composition of the sampled groundwaters.

As is to be expected, the dolomite groundwater exhibits the dominance of the Ca^{++} and Mg^{++} cations characteristic of this water, with HCO_3^- by far the dominant anion in all but four of these samples. Two of the latter samples (46 and 112) exhibit an anion composition in which $SO_4^{--} > HCO_3^- > Cl^-$ such that sulphate (SO_4^{--}) constitutes more than 50% of the constituent anion percentage (Appendix 5.2). The remaining two samples (85 and 95) maintain the $HCO_3^- > Cl^- > SO_4^{--}$ relative anion composition of the majority of the samples except that bicarbonate (HCO_3^-) in these two instances constitutes less than 50% of the constituent anion percentage (Appendix 5.2).

Figure 7.1 further illustrates the definitive plotting field in which groundwater samples obtained from boreholes tapping exclusively the granite aquifer are represented. The strong sodium (Na^{++}) cation component (> 50%) of this groundwater accounts for this plotting position.

The strongly bicarbonate (HCO_3^-) character of 97% of the sampled groundwater reflects the general freshness of groundwater in the study area. However, a subtle variation in the relative concentration of this anion in the carbonate groundwater is observed. This variation amounts to groundwater obtained from boreholes within some 1 000 m of the Hennops River exhibiting a lower bicarbonate concentration and higher TDS value than that obtained from the other dolomite boreholes. These samples also plot in a distinctive plotting field as illustrated in Figure 7.1.

Since the quantity and rate of removal of carbon dioxide is greater from surface water (an open system under atmospheric pressure) than from groundwater in a "closed" system under greater pressure, it is to be expected that surface water will have a relatively lower bicarbonate concentration than ambient groundwater. The above observation that dolomite groundwater in proximity to the Hennops River exhibits a relatively lower bicarbonate concentration than other dolomite groundwater in the study area therefore may reflect the existence of hydraulic continuity between the dolomite aquifer and this major surface drainage.

7.2.1 Electrical conductivity

The generally low (< 80 mS/m) conductivity of groundwater in the study area attests to the excellent quality thereof (Table 7.1). Figure 7.2 represents an electrical conductivity contour map of groundwater in the study area, and serves to verify observations relating to the hydrogeology (section 8) of the study area as follows.

- The gradual increase in conductivity (and TDS) from the south in the Erasmia catchment and the south-west in the Irene catchment towards the valley of the Hennops River substantiates the inferred direction of groundwater movement in the south-western quadrant of the study area (Figure 8.1). The electrical conductivity contours are also seen to "mirror" the configuration of the groundwater elevation contours to a substantial degree.

- The NE-SW striking zone of anomalously low conductivities south-west of the Hennops River corresponds to a similar zone of elevated groundwater levels (Figure 8.1), and can also be associated with the extensive occurrence of syenite sills in this area. In corroboration of the latter observation, it is noted that the quality of groundwater from boreholes 20 and 21 (map grid reference D6) approaches that of the granite aquifer.

- The generally high transmissivity of the dolomite aquifer in the West Fountain subcatchment of the Irene catchment (section 8.3.2.3) is reflected in the greater encroachment of Hennops River-influenced groundwater quality into the dolomite aquifer along this portion of the river than elsewhere along the course thereof in the study area (Figure 7.2).

7.2.2 Aggressiveness

The aggressiveness of groundwater can also be defined as the corrosion potential of such water, and is an important factor in the deterioration of water distribution systems and as a potential health hazard (Millette et. al., 1980). A measure thereof is the

Aggressive Index (AI), which is based on the calcium carbonate solubility of groundwater. An AI $\leq$ 10,0 indicates high aggression, 10,1 $\leq$ AI $\leq$ 11,9 indicates moderate aggression, and AI $\geq$ 12,0 indicates non-aggression (AWWA, 1977). The calculated AI value of each sample is presented in Appendix 5.2.

The areal distribution of this parameter is indicated in Figure 7.2, from which it is evident that only the granite groundwater shows high aggression. The moderate aggression indicated by dolomite groundwater in close proximity to the granite aquifer probably reflects the degree of mixing of dolomite groundwater with recharging granite groundwater, as the "pure" dolomite groundwater itself is generally non-aggressive.

A similar scenario exists along the eastern margin of the dolomite aquifer. The highly aggressive groundwater of the Pretoria Group (boreholes 118, 180 and 181-C) gradually loses this character following down-gradient mixing with the dolomite groundwater. Groundwater sample 149 (map grid reference B10), for example, indicates only moderate aggression. This borehole is located within 1 000 m of the Pretoria Group rocks.

It is significant to note that the groundwater samples 162 (map grid reference D9) and 184 and 108 (map grid reference E9) each indicate moderate aggression of the groundwater "trapped" in the wedge formed by the Pretoria dyke and it's off-shoot in this locality. Whether this can be ascribed to the general observation that groundwater in close proximity to dykes and sills (for example samples 14-C (map grid reference E5), 38 (map grid reference E4), 20 and 22 (map grid reference D6) and 76 (map grid reference B9)) also indicate moderate aggression, or to other hydrogeological/hydrochemical factor(s), is not clear without further specialised investigation.

It is concluded that dolomite groundwater in the study area is generally non-aggressive.

7.2.3 Calcium carbonate incrustation potential

Dolomite groundwater that is in equilibruim with solid calcuim carbonate ($CaCO_3$) at a high underground partial pressure of CO_2, loses CO_2 when brought to the surface until equality is attained between the CO_2 partial pressure in the air and that in the liquid (Loewenthal et. al., 1988). This loss of CO_2 may cause $CaCO_3$ precipitation. Evidence for such CO_2 loss from pumped groundwater was provided during the test pumping of exploration/production borehole G37820 (subsection 6.5.2.1). The implication of $CaCO_3$ precipitation in urban water supply distribution systems requires that this aspect be addressed as fully as possible with available data.

The Langelier Saturation Index (LSI) is a measure of the degree of calcium carbonate saturation in water (Langelier, 1936). It is mainly used to evaluate the potential for $CaCO_3$ incrustation in pipes, etc. If the index is zero, the water is in equilibruim. A positive LSI indicates oversaturation and a tendency to lay down a protective coating in the pipe, and a negative LSI indicates undersaturation or a tendency to be aggressive to the pipe interior. The greater the negative value, the greater the aggressiveness. The LSI of each groundwater sample is presented in Appendix 5.2.

The areal distribution of groundwater with a positive LSI is indicated in Figure 7.2, from which it is clear that most of the dolomite groundwater is supersaturated with respect to $CaCO_3$. This implies that calcium carbonate incrustation of pipes and pumping equipment that will distribute the groundwater supplied by the potential production boreholes (subsection 6.5.2) can be expected. The extent to which this can occur for each potential production borehole must be examined prior to the commissioning of these boreholes.

7.2.4 Corrosiveness

A third method for estimating the corrosive tendency of groundwater is provided by the calculation of the corrosion tendency ratio, which considers the influence of the chloride and sulphate anions on the ability of a water to corrode metals. These values are also presented in Appendix 5.2.

In the neutral pH range (7 to 8) and in the presence of dissolved oxygen, ratios equal to or below 0,1 indicate general freedom from corrosion, whereas increasingly higher ratios generally indicate more aggressive waters (Rand et. al., 1975).

Inspection of the corrosion tendency ratios provided in Appendix 5.2 reveals a general variation from 0,03 to 0,8 for groundwaters in the study area. Exceptionally high ratios are observed in samples 46 (2,98, map grid reference F6), 85 (1,07, map grid reference I10), 95 (1,17, map grid reference I10) and 112 (1,80, map grid reference E9), and reveals the greater concentration of $SO_4^{=}$ and Cl^- in these samples than in any of the other samples (subsection 7.2). This is discussed in greater detail in subsection 7.2.6.

Despite the fact that the corrosion tendency ratio of most dolomite groundwater in the study area exceeds the threshold value of 0,1, the probable development of $CaCO_3$ incrustation (subsections 7.2.2 and 7.2.3) in a water distribution system will provide protection against corrosion. This observation also holds true for the abovementioned anomalous samples for the reason that their Aggressive and Langelier Saturation Indices both indicate a greater potential for $CaCO_3$ incrustation than the other dolomite groundwater.

7.2.5 Quality for irrigation

Although the quality of groundwater for irrigation is of little consequence to this investigation specifically and groundwater use in the study area in general, it is noted (Appendix 5.2) that the sodium-absorption-ratio (SAR) values of groundwater in die study area are extremely low (<3,3). Combined with the generally low electrical conductivity (< 80 mS/m) of this groundwater, it produces an excellent quality groundwater for irrigation.

7.2.6 Pollution

Very little evidence of groundwater pollution is manifested in the study area. Only the two isolated samples 46 (map grid reference F6) and 112 (map grid reference E9) reveal excessive sulphate concentrations of 634 mg/ l and 317 mg/ l respectively. Both these samples also reveal excessively high calcium and magnesium concentrations compared with other dolomite groundwater. The source of these anomalous concentrations was not investigated or ascertained. Their isolated occurrence, however, negates their potential as sources of possible pollution to the dolomite aquifer as a whole.

Other samples showing signs of possible pollution are limited to the extreme southern portion of the study area. These are samples 85 and 95 (map grid reference I10), which both reveal a strong sodium - bicarbonate ($NaHCO_3$) character with chloride concentrations of 98 mg/ l and 120 mg/ l respectively, and sample 137 (map grid reference H10) having a predominantly $MgHCO_3$ character with a chloride concentration of 154 mg/ l. The source of these anomalous groundwater chemistries was not investigated. However, sample 137 was obtained from a borehole located some 150 m north of a recently abandoned urban solid waste disposal site, pollution from which might account for this anomalous sample.

7.2.7 Waste disposal sites

The location of the eight urban solid waste disposal sites within the Verwoerdburg Municipal area is indicated in Figure 7.2. Six of these sites are no longer operational, the most recent to close down being site 5 (map grid reference H11). Site 6 is used solely for the disposal of garden waste, while site 8 has replaced site 5 as a disposal site of municipal waste since end 1986.

Sites 1 and 2 (map grid references I3 and H5 respectively) are located on granite where the relatively shallow (<10 m) depth to groundwater level provides some cause for concern with regard to possible groundwater pollution. Although not definitive, the slightly anomalous electrical conductivity (20 mS/m) of the groundwater sample obtained from borehole 3-C (map grid reference H5) in the vicinity of site 2 might hint at possible pollution. However, a mitigating factor is the apparently low transmissivity of the granite aquifer in this vicinity. The relatively steep north-westerly groundwater gradient of some 0,038 (Figure 8.1) supports this premise. The absence of boreholes in the vicinity of site 1 precludes a similarly critical appraisal of this site in the above context.

Waste disposal sites 3 and 7 are located on dolomite terrain where the depth to groundwater level is relatively shallow. However, no deleterious effect on the groundwater quality in the immediate vicinity of site 3 is observed. The depth to groundwater level in this vicinity (boreholes 32 and 83, map grid reference D5) is less than 40 m.

In contrast, site 7 abandoned at the end of 1986 provides great cause for concern with regard to possible pollution of surface and groundwater. This site is located on the right bank of the Olifantspruit, and occupies a now filled-up depression in the dolomite originally some 30 m deep. The depth to groundwater at this locality is less than 10 m below surface, and leachate from this site probably drains into the Olifantspruit. The latter has been replaced as a source of potable water on the Salberg Cement property by borehole 136 at this location (map grid reference H11). This indicates the extent to which the quality of surface water in this drainage has deteriorated. A second cause of pollution is the runoff of Tembisa sewage effluent down the Kaalspruit, a major tributery of the Olifantspruit, into the study area.

The serious implications the above factors have for the general quality of dolomite groundwater along the reach of the Hennops River in the study area necessitates future more detailed investigation thereof.

The remaining waste disposal sites are located on dolomite where the depth to groundwater level exceeds 70 m. Nevertheless, especially sites 5 and 8 provide cause for concern as these sites are located above a potentially valuable aquifer with regard to emergency urban water supply. Potential production boreholes G37820, G37821, G37823 and G37825A penetrate this aquifer, and although the electrical conductivity (42 mS/m) of the groundwater sample obtained from borehole G37821 located some 600 m south of site 8 apparently represents the ambient conductivity of groundwater in this aquifer, it is possible that the 1,5 year period in which this site has been active is too short to have caused discernible pollution of the deep-seated aquifer. However, site 8 is rapidly expanding in size, and the longer this site remains operational, the greater the potential threat of pollution to the aquifer. This threat demands an investigation of the pollution potential at this site with a view to remedial action, and the drastic action of immediately closing down this site should be seriously considered. It is understood that the Directorate of Water Pollution Control (DWA) is already aware of the situation regarding waste disposal site 8.

8. HYDROGEOLOGY

8.1 Groundwater occurrence

Le R. Cilliers (1953), Temperley (1978) and Foster (1988) present an excellent exposition of the mode of groundwater occurrence in the dolomite aquifer, emphasising the essentially impermeable nature of dolomite with significant secondary porosity developed along bedding planes, joints, fissures and fractures as a result of dissolution by circulating groundwater. The more fractured and more calcitic nature of the chert-rich units (Monte Christo and Eccles Formations) of the Chuniespoort Group reveal an apparently greater susceptibility to the dissolution processes. With the insoluble chert "lattice" providing support from collapse, these units constitute better aquifers than their chert-poor counterparts, the Lyttelton and Oaktree Formations.

Equating the occurrence of groundwater in dolomite to a system of conduits, Temperley (1978) states that "a borehole only strikes water if it strikes a conduit that contains water, and the borehole only continues to yield water if the opening penetrated is part of the arterial system".

Intrusive dykes and sills (subsection 3.2.6) exercise greater geological control on the movement of groundwater (subsection 8.3) than on the occurrence thereof. However, anomalously shallow water levels in some boreholes in the west-central portion of the study area (Figure 8.1) represent apparently perched water levels that are possibly associated with the extensive syenite sills occurring in this area. SRK (1983) report an often noticeable increase in transmissivity in the dolomite with proximity to the Bank and Gemsbokfontein dykes in the West Rand. A similar situation is indicated in the study area as discussed in greater detail in subsection 8.3. The further hydrogeological significance of especially the Pretoria and Sterkfontein dykes is their association with major springs.

An analysis of the Verwoerdburg Municipality private borehole census data provides a general yet excellent perspective on the areal variation of groundwater occurrence in the study area as presented in Table 8.1.

TABLE 8.1: Areal variation of groundwater occurrence

Suburb	No of "registered" boreholes	Average yield (l/s)	Average depth (m)	Aquifer
Doringkloof	18	0,6	87	Dolomite
Clubview	29	1,6	63	Dolomite
The Reeds	68	0,8	46	Granite
Hennopspark	7	0,9	45	Dolomite
Lyttelton	31	0,5	119	Dolomite
Eldoraigne	49	1,1	59	Dolomite
Celtisdal	3	0,4	57	Dolomite
Rooihuiskraal	38	0,8	48	Granite
Bronberrik	18	1,6	49	Dolomite
Pierre van Ryneveld	21	0,7	53	Quartzite
Wierdapark	52	0,8	102	Dolomite
Irene	4	0,1	109	Dolomite
Total	338			
Average		0,8	70	

It must be remembered that the census data represents uncorroborated information provided by private borehole owners, and that the greater majority of reported yields therefore probably represents actual abstraction rates rather than tested yields. However, it is interesting to note that the higher yields for Clubview (1,6 l/s) and Eldoraigne (1,1 l/s) apparently relates to the proximity of these suburbs to the Hennops River where the Hennops River valley attains its greatest width.

8.2 Groundwater levels

Groundwater levels were measured in some 180 boreholes throughout the study area in the period June to August 1986 and during January 1987. Comprehensive borehole census data provided by the Verwoerdburg Municipality facilitated the selection of these boreholes such that the radial distance between these boreholes seldom exceeds 1 000 m, thereby providing an even yet representative spread of boreholes in the dolomite aquifer and adjacent geological formations. Deviation from this norm was inevitable in those localities where the distribution of boreholes is sparse, such as in the south of the study area.

Considerable effort was expended in ensuring that in all cases natural rest water levels were measured as far as this was possible. The collar elevations of the boreholes were interpolated from 1:10 000 scale orthophotos (1977), enabling groundwater elevations to be determined to an accuracy of some 2 m. It is doubtful whether the greater accuracy to be gained by the leveling of borehole collar elevations (in order to more accurately determine absolute groundwater elevations) warrants the time and cost inherent in such an exercise.

An absolute groundwater level elevation contour map for the first period of measurement is presented in Figure 8.1. This figure also portrays the depth to groundwater level as measured in each borehole. The data used to compile this map are presented in Appendix 4.

It is observed that boreholes located on the granite in the south-western quadrant of the study area reveal shallow water levels generally less than 20 m from surface. Boreholes tapping the Pretoria Group rocks along the eastern margin of the study area indicate relatively uniform "intermediate" depths to water level in the order of 20 to 50 m. Conversely, the "dolomite" water levels reveal little uniformity with regard to depth below surface. This varies from some 10 m to more than 100 m. The shallowest groundwater levels coincide with the course of surface drainages and, in the case of borehole 87 (Figure 8.1, map grid reference F7), with standing surface water in close proximity thereto.

Apparently perched water levels are revealed by anomalously shallow water levels in boreholes 47 and 48 (map grid reference E7) and, to a lesser extent, in borehole 24 (map grid reference E6). However, this observation must be qualified as follows. Both boreholes 24 and 47 exceed a depth of 150 m. It is reported (Appendix 4) that seepage water was struck at 18 m in borehole 47, and that this borehole was completed at a depth of 160 m without anywhere encountering syenite. Borehole 24 was completed at a depth of some 200 m, but no information on the geology in this bore is available. The yield of both these boreholes is less than 0,1 l/s. The anomalously shallow water levels in these boreholes must therefore be attributed to filling up of the bores with seepage water and the obviously impervious nature of the dolomite formation in these boreholes severely limiting the loss of this water from the bores. Borehole 48, on the other hand, is reported to be 45 m deep with syenite occurring in the 40 to 45 m interval. This observation supports the idea of perched water levels being associated with dipping intrusive bodies.

The anomalously shallow water level in borehole 111 (map grid reference C9), and to a lesser extent in borehole 163 (map grid reference D9), is similarly attributed to a perched water level associated with the westerly dipping Pretoria dyke. Both these boreholes were terminated in this structure well above the ambient groundwater elevation in the dolomite, with water being struck in weathered dyke material.

The anomalously deep water level measured in borehole 132 (map grid reference G8) is attributed to localised dewatering resulting from continued and excessive use of this borehole, especially if it is considered that the water strike in this borehole is probably associated with the weak water-bearing horizon at the contact of the dolomite with the overlying syenite (on which this borehole is located). In borehole 119 (map grid reference E10) the anomalously deep water level is attributed to exceedingly slow recovery of the water level following cessation of pumping. Evidence for this scenario is provided by the case of borehole 130 (map grid reference E8). The depth to water level in this borehole was recorded as some 83 m four days after the bore was completed. Five days later it was recorded as some 43 m. This borehole is not equipped as the insignificant yield provided by the seepage water does not warrant use of the borehole. A similar observation was made following the drilling and pump testing of exploration/production borehole G37824.

Figures 8.2 to 8.4 represent hydrogeological profiles illustrating the relationship of groundwater levels in the study area to dykes, regional topography, surface water features and geology. The positions of these sections are indicated on Figure 8.5. Profiles A-A' and B-B' (Figure 8.2) and profile C-C' (Figure 8.3) represent west-east sections along lines of latitude 25° 49'S, 25° 51' S and 25° 54'S respectively. Profile D-D' (Figure 8.3) represents a diagonal section from borehole 1 (Figure 8.1, map grid reference H4) in the south-west to borehole GF-1A (map grid reference A8) in the north. Profile E-E' (Figure 8.4) runs from south to north along line of longitude 28° 06'E. Profile F-F' has a south-east to north-west component originating at borehole L-21 (Figure 8.1, map grid reference J11) located immediately south of the Sterkfontein dyke near the Sterkfontein spring and terminating at the Irene dyke intersection with longitude 28° 11'E, and a south to north component thence to borehole GF-1A.

All six the profiles reveal the general adherence of "non-dolomite" groundwater levels to the form of the surface topography. This is especially true of the "granite" water levels evidenced in profiles C-C', D-D' and E-E'. In contrast, the "dolomite" water levels reveal little regard for the surface topography. They reveal generally much smaller gradients and a subhorizontal attitude as revealed in profiles A-A', B-B', D-D' and F-F'. An exception to this observation is the attitude of the water table in the vicinity of the groundwater divide indicated on profiles B-B' and D-D'.

Profiles A-A' and B-B' further reveal the elevated water table in the Pretoria Group rocks relative to that of the dolomite, resulting in a "step" of some 60 m across the geological contact along the eastern margin of the dolomite aquifer. Boreholes sunk in the Pretoria Group rocks generally yield sufficient water before penetrating the underlying dolomite, with the result that these boreholes have no need to penetrate the latter. These water levels must therefore be ragarded to belong to a distinctly separate groundwater regime from that of the dolomite aquifer.

The influence of dykes on groundwater levels in the dolomite aquifer is limited to four significant instances well illustrated in profiles A-A', B-B', C-C', D-D' and F-F'. The most significant of these is the elevated water table occurring between the Pretoria dyke and its easterly off-shoot located immediately west of the Lyttelton Dolomite Mine (profile B-B', Figure 8.2). The influence of the Pinedene dyke revealed in profile F-F' is discussed in greater detail in subsection 8.3 below.

A final interesting observation is the markedly subhorizontal groundwater level across the northern portion of the dolomite aquifer revealed by the groundwater level contours (Figure 8.1) and in profile A-A' (Figure 8.2). The significance hereof is also embroidered upon in subsection 8.3 below.

8.3 Groundwater movement

It is evident from Figure 8.1 that groundwater movement in the study area occurs in a north-westerly draining western catchment, and a notherly draining eastern catchment. These catchments are analogous to respectively the Erasmia and Irene groundwater catchments described by Temperley (1978). They are separated by a non-aligned groundwater divide roughly coincident with longitude 28° 10'E. The juxta-position of this divide occurs along the Irene dyke in the vicinity of Rooihuiskraal. For clarity when referring to these catchments in the text, the nomenclature introduced by Temperley (1978) will be adopted in this report.

8.3.1 Erasmia catchment

This catchment extends southwards from Erasmia across the Hennops River valley and up the valley of the Rietspruit, centering upon the latter, to Halfway House.

The direction of gound-water movement in this catchment is well illustrated in Figure 8.1, revealing a general convergence of flow from both the north, south and south-east on the Hennops River valley in the vicinity of the defunct Erasmia spring, which has been replaced by a pumping station comprising two boreholes. Temperley (1978) reports abstraction from this station to amount to 34.10^3 m^3 per month (13 l/s) during the winter months, 48.10^3 m^3 per month (19 l/s) during the summer months, and 55.10^3 m^3 per month (21 l/s) during the peak demand months of September and October.

Significant hydrogeological features revealed in this catchment (Figure 8.1) are summarised below.

- The morphological signature of the Rietspruit valley is mirrored in the pattern of the groundwater elevation contours along this surface drainage. The groundwater gradient along this drainage is a relatively steep and constant 0,01 except in the Hennops River valley near the confluence of the two drainages, where the groundwater gradient weakens to 0,0053.

- An extremely weak gradient from the north (0,001) and north-east (0,002) towards the Hennops River valley is indicated in the northern portion of this catchment.

- A relatively steep north-westerly groundwater gradient of 0,018 exists towards the Hennops River valley west of line of longitude 28°05' E.

- The Pinedene dyke apparently constitutes a groundwater barrier in the east-central portion of the catchment, realising a step of 20 to 50 m across the dyke in this vicinity, and resulting in a north-westerly to westerly groundwater flow component towards the Rietspruit along the south-western side of the dyke. The influence of this dyke as a groundwater barrier disappears to the north-west of the Rietspruit valley.

- The Irene dyke does not appear to form a groundwater barrier where it traverses the granite in this catchment, only acting as such east of the Black Reef Quartzite Formation/Chuniespoort Group contact, where it forms the southern boundary of the catchment in the central portion of the study area.

- A subcatchment "basin" open to the north-west, but otherwise bounded by the Pinedene and Irene dykes and the catchment groundwater divide, exists in the east-central portion of this catchment.

It is further evident from Figure 8.1 that the Erasmia catchment extends towards the west outside the present study area. At least two components of groundwater movement in this portion of the catchment are revealed . These are i) a north-westerly component towards the Hennops River valley, and ii) a westerly component coinciding with the course of the Hennops River. Component (i) above drains the western portion of the Erasmia catchment towards the Aalwynkop spring, the lowest spring in this catchment (Temperley, 1978), and which is situated on the left bank of the Hennops River some 4,5 km downstream from Erasmia and outside the present study area.

8.3.2 Irene catchment

This catchment comprises four subcatchments which are in hydraulic connection as evidenced by the direction of groundwater flow (Figure 8.1). The four subcatchments are analogous to the West

Fountain, East Fountain, West Doornkloof and East Doornkloof compartments described by Vegter (1986). However, the configuration of these compartments is not related to the quartering of this catchment by the Pretoria and Irene dykes as previously thought. The configuration of these compartments as revealed by this investigation is clearly illustrated in Figure 8.5.

The nomenclature adopted by Vegter (1986) in identifying the four "compartments" of this catchment is maintained in this report except that the term "compartment" is dropped in favour of the term subcatchment in view of the apparent subsurface hydraulic continuity that exists between them.

8.3.2.1 West Doornkloof subcatchment

This subcatchment drains groundwater from two "extraneous" sources into the West Fountains subcatchment. These are the granite in the south-west and the East Doornkloof subcatchment.

The dynamics of flow from these sources are qualified as follows.

- A steep groundwater gradient of 0,0400 is manifested across the Black Reef Quartzite Formation in a north-easterly direction. This gradient weakens to 0,024 in the dolomite where flow occurs across (through?) the Pinedene dyke between boreholes 113 (map grid reference G8) and 116 (map grid reference H10). The northern-most component of this flow i.e. that located in the quadrant formed by the Irene and Pinedene dykes, reveals an even weaker gradient of 0,0161 in an easterly direction parallel to and south of the Irene dyke. The groundwater elevation contours (Figure 8.1) indicate a step across the Pinedene dyke in the abovementioned quadrant, and it must therefore be presumed that little, if any, flow is contributed from the granite in this vicinity. In any event, the close proximity of the groundwater divide to the west substantiates this presumption.

- The second source of groundwater enters this subcatchment along the course of the Hennops River immediately south of Irene. This necessitates that groundwater movement must occur across the Pretoria dyke at this locality. The dynamics of this flow component is rooted in the groundwater movement in the East Doornkloof subcatchment, which is discussed in greater detail in subsection 8.3.2.2 below.

As regards groundwater flow in the dolomite aquifer in this subcatchment, significant flow in a northerly direction along the western side of the Pretoria dyke is indicated by the very weak gradient of 0,0092. It is concluded that the more transmissive zones in this subcatchment occur in an east-west striking direction immediately south of the Irene dyke, and in a north-south striking direction immediately west of the Pretoria dyke. Figure 8.1 clearly indicates the outlet of this subcatchment to be located along the course of the Hennops River at the intersection thereof with the Irene dyke. These observations are supported by the results ofthe gravity survey (subsection 4.3.2).

8.3.2.2 East Doornkloof subcatchment

Groundwater in this subcatchment drains in a general north-westerly direction. The major component of this flow is indicated along the eastern side of the Pretoria dyke coincident with the course of the Olifantspruit. The weak gradient of 0,0069 associated with this flow component is indicative of a high transmissivity.

A secondary southward draining flow component is identified in the "wedge" formed by the Pretoria dyke and its eastern off-shoot in the northern corner of this subcatchment. This flow links up with the previously described major flow component to drain into the West Doornkloof subcatchment. The outlet of this subcatchment has previously been described in subsection 8.3.2.1

8.3.2.3 West Fountain subcatchment

An extremely weak groundwater gradient of some 0,002 is manifested from immediately north of the Hennops River in a north-north-easterly direction toward the West Fountain spring, and indicating a high transmissivity of the dolomite aquifer in this subcatchment. The transmissivity value of some 6 000 m^2/day obtained from the pump testing of borehole ZP16 (Figure 8.5, map grid reference C8) by SRK (1985) provides an indication of the magnitude of this aquifer parameter. Temperley (1978) reported the average discharge of the West Fountain spring as 409.10^3 m^3 per month (157 l/s).

Figure 8.1 further reveals that equivalent groundwater level elevations exist in the West and East Fountain subcatchments in the immediate vicinity of the springs draining these subcatchments. These springs are bisected by the Pretoria dyke. However, it is hypothesised that the Pretoria dyke does not isolate the two subcatchments immediately south of the springs. Figure 8.1 indicates the likelihood that groundwater flow occurs across the Pretoria dyke from the south-west to the north-east over a distance of some 2 300 m along the strike of the dyke "upstream" of the springs. By implication, the individually gauged discharge of each spring does not represent the true discharge of the subcatchments that each drains. Further progression of this hypothesis implies that the gauged West Fountain spring discharge is probably deficient by the percentage of groundwater that is lost from this subcatchment across the Pretoria dyke and drained through the East Fountain spring.

This subcatchment receives groundwater from the West Doornkloof subcatchment as discussed in subsection 8.3.2.1.

8.3.2.4 East Fountain subcatchment

Groundwater in this subcatchment drains in a north-westerly direction to the East Fountain spring. The weak groundwater gradient of some 0,004 again indicates a relatively high aquifer transmissivity. The average yield of this spring was reported by Temperley (1978) as 273. $10^3 m^3$ per month (105 l/s). However, acceptance of the hypothesis put forward in subsection 8.3.2.3 implies that this does not represent the true discharge of this subcatchment, but an overestimate thereof.

Figures 8.1 and 8.5 further clearly reveal that this subcatchment extends southwards beyond the Irene dyke, and that the south-western boundary thereof as hypothesized from groundwater level elevation data can be viewed as the south-easterly extension of the Pretoria dyke off-shoot discussed in subsections 4.2.2 and 8.2. The obvious hydrogeological significance of this feature warrants that its existence as hypothesized be verified by means other than groundwater level elevation data and that, for the same reason, it be named. It is suggested that it be named the Lyttelton dyke after the suburb in which it was first discovered.

8.4 Groundwater balance

The foregoing qualitative definition of the groundwater regime in the study area allows and facilitates the quantification of the various hydro(geo)logic components that define the hydrodynamics of the groundwater flow systems in the study area. These components individually represent either gains or losses experienced by the systems, and can be formulated into a groundwater balance equation which, in generalised form, relates the sum of these components to the change in groundwater storage as follows.

WS (change in groundwater storage) = R(gains) - Q(losses) 8.1

8.4.1 Water balance components

Losses to be considered are primarily those represented by

- spring discharge,
- pumpage from existing high-yielding urban water supply production boreholes and the ever-increasing private domestic borehole population, and
- subsurface groundwater outflow.

Natural gains to the dolomite aquifer(s) that require consideration are

- recharge from losing surface drainages
- subsurface groundwater inflow from adjacent geological formations, and
- recharge from rainfall.

The relatively deep groundwater levels (>10 m) discount consideration of evapotranspiration as a loss component of groundwater balance studies in the study area.

Quantification of the above components is attempted in the following subsections. However, the lack of data for some of the above components renders their quantification problematical. In these cases, some attempt is made in the following subsections to place into perspective their relative importance to the hydrogeologic regime of the study area.

8.4.1.1 Spring discharge

Spring discharge accounts for the most significant groundwater losses in the study area. In this regard, the East and West Fountain springs are the most productive. The discharge of these springs is reliably gauged.

As reported in subsection 8.3.1, the Erasmia spring no longer serves as a natural groundwater outlet for the Erasmia catchment. The discharge of this spring has since at least 1972 been captured by various boreholes at this locality (Temperley, 1978) for Pretoria municipal water supply augmentation (subsection 8.4.2).

The mean annual yield of the East and West Fountain springs is reported by Temperley (1978) as $3{,}3.10^6$ m^3 and $4{,}9.10^6$ m^3 respectively. More recent mean monthly and mean annual discharges of these springs are presented in Table 8.2

TABLE 8.2: Recent Pretoria Fountains spring discharge

Spring	Mean monthly discharge		Mean annual discharge	
	7/78 to 6/88	10/82 to 6/88	7/78 to 6/88	10/82 to 6/88
East Fountain	341 727 m^3	296 834 m^3	$4{,}1.10^6$ m^3	$3{,}6.10^6$ m^3
West Fountain	466 285 m^3	469 003 m^3	$5{,}6.10^6$ m^3	$5{,}6.10^6$ m^3
Total	808 012 m^3	765 837 m^3	$9{,}7.10^6$ m^3	$9{,}2.10^6$ m^3

The mean monthly discharge of these springs for the period October 1982 to June 1988 is graphed in Figure 8.6, and clearly reflects the similar discharge regime of these two springs. This similarity hints at possible hydrogeological interconnection between these springs as hypothesized in subsections 8.3.2.3 and 8.3.2.4.

8.4.1.2 Pumpage

Pumpage from existing high-yielding production boreholes by the Municipalities of Pretoria and Verwoerdburg for urban water supply augmentation purposes represents a groundwater loss component of significant proportions. Fortunately, reliable gauging of this abstraction adequately quantifies these losses.

Pumpage from private domestic boreholes primarily for garden irrigation purposes in the study area is not monitored. However, an analysis of private borehole census information collected by and obtained from the Verwoerdburg Municipality indicates that groundwater losses by this usage are potentially alarmingly significant. (See table 8.4.)

8.4.1.2.1 Production boreholes

The location of active production boreholes in the study area is indicated in Figure 8.5.

Boreholes ZP13 and ZP16 located in the West Fountain subcatchment are operated by Verwoerdburg Municipality. Borehole ZP13 was commissioned in March 1987, and borehole ZP16 in April 1987. The combined monthly yield of these boreholes since their commissioning is graphed in Figure 8.6, and a comparison with the West Fountain spring discharge (Figure 8.6) since December 1987 hints at the possible deleterious influence of this abstraction on the discharge of the West Fountain spring.

Until December 1986, the municipality of Pretoria operated two boreholes in close proximity to the Erasmia pumping station (Figure 8.5). A detailed discussion of the history of this water supply is provided by Temperley (1978). Abstraction from this locality was accomplished by the lease of the water rights from the owners of the property, the Erasmia Syndicate. In December 1986 the Municipality of Pretoria terminated this lease, and pumping was discontinued. Following this, the Municipality of Pretoria acquired Departmental exploration borehole G36066 located some 1 300 m NNW of the Erasmia pumping station (Figure 8.5), and abstraction from this borehole commenced in July 1987. This borehole was pump tested at a yield of 100 l/s, and abstraction records reveal a significantly increased water supply from this borehole than was obtained from those at the Erasmia pumping station (Table 8.3).

In addition to this supply, the Municipality of Pretoria has also utilised a borehole(s) located in Montague Kneen Park in Valhalla. The history of this abstraction is also discussed in detail by Temperley (1978). However, abstraction from these boreholes was discontinued in July 1981 following technical failure through partial collapse of these boreholes. The municipality recently acquired borehole VA-3 drilled as part of the SRK (1985) groundwater investigation for the Department. This borehole was pump tested at a yield of 90 l/s, and came into production in July 1988.

A summary of the pumpage from all of the above boreholes is presented in Table 8.3 below.

TABLE 8.3: Production borehole abstraction

Catchment	Borehole/ locality	Mean monthly abstraction in m^3 and period	Mean annual abstraction (m^3)
Erasmia	Pumping Station	35 154 (6/78 - 12/86)	421 844
Erasmia	Valhalla	43 585 (11/78 - 6/81)	523 018
Erasmia	G36066	69 682 (7/87 - 6/88)	836 180
Irene	ZP13	76 234 (3/87 - 6/88)	914 808
Irene	ZP16	79 027 (4/87 - 6/88)	948 324

It is evident from Tables 8.2 (subsection 8.4.1) and 8.3 that the combined annual abstraction of $1{,}9.10^6$ m^3 from boreholes ZP13 and ZP16 in the Irene catchment amounts to some 34% of the mean annual discharge of the West Fountain spring ($5{,}6.10^6$ m^3).

8.4.1.2.2 Private boreholes

Table 8.1 (subsection 8.1) presents a synthesis of the information contained in the "register of boreholes" maintained by Verwoerdburg Municipality. This register almost certainly does not accurately reflect the true private borehole population in the Verwoerdburg municipal area. It is even hypothesised that a population of 700 boreholes i.e. twice as many as are registered, might still represent an underestimate especially when the dearth of census data for the numerous agricultural holdings in the study area is considered.

However, an estimate of annual potential abstraction from these boreholes as tabulated in Table 8.4 below and based on

. a doubling of the "registered" borehole population in each suburb (Table 8.1),

. an average yield of 0,6 l/s per borehole, and

. an average pumping regime of 8 hours per week per borehole

provides some indication of the potential magnitude of groundwater abstraction from these boreholes. Although groundwater abstraction for agricultural irrigation purposes in the study area is minimal, it shuld be noted that suburban areas outside of the Verwoerdburg municipal area e.g. Valhalla and Monument Park (suburbs of Pretoria) have not been considered due to a lack of relevant information.

TABLE 8.4: Potential private borehole abstraction

Catchment	No. of boreholes	Potential annual abstraction (m^3)
Erasmia (excl. Rooihuis-kraal)	374	336 061
Irene	226	203 075
TOTAL	600	539 136

8.4.1.3 Subsurface groundwater outflow

It is evident from Figure 8.1 that losses in this regard are only of significance in the Erasmia catchment as discussed in subsection 8.3.1. In the absence of sufficient hydrogeological information (in this area) such as is provided by gravity surveys, exploration drilling and test pumping these losses are extremely difficult to quantify. This aspect is realised as a shortcoming of this investigation and report. In mitigation, however, it should be noted that such quantification can only be accomplished by detailed hydrogeolocial investigations covering that portion of the Erasmia catchment to the west of the study area and not covered in this investigation. This will provide a wider hydrogeological perspective on the groundwater regime and flow system(s) in the entire Erasmia catchment.

8.4.1.4 Recharge from surface drainages

The Hennops River is the major surface drainage in the study area, and previous discussion (subsection 7.2) points to the fact that hydraulic continuity between this drainage and the dolomite aquifer it traverses might exist.

Le Riche Cilliers (1953) reports that Du Toit, in a report to the Pretoria City Council circa 1928, mentions that "information available points to losses in the flow of the Hennops River in crossing the farm Doornkloof from east to west". These losses have never been quantified, and the dearth of flow gauging stations on the Hennops River between Rietvlei Dam (station A2R04W) and Skurweberg (station A2M14A located to the west outside the study area) still negates quantification thereof. A correlation of the gauged flow for these two stations (Figure 8.7) is complicated by the following factors.

- The Hennops River receives flow from both the Olifantspruit and the Rietspruit that enter this river downstream of station A2R04W (Figure 8.5).
- Much of the area is heavily urbanised especially along the course of the Hennops River, which fact must considerably increase the amount of rainfall runoff reaching the river.

- The Aalwynkop spring drains into the Hennops River upstream of station A2M14A (subsection 8.3.1 and Temperley, 1978).

It is therefore not surprising that generally much higher flows are gauged at station A2M14A than at station A2R04W.

In the context of this discussion, however, Dr J. Venter of the consulting engineering firm Bruinette Kruger Stoffberg, personally communicated to the author that engineering geological investigations for the construction of Hennops Lake at Verwoerdburgstad revealed the presence of a reasonably impervious clay layer with a possible hydraulic conductivity of 10^{-4} to 10^{-5} cm/s beneath the riverbed at this locality. This does not necessarily hold true for the entire reach of the river through the study area, but does imply that recharge of the dolomite aquifer from this source is possibly of insufficient magnitude to be considered seriously as a "gain" component, at least not during periods of "normal" flow. However, this scenario might be different under flood conditions.

The large difference of some 70 m in elevation between the Hennops River and immediately adjacent groundwater levels in the East Fountain subcatchment indicates the unlikelihood of recharge from the river by "normal" vertical infiltration mechanisms in this locality. The possibility that "conduits" (solution channels) linking the near-surface with the deep-seated aquifer exist was not investigated, and cannot therefore be ruled out as a mechanism by which such recharge might occur, but this is thought to be unlikely.

8.4.1.5 Subsurface groundwater inflow

Groundwater inflow from geological formations adjoining the Chuniespoort Group dolomite is indicated by the configuration of groundwater level elevation contours (Figure 8.1). This is especialy true of the granite terrain to the south-west of the study area, and is supported by hydrochemical data (subsection 7.2.2).

However, the relatively steep groundwater gradient of 0,04 across the Black Reef Quartzite Formation along the south-western margin of the dolomite indicates significantly lower transmissivities associated with this formation than those indicated by the 0,024 and weaker gradients characteristic of the dolomite formation. Consequently, subsurface recharge of the dolomite aquifer(s) from the south-west is considered of insufficient magnitude to be seriously considered as a "gain" component. With regard to the West Doornkloof subcatchment specifically, the close proximity of a groundwater divide to the west (Figure 8.1) supports this presumption.

Arguments similar to the above discount the possibility that recharge of the dolomite aquifer from the Pretoria Group sediments overlying the dolomite along the eastern margin of the study area is of significant proportions. Groundwater level elevation differences in excess of 75 m (Figure 8.1) and differences of 30 mS/m in electrical conductivity of groundwater (Figure 7.2) serve as arguments in favour of this hypothesis.

Finally, the possible inflow of groundwater into the Irene catchment from the south across the Sterkfontein dyke is ruled out on the basis of the some 20 m step in groundwater level elevations that exists across this dyke, and indicating the apparent imperviousness of this intrusive. It must therefore be accepted that the yield of the Sterkfontein spring represents the total discharge of the Kempton Park dolomite aquifer along this geological boundary. This discharge does not enter the groundwater flow system of the Irene catchment as it is collected at the spring and piped across this catchment to the Pretoria Fountains collecting chamber.

8.4.1.6 Recharge from rainfall

Quantitative determinations of the percentage recharge to groundwater from rainfall over dolomite aquifers have been presented by numerous authors whose results have been summarised by Vegter (1984). Values that range from 2,5% to 19,8% of the mean annual rainfall are indicated. Vegter (1985) proposed a value of 10% to 13% as a reasonable average.

Bredenkamp (1988) has proposed the rainfall-recharge formula

$$RE = 0,30\ (RF - 313)$$

where RF represents the annual rainfall, as the general equation by which average rainfall-recharge for the dolomite aquifers in the summer rainfall regions of South Africa could be determined. The mean annual rainfall in the study area is 675 mm (subsection 2.2). Using this figure in equation 8.2 yields a value of 108,6 mm, or 16.1% of the mean annual rainfall.

If it is assumed that spring discharge represents the only outflow (loss) from an aquifer, and recharge from rainfall the only inflow (gain) to an aquifer, then the average annual spring discharge must equal the average annual recharge from rainfall for the aquifer to remain in equilibrium. This equivalence allows the average annual spring discharge to be expressed as an equivalent average annual depth of precipitation over the surface area of the catchment drained by the spring(s). Expressing this equivalent depth of precipitation as a percentage of the mean annual rainfall over the catchment therefore necessarily represents the average annual recharge (%) from rainfall accrueing to the aquifer.

Applying the above premise to the Irene catchment with an area underlain by dolomite of 129,6 km^2, a mean annual rainfall of 675 mm and a mean annual spring discharge of $9,7.10^6$ m^3 for the 10-year period July 1978 to June 1988 (subsection 8.4.1.1) yields a rainfall-recharge figure of 11,1%.

8.4.2 Water balance calculations

Following the definition of the groundwater flow systems and relevant groundwater balance components in the preceding subsections, it is apparent that hydrologic budget calculations using equation 8.1 can be attempted for each of the Erasmia and Irene catchments. However, the application of equation 8.1 requires that the parameter WS (change in groundwater storage) be quantififed for some time period of reasonable length (usually one year). Groundwater levels in the study area were measured at two separate time intervals (subsection 8.2 and Appendix 4) but only some 6 months apart. The observed change in groundwater levels only exceeded 2 m in 22 of the 120 boreholes monitored. If it is considered that the accuracy to which borehole collar elevations were determined is also 2 m (subsection 8.2), then WS for this time period is non-quantitive and for practical purposes can be regarded as nil. Historical data in this regard is too sparsely distributed to be of use. The following groundwater balance calculations are therefore based on the premise that WS equals zero over any extended ($\geq$ 1 year) period of time, and that the water balance loss components offset the gain components.

8.4.2.1 Irene catchment

Previous discussion (subsection 8.3.2) indicates that the West Fountain, West Doornkloof and East Doornkloof subcatchments are in hydraulic connection, and in practical terms therefore represent one large subcatchment ostensibly drained through the West Fountain spring. However, the hypothesised hydraulic connection between the West and East Fountain subcatchments (subsection 8.3.2.3) requires that a water balance for the West Fountain subcatchment must consider the natural loss from this subcatchment not gauged at the West Fountain spring. An attempt to quantify this loss (Table 8.5) is based on a comparison of the actual (gauged) mean annual discharge of the West and East Fountain springs with the theoretical mean annual discharge resulting from an 11% rainfall-recharge (subsection 8.4.1.6) over the respective subcatchment surface areas for the 10-year period July 1978 to June 1988.

It is clear from Table 8.5 that a mean annual volume of some $1{,}675.10^6$ m^3 could be lost by the West Fountain subcatchment to the East Fountain subcatchment by subsurface leakage across the Pretoria dyke as hypothesised in subsection 8.3.2.3.

Abstraction from the Verwoerdburg Municipality production boreholes ZP13 and ZP16 in the West Fountain subcatchment for urban water supply purposes commenced in March and April 1987 respectively, and amounted to some $2{,}48.10^6$ m^3 in the 16-month period to June 1988. The data presented in Table 8.6 represents an attempt to determine the influence of this abstraction on the West Fountain spring discharge by comparison with that for the preceding 16-month period November 1985 to February 1987. Further comparison is provided by the inclusion of East Fountain spring discharge data for the same two periods.

TABLE 8.5: Quantification of the West Fountain subcatchment subsurface groundwater outflow across the Pretoria dyke to the East Fountain subcatchment

Subcatchment	Area (km^2)	Spring	Actual* mean annual discharge (10^6m^3)	Theoretical** mean annual discharge (10^6m^3)	Loss (-) or gain (+) (10^6m^3)
West Fountain + West Doornkloof + East Doornkloof	97,4	West Fountain	5,59	7,23	-1,64
East Fountain	32,2	East Fountain	4,10	2,39	+1,71
Total	129,6	Pretoria Fountains	9,69	9,62	+0,07

* Gauged by Pretoria Municipality in the 10-year period July 1978 to June 1988.

** Assuming 11% mean annual rainfall-recharge and no hydraulic connection between subcatchments.

TABLE 8.6: Influence of production borehole abstraction on spring discharge

Period	Total rain-fall (mm)	Total gauged spring discharge ($10^6 m^3$) West Fountain spring	East Fountain spring	Total pumpage boreholes ZP13 + ZP 16 ($10^6 m^3$)
November 1985 to February 1987	833,8	7,51	4,43	0,00
March 1987 to June 1988	835,6	7,41	4,98	2,48

It is evident from Table 8.6 that the decreased discharge of $0{,}10.10^6\ m^3$ experienced by the West Fountain spring is anomalous when compared with the increased discharge of some $0{,}55.10^6\ m^3$ experienced by the East Fountain spring in the period spanning the production borehole abstraction. Given that the total rainfall in each of the two periods was practically the same, then this anomaly can only be accounted for by the influence of the abstraction from boreholes ZP13 and ZP16. Graphical confirmation of this fact is provided by Figure 8.6 (subsection 8.4.1.1).

In quantitative terms, this influence amounts to a mean annual abstraction of $1{,}86.10^6\ m^3$ which, expressed as a percentage of the actual mean ($5{,}6.10^6\ m^3$) and the theoretical mean ($7{,}2.10^6\ m^3$) annual West Fountain spring discharge, represents a loss of 33% and 26% respectively. Of greater importance, however, is the fact that this abstraction amounts to some 19% of the mean annual discharge ($9{,}69.10^6\ m^3$) of the Pretoria Fountains.

8.4.2.2 Erasmia catchment

Any groundwater balance calculation for this catchment is severely complicated by the following factors:

- The catchment is subdivided into two subcatchments by a groundwater divide roughly coincident with line of longitude 28°05'E (Figures 8.1 and 8.5).

- The northern portion of the eastern subcatchment is no longer naturally drained through the Erasmia spring.

- The eastern subcatchment is naturally drained by a groundwater flow component westwards down the Hennops River valley (Figure 8.1).

- The western subcatchment extends to the west outside the present study area, and although ostensibly naturally drained through the ungauged Aalwynkop spring, encompasses an area of undetermined extent.

From the above it is clear that although this investigation has better defined the groundwater regime in the eastern Erasmia subcatchment, it is still not possible to apply with reasonable confidence a groundwater balance calculation to this subcatchment. However, if a rainfall-recharge of 11% of the mean annual rainfall (675 mm) over the 71,7 km^2 extent of this subcatchment (dolomite only) is applied, then a mean annual gain of some $5{,}32.10^6$ m^3 could accrue to the dolomite aquifer in this subcatchment. Mean annual losses other than from subsurface groundwater outflow amount to some $0{,}84.10^6$ m^3 from production borehole abstraction (subsection 8.4.1.2.1) and $0{,}34.10^6$ m^3 from potential private borehole abstraction (subsection 8.4.1.2.2). This implies that some $4{,}14.10^6$ m^3 must be lost through subsurface groundwater outflow (as discussed in subsection 8.3.1) for the dolomite aquifer to remain in equilibrium. Some validation of this groundwater flow quantity is provided by applying the Darcy flow equation

$$Q = T.i.l.t \qquad 8.3$$

where

T = aquifer transmissivity, in m^2/day
i = groundwater gradient (dimensionless)
l = width of flow cross-section, in metres
t = time in days
Q = flow in m^3/year for t = 365 days

For the purpose of this validation exercise, that portion of the Hennops River valley between lines of longitude 28°05'E and 28°08'E defined by the 1 360 and 1 370 groundwater level elevation contours (Figure 8.1) will be considered. Accepting that $Q = 4{,}14.10^6$ m^3 per year, $i = 0{,}0025$, $l = 500$ m and $t = 365$ days then, from equation 8.3,

$$T = (4{,}14 \text{ m}^3\text{/year})/(0{,}0025 \times 500 \text{ m} \times 365 \text{ days})$$

$$= 9\ 074 \text{ m}^2\text{/day},$$

which transmissivity value is of the same magnitude as that determined from the pumping test performed on potential production borehole G37842 (subsection 6.5.2) i.e. 13 678 m^2/day and located within this flow segment (Figures 8.1 and 8.5). It is therefore not inconceivable that the magnitude of annual subsurface groundwater outflow from the eastern Erasmia subcatchment in a westerly direction along the course of the Hennops River valley could amount to some $4{,}0.10^6$ m^3.

8.5 Groundwater supply potential

The theoretical production potential of each of the high-capacity boreholes in an emergency urban water supply context is discussed and presented in subsection 6.5.5.2 (Table 6.3). Following the discussion in subsection 8.4, the application of these boreholes for this purpose needs to be placed into perspective with regard to the existing demand on the dolomite groundwater resources in the study area and the storage capacity of the aquifer(s) penetrated by these boreholes. A hypothetical comparison between the aquifer storage capacity and the emergency urban water supply potential is presented in Table 8.7. For the purpose of this exercise, the estimate of aquifer storage capacity represents the product of the surface area of the aquifer(s) (penetrated by the potential production boreholes) encompassed by the -1,0 mgal residual gravity contour (Figure 4.2), and the other aquifer dimensions provided.

It is evident from Table 8.7 that the theoretical aquifer storage capacity apparently cannot satisfy the theoretical optimum pumping rate over a period of one year. This anomalous observation partly reflects the possibility that especially the areal dimensions used in the storage capacity calculations are conservative.

However, the dolomite aquifers in the study area should not be regarded as closed systems, and it is therefore possible that such factors as subsurface groundwater movement through these aquifers and recharge from rainfall can considerably improve their ability to satisfy the theoretical one-year emergency abstraction potential. Nevertheless, it remains extremely doubtful that these components are of sufficient magnitude to compensate for this abstraction. Indeed, it is not expected that they should, and it is therefore inevitable that such abstraction would seriously prejudice existing demands on these aquifers.

8.5.1 Irene catchment

The theoretical one-year emergency abstraction potential from the recently established high-capacity exploration boreholes in this catchment amounts to some $38{,}9.10^{6}$ m^{3}. Accepting a maximum realistic pumping rate of 80 l/s per borehole because of pump limitations, and that no additional production boreholes are established, then the realistic one-year emergency abstraction potential amounts to some $22{,}4.10^{6}$ m^{3} (Table 8.7). However, the mean annual discharge of the Pretoria Fountains amounts to some $9{,}7.10^{6}$ m^{3} (subsection 8.4.1.1), which amount is already fully utilised by the Pretoria Municipality, although discussion in subsection 8.4.2.1 indicates that the pumpage by the Verwoerdburg Municipality in the West Fountain subcatchment possible prejudices this discharge by some 19%. Nevertheless, due regard of this discharge necessarily reduces the net benefit to be gained from an emergency urban water supply scheme in this catchment to some $12{,}7.10^{6}$ m^{3} for a period of one year.

8.5.2 Erasmia catchment

The theoretical one-year emergency abstraction potential from the high-capacity exploration borehole G37842 amounts to some $13{,}8.10^6$ m^3. In congruence with the assumption put forward in subsection 8.5.1 above, the realistic one-year production potential of this borehole amounts to some $2{,}5.10^6$ m^3. If it is considered that the annual subsurface groundwater flow in the vicinity of borehole G37842 could amount to some $4{,}0.10^6$ m^3 (subsection 8.4.2.2), then it is not inconceivable that the abstraction of $2{,}5.10^6$ m^3/year could be maintained over a longer period than one year without serius prejudice of existing demands on the dolomite groundwater resources in this catchment.

TABLE 8.7: Hypothetical comparison of aquifer storage capacity and emergency urban water supply potential

Catchment/ subcatchment	Borehole	Theoretical optimum pumping rate (m^3/year)	Realistic* optimum pumping rate (m^3/year)	Aquifer dimensions Area (m^2)	Depth (m)	S**	Theoretical aquifer storage capacity (m^3)
East Fountain	G37818A G37819C G37820 G37821 G37823 G37825A	$9,7.10^6$	$9,6.10^6$	5 500 000	30	0,03	$4,95.10^6$
West Doornkloof	G37832 G37834	$13,4.10^6$	$4,8.10^6$	350 000	60	0,10	$2,10.10^6$
	G37829A	$10,3.10^6$	$2,5.10^6$	1 050 000	50	0,10	$5,25.10^6$
	G37838	$2,5.10^6$	$2,5.10^6$	175 000	40	0,03	$0,21.10^6$
	G37831	$0,8.10^6$	$0,8.10^6$	?	?	0,01	?
East Doornkloof	G37836	$0,7.10^6$	$0,7.10^6$	4 300 000	30	0,01	$1,29.10^6$
	G37840	$1,5.10^6$	$1,5.10^6$	1 230 000	30	0,03	$1,10.10^6$
SUBTOTAL		$38,9.10^6$	$22,4.10^6$				$14,9.10^6$
Erasmia	G37842	$13,8.10^6$	$2,5.10^6$	?	30	0,10	?
TOTAL		$52,7.10^6$	$24,9.10^6$				$>14,9.10^6$

* Based on a maximum realistic pumping rate of 80 l/s ($2,5.10^6 m^3$/year) per borehole
** Storativity values obtained from Table 6.3

9. CONCLUSIONS

The main conclusions to be drawn from the preceding detailed discussion and evaluation of the dolomite groundwater regime in the Verwoerdburg area are summarised below:

- The integration of available geological and hydrogeological information with the valuable residual gravity data obtained from the regional scale gravity survey significantly aided the siting of successful (high-yielding) exploration boreholes and the better definition of the groundwater flow systems in the study area.

- Three types of highly productive aquifer occur in the study area, namely

  - highly leached chert-rich dolomite extending from the near-surface to sometimes considerable depths ($\pm$ 90 m), and representing phreatic aquifers characterised by shallow groundwater levels (<30 m from surface);

  - highly leached chert-rich dolomite underlying relatively "fresh" chert-rich dolomite and Karoo Sequence deposits with the aquifer zone occurring at depths below 80 m, extending to depths of some 160 m below surface, and representing semi-unconfined to semi-confined aquifers characterised by deep water levels (>70 m from surface);

  - deep-lying zones of highly fractured and fissured chert-rich dolomite representing confined aquifers characterised by piezometric groundwater levels some 30 m to 50 m from surface and some 100 m above the aquifer zone.

- The generally excellent quality (electrical conductivity <80 mS/m) of dolomite groundwater in the study area is tempered by the fact that most of this groundwater is supersaturated with respect to calcium carbonate, and that $CaCO_3$ incrustation of pipes and pumping equipment can therefore be expected if preventative treatment is not applied to the pumped groundwater.

- Two definitive groundwater catchments occur in the study area, namely

  - the Irene catchment in the east, and which comprises four subcatchments hydrogeologically interconnected and combining to drain this catchment in a northerly direction;

  - the Erasmia catchment in the west, and which comprises two subcatchments of which only the eastern subcatchment occurs within the study area, this subcatchment draining in a westerly direction into the undefined western subcatchment at a possible rate of some $4{,}0.10^6$ m^3 per year through the subsurface.

- The mean annual groundwater abstraction by the Verwoerdburg Municipality in the West Fountain subcatchment ($1,9.10^6\ m^3$) for augmentation of urban water supplies possibly prejudices the mean annual discharge ($9,7.10^6\ m^3$) of the Pretoria Fountains (East and West Fountain springs) by some 19%.

- The realistic one-year emergency abstraction potential of $22,4.10^6\ m^3$ from the 13 recently established potential production boreholes in the Irene catchment is severely prejudiced by the historic utilisation of the Pretoria Foutains discharge by the Pretoria Municipality for augmentation of urban water supplies.

- The realistic one-year emergency abstraction potential of $2,5.10^6\ m^3$ from the recently established potential production borehole in the Erasmia catchment could conveivably be maintained over a longer period than one year without serious prejudice of existing demands on the dolomite groundwater resources in this catchment.

10. RECOMMENDATIONS

The following recommendations address issues essential to a refined definition of the groundwater regime in the study area and the potential use of the dolomite groundwater resource for emergency urban water supply purposes.

- The hydrogeological significance of the Lyttelton dyke (subsections 4.2.2, 8.2 and 8.3.2.4) warrants that the existence thereof to the south-east as hypothesised on the basis of anomalous groundwater level elevation data (Figure 8.1) be verified by other means e.g. geophysics.

- A judicious survey of private boreholes in the East Fountain subcatchment is required primarily to obtain representative groundwater level elevation data necessary for a better definition of groundwater movement in this subcatchment.

- The hydrogeological nature of the contact between the Chuniespoort Group dolomite and Pretoria Group sediments along the eastern margin of the study area especially with regard to possible hydraulic continuity between these formations needs to be investigated. Such investigation will require the drilling of exploration boreholes through the Pretoria Group sediments into the underlying dolomite.

- The hypothesised hydraulic continuity between the East and West Fountain subcatchments across the Pretoria dyke immediately south of the Pretoria Fountains needs to be verified by exploration drilling and pump testing. Verification of this hypothesis is intrinsic to the validity of rainfall-recharge estimates based on spring discharge data (subsection 8.4.1.6).

- The dependence of the Pretoria Fountains spring discharge on rainfall requires that a critical analysis of this relationship be undertaken in order to

  - better define the dolomite aquifer behaviour and response to rainfaal recharge, and

  - develop a spring discharge prediction model invaluable to the optimum joint utilisation of the Irene catchment groundwater resources by the municipalities of Pretoria and Verwoerdburg.

- In order to gauge the increasing demand that groundwater abstraction from private (domestic) boreholes make on the dolomite groundwater resources of the study area, it is required that the municipalities of Pretoria and Verwoerdburg make every reasonable attempt to monitor the growth of this borehole population, especially in those suburbs located on dolomite, in order to gauge the magnitude of this demand.

- Thoroughness dictates that groundwater levels throughout the study area be measured again in June - July 1989, preferably in the same boreholes used for the compilation of the groundwater level contour map (Figure 8.1 and Appendix 4).

- In congruence with the previous recommendation, an accurate determination of groundwater level changes requires that all boreholes in which groundwater levels were/are measured be levelled, which action will necessarily improve the confidence limits of groundwater storage estimates and groundwater balance calculations over time.

- The potential prejudice of the dolomite groundwater quality in the East Fountain subcatchment provided by especially waste disposal site 8 (Figure 7.2 and subsection 7.2.7) operated by the Verwoerdburg Municipality demands that this terrain be critically evaluated in terms of its groundwater pollution/contamination potential. Further, that both the municipalities of Pretoria and Verwoerdburg vigorously refrain from locating municipal solid waste disposal sites on any dolomite terrain.

- The magnitude and possible influence of the groundwater abstraction from boreholes ZP13 and ZP16 by the Verwoerdburg Municipality (subsections 8.4.1.2.1 and 8.4.2.1) demands that this municipality makes every attempt to reliably and accurately monitor (preferably on a continuous basis) the groundwater level in the immediate vicinity of each of these boreholes. The worth and application of such data are legion.

- In congruence with the previous recommendation, it is advisable that the quality of groundwater abstracted from boreholes ZP13 and ZP16 be monitored regularly (preferably once a month) if not already done.

- The above two recommendations apply equally well to the groundwater abstraction from boreholes G36066 and VA-3 in the Erasmia catchment by the Pretoria Municipality.

- The nature of the dolomite aquifer penetrated by the high-yielding exploration boreholes G37829A, G37832, G37834 and G37842 (subsections 5.4, 6.5.2.1 and Table 6.3), together with the sensitive location of these boreholes with regard to existing and proposed infrastructure (mainly roads), demands that detailed engineering geological terrain stability investigations be undertaken at these sites before these boreholes can be commissioned for large-scale abstraction in an emergency (or any other) urban water supply context.

- It is finally recommended that this investigation be extended towards the west in order to define the full extent of the Erasmia catchment, and evaluate the supply potential of the dolomite groundwater resources in the seemingly less-prejudiced and less-sensitive western subcatchment of this catchment.

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APPENDIX 1.1

SUPPLEMENTARY DWA GRAVITY SURVEY DATA

PROFILE G-1

Station	Distance along traverse (m)	Elevation (mamsl)	Geology	Bouguer value (mgal)	Remarks
1.	0	1 491,73	Chert	– 147,47	
2.	50	1 490,45	Chert	– 147,61	
3.	70	1 490,02	Chert	– 147,6[illegible]	
4.	90	1 489,59	Chert	– 147,74	
5.	110	1 489,13	Chert	– 147,78	
6.	130	1 488,18	Chert	– 147,85	
7.	150	1 487,31	Chert	– 147,82	
8.	170	1 486,69	Dolomite	– 147,66	
9.	190	1 486,33	Dolomite	– 147,52	Borehole 159
10.	210	1 485,77	Dolomite	– 147,58	
11.	230	1 485,18	Dolomite	– 147,53	
12.	250	1 484,73	Dolomite	– 147,52	
13.	270	1 484,19	Dolomite	– 147,51	
14.	290	1 483,48	Dolomite	– 147,49	
15.	310	1 482,98	Dolomite	– 147,52	
16.	330	1 482,20	Dolomite	– 147,57	
17.	350	1 481,55	Dolomite	– 147,59	
18.	370	1 480,92	Dolomite	– 147,61	
19.	390	1 484,34	Dolomite	– 147,70	
20.	410	1 479,71	Dolomite	– 147,79	
21.	430	1 479,11	Dolomite	– 147,87	
22.	450	1 478,52	Dolomite	– 147,82	
23.	500	1 476,92	Dolomite	– 147,91	
24.	550	1 475,38	Dolomite	– 147,93	
25.	600	1 473,82	Dolomite	– 147,96	
26.	620	1 473,15	Dolomite	– 148,07	
27.	640	1 472,53	Dolomite	– 148,03	
28.	660	1 472,36	Chert	– 148,03	
29.	680	1 472,34	Chert	– 148,11	
30.	700	1 472,32	Chert	– 148,15	
31.	720	1 472,28	Chert	– 148,21	
32.	740	1 472,24	Chert	– 148,24	
33.	760	1 472,08	Chert	– 148,31	
34.	780	1 471,65	Chert	– 148,33	
35.	800	1 471,31	Chert	– 148,30	
36.	820	1 470,82	Chert	– 148,36	
37.	840	1 470,11	Chert	– 148,52	
38.	860	1 468,85	Chert	– 148,44	
39.	880	1 467,71	Chert	– 148,34	
40.	900	1 466,64	Dolomite	– 148,19	
41.	920	1 465,56	Dolomite	– 148,23	
42.	940	1 464,37	Dolomite	– 148,17	
43.	960	1 463,56	Dolomite	– 148,17	

APPENDIX 1.2

SUPPLEMENTARY DWA GRAVITY SURVEY DATA

PROFILE G-2

Station	Distance along traverse (m)	Elevation (mamsl)	Geology	Bouguer value (mgal)	Remarks
1.	0	1 476,85	Dolomite	– 147,92	
2.	20	1 477,30	Dolomite	– 147,95	
3.	40	1 476,98	Dolomite	– 147,97	
4.	60	1 476,82	Dolomite	– 148,01	
5.	80	1 476,64	Dolomite	– 148,05	
6.	100	1 476,50	Dolomite	– 148,03	
7.	120	1 476,43	Chert	– 148,09	
8.	140	1 476,54	Chert	– 148,09	
9.	160	1 476,34	Chert	– 148,07	
10.	180	1 475,98	Chert	– 148,06	
11.	200	1 475,43	Chert	– 148,04	
12.	220	1 474,83	Chert	– 148,08	
13.	240	1 474,21	Chert	– 148,15	
14.	260	1 473,38	Chert	– 148,17	
15.	280	1 472,63	Chert	– 148,21	
16.	300	1 471,70	Chert	– 148,46	
17.	320	1 470,23	Chert	– 148,51	
18.	340	1 469,23	Chert	– 148,53	
19.	360	1 468,16	Chert	– 148,23	
20.	380	1 467,03	Dolomite	– 148,21	

APPENDIX 1.3

SUPPLEMENTARY DWA GRAVITY SURVEY DATA

PROFILE G-3

Station	Distance along traverse (m)	Elevation (mamsl)	Geology	Bouguer value (mgal)	Remarks
1.	0	1 496,69	Dolomite	– 147,10	
2.	20	1 497,10	Dolomite	– 147,02	
3.	40	1 497,58	Chert	– 147,25	
4.	60	1 498,13	Chert	– 147,31	
5.	80	1 498,74	Chert	– 147,51	
6.	100	1 499,14	Chert	– 147,64	
7.	120	1 499,34	Chert	– 147,55	
8.	140	1 499,42	Chert	– 147,62	
9.	160	1 499,05	Chert	– 147,80	
10.	180	1 498,11	Chert	– 148,02	Borehole G37837
11.	200	1 496,37	Chert	– 148,07	
12.	220	1 495,01	Chert	– 148,08	
13.	240	1 493,51	Chert	– 148,09	
14.	260	1 491,56	Chert	– 148,08	
15.	280	1 490,21	Chert	– 147,78	
16.	300	1 488,65	Chert	– 147,76	
17.	320	1 487,05	Dolomite	– 147,49	
18.	340	1 485,90	Dolomite	– 147,40	
19.	360	1 484,80	Dolomite	– 147,42	
20.	380	1 484,15	Dolomite	– 147,50	

APPENDIX 2.

PRODUCTION/EXPLORATION BOREHOLE RECORDS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37818

LOCATION

PROPERTY : Ptn 106 Doornkloof 391 JR

OWNER : Mr H.J. Viljoen

ADDRESS : P.O. Box 58, Irene 1675 Tel: 6672669

SITE CO-ORDINATES : LATITUDE 25°52'55"S X + 2 863 780
LONGITUDE 28°15'10"E Y + 74 840

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CD

ORTHOPHOTO MAP REFERENCE NO. : 2528 CD 11

DRILLING RECORD

CONTRACTOR : Interdrills (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/03/25

DATE COMPLETED : 1987/06/23

TOTAL COST : R17 640,14

COST PER METRE : R141,12

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 125 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm		394 mm	
381 mm		343 mm	
330 mm	0 - 106,7 m	261 mm	0 - 106,47 m
254 mm	106,7 - 111,84 m	207 mm	0 - 111,84 m
203 mm	111,84 - 125 m	165 mm	
165 mm			

PERFORATED CASING:		LENGTH:	
394 mm		394 mm	
343 mm		343 mm	
261 mm		261 mm	
207 mm	75,84 - 108,84 m	207 mm	33 m
165 mm		165 mm	

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1460 mamsl

COLLAR ELEVATION: ± 1460 mamsl

DEPTH TO REST WATER LEVEL : 79,57 mbc

DATE : 1987/10/19

REST WATER LEVEL ELEVATION: ± 1380 mamsl

WATER STRIKE(S) : Indeterminate

FINAL BLOW YIELD : Indeterminate for total lack of returns

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

This borehole did not pass the straightness test. There appears to be significant deviation at 80 m. The borehole is not acceptable for production purposes. Only the cost of the casing installed in the bore was paid out to the contractor.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37818A

LOCATION

PROPERTY : Ptn 106 Doornkloof 391 JR

OWNER : Mr H.J. Viljoen

ADDRESS : P.O. Box 58, Irene 1675 Tel: 6672669

SITE CO-ORDINATES : LATITUDE 25°52'56"S X + 2 863 810
LONGITUDE 28°15'09"E Y + 74 880

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CD

ORTHOPHOTO MAP REFERENCE NO. : 2528 CD 11

DRILLING RECORD

CONTRACTOR : W.P. Drilling (Pty) Limited DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/22 DATE COMPLETED : 1987/09/16

TOTAL COST : R93 493,69 COST PER METRE : R467,68

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 200 m

DIAMETERS AND DEPTH INTERVALS:

BORE:	445 mm 0 - 38 m	CASING:	394 mm 0 - 38 m
	381 mm 38 - 75 m		343 mm 0 - 75,2 m
	330 mm 75 - 85 m		261 mm 0 - 83 m
	254 mm 85 - 114 m		207 mm 0 - 114,2 m
	203 mm 114 - 200 m		165 mm
PERFORATED CASING:	394 mm	LENGTH:	394 mm
	343 mm		343 mm
	261 mm		261 mm
	207 mm 102 - 114,2 m		207 mm 12,2 m
	165 mm		165 mm

METHOD PERFORATED: Torcht-cut by hand to provide some 4 % open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradiant on hill slope

LOGGED BY : P.J. Hobbs SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1460 mamsl COLLAR ELEVATION: ± 1460 mamsl

DEPTH TO REST WATER LEVEL : 80,29 mbc DATE : 1987/10/19

REST WATER LEVEL ELEVATION: ± 1380 mamsl WATER STRIKE(S) : 107-114 m

FINAL BLOW YIELD : ± 10 l/s but pulsating, therefore not reliable

WATER QUALITY : Potable FIELD EC : 41 mS/m

FIELD TEMP.: 21°C

GENERAL REMARKS

This borehole is located 53 m south-west of G37818, and can be regarded as a replacement borehole for G37818.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37819C

LOCATION

PROPERTY : Ptn 107 Doornkloof 391 JR

OWNER : Hon. Justice L.F. Weyers

ADDRESS : P.O. Box 13, Irene 1675 Tel: 6672045

SITE CO-ORDINATES : LATITUDE 25°53'08"S — X + 2 864 160
LONGITUDE 28°15'13"E — Y + 74 790

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CD

ORTHOPHOTO MAP REFERENCE NO. : 2528 CD 11

DRILLING RECORD

CONTRACTOR : Interdrills (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/05/04

DATE COMPLETED : 1987/06/25

TOTAL COST : R53 276,71

COST PER METRE : R300,49

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 177,3 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm	0 - 16,07 m	394 mm	
381 mm		343 mm	0 - 16,07 m
330 mm	16,07 - 91 m	261 mm	0 - 91 m
254 mm	91 - 133 m	207 mm	0 - 133 m
203 mm	133 - 158 m	165 mm	
165 mm	158 - 177,3 m		

PERFORATED CASING:		LENGTH:	
394 mm		394 mm	
343 mm		343 mm	
261 mm		261 mm	
207 mm	102 - 132 m	207 mm	30 m
165 mm		165 mm	

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1475 mamsl

COLLAR ELEVATION: ± 1475 mamsl

DEPTH TO REST WATER LEVEL : 95,28 mbc

DATE : 1987/06/09

REST WATER LEVEL ELEVATION: ± 1380 mamsl

WATER STRIKE(S) : 110 - 130 m, 158 m

FINAL BLOW YIELD : ± 13 l/s but pulsating, therefore not reliable

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

This borehole represents the fourth and successful attempt to drill a borehole at this site. The previous attempts viz. G37819, G37819A and G37819B do not exist as all were less than 30 m deep and therefore filled up. The borehole plumbs to 136,6 m with the 203 mm diameter "dummy".

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37820

LOCATION

PROPERTY : Ptn 5 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene, 1675 Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°52'10"S X + 2 862 350
LONGITUDE 28°15'22"E Y + 74 540

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CD

ORTHOPHOTO MAP REFERENCE NO. : 2528 CD 11

DRILLING RECORD

CONTRACTOR : Interdrills (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/05/15

DATE COMPLETED : 1987/06/17

TOTAL COST : R53 449,30

COST PER METRE : R253,31

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 211 m

DIAMETERS AND DEPTH INTERVALS:

BORE :
445 mm
381 mm
330 mm 0 - 128,3 m
254 mm 128,3 - 150,7 m
203 mm
165 mm 150,7 - 211 m

CASING:
394 mm
343 mm
261 mm 0 - 123,3 m
207 mm
165 mm

PERFORATED CASING:
394 mm
343 mm
261 mm
207 mm
165 mm

LENGTH:
394 mm
343 mm
261 mm
207 mm
165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1477 mamsl

COLLAR ELEVATION: ± 1477 mamsl

DEPTH TO REST WATER LEVEL : 97,3 mbc

DATE : 1987/05/21

REST WATER LEVEL ELEVATION: ± 1380 mamsl

WATER STRIKE(S) : 125 - 132 m, 159m, 198m

FINAL BLOW YIELD : Indeterminate due to pulsating nature of returns

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

Straightness test with 254 mm diameter "dummy" successful to ± 127 m.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37821

LOCATION

PROPERTY : Ptn 5 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675 Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°52'14"S — X + 2 862 460
LONGITUDE 28°15'02"E — Y + 75 090

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CD

ORTHOPHOTO MAP REFERENCE NO. : 2528 CD 11

DRILLING RECORD

CONTRACTOR : W.P. Drilling (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/08/08

DATE COMPLETED : 1987/09/02

TOTAL COST : R70 150,50

COST PER METRE : R501,07

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 140 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm	0 - 102 m	394 mm	not available
381 mm		343 mm	0 - 102 m
330 mm	102 - 132 m	261 mm	0 - 132 m
254 mm	132 - 140 m	207 mm	124,8 - 140 m
203 mm		165 mm	
165 mm			

PERFORATED CASING:		LENGTH:	
394 mm		394 mm	
343 mm		343 mm	
261 mm	119,8 - 132 m	261 mm	12,2 m
207 mm	124,8 - 140 m	207 mm	15,2 m drop-set
165 mm		165 mm	

METHOD PERFORATED: Plasma-cut to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient at base of ridge scarp

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1468 mamsl

COLLAR ELEVATION: ± 1468 mamsl

DEPTH TO REST WATER LEVEL : 90,25 mbc

DATE : 1987/10/19

REST WATER LEVEL ELEVATION: ± 1378 mamsl

WATER STRIKE(S) : 125 - 140 m

FINAL BLOW YIELD : ± 14 l/s but pulsating, therefore not reliable

WATER QUALITY : Potable

FIELD EC : 42 mS/m

FIELD TEMP.: 21°C

GENERAL REMARKS

Straightness test with 254 mm diameter "dummy" successful to ± 124 m, i.e. to top of drop-set.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37822

LOCATION

PROPERTY : Ptn 5 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675 Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°52'34"S X + 2 863 090
LONGITUDE 28°14'56"E Y + 75 280

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 15

DRILLING RECORD

CONTRACTOR : W.P. Drilling (Pty) Limited DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/10/08 DATE COMPLETED : 1987/10/16

TOTAL COST : R86 918,75 COST PER METRE : R455,07

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 191 m

DIAMETERS AND DEPTH INTERVALS:

BORE :	445 mm	0 - 44 m	CASING:	394 mm	0 - 44,36 m
	381 mm	44 - 110 m		343 mm	0 - 109,63 m
	330 mm	110 - 191 m		261 mm	
	254 mm			207 mm	
	203 mm			165 mm	
	165 mm				

PERFORATED CASING:	394 mm	LENGTH:	394 mm
	343 mm		343 mm
	261 mm		261 mm
	207 mm		207 mm
	165 mm		165 mm

METHOD PERFORATED: No perforated casing installed in this bore.

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Sloping valley at base of ridge scarp

LOGGED BY : P.J. Hobbs SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1466 mamsl COLLAR ELEVATION: ± 1466 mamsl

DEPTH TO REST WATER LEVEL : 87,81 mbc DATE : 1987/10/19

REST WATER LEVEL ELEVATION: ± 1378 mamsl WATER STRIKE(S) : 110 - 124 m

FINAL BLOW YIELD : Indeterminate for large amount of foam

WATER QUALITY : Unknown FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37823

LOCATION

PROPERTY : Ptn 5 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675, Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°52'40"S X + 2 863 300
LONGITUDE 28°15'04"E Y + 75 025

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CD

ORTHOPHOTO MAP REFERENCE NO. : 2528 CD 11

DRILLING RECORD

CONTRACTOR : W.P. Drilling (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/10/16

DATE COMPLETED : 1987/10/26

TOTAL COST : R81 760,75

COST PER METRE : R400,79

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 204 m

DIAMETERS AND DEPTH INTERVALS:

BORE :	445 mm	0 - 56 m	CASING:	394 mm	0 - 47 m
	381 mm	56 - 93 m		343 mm	0 - 93,4 m
	330 mm	93 - 204 m		261 mm	
	254 mm			207 mm	
	203 mm			165 mm	
	165 mm				

PERFORATED CASING:	394 mm	LENGTH:	394 mm
	343 mm		343 mm
	261 mm		261 mm
	207 mm		207 mm
	165 mm		165 mm

METHOD PERFORATED: No perforated casing installed in this bore.

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Medium gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1454 mamsl

COLLAR ELEVATION: ± 1455 mamsl

DEPTH TO REST WATER LEVEL : 73,91 mbc

DATE : 1987/10/27

REST WATER LEVEL ELEVATION: ± 1380 mamsl

WATER STRIKE(S) : 79 - 92 m

FINAL BLOW YIELD : High but indeterminate due to foam and erraticism

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

RECORD OF BOREHOLE: G37823

LOCATION

PROPERTY : Ptn 5 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675, Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°52'40"S X + 2 863 300
LONGITUDE 28°15'04"E Y + 75 025

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CD

ORTHOPHOTO MAP REFERENCE NO. : 2528 CD 11

DRILLING RECORD

CONTRACTOR : W.P. Drilling (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/10/16

DATE COMPLETED : 1987/10/26

TOTAL COST : R81 760,75

COST PER METRE : R400,79

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 204 m

DIAMETERS AND DEPTH INTERVALS:

BORE :	445 mm	0 - 56 m	CASING:	394 mm	0 - 47 m
	381 mm	56 - 93 m		343 mm	0 - 93,4 m
	330 mm	93 - 204 m		261 mm	
	254 mm			207 mm	
	203 mm			165 mm	
	165 mm				
PERFORATED CASING:	394 mm		LENGTH:	394 mm	
	343 mm			343 mm	
	261 mm			261 mm	
	207 mm			207 mm	
	165 mm			165 mm	

METHOD PERFORATED: No perforated casing installed in this bore.

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Medium gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1454 mamsl

COLLAR ELEVATION: ± 1455 mamsl

DEPTH TO REST WATER LEVEL : 73,91 mbc

DATE : 1987/10/27

REST WATER LEVEL ELEVATION: ± 1380 mamsl

WATER STRIKE(S) : 79 - 92 m

FINAL BLOW YIELD : High but indeterminate due to foam and erraticism

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37824

LOCATION

PROPERTY : Ptn 5 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675 Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°51'33"S X + 2 861 240
LONGITUDE 28°14'45"E Y + 77 590

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 15

DRILLING RECORD

CONTRACTOR : Interdrills (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/06/22

DATE COMPLETED : 1987/07/06

TOTAL COST : R56 797,40

COST PER METRE : R230,88

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 246 m

DIAMETERS AND DEPTH INTERVALS:

BORE :
445 mm 0 - 2 m
381 mm 2 - 54,2 m
330 mm 54,2 - 246 m
254 mm
203 mm
165 mm

CASING:
394 mm 0 - 2 m
343 mm 0 - 54,2 m
261 mm
207 mm
165 mm

PERFORATED CASING:
394 mm
343 mm
261 mm
207 mm
165 mm

LENGTH:
394 mm
343 mm
261 mm
207 mm
165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on crest of hill

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1515 mamsl

COLLAR ELEVATION: ± 1513 mamsl

DEPTH TO REST WATER LEVEL : 139,7 mbc

DATE : 1987/08/11

REST WATER LEVEL ELEVATION: ± 1375 mamsl

WATER STRIKE(S) : Indeterminate

FINAL BLOW YIELD : Indeterminate but low (< 5 l/s)

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37825A

LOCATION

PROPERTY : Ptn 5 Doornkloof 391 JR '

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675 Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°51'25"S — X + 2 861 010
LONGITUDE 28°14'00"E — Y + 77 875

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 15

DRILLING RECORD

CONTRACTOR : Interdrills (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/06/08

DATE COMPLETED : 1987/07/27

TOTAL COST : R64 519,62

COST PER METRE : R313,20

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 206 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm		394 mm	0 - 2 m
381 mm	0 - 101,65 m	343 mm	0 - 101,65 m
330 mm	101,65 - 157,86 m	261 mm	0 - 157,86 m
254 mm	157,86 - 206 m	207 mm	
203 mm		165 mm	
165 mm			

PERFORATED CASING:		LENGTH:	
394 mm		394 mm	
343 mm		343 mm	
261 mm	146,84 - 156,86 m	261 mm	10 m
207 mm		207 mm	
165 mm		165 mm	

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Flat ground at foot of gentle slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1494 mamsl

COLLAR ELEVATION: ± 1494 mamsl

DEPTH TO REST WATER LEVEL : 119,14 mbc

DATE : 1987/07/20

REST WATER LEVEL ELEVATION: ± 1375 mamsl

WATER STRIKE(S) : 148 - 158 m

FINAL BLOW YIELD : Indeterminate due to foam and erraticism

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

This borehole represents the second and successful attempt, the original attempt viz. G37825 having to be abandoned and filled in after considerable deviation at depth caused casing to break off in bore.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37827

LOCATION

PROPERTY : Ptn 5 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675, Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°52'33"S — X + 2 863 075
LONGITUDE 28°14'01"E — Y + 76 775

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 15

DRILLING RECORD

CONTRACTOR : W.P. Drilling (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/03

DATE COMPLETED : 1987/07/21

TOTAL COST : R104 132,73

COST PER METRE : R413,22

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 252 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING	
445 mm	0 - 27,9 m	394 mm	0 - 27,9 m
381 mm	27,9 - 61 m	343 mm	0 - 61 m
330 mm	61 - 180 m	261 mm	0 - 180 m
254 mm	180 - 252 m	207 mm	
203 mm		165 mm	
165 mm			

PERFORATED CASING	LENGTH
394 mm	394 mm
343 mm	343 mm
261 mm	261 mm
207 mm	207 mm
165 mm	165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1493 mamsl

COLLAR ELEVATION: ± 1493 mamsl

DEPTH TO REST WATER LEVEL : 69,64 mbc

DATE : 1987/07/22

REST WATER LEVEL ELEVATION: ± 1423 mamsl

WATER STRIKE(S) : Indeterminate

FINAL BLOW YIELD : Minimal (< 5 l/s)

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37828

LOCATION

PROPERTY : Ptn 1 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675 Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°52'04"S X + 2 862 115
: LONGITUDE 28°13'33"E Y 77 570

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC
ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 15

DRILLING RECORD

CONTRACTOR : W.P. Drilling (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/06/23

DATE COMPLETED : 1987/07/01

TOTAL COST : R66 890,08

COST PER METRE : R334,45

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 200 m

DIAMETERS AND DEPTH INTERVALS:

BORE : 445 mm 0 - 53 m
381 mm 53 - 200 m
330 mm
254 mm
203 mm
165 mm

CASING: 394 mm 0 - 53 m
343 mm
261 mm
207 mm
165 mm

PERFORATED CASING: 394 mm
343 mm
261 mm
207 mm
165 mm

LENGTH: 394 mm
343 mm
261 mm
207 mm
165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1473 mamsl

COLLAR ELEVATION: ± 1473 mamsl

DEPTH TO REST WATER LEVEL : 46,64 mbc

DATE : 1987/07/02

REST WATER LEVEL ELEVATION: ± 1426 mamsl

WATER STRIKE(S) : Indeterminate

FINAL BLOW YIELD : Minimal (< 5 l/s)

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37829A

LOCATION

PROPERTY : Ptn 2 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675, Tel: 6671000

SITE CO-ORDINATES : LATITUDE 25°53'21"S X + 2 864 570
LONGITUDE 28°12'32"E Y + 79 240

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 15

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/18

DATE COMPLETED : 1987/07/23

TOTAL COST : R40 605,35

COST PER METRE : R456,24

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 89 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm		394 mm	
381 mm	0 - 52 m	343 mm	0 - 55,82 m
330 mm	52 - 69 m	261 mm	0 - 75,55 m
254 mm	69 - 89 m	207 mm	
203 mm		165 mm	
165 mm			

PERFORATED CASING:		LENGTH:	
394 mm		394 mm	
343 mm	49,52 - 55,82 m	343 mm	6,3 m
261 mm	38,85 - 75,55 m	261 mm	36,7 m
207 mm		207 mm	
165 mm		165 mm	

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on hill slope

LOGGED BY : J.L. Jolly

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1458 mamsl

COLLAR ELEVATION: ± 1458 mamsl

DEPTH TO REST WATER LEVEL : 35,34 mbc

DATE : 1987/07/27

REST WATER LEVEL ELEVATION: ± 1423 mamsl

WATER STRIKE(S) : 40 - 89 m

FINAL BLOW YIELD : ± 50 l/s, but decreased to zero within 5 minutes of developing.

WATER QUALITY : Potable

FIELD EC : 48 mS/m

FIELD TEMP.: 19°C

GENERAL REMARKS

This borehole represents the second and successful attempt after the loss of equipment in the original borehole viz. G37829, which was abandoned and filled in.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37830

LOCATION

PROPERTY : Ptn 2 Doornkloof 391 JR

OWNER : Irene Estates (Pty) Limited

ADDRESS : P.O. Irene 1675, Tel. 6671000

SITE CO-ORDINATES : LATITUDE 25°53'07"S X + 2 864 150
LONGITUDE 28°12'21"E Y + 79 535

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 15

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/06

DATE COMPLETED : 1987/08/04

TOTAL COST : R61 315,38

COST PER METRE : R340,64

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 180 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING	
445 mm	0 - 19 m	394 mm	
381 mm		343 mm	0 - 35,03 m
330 mm	19 - 84 m	261 mm	0 - 84,41 m
254 mm	84 - 180 m	207 mm	
203 mm		165 mm	
165 mm			

PERFORATED CASING	LENGTH
394 mm	394 mm
343 mm	343 mm
261 mm	261 mm
207 mm	207 mm
165 mm	165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1463 mamsl

COLLAR ELEVATION: ± 1463 mamsl

DEPTH TO REST WATER LEVEL : 36,90 mbc

DATE : 1987/08/05

REST WATER LEVEL ELEVATION: ± 1426 mamsl

WATER STRIKE(S) : Indeterminate

FINAL BLOW YIELD : Minimal (< 5 l/s)

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37831

LOCATION

PROPERTY : Ptn 41 Doornkloof 391 JR

OWNER : RSA (Dept. of Agriculture and Water Supply)

ADDRESS : PB X116, Pretoria 0001 Tel. 2062822

SITE CO-ORDINATES : LATITUDE 25°53'33"S LONGITUDE 28°12'35"E — X + 2 864 915, Y + 79 130

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 15

DRILLING RECORD

CONTRACTOR : Interdrills (Pty) Limited

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/31

DATE COMPLETED : 1987/08/11

TOTAL COST : R38 971,00

COST PER METRE : R245,10

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 159 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm		394 mm	
381 mm	0 - 30,7 m	343 mm	0 - 30,7 m
330 mm	30,7 - 143 m	261 mm	0 - 61,2 m
254 mm	143 - 159 m	207 mm	
203 mm		165 mm	
165 mm			

PERFORATED CASING:	LENGTH:
394 mm	394 mm
343 mm	343 mm
261 mm	261 mm
207 mm	207 mm
165 mm	165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1467 mamsl

COLLAR ELEVATION: ± 1467 mamsl

DEPTH TO REST WATER LEVEL : 45,04 mbc

DATE : 1987/08/11

REST WATER LEVEL ELEVATION: ± 1422 mamsl

WATER STRIKE(S) : 147 - 149 m, 158 m

FINAL BLOW YIELD : > 70 l/s

WATER QUALITY : Potable

FIELD EC : 78 mS/m

FIELD TEMP.: 20°C

GENERAL REMARKS

Straightness test with 254 mm diameter "dummy" successful down to 146,65 m

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37832

LOCATION

PROPERTY : Ptn 150 Doornkloof 391 JR

OWNER : RSA (SADF - Kentron)

ADDRESS : PB X336, Pretoria 0001 Tel. 644120

SITE CO-ORDINATES : LATITUDE 25°52'42"S X + 2 863 415
LONGITUDE 28°11'55"E Y + 80 340

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 14

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/16

DATE COMPLETED : 1987/07/20

TOTAL COST : R32 813,65

COST PER METRE : R482,55

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 68 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm		394 mm	
381 mm	0 - 42 m	343 mm	0 - 45,5 m
330 mm	42 - 56 m	261 mm	0 - 56,85 m
254 mm	56 - 68 m	207 mm	
203 mm		165 mm	
165 mm			

PERFORATED CASING:		LENGTH:	
394 mm		394 mm	
343 mm	39,4 - 45,5 m	343 mm	6,1 m
261 mm	26,4 - 56,85 m	261 mm	30,45 m
207 mm		207 mm	
165 mm		165 mm	

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on hill slope

LOGGED BY : J.L. Jolly

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1453 mamsl

COLLAR ELEVATION: ± 1453 mamsl

DEPTH TO REST WATER LEVEL : 28,38 mbc

DATE : 1987/07/21

REST WATER LEVEL ELEVATION: ± 1425 mamsl

WATER STRIKE(S) : 30 - 68 m

FINAL BLOW YIELD : > 60 l/s

WATER QUALITY : Potable

FIELD EC : 48 mS/m

FIELD TEMP.: 16°C

GENERAL REMARKS

With development of this bore the blow yield gradually declined to zero.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37833

LOCATION

PROPERTY : Ptn 150 Doornkloof 391 JR

OWNER : RSA (SADF - Kentron)

ADDRESS : PB X336, Pretoria 0001 Tel. 644120

SITE CO-ORDINATES : LATITUDE 25°52'46"S X + 2 863 540
LONGITUDE 28°11'45"E Y + 80 630

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 14

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/21

DATE COMPLETED : 1987/07/27

TOTAL COST : R51 454,30

COST PER METRE : R343,03

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 348 m

DIAMETERS AND DEPTH INTERVALS:

BORE :
445 mm
381 mm 0 - 85 m
330 mm 85 - 150 m
254 mm
203 mm 150 - 348 m
165 mm

CASING:
394 mm
343 mm 0 - 86,1 m
261 mm
207 mm
165 mm

PERFORATED CASING:
394 mm
343 mm
261 mm
207 mm
165 mm

LENGTH:
394 mm
343 mm
261 mm
207 mm
165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle to medium gradient on hill slope

LOGGED BY : J.L. Jolly

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1463 mamsl

COLLAR ELEVATION: ± 1463 mamsl

DEPTH TO REST WATER LEVEL : 38,63 mbc

DATE : 1987/07/27

REST WATER LEVEL ELEVATION: ± 1424 mamsl

WATER STRIKE(S) : Indeterminate

FINAL BLOW YIELD : Minimal (< 5 l/s)

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

The borehole was drilled deeper from 150 m to 348 m by the DWA. The cost per metre refers only to the original 150 m drilled.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37834

LOCATION

PROPERTY : Ptn 150 Doornkloof 391 JR

OWNER : RSA (SADF - Kentron)

ADDRESS : PB X336, Pretoria 0001 Tel. 644120

SITE CO-ORDINATES : LATITUDE 25°52'48"S X + 2 863 575
LONGITUDE 28°12'07"E Y + 79 950

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 15

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/27

DATE COMPLETED : 1987/08/04

TOTAL COST : R31 684,50

COST PER METRE : R576,08

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 55 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm		394 mm	
381 mm	0 - 30 m	343 mm	0 - 36,6 m
330 mm	30 - 36 m	261 mm	0 - 37,53 m
254 mm	36 - 44 m	207 mm	0 - 46,59 m
203 mm	44 - 55 m	165 mm	
165 mm			

PERFORATED CASING:		LENGTH:	
394 mm		394 mm	
343 mm		343 mm	
261 mm	13,13 - 37,53 m	261 mm	24,4 m
207 mm	28,3 - 46,59 m	207 mm	18,29 m
165 mm		165 mm	

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle gradient on valley bottom

LOGGED BY : J.L. Jolly

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1434 mamsl

COLLAR ELEVATION: ± 1434 mamsl

DEPTH TO REST WATER LEVEL : 11,75 mbc

DATE : 1987/08/04

REST WATER LEVEL ELEVATION: ± 1422 mamsl

WATER STRIKE(S) : 20 - 55 m

FINAL BLOW YIELD : > 60 l/s

WATER QUALITY : Potable

FIELD EC : 49 mS/m

FIELD TEMP.: 19°C

GENERAL REMARKS

PJH/HK/0843K/0726A

RECORD OF BOREHOLE: G37835A

PROPERTY	: Ptn 41 Doornkloof 391 JR
OWNER	: RSA (Dept. of Agriculture and Water Supply
ADDRESS	: PB X116, Pretoria 0001 Tel. 2062822
SITE CO-ORDINATES	: LATITUDE 25°53'57"S X + 2 865 660 : LONGITUDE 28°12'39"E Y + 79 035
TOPOCADASTRAL MAP REFERENCE NO.	:2528 CC
ORTHOPHOTO MAP REFERENCE NO.	:2528 CC 15

DRILLING RECORD

CONTRACTOR : Interdrills (Pty) Limited DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/05/22 DATE COMPLETED : 1987/07/04

TOTAL COST : R40 240,51 COST PER METRE : R201,20

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 349 m

DIAMETERS AND DEPTH INTERVALS:

BORE :			CASING:	
	445 mm			394 mm	
	381 mm	0 32.5 m		343 mm	0 - 26,37 m
	330 mm	32,5 203,7 m		261 mm	
	254 mm			207 mm	
	203 mm	203,7 349 m		165 mm	
	165 mm				

PERFORATED CASING:		LENGTH:	
	394 mm		394 mm
	343 mm		343 mm
	261 mm		261 mm
	207 mm		207 mm
	165 mm		165 mm

METHOD PERFORATED: No perforated casing installed in this bore.

HYDROGEOLOGICAL RECORD

METHOD SITED	: Gravity anomaly		
TERRAIN DESCRIPTION	: Flat plateau		
LOGGED BY	: P.J. Hobbs	SAMPLE INTERVAL	: 1 m
SURFACE ELEVATION	: ± 1 491 mams l	COLLAR ELEVATION:	± 1 491 mams l
DEPHT TO REST WATER LEVEL	: 70,2 mbc	DATE	: 1987/06/03
REST WATER LEVEL ELEVATION	: ± 1 421 mams l	WATER STRIKE(S)	: Indeterinate
FINAL BLOW YIELD	: < 5 l/s		
WATER QUALITY	: Unknown	FIELD EC	: No water sample taken
		FIELD TEMP.	: No water saple taken

GENERAL REMARKS

This borehole represents the second and successful atempt after the first attempt was abondoned and filled in. The borehole was drilled deeper from 203,7 m to 349 m by DWA. The cost per metre refers only to the original 203,7 m drilled.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37836

LOCATION

PROPERTY : Ptn 15 Doornkloof 391 JR

OWNER : SAMANCOR (Pty) Limited

ADDRESS : Anderson Street, Johannesburg Tel: 8334411

SITE CO-ORDINATES : LATITUDE 25°54'21"S — X + 2 866 450
LONGITUDE 28°14'20"E — Y + 76 255

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 20

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/01

DATE COMPLETED : 1987/07/07

TOTAL COST : R61 233,76

COST PER METRE : R406,87

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 150,5 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm		394 mm	
381 mm	0 - 95,5 m	343 mm	0 - 35 m
330 mm	95,5 - 150,5 m	261 mm	0 - 150,99 m
254 mm		207 mm	
203 mm		165 mm	
165 mm			

PERFORATED CASING:		LENGTH:	
394 mm		394 mm	
343 mm		343 mm	
261 mm	96,4 - 144,89 m	261 mm	48,49 m
207 mm		207 mm	
165 mm		165 mm	

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Medium gradient on valley bottom

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1470 mamsl

COLLAR ELEVATION: ± 1470 mamsl

DEPTH TO REST WATER LEVEL : 27,90 mbc

DATE : 1987/07/13

REST WATER LEVEL ELEVATION: ± 1442 mamsl

WATER STRIKE(S) : 98 - 130 m

FINAL BLOW YIELD : > 86 l/s

WATER QUALITY : Potable

FIELD EC : 39 mS/m

FIELD TEMP.: 20°C

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37837

LOCATION

PROPERTY : Ptn 113 Doornkloof 391 JR

OWNER : SAMANCOR (Pty) Limited

ADDRESS : Anderson Street, Johannesburg Tel: 8334411

SITE CO-ORDINATES : LATITUDE 25°54'42"S X + 2 867 115
LONGITUDE 28°14'42"E Y + 75 660

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 20

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/01

DATE COMPLETED : 1987/07/06

TOTAL COST : R70 818,06

COST PER METRE : R283,27

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 250 m

DIAMETERS AND DEPTH INTERVALS:

BORE :	445 mm	CASING:	394 mm
	381 mm 0 - 31 m		343 mm 0 - 32,04 m
	330 mm 31 - 44 m		261 mm 0 - 44,71 m
	254 mm 44 - 250 m		207 mm
	203 mm		165 mm
	165 mm		
PERFORATED CASING:	394 mm	LENGTH:	394 mm
	343 mm		343 mm
	261 mm		261 mm
	207 mm		207 mm
	165 mm		165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Medium to steep gradient on hill slope

LOGGED BY : P.J. Hobbs

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1498 mamsl

COLLAR ELEVATION: ± 1498 mamsl

DEPTH TO REST WATER LEVEL : 61,34 mbc

DATE : 1987/08/12

REST WATER LEVEL ELEVATION: ± 1437 mamsl

WATER STRIKE(S) : 65 m

FINAL BLOW YIELD : < 5 l/s

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37837A

LOCATION

PROPERTY : Ptn 113 Doornkloof 391 JR

OWNER : SAMANCOR (Pty) Limited

ADDRESS : Anderson Street, Johannesburg Tel: 8334411

SITE CO-ORDINATES : LATITUDE 25°54'42"S X + 2 867 115
LONGITUDE 28°14'41"E Y + 75 705

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 20

DRILLING RECORD

CONTRACTOR : Boart Exploration Services DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/08/05 DATE COMPLETED : 1987/08/11

TOTAL COST : R50 625,07 COST PER METRE : R339,77

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 285 m

DIAMETERS AND DEPTH INTERVALS:

BORE :	445 mm		CASING: 394 mm	
	381 mm	0 - 82 m	343 mm	0 - 82,48 m
	330 mm	82 - 149 m	261 mm	
	254 mm		207 mm	
	203 mm	149 - 285 m	165 mm	
	165 mm			
PERFORATED CASING:	394 mm		LENGTH: 394 mm	
	343 mm		343 mm	
	261 mm		261 mm	
	207 mm		207 mm	
	165 mm		165 mm	

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Medium to steep gradient on hill slope

LOGGED BY : J.L. Jolly SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1495 mamsl COLLAR ELEVATION: ± 1495 mamsl

DEPTH TO REST WATER LEVEL : 57,6 mbc DATE : 1987/08/11

REST WATER LEVEL ELEVATION: ± 1437 mamsl WATER STRIKE(S) : Indeterminate

FINAL BLOW YIELD : < 5 l/s

WATER QUALITY : Unknown FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

This borehole was drilled deeper from 149 m to 285 m by the DWA. The cost per metre refers only to the original 149 m drilled.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37838

LOCATION

PROPERTY : Ptn 9 Olifantsfontein 410 JR

OWNER : Dr D.J. Botha

ADDRESS : 939 Louis Pasteur Bldg, Pretoria Tel: 465007

SITE CO-ORDINATES : LATITUDE 25°55'39"S X + 2 868 830
LONGITUDE 28°13'10"E Y + 78 160

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 20

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/08/11

DATE COMPLETED : 1987/08/15

TOTAL COST : R49 209,13

COST PER METRE : R328,06

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 150 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm		394 mm	
381 mm	0 - 28 m	343 mm	0 - 36,67 m
330 mm	28 - 37 m	261 mm	0 - 43,63 m
254 mm	37 - 150 m	207 mm	
203 mm		165 mm	
165 mm			

PERFORATED CASING:		LENGTH:	
394 mm		394 mm	
343 mm	30,58 - 36,67 m	343 mm	6,09 m
261 mm	19,42 - 43,63 m	261 mm	24,21 m
207 mm		207 mm	
165 mm		165 mm	

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle to medium gradient on hill slope

LOGGED BY : J.L. Jolly

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1475 mamsl

COLLAR ELEVATION: ± 1475 mamsl

DEPTH TO REST WATER LEVEL : 20,65 mbc

DATE : 1987/08/15

REST WATER LEVEL ELEVATION: ± 1454 mamsl

WATER STRIKE(S) : 30 - 45 m

FINAL BLOW YIELD : > 30 l/s

WATER QUALITY : Potable

FIELD EC : 75 mS/m

FIELD TEMP.: 19°C

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37839

LOCATION

PROPERTY : Rem. Olifantsfontein 402 JR

OWNER : Cullinan Holdings Limited

ADDRESS : PB X1, Olifantsfontein Tel. 612551

SITE CO-ORDINATES : LATITUDE 25°56'05"S — X + 2 869 680
LONGITUDE 28°13'53"E — Y + 77 010

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 20

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/08/13

DATE COMPLETED : 1987/08/15

TOTAL COST : R60 484,77

COST PER METRE : R302,42

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 200 m

DIAMETERS AND DEPTH INTERVALS:

BORE		CASING:	
445 mm		394 mm	
381 mm	0 - 61 m	343 mm	0 - 61,42 m
330 mm	61 - 200 m	261 mm	
254 mm		207 mm	
203 mm		165 mm	
165 mm			

PERFORATED CASING:	LENGTH:
394 mm	394 mm
343 mm	343 mm
261 mm	261 mm
207 mm	207 mm
165 mm	165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Flat plain

LOGGED BY : J.L. Jolly

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1491 mamsl

COLLAR ELEVATION: ± 1491 mamsl

DEPTH TO REST WATER LEVEL : 38,78 mbc

DATE : 1987/08/15

REST WATER LEVEL ELEVATION: ± 1452 mamsl

WATER STRIKE(S) : Indeterminate

FINAL BLOW YIELD : < 5 l/s

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37840

LOCATION

PROPERTY : Ptn 113 Doornkloof 391 JR

OWNER : SAMANCOR (Pty) Limited

ADDRESS : Anderson Street, Johannesburg Tel. 833441

SITE CO-ORDINATES : LATITUDE 25°55'21"S X + 2 868 330
LONGITUDE 28°15'27"E Y + 74 390

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CD

ORTHOPHOTO MAP REFERENCE NO. : 2528 CD 16

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/07/28

DATE COMPLETED : 1987/08/04

TOTAL COST : R59 457,64

COST PER METRE : R487,36

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 122 m

DIAMETERS AND DEPTH INTERVALS:

BORE :
445 mm
381 mm 0 - 67 m
330 mm 67 - 97,5 m
254 mm 97,5 - 122 m
203 mm
165 mm

CASING:
394 mm
343 mm 0 - 65,68 m
261 mm 0 - 98,59 m
207 mm 93,6 - 119,77 m
165 mm

PERFORATED CASING:
394 mm
343 mm
261 mm 68,08 - 98,59 m
207 mm 94,6 - 119,77 m
165 mm

LENGTH:
394 mm
343 mm
261 mm 30,51 m
207 mm 25,17 m drop-set
165 mm

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Flat plain

LOGGED BY : J.L. Jolly

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1497 mamsl

COLLAR ELEVATION: ± 1497 mamsl

DEPTH TO REST WATER LEVEL : 40,58 mbc

DATE : 1987/08/04

REST WATER LEVEL ELEVATION: ± 1456 mamsl

WATER STRIKE(S) : 97,5 - 122 m

FINAL BLOW YIELD : > 30 l/s

WATER QUALITY : Potable

FIELD EC : 41 mS/m

FIELD TEMP.: 20°C

GENERAL REMARKS

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37841

LOCATION

PROPERTY : Ptn 113 Doornkloof 391 JR

OWNER : SAMANCOR (Pty) Limited

ADDRESS : Anderson Street, Johannesburg Tel. 8334411

SITE CO-ORDINATES : LATITUDE 25°54'43"S X + 2 867 115
LONGITUDE 28°14'17"E Y + 76 335

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 20

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/08/04

DATE COMPLETED : 1987/08/12

TOTAL COST : R50 786,89

COST PER METRE : R338,58

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 402 m

DIAMETERS AND DEPTH INTERVALS:

BORE :
445 mm
381 mm 0 - 89 m
330 mm 89 - 150 m
254 mm
203 mm 150 - 402 m
165 mm

CASING:
394 mm
343 mm 0 - 89,36 m
261 mm
207 mm
165 mm

PERFORATED CASING:
394 mm
343 mm
261 mm
207 mm
165 mm

LENGTH:
394 mm
343 mm
261 mm
207 mm
165 mm

METHOD PERFORATED: No perforated casing installed in this bore

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Gentle to medium gradient on hill slope

LOGGED BY : J.L. Jolly

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1472 mamsl

COLLAR ELEVATION: ± 1472 mamsl

DEPTH TO REST WATER LEVEL : 30,00 mbc

DATE : 1987/10/19

REST WATER LEVEL ELEVATION: ± 1442 mamsl

WATER STRIKE(S) : Indeterminate

FINAL BLOW YIELD : < 5 l/s

WATER QUALITY : Unknown

FIELD EC : No water sample taken

FIELD TEMP.: No water sample taken

GENERAL REMARKS

The borehole was drilled deeper from 150 m to 402 m by the DWA. The cost per metre refers only to the original 150 m drilled.

PJH/HK/1188K/0734A

RECORD OF BOREHOLE: G37842

LOCATION

PROPERTY : Ptn 199 Swartkop 356 JR

OWNER : SADF and Verwoerdburg Municipality

ADDRESS : P.O. Box 14013, Verwoerdburg 0140 Tel. 621151

SITE CO-ORDINATES : LATITUDE 25°49'51"S X + 2 858 205
LONGITUDE 28°07'01"E Y + 88 560

TOPOCADASTRAL MAP REFERENCE NO.: 2528 CC

ORTHOPHOTO MAP REFERENCE NO. : 2528 CC 8

DRILLING RECORD

CONTRACTOR : Boart Exploration Services

DRILLING METHOD: Air rotary percussion

DATE COMMENCED: 1987/08/20

DATE COMPLETED : 1987/08/25

TOTAL COST : R21 099,51

COST PER METRE : R586,10

BOREHOLE CONSTRUCTION RECORD

TOTAL DEPTH : 36 m

DIAMETERS AND DEPTH INTERVALS:

BORE :

Diameter	Interval
445 mm	
381 mm	0 - 20 m
330 mm	20 - 34 m
254 mm	34 - 36 m
203 mm	
165 mm	

CASING:

Diameter	Interval
394 mm	
343 mm	0 - 29,9 m
261 mm	0 - 36,55 m
207 mm	
165 mm	

PERFORATED CASING:

Diameter	Interval
394 mm	
343 mm	24,25 - 29,9 m
261 mm	0 - 36,55 m
207 mm	
165 mm	

LENGTH:

Diameter	Length
394 mm	
343 mm	5,65 m
261 mm	36,55 m
207 mm	
165 mm	

METHOD PERFORATED: Torch-cut by hand to provide some 4% open area

HYDROGEOLOGICAL RECORD

METHOD SITED : Gravity anomaly

TERRAIN DESCRIPTION: Floodplain

LOGGED BY : J.L. Jolly

SAMPLE INTERVAL : 1 m

SURFACE ELEVATION : ± 1383 mamsl

COLLAR ELEVATION: ± 1383 mamsl

DEPTH TO REST WATER LEVEL : 8,14 mbc

DATE : 1987/08/25

REST WATER LEVEL ELEVATION: ± 1375 mamsl

WATER STRIKE(S) : 20 - 36 m

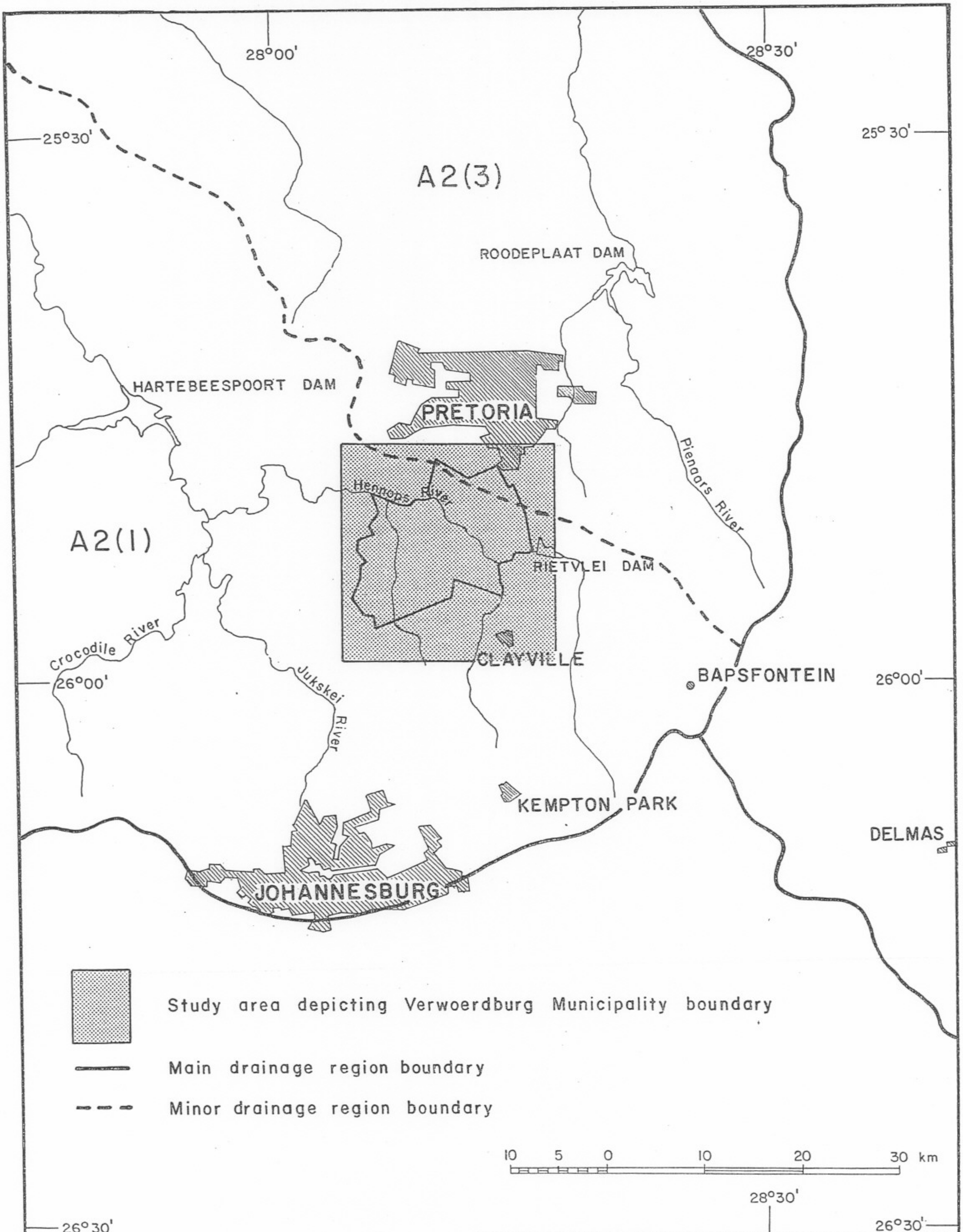
FINAL BLOW YIELD : > 40 l/s

WATER QUALITY : Potable

FIELD EC : 59 mS/m

FIELD TEMP.: 19°C

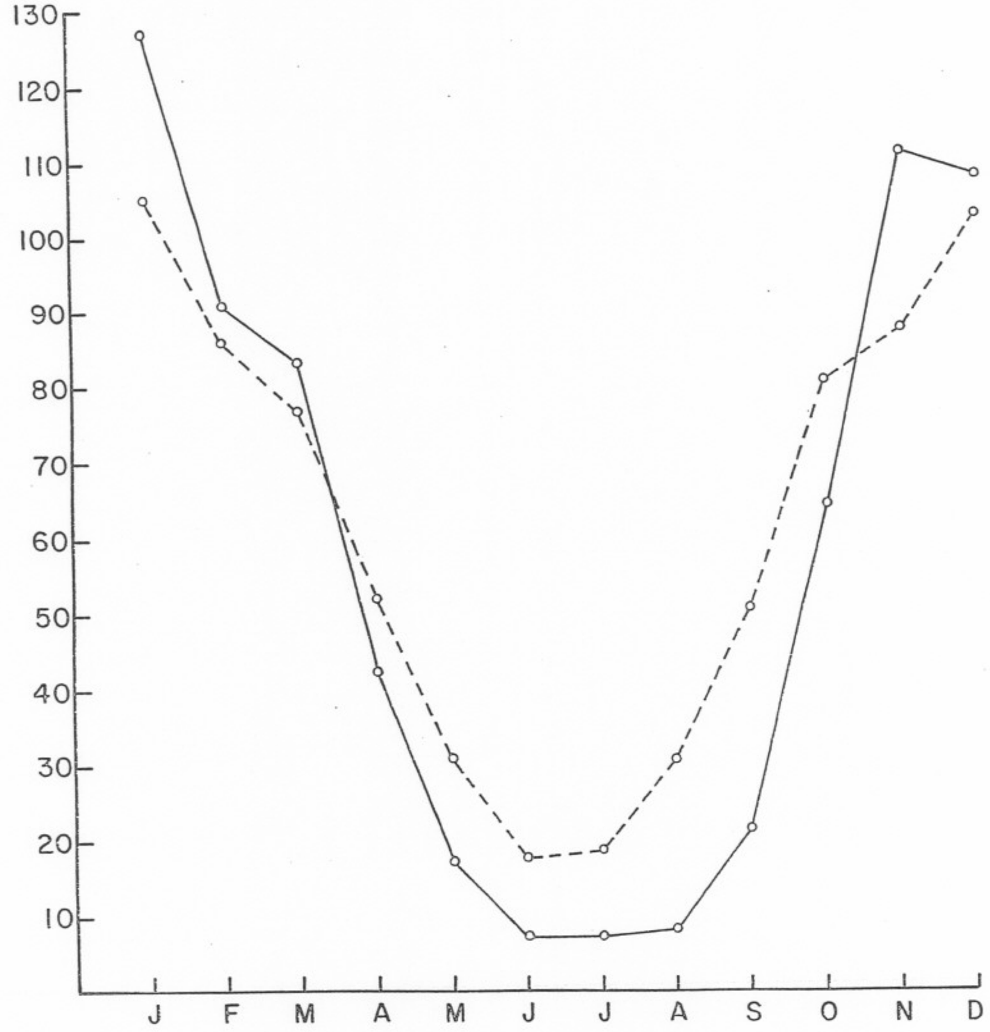
GENERAL REMARKS



DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE		DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY	
TITEL: TITLE:	FIGURE 1.1 : Locality map		
GETEKEN: DRAWN: P J Hobbs	DAT.:	NAGESIEN: CHECKED:	DAT.:
NAGETREK: TRACED:	DAT.:	VERSLAG No: REPORT No: GH3502	GHP No.:

Ozalid 86/1421

STATION 513/382 IRENE 25°52'S 28°13'E 1448 m



o——o Observed mean monthly rainfall (mm)

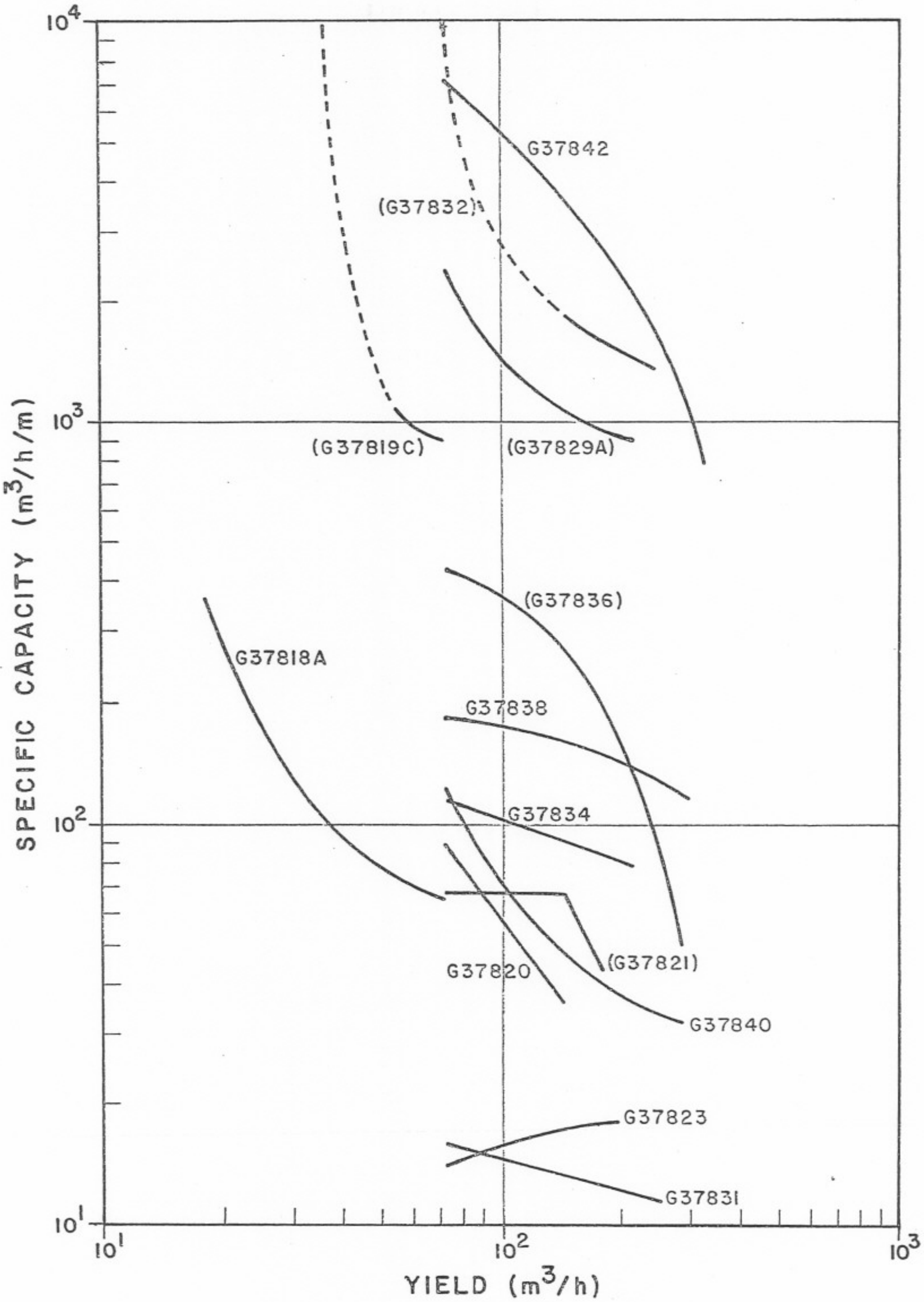
o- - - -o Calculated monthly potential evapotranspiration (mm)

DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE	DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY

TITEL:
TITLE: FIGURE 2.1:
Comparison between potential evapotranspiration and mean rainfall

GETEKEN: DRAWN: P J Hobbs	DAT.:	NAGESIEN: CHECKED:	DAT.:
NAGETREK: TRACED:	DAT.:	VERSLAG No: REPORT No: GH3502	GHP No.:

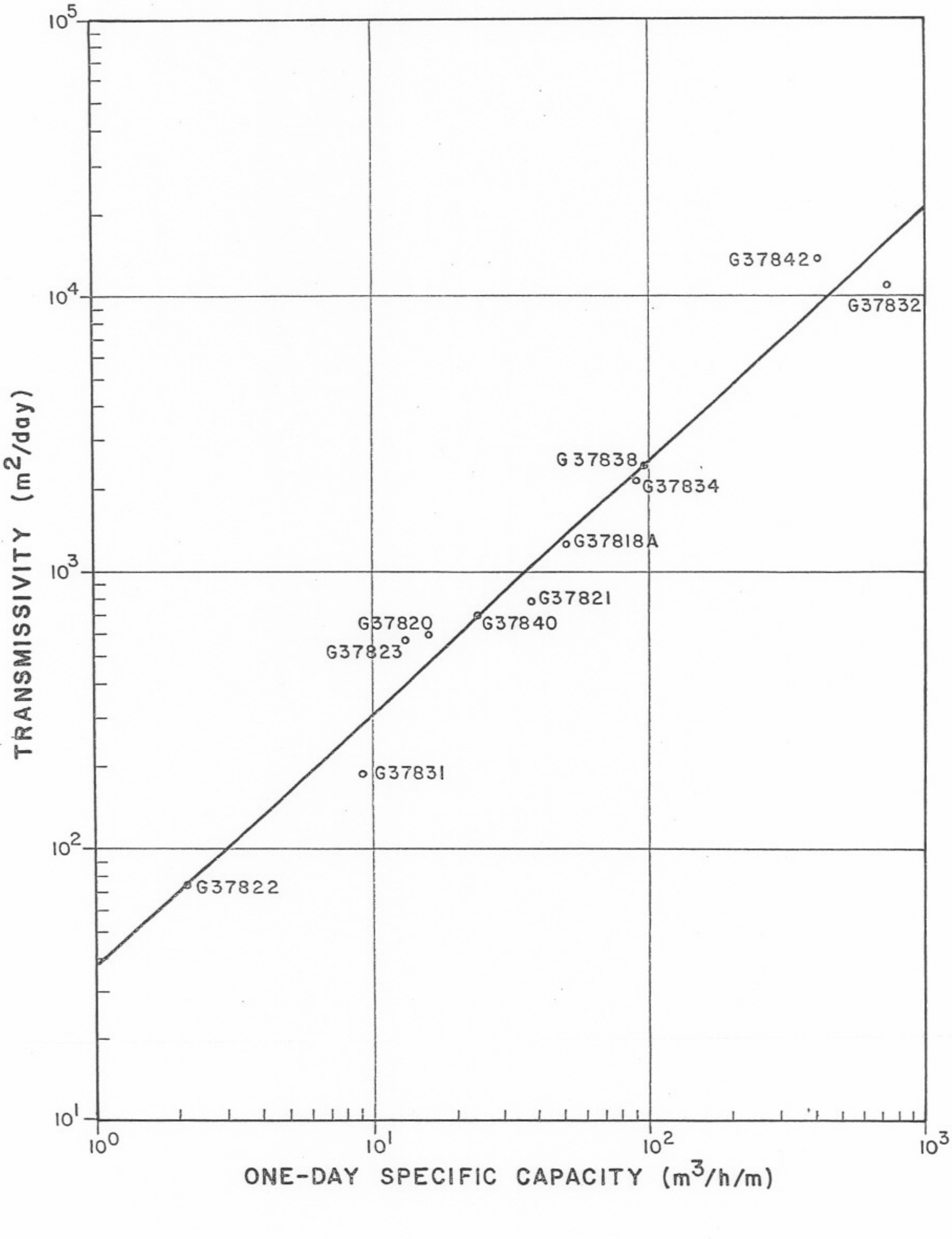
Ozalid 86/1421



NOTE : Bracketed curve labels indicate specific capacity data obtained from calibration tests.

DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE	DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY
TITEL: TITLE: FIGURE 6.2 : Yield vs specific capacity performance graphs for potential production boreholes	
GETEKEN: DRAWN: P J Hobbs DAT.:	NAGESIEN: CHECKED: DAT.:
NAGETREK: TRACED: DAT.:	VERSLAG No: REPORT No: GH3502 GHP No.:

Ozalid 86/1421



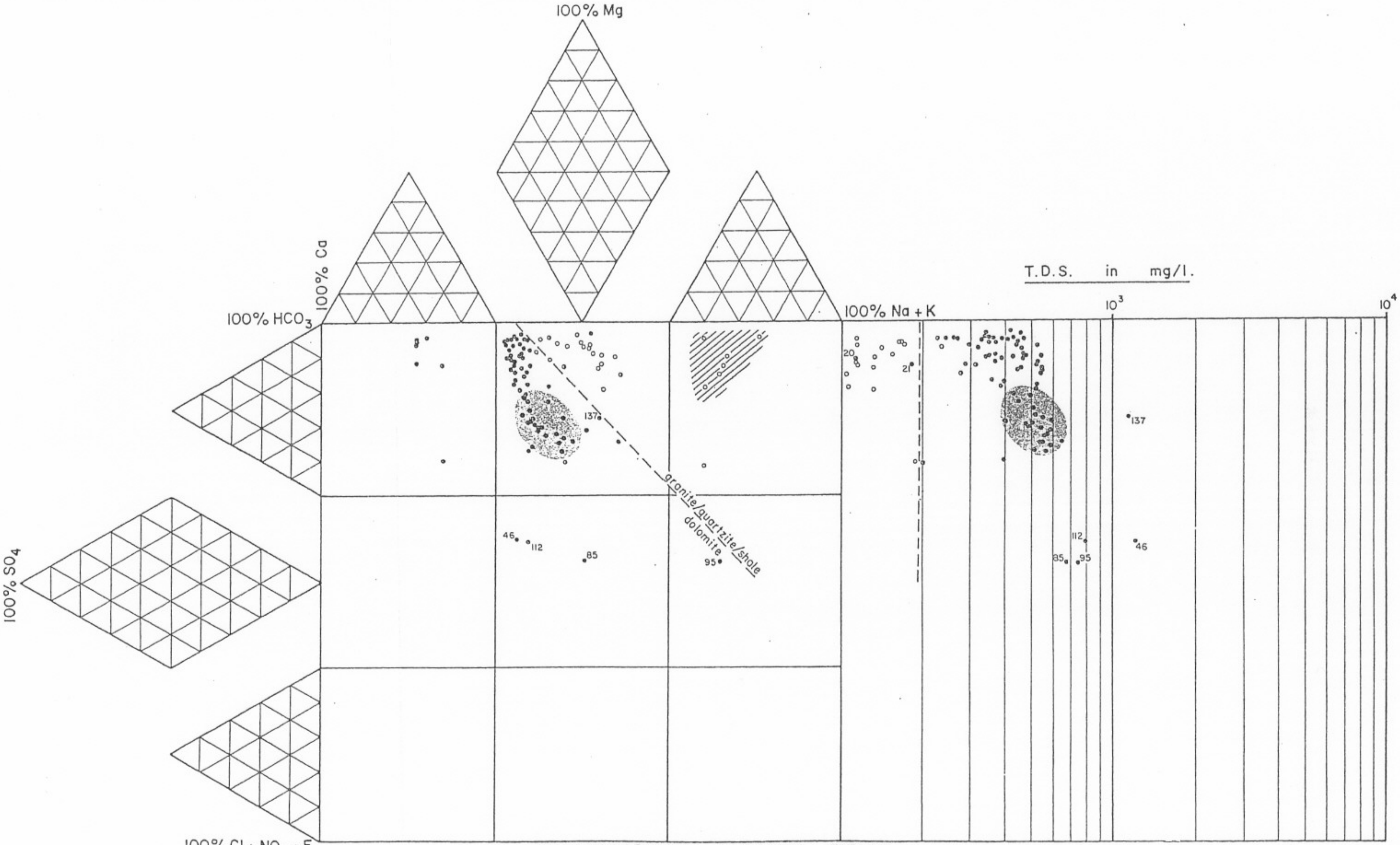
NOTE : Data fitted to a power curve ($y = ax^b$)

Coefficient of determination (R) = 0,95

Regression coefficients a = 37,83 and b = 0,91

DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE	DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY
TITEL: TITLE: FIGURE 6.3 : Transmissivity vs specific capacity graph for potential production boreholes	
GETEKEN: DRAWN : P J Hobbs DAT. :	NAGESIEN: CHECKED : DAT. :
NAGETREK: TRACED : DAT. :	VERSLAG No: REPORT No: GH3502 GHP No.:

Ozalid 86/1421



SYMBOLS

- Boreholes tapping dolomite
- Boreholes tapping granite or quartzite/shale
- Boreholes tapping "mixed" ground water

CHARACTERISTIC PLOTTING FIELDS

- Ground water from boreholes within 1000 m of the Hennops River
- Ground water from boreholes tapping the granite aquifer

DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE	DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY
TITEL: TITLE:	**FIGURE 7.1: Characterization of ground-water chemistry**
GETEKEN: DRAWN: P J Hobbs DAT.	NAGESIEN: CHECKED: DAT.
NAGETREK: TRACED: DAT.	VERSLAG No REPORT No GH3502 GHP No.

Ozalid 86/378

APPENDIX 3.1

LOGISTICS AND RESULTS OF THE

MULTI-RATE PUMPING TESTS

pjh/hk/1188K/0734A

Borehole No.	Date Tested	Contractor	Type of pump	Depth of pump inlet (m)	Rest water level (m)	Available drawdown (m)	Step No.	Pumping rate (l/s)	Drawdown (m)	Specific capacity (l/s/m)	Duration of step (min)	Duration of recovery (min)	Percentage recovery
G37818	Pumping test prohibited due to malconstruction of borehole												
G37818A	07.03.88	Groundwater Practitioners	BH250D	110	79,77	30	1	5	0,05	100	100		
							2	10	0,36	28	100		
							3	15	0,59	25	100		
							4	20	1,13	18	100	20	100%
G37819C	10.03.88	Groundwater Practitioners	BH250D	130	94,57	35	1	5	0,00		10*		
							2	10	0,00		10*		
							3	15	0,05	300	10*		
							4	20	0,08	250	10*	0,5	100%
							*Calibration test data. No multi-rate test performed						
G37820	27.04.88	Groundwater Practitioners	BP250M	118	97,23	20	1	20	0,78	25	10*		
							2	40	4,04	10	10*	30	100%
							*Calibration test data. Much CO_2 gas in water at a yield of 40 l/s causing cavitation of pump. No multi-rate test performed.						
G37821	29.04.88	Groundwater Practitioners	BP250M	110	89,93	20	1	20	1,02	19	15*		
							2	35	1,47	23	10*		
							3	40	2,03	19	10*		
							4	45	3,59	12	10*		
							5	50	3,93	12	10*		
							*Calibration test data. Cavitation of pump at a yield of 50 l/s. No multi-rate test performed						
G37822	26.02.88	Spray-Mor Irrigation	BH250	123	87,62	35	1	8,8	3,90	2	100		
							2	13,4	21,20	0,6	90	140	96%
							Excessive drop in water level when dynamic water level reaches 20 m drawdown. Simultaneous discolouration of water and borehole starts to yield wad gravels.						
G37823	05.05.88	Groundwater Practitioners	BP250M	92	73,91	18	1	20	5,17	3,9	100		
							2	35	7,37	4,7	100		
							3	55	10,93	5,0	100	30	100%
G37824	26.03.88	Spray-Mor Irrigation	BH150D	173	131,40	41	1	0,2	3,70	0,05	8*		
							2	0,4	5,60	0,07	5*		
							3	0,9	9,50	0,09	5*		
							4	2,9	21,10	0,14	5*	2 672	70%
							*Calibration test data. Duration of recovery taken from end of calibration test at 11h28 on 26.03.88 to start of constant rate test at 08h00 on 28.03.88						

Borehole No.	Date Tested	Contractor	Type of pump	Depth of pump inlet (m)	Rest water level (m)	Available drawdown (m)	Step No.	Pumping rate (l/s)	Drawdown (m)	Specific capacity (l/s/m)	Duration of step (min)	Duration of recovery (min)	Percentage recovery
G37825A	26.05.88	Groundwater Practitioners	BH250D	155	119,52	35	1	4,3	0		10*		
							2	8,8	0		10*		
							3	10,9	0		10*		
							4	18,8	0,09	210	10*	0,5	100%
							*Calibration test data. No multi-rate or constant rate test performed.						
G37827	24.02.88	Spray-Mor Irrigation	BH150D	120	67,88	52	No calibration test or multi-rate test performed. Excessive drawdown of 20 m at 0,7 l/s during first step of calibration test prompted conversion of calibration test into constant rate test						
G37828	23.03.88	Spray-Mor Irrigation	BH250	120	46,60	73	1	1,2	30,79	0,04	100		
							2	1,4	62,28	0,02	100		
							3	1,8	72,80		15	400	90%
							*Multi-rate test aborted on third step after 15 minutes, having exhausted available drawdown						
G37829A	22.03.88	Groundwater Practitioners	BP250M	70	35,21	34	1	20	0,03	667	10*		
							2	40	0,14	286	10*		
							3	60	0,24	250	10*		
							4	82	0,33	248	10*	0,5	100%
							*Calibration test data. No multi-rate test performed.						
G37830	21.03.88	Spray-Mor Irrigation	BH150D	120	36,90	83	1	0,7	21,60	0,03	12*		
							2	0,9	41,70	0,02	12*		
							3	1,3	60,38	0,02	12*		
							4	1,5	81,92	0,02	15*	600	57%
							*Calibration test data. No multi-rate test performed.						
G37831	23.03.88	Groundwater Practitioners	BP250M	90	44,92	45	1	20	4,58	4,4	100		
							2	40	10,56	3,8	100		
							3	60	18,40	3,3	100		
							4	70	21,73	3,2	100	3	100%
G37832	19.05.88	Groundwater Practitioners	BP250M	51	28,16	22	1	20	0,00		10*		
							2	40	0,08	500	10*		
							3	60	0,15	400	10*		
							4	68	0,18	378	10*	3	100%
							*Calibration test data. No multi-rate test performed.						
G37833	Pumping test prohibited due to loss of 207 mm ID casing in borehole during extraction following deepening of borehole by DWA												

Borehole No.	Date Tested	Contractor	Type of pump	Depth of pump inlet (m)	Rest water level (m)	Available draw-down (m)	Step No.	Pumping rate (l/s)	Draw-down (m)	Specific capacity (l/s/m)	Duration of step (min)	Duration of recovery (min)	Percentage recovery
G37834	20.05.88	Groundwater Practitioners	BP250M	35	11,70	23	1	20	0,63	32	100		
							2	40	1,63	25	100		
							3	60	2,72	22	100	50	100%
							4	85	4,09	21	10*		
							*From calibration test. Fourth step omitted from multi-rate test because of excessive turbulance in borehole making for inaccurate readings.						
G37835A	22.11.87	Spray-Mor Irrigation	BH150D	140	70,00	70	1	1	5,60	0,2	30		
							2	2,8	17,27	0,2	30		
							3	4,0	41,15	0,1	30	20	97%
G37836	10.05.87	Groundwater Practitioners	BH250M	60	27,72	32	1	20	0,17	118	10*		
							2	40	0,52	77	10*		
							3	60	0,74	81	10*		
							4	80	5,58	14	10*	70	97%
							*Calibration test data. No multi-rate test performed.						
G37837	18.11.87	Spray-Mor Irrigation	BH150D	125	61,10	64	1	1,2	37,72	0,03	35*		
							2	2,5	64,00	0,04	10*	170	52%
							*Calibration test data. No multi-rate test performed.						
G37837A	18.11.87	Spray-Mor Irrigation	BP150D	124	57,60	66	1	1,3	21,56	0,06	30		
							2	2,9	59,65	0,05	30	155	51%
G37838	18.03.88	Groundwater Practitioners	BP250M	40	21,01	19	1	20	0,39	51	100		
							2	40	0,89	45	100		
							3	60	1,55	39	100		
							4	83	2,56	32	100	120	92%
G37839	29.03.88	Spray-Mor Irrigation	BH150D	122	38,30	83	First step of calibration test continued as constant rate test						
G37840	15.03.88	Groundwater Practitioners	BP250M	90	50,56	39	1	20	0,59	34	100		
							2	40	3,01	13	100		
							3	60	5,75	10	100		
							4	80	8,95	9	100	250	95%

Borehole No.	Date Tested	Contractor	Type of pump	Depth of pump inlet (m)	Rest water level (m)	Available drawdown (m)	Step No.	Pumping rate (l/s)	Drawdown (m)	Specific capacity (l/s/m)	Duration of step (min)	Duration of recovery (min)	Percentage recovery
G37841	17.11.87	Spray-Mor Irrigation	BH150D	123	29,26	93	1	1,1	28,50	0,04	30		
							2	2,5	80,00	0,03	30		
							3	3,3	92,51	0,03	5	205	75%
							*Multi-rate test aborted after 5 minutes during step 3 with exhaustion of available drawdown						
G37842	13.05.88	Groundwater Practitioners	BP250M	31	7,98	23	1	20	0,01	2 000	10*		
							2	40	0,04	1 000	10*		
							3	60	0,07	857	10*		
							4	90	0,42	214	10*	0,5	100%
							*Calibration test data. No multi-rate test performed.						

APPENDIX 3.2

LOGISTICS OF THE CONSTANT RATE PUMPING TESTS

Borehole No.	Date tested	Contractor	Type of pump	Depth of pump inlet (m)	Rest water level (m)	Available drawdown (m)	Pumping rate (l/s)	Drawdown at end of test (m)	Specific capacity (l/s/m)	Duration of test (min)	Duration of recovery (min	Percen-tage recovery
G37818	Pumping test prohibited due to malconstruction of borehole											
G37818A	07.03.88	Groundwater Practitioners	BH250D	110	79,77	30	20	1,29	15	480	100	98%
G37819C	10.03.88	Groundwater Practitioners	BH250D	130	94,57	35	20	0,25	80	480	160	64%
G37820	27.04.88	Groundwater Practitioners	BP250M	118	97,23	20	35	7,43	4,7	450	250	98%
G37821	02.05.88	Groundwater Practitioners	BP250M	110	89,93	20	45	4,09	11	400	35	91%
G37822	26.02.88	Spray-Mor Irrigation	BH250	123	87,62	35	12,2	20,59	0,6	222	180	95%
G37823	05.05.88	Groundwater Practitioners	BP250M	92	73,91	18	30	8,05	3,7	480	30	99%
G37824	28.03.88	Spray-Mor Irrigation	BH150D	173	137,64	35	0,3	36,45	0,01	300	300	9%
G37825A	No constant rate test performed											
G37827	24.02.88	Spray-Mor Irrigation	BH150D	120	67,88	52	0,7	50,71	0,01	70	60	43%
G37828	24.03.88	Spray-Mor Irrigation	BH250	120	46,90	73	1,3	70,00	0,02	450	80	40%
G37829A	22.03.88	Groundwater Practitioners	BP250M	70	35,21	34	88	0,39	226	180	4	100%
G37830	No constant rate test performed following poor performance of borehole during calibration test											
G37831	24.03.88	Groundwater Practitioners	BP250M	90	44,92	45	70	22,31	3,1	30	0,5	100%
G37832	19.05.88	Groundwater Practitioners	BP250M	51	28,16	22	100	0,34	294	230	60	94%
G37833	Pumping test prohibited due to loss of 207 mm ID casing in borehole during extraction following deepening of borehole by DWA											
G37834	No constant rate test performed											
G37835A	22.02.88	Spray-Mor Irrigation	BP150D	140	70,20	69	3	19,13	0,2	380	120	99%
G37836	10.05.88	Groundwater Practitioners	BP250M	60	27,72	32	90	13,74	6,6	480	480	80%
G37837	No constant rate test performed following poor performance of borehole during calibration test											
G37837A	No constant rate test performed following poor performance of borehole during calibration test											
G37838	21.03.88	Groundwater Practitioners	BP250M	40	21,21	18	82	2,73	30	480	160	86%
G37839	29.03.88	Spray-Mor Irrigation	BH150D	122	38,30	83	0,7	78,94	0,01	500	120	27%
G37840	16.03.88	Groundwater Practitioners	BP250M	90	50,45	39	88	9,93	8,9	300	200	91%
G37841	No constant rate test performed following poor performance of borehole during calibration test											
G37842	17.05.88	Groundwater Practitioners	BP250M	31	7,98	23	90	0,66	136	330	60	83%

APPENDIX 3.3

RESULTS OF THE CONSTANT RATE

PUMPING TEST DATA ANALYSIS

pjh/hk/1188K/0734A

Borehole No.	Method of analysis	Transmissivity (m^2/day)	Specific capacity/yield relationship graphical (Q = m^3/h)	analytical (Q = m^3/h)	Comment on borehole efficiency and aquifer behaviour
G37818	Theis bi-log; constant rate time-drawdown data Cooper-Jacob semi-log; constant rate time-drawdown data for early (E) and late (L) time Theis semi-log; constant rate recovery data	1 250 867 1 265 1 665	$SC=10\ 400\ Q^{-1.21}$	$SC=(0,0002Q+0,0005)^{-1}$	3% of head loss at 20 l/s attributable to laminar flow
G37819C	Cooper-Jacob semi-log; constant rate time-drawdown data Boulton bi-log; constant rate time-drawdown data for early (E) and late (L) time	5 967 809 509	Indeterminable from calibration test data		
G37820	Cooper-Jacob semi-log; constant rate time-drawdown data Theis semi-log; constant rate recovery data	675 508	Indeterminable from calibration test data		
G37821	Cooper-Jacob semi-log; constant rate time-drawdown data Cooper-Jacob semi-log; 1st step calibration test time-drawdown data	880 660	Indeterminable from calibration test data		
G37822	Cooper-Jacob semi-log; 1st step multi-rate test time-drawdown data Cooper-Jacob semi-log; constant rate time-drawdown data	73 8	Indeterminable from calibration and multi-rate test data		Steepening of constant rate time-drawdown graph indicates aquifer possibly of limited extent
G37823	Cooper-Jacob semi-log; constant rate time-drawdown data Cooper-Jacob semi-log; 1st step multi-rate test time-drawdown data	832 307	Intererminable		Specific capacity improves with increasing yield
G37824	Uninterpretable				Constant rate time-drawdown data wholly reflects the effect of casing storage
G37825A	Uninterpretable				Data obtained from calibration test not definitive
G37827	Theis semi-log; constant rate recovery data	1	Indeterminable		Constant rate time-drawdown data wholly reflects the effect of casing storage
G37828	Cooper-Jacob semi-log; 1st step multi-rate test time-drawdown data Cooper-Jacob semi-log; constant rate time-drawdown data Theis semi-log; constant rate recovery data	0,8 0,6 0,7	Indeterminable from multi-rate test data		
G37829A	Uninterpretable		Indeterminable from calibration test data		Steady-state conditions reached during both calibration and constant rate tests

Borehole No.	Method of analysis	Transmissivity (m^2/day)	Specific capacity/yield relationship graphical ($Q = m^3/h$)	Specific capacity/yield relationship analytical ($Q = m^3/h$)	Comment on borehole efficiency and aquifer behaviour
G37830	Cooper-Jacob semi-log; 1st step calibration test time-drawdown data	0,2	Indeterminable from calibration test data		
G37831	Cooper-Jacob semi-log; 1st step multi-rate test time-drawdown data	132	$SC=47Q^{-0.25}$ test data	$SC=(0,00007Q+0,07)^{-1}$	80% of head loss at 70 l/s attributable to laminar flow
	Cooper-Jacob semi-log; constant rate time-drawdown data	240			
G37832	Cooper-Jacob semi-log; constant rate time-drawdown data	11 300	Indeterminable from calibration test data		
	Theis semi-log; constant rate recovery data	10 500			
G37834	Cooper-Jacob semi-log; 1st step calibration test time-drawdown data	2 108	$SC=138Q^{-0.34}$	$SC=(0,00002Q+0,01)^{-1}$	70% of head loss at 60 l/s attributable to laminar flow
G37835A	Cooper-Jacob semi-log; 1st step multi-rate test time-drawdown data	6	Indeterminable from multi-rate test data		
	Cooper-Jacob semi-log; constant rate time-drawdown data for early (E) and late (L) time	4,6 15,3			
G37836	Theis semi-log; constant rate recovery data	269	Indeterminable from calibration test data		
	Boulton bi-log; constant rate time-drawdown data for early (E) and late (L) time	103 111			
G37837	Cooper-Jacob semi-log; 1st step calibration test time-drawdown data	0,5	Indeterminable from calibration test data		
G37837A	Uninterpretable		Indeterminable from multi-rate test data		
G37838	Cooper-Jacob semi-log; constant rate time-drawdown data	1 995	$SC=202Q^{-0.31}$	$SC=(0,00001Q+0,005)^{-1}$	62% of head loss at 83 l/s attributable to laminar flow
	Cooper-Jacob semi-log; 1st step multi-rate test time-drawdown data	2 259			
	Theis semi-log; constant rate recovery data	2 947			
G37839	Cooper-Jacob semi-log; constant rate time-drawdown data	0,2	Indeterminable		
G37840	Cooper-Jacob semi-log; 1st step multi-rate test time-drawdown data	1 130	$SC=2021Q^{-0.98}$	$SC=(0,0001Q+0,01)^{-1}$	26% of head loss at 80 l/s attributable to laminar flow
	Cooper-Jacob semi-log; constant rate time-drawdown data for early (E) and late (L) time	870 291			
	Theis semi-log; constant rate recovery data	485			

Borehole No.	Method of analysis	Transmissivity (m^2/day)	Specific capacity/yield relationship		Comment on borehole efficiency and aquifer behaviour
			graphical ($Q = m^3/h$)	analytical ($Q = m^3/h$)	
G37841	Cooper-Jacob semi-log; 1st step multi-rate test time-drawdown data	0,7	Indeterminable from multi-rate test data		
G37842	Cooper-Jacob semi-log; constant rate time-drawdown data for early (E) and late (L) time Theis semi-log; constant rate recovery data	20 332 6 469 14 232	Indeterminable from calibration test data		

APPENDIX 4.

SELECTIVE BOREHOLE SURVEY DATA

JUNE - SEPTEMBER 1986

pjh/hk/1188K/0734A

Borehole No.	Map Grid ref.	Owner	Property	Suburb	Yield (l/s)	Total depth (m)	Collar elevation (mamsl)	Depth to water level (m)	Ground water elevation (mamsl)	Date	Depth to water level (m)	Ground water elevation (mamsl)	Date	Remarks
1	H4	Sanders, J.S.	1724	The Reeds	0,3	20	1461	6,61	1454,39	06/1986	4,36	1456,64	01/1987	0 - 9 m sand, 9 - 23 m dolomite? Cavities? 1st water at 13 m
2	G4	Wood, J.F.	1314	The Reeds	1,9	42	1438	6,26	1431,74	06/1986	5,41	1432,59	01/1987	
3	H5	Liebenberg, W.	104	The Reeds	?	?	1526	7,10	1518,90	06/1986	-	-	-	
4	G4		154	The Reeds	?	?	1455	12,70	1442,30	06/1986	13,23	1441,77	01/1987	
5	G4	Van Tonder, P.F.	402	The Reeds	0,1	49	1477	11,96	1465,04	06/1986	-	-	-	Weathered granite to 30 m, 1st water at 45 m
6	G5	Jooste, H.S.	677	The Reeds	0,8	45	1497	11,44	1485,56	06/1986	11,81	1485,19	01/1987	Weathered granite to 20 m. Fresh granite to 45 m
7	G6	Niewenhuysen, A.J.	1273	Rooihuiskraal	0,02	55	1525	8,74	1516,26	06/1986	9,07	1515,93	01/1987	
8	G6	Caroto, A.F.	1066	Rooihuiskraal	0,1	38	1524	14,84	1509,16	06/1986	15,59	1508,41	01/1987	
9	G6	Rademeyer, E.	263	Rooihuiskraal	Seepage	47	1547	18,68	1528,32	06/1986	19,76	1527,24	01/1987	
10	G5	Van Loggerenberg, J.H.	2345	Rooihuiskraal	0,3	42	1468	5,02	1462,98	06/1986	-	-	-	
11	G6		1567	Rooihuiskraal	?	?	1512	13,90	1498,10	06/1986	13,43	1498,57	01/1987	
12	F6	Venter, J.P.J.	1033	Rooihuiskraal	0,3	53	1488	15,66	1472,34	06/1986	16,49	1471,51	01/1987	
13	G6	Ennis Nursery			?	37	1504	15,79	1488,21	06/1986	15,59	1488,41	01/1987	0 - 8 m red soil, 8 - 23 m weathered dolomite? Fresh rock to 37 m.
14	F5	Steyn	99	Celtisdal	0,5	18	1441	10,89	1430,11	06/1986	-	-	-	1st water at 12 m
15	E5	Farrell, R.W.	751	Wierda Park	?	105	1456	69,76	1386,24	06/1986	59,94	1396,06	01/1987	Water at 102 m
16	E5	Lourens, C.P.	660	Wierda Park	0,3	85	1450	52,70	1397,30	06/1986	43,54	1406,46	01/1987	
17	E5	Du Plessis, L.	531	Wierda Park	0,5	100	1440	36,59	1403,41	06/1986	18,36	1421,64	01/1987	Dolomite outcrop in garden

Borehole No.	Map Grid ref.	Owner	Property	Suburb	Yield (l/s)	Total depth (m)	Collar elevation (mamsl)	Depth to water level (m)	Ground water elevation (mamsl)	Date	Depth to water level (m)	Ground water elevation (mamsl)	Date	Remarks
18	D5	Smit, H.A.	1502	Wierda Park	1,3	82	1439	26,97	1412,03	06/1986	25,04	1413,96	01/1987	
19	E6	Hanekom, P.M.	154	Wierda Park	6,3	142	1467	52,16	1414,84	06/1986	46,43	1420,57	01/1987	14 m soil above dolomite, 3 water strikes
20	D6	Pistorius, H.F.	810	Eldoraigne	0,1	67	1477	39,45	1437,55	06/1986	39,25	1437,75	01/1987	
21	D6	Paper	214	Eldoraigne	?	100	1447	31,98	1415,02	06/1986	31,86	1415,14	01/1987	
22	E5	Morkel	1718	Wierda Park	0,9	71	1450	43,72	1406,28	06/1986	-	-	-	1,5 m cavity in dolomite at 68 m
23	D5	Breytenbach, T.J.C.	29	Eldoraigne	1,5	31	1413	25,29	1387,71	06/1986	24,68	1388,32	01/1987	Dolomite with cavities from 18 - 28 m with loss of air and samples at 28 m
24	E6		1761	Eldoraigne	?	200	1453	33,28	1419,72	06/1986	30,75	1422,25	01/1987	
25	C6			Zwartkop			Not measurable			06/1986	-	-	-	SRK borehole ZP18
26	D5	Melle		Zwartkop	?	?	1389	8,71	1380,29	06/1986	8,13	1380,87	01/1987	
27	D4	Pretorius	155	Zwartkop	1,9	57	1394	27,11	1366,89	06/1986	-	-	-	
28	D4		Plot 12	Raslouw	6,9	30	1407	19,60	1387,40	06/1986	18,59	1388,41	01/1987	
29	C3	Van Essen, M.	148	Zwartkop	?	?	1380	7,80	1372,20	06/1986	7,56	1372,44	01/1987	
30	D3			Mooiplaas	?	?	1412	34,19	1377,81	06/1986	35,60	1376,40	01/1987	
31	D3		156	Zwartkop	?	30	1390	15,73	1374,27	07/1986	15,33	1374,67	01/1987	
32	D5		Plot 8	Raslouw	1,3	41	1413	22,61	1390,39	07/1986	21,70	1391,30	01/1987	Large cavity at 41 m
33	E4	Prinsloo, J.	Plot 79	Raslouw	?	?	1416	17,42	1398,58	07/1986	13,54	1402,46	01/1987	Chert outcrop
34	E4		130/1	Raslouw	?	?	1397	7,75	1389,25	07/1986	6,94	1390,06	01/1987	
35	E2	Du Preez, N.	Plot 165	Raslouw	?	?	1425	22,83	1402,17	07/1986	21,86	1403,14	01/1987	
36	E3		Plot 12	Raslouw	?	?	1420	22,74	1397,26	07/1986	21,56	1398,44	01/1987	Dolomite cuttings around borehole

Borehole No.	Map Grid ref.	Owner	Property	Suburb	Yield (l/s)	Total depth (m)	Collar elevation (mamsl)	Depth to water level (m)	Ground water elevation (mamsl)	Date	Depth to water level (m)	Ground water elevation (mamsl)	Date	Remarks
37	E4		Plot 182	Raslouw	0,8	37	1427	5,94	1421,06	07/1986	4,92	1422,08	01/1987	
38	E4		Plot 182	Raslouw	1,3	30	1420	5,43	1414,57	07/1986	-	-	-	Synite boulders on surface
39	F5			Brakfontein	?	43	1487	21,48	1465,52	07/1986	21,92	1465,08	01/1987	
40	F5	Rooihuiskraal Museum		Brakfontein	?	?	1486	18,92	1467,08	07/1986	-	-	-	
41	F3			Overkruin	?	?	1468	31,16	1436,84	07/1986	22,23	1445,77	01/1987	
42	E4	Boyazoglu		Raslouw	?	21	1415	14,84	1400,16	07/1986	14,76	1400,24	01/1987	
43	F2			Mona Voni	0,1	?	1480	26,92	1453,08	07/1986	-	-	-	
44	G2	Van der Merwe	Plot 83	Mona Voni	0,6	65	1510	23,40	1486,60	07/1986	23,45	1486,55	01/1987	Quartzite/granite
45	F6		2454	Eldoraigne	?	60	1463	Dry	-	07/1986	-	-	-	0 - 2 m soil, 2 - 20 m dolomite, 20 - 40 m black shale, 40 - 60 m syenite
46	F6	Mannamead Chicken Farm	Plot 31	Simarlo	?	?	1465	65,72	1399,28	07/1986	59,75	1405,25	01/1987	Dolomite outcrop
47	E7		1213	Bronberrik	0,1	160	1437	13,35	1423,65	07/1986	17,53	1419,47	01/1987	Small cavities. 1st seepage water at 18 m. 15 m E of 130 m-deep dry borehole
48	E7		24	Bronberrik	?	45	1434	15,14	1418,86	07/1986	-	-	-	0 - 10m soil, 10 - 15 m soil/dolomite 15 - 31 m jointed dolomite plus 1st water strike, 31 - 40 m jointed dolomite with cavities and chert, 40 - 45 m syenite
49	E6		242	Hennops Park	Very poor	122	1450	36,68	1413,32	07/1986	-	-	-	
50	D7	Zwartkop High School			Very poor	?	1420	35,40	1384,60	07/1986	-	-	-	Open borehole. Pumping borehole 10 m to SE, yield 6,3 l/s, depth 147 m, 1st water at 140 m

Owner	Property	S…
		Olifan…
…rydom	10	Olifan…
		Sunlaw…
		Randji…
…lis	Plot 90	White…
…lis	Plot 90	White…
…ber	Plot 102	Monavo…
…elbrecht, M.	Plot 17	Kloofs…
…Bruin	1183	Lyttle…
…woerdburg High …ool		
…der Merwe, J.J.	Plot 5	Brande…
…diner	Plot 20	Lyttle…
…na, P.R.		Lyttle…
…voerdburg Munic …eyard		
…e		Zwartk…
…e		Zwartk…
…er, H.A.		Raslou…
…dom		Olifan…
		Brakfo…

Borehole No.	Map Grid ref.	Owner	Property	Suburb	Yield (l/s)	Total depth (m)	Collar elevation (mamsl)	Depth to water level (m)	Ground water elevation (mamsl)	Date	Depth to water level (m)	Ground water elevation (mamsl)	Date	Remarks
51	D7		Plot 41	Lyttleton A.H.	1,1	45	1419	33,25	1385,75	07/1986	32,25	1386,75	01/1987	Solid dolomite to 37 m Cavities and water at depth
52	C7	Club Park Town Houses		Lyttleton	?	?	1445	58,50	1386,50	07/1986	-	-	-	
53	C7	Sanderson, C.G.	72	Clubview	0,2	80	1416	30,10	1385,90	07/1986	-	-	-	Dolomite and wad. 1st water at 35 m
54	C6		Plot 222	Clubview	?	?	1405	18,43	1386,57	07/1986	17,52	1387,48	01/1987	
55	D6	Bate, R.C.	305	Clubview	2,5	37	1410	24,31	1385,69	07/1986	23,61	1386,39	01/1987	No solid formation - clay
56	D7		36	Tamara Park	?	?	1404	17,46	1386,54	07/1986	16,69	1387,31	01/1987	
57	D1		384 JR	Hoekplaas	?	?	1385	10,28	1374,72	07/1986	10,48	1374,52	01/1987	Sinkhole + flowing some 40 m E of borehole
58	C1	Hotel Polaris		Mooiplaas	?	?	1365	16,40	1348,60	07/1986	17,70	1347,30	01/1987	
59	C2	Groengoud		Mooiplaas	?	?	1387	21,01	1365,99	07/1986	20,44	1366,56	01/1987	
60	E1	Palala Hatchery	385 JR	Knoppieslaagte	1,0	48	1415	14.63	1400,37	07/1986	-	-	-	Dolomite outcrops in streambed and near borehole.
61	E1				?	?	1440	16,80	1423,20	07/1986	-	-	-	Chert ridge with dolomite outcrops in lower areas
62	F1			Mona Voni A.H.	?	?	1470	24,31	1445,69	07/1986	-	-	-	
63	F1		Plot 21	Mnandi A.H.	0,1	55	1455	18,65	1436,35	07/1986	18,69	1436,31	01/1987	
64	F1	Tulip Nursery	Plot 82	Mnandi A.H.	0,5	58	1470	18,20	1451,80	08/1986	18,48	1451,52	01/1987	0 - 15 m sand, 15 - 58 m granite
65	G2			Mnandi A.H.	?	?	1538	37,18	1500,82	08/1986	38,75	1499,25	01/1987	White quartz vein outcrop
66	H7	Baard, S.P.		Brakfontein	?	?	1512	20,41	1491,59	08/1986	21,62	1490,38	01/1987	Granite
67	H7	Erasmus		Brakfontein	1,3	?	1536	25,70	1510,30	08/1986	25,24	1510,76	01/1987	Granite

Borehole No.	Map Grid ref.	Owner	Property	Suburb	Yield (l/s)	Total depth (m)	Collar elevation (mamsl)	Depth to water level (m)	Ground water elevation (mamsl)	Date	Depth to water level (m)	Ground water elevation (mamsl)	Date	Remarks
108	E9	Noome, H.M.	936	Doringkloof	1,1	88	1440	11,07	1428,93	08/1986	9,86	1430,14	02/1987	
109	E9	De Villiers, D.W.	996	Doringkloof	0,3	120	1445	19,78	1425,22	08/1986	-	-	-	
110	E9	Nienaber, W.L.	27	Doringkloof	1,0	44	1434	27,32	1406,68	08/1986	-	-	-	
111	C9	Henning, N.G.C.	306	Lyttleton Manor	0,1	147	1472	21,26	1450,74	08/1986	20,36	1451,64	02/1987	
112	E9	Gainsford	269	Doringkloof	?	75	1438	40,65	1397,35	08/1986	40,03	1397,97	02/1987	
113	G8				?	?	1464	9,96	1454,04	08/1986	6,59	1457,41	02/1987	
114	G9				?	?	1484	61,41	1422,59	08/1986	61,11	1422,89	02/1987	
115	G10				?	?	1462	29,74	1432,26	08/1986	-	-	-	
116	H10				?	?	1452	5,56	1446,44	08/1986	-	-	-	
117	C9	Keyter	1243	Lyttleton	?	?	1470	79,08	1390,92	08/1986	-	-	-	
118	D11	Van Zyl, J.	184	Pierre van Ryneveld	?	50	1515	20,73	1494,27	08/1986	19,12	1495,88	02/1987	
119	E10	Harrison		Irene	Seepage	130	1460	80,70	1379,30	08/1986	61,94	1398,06	02/1987	Questionable rest water level
120	F10	Des Champs	77	Irene	?	?	1464	43,04	1420,96	08/1986	-	-	-	
121	F9	Trollope	269/2	Irene	?	?	1458	31,51	1426,49	08/1986	30,67	1427,33	02/1987	
122	D9	Smit	512	Lyttleton	?	150	1480	83,67	1396,33	08/1986	88,11	1391,87	02/1987	Water at 112 m
123	D11	De Jager	1790	Pierre van Ryneveld	?	?	1513	15,63	1497,37	08/1986	-	-	-	
124	D9		1881	Lyttleton	?	?	1460	63,13	1396,87	08/1986	-	-	-	
125	E8	Verwoerdburg Munic.		Centurion Park	?	?	1418	14,73	1403,27	09/1986	-	-	-	Abandoned DWA borehole
126	E8	Lochoff	76	Brandenburg A.H.	?	?	1431	32,50	1398,50	09/1986	32,65	1398,35	02/1987	
127	D8	Van Rensburg	89	Brandenburg A.H.	?	?	1432	47,45	1384,55	09/1986	60,82	1371,18	02/1987	
128	J11				?	?	1479	12,30	1466,70	09/1986	11,46	1467,54	02/1987	

Borehole No.	Map Grid ref.	Owner	Property	Suburb	Yield (l/s)	Total depth (m)	Collar elevation (mamsl)	Depth to water level (m)	Ground water elevation (mamsl)	Date	Depth to water level (m)	Ground water elevation (mamsl)	Date	Remarks
130	E8	Taylor, R.D.	1009	Swartkop	Seepage	150	1464	48,20	1415,80	09/1986	-	-	-	0 - 23 m weathered dolomite, 23 - 39 m syenite, 39 - 73 m chert-rich dolomite, 73 - 85 m weathered dolomite, 85 - 99 m decomposed dolomite, 99 - 150 m fresh dolomite. Water from 80 - 100 m
131	E8	Du Plessis, G.	742	Swartkop	0,4	106	1453	38,69	1414,31	09/1986	-	-	-	
132	G8	Kentron		Irene	1,0	150	1477	71,10	1405,90	09/1986	24,04	145[illegible]6	02/1987	Syenite outcrop
133	G8	Kentron			1,0	109	1477	77,49	1399,51	09/1986	-	-	-	
134	G8	Kentron			0,1	95	1482	33,35	1448,65	09/1986	-	-	-	Syenite outcrop
135	G8	Kentron			0,8	46	1445	22,20	1422,80	09/1986	22,27	1422,73	02/1987	
136	H11	Salberg	391 JR	Doringkloof	?	?	1452	10,36	1441,64	09/1986	-	-	-	Drilled into cavity
137	H10	Van Heerden, V.C.			?	?	1454	10,09	1443,91	09/1986	10,21	1443,79	02/1987	Drilled into cavity
138	D9	Stiglingh	586	Lyttleton	1,1	144	1480	95,00	1385,00	09/1986	-	-	-	Water at 138 m. Dry cavity from 22 - 30 m, carbonaceous shale at 81 m, 85 m and 91 m, calcite? at 100 m
139	B2		370	Erasmia	?	?	1420	45,80	1374,20	09/1986	46,16	1373,84	02/1987	
140	C2	Dippenaar		Erasmia	?	45	1387	20,46	1366,54	09/1986	16,00	1371,00	02/1987	
141	C2			Erasmia	?	?	1380	12,90	1367,10	09/1986	12,55	1367,45	02/1987	
142	B4	TPA		Swartkop	?	?	1449	73,86	1375,14	09/1986	74,11	1374,89	02/1987	
143	B5			Valhalla	?	105	1466	90,03	1375,97	09/1986	89,55	1376,45	02/1987	
144	B5			Valhalla	?	?	1432	48,08	1383,92	09/1986	47,19	1384,81	02/1987	
145	C5			Valhalla	?	?	1418	34,60	1383,40	09/1986	33,60	1384,40	02/1987	

Borehole No.	Map Grid ref.	Owner	Property	Suburb	Yield (l/s)	Total depth (m)	Collar elevation (mamsl)	Depth to water level (m)	Ground water elevation (mamsl)	Date	Depth to water level (m)	Ground water elevation (mamsl)	Date	Remarks
146	C5			Monrick	?	?	1400	16,07	1383,93	09/1986	15,33	1384,67	02/1987	
147	C6			Valhalla	?	100	1408	23,45	1384,55	09/1986	-	-	-	
148	C7			Clubview	?	?	1403	19,29	1383,71	09/1986	19,54	1383,46	02/1987	
149	B10			Monument Park	?	100	1463	88,10	1374,90	09/1986	87,68	1375,32	02/1987	
150	G12		391 JR	Doornkloof	?	?	1489	34,45	1454,55	09/1986	23,18	1465,82	02/1987	
151	H13	Larson			?	?	1542	58,02	1483,98	09/1986	55,72	1486,28	02/1987	
152	B6	SADF		Valhalla	?	?	1445	61,76	1383,24	09/1986	61,23	1383,77	02/1987	
153	A5	SADF		Voortrekkerhoogte	?	?	1465	88,54	1376,46	09/1986	88,46	1376,54	02/1987	
154	B8	SADF		Kloofsig	?	125	1457	73,79	1383,21	09/1986	-	-	-	
155														
156	H11	SAMANCOR	391 JR	Doornkloof	?	85	1469	10,90	1458,57	09/1986	1,25	1467,75	02/1987	
157	G11	SAMANCOR			?	159	1465	29,59	1435,01	09/1986	-	-	-	
158	G11	SAMANCOR			?	163	1457	27,10	1429,56	09/1986	26,90	1430,10	02/1987	
159	H11	SAMANCOR			?	72	1486	36,72	1449,69	09/1986	-	-	-	
160	H11	SAMANCOR			?	108	1495	47,82	1446,93	09/1986	-	-	-	
161	H11	SAMANCOR			?	149	1495	55,20	1439,92	09/1986	-	-	-	
162	D9	Van Vuuren	1908	Lyttleton	?	61	1465	16,00	1449,00	09/1986	-	-	-	Not measured. Owner's information
163	D9	Myburgh, J.L.	393	Lyttleton	Seepage	± 70	1478	40,40	1437,60	09/1986	-	-	-	Syenite (Pta dyke?)
L-21	J11	PCC			?	?	1483	2,70	1480,30	09/1986	-	-	-	DWA exploration borehole G37330
L-22	J11						1494	6,61	1487,39	09/1986	6,35	1487,65	02/1987	
L-23	J9						1486	11,14	1474,86	09/1986	10,76	1475,24	02/1987	

Borehole No.	Map Grid ref.	Owner	Property	Suburb	Yield (l/s)	Total depth (m)	Collar elevation (mamsl)	Depth to water level (m)	Ground water elevation (mamsl)	Date	Depth to water level (m)	Ground water elevation (mamsl)	Date	Remarks
L-24	J11						1505	16,92	1488,08	09/1986	16,65	1488,35	02/1987	
L-7	J13													
L-2	I13	Frolhand					1523	37,18	1485,82	09/1986	36,55	1486,45	02/1987	
GF-8	A9	PCC		Groenkloof Plantation			1399	10,46	1388,54	09/1986	24,53	1374,47	02/1987	SRK exploration bore
GF-4	A9	PCC		Groenkloof Plantation			1411	35,55	1375,45	09/1986	34,93	1376,07	02/1987	SRK exploration bore
GF-7	A9	PCC		Groenkloof Plantation			1425	49,39	1375,61	09/1986	49,18	1375,82	02/1987	SRK exploration bore
GF-1	A8	PCC					1420	44,44	1375,56	09/1986	44,38	1375,62	02/1987	SRK exploration bore
EA-1	B3			Erasmia			1410	34,59	1375,41	09/1986	33,59	1376,41	02/1987	SRK exploration bore
ZP-14B	C3			Klipfontein			1379	6,17	1372,83	09/1986	5,65	1373,35	02/1987	SRK exploration bore
VA-3	B5			Valhalla			1417	33,95	1383,05	09/1986	33,33	1383,67	02/1987	SRK exploration bore
AG-2	A4						1439	62,06	1376,94	09/1986	60,95	1378,05	02/1987	SRK exploration bore
ZP-12A	C7	SADF		Snake Valley			1433	50,14	1382,86	09/1986	49,52	1383,48	02/1987	SRK exploration bore
ZP-13	C7	SADF		Snake Valley			1434	50,65	1383,35	09/1986	-	-	-	SRK exploration bore
G36069	B6			Valhalla			1434	58,10	1375,90	09/1986	57,86	1376,14	02/1987	SRK exploration bore

APPENDIX 5.1

CHEMICAL WATER ANALYSIS DATA

Concentrations expressed in mg/l

pjh/hk/1188K/0734A

Borehole No.	Grid ref. co-ord	Sample H. No.	Date	Latitude	Longitude	E.C. mS/m	pH	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO_3 mg/l	Cl mg/l	SO_4 mg/l	NO_3 mg/l	F mg/l	Si mg/l	TDS mg/l
1	H4	86404208	08/10/86	25°54'15"	28°07'35"	13,0	7,2	5	2	11	0,7	44	2	4	2,35	0,1	25,3	104
2	G4	-4193	08/10/86	25°53'55"	28°07'29"	18,4	6,9	11	4	17	1,1	76	2	3	3,86	0,1	22,0	154
3-C	H5	-4240	08/10/86	25°54'26"	28°08'33"	20,2	7,3	17	4	15	1,2	101	1	4	0,95	0,2	22,2	170
4	G4	-4216	08/10/86	25°53'27"	28°07'55"	12,5	7,1	5	2	12	1,3	46	4	3	2,14	0,1	28,9	113
7	G6	-3553	29/09/86	25°53'50"	28°09'03"	14,7	6,8	12	3	14	1,5	71	1	3	1,99	0,1	27,2	141
8	G6	-4509	13/10/86	25°53'32"	28°09'14"	14,6	6,8	9	4	12	3,0	57	2	2	3,92	0,1	25,7	132
9	G6	-3545	29/09/86	25°53'59"	28°09'30"	10,7	6,6	6	2	9	3,3	37	2	2	4,05	0,1	26,2	106
11-C	G6	-4224	08/10/86	25°53'16"	28°09'04"	12,7	7,0	7	3	10	1,6	52	2	3	2,12	0,1	25,2	114
12	F6	-4232	08/10/86	25°52'57"	28°09'39"	41,2	7,7	28	23	21	1,7	207	14	8	0,05	0,7	9,2	313
13	G6	-3537	29/09/86	25°35'28"	28°09'40"	17,8	7,0	16	6	11	1,8	96	2	3	0,40	0,2	26,0	163
14-C	E5	-3969	02/10/86	25°52'00"	28°08'21"	35,2	7,9	17	10	44	1,0	176	14	5	0,02	2,1	9,1	278
15	E5	-3888	01/10/86	25°51'48"	28°08'54"	59,5	7,9	49	41	9	2,7	280	15	41	0,00	0,3	7,7	447
17	E5	-3870	01/10/86	25°51'23"	28°08'16"	70,0	7,8	60	53	7	2,8	338	16	61	0,04	0,2	6,6	545
18	D5	-3862	01/10/86	25°50'55"	28°08'33"	71,0	7,7	72	42	11	1,8	340	17	29	7,65	0,3	10,6	557
19	E6	-3951	02/10/86	25°51'13"	28°09'04"	67,0	7,7	70	42	7	2,2	330	11	26	6,59	0,2	7,7	526
20	D6	-3757	30/09/86	25°50'46"	28°09'36"	13,7	7,2	11	6	6	1,8	62	3	5	0,01	0,1	20,5	115
21	D6	-3731	30/09/86	25°50'26"	28°09'06"	21,7	7,4	21	6	9	2,3	100	6	3	2,31	0,1	24,2	183
22	E5	-3854	01/10/86	25°51'00"	28°08'38"	70,0	7,9	72	44	11	4,5	345	18	47	0,01	0,4	8,8	551
23	D5	-3749	30/09/86	25°50'02"	28°08'54"	69,0	7,7	53	35	25	1,1	258	57	36	3,04	0,1	12,7	492
24	E6	-3977	06/10/86	25°51'25"	28°09'37"	60,4	7,6	62	35	6	2,7	324	3	16	2,65	0,3	10,4	472
27	D4	-3715	30/09/86	25°50'13"	28°07'20"	70,0	7,7	59	39	19	1,4	287	48	31	2,83	0,2	11,4	507
28	D4	-4038	07/10/86	25°50'40"	28°07'13"	68,0	8,0	74	43	7	1,2	356	13	19	4,87	0,2	11,4	546
29	C3	-3692	30/09/86	25°49'42"	28°06'44"	71,0	7,7	61	39	16	1,1	287	39	29	3,08	0,2	12,1	497
30	D3	-4062	07/10/86	25°50'44"	28°06'22"	58,8	7,7	48	39	12	1,8	290	9	8	6,54	0,2	25,6	463
31	D3	-3707	30/09/86	25°50'05"	28°06'45"	72,0	7,8	69	40	16	1,3	305	34	27	4,00	0,1	12,0	522
32	D5	-4054	07/10/86	25°50'40"	28°08'03"	56,6	7,7	58	33	7	0,7	277	8	27	2,45	0,2	8,5	430
33	E4	-4020	07/10/86	25°51'22"	28°07'32"	49,2	7,6	52	29	4	0,8	257	5	13	1,37	0,2	7,2	372
35-C	E2	-4070	07/10/86	25°51'20"	28°05'56"	56,3	7,7	58	32	9	1,4	308	6	6	3,44	0,2	14,8	451
36-C	E3	-4012	06/10/86	25°51'34"	28°06'40"	59,5	7,7	60	36	9	4,6	332	3	15	0,24	0,2	11,8	473
38	E4	-3993	06/10/86	25°51'50"	28°07'52"	41,6	7,5	45	23	6	0,6	222	3	7	1,18	0,2	13,8	326
39	F5	-4185	08/10/86	25°52'44"	28°08'16"	24,6	6,1	13	4	22	4,4	54	16	4	9,43	0,1	27,0	186
41	F3	-4169	08/10/86	25°52'54"	28°06'30"	41,2	7,6	41	23	7	1,1	224	2	2	3,10	0,1	19,0	334
42	E4	-4004	06/10/86	25°51'56"	28°07'08"	59,5	7,6	54	40	10	2,2	309	5	30	0,70	0,2	10,2	463
43	F2	-4135	08/10/86	25°52'34"	28°05'36"	30,7	7,7	33	12	9	1.9	168	2	4	0,05	0,1	11,4	241
44	G2	-4143	08/10/86	25°53'06"	28°05'35"	7,8	6,7	2	1	8	2,3	35	0	2	0,10	0,1	25,7	77
46	F6	-3927	02/10/86	25°52'17"	28°09'34"	141,0	7,6	163	102	19	7,9	273	6	634	0,04	0,4	6,3	1211
48	E7	-3935	02/10/86	25°51'23"	28°10'01"	66,0	7,6	70	39	7	1,6	321	15	20	5,54	0,3	11,9	510
49	E6	-3943	02/10/86	25°51'51"	28°09'51"	57,2	7,6	58	35	7	3,3	304	4	23	0,03	0,3	7,8	441
50	D7	-3901	01/10/86	25°50'52"	28°10'05"	51,2	7,7	40	30	18	3,6	238	26	17	0,06	0,8	11,0	385
51	D7	-4525	14/10/86	25°50'42"	28°10'50"	80,0	7,7	58	36	58	1,4	290	65	52	2,08	0,1	11,5	584
52	C7	-3838	01/10/86	25°49'51"	28°10'54"	77,0	7,7	65	40	31	1,2	277	64	46	4,33	0,1	12,2	555
53	C7	-3846	01/10/86	25°49'58"	28°10'26"	74,0	7,7	62	39	29	1,4	282	62	38	3,23	0,1	11,1	539
54	C6	-4517	14/10/86	25°49'26"	28°09'52"	76,0	7,5	64	38	45	1,3	279	64	57	1,25	0,1	13,7	567
55	D6	-4101	01/10/86	25°50'04"	28°09'44"	56,9	7,4	47	30	18	1,1	200	39	16	8,30	0,1	13,2	403

PJH/HK/1188K/0734A

Borehole No.	Grid ref. co-ord	Sample H. No.	Date	Latitude	Longitude	E.C. mS/m	pH	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO_3 mg/l	Cl mg/l	SO_4 mg/l	NO_3 mg/l	F mg/l	Si mg/l	TDS mg/l
56	D7	86403896	01/10/86	25°50'15"	28°10'05"	78,0	7,3	61	38	45	1,3	261	79	56	2,36	0,1	11,1	565
57	D1	-3676	29/09/86	25°50'01"	28°04'15"	49,9	7,7	51	30	3	0,8	269	3	6	3,41	0,1	10,5	390
58	C1	-3668	29/09/86	25°49'22"	28°04'22"	77,0	7,7	56	32	51	3,9	245	58	73	5,98	0,2	8,2	553
59	C2	-3684	30/09/86	25°49'51"	28°05'41"	64,0	7,7	63	41	9	0,9	335	15	14	7,08	0,1	13,0	522
60	E1	-4127	08/10/86	25°51'44"	28°03'59"	60.1	7,5	61	34	11	1,7	296	19	9	2,47	0,1	12,4	457
61-C	E1	-4119	08/10/86	25°51'36"	28°04'39"	45,4	7,5	38	29	15	2,6	255	3	8	0,01	0,3	9,8	361
62	F1	-4088	07/10/86	25°52'22"	28°04'59"	26,8	7,4	24	10	13	4,5	144	2	4	0,85	0,2	20,3	224
63	F1	-4096	07/10/86	25°52'33"	28°04'17"	28,1	7,4	18	12	19	3,3	141	4	4	1,00	0,1	25,1	232
65	G2	-4151	08/10/86	25°53'30"	28°05'12"	12,0	7,0	7	2	11	2,7	60	1	2	0,12	0,2	25,2	112
66	H7	-4452	13/10/86	25°54'08"	28°10'27"	28,1	7,4	20	8	17	1,7	74	26	8	5,07	0,1	21,9	200
67	H7	-4478	13/10/86	25°54'33"	28°10'43"	11,6	6,3	8	2	10	1,4	57	1	2	0,98	0,1	26,1	112
68	H8	-4486	13/10/86	25°54'42"	28°11'32"	48,0	7,5	50	27	8	0,9	220	6	6	7,81	0,1	16,7	368
72	G3	-4672	15/10/86	25°53'40"	28°06'23"	13,6	6,8	6	3	17	1,1	61	2	2	2,43	0,1	29,3	132
74	G3	-4177	08/10/86	25°53'21"	28°06'19"	59,2	7,2	55	15	27	2,2	131	36	8	23,63	0,1	19,1	397
75	B9	-3773	01/10/86	25°48'33"	28°12'29"	Laboratory analysis not received												
76	B9	-3781	01/10/86	25°48'51"	28°12'13"	34,5	7,8	27	24	5	0,6	193	1	8	0,12	0,1	8,6	268
77	C8	-3799	01/10/86	25°49'38"	28°11'54"	Laboratory analysis not received												
78	C8	-3804	01/10/86	25°49'48"	28°11'32"	54,4	7,7	53	35	5	0,7	306	2	19	0,01	0,2	6,7	427
79	D7	-3820	01/10/86	25°50'18"	28°10'51"	84,0	7,6	71	44	28	1,3	283	80	35	7,97	0,1	11,6	587
80	D8	-3812	01/10/86	25°50'45"	28°11'40"	78,0	7,6	63	39	34	1,3	267	64	52	5,32	0,1	12,2	557
81	E7	-3919	01/10/86	25°51'42"	28°10'18"	64,0	7,7	70	39	7	1,8	348	7	11	6,56	0,3	12,6	526
83	D5	-4046	07/10/86	25°50'28"	28°08'07"	70,0	7,5	66	38	22	1,4	273	55	29	2,45	0,1	12,8	508
85	I10	-4606	14/10/86	25°55'26"	28°13'20"	96,0	7,4	65	39	75	2,6	254	98	82	11,08	0,1	10,1	675
86	G7	-4460	13/10/86	25°53'07"	28°10'33"	57,2	7,5	56	31	13	0,5	305	7	10	2,59	0,2	16,5	450
87	F7	-4711	15/10/86	25°52'27"	28°10'55"	60,1	7,6	66	36	6	0,6	323	6	8	3,77	0,1	11,4	474
88	I8	-4494	13/10/86	25°55'19"	28°11'21"	10,2	6,9	6	3	7	2,5	45	1	2	1,68	0,1	20,8	95
89	I10	-4698	15/10/86	25°55'11"	28°13'53"	64,0	7,4	47	35	24	1,2	237	31	28	7,38	0,1	10,2	447
90	I10	-4680	15/10/86	25°55'29"	28°13'59"	71,0	7,7	67	40	16	1,3	249	36	30	15,37	0,1	10,6	518
95	I10	-4614	14/10/86	25°55'33"	28°13'13"	106,0	7,9	51	30	121	8,6	283	120	98	6,95	0,2	9,1	754
97	J9	-4622	14/10/86	25°56'15"	28°12'25"	88,0	7,5	62	36	72	2,4	288	72	79	2,56	0,5	12,8	648
99	F10	-4428	13/10/86	25°52'34"	28°13'24"	50,5	7,5	47	30	8	0,6	212	16	14	6,81	0,1	7,4	364
100	G10	-4567	14/10/86	25°53'07"	28°13'46"	74,0	7,6	58	38	45	0,6	274	43	86	0,11	0,1	10,4	556
102	C8	-4266	08/10/86	25°49'14"	28°12'01"	46,7	7,7	38	33	3	0,5	233	10	12	2,29	0,1	5,8	346
104	E9	-4541	14/10/86	25°51'05"	28°12'59"	63,0	7,4	56	36	13	0,4	278	16	18	7,29	0,1	9,1	459
105	E9	-4305	09/10/86	25°51'01"	28°12'27"	80,0	7,6	67	47	24	0,9	267	30	127	4,23	0,2	12,5	595
107	E9	-4321	09/10/86	25°51'41"	28°12'02"	76,0	7,6	56	37	38	0,9	245	65	58	5,41	0,1	12,1	535
108	E9	-4339	09/10/86	25°51'32"	28°12'39"	55,3	7,5	50	32	8	0,6	238	20	20	4,54	0,2	15,4	403
111	C9	-4274	08/10/86	25°49'43"	28°12'25"	68,0	7,7	60	39	19	0,8	291	25	20	10,89	0,2	21,1	525
112	E9	-4313	09/10/86	25°51'24"	28°12'19"	114,0	7,5	104	70	32	1,2	267	46	317	7,26	0,1	12,9	881
113	G8	-4703	15/10/86	25°53'56"	28°11'43"	56,3	7,7	59	33	11	1,1	326	3	6	0,97	0,2	13,4	458
115	G10	86404591	14/10/86	25°53'46"	28°13'22"	78,0	7,6	62	36	51	1,4	273	67	53	3,82	0,1	11,2	573
117	C9	-4282	09/10/86	25°49'19"	28°12'29"	34,5	7,7	26	24	4	0,4	188	1	9	0,46	0,1	7,6	262
118	D11	-4371	13/10/86	25°50'47"	28°14'53"	6,7	6,8	6	4	1	0,4	37	0	4	0,02	0,1	6,5	59
119	E10	-4347	09/10/86	25°51'40"	28°13'10"	55,3	7,7	50	38	3	0,5	298	3	15	0,10	0,2	5,8	413

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Borehole No.	Grid ref. co-ord	Sample H. No.	Date	Latitude	Longitude	E.C. mS/m	pH	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO_3 mg/l	Cl mg/l	SO_4 mg/l	NO_3 mg/l	F mg/l	Si mg/l	TDS mg/l
121	F9	-4355	09/10/86	25°52'08"	28°12'55"	62,0	7,7	58	41	6	0,7	307	9	37	0,02	0,2	5,5	466
122	D9	-4258	08/10/86	25°50'08"	28°12'46"	51,2	7,9	41	38	6	0,5	269	6	14	2,20	0,1	6,5	392
124	D9	-4290	09/10/86	25°50'36"	28°12'48"	44,1	7,7	36	32	4	0,4	249	1	9	0,02	0,2	5,4	336
125	E8	-4410	13/10/86	25°51'31"	28°11'41"	63,0	7,5	54	36	16	0,9	262	38	19	3,55	0,2	11,8	454
126	E8	-4402	13/10/86	25°51'10"	28°11'40"	74,0	7,6	63	42	22	1,1	252	77	35	2,26	0,1	11,2	514
127	D8	-4397	13/10/86	25°50'37"	28°11'05"	39,0	7,6	32	26	5	0,7	213	7	4	0,45	0,2	8,3	300
128	I11	-4648	14/10/86	25°56'00"	28°14'47"	46,0	7,7	46	28	4	0,8	213	7	16	3,85	0,1	8,4	341
131	E8	-4559	14/10/86	25°51'45"	28°11'02"	49,6	7,7	31	26	41	2,8	293	2	6	0,23	0,2	13,8	417
132	G8	-4436	13/10/86	25°53'23"	28°11'11"	60,8	7,7	54	41	11	2,0	311	8	30	0,94	0,3	13,3	476
135	G8	-4444	13/10/86	25°53'06"	28°11'54"	49,9	7,5	47	30	6	0,6	239	12	12	2,98	0,2	10,5	371
136	H10	-4575	14/10/86	25°54'23"	28°14'01"	44,8	7,4	45	28	4	0,3	244	3	7	2,14	0,1	7,0	348
137	H10	-4583	14/10/86	25°54'38"	28°14'00"	144,0	7,7	59	63	72	39,3	683	154	12	0,92	0,1	4,7	1140
138	D9	-4533	14/10/86	25°50'27"	28°12'23"	60,8	7,5	59	37	6	0,8	318	10	7	3,68	0,1	14,0	469
139	B2	-3650	29/09/86	25°48'29"	28°05'38"	68,0	7,7	67	44	9	0,7	334	17	13	8,18	0,2	6,8	527
140	C2	-3642	29/09/86	25°49'04"	28°05'13"	60,1	7,8	60	36	7	0,6	291	14	10	6,68	0,1	9,9	459
141	C2	-3634	29/09/86	25°49'13"	28°05'45"	44,1	7,5	36	27	2	0,5	221	7	8	3,18	0,0	6,6	323
142	B4	-3626	29/09/86	25°48'29"	28°07'19"	40,9	7,6	37	25	3	0,5	230	3	6	0,79	0,1	4,7	313
143	B5	-3600	29/09/86	25°48'02"	28°08'08"	36,4	7,8	38	22	1	0,3	171	7	3	5,96	0,0	6,1	275
144	B5	-3595	29/09/86	25°48'38"	28°08'29"	51,8	7,7	48	32	5	0,7	248	17	8	3,73	0,0	6,9	382
145	C5	-3587	29/09/86	25°49'04"	28°08'50"	55,0	7,6	50	30	10	0,6	228	31	15	4,30	0,1	9,1	392
146	C5	-3723	30/09/86	25°49'27"	28°08'35"	67,0	7,6	55	35	25	1,2	254	53	35	3,23	0,1	11,0	482
147	C6	-3579	29/09/86	25°49'20"	28°09'12"	59,5	7,7	57	32	19	1,1	263	34	27	0,04	0,1	8,5	442
148	C7	-3561	29/09/86	25°49'31"	28°10'04"	67,0	7,6	60	38	19	1,3	260	44	33	2,09	0,1	10,8	475
149	B10	-3765	01/10/86	25°48'21"	28°13'19"	26,2	7,6	24	15	1	0,5	141	3	3	1,10	0,0	6,5	200
150	G12	86404363	09/10/86	25°53'06"	28°15'36"	5,7	6,6	4	4	1	0,3	28	0	4	0,02	0,1	4,6	47
151-C	H12	-4664	14/10/86	25°53'08"	28°15'44"	10,2	6,7	5	6	4	1,2	54	0	2	0,16	0,1	4,3	77
152	B6	-3618	29/09/86	25°48'33"	28°09'31"	62,0	7,6	57	35	12	0,9	249	2	14	13,45	0,1	8,4	455
162	D9	-4389	13/10/86	25°50'41"	28°12'41"	62,0	7,4	57	35	11	0,6	274	16	11	9,38	0,2	10,2	457
C1	J9	-2971	17/09/86	25°56'29"	28°11'34"	18,8	7,4	13	6	14	0,7	96	1	4	1,02	0,1	25,3	166
C2	J9	-3008	17/09/86	25°56'03"	28°12'27"	38,0	7,6	30	21	10	1,1	173	9	10	5,00	0,1	17,8	292
C4	I11	-2997	17/09/86	25°55'41"	28°14'25"	49,2	7,7	44	31	5	0,8	243	10	15	3,34	0,1	9,3	373
C5	I10	-3016	17/09/86	25°55'49"	28°13'53"	56,9	7,7	52	34	6	0,7	267	18	10	6,40	0,0	9,9	427
C6	J11	-2989	17/09/86	25°56'19"	28°14'14"	56,6	7,7	48	32	11	0,9	230	24	42	3,05	0,1	9,7	412
C7	J9	-3121	18/09/86	25°56'41"	28°12'19"	49,2	7,7	46	27	8	1,8	188	35	6	7,06	0,0	19,9	363
C8	K8	-3113	18/09/86	25°57'14"	28°11'29"	15,2	6,7	9	3	13	1,9	59	6	4	1,99	0,0	25,8	131
C9	J10	-3074	18/09/86	25°57'00"	28°13'01"	51,8	7,8	47	33	7	1,2	282	6	6	1,64	0,0	11,6	400
C15	I12	-3139	18/09/86	25°55'12"	28°15'59"	31,8	7,7	30	20	3	0,6	173	3	5	0,94	0,0	7,5	248
C16	I12	-3024	17/09/86	25°55'56"	28°15'14"	34,5	7,8	27	23	4	0,4	200	1	4	0,32	0,1	12,7	275
C17	I12	-3147	18/09/86	25°56'01"	28°15'59"	8,0	6,4	2	4	5	0,3	38	1	4	0,06	0,0	6,0	62

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APPENDIX 5.2

CHEMICAL WATER ANALYSIS DATA

Ionic percentages and other analytical parameters

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Borehole No.	Piper and expanded Durov percentages						% Error on analysis	Total hardness mg/l $CaCO_3$	Aggressive index	LSI	Corrosion tendency ratio	SAR	Ca/Mg ratio
	Cations			Anions									
	Ca	Mg	Na+K	HCO_3	$Cl+NO_3+F$	SO_4							
1	27,4	18,1	54,5	79,7	11,0	9,2	0,5	21	9,9	-2,00	0,19	1,1	1,5
2	33,4	20,0	46,6	86,9	8,7	4,4	7,2	44	10,1	-1,77	0,10	1,1	1,7
3-C	45,6	17,7	36,7	92,4	3,0	4,6	1,8	59	10,8	-1,06	0,07	0,9	2,6
4	25,7	17,0	57,3	77,9	15,7	6,4	0,3	21	9,8	-2,09	0,23	1,1	1,5
7	40,1	16,5	43,4	90,1	5,1	4,9	7,4	42	10,0	-1,85	0,08	0,9	2,4
8	32,6	23,9	43,5	84,9	11,3	3,8	10,9	39	9,8	-2,06	0,10	0,8	1,4
9	31,9	17,5	50,6	78,0	16,5	5,4	10,1	23	9,3	-2,61	0,16	0,8	1,8
11-C	32,6	23,0	44,4	84,4	9,4	6,1	2,6	30	9,9	-1,99	0,14	0,8	1,4
12	32,9	44,6	22,5	85,0	10,8	4,2	3,0	164	11,8	-0,21	0,17	0,7	0,7
13	44,0	27,2	28,9	92,1	4,3	3,6	2,9	65	10,5	-1,41	0,08	0,6	1,6
14-C	23,5	22,8	53,7	82,5	14,5	3,0	1,7	84	11,7	-0,28	0,17	2,1	1,0
15	38,9	53,7	7,3	78,0	7,5	14,5	3,2	291	12,3	0,32	0,28	0,2	0,7
17	38,7	56,4	4,9	76,1	6,4	17,5	3,1	368	12,4	0,37	0,31	0,2	0,7
18	47,4	45,6	6,9	82,0	9,1	8,9	5,4	352	12,4	0,35	0,19	0,3	1,0
19	47,8	47,3	4,9	84,8	6,7	8,5	6,8	347	12,4	0,33	0,16	0,2	1,0
20	40,7	36,6	22,8	84,0	7,4	8,6	5,3	52	10,3	-1,52	0,19	0,4	1,1
21	52,6	24,8	22,6	85,7	11,1	3,3	2,0	77	11,0	-0,89	0,14	0,4	2,1
22	46,0	46,4	7,6	79,0	7,4	13,7	4,3	361	12,6	0,56	0,26	0,3	1,0
23	39,8	43,4	16,8	63,7	25,0	11,3	0,1	276	12,1	0,11	0,56	0,7	0,9
24	49,1	45,7	5,2	91,8	2,5	5,8	4,2	299	12,2	0,18	0,08	0,2	1,1
27	42,0	45,7	12,3	69,6	20,9	9,6	1,9	308	12,2	0,20	0,43	0,5	0,9
28	48,8	46,8	4,4	87,3	6,8	5,9	6,2	361	12,7	0,68	0,13	0,2	1,0
29	43,6	46,0	10,4	72,7	18,0	9,3	3,8	313	12,3	0,22	0,36	0,4	0,9
30	38,8	52,0	9,2	89,9	7,0	3,1	7,7	280	12,2	0,13	0,09	0,3	0,7
31	46,1	44,1	9,8	75,8	15,6	8,5	6,2	337	12,4	0,39	0,30	0,4	1,0
32	48,8	45,8	5,4	84,4	5,1	10,5	4,9	280	12,2	0,20	0,17	0,2	1,1
33	50,1	46,1	3,8	90,5	3,7	5,8	5,2	249	12,1	0,13	0,10	0,1	1,1
35-C	48,6	44,2	7,2	93,3	4,3	2,3	4,7	276	12,3	0,24	0,06	0,2	1,1
36-C	46,3	45,8	7,9	93,0	1,7	5,3	5,0	298	12,3	0,28	0,07	0,2	1,0
38	50,9	42,9	6,3	93,3	2,9	3,7	6,2	207	11,8	-0,18	0,06	0,2	1,2
39	31,7	16,1	52,2	56,0	38,7	5,3	13,2	49	9,3	-2,67	0,61	1,4	2,0
41	47,9	44,3	7,8	96,0	2,9	1,1	5,4	197	11,9	-0,11	0,03	0,2	1,1
42	41,6	50,8	7,6	86,5	2,8	10,7	5,1	299	21,1	0,10	0,15	0,3	0,8
43	53,6	32,1	14,3	95,0	2,2	2,9	2,9	132	11,8	-0,20	0,05	0,3	1,7
44	16,9	14,0	69,1	92,3	1,1	6,6	3,2	9	8,9	-2,96	0,07	1,2	1,2

Bore-hole no.	Piper and expanded Durov percentages						% Error on analysis	Total hard-ness mg/l $CaCO_3$	Aggre-sive index	LSI	Corro-sion tendency ratio	SAR	Ca/Mg Ratio
	Cations			Anions									
	Ca	Mg	Na+K	HCO_3	$Cl+NO_3+F$	SO_4							
46	46,3	47,8	5,9	25,1	1,1	73,9	0,9	826	12,6	0,41	2,98	0,3	1,0
48	49,6	45,5	4,9	84,8	8,5	6,7	6,4	335	12,3	0,22	0,16	0,2	1,1
49	47,0	46,7	6,3	89,1	2,3	8,6	4,9	289	12,2	0,13	0,12	0,2	1,0
50	37,4	46,2	16,4	77,5	15,4	7,0	3,0	223	12,0	-0,02	0,28	0,5	0,8
51	34,4	35,2	30,4	61,7	24,3	14,0	4,4	293	12,2	0,18	0,61	1,5	1,0
52	41,0	41,6	17,4	61,5	25,5	13,0	3,5	327	12,3	0,22	0,61	0,7	1,0
53	40,7	42,2	17,1	64,0	25,0	11,0	2,6	315	12,3	0,21	0,55	0,7	1,0
54	38,4	37,6	24,0	60,3	24,1	15,6	4,5	316	12,1	0,01	0,65	1,1	1,0
55	41,7	43,9	14,4	67,6	25,6	6,9	7,4	241	11,7	-0,33	0,44	0,5	1,0
56	37,3	38,3	24,4	55,4	29,5	15,1	2,8	308	11,8	-0,24	0,79	1,1	1,0
57	49,3	47,8	2,9	94,2	3,1	2,7	4,8	251	12,1	0,14	0,05	0,1	1,0
58	36,1	34,0	29,9	55,2	23,9	20,9	3,1	271	12,1	0,10	0,79	1,3	1,1
59	45,4	48,7	6,0	86,8	8,6	4,6	4,5	326	12,3	0,29	0,13	0,2	0,9
60	47,8	44,0	8,2	86,3	10,3	3,3	6,2	292	12,1	0,04	0,15	0,3	1,1
61-C	37,9	47,7	14,4	94,0	2,3	3,7	5,9	214	11,8	-0,20	0,06	0,4	0,8
62	44,3	30,4	25,2	93,5	3,2	3,3	3,4	101	11,2	-0,69	0,06	0,6	1,5
63	32,1	35,3	32,6	91,2	5,5	3,3	4,8	94	11,1	-0,83	0,08	0,9	0,9
65	32,9	15,5	51,6	92,7	3,4	3,9	0,2	26	9,9	-1,93	0,07	0,9	2,1
66	40,9	27,0	32,1	55,3	37,2	7,6	5,0	83	10,9	-1,05	0,74	0,8	1,5
67	38,6	15,9	45,5	91,2	4,8	4,0	0,2	28	9,3	-2,59	0,07	0,8	2,4
68	49,0	43,7	7,3	89,4	7,5	3,1	11,7	236	11,9	0,15	0,08	0,2	1,1
72	22,8	18,8	58,4	87,5	8,8	3,6	7,0	27	9,7	-2,21	0,10	1,4	1,2
74	52,7	23,7	23,6	57,7	37,8	4,5	16,9	199	11,4	-0,64	0,55	0,8	2,2
75	No laboratory analysis received for this sample												
76	37,9	55,5	6,6	94,0	1,1	5,0	2,8	166	11,8	-0,14	0,06	0,2	0,7
77	No laboratory analysis received for this sample												
78	45,9	50,0	4,1	91,6	1,2	7,2	2,5	276	12,2	0,20	0,09	1,0	0,9
79	42,1	43,0	14,9	59,8	30,8	9,4	4,1	358	12,2	0,16	0,64	0,6	1,0
80	40,0	40,8	19,2	59,5	25,8	14,7	3,3	318	12,1	0,09	0,66	0,8	1,0
81	49,5	45,5	5,0	91,2	5,1	3,7	6,1	335	12,4	0,35	0,07	0,2	1,1
83	44,4	42,2	13,4	67,0	23,9	9,0	5,2	321	12,1	0,03	0,48	0,5	1,1
85	33,2	32,8	34,0	47,2	33,5	19,4	5,2	323	11,9	-0,15	1,07	1,8	1,0
86	47,2	43,1	9,8	91,6	4,6	3,8	4,1	267	12,0	0,02	0,08	0,3	1,1
87	50,4	45,3	4,2	92,9	4,1	2,9	6,8	313	12,2	0,21	0,06	0,1	1,1
88	32,7	27,0	40,3	87,9	7,2	4,9	4,2	27	9,6	-2,20	0,09	0,6	1,2
89	37,2	45,7	17,1	71,0	18,3	10,7	7,1	261	11,8	-0,27	0,38	0,6	0,8
90	45,4	44,7	9,9	68,3	21,3	10,5	10,4	332	12,2	0,19	0,40	0,4	1,0
95	24,2	23,5	52,2	45,5	34,4	20,0	1,5	251	12,4	0,28	1,17	3,3	1,0
97	33,5	32,0	34,5	55,7	24,8	19,4	4,5	303	12,1	-0,01	0,78	1,8	1,0
99	45,3	47,7	7,0	80,2	13,1	6,7	8,8	241	11,8	-0,19	0,21	0,2	1,0
100	36,2	39,1	24,7	59,9	16,3	23,9	3,1	301	12,1	0,06	0,67	1,1	0,9
102	39,9	57,1	3,0	86,9	7,4	5,7	4,0	231	12,0	-0,04	0,14	0,1	0,7
104	44,1	46,8	9,1	82,8	10,4	6,8	7,0	288	11,9	-0,12	0,18	0,3	0,9
105	40,4	46,7	12,9	55,1	11,6	33,3	2,0	360	12,2	0,10	0,80	0,5	0,9

Bore-hole no.	Piper and expanded Durov percentages: Cations			Anions			% Error on analysis	Total hard-ness mg/l $CaCO_3$	Aggre-sive index	LSI	Corro-sion tendency ratio	SAR	Ca/Mg Ratio
	Ca	Mg	Na+K	HCO_3	$Cl+NO_3+F$	SO_4							
107	37,2	40,5	22,3	56,2	26,9	16,9	2,5	292	12,0	0,00	0,76	1,0	0,9
108	45,4	47,9	6,6	78,5	13,1	8,4	5,1	256	11,9	-0,13	0,25	0,2	0,9
111	42,5	45,5	12,0	78,5	14,7	6,8	7,4	310	12,3	0,21	0,23	0,5	0,9
112	42,0	46,5	11,5	35,3	11,5	53,2	0,1	547	12,3	0,15	1,80	0,6	0,9
113	47,8	44,0	8,2	95,8	2,0	2,2	5,1	283	12,3	0,27	0,04	0,3	1,1
115	37,2	35,6	27,1	59,4	26,0	14,6	4,9	303	12,1	0,09	0,67	1,3	1,0
117	37,5	57,1	5,3	93,1	1,2	5,7	2,2	164	11,7	-0,26	0,07	0,1	0,7
118	43,9	48,2	7,9	87,1	0,8	12,1	0,5	31	9,5	-2,34	0,14	0,1	0,9
119	43,3	54,2	2,5	92,3	1,8	5,9	4,3	281	12,2	0,17	0,08	0,1	0,8
121	44,2	51,5	4,3	82,9	4,4	12,7	3,8	313	12,3	0,23	0,20	0,1	0,9
122	37,6	57,4	5,0	89,8	4,3	5,9	5,1	259	12,3	0,25	0,10	0,2	0,7
124	38,9	57,1	4,0	94,7	0,9	4,4	3,5	221	12,0	-0,03	0,05	0,1	0,7
125	42,3	46,5	11,3	73,7	19,5	6,8	4,5	283	12,0	-0,06	0,34	0,4	0,9
126	41,5	45,6	13,0	58,4	31,3	10,3	3,4	330	12,1	0,07	0,70	0,5	0,9
127	40,2	53,9	5,9	92,1	5,7	2,2	2,3	187	11,7	-0,23	0,08	0,2	0,7
128	47,9	48,1	4,1	85,4	6,5	8,1	7,9	230	12,0	0,01	0,15	0,1	1,0
131	27,9	38,6	33,5	96,1	1,4	2,5	5,2	184	12,0	-0,05	0,04	1,3	0,7
132	40,8	51,1	8,0	85,3	4,3	10,5	4,9	303	12,2	0,20	0,17	0,3	0,8
135	46,1	48,5	5,4	85,8	8,7	5,5	5,4	241	11,9	-0,14	0,15	0,2	1,0
136	47,5	48,7	3,8	93,7	2,9	3,4	5,2	227	11,8	-0,24	0,06	0,1	1,0
137	24,0	42,3	33,7	70,8	27,6	1,6	12,6	406	12,6	0,48	0,41	1,6	0,6
138	47,0	48,5	4,5	91,4	6,1	2,6	4,7	299	12,1	0,05	0,08	0,2	1,0
139	45,4	49,1	5,6	86,0	9,8	4,3	7,3	348	12,4	0,32	0,14	0,2	0,9
140	47,7	47,2	5,1	87,0	9,2	3,8	6,7	298	12,4	0,33	0,13	0,2	1,0
141	43,6	53,9	2,4	89,7	6,2	4,1	1,0	201	11,7	-0,27	0,10	0,10	0,8
142	45,6	50,8	3,5	94,3	2,6	3,1	0,5	195	11,8	-0,14	0,06	0,1	0,9
143	50,5	48,2	1,4	88,7	9,3	2,0	8,7	185	11,9	-0,04	0,09	0,0	1,0
144	45,5	50,0	4,5	85,2	11,3	3,5	5,0	251	12,1	0,08	0,16	0,1	0,9
145	46,1	45,6	8,3	74,8	19,0	6,2	4,0	248	12,0	-0,04	0,32	0,3	1,0
146	40,7	42,7	16,6	64,6	24,1	11,3	2,3	281	12,1	0,02	0,53	0,6	1,0
147	44,9	41,6	13,5	73,9	16,5	9,6	4,0	274	12,2	0,16	0,35	0,5	1,1
148	42,9	44,8	12,3	68,4	20,6	11,0	5,7	306	12,1	0,07	0,45	0,5	1,0
149	48,1	49,6	2,3	93,4	4,1	2,5	0,1	122	11,4	-0,49	0,06	0,0	1,0
150	34,4	56,7	8,8	83,8	1,0	15,2	2,8	26	9,0	-2,81	0,18	0,1	0,6
151-C	26,3	52,1	21,6	94,7	0,8	4,5	1,0	37	9,4	-2,38	0,05	0,3	0,5
152	45,4	49,9	8,7	87,7	6,0	6,3	14,9	286	12,1	0,04	0,09	0,3	1,0
162	45,7	46,3	7,9	84,2	11,5	4,3	7,6	286	11,9	-0,12	0,15	0,3	1,0
C1	36,7	27,9	35,4	92,2	2,9	4,9	1,6	57	10,8	-1,10	0,07	0,8	1,3
C2	40,6	46,8	12,6	83,8	10,0	6,2	4,3	161	11,6	-0,35	0,16	0,3	0,9
C4	44,1	51,2	4,8	85,9	7,4	6,7	3,7	237	12,0	0,04	0,15	0,1	0,9
C5	45,8	49,3	4,9	84,2	11,8	4,0	4,4	270	12,2	0,13	0,16	0,2	0,9
C6	43,3	47,6	9,1	70,2	13,6	16,2	1,3	251	12,1	0,04	0,41	0,3	0,9
C7	46,7	45,2	8,0	71,5	25,6	2,9	6,6	226	11,9	-0,05	0,36	0,2	1,0
C8	34,3	18,8	46,9	77,1	16,2	6,7	2,6	35	9,7	-2,15	0,26	1,0	1,8
C9	43,5	50,3	6,2	93,5	4,0	2,5	4,4	253	12,2	0,22	0,06	0,2	0,9
C15	45,5	50,0	4,4	93,3	3,3	3,4	3,9	157	11,7	-0,23	0,07	0,1	0,9
C16	39,4	55,3	5,4	96,4	1,1	2,5	0,4	162	11,8	-0,12	0,03	0,1	0,7
C17	15,3	50,3	34,4	84,6	4,0	11,4	5,6	21	10,2	-1,61	0,18	0,5	0,3

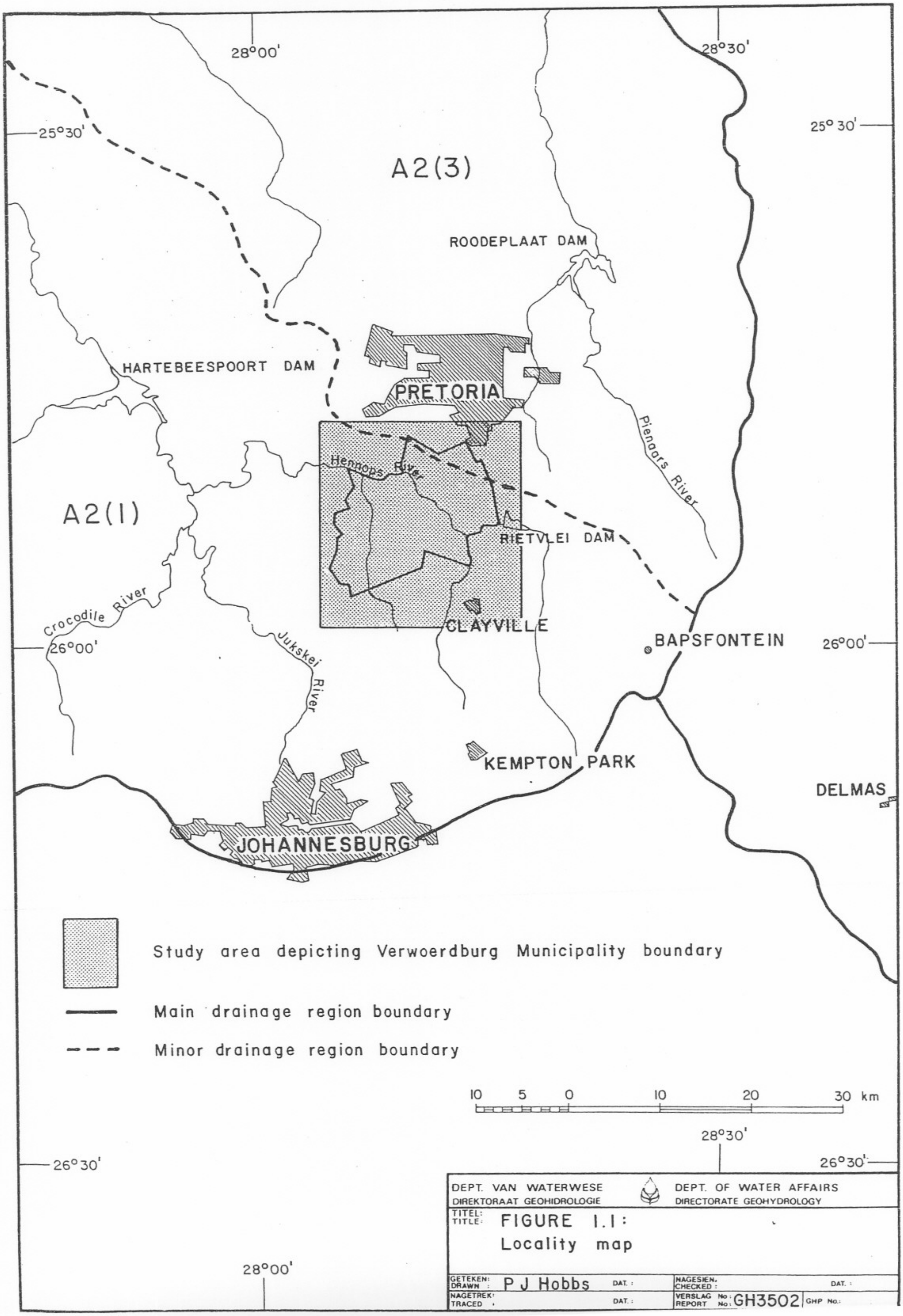
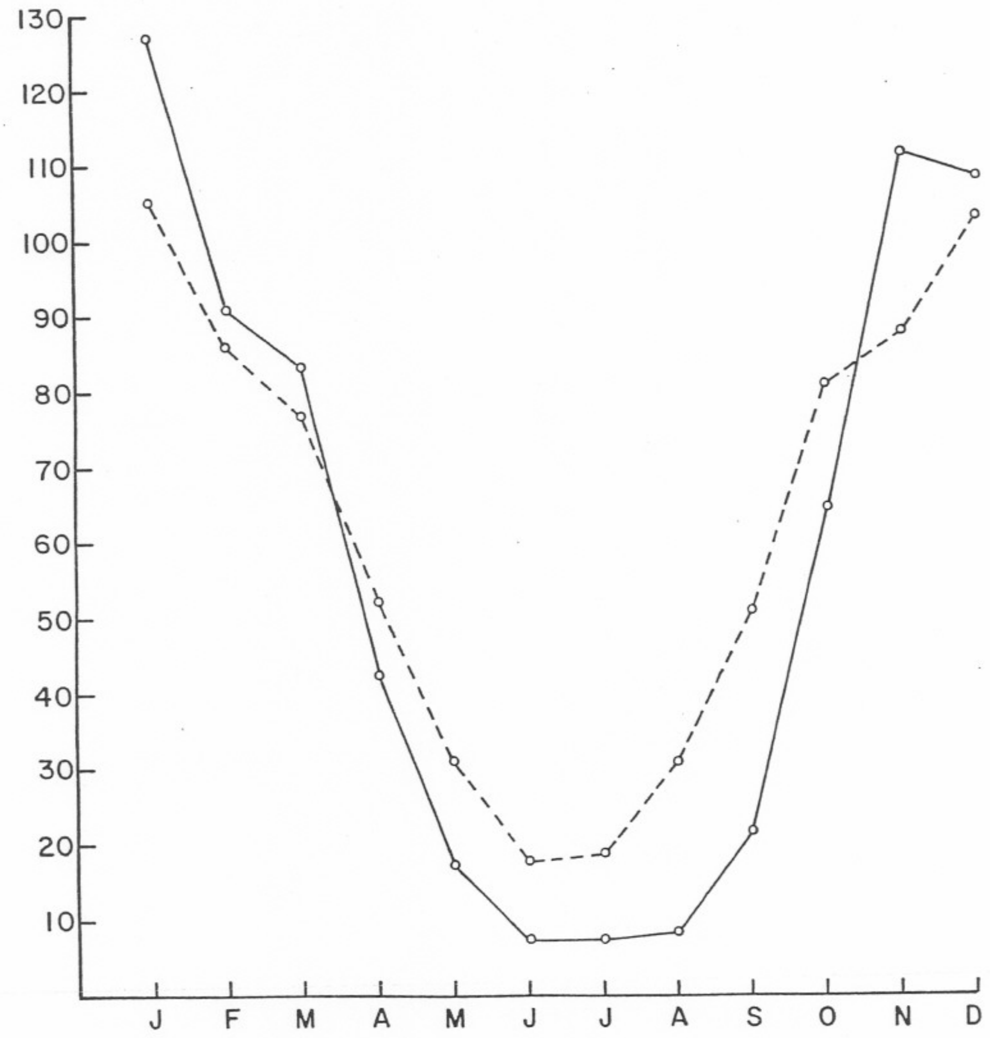


FIGURE 1.1: Locality map

STATION 513/382 IRENE 25°52'S 28°13'E 1448 m

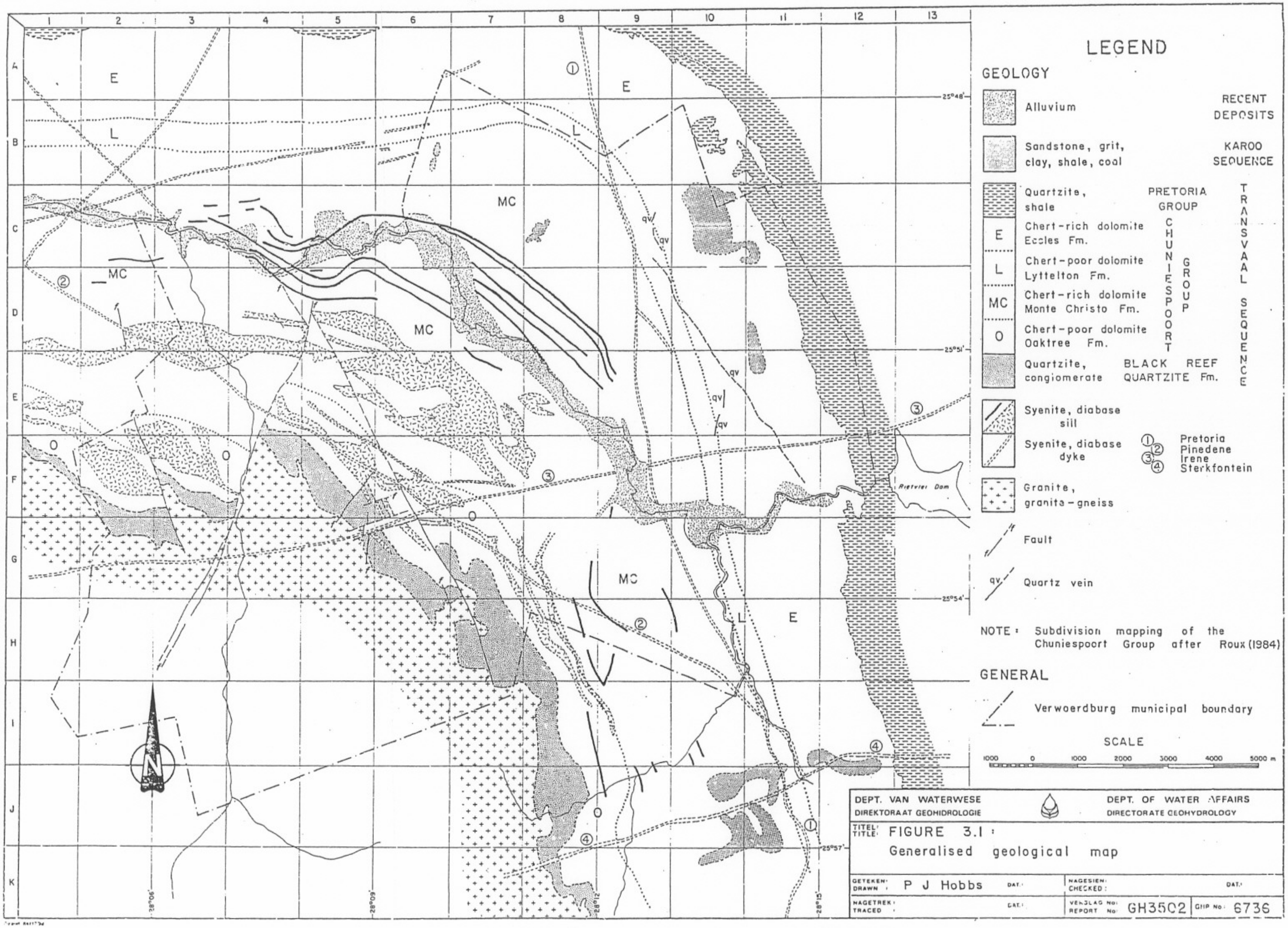


Observed mean monthly rainfall (mm)

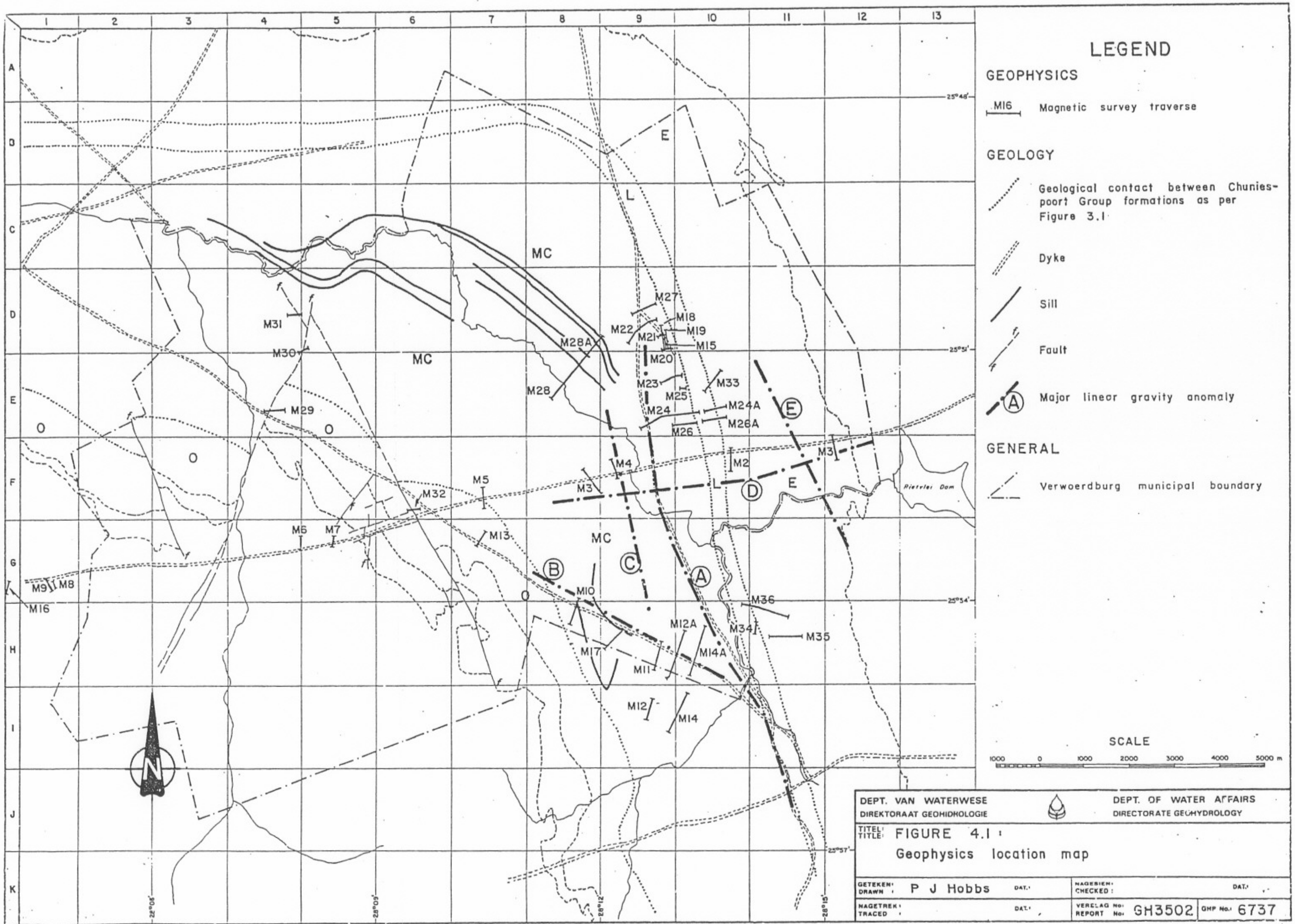
Calculated monthly potential evapotranspiration (mm)

DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE	DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY
TITEL: TITLE: FIGURE 2.1: Comparison between potential evapo-transpiration and mean rainfall	
GETEKEN: DRAWN: P J Hobbs DAT.:	NAGESIEN: CHECKED: DAT.:
NAGETREK: TRACED: DAT.:	VERSLAG No.: REPORT No.: GH3502 GHP No.:

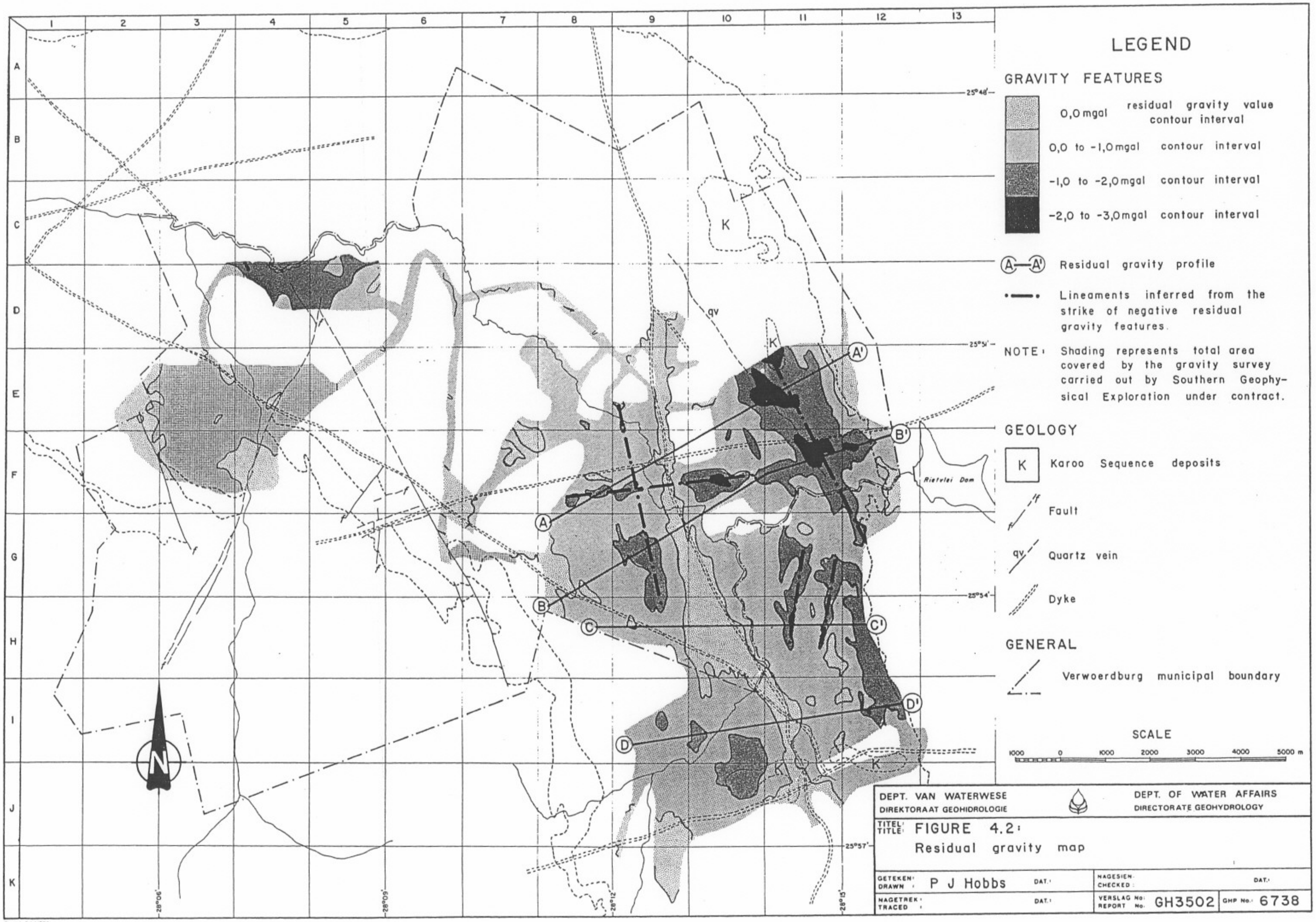
Ozalid 86/1421



TITEL: TITLE: FIGURE 3.1 : Generalised geological map

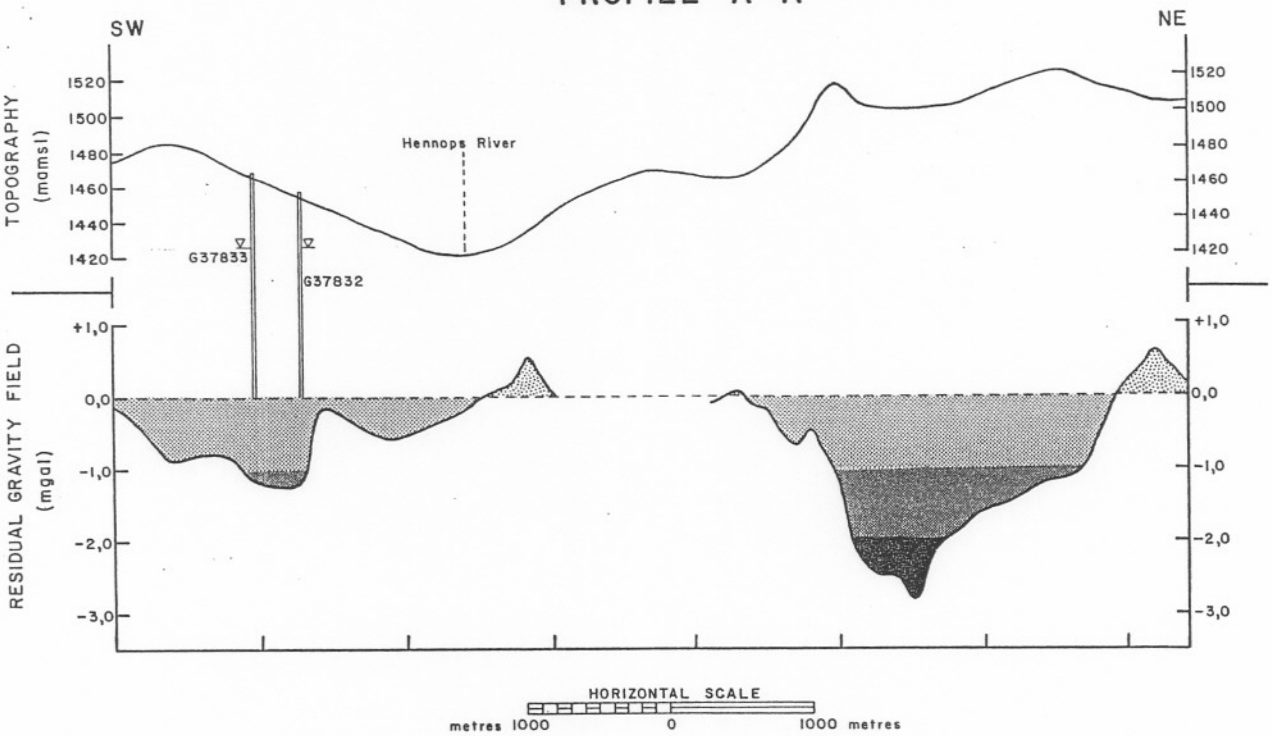


LEGEND
GEOPHYSICS
M16 Magnetic survey traverse
GEOLOGY
Geological contact between Chuniespoort Group formations as per Figure 3.1
Dyke
Sill
Fault
Major linear gravity anomaly
GENERAL
Verwoerdburg municipal boundary
SCALE
1000 0 1000 2000 3000 4000 5000 m
DEPT. VAN WATERWESE
DIREKTORAAT GEOHIDROLOGIE
DEPT. OF WATER AFFAIRS
DIRECTORATE GEOHYDROLOGY
TITEL: TITLE: FIGURE 4.1 :
Geophysics location map
GETEKEN: DRAWN: P J Hobbs
DAT.:
NAGESIEN: CHECKED:
NAGETREK: TRACED:
VERSLAG No: REPORT No: GH3502
GHP No.: 6737
MC
O
L
E
Pietvlei Dam
25°48'
25°51'
25°54'
25°57'
28°06'
28°09'
28°12'
28°15'
M1 M2 M3 M4 M5 M6 M7 M8 M9 M10 M11 M12 M12A M13 M14 M14A M15 M16 M17 M18 M19 M20 M21 M22 M23 M24 M24A M25 M26 M26A M27 M28 M28A M29 M30 M31 M32 M33 M34 M35 M36
A B C D E

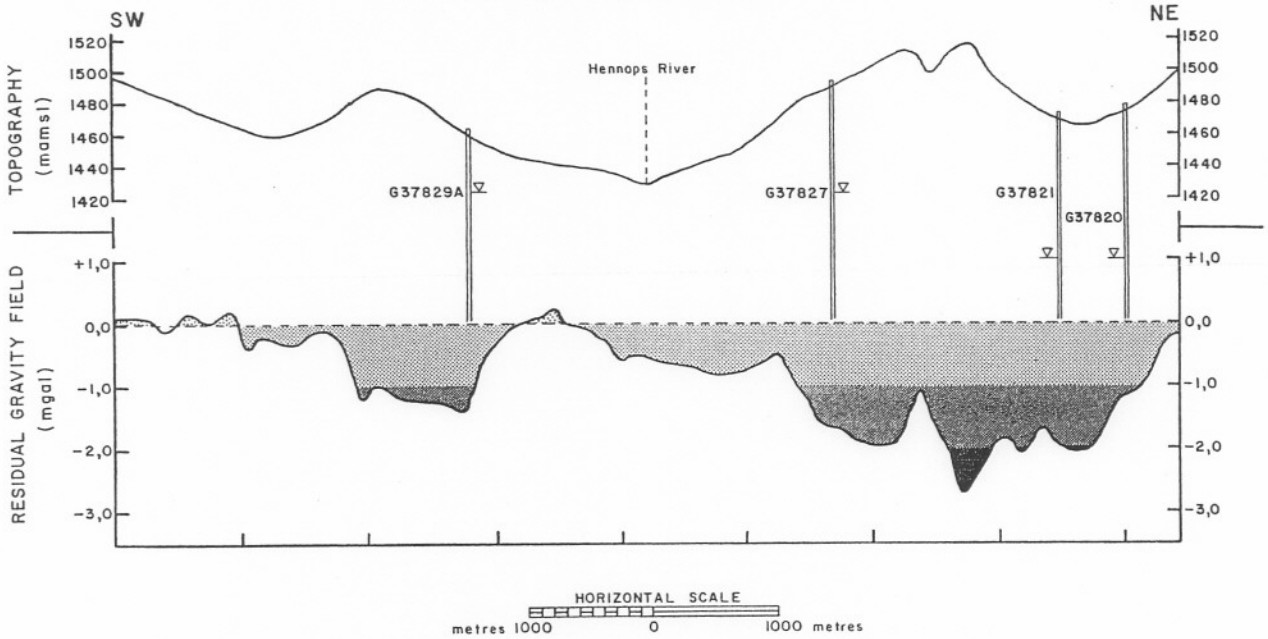


TITEL: TITLE: FIGURE 4.2: Residual gravity map

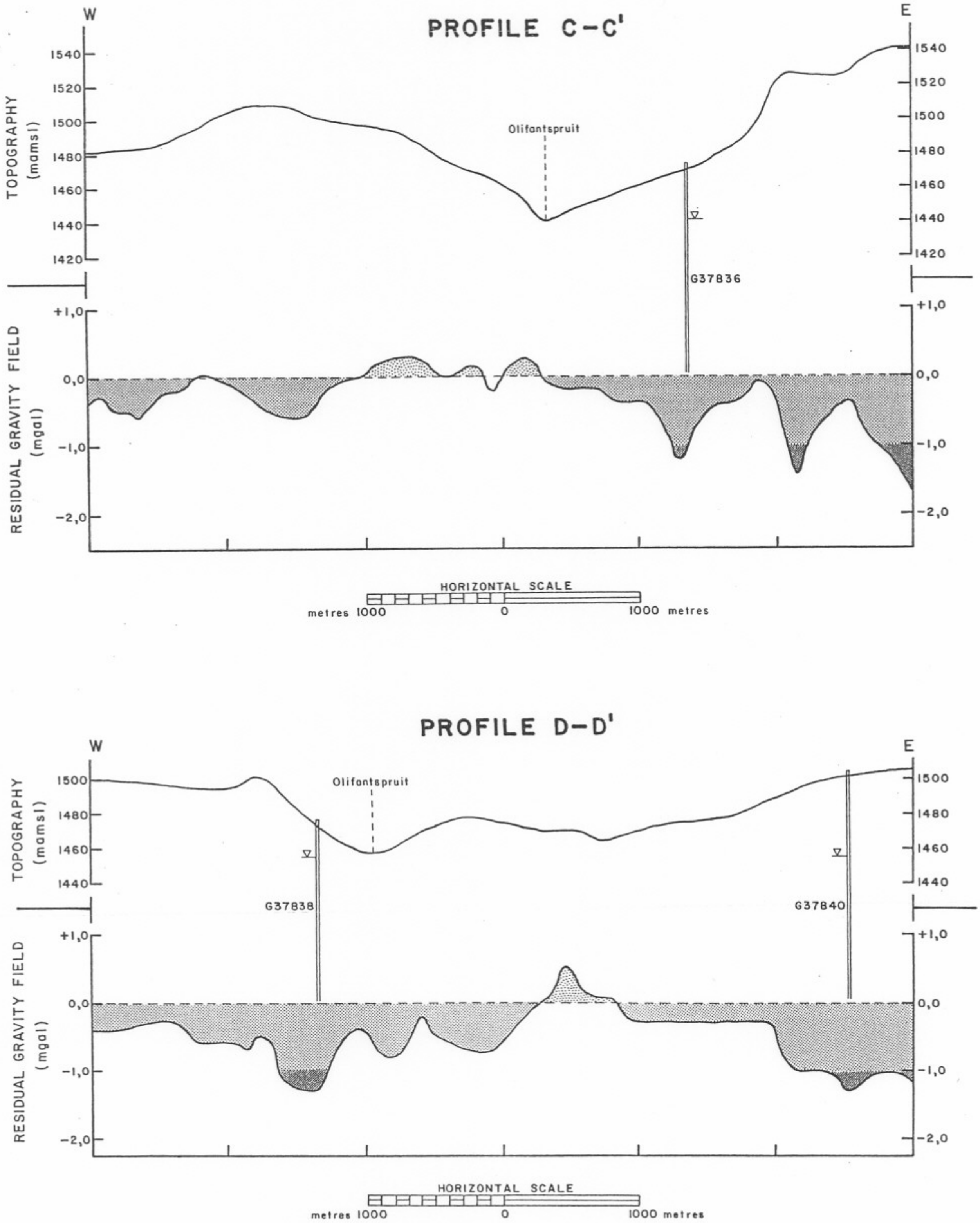
PROFILE A–A'



PROFILE B–B'



DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE	DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY
TITEL / TITLE	FIGURE 4.3 : Residual gravity profiles A–A' and B–B'
GETEKEN / DRAWN: P J Hobbs DAT	NAGESIEN / CHECKED: DAT.
NAGETREK / TRACED: DAT	VERSLAG No. / REPORT No. GH3502 GHP No.



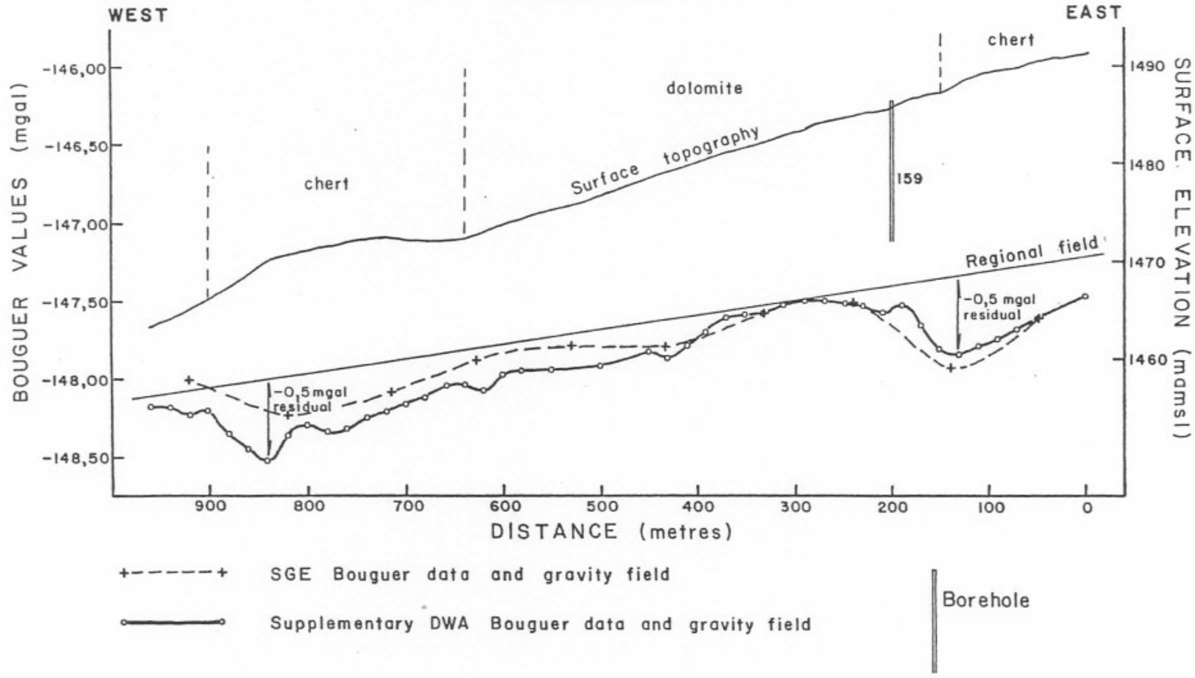
DEPT. VAN WATERWESE
DIREKTORAAT GEOHIDROLOGIE

DEPT. OF WATER AFFAIRS
DIRECTORATE GEOHYDROLOGY

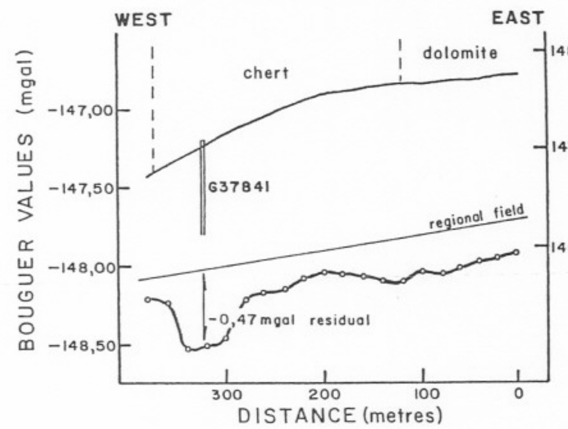
TITEL / TITLE: FIGURE 4.4 :
Residual gravity profiles C–C' and D–D'

GETEKEN / DRAWN: P J Hobbs	DAT	NAGESIEN / CHECKED	DAT
NAGETREK / TRACED	DAT.	VERSLAG No. / REPORT No: GH3502	GHP No.

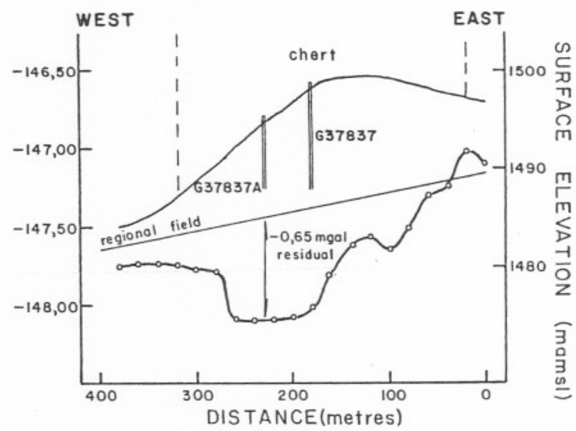
PROFILE G-1



PROFILE G-2



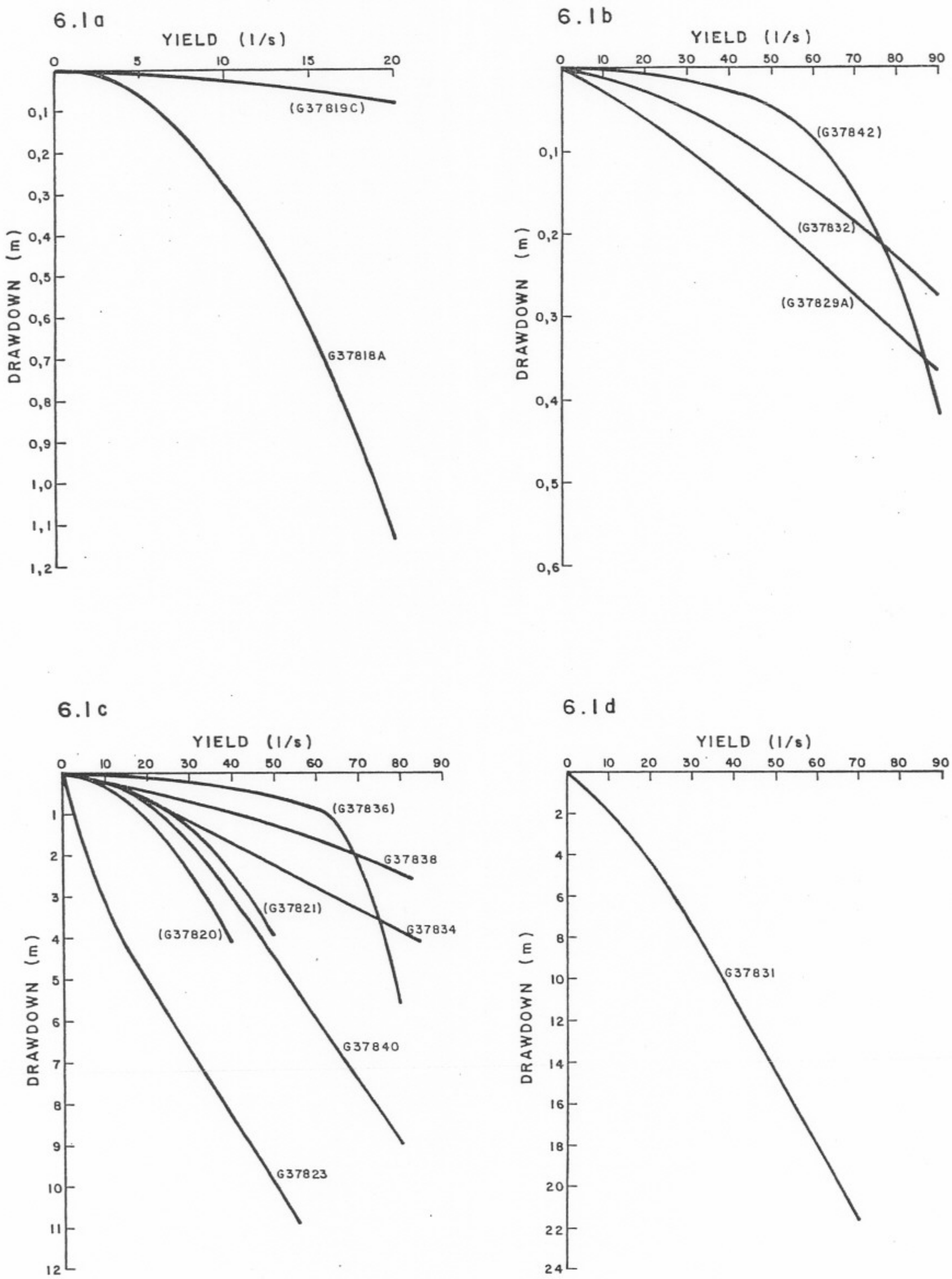
PROFILE G-3



NOTES:

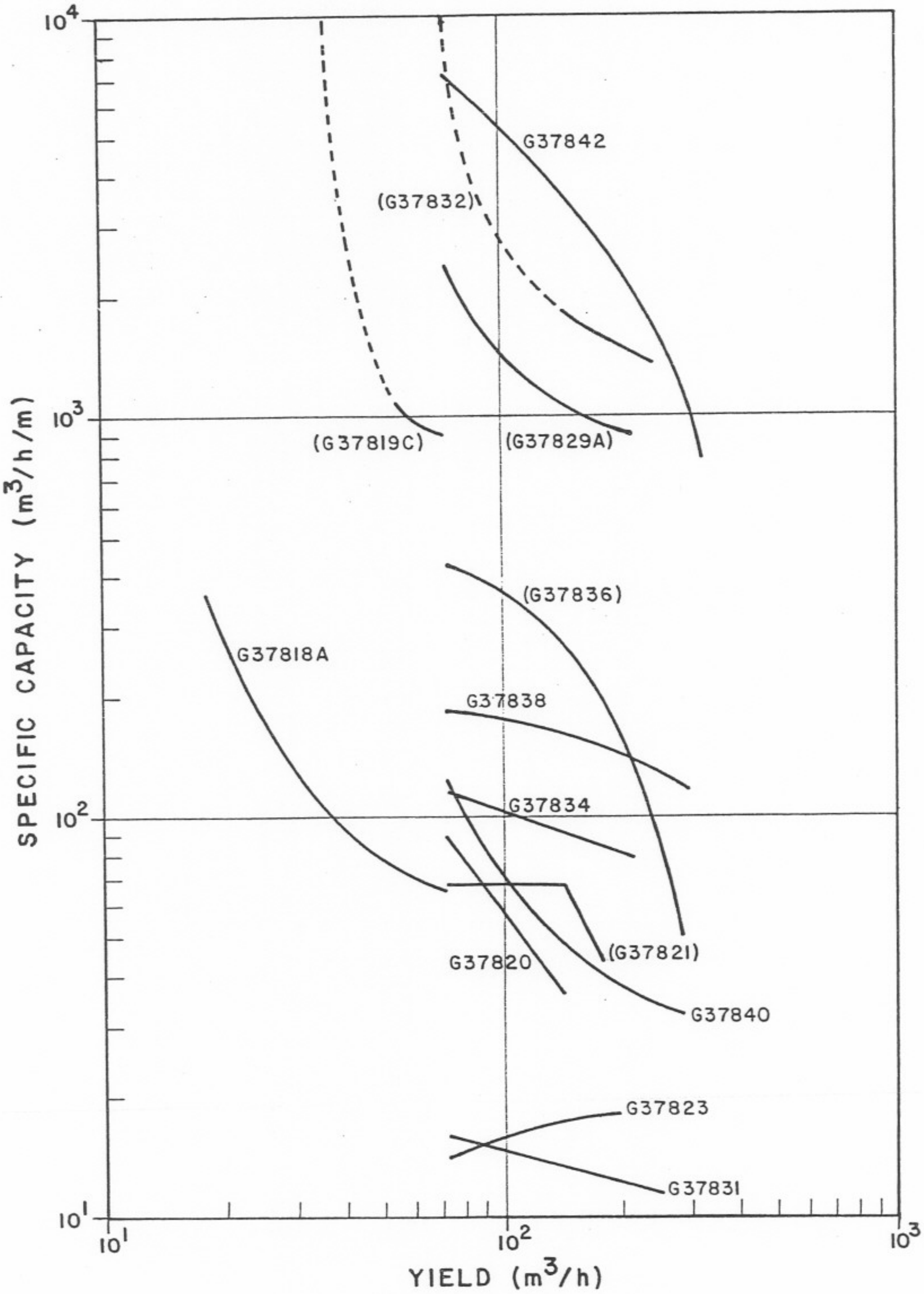
1. All left ordinates reference Bouguer values in mgal
2. All right ordinates reference surface elevation in metres above mean sea level
3. Data from Tables 4.2.1, 4.2.2 and 4.2.3 in text
4. Horizontal scale = 10 x right ordinate scale

DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE	DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY
TITEL TITLE: FIGURE 4.5: Supplementary DWA gravity survey profiles	
GETEKEN: DRAWN: P J Hobbs DAT:	NAGESIEN: CHECKED: DAT:
NAGETREK: TRACED: DAT:	VERSLAG No: REPORT No: GH3502 GHP No:



NOTE : Bracketed curve labels indicate data obtained from calibration tests.

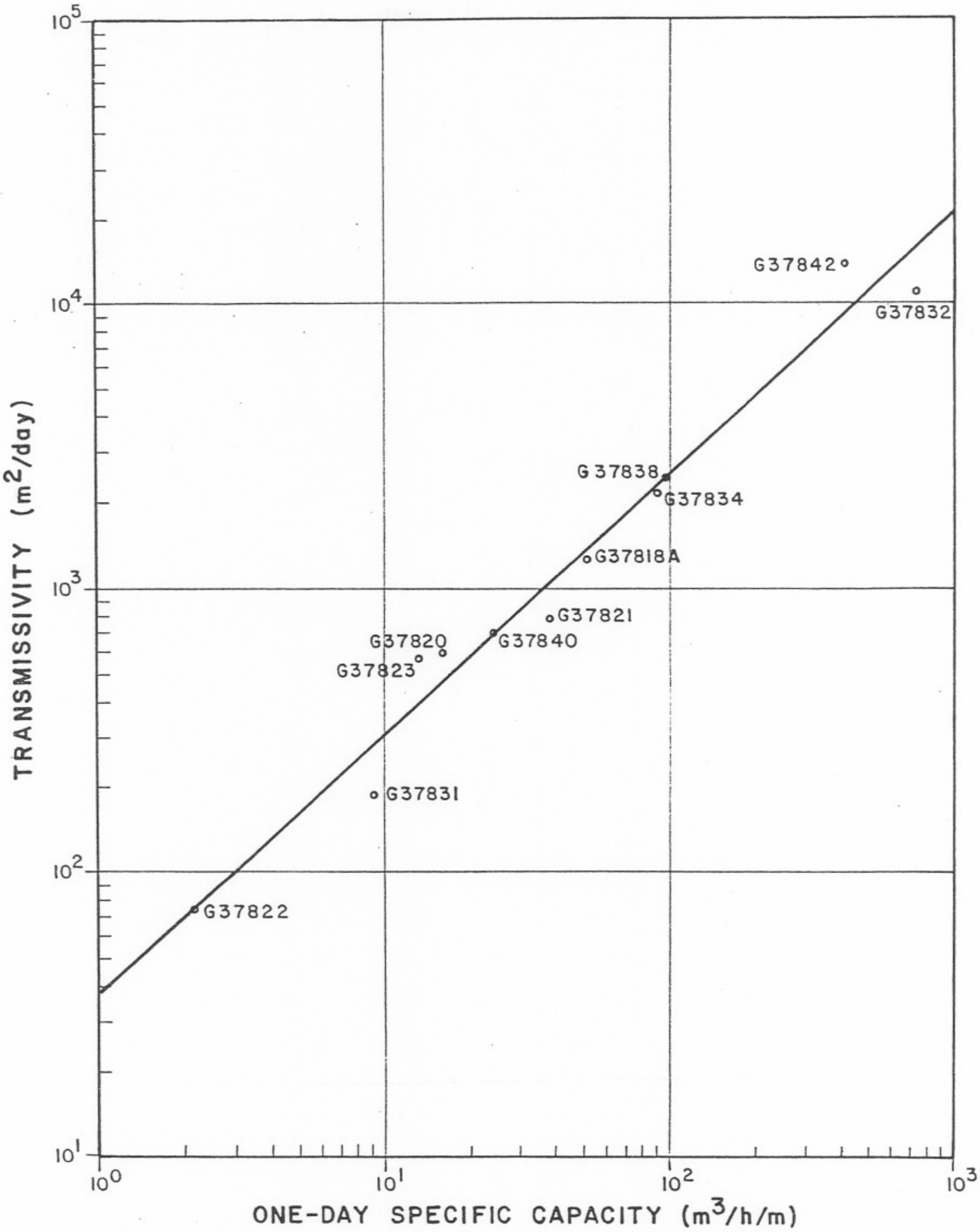
DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE		DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY	
TITEL TITLE	FIGURE 6.1: Yield versus drawdown performance graphs for potential production boreholes		
GETEKEN DRAWN	P J Hobbs DAT.	NAGESIEN CHECKED	DAT.
NAGETREK TRACED	DAT.	VERSLAG No. REPORT No.	GH3502 GHP No.



NOTE : Bracketed curve labels indicate specific capacity data obtained from calibration tests.

DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE		DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY	
TITEL: TITLE: **FIGURE 6.2 :** Yield vs specific capacity performance graphs for potential production boreholes			
GETEKEN: DRAWN : P J Hobbs	DAT. :	NAGESIEN: CHECKED :	DAT. :
NAGETREK: TRACED :	DAT. :	VERSLAG No: REPORT No: GH3502	GHP No.:

Ozalid 86/1421



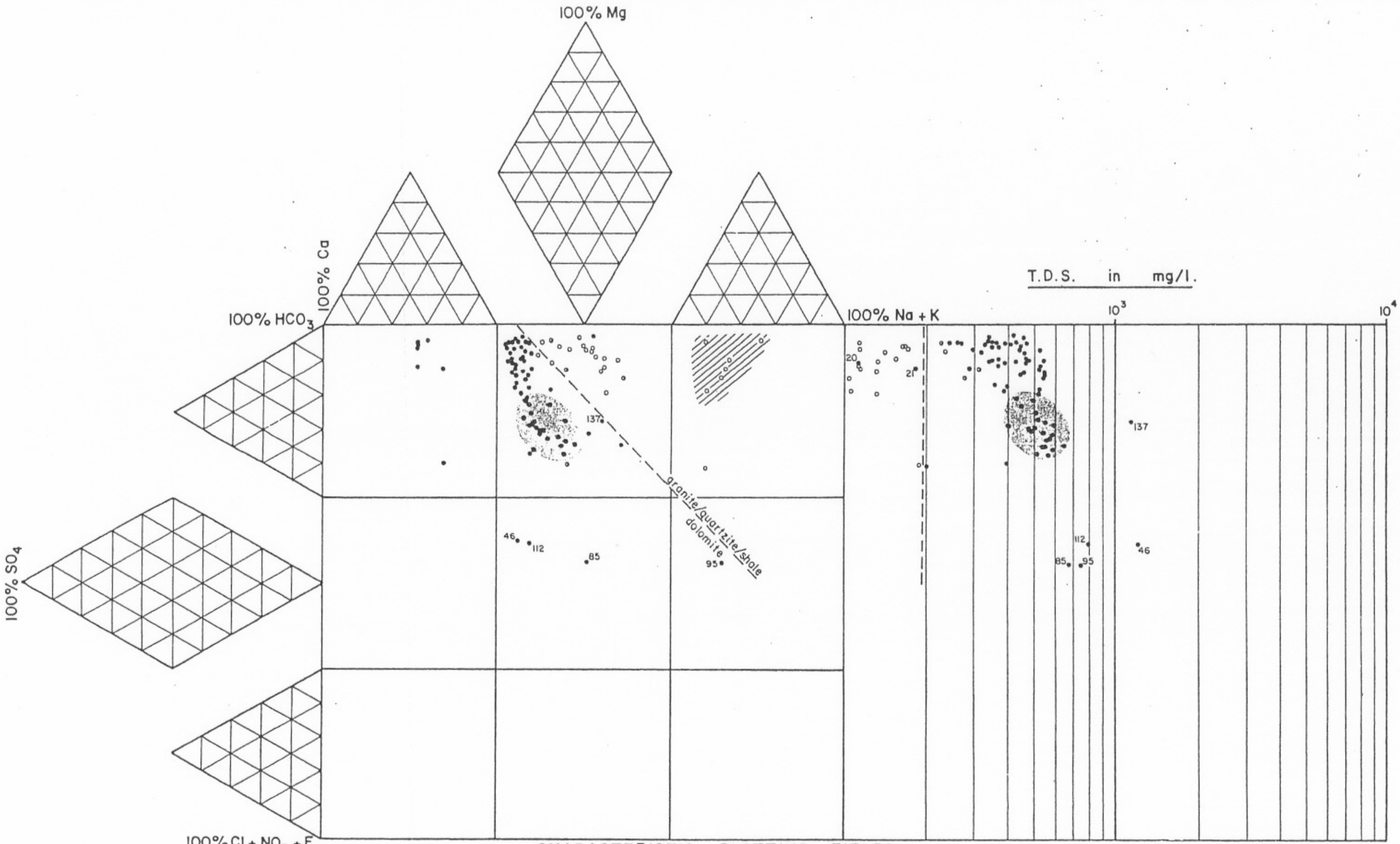
NOTE : Data fitted to a power curve ($y = ax^b$)

Coefficient of determination (R) = 0,95

Regression coefficients a = 37,83 and b = 0,91

DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE	DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY
TITEL: TITLE: **FIGURE 6.3 :** Transmissivity vs specific capacity graph for potential production boreholes	
GETEKEN: DRAWN : P J Hobbs DAT. :	NAGESIEN: CHECKED : DAT. :
NAGETREK: TRACED : DAT. :	VERSLAG No: REPORT No: GH3502 GHP No.:

Ozalid 86/1421



SYMBOLS

- ● Boreholes tapping dolomite
- ○ Boreholes tapping granite or quartzite/shale
- ◑ Boreholes tapping "mixed" ground water

CHARACTERISTIC PLOTTING FIELDS

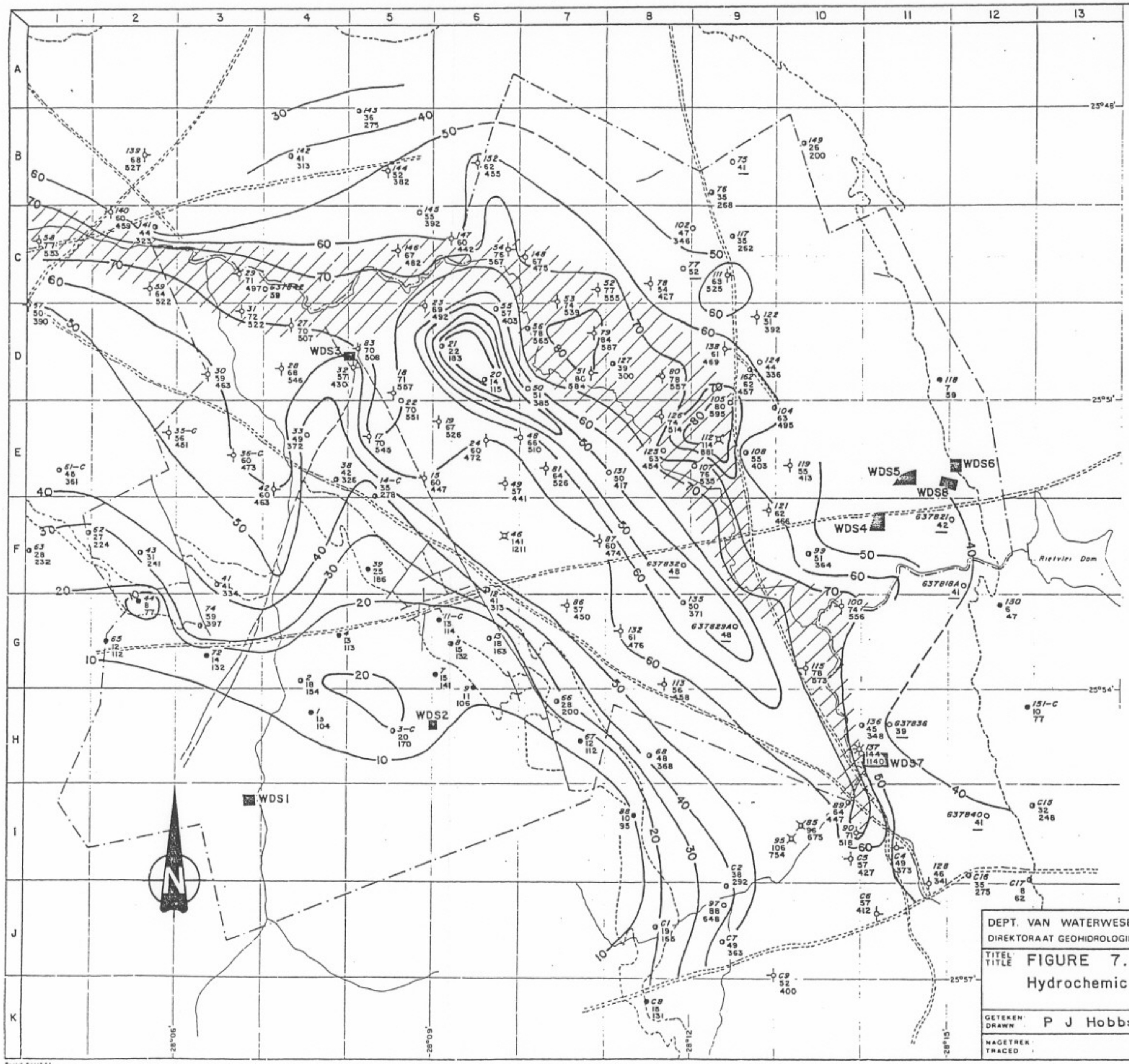
- Ground water from boreholes within 1000 m of the Hennops River
- Ground water from boreholes tapping the granite aquifer

DEPT. VAN WATERWESE — DIREKTORAAT GEOHIDROLOGIE
DEPT. OF WATER AFFAIRS — DIRECTORATE GEOHYDROLOGY

TITEL/TITLE: FIGURE 7.1 : Characterization of ground-water chemistry

GETEKEN/DRAWN: P J Hobbs	DAT.	NAGESIEN/CHECKED	DAT.
NAGETREK/TRACED	DAT.	VERSLAG No/REPORT No GH3502	GHP No

Ozalid 86/378



LEGEND

HYDROCHEMISTRY

149 / 26 / 200 — Borehole location with, from top to bottom, borehole number, ground-water electrical conductivity in mS/m and total dissolved solids concentration in mg/l.

Ground water with a positive Langelier Saturation Index indicating $CaCO_3$ oversaturation.

Ground water with an Aggressive Index less than or equal to 10,0 indicating high corrosion potential.

Ground water with an Aggressive Index between 10,1 and 11,9 indicating moderate corrosion potential.

Ground water showing sign of possible pollution.

Zone of "poor" quality ground water (conductivity greater than 60 mS/m) indicating possible hydraulic connection with the Hennops River.

Electrical conductivity contour in mS/m.

WDS2 — Waste disposal site.

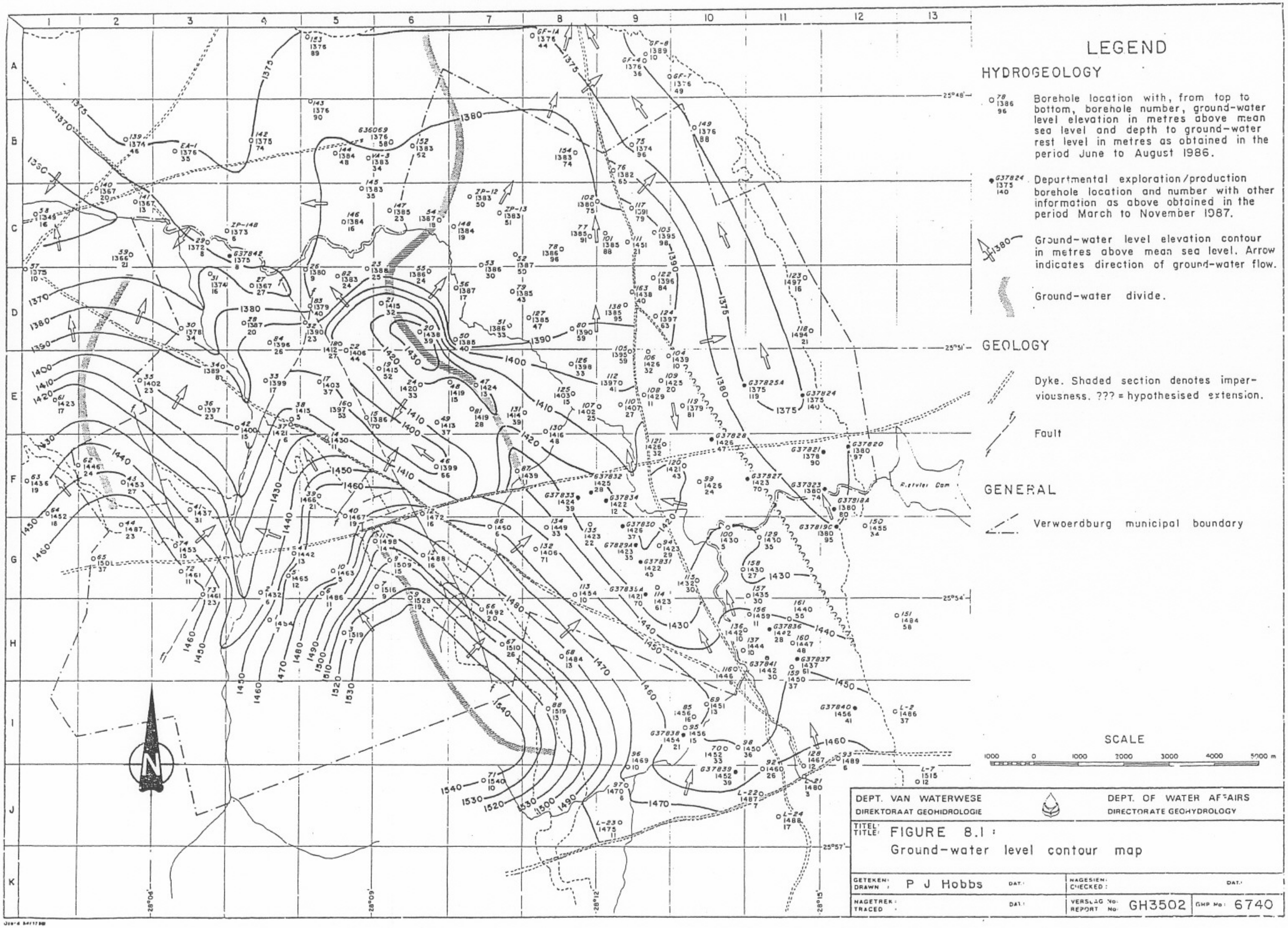
GENERAL

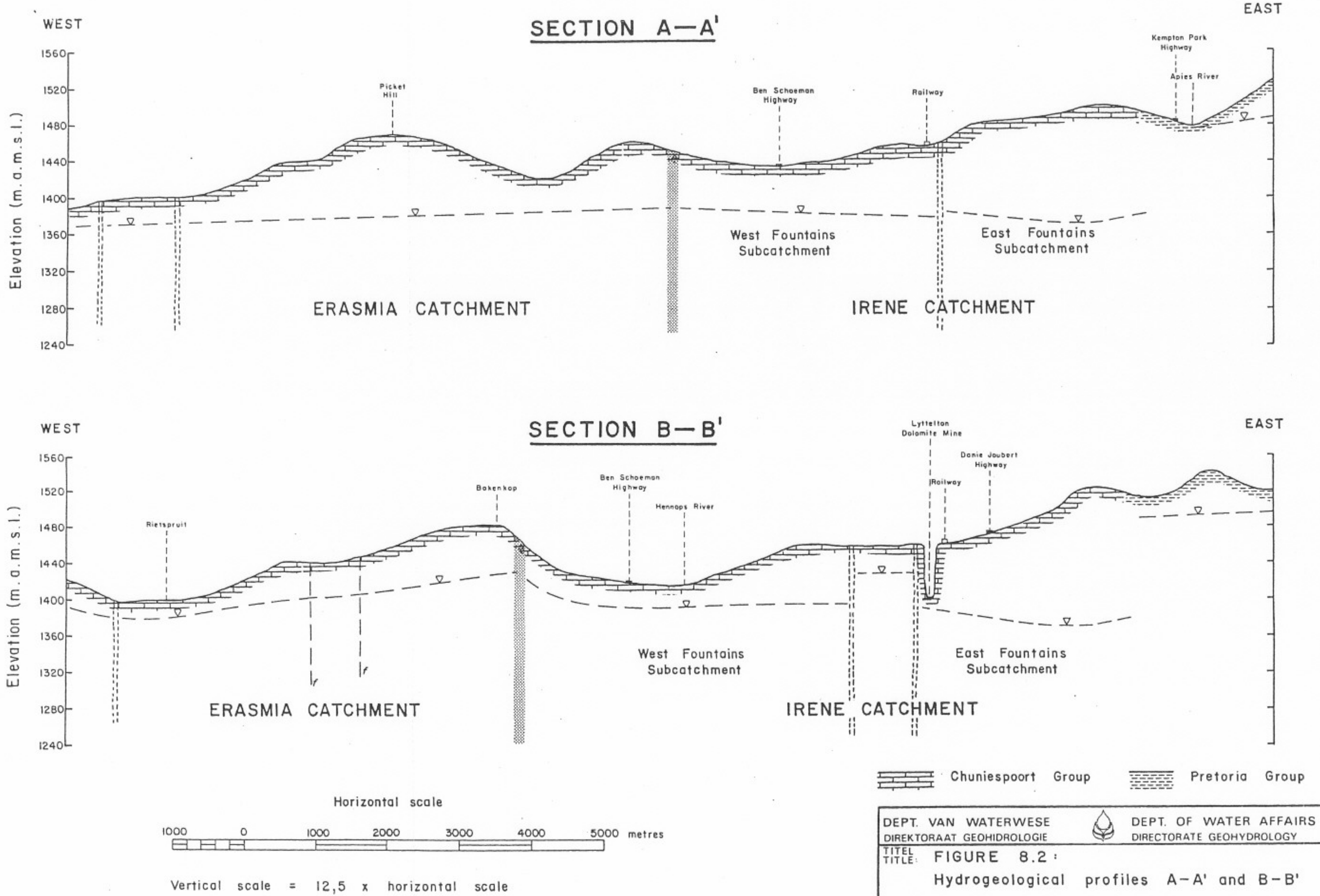
Verwoerdburg municipal boundary.

SCALE

1000 0 1000 2000 3000 4000 5000 m

DEPT. VAN WATERWESE DIREKTORAAT GEOHIDROLOGIE		DEPT. OF WATER AFFAIRS DIRECTORATE GEOHYDROLOGY	
TITEL / TITLE	FIGURE 7.2: Hydrochemical map		
GETEKEN / DRAWN	P J Hobbs DAT:	NAGESIEN / CHECKED	DAT:
NAGETREK / TRACED	DAT:	VERSLAG No / REPORT No: GH3502	GHP No: 6739


LEGEND
HYDROGEOLOGY
Borehole location with, from top to bottom, borehole number, ground-water level elevation in metres above mean sea level and depth to ground-water rest level in metres as obtained in the period June to August 1986.
Departmental exploration/production borehole location and number with other information as above obtained in the period March to November 1987.
Ground-water level elevation contour in metres above mean sea level. Arrow indicates direction of ground-water flow.
Ground-water divide.
GEOLOGY
Dyke. Shaded section denotes imperviousness. ??? = hypothesised extension.
Fault
GENERAL
Verwoerdburg municipal boundary
SCALE
1000 0 1000 2000 3000 4000 5000 m
DEPT. VAN WATERWESE
DIREKTORAAT GEOHIDROLOGIE
DEPT. OF WATER AFFAIRS
DIRECTORATE GEOHYDROLOGY
TITEL: TITLE: FIGURE 8.1 :
Ground-water level contour map
GETEKEN: DRAWN: P J Hobbs
NAGESIEN: CHECKED:
NAGETREK: TRACED:
VERSLAG No: REPORT No: GH3502
GHP No: 6740
Rietvlei Dam
25°48'
25°51'
25°54'
25°57'
28°04'
28°09'
28°12'
28°15'



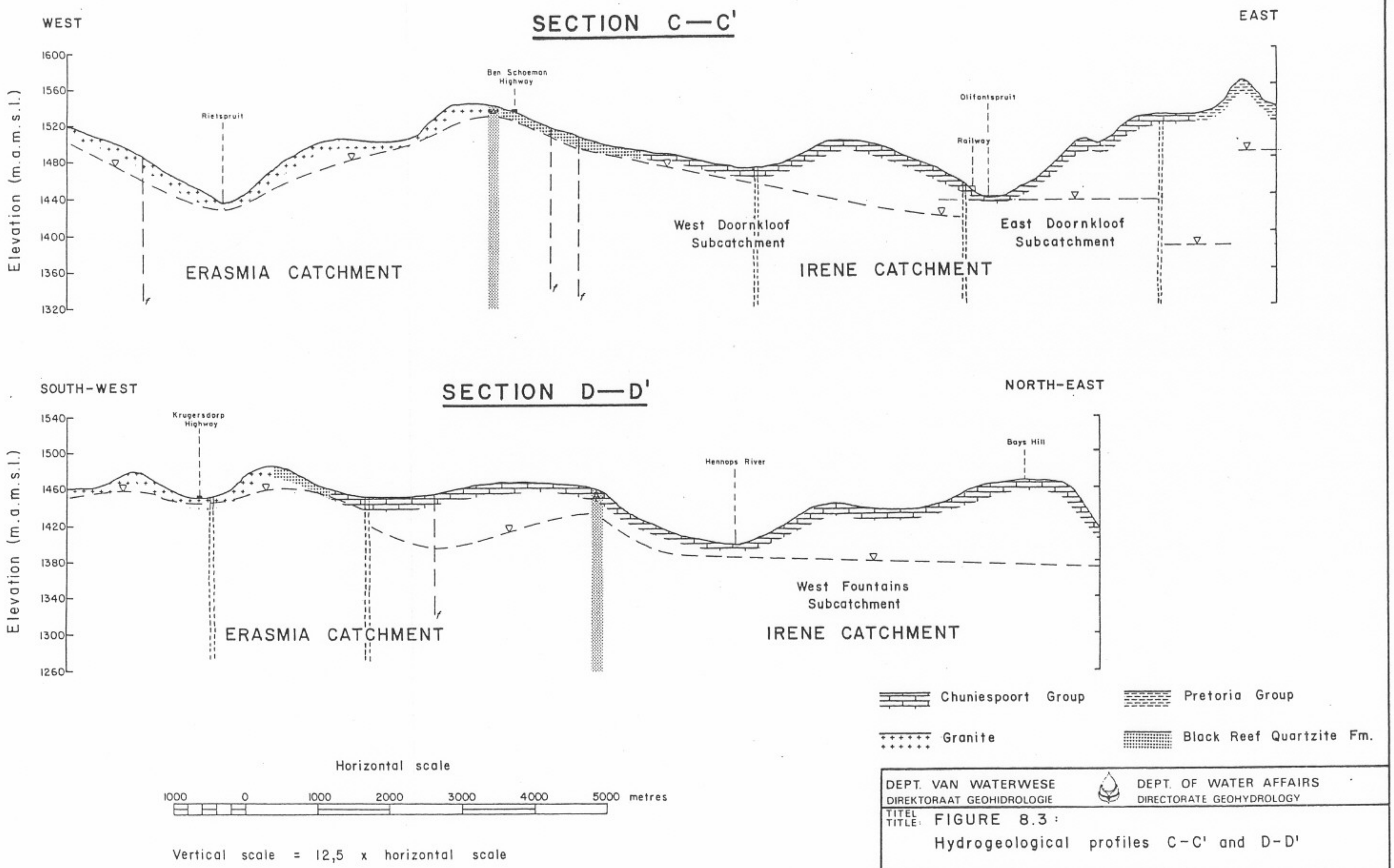
DEPT. VAN WATERWESE
DIREKTORAAT GEOHIDROLOGIE

DEPT. OF WATER AFFAIRS
DIRECTORATE GEOHYDROLOGY

TITEL / TITLE: FIGURE 8.2 : Hydrogeological profiles A–A' and B–B'

GETEKEN / DRAWN: P J Hobbs	DAT.:	NAGESIEN / CHECKED:	DAT.
NAGETREK / TRACED:	DAT.:	VERSLAG No. / REPORT No. GH3502	GHP No:

Ozalid 84/1799



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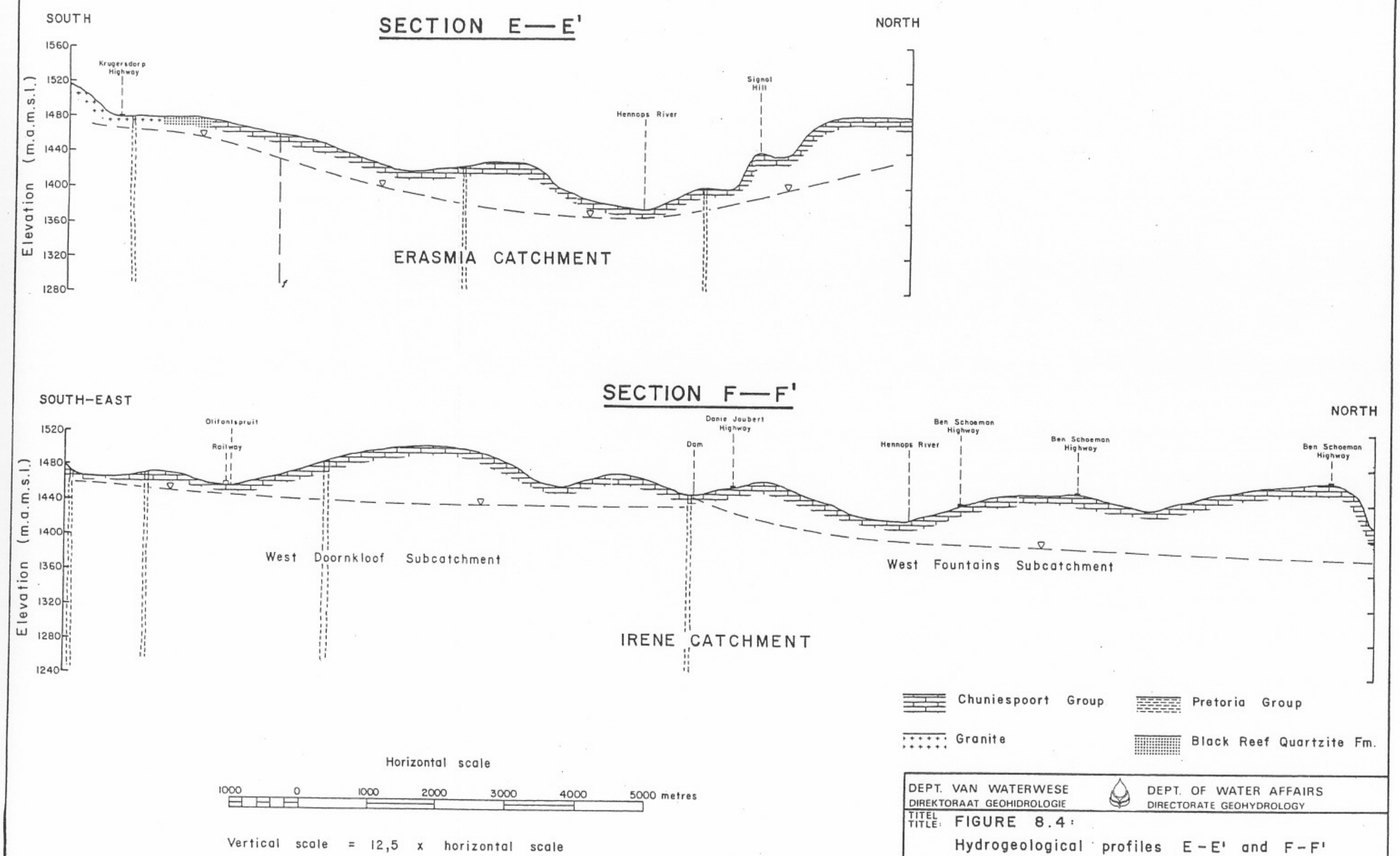
DIRECTORATE GEOHYDROLOGY

TITEL / TITLE: FIGURE 8.3 : Hydrogeological profiles C-C' and D-D'

GETEKEN / DRAWN: P J Hobbs	DAT:	NAGESIEN / CHECKED	DAT:
NAGETREK / TRACED:	DAT:	VERSLAG No / REPORT No: GH3502	GHP No:

Ozalid 84/1799



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TITEL / TITLE: FIGURE 8.4: Hydrogeological profiles E-E' and F-F'

GETEKEN: / DRAWN: P J Hobbs	DAT.:	NAGESIEN / CHECKED:	DAT.:
NAGETREK: / TRACED:	DAT.:	VERSLAG No. / REPORT No.: GH3502	GHP No.:

Ozalid 84/1799

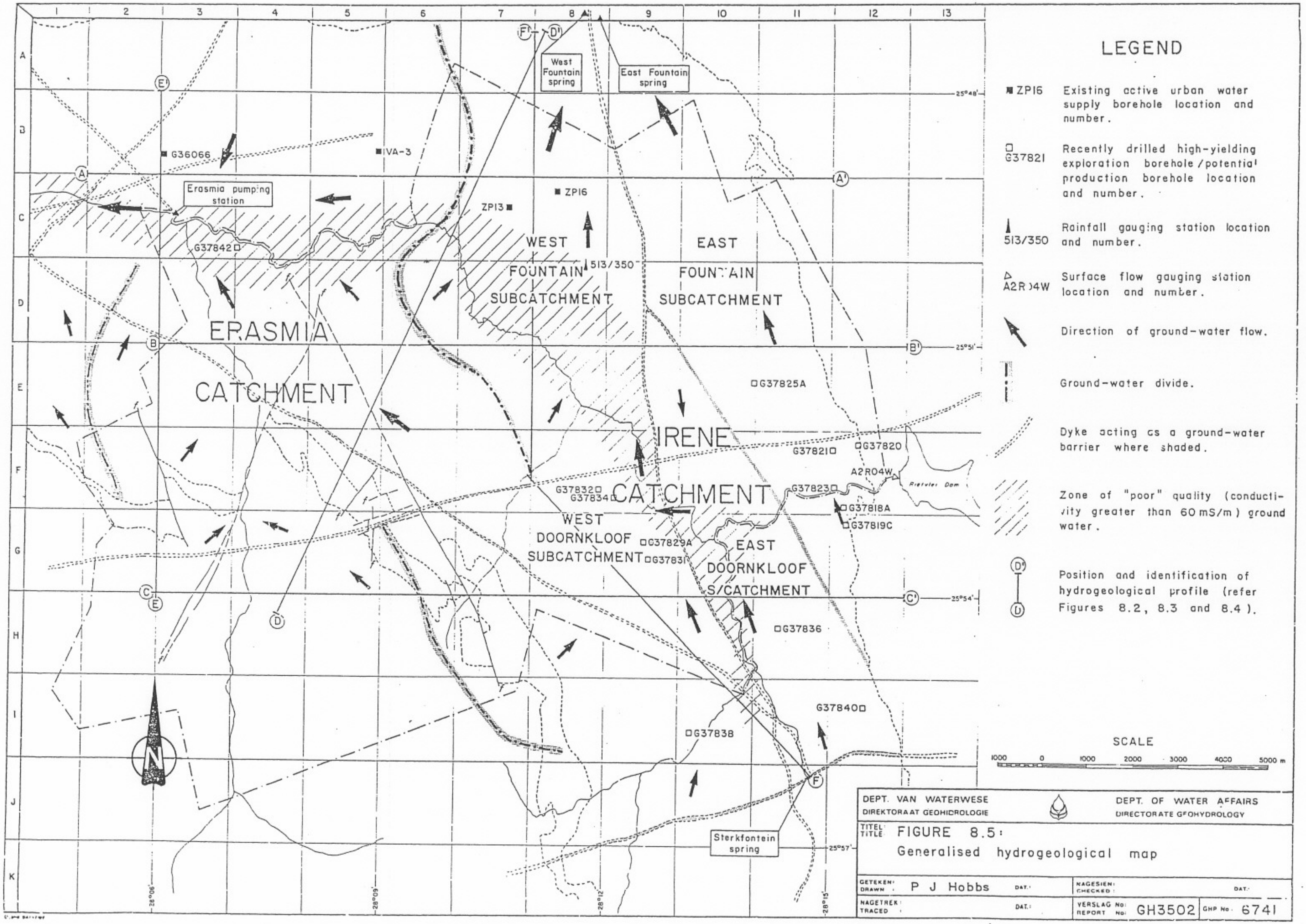
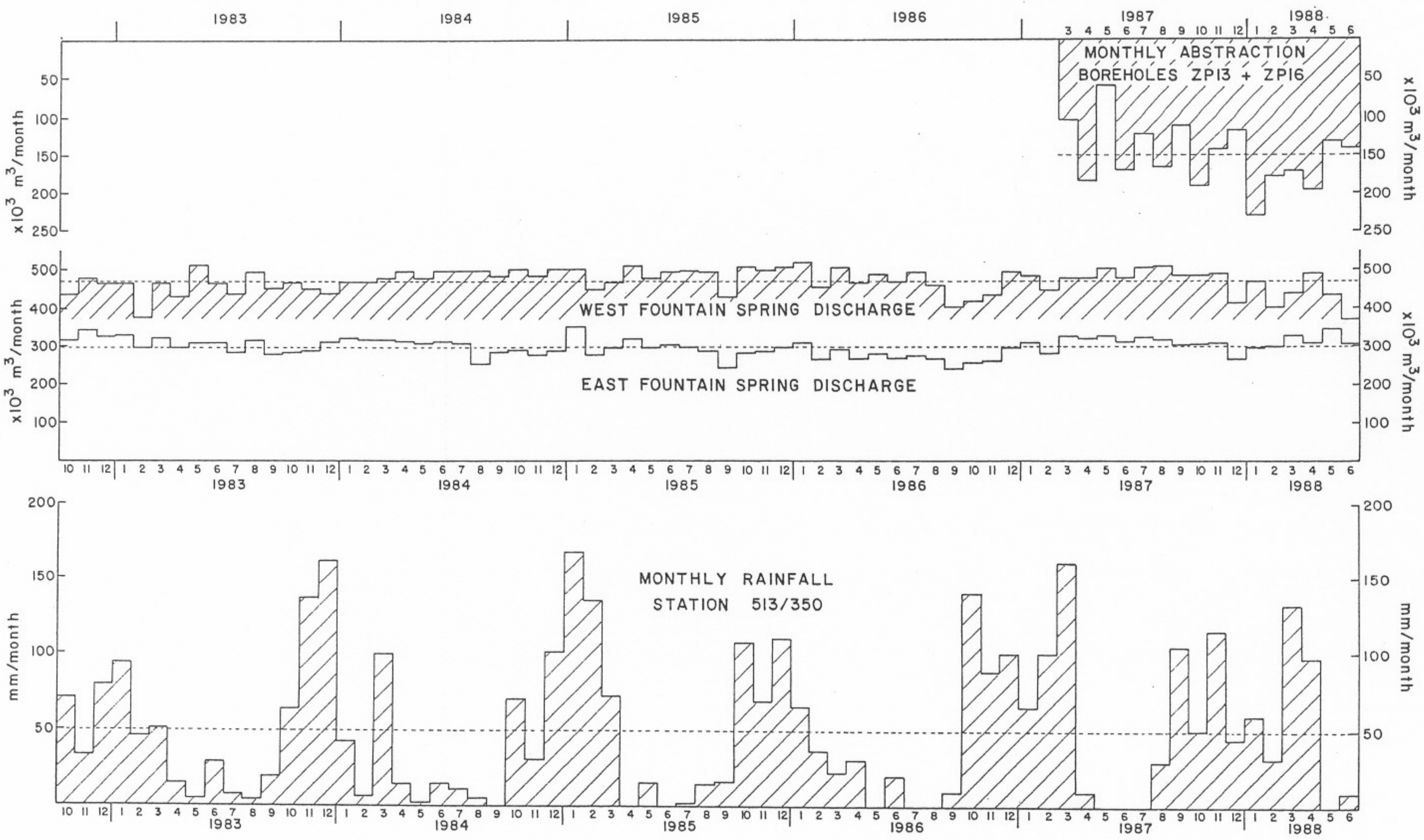


FIGURE 8.5: Generalised hydrogeological map



------------ mean monthly discharge/rainfall for the period 10/1982 to 06/1988.

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TITEL / TITLE: FIGURE 8.6 : Correlation between rainfall, spring discharge and production borehole abstraction

GETEKEN / DRAWN: P J Hobbs	DAT.	NAGESIEN / CHECKED	DAT.
NAGETREK / TRACED	DAT.	VERSLAG No / REPORT No: GH3502	GHP No.

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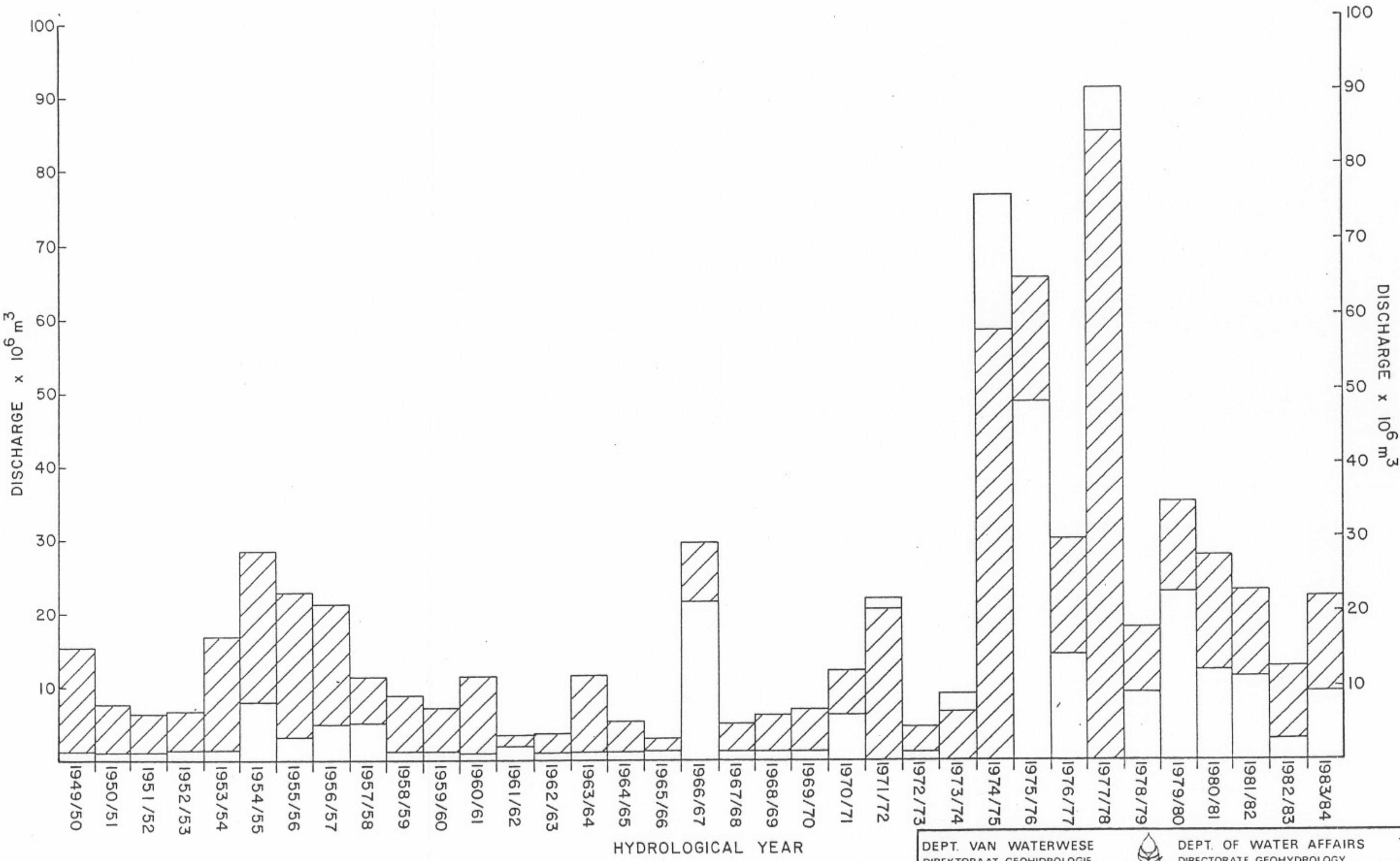

DEPT. VAN WATERWESE
DIREKTORAAT GEOHIDROLOGIE

DEPT. OF WATER AFFAIRS
DIRECTORATE GEOHYDROLOGY

TITEL / TITLE: FIGURE 8.7 :
Discharge of the Hennops River

GETEKEN / DRAWN: P J Hobbs	DAT	NAGESIEN / CHECKED	DAT.
NAGETREK / TRACED	DAT	VERSLAG No / REPORT No: GH3502	GHP No.

Ozalid 84/1799