THE EXPLORATION AND EVALUATION OF GROUNDWATER UNITS SOUTH AND WEST OF GRAAFF-REINET, CAPE PROVINCE, SOUTH AFRICA

Volume 1 : Text and Enclosures

by

ROGER PAUL PARSONS

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SYNOPSIS

The investigation reported in the thesis concerns an area south and west of Graaff-Reinet, in the Cape Province. The research project identified the existence of four groundwater units. The aquifers predominantly occur in Beaufort Group sediments and the boundary of each unit is formed by dolerite intrusives or with topographical highs. The objective of the study was to quantitatively assess these units in terms of both quantity and quality for possible future development as a municipal supply for Graaff-Reinet.

In order to achieve the objective, fieldwork was carried out involving a hydrocensus, geological mapping, drilling, aquifer testing and hydrochemical sampling. The analysis of these data revealed that the Sundays and Kamdeboo aquifer units are unsuitable for further development. The Moordenaars and Swart units, both of which produce good quality water, have a combined exploitation potential in the order of 30 000 m^3/d.

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CHAPTER 1

HYDROLOGICAL PROBLEM, BACKGROUND INFORMATION, AIMS AND HYPOTHESES

1.1 INTRODUCTION

Graaff-Reinet's major source of water is the Van Reynevelds Pass Dam, built in 1924. Because of droughts and ever increasing water demands the dam has proved to be an unreliable source of water. To alleviate the problem an emergency borehole scheme was developed in the alluvial basin north of the town. Recurring water shortages resulted in the progressive expansion of the well field to the present nine boreholes. A detailed geohydrological investigation of the alluvial basin by Woodford (1984) revealed that there is limited scope for further development of this source, principally owing to the deterioration of the groundwater quality.

The present investigation aims to identify, define and assess the potential of groundwater units south and west of Graaff-Reinet. The study area, which covers approximately 1800 km^2, is situated 220 km north of Port Elizabeth, Cape Province (Fig. 1) and includes:

a) the catchments of the Moordenaars and Swart Rivers.

b) the portion of the Kamdeboo River catchment below the confluence with the Kraai River.

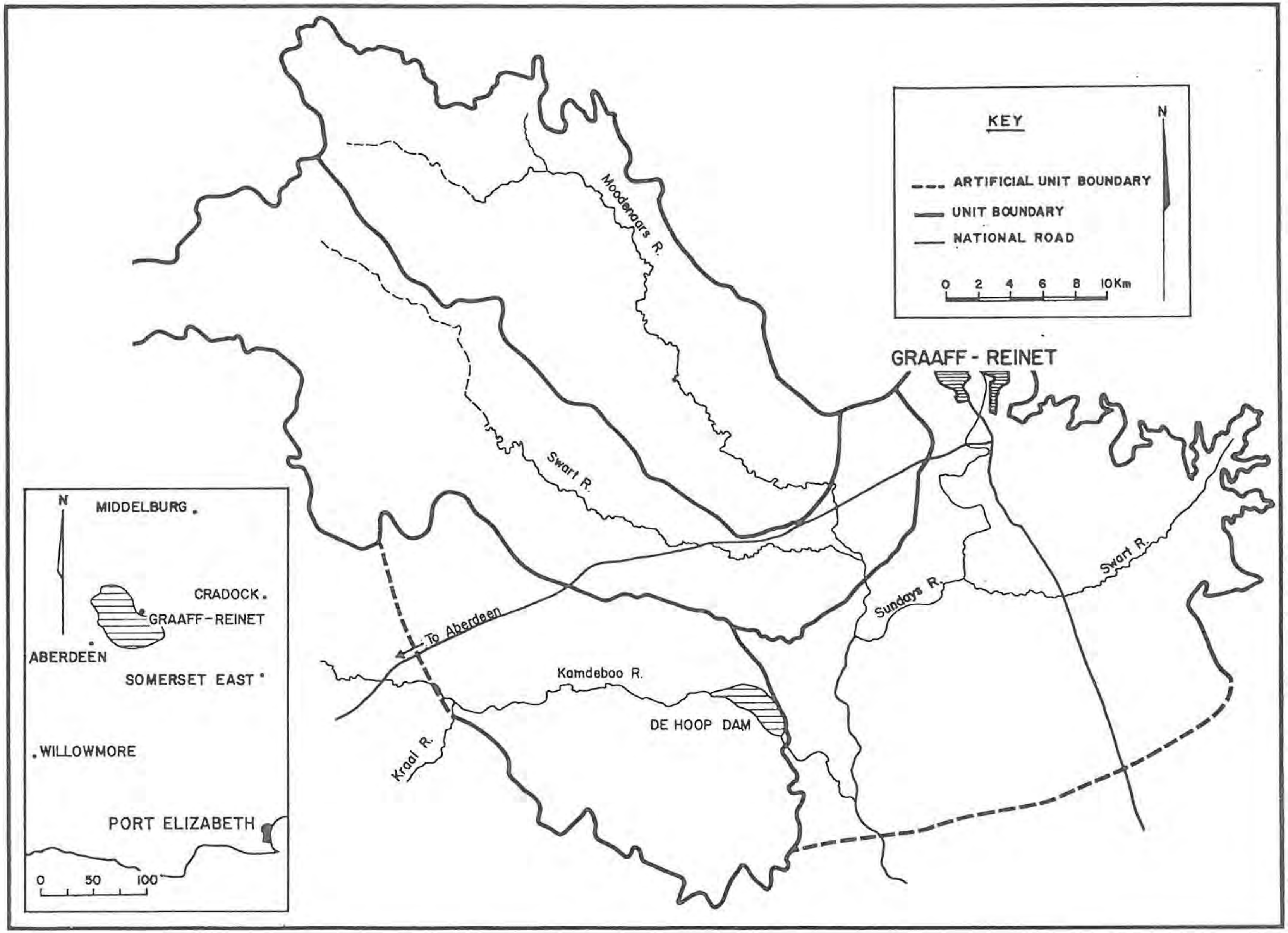


Figure 1: Regional and local location map of the investigation area.

c) the portion of the Sundays River catchment between Graaff-Reinet and Kendrew.

The delineation of each unit is discussed in section 3.1. The investigation will provide a quantitative assessment of the groundwater resources south and west of Graaff-Reinet. The data are required for the future planning of Graaff-Reinet's water supply.

1.2 THESIS STRUCTURE

The thesis has been structured in much the same sequence as the investigation was carried out. The hydrological problem and general background information pertaining to the investigation is presented in Chapter 1 together with the aims and objectives of the study. The study hypotheses are included in the initial chapter. Chapter 2 considers the theoretical aspects of the geohydrological techniques employed during the fieldwork phase of the investigation and presents the results of the hydrocensus, geological mapping, geophysics, drilling, aquifer tests and hydrochemistry survey. A detailed discussion of the geohydrology of the investigation area (Chapter 3) is followed by estimates of the exploitation potentials of the four groundwater units in the study area (Chapter 4). Chapter 5 examines whether the aims and objectives of the study have been fulfilled in addition to testing the validity of the hypotheses presented in Chapter 1. The final chapter (Chapter

6) deals with the conclusions and recommendations of the study.

1.3 THE HYDROLOGICAL PROBLEM

1.3.1 Graaff-Reinet's Water Supply

Prior to the construction of the Van Reynevelds Pass Dam in 1924, Graaff-Reinet obtained its water supply from springs (Mackies Pits) and, on a more sporadic basis, from the Sundays River. The erratic nature of the flow of the Sundays River prompted the decision to construct the dam, which was intended mainly for irrigation purposes. Because the dam would result in the flooding of the Mackies Pits, the following agreement was entered into by the Graaff-Reinet Municipality and the Van Reynevelds Pass Dam Irrigation Board (VRPDIB):

a) the Municipality had the right to maintain access to the Mackies Pits water supply by means of sealed canals.

b) the Municipality was entitled to draw a maximum of $9000m^3/d$ from the dam.

c) when the level of the dam fell to such a point that there was only storage for one years supply (at $9000m^3/d$), the drawing of water for irrigation purposes would cease (Ninham Shand, 1947).

After the completion of the dam in 1924, the quality of the water from the Mackies Pits deteriorated to such an extent that the water became unfit for human consumption (Vegter, 1947). In

1920 the quality of the spring water was 1080 mg/l TDS while in 1956, the total dissolved solid (TDS) content had increased to 3290 mg/l. The water was then only used for irrigation purposes and the sole source of water for the town became the Van Reynevelds Pass Dam.

At 23,75% reduction of dam storage capacity over a 29 year period as a result of sedimentation (van der Boon, pers. comm.), together with long drought periods, necessitated the development of the emergency borehole scheme. In 1957 two high yielding boreholes were used to supplement the dam water supply. The size of the well field was steadily increased to the present nine boreholes (Woodford, 1984). The maximum possible combined yield of the well field is 8500 m^3/d but, because of the limited capacity of the rising main, the well field can only deliver 5800 m^3/d. The emergency boreholes are only used to full capacity when the dam is empty. Woodford (1984) noted that during the last 30 years the quality of water obtained from the well field has shown a marked deterioration and at present, the TDS of this water exceeds 2000 mg/l.

1.3.2 Water Consumption and Future Requirements

A continual increase in population (Fig. 2) has resulted in a steady increase in water demand (Fig. 3).

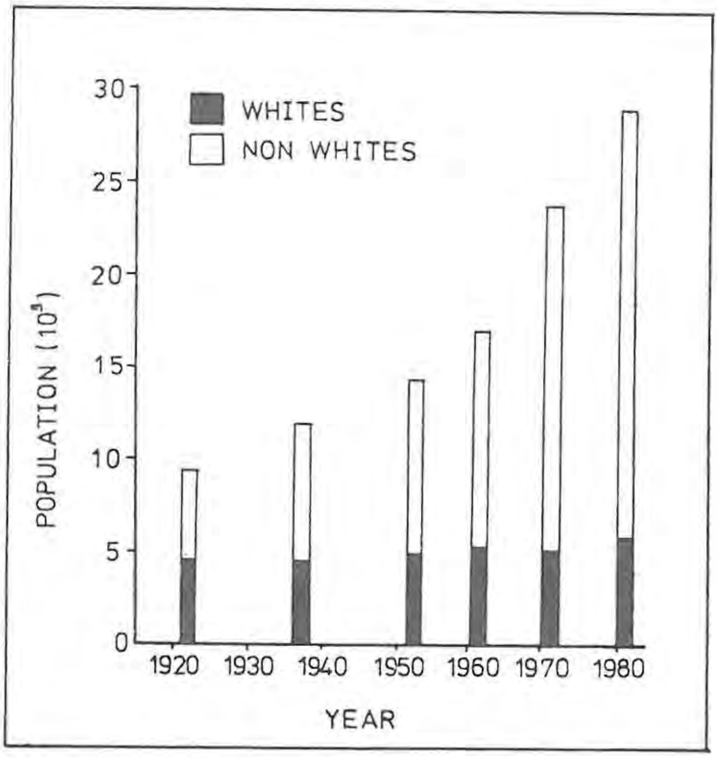


Figure 2: Graaff-Reinet's population 1920 - 1980 (After Woodford, 1984)

Woodford (1984) attempted to estimate the future water requirements for Graaf-Reinet (Table 1). He took into account the expected population trends as well as an anticipated improvement in the standard of living of the non-white population. Based of these estimates, the following is evident:

a) during drought periods, the present emergency borehole scheme cannot meet peak daily demand.

b) by the year 2003, the well field will need to be in continual use unless the 1924 agreement between the municipality and the VRPDIB is modified.

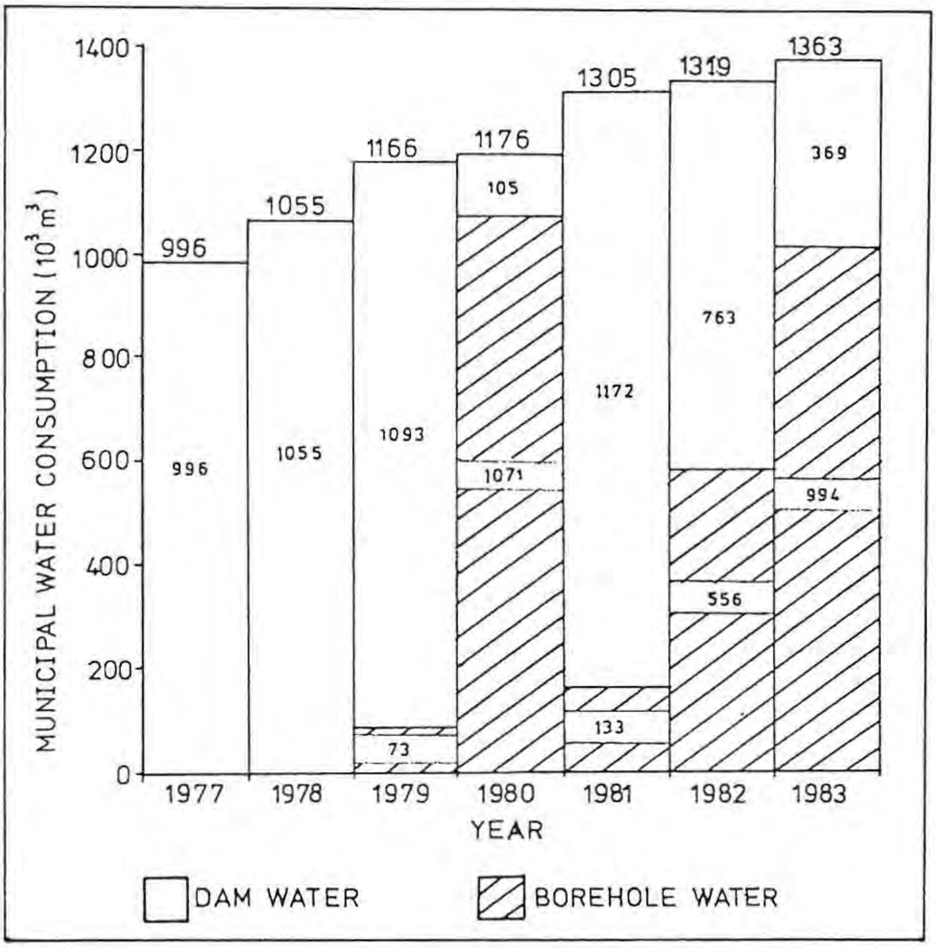


Figure 3: Graaff-Reinet's water consumption 1977 -1983 (After Woodford, 1984)

The general lowering of the groundwater level by 10m in the vicinity of the well field during periods of prolonged abstraction (Marx, pers. comm.) and the continual deterioration of the groundwater quality are also worrying factors when assessing the long term water supply for Graaff-Reinet.

Table 1: Expected population and water consumption trends for Graaff-Reinet (After Woodford, 1984).

YEAR	1983					2003					2023				
	POPULATION		CONSUMPTION			POPULATION		CONSUMPTION			POPULATION		CONSUMPTION		
		PER CAPITA ℓ/p/d	YEARLY $10^6 m^3$	DAILY m^3/day	PEAK m^3/day		PER CAPITA ℓ/p/d	YEARLY $10^6 m^3$	DAILY m^3/day	PEAK m^3/day		PER CAPITA ℓ/p/d	YEARLY $10^6 m^3$	DAILY m^3/day	PEAK m^3/day
WHITE	6 000	446	0,96			6 500	500	1,17			7 000	520	1,32		
COLOURED	14 800	71	0,38			17 200	120	0,75			20 000	160	1,17		
BLACK	8 400	15	0,05			12 400	80	0,36			16 000	120	0,70		
TOTAL	29 200		1,39	3 808	6 093	36 100		2,32	6 356	10 170	43 000		3,19	8 740	13 984

1.4 BACKGROUND INFORMATION

1.4.1 Previous Work in the Graaff-Reinet Area

The lack of reliable water supplies for Graaff-Reinet has necessitated an ongoing search for further resources. A number of reports deal specifically with work conducted in the alluvial basin north of the town which includes the present emergency supply scheme: Vegter (1947, 1957); Joubert (1956, 1972, 1980, 1982); Ninham Shand (1956); Kok (1974) and Woodford (1984). In addition, Ninham Shand (1947, 1982) compiled reports that investigated the then municipal supply, estimated future requirements and alternative supply schemes. The latter report recommended that a detailed, large-scale geohydrological investigation be undertaken.

The following reports are of specific importance to the present investigation:

a) Buchanan (1970) conducted a pilot geohydrological study in the Graaff-Reinet area and recommended that further work be carried out.

b) In response to the work by Buchanan, De Bruin (1972) conducted a large-scale borehole survey in the vicinity of Graaff-Reinet. The report lists all the geohydrological data collected during the survey and contains rough geological maps based on aerial photographic studies. The occurrence of groundwater is discussed in terms of yield and water quality. De Bruin suggested that water for Graaff-Reinet could be obtained from a number of areas, including the following farms in the present study area (see Enclosure 1): i) Swart River Valley - Fertility 315, Uitkomst 314, Krugers Kraal 322 and Doordrift 323; ii) Kamdeboo River Valley - Oudedrift A133, Groote Vlakte 132 and possibly Louws Kloof 136; iii) Sundays River Valley - De Hoop 436.

c) Venables (1983) reported on the occurrence of sulphur-rich artesian groundwater on the farm Groote Vlakte 132. A north-south trending dolerite dyke on the farm Oudedrift A133 was presumed to be the cause of the artesian conditions while the sulphur content was thought to be derived from the breakdown of sulphides in the dolerite with a possible contribution of sulphates (notably gypsum) in the mudstones.

d) Woodford (1984) conducted a detailed geohydrological investigation in the alluvial basin north of Graaff-Reinet which showed that: i) the volume of water stored in the alluvial aquifer (Graaff-Reinet aquifer) upstream of the dam is 27,0 x 10^6 m^3. The exploitation potential of the aquifer is 9300 m^3/d but the quality of the water is not fit for direct human consumption; ii) important groundwater units within the Beaufort Group sediments of the study area are associated with dolerite intrusions. Two dyke aquifer units, the Welgevonden and Perries units, were identified. The safe yields of these units are about 380 and 480 m^3/d respectively. Both aquifers produce good quality water (TDS less than 1000 mg/l). Woodford also noted that the deterioration of groundwater quality may, amongst other factors, be related to irrigation practises.

1.4.2 Climate and Physiography

As the study area lies at the base of the South African escarpment, two distinctive morphologies are recognised, namely the mountainous region to the north and north-west and broad, flat plains to the south (Encl.1, topographical map). The mountain peaks are generally capped by dolerite sheets and rise to an elevation of almost 1600 m above mean sea level. The plains are dissected by three gently dipping ring structured dolerite sheets. The average elevation of the plains is 680 m above mean sea level.

The climate in the Graaff-Reinet region is semi-arid with most of the rainfall occurring in the summer months as heavy downpours. Some of the winter precipitation on the escarpment comes in the form of snow. The rainfall of the area is erratic (Fig. 4). The thirty year average precipitation for six stations within and near the boundaries of the study area is presented in Table 2. The slopes of the escarpment generally receive a slightly higher rainfall than lower lying areas.

The local vegetation of the study area was classified by Acocks (1975) into two basic veld types. The plains are covered by

False Upper Karoo while the vegetation of the higher lying areas is of the False Karroid Broken Veld type.

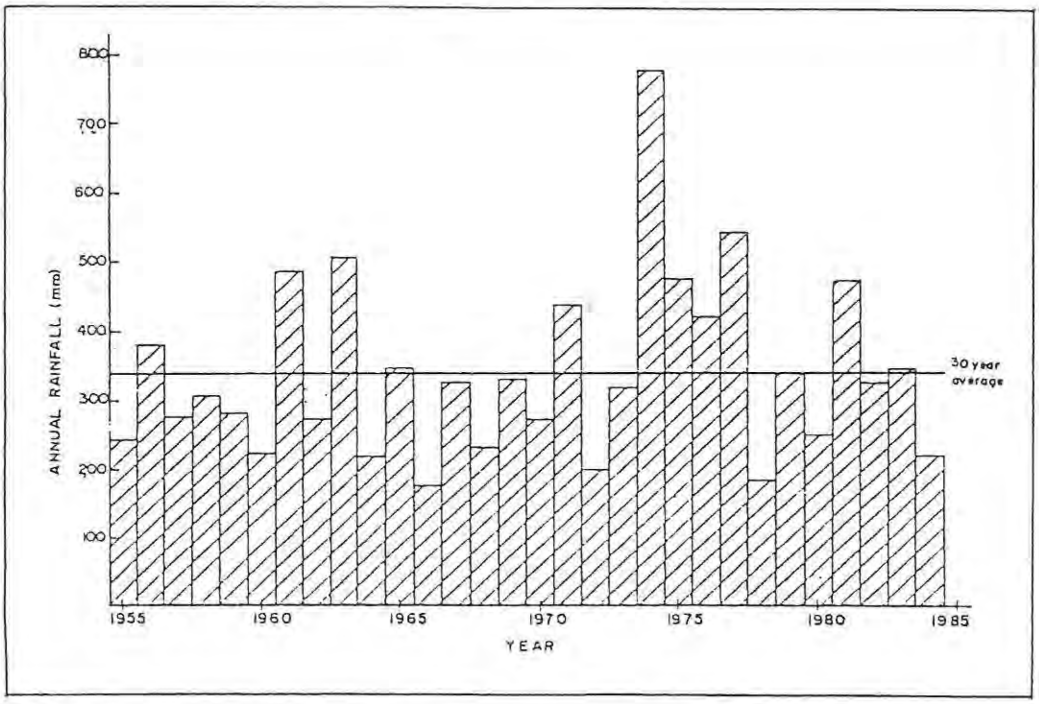


Figure 4: Thirty year rainfall record of the farm Krugers Kraal 332, Graaff-Reinet

The area under investigation falls into drainage subregion 1313 (Moordenaars River, Swart River and Sundays River) and partly in subregion 1314 (Kamdeboo River). The orientation of the drainage channels is influenced by the geology of the area and is in a southerly to south-easterly direction. The ephemeral

Table 2: Thirty year average precipitation at six stations in the area between Graaff-Reinet and Aberdeen.

STATION (CADASTRAL FARM)	ELEVATION (m)	30 YEAR AVERAGE RAINFALL (mm)
ABERDEEN	730	293
KRUGERS KRAAL 322	745	368
RATELSFONTEIN 329	730	323
VAN REYNEVELDS PASS DAM	770	317
DE VREDE 286	910	386
VAN DER WALTS HOEK 179	910	331

rivers only flow after substantial rainfall events, usually in the summmer. The run-off from the catchments however is greatly reduced by a number of farm dams and weirs that have been built across the main rivers. The De Hoop dam was last full in March 1974 and has only contained water three times since.

1.4.3 General Geology

The geology of the investigation area comprises of Beaufort Group sediments, Karoo dolerite intrusives, alluvial and colluvial deposits and surface limestone.

1.4.3.1 Beaufort Group Sediments

The relevant part of the stratigraphy of the Karoo Sequence is outlined in Table 3. The sediments of the Middleton Formation and lower members of the Balfour Formation outcrop in the study area.

Table 3: Part of the stratigraphy of the Karoo Sequence

PERIOD	SEQUENCE	GROUP	SUB-GROUP	FORMATION
TRIASSIC 225 Ma	KAROO	BEAUFORT	TARKASTAD	KATBERG
			ADELAIDE	BALFOUR
				MIDDLETON
				KOONAP
PERMIAM		ECCA		

(S.A.C.S., 1980)

The Middleton Formation consists of a sequence of cyclic deposits each commencing with a lenticular body of sandstone at the base. The sequence fines upwards into greenish-grey mudstones, while red mudstones are found in places. The Formation represents a typical fluviatile depositional sequence. At the base of the major cycles, the sandstones reach a thickness of 10 to 15 m and a lateral extent of a few hundred meters (S.A.C.S., 1980). Towards the top of the Formation the sandstone units attain a maximum thickness of 30 m.

The boundary between the Middleton Formation and the Balfour Formation is generally considered to be the laterally extensive arenaceous Ouberg Sandstone Member. Sandstones comprise approximately 70% of this unit which has a maximum thickness of 9 m in the Graaff-Reinet district (Tordiffe, 1978). The argillaceous Daggaboersnek Member, conformably overlies the Ouberg Sandstone Member.

The deposition of the Beaufort Group sediments can be regarded as a continuation of the infilling of the Karoo Basin, but differs from the deposition of the Dwyka and Ecca Groups in that it was deposited under fluviatile conditions. Three periods of major tectonic activity are recognised in the Beaufort Group sediments. The first period, which coincided with the first pulse of the Cape Orogeny (140 Ma) resulted in the rapid deposition of the Ouberg Sandstone Member over a vast but flat area. The tectonic activity also resulted in the gentle folding of the sediments south of Graaff-Reinet. The trend of the fold axes is east-west. Both Tordiffe (1978) and Woodford (1984) found that the principal joint and fracture orientation is north-south. A secondary but still prominent east-west joint set is also present.

1.4.3.2 Karoo Dolerite

The injection of Karoo dolerites into the Beaufort Group sediments during the early to mid-Jurassic resulted in the formation of dyke, sill and sheet structures (Truswell, 1977). The dykes vary in thicknesses from a few centimeters to several meters and have an average length of 1 km. The dykes tend to be vertical to near vertical while the orientation of the sheet and sill structures is more complex - varying between horizontal, evenly inclined and undulating. The sills and sheets may reach thicknesses in excess of 300 m. An important feature of the Karoo intrusives is the alteration of the nearby country rock, which may result in the alternation of the country rock's porosity and permeability. The extent of alteration is, amongst other factors, dependent on the size of the intruding body and the nature of the surrounding sediments. Radiometric dating of the Karoo dolerites have yielded ages ranging from 150 to 190 Ma (S.A.C.S., 1980).

1.4.3.3 Superficial Deposits

These deposits include alluvial and colluvial sediments and surface calcareous evaporite deposits. The in-situ colluvial deposits are derived from the weathering and erosion of country rocks and usually occur as pediment close to the mountains. It is estimated that these very localized deposits may reach thicknesses in excess of 50 m. The alluvial deposits which consist of clays, fine sands, pebbles and boulders, are generally confined to a strip near the drainage channels.

Calcareous deposits are found in the study area but are very localized and thin. These deposits tend to be associated with dolerite or areas which have or have had a shallow water table or piezometric surface.

1.5 AIMS AND OBJECTIVES

The principal objective of the study is to identify and assess the groundwater resources south and west of Graaff-Reinet, in terms of both quantity and quality, for possible future development as a municipal water supply.

The specific aims are:

a) to identify and define the major aquifer within the study area in terms of lithology, geometry and extent.

b) to define the hydraulic properties of the major water - bearing formations in terms of flow regime, storage and recharge.

c) to identify the principal factors controlling groundwater chemistry.

1.6 HYPOTHESES

In order to provide a scientific framework for the investigation a number of hypotheses have been formulated. These are based on previous Karoo groundwater investigations and on theoretical geohydrological concepts.

1. The major transmissive zones within the groundwater units are associated with fractured sandstone horizons.
2. Together with sandstones, interbedded siltstones and mudstones of low permeability form laterally extensive storage zones.
3. The fractures and joints have a low storativity.
4. Hydraulic continuity exists between the alluvial deposits and the consolidated sandstones, siltstones and mudstones.
5. The secondary nature of the groundwater units leads to anisotropic geohydrological conditions.
6. The principal recharge areas are located in the higher lying areas.
7. Good quality water is associated with recent recharge.
8. None of the groundwater in the study area is polluted.

CHAPTER 2

METHOD OF INVESTIGATION AND RESULTS

2.1 HYDROCENSUS

An often underrated phase of a regional geohydrological investigation is the hydrocensus or borehole survey. By developing groundwater supplies, the local farming population has provided a large number of sampling points from which data relating to groundwater conditions can be obtained. "The collection of this data will form the basis for a good working knowledge of the physical principles governing the movement and storage of groundwater.," (Walton, 1970, page 56). All data pertaining to water supply, from both surface asnd subsurface sources, was collected and analysed before the start of the main phase of the investigation. Much of the project planning was based on this early data. The region investigated is indicated on Enclosure 2. Only a few plots in Adendorp were visited as most of the landowners could not easily be contacted.

2.1.1 Data collection and results

The hydrocensus itself was conducted in two phases:

a) a detailed borehole inventory and

b) the collection of data concerning land and water usage.

Both components continued until the end of the fieldwork and the data were continually checked and updated. The data were supplied by the farmers in the region and hence may not be entirely accurate.

During the borehole inventory the following particulars were recorded:

- borehole location (Encl. 1)
- borehole depth
- borehole yield
- piezometric level (Encl. 3)
- water conductivity (Encl. 4)
- type of pumping equipment installed
- lithology and depth of water interceptions

The inventory data are presented in Appendix 1a.

The second component of the hydrocensus concerned the collection of detailed data with respect to land and water use. The data were required to verify the annual abstraction figures as well as to help explain large variations in water quality. This work was not conducted in the Sundays River Valley owing to time and budget constraints. The data obtained are presented in Appendix 1b, while fertilizer application data are presented separately in Appendix 1c. The data were used to construct a land and water use map (Encl. 2).

Since the beginning of January 1985, the hydrocensus also included monthly measurements of piezometric levels in a selected number of boreholes (Encl. 5). The aim of these measurements was primarily to record the response of the piezometric level to rainfall events. However, the record is short (January 1985

- August 1985) and it would be extremely difficult to try and calculate a recharge estimate on the basis of these data. In general terms, the piezometric level of boreholes in the plains did not usually rise more than 0,5 m over the 6 month measuring period. The response to rainfall of the piezometric level of boreholes in areas of lower permeability and porosity was, in some cases, greater than 2 m.

Some relevant hydrocensus statistics are presented in Tables 4, 5, 6 and 7.

In addition to the abstraction data presented in Table 6, it was estimated that approximately 30 engine-driven pumps were in use in the Adendorp Allotment Area. Assuming an average pumping rate of 5 l/s and an average pumping regime of 5 hours a day then the estimated annual abstraction for the Adendorp area is 980 000 m^3/year, say one million m^3/year.

Table 4: Number and nature of boreholes

CATCHMENT	EQUIPMENT			TOTAL
	Windpump	Engine	Open	
MOORDENAARS	82	15	17	114
SWART	84	27	22	133
KAMDEBOO	95	54	39	188
SUNDAYS	105	30	12	147
TOTAL	366	126	90	582

Table 5: Yield distribution of boreholes (%)

YIELD ℓ/s	CATCHMENT				TOTAL
	MOORDENAARS	SWART	KAMDEBOO	SUNDAYS	
< 5	92,9	69,2	64,4	68,7	72,2
5 - 9,9	4,4	15,8	13,3	15,0	12,5
10 - 14,9	0,9	7,5	13,8	9,5	8,7
> 15	1,8	7,5	8,5	6,8	6,5

Table 6: Estimated annual abstraction

CATCHMENT	m^3/yr	%
MOORDENAARS	397 000	3,6
SWART	2 787 000	25,5
KAMDEBOO	4 550 000	41,6
SUNDAYS	3 210 000	29,3
TOTAL	10 944 000	100,0

Table 7: Fertilizer application in the study area

Fertilizer	Application tons/year
gypsum	2 080
ammonium sulphate	660
urea	75
super phospate	375

2.2 GEOLOGICAL MAPPING

Groundwater flow regimes are dependent on geological conditions and topography (Allen and Davidson, 1984). The intrinsic permeability of lithologic units in primary aquifers is of great importance in the movement and storage of groundwater. However, during cementation and compaction of sediments, the pore spaces are commonly reduced to a fraction of their original size (Earl and Meiser, 1984), rendering the potential of primary aquifers low.

The creation of secondary hydraulic properties by either weathering,sediment compaction or by igneous or tectonic activity enhances the hydraulic potential of indurated sediments. The size, frequency and orientation of fractures has a large influence on the recharge, storage, movement and yield of fractured rocks. Based on the earlier geological discussion (section 1.4.3), it was expected that structural geological mapping would provide valuable information in the investigation. The interpretation of aerial photographs and LANDSAT imagery was particularly useful in this regard.

2.2.1 Data Collection and Results

Initially a provisional 1:50 000 geological map and a 1:10 000 photo-geological map, obtained from the geological survey and Southern Oil Exploration Corporation (SOEKOR) respectively, were used as a geological framework for fieldwork. Both maps lacked sufficient and accurate structural data. The basic surface geology was therefore remapped and particular attention was paid to the structural geology of the area (Encl. 6, geological map). Structural mapping revealed that the joint and fracture orientation in the area is in accordance with that found in other parts of the Karoo (Tordiffe, 1978; Vandoolaeghe 1980). A rose diagram of joint and fracture orientations is presented in Figure 5.

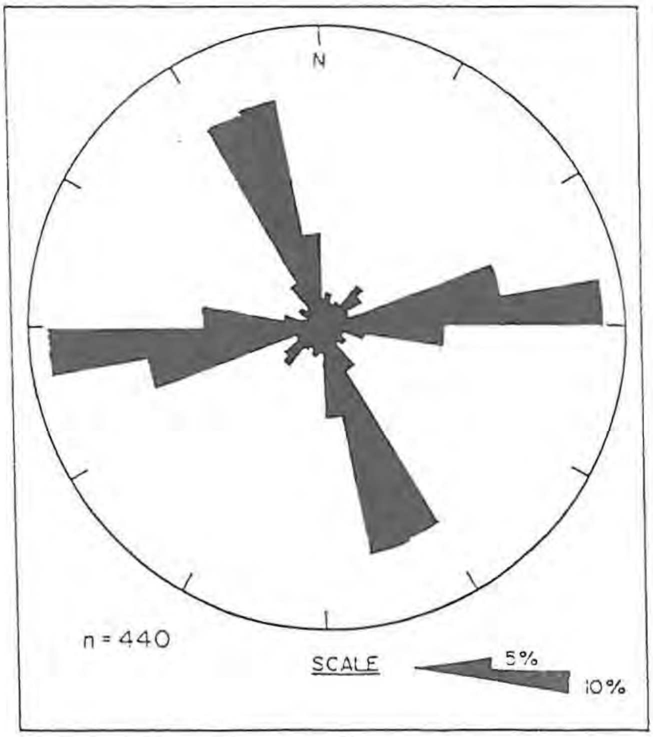


Figure 5: Rose diagram of joint and fracture orientations.

2.3 GEOPHYSICS

The geophysical work consisted of magnetics, geo-electrical profiling (CESP), vertical electrical sounding (VES) and geophysical borehole logging. Except for the magnetic work, the geophysical programme coincided with the drilling and aquifer test phase of the exploration work.

2.3.1 Magnetics

2.3.1.1 Magnetic Theory

A high concentration of magnetic minerals results in a local magnetic field which is superimposed on that of the Earth's. By measuring and recording the local departure from the earth's magnetic field, magnetic bodies may be located. The size of departure or anomaly is dependent on the depth of burial, degree and directions of magnetism as well as the attitude and size of the body in relation to the direction of the earth's field at that locality (Roux, 1979).

Magnetic minerals, such as magnetite, result in dolerite having a magnetic nature. Structural features may also result in a disturbance of the earth's total magnetic field. Davis and De Wiest (1966) note that the use of magnetometers is a rapid and inexpensive form of locating such features. Care however has to be taken when working near man-made magnetic structures such as borehole casing and fences.

2.3.1.2 Data Collection and Results

A total of 54 000 m of magnetic traverses were run using the Geometrics instrument. Most traverses were of a reconnaissance nature (position of traverses indicated on Encl. 7). The aim of the work was to trace dolerite dykes indicated on the provisional 1:50 000 geological map. Many of the dykes indicated were in fact old farm roads or fences. Only the most relevant magnetic data have been included in this report (appendix 2a).

The dolerite dykes gave fairly good positive anomalies (e.g. magnetic traverses B.1 and E.10), but the magnetic data of traverses across the sheets was of little use for dip and thickness determination. However, magnetic traverse A.8 was used to determine the dip of the southernmost sheet on the farm Zeekoeigat 133. The results of the interpretations of six magnetic traverses are presented in Table 8.

Table 8: Results of the interpretation of six magnetic traverses

TRAVERSE NO	TOTAL MAGNETIC FIELD (nT)	MAGNETIZED BODY	WIDTH OF BODY (m)	DIP OF STRUCTURE
A.8	28 140	0,002	12-15	40° E
E.10	28 240	0,001	4,5	88° W or 88° E
E.11	28 240	0,0008	7,5	87° W or 87° E
E.12	28 235	0,0006	5,0	70° W
H.1	28 070	0,003	2,5	55° SW
J.2	28 055	0,00003	-	0°

A number of traverses were carried out over lineaments in order to determine their exact location. Examples of work conducted over the Brooklyn fracture (H.3, H.4 and H.6) and Vorster syncline (J.1, J.2 and J.3) are included in Appendix 2a.

The results of the magnetic work did not indicate the fracture location. Where an anomaly was obtained, interpretation suggests that the anomalies resulted from a concentration of ferromagnetic minerals near the surface or close to the water-table.

2.3.2 Resistivity

2.3.2.1 Resisitivity Theory

The drilling of boreholes for the purpose of obtaining subsurface information is usually expensive and time consuming. The use of electrical resistivity surveys provides a relatively inexpensive and rapid alternative to obtaining such data. Work by Van Zyl (1967), Worthington (1978) and Van der Westhuizen (1983) has proved the worth and applicability of resistivity techniques in South Africa. However, extensive resistivity work by B.R.G.M. (1978) and Vandoolaeghe (1978, 1980) in Karoo sediments indicated that, owing to poor electrical contrasts, the method has a limited application in such geological terrains. Woodford (1984) working in the alluvial basin north of Graaff-Reinet, used the resistivity technique with some success in defining the depth to bedrock. Based on these findings, it was decided that limited resisitivity work would be conducted and if successful, this phase of the work would be extended. The vertical electrical sounding technique (VES) was used to determine alluvium thickness and locate arenaceous units while the fracture zones were pinpointed with the aid of a constant electrode spacing technique (CES).

The concept of resistivity is based on Ohm's Law which states that:

$$R = V.I$$

where R = resistance (Ω)

V = potential difference (V)

I = current strength (amps)

Resistivity can be mathematically defined as:

$$\rho = \frac{R.A.}{L}$$

where ρ = resistivity (Ω.m)

A = area (m^2)

L = length (m)

Each lithological unit has a characteristic range of resistivity. For example, Lloyd (1981) states that the characteristic resistivity of sandstones ranges between 80 Ω.m and 1200 Ω.m while that of shales ranges between 1 Ω.m and 150 Ω.m. Besides being a function of rock type, resistivity is also a function of rock porosity, hardness, the chemistry of the fluid present and the degree of saturation or a combination of these factors.

It is impossible to measure the true resistivity of a subsurface formation when measurements are recorded at the surface. Instead, apparent resistivity, which is "a measure of the effects of all the layers between the maximum depth of penetration and the surface", is recorded (Bouwer, 1978, page 285). True resistivity is later determined by interpretation.

The Schlumberger technique requires that the current electrodes (AB) are moved progressively outwards while the distance between the potential electrodes (MN) remains fairly constant. The AB spacing is always kept at least five times greater than the MN spacing (Walton, 1970). By increasing the AB spacing, the depth of current penetration increases while the MN electrode spacing is increased slightly in order to reduce local inhomogeneous effects. Apparent resistivity (ρa) is calculated by:

$$\rho a = K . \frac{V}{I}$$

where K = constant

The constant is a function of the electrode configuration. By plotting pa against AB/2 and comparing the field curve to a set of master curves, the Dar Zarrouk parameters (T and S) can be determined:

$$T = h.\rho$$

where T = transverse resistance

h = layer thickness

$$S = h/\rho$$

where S = longitudinal conductance

Once the above parameters have been determined, true resistivity and layer thickness can be caluclated (Smith, 1982). Owing to the effects of equivalence and suppression, difficulties are often encountered during interpretation. The principle of equivalence applies where a formation is neither resistive nor conductive in relation to the overlying or underlying layers while the principle of suppression applies where a formation possesses an intermediate resistivity in relation to the overlying or underlying layers. These two principles are thought to be the cause of the poor resistivity results obtained by B.R.G.M. (1978) and Vandoolaeghe (1978, 1980) which were discussed earlier in the chapter.

The CES profiling technique requires that the electrode spacing remains constant and the whole configuration moves in the same direction. The depth of current penetration theoretically remains constant and the lateral changes in resistivity are recorded. The interpretation is usually qualitative (Van der Westhuizen, 1983) but the order of magnitude of ρa can be determined. The CES profile technique is particularly useful in defining vertical structures such as faults or fractures.

2.3.2.2 Data Collection and Results

2.3.2.2.1 Constant Electrode Spacing Profiles

A total of 14 CES profiles, each averaging 1200 m in length, were conducted in a further attempt to accurately define the location of lineaments as well as to try and determine the attitude of the linear features (Appendix 2b). The results were generally disappointing as in some places an anomaly was obtained but elsewhere on the same feature, no anomaly was recorded. A good example of this is the work conducted over the Brooklyn fracture (CESP 1.1, 1.2, 1.9, 1.10, 1.11, 1.12 and 1.13). The profile positions are indicated in Enclosure 7.

It would be expected that any fracture could be distinguished by a lower resistivity than the surrounding country rock owing to deeper and more extensive weathering in the fracture zone. Two anomaly types were recognised:

a) a negative anomaly - the anomaly is principally governed by lower resistivities resulting from preferential weathering
b) a positive anomaly - the resistivity values basically reflect the low conductance of the saturating fluid where fracture zones can be considered as preferential zones of groundwater transport. The quality of the water in such zones is better than in the unfractured surrounding sediments.

A third anomaly, resembling a straight line, was also obtained. In this case the lower resistivity of the fracture zone may be compensated by the higher resistivities resulting from better quality water associated with the fracture. The compensation phenomena resulted in the CES profiling technique not being conclusive in demarcating fracture zones in the Graaff-Reinet district.

2.3.2.2.2 Vertical Electrical Soundings

A traverse consisting of 10 VES stations was conducted across the Swart River valley on the farms DOORDRIFT 323 and KLIPDRIFT 426 (position of traverses indicated on Encl. 7). The Schlumberger array was employed. Geological logs and geophysical borehole logging data of five boreholes were available for calibration purposes. No acceptable degree of accuracy could be obtained in the correlation between actual alluvium thickness and interpreted thickness (Fig. 6).

Two further soundings were conducted in areas with thick alluvial deposits (G 33346, DT 101). Again, no correlation could be obtained. It is interesting to note that a number of soundings indicated changes in resistivity in the vicinity of the watertable. As no useful information was obtained from the exercise, the resistivity work was terminated.

2.3.3 Geophysical Logging

Drilling is the only means of direct access to the subsurface. The description of borehole lithology by means of geological samples is usually subjective and based on point source mea-

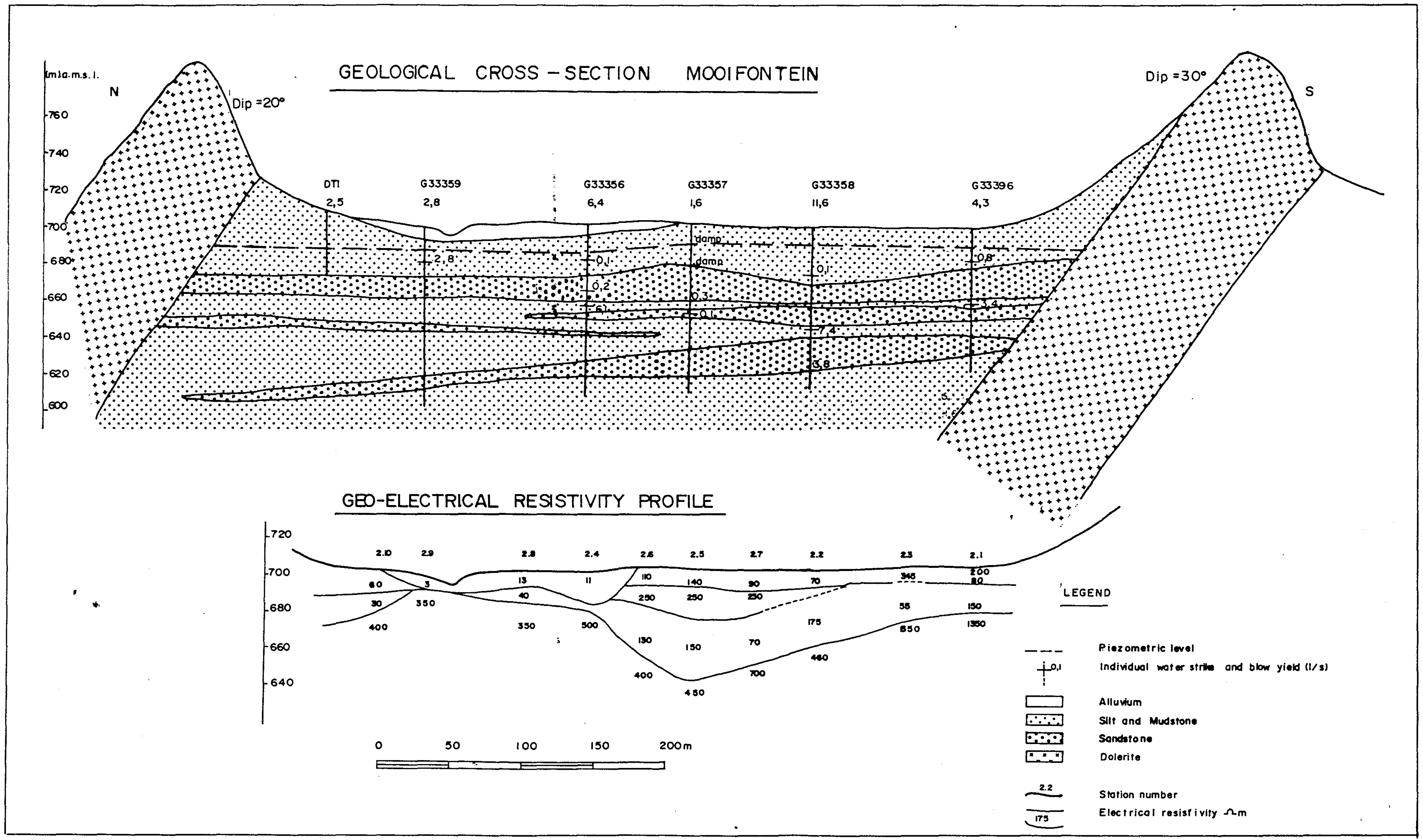


Figure 6: Geological cross-section and resistivity profile on the farms Doordrift 323 and Klipdrift 426 (borehole positions indicated on Encl. 6).

surement. The use of geophysical logging techniques removes subjectivity, is constant, available for reinterpretation and provides continuous data (Keys and McGary, 1976). By lowering a sensing device into a borehole and measuring a variety of physical parameters, the following can be determined or deducted.

a) lithological identification and correlation

b) borehole construction and geometry

c) water level and well dynamics

In addition, the electrical logs may be used to correlate surface electrical resistivity data. Unfortunately, much of the interpretation only provides qualitative data (Lloyd, 1981). However, the power of geophysical logs lies in the combined use and interpretation of the various log types. Where applicable, the lithological borehole logs were corrected with the aid of data obtained from the geophysical logs.

2.3.3.1 Data Collection and Results

Forty three project boreholes and three private wells were logged with a Mount Sopris geophysical logger. The statistics of the geophysical logging programme are presented in Table 9. The application of the various geophysical logs was limited as very little quantitative data could be obtained. However, the down-the-hole logging did assist in the following:

a) correction of sample descriptions

b) refinement of geological logs : - depth of weathering

- changes in lithology

Table 9: Statistics of geophysical logging programme

	γ	γ-γ	N-N	ρ	R	SP	Wρ	T	Cal
Number of runs	46	34	14	25	43	25	42	42	42
Total run length (m)	3320	2514	9353	1674	3063	1674	3073	3073	3005
Average run length (m)	72,2	73,9	68,1	67,0	71,2	67,0	73,2	73,2	71,5

- depth of water interception
- depth of casing

The short normal resistivities and natural gamma counts for the different lithologies encountered are presented in Table 10.

Table 10: Values obtained from the natural gamma and short normal resistivity logs

LITHOLOGY	γ cps	ρ Ω.m
medium to fine-grained sandstone	85-95	350-700
fine-grained sandstone	95-115	-
siltstone	120-140	170-400
mudstone	150-180	100-200
dolerite	10-20	1000-3700

2.4 Drilling

2.4.1 Drilling Theory

The absence of any proven geophysical exploration method to differentiate between lithological units and to pinpoint fracture zones in the given geohydrological environment, plus a widespread albeit thin alluvial and soil cover, necessitated an extensive drilling programme. Johnson (1980) maintains the surest way to learn the character of the formations beneath the earth's surface is to drill through them, obtain samples while drilling and record a log of the borehole. The chief aims of the drilling phase of the project were:

a) to determine the occurrence, geometry and nature of water-bearing formations (exploration boreholes)

b) to determine the hydraulic characteristics of the aquifer units (test and observation boreholes).

However, as drilling usually proves to be one of the most expensive phases of a geohydrological project (Lloyd, 1981), the following data were carefully collected in order to obtain as much information as possible from each borehole:

a) geological samples (taken at 1m intervals)

b) depth, yield and electrical conductivity of each water interception

c) full hydrochemical samples (taken on completion of selected boreholes).

The optimum drilling depth obviously varies from region to region and is dependent on the geology of the area. "Many authors have pointed out that the permeability of fractured rock decreases with depth and that there is an optimum depth at which unsuccessful wells should be abandoned" (Read, 1982, page 191). Based on the findings of Vandoolaeghe (1980) and Woodford (1984), both working in Karoo geological environments, it was expected that not many boreholes would be drilled deeper than 60 m.

A rotary percussion air drill was used to carry out the drilling requirements. This type of drill is most suited to hard-rock formations (Johnson, 1980) and is advantageous in that the yield of a borehole can be continuously estimated during drilling operations. However, the electrical conduction measurements reflect the "average" quality of the borehole water and not necessarily the quality of each individual water strike.

2.4.2 Data Collection and Results

Fifty boreholes were drilled between 05.11.1984 and 13.08.1985 by rotary percussion air drill. The positions of the project boreholes are shown in Enclosure 8. The initial reason for the drilling of each borehole is presented in Table 11. However, a number of the exploration boreholes were later used for test and observation purposes.

The statistics of the drilling programme are presented in Table 12. Four boreholes had to be scrapped after collapsing as a result of insufficient casing or poor construction, (G 33350,

Table 11: Initial reason for the drilling of project boreholes

EXPLORATION BOREHOLES A. General exploration boreholes G 33340, G 33341, G 33342, G 33343, G 33344, G 33346, G 33347, G 33352, G 33353, G 33354, G 33356, G 33357, G 33358, G 33359, G 33363 B Geological exploration boreholes i) Dolerite related exploration boreholes G 33337, G 33338, G 33339, G 33345, G 33348 G 33349, G 33350, G 33351 ii) Structural related exploration boreholes G 33360, G 33396, G 33399, G 33400, G 33401, G 33403, G 33405, G 33406, G 33407, G 33411, G 33412, G 33413
TEST AND OBSERVATION BOREHOLES A. Standard tests G 33355, G 33361, G 33362, G 33364, G 33402, G 33404, G 33408, G 33409, G 33410 B. Multiple piezometer tests G 33365, G 33393, G 33394, G 33395, G 33397, G 33398

G 33361, G 33363 and G 33364). Excluding the abandoned wells, the average drilled depth was 76,3 m and the average length of casing inserted was 15,5 m. The drilling and geohydrological details of each borehole are presented in Appendix 3.

Table 12: Drilling depth and casing statistics

	Borehole diameter (mm)	
	165 mm	200 mm
Total drilled depth	3526 m	104 m
Total casing used	676 m	50 m
Meterage of scrapped wells	120 m	-

Two important relationships were established from a synthesis of the drilling data:

a) the depth - water interception - yield relationship

b) the lithology - water interception - yield relationship

The cumulative percentage frequency diagram (Fig. 7) clearly indicates that the optimum drilling depth is in the order of 60 m. Ninety percent of all water interceptions were obtained above this depth. The histogram (Fig. 8), showing the depth - water interception - yield relationship also indicated the following:

a) the bulk of the water interception occured at shallow depths (0 - 20 m) but individual yields were low.

b) the greatest yield were obtained between 30 m and 55 m below piezometric level.

c) an increase in depth does not necessarily mean an increase in yield. It should be noted that the water interceptions struck at 100 m below piezometric level occurred in two boreholes 80 m apart on the farm UITKOMST 314.

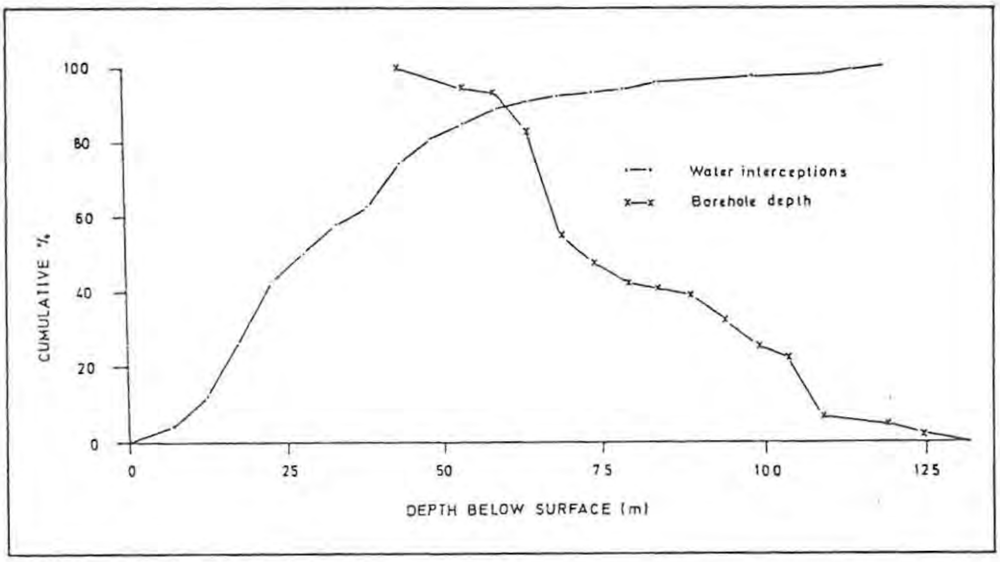


Figure 7: Cumulative percentage frequency diagramme of borehole depth and water interception

Table 13 Lithology of water interception

LITHOLOGY	YIELD (ℓ/s)						
	Damp	3	3-6	6-9	9-12	15-15	>15
Alluvium	4	3					
Siltstone/mudstone	15	37	11	1			
Sandstone	3	28	14	2	2	1	2
Dolerite contact	2	1	1				
Dolerite	2	2					

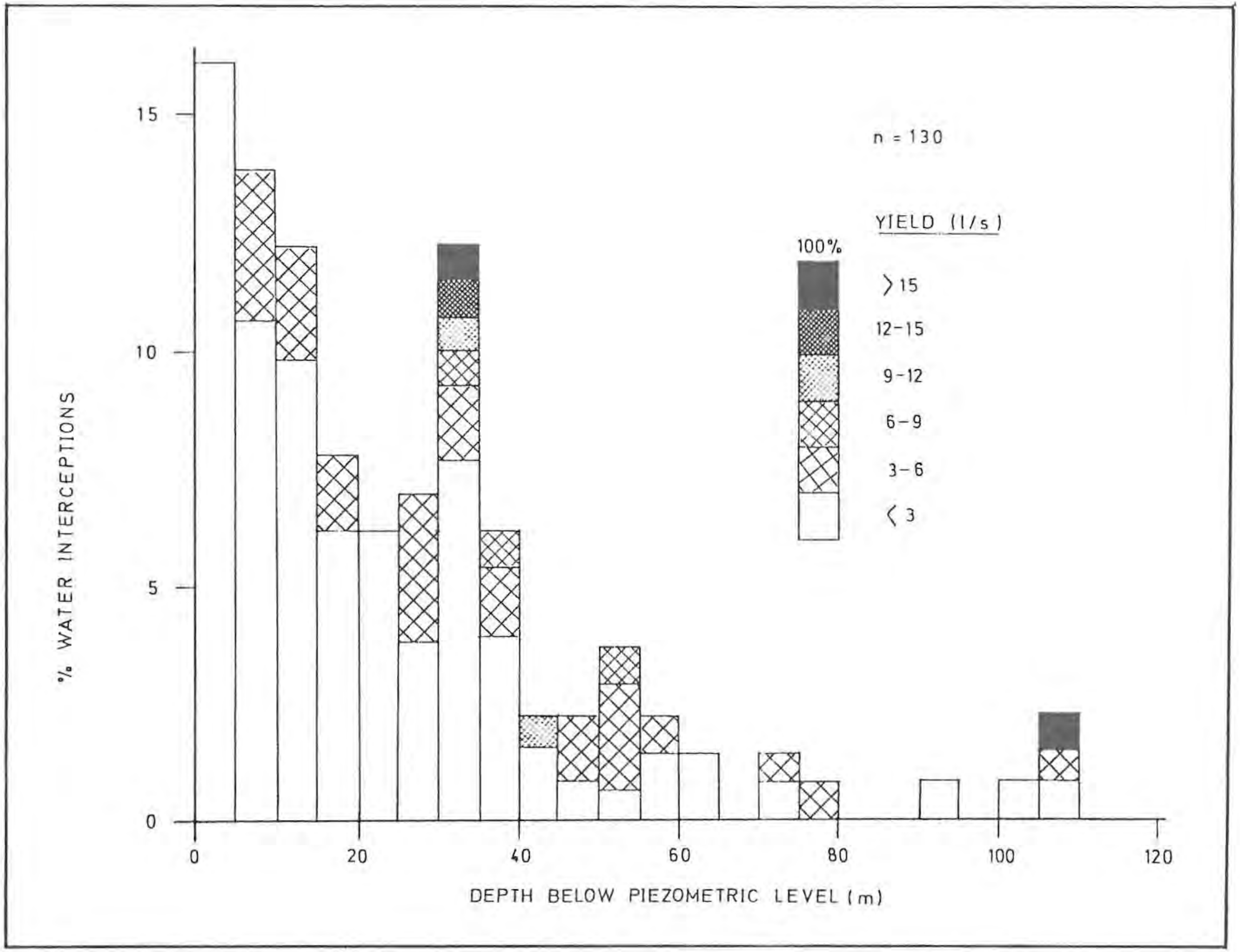


Figure 8: Histogram showing percentages of water interceptions and relative percentages of blow-yield test for 5 m intervals below pizometric level

The results presented above compare favourably with conclusions concerning drilling depths reached in other parts of the Karoo (Woodford, 1984, Vandoolaeghe, 1980).

Even though sandstones did not yield the greatest number of water interceptions, they were more prolific than siltstones and mudstones in producing yields in excess of 6 l/s (Table 13). The alluvial deposits, though not frequently encountered, did not produce yields higher than 3 l/s. Little significance should be placed on dolerite-related water occurrences as only four boreholes penetrated dolerite. Besides when boreholes were sited on or near dolerite, dolerite was never the main exploration target.

It can be concluded that the alluvial deposits and weathered sediments produced the greatest number of water interceptions, all of which were low-yielding. The fractured sediments, particularly fractured sandstone, accounted for the high-yielding strikes.

Electrical conductivity measurements were collected at each water interception while samples for hydrochemical analysis were taken on completion of boreholes. The conductivity measurements were used to expand the data base for the water conductivity map (Encl. 4). Conductivity values range from 60 mS/m to almost 1400 mS/m. Little variation occurred with depth and the change in electrical conductivity is attributed to borehole position.

2.5 AQUIFER TESTS

2.5.1 Aquifer Test Theory

A pumping test may serve two main objectives, namely to provide quantitative parameters pertaining to the hydraulic characteristics of the aquifer (aquifer test) or to provide information about the well itself (Kruseman and De Ridder, 1970). The latter test is referred to as a pump test or well test. Only aquifer tests were required to satisfy the objectives of this study, set out in section 1.5.

2.5.1.1 General Theory

Based on the early work of Henri Darcy and Jules Dupont in the middle of the nineteenth century, Adolph Theim put forward in 1870 a steady-state flow equation, which required that during pumping, the water level or piezometric level remained constant. However, this often required lengthy periods of pumping before equilibrium conditions were reached (Lloyd, 1981). In 1935, Charles Theis developed the first non-steady state flow equation:

$$s = \frac{Q \;.\; W(u)}{4 \pi T}$$

where $u = \frac{r^2 . S}{4Tt}$

s = drawdown measured at a distance r from the pumped well (m)

Q = discharge (m^3/day)

T = transmissivity (m^2/day)

t = time in days since pumping started

S = coefficient of storage.

W (u) is read as the Theis well function and is an exponential integral which varies with u. By matching the drawdown-time data (s/t) during the aquifer test to the Theis type curve, values of T and S can be computed. Theis also developed an equation involving the recovery data which permits the calculation of T and can be used as a check against the aquifer test results (Todd, 1980).

The Theis equation is based on a number of assumptions, outlined by Kruseman and De Ridder (1970):

a) the aquifer has seemingly infinite areal extent

b) the aquifer is homogeneous, isotropic and of uniform thickness over the entire area influenced by the aquifer test

c) prior to pumping, the piezometric surface and /or phreatic surface are (nearly) horizontal over the area influenced by the test

d) the aquifer is pumped at a constant discharge rate

e) the pumped well penetrates the entire aquifer.

The following conditions should also be met before applying the Theis equation:

a) the aquifer is confined

b) the flow to the well is in an unsteady state

c) the water removed from storage is discharged instantaneously with decline of head

d) the diameter of the pumped well is small i.e. the storage in the well can be neglected.

The Jacob method (Cooper and Jacob, 1946) and Chow method (Chow, 1952) were later developed, both of which were based on the Theis formula. Methods for the evaluation of aquifer test data from semi-confined aquifers (Hantush methods, Walton method) and unconfined aquifers (Boulton method) followed. The assumptions related to each of these methods are similar to those presented above. These methods (conventional methods) are used widely and are often successful even though the ideal conditions are rarely met in field situations (Smith and Vaughan, 1985).

Slight deviations from the assumptions are not prohibitive for the application of the methods. Kruseman and De Ridder (1970) discuss a number of interpretation methods which may be used if the basic assumptions are not met. However, both the conventional curve-matching and straight-line techniques are subjective, as unique fits are rarely obtained (Goyal, 1984). The interpreted aquifer test results are thus dependent on the analyst's personal judgement and experience. Randolph et al (1985) found that the graphical methods produced similar results to those produced by a rigorous mathematical technique.

2.5.1.2 Boundary Conditions

Aquifers rarely have a seemingly infinite areal extent and boundary conditions are often experienced during aquifer tests (Waterhouse and Read, 1982; Way and McKee, 1984). The detection of boundaries is important when predicting the behaviour of the resevoir under exploitation conditions (Sageev, et al, 1984). Boundaries are the result of a change in one or more hydraulic properties of the aquifer some distance away from the pumped well. Such conditions, whether representing impermeable or recharging barriers lead to complex s/t curves. Bear (1979) notes that the method of images is most useful in determining the hydraulic properties of geohydrological boundaries. Both the Dietz and Stallman methods are based on image well theory. Based on optical theory, Seward (1982), developed a method for identifying the particular boundary types and calculating T of the different zones.

Boundary conditions can be recognised by an inflection point on the s/t semi-log plot or by a sharp deviation of the s/t curve from the type curve.

2.5.1.3 Heterogeneous and anisotropic conditions

The Theis formula is based on the assumption that radial flow conditions prevail, and that a cone of depression will form around a pumped well. In anisotropic fractured aquifer systems however, most of the flow occurs preferentially in the fracture and very little in the matrix rock itself (Gringarten and Witherspoon, 1972). The flow of groundwater would be linear towards a natural production surface (fracture zone) rather than radial toward a pumping well. The direction of flow would depend on fracture orientation and a trough of depression would form. The longitudinal axis of the trough would be aligned parallel to the principal fracture orientation. Single fractures or fracture zones would then behave in a similar fashion to an extended well. Drawdown would be a function of the perpendicular distance from the extended well rather than a function of the radial distance from the pumped well (Jenkins and Prentice, 1982).

Amongst other, Papadopoulous (1964), Gringarten and Witherspoon (1972), Boulton and Streltsova (1977, 1978 a, 1978 b) and Jenkins and Prentice (1982) have all developed methods aimed at determining the hydraulic properties of fractured aquifer systems from aquifer test data. These methods either require at least three observation boreholes or s/t data from the pumped well. Houlden (1984) states that the Jenkins and Prentice method only produces qualitative information.

As the area influenced by the aquifer test increases, the system begins to behave in a more homogeneous manner (Gringarten and Witherspoon, 1972) and pseudo-radial flow is induced. The induction of pseudo-radial flow is a function of time and distance. Conventional aquifer test interpretation methods may then be used. Randolph et al (1985), working in secondary limestone aquifers, conducted a local (24 hour) and regional (21 day) aquifer test on the same well field. They found that even though there were differences in the hydraulic parameter obtained from the two tests, the differences were within the accuracy of the interpretation methods used. Holden (1984) applied both conventional and fracture flow interpretation methods to aquifer test data obtained from various different fractured aquifer systems in South Africa and found that realistic T values could be obtained using conventional methods but noted that the S value tended to be overestimated. Both of the above examples are obviously area-bound but indicate that conventional methods can be applied to fractured aquifer systems.

Linear flow can be recognised in three ways:

a) semi-log s/t plot - curvilinear graph

b) log-log s/t plot - 1/2 unit slope graph

c) s vs t plot - straight line graph

Once pseudo-radial flow is induced, the s/t curves will follow conventional type curves or form a straight line when plotted on semi-log graph paper.

Previous Karoo geohydrological investigations have indicated the environment to be extremely complex (Vandoolaeghe, 1980; Seward, 1983; Woodford, 1984). The following conditions can be expected:

a) confined, semi-confined and unconfined aquifers

b) lateral boundary conditions

c) anisotropy with linear and pseudo-radial flow.

The oversimplification of a complex system or the indiscriminate use of conventional interpretation methods could have led to the anomolous T and S values obtained, for instance, in the Beaufort West vicinity (Campbell, 1977; B.R.G.M., 1978; Leskiewicz, 1979).

2.5.1.4 Multiple Piezometer Approach

The ideal aquifer test would consist of pumping individual sections of an aquifer system using borehole packers and observing the drawdown at equal depth intervals in a number of radially spaced monitor boreholes also equipped with packers. Since the packer approach was for practical reasons not possible, it was decided that, in this investigation, individual aquifer elements would be tested at a few sites by means of the multiple piezometer approach. This approach has previously been used with success by Briz-Kishore and Bhimasonhoran (1982) in India and by Walthall and Ingram (1984) in England.

The multiple piezometer approach requires that a series of stacked, independent piezometers are placed at predetermined depths in a single borehole. A number of test wells are drilled near the piezometer borehole in such a way that each water interception could be pumped independently. A series of aquifer tests are required where the response of the pumped section of the aquifer is monitored together with the response of the non-pumped sections. The objectives of the multiple piezometer test approach are then:

a) to compare the results of the conventional test approach with the results of the discrete element test approach

b) to monitor the change in T and S with depth

c) to obtain meaningful hydraulic parameters which would assist in estimating the exploitation potential of the different aquifer units.

2.5.1.5 Test Procedure

The execution of an aquifer test is usually a simple procedure, but can be hampered by mechanical problems, resulting in a variable discharge rate. Kruseman and De Ridder (1970) note that interpretation methods which take variable discharge into account are available. The following measurements are taken at predetermined time intervals:

a) discharge rate

b) water level/piezometric level in both the pumped and observation wells.

Water samples were taken in order to assess temporal water quality variations. The distance of the observation well from the pumped well should also be recorded.

2.5.2 <u>Data Collection and Results</u>

2.5.2.1 General Information

Fifteen tests were performed at nine different sites. Five of the tests took place on existing private production boreholes. Making use of these private abstraction points meant that observations in the pumped borehole were not possible and that the duration and discharge rate of the tests were predetermined by farming requirements The remaining tests were performed with two mobile 140 mm diameter turbine pumps. One pump was old and troublesome and was later replaced with a third unit while the other unit, although relatively new, performed erratically. Pump and engine breakdowns and unacceptable yield variations necessitated that some tests be conducted twice (e.g. G 33365, G 33401) while others had to be shortened (e.g. G 33395). It was not usually possible to make water level observations in the pumped borehole, because insufficient space was available to lower an observation pipe. Prior to each aquifer test conducted with a mobile pump, the discharge rate at which each test was to be performed was determined by means of a thirty minute "step drawdown type test". The engine revolutions were calibrated against water level recession. This ensured that the correct discharge rate could be obtained as soon as possible after the start of each aquifer test. Yield determinations using a tank and stop watch, as well as water conductivity measurements were made at various time intervals throughout the tests. Discharge water was piped downstream as far as possible in natural drainage channels. The discharge water of private boreholes was used for irrigation.

The location of the aquifer test sites and the position of the test boreholes is shown in Figure 9. The relevant aquifer test data are grouped together in Table 14. Because yield decline with time is typical for production boreholes in secon-

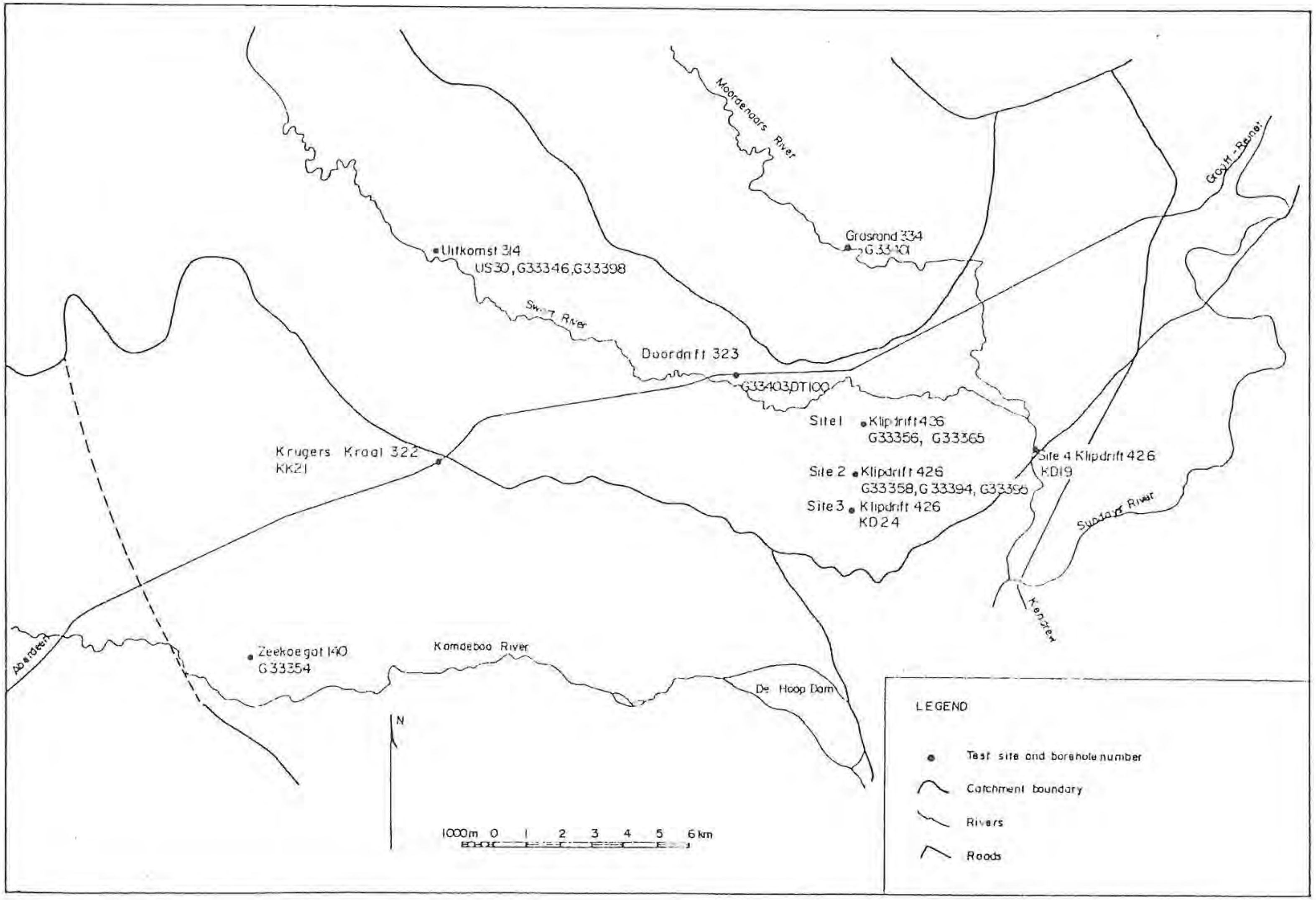


Figure 9: Position of aquifer test sites

Table 14: Relevant aquifer test data

DATE COMMENCED	PUMPED WELL NO.	OBSERVATION WELL NO.	DISTANCE TO PUMPED WELL (m)	TEST DURATION (min.)	RECOVERY DURATION (min.)	AVERAGE YIELD (ℓ/s)	YIELD RANGE (ℓ/s)	DEPTH OF PUMP INTAKE (m)	REST WATER LEVEL BELOW REFERENCE (m) *	MAXIMUM DRAWDOWN (m)	WATER LEVEL DEFICIT ** (m)	AVERAGE CONDUCTIVITY mS/m AT 25°C
19-2-85	US 30			1590	1600	29,4	30,2/28,5	50				116
		G33346	80,2						6,83	18,92	2,72	
19-6-85	G33346			4320	4320	20,2	21,2/18,2	97				119
		G33397	41,7						10,20	6,68	+0,36	
		G33398	65,0						8,01	11,35	1,89	
28-9-85	G33398			7280	4320	13,3	13,3/12,0	102	5,67	37,24		118
		G33346/0	65,0						5,25	10,13		
		G33346/1	65,0						5,27	11,09		
		G33346/2	65,0						9,17	2,53		
		G33346/3	65,0						11,21			
		G33347	60,0						10,85	9,23		
24-5-85	G33356			4320	4320	7,1	7,3/6,9	50	15,52	9,55	+0,03	100
		G33365	23,5						15,74	8,24	+0,41	
4-9-85	G33365			4300	4320	4,4	4,8/4,1	40	15,38	6,99	0,06	123
		G33356/0	23,5						10,93	1,63	0,05	
		G33356/1	23,5						15,25	6,35	0,05	
		G33356/2	23,5						14,79	4,71	0,13	
		G33356/3	23,5						13,69	1,33	0,63	
11-6-85	G33358			4230	4230	11,0	11,3/10,8	80	7,73	6,76	0,22	137
		G33393	30,0						7,73	3,55	0,14	
		G33394	23,5						7,71	4,09	0,21	
		G33395	67,5						7,78	2,96	0,17	
29-7-85	G33394			2100	2100	11,4	11,6/11,2	52	8,53	21,07	+0,26	122
		G33393	36,1						8,56	5,10	+0,38	
		G33395	91,0						8,44	2,28	+0,23	
		G33358/0	23,5						8,35	2,27	+0,18	
		G33358/1	23,5						8,42	7,33	+0,23	
		G33358/2	23,5						8,56	6.82	+0,38	
		G33358/3	23,5						7,82	0,24	0,13	
8-8-85	G33395			4320	4320	5,3	6,1/4,7	85	8,18	26,09	0,05	124
		G33358/0	67,5						8,10	2,45	0,09	
		G33358/1	67,5						8,07	1,42	0,14	
		G33358/2	67,5						7,98	0,65	0,06	
		G33358/3	67,5						7,80	0,25	0,11	
4-6-85	KD24			1440	1440	5,4	6,7/5,0	20				
		G33396	74,0						10,09	0,80	0,04	
11-9-85	KK21			2820	2820	12,4	14,5/10,5	40				77
		KK25	170						19,52	3,10	1,80	
		KK26	63,0						18,35	4,67	1,43	
		G33345/1	306						16,94	0,51	0,83	
		G33345/2	306						16,94	0,50	0,82	
		G33345/3	306						17,00	0,49	0,83	
		G33345/4	306						15,33	0,26	0,47	
8-7-85	G33403			4320	4320	10,1	10,5/9,6	59	10,63	4,54	+0,16	131
		G33404	43,0						10,46	1,74	+0,16	
	DT100			4320	4320	24,2		50				
		G33404	244,0						10,84	0,53	0,01	
		G33405	413						9,24	3,13	0,12	
		G33406	383						14,08	0,79	0,04	
		G33407	770						14,65	2,42	+0,06	
4-7-85	G33354			3310	1200	3,4	3,6/3,2	50	10,69	8,33		573
		G33355	42,0						11,09	0,96		
6-8-85	KD19			4320	4320	26,3		60				
		G33409	30,3						8,48	14,82	0,92	
		G33410	203						8,55	8,40	0,74	
		G33338	450						6,94	2,50		
		KD101	72,0						10,01	14,16	1,04	
16-7-85	G33401			1600	3800	17,3	17,5/17,2	40	8,09	5,36	2,04	74
		G33399	50,6						8,68	1,75	1,46	
		G33400	124						9,41	0,53	0,55	
		G33402	62,6						8,35	3,67	1,77	

dary aquifers, the constant discharge rate is taken to be the weighted mean of all intermittent pumping rates.

The duration of the tests varied from 1200 to 7280 minutes. Unfortunately some tests were cut short due to mechanical failure and others, specifically those on private boreholes, could not be prolonged for more than one or two days, resulting in loss of aquifer information. Taking into account both the economics of aquifer tests and the geohydrological information to be gleaned from such tests, it is felt that a standard long duration test should last a minimum of 5 days in the given geohydrological environment.

2.5.2.2 Multiple Piezometer Construction and Test Procedure

Three multiple piezometer test sites were developed : UITKOMST 314 (G 33346) and KLIPDRIFT 426 (G 33356 and G 33358). At a later stage multiple piezometers were installed in boreholes G 33345 (KRUGERS KRAAL 322) and G 33407 (DOORDRIFT 323), (Encl. 8). The aim of the latter two installations is to collect data on long-term water level fluctuations caused by recharge and private abstraction.

Three exploration boreholes, with water interceptions of varying yield at different depths, were chosen for the discrete element test approach. Subsequently, additional boreholes were drilled at varying distances from the first borehole in such a way that each of them is hydraulically connected to only one of the different interceptions obtained in the original exploration borehole. A test was then carried out in the original exploration borehole with the other borehole(s) being used as observation point(s).

The exploration borehole was then equipped with piezometers in the following manner (Appendix 4):

- PVC piping was placed at the required depth, the 3 m section opposite the deepest interception being perforated
- the annular space between the perforated PVC piping and the borehole wall was fitted with 18 mm ø graded gravel
- one meter of 6 mm ø graded gravel, followed by a few meters of drilling chips were then installed
- a bentonite plug was then installed to prevent leakage along the bore opening. The bentonite was mixed with diesel fuel to retard the rate of swelling. Once sufficient time had passed for the bentonite to settle to the required depth, a few meters of drilling chips were added so that the bentonite would expand in a horizontal manner
- the borehole was subsequently filled with drilling chips to the depth of the next piezometer.

During the tests in the discrete production zones, observations were made in the different piezometer tubes.

2.5.2.3 Aquifer Test Analysis and Results

The following interpretation methods were applied:

a) the Theis curve-matching technique
b) the Walton curve-matching technique

c) the Chow straight-line method

d) the Jacob straight-line method

e) the Hantush I straight-line method

f) the Theis recovery method

g) the Seward lateral boundary method

Difficulty was often experienced in obtaining unique fits when curve-matching techniques were used owing to the secondary nature of the geohydrological environment. The s/t curves featured a number of local or regional aquifer characteristics e.g. linear flow, pseudo-radial flow, boundary conditions, permeability contrasts, leakage, delayed yield, vertical flow as well as aquifer and fracture dewatering. The semi-log s/t plots showed a number of segments reflecting a change in the dominant groundwater flow component in the vicinity of the test site. It was useful, prior to the actual interpretation, to draw up conceptual flow models for the different test sites and test configurations to help understand the hydrodynamics prevailing at each site (Appendix 4).

The conceptual flow models, together with the discriminate application of the various interpretation methods, allowed the determination of realistic hydraulic parameters. At least two appropriate methods were used on each set of s/t curves in order to verify the reliability of the results. Owing to the volume of data, all aquifer test data and interpretation results are presented and discussed in Appendix 4.

Three groundwater elements were identified, namely the fractured aquifer, the transmissive production zone and, in places, a top leaky layer. The hydraulic characteristics of each element are discussed in section 3.3.

2.5.2.4 Application of Multiple Piezometer Approach

The multiple piezometer approach enabled the monitoring of aquifer response to abstraction at different depths. The approach allowed for only one production zone to be pumped at a time and hence the s/t curve obtained was for that zone only. Also, the response of other levels within the system could be monitored, which assisted in the identification of various flow components. The s/t curves tended to be less complex than those obtained from the standard aquifer test approach. The standard approach yielded complex s/t curves which were an expression of the "average response" of the total aquifer system to abstraction. These curves could easily be erroneously interpreted as little insight could be obtained regarding:

a) which part of the system was being pumped
b) the dominant flow component
c) the origin of leakage

The multiple piezometer approach, by providing a better understanding of the geohydrological conditions prevailing at each site, yielded more numerous and representative hydraulic parameters than the more standard approach.

The second objective relating to the multiple piezometer approach (section 2.5.1.4), was to monitor the change in T and S with depth. Unfortunately no information pertaining to these changes could be obtained. Usually one transmissive zone in the borehole proved to be dominant. By pumping a lesser zone above or below the dominant zone, vertical flow originating from the dominant zone was induced (see aquifer test results of test G 33394, Appendix 4) and unreliable results were obtained. However, the multiple piezometer approach did allow for distinction to be made between the storativity of the fractured aquifer ($5,7 \times 10^{-3}$ to $1,2 \times 10^{-4}$) and the transmissive production zone ($1,3 \times 10^{-4}$ to $1,9 \times 10^{-5}$). This indicates that even though the fractures (transmissive production zones) allow for the rapid movement of water, the fracture themselves store little water. Most water is stored in the matrix rock i.e. the fractured aquifer itself.

2.6 HYDROCHEMISTRY

2.6.1 Hydrochemistry Theory

In terms of groundwater resources, quality considerations are as important as quantity. Besides assessing the suitability of groundwater for domestic or industrial use, hydrochemical data can be used to obtain a better understanding of prevailing geohydrological conditions. Rosenthal and Mandel (1985) were able to delineate flow paths by assessing the relative changes in certain ionic concentrations. Vandoolaeghe (1978, 1980) used similar principles to good effect in the Middelburg area. Parsons (1983) and Venables (1985) were able to define the origin of subsurface flow in the Uitenhage area by determining the chemical characteristics of waters from the Table Mountain Group aquifer and Uitenhage Group aquiclude.

2.6.1.1 Ionic Source and Characteristics

Before discussing the factors controlling the hydrochemical nature of groundwater, the possible source of major ions as well as the major chemical characteristics are briefly outlined:

a) Sodium (Na): Na is not a major rock-forming mineral. An important source of this ion is the breakdown of plagioclase feldspar and cementing minerals (Mathess and Harvey, 1982). Seawater is also a major source of Na. The element has a high solubility and mobile Na features in cation exchange with calcium (Ca) and magnesium (Mg) from clay minerals.

b) Potasium (K): A common source of K in groundwater is from the breakdown of feldspars, fledspathoids and micas. The abundance of K in the earth's crust is similar to that of Na but, owing to the resistance of potassic minerals to weathering, the concentration of K in groundwater is far less than that of Na (Davis and De Wiest, 1966). K also has the ability to enter the structure of clay minerals after weathering.

c) Magnesium (Mg): Mg has a relatively low geochemical abundance in the natural environment. The main source of Mg is silicate minerals, dolomite and calcite. Hem (1970) notes that Mg has a relatively high solubility but, owing to a low abundance, the concentration of Mg in subsurface water is usually low.

d) Calcium (Ca): Ca is relatively abundant in soils and rocks (especially carbonate and silicate minerals). Marine derived deposits are usually rich in Ca. The ion has a low solubility (Hem, 1970) and attains saturation easily in a stable environment. Ca is readily exchanged for Na by clay minerals.

e) Chloride (Cl): Cl is a minor constituent of the earth's crust yet is abundant in most groundwater. The element has a high solubility and is chemically inert, and hence does not enter significantly into any oxidation or reduction reactions. The concentration of Cl and Na are often similar and if conditions are favourable, the two will precipitate to form halite.

f) Sulphate (SO_4): Sulphur is an abundant geochemical element and may occur in an oxidized state (S^{6+}) or in a reduced state (S^{2-}) (Hem, 1970). In groundwater, sulphur commonly occurs as oxidized SO_4, which is stable over a wide range of pH. Hydrogen sulphide (H_2S) is a reduced form of sulphur but is only stable when the pH is less than 7. Oxidation and reduction reactions involving sulphur are slow, resulting in non-equilibrium sulphur forms persisting for long periods.

g) Total Alkalinity (TAL): "TAL is the capacity of a solution to neutralize an acid" (Hem, 1970, page 152), and is a measurement of titrateable amounts of carbonates (CO_3) and bicarbonates (HCO_3). When the pH is less than 8.2, CO_3 is not usually present. TAL may be derived from atmospheric CO_2, CO_2 produced by biota of the soil and from carbonate rocks and minerals (Bouwer, 1978). HCO_3 is usually abundant in recently recharged groundwater.

h) Hydrogen Ion Concentration (pH): The symbol pH is used to designate the logarithm (base 10) of the reciprocal of H^+ concentration. The pH differs from TAL in that the former is an intensity function while the latter is a capacity function. Davis and De Wiest (1966) note that care should be taken when sampling for pH. The solubility of CO_2 changes with temperature and pressure, resulting in modifications in the pH. Such changes occur either during pumping or storage in a sample bottle.

2.6.1.2 Hydrochemical Evolution

The chemistry of groundwater is controlled by a complex set of interrelated factors. These factors include chemical environment, climate, geology, biochemical activity and man (Hem, 1970; Austrup and Axelson, 1984). It is beyond the scope of this thesis to fully discuss the entire hydrochemical evolution process but the impact of climate, time and man's activity are expected to be of importance (Tordiffe, 1978).

The duration that subsurface water is in contact with the various lithological units will influence the relative quality of the water. Krothe (1983) recorded a general deterioration of quality in the direction of flow. Chebotarev (1955), in his classic paper dealing with hydrochemical evolution proposed the following changes with time:

$$HCO_3^- \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_4^{2-} + HCO_3^- \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^-$$

To propose a similar theory involving cations is more difficult as there are so many exceptions to the rule. Cation exchange between groundwater and argillaceous sediments, for example, continually results in alterations of subsurface hydrochemistry.

Graaff-Reinet experiences a semi-arid climate and as a result the potential evapotranspiration is high. Evaporated water is essentially free of salts (Eaton, 1950). The salts remain in the soil profile and are later flushed into the groundwater system by infiltrating rain. Therefore, it would be expected that areas with a shallow water table would produce relatively poor quality water.

An aspect of hydrochemistry receiving more and more attention is the influence of man on water quality, particularly the re-use of groundwater and the impact of solid waste disposal (Bouwer, 1978). Based on the findings of Tordiffe (1978), it was expected that the impact of agricultural development in the Graaff-Reinet area may require special attention. The continual re-use of groundwater for irrigation practises results in a progressive deterioration of water quality (Evans, 1983). Affected areas should show a progressive decrease in secondary salinization with depth. In addition Na and Cl, owing to high solubilities, should dominate the hydrochemistry of contaminated groundwater.

2.6.1.3 Water Quality Classification

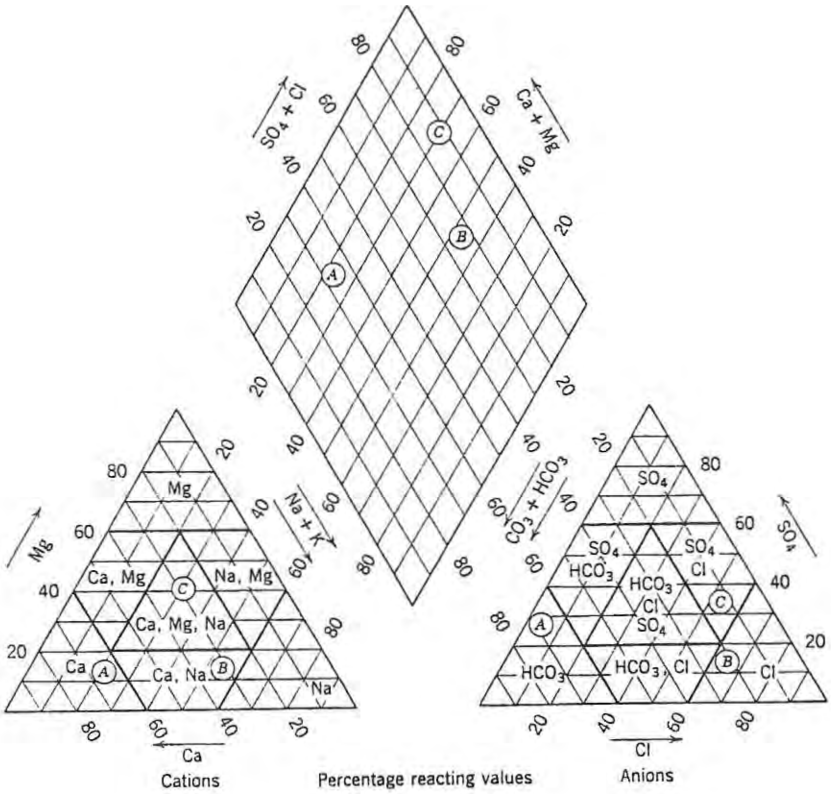
The chemistry of water can be classified by either total dissolved solids (TDS) or by the full hydrochemical nature of the water. TDS is calculated by adding the major ion concentration ($mg.l^{-1}$) as determined by full hydrochemical analysis. As the constant K has to be determined for each specific region, the following relationship will not be used:

$$TDS = EC \times K$$

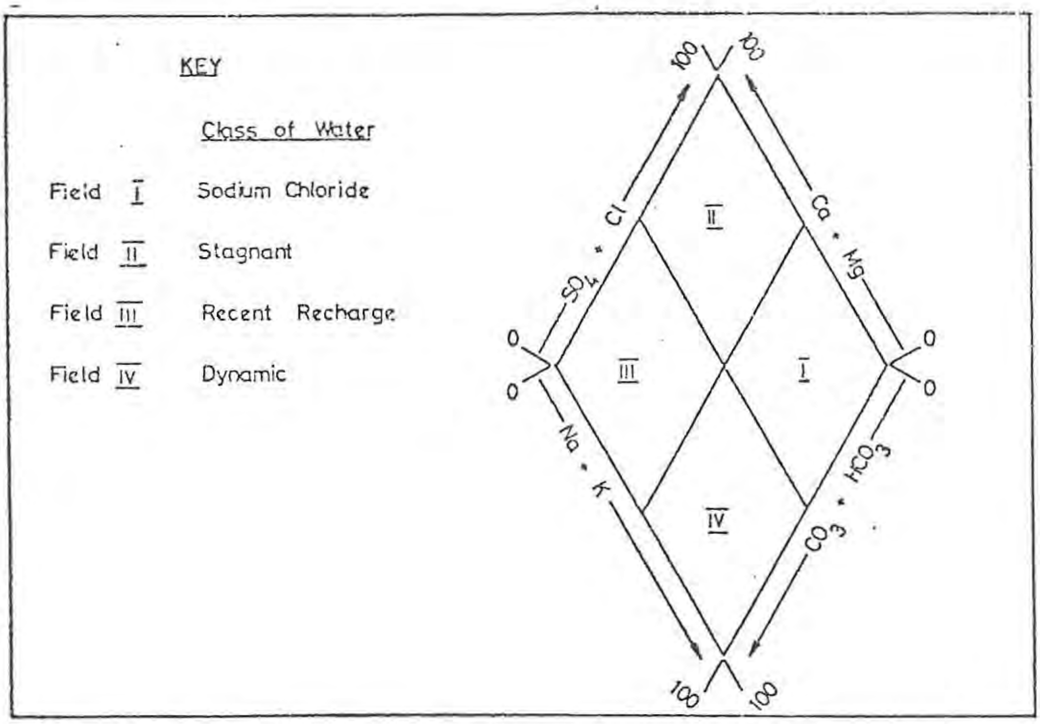
where EC = electrical conductivity

Instead, the general water quality will be indicated by EC alone which is a function of the type and concentration of dissolved solids present and temperature.

One of the most widely used classifications is the trilinear diagram developed by Piper (1944). The concentration of each ion ($mg.l^{-1}$) is converted to equivalents per million (epm) and expressed as a percentage (Ward, 1975). The epm is calculated by dividing the concentration of the ion by the equivalent weight, where the equivalent weight is equal to atomic weight of the ion divided by the valence of the ion. Two forms of Piper diagram will be used. Firstly, the more classic diagram which indicates the dominant ions (Figure 10) and secondly, Johnson's (1975) adaption of this version (Figure 11) which indicates the hydraulic state of the sampled groundwater.



<u>Figure 10</u>: The Piper diagram (Davis and De Wiest, 1966).



<u>Figure 11</u>: Johnson's (1975) adaption of the Piper diagram.

2.6.2 Data Collection and Results

Water samples for chemical analysis were taken from both private and project boreholes. The principal aim of taking the samples was to assess the suitability of groundwater for domestic use. The selection of sampling points from private boreholes was based on conductivity and piezometric data obtained during the course of the borehole inventory. The samples were taken throughout the fieldwork phase of the project and the results of the hydrochemical analysis are presented in Appendix 5 a.

Hydrochemical samples were taken during the drilling phase of the exploration programme in order to evaluate chemical variations with depth. The results of the analyses of the samples are presented in Appendix 5 b. It should be noted that at the time of writing some laboratory analysis results were still outstanding.

CHAPTER 3

DISCUSSION OF GEOHYDROLOGY

3.1 GROUNDWATER UNIT GEOMETRY

On a regional scale the groundwater system or any part of it within the study area does not stand as a separate groundwater unit. The units under investigation are part of what can be termed a hierarchical chain of groundwater bodies within the Sundays River drainage region. As opposed to the more generally accepted approach of studying individual aquifers, the concept of groundwater units has been employed in this study. Previously the complex nature of groundwater bodies in Karoo geological environments was discussed (section 2.5.1). Each individual fracture zone could, for example, be classified as a single aquifer with a characteristic set of hydraulic parameters. A large amount of drilling work and aquifer tests would be required to quantitatively define each aquifer in terms of recharge, storage, flow regime, aquifer interconnectivity (gains and losses) and exploitability. Further, a detailed and complex geohydrological model would have to be developed to predict aquifer behaviour under a given set of conditions. The groundwater unit approach is more simplistic in nature than the above approach. A set of aquifers which can be defined by distinctive hydraulic boundaries are considered to be fairly homogeneous. Zones or components within each unit can be defined. Groundwater units are delineated in the study area (Encl. 3).

The boundaries of each unit are defined by zero-flow boundaries which coincide with:

a) topographic divides on the northern, north-western and north-eastern highlands

b) the ridges of the ring-structured dolerite sheets.

The zero-flow boundaries are intersected by flow-controlled boundaries which allow outflow from each unit. The outlet points (or inlet in relation to the unit downgradient) are confined to the poorts at Corndale, Kriegerskraal and Kransplaas (Encl. 3). Geohydrological evidence suggests that little, if any, outflow occurs through the De Hoop poort, while the southern boundary of the Sundays unit (outlet) represents part of the southern boundary of the investigation area and is totally artificial.

Only a portion of the Kamdeboo unit was investigated, the western limit being defined as an internal flow-controlled boundary on the farm ZEEKOEIGAT 140. The surface areas of the four units are:

a) Moordenaars unit - 430 km^2

b) Swart unit - 520 km^2

c) Kamdeboo unit - 340 km^2

d) Sundays unit - 560 km^2

The vertical dimensions of the groundwater units are less easily defined, but considering the depth - water interception relationship determined in this study (section 2.4.2), an average aquifer thickness was obtained. Drilling and borehole geophysical data were used to determine that 90% of all water interceptions occur shallower than 65 m below surface level (Fig. 7). The corresponding depth below piezometric level is in the order of 55 m to 60 m (Fig. 8). Even though significant water interceptions were obtained at greater depths on the farm UITKOMST 314, this is considered to be more of an exception than the rule.

3.2 GEOLOGICAL CHARACTERISTICS OF THE GROUNDWATER UNITS

The geohydrological conditions prevailing in the study area are principally controlled by lithological and structural variations.

3.2.1 Lithological Variations

3.2.1.1 Dolerite

The Karoo dolerite intrusives occur either as dykes or as irregular sheets. In an unweathered or non-fractured state, dolerite is impervious and hence plays an important role in defining groundwater unit boundaries. Initially it was thought that the fractured sedimentary rock associated with the sheet intrusives could be important transmissive zones. However, no high-yielding boreholes are associated with these structures. The high-yielding boreholes located near dolerite sheets occur downstream and topographically below the poorts, where important river courses have broken through the sheets. The local removal of overburden and simultaneous weathering in these passages probably resulted in stress relaxation and fracture opening. A typical dolerite sheet-sediment contact is presented in Plate 1.

Plate 1: The contact between the northern-most dolerite sheet and the Middleton Formation sediments.

Plate 2: A typical Middleton Formation sequence, capped by a dolerite sheet.

Five dolerite dykes, ranging from 1 km to 5,5 km in length, were identified (Encl. 6). Their thicknesses do not exceed 10 m (see section 2.3.1.2 for discussion). With the exception of the Brooklyn dyke, all dykes have a near vertical attitude. The exception has a dip of 55 SW which indicates that it could be an extention or the termination of the dolerite sheet that stretches in the NNW direction from the De Hoop dam. No high-yielding boreholes are associated with the dykes but it appears that the boreholes may not have been drilled in optimal production positions adjacent to the dykes. In a regional geohydrological context, the dykes appear to be of minimal importance.

Plate 3: Vertically dipping sandstones which are associated with the Vorster syncline, as seen in the Moordenaars River.

It is of interest to note that the 1: 1 000 000 geological map of the Republic of South Africa (1984) indicates a long dolerite dyke east of the Zevenfontyn dyke (Encl. 6). This "dyke" was later identified to be a section of the old wagon trail from Port Elizabeth to Graaff-Reinet.

3.2.1.2 Karoo Sediments

The Middleton Formation consists of mudstones, siltstones and sandstones. Most of the sandstones can be classified as discontinuous channel sandstones (Plate 2). Due to compaction and cementation, these rocks have virtually no primary porosity and

Plate 4: Highly fractured and weathered sandstone associated with the Vorster syncline.

permeability, but the competent sandstones and to a lesser extent siltstones, have been subjected to brittle fracturing which is probably a result of differential compaction. The sandstones and siltsones exhibit secondary openings upon weathering. The secondary hydraulic properties of the rock developed in this way are important in terms of recharge, storage and direct or indirect (leakage) groundwater transmission.

3.2.1.3 Superficial Deposits

By virtue of their location (at the foot of the steep mountain slopes which receive higher precipitation) and composition (boulders, pebbles and sand) the colluvial deposits are very

Plate 5: A localized tight anticlinal structure, seen on the farm ZITRUG 427.

important in terms of recharge.

The evaporite or calcrete deposits have a limited regional geohydrological importance but can be used to identify:

a) natural groundwater discharge zones where evaporation from the water table was and is significant

b) the location of ancient river courses (river terraces).

The primary importance of alluvial deposits in the Karoo is their storage capacity which, in relative terms, is higher than that of fractured sedimentary rocks. Also these deposits have a more rapid recharge rate than their consolidated counterparts and where thick alluvial deposits occur, enhance the recharge of fractured sediments through leakage. Woodford (1984)

Plate 6: An oblique photograph of the Groote Vlakte and Oudedrift fractures, looking south.

and Leskiewicz (1979) found the unconsolidated deposits to be of major importance in their study areas.

Thick alluvial deposits are confined to areas near the major drainage channels where the maximum measured thickness was 15 m e.g. DOORDRIFT 323, UITKOMST 314 and ZEEKOEIGAT 140. However, hydrocensus and drilling information indicate that the total volume of saturated alluvium is at present small. Nevertheless, the potential importance of the alluvial deposites should not be underestimated during and after significant and prolonged precipitation events.

Plate 7: An oblique aerial photograph of the Brooklyn fracture.

3.2.2 Structural Variations

The secondary hydraulic features of the consolidated rock, as a result of jointing and fracturing, greatly enhance the geohydrological characteristics of the sedimentary rock. The degree of fracturing is partly controlled by rock competency. Sandstone horizons have preferentially been subjected to brittle fracturing while the more elastic siltstones and mudstones contain tight, hairline fractures. Apart from differential compaction, jointing and fracturing in the study area is either a result of orogenic folding or dolerite intrusion.

3.2.2.1 Fold-related Fracturing

A number of east-west trending regional synclines and anticlines were identified in the study area e.g. Kamdeboo syncline and anticline and Swart syncline (Encl. 6). The dip of the sediments in these structures does not exceed 15°. A number of smaller east-west fold structures were also mapped (Vorster syncline, Fig. 12; Bloemfontein syncline, Fig. 13). The attitude and the degree of fracturing of the Vorster syncline is seen in Plates 3 and 4. Plate 5 is another example of tight synclinal and anticlinal structures, here seen in the Dwarsberg mountains.

The identification and detailed mapping of the smaller fold structures was hampered by poor exposure and the extensive soil and alluvial cover. However, the dip of the sediments often reaches a near vertical status while the length and width of these fold features are generally less than 2 km and 200 m respectively. The Vorster syncline was, however, mapped for 9 km and it is possible that it extends a further 6 km westward towards the farm UITKOMST 314 (Encl. 6). The positions of the Vorster and Bloemfontein synclines are indicated on the geological map (Encl. 6).

3.2.2.2 Dolerite-related Fracturing

A number of randomly orientated linear features were identified on aerial photographs. Some of these linear features were later found to be fracture zones (Encl. 6). The positions of the

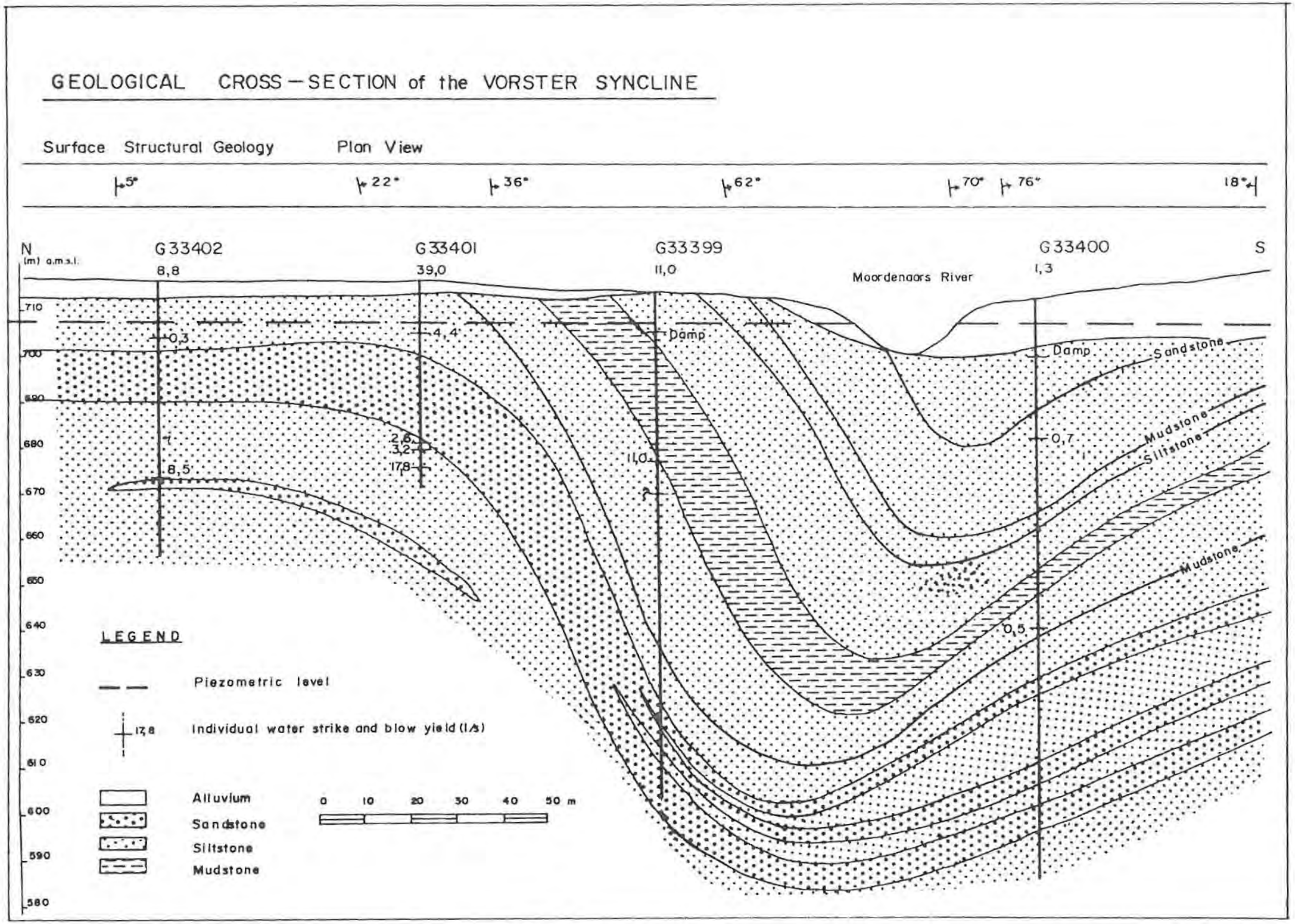


Figure 12: Geological cross-section of the Vorster syncline.

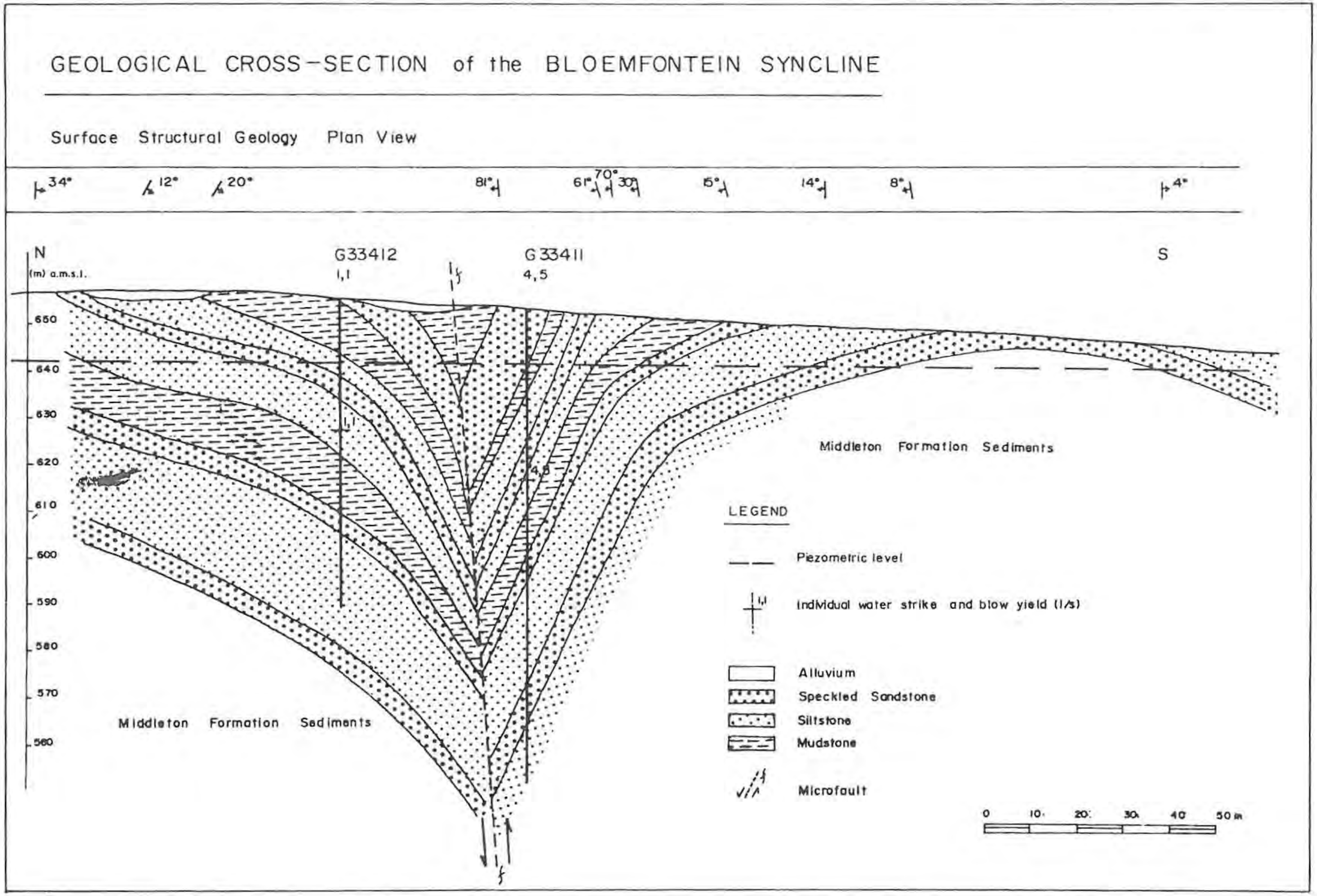


Figure 13: Geological cross-section of the Bloemfontein syncline

Groote Vlakte and Oudedrift fractures are indicated on Plate 6 while the Brooklyn fracture is seen on Plate 7. Venables (1983) identified the Oudedrift fracture as a dolerite dyke.

Although their exact origin has not yet been described, it is hypothesized that these linear features might be the result of volatile releases which often accompanies magmatic action (Hobbs et al, 1976). Such releases would fracture both the dolerite and sedimentary formations and encourage preferential physical and chemical weathering. These points would be the easiest places for river courses to erode their way through and would eventually result in the formation of poorts.

3.3 HYDRAULIC CHARACTERISTICS

The aquifer systems in the study area are usually semi-confined, although locally they may be more of a semi-unconfined nature. Geological evidence and the results of the aquifer tests (Appendix 4) favour the division of the aquifer system into three components, each with distinctive hydraulic characteristics.

3.3.1 Fractured Aquifer

The upper part of the Beaufort Group sediments which contain groundwater in secondary openings can, on a large scale, be considered to be uniformly fractured. The aquifer matrix ranges in thickness from 20 m to 80 m with an average thickness of approximately 45 m. The range of hydraulic parameters obtained for this part of the system are:

Hydraulic conductivity (k)	: 0,5 - 10.0 m/d
Transmissivity (T)	: 10 - 300 m^2/d
Hydraulic resistance (c)	: 30 - 800 days
Vertical permeability (k')	: 0,1 - 0,5 m/d
Storativity (S)	: 5,7 x 10^{-3} to 1,2 x 10^{-4}
	average S = 1,1 x 10^{-3}

3.3.2 Transmissive Production Zones

The transmissive production zones are the seemingly random and discontinuous zones within the fractured aquifer from which groundwater can be produced in large quantities. The horizontal to sub-horizontal fracture zones tend to be associated with sandstone horizons. The zones occur at varying depths. The maximum recorded thickness of a fracture zone was 10 m. The hydraulic parameters obtained for these transmissive production zones are:

hydraulic conductivity (k)	: 5 - 40 m/d
transmissivity (T)	: 20 - 400 m^2/d
storativity (S)	: 1,3 x 10^{-4} to 1,9 x 10^{-5}

Only one major vertical fracture zone was tested (Brooklyn fracture) and a transmissivity value of 1270 m^2/d was obtained.

The hydraulic characteristics of the fractured aquifer and the transmissive production zones indicate that:

a) the fractured aquifer is chiefly responsible for the storage of groundwater and little water is stored in the discrete production fractures proper.

b) groundwater movement takes place preferentially along the discrete fracture zones which, when pumped, act as extended wells.

3.3.3 Top Leaky Layer

The top leaky layer is a combination of saturated alluvium (where present) and the underlying weathered zone. The presence of this top layer above the fractured aquifer results in semi-confined conditions. The distribution of the leaky layer is generally confined to the central part of the groundwater units with a thickness ranging between 15 m and 25 m. The characteristic hydraulic parameters are:

hydraulic conductivity (k)	: 3 - 4,5 m/d
transmissivity (T)	: 70 m^2/d
hydraulic resistance (c)	: 500 - 30 000 days
vertical permeability (k')	: 5,0 x 10^{-3} to 7,5 x 10^{-4} m/d

3.4 PIEZOMETRIC LEVELS

The piezometric level contour map (Encl. 3) was used to determine the general pattern of groundwater movement. Flow-lines were used for this purpose. The patterns indicated are validated by electrical conductivity trends (Encl. 4) and by the relative change in the HCO_3/Cl ratio (Fig. 14). Figure 14 is based on the chemical changes resulting from hydrochemical evolution, as proposed by Chebotarev (discussed in section

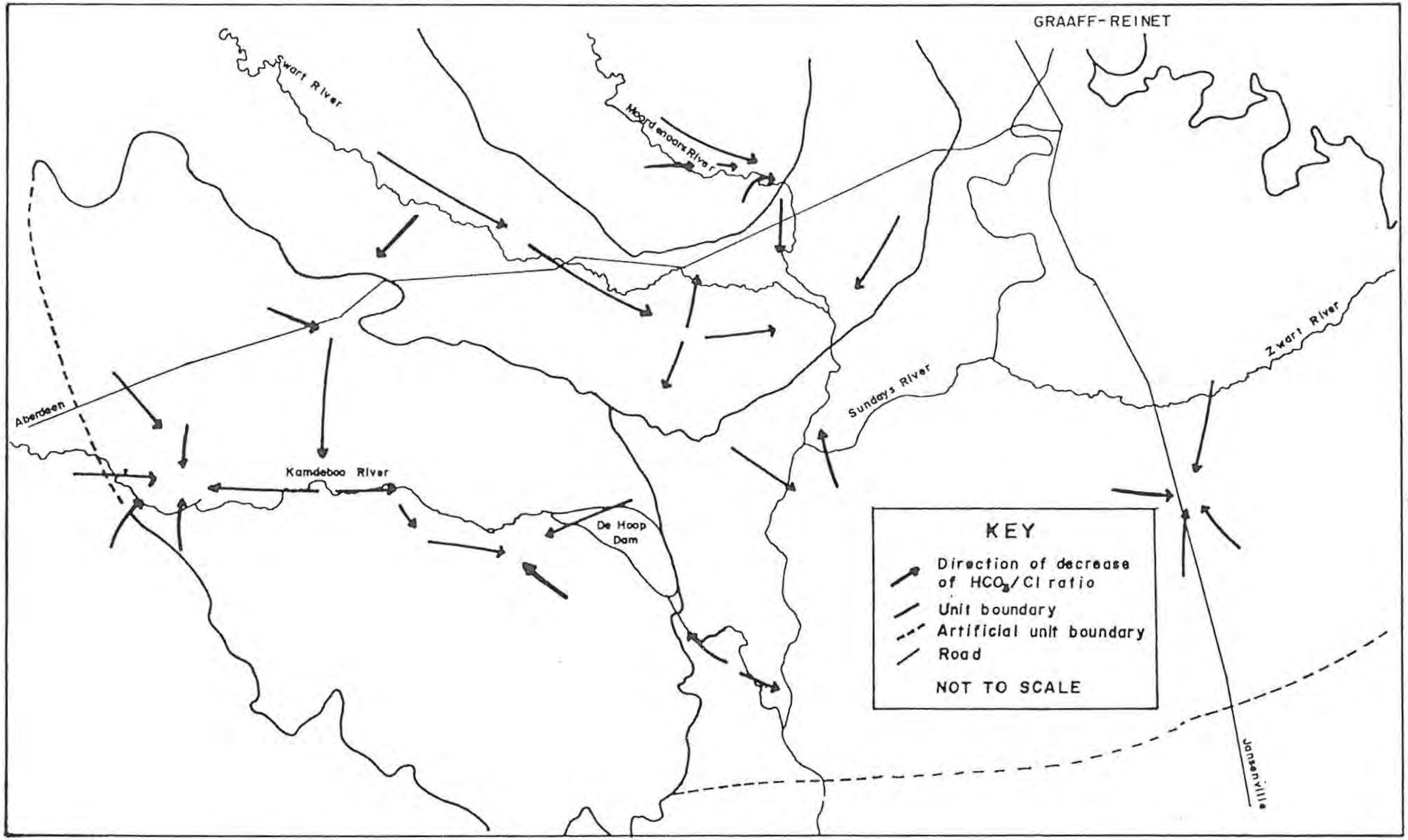


Figure 14: A schematic representation of the relative decrease in the HCO_3/Cl ratio, used as an indicator of groundwater flow paths (see Enclosure 5 for sampling points).

2.6.1.2). Anomalies do however exist, the causes of which are outlined in section 3.8.2.

The problems associated with calculating groundwater unit exploitation potential from limited qualitative data are discussed in Chapter 4. In an attempt to provide realistic potential etimates three types of terrain were delineated:

a) recharge zone

b) aquifer zone

c) discharge zone

The zones were demarcated on the basis of potentiometric and hydraulic gradient characteristics as well as the dominant hydrological function of each zone. The characteristics of each zone are discussed in sections 3.5, 3.6 and 3.7.

The discharge zones are located at the poorts but are too small to indicate of Figure 15. The surface area of the recharge and aquifer zones is given in Table 15.

Table 15: Extent of the aquifer and recharge zones.

Groundwater unit	Aquifer Zone km^2	Recharge Zone km^2	Total km^2
Moordenaars	110	320	430
Swart	110	410	520
Kamdeboo	160	180	340
Sundays	340	220	560

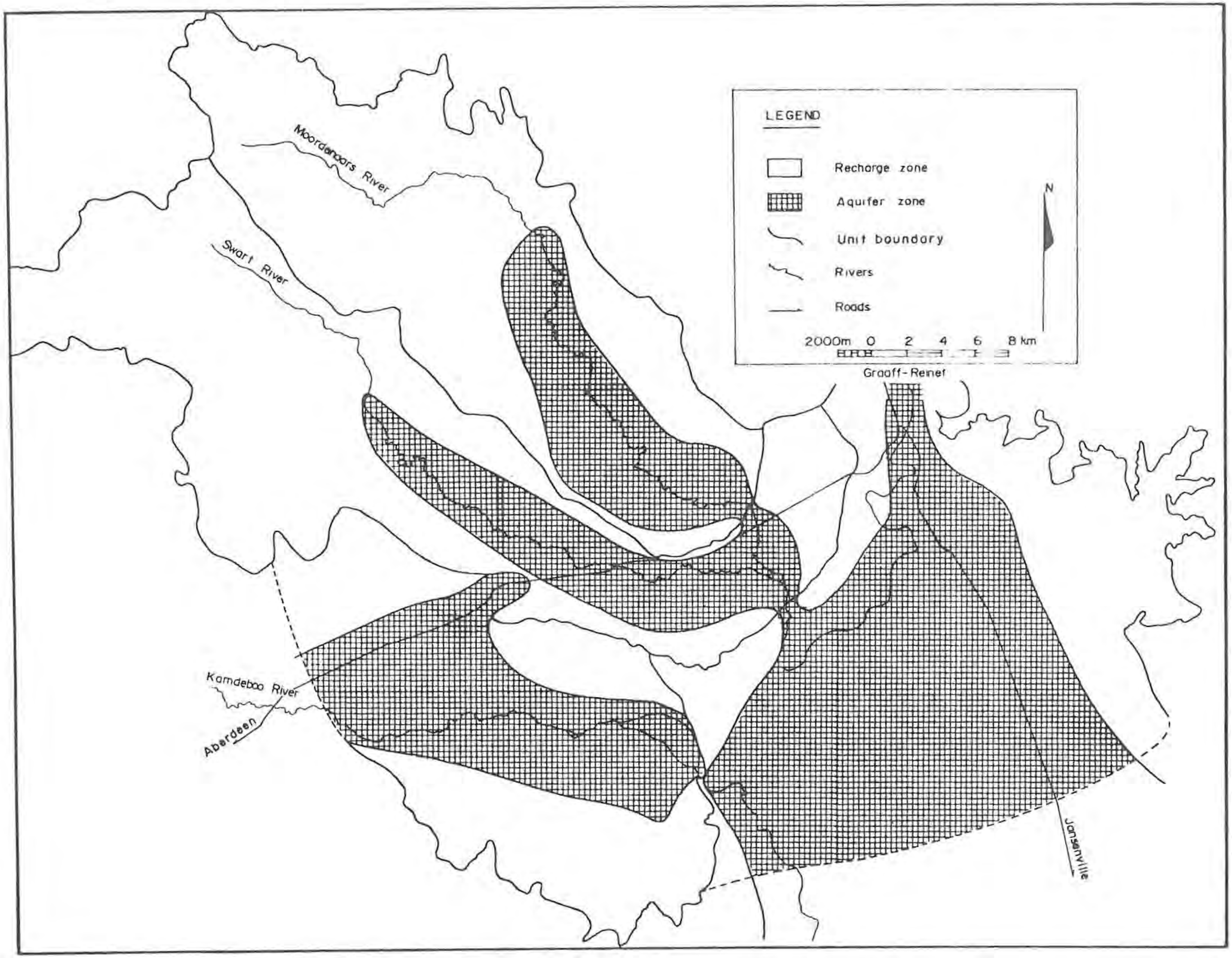


Figure 15: The position of the recharge and aquifer zones.

3.5 RECHARGE

The most important recharge mechanism appears to concern the direct infiltration of precipitation in the high-lying areas towards the sides of the groundwater units. This statement is based on limited periodic piezometric level monitoring (section 2.1.1) and field observations during rainfall events. Percolation takes place either through the permeable colluvial deposits or directly through the surface fractures and joints. The precipitation in these areas tends to be somewhat higher than in the flats (380 mm p.a. as opposed to 330 mm p.a.). The recharge zones are characterized by a steep hydraulic gradient (in the order of 0,01) and relatively low potentiometric pressures. Probably the most difficult part of any regional groundwater investigation is the estimation of annual recharge. However, in the Karoo environment, it is often assumed that 5% of the annual precipitation is effectively recharging the groundwater system (Seward, 1983), although there is little evidence to substantiate this figure. The following formula is used to estimate the average recharge in the recharge zone:

(surface area x mean annual rainfall x 5%) ÷ 365 days.

The average precipitation recorded at VREDE 286 (386 mm p.a.) is considered to be representative of the average precipitation of the recharge zones. The estimated average recharge from precipitation for the four groundwater units is then:

Moordenaars unit : 16 660 m^3/d

Swart unit : 21 340 m^3/d

Kamdeboo unit : 9 370 m^3/d

Sundays unit : 11 450 m^3/d

It should be emphasized that these estimates are for the recharge zones only (Fig. 15). During prolonged periods of rainfall, recharge of the groundwater units will also take place in the aquifer zone, through soil or river bank percolation. This mechanism is time dependent and occurs at very irregular intervals. Without long-term rainfall and piezometric data, it was not really possible to calculate the proportion of recharge of the aquifer zone from direct infiltration. The contribution is however reckoned to be small.

The recharge figures presented above are therefore conservative estimates for the groundwater units as a whole. Limitations associated with the average recharge estimates are discussed in Chapter 4.

Water passing through the groundwater unit outlet (poort) is also considered to be a form of recharge to the down-gradient unit and will be discussed in section 3.7.

3.6 AQUIFER ZONE

The aquifer zone is characterized by fairly low hydraulic gradients (in the order of 0,001) and relatively high potentiometric pressure in boreholes. These zones are located in the plains of the study area (Fig. 15). A striking feature of the groundwater movement in the aquifer zone is that groundwater flow generally tends to concentrate towards the middle of the unit. The position of the flow convergence zone appears to be controlled by lithological, structural and topographical factors but does not necessarily coincide with the major drainage channels (Encl. 3). The above condition is probably a natural condition as:

a) piezometric levels in the plains are generally shallow (between 5 m and 15 m) which indicates that little, if any, permanent lowering of the piezometric level due to groundwater abstraction has occurred
b) piezometric levels in the higher lying regions of the study area tend to be at a greater height above mean sea level than the average elevation of the plains
c) the Moordenaars unit, from which relatively little groundwater is abstracted, exhibits similar trends as the other three more developed groundwater units. Groundwater abstraction may however have enhanced the flow convergence pattern slightly.

All high-yielding boreholes in the study area are located in the vicinity of the flow convergence zone. This is illustrated by the results of drilling work conducted on the Vorster and Bloemfontein synclines (Figs. 12 and 13). Both synclines are structurally similar. The former, which is located on the Moordenaars unit convergence zone, produced two high-yielding boreholes while the latter, located north of the Kamdeboo convergence zone, produced boreholes with very average yields. The relationship between the location of high-yielding boreholes and the position of the flow convergence zone in the study area is extremely interesting. The contention that the analysis of piezometric and structural geological data could be a useful exploration tool for the siting of high-yielding boreholes would however have to be fully tested in other areas with similar geohydrological conditions.

The artesian conditions prevailing on the farm GROOTE VLAKTE 132, previously investigated by Venables (see section 1.4.1), are the combined result of:

a) the hydraulic head difference between the upper and lower points of the Groote Vlakte and Oudedrift fractures
b) the presence of a hydraulic discontinuity at the discharge zone of the fractures, which is a result of the dipping argillaceous sediments.

The above two controls, together with the semi-confined nature of the aquifer, provide the correct geohydrological setting for artesian conditions.

The storage characteristics of the fractured aquifer have previously been discussed (section 3.3). All aquifer tests were conducted in the aquifer zone, thus no storativity value for the recharge zone is available. A low coefficient of storage of 1×10^{-4} will therefore be used. The volumes of groundwater stored in the aquifer and recharge zones can therefore be estimated (Table 16).

Table 16: Estimated groundwater storage in the four groundwater units

CATCHMENT	AQUIFER ZONE ($x 10^6 m^3$)	RECHARGE ZONE ($x 10^6 m^3$)
Moordenaars	5,45	1,44
Swart	5,45	1,85
Kamdeboo	7,92	0,18
Sundays	16,83	0,99

3.7 DISCHARGE

Discharge from the groundwater units takes place by way of either groundwater abstraction, evapotranspiration or by surface or subsurface outflow through the poorts. An estimate of the annual groundwater abstraction is presented in Table 6. Most abstraction takes place in the aquifer zone. For purposes of standardization (as opposed to the annual abstraction estimates presented in Table 6), the average daily abstraction is presented in Table 17 and includes the abstraction from the Adendorp Allotment Area.

At present it is impossible to estimate the volume of groundwater lost from the units by way of evapotranspiration. The mean annual potential evaporation is 1210 mm (Woodford, 1984). However, substantial evapotranspiration losses can only be expected in areas which have a shallow water table (less than 4 m), which are densely vegetated or which are intensively irrigated.

Table 17: Estimated average daily groundwater abstraction.

Groundwater unit	Average daily abstraction (m^3/d)
Moordenaars	108
Swart	7 640
Kamdeboo	12 470
Sundays	11 530

The outlet zone at the poorts are characterized by a very flat hydraulic gradient above the flow-controlled boundary, a shallow water table, dense vegetation and springs. The presence of the latter is determined by the depth of weathering of the dolerite, the width of the poort itself, the transmissivity of the outlet zone and the hydraulic gradient across the poort outlet.

Previously (section 3.1) it was noted that little, if any water passes through the De Hoop poort, probably as a result of limited weathering and the presence of the De Hoop dam wall. The Kamdeboo unit can therfore be considered to be a closed basin which receives input from either precipitation or from subsurface flow through the western internal flow-controlled boundary on the farm ZEEKOEIGAT 140.

Attempting to estimate the volume of water passing through the southern boundary of the Sundays unit is difficult because:

a) the arbitary boundary is approximately 30 km in length

b) the piezometric level contour map (Encl. 3) indicates that most of the outflow occurs near the western portion of the boundary.

The average daily discharge from the Moordenaars and Swart units and the daily inflow into the Kamdeboo unit were calculated using data obtained from aquifer tests (Appendix 4) and piezometric data (Encl. 3). The estimates are presented in Table 18.

Table 18: Average daily through-flow through the flow-controlled boundaries

GROUNDWATER UNIT	FLOW-CONTROLLED BOUNDARY	SURFACE FLOW (m^3/d)	SUBSURFACE FLOW (m^3/d)	TOTAL (m^3/d)
Moordenaars	Corndale	130	100	230
Swart	Mooifontein	170	-	
	Kransplaas	80	940	1190
Kamdeboo	Zeekoeigat	-	2000	2000

3.8 HYDROCHEMISTRY

3.8.1 General Observations

The groundwater of the four geohydrological units can be classified into NaCl or stagnant type (Appendix 5c). This is in accordance with the findings of Tordiffe (1978) in his regional hydrochemical survey of the Karoo. There are however a few exceptions, namely groundwater south of the Kriegerskraal farm dam (G 33345, KK22, VN12 and VK2) which is of the bicarbonate type (dynamic)

3.8.2 Lateral Water Quality Variation

The groundwater quality within the study area varies considerably and will be discussed separately for each unit.

3.8.2.1 Moordenaars Unit

The quality of groundwater in the recharge areas is good (EC< 100 mS/m) but steadily worsens in the direction of groundwater flow (Encl. 4). The Corndale spring water has a conductivity of 500 mS/m. Figure 16a is a hydrochemical profile of the unit (see Encl. 5 for sampling positions) but the profile is not representative of down-gradient mineralization as the following influences are apparent:

a) the addition of fresh water via the Vorster syncline (GD19 and G 33401)
b) the addition of local recharge originating from the dolerite hills which form the southernmost boundary of the unit (CE9)
c) the build-up of salts as a result of transpiration and evaporation from the shallow water table (GDS1)
d) the dispersion of concentrated salts and the addition of better quality water below the Corndale poort (GD9).

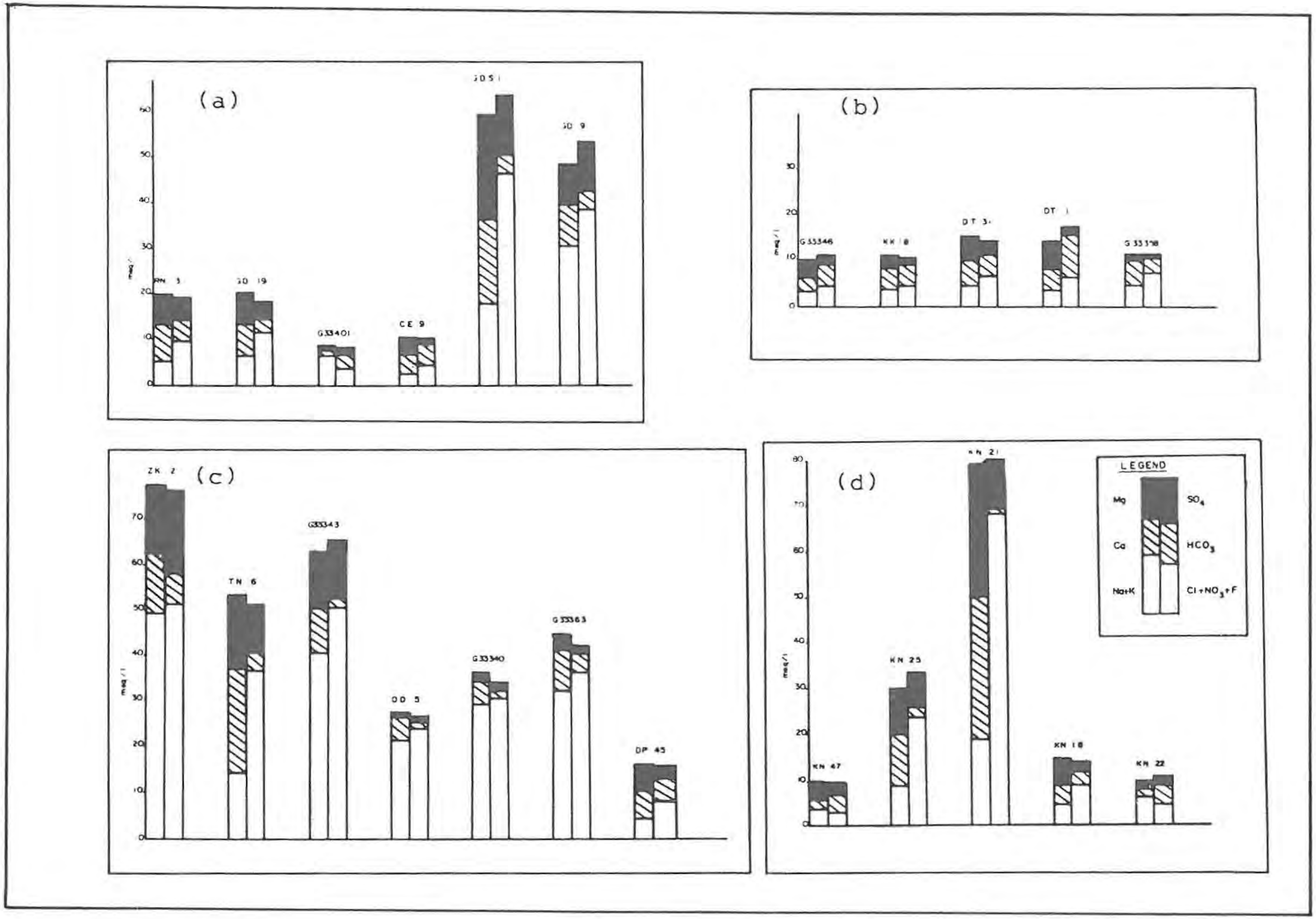


Figure 16: Hydrochemical profiles of (a) the Moordenaars unit; (b) the Swart unit; (c) the Kamdeboo unit and (d) of water samples taken on the farm KRUIDFONTEIN 413

3.8.2.2 Swart Unit

The quality of groundwater in the Swart unit is fairly good (EC < 200 mS/m) except near the outlet where the evapotranspiration of shallow water and the addition of poor quality water from the Moordenaars unit has resulted in a high salt concentration (EC ranges between 200 mS/m and 500 mS/m). The hydrochemical profile of this unit (Fig. 16b) is probably most representative of natural hydrochemical changes that take place in the direction of groundwater flow. However, the chemistry of water sampled from G 33358 is modified by the addition of local recharge water originating from the dolerite hills in the south.

3.8.2.3 Kamdeboo Unit

The lateral hydrochemical variations of groundwater in the unit are complex (Encl. 4; Fig. 16c) with EC measurements ranging between 100 mS/m and 800 mS/m. For the reasons listed below, no natural hydrochemical evolution of groundwater along this portion of the Kamdeboo unit is apparent:

a) highly mineralized water is present in the vicinity of irrigated lands (ZK2, TN6)
b) areas downstream of the irrigated lands undergo natural hydrochemical evolution as well as receive additional soluble salts from irrigation return flow (G 33343)
c) the addition of fresh water from the north (OD 5, G 33340 and G 33363). However, the water quality does deteriorate to the east. Note the high concentration of Na and Cl in

all seven boreholes, which indicates a relative reduction in the concentration of Ca, Mg, HCO_3 and SO_4

d) the addition of good quality water from the flanks of the valley (DP45).

3.8.2.4 Sundays Unit

The quality of water in the Sundays groundwater unit is generally good (EC < 200 mS/m) except in the following areas:

a) south-east of the De Hoop Dam (EC < 900 mS/m)

b) south of the Kransplaas outlet (EC < 500 mS/m)

c) in the Adendorp Allotment area (300 mS/m < EC < 400 mS/m)

d) on the farm KRUIDFONTEIN 413 (EC < 700 mS/m).

The poor quality of groundwater south-east of the De Hoop Dam is probably a result of irrigation practices as geohydrological evidence suggests that little, if any, groundwater passes through the De Hoop poort. The quality of water in the Adendorp area may also be explained by irrigation practices while the poor quality groundwater south of the Kransplaas outlet is due to the evapotranspiration of shallow groundwater north of the poort and is possibly also influenced by agricultural activities.

The poor water quality on the farm KRUIDFONTEIN 413 cannot be explained. The electrical conductivity and hydrochemical composition of the samples taken indicate similar mineralization trends, so the reason cannot be measurement error. The centre of poor quality water is in the vicinity of KN21 (Fig. 16d) and it is evident that the source is very localized. The north-south hydrochemical profile on the farm KRUIDFONTEIN 413 indicates a high proportion of Cl and an almost total absence of HCO_3.

3.8.2.5 Possible Factors Responsible for the Occurance of Mineralized Groundwater in the Study Area

Tordiffe (1978) concluded that the dominant control on the quality of the groundwater in the Middleton Formation is the natural hydrochemical evolution. The major factors controlling this evolution include geology, topography, climate and time. For practical purposes the former two factors can be considered constant. The influence of the semi-arid climate becomes dominant in places with a shallow groundwater table, usually in the discharge zones. In such cases, the soluble salts are concentrated by evapotranspiration. The duration with which water is in contact with the various lithological units varies considerably. It is not possible to plot salt concentration against distance from source as no water quality data were available for the portion of the Kamdeboo unit west of the investigation area. For this reason a comparison of the hydrochemical evolution of the waters in all four catchments cannot be made. However, except for isolated areas, the mineralization trends in the Moordenaars, Swart and Sundays units are similar. The Kamdeboo unit contains highly mineralized water even after mixing with good quality water from the mountain slopes in the north. The mineralization in this unit could be a result of the duration of water-rock contact and/or the closed basin nature of the unit.

A comparison of the water conductivity map (Encl. 4) and the land-use map (Encl. 2) indicates a good visual correlation between the location of poor quality groundwater and centres of irrigation activities. It was calculated that on a regional scale, the application of fertilizers to irrigated lands contributes a limited volume of salts to the groundwater system in comparison to the volume of salts originating from the use of groundwater for irrigation purposes (Table 19).

If irrigation practices are to some extent responsible for the deterioration of groundwater quality, two trends would be expected to become apparent:

a) contaminated groundwater would contain a higher percentage of relatively inert and soluble salts (Na and Cl) than uncontaminated water
b) TDS-content of groundwater would decrease with depth.

A comparison of Na and Cl concentrations in water samples taken from both windpumps and production boreholes in or near irrigation areas is presented in Figures 17 and 18. The following deductions can be made:

a) poorer quality groundwater is used for irrigation (Fig. 17)
b) waters from both sources have a similar Na concentration (Fig. 17)
c) irrigation waters tend to have a higher Cl concentration than non-irrigated water (Fig. 18).

Table 19: The relative contribution of soluble salts to the groundwater system from fertilizer application and groundwater irrigation

GROUNDWATER UNIT	Moordenaars	Swart	Kamdeboo
GROUNDWATER ABSTRACTED FOR IRRIGATION m^3/yr ($x10^6$)	0,33	2,70	4,47
AVERAGE TDS CONTENT OF WATER USED FOR IRRIGATION (mg/l)	750	1000	2200
SALTS ORIGINATING FROM GROUNDWATER APPLICATION kg/yr ($x\ 10^6$)	0,25	2,70	9,84
SALTS ADDED TO LANDS AS FERTILIZERS kg/yr ($x\ 10^6$)	0,04	0,19	0,03
% SALTS FROM GROUNDWATER	86,0	93,1	99,7

Water quality and hydrochemical samples (results of analyses presented in Appendix 5b) taken during drilling operations indicate that little stratification of water quality with depth

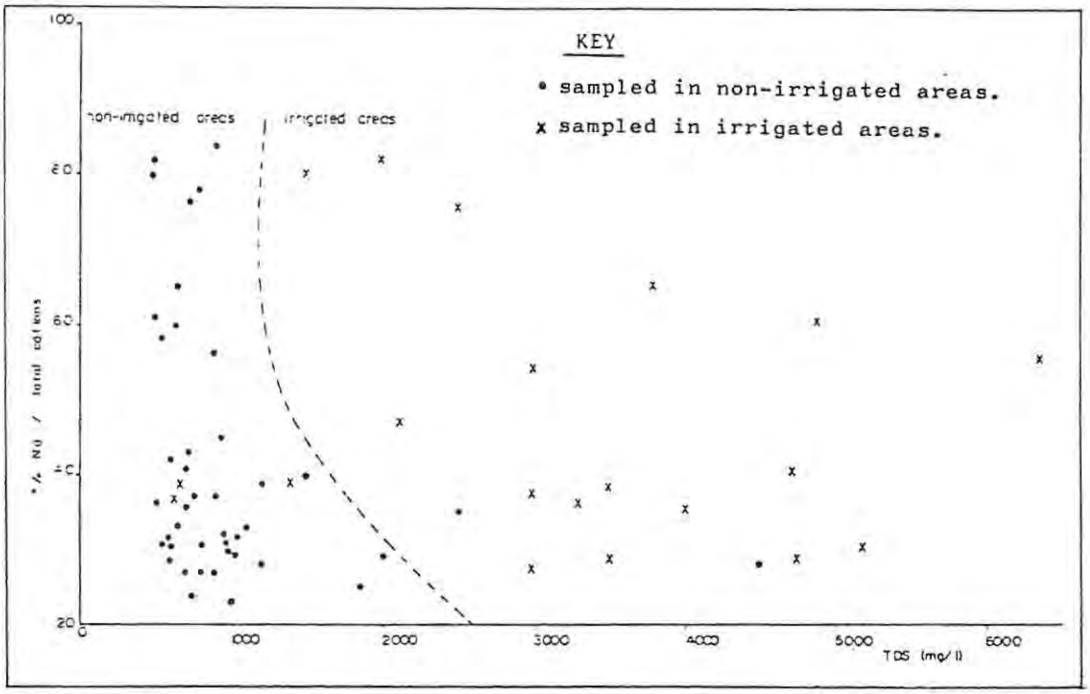


Figure 17: Na concentration plotted against TDS

occurs.

However, Foster and Bath (1983) noted that in the upper zones solute movement is strongly dispersive with a rapid downward movement. This, together with the flushing of salts into the groundwater system by either flood irrigation practices or rainfall recharge, would account for the limited variation in mineralization with depth.

It is not been possible to statistically establish the impact that irrigation has on groundwater quality. Firstly, the hydo-

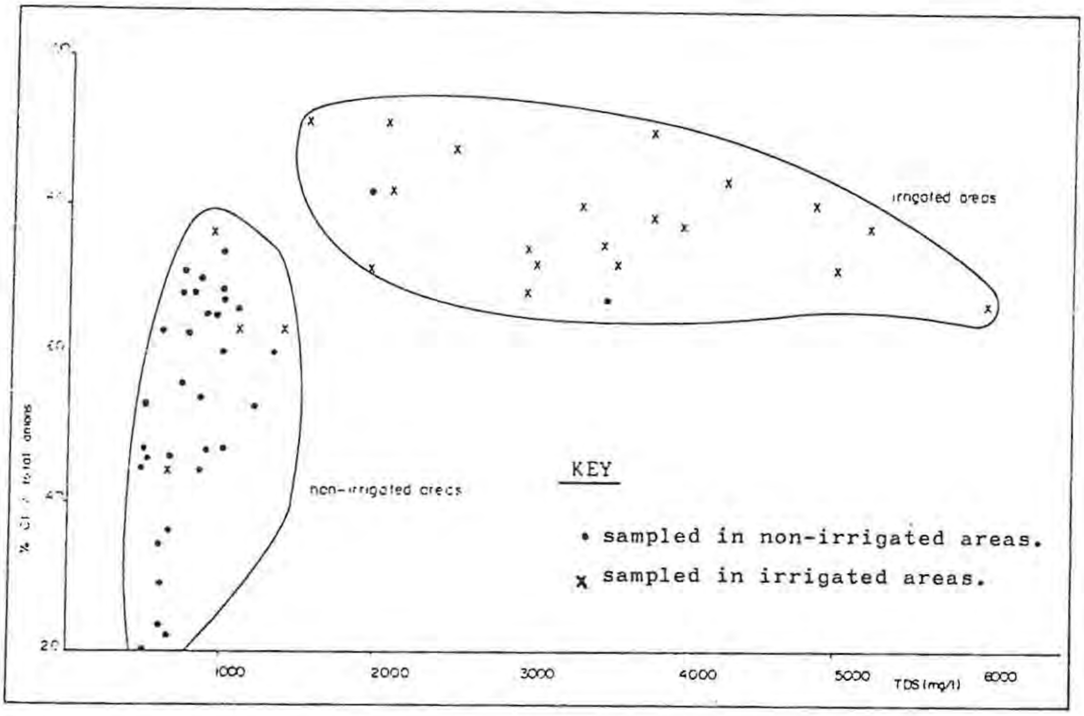


Figure 18: Cl concentration plotted against TDS

chemical sampling programme was geared towards assessing the suitability of groundwater for domestic use and secondly, a comparison between the quality of water obtained from irrigated and non-irrigated areas with similar geohydrological conditions was not possible (see section 3.8.2). However, the evidence presented here strongly supports the contention that salts are being recycled by groundwater abstraction for irrigation purposes and may have led to an acceleration of the rate of groundwater mineralization. This state of affairs can be expected in a closed basin situation.

3.8.3 Water Quality Variations with Depth

No evidence was found that the concentration of the major ion constituents or the general water quality varies with depth.

3.8.4 Water Quality Variation with Time

3.8.4.1 Short-term Variations

Electrical conductivity measurements taken during the aquifer tests indicate little quality variation with time (Appendix 5d). Where a recently drilled borehole was tested, an improvement in water quality was recorded in the first 1000 minutes and thereafter the TDS-content remained constant. This is probably a result of the removal of oil (from the drilling machine) and fine dust particles during the early stages of pumping.

3.8.4.2 Long-term Variations

The hydrochemical data of samples taken from six boreholes in 1972 (De Bruin, 1972) and 1985 were compared (DT1, DP49, GD7, GV14, ZF21 and US30). The following trends were recorded:

a) an average Cl concentration increase of 7,5% epm

b) an average TAL concentration decrease of 8,3% epm

c) a 10% and 22% epm Na increase in the case of ZF21 and DP49 and an 8% and 17% epm Na reduction in water sampled from US30 and GD7. Water sampled from DT1 and GV14 contained similar Na concentrations

d) ZF21 and DP48 waters show a 12% and 21% reduction in Mg concentration while samples taken from GD7 and US30 show a reduction of approximately 9%. The Mg concentration in DT1 and GV14 remained constant

e) the SO_4 and Ca concentrations remained constant in all six cases.

These changes indicate that the trend is towards increased mineralization in certain areas (DP49, GD7, ZF21).

3.8.5 Sulphurous Water

Sulphurous-smelling groundwater is found throughout the study area and may be an important consideration in the planning of groundwater abstraction for domestic use. The H_2S-type water, although found at various depths, occurs in the fractured aquifer only. It is often associated with sediments containing an abundance of pyrite. The water gives off a gas which smells of rotten eggs and the gas is inflammable. The H_2S-type water can be freed of its smell by inducing turbulence or aeration but a black residue may remain.

A plot of the H_2S-type and non-H_2S-type waters on separate Piper-diagrams (Figs. 19 and 20) reveals that:

a) the H_2S-type water is classified as "stagnant" to "NaCl-type" while the non-H_2S-type water ranges from "recent recharge-type" to "stagnant-type" water

b) the H_2S-type water has a cation range from "no dominant cation" to "sodium-type" while the non-H_2S-type water has "no dominant cation-type"

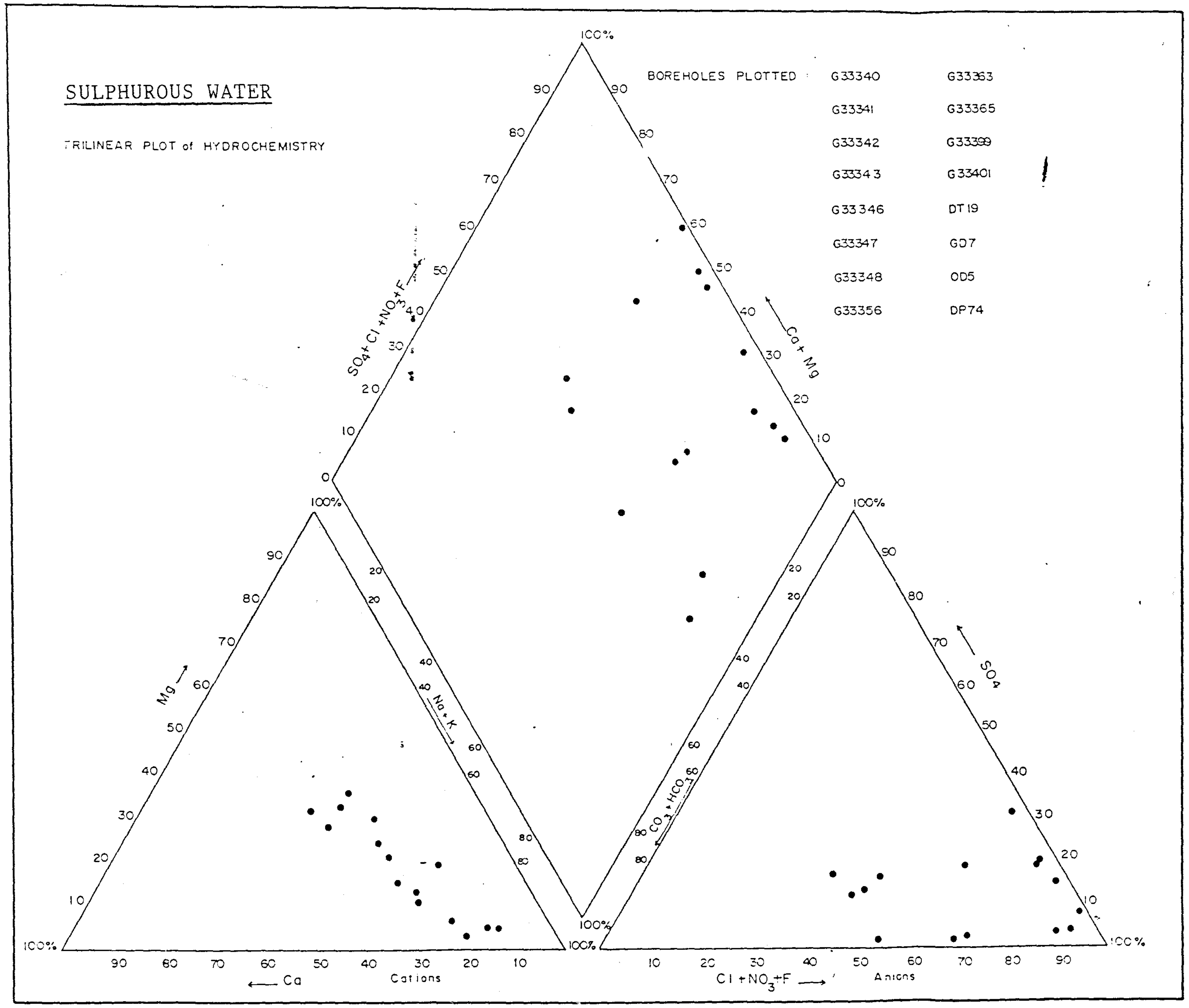


Figure 19: Piper plot of sulphurous-type water.

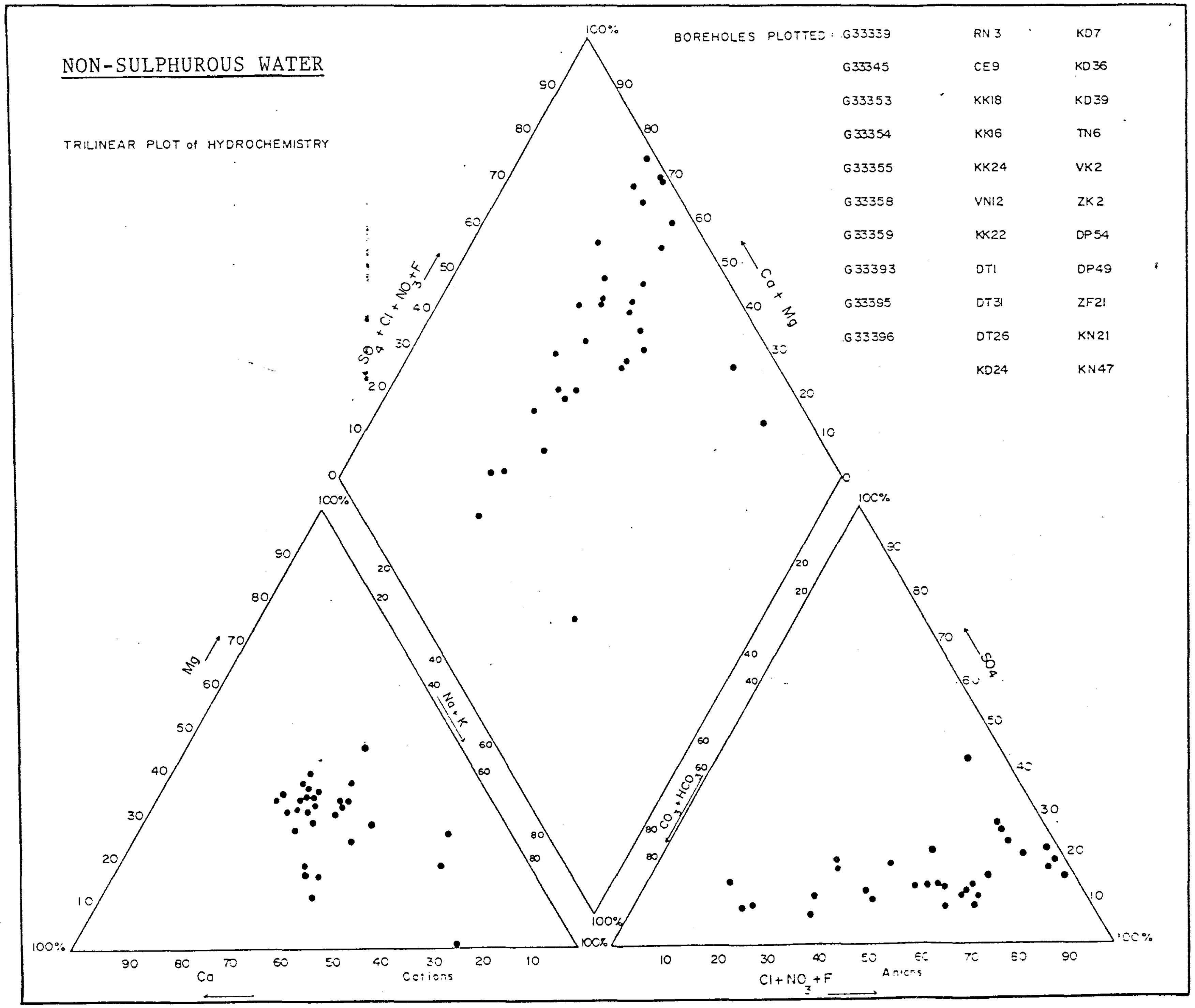


Figure 20: Piper plot of non-sulphurous-type water.

c) the anions of the H_2S-type water can be classified as "Cl-type" while the non-H_2S-type water has a anion concentration that ranges between "HCO_3-type" and "Cl-type". The two water types contain similar concentrations of SO_4.

In order to assess the origin of the H_2S-type water, the stability fields of various sulphur compounds need to be considered (Hem, 1970).

H_2S (aq) - stable in reducing conditions with a pH less than 7

HS^- - stable in reducing conditions with a pH greater than 7

SO_4^{2-} - stable in oxidizing conditions with a pH range of 2 to 14

FeS_2 - stable in reducing conditions and the pH may range between 0 and 14.

Because of the slowness of the oxidation and reduction reactions involving S^2-ions, non-equilibrium S compounds can persist for long periods of time, e.g. H_2S and FeS_2 can persist in aerated zones. Also, non-equilibrium forms such as H_2S and SO_4^{2-} can co-exist under the same conditions.

The origin of H_2S-type water may be two-fold. Firstly the "stinky" water appears to be exclusively associated with the Middleton Formation which was deposited under reducing conditions. The Karoo sediments stratigraphically below and above this formation were all deposited under oxidizing conditions.

The H_2S within the system is thus probably inherent to the Middleton Formation and remains under non-equilibrium conditions. The second possible origin of the H_2S-type water is of a more contemporary nature. For the production of H_2S, the H^+ ion and S^{2-} ion are required. The H^+ ion is produced in many chemical reactions involving water while the S^{2-} ion may originate from the oxidation of pyrite or the reduction of SO_4^{2-} compounds. Bacteria may be important in this regard. Important sources of SO_4^{2-} include rainwater, weathering of sediments (especially mudstones and gypsum) as well as the weathering of dolerite.

The sulphurous gas is soluble under pressure and will remain in solution in the groundwater system. The migration of the gas in groundwater systems is complex and is beyond the scope of this report. However, when H_2S containing groundwater is abstracted, a rapid pressure reduction forces the gas out of solution. The volume of gas released is dependent on the pressure reduction. Thus by agitating the water, most of the H_2S-gas will be released.

3.8.6 Suitability of the Groundwater for Domestic Use

The criteria used to assess the suitability of groundwater for domestic use are presented in Table 20.

Water sampled in four areas consistently contained excessive concentrations of TDS, Na, Cl and SO_4. These areas are:

a) the whole Kamdeboo unit

Table 20: Some concentration limits affecting the suitability of water for domestic purposes.

PROPERTY	RECOMMENDED LIMIT (mg/ℓ)	MAXIMUM ALLOWABLE LIMIT (mg/ℓ)
TDS	500	2000
pH	6 - 9	5,5 - 9,0
Na	100	400
K	200	400
Mg	100	150
Cl	250	600
SO_4	250	400
Total hardness (as $CaCO_3$)	20 -200	1000
F	1,1	1,5
Nitrate (as N)	10	-

(S.A.B.S., 1971)

b) south of the De Hoop dam

c) south of the Moordenaars unit outlet

d) the area in the vicinity of KN21 on the farm KRUIDFONTEIN 314.

All samples analysed had a pH of between 7,0 and 8,1 while no excessive K or TAL concentrations were recorded.

Most of the recorded F concentrations were below the recommended limit. However, water samples taken during drilling operations near the southern boundary of the Vorster syncline, in the middle of the Swart River valley and on the farm Grootvlakte contained F concentrations ranging between 2,2 and 6,7 mg/l. These apparently anomalous concentrations cannot readily be explained.

CHAPTER 4

EXPLOITATION POTENTIAL ESTIMATES

4.1 INTRODUCTION

"When the hydrogeological investigation has been completed and the inflow and outflow component of the aquifer have been quantified, the overall groundwater balance of the basin must be assessed" (Boonstra and De Ridder, 1981, page 69). Because of time and budget constraints it was not possible to quantify all the parameters required to satisfy the general groundwater balance equation, as proposed by Boonstra and De Ridder (1981). In addition it was felt that because estimates of the required parameters could lead to large errors in the final calculation, alternative methods would be employed. Three simple equations, based on parts of a groundwater balance equation presented by Boonstra and De Ridder (1981), were derived and applied in an attempt to estimate groundwater unit exploitation potentials. It should be noted at the outset, however, that the methods are conservative.

(1) RECHARGE METHOD

EXPLOITATION POTENTIAL = R + I - 0

where R = long-term average potential recharge from precipitation in the recharge zone (section 3.5)

I = subsurface inflow into the groundwater unit

(Table 18)

O = outflow (subsurface and springflow) from the groundwater unit

The assumptions related to the method are:

a) 5% of the average annual precipitation effectively recharges the groundwater units (Seward, 1983)

b) recharge in the aquifer zone is intermittent, assumed to be lower than in the recharge zones and can be considered to compensate for evapotranspiration losses

c) based on the 100 year rainfall record of Graaff-Reinet (Woodford, 1984), below-average rainfall lasts about 3 years and is followed by a 2 year above-average rainfall period. This means that, on average, the groundwater units can be expected to be fully recharged every 3 years.

The exploitation figure obtained with this method is probably the mean volume of groundwater which could, on an annual basis, be abstracted under optimal exploitation conditions. This implies a widespread production network and an optimal management strategy.

(2) GROUNDWATER OUTPUT METHOD

EXPLOITATION POTENTIAL = A + O

where A = the mean volume of groundwater currently abstracted from each unit (Table 17)

O = outflow (subsurface and springflow) from the groundwater unit (Table 18)

The exploitation figure derived using this method is the minimum volume of groundwater which can be taken from each unit without creating undesirable effects, except when such effects have already been encountered as a result of existing groundwater withdrawal. This is the only method not based on an assumption.

(3) AQUIFER STORAGE METHOD

EXPLOITATION POTENTIAL = S ÷ 3

where S = the volume of groundwater in the aquifer zone (Table 16).

The aquifer storage method is based on the assumption that the volume of groundwater stored in the aquifer zone has to last a run of three years with limited effective reharge. The average storativity value of $1{,}1 \times 10^{-3}$, as derived from aquifer tests, was used. This method is the most conservative of the three because:

a) a run of three years with no recharge is unlikely to occur except under extreme conditions
b) the volume of water stored in the recharge zone is not considered. It is considered to compensate for the residual volume of groundwater in the aquifer zone which can never really be abstracted economically
c) the average storativity value is probably conservative.

Vanhoolaeghe (1985) determined an S-value of $2,5 \times 10^{-3}$ for the Gamka fractured aquifer north of Beaufort West which has similar characteristics to the units in the present investigation area. He calculated this value from the abstraction record and piezometric data of an aquifer that was effectively dewatered by pumping during the recent drought.

(4) MINIMUM EXPLOITATION POTENTIAL

Without the required quantified data, the calculation of exploitation potentials is extremely difficult. Of the three equations employed, the recharge method must be considered to be the weakest owing to the assumptions related to the method. Johnson (1980) notes that recharge is controlled by both physical conditions (topography, vegetation, geology, soil characteristics) and climatic conditions (individual precipitation event characteristics; seasonal climatic characteristics). In this thesis it was not possible to take cognizance of all factors effecting recharge owing to the lack of quantified data. Rather, average conditions have been used. By delineating the recharge and aquifer zone (section 3.4) it was felt that a more realistic effective recharge volume for the whole unit was obtained. The simplistic approach employed is conservative, necesitated by the lack of the quantified data.

The groundwater output method is not based on an assumption but the results obtained are dependent on the extent of groundwater development in each unit. Unless undesirable effects such as the lowering of the piezometric levels or the induction of poorer quality water have been recorded, this method is considered to be a minimum exploitation potential.

The assumptions related to the aquifer storage method are outlined in detail in section 4.1. The major weakness of the method is the assumption that the aquifer is only fully recharged every 3 years, except under extreme conditions. However, as municipal groundwater abstraction from the study area will probably only take place during drought periods, the assumption is justified.

The minimum exploitation of a given groundwater unit is the lowest of the three methods with the provision that the ouput figure (method 2) will be preferred whenever higher than the volumes derived with the other methods. It is however ruled that no undesirable effects should have been recorded whenever method 2 has to be accepted.

4.2 POTENTIAL ESTIMATES OF THE FOUR GROUNDWATER UNITS

4.2.1 Moordenaars Unit

EXPLOITATION POTENTIAL : Method 1 = 16430 m^3/d

Method 2 = 430 m^3/d

Method 3 = 5000 m^3/d

For undetermined reasons, large-scale groundwater utilization in this catchment has not yet taken off. Method 2 therefore gives a grossly underestimated figure. The minimum exploitation potential of the the Moordenaars unit is 5000 m^3/d while the long-term optimal exploitation potential is in the order of 16400 m^3/d.

Because the quality of groundwater in this unit is good (EC < 100 mS/m), the safe yield of the unit will ultimately be determined by:

a) the effect that increased groundwater abstraction has on recharge and/or evapotranspiration losses
b) the effectiveness of groundwater abstraction which is, amongst other factors, a function of the availability of economical abstraction points
c) legal constraints.

4.2.2 Swart Unit

EXPLOITATION POTENTIAL : Method 1 = 20370 m^3/d
Method 2 = 8660 m^3/d
Method 3 = 5000 m^3/d

The volume of groundwater currently abstracted for irrigation purposes has not yet led to a drastic decline of the piezometric surface nor a noticeable increase of groundwater mineralization. The minimum exploitation potential is therefore 8660 m^3/d while the average long-term optimum exploitation potential is about 20000 m^3/d.

The groundwater quality of the Swart unit is fit for direct human consumption (EC generally less than 150 mS/m) except north of the Kransplaas poort. This portion would have to be avoided if large-scale abstraction schemes were to be developed. All abstraction should therefore take place west of G33356, G 33357 and G 33358. The optimum exploitation potential would then be in the order of 14000 m^3/d.

The observations about the "safe-yield" of the Moordenaars unit are also applicable to the Swart unit.

4.2.3 Kamdeboo Unit

EXPLOITATION POTENTIAL : Method 1 = 11370 m^3/d
Method 2 = 12470 m^3/d
Method 3 = 7230 m^3/d

The future long-term assured supply from this unit is probably closer to 7230 m^3/d than to 11370 m^3/d, because recharge comes, to a large extent, from upstream subsurface import. The inflow is likely to decrease in future as indications are that groundwater utilization, in the middle and upper reaches of the Kamdeboo catchment, is still expanding. During periods of average and below-average rainfall, groundwater storage is already being abstracted and therefore little room for additional groundwater development exists.

The potential is further reduced by the poor quality of groundwater in the aqifer zone (maximum EC recorded was 800 mS/m). The quality is bound to worsen because of the closed basin nature of the unit, irrigation practices and poor quality water import.

The fresh water exploitation potential of this unit is limited to 420 m^3/d (EC < 90 mS/m). This can be obtained at the Kriegerskraal poort (KK21 and KK25).

4.2.4 Sundays Unit

EXPLOITATION POTENTIAL : Method 1 = not applicable
Method 2 = 11530 m^3/d
Method 3 = 15370 m^3/d

Apart from the hydrocensus, limited research was carried out in the Sundays unit. The lack of geohydrological information across the arbitary southern boundary makes it very difficult to estimate the recharge potential of the unit.

Large-scale groundwater abstraction takes place in the Adendorp Allotment area and on the farm DE HOOP 436, south of the De Hoop dam. Both areas produce poor quality groundwater which is not fit for direct human consumption (EC ranges between 200 mS/m and 900 mS/m). Because of the undesirable quality of the groundwater, the minimum exploitation potential of the Sundays unit (11530 m^3/d) has to be accepted with reservation.

The prime target areas for developing large-scale production boreholes are located in the flow convergence zones. In the

Sundays unit, this zone is located near three areas which produce groundwater not suitable for direct human consumption (Adendorp Allotment area, south of Kransplaas and south of the De Hoop dam). Therefore, it is unlikely that large volumes of good quality groundwater could be obtained from the Sundays unit.

4.3 DISCUSSION

Some basic exploitation potential calculations have shown that the possibilities for large-scale additional groundwater development in the Sundays and Kamdeboo units are slight to almost non-existent. Most groundwater in these units is also unsuitable for direct urban and industrial supply. A portion of the water could not even be recommended for irrigation purposes. The present large-scale use of poor quality groundwater is borne out of necessity. With time, less surface water, either directly as flood water or indirectly via reservoirs (e.g. Van Reynevelds Pass Dam, De Hoop Dam), has become available and the deficit is increasingly drawn from groundwater sources. It can be expected that both the water supply and water quality situations will worsen even further in these units, because irrigation-based agricultural development in the upper sectors of the catchment is apparently still expanding.

The lower limit of groundwater exploitation in the Swart and Moordenaars units was determined as 8660 m^3/d and 5000 m^3/d respectively. However, if a groundwater draft of 8660 m^3/d can easily be maintained in the Swart unit, surely the same quantity could in the long run be withdrawn from a unit of similar size and nature. The combined minimum potential of these units is therefore no less than about 17000 m^3/d. Their optimum combined potential may be of the order of 30000 m^3/d. The volume of surplus groundwater currently available from these units is approximately 21000 m^3/d.

The groundwater in these units is suitable for direct urban supply. No drastic quality deterioration is anticipated if the above-mentioned volumes are to be exported from the units.

4.4 POSSIBLE LARGE-SCALE PRODUCTION SITES

If the Swart and Moordenaars units are to be developed for large-scale abstraction, widely spaced abstraction points would have to be found. The spacing of the production boreholes that would be required is best illustrated by considering five high-yielding boreholes in the Swart unit (US30, KK17, DT100, G33358 and KD103). If these boreholes were to be pumped for 22 hours a day, 11000 m^3/d could easily be abstracted. In order to abstract similar quantities from the Moordenaars unit, as many as 10 production boreholes may be required because this unit does not appear to have many high transmissive zones.

The best sites for the production boreholes are associated with:

a) the flow convergence zone
b) densely fractured geological structures (synclines, anti-

clines, fracture zones).

The Vorster syncline in the Moordenaars unit would be an obvious prime target as two high-yielding production boreholes (± 15 l/s) could possibly be sited on the structure. Fracture-related geological structures do exist to the north of this syncline but would have to be explored and located. Aerial photographic studies may be helpful in this regard. A number of potential production zones were also identified in the Swart unit (Brooklyn fracture, Brooklyn dyke, Swart syncline, etc.). Further detailed geological mapping may reveal more structures of a similar nature in this unit.

CHAPTER 5

FULFILLMENT OF OBJECTIVES AND HYPOTHESIS TESTING

The principal objective and the specific aims of the study were outlined in Chapter 1. A set of study hypotheses were also proposed. Chapters 3 and 4 discuss in detail the geohydrology and estimated exploitation potential of the investigation area. This chapter serves to check whether the aims of the study have been fulfilled and to test the hypotheses presented earlier (Chapter 1).

5.1 FULFILLMENT OF THE AIMS AND OBJECTIVES OF THE STUDY

The principal objective of this study was to quantitatively assess the groundwater potential south and west of Graaff-Reinet, in terms of both quantity and quality. Four groundwater units were identified (section 3.1), namely the Moordenaars, Swart, Kamdeboo and Sundays units. Owing to the lack of quantified data requied for the implementation of a groundwater balance equation, three simple equations were derived in an attempt to estimate groundwater exploitation in the study area. The former two units were found to be suitable for further groundwater development as both contained good quality water (section 3.8.2.1 and 3.8.2.2). The combined optimum potential of the Moordenaars and Swart unit was put at 30000 m^3/d of which 21000 m^3/d would be available for municipal use (section 4.3). The Kamdeboo and Sundays units, owing to low exploitation potentials and poor quality groundwater are not suitable for further development.

In order to fulfill the above objective, three specific aims and a set of hypotheses were proposed. As the two are closely related, the discussion regarding the fulfillment of the aims of the study is included in the next section.

5.2 TESTING OF HYPOTHESES

Hypothesis 1 : The major transmissive zones within the groundwater units are associated with fractured sandstone horizons.

Forty percent of all water interceptions were obtained in sandstone layers while the remaining sixty percent of interceptions were obtained in mudstone, siltstone, alluvial deposits and dolerite (Table 13). Of the 8 interceptions that yielded more than 6 l/s, 5 were related to the presence of sandstone. A number of minor water strikes were obtained in siltstone deposits. Although it was not possible to determine characteristic T values for the different lithologies, the hypothesis, based on the drilling results, is accepted.

Hypothesis 2 : Together with sandstones, interbedded siltstones and mudstones of low permeability, form laterally extensive storage zones.

The upper part of the Beaufort Group sediments which contains the groundwater in secondary openings can, on a large scale, be considered to be uniformly fractured. Three aquifer elements were identified, namely the fractured aquifer, the transmissive production zones and the top leaky layer (section 3.3). The transmissive production zones were found to have a storativity ranging between $1,3 \times 10^{-4}$ and $1,9 \times 10^{-5}$, the storativity of the fractured aquifer ranged between $5,7 \times 10^{-3}$ and $1,2 \times 10^{-4}$ while the storativity of the leaky layer could not be quantified. It is evident from these figures that most groundwater is stored in the fractured aquifer which consists of sandstones, siltstones and mudstone. The hypothesis is therefore accepted.

Hypothesis 3 : The fractures and joints have a low storativity.

The storativity of the fractured aquifer and the transmissive production zones (fracture zone) are presented in section 3.3. From the storativity values obtained for the two aquifer elements, it is evident that most water is stored in the fractured aquifer and little in the transmissive production zones. The production zones are areas which are highly fractured or contain fracture zones. These zones act as conduits and allow for the rapid movement of groundwater, but store little water themselves. The hypothesis is accepted.

Hypothesis 4 : Hydraulic continuity exists between the alluvial deposits and the consolidated sandstones, siltstones and mudstones.

A top leaky layer, which consists of both alluvial deposits and weathered sediments, was identified (section 3.3.3). The layer is not found throughout the study area but is generally confined to the central part of the groundwater units. The presence of this layer above the fractured aquifer results in semiconfined conditions. The vertical permeability of the top layer was measured to range between $5{,}0 \times 10^{-3}$ and $7{,}5 \times 10^{-4}$ m/d. Even though these values are relatively low, hydraulic conductivity does exist between the alluvial deposits and the consolidated sediments. This hypothesis is therefore accepted.

Hypothesis 5 : The secondary nature of the groundwater units leads to anisotropic geohydrological conditions.

The initial interpretation of aquifer test data proved problematic. The construction of conceptual flow models, based on geohydrological conditions, and the relative change in piezometric levels indicated the anisotropic conditions prevailing at each site (discssed in section 2.5.2.3 and Appendix 4). Linear flow or fracture flow was encountered on numerous occasions. Pseudo-radial flow was induced after the early stages of pumping, the time of induction being related primarily to the degree of anisotropy. The aquifer test data from boreholes KK21 and G33401 are good examples of anisotropic flow conditions (see notes in Appendix 4). The hypothesis is accepted.

Hypothesis 6 : The principal recharge areas are located in the higher lying areas.

For the sake of convenience, each groundwater unit was divided into a recharge and an aquifer zone (section 3.4). The divisions were made on the basis of piezometric data (Encl. 3), water quality data (Encl. 4) and the principal function of each area. Groundwater flow directions indicate that the greater part of groundwater recharge takes place in the high-lying areas. The recharge zones are characterised by steep hydraulic gradients and low potentiometric pressures. It was also recognised, however, that during prolonged periods of rainfall, recharge would take place through the alluvial deposits located in the central parts of the groundwater units (section 3.5). As it was not possible to accurately quantify recharge in each zone, the hypothesis cannot be accepted.

Hypothesis 7 : Good quality water is associated with recent recharge.

On the basis of piezometric and water quality data, it was found that good quality groundwater is associated with recent recharge (section 3.8.2). Electrical conductivity measurements taken near the recharge zones tend to be less than 100 mS/m, gradually increasing in the direction of flow. Artificial recharge from the Kriegerskraal farm dam also resulted in good quality water (EC < 100 mS/m). The hypothesis is accepted.

Hypothesis 8 : None of the groundwater in the study area is polluted.

The change of water quality in the direction of flow (Encl. 4; Fig. 14) indicates that natural hydrochemical evolution of groundwater plays an important role in determining water quality. However, a comparison of the water conductivity map (Encl. 4) and the land-use map (Encl. 2) indicates a good visual correlation between the location of poor quality groundwater and centres of irrigation activities (discussed in section 3.8.2.5). This together with the comparison of Na and Cl content of waters sampled in irrigated and non-irrigated areas (Fig. 17; Fig. 18) strongly suggest that man's activities also play a major role in determining groundwater quality. It was calculated that the application of fertilizers to irrigated lands contributes a limited volume of salts to the groundwater system, in comparison to the volume of salts originating from the use of groundwater for irrigation purposes (section 3.8.2.5). The hypothesis is rejected.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Four large groundwater units were identified to the west and south of Graaff-Reinet, the lateral boundaries of each unit being defined principally by topographic highs and ring-structured dolerite sheets. The aquifers consist of three components, namely the fractured aquifer, the transmissive production zones and, in places, a top leaky layer. Of the four units identified only the Moordenaars and Swart units were found to be suitable for further large scale groundwater development. The combined optimum potential of the two units is in the order of 30000 m^3/d, of which about 21000 m^3/d is available for municipal supply. The most suitable areas for production boreholes are associated with flow convergence zones and highly fractured sedimentary rocks. Any production boreholes would have to be spread over the entire aquifer zone. Groundwater quality is chiefly determined by natural hydrochemical evolution processes but, in places, large scale abstraction for irrigation has lead to the acceleration of groundwater mineralization.

Detailed hydrocensus work and geological mapping provided a basic framework of the geohydrology of the investigation area from which further exploration could be planned. The conjunctive use of geological and piezometric data (used to define the flow convergence zones) proved to be an effective exploration tool for the siting of high yielding boreholes, while resistivity work had a limited application to the investigation. The multiple piezometer aquifer test approach helped to develop a good understanding of the prevailing geohydrological conditions and meaningful hydraulic parameters could thus be obtained.

6.2 RECOMMENDATIONS FOR FURTHER RESEARCH

In order to facilitate the re-evaluation of the groundwater exploitation potential and to monitor the response of the system to increased abstraction, the following work should in future be conducted in the investigation area :

a) a large scale hydrocensus at, say, five yearly intervals;

b) monthly water level measurements in a selected number of boreholes in both the recharge and aquifer zones. Permanent automatic water level recorders should be placed in key areas such that inflow, outflow and abstraction patterns can be monitored;

c) periodic water quality monitoring in specific boreholes:

- electrical conductivity measurements should be taken at the start and end of the irrigation season (August and April);
- full hydrochemical sampling once a year at a fixed date

(either August or April).

Little attempt has been made in the past to quantify effective recharge in the Karoo. Rather a percentage of average annual precipitation has been assummed to effectively recharge groundwater systems (section 3.5). Owing to the importance of recharge when considering groundwater balance equations, it is imperative that recharge studies be conducted. Greater attention should also be paid to the hydraulic characteristics of what was in this study termed the recharge zone. The Moordenaars groundwater unit would be suitable for such a study as:

a) limited large scale abstraction takes place in the unit
b) the only input into the system is recharge from precipitation
c) outflow from the unit can easily be determined.

The results obtained from such a study could then be applied to other parts of the Karoo which exhibit similar geohydrological characteristics as the present study area.

In this study the conjunctive use of piezometric and geological data was found to be a useful exploration tool. The contention that the analysis of these data could be used in other areas of similar geohydrological characteristics would however have to be tested.

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Mean magnetic declination 22°. 6 West of True North (1973. 0). Mean annual change 1' Westwards (1966-1970)
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Gemiddelde magnetiese deklinasie 22°. 6 Wes van Ware Noorde (1973. 0). Gemiddelde jaarlikse verandering 1' Weswaarts (1966-1970)
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SUID-AFRIKA
3224AA TOORBERG
24°00'
32°00'
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Pietberg

TOORBERG

Refer to this Map as SOUTH AFRICA 1:50 000 Sheet 3224AA TOORBERG
Verwys na hierdie Kaart as SUID-AFRIKA 1:50 000 Vel
FIRST EDITION EERSTE UITGAWE

1:50 000

KONTOERTUSSENRUIMTE 50 ENGELSE VOET

5 000 | 10 000 | 15 000 Engelse Voet

1 | 2 | 3 Landmyl

1 000 | 2 000 | 3 000 | 4 000 | 5 000 Meter

Elevations are in English Feet to ground level
Hoogtes is in Engelse Voet op grondhoogte

Conform Projection Central Meridian 25° East Clarke 1880 Spheroid
Conforme Projeksie Middelmeridiaan 25° Oos Clarke 1880 Sferoïed

Die ruitlyne van die Suid-Afrikaanse Koördinaatstelsel word in die kantruimte aangetoon deur kort swart strepies 10 000 meter van mekaar met koördinaatwaardes in eenhede van 10 000 meter in blou.
Die ruitlyne van die aangrensende ruitnet word op dieselfde manier aan die buitekant van die graadnetkanteling aangetoon.

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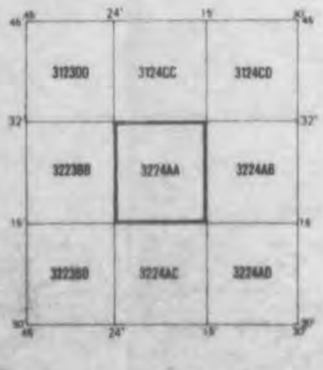

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REFERENCE VERKLARING

REFERENCE	VERKLARING
Magnetic Stations and Ground Signs	Magnetiese Stasies en Grondtekens
Huts	Hutte
Monuments	Monumente
Dipping Tanks	Dipbakke
Windmills	Windpompe
Walls	Mure
Anti erosion Walls	Grondbewaringswalle
Excavations	Uitgrawings
Perennial Water	Standhoudende Water
Non perennial Water	Nie-standhoudende Water
Dry Pans	Droë Panne
Springs, Waterholes and Wells	Fonteine, Watergate en Putte
Marshes, Swamps and Vleis	Moerasse en Vleie
Pipelines	Pyplyne
Photo Centres	Fotomiddelpunte
Prominent Rock Outcrops	Prominente Klipbanke
Terraces	Terrasse
Cultivated Lands	Bewerkte Lande
Orchards and Vineyards	Boorde en Wingerde
Trees and Bush	Bome en Bos

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CONTOUR INTERVAL 50 ENGLISH FEET

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Statute Miles 1 0 1

Metres 1 000 0 1 000 2 000 3 0

REFERENCE VERKLARING

REFERENCE	VERKLARING
International Boundaries	Internasionale Grense
Provincial Boundaries	Provinsiale Grense
Multiple Track Railways	Veelvoudige Spoorlyne
Single Track Railways	Enkelspoorlyne
Electrified Railways	Geëlektrifiseerde Spoorlyne
Narrow Gauge Railways	Smalspoorlyne
Service Railways	Diensspoorlyne
Arterial Roads	Hoofverkeerspaaie
Main Roads	Grootpaaie
Secondary Roads	Sekondêre Paaie
Other Roads	Ander Paaie
Tracks and Footpaths	Dowwe Paaie en Voetpaaie
Power Lines	Kraglyne
Telephone Lines	Telefoonlyne
Post Offices, Police Stations and Posts, Stores, Hotels, Schools and Places of Worship	Poskantore, Polisiestasies en poste, Winkels, Hotelle, Skole en Plekke van Aanbidding
Lighthouses and Marine Lights	Vuurtorings en Seevaartligte
Marine Beacons	Seevaartbakens
Trig. Beacons (Number to right and height below)	Trig Bakens (Nommer regs en hoogte onder)

The grid lines of the South African Co-ordinate System are indicated in the margin by short black ticks at 10 000 metre intervals with co-ordinate values in units of 10 000 metres in blue.
The grid lines of the adjoining grid are indicated similarly on the outside of the graticule dicing.

Elevations are in English Feet to ground lev...
Hoogtes is in Engelse Voet op grondhoogt...

Gauss Conform Projection. Central Meridian 25° East. Clarke...
Gauss se Konforme Projeksie. Middelmeridiaan 25° Oos. Cla...

INDEX TO SHEETS INDEKS VAN VE...

3123DD	3124CC	3124CD
3223BB	3224AA	3224AB
3223BD	3224AC	3224AD

COPYRIGHT KOPIEREG

ENCLOSURE Ia.

BORHOLE LOCATION MAP


1:50 000 SUID-AFRIKA SOUTH AFRICA
3224AB OUBERG
DEPT. VAN WATERWESE
AFDELING GEOHIDROLOGIE
PRIVAATSAK/PRIVATE BAG X313
DE RUST 129
VLAK PLAATS 128
FARM 127
MAIDESVALLEY
Boesmanskop
ROUD CONSTANT 172
RUST 126
FARM 169
167
HOUD CONSTANT 122
FARM 130
WOLVE KLOOF 168
VD12
VEITJESVOORUITZIGT 177
171
VD11
VD10
BOSCHMANS KLOOF 174
KT16
KT15
KT17
SAAPPLAATS 171
Perdeberg
202
ROODE WAL
VAN DER WAATS HOEK
VD9
VD15
VD7
VD8
KT18
KT14
KT13
KT12
TWEEFONTEIN 181
KT11
KT10
KT7
KT9
KT6
KT2
KT8
KT4
KT20
KT21
VD2
VD1
KLIPPEDRIFT 194
WE3
KT1
KT22
REEBOKS BERG
Gemiddelde magneuese deklinasie 22°,7Wes van Ware Noorde (1974,0). Gemiddelde jaarlikse verandering 1' Weswaarts (1966-1971).
Mean magnetic declination 22°,7West of True North (1974,0). Mean annual change 1' Westwards (1966-1971).
Ware N.
True N.
24°15'
32°00'
05'
10'
20'

OUBERG

Verwys na hierdie Kaart as SUID-AFRIKA 1:50 000 Vel **3224AB OUBERG** EERSTE UITGAWE
Refer to this Map as SOUTH AFRICA 1:50 000 Sheet FIRST EDITION

1:50 000

CONTOUR INTERVAL 50 ENGLISH FEET

5 000 10 000 15 000 English Feet

1 2 3 Statute Miles

1 000 2 000 3 000 4 000 5 000 Metres

Hoogtes is in Engelse Voet op grondhoogte
Elevations are in English Feet to ground level

...orme Projeksie Middelmeridiaan 25° Oos Clarke 1880 Sferoïed
...n Projection Central Meridian 25° East Clarke 1880 Spheroid

Gedruk en uitgegee deur die Staatsdrukker, Privaatsak X85, Pretoria 1974
Printed and published by the Government Printer, Private Bag X85, Pretoria 1974

PRYS PER VEL 60c PRICE PER SHEET

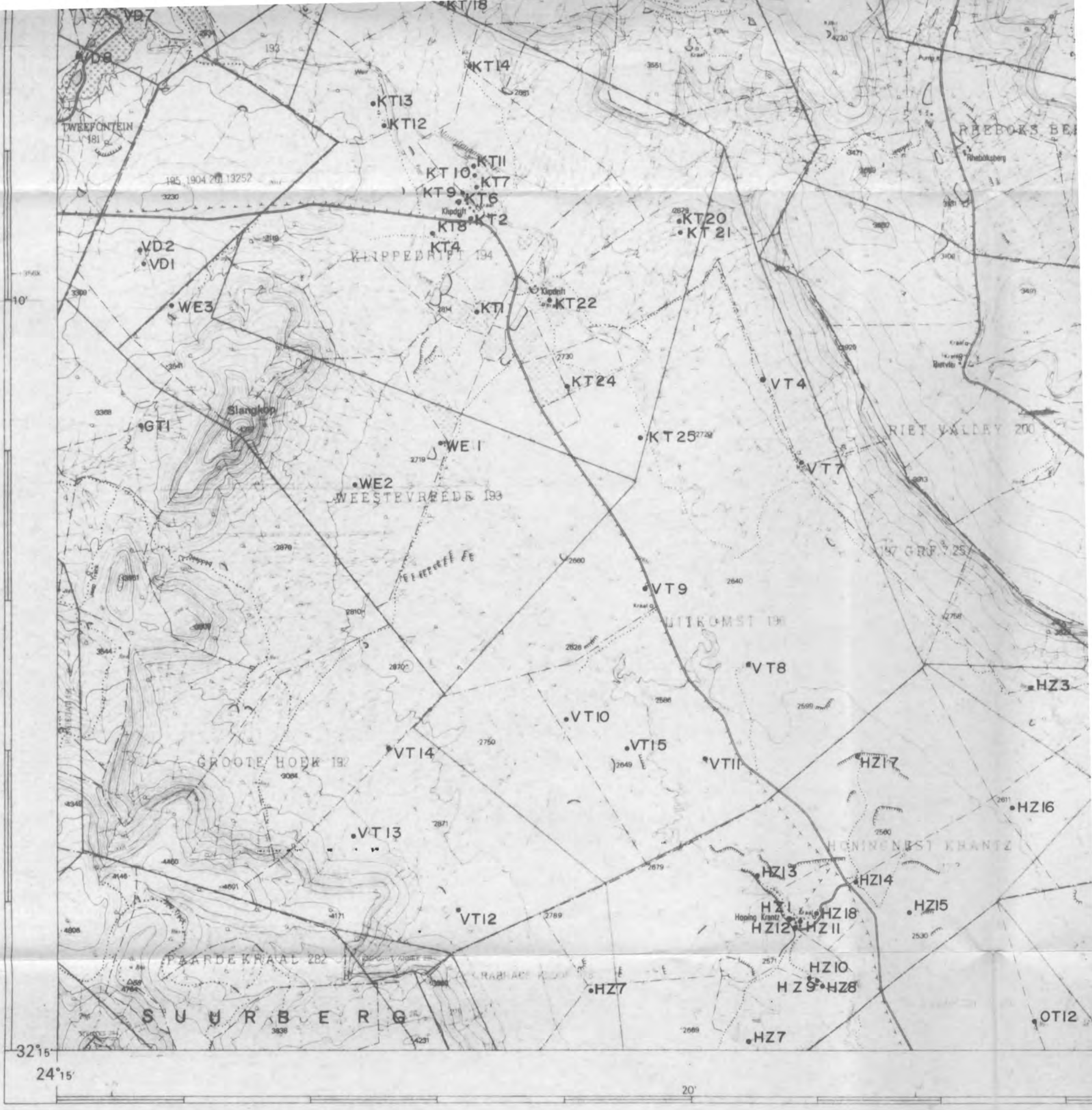
VERKLARING — REFERENCE

Verklaring	Reference
Magnetiese Stasies en Grondtekens	Magnetic Stations and Ground Signs
Hutte	Huts
Monumente	Monuments
Dipbakke	Dipping Tanks
Windpompe	Windmills
Mure	Walls
Grondbewaringswalle	Anti-erosion Walls
Uitgrawings	Excavations
Standhoudende Water	Perennial Water
Nie-standhoudende Water	Non-perennial Water
Droë Panne	Dry Pans
Fonteine, Watergate en Putte	Springs, Waterholes and Wells
Moerasse en Vleie	Marshes, Swamps and Vleis
Pyplyne	Pipelines
Fotomiddelpunte	Photo Centres
Prominente Klipbanke	Prominent Rock Outcrops
Terrasse	Terraces
Bewerkte Lande	Cultivated Lands
Boorde en Wingerde	Orchards and Vineyards
Bome en Bos	Trees and Bush

...IDEKS VAN VELLE — INDEX TO SHEETS

3124CC	3124CD	3124DC
3224AA	3224AB	3224BA
3224AC	3224AD	3224BC

3224AB OUBERG EERSTE UITGAWE FIRST EDITION



Lugfotografie 1964 (Taak No. 523/64) Opgemeet in 1972 en geteken in 1974 deur die Direkteur-generaal van Opmetings
Air Photography 1964 (Job No. 523/64) Surveyed in 1972 and drawn in 1974 by the Director-General of Surveys

KONTOERTUSSENRUIMTE 50 ENGELSE VOET

1:50 000

Engelse Voet 5 000 — 0 — 5 000

Landmyl 1 — 0 — 1

Meter 1 000 — 0 — 1 000 — 2 000 — 3 000

T.S.O. 200/6234

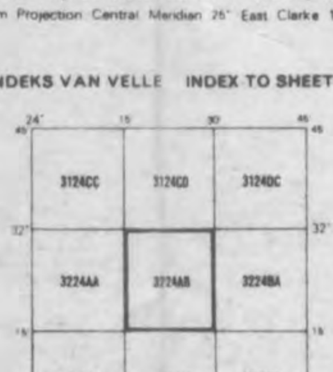
VERKLARING — REFERENCE

VERKLARING	REFERENCE
Internasionale Grense	International Boundaries
Provinsiale Grense	Provincial Boundaries
Veelvoudige Spoorlyne	Multiple Track Railways
Enkelspoorlyne	Single Track Railways
Geëlektrifiseerde Spoorlyne	Electrified Railways
Smalspoorlyne	Narrow Gauge Railways
Diensspoorlyne	Service Railways
Hoofverkeerspaaie	Arterial Roads
Grootpaaie	Main Roads
Sekondêre Paaie	Secondary Roads
Ander Paaie	Other Roads
Dowwe Paaie en Voetpaaie	Tracks and Footpaths
Kraglyne	Power Lines
Telefoonlyne	Telephone Lines
Poskantore, Polisiestasies en poste, Winkels, Hotelle, Skole en Plekke van Aanbidding	Post Offices, Police Stations and Posts, Stores, Hotels, Schools and Places of Worship
Vuurtorings en Seevaartligte	Lighthouses and Marine Lights
Seevaartbakens	Marine Beacons
Trig Bakens (Nommer regs en hoogte onder)	Trig Beacons (Number to right and height below)

Hoogtes is in Engelse Voet op grondhoogte
Elevations are in English Feet to ground level

Gauss se Konforme Projeksie Middelmeridiaan 25° Oos Clarke
Gauss Conform Projection Central Meridian 25° East Clarke

INDEKS VAN VELLE — INDEX TO SHEETS



KOPIEREG — COPYRIGHT

ENCLOSURE 1b.

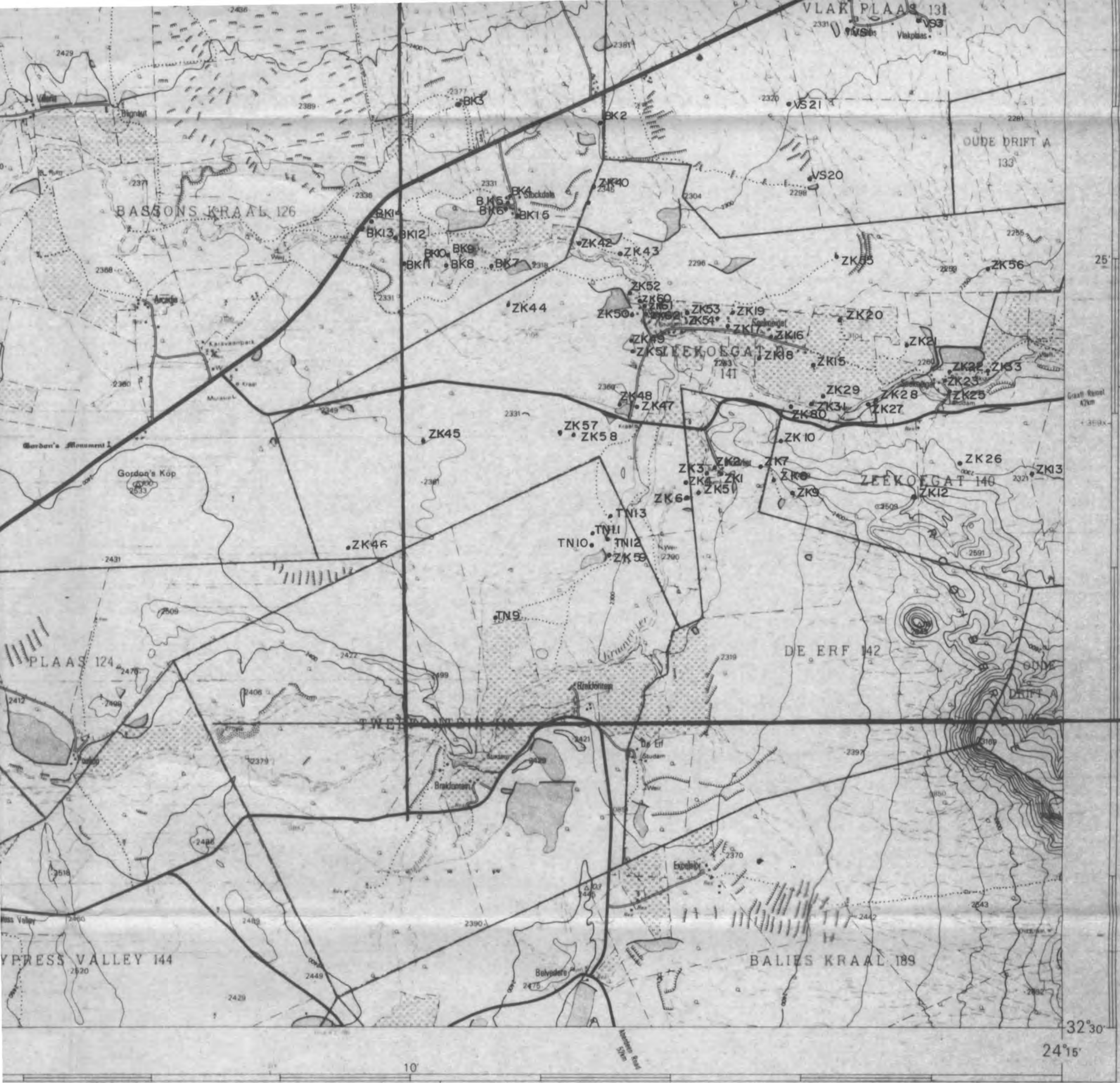
BOREHOLE LOCATION MAP

1:50 000 SOUTH AFRICA SUID-AFRIKA

3224AC ABERDEEN

BERDEEN

Refer to this Map as SOUTH AFRICA 1:50 000 Sheet **3224AC ABERDEEN**
Verwys na hierdie Kaart as SUID AFRIKA 1:50 000 Vel
FIRST EDITION EERSTE UITGAWE



1:50 000

5 000 10 000 15 000 Engelse Voet

1 2 3 Landmyl

00 2 000 3 000 4 000 5 000 Meter

KONTOERTUSSENRUIMTE 50 ENGELSE VOET

evations are in English Feet to ground level
hoogtes is in Engelse Voet op grondhoogte

Projection Central Meridian 25° East Clarke 1880 Spheroid
e Projeksie Middelmeridiaan 25° Oos Clarke 1880 Sferoïed

Printed and published by the Government Printer, Private Bag X85, Pretoria 1973
Gedruk en uitgegee deur die Staatsdrukker, Privaatsak X85, Pretoria 1973

PRICE PER SHEET 60c PRYS PER VEL

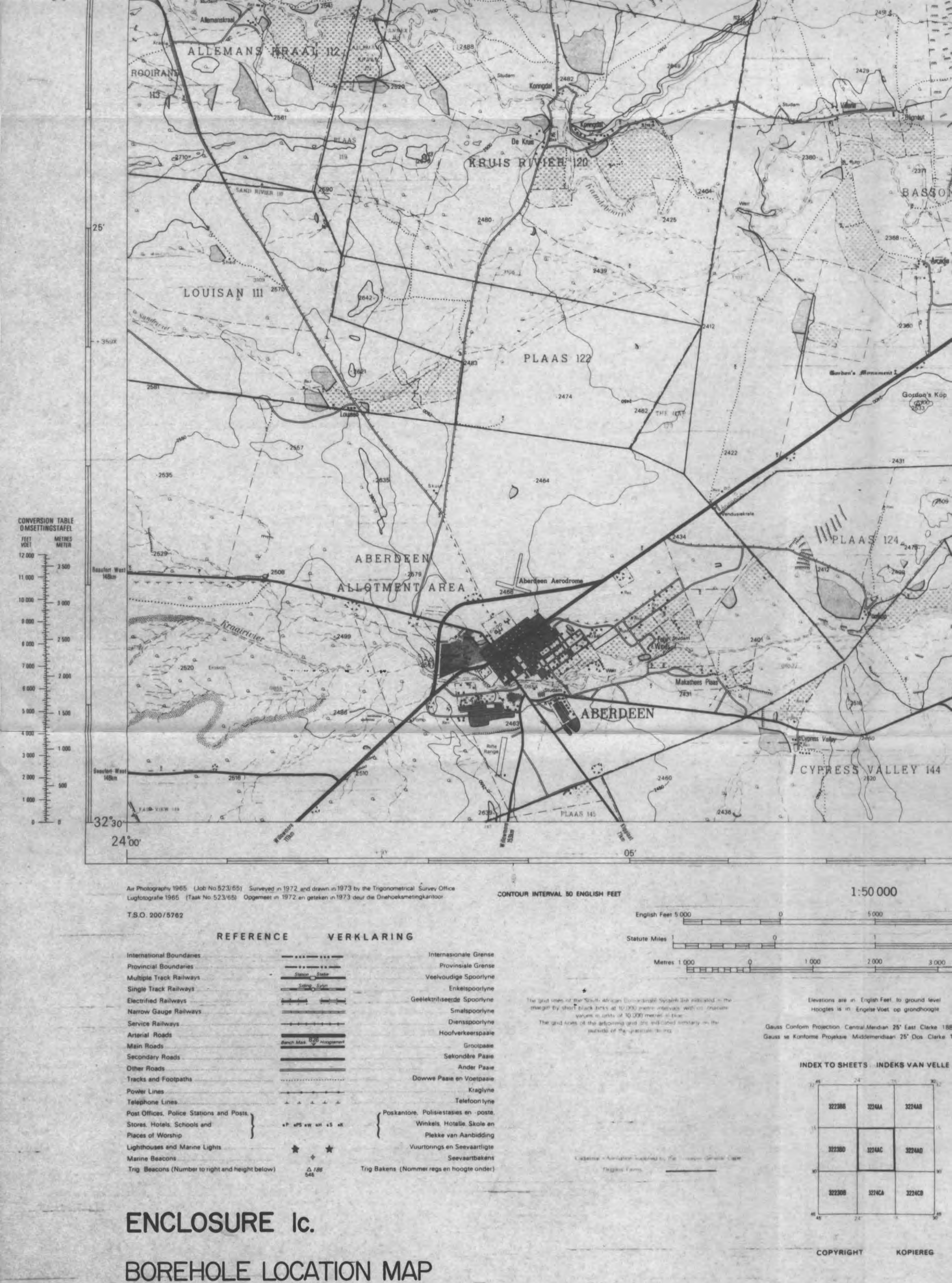
REFERENCE VERKLARING

Reference	Verklaring
Magnetic Stations and Ground Signs	Magnetiese Stasies en Grondtekens
Huts	Hutte
Monuments	Monumente
Dipping Tanks	Dipbakke
Windmills	Windpompe
Walls	Mure
Anti-erosion Walls	Grondbewaringswalle
Excavations	Uitgrawings
Perennial Water	Standhoudende Water
Non-perennial Water	Nie-standhoudende Water
Dry Pans	Droë Panne
Springs, Waterholes and Wells	Fonteine, Watergate en Putte
Marshes, Swamps and Vleis	Moerasse en Vleie
Pipelines	Pyplyne
Photo Centres	Fotomiddelpunte
Prominent Rock Outcrops	Prominente Klipbanke
Terraces	Terrasse
Cultivated Lands	Bewerkte Lande
Orchards and Vineyards	Boorde en Wingerde
Trees and Bush	Bome en Bos

EX TO SHEETS INDEKS VAN VELLE

3223BB	3224AA	3224AB
3223BD	3224AC	3224AD
3223DB	3224CA	3224CB

3224AC ABERDEEN FIRST EDITION EERSTE UITGAWE

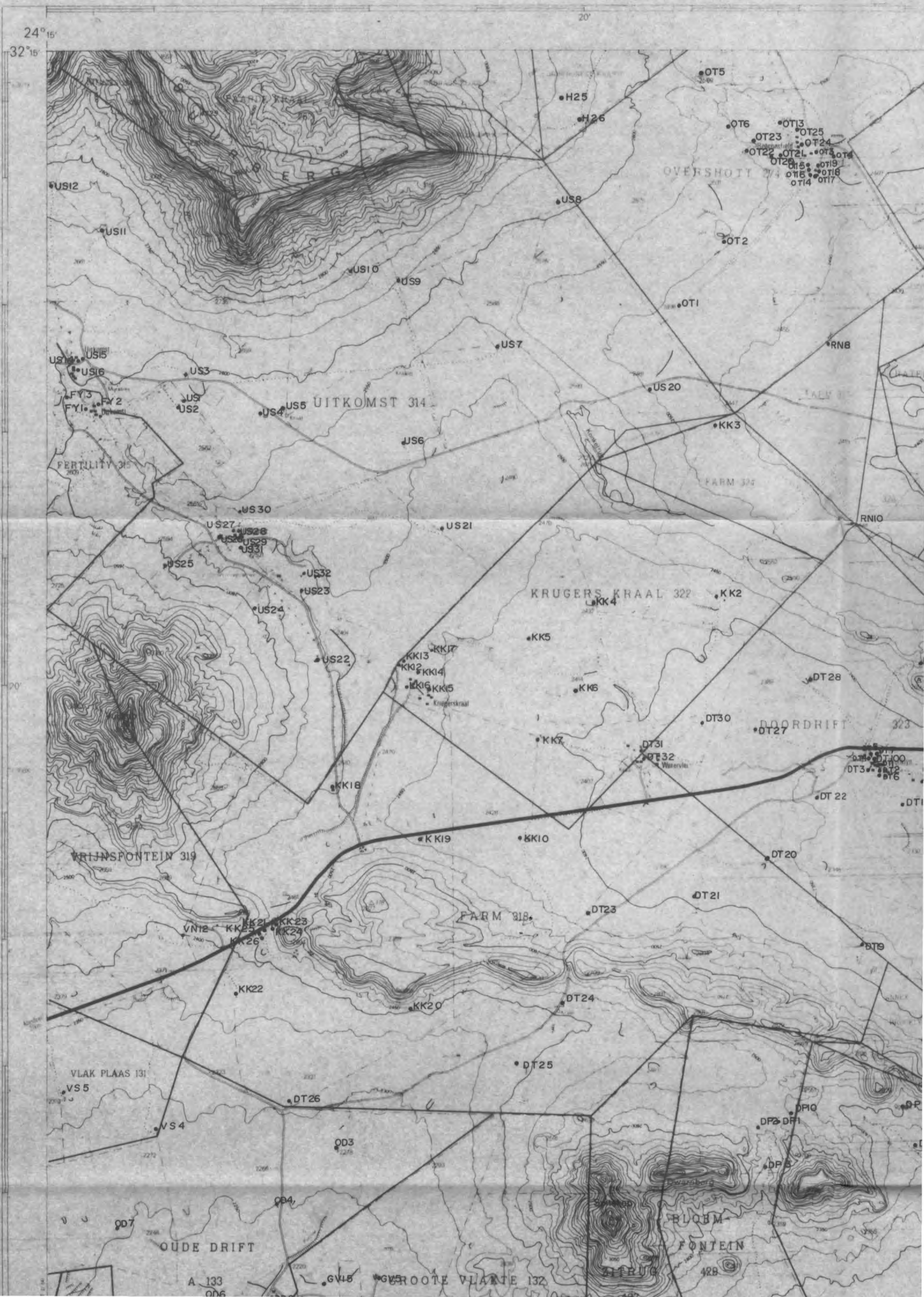


ENCLOSURE Ic.

BOREHOLE LOCATION MAP

1:50 000 SUID-AFRIKA SOUTH AFRICA

3224AD BROOKLYN



BROOKLYN

Verwys na hierdie Kaart as SUID AFRIKA 1:50 000 Vel 3224 AD BROOKLYN
Refer to this Map as SOUTH AFRICA 1:50 000 Sheet

1:50 000

CONTOUR INTERVAL 50 ENGLISH FEET

5 000 — 10 000 — 15 000 English Feet

1 — 2 — 3 Statute Miles

1 000 — 2 000 — 3 000 — 4 000 — 5 000 Metres

Hoogtes is in Engelse Voet op grondhoogte
Elevations are in English Feet to ground level

...nforme Projeksie Middelmeridiaan 25° Oos Clarke 1880 Sferoïed
...orm Projection Central Meridian 25° East Clarke 1880 Spheroid

INDEKS VAN VELLE INDEX TO SHEETS

3224AA	3224AB	3224BA
3224AC	3224AD	3224BC
3224CA	3224CB	3224DA

VANAF 1/4/1980
PLAASLIK R1,00 LOCAL
4% AVB R0,04 4% GST
R1,04
AS FROM 1/4/1980

Gedruk en uitgegee deur die Staatsdrukker, Privaatsak X85, Pretoria 1974
Printed and published by the Government Printer, Private Bag X85, Pretoria 1974

PRYS PER VEL 80c PRICE PER SHEET

VERKLARING REFERENCE

VERKLARING	REFERENCE
Magnetiese Stasies en Grondtekens	Magnetic Stations and Ground Signs
Hutte	Huts
Monumente	Monuments
Dipbakke	Dipping Tanks
Windpompe	Windmills
Mure	Walls
Grondbewaringswalle	Anti-erosion Walls
Uitgrawings	Excavations
Standhoudende Water	Perennial Water
Nie-standhoudende Water	Non-perennial Water
Droë Panne	Dry Pans
Fonteine, Watergate en Putte	Springs, Waterholes and Wells
Moerasse en Vleie	Marshes, Swamps and Vleis
Pyplyne	Pipelines
Fotomiddelpunte	Photo Centres
Prominente Klipbanke	Prominent Rock Outcrops
Terrasse	Terraces
Bewerkte Lande	Cultivated Lands
Boorde en Wingerde	Orchards and Vineyards
Bome en Bos	Trees and Bush

3224 AD BROOKLYN EERSTE UITGAWE FIRST EDITION

Lugfotografie 1964 (Taak No. 523/64) Opgemeet in 1972 en geteken in 1973 deur die Direkteur-generaal van Opmetings
Air Photography 1964 (Job No. 523/64) Surveyed in 1972 and drawn in 1973 by the Director-General of Surveys

T.S.O. 200/0236

KONTOERTUSSENRUIMTE 50 ENGELSE VOET

1:50 000

Engelse Voet 5 000 0 5 000

Landmyl 1 0 1

Meter 1 000 0 1 000 2 000 3 000

VERKLARING	REFERENCE
Internasionale Grense	International Boundaries
Provinsiale Grense	Provincial Boundaries
Veelvoudige Spoorlyne	Multiple Track Railways
Enkelspoorlyne	Single Track Railways
Geelektrifiseerde Spoorlyne	Electrified Railways
Smalspoorlyne	Narrow Gauge Railways
Diensspoorlyne	Service Railways
Hoofverkeerspaaie	Arterial Roads
Grootpaaie	Main Roads
Sekondêre Paaie	Secondary Roads
Ander Paaie	Other Roads
Dowwe Paaie en Voetpaaie	Tracks and Footpaths
Kraglyne	Power Lines
Telefoonlyne	Telephone Lines
Poskantore, Polisiestasies en poste Winkels, Hotelle, Skole en Plekke van Aanbidding	Post Offices, Police Stations and Posts Stores, Hotels, Schools and Places of Worship
Vuurtorings en Seevaartligte	Lighthouses and Marine Lights
Seevaartbakens	Marine Beacons
Trig Bakens (Nommer regs en hoogte onder)	Trig Beacons (Number to right and height below)

Hoogtes is in Engelse Voet op grondhoogte
Elevations are in English Feet to ground level

Gauss se Konforme Projeksie Middelmeridiaan 25° Oos Clarke
Gauss Conform Projection Central Meridian 25° East Clarke

INDEKS VAN VELLE INDEX TO SHEETS

KOPIEREG COPYRIGHT

ENCLOSURE Id.

BOREHOLE LOCATION MAP

1:50 000 SOUTH AFRICA SUID-AFRIKA

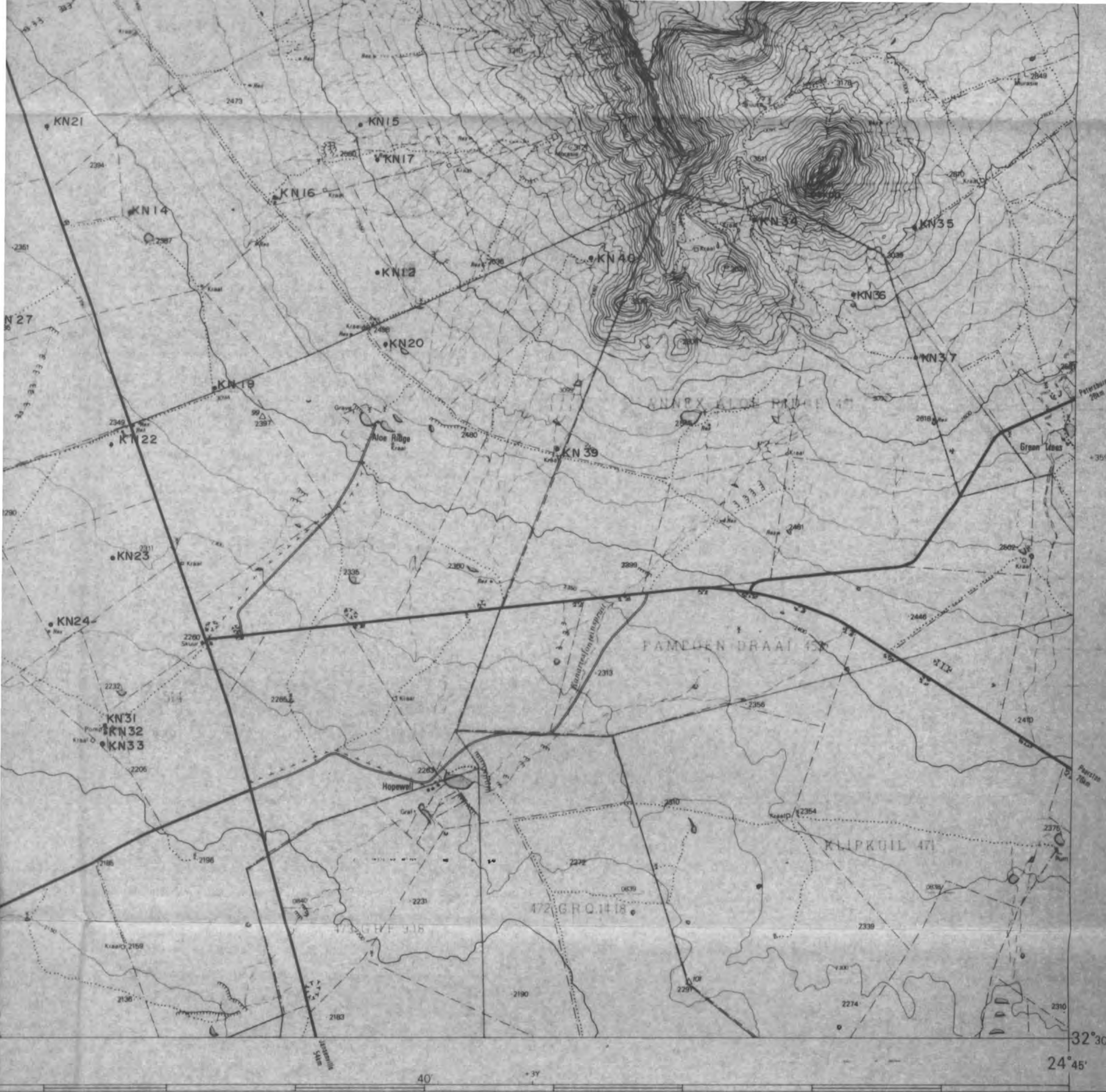
3224BC GRAAFF-REINET (SU

REINET (SUID)

Refer to this Map as SOUTH AFRICA 1:50 000 Sheet
Verwys na hierdie Kaart as SUID-AFRIKA 1:50 000 Vel

3224 BC GRAAFF-REINET (SUID)

FIRST EDITION EERSTE UITGAWE



1:50 000

KONTOERTUSSENRUIMTE 50 ENGELSE VOET

5 000 | 10 000 | 15 000 Engelse Voet

1 | 2 | 3 Landmyl

1 000 | 2 000 | 3 000 | 4 000 | 5 000 Meter

Elevations are in English Feet to ground level
Hoogtes is in Engelse Voet op grondhoogte

...nform Projection Central Meridian 25° East Clarke 1880 Spheroid
Konforme Projeksie Middelmeridiaan 25° Oos Clarke 1880 Sferoïed

Die ruitlyne van die Suid-Afrikaanse Koordinaatstelsel word in die kantruimte aangetoon deur kort swart strepies, 10 000 meter van mekaar met koordinaatwaardes in eenhede van 10 000 meter in blou

INDEX TO SHEETS INDEKS VAN VELLE

3224AB	3224BA	3224BB
3224AD	**3224BC**	3224BD
3224CB	3224DA	3224DB

Printed and published by the Government Printer, Private Bag X85, Pretoria 1973.
Gedruk en uitgegee deur die Staatsdrukker, Privaatsak X85, Pretoria 1973.

PRICE PER SHEET 80c PRYS PER VEL

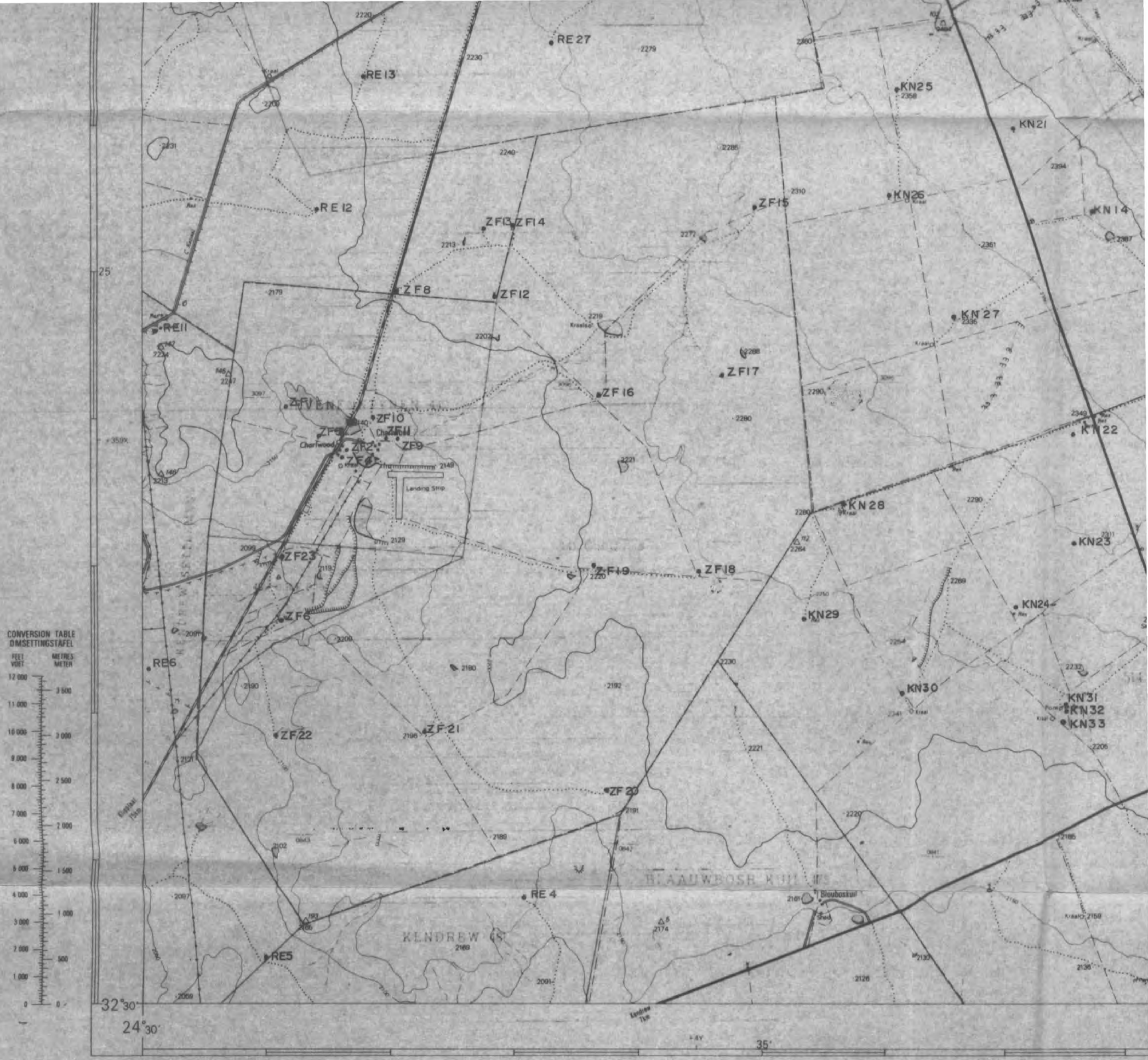
REFERENCE VERKLARING

Reference	Verklaring
Magnetic Stations and Ground Signs	Magnetiese Stasies en Grondtekens
Huts	Hutte
Monuments	Monumente
Dipping Tanks	Dipbakke
Windmills	Windpompe
Walls	Mure
Anti-erosion Walls	Grondbewaringswalle
Excavations	Uitgrawings
Perennial Water	Standhoudende Water
Non-perennial Water	Nie-standhoudende Water
Dry Pans	Droë Panne
Springs, Waterholes and Wells	Fonteine, Watergate en Putte
Marshes, Swamps and Vleis	Moerasse en Vleie
Pipelines	Pyplyne
Photo Centres	Fotomiddelpunte
Prominent Rock Outcrops	Prominente Klipbanke
Terraces	Terrasse
Cultivated Lands	Bewerkte Lande
Orchards and Vineyards	Boorde en Wingerde
Trees and Bush	Bome en Bos

3224BC GRAAFF-REINET (SUID)

FIRST EDITION
EERSTE UITGAWE

VANAF 1/4/1980
PLAASLIK R1,00 LOCAL
4% AVB R0,04 4% GST
R1,04
AS FROM 1/4/1980



Air Photography 1965 (Job No. 523/65) Surveyed in 1972 and drawn in 1973 by the Trigonometrical Survey Office.
Lugfotografie 1965 (Taak No. 523/65) Opgemeet in 1972 en geteken in 1973 deur die Driehoeksmetingkantoor

T.S.O. 200/5837

CONTOUR INTERVAL 50 ENGLISH FEET

1:50 000

English Feet 5 000 0 5 000

Statute Miles 1 0 1

Metres 1 000 0 1 000 2 000 3 000

REFERENCE VERKLARING

Reference	Verklaring
International Boundaries	Internasionale Grense
Provincial Boundaries	Provinsiale Grense
Multiple Track Railways	Veelvoudige Spoorlyne
Single Track Railways	Enkelspoorlyne
Electrified Railways	Geëlektrifiseerde Spoorlyne
Narrow Gauge Railways	Smalspoorlyne
Service Railways	Dienspoorlyne
Arterial Roads	Hoofverkeerspaaie
Main Roads	Grootpaaie
Secondary Roads	Sekondêre Paaie
Other Roads	Ander Paaie
Tracks and Footpaths	Dowwe Paaie en Voetpaaie
Power Lines	Kraglyne
Telephone Lines	Telefoonlyne
Post Offices, Police Stations and Posts, Stores, Hotels, Schools and Places of Worship	Poskantore, Polisiestasies en -poste, Winkels, Hotelle, Skole en Plekke van Aanbidding
Lighthouses and Marine Lights	Vuurtorings en Seevaartligte
Marine Beacons	Seevaartbakens
Trig. Beacons (Number to right and height below)	Trig Bakens (Nommer regs en hoogte onder)

The grid lines of the South African Co-ordinate System are indicated in the margin by short black ticks at 10 000 metre intervals, with co-ordinate values in units of 10 000 metres in blue.

Elevations are in English Feet to ground level
Hoogtes is in Engelse Voet op grondhoogte

Gauss Conform Projection. Central Meridian 25° East. Clarke
Gauss se Konforme Projeksie. Middelmeridiaan 25° Oos. Clark

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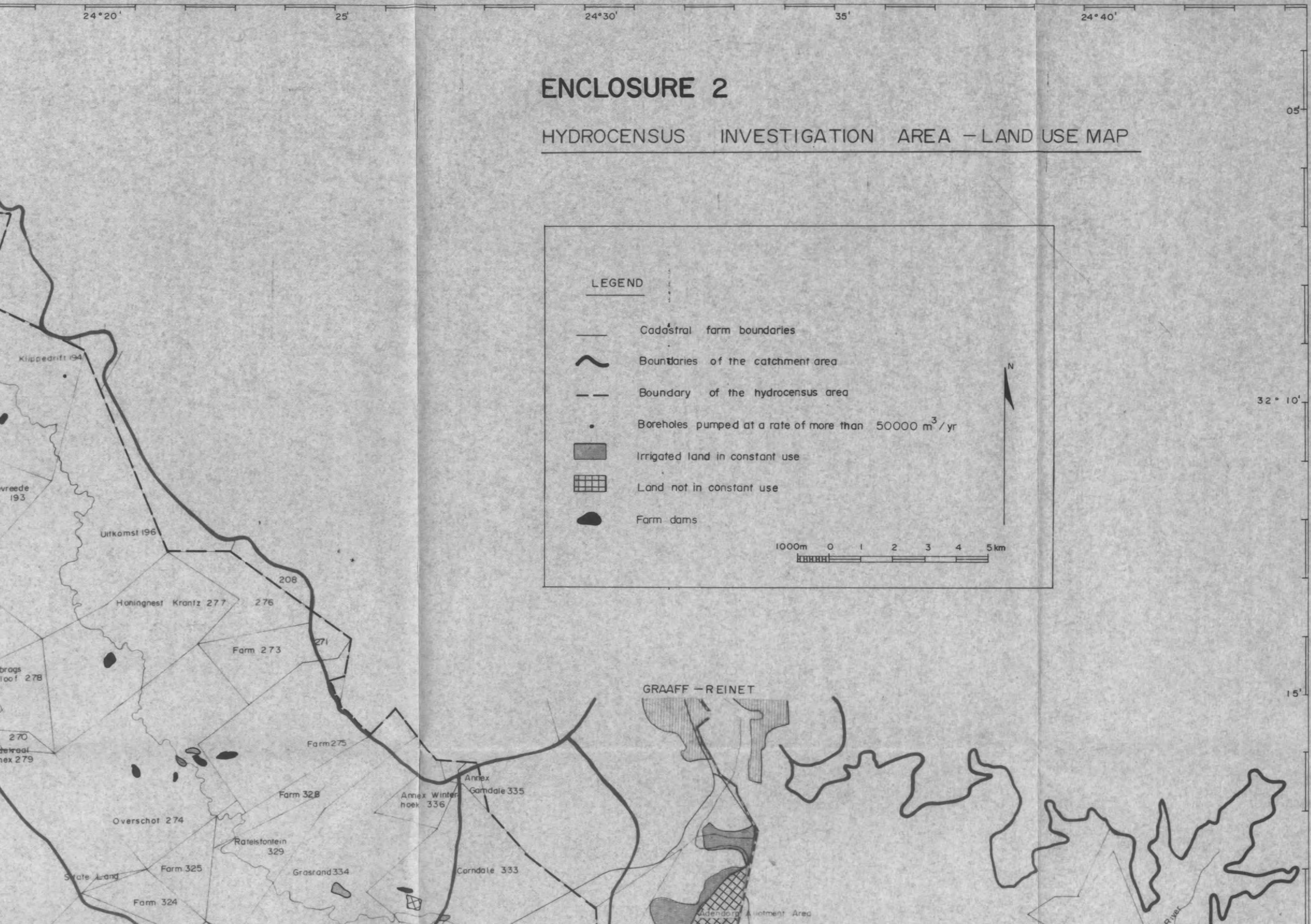
3224CB	3224DA	3224DB

ENCLOSURE Ie.

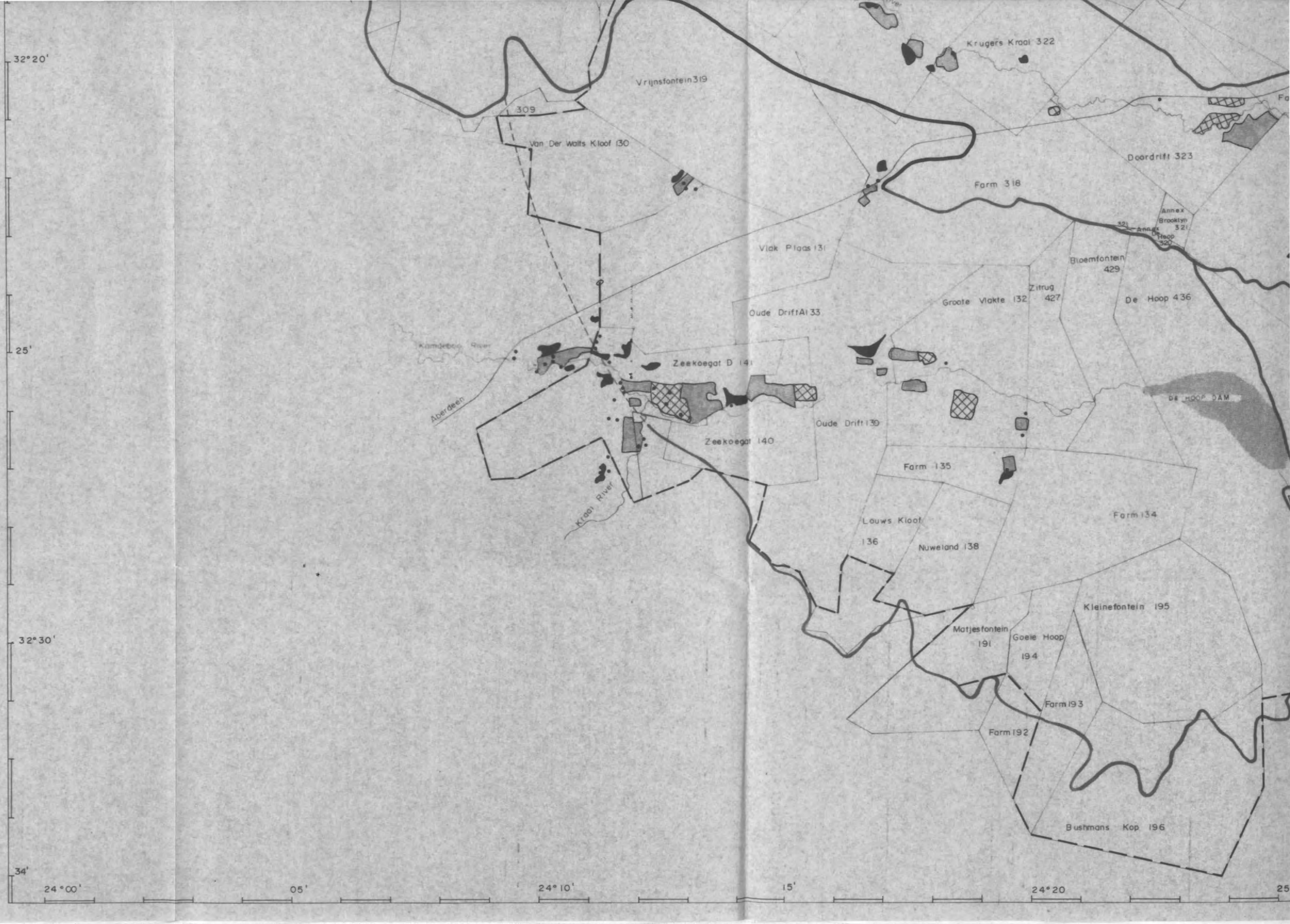
BORHOLE LOCATION MAP

ENCLOSURE 2

HYDROCENSUS INVESTIGATION AREA – LAND USE MAP



Krugers Kraal 322
Oeverwagt 330
Farm 326
Klipdrif 426
Doordrift 323
Farm 318
Annex
Brooklyn
321
321
Hoop
320
Bloemfontein
429
Zitrug
427
Groote Vlakte 132
De Hoop 436
DE HOOP DAM
Rynheath 417
Kruidfontein 413
444
445
442
420
440
441
514
Kendrew
Area
439
Farm 134
and 138
Kleinefontein 195
Matjesfontein
191
Goele Hoop
194
Farm 193
Farm 192
Bushmans Kop 196
Klipplaat
Jansenville
32° 20'
25'
32° 30'
34'
24° 20
25'
24° 30'
35'
24° 40'


32°20'
25'
32°30'
34'
24°00'
05'
24°10'
15'
24°20'
25
Krugers Kraal 322
Vrijnsfontein 319
309
Van Der Walts Kloof 130
Doordrift 323
Farm 318
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321
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320
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427
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Oude DriftA133
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Zeekoegat 140
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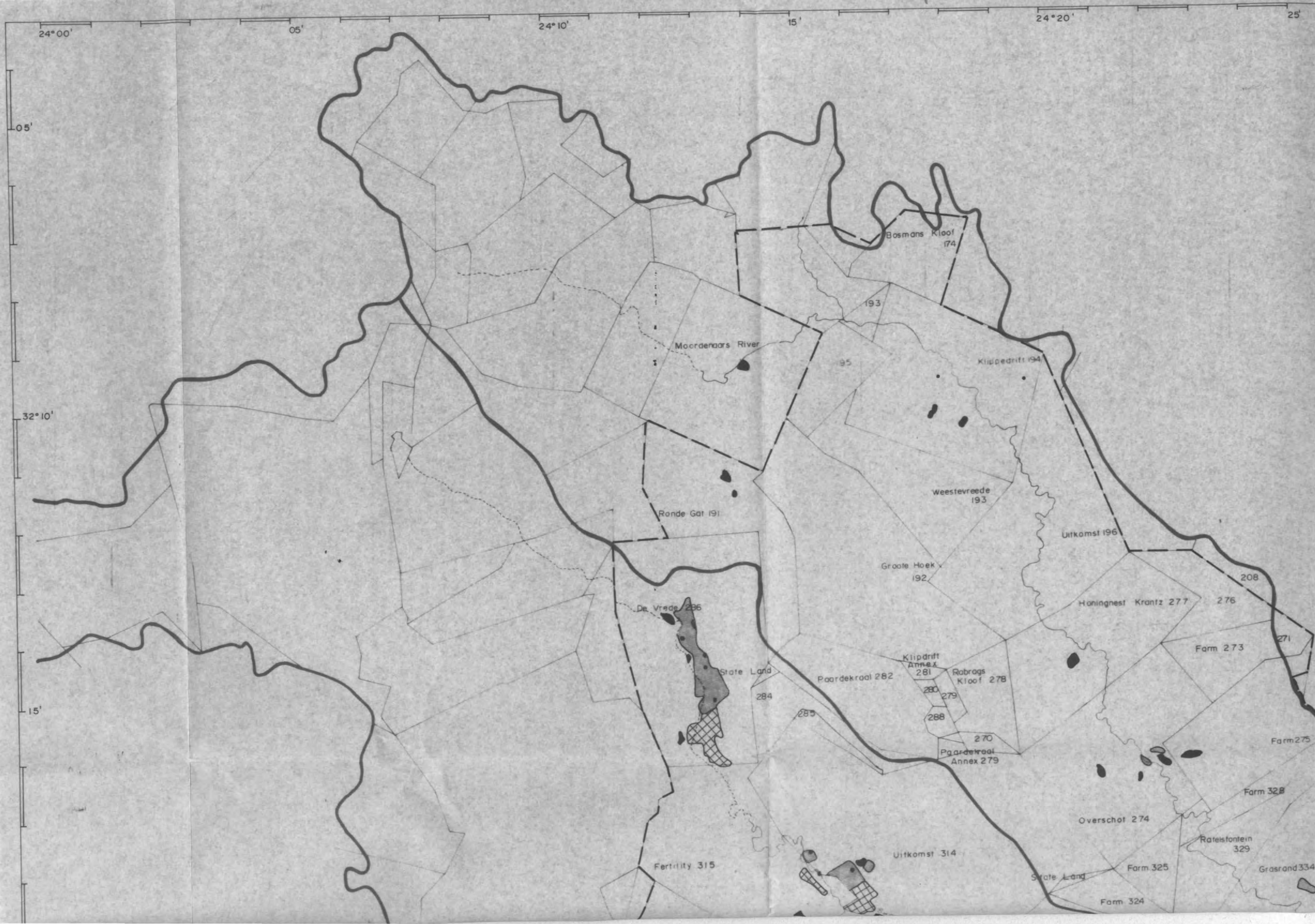
136
Nuweland 138
Kleinefontein 195
Matjesfontein
191
Goele Hoop
194
Farm 193
Farm 192
Bushmans Kop 196


24°00'
05'
24°10'
15'
24°20'
25'
05'
32°10'
15'
Bosmans Kloof 174
193
Moordenaars River
95
Klipdrift 194
Weestevreede 193
Ronde Gat 191
Uitkomst 196
Groote Hoek 192
208
Honingnest Krantz 277
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De Vrede 286
Farm 273
271
State Land
Klipdrift Annex 281
Rabrags Kloof 278
Paardekraal 282
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280
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270
Paardekraal Annex 279
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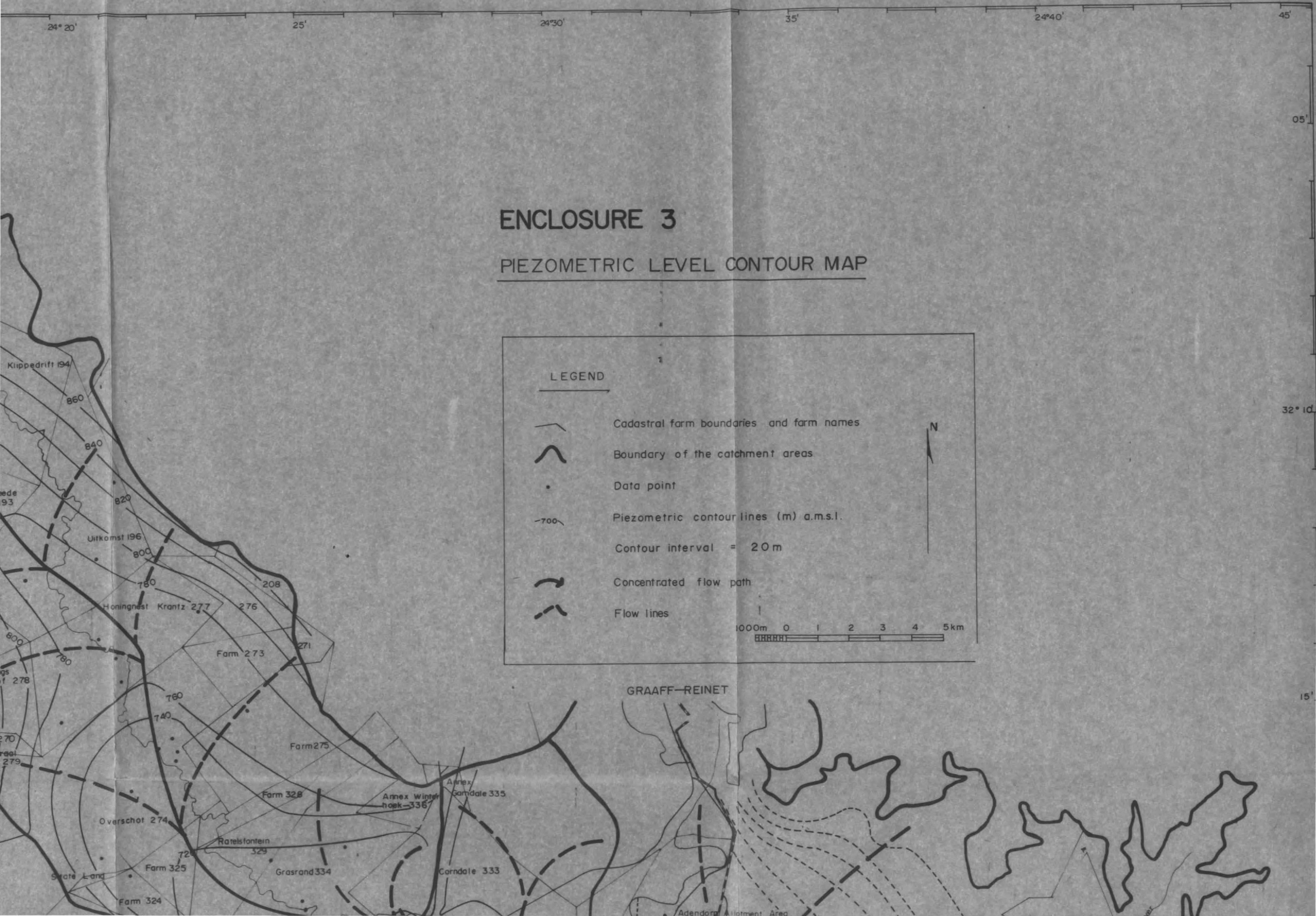
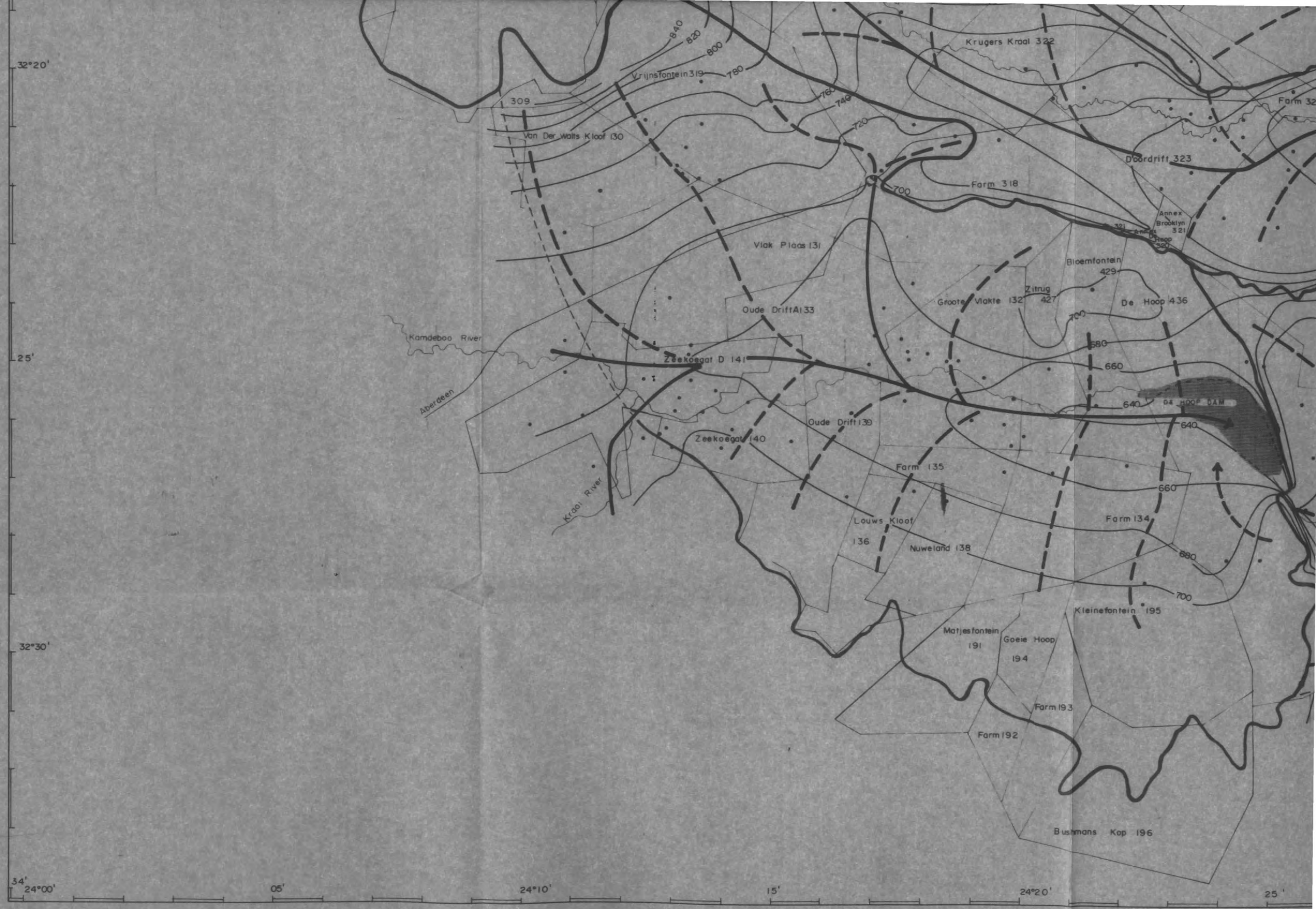
Farm 328
Overschot 274
Uitkomst 314
Rateisfontein 329
Fertility 315
Farm 325
Grasrand 334
State Land
Farm 324

ENCLOSURE 3

PIEZOMETRIC LEVEL CONTOUR MAP



24°00'
05'
24°10'
15'
24°20'
25'
05'
32°10'
15'
Bosmans Kloof 174
193
Moordenaars River
195
Klippedrift 194
860
840
820
Weestevreede 193
Uitkomst 196
800
Ronde Gat 191
Groote Hoek 192
780
208
De Vrede 286
Honingnest Krantz 277
276
860
840
820
800
780
271
Klipdrift Annex 281
Rabrags Kloof 278
Farm 273
888
State Land
Paardekraal 282
280
279
284
285
760
288
740
270
Paardekraal Annex 279
Farm 275
860
840
820
800
Farm 328
Overschot 274
Fertility 315
Uitkomst 314
Rateisfontein 329
720
860
Farm 325
State Land
Grasrand 334
Farm 324



32°20'
25'
32°30'
34'
24°00'
05'
24°10'
15'
24°20'
25'
840
820
800
780
760
740
720
700
680
660
640
Vrijnsfontein 319
309
Van Der Walts Kloof 130
Krugers Kraal 322
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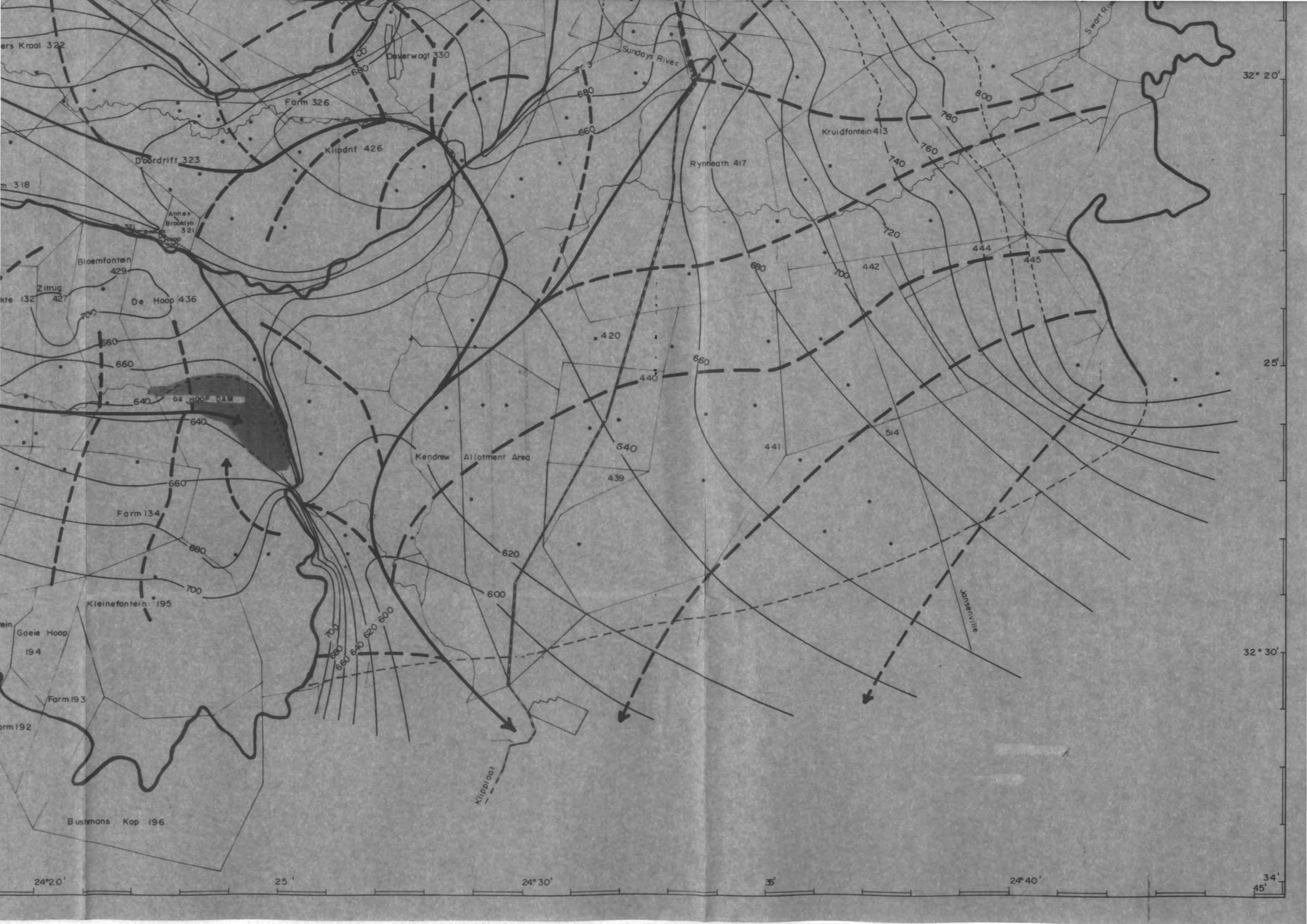
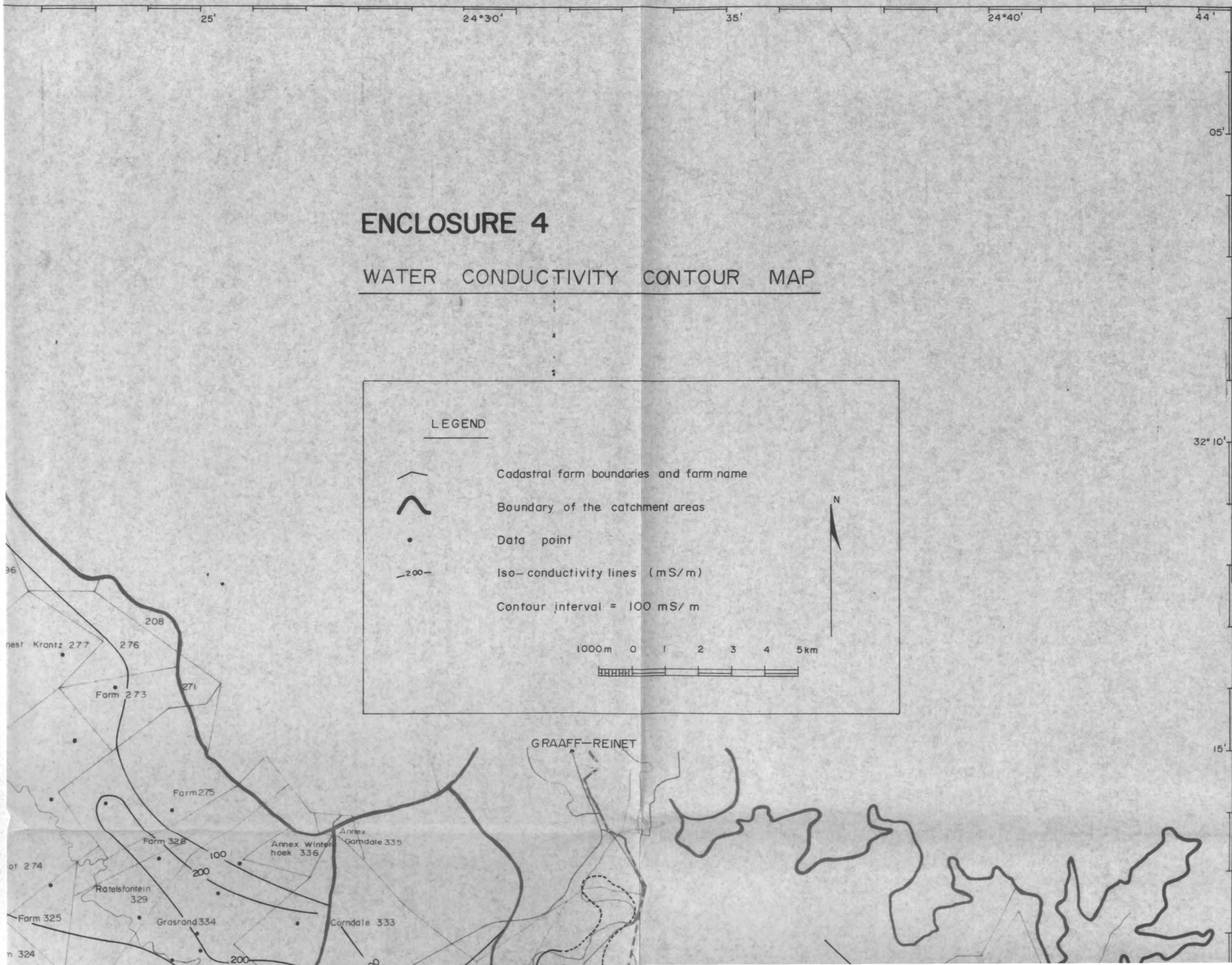
Oude DriftA133
Kamdeboo River
Zeekoegat D 141
Aberdeen
DE HOOP DAM
Oude Drift 139
Zeekoegat 140
Farm 135
Kraai River
Louws Kloof 136
Nuweland 138
Farm 134
Kleinefontein 195
Matjesfontein 191
Goeie Hoop 194
Farm 193
Farm 192
Bushmans Kop 196

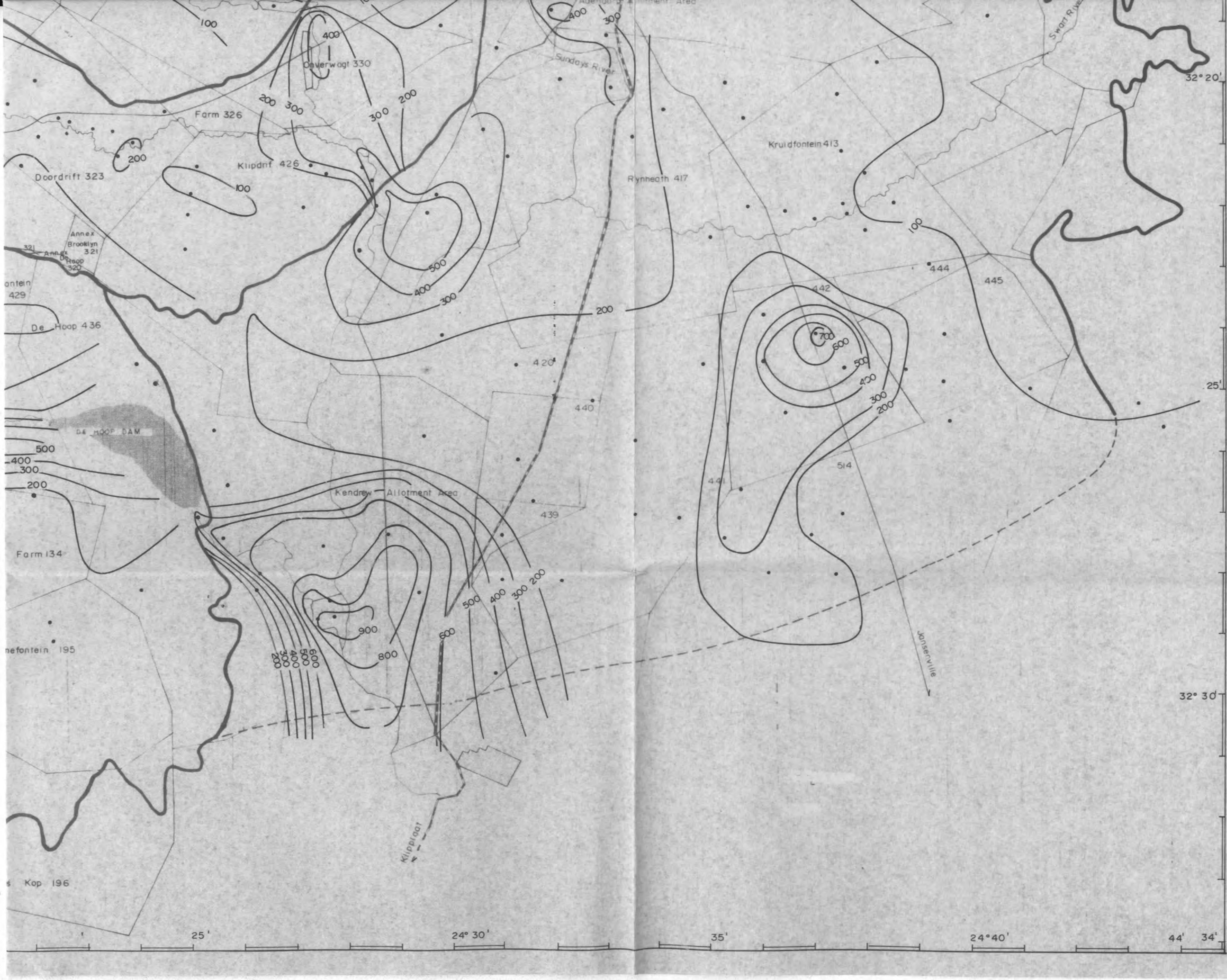


ers Kraal 322
Oesterwagt 330
Sundays River
Farm 326
Klipdrif 426
Doordrift 323
m 318
Annex Brooklyn 321
Bloemfontein 429
Zitrug 427
kte 132
De Hoop 436
DE HOOP DAM
Kruidfontein 413
Rynneath 417
442
444
445
420
440
439
441
514
Kendrew Allotment Area
Farm 134
Kleinefontein 195
Goeie Hoop 194
Farm 193
arm 192
Bushmans Kop 196
Klipplaat
Jansenville
800
780
760
740
720
700
680
660
640
620
600
540
32° 20'
25'
32° 30'
34'
45'
24°20'
25'
24°30'
35'
24°40'

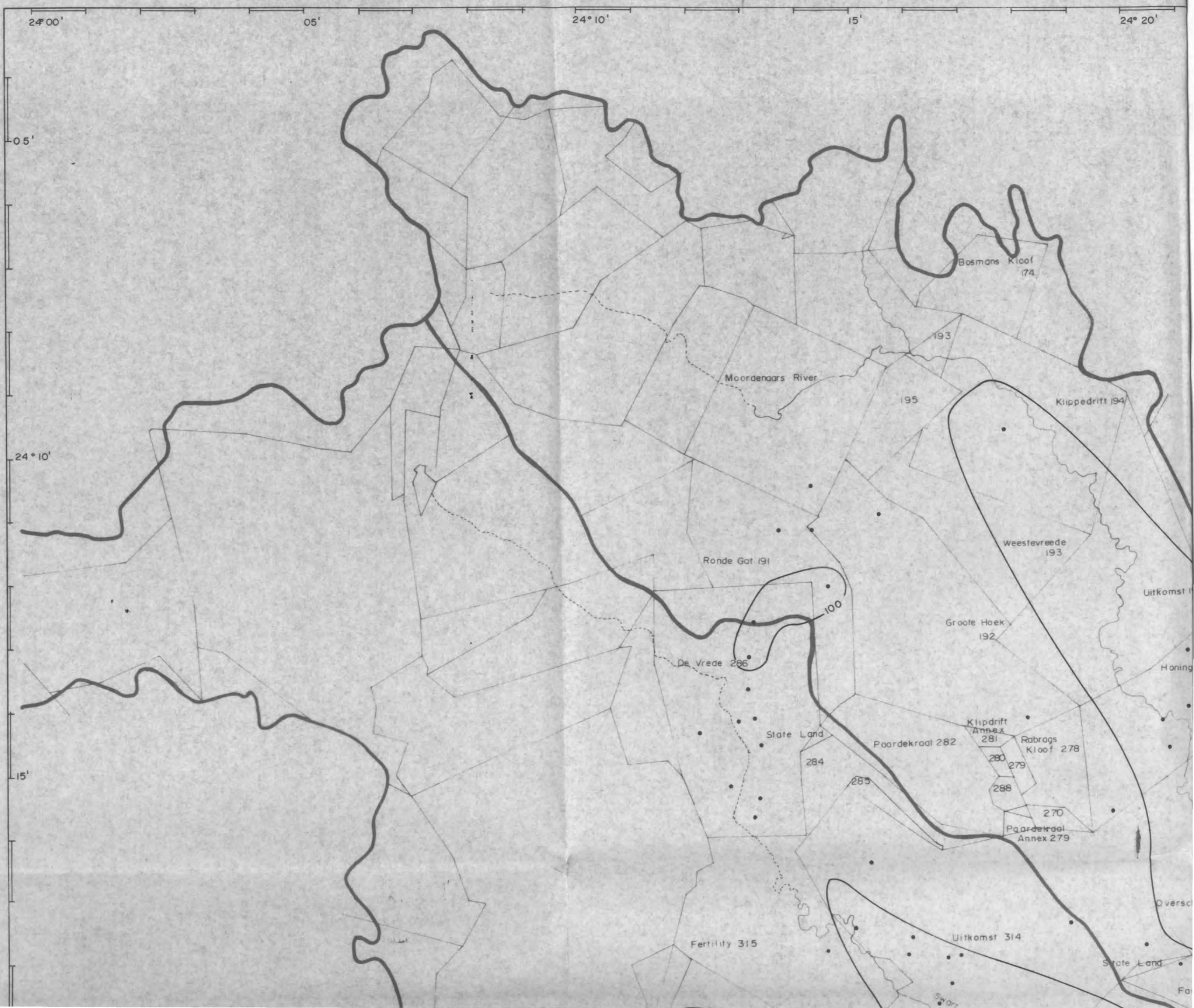
ENCLOSURE 4

WATER CONDUCTIVITY CONTOUR MAP

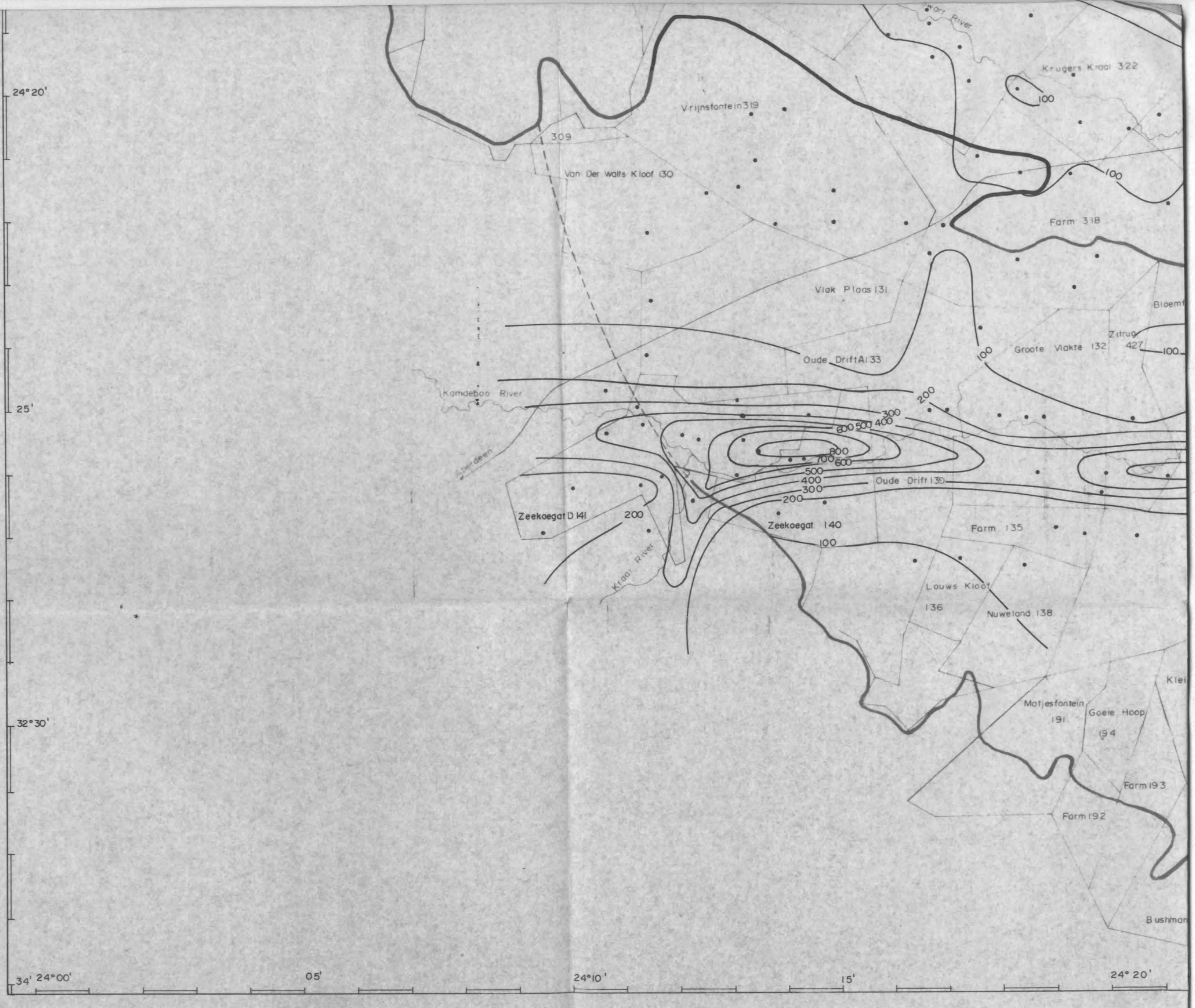




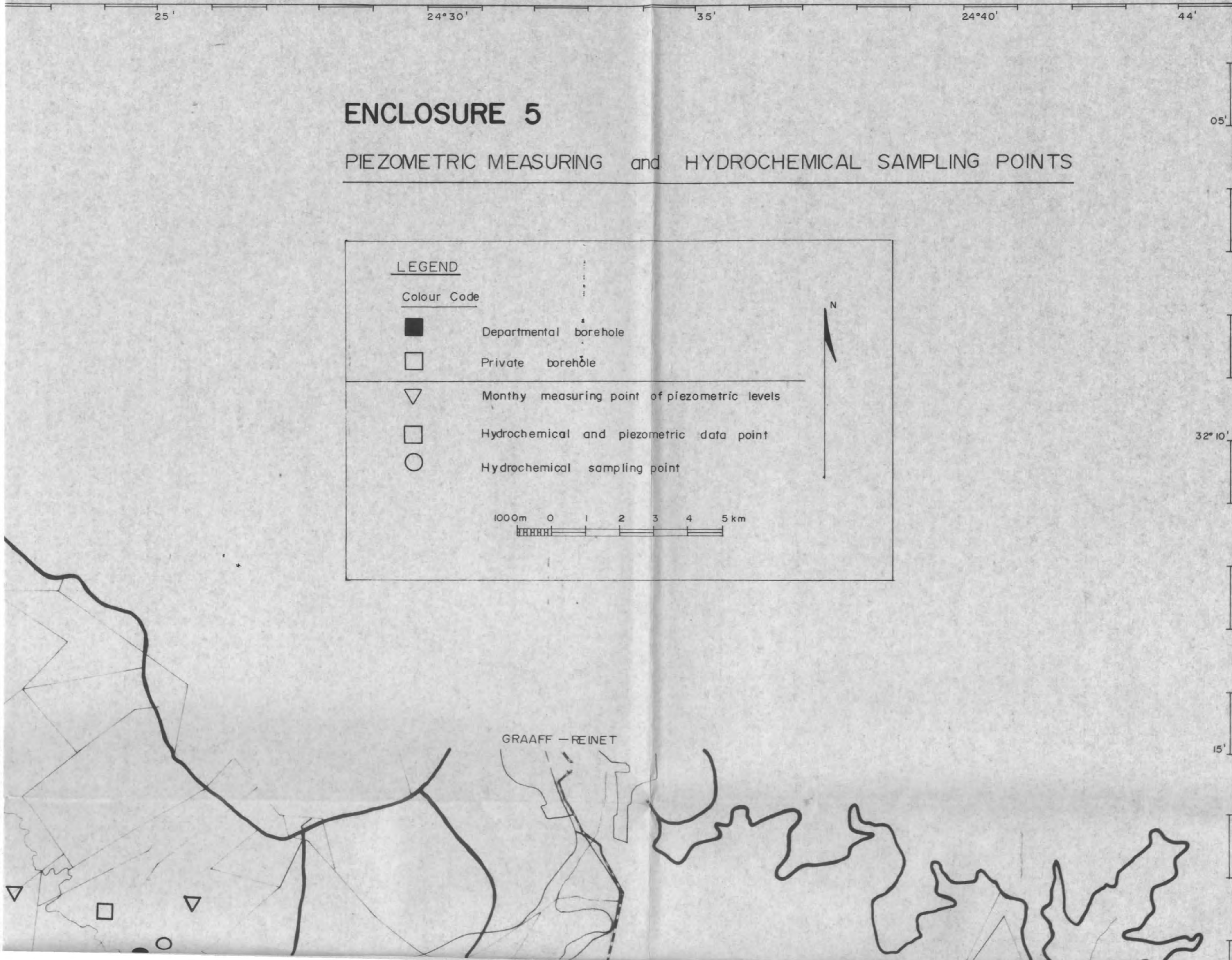
Sundays River
Swart River
Oeverwagt 330
Farm 326
Klipdrif 426
Doordrift 323
Annex
Brooklyn
321
De Hoop
320
429
De Hoop 436
DE HOOP DAM
Kendrew Allotment Area
Farm 134
nefontein 195
Kop 196
Rynheath 417
Kruidfontein 413
420
440
439
441
442
444
445
514
Jansenville
Klipplaat
100
200
300
400
500
600
700
800
900
32° 20'
25'
32° 30'
25'
24° 30'
35'
24° 40'
44'
34'

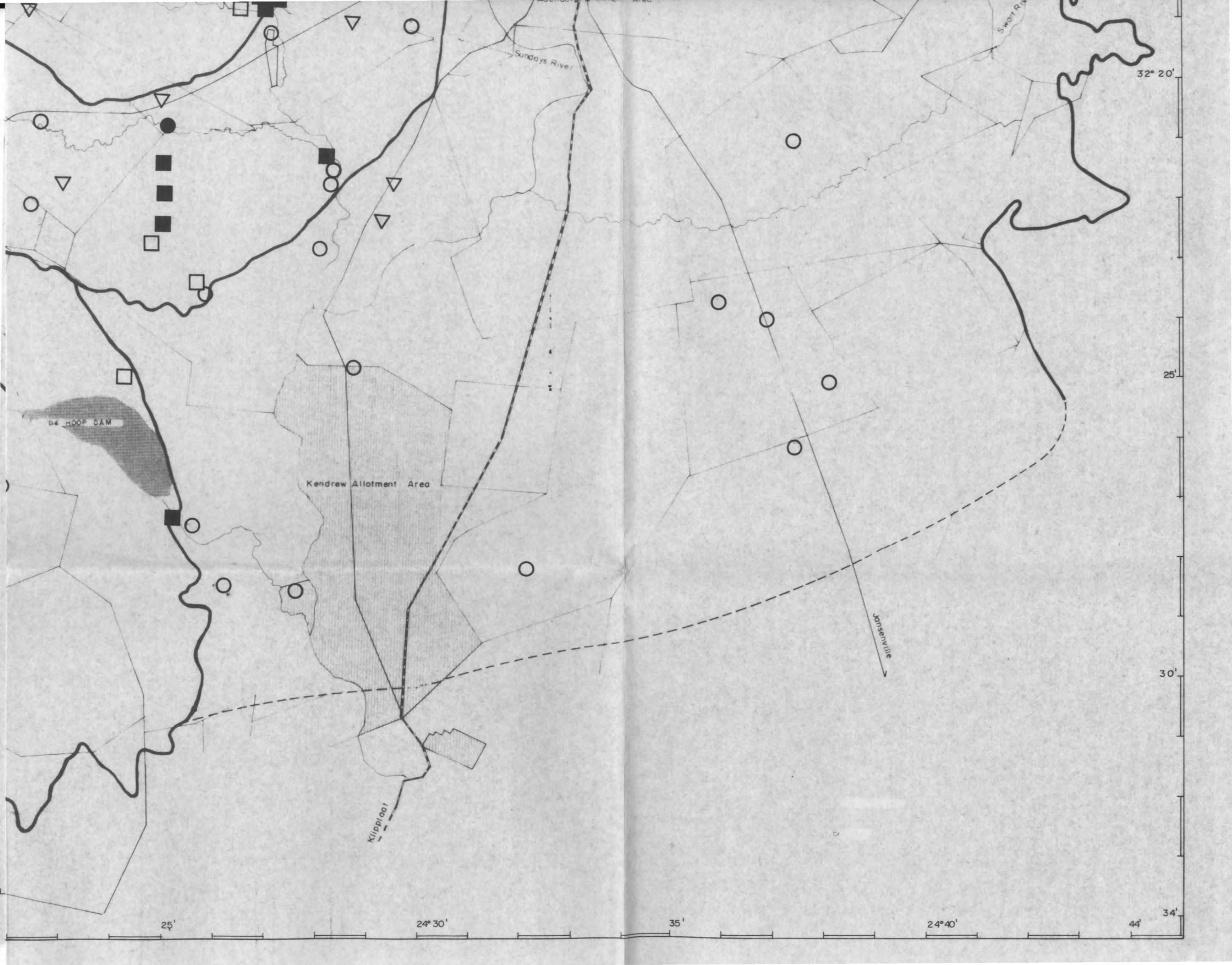


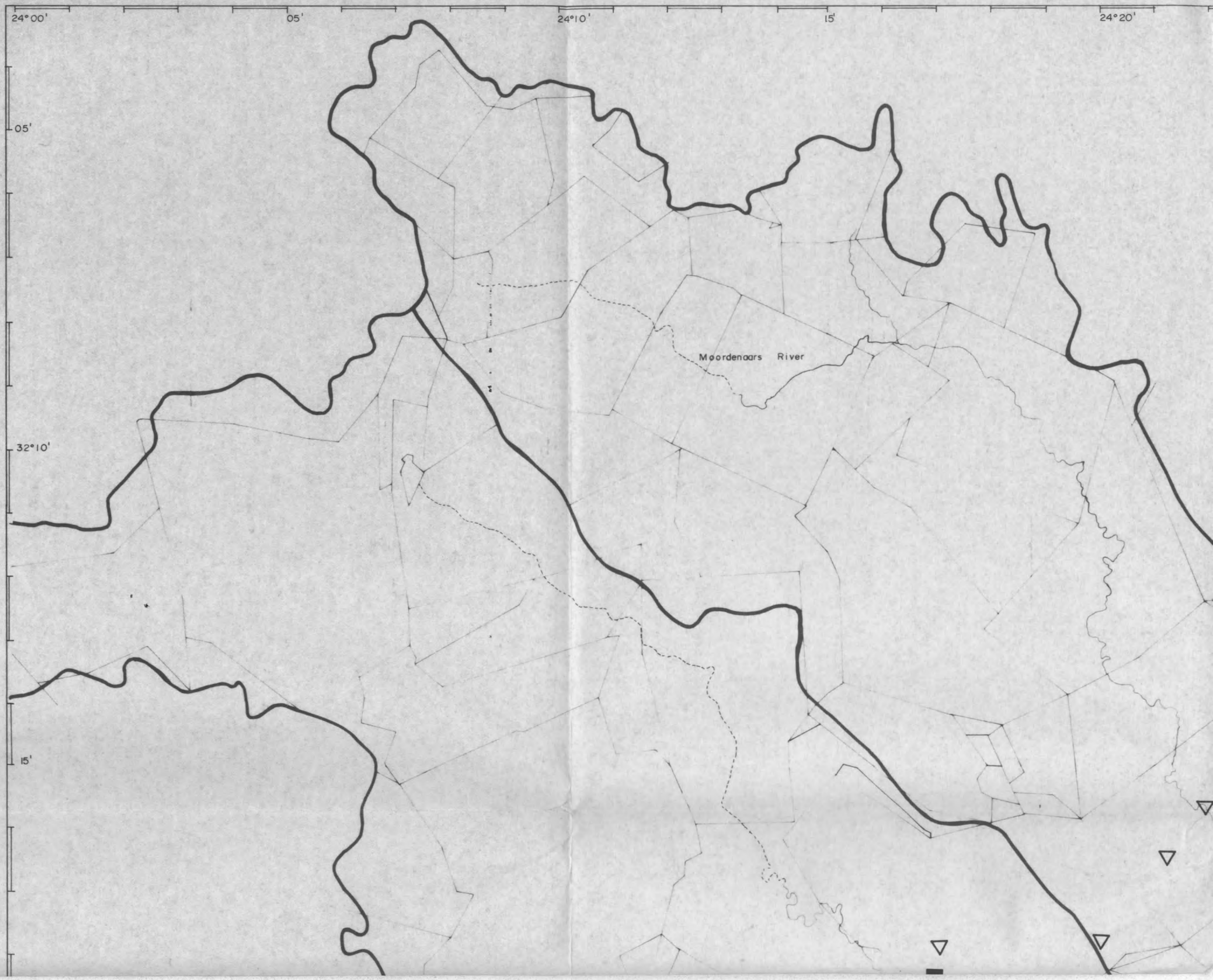
24°00'
05'
24°10'
15'
24°20'
05'
24°10'
15'
Bosmans Kloof 174
193
Moordenaars River
195
Klippedrift 194
Weestevreede 193
Ronde Gat 191
100
Uitkomst
Groote Hoek 192
De Vrede 286
State Land
Klipdrift Annex 281
Rabrags Kloof 278
Poordekraal 282
284
280
279
285
288
270
Paardekraal Annex 279
Fertility 315
Uitkomst 314
State Land



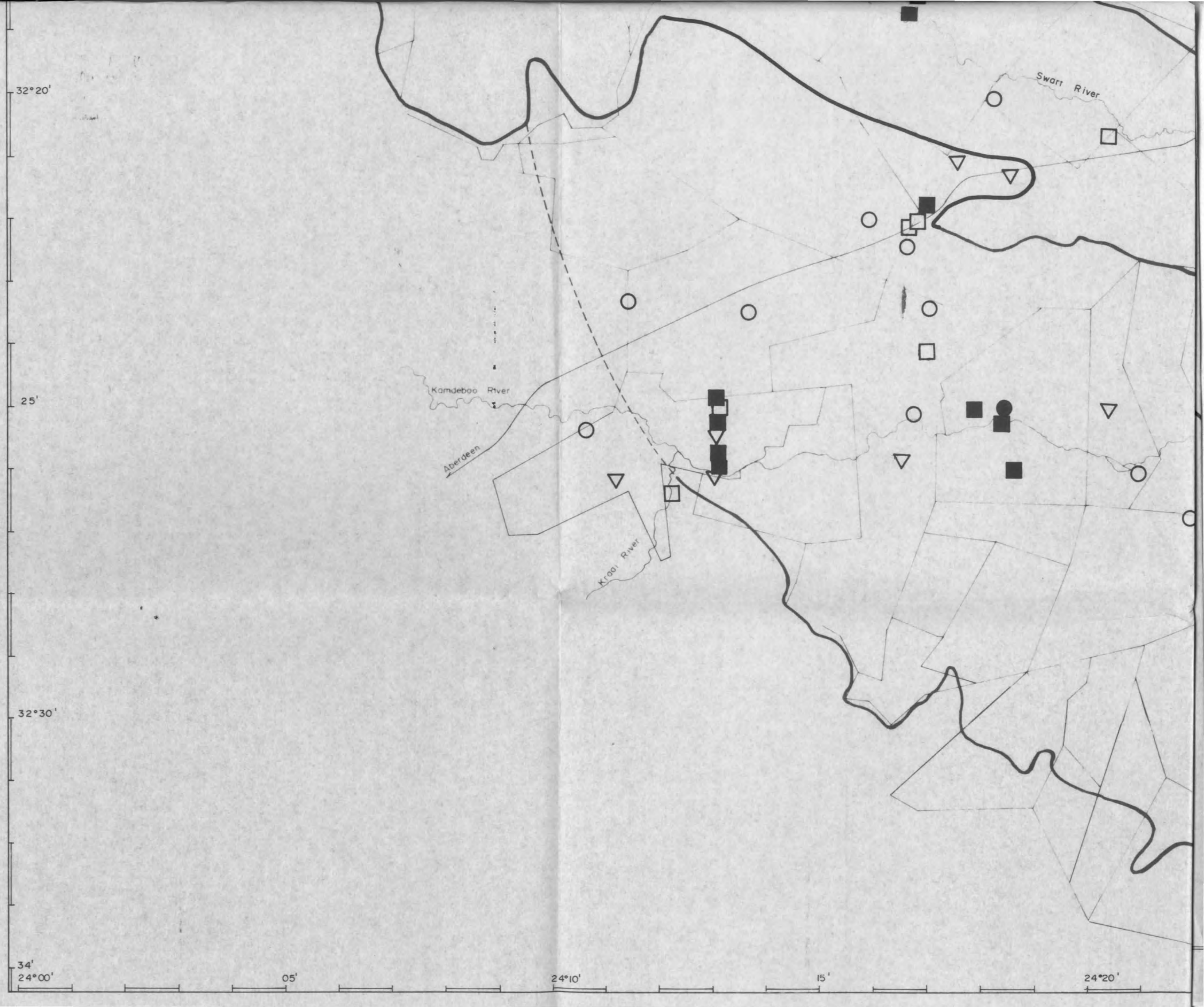
24°20'
Krugers Kraal 322
Vrijnstfontein 319
309
Van Der Walts Kloof 130
Farm 318
Vlak Plaas 131
Bloemf
Zitrug 427
Groote Vlakte 132
Oude Drift A 133
Kamdeboo River
25'
Aberdeen
Oude Drift 139
Zeekoegat D 141
Zeekoegat 140
Farm 135
Kraai River
Louws Kloof 136
Nuweland 138
Klei
Matjesfontein 191
Goeie Hoop 194
32°30'
Farm 193
Farm 192
Bushman
34'
24°00'
05'
24°10'
15'
24°20'
100
200
300
400
500
600
700
800


25'
24°30'
35'
24°40'
44'
ENCLOSURE 5
PIEZOMETRIC MEASURING and HYDROCHEMICAL SAMPLING POINTS
LEGEND
Colour Code
Departmental borehole
Private borehole
Monthy measuring point of piezometric levels
Hydrochemical and piezometric data point
Hydrochemical sampling point
N
1000m 0 1 2 3 4 5 km
05'
32°10'
15'
GRAAFF — REINET


Sundays River
Swart Riv
32° 20'
25'
30'
34'
Kendrew Allotment Area
Jansenville
Klipplaat
25'
24° 30'
35'
24° 40'
44'



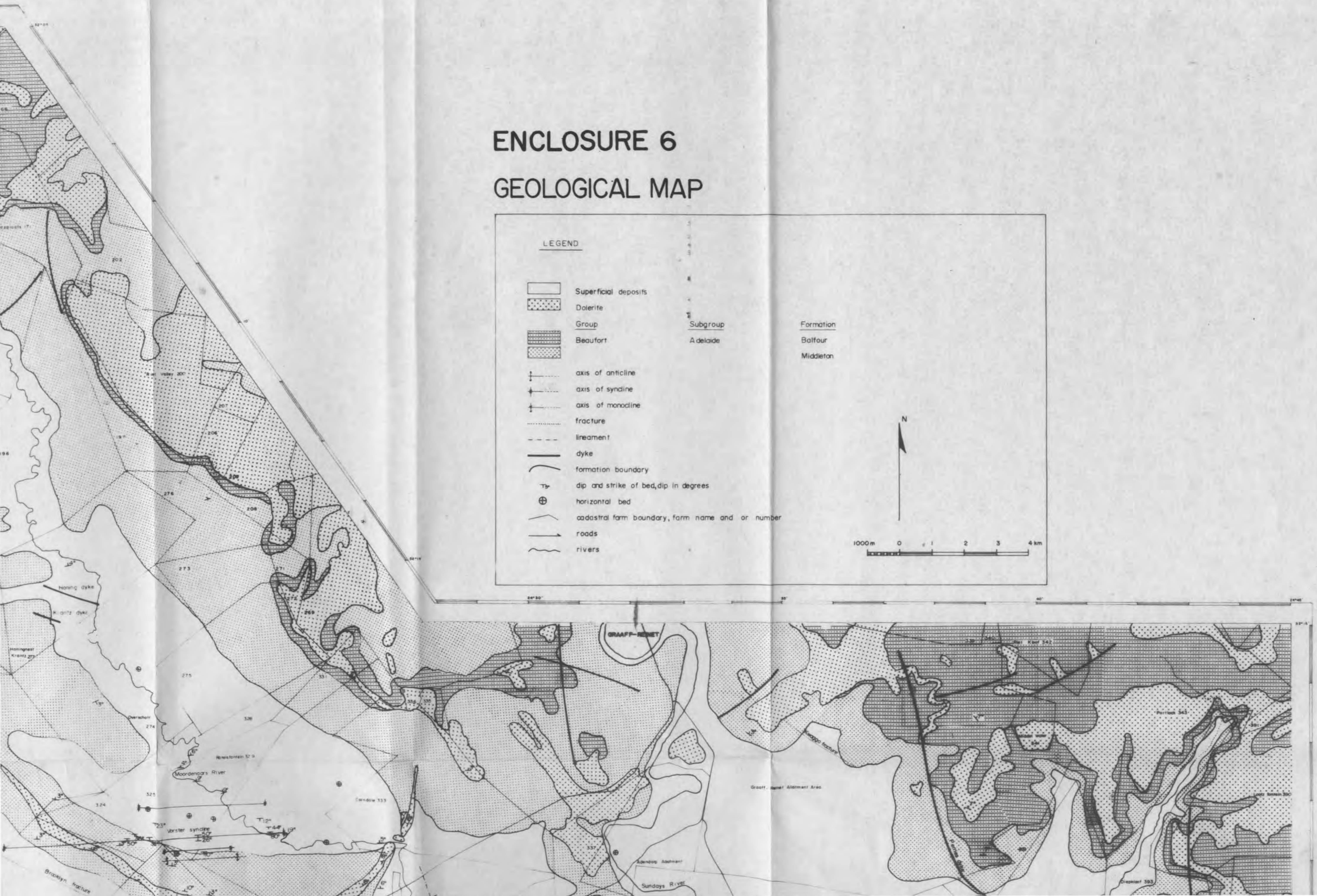
24°00'
05'
24°10'
15'
24°20'
05'
32°10'
15'
Moordenaars River



32°20'
25'
32°30'
34'
24°00'
05'
24°10'
15'
24°20'
Swart River
Kamdeboo River
Aberdeen
Kraai River

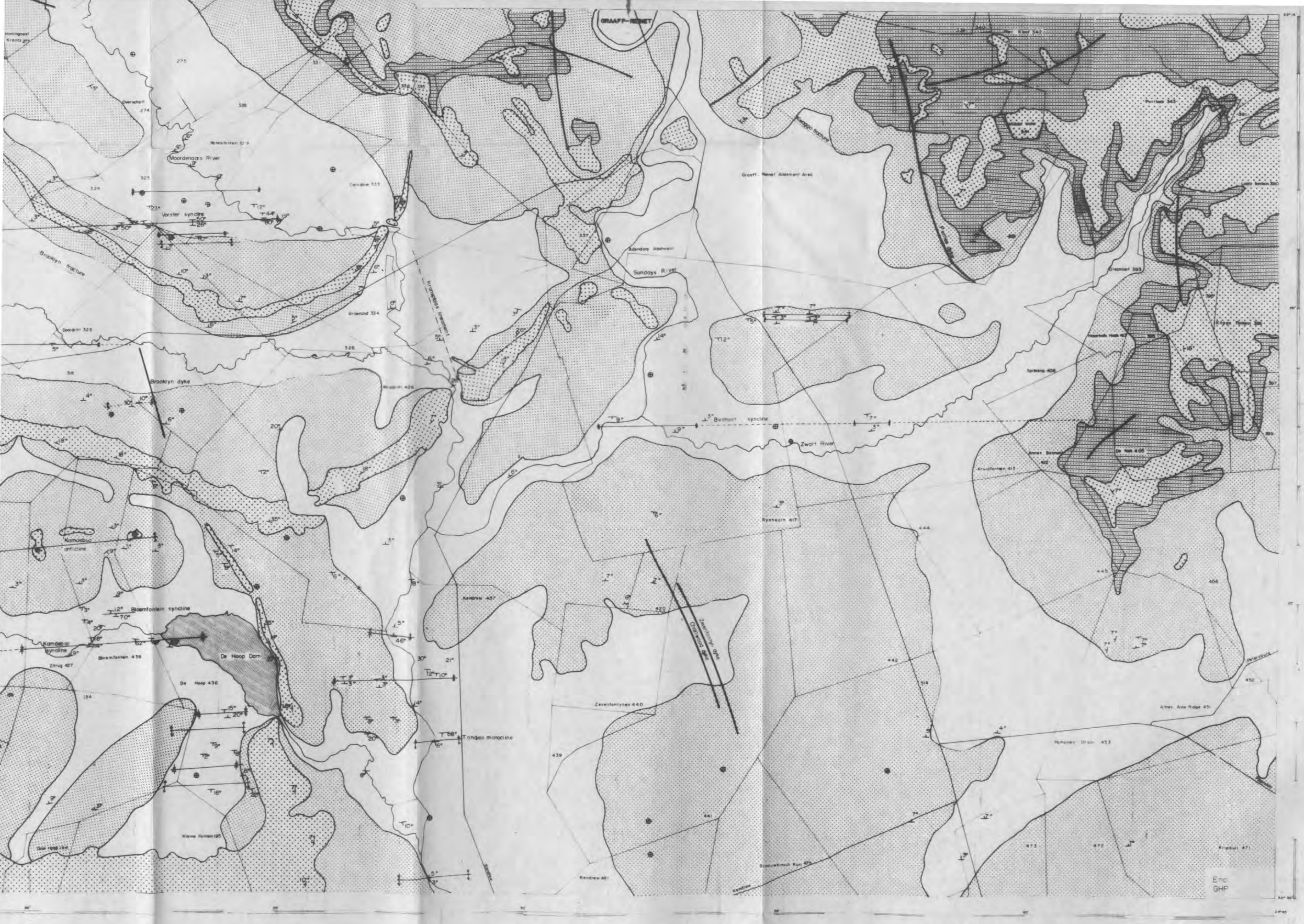
ENCLOSURE 6

GEOLOGICAL MAP



ENCLOSURE 6

GEOLOGICAL MAP

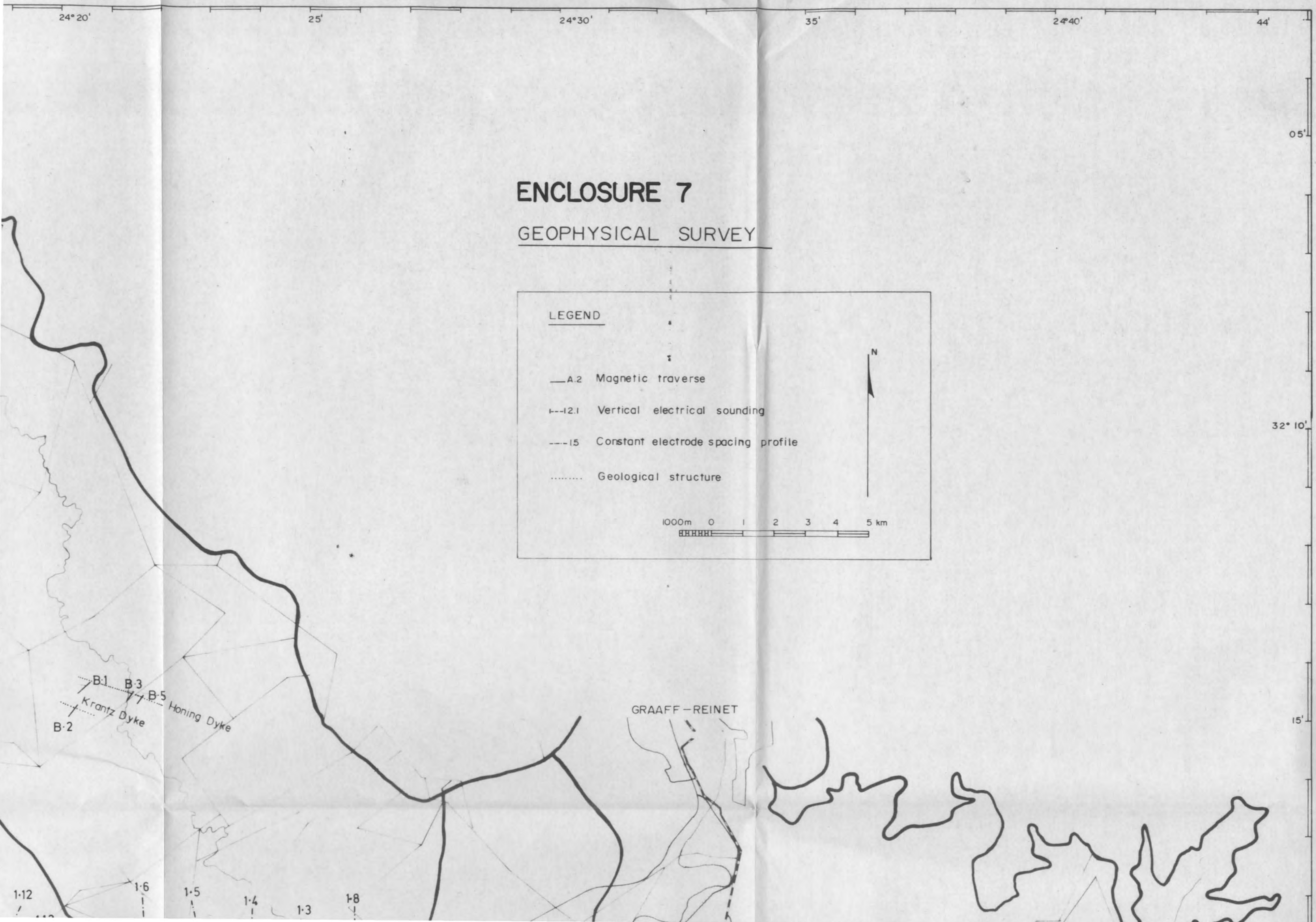


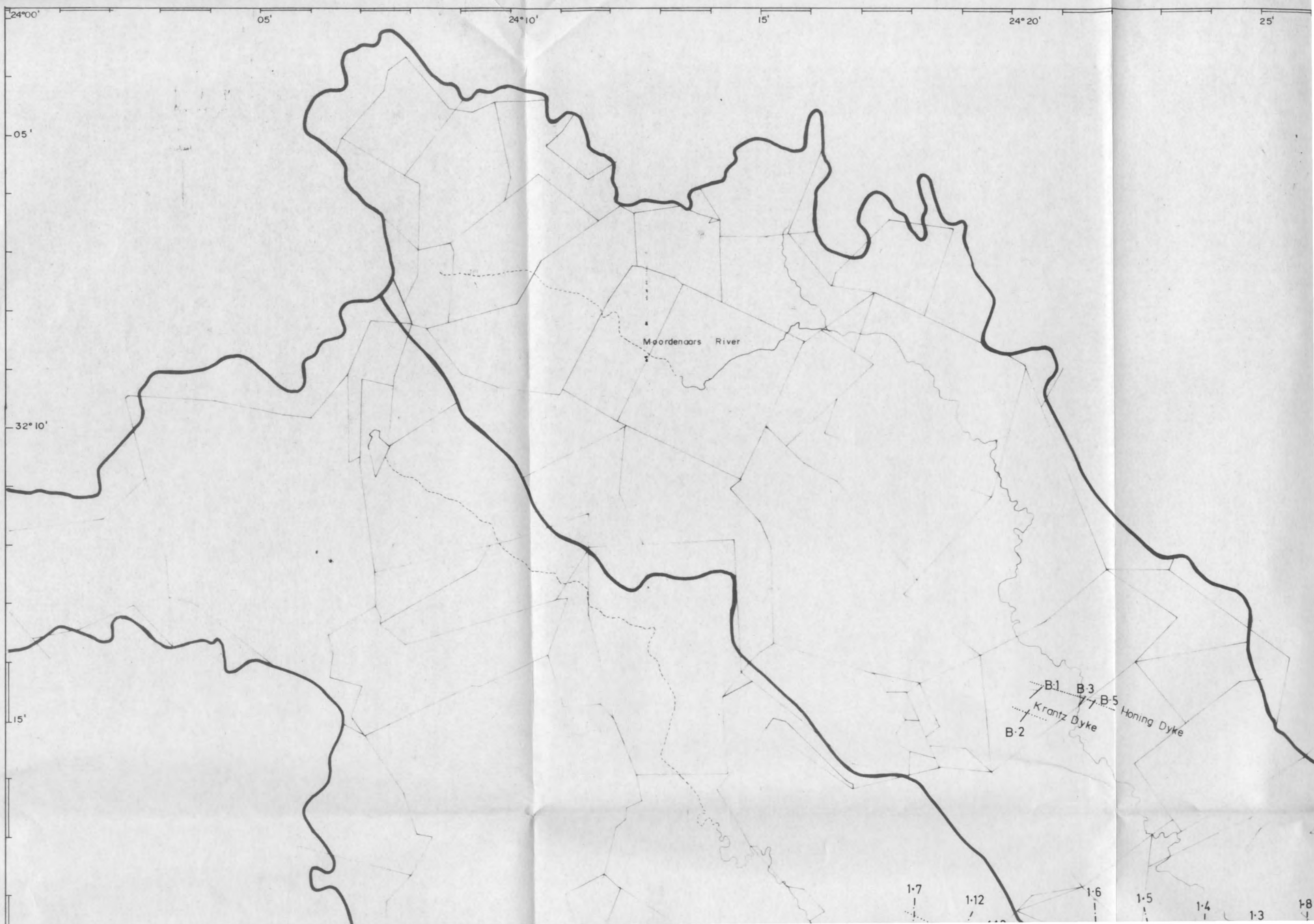
GRAAFF-REINET
Moordenaars River
Vorster syncline
Brooklyn fracture
Brooklyn dyke
Graaff-Reinet Allotment Area
Sundays River
Belmont syncline
Zwart River
Kamdeboo
anticline
Bloemfontein syncline
Kamdeboo
syncline
De Hoop Dam
De Hoop 436
Bloemfontein 439
Tandjes monocline
Zevenfontynen 440
Kendrew 461
Kendrew 467
Kruisfontein 413
Rynhoek 417
Eno
GHP

GRAAFF-REINET
Moordenaars River
Vorster syncline
Brooklyn fracture
Swart River
Swart syncline
Brooklyn dyke
Sundays River
Kamdebo anticline
Bloemfontein syncline
Kamdebo River
Kamdebo syncline
De Hoop Dam
Aberdeen syncline
Aberdeen anticline
Tandjes monocline
Oude Drift fracture
Vlakplaas 131
Oude Drift 139
De Hoop 436

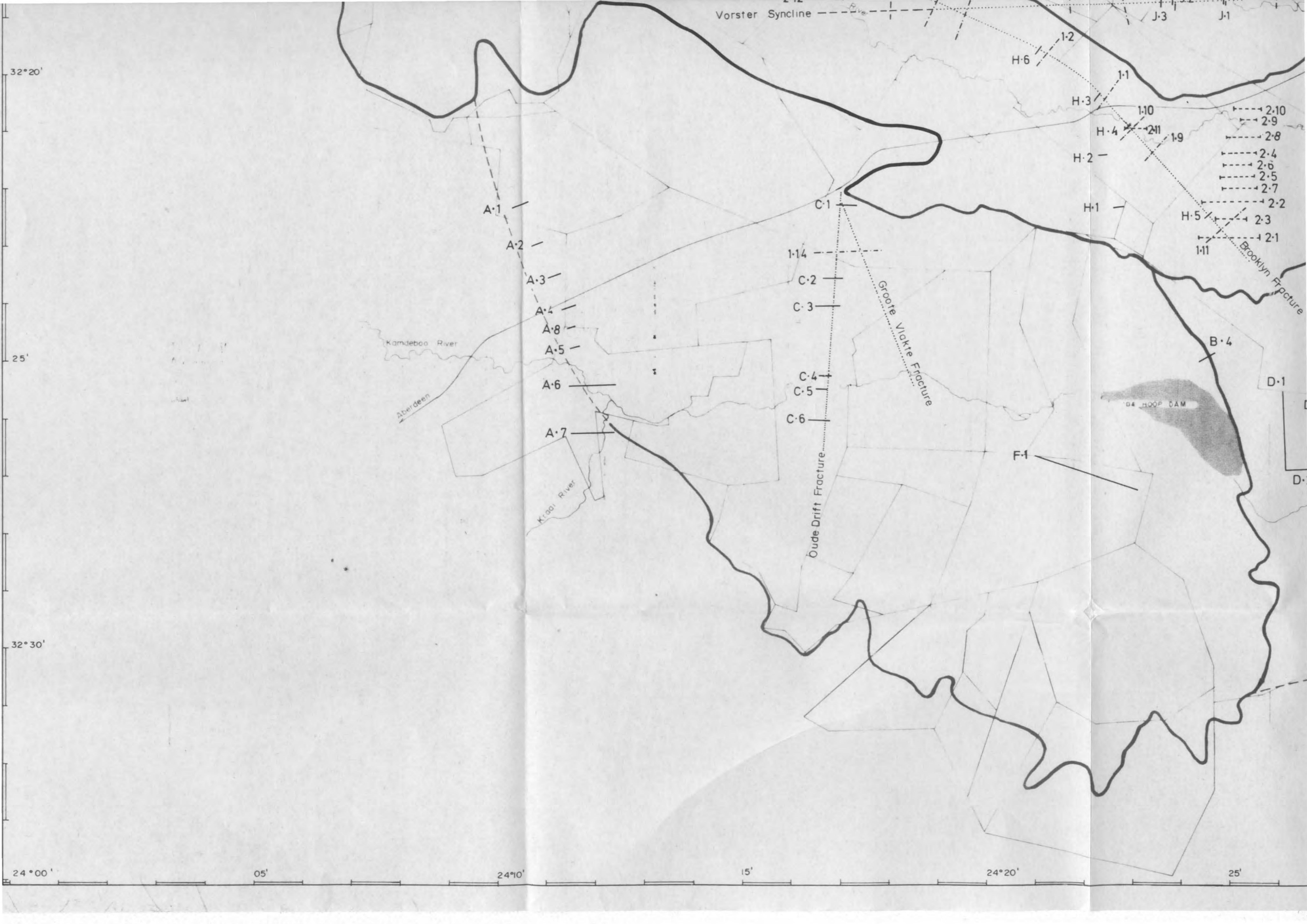
ENCLOSURE 7

GEOPHYSICAL SURVEY




24°00'
05'
24°10'
15'
24°20'
25'
05'
32°10'
15'
Moordenaars River
B·1
B·3
B·5
B·2
Krantz Dyke
Honing Dyke
1·7
1·12
1·6
1·5
1·4
1·3
1·8

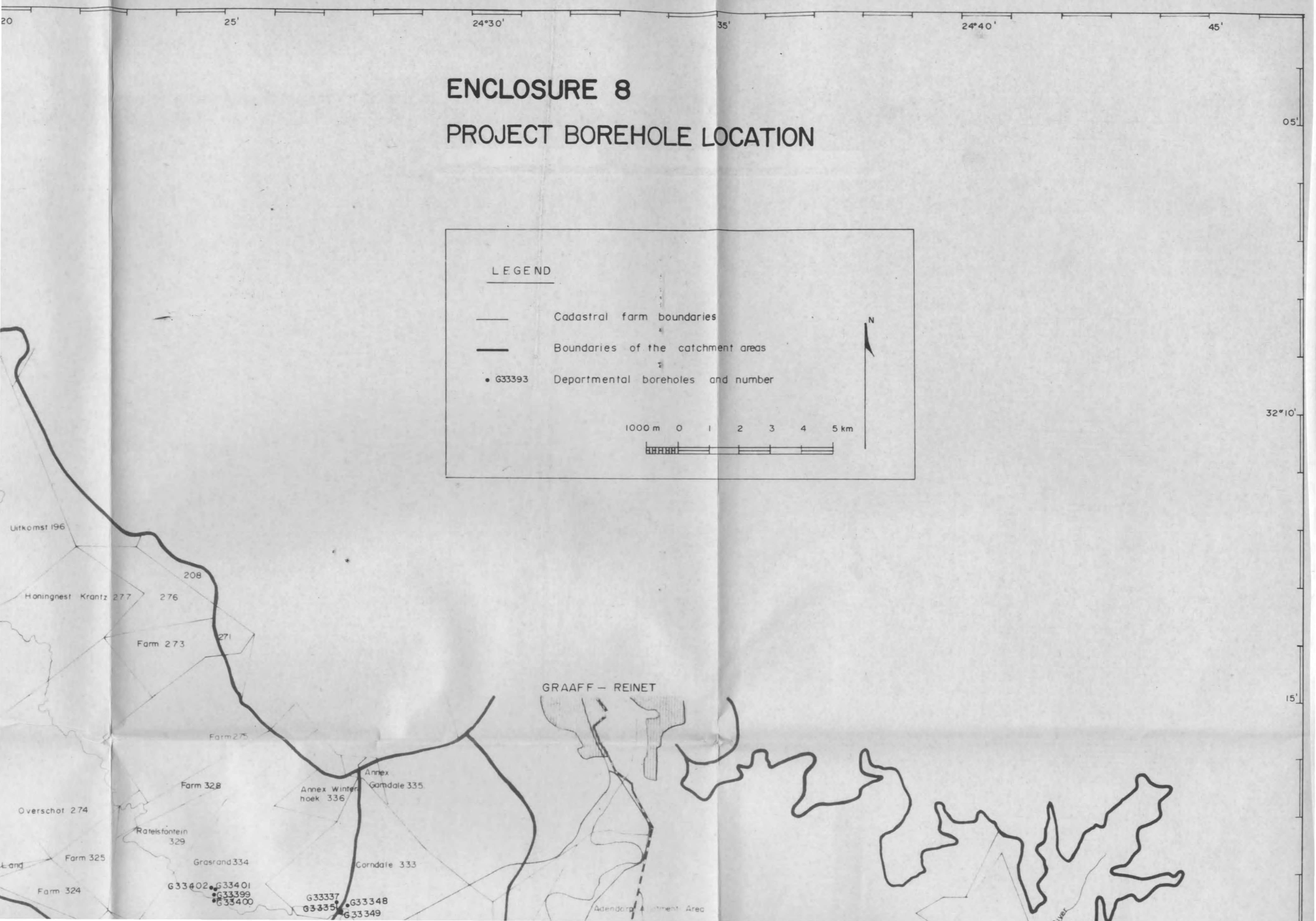
1·13
J·2
J·3
J·1
Adendorp Allotment Area
Sundays River
Swart River
1·2
H·6
1·1
H·3
1·10
H·4
2·11
1·9
H·2
2·10
2·9
2·8
2·4
2·6
2·5
2·7
2·2
2·3
2·1
H·1
H·5
1·11
Brooklyn Fracture
G·1
G·2
G·3
E·1
E·2
E·3
E·4
E·13
E·5
E·6
E·7
E·10
E·12
E·11
E·8
E·9
B·4
D·4
D·5
D·1
D·3
D·2
F·1
Kendrew Allotment Area
Charlwood Dyke
Zevenfontyn Dyke
Jansenville
Klipplaat
32° 20'
25'
32° 30'
24° 20'
25'
24°30'
35'
24°40'
44'
34'

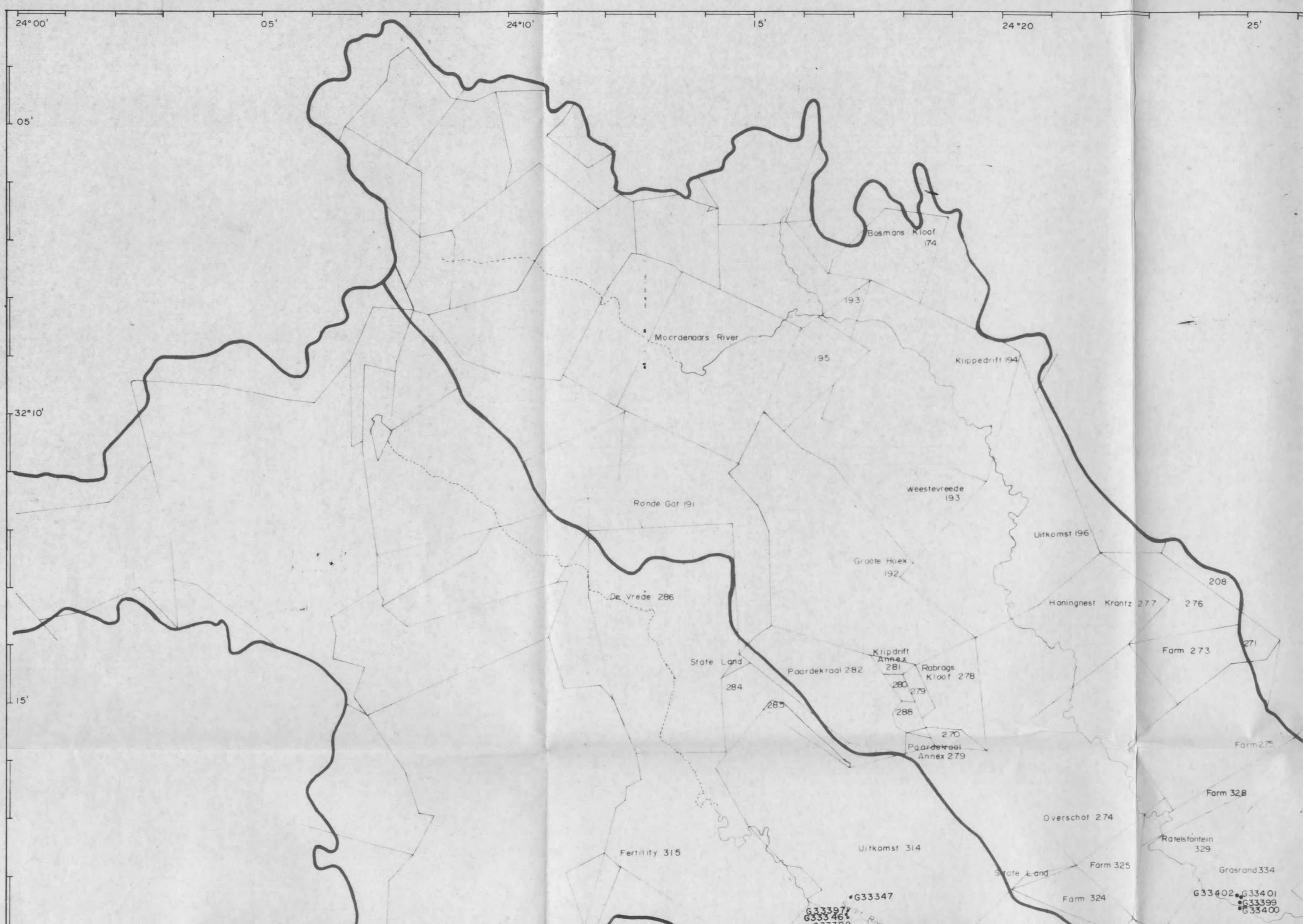


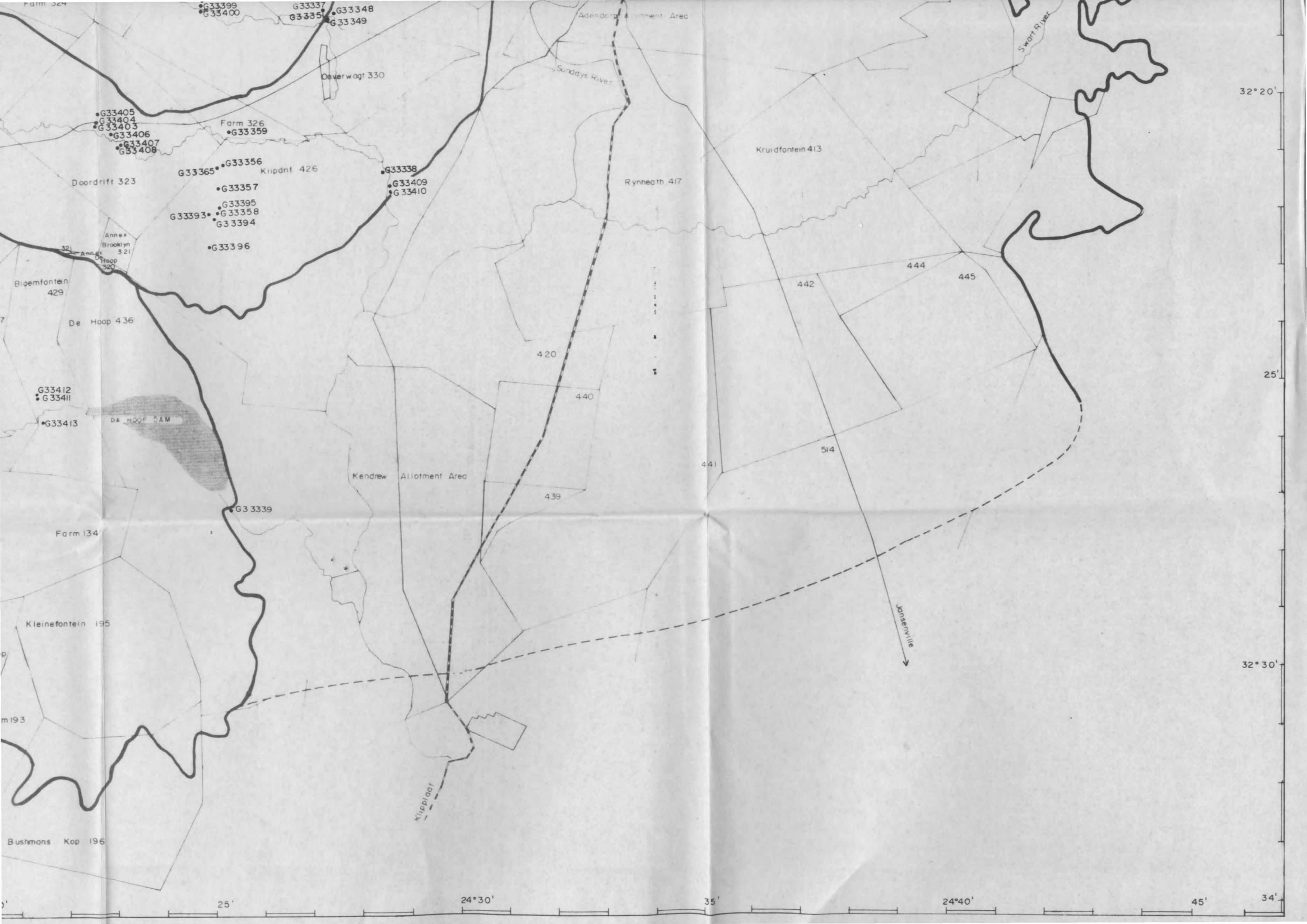
Vorster Syncline
J·3
J·1
1·2
H·6
1·1
H·3
1·10
H·4
2·11
1·9
H·2
2·10
2·9
2·8
2·4
2·6
2·5
2·7
2·2
H·1
H·5
2·3
2·1
1·11
Brooklyn Fracture
C·1
A·1
A·2
1·14
C·2
C·3
A·3
A·4
A·8
A·5
Groote Vlakte Fracture
Kamdeboo River
Aberdeen
A·6
C·4
C·5
C·6
A·7
B·4
D·1
Oude Drift Fracture
F·1
Kraai River
32°20'
25'
32°30'
24°00'
05'
24°10'
15'
24°20'
25'

ENCLOSURE 8

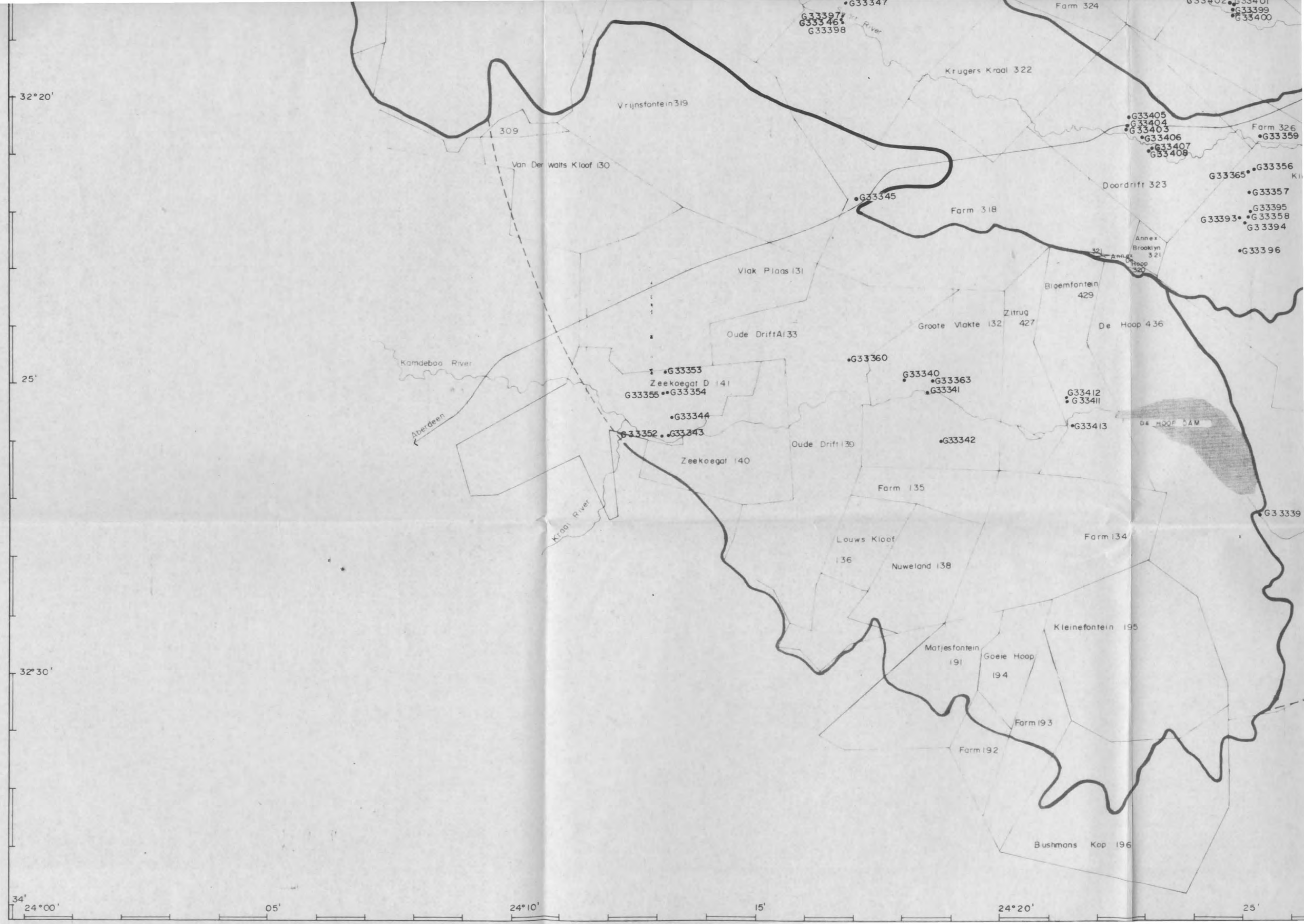
PROJECT BOREHOLE LOCATION




24°00'
05'
24°10'
15'
24°20
25'
05'
32°10'
15'
Bosmans Kloof
174
193
Moordenaars River
195
Klippedrift 194
Weestevreede
193
Ronde Gat 191
Uitkomst 196
Groote Hoek
192
208
De Vrede 286
Honingnest Krantz 277
276
Farm 273
271
State Land
Klipdrift
Annex
281
Rabrags
Kloof 278
Paardekraal 282
284
280
279
285
288
270
Paardekraal
Annex 279
Farm 275
Farm 328
Overschot 274
Ratelsfontein
329
Fertility 315
Uitkomst 314
State Land
Farm 325
Grasrand 334
G33347
Farm 324
G33402
G33401
G33399
G33400
G33397
G33346



G33399
G33400
G33337
G33348
G33349
Adendorp Allotment Area
Swart River
Onverwagt 330
Sundays River
32°20'
G33405
G33404
G33403
G33406
G33407
G33408
Farm 326
G33359
Kruidfontein 413
G33356
G33365
Klipdrif 426
G33338
Doordrift 323
G33409
G33410
Rynhoath 417
G33357
G33395
G33393
G33358
G33394
Annex
Brooklyn
321
G33396
444
445
442
Bloemfontein
429
De Hoop 436
420
25'
G33412
G33411
440
G33413
De Hoop Dam
514
441
Kendrew Allotment Area
439
G33339
Farm 134
Jansenville
Kleinefontein 195
32°30'
Klipplaat
Bushmans Kop 196
25'
24°30'
35'
24°40'
45'
34'



G33347
G33397
G33346
G33398
Farm 324
G33399
G33400
Krugers Kraal 322
Vrijnsfontein 319
309
Van Der Walts Kloof 130
G33405
G33404
G33403
G33406
G33407
G33408
Farm 326
G33359
G33365
G33356
Doordrift 323
G33345
Farm 318
G33357
G33395
G33393
G33358
G33394
G33396
Annex Brooklyn 321
Vlak Plaas 131
Bloemfontein 429
Zitrug 427
Groote Vlakte 132
De Hoop 436
Oude DriftA133
Kamdebao River
G33360
G33353
Zeekoegat D 141
G33355
G33354
G33340
G33363
G33341
G33412
G33411
G33344
G33413
DE HOOP DAM
Aberdeen
G33352
G33343
G33342
Oude Drift 139
Zeekoegat 140
Farm 135
G33339
Kraai River
Louws Kloof 136
Farm 134
Nuweland 138
Kleinefontein 195
Matjesfontein 191
Goeie Hoop 194
Farm 193
Farm 192
Bushmans Kop 196
32°20'
25'
32°30'
34'
24°00'
05'
24°10'
15'
24°20'
25'

THE EXPLORATION AND EVALUATION OF GROUNDWATER UNITS SOUTH AND WEST OF GRAAFF-REINET, CAPE PROVINCE, SOUTH AFRICA

Volume 2 : Appendices

by

ROGER PAUL PARSONS

Submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Geography, Rhodes University, Grahamstown.

June, 1986

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   1B. Land and water usage questionnaire
   1C. Fertilizer application data

2. GEOPHYSICAL DATA - green

   2A. Magnetic anomalies
   2B. CES profiles

3. PROJECT BOREHOLE LOGS - white

4. AQUIFER TEST DATA - pink

5. WATER QUALITY DATA - yellow

   5A. Hydrochemical data - private boreholes
   5B. Hydrochemical data - project boreholes
   5C. Piper diagram showing the hydrochemical composition of the groundwater in the different groundwater units
   5D. Electrical conductivity variations during the aquifer tests

APPENDIX 1:

HYDROCENSUS DATA

Appendix 1A

Borehole inventory data

LIST OF INVENTORIED FARM UNITS

CADASTRAL FARM	LOCAL FARM
ADENDORP ALLOTMONT AREA	
BASONSKRAAL 126	Stockdale
CORNDALE 333	Corndale
DE HOOP 436	De Hoop
	Klein De Hoop
	Tandjies View, The Island
DE VREDE 286	Vrede
	Brooklyn
DOORDRIFT 323	Watervlei
FERTILITY 315	Uitkomst
GRASRAND 334	Erica
	Grasrand
	Mimmosadale
GROOTE VLAKTE 132	Grootvlakte
HONINGNEST KRANTZ 277	Honing Kranz
KLEINE FONTEIN 195	Roodeberg
KLIPDRIFT 426	Kransplaas
	Mooifontein
KLIPPEDRIFT 194	Klipdrift
	Klipdrift
KRUGERS KRAAL 322	Kriegerskraal
KRUIDFONTEIN 413	Belmont
	Kruidfontein
	Melrose
LOUWS KLOOF 136	Daglumier
OUDEDRIFT A133	Oudedrift
OVERSHOTT 274	Beaconsfield
RATELSFONTEIN 329	Irene
RONDE GAT 191	Bothashoop
RHYNHEATH ESTATES 417	Rhynheath
SPITSKOP 408	Spitskop
UITKOMST 196	Klipdrift
UITKOMST 314	Uitkomst
	Uitkomst
VAN DER WALTS HOEK 179	Van Der Walts Hoek
VAN DER WALTS KLOOF 130	Grand View
VLAKPLAAS 131	Grand View
	Vlakplaas

CADASTRAL FARM	LOCAL FARM
ZEEKOEIGAT 140D	Zeekoeigat
	Zeekoeigat
ZEVENFONTEIN 440	Charlwood

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
AD 1	60	1	317				Krag		H_2S water
AD 2	60	1					Mono		H_2S water
AD 3	60			13,84	695,1	681,3	WP	821	
AD 4	60			11,64	698,2	686,6	-	-	
AD 5		12	376				Mono		
AD 6	45			13,52	707,3	693,8	WP	821	
AD 7	45						WP	821	
AD 8	45	25	474				Mono		
AD 9	35	25	193				Mono		
AD 10	55	25					Turb		
AD 11	65	16		19,00	716,5	697,5	Subm		
AD 12	70	22					-	-	sealed

ADENDORP ALLOTMENT AREA

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
VS 20		2	186				WP	821	
BK 2		low	126				WP	821	
BK 3		2					WP	821	
BK 4	30	2					Mono	18396	
BK 5	45	2					Krag	18396	
BK 6	25	2	248				Mono	18396	
BK 7		8					Mono	73584	
BK 8		8					Mono	73584	
BK 9		6					Mono	55188	
BK 10		14					Turb	128772	
BK 11		11					Mono	101178	
BK 12		17					Mono	156366	
BK 13	110	11					Mono	101178	Water strikes 10m, 25m, 37m
BK 14		5					Mono	45990	
BK 15	47	9	247	4,68	707,3	702,6	-	-	
VS 21	50	9		7,47	701,2	693,7	-	-	
							TOTAL:	793491 m^3	

OWNER : MR. A. CRUICKSHANK

CADASTRAL FARM NAME : BASSONS KRAAL 126

LOCAL FARM NAME : STOCKDALE

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
CE 3	48	0.5	245				WP	821	Alluvium, Sediments
CE 4	55	0.5	74				WP	821	Alluvium,Sediments
CE 6		8.8					-	-	Hole collapsed
CE 7		8.8					-	-	Hole collapsed
CE 8	13	1.0					-	-	dry pit, alluvium 4m
CE 9	24	1.0	106	8,10	707,3	699,2	WP	821	domestic supply
CE 100	54	2.0	109				-	-	sediments 38m,dolente 54m
							TOTAL:	2463m^3	

NOTE: Springflow originates on the farm and has an estimated flow of 187 955 m^3/yr (see land use questionnaire)

SWART UNIT									
CE 1	60	0.6					WP	821	Sediments
CE 2	60	0.6	79				WP	821	Sediments
CE 10	42	1.5	100				WP	821	Sediments
CE 11	48	0.2					-	-	Sediments
CE 15	33	0.1					-	-	Blocked
CE 16	50	2.0					-	-	Blocked
CE 17	66	2.5	104				WP	821	Sediments
CE 19	34	4.0	149	11,54	689,0	677,5	Turb	35942	Sediments
							TOTAL:	39226m^3	

OWNER : MR. W.F.B. VORSTER

CADASTRAL FARM NAME : CORNDALE 333

LOCAL FARM NAME : CORNDALE

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/M (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
DP 1	45	0.2		61,35	774,4	713,0			Sediments
DP 2	70	0.1		39,67	777,4	737,3	WP	821	Sediments, borehole collapsed.
DP 3	45	1.0	132	29,02	747,0	718,0	WP	821	Sediments
DP 4							–	–	Blocked
DP 5	45	0.5	138	31,38	685,9	654,5	WP	821	Sediments
DP 6	30	2.5		16.56	716,5	699,9	–	–	Sediments, dolerite
DP 11	66	low					WP	821	Sediments
							TOTAL:	$3284m^3$	
SUNDAYS UNIT									
DP 7	30	4	608				WP	821	
DP 8	60	17		26,10	646,3	620,2	WP	821	
DP 9	60	17	583	26,33	646,3	620,0	WP	821	
							TOTAL:	$2463m^3$	

OWNER : O. J. OLIVIER
CADASTRAL FARM NAME : DE HOOP 436

LOCAL FARM NAME : DE HOOP

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
DP 45		1.0	152	19,23	673,8	654,6	WP	821	
DP 46	66	0.2	176				WP	821	
DP 47	55	19	167	20,96	698,2	677,2	WP	821	
							TOTAL:	2463m^3	
SUNDAYS UNIT									
DP 41	60	19	621	12,87	628,0	615,1	submers	49275	
DP 42	60	0.2							Collapsed
DP 43	60	6							Collapsed, alluvium 12m, Sediments
DP 44	60	5	200	14,09	634,1	620,0			Dolerite at 42m
DP 49	60	0.5	143	31,66	637,2	605,5	WP	821	Dolerite at 42m
							TOTAL:	50096m^3	

OWNER : MR. P. VAN DER BERG

CADASTRAL FARM NAME : DE HOOP 436

LOCAL FARM NAME : KLEIN DE HOOP

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
DP 50	65	low					WP	–	Broken, sediments
DP 51		low					WP	821	
DP 52	65	low					WP	–	Broken, sediments
DP 53	65	low					WP	–	Broken, sediments
DP 54	55	1,0	171				WP	821	On calcrete muge, sediments
DP 55		1,0	111	10,15	652,0	641,8	WP	821	Sediments
							TOTAL:	2463m³	
SUNDAYS UNIT									
DP 56		low		11,50	634,1	622,6	WP	–	Broken, sediments
DP 58		low		23,17	661,6	638,4	–	–	Sediments
DP 60	55	low		19,98	661,6	641,6	–	–	Sediments
DP 61		low	235	19,07	649,4	630,3	WP	821	Sediments
DP 62	55	low	230	14,74	640,2	625,5	WP	821	Sediments
DP 66	55						WP	821	Poor condition
DP 67	60	3	6500				Mono	39420	Sediments
DP 68	66	3	734				Mono	39420	Sediments, struck water at ±80m
DP 69	90	8					Mono	105120	Sediments "
DP 70	90	10					Mono	181400	Sediments "
DP 71	90	18					Mono	236520	Sediments "
DP 72		low		11,82	621,9	610,1	WP	–	Dried up by pumping DP 70, DP 71
DP 73	10						WP	–	Broken, dry
DP 74	60	18	796				Turb	236520	H_2S water
DP 75	60	18	926				Turb	236520	Sediments, struck water at ± 50m
DP 76	60	18	937				Turb	236520	Sediments "
DP 78	60	20	903				Mono	262800	Sediments "
							TOTAL:	1526703m³	

OWNER : MR. R.A.H. MURRAY

CADASTRAL FARM NAME : DE HOOP 436

LOCAL FARM NAME : TANDJIES VIEW, THE ISLANDS

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SWART UNIT									
DV 1		low	60	21,10	908,5	887,4	WP	821	
DV 2		low	38	7,83	868,9	861,1	WP	821	H_2S water
DV 3	30	low	117				WP	821	
DV 4	90	low		28,68	902,4	873,7	-	-	
DV 5	37	1,5	122				Krag	5913	Domestic supply
DV 6	30	0,5					Submers	657	Effected by level of dam
DV 7		low	80	17,40	884,1	866,7	WP	821	
DV 8		6	salty	7,12	862,8	855,7	-	-	
DV 9		8					Turb	147196	
DV 10		low	69				WP	821	
DV 11		8		12,10	859,7	847,6	-	-	Water level effected by river
DV 12	35	low	69				WP	821	
DV 13		low					WP	821	
DV 14									Dry since pumping DV
DV 15	90	8	81				Turb	10512	Use for stock as unreliable
DV 16		low	71	10,97	850,6	839,6	WP	821	
DV 17	90	6					Turb	-	Not in use, water level effected by ri
DV 18	90	6		12,37	850,6	838,2			
DV 19	90			36,50	914,6	878,1	-	-	Waterlevel fluctuate
DV 20		low	52				WP	821	H_2S water
DV 21		low	76				WP	821	
DV 22	90	10	77				Turb	183996	Strike water at 79m
DV 23	90	5					Turb	91998	
DV 25	90	9					Turb	165596	
DV 26	90	9	92				Turb	165596	
							TOTAL:	779674m^3	

OWNER : MR. J.A. BIGGS

CADASTRAL FARM NAME : DE VREDE 286 LOCAL FARM NAME : VREDE

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
DT 102	100	0.1		21,03	756,1	735,1	–	–	Dolerite
SWART UNIT									
DT 1	25	8					Turb	29952	Domestic use, sediments
DT 2	30	2,5		10,75	716,5	705,7	WP	821	Effected by DT 1
DT 3	12	5					WP	821	Alluvium & Sediments
DT 4	33	2.5		11,70	716,5	704,8	WP	821	Sediments
DT 5	38	3.8					WP	–	Broken
DT 6	27	5		10,27	716,5	706,2	–	–	
DT 8	36	1	159	17,18	704,3	687,1	WP	821	
DT 9	30	2.5	197	20,55	701,2	680,7	WP	821	
DT 10	30	2.5					–	–	Collapsed
DT 11	35	2.5	142	8,23	710,4	702,2	WP	821	H_2S water
DT 12	36	4.4	175	10,10	704,3	694,2	WP	821	
DT 13	68	13					Turb	46800	
DT 14	30	2.5	228	10,60	698,2	687,6	WP	821	
DT 15	78	13					–	–	Blocked
DT 16	36	3.8		14,81	698,2	683,4	–	–	
DT 17	34	2.5	222	11,46	707,3	695,8	WP	821	
DT 18	29			13,22	708,8	695,6	–	–	
DT 19	60	1		21,89	719,5	697,6	WP	821	H_2S water
DT 20	30	0.3	68	10,22	719,5	709,3	WP	821	H_2S water
DT 21	42		100				WP	821	H_2S water
DT 22	29	2.5	157				WP	821	
DT 23	45	2.5					WP	–	Broken
DT 27	30	2.5	152				WP	821	
DT 28	47	2.5	118	13,61	725,6	712,0	WP	821	
DT 29	58	0.6	94	30,03	777,4	747,4	WP	821	
DT 100	70	35		13,97	716,4	702,4	TURB	433620	Sediments, water strikes 24,36-56,70, H_2S water
DT 101	100	35		7,87	707,3	699,4	–	–	Sedements, water strikes 13,22-46,54,70, alluvium 14m

CONT. ON PAGE 2

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
							TOTAL:	523508 m^3	
KAMDEBOO UNIT									
DT 24	67	1	129				WP	821	
DT 25	47	1	110	29,14	725,6	696,5	WP	821	
DT 26	45	1	154				WP	821	
							TOTAL:	2463 m^3	

OWNER : MR. D.W. HEROLD
CADASTRAL FARM NAME : DOORDRIFT 323

LOCAL FARM NAME : BROOKLYN

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
KK 3	50	0.2	94	22,66	754,6	731,9	WP	821	Dolerite, sediments
							TOTAAL:	821 m^3	
SWART UNIT									
DT 30	20	0.5	140	9,47	725,6	716,1	WP	821	Sediements
DT 31	60	9	147	12,94	727,1	714,2	WP	821	
DT 32	30	4	147				WP	821	
KK 2	20	0.5					-	-	
KK 4	20	0.5	130				WP	821	
KK 5	20	0.3	156				WP	821	
KK 6	25	0.3		13,42	737,8	724,4	WP	821	
KK 7	25	0.3	136				WP	821	
KK 10	30	0.5	81	16,30	739,3	723,0	WP	821	
							TOTAL:	6568 m^3	

OWNER : MR. N. KROON

CADASTRAL FARM NAME : DOORDRIFT 323

LOCAL FARM NAME : WATERVLEI

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SWART UNIT									
FY 1	40	7.5		12,85	786,6	773,7	WP	821	Sediments
FY 2	30	23					Turb	112320	Sediments, H_2S water
FY 3	50	28					-	-	Blocked
FY 4	20	10	71				WP	821	
FY 5	15						WP	821	
FY 6	40	7.5		24,85	823,2	798,3	WP	-	Broken
FY 7	30	25		10,13	838,4	828,1	WP	821	
FY 8	70	5					WP	821	
FY 9	30	5		13,85	820,1	806,2	WP	821	
FY 11	65	12		41,72	871,9	803,2	Krag	18532	
							TOTAL:	135778 m^3	

OWNER : MR. J.A. HAARHOFF

CADASTRAL FARM NAME : FERTILITY 315

LOCAL FARM NAME : UITKOMST

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SWART UNIT									
GD 1	55	3.1	306				WP	821	Contact zone
GD 2	64	2.8	437				WP	821	Contact zone
GD 3	55	37					Turb		Contact zone, H_2S water broken
GD 4	48	low		8,63	701,2	692,6	-	-	Brack, blocked
							TOTAL:	1642 m^3	
SWART UNIT									
GD 7	36	8.1	138				Turb	58787	Sandstone ? H_2S water
GD 8	36		412				WP	821	H_2S water
GD 9	36	15	469				Mono	117936	
GD 10	43	1.5	100	27,18	714,9	687,7	WP	821	
							TOTAL:	178365 m^3	

Note: Has got low yielding seasonal spring with H_2S smell - not used for any purpose

OWNER ; MR. C.J. VAN DEN BERG, MR. K. VENTER

CADASTRAL FARM NAME : GRASRAND

LOCAL FARM NAME : ERICA, GRASRAND

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
GD 11	76	0.4	58				WP	821	sediments
GD 12	30	0.4	248				WP	821	sediments
GD 13	31	12					–	–	sediments
GD 14	30	1.3					WP	821	sediments
GD 15	30	1.3					WP	821	sediments
GD 16	27	1.3					WP	821	sediments
GD 17	30	3.8					Turb	4914	
GD 18	30	1.3					WP	821	sediments
GD 19	40	35					Mono	24570	sediments
GD 20	30	3.8	201				Turb	14742	H_2S water, sedimen
							TOTAL:	49152 m^3	

OWNER : MR. D.C. CONRADIE

CADASTRAL FARM NAME : GRASRAND 334

LOCAL FARM NAME : MIMOSADALE

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
GV 1				2,54	676,8	674,3	-	-	H_2S water
GV 2	50	37,5					Turb	54000	H_2S water
GV 3	40	25					Turb	36000	H_2S water
GV 4				2,04	676,8	674,8	-	-	H_2S water
GV 5	30						WP	821	
GV 7									Dry hole
GV 8				4,60	676,8	672,2	-	-	
GV 9			97	4,60	676,8	672,2	WP	821	
GV 10				2,29	670,7	668,4	-	-	
GV 11	30	12	114	0,48	670,7	670,2	-	-	artesian
GV 12	30	12	141	0,32	670,7	670,4	-	-	artesian
GV 13				0,80	673,8	673,0	-	-	artesian
GV 14	30	50	143	0,00	670,7	670,7	Centrif	74520	artesian,H_2S,flowing
GV 15				3,58	681,4	677,8	-	-	
GV 16				2,92	676,8	673,9	-	-	
GV 17		low	144	9,30	670,7	661,4	WP	821	
GV 18	30	low	68	19,02	670,7	651,6	WP	821	
GV 19									dry hole
GV 20	80	low					WP	821	
							TOTAL:	168625 m^3	

OWNER : MR. C. DORFLING

CADASTRAL FARM NAME : GROOT VLAKTE 132

LOCAL FARM NAME : GROOTVLAKTE

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
RB 1	30	0.5	152	23,85	716,5	692,6	WP	821	
RB 2	33	0.5	144	16,80	731,1	714,9	WP	821	
							TOTAL:	1642 m^3	

OWNER : MR. B. HOBSON

CADASTRAL FARM NAME : KLEINE FONTEIN 195

LOCAL FARM NAME : ROODEBERG

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
HZ 1	45	1	153				WP	821	
HZ 4	45	1					WP	821	
HZ 5	60	1	67	43,93	817,1	773,2	WP	821	weak
HZ 6	45	1					WP	821	
HZ 7	55	1					WP	821	
HZ 8	45	2.5		12,60	777,4	764,8	WP	821	
HZ 9	2.5	1342					WP	821	
HZ 10	45	2.5					WP	821	
HZ 11	45	1		15,78	777,4	761,6	WP	821	
HZ 12	60			20,16	780,4	760,2	WP	821	weak
HZ 13	45	1		8,43	789,7	781,3	WP	821	
HZ 14	45	1	349				WP	821	
HZ 15	45	1					WP	821	
HZ 16	45	1	164	25,33	798,8	773,5	WP	821	
HZ 17	45	1	129				WP	821	
HZ 18	45	3.8					Turb	5200	
HZ100									dyke contact
							TOTAL:	17515 m^3	

OWNER : MR. R. BIGGS

CADASTRAL FARM NAME : HONINGNEST KRANZ 277

LOCAL FARM NAME : HONING KRANZ

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SWART UNIT									
KD 1	50	low					WP	821	dolerite at 50m
KD 2	23	low		8,59	689,0	680,4	WP	821	sediments
KD 3	blocked								H_2S, artesian
KD 4	60	3	197	8,07	685,9	677,8	WP	821	sediments
KD 5	33	0.2	178	11,51	689,0	677,5	WP	821	
KD 19	66	50	457				Turb	483840	sediments, strikes a at 30m, 45m, 52m
KD 100	100	20	460	7,80	685,9	678,1	–	–	H_2S water, 250mm diameter. Main water strikes 18m, 49m, 60m, 73m, speckled sandstone 60m to 75m
KD 103	44	50	372				–	–	H_2S water, 250m diameter. Main water strikes 16m, 30m, 43m
							TOTAL:	487124 m^3	
SUNDAYS UNIT									
KD 6	76	0.2					WP	821	
KD 7	66	low	419				WP	821	sediments, water level dropped
KD 8	60	low		30,80	652,4	621,6	–	–	dolerite contact, waterlevel dropped
KD 9	55	0.2		20,66	655,4	634,7	–	–	sediments
KD 10	66	low	203				WP	821	sediments
KD 11	85	low		20,84	658,5	637,3	–	–	sediments
KD 12	55	0.2					WP	821	sediments

CONT. PAGE 2

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SUNDAYS UNIT (CONT. FROM PAGE 1)									
KD 13	33	low		14,24	662,4	648,2	–	–	sediments
KD 14	40		544	16,16	667,8	651,6	WP	821	sediments
KD 15	40	50	560	16,74	670,7	654,0	WP	821	yield suspect?
KD 16	66	low		19,40	673,7	654,3	–	–	sediments
KD 17	40	low	163	41,33	701,2	659,9	wp	821	sediments
KD 20	66	6	475				Turb	11700	domestic use

TOTAL: 17447m^3

OWNER : MR. C.B. ENSLIN

CADASTRAL FARM NAME : KLIPDRIFT 426

LOCAL FARM NAME : KRANSPLAAS

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°c)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SWART UNIT									
KD 22	60	6	266	6,56	682,9	676,3	WP	821	H_2S sediments
KD 23	60	0.6		23,72	713,4	689,7	WP	–	broken
KD 24	60	13	178	9,51	699,0	689,5	Turb	10483	sediments
KD 25	60	1					WP	821	
KD 26	60	1					–	–	blocked
KD 37	106	0.1	100				WP	821	sediments, dolerite
KD 38	60	0.1	107				WP	821	sediments, dolerite
KD 102	50	1.5		3,77					0-6m sediments, 7-33 dolerite 3450m sediments drilled in spring
KD 104	60	0.4					–	–	sediments, water strikes 43m,53m
KD 105	50	3					–	–	sediments
							TOTAL:	13767m^3	
SUNDAYS UNIT									
KD 27	60	0.5		35,71	682,9	647,2	WP	821	
KD 28	60	6					–	–	collapsed
KD 29	60	6		8,09	637,2	629,1	–	–	H_2S water
KD 30	60	1					WP	821	sediments
KD 31	60	0.2					–	–	blocked
KD 32	60	low					–	–	blocked
KD 33	60	low					–	–	blocked
KD 34	60	15					Turb	78840	
KD 35	60	5					–	–	sealed
KD 36	100	18					Turb	94608	
KD 39	60	3	205				Turb	27594	
KD 40	36	6					Turb	–	not in use
							TOTAL:	202684 m^3	

OWNER : MR. J. KROON

CADASTRAL FARM NAME : KLIPDRIFT 426   LOCAL FARM NAME : MOOIFONTEIN

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
KT 1	60	low	brak				WP	821	effected by level of dam
KT 2	40	1					WP		dolerite, WP broken
KT 3	30	1					WP	821	sediments
KT 4	30	0.5	116				WP	821	sediments
KT 5	60	low					–	–	sediments
KT 6	60	low		21,65	656,7	835,0	WP	–	broken
KT 7	29	3.8					–	–	sediments
KT 8	38	1					–	–	
KT 9	67	6					Mono	55188	H_2S water
KT 10	55	7					–	–	sediments, collapsed
KT 11	55						–	–	H_2S water, blocked
KT 12	67	1		24,15	875	850,9	Subm	9198	H_2S, dolerite 12m,sediments 55m
KT 13	67	1					WP	821	H_2S, dolerite 12m, sediments 55m
KT 14	30			16,37	884,1	867,7	–	–	
KT 15	25	1	56				WP	821	
KT 16	118	0.1		33,28	939,0	905,7	–	–	dolerite to 69, sediments 49m
KT 17	125	0.1					–	–	hit dolerite at 125m
KT 18	100	0.1					–	–	dolerite to 72m
WE 1	55	1		27,62	826,2	798,6	WP	821	sediments
WE 2	67	1					WP	821	bated sediments
WE 3	24	0.1					–	–	dolerite from 8m
							TOTAL:	70133 m^3	

OWNER : MR. C. JOUBERT

CADASTRAL FARM NAME : KLIPPEDRIFT 194 LOCAL FARM NAME : KLIPDRIFT

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
KT 20	60	11					Mono	72270	dolerite 21-52m
KT 22	45	low					-	-	blocked, allivium & sediments
KT 21	60	8					WP	821	alluvium & sediments
KT 24	90	0.2					-	-	collapsed
KT 25	24	0.1					-	-	collapsed
							TOTAL:	73091 m^3	

OWNER : MRS. W. KROON

CADASTRAL FARM NAME : KLIPPEDRIFT 194 LOCAL FARM NAME : KLIPDRIFT

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SWART									
KK 12	60	12					Mono	26460	sediments
KK 13	85	8					–	–	sediments
KK 14	100	3	83				WP	821	sediments
KK 15	30	2					WP	821	sediments
KK 16	85	6	88				Mono	1404	sediments
KK 17	85	19					Turb	75600	sediments
KK 18	60	2	110	33,76	762,2	728,4	WP	821	sediments
KK 19	32	1	137	24,62	743,9	719,3	WP	821	dolerite at 25m?
							TOTAL:	106748 m^3	
KAMDEBOO									
KK 20	24	2	91				WP	821	
KK 21	75	40					Turb	57915	
KK 22	53	low	93				WP	821	
KK 23	60	15					–	–	blocked
KK 24	60	15		13,53	716,5	703,0	Turb	22275	flows with good rains
KK 25		6		13,50	716,5	703,0	–	–	open
KK 26	73	15		15,26	716,5	701,2	–	–	open
VN 12	25	2	89				WP	821	
VN 13	30	2	89				WP	821	
VN 14	30	2					WP	821	broken
							TOTAL:	84295 m^3	

OWNER : MR. G.O. SPENCE

CADASTRAL FARM NAME : KRUGERSKRAAL 322 LOCAL FARM NAME : KRIEGERSKRAAL

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SUNDAYS UNIT									
KN 1	83	1	92	22,00	762,2	740,2	WP	821	sediments
KN 2	66	1	108				WP	821	sediments & alluvium
KN 3	66	1					WP	821	sediments & alluvium
KN 4	66	1					WP	821	alluvium & sediments
KN 5	73	1		25,40	765,2	739,8	WP	821	alluvium & sediments
KN 6			93	19,00	774,4	755,4	WP	821	
KN 7	73	1	102				WP	821	alluvium & sediments
KN 8	90	10	110				Turb	131400	alluvium & sediments water strike 25m
KN 9	83	1		35,20	762,2	727,0	WP	821	alluvium & sediments
KN 10	66	1	126				WP	821	alluvium & sediments
KN 11							–	–	
KN 12			107				WP	821	sediments
KN 13			107				WP	821	
KN 14			552				WP	821	
KN 15	50	1	110				WP	821	alluvium & sediments
KN 16	66	1					WP	821	sediments
KN 17			121				WP	821	
KN 18			168	31,60	759,1	727,5	WP	821	
KN 19	60	1					WP	821	alluvium & sediments
KN 20	70	1	145	58,48	759,1	700,6	WP	821	alluvium & sediments
KN 20	50	1	755	26,47	725,6	699,13	WP	821	alluvium & sediments
KN 22			96				WP	821	
KN 23			183				WP	821	
KN 24			192	23,30	689,0	665,7	WP	821	sediments
KN 25	66		348				WP	821	
KN 26	50	1	558	22,62	713,4	690,8	WP	821	alluvium & sediments

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BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m (25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l.	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KN 26	60	1	370	24,81	710,4	685,6	WP	821	alluvium & sediments
KN 27	33	1	327	21,72	695,1	673,4	WP	821	alluvium & sediments
KN 29			314				WP	821	
KN 30	60	1	207	17,64	683,2	665,6	WP	821	alluvium & sediments
KN 31	30	10	221				Turb	131400	
KN 32	63	1					WP	821	alluvium & sediments
KN 33	36	1		12,20	673,8	661,6	WP	821	alluvium & sediments
KN 34							WP	821	sediments
KN 35	76	1					WP	821	alluvium & sediments
KN 36	36	1	92	27,54	865,8	838,3	WP	821	sediments
KN 37			211	47,30	817,1	769,8	WP	821	
KN 38			106				WP	821	
KN 39	53			39,88	754,6	714,6	WP	821	alluvium & sediments
KN 40	60		92	30,96	841,5	810,5	WP	821	sediments
							TOTAL:	293177 m^3	

OWNER : MR. A.G. MC NAUGHTON

CADASTRAL FARM NAME : KRUIDFONTEIN 413 LOCAL FARM NAME : BELMONT

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SUNDAYS UNIT									
KN 41	25	low	124				WP	821	Sediments, H_2S
KN 42	25	8					Turb	105120	Sediments, H_2S
KN 43	25	8					Turb	105120	Sediments, H_2S
KN 44	60	low	106	10,77	731,7	720,9	WP	821	Sediments
KN 45	45	low	97				WP	821	Sediments
							TOTAL:	212703m^3	

OWNER : MR. O.P.J. FOURIE

CADASTRAL FARM NAME : KRUIDFONTEIN 413 LOCAL FARM NAME : KRUIDFONTEIN

SUNDAYS UNIT									
KN 46	40	low	144				WP	821	Sediments
KN 47	40	low	117				WP	821	Sediments
KN 48	30	8					WP	821	Windpump
KN 49	33	21		5,63	728,7	723,1	Turb	105120	large well, water level perched
KN 50	35	8					Turb	105120	Sediments, H_2S water
KN 51	66	8		7,10	719,5	712,4	WP	821	Sediments, H_2S water
KN 52	35	13		6,92	719,5	712,6	Subm	65700	Sediments, near pit
							TOTAL:	279224m^3	

OWNER: MR. N.L. KROON

CADASTRAL FARM NAME: KRUIDFONTEIN 413 LOCAL FARM NAME: MELROSE

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
OD 1		13	148				Mono	–	not in use
OD 2	35	40					Mono	–	not in use
OD 3			85	12,57	694,5	681,9	WP	821	
OD 4	33	low	59	9,77	686,0	676,2	WP	821	sediments
OD 5		20	127				Mono	–	H_2S, sediments, not in use
OD 6		12	120				Mono	14400	H_2S, sediments
OD 7		low	75	10,42	689,0	678,6	WP	821	
OD 8							WP	–	broken
OD 9	21		148	8,08	676,8	668,7	WP	821	alluvium= 14m
OD 10	33	low		11,05	682,9	671,8	WP	–	broken, sediments
OD 11		low	60	30,56	722,6	692,0	WP	821	
OD 12		low		9,64	678,4	668,8	WP	821	
OD 13			61				WP	821	
OD 14							WP	821	
OD 15	22	low					WP	821	
OD 16	22	low					WP	821	
OD 17		3					Sub	16848	domestic supply
							TOTAL:	39458m^3	

OWNER : MR. H. STEVEN - JENNINGS

CADASTRAL FARM NAME : OUDEDRIFT A133

LOCAL FARM NAME : OUDEDRIFT

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO									
DL 1	73	19	477				Mono	65520	
DL 2		2					-	-	Collapsed
DL 3		1		6,11	664,6	658,5	-	-	very brack, near river
DL 4	45	1	1370				WP	821	very brack
DL 5	30	1					WP	821	
DL 6	45	1		20,36	676,8	656,4	WP	821	
DL 7	33	7	121	20,34	676,8	676,8	Sub	68796	
DL 8	45	2	102				WP	821	
DL 9	45	1	126	40,50	722,6	682,1	WP	821	
DL 10		1					WP	821	
DL 11	26	8	110				Mono	65520	
DL 12	60	1		23,75	689,0	665,2	-	-	
DL 13		1		17,67	676,8	659,1	-	-	
DL 14		1		15,37	667,7	652,3	-	-	
DL 15	63	12					Mono	45864	H_2S water
DL 16	45	1		30,93	716,4	685,5	WP	821	
DL 17	30	8					WP	821	
DL 18	30	4					-	-	
DL 19	45	0.1					WP	821	
							TOTAL:	253089m^3	
KAMDEBOO									
MN 1							WP	821	
MN 2							WP	821	
							TOTAL:	1642m^3	

OWNER : MR. S. STEYNBURG

CADASTRAL FARM NAME : LOUWS KLOOF 136 LOCAL FARM NAME : DAGLUMIER

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
OT 1	50	low	119				WP	821	Sediments
OT 2	90	5		33,82	768,3	734,5	WP	821	Sediments
OT 3	60	4		12,33	753,0	740,7	-	-	sandstone - soft
OT 4	90	3		11,12	753,0	741,9	-	-	sandstone - soft
OT 5	50	low					WP	821	Sediments
OT 6	50	low					WP	821	Sediments
OT 7	50	5	204				WP	821	alluvium & sediments
OT 8	50	low	80				WP	821	alluvium & sediments
OT 9	90	low					WP	821	water level dropping
OT10	50	0.5	70	8,64	780,4	771,8	WP	821	Sediments
OT11	50	low	110				WP	821	Sediments
OT12	50	low	127				WP	821	alluvium & sediments
OT13	90	15					Turb	46656	Sediments
OT14	90	6					Turb	18662	Sediments
OT15							WP	821	Sediments
OT16				12,97	753,0	740,0	WP	821	Sediments
OT17							WP	821	Sediments
OT18							WP	821	Sediments
OT19			137	11,44	753,0	741,6	WP	821	Sediments
OT20	90	3					Turb	3888	Sediments
OT21				15,40	756,1	740,7	WP	821	effected by river flow
OT22							WP	821	Sediments
OT23							WP	821	Sediments
OT24	50	low					WP	821	domestic supply, sediments
OT25	50	low		15,60	753	737,4	WP	821	Sediments
							TOTAL:	85626m^3	

OWNER : MR. T. SPENCE

CADASTRAL FARM NAME : OVERSHOT 274

LOCAL FARM NAME : BEACONSFIELD

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
RN 1	60	0.1					WP	821	Sediments
RN 2	30	low	231				WP	821	H_2S, Sediments
RN 3	45	low		8,42	725,6	717,2	WP	821	Sediments
RN 4	45	low					WP	821	Sediments
RN 5	45	low					WP	821	Sediments
RN 6	45	low	145				WP	821	Sediments
RN 7	60	60					Turb	–	broken, sediments
RN 8	60	0.2	138	15,14	739,3	724,2	WP	821	Sediments
RN 9	60	10					WP	821	Sediments
RN 10	60	low		29,99	743,9	713,9	WP	821	Sediments
							TOTAL:	7389m^3	

OWNER : MR. W.F.B. VORSTER

CADASTRAL FARM NAME : RATELSFONTEIN 329 LOCAL FARM NAME : IRENE

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
GT 1	45	0.3	71				WP	821	
GT 2	15	2.5	70				Krag	9034	
GT 3	75	0.3	156				WP	821	
GT 4	15	2.5	70	6,36	960,4	954,0	Krag	18067	
GT 5	45	2.5					Mono	26280	
							TOTAL:	$55023m^3$	

<u>OWNER</u> : MR. S. ROSE-INNES

<u>CADASTRAL FARM NAME</u> : RONDE GAT 191

<u>LOCAL FARM NAME</u> : BOTHASHOOP

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
RE 36		10		34,13	698,2	664,1	–	–	Corrosive water
RE 39		9	370				Mono	59130	
RE 40	60	3		35,86	716,5	680,6	WP	821	
REF 1	33	3							Flowing pit

TOTAL: 307142m^3

OWNER : MR. J. VAN RENSBURG

CADASTRAL FARM NAME : RYNHEATH ESTATES 417

LOCAL FARM NAME : RYNHEATH

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SUNDAYS UNIT									
SP 1	52	0.6					WP	821	dolerite
SP 2	33	0.6	63				WP	821	dolerite
SP 3	27	1	107	8,91	841,5	832,6	WP	821	dolerite
SP 4	12	low					Well	–	sandstone
SP 5	20			12,40	832,3	819,9	–	–	dolerite
SP 6	26	4					Mono	–	not in use
TH 1	90	1	131	12,28	795,7	783,4	WP	821	
SPF 1	–	3							in good years fountain ± 5ℓ/s

TOTAL: 3284m^3

OWNER : MR. VAN DER RYST

CADASTRAL FARM NAME : SPITSKOP 408

LOCAL FARM NAME : SPITSKOP

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
UT 7	70	low					WP	821	Sediments
UT 8	30	low		17,60	798,7	781,1	WP	821	Sediments
UT 9	30	low					WP	821	Sediments
UT 10	40	low		29,64	804,9	775,3	WP	821	Sediments
UT 11	30	low					WP	821	alluvium & sediments
UT 12	30	low	052	25,47	881,1	855,6	WP	821	sediments
UT 13	50	low					WP	821	sediments
UT 14	73	low							collapsed
UT 15	36						WP	821	
UT 4	50	low		44,21	868,9	824,7	WP	821	
							TOTAL:	$7389m^3$	

OWNER : MRS. W.KROON

CADASTRAL FARM NAME : UITKOMST 196

LOCAL FARM NAME : KLIPDRIFT

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SUNDAYS UNIT									
RE 1	75	0.5					–	–	Sediments
RE 2	75	0.2					–	–	Sediments
RE 3	76	0.6	128				WP	821	Sediments
RE 4	60	0.6					WP	821	Sediments, dolerite
RE 5	60	0.6	286	20,58	634,0	613,4	WP	821	Sediments, dolerite
RE 6	75	0.2					WP	821	Sediments
RE 7	90	0.6	798	10,34	632,6	622,3	WP	821	Sediments
RE 8	55	5					–	–	Collapsed, H_2S water
RE 9	55	5	52	3,33	646,3	643,0	WP	821	H_2S water, sediments
RE 10	85	0.2		8,69	646,3	637,6	WP	821	10m of calcrete
RE 11	90	0.8					WP	821	dolerite 55m to 90m
RE 12	45	0.9	173	27,41	667,7	640,3	WP	821	calcrete, sediments
RE 13	62	0.8					–	–	blocked
RE 14	62	0.2					–	–	
RE 15	62	1					WP	821	Sediments, dolerite
RE 16	60	12	277				Turb	78840	
RE 17	45	0.8	335	23,58	685,9	662,3	WP	821	dolerite, sediments
RE 18	75	1	207	24,80	707,3	682,5	WP	821	dolerite, sediments
RE 19	30	13	409				Turb	85410	dolerite, sediments
RE 20	90	1	120	19,97	689,0	669,0	WP	821	dolerite, sediments
RE 21	55	0.2	183	11,82	716,5	704,7	WP	821	Sediments
RE 22	75	0.9	129	21,80	747,0	725,2	WP	821	Sediments
RE 23	75	1	153				WP	821	Sediments, dolerite
RE 24	75	1	222	20,70	701,2	680,5	WP	821	Sediments, dolerite
RE 25	75	0.9					WP	–	broken
RE 26	60	2	163	12,40	707,3	694,9	WP	821	Sediments
RE 27	60	2	228	28,34	686,0	657,7	WP	821	dolerite, sediments
RE 28	60	2		25,48	725,6	700,1	WP	821	dolerite
RE 30			705	11,39	631,1	619,7	WP	821	
RE 29				10,32	692,1	681,8	WP	–	broken
RE 35	60	10	203				Mono	65700	H_2S

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BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
US 8	70	2	76	39,30	798,7	759,4	WP	821	Sediments
							TOTAL:	$821m^3$	
SWART UNIT									
US 1	53	7	121	12,14	788,1	776,0	WP	821	H_2S water, sediments
US 2	120	13					Turb	112320	Sediments
US 3	23	4	103	12,33	791,2	778,9	WP	821	Sediments
US 4	23	3	106	9,04	785,1	776,1	WP	821	Sediments
US 5	23	4	107	10,56	785,1	774,5	WP	821	Sediments
US 6	56	4	108				WP	821	Sediments
US 7	30	8	91	39,3	759,1	719,8	WP	821	Sediments
US 9	60	2	61				WP	821	Sediments
US 10	60	2					WP	821	Sediments
US 11	55	low	73	28,01	823,2	795,2	WP	821	Sediments
US 12	50	low		12,60	838,4	825,8	WP	821	Sediments
US 13	65						WP	821	Sediments
US 14	82	13	131				Turb	285120	Sediments
US 15	53	7					-	-	Sediments, blocked
US 16	54	0.6		14,80	798,8	775,0	WP	821	
							TOTAL:	$407292m^3$	

OWNER : MR. J.A. THERON

CADASTRAL FARM NAME : UITKOMST 314

LOCAL FARM NAME : UITKOMST

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
US 20	45	low	84	32,33	762,2	729,9	WP	821	Sediments, dolerite
							TOTAL:	$821m^3$	
SWART UNIT									
US 21	45	low	156				WP	821	Sediments
US 22	66		143				WP	821	Sediments
US 23	46	low	159				WP	821	
US 24	100	low	89	62,82	789,6	726,8	WP	821	Sediments
US 25			102	40,22	798,8	758,6	WP	821	Sediments
US 26	133			11,59	769,8	758,2	WP	821	Sediments
US 27				8,48	769,8	761,3	WP	821	Sediments
US 28	100	19	195				Turb	37800	Sediments
US 29	50						WP	821	Sediments
US 30	133	45	130				Turb	63504	Sediments, H_2S water
US 31		13					-	-	blocked
US 32		13		13,16	765,2	752,0	-	-	open
							TOTAL:	$107872m^3$	

OWNER : MR. P.A. CROUSE

LOCAL FARM NAME : UITKOMST

CADASTRAL FARM NAME : UITKOMST 314

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
MOORDENAARS UNIT									
VD 7	45	2		2,17	914,6	912,4	-	-	open
VD 8	60	low	42	16,15	914,6	898,4	WP	821	
VD 9	5	4					WP	821	fractured sandstone
VD 10	60	low					-	-	sediments
VD 11	60	19					Mono	24966	on minor fault
VD 12	45	19		2,47	1036,5	1034	-	-	sediments
VD 15	45	low		5,57	920,7	915,1	-	-	sediments
VD 16	35	2	115	23,09	984,8	961,7	WP	821	sediments
							TOTAL:	27429m^3	

OWNER : MR. M. VAN VUUREN

CADASTRAL FARM NAME : VAN DER WALTS HOEK 179

LOCAL FARM NAME : VAN DER WALTS HOEK

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
VK 1	60	low					WP	821	
VK 2	35	5	84	33,23	731,7	698,5	WP	821	dolerite at 35 m
VK 3	30	2		18,15	747,0	728,8	WP	821	
VK 4	60		66	38,65	762,2	723,5	WP	821	
VK 5	60	5		17,46	743,9	726,4	-	-	sediments
VK 6	60		59				WP	821	
VK 7	60	5		14,71	740,1	725,4	Subm	17550	sediments
VK 8	60	5		12,58	740,1	727,5	-	-	sediments
VK 9	60	15					Turb	52650	sediments
VK 10	60	12					Turb	52650	sediments
VK 11	60	5		12,48	737,8	725,3	-	-	sediments
VK 12	60	12		11,41	734,8	723,4	Mono	52650	sediments
VK 13	60	5					-	-	sediments
VK 14	60	5		11,74	784,8	723,1	-	-	sediments

TOTAL: 179605m^3

OWNER : MR. J. HARTZENBERG

CADASTRAL FARM NAME : VAN DER WALTS KLOOF 130

LOCAL FARM NAME : GRAND VIEW

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCT-IVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
VN 20	60	low	218				WP	821	sediments
VN 21	45	2.5	96	14,25	734,8	720,6	WP	821	sediments
VN 22		12					-	-	totally covered
VN 23	45	9	79	24,00	762,2	738,2	WP	821	sediments
VN 24							WP	821	sediments
VN 25	92	2.5		57,44	807,9	750,5	WP	821	decomposed dolerite, fracture
VN 26			62	18,11	798,8	780,7	WP	821	sediments
VN 27			70	34,26	810,9	776,6	WP	821	sediments
VN 28			81	16,25	753,0	736,7	WP	821	sediments
							TOTAL:	$6568m^3$	

OWNER : MR. N. KROON

CADASTRAL FARM NAME : VRIJNSFONTEIN 319

LOCAL FARM NAME : FREYNSFONTEIN

KAMDEBOO UNIT									
VS 1	40	low	162				WP	821	
VS 2	40	low	99				WP	821	
VS 3			109	21,38	707,3	685,9	WP	821	
VS 4	25		115	13,10	695,1	682,0	WP	821	
VS 5	45		120				WP	821	
VS 6	55			26,04	743,9	717,9	-	-	
VS 7	75						WP	821	
VS 8	20	low	110				WP	821	
							TOTAL:	$5747m^3$	

OWNER : MR. J. HARTZENBERG

CADASTRAL FARM NAME : VLAKPLAAS 131

LOCAL FARM NAME : GRAND VIEW, VLAKPLAAS

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
ZK 1	45	6	411	6,12	698,2	692,1	Mono	86400	sediments
ZK 2	45	19					Mono	273600	sediments
ZK 3	45	19		4,00	698,2	694,2	-	-	sediments
ZK 4	45	12					Mono	172800	sediments
ZK 5	45	19					-	-	blocked
ZK 6	45	19		1,86	695,1	693,2	-	-	in river
ZK 7	45	1		13,80	716,5	702,7	WP	821	contact zone
ZK 8	45	1		15,26	716,5	701,2	WP	821	contact zone
ZK 9	45	1		19,45	716,5	697,0	WP	821	contact zone
ZK 10	45	1		18,68	701,2	682,5	WP	821	dolerite, sediments
ZK 12	45	1	165	23,07	781,7	708,6	WP	821	contact
ZK 13	45	1	106				WP	821	contact zone
ZK 14	45	1		24,66	707,3	682,6	WP	821	contact zone
ZK 15	45	1		8,88	698,1	689,2	WP	821	
ZK 16	45	9					Turb	129600	
ZK 17	45	9					Mono	129600	slightly H_2S water
ZK 18	45	15					Turb	216000	
ZK 19	45	5					-	-	collapsed, alluvium & sediments
ZK 20	45	19	770	8,90	695,1	686,1	WP	821	
ZK 21	45	1		6,28	698,2	691,9	WP	821	
ZK 22	45	15	889				Mono	180000	
ZK 23	45	6					-	-	used to be equiped with Mono
ZK 25	55	5					-	-	sediments
ZK 26	45	15		9,16	698,2	689,0	-	-	contact zone
ZK 27	45	18		1,00	682,9	681,9	-	-	in river
ZK 28	45	18					-	-	in stream
ZK 29	45	19		8,69	695,1	686,4	Mono	144000	recently cleaned
ZK 31	45	6					Mono	86400	recently cleaned
ZK 33	45	1	812	7,58	692,1	684,5	WP	821	
ZK 80	45			6,10	695,1	689,0	-	-	dolerite at 27m
							TOTAL: 1,427431m^3		

OWNER : MR. A.J. FEATHERSTONE

CADASTRAL FARM NAME : ZEEKOEIGAT 140D

LOCAL FARM NAME : ZEEKOEIGAT

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
KAMDEBOO UNIT									
ZK 40	45	10	175				Mono	118260	sediments, contact zone
ZK 41	45	15					Turb	118260	sediments, contact zone
ZK 42	45	18	330				Turb	164250	sediments
ZK 43	45	18	374				Turb	164250	sediments, H_2S water
ZK 44	35	0.5	469	3,24	707,3	704,1	WP	821	sediments
ZK 45	35	0.5	172	13,70	716,5	702,8	WP	821	sediments
ZK 46	35	0.5	202				WP	821	sediments
ZK 47	55	18	173				Turb	118260	
ZK 48	55	23					Turb	118260	sediments, contact zone
ZK 49	35	1.5		7,16	719,5	712,3	WP	821	sediments, contact zone
ZK 50	35	1.5					WP	821	sediments, contact zone
ZK 51	55	14	311				Turb	118260	sediments
ZK 52	55	10	132				Turb	78840	sediments
ZK 53	30	0.5	575				WP	821	sediments
ZK 54	30	0.5	477	9,86	695,1	685,2	WP	821	sediments
ZK 55	30	0.5	544	12,29	692,1	679,8	WP	821	sediments
ZK 56	30	0.5	403				WP	821	sediments
ZK 57	55	10		10,33	710,4	699,6	–	–	sediemnts
ZK 58	55	10	154	10,54	710,4	699,9	–	–	sediments
ZK 59	50	2					Mono	32850	sediments
ZK 60	60	2					Mono	32850	sediments
ZK 61	60	4					Mono	52560	sediments
ZK 62	60	4					Mono	52560	sediments
TN 9							WP	821	
TN 10	55	19		10,46	707,3	696,8	Mono	78840	sediments, contact zone
TN 11	55	12					Turb	78840	sediments, contact zone
TN 12	55	14	244				Turb	78840	sediments, contact zone
TN 13	55	18	244				Turb	164250	sediments, contact zone
							TOTAL:	1578440	

OWNER : MR. J.D. VAN DER MERWE

CADASTRAL FARM NAME : ZEEKOEIGAT 140D

LOCAL FARM NAME : ZEEKOEIGAT

BOREHOLE NO.	BOREHOLE DEPTH(m)	YIELD ℓ/s	WATER CONDUCTIVITY mS/m(25°)	WATERLEVEL BELOW COLLAR (m)	COLLAR ELEVATION (m) a.m.s.l	ABSOLUTE WATERLEVEL ELEVATION (m) a.m.s.l	TYPE OF EQUIPMENT	ANNUAL ABSTRACTION (m^3)	REMARKS
SUNDAYS UNIT									
ZF 2	35	2					-	-	blocked
ZF 3	30	6	167	10,10	652,4	642,3	WP	821	sediments, H_2S
ZF 4	35	4					-	-	blocked
ZF 5	30	1	171				WP	821	sediments
ZF 6	60	10	307				Turb	131400	sediments
ZF 8	45	2	173				WP	821	sediments
ZF 9	40	12					Sub	86400	sediments
ZF 10	45	12		15,04	649,4	634,4	Sub	86400	sediments
ZF 11	60	9					-	-	sediments, blocked
ZF 12	30	2	123				WP	821	sediments
ZF 13							-	-	collapsed
ZF 14	30	0.1		21,19	678,4	657,2	WP	821	sediments
ZF 15	30	2	132	32,55	704,3	671,7	WP	821	sediments
ZF 16	30	1	98	13,59	676,9	663,3	WP	821	dyle contact
ZF 17	30	2		20,62	692,0	671,4	WP	821	sediments
ZF 18	35	1	131				WP	821	sediments
ZF 19	30	1	137	24,20	676,8	652,6	WP	821	sediments
ZF 20	30			16,01	667,7	651,7	WP	821	sediments
ZF 21	30	2	168				WP	821	sediments
ZF 22	38	2	276	23,13	646,3	623,2	WP	821	sediments
ZF 23			162				WP	821	sediments
							TOTAL:	315694m^3	

OWNER : MR. R.H. VAN DEN BERG

CADASTRAL FARM NAME : ZEVENFONTEIN 440

LOCAL FARM NAME : CHARLWOOD

Appendix 1B

Land and water usage questionaire

LIST OF FARM UNITS COVERED BY THE LAND AND WATER USE SUREVEY

CADASTRAL	LOCAL
CONRNDALE 333	Corndale
DE VREDE 286	Vrede
DOORDRIFT 323	Brooklyn
FERTILITY 315	Uitkomst
GRASRAND 334	Grasrand
	Erica
	Mimmosadale
GROOTE VLAKTE 132	Grootvlakte
HONINGNEST KRANTZ 277	Honing Kranz
KLIPDRIFT 426	Kransplaas
	Mooifontein
KRUGERS KRAAL 322	Kriegerskraal
LOUWS KLOOF 136	Daglumier
OUDEDRIFT A133	Oudedrift
OVERSHOTT 274	Beaconsfield
RATELSFONTEIN 329	Irene
UITKOMST 314	Uitkomst
	Uitkomst
VAN DER WALTS KLOOF 130	Grand View
ZEEKOEIGAT 140D	Zeekoeigat

LAND AND WATER USE QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

CORNDALE	333	CORNDALE

2. District

GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

MNR. W F B VORSTER		
BOX 271 GRAAFF-REINET	0491	23012

4. Drainage region & number

1313

5. Size of Farm unit

2150 ha

6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?

45 ha

7. Additional area that could be brought under cultivation?

ha

8. What is the average total area which is irrigated at least once a year ?

12 ha

9. What is the balance (area which is not irrigated in an average year) ?

33 ha

10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
			X		

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

Commenced (about) 1900 year
Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
X		

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?

one site, gravity

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	m^3	4	m^3
2	m^3	5	m^3
3	m^3	6	m^3

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?

m^3/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?

______ every ______ years
______ days/weeks/months/years All year round - Springflow

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual
		X

basis 47313 m^3

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES	X	NO	
YES	X	NO	

Name of organization ______

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
	X			

YES		NO	X

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

m^3/year

Groundwater 41689 m^3/yr Springflow 187 955 m^3/yr

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS						ℓ/s ℓ/s ℓ/s
Abstraction hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m^3/y (x106)
Waterlevels onset end							m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate - ℓ/s		total flow - m^3
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily			Seasonal			Longterm	
4/5	3/4	2/3	1/2	1/3	1/4	1/5	1/10
							X

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
		X				

change/variation in quality

YES		NO	

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

YES	X	NO	

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)
	Lucerne	all year	12	60	42
Permanent crops					
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		x		x		

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

Pipes	Earthen canals	Lined canals	Combination
	x		

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		x						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
		x						

33. Does any salinity or alkalinity occur in the soil ?

Salinity	YES	
	NO	

Alkalinity	YES	x
	NO	

pH = 8.1

34. How often is gypsum or lime applied on the lands ?

Once every 4 XXXXX/year(s)

35. What fertilizers are regularly used ?

gypsum

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

± 10m metres

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

Seasonally	YES	
	NO	x

metres

Longterm	YES	
	NO	x

metres

38. Any remarks ?

intends drilling in near future so that lands can be extended

39. Date 22.04.85

40. Official

Name R PARSONS

LAND AND WATER USE QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

DE VREDE	286	VREDE

2. District

GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mr. J.A. Biggs		
Box 34 GRAAFF-REINET	0491	22009

4. Drainage region & number — 1313
5. Size of Farm unit — 5400 ha
6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)? — 400 ha
7. Additional area that could be brought under cultivation? — 50 ha
8. What is the average total area which is irrigated at least once a year ? — 350 ha
9. What is the balance (area which is not irrigated in an average year) ? — 50 ha
10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

Commenced (about) 1920 year
Expanded (about) 1970 year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

Use groundwater when limited surface water available

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?

6 sites, gravity

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
X		

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	998 000	m³	4		m³
2	Total of 7 dams	m³	5		m³
3		m³	6		m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?

don't know m³/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?

once every 2 years
6 ~~xxxx~~/months/~~xxxx~~

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual

basis m³

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	X
YES		NO	X

Name of organization

22. What is the quality of the surface water and has the overall quality changed over the years ?

22.

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES		NO	X

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. 779 674 m^3/year m^3/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

24.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m^3/y (x106)
Waterlevels onset end							 m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

25.

Spring	flowrate - ℓ/s		total flow - m^3
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

26.

Daily	Seasonal	Longterm
	X	

4/5	3/4	2/3	1/2	1/3	1/4	1/5	
					X		

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
				X		

change/variation in quality

YES		NO	X

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28.

YES		NO	X

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each the crops and (d) the average monthly irrigation field application

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)
	Lucerne	summer	1	100	50
Permanent crops					
Seasonal or cash crops	Wheat	winter			35
	Fruit	all year			35

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

Surface - Groundwater

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X		X		

31.

Pipes	Earthen canals	Lined canals	Combination
			X

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
			X					

33.

Salinity	YES	
	NO	

Alkalinity	YES	X
	NO	

7.2 to 8.0

34. Once every 10 ~~xxxxxx~~/year(s) ± 5-10 per hectare

35.

36. metres

37.

Seasonally	YES	X
	NO	

5 metres

Longterm	YES	
	NO	X

metres

38.

39. Date 02/07/85

40. Name R. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

DOORDRIFT	323	BROOKLYN

2. District

GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mnr. D.W. Herold		
	0491	23063

4. Drainage region & number

1313

5. Size of Farm unit

5000 ha ha

6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?

150 ha ha

7. Additional area that could be brought under cultivation?

ha

8. What is the average total area which is irrigated at least once a year ?

100 ha ha

9. What is the balance (area which is not irrigated in an average year) ?

50 ha ha

10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
					X

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

Commenced (about) 1900 year
Expanded (about) 1985 year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

use groundwater when no surface water

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?

one site, gravity

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	m^3	4	m^3
2	m^3	5	m^3
3	m^3	6	m^3

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?

don't know m^3/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?

once every five years
? days/weeks/months/years

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual

basis m^3

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	X
YES		NO	X

Name of organization

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C

YES		NO	X

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

525971 m^3/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

Borehole no.							
Tested yield	SEE HYDROCENSUS DATA						ℓ/s
Pumped yield							ℓ/s
Measured yield							ℓ/s
Abstraction							
hours/day							
days/week							
weeks/year							
months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m^3/y (x106)
Waterlevels							
onset							m
end							m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate - ℓ/s		total flow - m^3
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily	Seasonal	Longterm

4/5	3/4	2/3	1/2	1/3	1/4	1/5	

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
		X				

change/variation in quality

YES		NO	

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

YES	X	NO	

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)
	pasture	all year	70		65
Permanent crops	lucerne	all year	30		65
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X		X		

31.

Pipes	Earthen canals	Lined canals	Combination
X	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
		X						

33.

Salinity	YES	
	NO	X

Alkalinity	YES	
	NO	X

34. Once every months/year(s) NEVER

35.

36. ± 10m metres

37.

Seasonally	YES	
	NO	

don't know metres

Longterm	YES	
	NO	

don't know metres

38.

39. Date 23/4/85

40. Name R. PARSONS

LAND AND WATER USE QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name — FERTILITY | 315 | UITKOMST
2. District — GRAAFF-REINET
3. Proprietor - Postal address - Telephone Code & Number — Mr. J.A. Haarhoff, Posbus 115, Graaff-Reinet | 0491 | 23010
4. Drainage region & number — 1313
5. Size of Farm unit — 2465 ha
6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)? — 86 ha
7. Additional area that could be brought under cultivation? — – ha
8. What is the average total area which is irrigated at least once a year? — 86 ha
9. What is the balance (area which is not irrigated in an average year)? — – ha
10. For what reason(s) is the balance not irrigated?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm? — Commenced (about) 1940 year; Expanded (about) ____ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...)? — use groundwater when surface water not available
14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping? — several sites, gravity
15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
X		

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	123400 m³		4	m³
2	m³		5	m³
3	m³		6	m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum? — don't know m³/year
19. If surface water is available on an irregular basis, what is the frequency and average duration of availability? — ____ every ____ years; ____ days/weeks/months/years — Dams last for 6 months when full
20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted? — Springflow contributes on a

daily	seasonal	annual

basis ____ m³

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board)?

YES		NO	X
YES		NO	X

Name of organization ____________

22. What is the quality of the surface water and has the overall quality changed over the years ?

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

22.

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES		NO	X

23. 135778 m³/year m³/year

24.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x106)
Waterlevels onset end							m m

25.

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1	2 ℓ 5 -1		63072
2			
3			
4			

26.

	Daily			Seasonal			Longterm
No	4/5	3/4	2/3	1/2	1/3	1/4	1/5

of average original rate/yield

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
			X			

change/variation in quality YES [ ] NO [X]

28. YES [X] NO [ ]

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)
Permanent crops	lucern	all year	35		150
	maize	all year	16		38
	oats	all year	35		25
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X		X		

31.

Pipes	Earthen canals	Lined canals	Combination
	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other
		X					

SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
			X					

33.

Salinity	YES	
	NO	X

Alkalinity	YES	
	NO	X

34. Once every months/year(s)

35. Does'nt use fertilizer

36. 30 m metres

37.

Seasonally	YES	7 m
	NO	

metres

Longterm	YES	
	NO	

metres

38. Yields of hydrocensus data not reliable

39. Date 23/04/85

40. Name R. PARSONS

LAND AND WATER USE

QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name — GRASRAND | 334 | GRASRAND
2. District — GRAAFF-REINET
3. Proprietor - Postal address - Telephone Code & Number — Mr. K. Venter, Box 130, Graaff-Reinet | 0491 | 22207
4. Drainage region & number — 1313
5. Size of Farm unit — 970 ha
6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)? — 85 ha
7. Additional area that could be brought under cultivation? — ha
8. What is the average total area which is irrigated at least once a year? — 10 ha
9. What is the balance (area which is not irrigated in an average year)? — 75 ha
10. For what reason(s) is the balance not irrigated?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm? — Commenced (about) 1812 year; Expanded (about) 1975 year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...)? — use both conjuntively all the time
14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping? — one sit, gravity
15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage?

daily	seasonal	annual	other

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	m³	4	m³
2	m³	5	m³
3	m³	6	m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum? — m³/year
19. If surface water is available on an irregular basis, what is the frequency and average duration of availability? — every ___ years (days/weeks/months/years) All year round - Springflow
20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted? — Springflow contributes on a

daily	seasonal	annual

basis m³ — 30111 m³/year

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board)?

YES	X	NO	
YES	X	NO	

Name of organization ______

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
	X			

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

YES [ ] NO [X]

178365 m³/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction							
hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x106)
Waterlevels							
onset end							m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily	Seasonal	Longterm
	X	

with draught

4/5	3/4	2/3	1/2	1/3	1/4	1/5	
	X						

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
		X				

change/variation in quality YES [ ] NO [X]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

YES [ ] NO [X]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)
	lucern	all year	12		
Permanent crops					
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X				

31.

Pipes	Earthen canals	Lined canals	Combination
	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other

33.

Salinity	YES	
	NO	

Alkalinity	YES	X
	NO	

34. Once every three ~~months~~/year(s)

35.

36. 10m metres

37.

Seasonally	YES	X
	NO	

1 metres

Longterm	YES	
	NO	

metres

38.

39. Date 23/04/85

40. Name R.P. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

GRASRAND	334	ERIKA

2. District — GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mnr. C.J. van den Berg		
Box 439 Graaff-Reinet	0491	23021

4. Drainage region & number — 1313
5. Size of Farm unit — 978 ha
6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)? — 7 ha
7. Additional area that could be brought under cultivation? — ha
8. What is the average total area which is irrigated at least once a year ? — 7 ha
9. What is the balance (area which is not irrigated in an average year) ? — ha
10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

Commenced (about) 1850 year
Expanded (about) 1963 year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
X		

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ? — one site, gravity

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	m^3	4		m^3
2	m^3	5		m^3
3	m^3	6		m^3

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ? — m^3/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ? — every ____ years, days/weeks/months/years — All year round - Springflow

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual

basis

30111 m^3/year

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES	X	NO	
YES	X	NO	

Name of organization ______

22. What is the quality of the surface water and has the overall quality changed over the years ?

22.

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
	X			

YES [ ] NO [X]

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. 1642 m³/year m³/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

24.

SEE HYDROCENSUS DATA

Borehole no.							
Tested yield							ℓ/s
Pumped yield							ℓ/s
Measured yield							ℓ/s
Abstraction							
hours/day							
days/week							
weeks/year							
months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x106)
Waterlevels							
onset							m
end							m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

25.

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

26.

Daily	Seasonal	Longterm
	X	

4/5	3/4	2/3	1/2	1/3	1/4	1/5	
				X			

winter

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
	X					

change/variation in quality YES [ ] NO [X]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28. YES [ ] NO [X]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)
	lucern	all year	3		
	citrus	all year	4		
Permanent crops					
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X				

31.

Pipes	Earthen canals	Lined canals	Combination
	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
			X					

33.

Salinity	YES	X
	NO	

Alkalinity	YES	
	NO	

34. Once every 6 months/year(s)

35. gypoum

36. 10m metres

37.

Seasonally	YES	X
	NO	

metres

Longterm	YES	
	NO	X

metres

38. drought is effecting springflow, to get turbine working soon.

39. Date 22/04/85

40. Name R.P. PARSONS

LAND AND WATER USE

QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name
   - GRASRAND | 334 | MIMOSADALE
2. District
   - GRAAFF-REINET
3. Proprietor - Postal address - Telephone Code & Number
   - Mr. D.C. Conradie
   - Box 10 Graaff-Reinet | | 23013
4. Drainage region & number
   - 1313
5. Size of Farm unit
   - 1970ha ha
6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?
   - 25ha ha
7. Additional area that could be brought under cultivation?
   - 15ha ha
8. What is the average total area which is irrigated at least once a year ?
   - 10ha ha
9. What is the balance (area which is not irrigated in an average year) ?
   - 15ha ha
10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?
   - Commenced (about) 1935 year
   - Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?
   - after rains - flood, pump groundwater when dams are empty
14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?
   - several, gravity
15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
X			

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
		X

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	3 earth dams-size not known	m³	4		m³
2		m³	5		m³
3		m³	6		m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?
   - don't know m³/year
19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?
   - ______ every ______ years when it rains
   - days/weeks/months/years
20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?
   - Springflow contributes on a basis ______ m³

daily	seasonal	annual

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	X
YES		NO	X

Name of organization ______

22. What is the quality of the surface water and has the overall quality changed over the years ?

22.

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES | NO X

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. m^3/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

24.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m^3/y (x106)
Waterlevels onset end							m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

25.

Spring	flowrate - ℓ/s		total flow - m^3
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

26.

Daily		Seasonal			Longterm		
4/5	3/4	2/3	1/2	1/3	1/4	1/5	no

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
		X				

change/variation in quality YES | NO

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28. YES x | NO

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)	
	lucern	all year	4	25		flood
Permanent crops	oats	all year	6	10		spray
Seasonal or cash crops						

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X		X		

31.

Pipes	Earthen canals	Lined canals	Combination
X			

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
		X						

33.

Salinity	YES	X
	NO	

Alkalinity	YES	
	NO	

34. Once every 6 months/~~year(s)~~

35.

36. ±10m metres

37.

Seasonally	YES	
	NO	X
		metres

Longterm	YES	
	NO	X
		metres

38.

39. Date 23/04/85

40. Name R. PARSONS

LAND AND WATER USE QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1.	Cadastral Farm name and number - Local Farm name	1.	GROOTVLAKTE | 132 | GROOTVLAKTE
2.	District	2.	ABERDEEN
3.	Proprietor - Postal address - Telephone Code & Number	3.	Mr. C. Dorfling Grootvlakte Aberdeen | Aberdeen | 2703
4.	Drainage region & number	4.	1314
5.	Size of Farm unit	5.	2400ha ha
6.	Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?	6.	250ha ha
7.	Additional area that could be brought under cultivation?	7.	– ha
8.	What is the average total area which is irrigated at least once a year ?	8.	50ha ha
9.	What is the balance (area which is not irrigated in an average year) ?	9.	200ha ha
10.	For what reason(s) is the balance not irrigated ?	10.	see table below
11.	At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?	11.	Commenced (about) 1800 year Expanded (about) 1985 year

10.

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				X

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
		X

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

13. previous owner also used surface water

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?

14.

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
X		

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	128535	m³	4		m³
2		m³	5		m³
3		m³	6		m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?

18. don't know m³/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?

19. every years / days/weeks/months/years — when it rains

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

20. Springflow contributes on a

daily	seasonal	annual

basis

m³ — 78840 m³/year

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	X
YES		NO	X

Name of organization ____________

22. What is the quality of the surface water and has the overall quality changed over the years ?

22.

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
X				

YES [ ] NO [ ]

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. m^3/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

24.

Borehole no.							
Tested yield							ℓ/s
Pumped yield			SEE HYDROCENSUS DATA				ℓ/s
Measured yield							ℓ/s
Abstraction							
hours/day							
days/week							
weeks/year							
months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m^3/y (x106)
Waterlevels							
onset							m
end							m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

25.

Spring	flowrate - ℓ/s		total flow - m^3
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

26.

Daily	Seasonal	Longterm
	X	

4/5	3/4	2/3	1/2	1/3	1/4	1/5	
						X	

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
		X				

change/variation in quality YES [ ] NO [X]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28. YES [x] NO [ ]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)
Permanent crops	lucerne	all year	34	63	
	oats	all year	16	30	
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X				

31.

Pipes	Earthen canals	Lined canals	Combination
	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
		X						

33.

Salinity	YES	
	NO	X

Alkalinity	YES	?
	NO	

34. Once every months/year(s)

35. never

36. 5 to 10m metres

37.

Seasonally	YES	X
	NO	

1/2 metres

Longterm	YES	
	NO	

metres

38.

39. Date 24/05/85

40. Name R. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1.	Cadastral Farm name and number - Local Farm name	1.	HONINGNEST KRANTZ | 277 | HONING KRANZ
2.	District	2.	GRAAFF-REINET
3.	Proprietor - Postal address - Telephone Code & Number	3.	Mr. R. Biggs, Box 495, Graaff-Reinet | 0491 | 23014
4.	Drainage region & number	4.	1313
5.	Size of Farm unit	5.	3560 ha
6.	Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?	6.	3 ha
7.	Additional area that could be brought under cultivation?	7.	ha
8.	What is the average total area which is irrigated at least once a year ?	8.	3 ha
9.	What is the balance (area which is not irrigated in an average year) ?	9.	ha

10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

Commenced (about) ______ year
Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

use groundwater when surface water not available

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
X		

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	121457 m³ m³	4	m³
2	m³	5	m³
3	m³	6	m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?

was last full in 1974 m³/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?

______ every ______ years
days/weeks/months/years

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual

basis ______ m³

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	X
YES		NO	X

Name of organization ______

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES [ ] NO [X]

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

m³/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x106)
Waterlevels onset end							m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate – ℓ/s		total flow – m³
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily	Seasonal X	Longterm	borehole on hills

4/5	3/4	2/3	1/2	1/3	1/4	1/5	
					X		

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
			X			

change/variation in quality YES [ ] NO [ ]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

YES [ ] NO [X]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)
	lucerne	all year.	3		
Permanent crops					
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X				

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

Pipes	Earthen canals	Lined canals	Combination
	X		

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
	X	X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other

33. Does any salinity or alkalinity occur in the soil ?

Salinity		
	YES	X
	NO	

Alkalinity		
	YES	
	NO	X

34. How often is gypsum or lime applied on the lands ?

Once every months/year(s)

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

metres

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

Seasonally		
	YES	X
	NO	

5 metres

Longterm		
	YES	
	NO	

metres

38. Any remarks ?

39. Date 24/04/85

40. Official — Name R. PARSONS

LAND AND WATER USE QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

KLIPDRIFT	426	KRANSPLAAS

2. District — GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mr. C.B. Enslin		
Box 384		
Graaff-Reinet	0491	23051

4. Drainage region & number — 1313

5. Size of Farm unit — 4440 ha

6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)? — 500 ha

7. Additional area that could be brought under cultivation? — 400 ha

8. What is the average total area which is irrigated at least once a year ? — 100 ha ha

9. What is the balance (area which is not irrigated in an average year) ? — 400 ha ha

10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?
Commenced (about) 1850 year
Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ? — use groundwater when surface water not available

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ? — 2 sites, gravity

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
	X	

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	100 000m³	m³	4		m³
2	1 780m³	m³	5		m³
3		m³	6		m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ? — don't know m³/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ? — ______ every ______ years; ______ days/weeks/months/years — one leading turn over last 3 years

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual
	X	

basis — 31536m m³

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES	X	NO	
YES	X	NO	

Name of organization: Van Ryneveldspas Dam Irrigation Board

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES [ ] NO [ ] don't know

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. m³/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

24.

Borehole no.							
Tested yield							ℓ/s
Pumped yield		SEE HYDROCENSUS DATA					ℓ/s
Measured yield							ℓ/s
Abstraction							
hours/day							
days/week							
weeks/year							
months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x106)
Waterlevels							
onset							m
end							m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

25.

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

26.

Daily			Seasonal				Longterm
4/5	3/4	2/3	1/2	1/3	1/4	1/5	no

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
	X					

change/variation in quality YES [ ] NO [ ]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28. YES [ ] NO [X]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)
Permanent crops	lucerne	summer	80		
	oats	winter	20		
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X				

31.

Pipes	Earthen canals	Lined canals	Combination
	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X	X					
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
		X						

33.

Salinity	YES	
	NO	

Alkalinity	YES	X
	NO	

8.5

34. Once every 1 xxxxxx/year(s)

35. ammonium sulphate, phosphotes

36. 15 to 20m metres

37.

Seasonally	YES	
	NO	X

metres

Longterm	YES	
	NO	X

metres

38.

39. Date 24/04/85

40. Name R.P. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

KLIPDRIFT	426	MOOIFONTEIN

2. District

GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mr. J. Kroon		
Box 258 Graaff-Reinet	Kendrew	513

4. Drainage region & number

1314

5. Size of Farm unit

4500 ha

6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?

450 ha

7. Additional area that could be brought under cultivation?

2000 ha

8. What is the average total area which is irrigated at least once a year ?

150 ha

9. What is the balance (area which is not irrigated in an average year) ?

300 ha

10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

Commenced (about) 1926 year
Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

use groundwater when no loading turns

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?

one site gravity

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	m³	4	m³
2	m³	5	m³
3	m³	6	m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?

don't know m³/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?

______ every ______ years
______ days/weeks/months/years

In last five years only 9 leading turns

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual

basis ______ m³

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	
YES		NO	

Name of organization ______

as previous Board

22. What is the quality of the surface water and has the overall quality changed over the years ?

22.

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. YES [ ] NO [X] m³/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

24.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x106)
Waterlevels onset end							m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

25.

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

26. Daily | Seasonal | Longterm

4/5	3/4	2/3	1/2	1/3	1/4	1/5	no

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
	x					x

change/variation in quality YES [ ] NO [ ]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28. YES [ ] NO [x]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)
Permanent crops	lucerne		60	150	
	wheat		90	80	
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X		X		

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

Pipes	Earthen canals	Lined canals	Combination
X	X		

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other
		X		X			

SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
			X					

33. Does any salinity or alkalinity occur in the soil ?

Salinity		
	YES	X
	NO	

Alkalinity		
	YES	X
	NO	

34. How often is gypsum or lime applied on the lands ?

Once every 5 XXXXXX/year(s)

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

10 to 15 m metres

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

Seasonally		
	YES	
	NO	X

metres

Longterm		
	YES	
	NO	X

metres

38. Any remarks ?

39. Date 25/04/85

40. Official / Name R.P. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

KRUGERS KRAAL	322	KRIEGERSKRAAL

2. District — GRAAFF-REINET
3. Proprietor - Postal address - Telephone Code & Number

Mr. G.O. Spence		
Box 142 Graaff-Reinet	0491	23027

4. Drainage region & number — 1313/1314
5. Size of Farm unit — 3300ha ha
6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)? — 800ha ha
7. Additional area that could be brought under cultivation? — ha
8. What is the average total area which is irrigated at least once a year ? — 50ha ha
9. What is the balance (area which is not irrigated in an average year) ? — 750 ha
10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

    Commenced (about) 1950 year
    Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ? — use groundwater when surface water not available
14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ? — one site, pumping
15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	750 000	m^3	4		m^3
2	75 000	m^3	5		m^3
3		m^3	6		m^3

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ? — don't know m^3/year
19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ? — ______ every ______ years — days/weeks/months/years — once every five years
20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

    Springflow contributes on a

daily	seasonal	annual

    basis m^3

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	X
YES		NO	X

    Name of organization ______

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES [ ] NO [X]

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

m³/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

Borehole no.							
Tested yield	SEE HYDROCENSUS DATA						ℓ/s
Pumped yield							ℓ/s
Measured yield							ℓ/s
Abstraction							
hours/day							
days/week							
weeks/year							
months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x106)
Waterlevels							
onset							m
end							m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily			Seasonal				Longterm
				X			
4/5	3/4	2/3	1/2	1/3	1/4	1/5	

effected by dam levels

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
			X			

change/variation in quality YES [ ] NO [X]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

YES [X] NO [ ]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)
	lucerne	all year	50		85
Permanent crops					
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X		X		

31.

Pipes	Earthen canals	Lined canals	Combination
X	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other
		X	X				

SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other

33.

Salinity		
	YES	
	NO	X

Alkalinity		
	YES	X
	NO	

8.6

34. Once every 0 months/year(s)

35.

36. metres

37.

Seasonally		
	YES	X
	NO	

metres

Longterm		
	YES	
	NO	X

metres

38. use KK 21 and KK24 only in drought

39. Date 8/5/85

40. Name R.P. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

LOUWS KLOOF	136	DAGLUIMER

2. District

GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mr. S. Steynbrg		
Box Aberdeen	Aberdeen	2712

4. Drainage region & number

1314

5. Size of Farm unit

2457 ha ha

6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?

50 ha ha

7. Additional area that could be brought under cultivation?

ha

8. What is the average total area which is irrigated at least once a year ?

20 ha ha

9. What is the balance (area which is not irrigated in an average year) ?

30 ha ha

10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	x				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

Commenced (about) 1900 year
Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	x	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

use groundwater when surface water not available

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?

several, gravity & pumping

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
	x		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

4 small earth dams

1		m^3	4		m^3
2		m^3	5		m^3
3		m^3	6		m^3

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?

don't know m^3/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?

1 every 2 years
days/weeks/months/years

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual

basis m^3

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES			NO	x
YES			NO	x

Name of organization ______

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
	X			

YES		NO	X

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. m^3/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m^3/y (x106)
Waterlevels onset end							m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate - ℓ/s		total flow - m^3
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily	Seasonal	Longterm
X	X	

DL 1, DL 11

4/5	3/4	2/3	1/2	1/3	1/4	1/5	
X	X						

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
		X				

change/variation in quality

YES		NO	X

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

YES		NO	X

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)
Permanent crops	lucerne	all year	10		
	oats		10		
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X		X		

31.

Pipes	Earthen canals	Lined canals	Combination
X	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
				X				
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other

33.

Salinity	YES	X
	NO	

Alkalinity	YES	X
	NO	

34. Once every 5 XXXXX/year(s)

35. ammonium sulphate (300kg/ha)

36. metres

37.

Seasonally	YES	
	NO	X

metres

Longterm	YES	
	NO	X

metres

38.

39. Date 25/4/85

40. Name R.P. PARSONS

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
	x	x		

YES [ ] don't know NO [ ]

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

m³/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

SEE HYDROCENSUS DATA

Borehole no.								
Tested yield								ℓ/s
Pumped yield								ℓ/s
Measured yield								ℓ/s
Abstraction								
hours/day								
days/week								
weeks/year								
months/year								
TDS (@ 25°C)								mg/ℓ
Total abstraction								m³/y (x106)
Waterlevels								
onset								m
end								m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily				Seasonal			Longterm
4/5	3/4	2/3	1/2	1/3	1/4	1/5	

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
	X	X				x

change/variation in quality YES [ ] NO [ ]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

YES [x] NO [ ]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)
Permanent crops	lucerne		5		320
	Italian rye		15		320
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X				

31.

Pipes	Earthen canals	Lined canals	Combination
	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
	X	X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other

33.

Salinity	YES	
	NO	X

Alkalinity	YES	X
	NO	

8.0 to 8.5

34. Once every 6 months/yxxxxxx

35.

36. 5 – 10m metres

37.

Seasonally	YES	X
	NO	

1 metres

Longterm	YES	
	NO	X

metres

38.

39. Date 24/4/85

40. Name R.P. PARSONS

LAND AND WATER USE

QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

OVERSHOTT	274	BEACONSFIELD

2. District — GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mr. T. Spence		
Box 135		
Graaff-Reinet	0491	23011

4. Drainage region & number — 1313
5. Size of Farm unit — 3967ha ha
6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)? — ha
7. Additional area that could be brought under cultivation? — ha
8. What is the average total area which is irrigated at least once a year ? — 8 ha ha
9. What is the balance (area which is not irrigated in an average year) ? — ha
10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

Commenced (about) 1940 year
Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ? — irragate 3 ha with groundwater, 5 ha with surface water

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ? — surface dams

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	don't know	m^3	4		m^3
2		m^3	5		m^3
3		m^3	6		m^3

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ? — m^3/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ? — ______ every ______ years; ______ days/weeks/months/years — don't know

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual

basis ______ m^3

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	X
YES		NO	X

Name of organization ______

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

YES [ ] NO [X]

m^3/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

Borehole no.							
Tested yield							ℓ/s
Pumped yield							ℓ/s
Measured yield							ℓ/s
Abstraction							
hours/day							
days/week							
weeks/year							
months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m^3/y (x106)
Waterlevels							
onset							m
end							m

SEE HYDROCENSUS DATA.

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate - ℓ/s		total flow - m^3
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily			Seasonal				Longterm
4/5	3/4	2/3	1/2	1/3	1/4	1/5	no

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
			X			

change/variation in quality YES [ ] NO [X]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

YES [X] NO [ ]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)
	lucerne	all year	3		
Permanent crops	oats	winter	5		
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X				

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

Pipes	Earthen canals	Lined canals	Combination
		X	

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other

33. Does any salinity or alkalinity occur in the soil ?

Salinity		
	YES	X
	NO	

Alkalinity		
	YES	X
	NO	

34. How often is gypsum or lime applied on the lands ?

Once every 1 ~~month(s)~~/year(~~s~~)

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

12-15m metres

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

Seasonally		
	YES	X
	NO	

Longterm		
	YES	
	NO	X

1 to 10 metres with drought metres

38. Any remarks ?

39. Date 24/4/85

40. Official

Name R.P. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name
   1. | UITKOMST | 314 | UITKOMST |
   |---|---|---|

2. District
   2. GRAAFF-REINET
3. Proprietor - Postal address - Telephone Code & Number
   3. Mr. J.A. Theron
   Box 149
   Graaff-Reinet | | 23019
4. Drainage region & number
   4. 1313
5. Size of Farm unit
   5. 3600 ha ha
6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?
   6. 40 ha ha
7. Additional area that could be brought under cultivation?
   7. 80 ha ha
8. What is the average total area which is irrigated at least once a year ?
   8. 40 ha ha
9. What is the balance (area which is not irrigated in an average year) ?
   9. 80 ha ha
10. For what reason(s) is the balance not irrigated ?

10.

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?
   11. Commenced (about) 1900 year
   Expanded (about) 1953 year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

12.

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?
   13. use groundwater only when river flows
14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?
   14. gravity, one site
15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

15.

daily	seasonal	annual	other

16. Are the reservoirs used for the storage of surface water or ground water or for both?

16.

Surface water	Surface & Ground water	Groundwater

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

17.

1		m^3	4		m^3
2		m^3	5		m^3
3		m^3	6		m^3

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?
   18. ? m^3/year
19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?
   19. don't know every years
   days/weeks/months/years
20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

20. Springflow contributes on a

daily	seasonal	annual

basis 39420 m^3/year

2 springs at 500 g/hr

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

21.

YES		NO	X
YES		NO	X

Name of organization ____________

22. What is the quality of the surface water and has the overall quality changed over the years ?

22.

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES | | NO | X

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. m³/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

24.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x10⁶)
Waterlevels onset end							m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

25.

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

26.

Daily			Seasonal				Longterm
4/5	3/4	2/3	1/2	1/3	1/4	1/5	

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
		X				

change/variation in quality YES | | NO | X

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28. YES | X | NO |

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)
	lucerne	all year	40		75
Permanent crops					
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X		X		

31.

Pipes	Earthen canals	Lined canals	Combination
X			

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
		X						

33.

Salinity	YES	X
	NO	

low

Alkalinity	YES	
	NO	X

34. Once every 6 xxxxx/year(s)

35.

36. 15 to 20m metres

37.

Seasonally	YES	
	NO	X

metres

Longterm	YES	
	NO	X

metres

38.

39. Date 23/4/85

40. Name R.P. PARSONS

L A N D   A N D   W A T E R   U S E
Q U E S T I O N N A I R E

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

UITKOMST	314	UITKOMST

2. District

GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mr. P.A. Crouse
Box 99
Jansenville

4. Drainage region & number

1313

5. Size of Farm unit

2000 ha

6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?

25 ha

7. Additional area that could be brought under cultivation?

90 ha

8. What is the average total area which is irrigated at least once a year ?

25 ha

9. What is the balance (area which is not irrigated in an average year) ?

90 ha

10. For what reason(s) is the balance not irrigated ?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?

Commenced (about) 1900 year
Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

use groundwater when surface water not available

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?

several, gravity

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
X		

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	35 000 m³	4	m³
2	17 000 m³	5	m³
3	m³	6	m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?

don't know m³/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?

______ every ______ years
days/weeks/months/years when it rains or snows

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual

basis ______ m³

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	X
YES		NO	X

Name of organization ______

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES [ ] NO [x]

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. m³/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x106)
Waterlevels onset end							 m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily				Seasonal			Longterm
4/5	3/4	2/3	1/2	1/3	1/4	1/5	

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
		X				X

change/variation in quality YES [x] NO [ ]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28. YES [x] NO [ ]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)
lucerne		summer	25		75mm for 6 months
Permanent crops					
Seasonal or cash crops					

30. What field irrigation method(s) is (are) used ?

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X				

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

Pipes	Earthen canals	Lined canals	Combination
	X		

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
		X						

33. Does any salinity or alkalinity occur in the soil ?

Salinity	YES	
	NO	X

Alkalinity	YES	
	NO	X

34. How often is gypsum or lime applied on the lands ?

Once every 0 months/year(s)

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

10 – 20m metres

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

Seasonally	YES	
	NO	X

metres

Longterm	YES	
	NO	X

metres

38. Any remarks ?

39. Date 26/4/85

40. Official — Name R.P. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

VAN DER WALTS KLOOF	130	GRAND VIEW

2. District — GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mr. J. Hartzenberg
Box 199 Graaff-Reinet

4. Drainage region & number — 1314

5. Size of Farm unit — 4400 ha ha

6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)? — ha

7. Additional area that could be brought under cultivation? — ha

8. What is the average total area which is irrigated at least once a year? — 30 ha ha

9. What is the balance (area which is not irrigated in an average year)? — ha

10. For what reason(s) is the balance not irrigated?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm?

Commenced (about) ________ year
Expanded (about) 1980 year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...)? — use groundwater when surface water not available

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping?

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
X		

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	20 000	m³	4		m³
2	20 000	m³	5		m³
3		m³	6		m³

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum? — don't know m³/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability? — ________ every ________ years / days/weeks/months/years — dams are filled twice a year

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted? — Springflow contributes on a

daily	seasonal	annual

basis ________ m³

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board)?

YES		NO	x
YES		NO	x

Name of organization ________

22. What is the quality of the surface water and has the overall quality changed over the years ?

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES [ ] NO [X]

23. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

m^3/year

24. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction							
hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m^3/y (x106)
Waterlevels							
onset end							m m

25. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

Spring	flowrate - ℓ/s		total flow - m^3
	Estimated	Measured	Annual
1			
2			
3			
4			

26. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

Daily			Seasonal				Longterm
4/5	3/4	2/3	1/2	1/3	1/4	1/5	

of average original rate/yield

27. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
			X			

change/variation in quality YES [ ] NO [ ]

28. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

YES [ ] NO [X]

C. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

CROP TYPE		a	b (ha)	c (mm)	d (mm)	
Permanent crops	lucerne	summer	10		150	for 6 months
	oats	winter	20		110	for 6 months
Seasonal or cash crops						

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
				X		

31.

Pipes	Earthen canals	Lined canals	Combination
X			

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
		X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other

33.

Salinity	YES	
	NO	

Alkalinity	YES	X
	NO	

34. Once every 2 ~~months~~/year(s)

35. superphosphate

36. 10 – 30m metres

37.

Seasonally	YES	X
	NO	

10 metres

Longterm	YES	
	NO	X

metres

38.

39. Date 11/6/85

40. Name R.P. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1. Cadastral Farm name and number - Local Farm name

ZEEKOEIGAT	140D	ZEEKOEIGAT

2. District — GRAAFF-REINET

3. Proprietor - Postal address - Telephone Code & Number

Mr. A.J. Featherstone
Box 90
Aberdeen | Aberdeen | 2721

4. Drainage region & number — GRAAFF-REINET

5. Size of Farm unit — 3000 ha

6. Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)? — 500 ha

7. Additional area that could be brought under cultivation? — ha

8. What is the average total area which is irrigated at least once a year? — 200 ha

9. What is the balance (area which is not irrigated in an average year)? — 300 ha

10. For what reason(s) is the balance not irrigated?

lack of irr. facilities	lack of water	sufficient rainfall	economic reasons	annual fallow	other
	X				

11. At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm?

Commenced (about) 1980 year
Expanded (about) 1980 year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...)? — use groundwater when surface water not available

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping? — several sites, pumping

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage?

daily	seasonal	annual	other
	X		

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
X		

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1		m^3	4		m^3
2		m^3	5		m^3
3		m^3	6		m^3

don't know

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum? — don't know m^3/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability? — every years; days/weeks/months/years

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted?

Springflow contributes on a

daily	seasonal	annual

basis — 5 months a year m^3

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board)?

YES		NO	X
YES		NO	X

Name of organization

2. What is the quality of the surface water and has the overall quality changed over the years ?

22.

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES		NO	X

3. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. m^3/year

4. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

24.

Borehole no.							
Tested yield Pumped yield Measured yield	SEE HYDROCENSUS DATA						ℓ/s ℓ/s ℓ/s
Abstraction							
hours/day days/week weeks/year months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m^3/y (x106)
Waterlevels							
onset end							m m

5. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

25.

Spring	flowrate - ℓ/s		total flow - m^3
	Estimated	Measured	Annual
1			
2			
3			
4			

6. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

26.

Daily			Seasonal				Longterm
4/5	3/4	2/3	1/2	1/3	1/4	1/5	

spring in river dry

of average original rate/yield

7. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
	X					

change/variation in quality YES ☐ NO X

8. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28. YES X NO ☐

. AGRICULTURE

29. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)	
Permanent crops	lucerne	summer	155		170	for 6 months
	wheat	summer	30		85	for 6 months
	mielies	winter	15		40	for 6 months
Seasonal or cash crops						

30. What field irrigation method(s) is (are) used ?

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more.?

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

33. Does any salinity or alkalinity occur in the soil ?

34. How often is gypsum or lime applied on the lands ?

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

38. Any remarks ?

39. Date

40. Official

30.

Basin irrigation	Furrow patterns	Flooding	Submurface irrigation	sprinklers	microjet	other
		X				

31.

Pipes	Earthen canals	Lined canals	Combination
X	X		

32.

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other	
	X	X						
SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other
		X						

33.

Salinity	YES	X
	NO	

Alkalinity	YES	
	NO	X

34. Once every 0 months/year(s)

35.

36. 5 – 15m metres

37.

Seasonally	YES	
	NO	X

metres

Longterm	YES	
	NO	X

metres

38.

39. Date 25/4/85

40. Name R.P. PARSONS

LAND AND WATER USE
QUESTIONNAIRE

Please complete the appropriate sections or mark ✓ where applicable

A. GENERAL INFORMATION

1.	Cadastral Farm name and number - Local Farm name	1.	ZEEKOEIGAT / 140 D / ZEEKOEIGAT
2.	District	2.	GRAAFF-REINET
3.	Proprietor - Postal address - Telephone Code & Number	3.	Mr. J.D. van der Merwe Box 56 Aberdeen
4.	Drainage region & number	4.	1314
5.	Size of Farm unit	5.	2800 ha
6.	Total area of Cultivable Land (dry land, flood irrigation, furrow irrigation etc.)?	6.	150 ha
7.	Additional area that could be brought under cultivation?	7.	ha
8.	What is the average total area which is irrigated at least once a year ?	8.	150 ha
9.	What is the balance (area which is not irrigated in an average year) ?	9.	ha
10.	For what reason(s) is the balance not irrigated ?	10.	lack of irr. facilities / lack of water / sufficient rainfall / economic reasons / annual fallow / other
11.	At what (approx.) time has irrigation commenced and/or was significantly expanded on the farm ?	11.	Commenced (about) 1900 year Expanded (about) ______ year

B. WATER SOURCES AND DISTRIBUTION

12. Is the irrigation water supplied from surface or groundwater resources or from both?

Surface water	Surface & Ground water	Groundwater
	X	

13. If surface and ground water are used conjunctively, what is the general pattern of interaction (e.g. ground water pumped when riverflow decreases ...) ?

use groundwater when no surface water available

14. If the farm unit is, partly or entirely, supplied with surface water, is the flow diverted at one site or at several sites and is (are) the diversion(s) by gravity or by pumping ?

several, gravity & pumping

15. Do any storage reservoirs exist and if so, is this storage mainly for daily, seasonal or carry-over (annual) storage ?

daily	seasonal	annual	other
		X	

16. Are the reservoirs used for the storage of surface water or ground water or for both?

Surface water	Surface & Ground water	Groundwater
X		

17. Please list the capacity of all reservoirs used for the storage of irrigation water.

1	m^3	4	m^3
2	m^3	5	m^3
3	m^3	6	m^3

18. What is the volume of surface water diverted (either for direct application or for temporary storage) per annum ?

don't know m^3/year

19. If surface water is available on an irregular basis, what is the frequency and average duration of availability ?

every ______ years ______ days/weeks/months/years — when it rains

20. Does the surface water flow, partly or entirely, originate from springflow and if so, what is the pattern and average annual contribution of springflow to the total volume of surface water diverted ?

Springflow contributes on a

daily	seasonal	annual

basis ______ m^3

21. Are any surface water resources shared with other proprietors at the diversion point, and if so, is this done on an organized basis (e.g. Irrigation Board) ?

YES		NO	X
YES		NO	X

Name of organization ______

. What is the quality of the surface water and has the overall quality changed over the years ?

22.

Saline	brackish	fresh	mg/ℓ (25°C)	mS/m @ 25°C
		X		

YES [ ] NO [X]

. If the farm unit, partly or entirely, is supplied from groundwater, what is the average total yearly groundwater abstraction from all sources (boreholes and springs other than included under section 20) ?

23. m³/year

. Supply the following particulars for each borehole pumped for irrigation: number; tested, pumped and measured yield; abstraction schedule; average total volume abstracted per year; waterquality; waterlevels at the onset and end of an irrigation cycle.

24.

Borehole no.							
Tested yield	SEE HYDROCENSUS DATA						ℓ/s
Pumped yield							ℓ/s
Measured yield							ℓ/s
Abstraction							
hours/day							
days/week							
weeks/year							
months/year							
TDS (@ 25°C)							mg/ℓ
Total abstraction							m³/y (x106)
Waterlevels							
onset							m
end							m

. If springflow (other than that included in section 20) is used for irrigation purposes, what is the (estimated or measured) flow rate and average total annual flow of each spring ?

25.

Spring	flowrate - ℓ/s		total flow - m³
	Estimated	Measured	Annual
1			
2			
3			
4			

. Do borehole yields and rates of springflow decline with time, and if so, when and to what extent ?

26.

Daily			Seasonal				Longterm
4/5	3/4	2/3	1/2	1/3	1/4	1/5	

of average original rate/yield

. What is the overall quality of the groundwater used for irrigation and has a quality change with time been noticed ?

27.

Saline	brackish	slightly brackish	fresh	very fresh	alkaline	sulphurous
	X					

change/variation in quality YES [X] NO [ ]

. Is the present supply of surface and/or ground water for irrigation purposes sufficient?

28. YES [X] NO [ ]

AGRICULTURE

. Please list the types of crops under irrigation, the (a) growing or irrigation season, (b) the acreage of each crop, (c) the average monthly consumptive use of each of the crops and (d) the average monthly irrigation field application

29.

CROP TYPE		a	b (ha)	c (mm)	d (mm)	
	lucerne	summer	120		120	for 6 months
Permanent crops	oats	winter	330		80	for 6 months
	wheat	winter	30		80	for 6 months
Seasonal or cash crops						

30. What field irrigation method(s) is (are) used ?

Basin irrigation	Furrow patterns	Flooding	Subsurface irrigation	sprinklers	microjet	other
		X				

31. Is the water conveyed from the point(s) of diversion, issue or pumping by means of pipes, earthen canals or lined canals or a combination of two or more ?

Pipes	Earthen canals	Lined canals	Combination
	X		

32. How can the surface soil and the substratum (subsoil) of the irrigated lands be characterized ?

SOIL	Clayey	Loamy	Silty	Sandy	Gravelly	Rocky	Other
		X					

SUB-SOIL	Clayey	Silty	Sandy	Gravelly	Shale	S'stone	Granitic	Other

33. Does any salinity or alkalinity occur in the soil ?

Salinity		
	YES	X
	NO	

Alkalinity		
	YES	X
	NO	

34. How often is gypsum or lime applied on the lands ?

Once every 0 months/year(s)

35. What fertilizers are regularly used ?

36. Is the ground water table within measurable distance from the surface, and if so, what is the average depth of the watertable below the surface ?

10 – 30m metres

37. If the watertable fluctuates seasonally or on a longterm basis, what is approximately the fluctuation ?

Seasonally		
	YES	X
	NO	

10 metres

Longterm		
	YES	
	NO	X

metres

38. Any remarks ?

39. Date 23/5/85

40. Official — Name R.P. PARSONS

Appendix 1C

Fertilizer application data

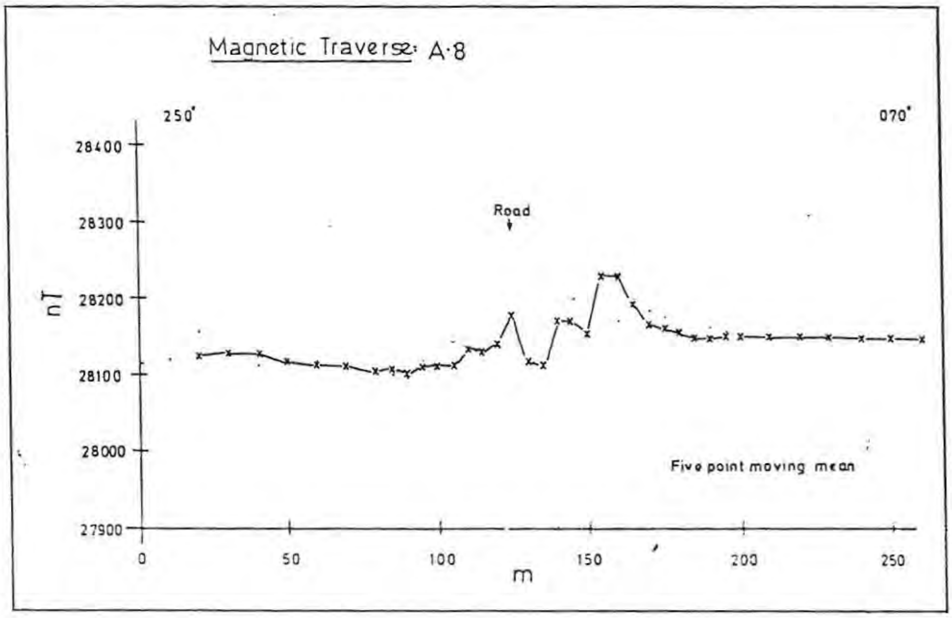
Local farm	Fertilizer	Area fertilized ha	Quantity kg/ha	Frequency years
CORNDALE	gypsum	5	6000	1/5
DAGLUMIER	gypsum	10	5000	1/5
	ammonium sulphate	10	350	2/5
GRASRAND	gypsum	10	5000	1/3
ERICA	gypsum	7	5000	1/6
KRANSPLAAS	ammonium sulphate	100	350	1/5
KRIEGERSKRAAL	gypsum	2	5500	1/10
MIMMOSADALE	gypsum	10	5000	1/2
MOOIFONTEIN	gypsum	100	2500	2/10
	ammonium sulphate	100	100	5/10
	urea	100	50	5/10
	super phosphate	100	50	5/10
BEACONSFIELD	gypsum	8	5000	1/10
UITKOMST	ammonium sulphate	40	350	2/1
	gypsum	40	5000	1/6
GRAND VIEW	super phosphate	30	100	1/2
VREDE	gypsum	100	5000	1/10
	ammonium phosphate	100	250	1/1
	urea	10	500	1/1
	super phosphate	100	200	1/1

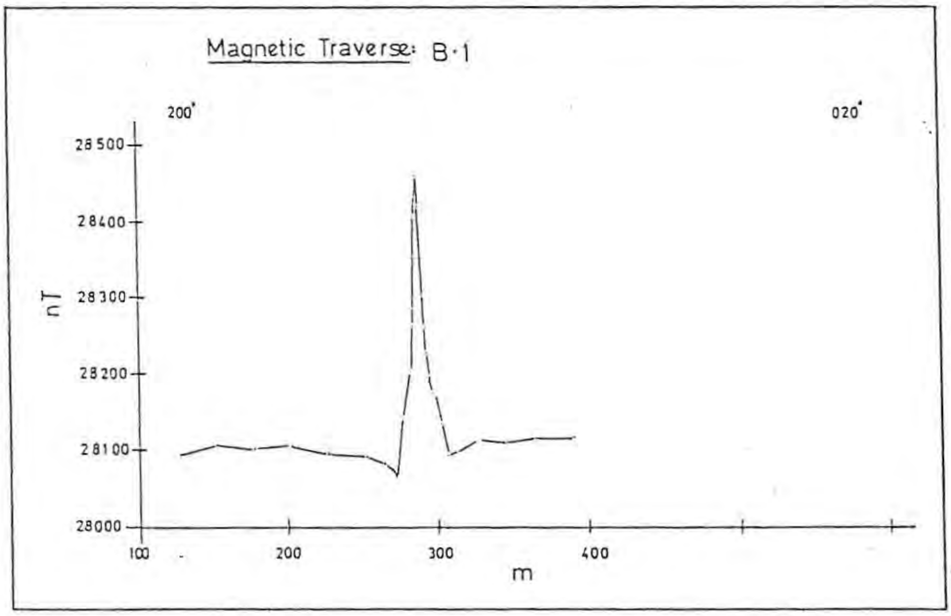
APPENDIX 2:

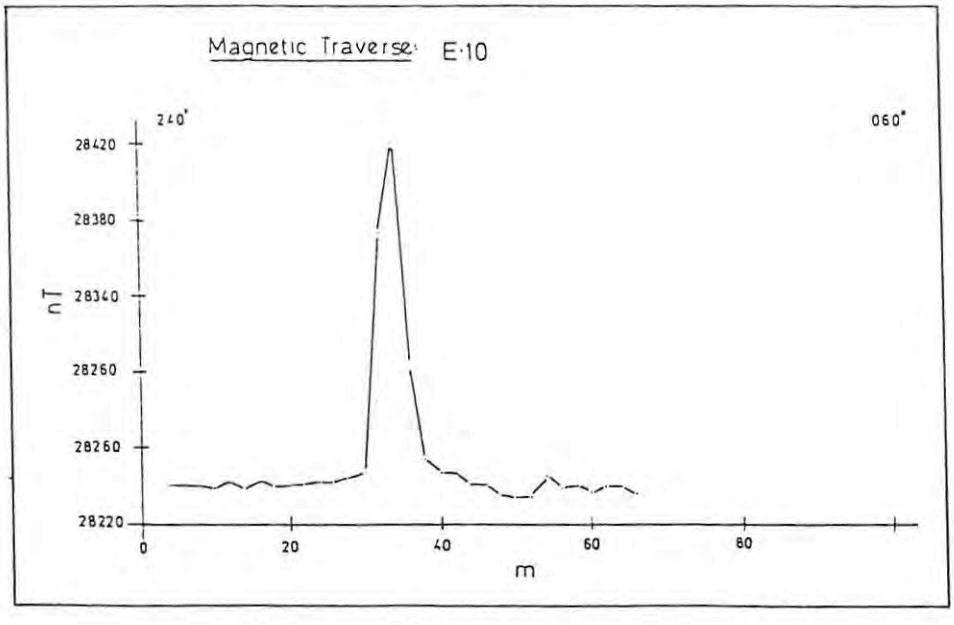
GEOPHYSICAL DATA

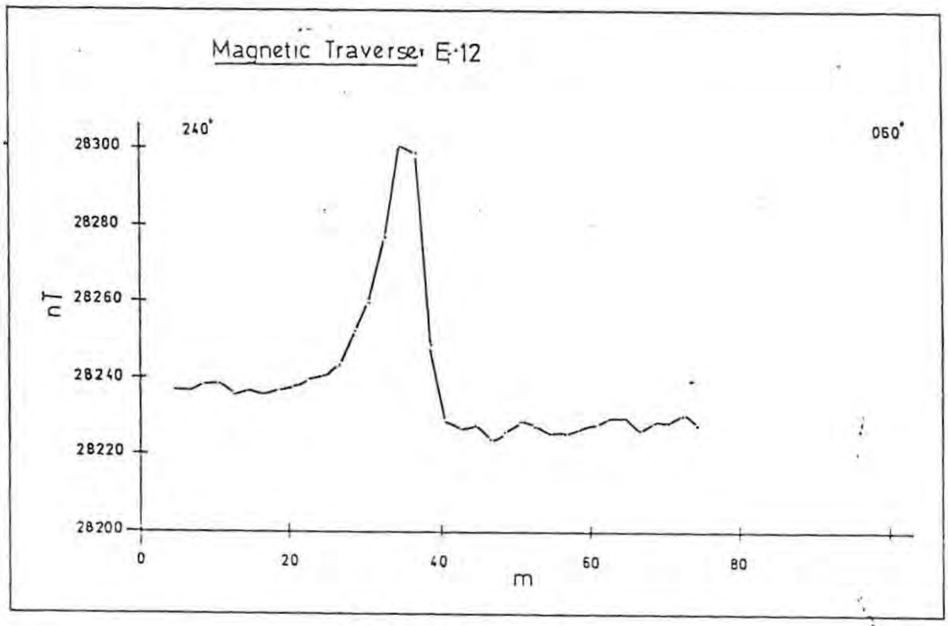
Appendix 2A

Magnetic anomalies

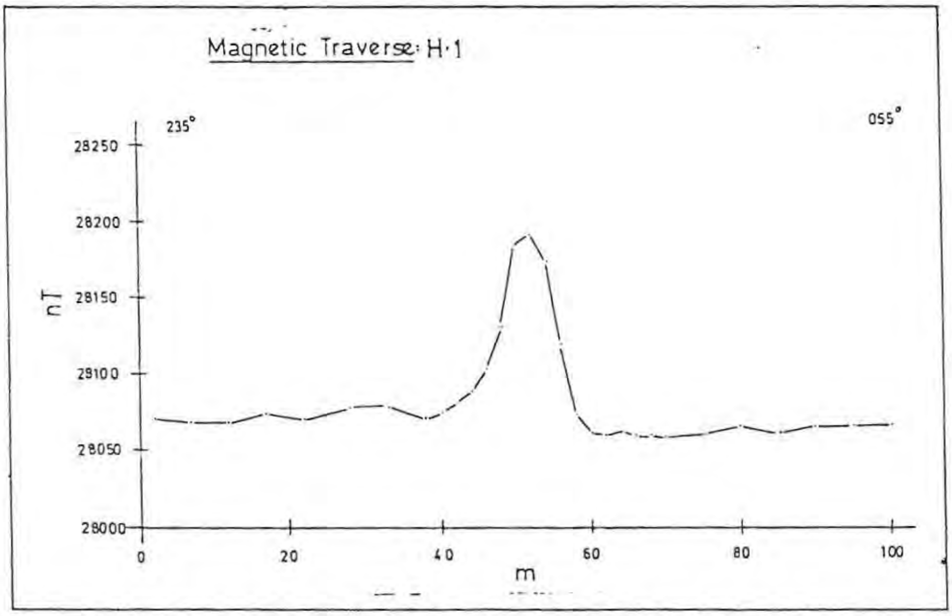

Magnetic Traverse: A·8
250°
070°
28400
28300
28200
28100
28000
27900
nT
Road
Five point moving mean
0
50
100
150
200
250
m


Magnetic Traverse: B·1
200°
020°
28500
28400
28300
28200
28100
28000
nT
100
200
300
400
m

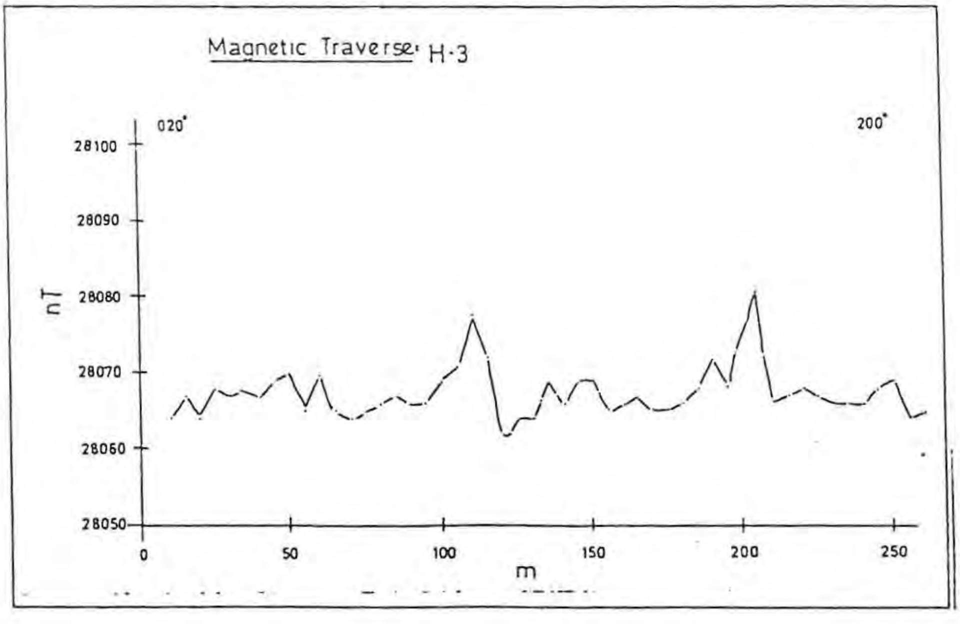

Magnetic Traverse: E·10
240°
060°
28420
28380
28340
28260
28260
28220
nT
0
20
40
60
80
m



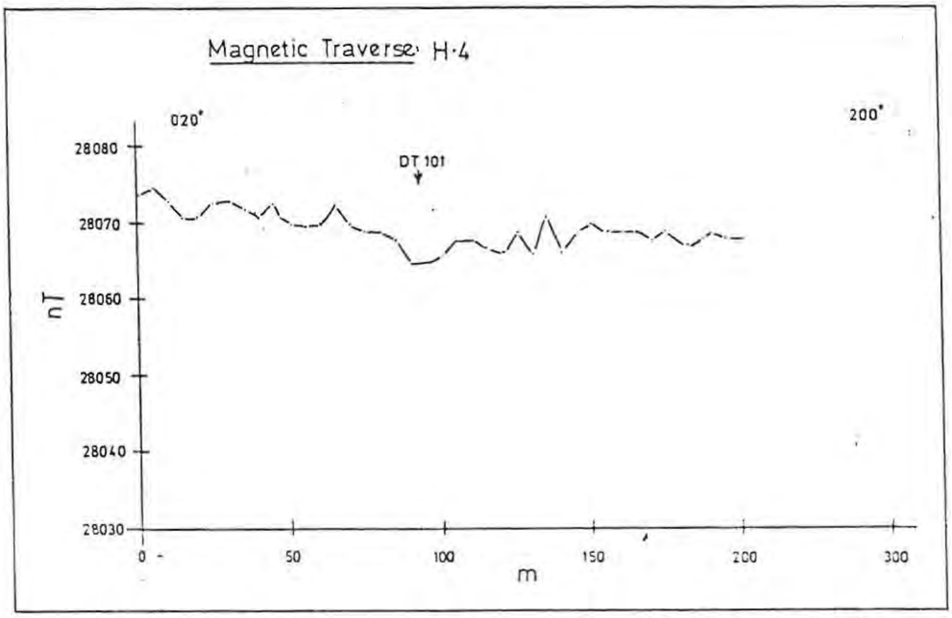
Magnetic Traverse: E-12
240°
060°
nT
28300
28280
28260
28240
28220
28200
0
20
40
60
80
m

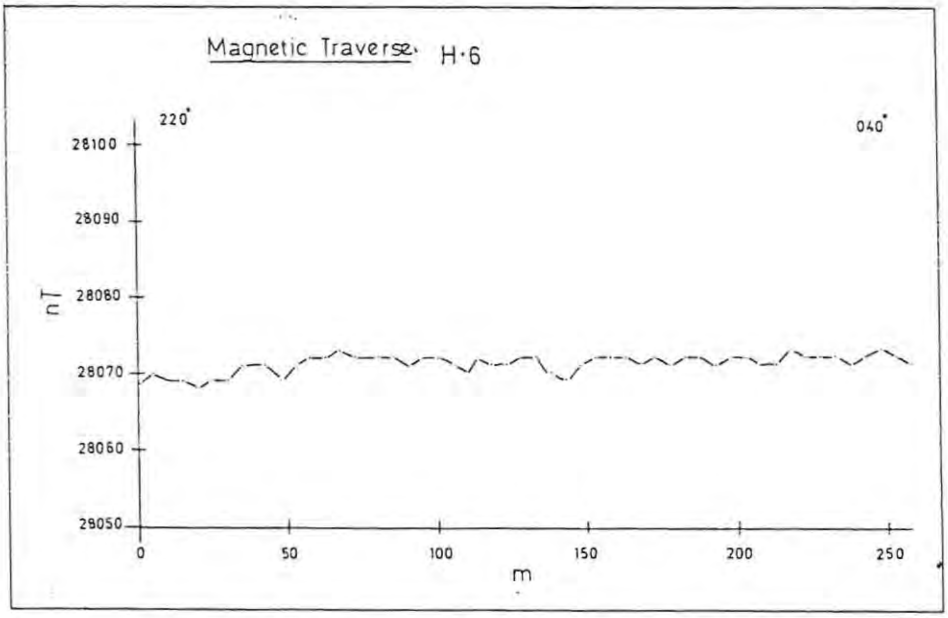


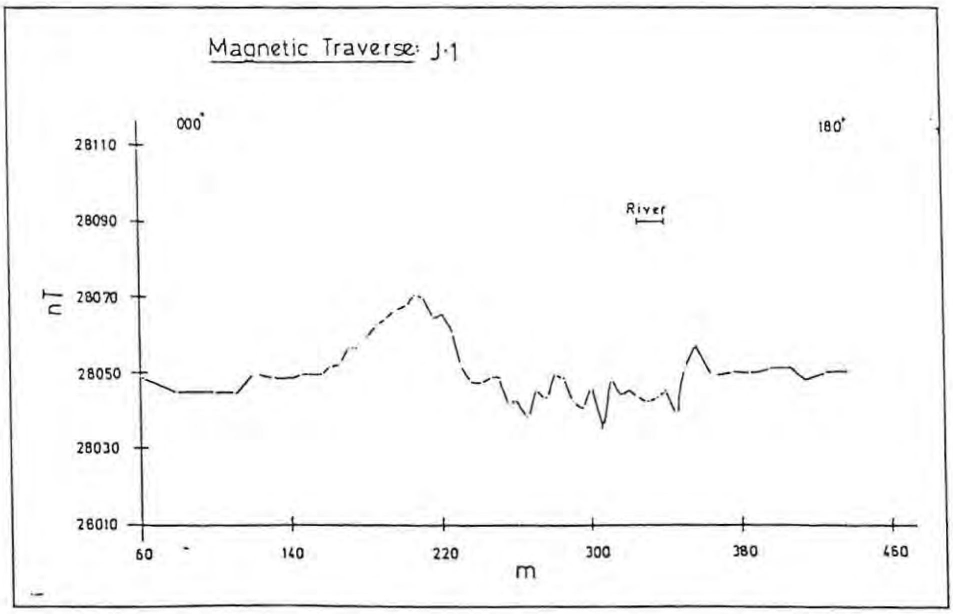
Magnetic Traverse: H-1
235°
055°
nT
28250
28200
28150
28100
28050
28000
0
20
40
60
80
100
m

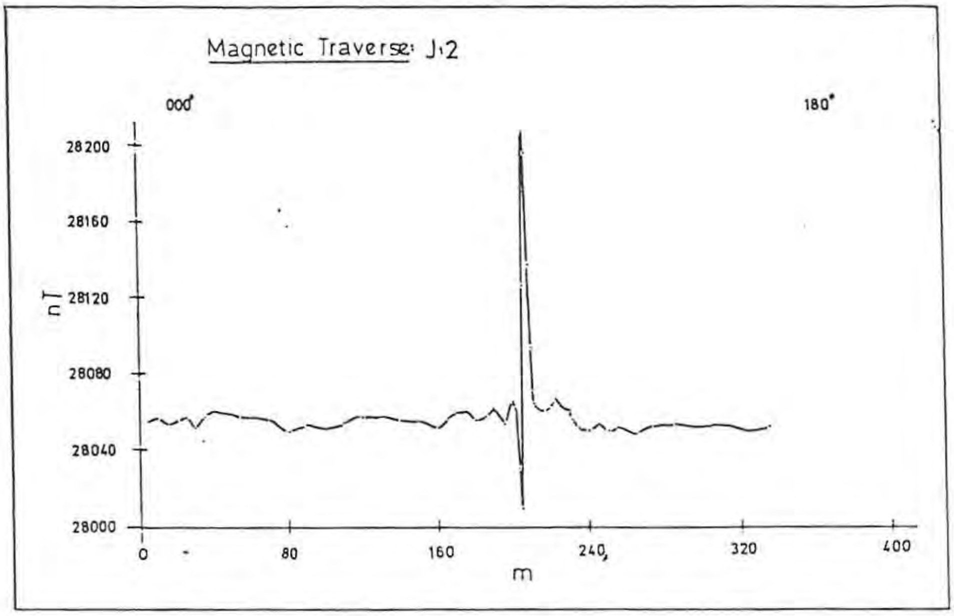


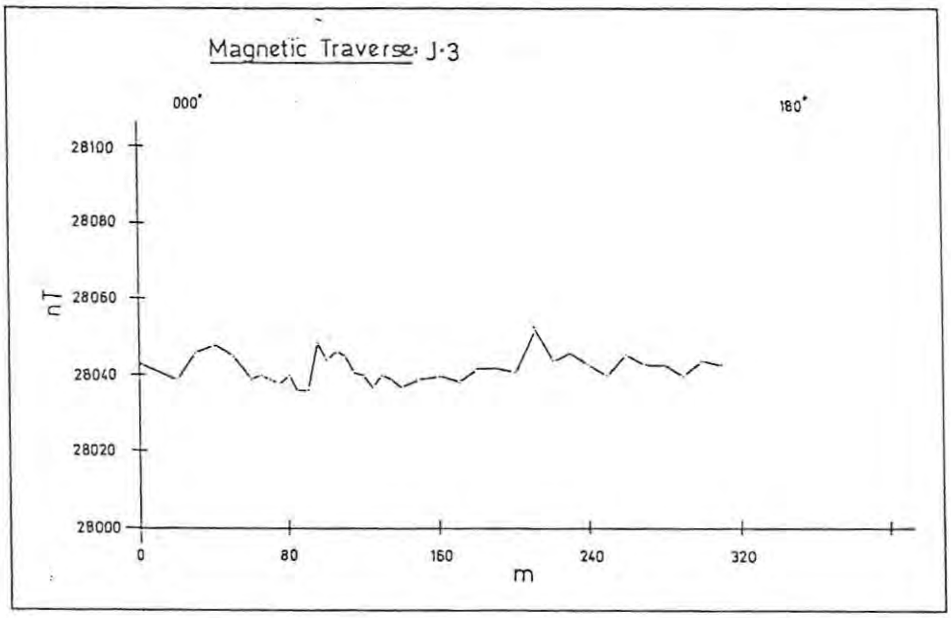
Magnetic Traverse: H-3
020°
200°
nT
28100
28090
28080
28070
28060
28050
0
50
100
150
200
250
m


Magnetic Traverse: H·4
020°
200°
DT 101
28080
28070
28060
28050
28040
28030
nT
0
50
100
150
200
300
m


Magnetic Traverse: H·6
220°
040°
28100
28090
28080
28070
28060
28050
nT
0
50
100
150
200
250
m

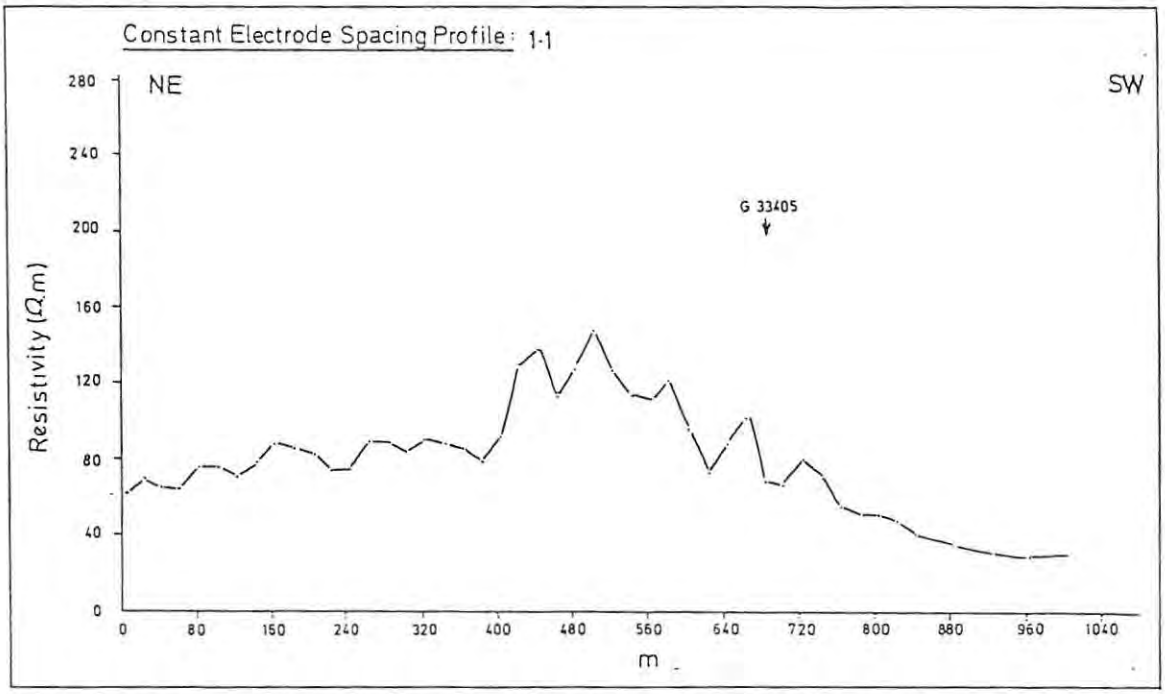

Magnetic Traverse: J·1
000°
180°
River
28110
28090
28070
28050
28030
28010
nT
60
140
220
300
380
460
m

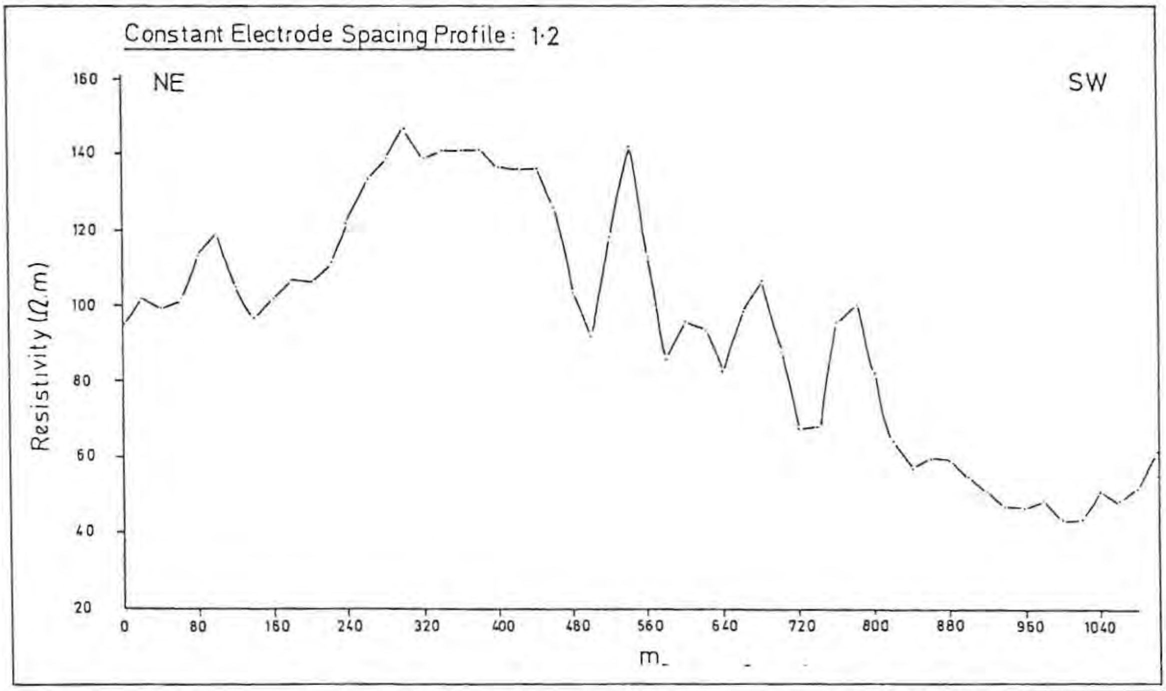

Magnetic Traverse: J·2
000°
180°
28200
28160
28120
28080
28040
28000
nT
0
80
160
240
320
400
m

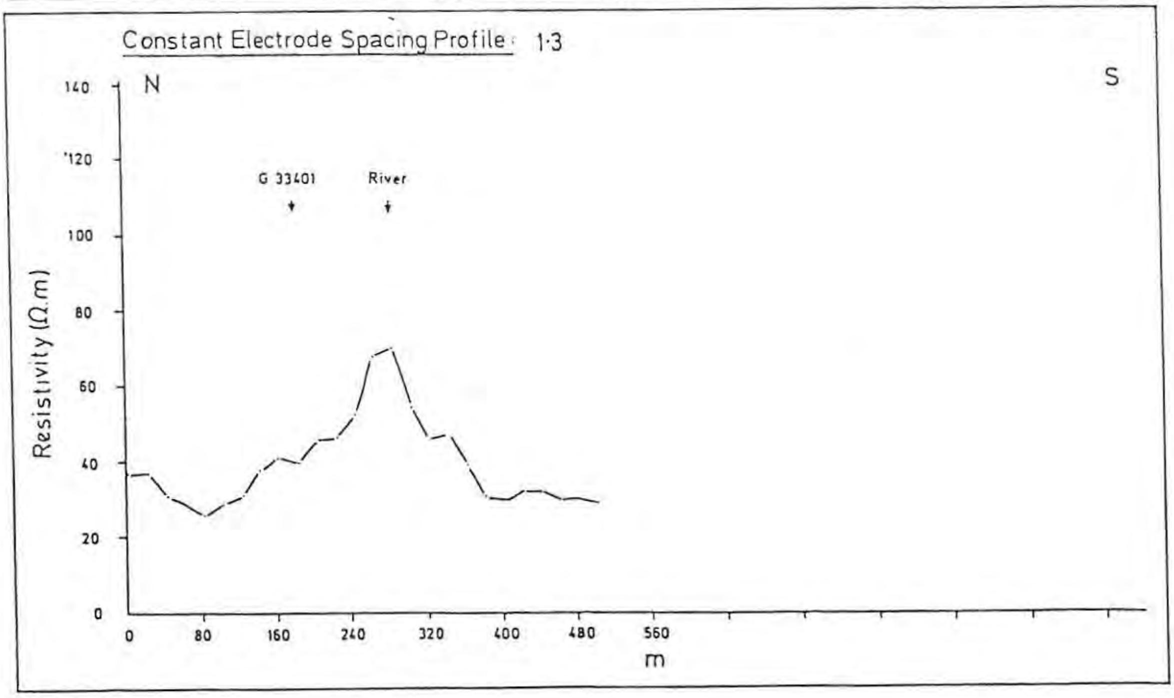

Magnetic Traverse: J·3
000°
180°
28100
28080
28060
28040
28020
28000
nT
0
80
160
240
320
m

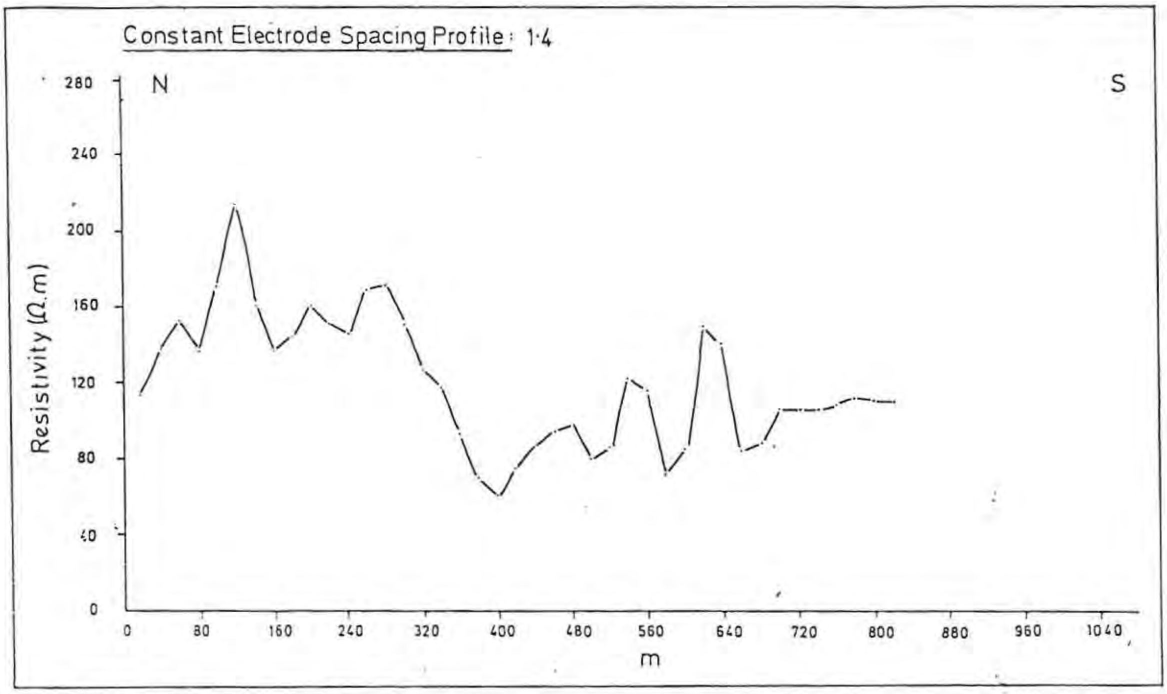
Appendix 2B

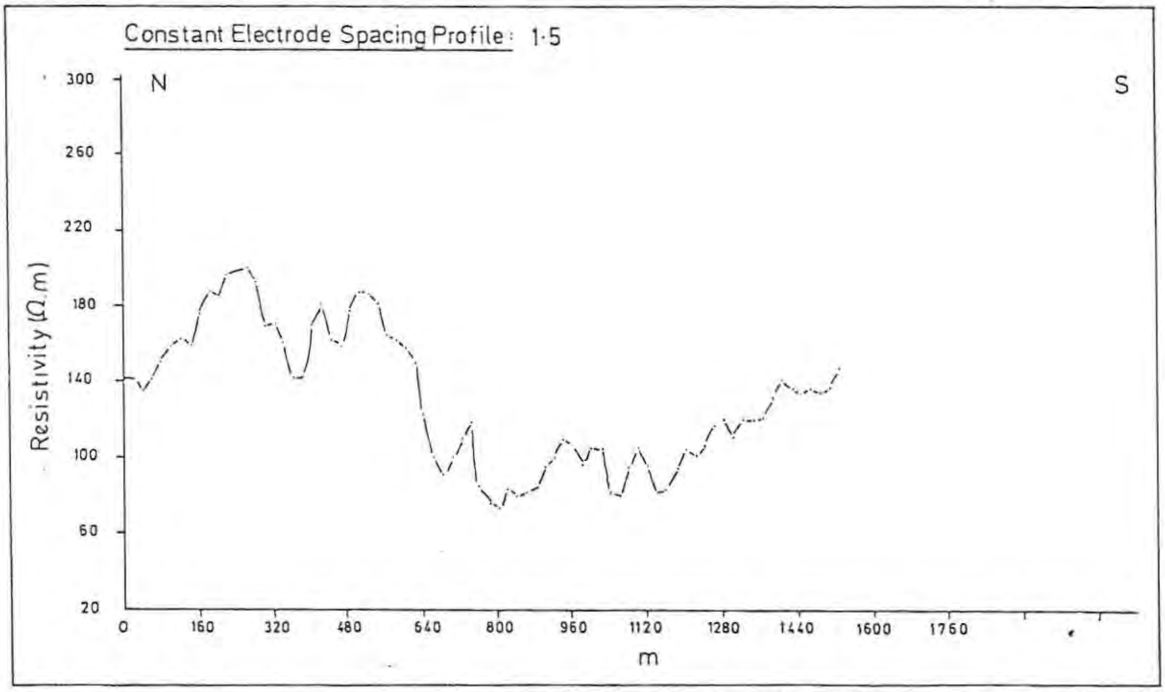
CES profiles

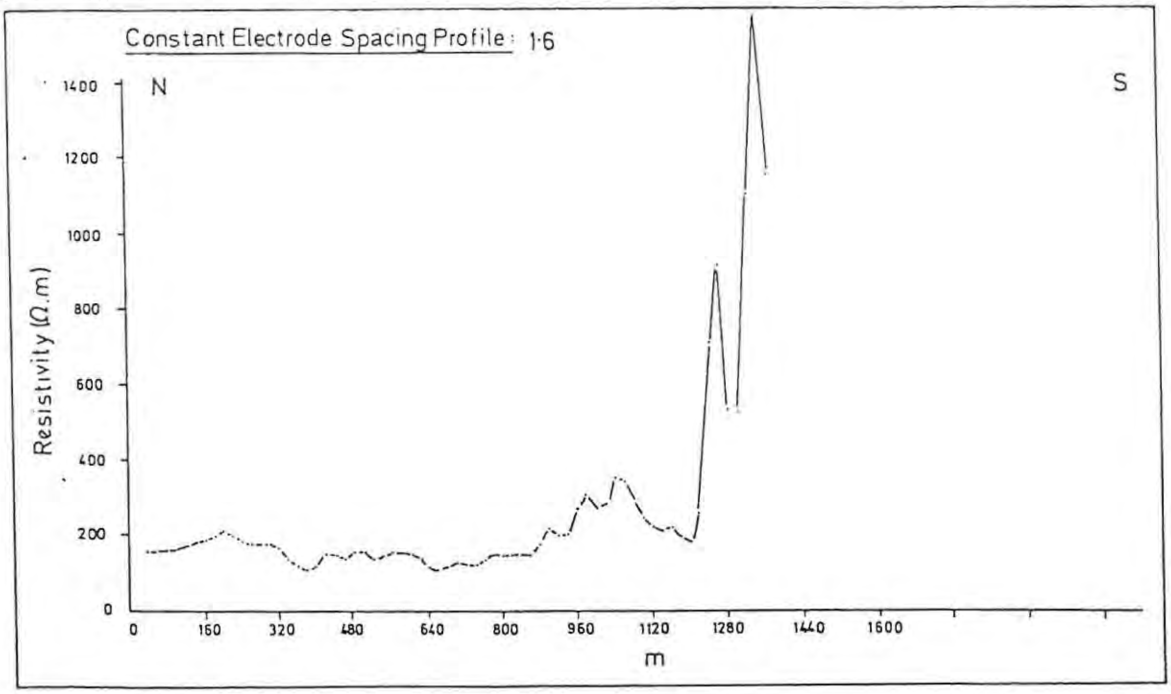

Constant Electrode Spacing Profile: 1·1
NE
SW
G 33405
Resistivity (Ω.m)
280
240
200
160
120
80
40
0
0
80
160
240
320
400
480
560
640
720
800
880
960
1040
m

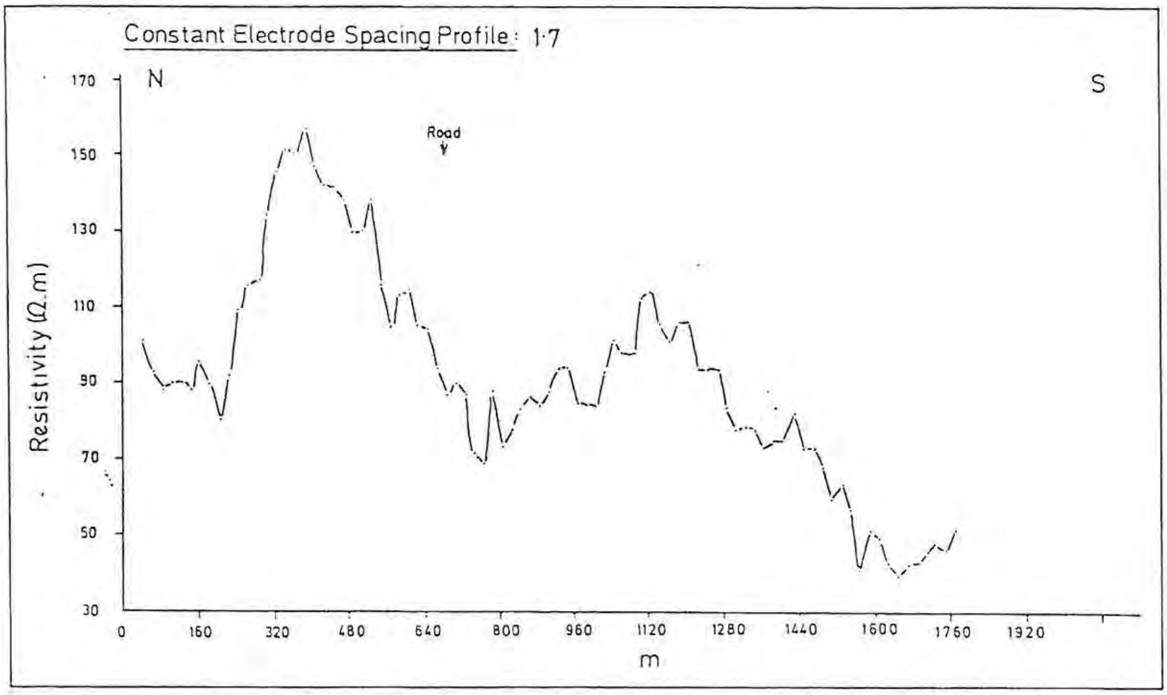

Constant Electrode Spacing Profile: 1·2
NE
SW
Resistivity (Ω.m)
160
140
120
100
80
60
40
20
0
80
160
240
320
400
480
560
640
720
800
880
960
1040
m

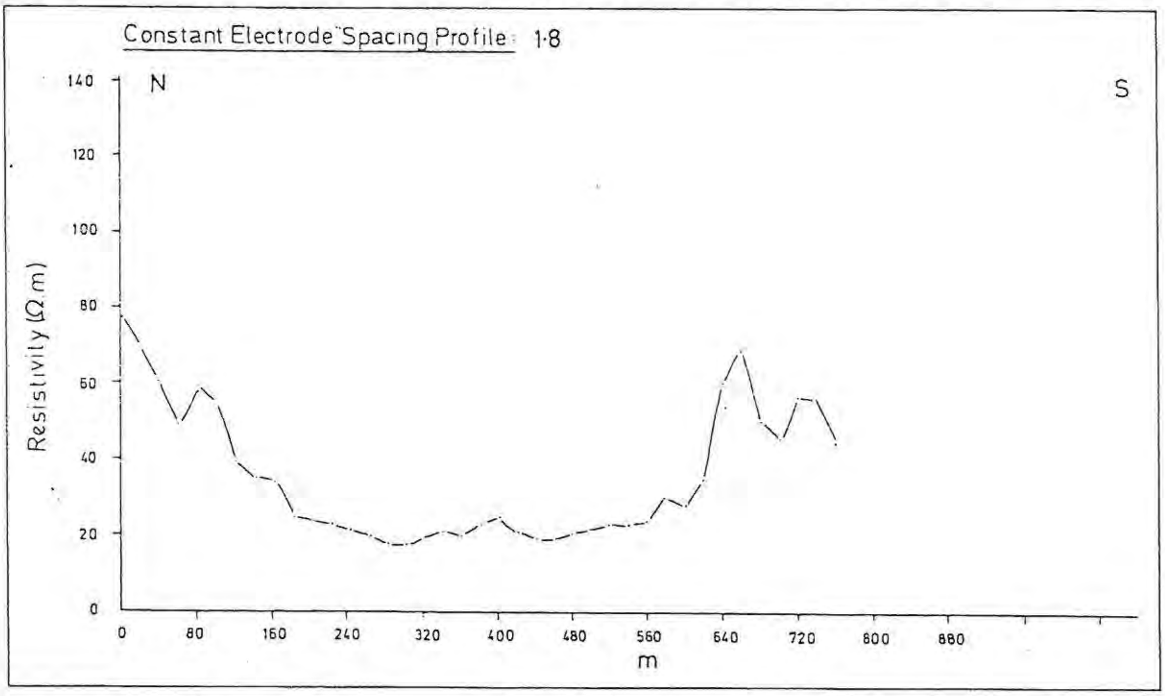

Constant Electrode Spacing Profile: 1·3
N
S
G 33401
River
Resistivity (Ω.m)
140
120
100
80
60
40
20
0
0
80
160
240
320
400
480
560
m

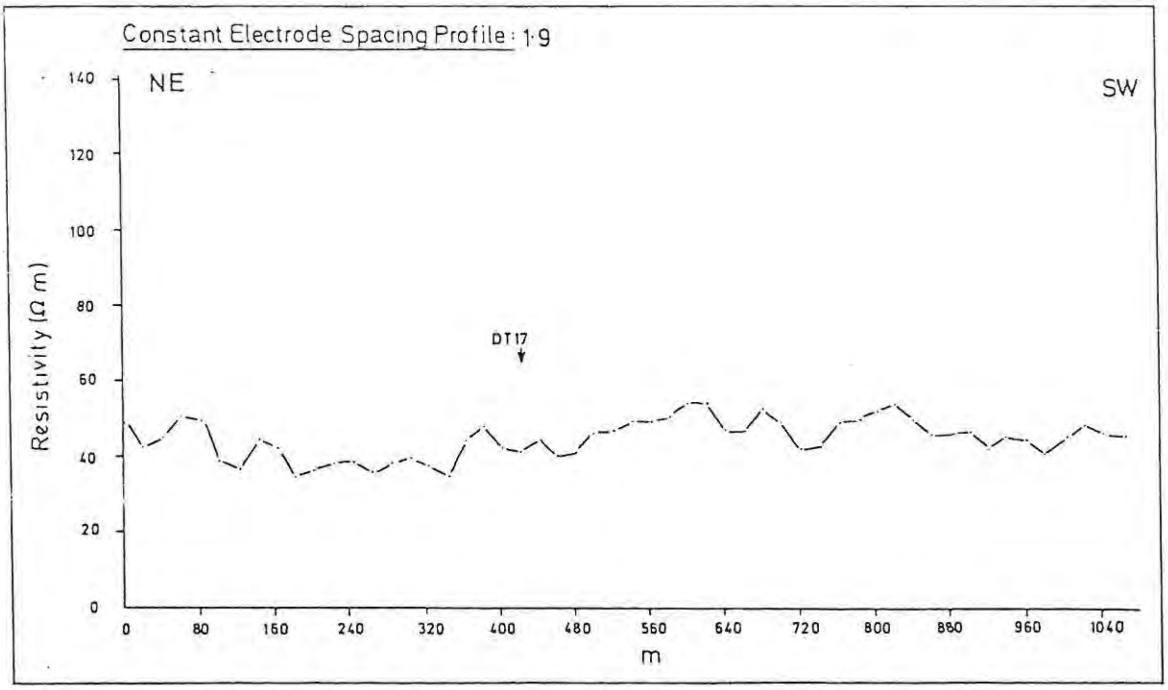

Constant Electrode Spacing Profile: 1·4
N
S
Resistivity (Ω.m)
280
240
200
160
120
80
40
0
0
80
160
240
320
400
480
560
640
720
800
880
960
1040
m

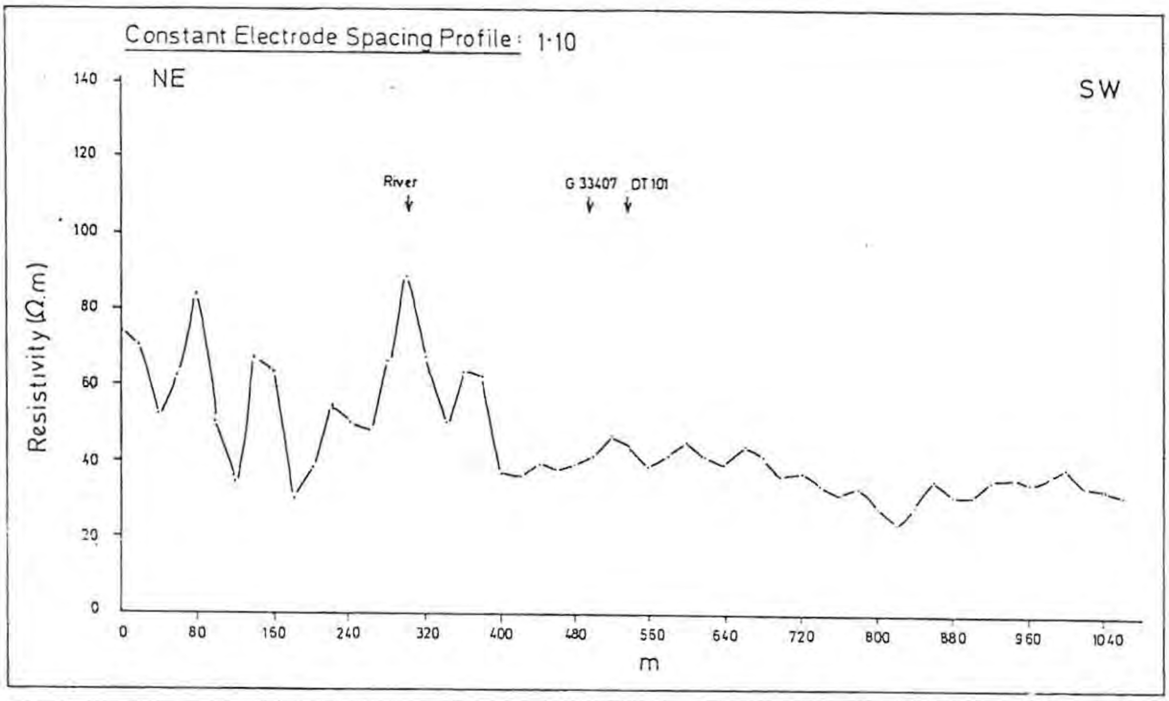

Constant Electrode Spacing Profile: 1·5
N
S
Resistivity (Ω.m)
300
260
220
180
140
100
60
20
0
160
320
480
640
800
960
1120
1280
1440
1600
1760
m


Constant Electrode Spacing Profile: 1·6
N
S
Resistivity (Ω.m)
1400
1200
1000
800
600
400
200
0
0
160
320
480
640
800
960
1120
1280
1440
1600
m

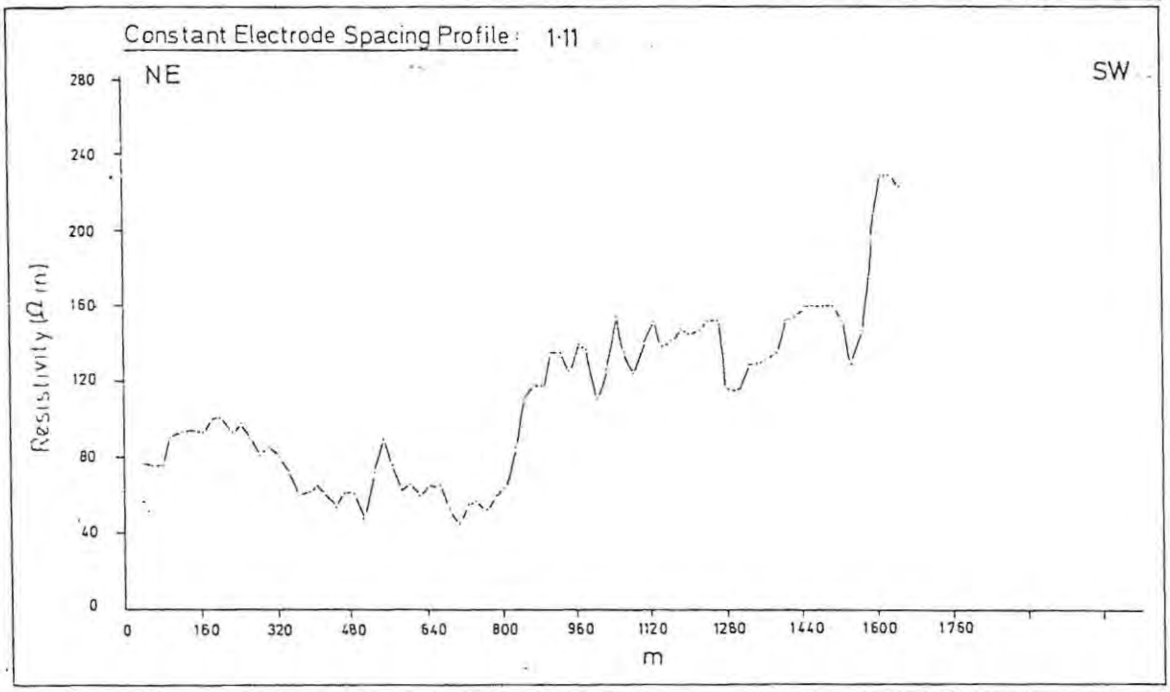

Constant Electrode Spacing Profile: 1·7
N
S
Road
Resistivity (Ω.m)
170
150
130
110
90
70
50
30
0
160
320
480
640
800
960
1120
1280
1440
1600
1760
1920
m


Constant Electrode Spacing Profile: 1·8
N
S
Resistivity (Ω m)
140
120
100
80
60
40
20
0
0
80
160
240
320
400
480
560
640
720
800
880
m

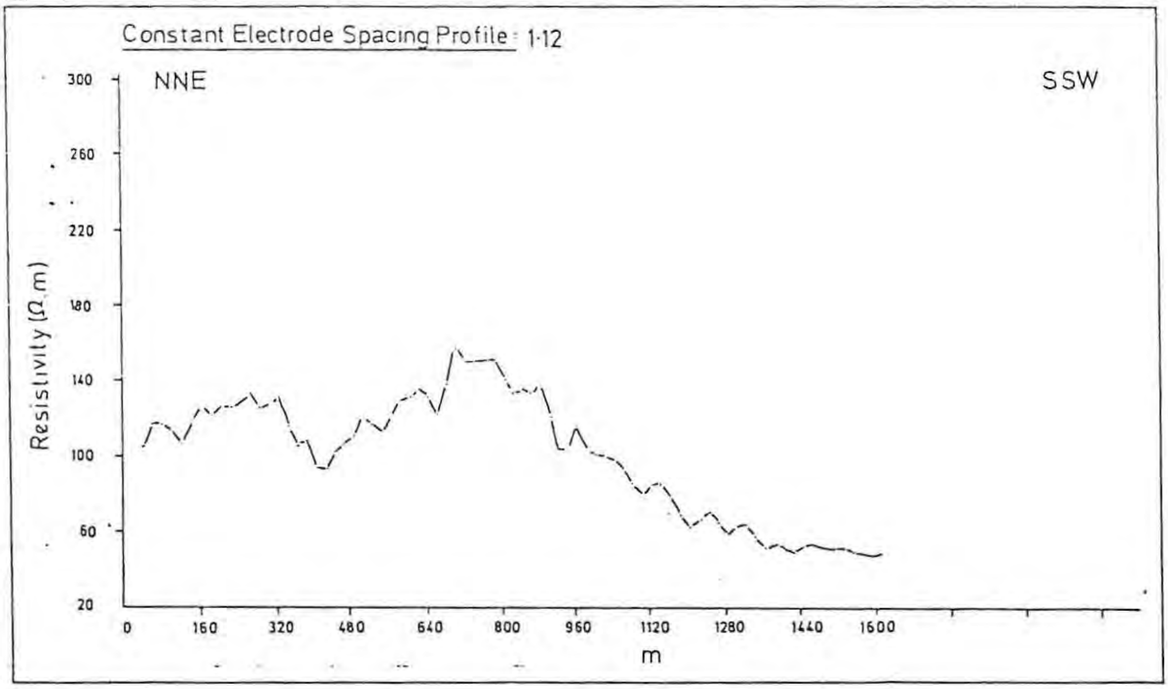

Constant Electrode Spacing Profile: 1·9
NE
SW
DT17
Resistivity (Ω m)
140
120
100
80
60
40
20
0
0
80
160
240
320
400
480
560
640
720
800
880
960
1040
m



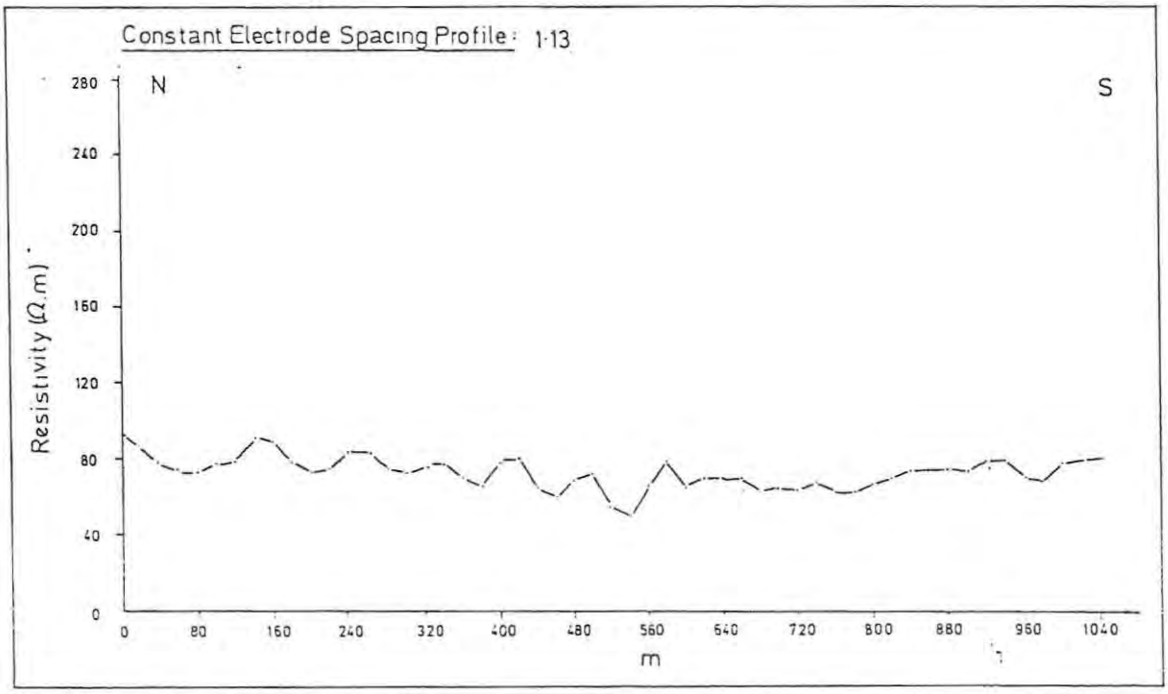
Constant Electrode Spacing Profile: 1·10
NE
SW
River
G 33407
DT 101
Resistivity (Ω.m)
m

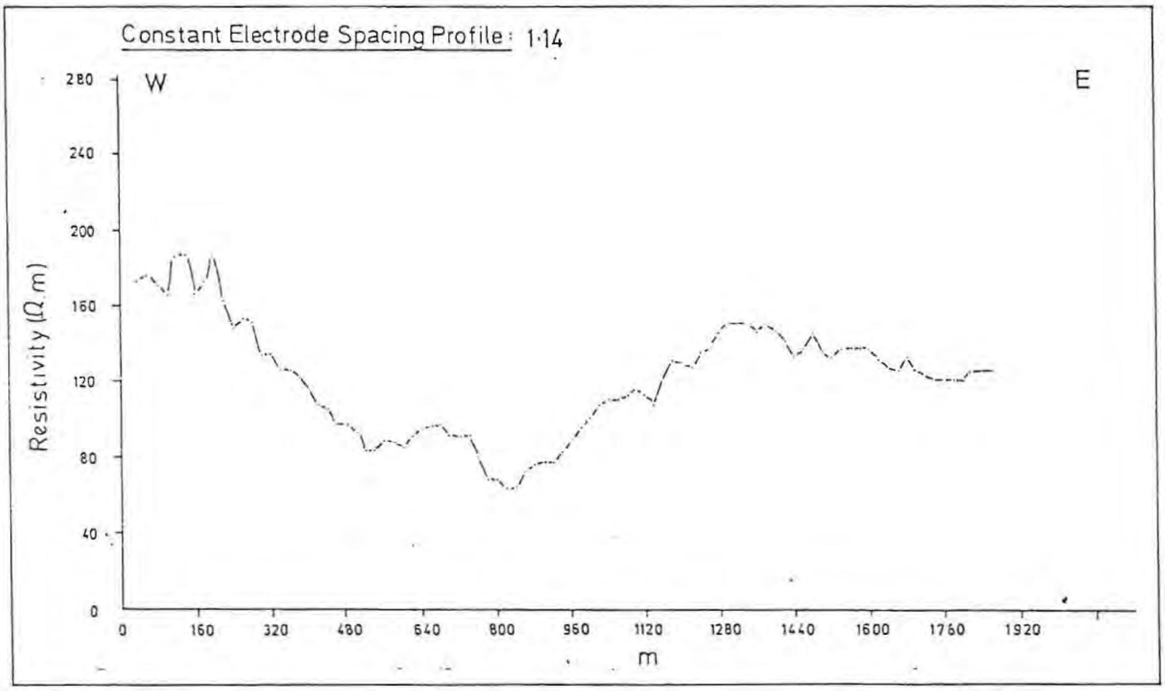


Constant Electrode Spacing Profile: 1·11
NE
SW
Resistivity (Ω.m)
m



Constant Electrode Spacing Profile: 1·12
NNE
SSW
Resistivity (Ω.m)
m


Constant Electrode Spacing Profile: 1·13
N
S
Resistivity (Ω.m)
280
240
200
160
120
80
40
0
0
80
160
240
320
400
480
560
640
720
800
880
960
1040
m


Constant Electrode Spacing Profile: 1·14
W
E
Resistivity (Ω.m)
280
240
200
160
120
80
40
0
0
160
320
480
640
800
960
1120
1280
1440
1600
1760
1920
m

APPENDIX 3:

PROJECT BOREHOLE LOGS

BOREHOLE NO : G33337
DATE DRILLED : 5/11/84 to 6/11/84, deepened 19/12/84 to 20/12/84
CADASTRAL FARM : CORNDALE 333
CO-ORDINATES : LATITUDE : 32°18'42" LONGITUDE : 24°27'11"
TOTAL DEPTH (m) : 90m CASING : 4m of 165 steel casing
WATER LEVEL (m) : 12,91m COLLAR ELEVATION : (a.m.s.l) : 707,3m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
46m	damp	-
76m	0,1	-
final m	0,1	-

GEOLOGY

0-4 m highly weathered dolerite
-23m medium-grained dolerite
-29m blue-grey fine-grained sandstone
-74m medium-grained dolerite -calcite at 72-74m
-90m alternating blue-grey siltstone and maroon mudstone -calcite at 74m-81m

BOREHOLE NO : G33338
DATE DRILLED : 8/11/84 to 9/11/84
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°21'20" LONGITUDE : 24°28'27"
TOTAL DEPTH (m) : 60m CASING : 6m of 165mm steel casing
WATER LEVEL (m) : 11,62m COLLAR ELEVATION : (a.m.s.l.) : 670,7m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
35m	0,1	499
46m	4,4	438
final	4,4	440

GEOLOGY

0-5 m sandy alluvium
-7 m weathered blue-grey fine-grained sandstone
-45m medium-grained dolerite
-60m alternating blue-grey siltstone and blue-grey fine-grained sandstone -calcite at 56m

BOREHOLE NO : G33339
DATE DRILLED : 12/11/84 to 13/11/84
CADASTRAL FARM : DE HOOP 436
CO-ORDINATES : LATITUDE : 32°27'15" LONGITUDE : 24°25'25"
TOTAL DEPTH (m) : 60m CASING : 13m of 165mm steel casing slotted 10-13m
WATER LEVEL (m) : 7,16m COLLAR ELEVATION : (a.m.s.l.) : 640,2m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
11m	1.9	475
final	1.9	475

GEOLOGY

0-3 m sandy alluvium
-5 m rounded pebbles
-6 m weathered blue-green sandstone
-24m blue-grey fine-grained sandstone -calcite at 17-24m
-60m alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33340
DATE DRILLED : 14/11/84
CADASTRAL FARM : GROOTE VLAKTE 132
CO-ORDINATES : LATITUDE : 32°25'00" LONGITUDE : 24°17'59"
TOTAL DEPTH (m) : 60m CASING : 8m of 165mm steel casing
WATER LEVEL (m) : 3,08m COLLAR ELEVATION :(a.m.s.l) : 673,8m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)	
12m	damp	245	H_2S
22m	4,7	263	H_2S
26m	5,4	268	H_2S
32m	6,0	267	H_2S
34m	8,1	268	H_2S
37m	10,5	283	
40m	14,6	284	
final	14,6	354	

GEOLOGY

0-1 m	calcrete
-6 m	weathered brown-grey siltstone
-12m	blue-grey fine-grained sandstone
-24m	alternating blue-grey siltstone and maroon mudstone
-30m	blue-grey fine to medium-grained sandstone - calcite and pyrite staining
-34m	light blue fine-grained sandstone - calcite
-48m	blue-grey siltstone - calcite and pyrite staining
-57m	blue-grey fine to medium-grained sandstone - calcite and pyrite staining
-60m	dark blue-grey siltstone

BOREHOLE NO : G33341
DATE DRILLED : 15/11/84
CADASTRAL FARM : GROOTE VLAKTE 132
CO-ORDINATES : LATITUDE : 32°25'16" LONGITUDE : 24°18'28"
TOTAL DEPTH (m) : 60m CASING : 8m of 165mm steel casing
WATER LEVEL (m) : 6,60m COLLAR ELEVATION : (a.m.s.l.) : 669,2m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)	
13	damp	1379	H_2S
20	3,4	739	
41	4,5	680	
final	4,5	569	

GEOLOGY

0-2m	sandy alluvium
-13m	weathered greenish grey siltstone
-20m	blue-grey fine-grained sandstone - calcite at 20m
-53m	alternating blue-grey siltstone and maroon mudstone
-55m	blue-grey fine-grained sandstone
-60m	dark blue-grey siltstone

BOREHOLE NO : G33342
DATE DRILLED : 16/11/84 to 19/11/84
CADASTRAL FARM : GROOTE VLAKTE 132
CO-ORDINATES : LATITUDE : 32°26'05" LONGITUDE : 24°18'51"
TOTAL DEPTH (m): 60m CASING : 7m of 165mm steel casing
WATER LEVEL (m): 13,94m COLLAR ELEVATION : (a.m.s.l.) : 672,3m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)	
15m	damp	491	
26m	0,2	491	
41m	1,0	440	H_2S
final	1,0	380	

GEOLOGY

0-5 m	calcified sandy alluvium
-37m	alternating blue-grey siltstone and maroon mudstone - pyrite staining at 25m-27m
-41m	speckled blue-grey medium-grained sandstone
-60m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33343
DATE DRILLED : 19/11/84 to 21/11/84
CADASTRAL FARM : ZEEKOEIGAT 140D
CO-ORDINATES : LATITUDE : 32°25'55" LONGITUDE : 24°13'02"
TOTAL DEPTH (m) : 60m CASING :12m of 165mm steel casing
WATER LEVEL (m) : 8,74m COLLAR ELEVATION :(a.m.s.l) : 689,0m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
10	damp	-
17	0,7	659 H₂S
45	0,8	548
final	0,8	540

GEOLOGY

0-6 m calcareous sandy alluvium
-7 m rounded pebbles
-52m alternating blue-grey siltstone and maroon mudstone - calcite at 45-52m
-60m fine-grained dolerite

BOREHOLE NO : G33344
DATE DRILLED : 21/11/84 to 22/11/84
CADASTRAL FARM : ZEEKOEIGAT 140D
CO-ORDINATES : LATITUDE : 32°25'39" LONGITUDE :24°13'10"
TOTAL DEPTH (m) : 60m CASING :16m of 165mm steel casing
WATER LEVEL (m) : 9,06m COLLAR ELEVATION : (a.m.s.l.) :690,5m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
12	damp	-
21	1,8	636
30	2,0	664
47	2,3	659
final	2,6	634

GEOLOGY

0-6 m calcareous sandy alluvium
-12m rounded pebbles
-40m alternating blue-grey siltstone and maroon mudstone
-49m blue-grey fine-grained sandstone - calcite, pyrite staining
-60m blue-grey siltstone - calcite, pyrite staining

BOREHOLE NO : G33345
DATE DRILLED : 23/11/85 to 27/11/84
CADASTRAL FARM : KRUGERS KRAAL 322
CO-ORDINATES : LATITUDE : 32°21'50" LONGITUDE :24°16'58"
TOTAL DEPTH (m): 96m CASING :6,1m of 165mm steel casing
WATER LEVEL (m): 23,11m COLLAR ELEVATION : (a.m.s.l.) :750,0m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
25m	0,1	74
34m	0,2	70
43m	0,8	75
final	0,8	81

GEOLOGY

0-3 m sandy alluvium
-4 m rounded pebbles
-6 m highly weathered kharki mudstone
-25m alternating blue-grey siltstone and maroon mudstone
-42m fine-grained dolerite
-44m blue-grey siltstone
-54m speckled blue-grey fine-grained sandstone
-96m alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33346
DATE DRILLED : 28/11/84 to 7/12/84
CADASTRAL FARM : UITKOMST 314
CO-ORDINATES : LATITUDE : 32°18'39" LONGITUDE :24°16'42"
TOTAL DEPTH (m) : 117m CASING :18m of 165mm steel casing
WATER LEVEL (m) : 6,85m COLLAR ELEVATION :(a.m.s.l) : 774,4m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
20m	0,1	134
27m	0,8	134
50m	2,6	133
116m	24,1	121 H_2S
final	24,1	121 H_2S

GEOLOGY

0-8 m	sandy alluvium
-16m	rounded pebbles
-25m	alternating blue-grey siltstone and maroon mudstone
-27m	weathered light-grey medium-grained sandstone
-69m	alternating blue-grey siltstone and maroon mudstone
-70m	blue-grey medium-grained sandstone
-83m	alternating blue-grey siltstone and maroon mudstone
-89m	speckled blue-grey medium-grained sandstone - calcite
-103m	alternating blue-grey siltstone and maroon mudstone
-116m	speckled blue-grey medium-grained sandstone
-117m	blue-grey siltstone - calcite

BOREHOLE NO : G33347
DATE DRILLED : 7/12/84 to 19/12/84
CADASTRAL FARM : UITKOMST 314
CO-ORDINATES : LATITUDE : 32°18'22" LONGITUDE : 24°16'49"
TOTAL DEPTH (m) : 70m CASING : 20,5m of 165mm steel casing
WATER LEVEL (m) : 13,18m COLLAR ELEVATION : (a.m.s.l.) : 777,4m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
17m	0,2	186
54m	9,3	143 H_2S
65m	13,1	116 H_2S
final	13,1	109 H_2S

GEOLOGY

0-12 m	sandy alluvium
-20 m	rounded pebbles
-22 m	blue-grey fine-grained sandstone
-66 m	alternating blue-grey siltstone and maroon mudstone
-70 m	speckled blue-grey medium-grained sandstone

BOREHOLE NO : G33348
DATE DRILLED : 20/12/84 to 14/1/85
CADASTRAL FARM : CORNDALE 333
CO-ORDINATES : LATITUDE : 32°18'41" LONGITUDE : 24°27'30"
TOTAL DEPTH (m): 66m CASING : 9m of 165mm steel casing
WATER LEVEL (m): 9,09m COLLAR ELEVATION : (a.m.s.l.) : 698,2m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
10m	damp	192 H_2S
23m	5,1	192 H_2S
final	5,1	221 H_2S

GEOLOGY

0-5 m	sandy alluvium
-7 m	rounded dolerite pebbles
-66m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33349
DATE DRILLED : 15/1/85 to 17/1/85, deepened 29/4/85 to 6/5/85
CADASTRAL FARM : CORNDALE 333
CO-ORDINATES : LATITUDE : 32°18'46" LONGITUDE : 24°27'13"
TOTAL DEPTH (m) : 101m CASING : 6m of 165mm steel casing
WATER LEVEL (m) : 8,33m COLLAR ELEVATION : (a.m.s.l) : 698,2m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
22m	0,6	500
final	0,6	445

GEOLOGY

0-6 m	rounded dolerite boulders
-28m	alternating light and dark blue-grey siltstone
-30m	light grey fine-grained sandstone - pyrite staining
-91m	alternating blue-grey siltstone and maroon mudstone
-99m	speckled blue-grey medium-grained sandstone - calcite
-101m	blue-grey siltstone

BOREHOLE NO : G33351
DATE DRILLED : 23/1/85 to 24/1/85
CADASTRAL FARM : CORNDALE 333
CO-ORDINATES : LATITUDE : 32°18°44° LONGITUDE : 24°27'13"
TOTAL DEPTH (m) : 42m CASING : 9m of 165mm steel casing
WATER LEVEL (m) : 6,92m COLLAR ELEVATION : (a.m.s.l.) : 698,2m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
11m	damp	434
final	damp	434

GEOLOGY

0-6 m	clayey alluvium
-8 m	dolerite boulders
-42m	alternating light and dark blue-grey siltstone

BOREHOLE NO : G33352
DATE DRILLED : 24/1/85 to 28/1/85
CADASTRAL FARM : ZEEKOEIGAT 140D
CO-ORDINATES : LATITUDE : 32°25'55" LONGITUDE : 24°12'58"
TOTAL DEPTH (m): 60m CASING : 12m of 165mm steel casing
WATER LEVEL (m): 9,83m COLLAR ELEVATION : (a.m.s.l.) : 689,0m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
8m	damp	-
16m	0,1	677
20m	5,0	667
29m	5,1	672
final	5,1	731

GEOLOGY

0-7 m	sandy alluvium
-9 m	rounded pebbles
-52m	alternating blue-grey siltstone and maroon mudstone - calcite at 40m-54m
-60m	fine-grained dolerite

BOREHOLE NO : G33353
DATE DRILLED : 29/1/85 to 30/1/85
CADASTRAL FARM : ZEEKOEIGAT 140D
CO-ORDINATES : LATITUDE : 32°24'47" LONGITUDE : 24°13'03"
TOTAL DEPTH (m) : 60m CASING : 18m of 165mm steel casing
WATER LEVEL (m) : 11,87m COLLAR ELEVATION : (a.m.s.l) : 693,6m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
20m	1,5	171
50m	4,6	194
final m	4,6	214

GEOLOGY

0-2 m	calcified sands
-20m	weathered alternating blue-grey siltstone and maroon mudstone
-44m	alternating blue-grey siltstone and maroon mudstone - calcite at 41-44m
-49m	speckled blue-grey fine-grained sandstone
-54m	alternating blue-grey siltstone & kharki mudstone - calcite
-57m	blue-grey fine-grained sandstone - calcite
-60m	blue-grey siltstone

BOREHOLE NO : G33354
DATE DRILLED : 31/1/85 to 1/2/85
CADASTRAL FARM : ZEEKOEIGAT 140D
CO-ORDINATES : LATITUDE : 32°25'11" LONGITUDE : 24°13'09"
TOTAL DEPTH (m) : 60m CASING : 21m of 165mm steel casing
WATER LEVEL (m) : 10,60m COLLAR ELEVATION : (a.m.s.l.) : 692,1m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
16m	0,2	750
25m	1,7	750
final	1,7	728

GEOLOGY

0-4 m	calcified sands
-5 m	rounded pebbles
-8 m	kharki mudstone
-16m	weathered blue-grey medium-grained sandstone
-20m	weathered kharki mudstone
-25m	weathered speckled blue-grey medium-grained sandstone
-60m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33355
DATE DRILLED : 1/2/85 to 5/2/85
CADASTRAL FARM : ZEEKOEIGAT 140D
CO-ORDINATES : LATITUDE : 32°25'11" LONGITUDE : 24°13'07"
TOTAL DEPTH (m): 60m CASING : 18m of 165mm steel casing
WATER LEVEL (m): 10,93 COLLAR ELEVATION : (a.m.s.l.) : 692,1m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
12m	0,1	762
42m	1,5	762
final	1,5	679

GEOLOGY

0-4 m	calcified sands
-5 m	rounded pebbles
-17m	kharki mudstone
-23m	weathered speckled blue-grey medium-grained sandstone
-43m	alternating blue-grey siltstone and maroon mudstone
-47m	speckled blue-grey medium-grained sandstone
-51m	blue-grey siltstone - calcite
-52m	speckled blue-grey medium-grained sandstone
-60m	blue-grey siltstone - calcite

BOREHOLE NO : G33356
DATE DRILLED : 11/2/85 to 12/2/85, deepen 8/5/85 to 9/5/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°21'27" LONGITUDE : 24°25'08"
TOTAL DEPTH (m) : 90m CASING : 12m of 165mm steel casing
WATER LEVEL (m) : 15,78m COLLAR ELEVATION : (a.m.s.l) : 693,6m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
18m	0,1	192
35m	0,3	121 H_2S
44m	6,4	84
final m	6,4	100

GEOLOGY

0-9 m	sandy loam
-29m	alternating blue-grey siltstone and maroon mudstone
-41m	speckled blue-grey medium-grained sandstone - calcite at 34m to 36m
-49m	alternating blue-grey siltstone and maroon mudstone
-50m	speckled blue-grey fine-grained sandstone
-66m	alternating blue-grey siltstone and maroon mudstone
-68m	speckled blue-grey medium-grained sandstone
-74m	blue-grey siltstone
-84m	speckled blue-grey medium-grained sandstone
-90m	alternating blue-grey siltstone and maroon sandstone

BOREHOLE NO : G33357
DATE DRILLED : 12/2/85 to 14/2/85, deepened 9/5/85 to 10/5/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°21'55" LONGITUDE : 24°25'00"
TOTAL DEPTH (m) : 88m CASING : 12m of 165mm steel casing
WATER LEVEL (m) : 9,94m COLLAR ELEVATION : (a.m.s.l.) : 693,6m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
9m	damp	-
21m	damp	-
44m	0,3	83
47m	1,0	84
final	1,6	85

GEOLOGY

0-5 m	weathered brownish siltstone
-9 m	weathered brownish speckled medium-grained sandsonte
-23m	weathered blue-grey siltstone
-36m	weathered blue-grey speckled medium-grained sandstone
-46m	alternating blue-grey siltstone and maroon mudstone
-48m	speckled blue-grey medium-grained sandstone
-69m	alternating blue-grey siltstone and maroon mudstone
-81m	speckled blue-grey medium-grained sandstone
-88m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33358
DATE DRILLED : 14/2/85 to 19/2/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°22'16" LONGITUDE : 24°24'47"
TOTAL DEPTH (m): 87m CASING : 11m of 165mm steel casing
WATER LEVEL (m): 7,30m COLLAR ELEVATION : (a.m.s.l.) : 695,1m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
25m	0,1	165
58m	7,5	148
80m	11,3	138
final	11,6	132

GEOLOGY

0-3 m	highly weathered kharki mudstone
-14m	weathered blue-grey siltstone
-16m	weathered brownish fine-grained sandstone
-32m	alternating blue-grey siltstone and maroon mudstone
-58m	speckled blue-grey medium-grained sandstone
-63m	blue-grey siltstone
-83m	speckled blue-grey medium-grained sandstone
-87m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33359
DATE DRILLED : 20/2/85 to 28/2/85
CADASTRAL FARM : DOORDRIFT 323
CO-ORDINATES : LATITUDE : 32°20'57" LONGITUDE :24°25'09"
TOTAL DEPTH (m) : 96m CASING :17m of 165mm steel casing
WATER LEVEL (m) : 10,46m COLLAR ELEVATION :(a.m.s.l) : 690,6m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
18m	1,9	168
final	2,8	156

GEOLOGY

0-10m clayey alluvium
-21m weathered speckled brownish medium-grained sandstone
-27m alternating blue-grey siltstone and maroon mudstone
-40m speckled blue-grey medium-grained sandstone
-57m alternating blue-grey siltstone and maroon mudstone
-60m speckled blue-grey fine-grained sandstone
-96m alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33360
DATE DRILLED : 1/3/85 to 5/3/85
CADASTRAL FARM : OUDEDRIFT A133
CO-ORDINATES : LATITUDE : 32°24'36" LONGITUDE : 24°16'40"
TOTAL DEPTH (m) : 60m CASING : 6m of 165mm steel casing
WATER LEVEL (m) : 4,51m COLLAR ELEVATION : (a.m.s.l.) : 676,8

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
16m	1,7	119
final	1,7	193

GEOLOGY

0-51m alternating blue-grey siltstone and maroon mudstone - calcite at 41-44m
-57m speckled blue-grey fine-grained sandstone - calcite
-60m blue-grey siltstone

BOREHOLE NO : G33363
DATE DRILLED : 21/3/85 to 25/3/85
CADASTRAL FARM : GROOTE VLAKTE 132
CO-ORDINATES : LATITUDE : 32°25'00" LONGITUDE : 24°18'21"
TOTAL DEPTH (m): 60m CASING : 5m of 165mm steel casing
WATER LEVEL (m): 4,88m COLLAR ELEVATION : (a.m.s.l.) : 670,7m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
6m	0,1	510
7m	0,4	400 H_2S
22m	1,8	389 H_2S
40m	3,3	398 H_2S
final	3,5	407 H_2S

GEOLOGY

0-36m alternating blue-grey siltstone and maroon mudstone
-42m speckled blue-grey medium-grained sandstone - calcite
-43m blue-grey siltstone - calcite
-45m speckled blue-grey medium-grained sandstone - calcite
-53m blue-grey siltstone
-55m speckled blue-grey medium-grained sandstone
-60m alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33365
DATE DRILLED : 7/5/85 to 8/5/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°21'27" LONGITUDE : 24°25'08"
TOTAL DEPTH (m) : 53m
CASING : 37,2m of 165mm steel casing
WATER LEVEL (m) : 14,18m
COLLAR ELEVATION : (a.m.s.1) : 693,6m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)	
16m	damp		
18m	damp		
24m	0,1		
32m	1,6	115 H_2S	cased off
41m	1,2	113 H_2S	
45m	2,0	124 H_2S	
47m	10,5	127 H_2S	
final	9,8	117 H_2S	

GEOLOGY

0-3 m	sandy loam
-26m	alternating blue-grey siltstone and maroon mudstone
-27m	speckled blue-grey medium-grained sandstone
-31m	alternating blue-grey siltstone and maroon mudstone
-41m	speckled blue-grey medium-grained sandstone
-49m	alternating blue-grey siltstone and maroon mudstone - calcite
-51m	speckled blue-grey medium-grained sandstone
-53m	blue-grey siltstone

BOREHOLE NO : G33393
DATE DRILLED : 11/5/85 to 20/5/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°22'16" LONGITUDE : 24°24'27"
TOTAL DEPTH (m) : 89m
CASING : 29m of 165mm steel casing
WATER LEVEL (m) : 7,99m
COLLAR ELEVATION : (a.m.s.l.) : 695,1m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)	
16m	1,8	175	cased off
63m	0,1	69	
final	0,1	70	

GEOLOGY

0-14m	weathered alternating blue-grey siltstone and khaki mudstone
-17m	weathered brownish fine-grained sandstone
-32m	alternating blue-grey siltstone and maroon mudstone
-55m	speckled blue-grey medium-grained sandstone
-63m	blue-grey siltstone
-81m	speckled blue-grey medium-grained sandstone
-89m	green-grey siltstone

BOREHOLE NO : G33394
DATE DRILLED : 21/5/85 to 22/5/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°22'16" LONGITUDE : 24°24'27"
TOTAL DEPTH (m): 65m
CASING : 37m of 165mm steel casing
WATER LEVEL (m): 7,90m
COLLAR ELEVATION : (a.m.s.l.) : 695,1m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)	
30m	0,1	100	cased off
58m	2,9	156	
62m	6,2	081	
63m	7,7	093	
final	8,0	093	

GEOLOGY

0-14m	weathered alternating blue-grey siltstone and maroon mudstone
-17m	speckled blue-grey medium-grained sandstone
-35m	alternating blue-grey siltstone and maroon mudstone
-57m	speckled blue-grey medium-grained sandstone
-63m	blue-grey siltstone - pyrite staining
-65m	speckled blue-grey medium-grained sandstone

BOREHOLE NO : G33395
DATE DRILLED : 23/5/85 to 27/5/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°22'16" LONGITUDE : 24°24'47"
TOTAL DEPTH (m) : 90m CASING : 64m of 165mm steel casing
WATER LEVEL (m) : 7,92m COLLAR ELEVATION : (a.m.s.l) : 695,1m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)	
17m	damp	177	
25m	4,4	186	
57m	7,8	173	cased off
80m	0,7	128	
84m	4,4	165	
final	5,0	149	

GEOLOGY

0-12m	alternating blue-grey siltstone and maroon mudstone
-18m	speckled blue-grey medium-grained sandstone
-29m	alternating blue-grey siltstone and maroon mudstone
-55m	speckled blue-grey medium-grained sandstone
-61m	alternating blue-grey siltstone and maroon mudstone
-79m	speckled blue-grey fine-grained sandstone
-90m	alternating blue-grey siltstone and maroon mudstone - calcite at 85m

BOREHOLE NO : G33396
DATE DRILLED : 27/5/85 to 30/5/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°22'52" LONGITUDE : 24°24'46"
TOTAL DEPTH (m) : 76m CASING : 6m of 165mm steel casing
WATER LEVEL (m) : 9,91m COLLAR ELEVATION : (a.m.s.l.) : 698,2m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
16m	0,8	152
43m	4,2	170
final	4,3	167

GEOLOGY

0-7 m	blue-grey siltstone
-12m	speckled blue-grey medium-grained sandstone - calcite at 12m
-22m	alternating blue-grey siltstone and maroon mudstone
-41m	speckled blue-grey medium-grained sandstone - calcite
-42m	blue-grey siltstone
-48m	speckled blue-grey medium-grained sandstone
-60m	blue-grey siltstone
-63m	speckled blue-grey medium-grained sandstone
-64m	blue-grey siltstone
-66m	speckled blue-grey fine-grained sandstone
-76m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33397
DATE DRILLED : 3/6/85 to 6/6/85
CADASTRAL FARM : UITKOMST 314
CO-ORDINATES : LATITUDE : 32°18'39" LONGITUDE : 24°16'42"
TOTAL DEPTH (m): 55m CASING : 36m of 165mm steel casing
WATER LEVEL (m): 9,64m COLLAR ELEVATION : (a.m.s.l.) : 774,4m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)	
20	2,3	-	cased off
44	damp	-	
49	1,5	-	

GEOLOGY

0-10m	sandy alluvium
-19m	rounded pebbles
-24m	weathered speckled blue-grey fine-grained sandstone
-55m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33398
DATE DRILLED : 6/6/85 to 12/6/85
CADASTRAL FARM : UITKOMST 314
CO-ORDINATES : LATITUDE : 32°18'39" LONGITUDE : 24°16'42"
TOTAL DEPTH (m) : 118m CASING : 64m of 165mm steel casing
WATER LEVEL (m) : 5,94m COLLAR ELEVATION : (a.m.s.l) : 774,4m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)	
16m	0,1	130	
22m	0,2	121	
27m	1,8	111	
59m	4,7	121	cased off
96m	0,1	093 H_2S	
108m	1,3	095 H_2S	
111m	5,2	106 H_2S	
114m	7,7	114 H_2S	
final	7,7	116 H_2S	

GEOLOGY

0-10m	sandy alluvium
-20m	rounded pebbles
-24m	blue-grey siltstone
-32m	light grey medium-grained sandstone
-53m	alternating blue-grey siltstone and maroon mudstone
-55m	speckled blue-grey medium-grained sandstone
-82m	alternating blue-grey siltstone and maroon mudstone
-93m	speckled blue-grey medium-grained sandstone
-102m	blue-grey siltstone
-109m	speckled blue-grey medium-grained sandstone - calcite at 108m
-118m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33399
DATE DRILLED : 13/6/85 to 17/6/85
CADASTRAL FARM : GRASRAND 334
CO-ORDINATES : LATITUDE : 32°18'38" LONGITUDE : 24°24'41"
TOTAL DEPTH (m) : 109m CASING : 3m of 165mm steel casing
WATER LEVEL (m) : 5,91m COLLAR ELEVATION : (a.m.s.l.) : 716,5m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
9m	damp	097
37m	11,0	069 H_2S
final	11,0	070 H_2S

GEOLOGY

0-53m	blue-grey siltstone - calcite
-57m	blue-grey fine-grained sandstone - calcite
-61m	maroon mudstone
-62m	blue-grey fine-grained sandstone - calcite
-90m	alternating blue-grey siltstone and maroon mudstone - calcite
-92m	speckled blue-grey medium-grained sandstone - calcite
-96m	blue-grey siltstone - calcite
-98m	speckled blue-grey medium-grained sandstone - calcite
-101m	alternating blue-grey siltstone and maroon mudstone
-109m	speckled blue-grey medium-grained sandstone - calcite

BOREHOLE NO : G33400
DATE DRILLED : 17/6/85 to 19/6/85
CADASTRAL FARM : GRASRAND 334
CO-ORDINATES : LATITUDE : 32°18'44" LONGITUDE : 24°24'41"
TOTAL DEPTH (m): 126m CASING : 10m of 165mm steel casing
WATER LEVEL (m): 5,92m COLLAR ELEVATION : (a.m.s.l.) : 716,5m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
12m	damp	-
32m	0,7	074
69m	1,2	137
final	1,3	120

GEOLOGY

0-9 m	alluvium and rounded pebbles
-37 m	alternating blue-grey siltstone and maroon mudstone
-39 m	blue-grey fine-grained sandstone
-50 m	alternating blue-grey siltstone and maroon mudstone
-52 m	blue-grey fine-grained sandstone - calcite
-84 m	alternating blue-grey siltstone and maroon mudstone - calcite at 53m to 72m
-87 m	speckled blue-grey medium-grained calcite
-100m	alternating blue-grey siltstone and maroon mudstone - calcite at 98m
-105m	speckled blue-grey medium-grained sandstone - calcite
-111m	alternating blue-grey siltstone and maroon mudstone - calcite
-116m	speckled blue-grey medium-grained sandstone - calcite
-126m	blue-grey siltstone

BOREHOLE NO : G33401
DATE DRILLED : 19/6/85 to 20/6/85
CADASTRAL FARM : GRASRAND 334
CO-ORDINATES : LATITUDE : 32°18'37" LONGITUDE : 24°24'43"
TOTAL DEPTH (m) : 44m CASING : 5m of 200mm steel casing
WATER LEVEL (m) : 8,35m COLLAR ELEVATION : (a.m.s.l) : 717,9m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
18m	4,4	105 H_2S
36m	7,0	072 H_2S
38m	10,2	072 H_2S
42m	28,0	072 H_2S
final	39,0	072 H_2S

GEOLOGY

0-2 m	calcareous sandy alluvium
-10m	alternating blue-grey siltstone and maroon mudstone
-12m	blue-grey fine-grained sandstone
-17m	maroon mudstone
-39m	speckled blue-grey medium-grained sandstone - calcite and pyrite staining
-44m	alternating blue-grey and maroon mudstone - calcite

BOREHOLE NO : G33402
DATE DRILLED : 20/6/85 to 21/6/85
CADASTRAL FARM : GRASRAND 334
CO-ORDINATES : LATITUDE : 32°18'36" LONGITUDE : 24°24'42"
TOTAL DEPTH (m) : 59m CASING : 11m of 165mm steel casing
WATER LEVEL (m) : 8,88m COLLAR ELEVATION : (a.m.s.l.) : 719,5m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
13m	0,3	080
44m	8,8	090
final	8,8	085

GEOLOGY

0-5 m	calcareous sandy alluvium
-16m	weathered blue-grey siltstone
-26m	speckled blue-grey medium-grained sandstone - calcite
-33m	alternating blue-grey siltstone and maroon mudstone
-34m	speckled blue-grey medium-grained sandstone - calcite
-59m	blue-grey siltstone - calcite

BOREHOLE NO : G33403
DATE DRILLED : 24/6/85 to 25/6/85
CADASTRAL FARM : DOORDRIFT 323
CO-ORDINATES : LATITUDE : 32°20'44" LONGITUDE : 24°23'00"
TOTAL DEPTH (m): 83m CASING : 6m of 165mm steel casing
WATER LEVEL (m): 10,63m COLLAR ELEVATION : (a.m.s.l.) : 716,5m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
15m	0,1	133
20m	3,4	133
25m	5,0	134
52m	6,2	128
final	6,2	100

GEOLOGY

0-19m	alternating blue-grey siltstone and maroon mudstone
-20m	weathered speckled brownish medium-grained sandstone
-52m	alternating blue-grey siltstone and maroon mudstone - calcite at 37m to 52m
-64m	speckled blue-grey medium-grained sandstone - calcite
-83m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33404
DATE DRILLED : 25/6/85 to 26/6/85
CADASTRAL FARM : DOORDRIFT 323
CO-ORDINATES : LATITUDE : 32°20'42" LONGITUDE : 24°23'00"
TOTAL DEPTH (m) : 59m CASING : 6m of 165mm steel casing
WATER LEVEL (m) : 10,83m COLLAR ELEVATION : (a.m.s.l) : 716,5m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
17m	0,2	132
23m	1,8	138
final	2,9	117

GEOLOGY

0-24m	alternating blue-grey siltstone and maroon mudstone
-25m	weathered speckled brownish medium-grained sandstone
-59m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33405
DATE DRILLED : 26/6/85 to 16/7/85
CADASTRAL FARM : DOORDRIFT 323
CO-ORDINATES : LATITUDE : 32°20'18" LONGITUDE : 24°22'32"
TOTAL DEPTH (m) : 101m CASING : 6m of 165mm steel casing
WATER LEVEL (m) : 13,08m COLLAR ELEVATION : (a.m.s.l.) : 719,5m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
16m	damp	117
34m	2,2	118
final	2,2	097

GEOLOGY

0-13 m	weathered alternating blue-grey siltstone and maroon mudstone
-15 m	speckled blue-grey medium-grained sandstone
-16 m	maroon mudstone
-20 m	speckled blue-grey medium-grained sandstone
-24 m	blue-grey siltstone
-29 m	speckled blue-grey medium-grained sandstone
-56 m	alternating blue-grey siltstone and maroon mudstone
-57 m	speckled blue-grey medium-grained sandstone
-59 m	blue-grey siltstone
-60 m	speckled blue-grey medium-grained sandstone
-71 m	alternating blue-grey siltstone and maroon mudstone
-74 m	speckled blue-grey medium-grained sandstone
-78 m	blue-grey siltstone
-82 m	speckled blue-grey medium-grained sandstone
-101m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33406
DATE DRILLED : 16/7/85 to 23/7/85
CADASTRAL FARM : DOORDRIFT 323
CO-ORDINATES : LATITUDE : 32°20'51" LONGITUDE : 24°23'04"
TOTAL DEPTH (m): 101m CASING : 12m of 165mm steel casing
WATER LEVEL (m): 9,99m COLLAR ELEVATION : (a.m.s.l.) : 714,9m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
17m	5,8	128
final	5,6	112

GEOLOGY

0-11 m	sandy alluvium
-29 m	alternating blue-grey siltstone and maroon mudstone
-36 m	blue-grey fine-grained sandstone
-39 m	maroon mudstone
-40 m	blue-grey fine-grained sandstone
-93 m	alternating blue-grey siltstone and maroon mudstone - calcite
-97 m	speckled blue-grey medium-grained sandstone - calcite
-100m	blue-grey siltstone
-101m	speckled blue-grey medium-grained sandstone

BOREHOLE NO : G33407
DATE DRILLED : 23/7/85 to 25/7/85
CADASTRAL FARM : DOORDRIFT 323
CO-ORDINATES : LATITUDE : 32°20'58" LONGITUDE : 24°23'06"
TOTAL DEPTH (m) : 100m CASING : 15m of 165mm steel casing
WATER LEVEL (m) : 8,69m COLLAR ELEVATION : (a.m.s.l) : 708,8m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
22m	0,8	138
41m	12,1	118
final	12,1	117

GEOLOGY

0-13 m	sandy alluvium
-15 m	rounded pebbles
-61 m	alternating blue-grey siltstone and maroon mudstone - calcite and pyrite staining from 33m to 61m
-65 m	speckled blue-grey medium-grained sandstone - calcite
-100m	alternating blue-grey siltstone and maroon mudstone - calcite from 87m to 100m

BOREHOLE NO : G33408
DATE DRILLED : 25/7/85 to 29/7/85
CADASTRAL FARM : DOORDRIFT 323
CO-ORDINATES : LATITUDE : 32°20'50" LONGITUDE : 24°23'06"
TOTAL DEPTH (m) : 100m CASING : 16m of 165mm steel casing
WATER LEVEL (m) : 8,50m COLLAR ELEVATION : (a.m.s.l.) : 708,8m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
24m	0,5	149
41m	1,8	139
68m	5,6	117
final	5,6	118

GEOLOGY

0-12 m	sandy alluvium
-15 m	rounded pebbles
-20 m	alternating blue-grey siltstone and maroon mudstone
-24 m	speckled blue-grey medium-grained sandstone
-67 m	alternating blue-grey siltstone and maroon mudstone - calcite from 33m to 67m
-69 m	speckled blue-grey medium-grained sandstone - calcite and pyrite staining
-82 m	alternating blue-grey siltstone and maroon sandstone - calcite
-83 m	speckled blue-grey medium-grained sandstone
-100m	alternating blue-grey siltstone and maroon mudstone

BOREHOLE NO : G33409
DATE DRILLED : 30/7/85 to 31/7/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°21'38" LONGITUDE : 24°28'54"
TOTAL DEPTH (m): 60m CASING : 12m of 200mm steel casing
WATER LEVEL (m): 8,47m COLLAR ELEVATION : (a.m.s.l.) : 663,1m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
12m	1,8	483
34m	5,6	486
54m	10,2	489
final	10,2	472

GEOLOGY

0-7 m	alluvium
-12m	rounded pebbles
-15m	highly weathered brownish siltstone
-24m	alternating weathered blue-grey siltstone and maroon mudstone
-31m	highly weathered speckled blue-grey medium-grained sandstone
-34m	alternating blue-grey siltstone and maroon mudstone
-36m	speckled blue-grey medium-grained sandstone
-47m	alternating blue-grey siltstone and maroon mudstone
-49m	speckled blue-grey medium-grained sandstone
-56m	alternating blue-grey siltstone and maroon mudstone
-60m	speckled blue-grey medium-grained sandstone

BOREHOLE NO : G33410
DATE DRILLED : 31/7/85 to 1/8/85
CADASTRAL FARM : KLIPDRIFT 426
CO-ORDINATES : LATITUDE : 32°21'46" LONGITUDE : 24°28'54"
TOTAL DEPTH (m) : 71m CASING : 11m of 165mm steel casing
WATER LEVEL (m) : 7,87m COLLAR ELEVATION : (a.m.s.l) : 660,0m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
16m	3,6	452
53m	5,3	421
final	5,3	

GEOLOGY

0-4 m	sandy alluvium
-6 m	rounded pebbles
-28m	alternating weathered blue-grey siltstone and maroon mudstone
-31m	weathered speckled blue-grey medium-grained sandstone
-32m	blue-grey siltstone
-34m	speckled blue-grey medium-grained sandstone
-45m	alternating blue-grey siltstone and maroon mudstone
-48m	speckled blue-grey medium-grained sandstone
-56m	alternating blue-grey siltstone and maroon mudstone
-61m	speckled blue-grey medium-grained sandstone
-67m	alternating blue-grey siltstone and maroon mudstone
-71m	speckled blue-grey medium-grained sandstone

BOREHOLE NO : G33411
DATE DRILLED : 2/8/85 to 8/8/85
CADASTRAL FARM : BLOEMFONTEIN 429
CO-ORDINATES : LATITUDE : 32°25'22" LONGITUDE : 24°21'17"
TOTAL DEPTH (m) : 101m CASING : 5m of 165mm steel casing
WATER LEVEL (m) : 11,29m COLLAR ELEVATION : (a.m.s.l.) : 661,6m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
34m	damp	155
37m	4,5	140
final	4,5	138

GEOLOGY

0-5 m	boulders
-13 m	highly speckled blue-grey medium-grained sandstone
-20 m	speckled blue-grey medium-grained sandstone
-53 m	alternating blue-grey siltstone and maroon mudstone - calcite
-56 m	speckled blue-grey medium-grained sandstone - calcite
-72 m	alternating blue-grey siltstone and maroon mudstone - calcite
-73 m	speckled blue-grey medium-grained sandstone - calcite
-81 m	alternating blue-grey siltstone and maroon mudstone - calcite
-91 m	speckled blue-grey medium-grained sandstone - calcite
-99 m	alternating blue-grey siltstone and maroon mudstone
-100m	speckled blue-grey medium-grained sandstone
-101m	maroon mudstone

BOREHOLE NO : G33412
DATE DRILLED : 8/8/85 to 12/8/85
CADASTRAL FARM : BLOEMFONTEIN 429
CO-ORDINATES : LATITUDE : 32°25'20" LONGITUDE : 24°21'15"
TOTAL DEPTH (m): 65m CASING : 5m of 165mm steel casing
WATER LEVEL (m): 13,30m COLLAR ELEVATION : (a.m.s.l.) : 664,6m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
26m	1,1	154
final	1,1	152

GEOLOGY

0-17m	highly weathered blue-grey siltstone
-20m	weathered speckled blue-grey medium-grained sandstone
-25m	alternating blue-grey siltstone and maroon mudstone
-27m	speckled blue-grey medium-grained sandstone - calcite
-29m	blue-grey siltstone - calcite
-30m	speckled blue-grey medium-grained sandstone - calcite
-35m	alternating blue-grey siltstone and maroon mudstone - calcite
-36m	speckled blue-grey medium-grained sandstone - calcite
-48m	alternating blue-grey siltstone and maroon mudstone - calcite
-50m	speckled blue-grey medium-grained sandstone - calcite
-65m	alternating blue-grey siltstone and maroon mudstone - calcite

BOREHOLE NO : G33413
DATE DRILLED : 12/8/85 to 13/8/85
CADASTRAL FARM : BLOEMFONTEIN 429
CO-ORDINATES : LATITUDE : 32°25'41" LONGITUDE : 24°21'21"
TOTAL DEPTH (m) : 59m CASING : 11m of 165mm steel casing
WATER LEVEL (m) : 5,34m COLLAR ELEVATION : (a.m.s.l) : 646,3m

DEPTH OF INTERCEPTIONS (m)	BLOW-OUT YIELD (ℓ/s)	CONDUCTIVITY (mS/m)
9	damp	1175
37	1,1	1112
final	1,1	1075

GEOLOGY

0-9 m	sandy alluvium
-11m	weathered blue-grey siltstone
-19m	speckled blue-grey medium-grained sandstone
-59m	alternating blue-grey siltstone and maroon mudstone

APPENDIX 4 :

AQUIFER TEST DATA

Multiple piezometer construction diagrams

LEGEND

GEOLOGY

- Alluvium
- Siltstone and Mudstone
- Sandstone
- Dolerite

BOREHOLE CONSTRUCTION

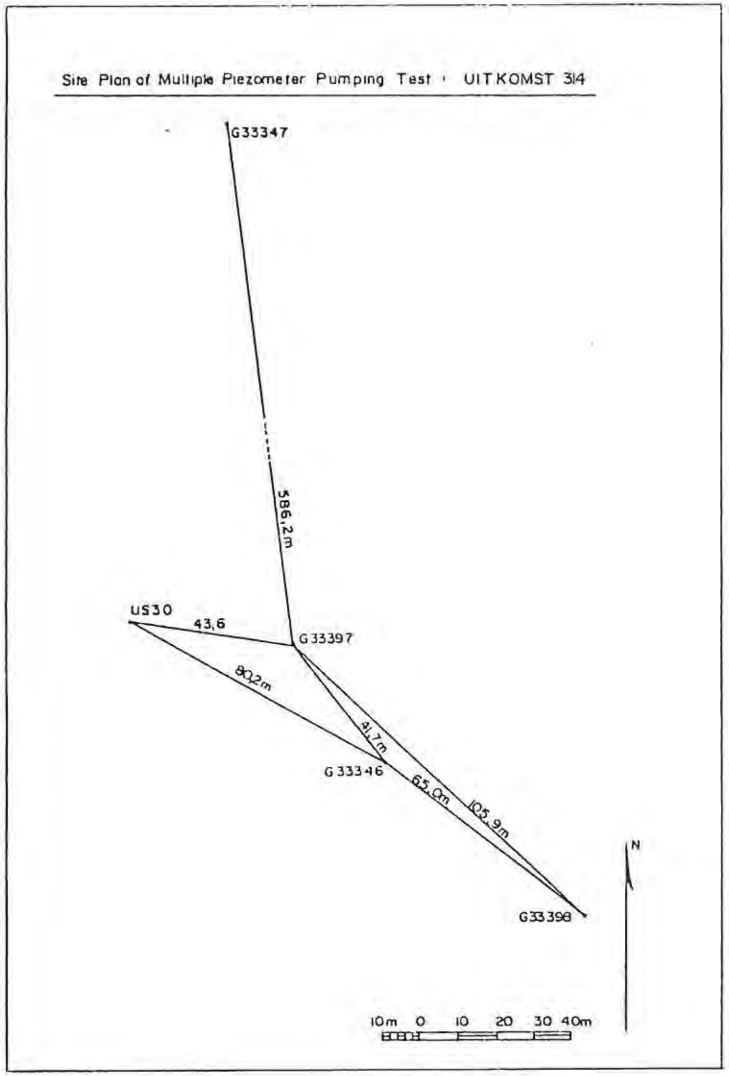
- Solid PVC casing
- Perforated PVC casing
- Solid steel casing
- 3/4" Gravel
- 1/4" Gravel
- Bentonite plug
- Drilling chips
- 0,1 — Individual water strike and blow yield (l/s)
- 01234 — Piezometer number
- l=8,53m — Water level

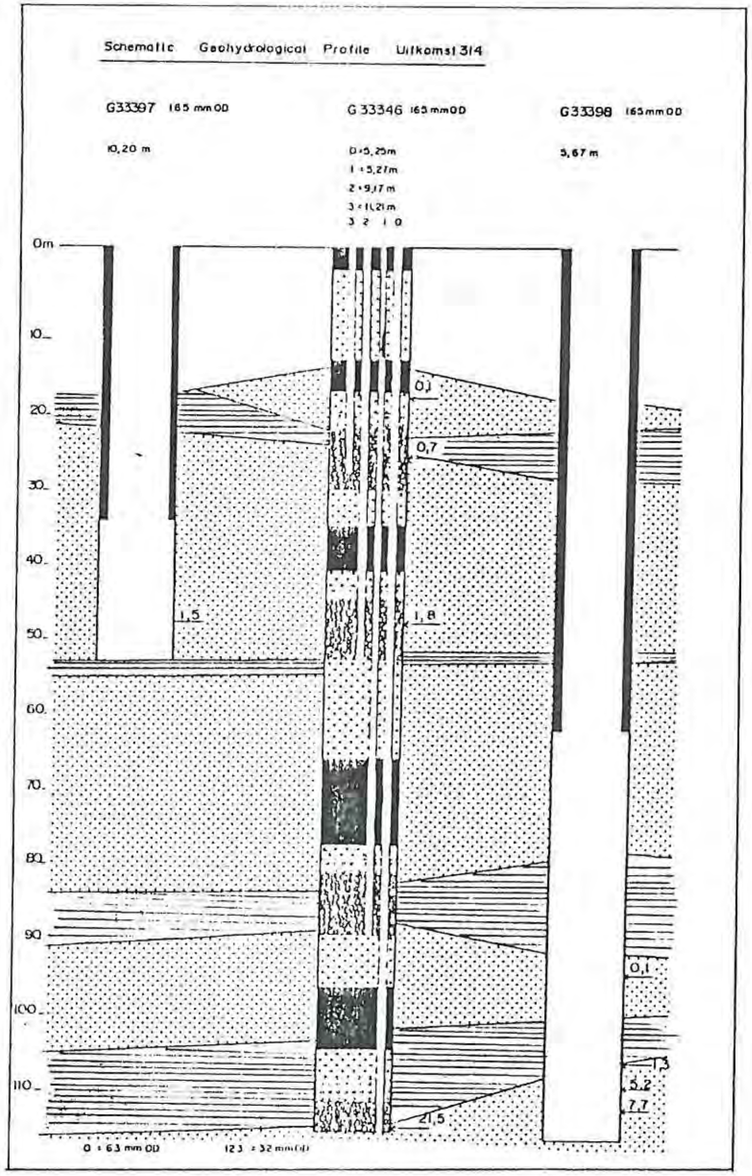
Conceptual flow and hydraulic models

LEGEND

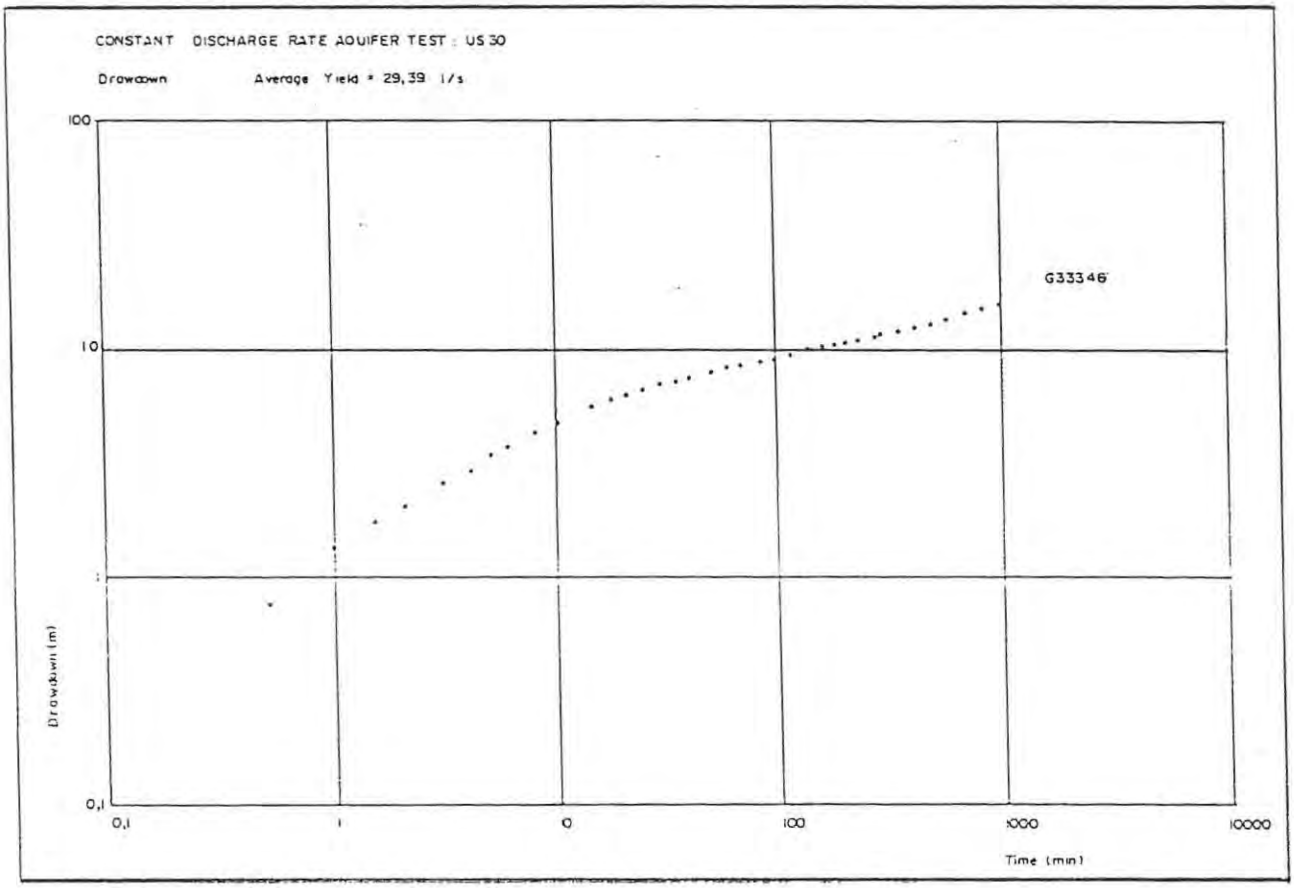
- Lithological boundary
- Rest water level
- Fracture
- Flow direction
- G33402 — Borehole
- Casing
- Pump intake
- Multiple piezometer

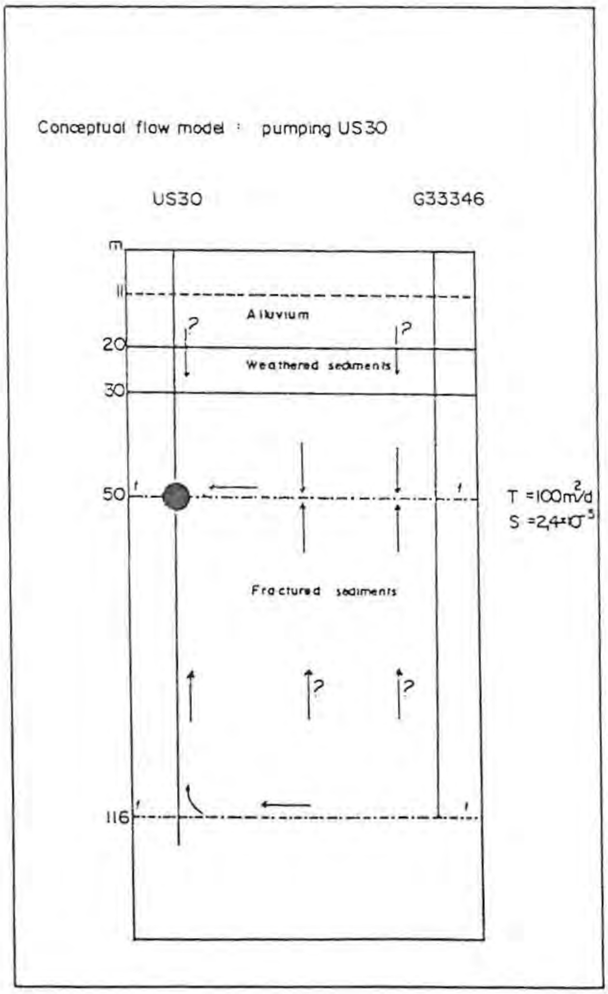
AQUIFER TEST SITE : UITKOMST 314



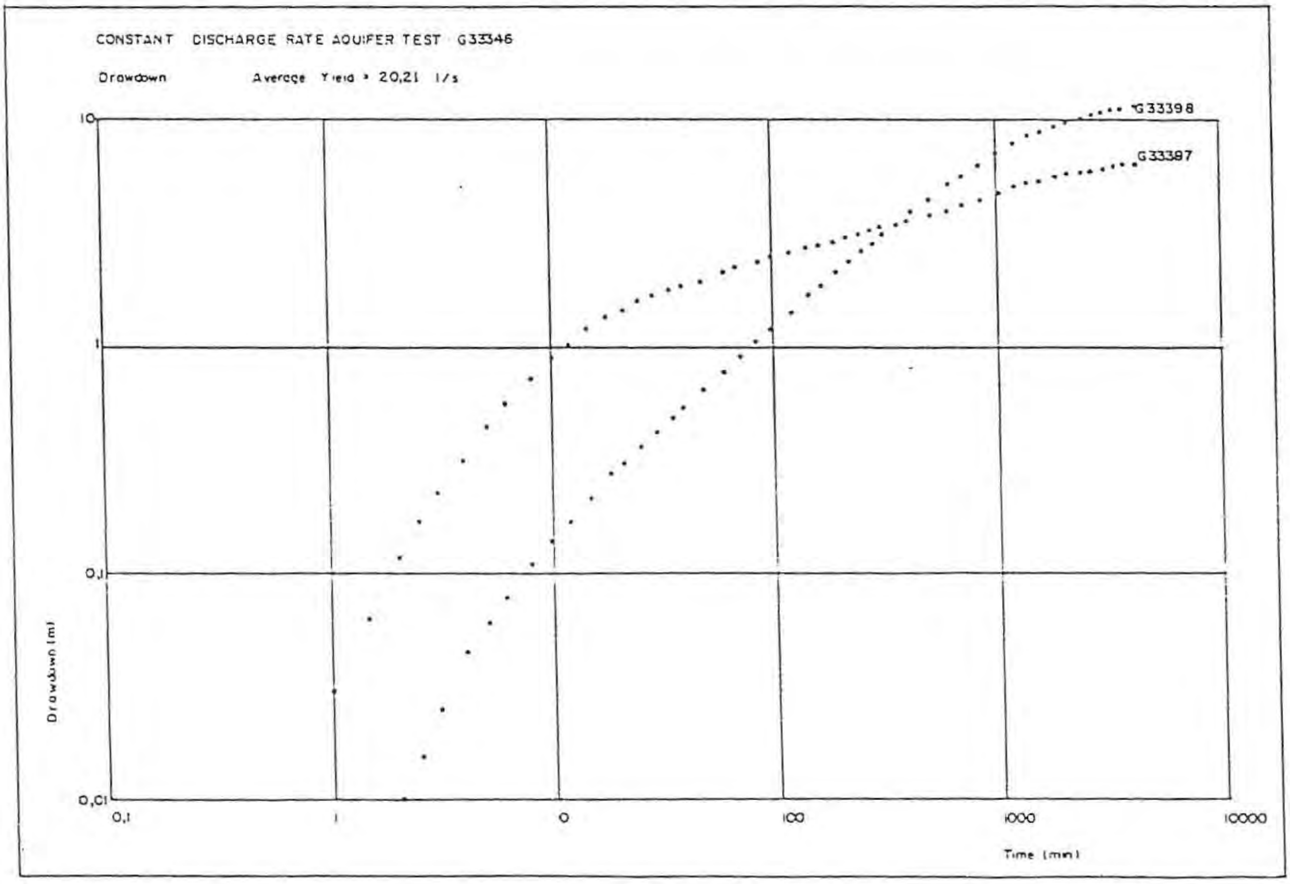


- water levels in G33346 indicate that alluvium is partly saturated
- groundwater is under increasing pressure with depth
- if vertical flow takes place or is possible, it is in an upward direction

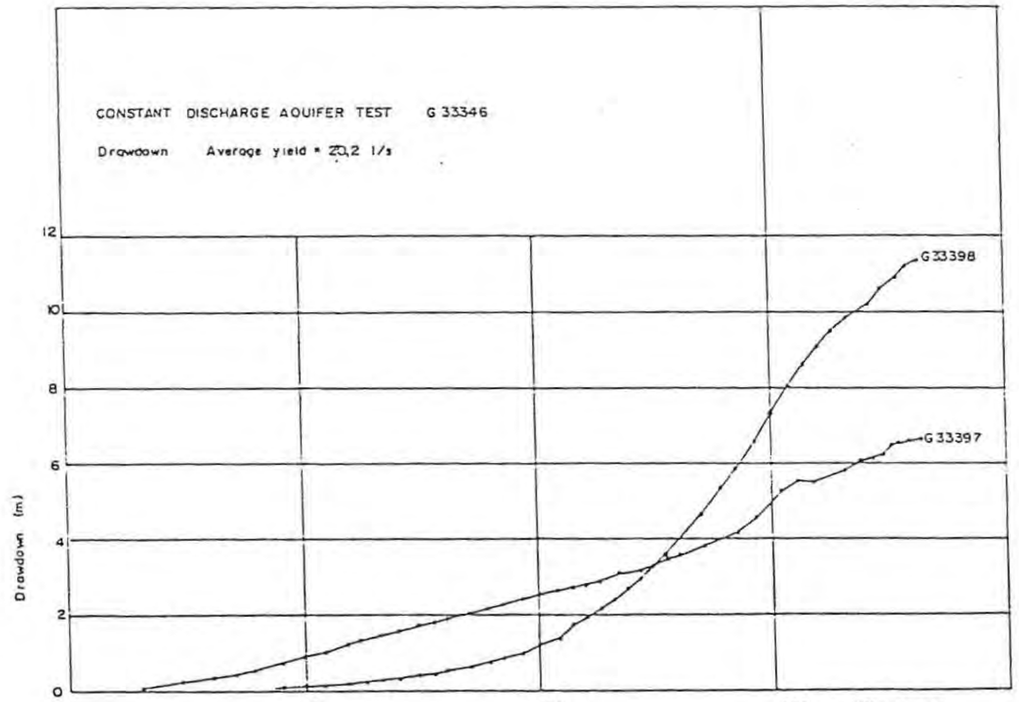




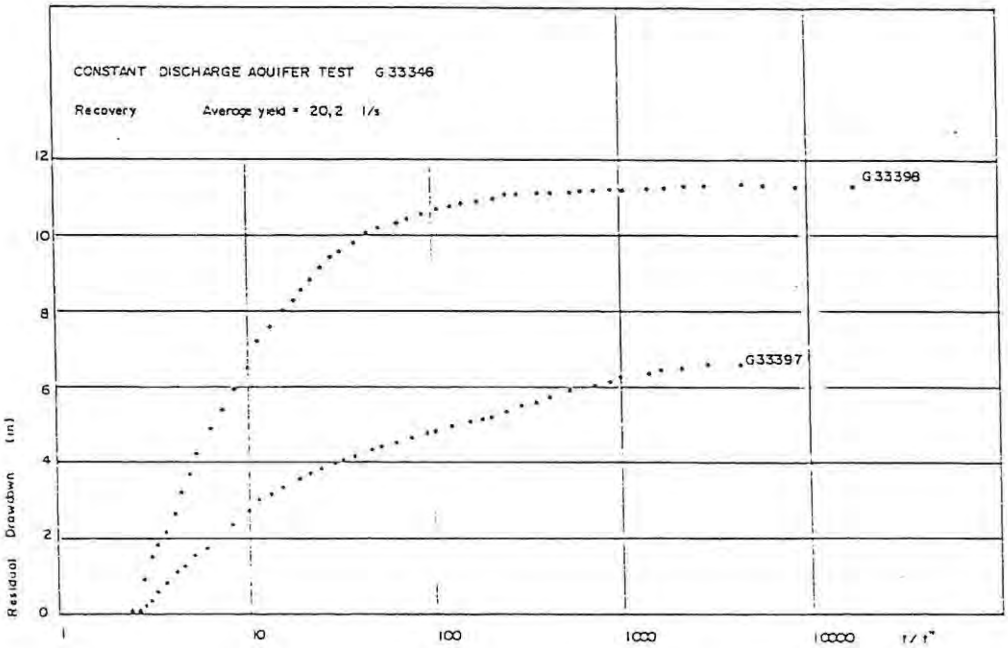
- typical standard test approach
- discharge water presumably derived mainly from upper fracture, contribution from lower fracture not known
- t/s curve reflects pseudo-radial flow (fracture dewatering)
- leakage from matrix rock, if present, is not yet apparent
- T and S values considered representative of upper fracture
- interpretation methods : Theis curve-matching, Chow straight-line



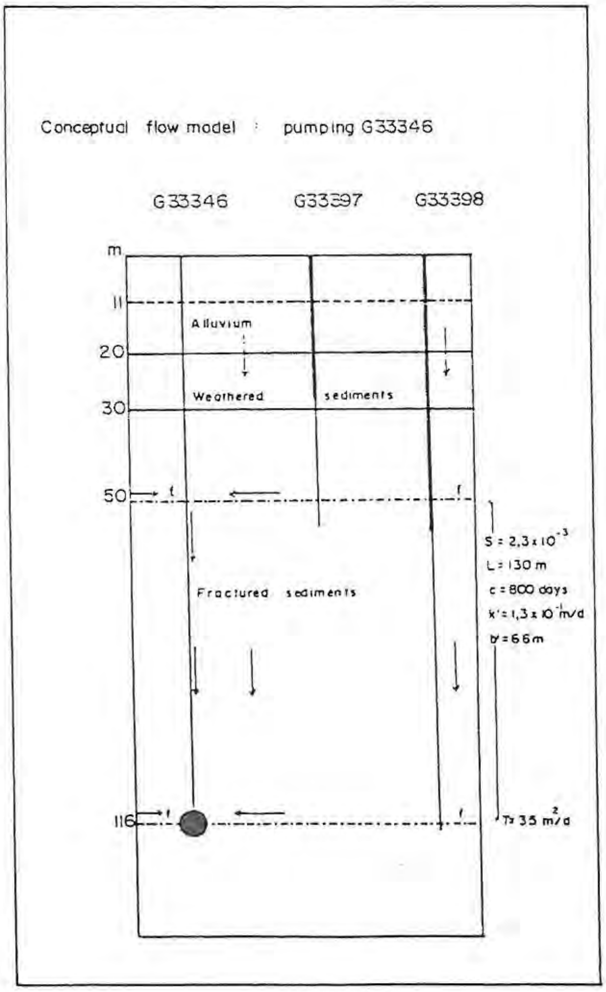
CONSTANT DISCHARGE RATE AQUIFER TEST G33346
Drawdown Average Yield = 20,21 l/s
G33398
G33397
10
1
0,1
0,01
Drawdown (m)
0,1
1
10
100
1000
10000
Time (min)



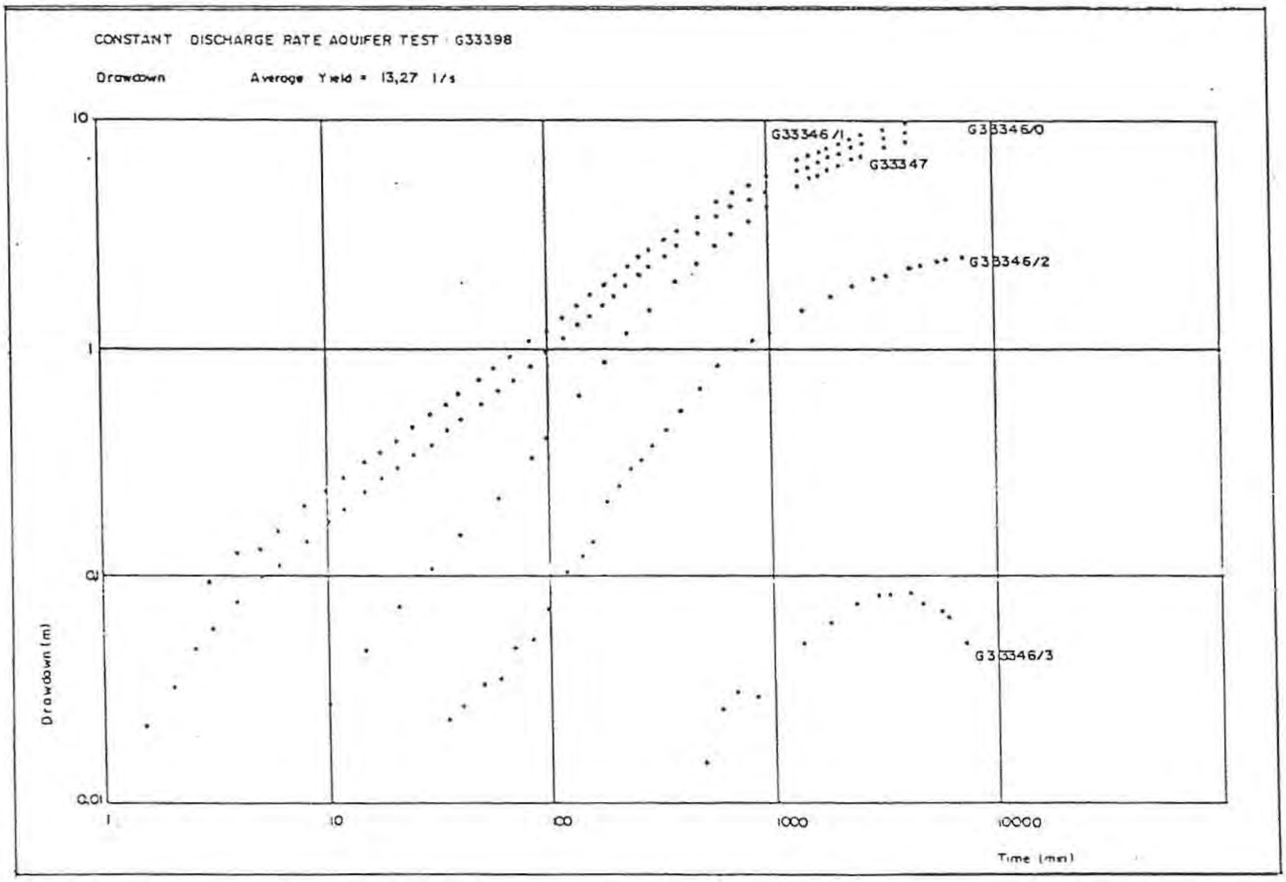
CONSTANT DISCHARGE AQUIFER TEST G 33346
Drawdown Average yield = 20,2 l/s
G33398
G33397
12
10
8
6
4
2
0
Drawdown (m)
1
10
100
1000
Time (min.)

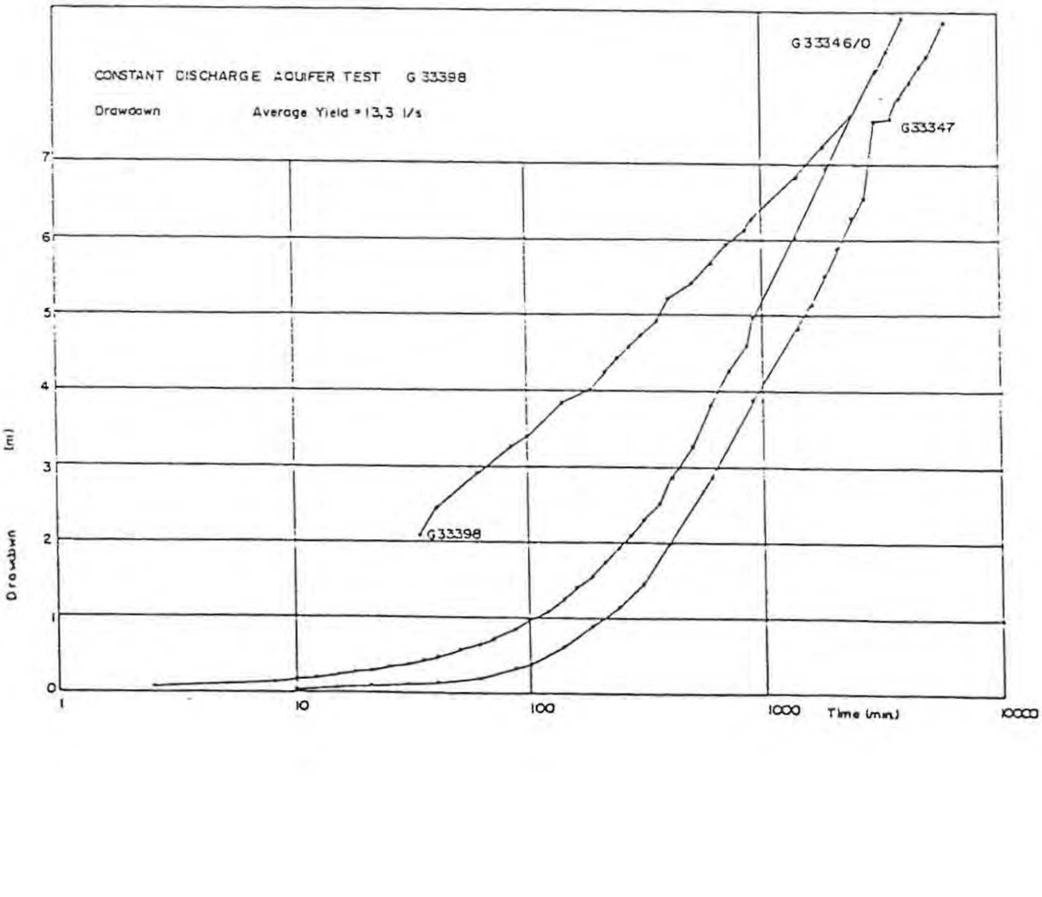


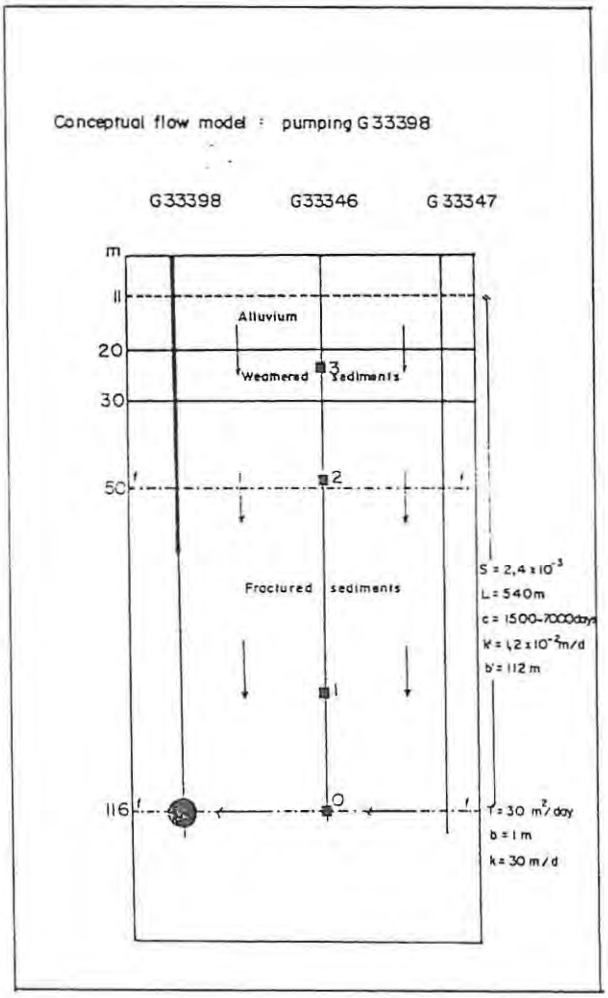
- this plot clearly shows that the Theis recovery method is difficult to use for the interpretation of the recovery data



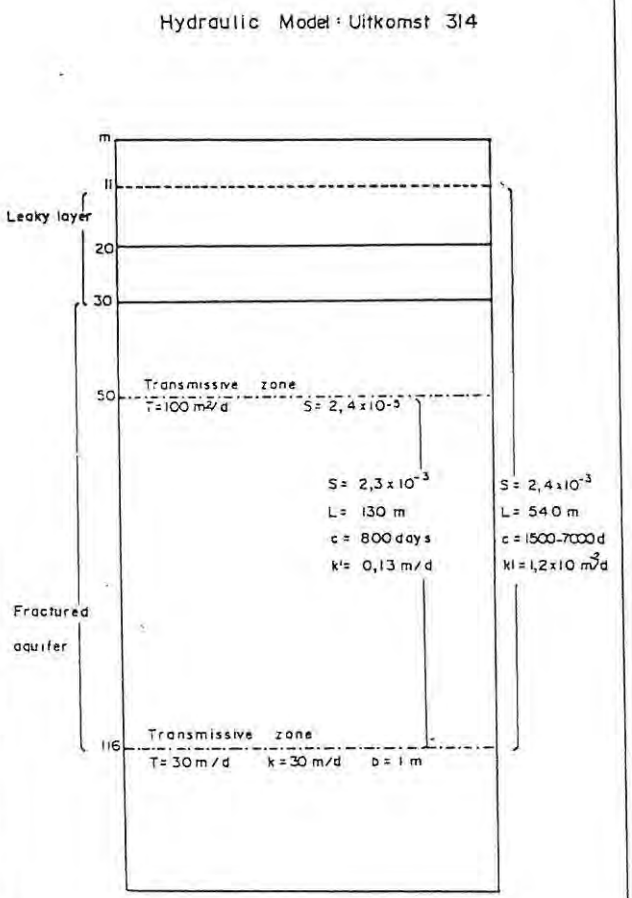
- the relative contribution of the upper fracture to the yield is unknown, but is probably negligible at later times thus interpreted results for G33397 are suspect
- interpreted hydraulic parameters are representative of the lower fracture and lower matrix block
- interpretation methods : Walton curve-matching method, Hantush I straight-line method


CONSTANT DISCHARGE RATE AQUIFER TEST G33398
Drawdown
Average Yield = 13,27 l/s
G33346/1
G33346/0
G33347
G33346/2
G33346/3
Drawdown (m)
Time (min)
10
1
0.01
1
10
100
1000
10000


CONSTANT DISCHARGE AQUIFER TEST G 33398
Drawdown
Average Yield = 13,3 l/s
G33346/0
G33347
G33398
Drawdown (m)
Time (min)
0
1
2
3
4
5
6
7
1
10
100
1000
10000



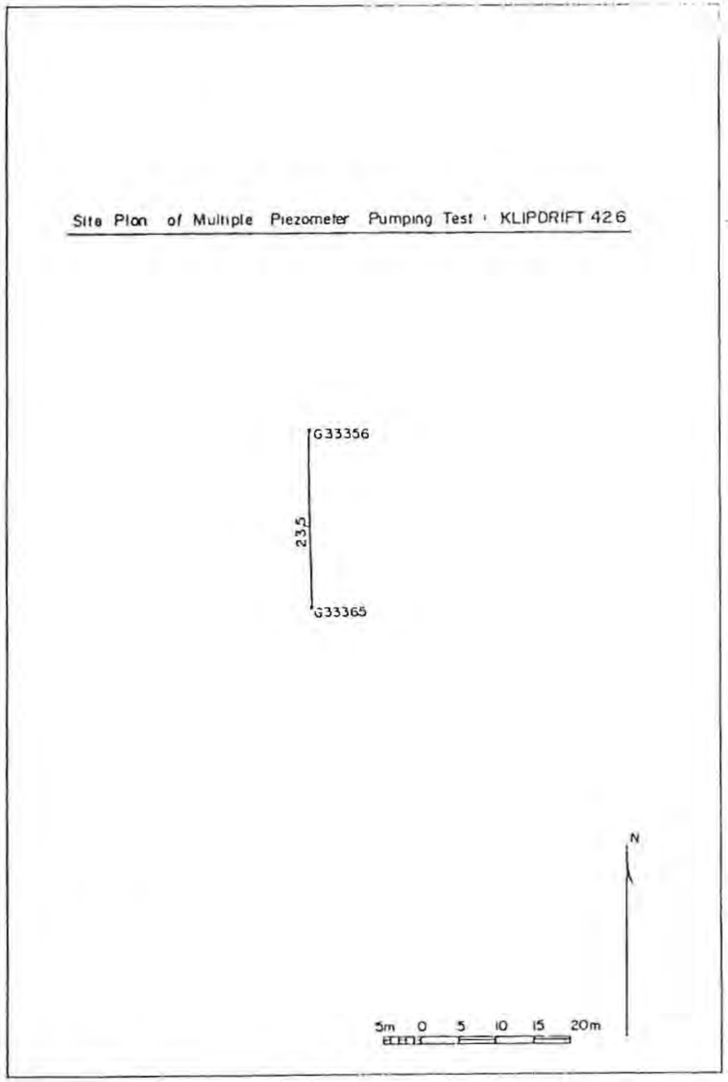
- curve G33346/3 is typical of water level recession in a leaky layer, later affected by infiltrating discharge water
- G33346/0, G33346/1 and G33347 are situated in the same transmissive zone
- G33346/2 may be an expression of leakage and/or vertical flow
- interpretation methods : Walton curve-matching, Chow straight-line

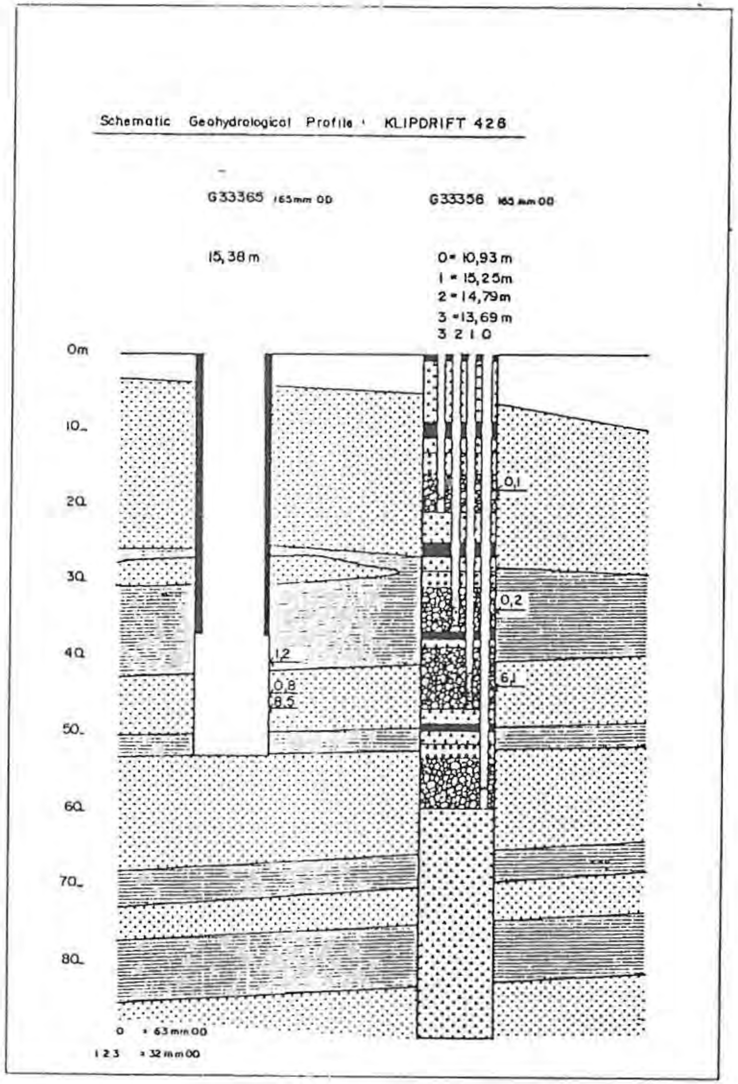


- the fractured sediments between the two fracture zones are less resistive than the rock above the upper fracture
- storativity and vertical permeability of the aquifer is fairly high
- T-value for the upper fracture is probably an overestimate (being derived from standard test, the drawdown was positively influenced by leakage and flow from the lower fracture) T is closer to 10 m^2/d
- US30 can produce at a rate of : short term = 30ℓ/s
  medium term = 20ℓ/s
  long term = 12ℓ/s

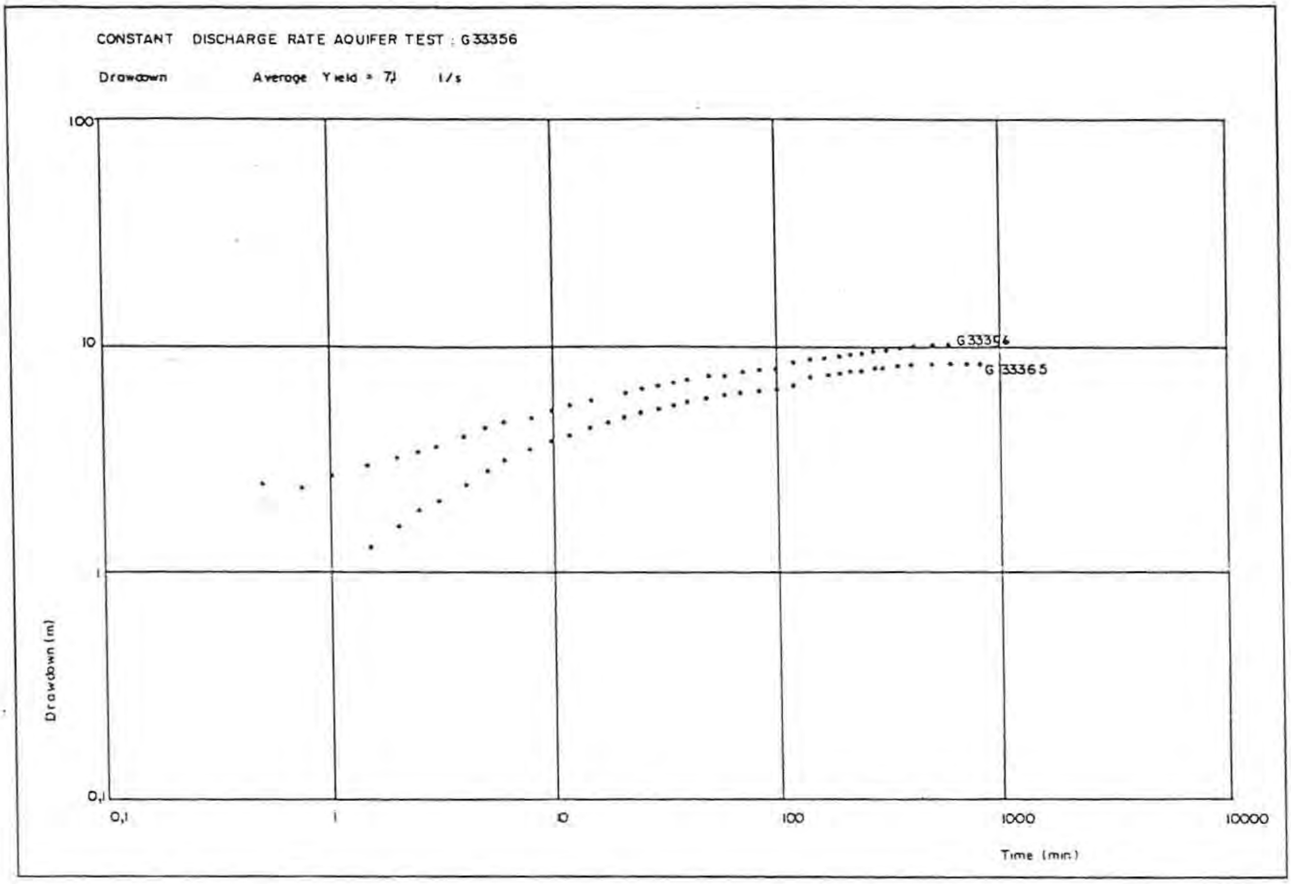
AQUIFER TEST SITE 1 : KLIPDRIFT 426

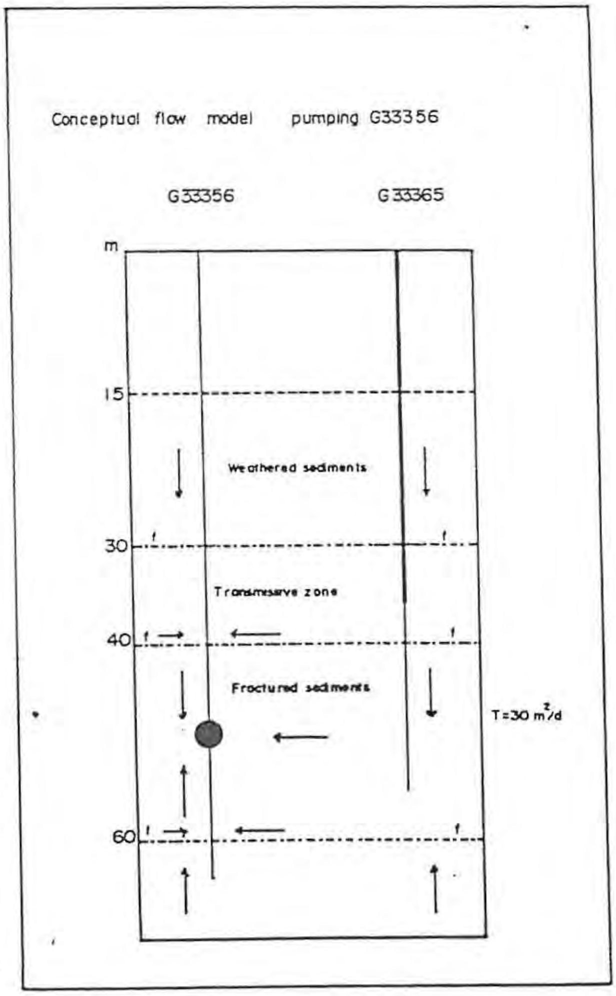
(see fig. 4 for geological cross-section)



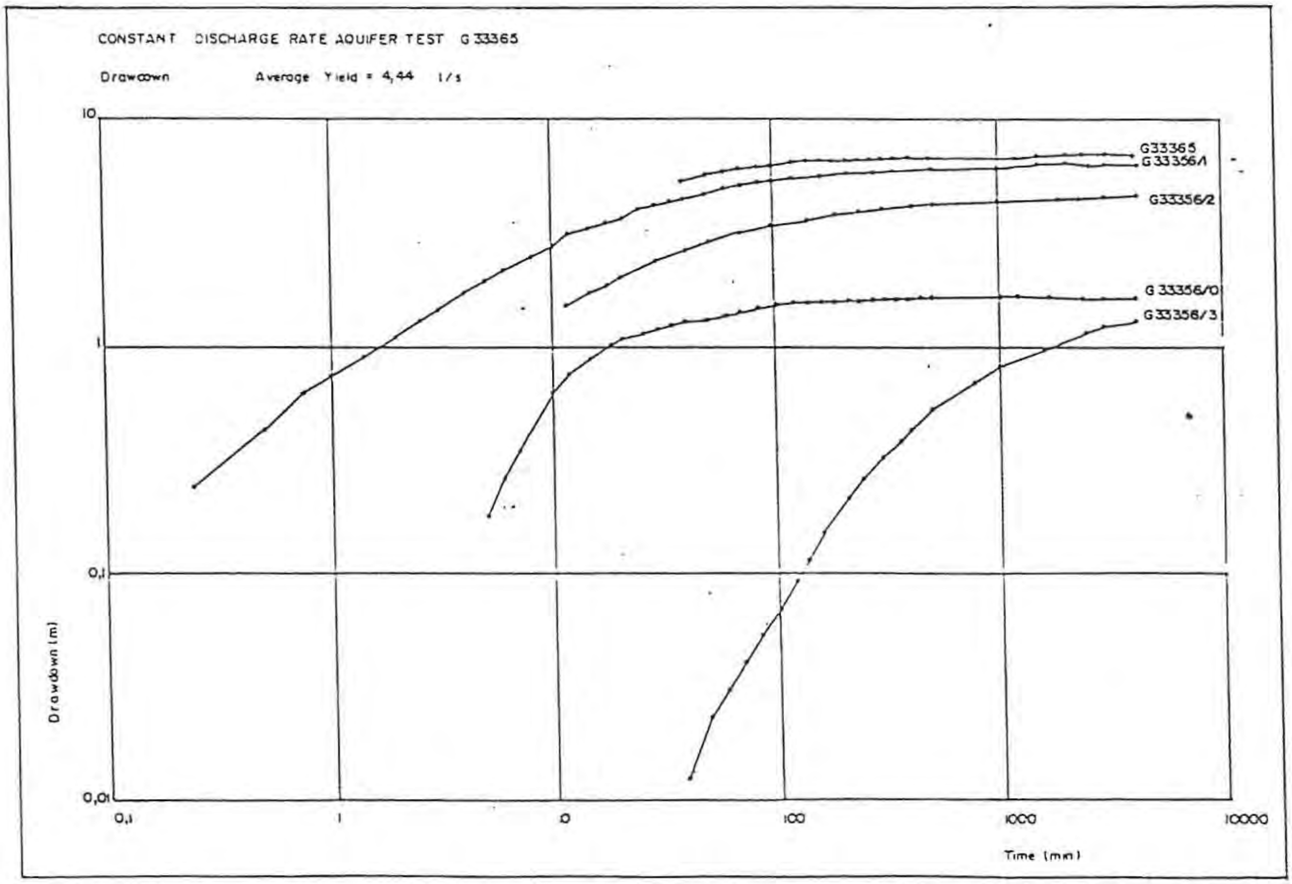


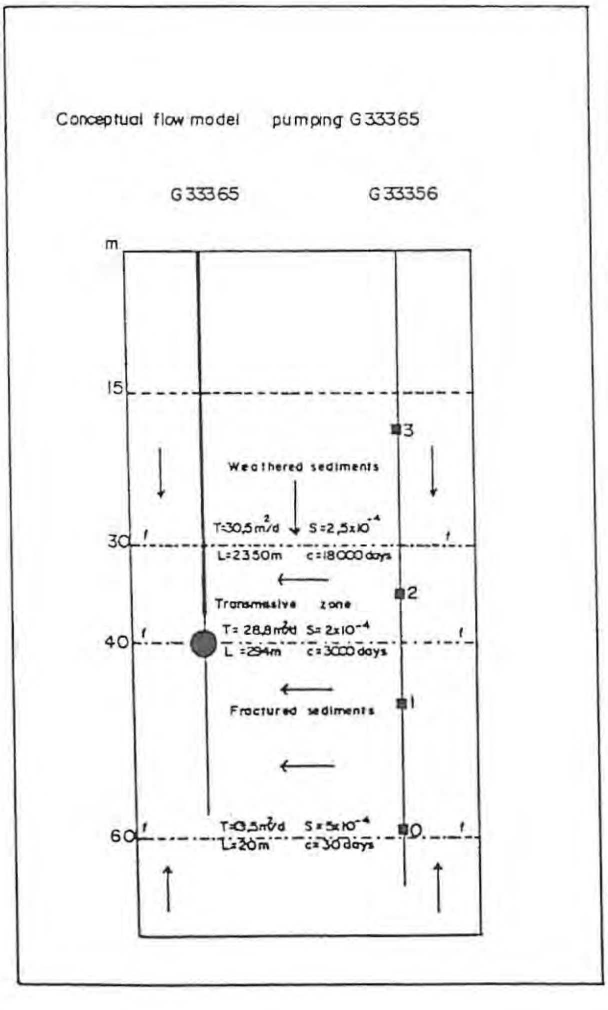
- water levels indicate that under steady state rest conditions, groundwater flow concentrates in the fractured sandstone between 30 m and 40 m
- recharge therefore comes from both alluvial deposits of the Swart River and from underflow from the southern dolerite hills



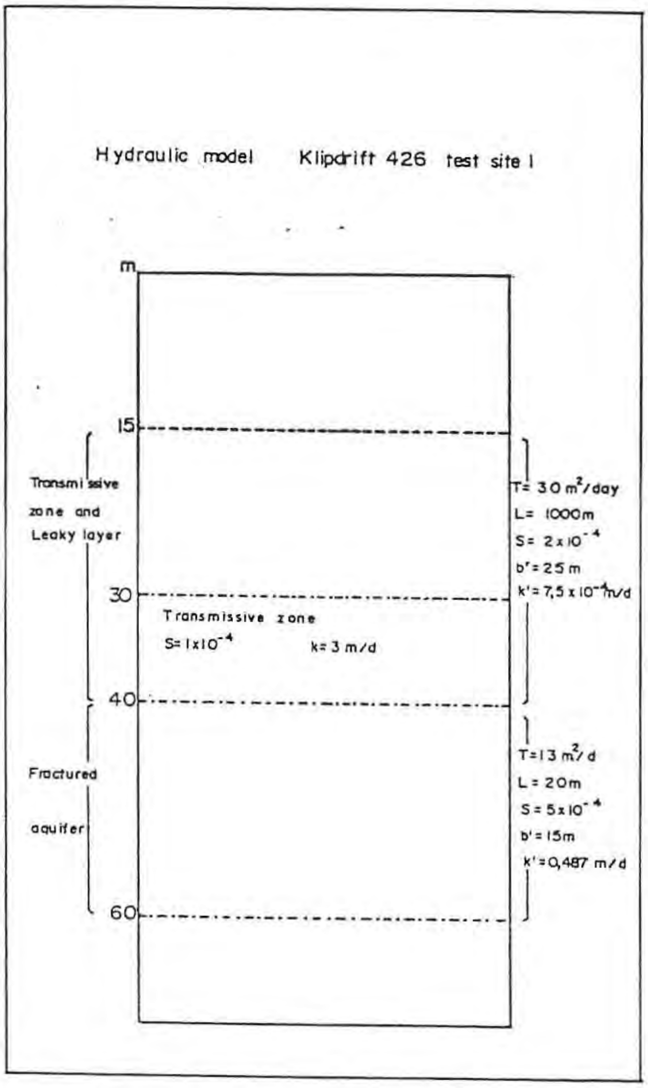


- linear flow is apparent at early times on test hole curve
- drawdown is otherwise typical for an isotropic, homogeneous semi-confined (leaky) aquifer
- interpretation methods : Walton curve-matching, Hantush I straight-line





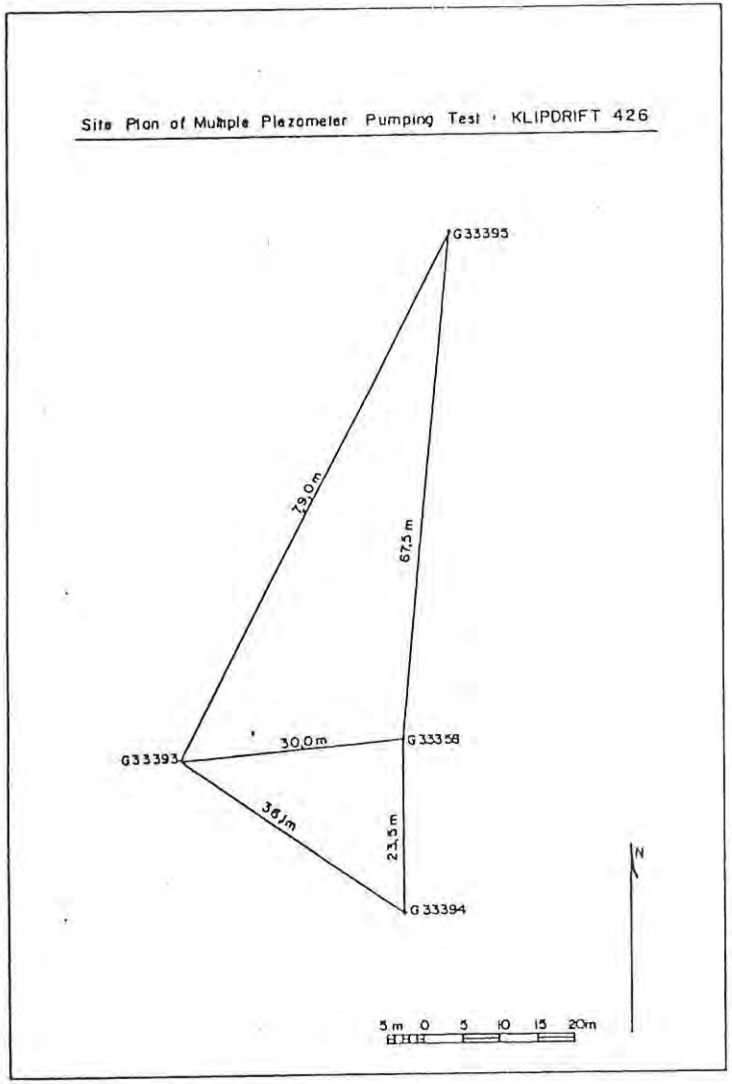
- curve G33356/3 indicates a typical response in a leaky layer
- t/s curves are similar to those obtained from the standard test
- fractured aquifer is semi-confined
- interpretation methods : Walton curve-matching, Hantush I straight-line

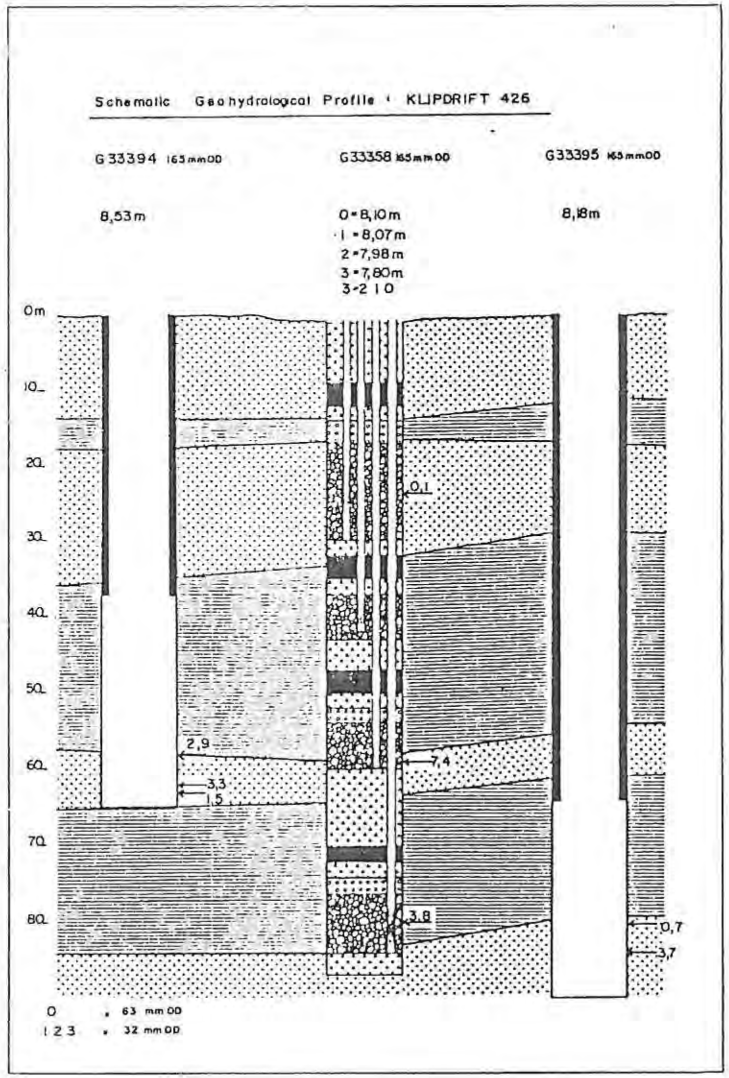


- the local aquifer system is :
  - i) at least two-layered with two transmissive production zones and both an upper and intermediate leaky layer
  - ii) anisotropic, particularly in a vertical direction
  - iii) laterally continuous

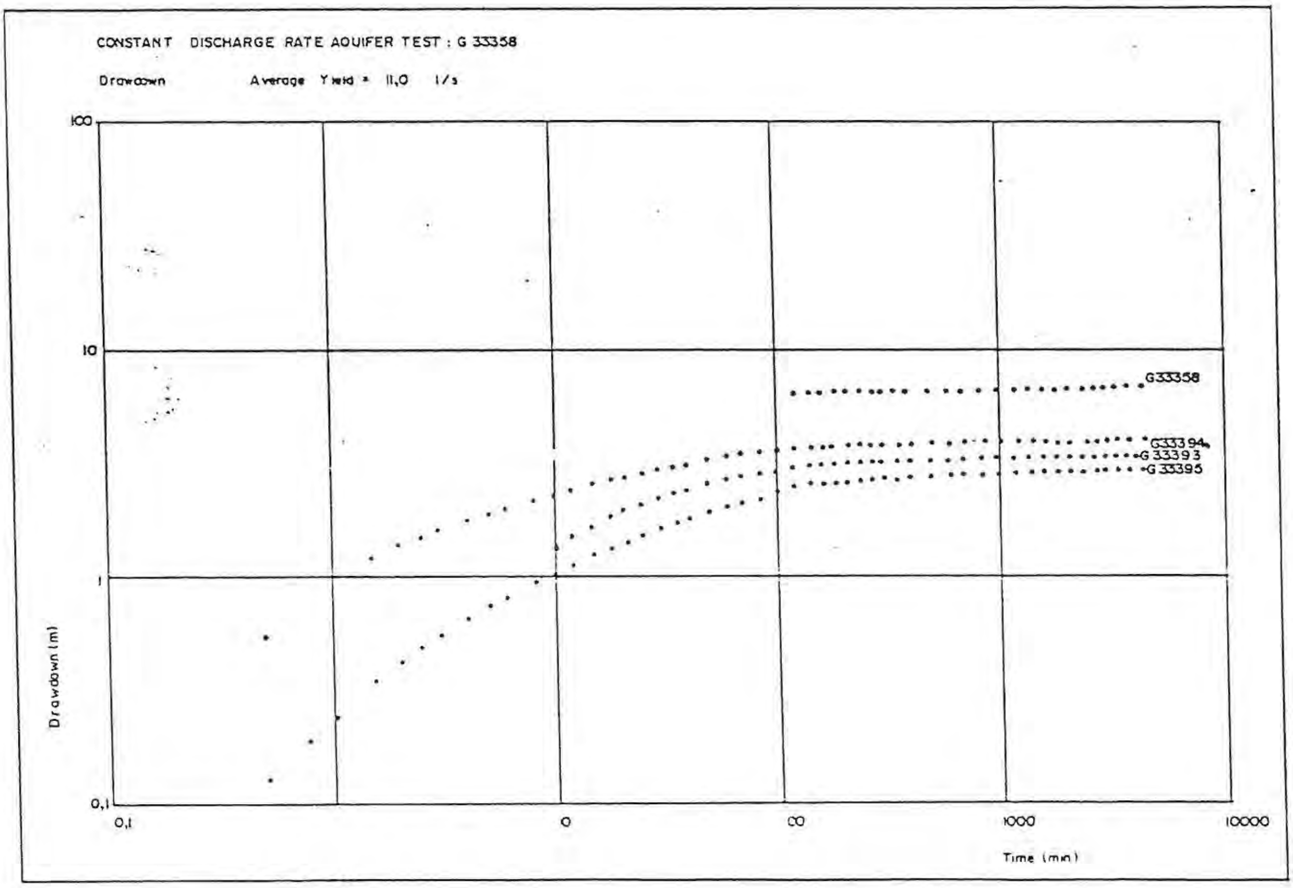
AQUIFER TEST SITE 2 : KLIPDRIFT 426

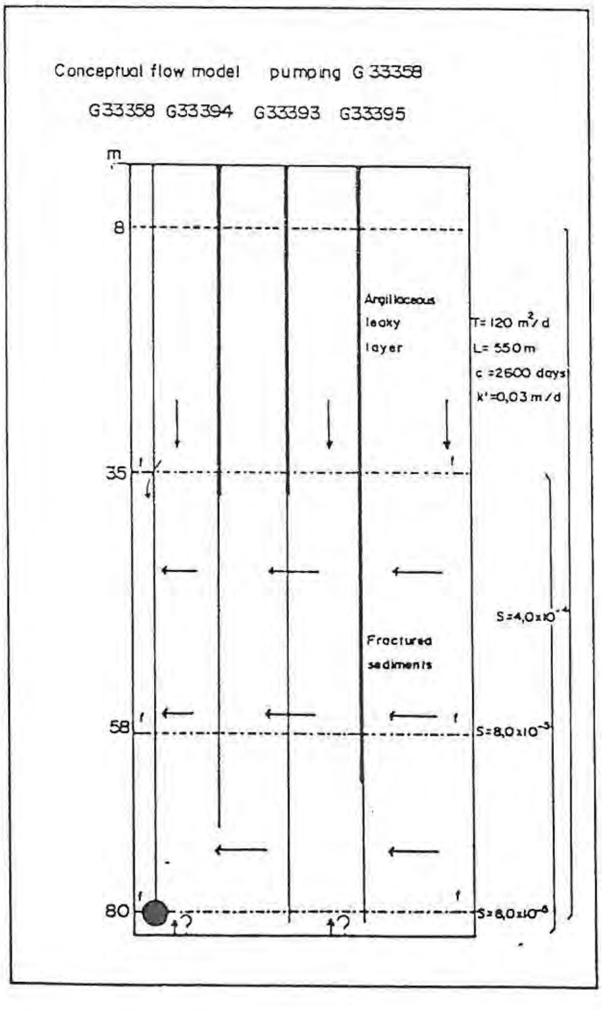
(see fig. 4 for geological cross-section)



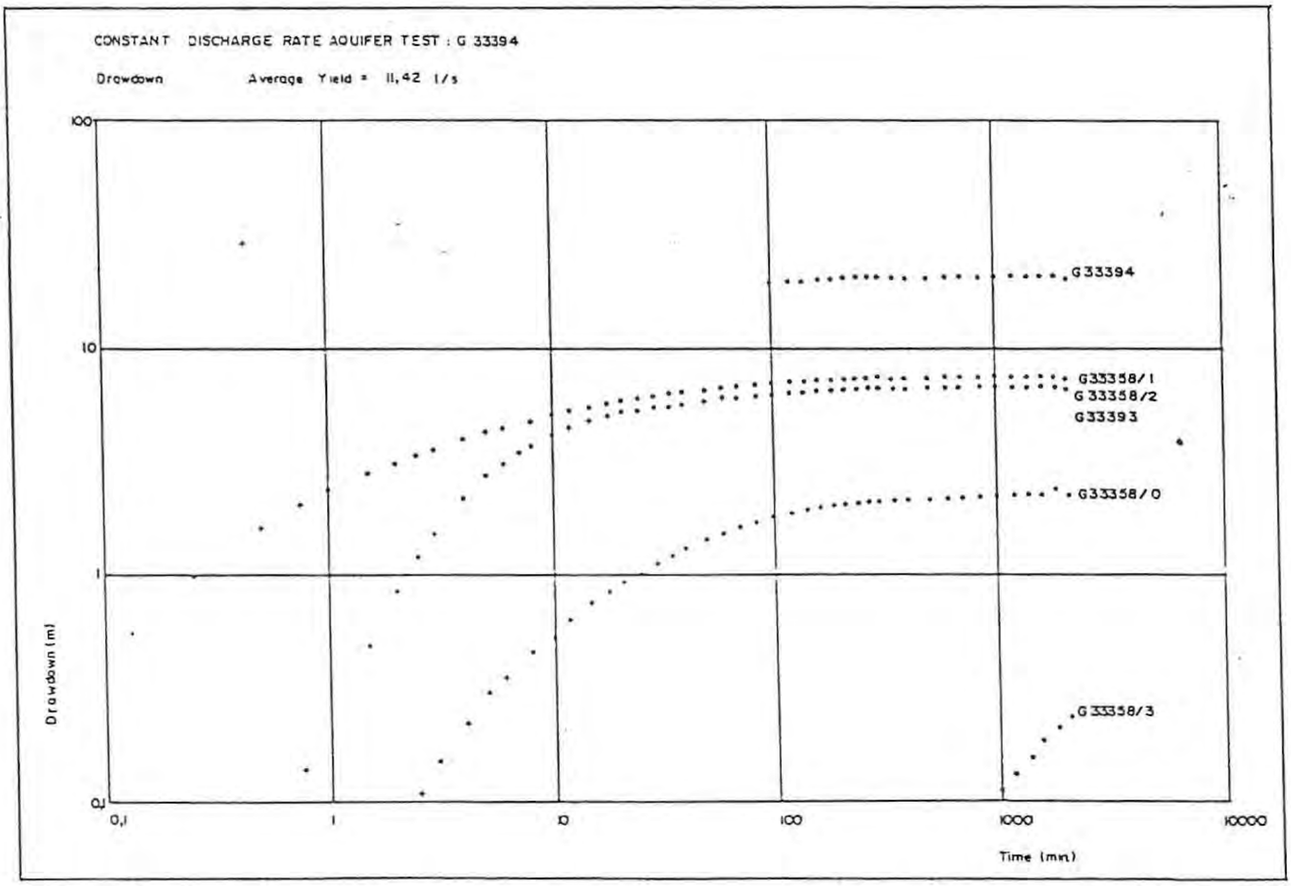


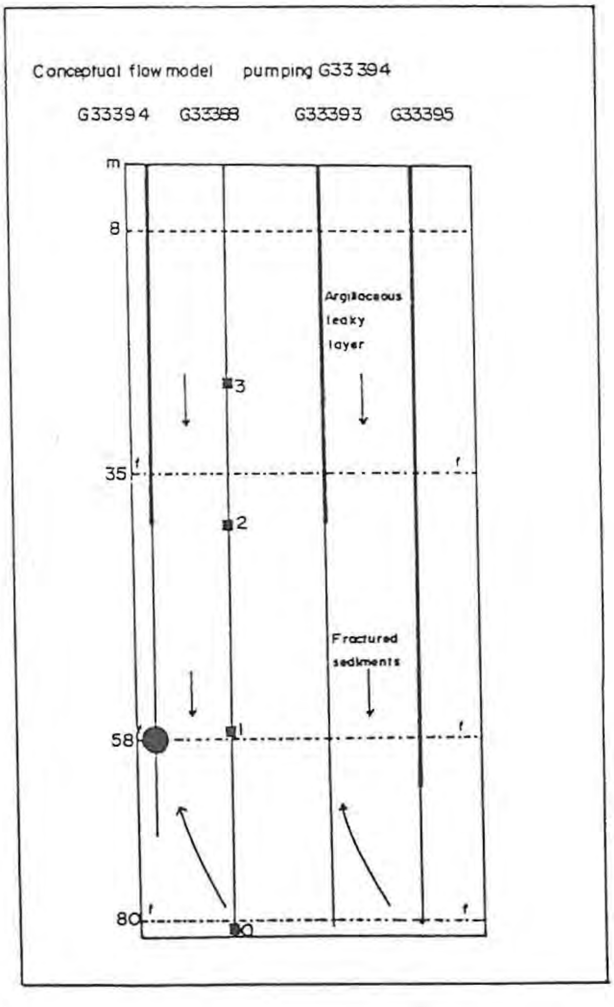
- under steady state rest conditions, groundwater exchange between the different zones is in a downward direction only
- the system is situated in a recharge area



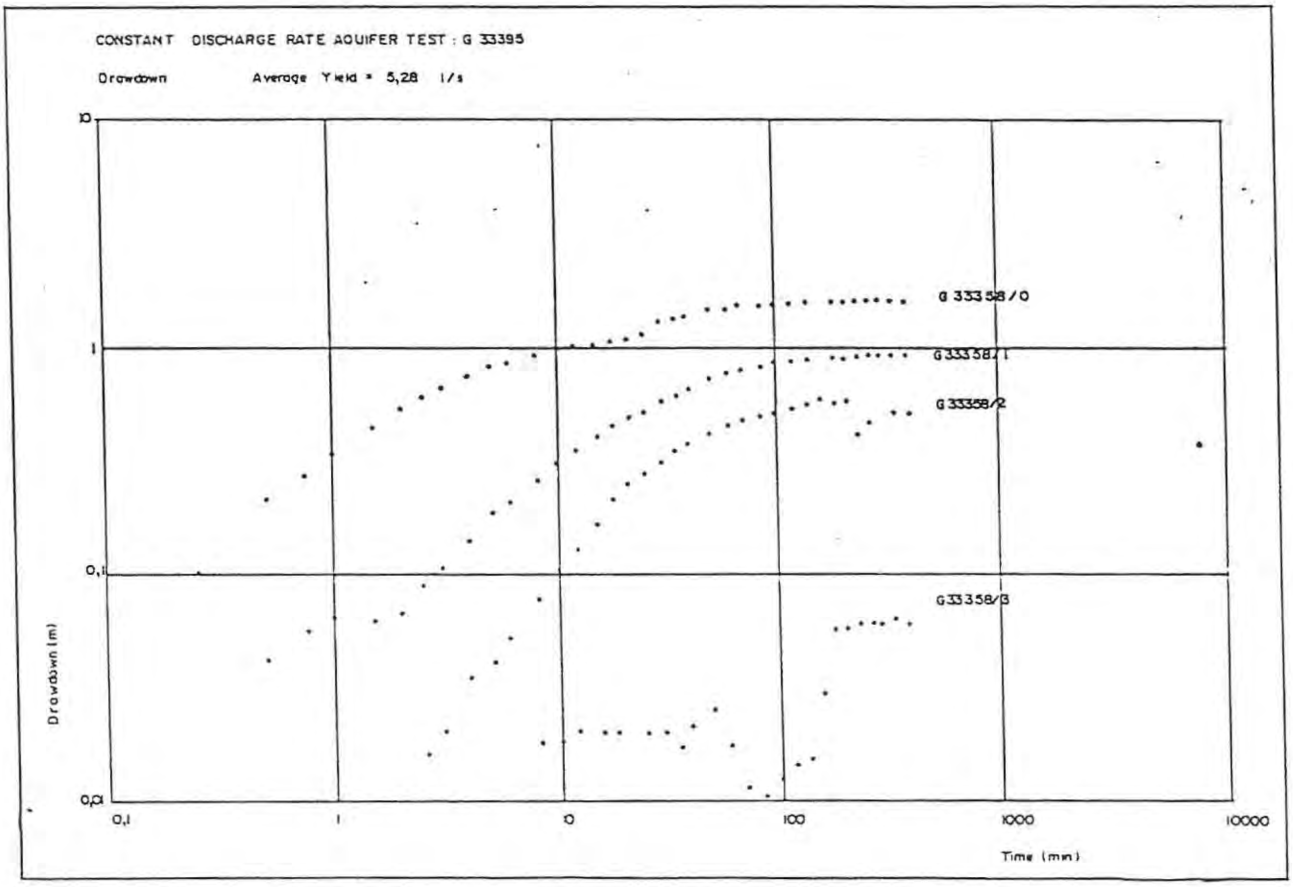


- T-values for G33393, G33394 and G33395 are similar (120 m^2/d) and reflect the transmissivity of the fractured sediments and leaky layer
- S-values for G33394 and G33395 reflect the the storativity of the middle and lower transmissive fractures proper
- S-value for G33395 stands for storativity of secondary aquifer (this borehole did not penetrate any of the discrete transmissive fractures
- downward leakage is apparent
- interpretation methods : Walton curve-matching, Hantush I straight-line

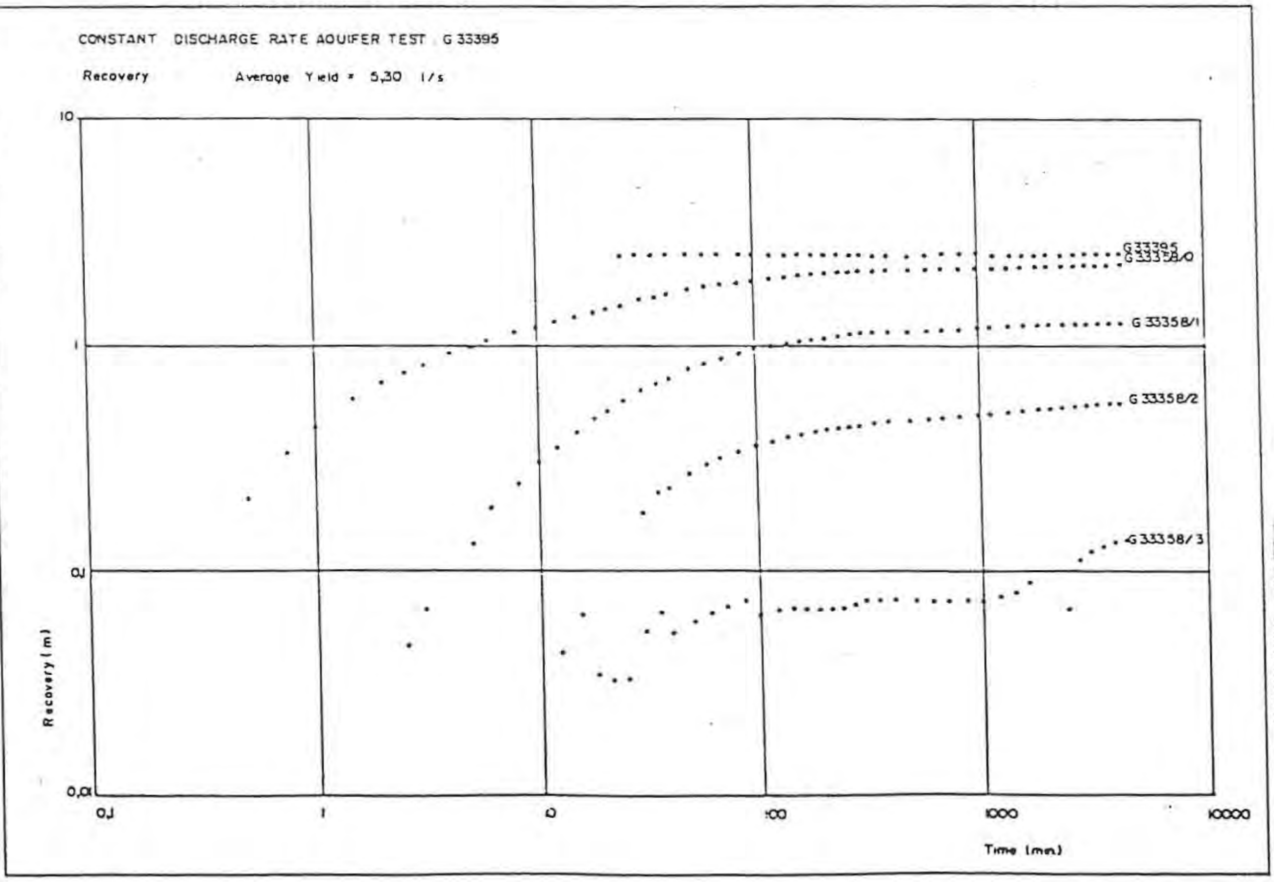




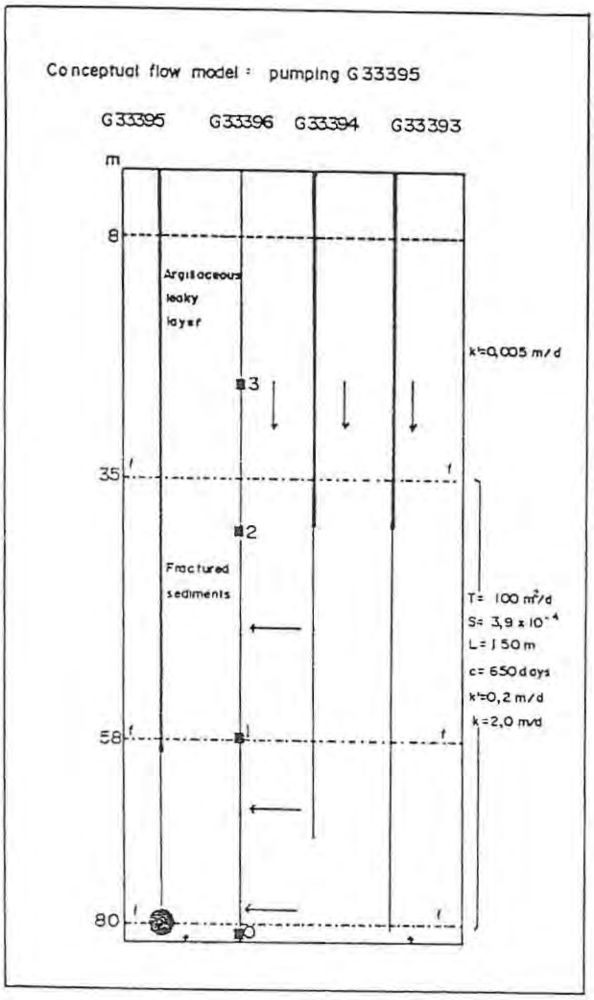
- fractured aquifer between 35 m and 80 m acts as a hydraulic unit
- pumping at 58 m induces an excessive upward flow component, laminar flow conditions are not reached, thus drawdown data is unreliable
- leakage is apparent (curve G33358/3)



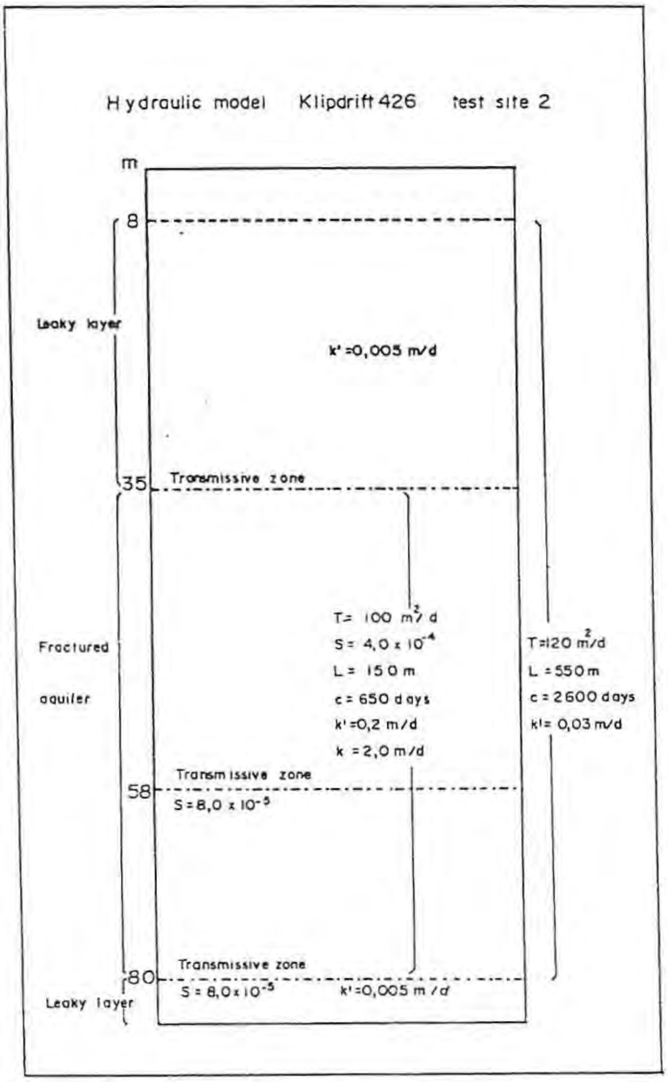
- the yield variation is excessive after 500 minutes



- the recovery data was used to check the hydraulic parameters obtained from the drawdown data



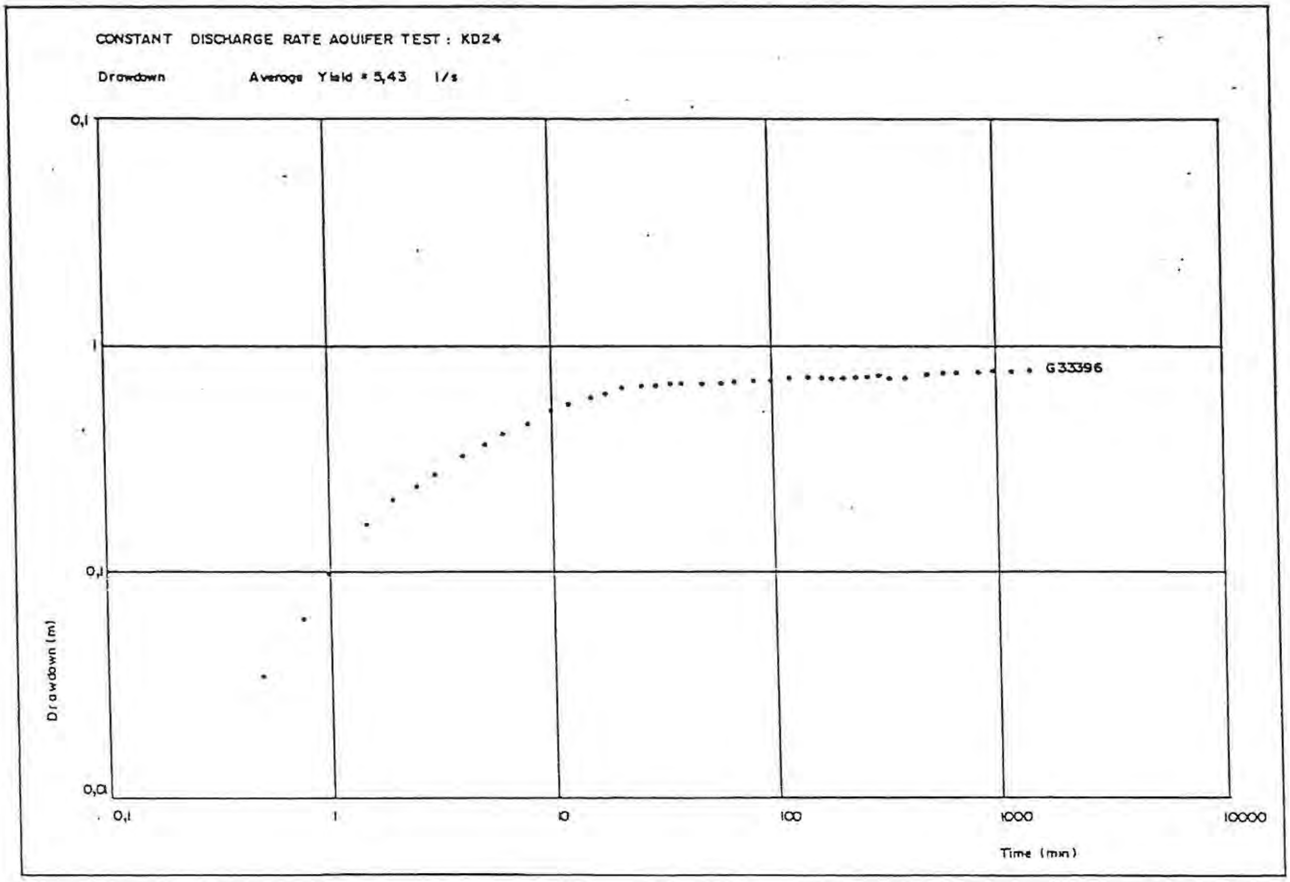
- leakage is apparent (G33358/3)
- t/s curve of G33358/0 affected by turbulent flow until 50 minutes
- T and S for the fracture aquifer (transmissive zones and matrix) can be calculated
- interpretation methods : Walton curve-matching Hantush I and Chow straight-line

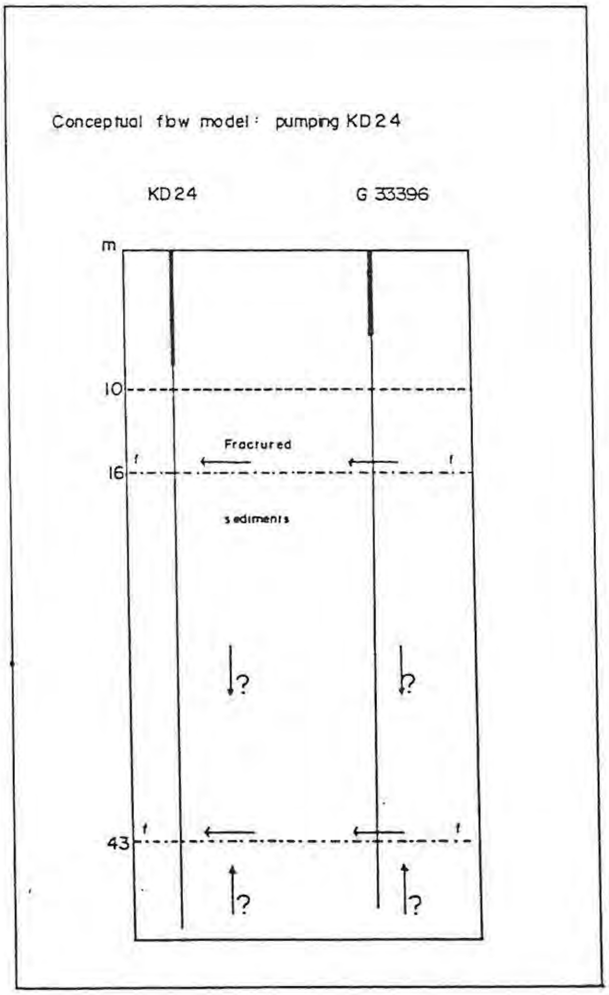


- the leakage factor and vertical permeability of the system was obtained from the standard test data
- the leakage factor and vertical permiability of the fractured aquifer was calculated from G33358/1
- k' of the upper leaky layer could then be calculated
- k' of the bottom leaky layer was derived from G33358/0
- the hydraulic conductivities of the discrete fractures cannot be obtained

AQUIFER TEST SITE 3 : KLIPDRIFT 426

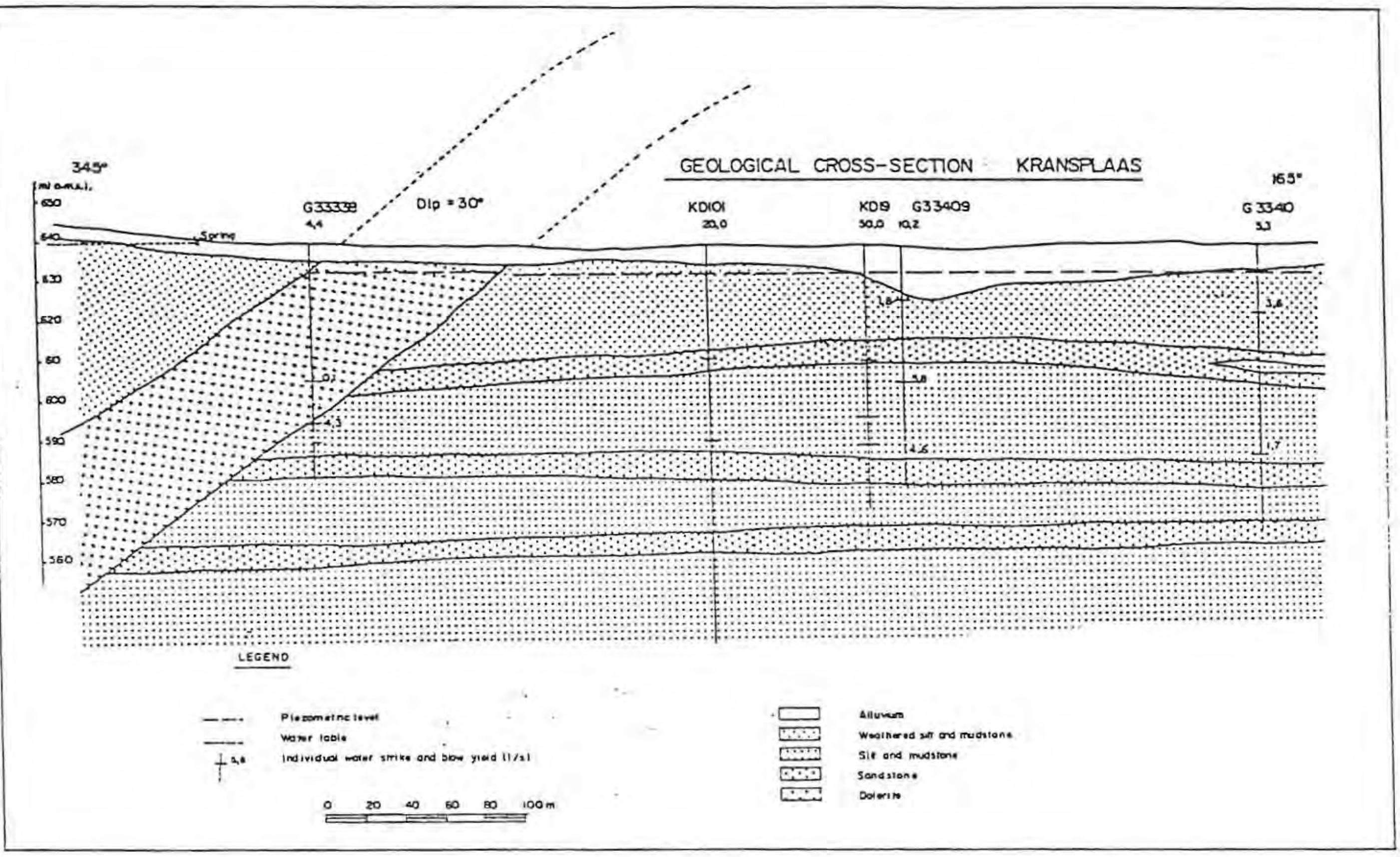
(see fig. 4 for geological cross-section)

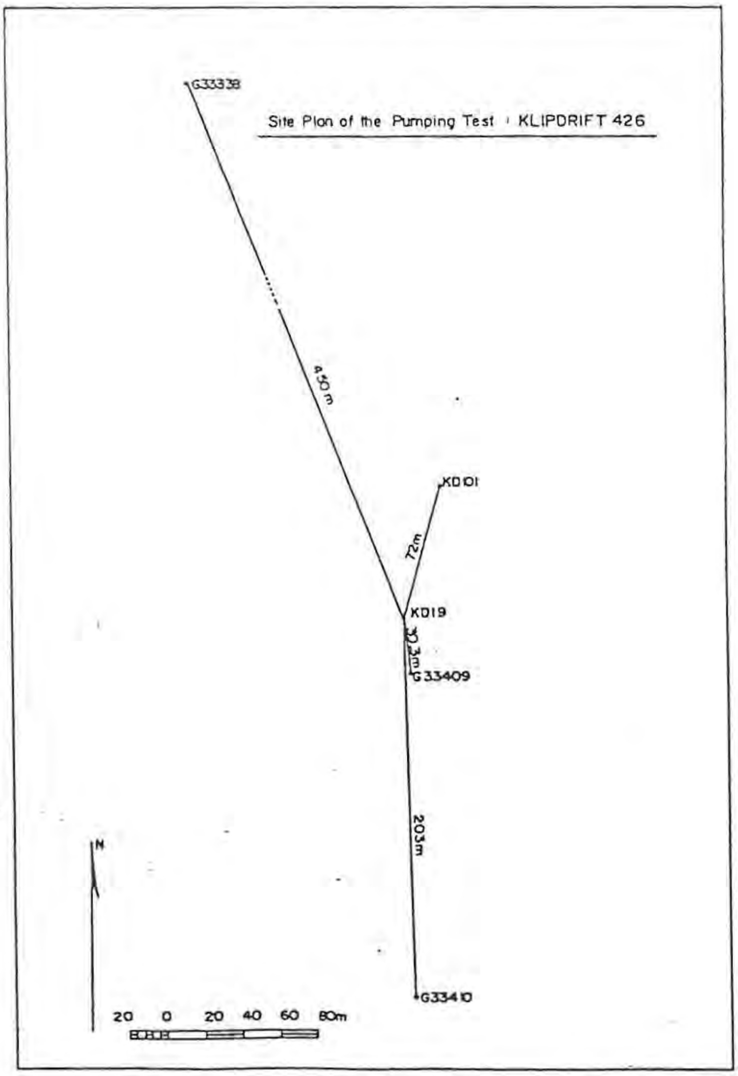


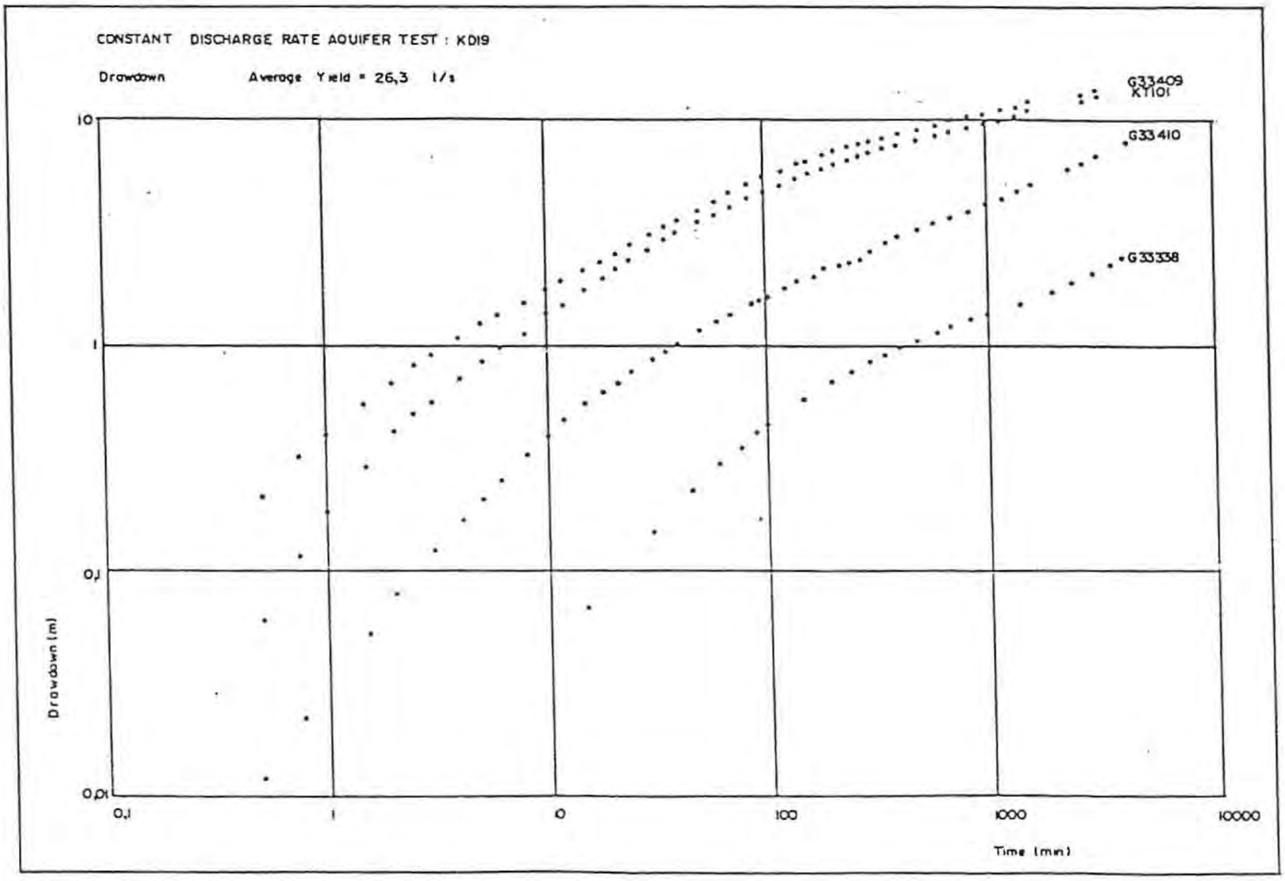


- this is a typical standard test
- the discharge water is derived from two zones, but individual yield contributions are unknown
- the origion of leakage and the thickness of the leaky zone(s) are not known
- the Walton curve-matching and Hantush I straight-line interpretation methods gave the following parameters for G33396:
  $T = 130\ m^2/d$
  $S = 4,5 \times 10^{-5}$
  $L = 260$ m
  $c = 500$ days
- it cannot be determined whether T and S are representative for the transmissive zones only or for the entire sequence

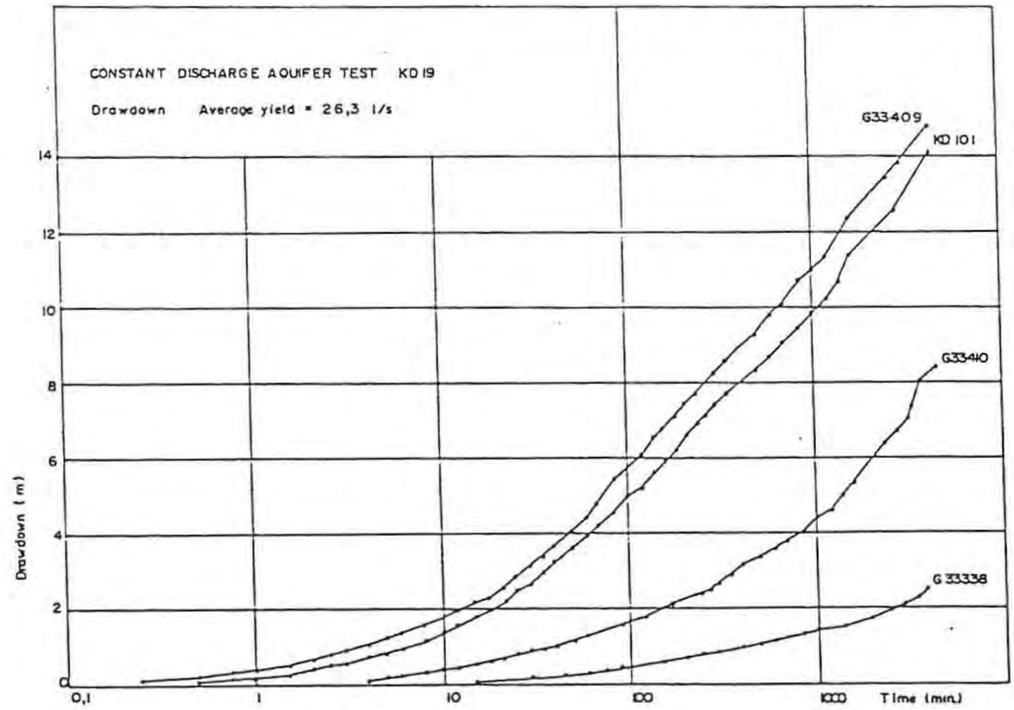
AQUIFER TEST SITE 4 : KLIPDRIFT 426


GEOLOGICAL CROSS-SECTION KRANSPLAAS
345°
165°
m a.m.s.l.
630
620
610
600
590
580
570
560
Spring
G33338
4,4
Dip = 30°
KD101
20,0
KD19
50,0
G33409
10,2
G 3340
3,3
LEGEND
Piezometric level
Water table
Individual water strike and blow yield (l/s)
0 20 40 60 80 100m
Alluvium
Weathered silt and mudstone
Silt and mudstone
Sandstone
Dolerite

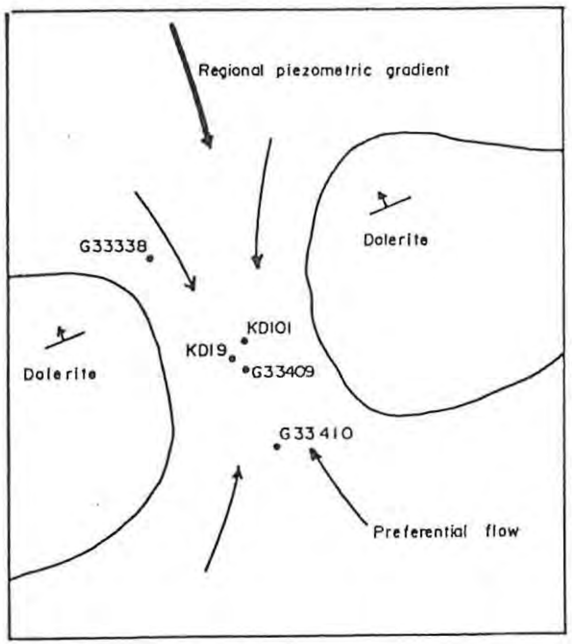

Site Plan of the Pumping Test : KLIPDRIFT 426
G33338
450m
KD101
72m
KD19
30,3m
G33409
203m
G33410
N
20 0 20 40 60 80m



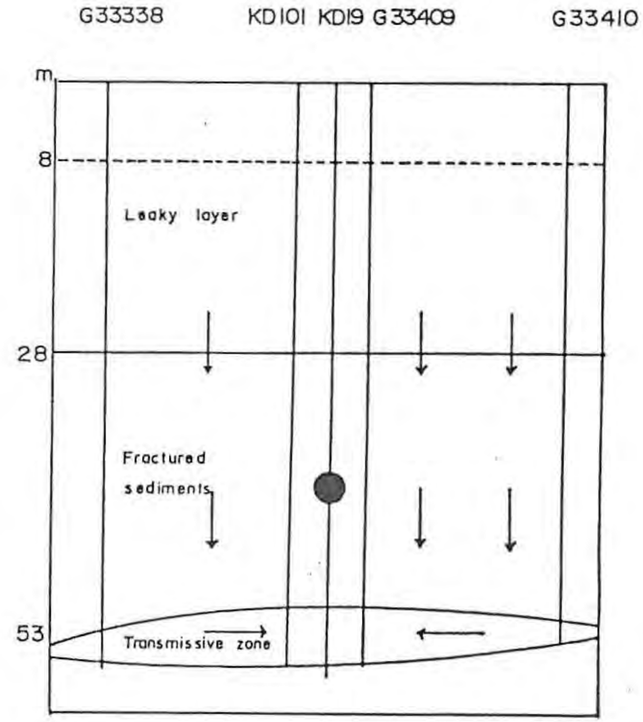
- two semi-permeable boundary effects are noticeable
- the leakage effects are suppressed by the boundary conditions
- interpretation methods : Theis curve-matching, Seward

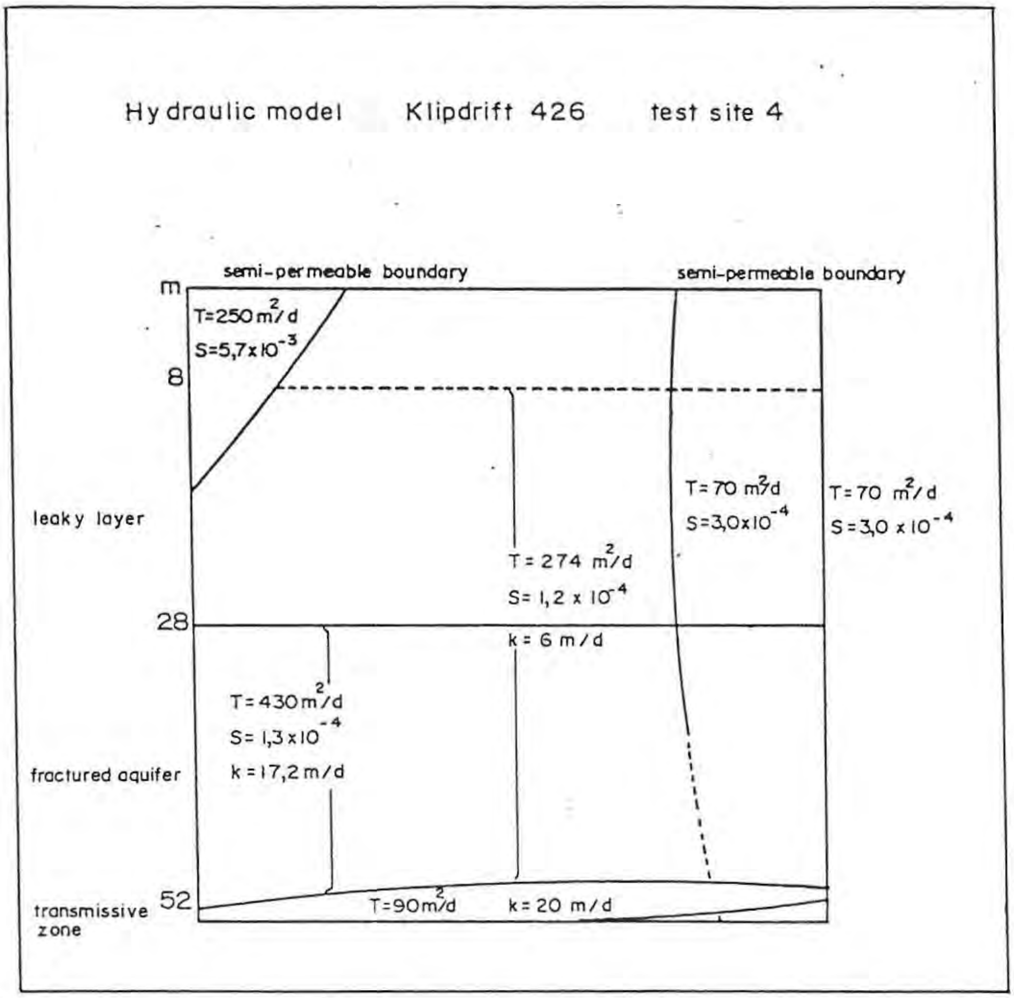


Conceptual flow model : pumping KD19



Conceptual flow model : pumping KD19

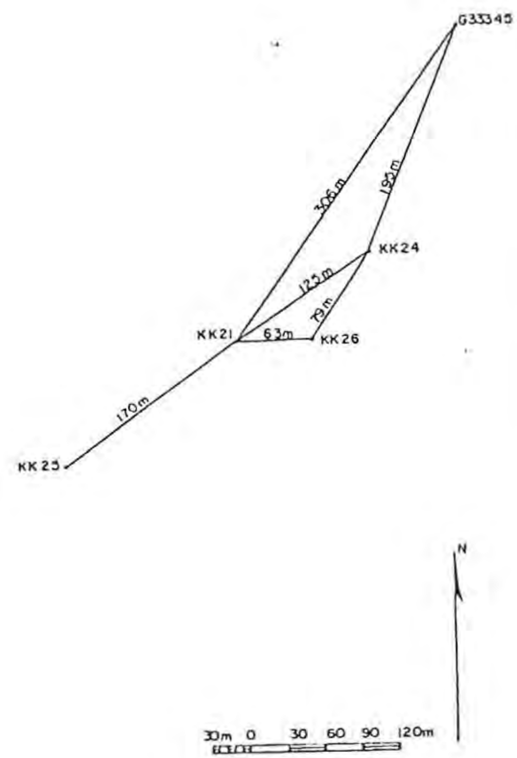




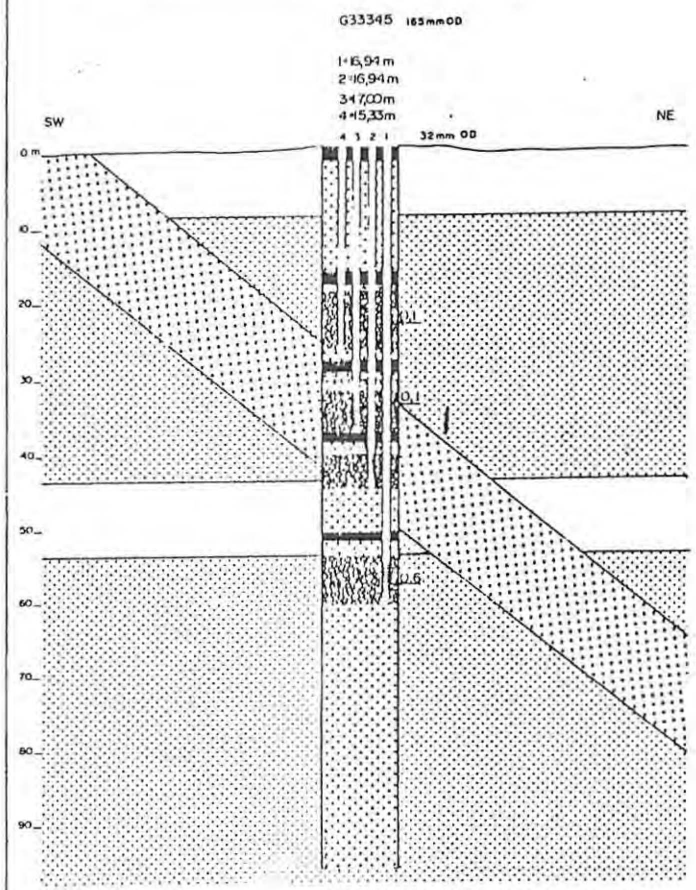
- the T-value obtained for the transmissive zone is probably a minimum value owing to turbulent losses near the production well

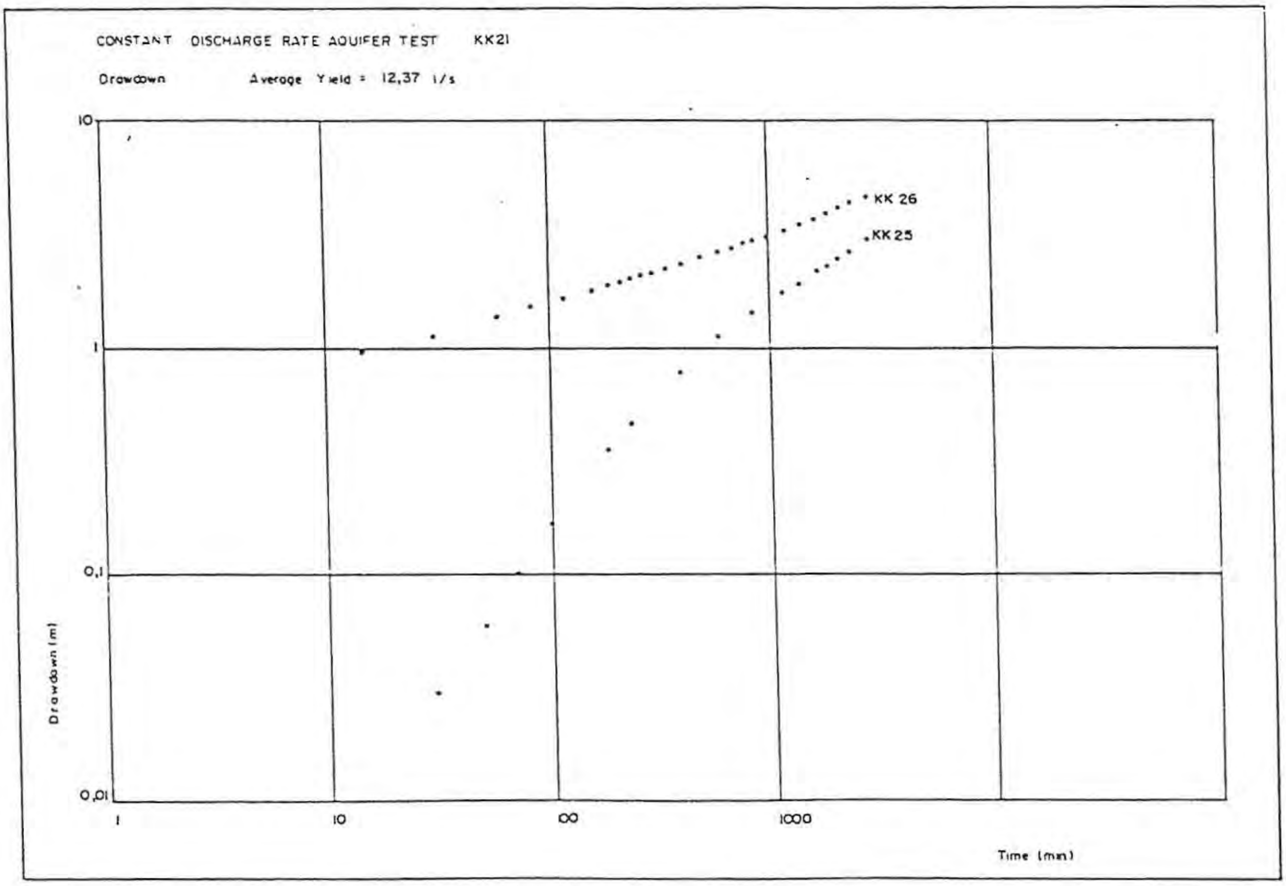
AQUIFER TEST SITE : KRUGERS KRAAL 322

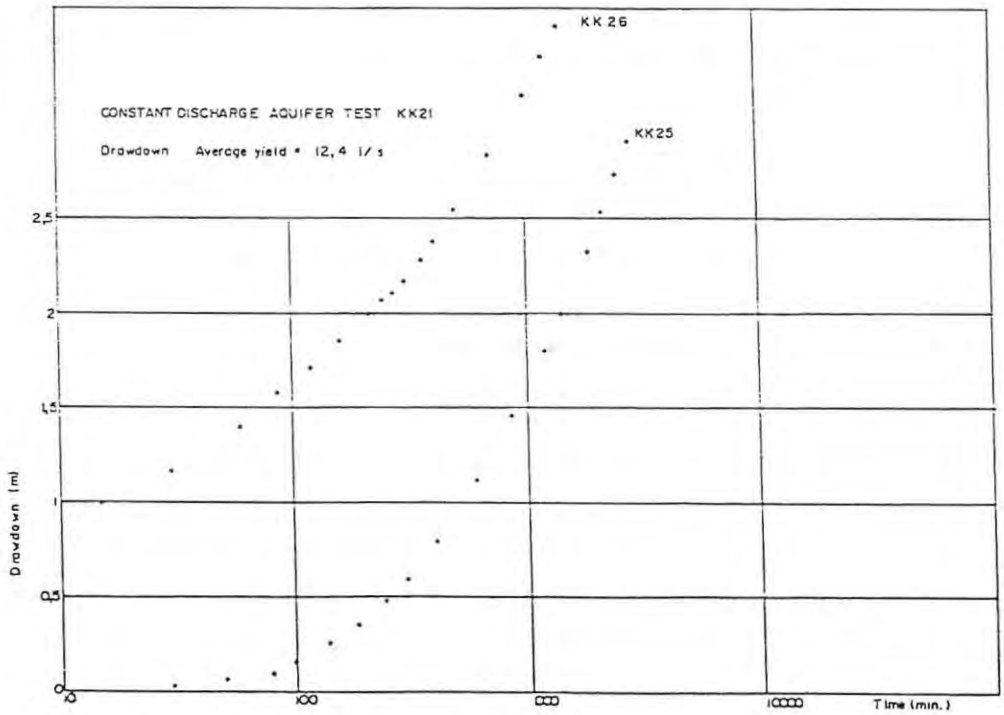
Site Plan of Multiple Piezometer Test · KRUGERSKRAAL 322



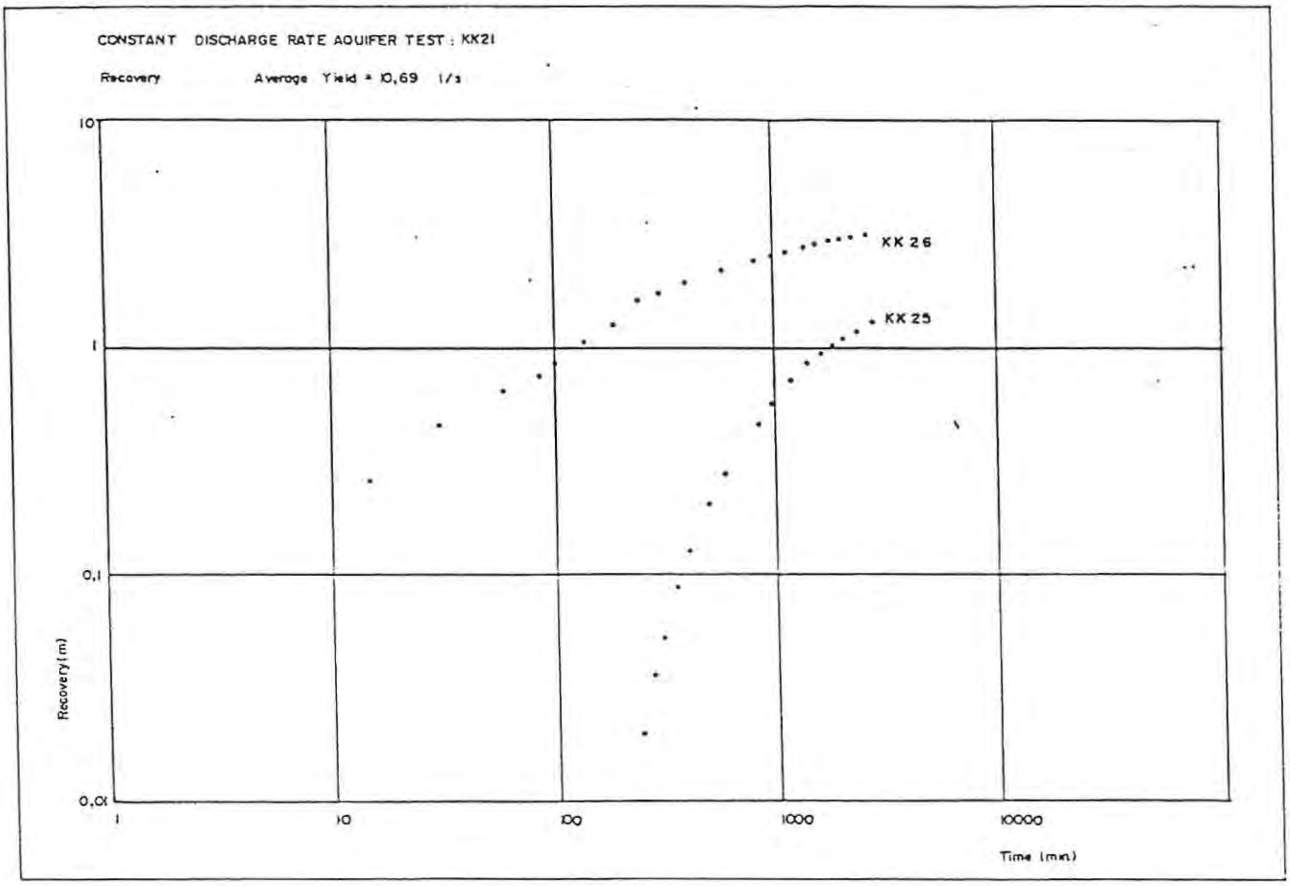
Schematic Geohydrological Profile · KRUGERSKRAAL 322

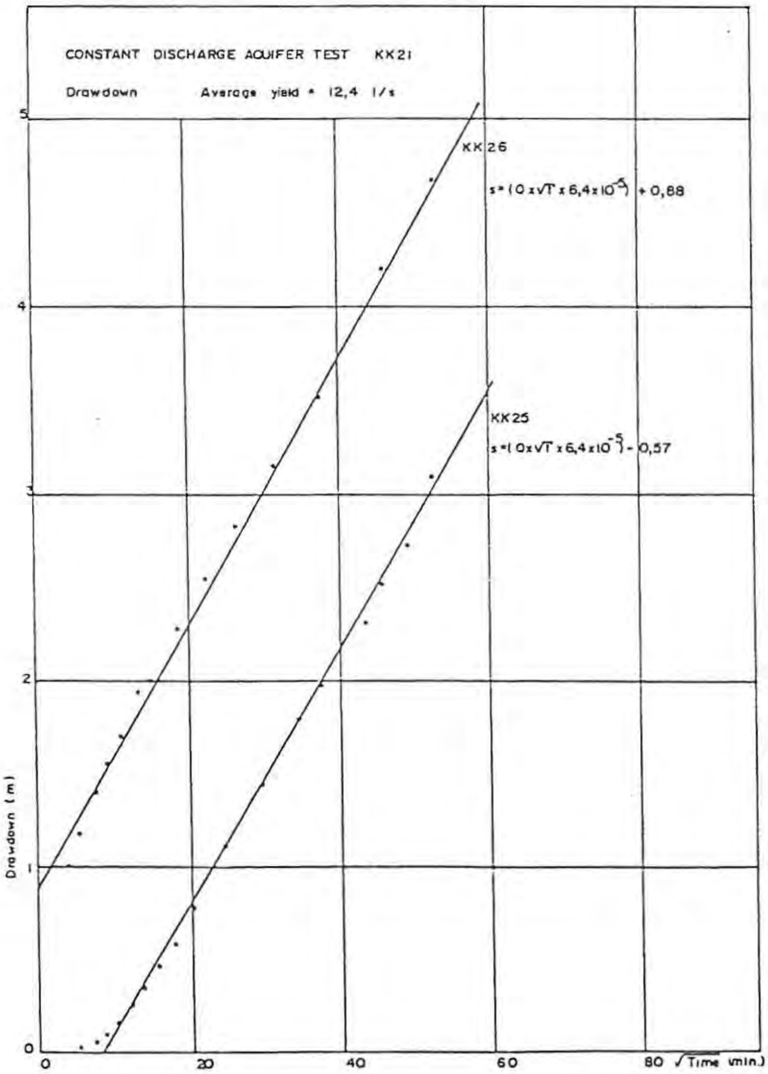




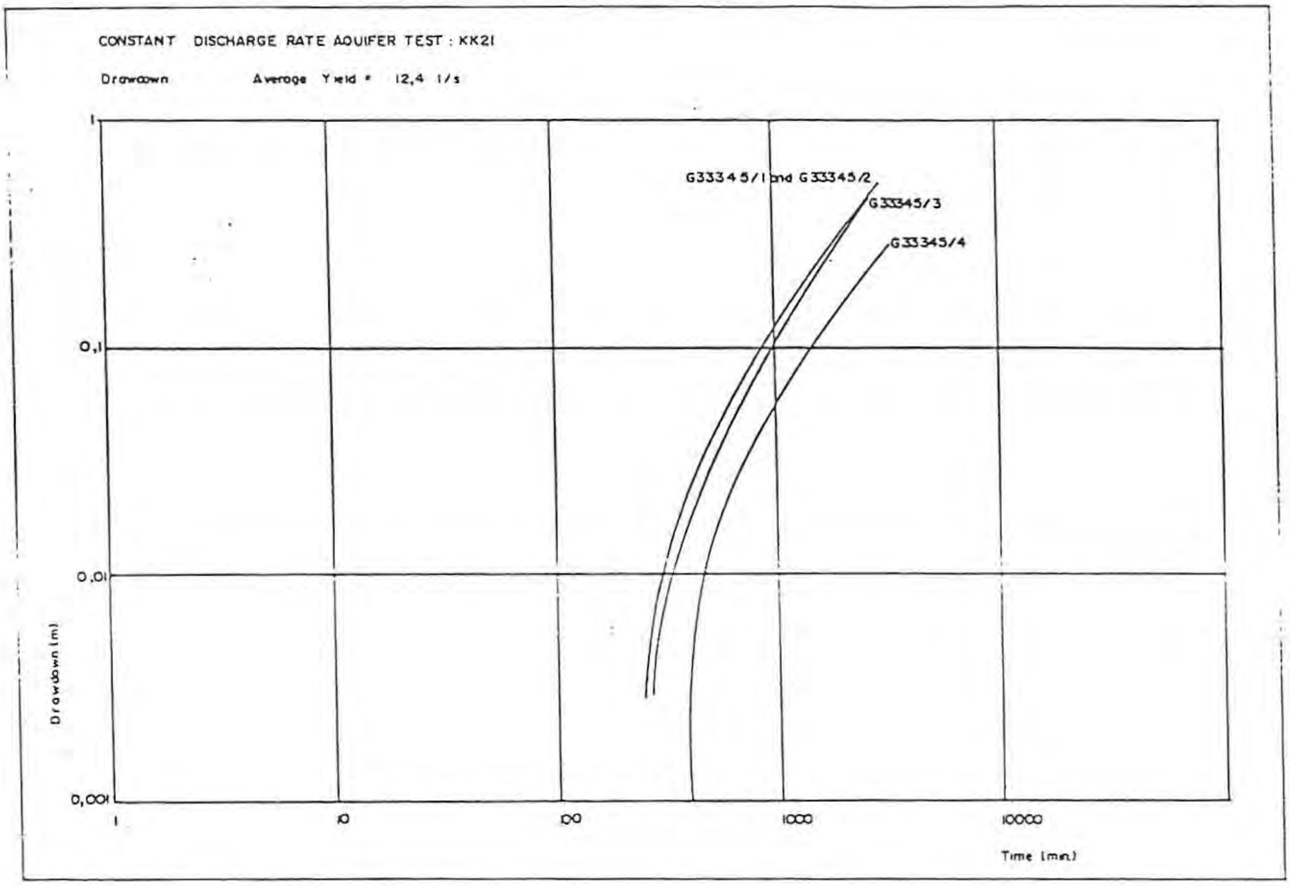


- the curvilinear nature of this graph is characteristic of linear flow conditions

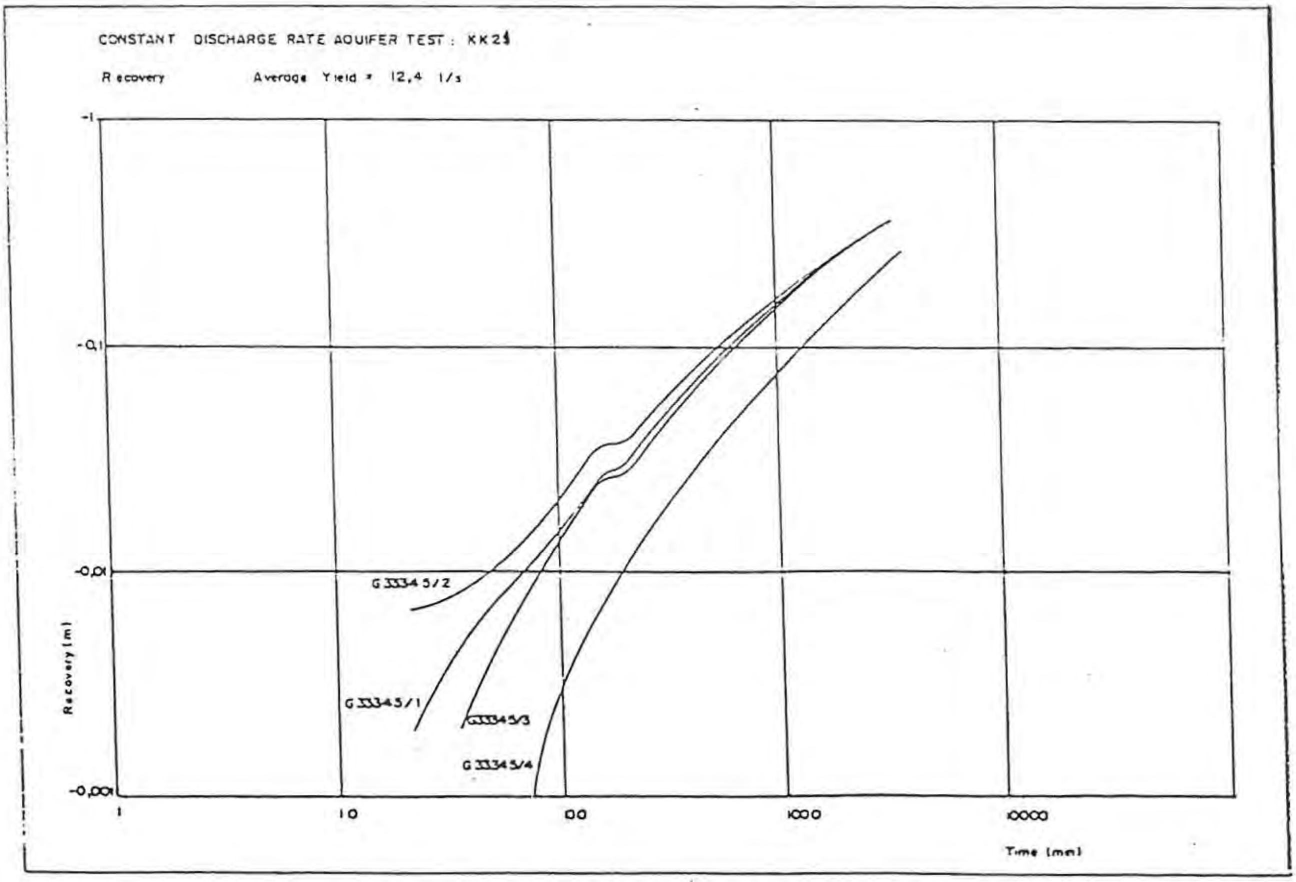




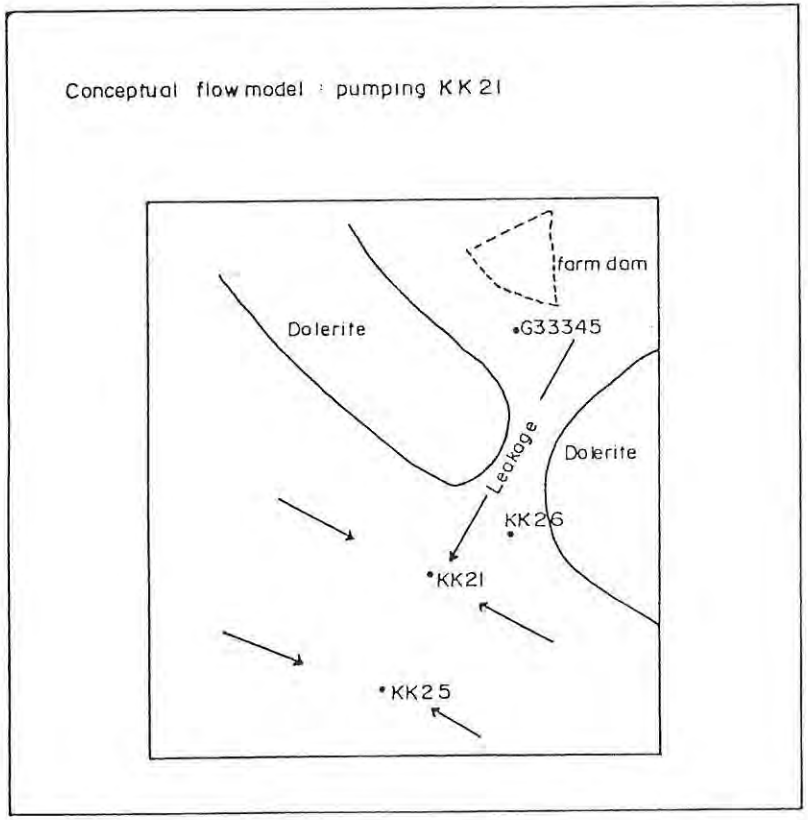
s/ t relationship is typical of linear flow conditions, but here the straight-line relationship is an expression of linear flow, pseudo-radial flow, the semi-permeable boundary and leakage

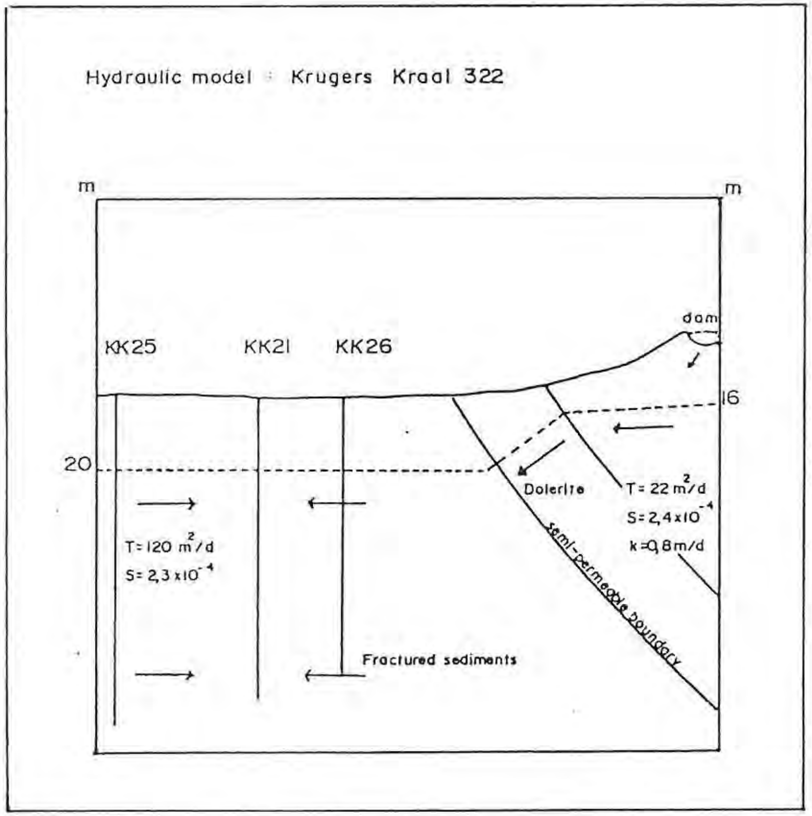


- the response of the water level to pumping is typical of a leaky aquifer



- the water levels in all piezometers continue to drop after pumping was stopped, this is due to the leaky nature of the system and hydraulic head differences



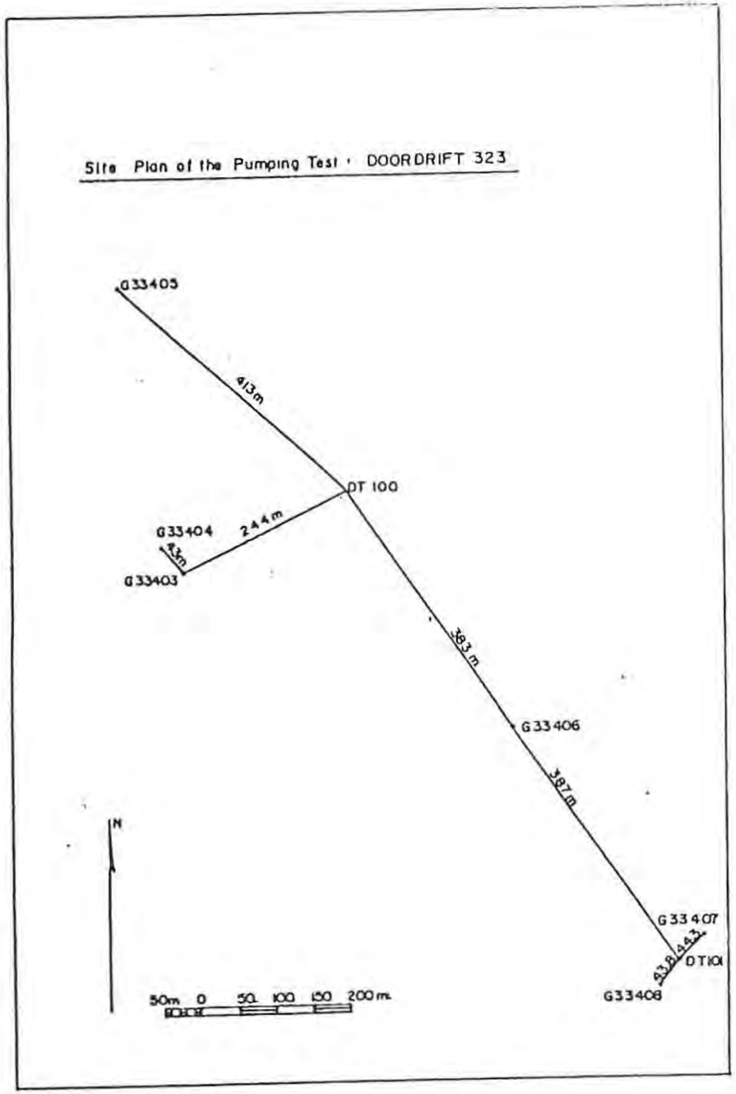


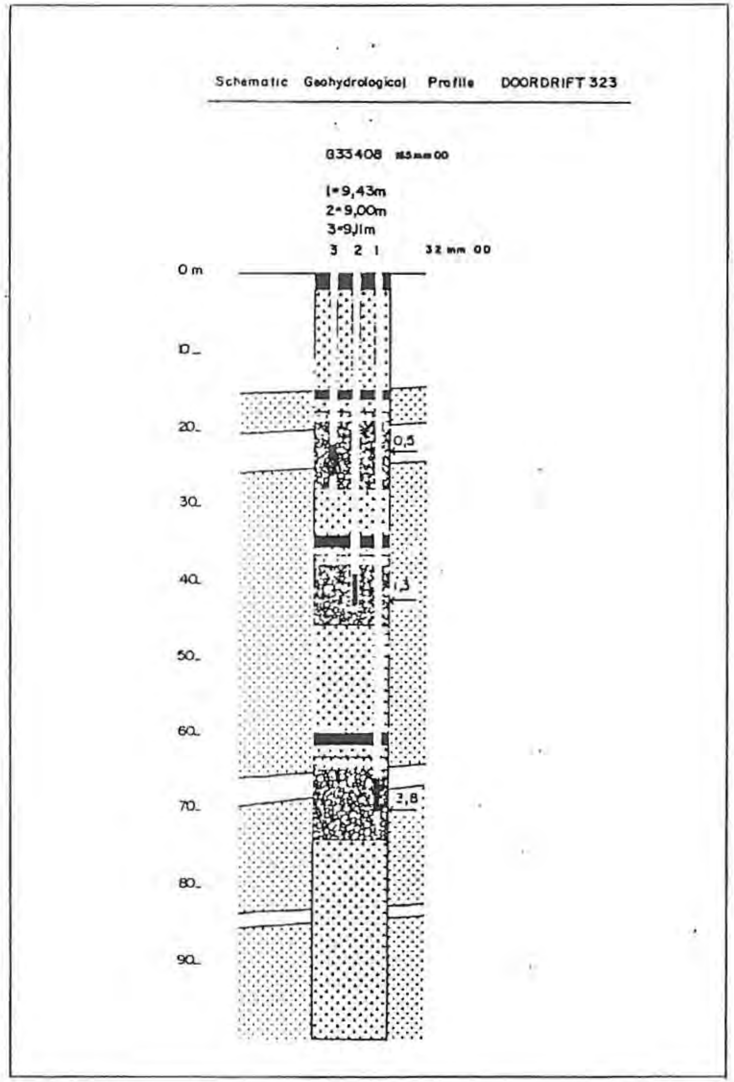
The analysis of the aquifer test data revealed that a rather unusual set of geohydrological conditions occur at this test site - leakage from the north-east to the south-west takes place through the poort under steady state rest conditions and when pumping.

- when pumping KK21, initially linear flow conditions prevail before pseudo-radial flow is induced
- a semi-permeable or semi-impermeable boundary is present
- the volume of water stored in the dolerite-related fractured aquifer is limited but is replenished by leakage through the poort, which was calculated to be in the order of 420m^3/day. The leakage figure is only relevant for the hydraulic conditions that prevailed at the time of the aquifer test.

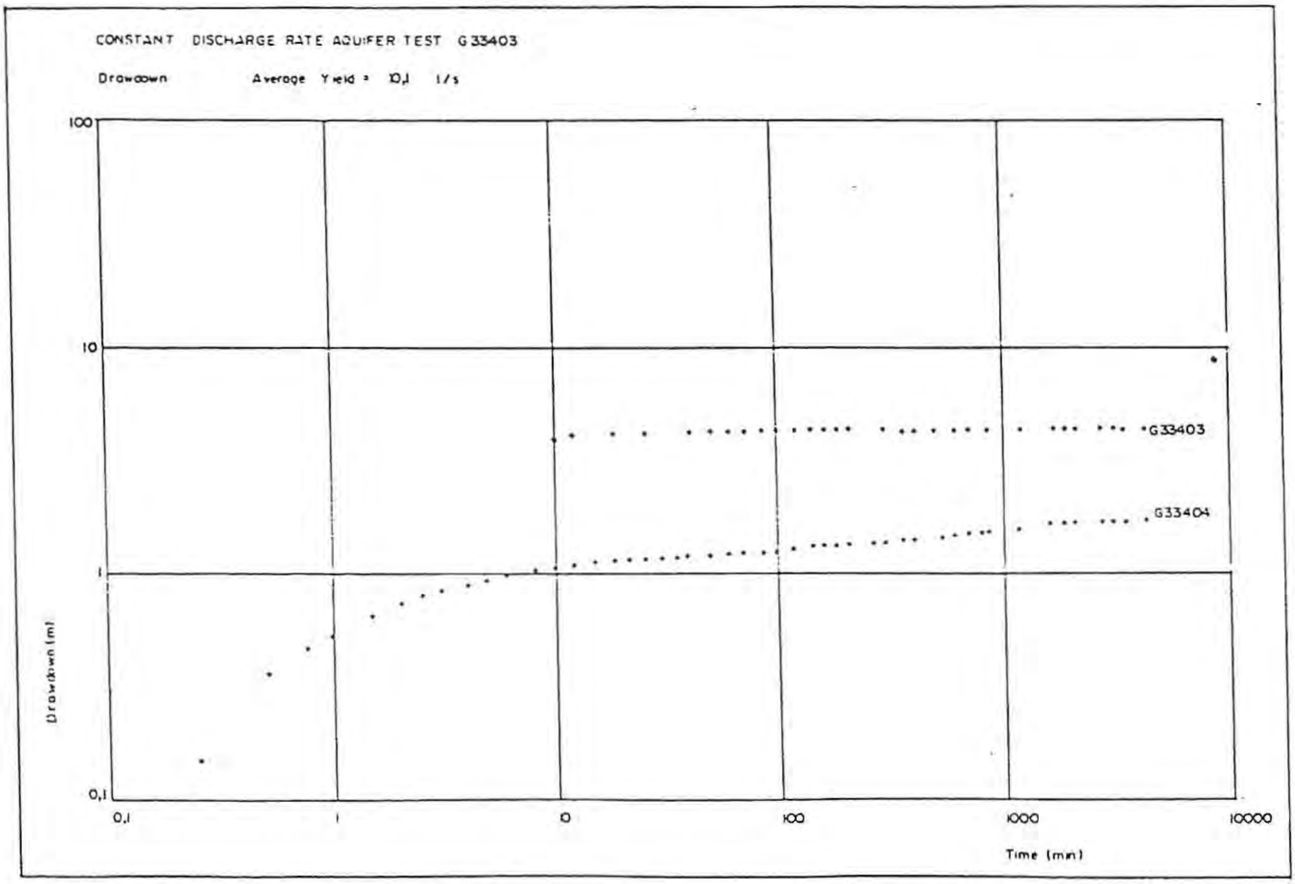
The safe yield of the test site, assuming effective recharge occurs only once in 5 years, was calculated to be 440 m^3/day. It is therefore evident that the dolerite-related fractured aquifer is merely a transmissive zone.

AQUIFER TEST SITE : DOORDRIFT 323



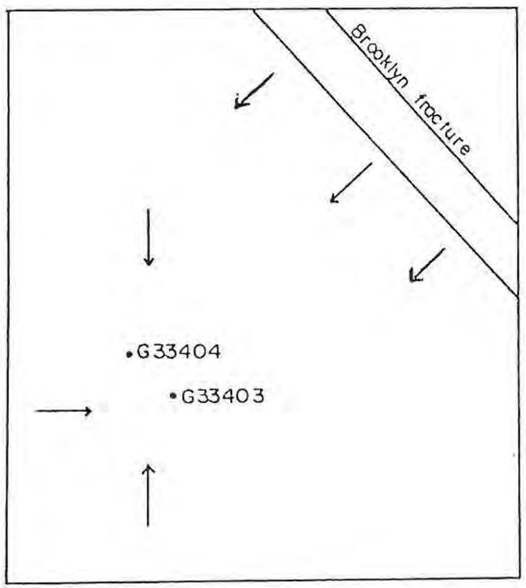


- piezometric levels indicate that under steady state conditions, flow of groundwater converges to the zone between 30 m and 60 m
- the multiple piezometer was not used for aquifer test purposes

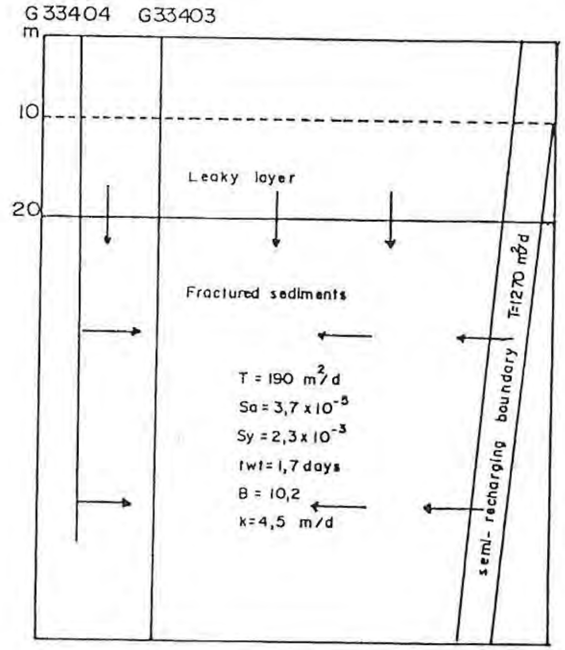


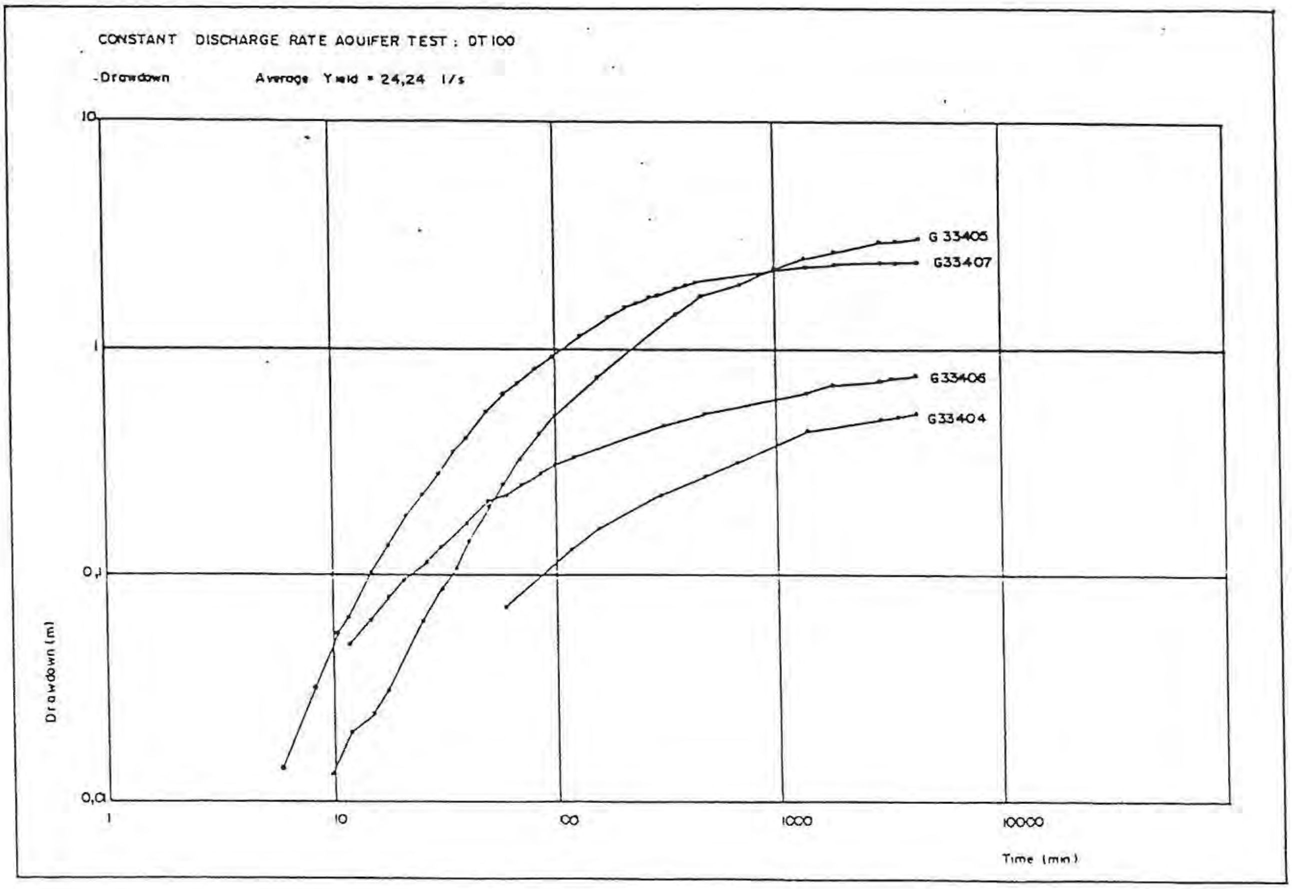
- the curve of G33404 shows semi-unconfined aquifer response (delayed yield, gravity drainage) thus the Boulton interpretation method was used
- as from 500 minutes the influence of a semi-recharging boundary is noticeable (Brooklyn fracture) and the Seward method of interpretation was employed

Conceptual flow model pumping G33403

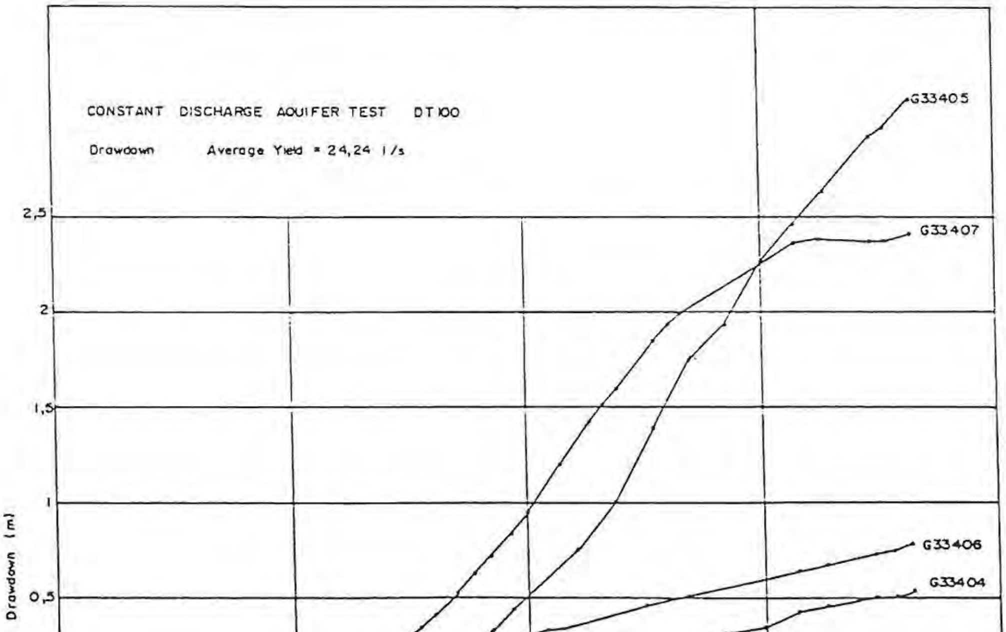


Conceptual flow model : pumping G33403

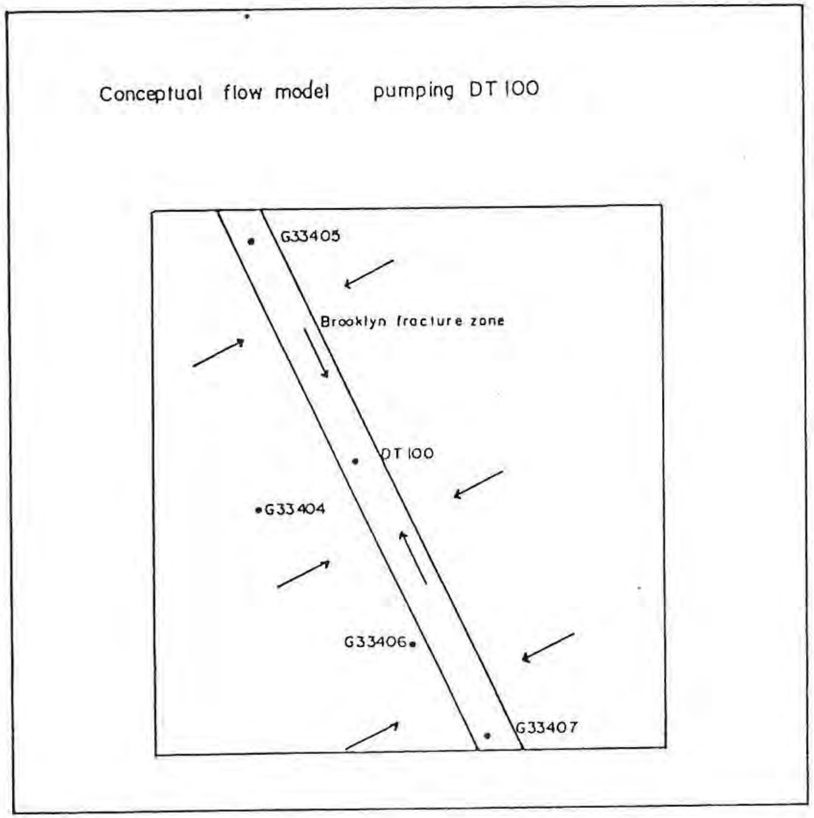


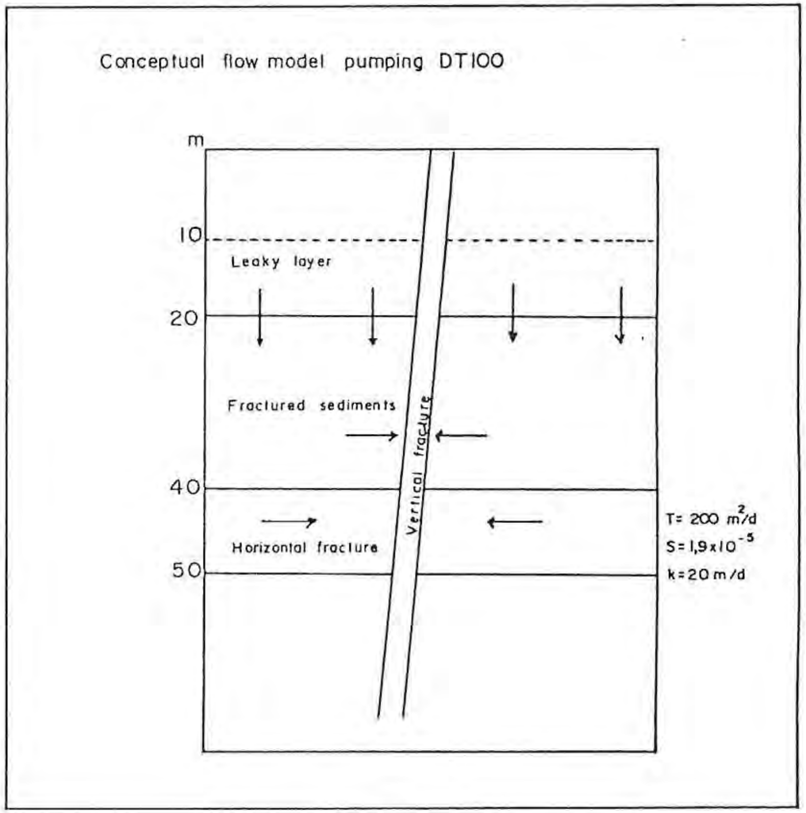


- the effect of leakage is only just apparent, the test should have been longer

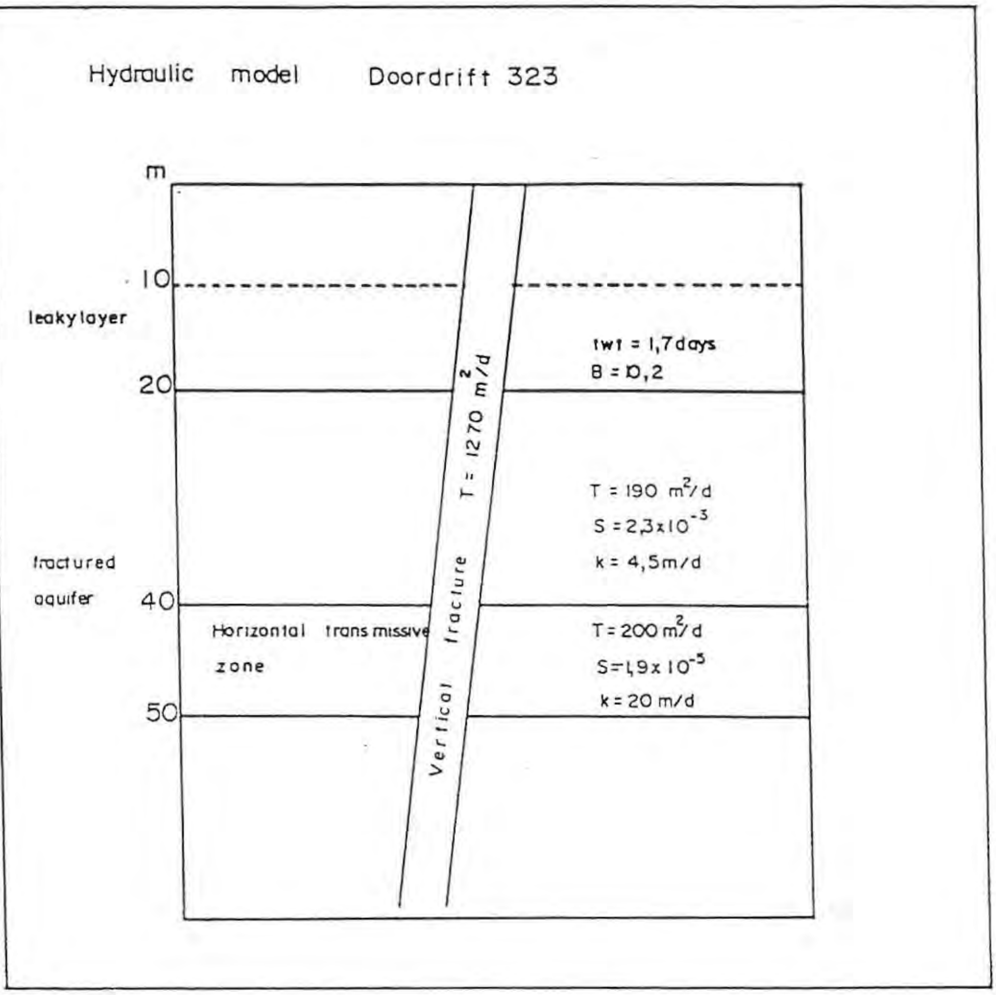


- pseudo-radial flow is the dominant flow component, linear flow only evident at early times (until 12 minutes)

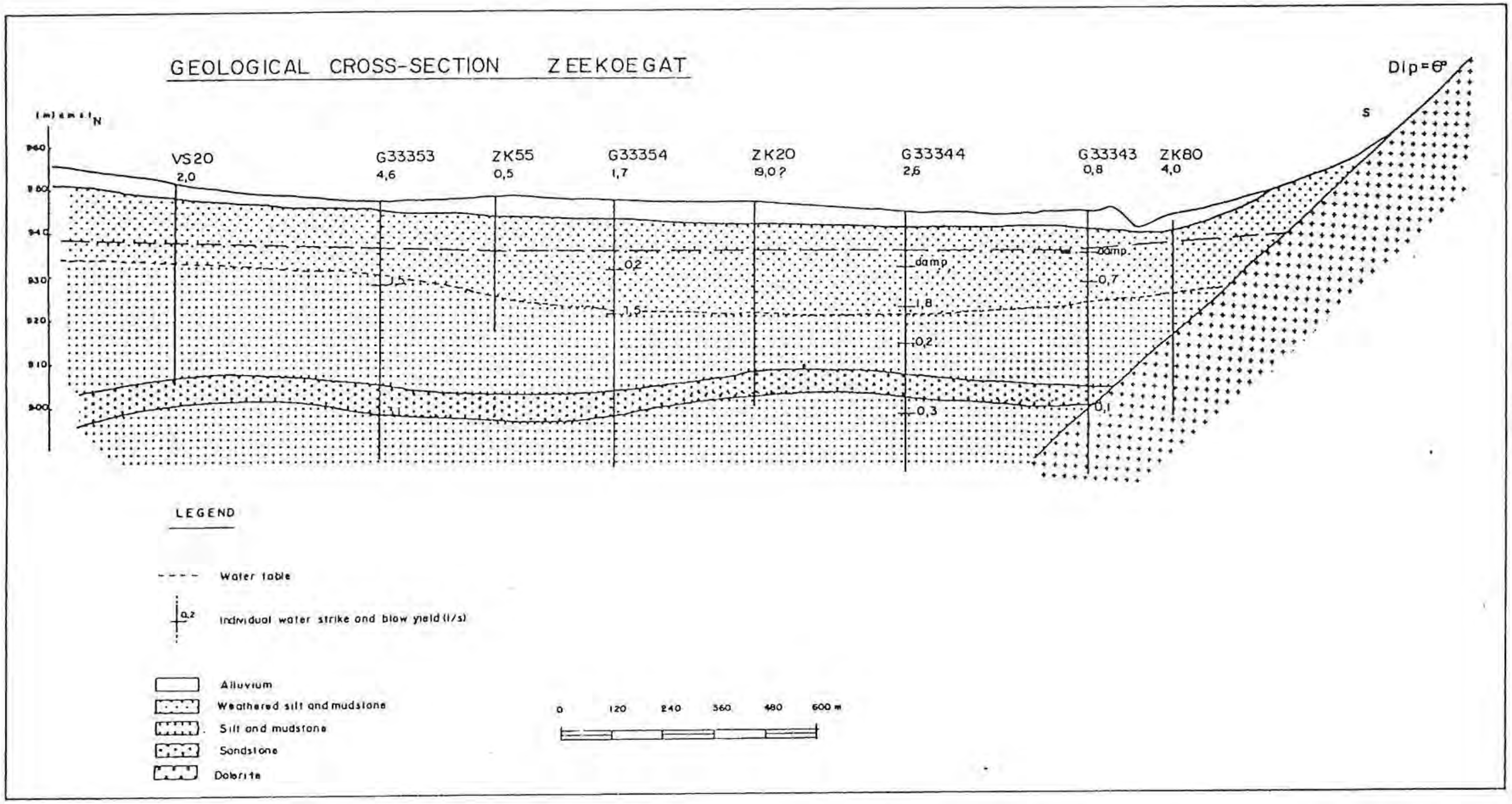




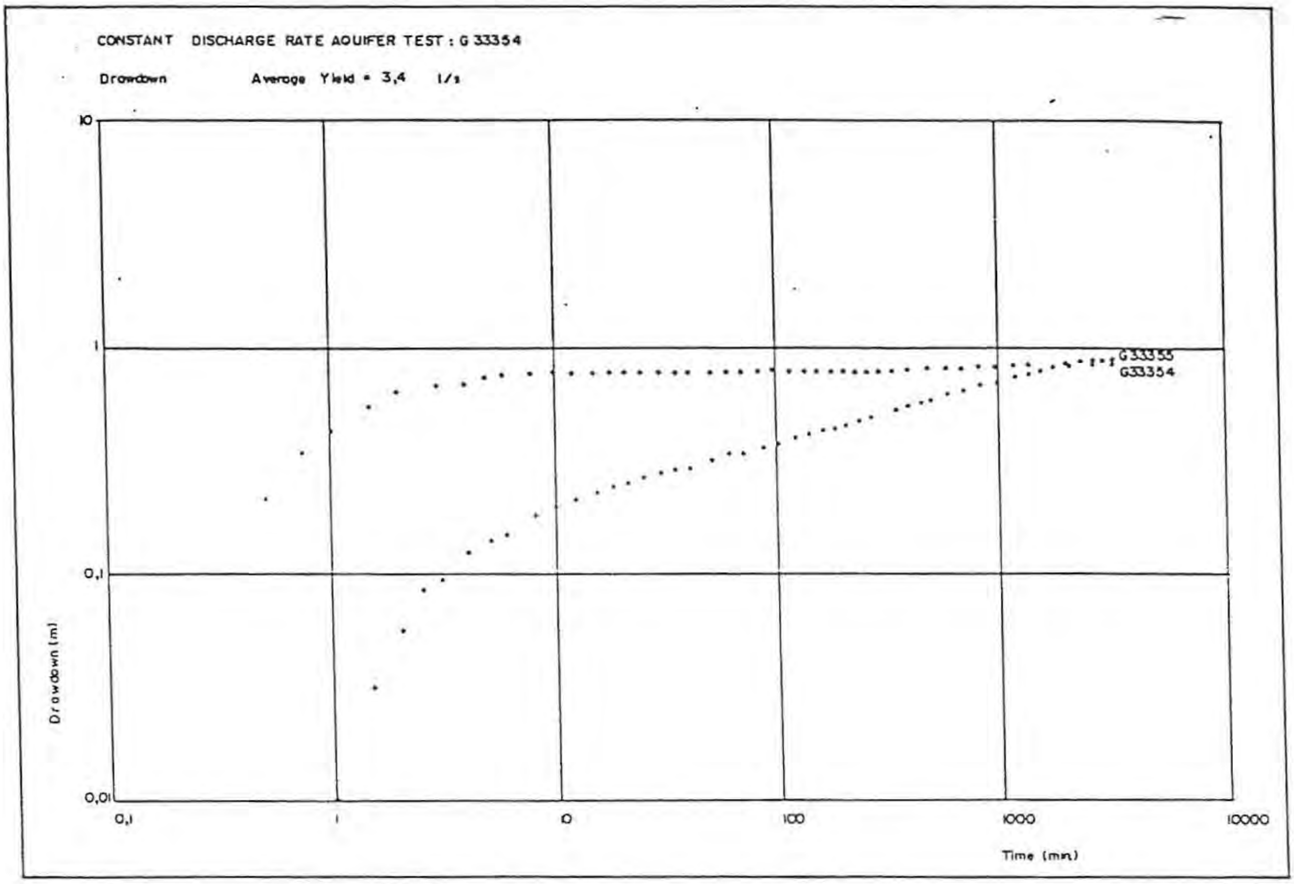
- the fractures act as an extended well
- G33404 and G33406 do not appear to have intersected the horizontal fracture zone, therefore the parameters obtained from these two wells cannot be taken at face value
- interpretation methods : Walton curve-matching, Hantush I and Chow straight-line

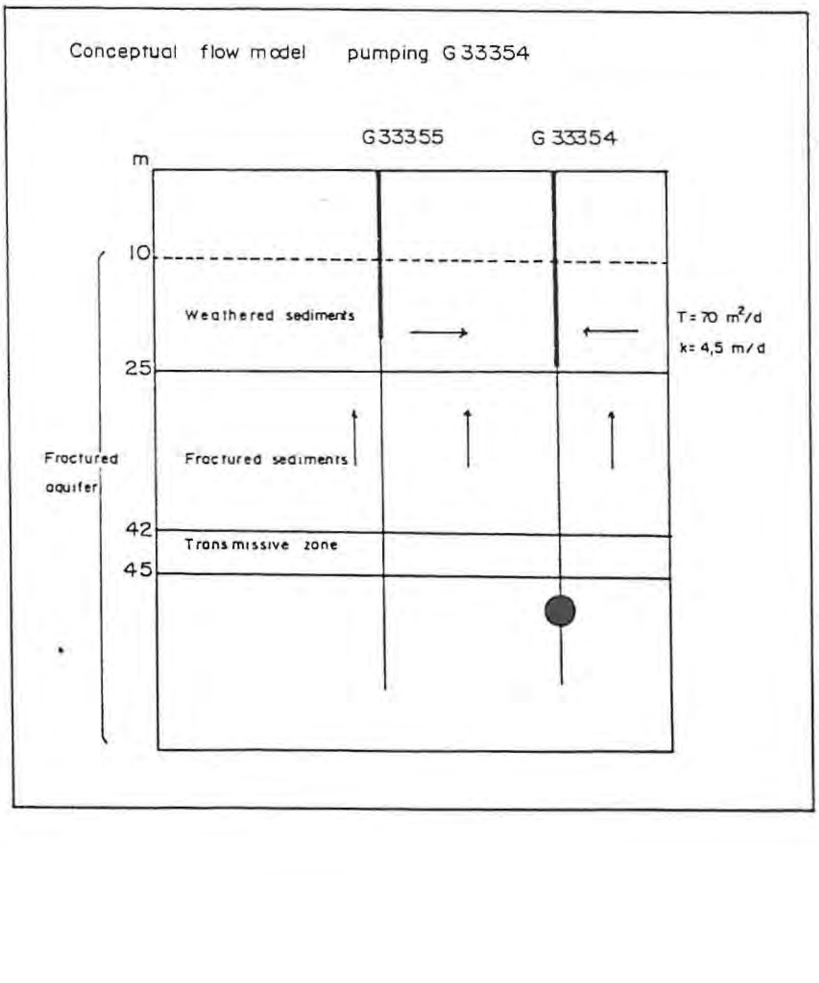

Hydraulic model Doordrift 323
m
10
leakylayer
20
twt = 1,7days
B = 10,2
T = 1270 m²/d
T = 190 m²/d
S = 2,3x10⁻³
k = 4,5m/d
fractured
aquifer
40
Horizontal transmissive
zone
T = 200 m²/d
S = 1,9x10⁻³
k = 20 m/d
50
Vertical fracture

AQUIFER TEST SITE : ZEEKOEIGAT 140



- groundwater transmission across the Zeekoeigat section occurs through the weathered zone and along a transmissive zone in the fractured sandstone
- leakage from the upper zone will take place if the transmissive layer is pumped

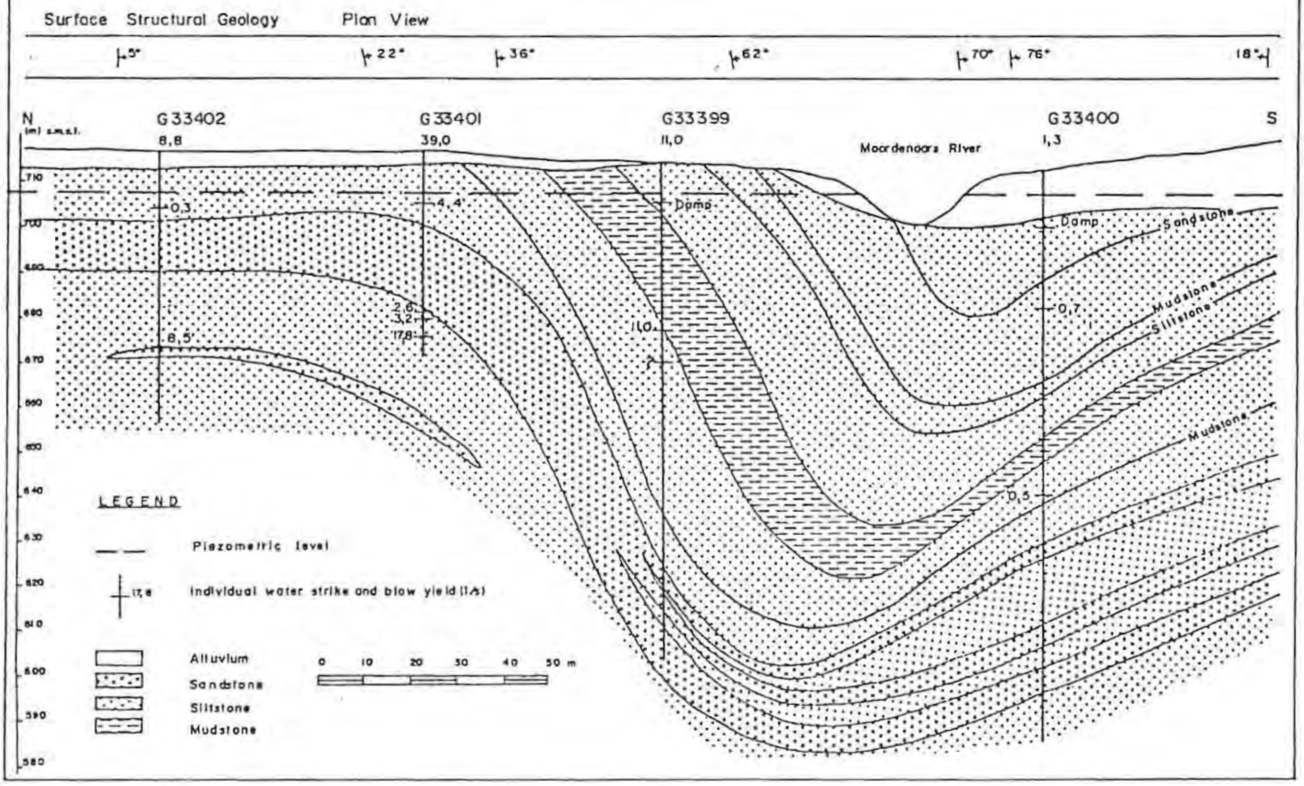




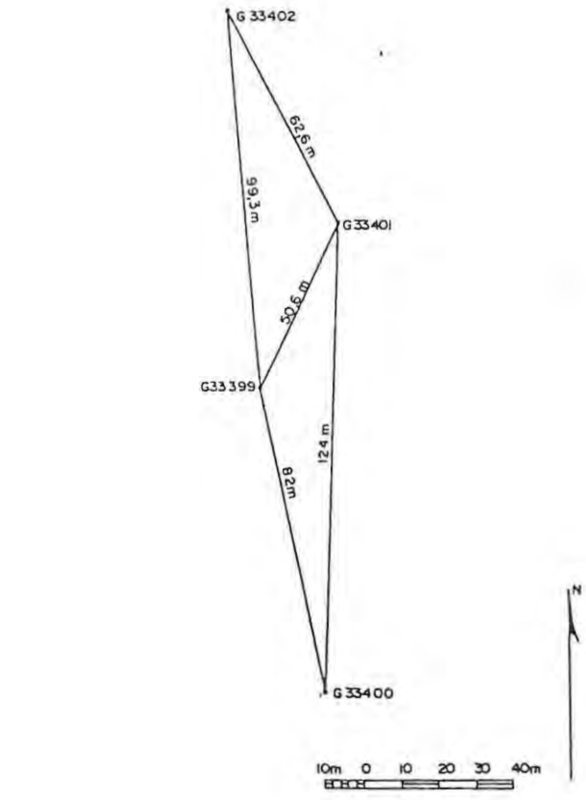
- in the pumped well water was intercepted at 25 m, thus only water from the weathered zone is abstracted
- the drawdown in G33355 is to a large extent an expression of the pressure head reductions in the underlying layers which results from upward seepage

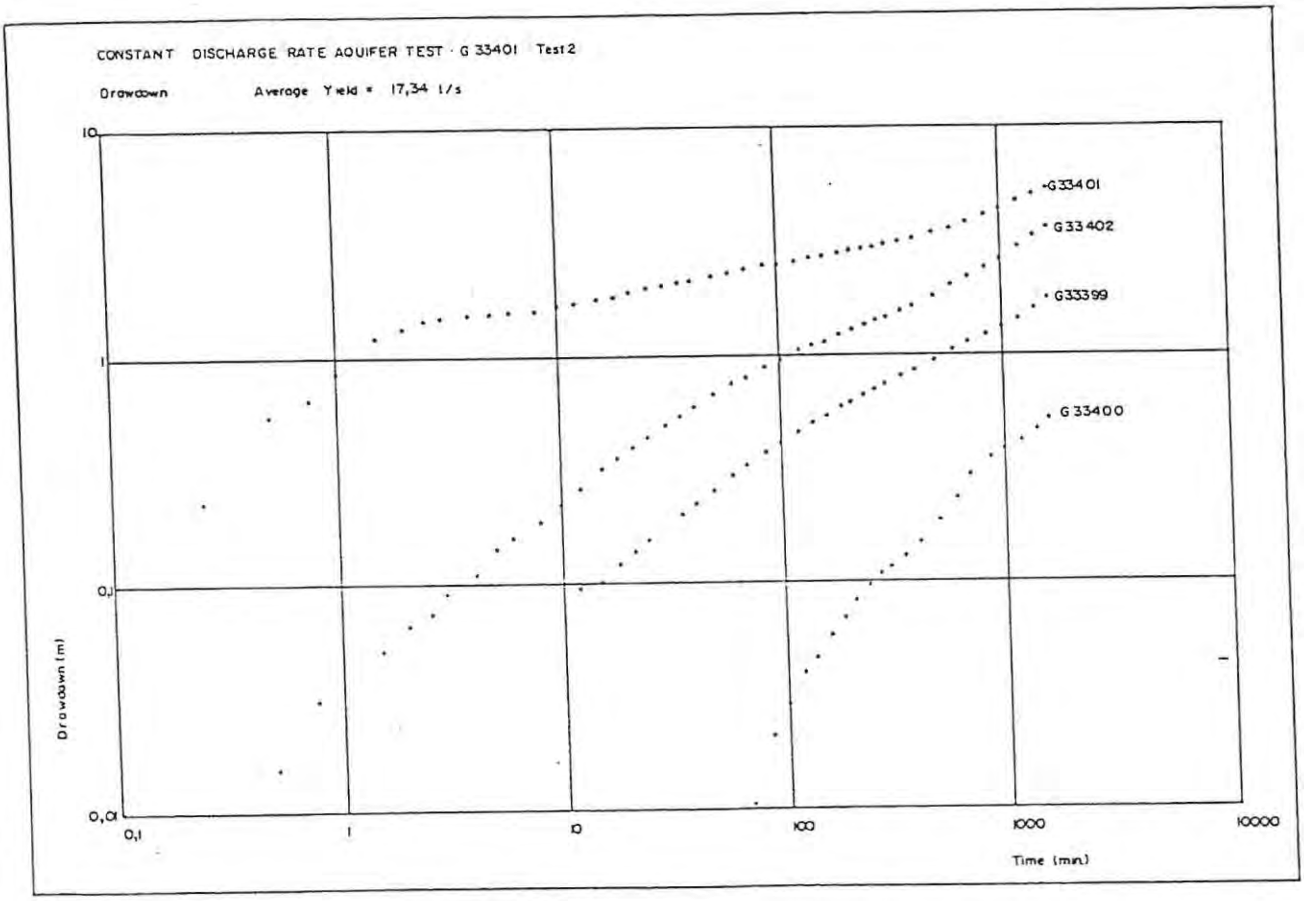
AQUIFER TEST SITE : GRASRAND 334

GEOLOGICAL CROSS – SECTION of the VORSTER SYNCLINE

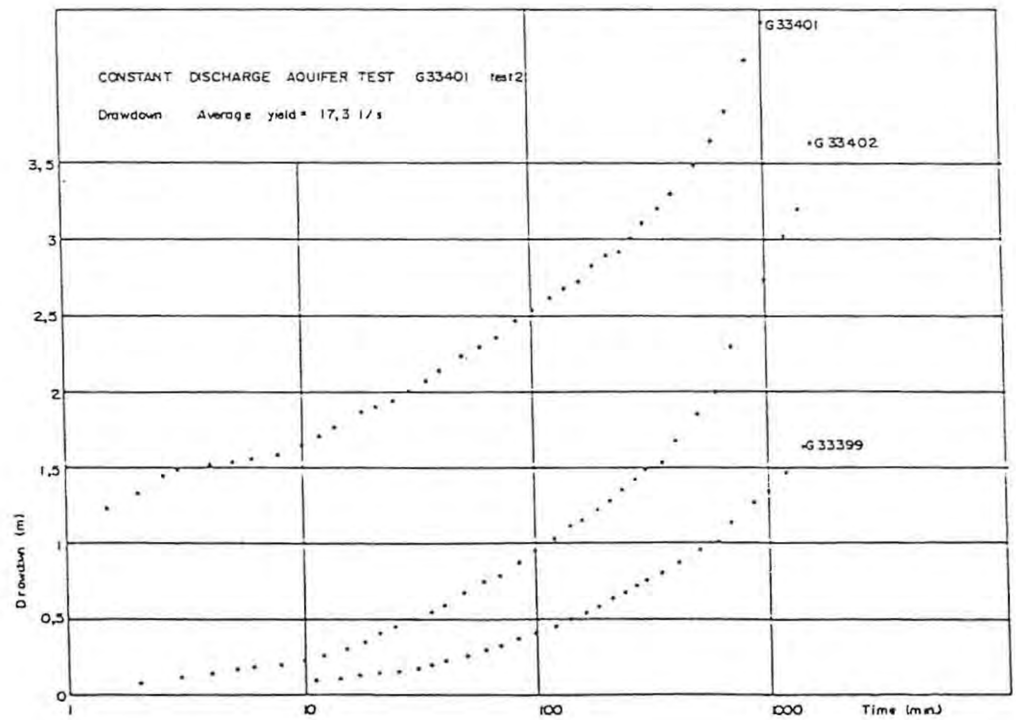


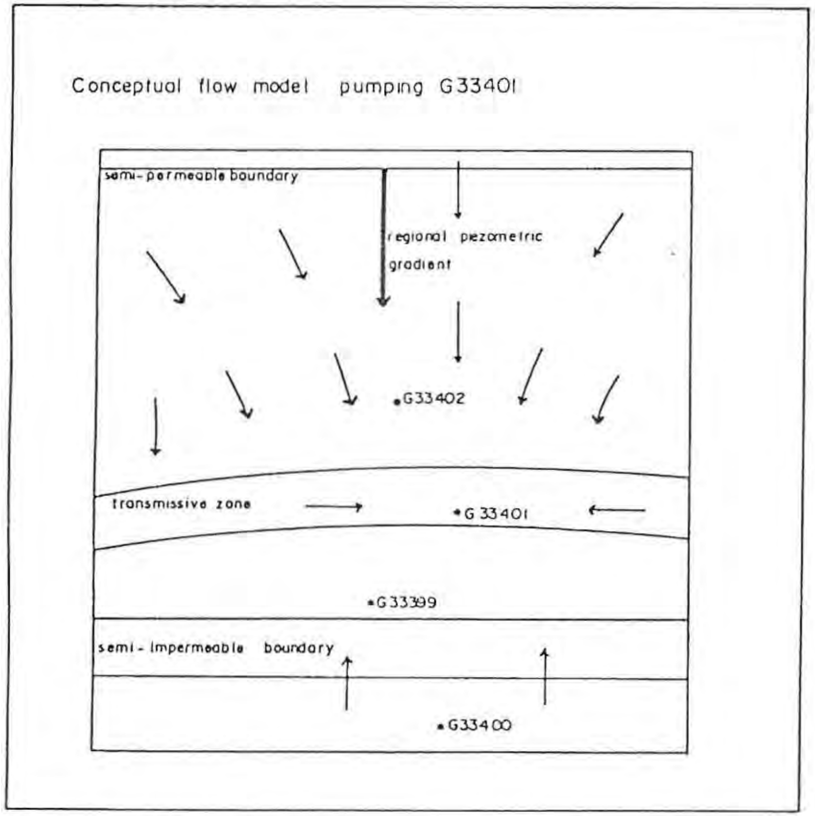
Site Plan of the Pumping Test : GRASRAND 334

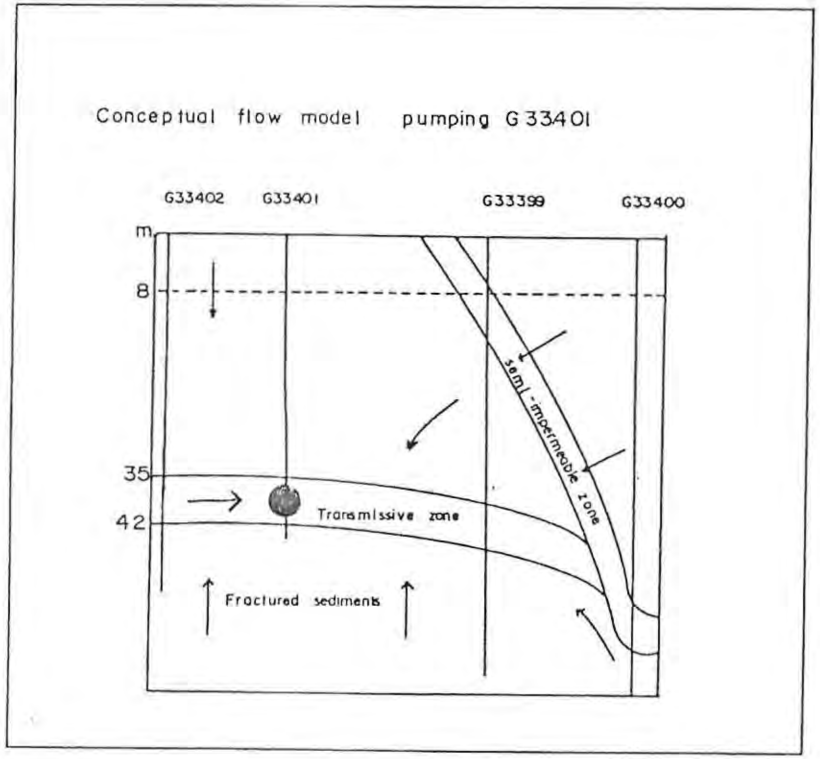




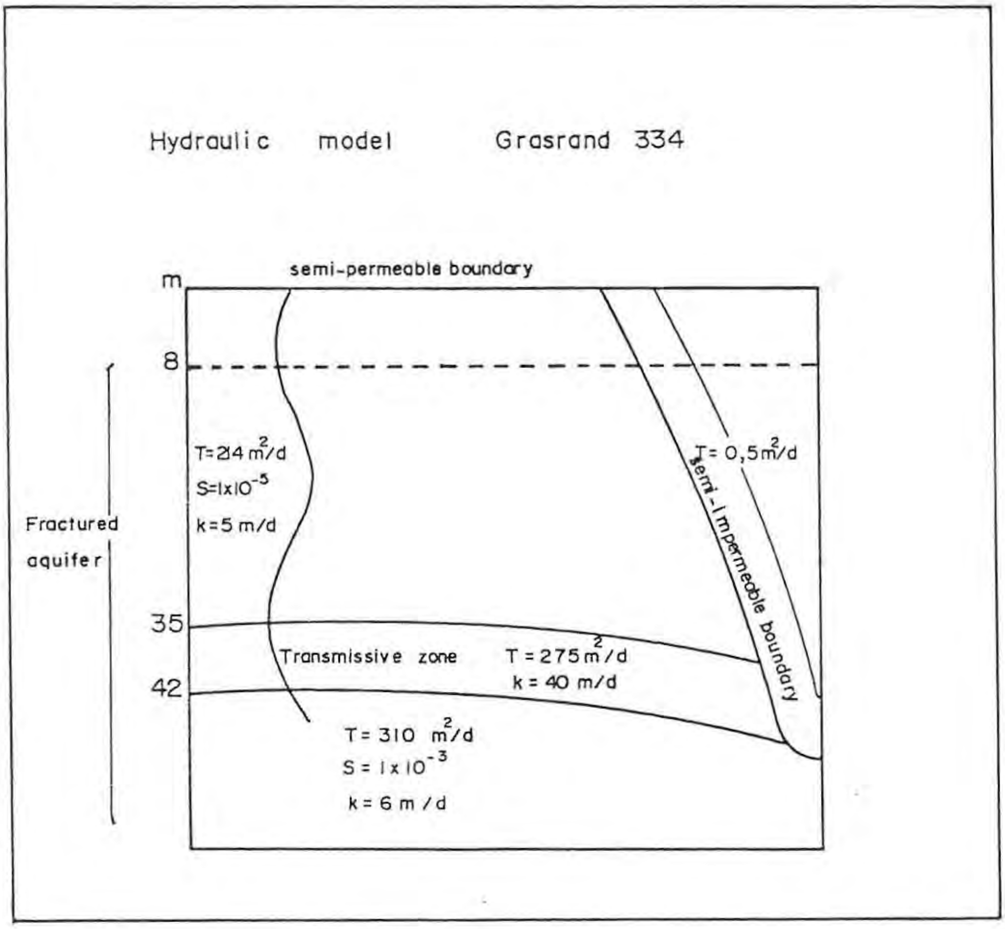
- the s/t curve of G33400 is the typical water level response for an observation point in a leaky layer
- the other curves indicate linear flow, pseudo-radial flow and boundary conditions







- an extremely anisotropic flow pattern is developed, particilarly at early pumping times
- the transmissive zone acts as an extended well
- the hydraulic gradient between G33401 and G33399 and the attitude of the fractured transmissive zone must be taken into account when interpreting the drawdown data of G33399


Hydraulic model Grasrand 334
semi-permeable boundary
m
8
35
42
Fractured aquifer
T=214 m²/d
S=1x10⁻⁵
k=5 m/d
T= 0,5 m²/d
semi-impermeable boundary
Transmissive zone
T = 275 m²/d
k = 40 m/d
T = 310 m²/d
S = 1 x 10⁻³
k = 6 m / d

The usefulness and applicability of the discrete element approach

The basic aim of an aquifer test is to obtain useful hydraulic parameters which can then be used to dertermine the exploration potential of a given aquifer unit. The standard test approach yielded complex drawdown- time curves which were an expression of the "average response" of the total aquifer system to abstraction. These curves could easily be erroneously interpretated as little insight can be obtained regarding:

i) which part of the system is being pumped.

ii) the dominant flow component.

iii) the origin of leakage.

Also, is was found that the S-value obtained from this approach represented the storativity of the transmissive fracture zones only.

The discrete element approach enabled the monitoring of aquifer response at different depths. This approach allowed that only one production zone was pumped at a time and hence the drawdown- time curve obtained was for that zone only. The curves tended to be less complex than those obtained from the standard tests. By evaluating each drawdown- time curve for the different depths and understanding the geohydrology prevailing at each site, more numerous and more representative hydraulic parameters were obtained.

APPENDIX 5:

HYDROCHEMICAL DATA

Appendix 5A

Hydrochemical data - private boreholes

HYDROCHEMICAL DATA

CONSTITUENTS IN mg/l

BOREHOLE Nº	DATE	Ca	Mg	Na	K	HCO_3	SO_4	Cl	Nitrate as N	F	Si	P	NH_4	PH	TAL as mg/l $CaCO_3$	E.C.	TDS	Nitrate as NO_3
MOORDENAARS UNIT																		
CE 9.	23-1-85	72	48	65	1.5	243.84	57	131	8.84	0.6	21.1	0.010	0.02	7.9	200	110.9	679	39.13
GD 19	5-2-85	123	82	148	1.0	159.72	183	399	1.22	0.7	16.1	0.028	0.25	7.8	131	186.6	1120	5.40
GDS 1	31-1-85	367	272	413	4.8	214.58	622	1637	0.54	0.5	15.5	0.006	0.04	7.8	176	554.3	3549	2.39
RN 3	23-1-85	155	76	130	0.5	276.76	193	347	2.12	0.5	15.7	0.012	0.01	7.9	227	193.9	1205	9.38
SWART UNIT																		
DT 1	7.2.85	85	64	83	1.3	241.40	80	226	3.76	0.6	17.7	0.031	0.07	7.8	198	129.2	817	16,64
DT 19	12-4-85	48	18	132	0.7	243.84	73	110	0.23	1.7	12.6	0.028	0.03	8.0	200	93.3	641	1.02
DT 31	12-4-85	106	60	109	1.1	297.49	122	226	2.33	0.6	16.2	0.029	0.05	7.9	244	141.1	949	10.31
GD 7	16-1-85	66	36	170	0.5	34.14	125	366	1.54	0.5	4.8	0.054	0.02	6.8	28	152.1	811	6.82
GD 9	16-1-85	175	98	703	5.9	190.20	486	1363	0.08	4.6	13.0	0.020	0.02	7.8	156	486.6	3039	0.35
KD 24	9-1-85	145	72	94	1.8	206.05	80	387	4.78	0.4	16.7	0.005	0.04	7.9	169	177.8	1025	21.16
KDS 1	30-1-85	131	60	89	1.8	232.87	73	289	6.51	0.5	19.2	0.021	0.03	7.9	191	156.3	925	28.82
KK 16	10-2-85	75	30	63	0.5	260.91	42	95	1.72	0.7	15.8	0.009	0.03	7.8	214	93.1	589	7.61
KK 18	29-1-85	97	26	91	1.8	254.82	48	143	8.59	1.0	13.8	0.020	0.03	7.9	209	114.6	715	38.02
RP 1	14-5-85	320	83	221	3.9	85.35	187	998	0.72	1.1	9.6	0.031	1.33	7.6	70	350.1	1914	3.19
KAMDEBOO UNIT																		
DP 45	30-9-84	108	64	107	4.2	254.82	107	264	11.70	0.7	16.1	0.021	0.09	7.5	209	157.3	977	51.79
DP 54	3-9-84	65	47	98	1.9	106.07	80	244	4.59	0.7	14.5	0.006	0.03	7.8	87	120.3	678	20.32
DT 26	30-1-85	111	58	107	4.1	231.65	92	290	6.51	0.6	13.5	0.004	0 03	7.9	190	169.6	936	28.82
KK 22	30-1-85	60	37	60	1.5	259.69	50	72	2.67	0.6	14.4	0.007	0.02	7.8	213	92.6	567	11.82
KK 22	3-9-84	50	34	60	1.8	295.05	55	80	2.22	0.9	14.1	0.011	0.07	8.0	242	78.8	602	9.83
KK 24	30-1-85	54	36	59	1.0	315.78	32	50	5.85	0.5	17.3	0.04	0.02	8.0	259	91.8	591	25.90
OD 4	3-9-84	17	9	139	0.7	135.33	44	138	0.24	1.5	8.2	0.006	0.02	8.2	111	83.0	495	1.06
OD 5	10-2-85	95	11	488	6.2	90.22	37	848	0.14	1.8	7.7	0.005	0.03	7.8	74	292.7	1586	0.62
TN 6	22-8-84	441	202	326	5.9	225.55	494	1290	4.22	0.7	15.8	0.021	0.09	7.6	185	478.6	3020	18.68
TN 25	22-8-84	399	205	522	2,8	315.78	514	1449	1.29	0.8	15.4	0.021	0.09	7.8	259	553.1	3431	5.71

HYDROCHEMICAL DATA

CONSTITUENTS IN mg/l

BOREHOLE N°	DATE	Ca	Mg	Na	K	HCO_3	SO_4	Cl	Nitrate as N	F	Si	P	NH_4	PH	TAL as mg/l $CaCO_3$	E.C.	TDS	Nitrate as NO_3
VK 2	22-8-84	39	28	56	1.6	254.82	23	93	0.98	0.7	13.9	0.009	0.09	8.0	209	67.0	514	4.34
VN.12.	29-1-85	59	39	55	1.0	342.60	34	54	3.65	0.5	16.5	0.004	0.03	8.0	281	96.1	619	16.16
ZK 2	20-8-84	260	179	1140	6.5	375.52	847	1803	6.39	1.6	12.8	0.021	0.09	7.9	308	722.9	4654	28.29
SUNDAYS UNIT																		
DP 9	30-9-84	512	231	400	6.3	195.07	582	1559	3.93	0.8	12.3	0.021	0.09	7.6	160	572.5	3517	17.40
DP 49	5-9-84	62	1	236	1.2	67.06	175	292	0.12	5.0	6.6	0.013	0.10	7.3	55	142.5	847	0.53
DP 74	5-9-84	572	356	1347	26.6	187.76	1826	2863	0.01	1.4	14.5	0.011	0.10	7.6	154	1004.8	7195	0.04
KD 7	25-2-85	233	157	340	5.3	204.83	490	882	8.70	0.8	12.8	0.034	0.21	7.7	168	379.0	2364	38.51
KD 36	7-9-84	147	90	223	4.0	114.61	510	433	7.97	0.8	13.3	0.021	0.09	7.8	94	272.7	1571	35.28
KD 39	30-1-85	151	79	147	2.2	310.90	125	368	13.83	0.6	21.3	0.013	0.04	7.9	255	199.9	1266	61.22
KN 18	12-9-84	79	65	101	1.0	174.35	91	272	6.81	0.7	16.8	0.021	0.09	7.6	143	162.3	831	30.15
KN 21	25-9-84	621	342	417	20.0	58.52	597	2389	8.32	0.8	13.2	0.021	0.09	7.5	48	779.0	4496	36.83
KN 22	30-1-85	60	37	60	1.5	259.69	50	72	2.67	0.6	14.4	0.007	0.02	7.8	213	82.6	567	11.82
KN 25	12-1-84	232	133	188	1.7	102.41	345	786	7.76	0.7	14.0	0.021	0.09	7.8	84	340.5	1848	34.35
KN 47	25-9-84	35	52	74	1.2	238.97	84	102	3.34	0.7	17.9	0.021	0.09	7.8	196	111.4	621	14.78
ZF 21	25-9-84	38	14	139	0.9	193.86	61	142.0	0.50	2.3	9.3	0.021	0.09	7.7	159	101.7	602	2.21

HYDROCHEMICAL DATA

CONSTITUENTS IN meq/1

BOREHOLE Nº	Ca	Mg	Na	K	Na+K	TOTAL CATIONS	%Ca	%Mg	%Na+K	HCO_3	SO_4	Cl	NO_3	F	$Cl+NO_3+F$	TOTAL ANIONS	$\%HCO_3$	$\%SO_4$	$\%Cl+NO_3+F$	SAR
MOORDENAARS UNIT																				
CE 9	3.59	3.95	2.83	0.04	2.87	10.41	34.5	37.9	27.5	4.00	1.19	3.70	0.63	0.03	4.36	9.54	41.9	12.4	45.7	1.5
GD 19	6.14	6.75	6.44	0.03	6.46	19.35	31.7	34.9	33.4	2.62	3.81	11.26	0.09	0.04	11.38	17.81	14.7	21.4	63.9	2.5
GDS 1	18.31	22.37	17.97	0.12	18.09	58.78	31.2	38.1	30.8	3.52	12.95	45.18	0.04	0.03	46.24	62.71	5.6	20.7	73.7	4.0
RN 3	7.73	6.25	5.66	0.01	5.67	19.65	39.4	31.8	28.8	4.54	4.02	9.79	0.15	0.03	9.97	18.52	24.5	21.7	53.8	2.1
SWART UNIT																				
DT 1	4.24	5.26	3.61	0.03	3.64	13.15	32.3	40.0	27.7	8.96	1.67	6.38	0.27	0.03	6.68	12.30	32.2	13.5	54.3	1.7
DT 19	2.40	1.48	5.74	0.02	5.76	9.64	24.9	15.4	59.8	4.00	1.52	3.10	0.02	0.09	3.21	8.73	45.8	17.4	36.8	4.1
DT 32	5.28	4.94	4.74	0.03	4.77	14.99	35.3	32.9	31.8	4.88	2.54	6.38	0.17	0.03	6.57	13.99	34.9	18.2	47.0	2.1
GD 7	3.29	2.96	7.40	0.01	7.41	13.66	24.1	21.7	54.2	0.56	2.60	10.32	0.11	0.03	10.46	13.62	4.1	19.1	76.8	4.2
GD 9	8.73	8.06	30.58	0.15	30.73	47.53	18.4	17.0	64.7	3.12	10.12	38.45	0.01	0.24	38.70	51.93	6.0	19.5	74.5	70.6
KD 24	7.24	5.92	4.09	0.05	4.14	17.29	41.8	34.2	23.9	3.38	1.67	10.92	0.34	0.02	11.28	16.32	20.7	10.2	69.1	1.6
KDS 1	6.54	4.94	3.87	0.05	3.92	15.39	42.5	32.1	25.5	3.82	1.52	8.15	0.46	0.03	8.64	13.98	27.3	10.9	61.8	1.6
KK 16	3.74	2.47	2.74	0.01	2.75	8.96	41.8	27.5	30.7	4.28	0.87	2.68	0.12	0.04	2.84	7.99	53.5	10.9	35.5	1.6
KK 18	4.84	2.14	3.96	0.05	4.00	10.98	44.1	19.5	36.5	4.18	1.00	4.03	0.61	0.05	4.70	9.88	42.3	10.1	47.6	2.1
RP 1	15.97	6.83	9.61	0.10	9.71	32.51	49.1	21.0	29.9	1.40	3.89	28.15	0.05	0.06	28.26	33.56	4.2	11.6	84.2	2.8
KAMDEBOO UNIT																				
DL 4	44.51	39.48	37.15	0.28	37.43	121.42	36.7	32.5	30.8	4.94	20.74	89.93	0.37	0.04	90.34	116.01	4.3	17.9	77.9	5.7
DP 45	5.39	5.26	4.65	0.11	4.76	15.42	35.0	34.2	30.9	4.18	2.23	7.45	0.84	0.04	8.32	14.72	28.4	15.1	56.5	2.0
DP 54	3.24	3.87	4.26	0.05	4.31	11.42	28.4	33.9	37.8	1.74	1.67	6.88	0.33	0.04	7.25	10.66	16.3	15.6	68.0	2.3
DT 26	5.54	4.77	4.65	0.10	4.76	15.07	36.8	31.7	31.6	3.80	1.92	8.18	0.46	0.03	8.68	14.39	26.4	13.3	60.3	2.1
KK 22	2.99	3.04	2.61	0.04	5.65	8.69	34.5	35.0	30.5	4.26	1.04	0.04	0.19	0.03	0.26	5.56	76.6	18.7	4.7	1.5
KK 22	2.50	2.90	2.61	0.05	2.66	7.95	31.4	35.2	33.4	4.84	1.15	2.26	0.16	0.05	2.46	8.44	57.3	13.6	29.2	1.6
KK 24	2.69	2.96	2.57	0.03	2.59	8.25	32.7	35.9	31.4	5.18	0.67	1.41	0.42	0.03	1.85	7.70	67.2	8.7	24.1	1.5
OD 4	8.85	0.74	6.05	0.02	6.06	7.65	11.1	9.7	79.2	2.22	0.92	3.89	0.02	0.08	3.99	7.12	31.1	12.9	56.0	6.8
OD 5	4.74	0.90	21.23	0.16	21.39	27.03	17.2	3.3	79.1	1.48	0.77	23.92	0.01	0.09	24.03	26.28	5.6	2.9	91.4	12.6
TN 6	22.01	16.62	14.18	0.15	14.33	52.95	41.6	31.4	27.1	3.70	10.29	36.39	0.30	0.04	36.73	50.71	7.3	20.3	72.4	5.3

HYDROCHEMICAL DATA

CONSTITUENTS IN meq/1

BOREHOLE Nº	Ca	Mg	Na	K	Na+K	TOTAL CATIONS	%Ca	%Mg	%Na+K	HCO_3	SO_4	Cl	NO_3	F	$Cl+NO_3+F$	TOTAL ANIONS	%HCO_3	%SO_4	%Cl+ NO_3+F	SAR
VK 2	1.95	2.30	2.44	0.04	2.48	6.73	28.9	34.2	36.8	4.18	0.48	2.62	0.07	0.04	2.73	7.39	56.5	6.5	37.0	1.7
VN 12	2.94	3.21	2.39	0.03	2.42	8.57	34.4	37.4	28.2	5.62	0.71	1.52	0.26	0.03	1.8	8.13	69.0	8.7	22.3	1.4
ZK 2	12.97	14.72	49.59	0.17	49.76	77.45	16.8	19.0	64.0	6.15	17.63	50.86	0.46	0.08	51.40	75.19	8.2	23.5	68.4	13.3
SUNDAYS UNIT	—																			
DP 9	25.55	19.00	17.40	0.16	17.56	62.11	41.1	30.6	28.3	3.20	12.12	43.98	0.28	0.04	44.30	59.62	5.4	20.3	74.3	3.7
DP 49	3.09	0.08	10.27	0.03	10.30	13.47	23.0	0.6	76.4	1.10	3.64	8.24	0.01	0.26	8.51	13.25	8.3	27.5	64.2	8.1
DP 74	28.54	29.28	58.59	0.68	59.27	117.10	24.4	25.0	50.6	3.08	38.0	80.77		0.07	80.84	121.93	2.5	31.2	66.3	10.9
KD 7	11.63	12.91	14.79	0.14	14.93	39.47	29.5	32.7	37.8	3.36	10.20	24.88	0.62	0.04	25.54	39.10	8.6	26.1	65.3	4.2
KD 36	7.34	7.40	9.70	0.10	9.80	24.54	29.9	30.2	39.9	1.88	10.62	12.21	0.57	0.04	12.83	25.32	7.4	41.9	50.7	3.6
KD 39	7.53	6.50	6.39	0.06	6.45	20.48	36.8	31.7	31.5	5.10	2.60	10.38	0.88	0.03	11.40	19.10	26.7	13.6	59.7	2.4
KN 18	3.94	5.35	4.39	0.03	4.42	13.71	28.8	39.0	32.2	2.86	1.89	7.67	0.49	0.04	8.20	12.95	22.1	14.6	63.3	2.0
KN 21	30.99	28.13	18.14	0.51	18.65	77.77	39.8	36.7	24.0	0.96	12,43	67.39	0.59	0.04	68.03	81.42	1.2	15.3	83.6	3.3
KN 22	1.90	1.15	6.05	0.02	6.07	9.12	20.8	12.6	66.6	3.18	1.27	4.01	0.04	0.12	4.16	8.61	36.9	14.8	48.3	4.9
KN 25	11.58	10.94	8.18	0.04	8.22	30.74	37.7	35.6	26.7	1.68	7.18	22.46	0.55	0.04	23.05	31.91	5.3	22.5	72.2	2.4
KN 47	1.75	4.28	3.22	0.03	3.25	9.27	18.8	46.1	35.0	3.92	1.75	2.88	0.24	0.04	3.15	8.82	44.4	19.8	35.8	1.9
ZF 21	4.69	3.54	6.13	0.20	6.34	14.57	32.2	24.3	43.5	4.02	1.79	6.97	0.84	0.06	7.87	13.67	29.4	13.1	57.5	3.0

Appendix 5B

Hydrochemical data - departmental boreholes

HYDROCHEMICAL DATA

CONSTITUENTS IN mg/l

DEPTH m	BOREHOLE N°	DATE	Ca	Mg	Na	K	HCO_3	SO_4	Cl	Nitrate as N	F	Si	P	NH_4	PH	TAL as mg/l $CaCO_3$	E.C.	TDS	Nitrate as NO_3
11m	33339	13-11-84	287	261	466	2.4	114.61	486	1648	0.25	1.3	13.1	0.60	0.06	7.8	94	534.5	3280	1.11
22m	33340	14-11-84	105	45	355	6.0	151.18	22	748	0.15	1.8	10.1	0.039	0.03	7.8	124	272.3	1445	0.66
37m	33340	14-11-84	131	52	351	2.4	147.52	21	806	0.07	1.6	11.1	0.025	0.03	7.8	121	289.1	1524	0.31
F	33340	14-11-84	92	20	674	1.3	106.07	56	1090	0.15	3.5	9.7	0.031	0.13	7.8	87	409.6	2053	0.66
13m	33341	15-11-84	1136	682	1548	19.1	56.08	1114	5358	0.10	1.2	7.9	0.028	0.42	7.5	46	1566.1	9924	0.44
20m	33341	15-11-84	619	299	696	7.2	80.47	393	2582	0.07	1.3	10.8	0.019	0.03	7.6	66	823.8	4690	0.31
F	33341	15-11-84	436	227	599	1.6	64.62	271	2221	0.09	1.1	10.4	0.019	0.04	7.5	53	660.0	3831	0.40
13m	33342	16-11-84	267	194	456	10.4	142.65	376	1407	7.16	0.7	12.0	0.010	0.04	7.5	117	518.4	2898	31.69
41m	33342	16-11-84	243	180	524	5.8	139.86	389	1453	4.45	0.8	14.3	0.049	0.10	7.8	159	482.6	3023	19.70
F	33342	19-11-84	158	128	380	6.5	15.21	262	1046	5.31	0.6	13.6	0.013	0.04	0.7	42	375.7	2070	23.51
17m	33343	20-11-84	216	207	1066	32.7	192.64	771	2104	1.44	1.3	8.7	0.024	0.03	7.7	158	742.9	4605	6.37
45m	33343	21-11-84	185	145	908	27.4	117.04	610	1797	1.49	1.4	9.1	0.022	0.29	7.8	96	630.8	3807	6.60
21m	33344	21-11-84	605	326	558	40.4	29.26	739	2412	3.06	0.7	7.7	0.028	0.07	7.5	24	1412.0	4732	13.55
47m	33344	21-11-84	543	285	590	7.2	135.33	729	1967	3.05	1.0	11.5	0.022	0.03	7.6	111	708.5	4283	13.50
F	33344	22-11-84	436	276	571	2.9	54.86	709	1953	3.07	0.3	15.6	0.010	0.02	7.5	45	660.0	4032	13.59
24m	33345	26-11-84	17	24	72	8.0	234.09	35	40	2.07	0.7	10.9	0.010	0.05	8.5	192	60.0	450	9.16
34m	33345	26-11-84	16	22	73	21.8	268.23	33	32	2.10	1.1	11.1	0.114	0.17	8.5	220	61.8	488	9.30
F	33345	27-11-84	17	22	85	19.1	307.24	51	32	3.70	1.0	11.2	0.002	0.53	8.0	252	80.4	563	16.38
27m	33346	3-12-84	34	54	101	26.7	236.53	77	188	1.51	0.5	11.1	0.118	0.25	8.2	194	114.6	735	6.68
50m	33346	3-12-84	68	54	109	9.5	229.21	224	171	0.83	0.7	14.3	0.017	0.02	7.9	188	123.8	883	3.67
F	33346	5-12-84	46	40	80	1.7	257.25	56	149	0.31	0.4	14.1	0.000	0.22	7.8	211	110.0	647	1.37
17m	33347	10-01-85	25	70	155	7.8	388.93	131	191	1.06	0.8	13.9	0.018	0.17	7.9	319	140.8	988	4.69
54m	33347	10-01-85	65	36	83	4.5	198.73	49	172	0.37	0.3	14.7	0.023	0.06	7.8	163	85.7	625	1.64
65m	33347	17-01-85	61	36	78	1.3	198.73	50	136	0.06	0.2	16.8	0.013	0.02	7.9	163	96.9	579	0.27
F	33347	19-01-85	73	41	80	1.7	232.87	62	148	1.34	0.4	14.0	0.025	0.04	7.9	191	107.4	659	5.93
23m	33348	21-01-85	106	96	174	6.5	251.16	126	431	0.06	2.7	17.2	0.077	0.11	8.1	206	219.4	1213	0.27
66m	G33348	13-1-85	134	96	206	7.9	249.94	191	484	0.00	4.2	14.7	0.036	0.06	8.2	205	241.3	1387	0.00
22m	33349	15-1-85	286	359	476	31.5	363.33	717	1507	4.69	1.0	15.8	0.030	0.05	8.0	298	603.0	3778	20.76
F	33349	17-1-85	226	238	414	15.8	329.19	514	1190	13.57	1.9	12.8	0.022	0.04	8.0	270	463.6	3002	60.07

HYDROCHEMICAL DATA

CONSTITUENTS IN mg/l

DEPTH m	BOREHOLE Nº	DATE	Ca	Mg	Na	K	HCO_3	SO_4	Cl	Nitrate as N	F	Si	P	NH_4	PH	TAL as mg/l $CaCO_3$	E.C.	TDS	Nitrate as NO_3
11m	33351	23-1-85	242	299	485	55.7	277.98	684	1488	0.94	1.4	13.0	0.016	0.04	7.6	228	540.9	3551	4.16
16m	33352	25-1-85	329	272	841	24.5	203.61	886	2097	2.16	0.8	8.8	0.017	0.04	7.6	167	734.0	4672	9.56
20m	33352	25-1-85	259	260	946	5.6	187.76	844	2019	2.63	0.8	14.6	0.005	0.09	7.7	154	723.2	4548	11.64
29m	G 33352	26-1-85	204	260	1064	11.2	209.70	890	2033	2.96	1.0	14.0	0.007	0.05	7.7	172	743.1	4701	13.10
F	33352	28-1-85	284	220	1083	6.4	186.54	1006	2098	2.49	0.8	13.6	0.029	0.05	7.8	153	773.1	4909	11.02
19m	33353	29-1-85	105	55	144	16.7	207.27	96	346	2.92	0.6	11.8	0.023	0.03	7.7	170	171.7	994	12.93
50m	33353	30-1-85	52	70	153	7.2	182.88	106	373	2.99	0.5	13.3	0.011	0.06	7.8	150	167.7	971	13.24
F	33353	28-1-85	121	70	153	6.4	215.80	112	397	2.97	0.6	13.0	0.039	0.05	7.8	177	187.5	1101	13.15
16m	33354	31-1-85	673	384	646	8.4	41.45	983	2668	1.21	0.4	14.9	0.002	0.85	7.5	34	867.8	5426	5.36
25m	33354	31-1-85	600	396	699	28.9	53.65	986	2728	1.42	0.6	12.8	0.015	0.93	7.5	44	871.2	5509	6.29
F	33354	31-1-85	674	404	645	5.9	56.08	930	2504	1.03	0.4	12.1	0.024	0.21	7.4	46	818.0	5236	4.56
12m	33355	2-2-85	515	366	702	6.6	53.65	953	2244	1.49	0.6	15.7	0.006	0.93	7.6	44	839.4	4865	6.60
42m	33355	2-2-85	745	452	541	6.0	9.75	992	2771	0.58	0.1	12.5	0.003	0.90	7.5	8	874.0	5533	2.57
F	33355	5-2-85	651	365	557	11.7	64.62	740	2314	0.23	0.6	10.2	0.040	0.17	7.4	53	769.5	4714	1.02
35m	33356	11-2-85	54	21	175	1.8	210.92	5	281	0.08	3.0	8.7	0.028	0.03	7.5	173	121.7	762	0.35
44m	33356	11-2-85	31	10	143	5.8	277.98	1	157	0.07	2.4	8.9	0.213	0.06	7.7	228	89.5	638	0.31
F	33356	8-5-85	51	17	159	3.8	186.54	8	246	0.13	2.5	7.6	0.085	0.17	8.0	153	114.5	682	0.58
54m	33357	13-2-85	31	19	107	2.7	206.05	11	131	0.39	0.8	9.2	0.025	0.02	7.8	169	79.1	520	1.73
F	33357	13-2-85	47	16	112	3.5	193.86	51	131	0.49	2.5	9.1	0.025	0.06	8.0	159	85.2	569	2.17
25m	33358	14-2-85	111	52	143	22.6	137.77	59	419	3.77	0.6	5.4	0.015	0.02	7.3	113	167.6	967	16.69
58m	33358	14-2-85	138	37	109	6.9	199.95	47	342	0.24	0.6	12.3	0.012	0.03	7.3	164	148.5	893	1.06
80m	33358	15-2-85	117	33	111	2.7	219.46	42	307	0.68	0.6	12.2	0.131	0.07	7.3	180	134.9	848	3.01
F	33358	15-2-85	101	24	111	2.3	143.87	45	254	0.40	0.8	11.5	0.028	0.07	7.3	118	122.1	694	1.77
18m	33359	20-2-85	74	61	166	3.3	268.23	55	347	2.56	0.8	16.5	0.048	0.02	7.5	220	159.0	1004	11.33
F	33359	20-2-85	79	52	155	6.8	197.51	81	325	2.07	0.7	15.3	0.068	0.14	7.8	162	149.6	921	9.16
F	33363	25-3-85	166	35	752	5.7	213.36	63	1277	0.32	2.2	7.1	0.035	0.13	7.9	175	451.8	2523	1.42
F	33365	8-5-85	55	16	170	2.6	176.79	7	260	0.12	2.5	8.4	0.066	0.08	8.0	145	119.8	700	0.53
F	33393	22-5-85	90	14	90	8.1	149.96	34	188	0.17	1.4	8.9	0.127	0.24	7.8	123	97.9	585	0.75
F	33395	23-5-85	135	32	125	8.3	187.76	80	322	0.22	0.8	11.0	0.099	0.15	7.6	154	148.4	904	0.97

HYDROCHEMICAL DATA

CONSTITUENTS IN mg/l

DEPTH m	BOREHOLE N°	DATE	Ca	Mg	Na	K	HCO_3	SO_4	Cl	Nitrate as N	F	Si	P	NH_4	PH	TAL as mg/l $CaCO_3$	E.C.	TDS	Nitrate as NO_3
F	33396	29-5-85	151	72	97	9.1	201.17	107	370	5.87	0.6	14.6	0.056	0.13	7.6	165	170.7	1049	25.98
F	33399	13-6-85	19	6	136	6.5	182.88	4	115	0.46	6.7	8.4	0.170	0.64	8.1	150	72.4	487	2,04
F	33400	17-6-85	33	12	220	10.7	213.36	6	306	0.31	4.9	7.1	0.330	1.38	8.0	175	125.4	816	1.37
F	33401	20-6-85	19	5	142	1.4	167.03	57	121	0.14	1.2	8.3	0.075	1.18	8.1	137	76.7	524	0.62

HYDROCHEMICAL DATA

CONSTITUENTS IN meq/l

DEPTH m	BOREHOLE N°	Ca	Mg	Na	K	Na+K	TOTAL CATIONS	%Ca	%Mg	%Na+K	HCO_3	SO_4	Cl	NO_3	F	$Cl+NO_3+F$	TOTAL ANIONS	$\%HCO_3$	$\%SO_4$	$\%Cl+NO_3+F$	SAR
11m	G33339	14.32	21.47	20.27	0.06	20.33	56.12	25.5	38.3	36.2	1.88	10.12	46.49	0.02	0.07	46.58	58.57	3.2	17.3	79.5	4.8
22m	33340	5.24	3.70	15.44	0.15	15.60	24.54	21.4	15.1	63.6	2.48	0.46	21.10	0.01	0.09	21.21	24.14	10.3	1.9	87.8	7.3
37m	33340	4.28	15.27	0.06	15.33	26.14	26.14	25.0	16.4	58.6	2.42	0.44	22.74	5.00	0.08	22.83	25.68	9.4	1.7	88.9	6.6
F	33340	4.59	1.65	29.32	0.03	29.35	35.59	12.9	4.6	82.5	1.74	1.17	30.75	0.01	0.18	30.94	33.85	5.1	3.4	91.4	16.6
13m	33341	56.69	56.10	67.34	0.49	67.83	180.61	31.4	31.1	37.6	0.92	23.19	151.15	0.01	0.06	151.22	175.33	0.5	13.2	86.2	9.0
20m	33341	30.89	24.60	30.28	0.18	30.46	85.94	35.9	28.6	35.4	1.32	8.18	72.84	5.00	0.07	72.91	82.41	1.6	9.9	88.5	5.7
F	33341	21.76	18.67	26.06	0.04	26.10	66.53	32.7	28.1	39.2	1.06	5.64	62.65	0.01	0.06	62.72	69.42	1.5	8.1	90.3	5.8
13m	33342	13.32	15.96	19.84	0.27	20.10	49.38	27.0	32.3	40.7	2.34	7.83	39.69	0.51	0.04	40.24	50.41	4.6	15.5	79.8	5.2
41m	33342	12.13	14.81	22.79	0.15	22.94	49.87	24.3	29.7	46.0	3.18	8.10	40.99	0.32	0.04	41.35	52.63	6.0	15.4	78.6	6.2
F	33342	7.88	10.53	16.53	0.17	16.70	35.11	22.5	30.0	47.6	0.84	5.45	29.51	0.38	0.03	29.92	36.21	2.3	15.1	82.6	5.4
17m	33343	10.78	17.03	46.37	0.84	47.21	75.01	14.4	22.7	62.9	3.16	16.05	59.35	0.10	0.07	59.53	78.73	4.0	20.4	75.6	12.4
45m	33343	9.23	11.93	39.50	0.70	40.20	61.36	15.0	19.4	65.5	1.92	12.70	50.69	0.11	0.07	50.87	65.49	2.9	19.4	77.7	12.1
21m	33344	30.19	26.82	24.27	1.03	25.31	82.81	36.7	32,6	30.7	0.48	15.39	68.04	0.22	0.04	68.30	84.16	0.6	18.3	81.1	4.5
47m	33344	27.10	23.44	25.67	0.18	25.85	76.39	35.5	30.7	33.8	2.22	15.18	55.49	0.22	0.05	55.76	73.16	3.0	20.7	76.2	5.1
F	33344	21.76	22.70	24.84	0.07	24.91	69.37	31.4	32.7	35.9	0.90	14.76	55.09	0.22	0.02	55.33	70.99	1.3	20.8	77.9	5.3
24m	33345	0.85	1.97	3.13	0.20	3.34	6.16	13.8	32.1	54.2	3.84	0.73	1.13	0.15	0.04	1.31	5.88	65.3	12.4	22.3	2.6
34m	33345	0.80	1.81	3.18	0.56	3.73	6.34	12.6	28.5	58.9	4.40	0.69	0.90	0.15	0.06	1.11	6.19	71.0	11.1	17.9	2.8
F	33345	0.85	11.81	3.70	0.49	4.19	6.84	12.4	26.4	61.2	5.04	1.06	0.90	0.26	0.05	1.22	7.32	68.8	14.5	16.7	3.2
27m	33346	1.70	4.44	4.39	0.68	5.08	11.21	15.1	39.6	45.3	3.88	1.60	5.30	0.11	0.03	5.44	10.92	35.5	14.7	49.8	2.5
50m	33346	3.39	4.44	4.74	0.24	4.98	12.82	26.5	34.7	38.9	3.76	4.66	4.82	0.06	0.04	4.92	13.34	28.2	35.0	36.9	2.4
F	33346	2.30	3.29	3.48	0.04	3.52	9.11	25.2	36.1	38.7	4.22	1.17	4.20	0.02	0.02	4.25	9.63	43.8	12.1	44.1	2.1
17m	33347	1.25	5.76	6.74	0.20	6.94	13.95	8.9	41.3	49.8	6.37	2.73	5.39	0.08	0.04	5.51	14.61	43.6	18.7	37.7	3.6
54m	33347	3.24	2.96	3.61	0.12	3.73	9.93	32.7	29.8	37.5	3.26	1.02	4.85	0.03	0.02	4.89	9.17	35.5	11.1	53.4	2.0
65m	33347	3.04	2.96	3.39	0.03	3.43	9.43	32.3	21.4	36.3	3.26	1.04	3.84	4.28	0.14	3.98	8.28	39.3	12.6	48.1	2.0
F	33347	3.64	3.37	3.48	0.04	3.52	10.54	34.6	32.0	33.4	3.82	1.29	4.18	0.10	0.01	4.20	9.40	40.6	13.7	45.7	1.9
23m	33348	5.29	7.90	7.57	0.17	7.74	20.92	25.3	37.7	37.0	4.12	2.62	12.16	4.28	0.14	12.30	19.04	21.6	13.8	64.6	2.9
66m	33348	6.69	7.90	8.96	0.20	9.16	23.75	28.2	33.3	38.6	4.10	3.98	13.65	0.00	0.22	13.87	21.95	18.7	18.1	63.2	3.3
22m	33349	14.27	29.53	20.71	0.81	21.51	65.31	21.9	45.2	32.9	5.95	14.93	42.51	0.33	0.05	42.90	63.78	9.3	23.4	67.3	4.4
F	33349	11.28	19.58	18.01	0.40	18.41	49.27	22.9	39.7	37.4	5.40	10.70	33.57	0.97	0.10	34.64	50.74	10.6	21.1	68.3	4.6

HYDROCHEMICAL DATA | CONSTITUENTS IN meq/l

DEPTH m	BOREHOLE Nº	Ca	Mg	Na	K	Na+K	TOTAL CATIONS	%Ca	%Mg	%Na+K	HCO_3	SO_4	Cl	NO_3	F	$Cl+NO_3+F$	TOTAL ANIONS	$\%HCO_3$	$\%SO_4$	$\%Cl+NO_3+F$	SAR
11m	33351	12.08	24.60	21.10	1.42	22.52	59.19	20.4	41.5	38.0	4.56	14.24	41.98	0.07	0.07	42.12	60.91	7.5	23.4	69.1	4.9
16m	33352	16.42	22.37	36.58	0.63	37.21	76.00	21.6	29.4	49.0	3.34	18.45	59.16	0.15	0.04	59.35	81.14	4.1	22.7	73.2	8.3
20m	33352	12.92	21.39	41.15	0.14	41.29	75.61	17.1	28.3	54.6	3.08	17.57	56.96	0.19	0.04	57.19	77.84	4.0	22.6	73.6	9.9
29m	33352	10.18	21.39	46.28	0.29	46.57	78.14	13.0	27.4	59.6	3.44	18.53	57.35	0.21	0.05	57.61	79.58	4.3	23.3	72.4	11.7
F	33352	14.17	18.10	47.11	0.16	47.27	79.54	17.8	22.8	59.4	3.06	20.94	59.18	0.18	0.04	59.40	83.41	3.7	25.1	71.2	11.7
19m	33353	5.24	4.52	6.26	0.43	6.69	16.45	31.8	27.5	40.7	3.40	2.00	9.76	0.21	0.03	10.00	15.40	22.1	13.0	65.0	2.8
50m	33353	2.59	5.76	6.66	0.18	6.84	15.19	17.1	37.9	45.0	3.00	2.21	10.52	0.21	0.03	10.76	15.97	18.8	13.8	67.4	3.3
F	33353	6.04	5.76	6.66	0.16	6.82	18.62	32.4	30.9	36.6	3.54	2.33	11.20	0.21	0.03	11.44	17.31	20.4	13.5	66.1	2.7
16m	33354	33.58	31.59	28.10	0.21	28.32	93.49	35.9	33.8	30.3	0.68	20.47	75.26	0.09	0.02	75.37	96.32	0.7	21.2	78.1	4.9
25m	33354	29.94	32.57	30.41	0.74	31.15	93.66	32.0	34.8	33.3	0.88	20.53	76.96	0.10	0.03	77.09	98.50	0.9	20.8	78.3	5.4
F	33354	33.63	33.23	28.06	0.15	28.21	95.07	35.4	35.0	29.7	0.92	19.36	70.64	0.07	0.02	70.73	91.01	1.0	21.3	77.7	4.9
12m	33355	25.70	30.11	30.54	0.17	30.71	86.51	29.7	34.8	35.5	0.88	19.84	63.30	0.11	0.03	63.44	84.16	1.0	23.6	75.4	5.8
42m	33355	37.18	37.18	23.53	0.15	23.69	98.04	37.9	37.9	24.2	0.16	20.65	78.17	0.04	0.01	78.22	99.03	0.2	20.9	79.0	3.9
F	33355	32.48	30.02	24.23	0.30	24.53	87.04	37.3	34.5	28.2	1.06	15.41	65.28	0.02	0.03	65.33	81.79	1.3	18.8	79.9	4.3
35m	33356	2.69	1.73	7.61	0.05	7.66	12.08	22.3	14.3	63.4	3.46	0.10	7.83	0.01	0.16	8.09	11.65	29.7	0.9	69.4	5.1
44m	33356	1.55	0.82	6.22	0.15	6.37	8.74	17.7	9.4	72.9	4.56	0.02	4.43	0.005	0.13	4.56	9.14	49.9	0.2	49.9	5.7
F	33356	2.54	1.40	6.92	0.10	7.01	10.96	23.2	12.8	64.0	3.06	0.17	6.94	0.01	0.13	7.08	10.30	29.7	1.6	68.7	4.9
54m	33357	1.55	1.56	4.65	0.07	4.72	7.83	19.7	20.0	60.3	3.38	0.23	3.70	0.03	0.04	3.77	7.37	45.8	3.1	51.1	3.7
F	33357	2.35	1.32	4.87	0.09	4.96	8.62	27.2	15.3	57.5	3.18	1.06	3.70	0.03	0.13	3.86	8.10	39.2	13.1	47.7	3.6
25m	33358	5.54	4.28	6.22	0.58	6.80	16.61	33.3	25.7	40.9	2.26	1.23	11.82	0.27	0.03	12.12	15.61	14.5	7.9	77.7	2.8
58m	33358	6.89	3.04	4.74	0.18	4.92	14.85	46.4	20.5	33.1	3.28	0.98	9.65	0.02	0.03	9.70	13.95	23.5	7.0	69.5	2.1
80m	33358	5.84	2.71	4.83	0.07	4.90	13.45	43.4	20.2	36.4	3.60	0.87	8.66	0.05	0.03	8.74	13.21	27.2	6.6	66.2	2.3
F	33358	5.04	1.97	4.83	0.06	4.89	11.90	42.3	16.6	41.1	2.36	0.94	7.17	0.03	0.04	7.24	10.53	22.4	8.9	68.7	2.6
18m	33359	3.69	5.02	7.22	0.08	7.31	16.02	23.1	31.3	45.6	4.40	1.15	9.79	0.18	0.04	10.01	15.56	28.3	7.4	64.4	3.5
F	33359	3.94	4.28	6.74	0.17	6.92	15.14	26.0	28.3	45.7	3.24	1.69	9.17	0.15	0.04	9.35	14.28	22.7	11.8	65.5	3.3
F	33363	8.28	2.88	32.71	0.15	32.86	44.02	18.8	6.5	74.6	3.50	1.31	36.02	0.02	0.12	36.16	40.97	8.5	3.2	88.3	13.8
F	33365	2.74	1.32	7.40	0.07	7.46	11.52	23.8	11.4	64.8	2.90	0.15	7.33	0.01	0.13	7.47	10.52	27.5	1.4	71.1	5.2
F	33393	4.49	1.15	3.92	0.21	4.12	9.76	46.0	11.8	42.2	2.46	0.71	5.30	0.01	0.07	5.39	8.56	28.7	8.3	63.0	2.3
F	33395	6.74	2.63	5.44	0.21	5.65	15.02	44.9	17.5	37.6	3.08	1.67	9.08	0.02	0.04	9.14	13.88	22.2	12.0	65.8	2.5

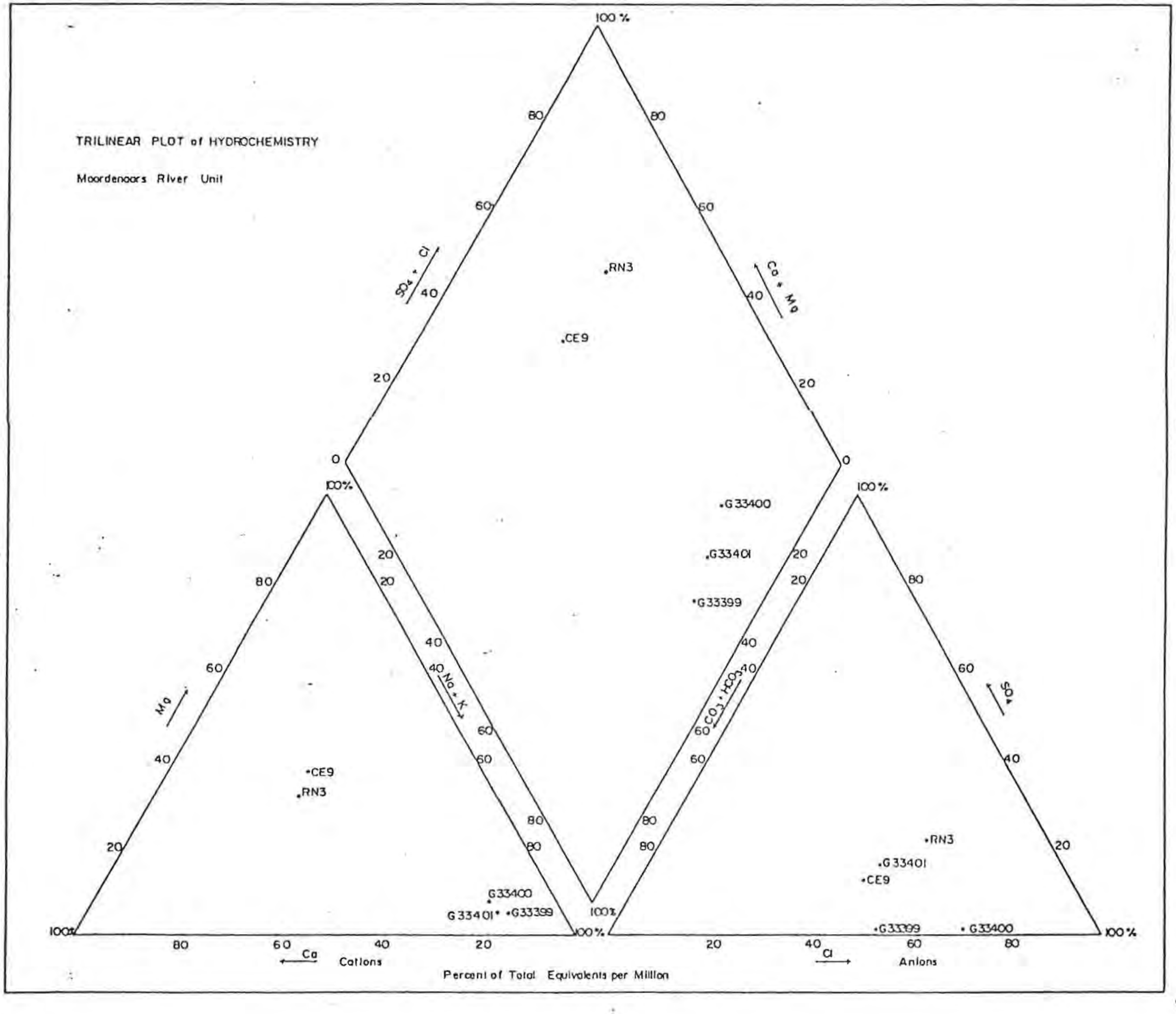
HYDROCHEMICAL DATA

CONSTITUENTS IN meq/1

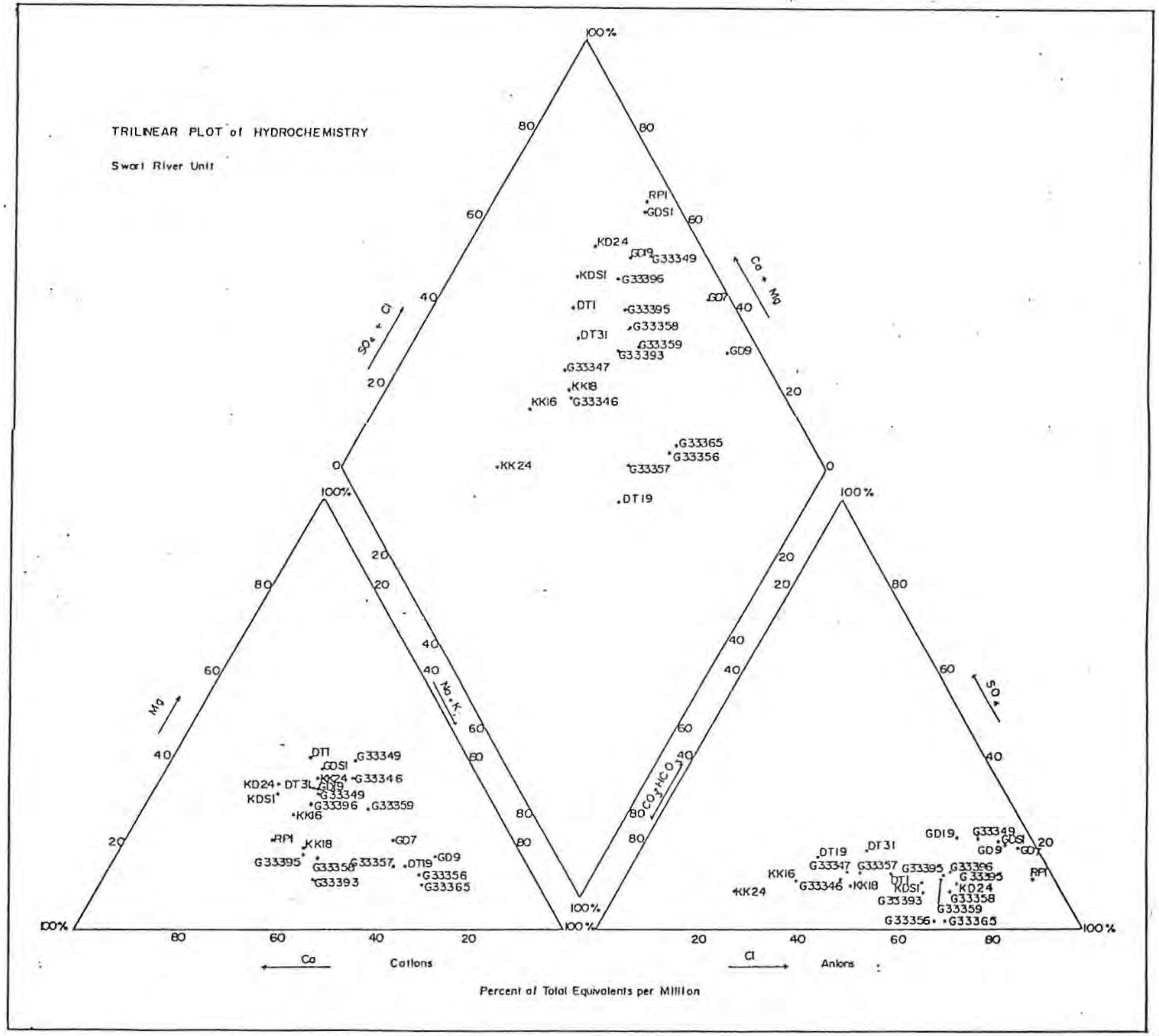
DEPTH m	BOREHOLE N°	Ca	Mg	Na	K	Na+K	TOTAL CATIONS	%Ca	%Mg	%Na+K	HCO_3	SO_4	Cl	NO_3	F	$Cl+NO_3+F$	TOTAL ANIONS	$\%HCO_3$	$\%SO_4$	$\%Cl+NO_3+F$	SAR
F	33396	7.53	5.92	4.22	2.33	6.55	20.00	37.7	29.6	32.7	3.30	2.23	10.44	0.42	0.03	10.89	16.41	20.1	13.6	66.3	1.6
F	33399	0.95	0.49	5.92	1.66	7.58	9.02	10.5	5.5	84.0	3.00	0.08	3.24	0.03	0.35	3.63	6.71	44.7	1.2	54.1	7.0
F	33400	1.65	0.99	9.57	0.27	9.84	12.84	13.2	7.9	78.9	3.50	0.12	8.63	0.02	0.26	8.91	12.53	27.9	1.0	71.1	8.3
F	33401	0.95	0.41	6.18	0.04	6.21	7.57	12.5	5.4	82.0	2.74	1.19	3.41	0.01	0.06	3.49	7.41	36.9	16.0	47.0	7.5

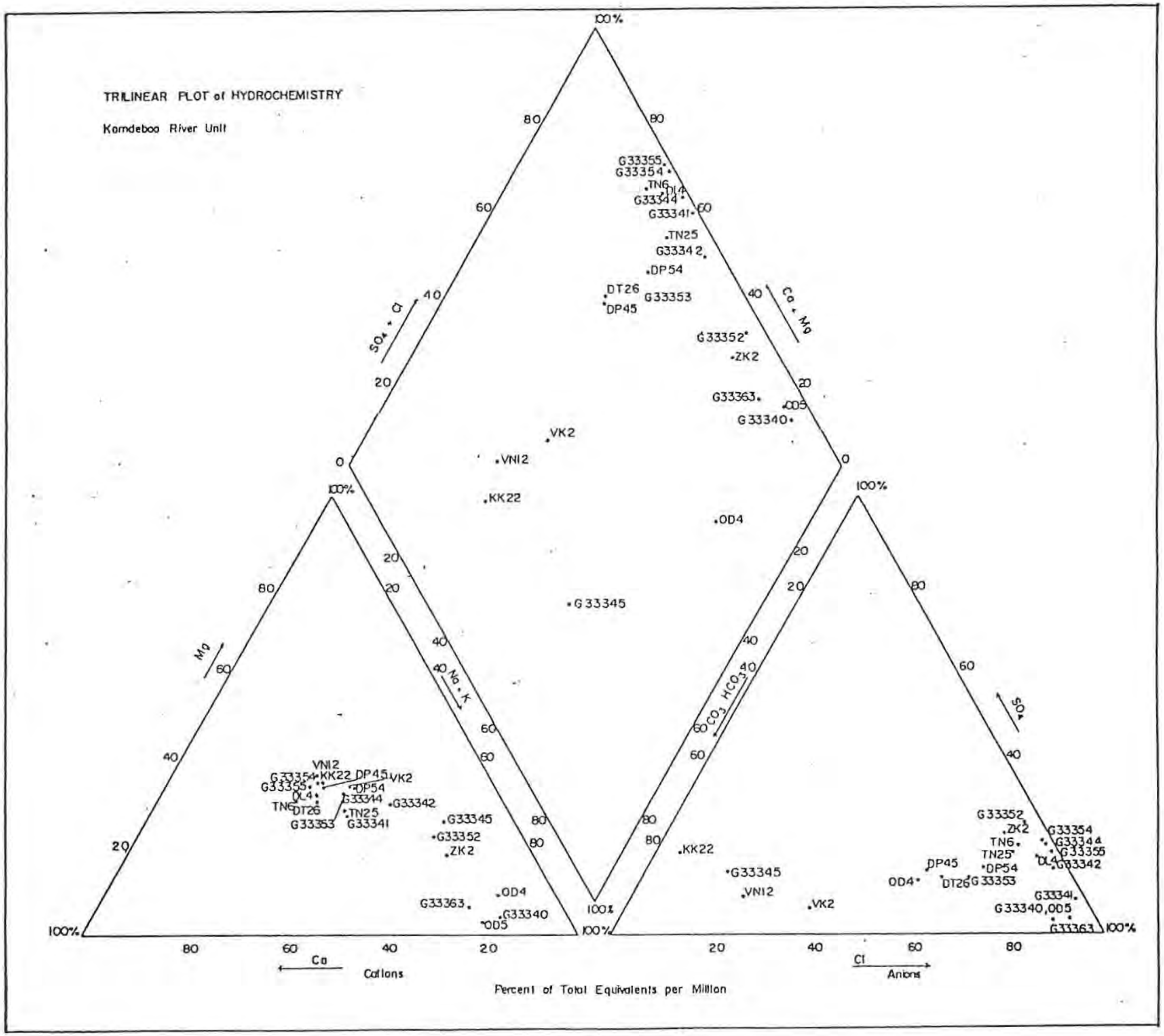
Appendix 5C

Piper diagram showing the hydrochemical composition of the groundwater in the different groundwater units

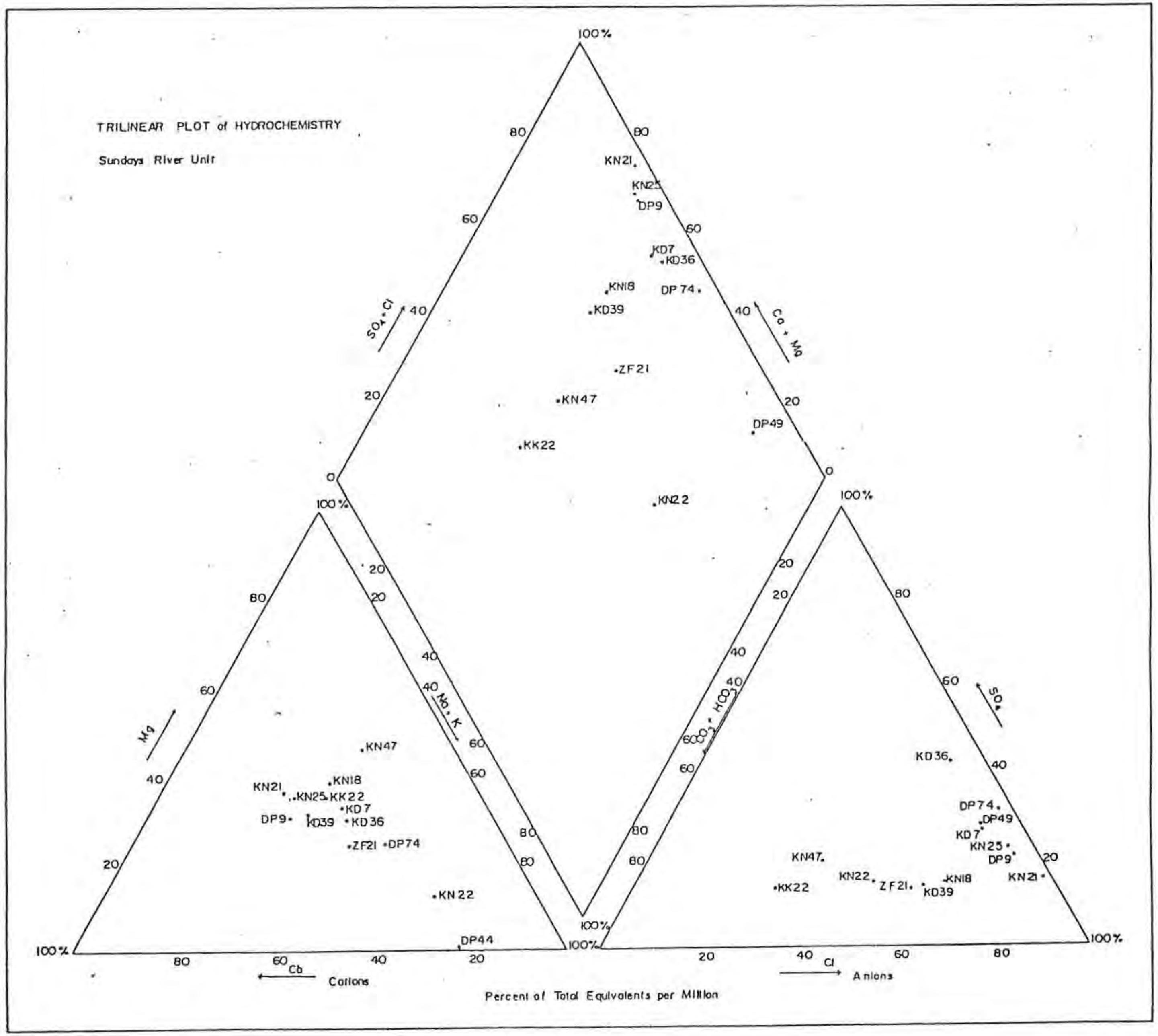


TRILINEAR PLOT of HYDROCHEMISTRY
Moordenaars River Unit
100 %
80
60
40
20
0
SO_4 + Cl
Ca + Mg
RN3
CE9
G33400
G33401
G33399
Mg
Na + K
CO_3 + HCO_3
SO_4
Ca
Cations
Cl
Anions
Percent of Total Equivalents per Million


TRILINEAR PLOT of HYDROCHEMISTRY
Swart River Unit
100%
80
60
40
20
0
$SO_4 + Cl$
Ca + Mg
Mg
Na + K
$CO_3 + HCO_3$
SO_4
Ca
Cations
Cl
Anions
Percent of Total Equivalents per Million
RP1
GDS1
KD24
GD19
G33349
KDS1
G33396
GD7
DT1
G33395
G33358
DT31
G33359
G33393
GD9
G33347
KK18
KK16
G33346
G33365
G33356
KK24
G33357
DT19



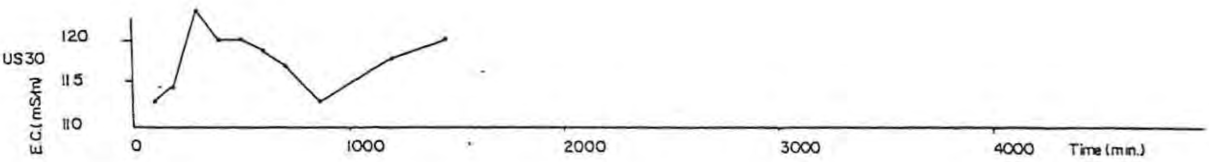
TRILINEAR PLOT of HYDROCHEMISTRY
Korndeboo River Unit
SO_4 + Cl
Ca + Mg
Mg
Na + K
CO_3 HCO_3
SO_4
Ca
Cations
Cl
Anions
Percent of Total Equivalents per Million

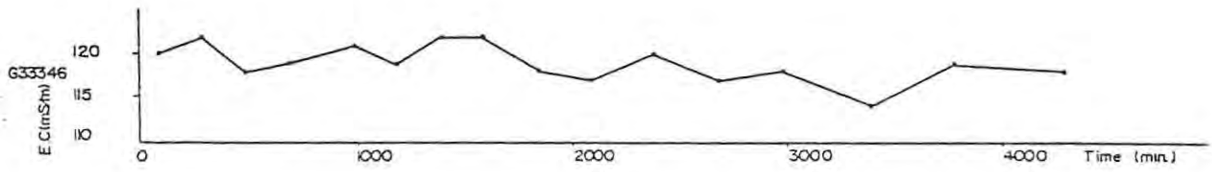


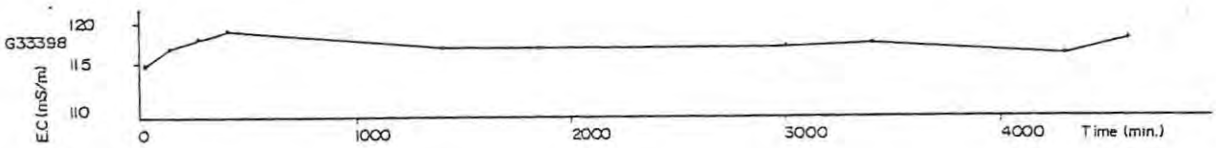
TRILINEAR PLOT of HYDROCHEMISTRY
Sundays River Unit
SO4 + Cl
Ca + Mg
Mg
Na + K
Ca
Cations
CO3 + HCO3
SO4
Cl
Anions
Percent of Total Equivalents per Million
KN21
KN25
DP9
KD7
KD36
KN18
DP 74
KD39
ZF21
KN47
DP49
KK22
KN22
KD 36
DP44

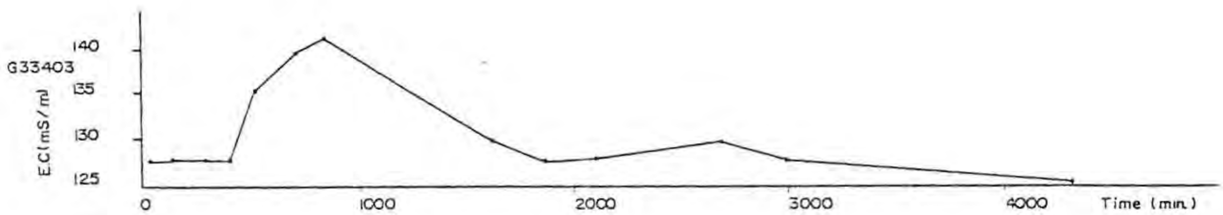
Appendix 5D

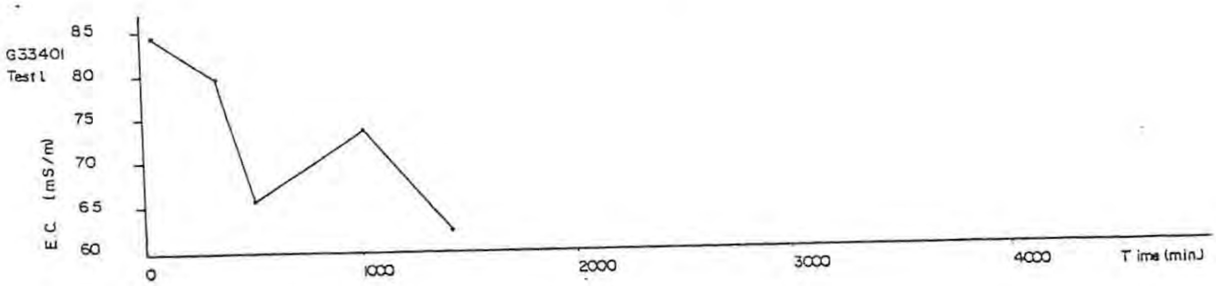
Electrical conductivity variations during aquifer tests

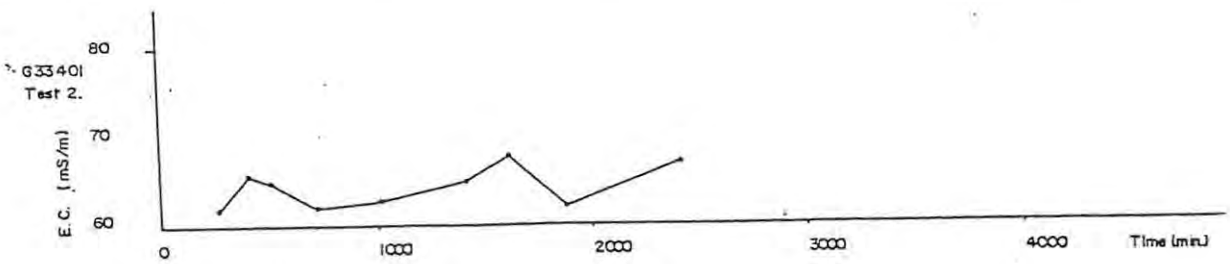

US30
E.C (mS/m)
120
115
110
0
1000
2000
3000
4000
Time (min.)

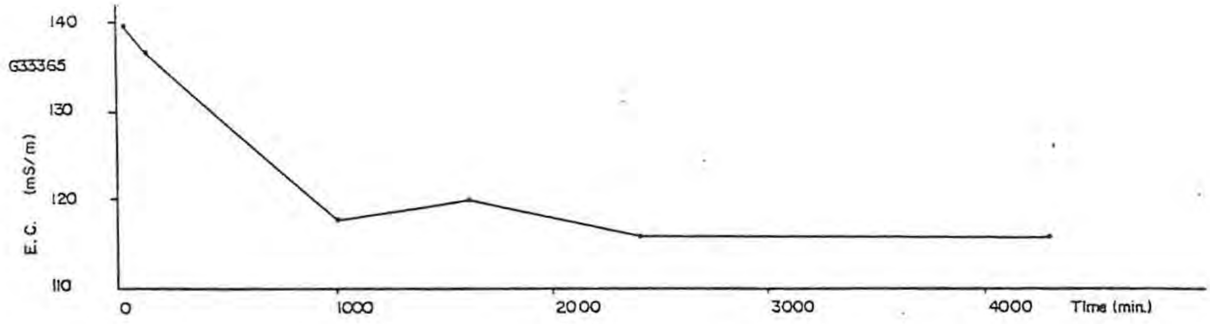

G33346
E.C(mS/m)
120
115
110
0
1000
2000
3000
4000
Time (min.)

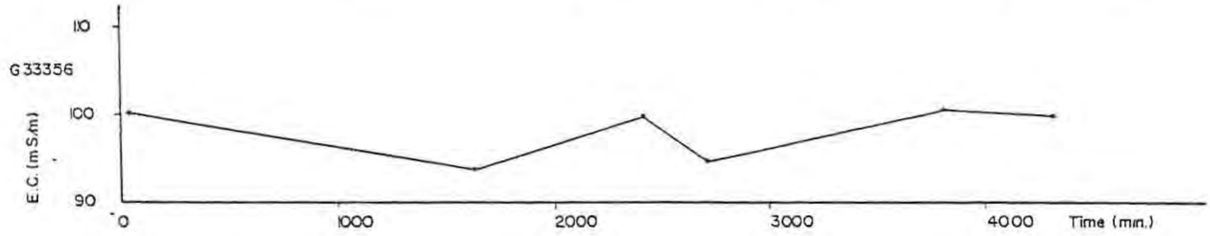

G33398
E.C(mS/m)
120
115
110
0
1000
2000
3000
4000
Time (min.)

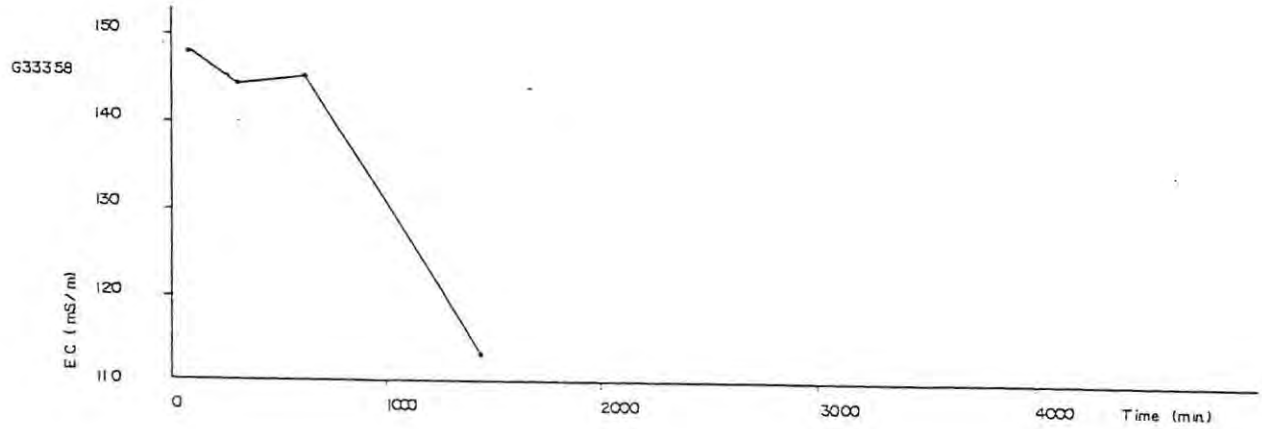

G33403
E.C(mS/m)
140
135
130
125
0
1000
2000
3000
4000
Time (min.)

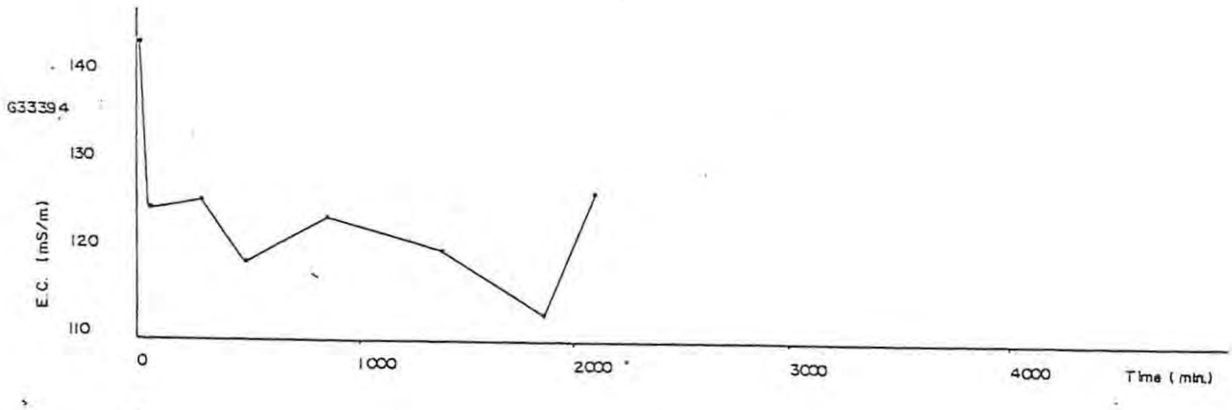

G33401
Test 1
E.C. (mS/m)
85
80
75
70
65
60
0
1000
2000
3000
4000
Time (min.)

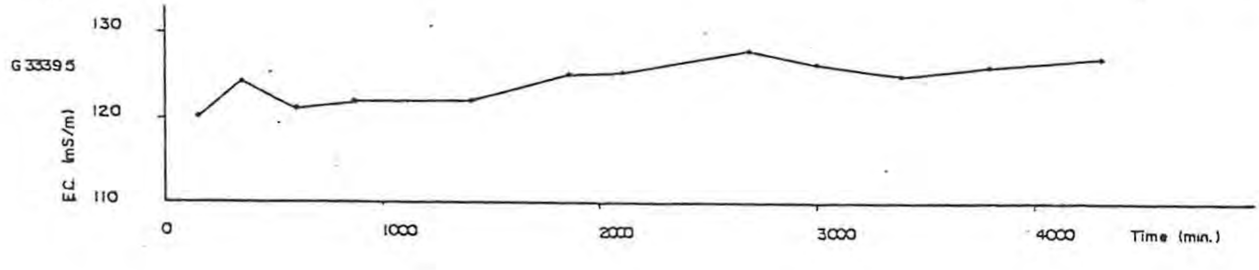

G33401
Test 2.
E.C. (mS/m)
80
70
60
0
1000
2000
3000
4000
Time (min.)

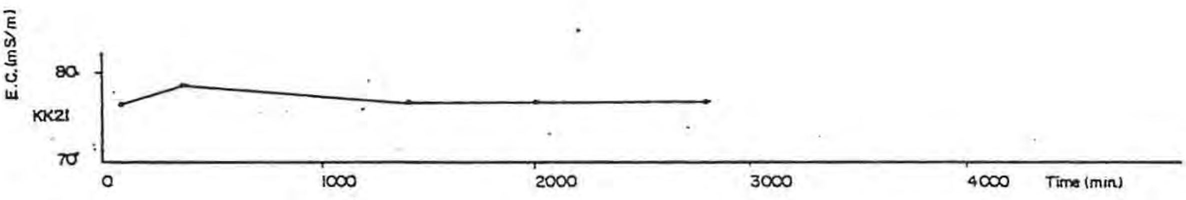

G33365
140
130
120
110
E.C. (mS/m)
0
1000
2000
3000
4000
Time (min.)

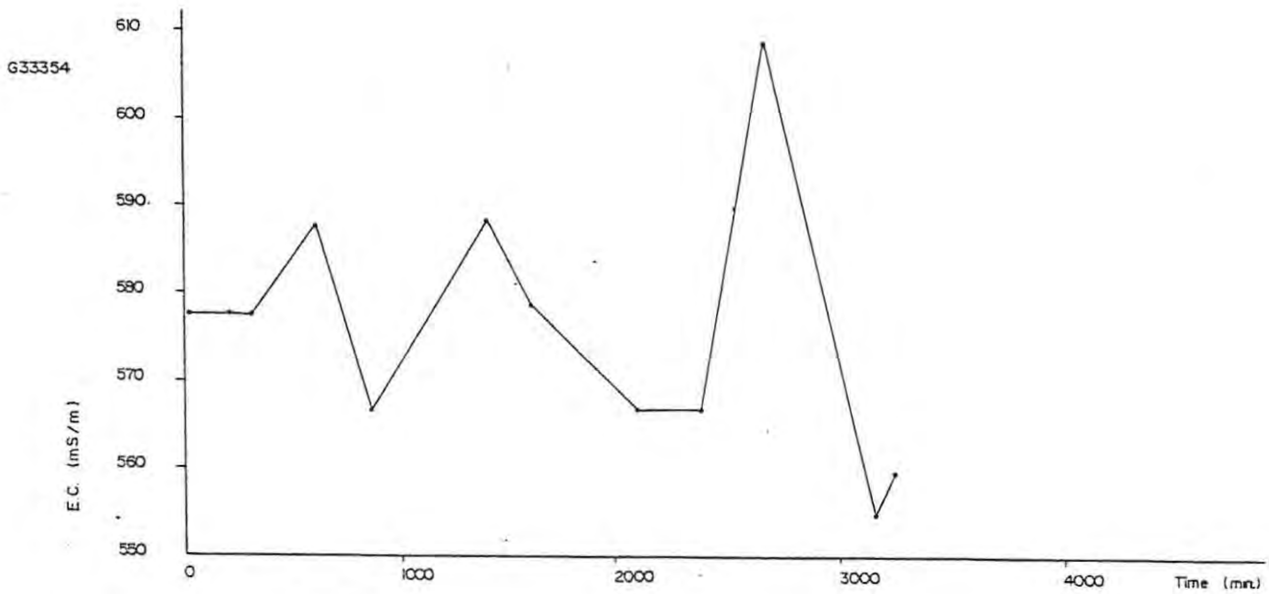

G 33356
110
100
90
E.C. (m S/m)
0
1000
2000
3000
4000
Time (min.)


G33358
150
140
130
120
110
E.C (mS/m)
0
1000
2000
3000
4000
Time (min)


G33394
140
130
120
110
E.C. (mS/m)
0
1000
2000
3000
4000
Time (min.)


G 33395
130
120
110
E.C. mS/m)
0
1000
2000
3000
4000
Time (min.)


E.C.(mS/m)
80
KK21
70
0
1000
2000
3000
4000
Time (min.)


G33354
610
600
590
580
570
560
550
E.C. (mS/m)
0
1000
2000
3000
4000
Time (min.)