The Geohydrology of the Graafwater Government Subterranean Water Control Area.

Report Number Gh 3778

By
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ABSTRACT.

A palaeovalley occurs between Graafwater and the coast at Lamberts Bay. The palaeovalley is filled with unconsolidated sands of the Bredasdorp, Elandsfontyn and Varswater Formations. The Varswater Formation consists of very fine sands, silts and clays, occuring from the coast up to a distance of 8 kms inland - groundwater potential is low. Of greater groundwater potential are the deposits of the Bredasdorp Fm (aeolianites) and the underlying Elandsfontyn Fm (alluvium) which fill the remainder of the palaeovalley. The coarser Elandsfontein Fm sands comprise the major aquifer in terms of borehole yields - up to 15 l/sec. Production boreholes drilled into the overlying Bredasdorp sands deliver lower yields (<3 l/sec), because of the finer grain size. However the upper Bredasdorp aquifer has the greatest storage potential of the two - 910 million m^3 as apposed to 270 million m^3 (Total storage of 1180 million m^3). The exploitable potential of the aquifer is dictated by the recharge occuring to the aquifer from rainfall. Average recharge is estimated at 8% of the average annual rainfall, giving an exploitable volume of 2.25 million m^3/year. Allocations for groundwater use in the Graafwater Government Subterranean Water Control Area were made based on the recharge available per farm, existing usage, houshold and stock requirements, and requirements for the irrigation of stock fodder.

SAAMEVATING.

'n Palaeo-vallei is tussen Graafwater en die kus by Lambertsbaai gevind. Die vallei is gevul met ongekonsolideerde sedimente van die Bredasdorp, Ealndsfontyn en Varswater Formasies. Die Varswater Formasie, tussen die kus en sowat 8km binneland voorkom, bestaan uit baie fyn sand, slyk en klei, en die grondwaterpotensiaal- is dus laag. Eolionied en spoelsand van onderskeidelik die Bredasdorp Fm en die Elandsfontein Fm is in die res van the palaeo-vallei gevind en die grondwaterpotensiaal in die materiaal is dus heelwat gunstiger.Goeie boorgat lewerings van tot 15 l/s word in growwe sande van die Elandsfontyn Fm aangetref. Produksiegate in sande van die Bredasdorp sande lewer oor die algemeen minder as 3 l/s. Desnieteminstaande beskik die boonste Bredasdorpwaterdraer het die grootste bergin nl'n beraamde 910 miljoen m^3, in vergelyking met 270 miljoen m^3 van die Elandsfontynwaterdrear (Die totale geskatte groundwaterberging kom op sowat 1180 miljoen m^3 te staan). Die ontginningspotentiaal van die totale waterdraer word gedikteer deur reenvalaanvulling. Reenvalaanvulling is uitgewerk beraam op 8% van the gemiddelde jaarlikse reenval, waarvolgens die ontginbaare grondwatervolume op 2.25 miljoen m^3/jaar te staan kom. Toekenning vir grondwaterontrekking in die Graafwater Ondergrondse Staatswaterbeheergebeid is proporsioneel bebaseer op die aanvuuling per plaas, bestaande gebruik, huishoudelike- en veevereistes, en vereistes vir veevoergewasbesproeing.

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1. INTRODUCTION

Once the primary aquifer north-west of Graafwater had been identified (Timmerman, 1986), a decision was made to utilize this aquifer as the water supply for the Graafwater community. In order to protect this aquifer from over exploitation the Graafwater Subterranean Government Water Control Area (GSGWCA) was declared on the 29th of June 1990 (Government Gazette No. 1423 - Appendix A). Although a portion of the aquifer in the control area had been previously investigated (Jolly, 1990), and a production well-field developed, the extent and characterization of the total primary aquifer was unknown.

This study aimed to investigate the geohydrology of the primary aquifer running east-west between Graafwater and Lambert's Bay. Ultimately the study had to :

- assess the exploitation potential of the aquifer,
- determine whether the existing GSGWCA boundaries were correctly positioned, and
- make an allocation of available water resources for each of the properties in the control area.

2.0 BACKGROUND INFORMATION

2.1 Location

The GSGWCA is situated between Graafwater and the coast at Lambert's Bay (Figure 1), approximately 300 km north of Cape Town. The control area is approximately 25 km long and varies between 7 and 16 km in width, enclosing 10 cadastral farms. The farm names, together with the relevant Government Gazette proclaiming the control area, are shown in Appendix A.

2.2 Topography

To the east of Graafwater the countryside is mountainous, rising 630 m above the coastal plain. Running through the coastal plain, and forming the southern boundary of the control area, is the Jakkals river. This stream is in a valley approximately 60m below the coastal plain, being fed by springs and seepage along the northern flank of the river valley.

2.3 Climate

Detailed climatological data was available from two Department of Agriculture stations : Graafwater (1973-1991) and the Nortier Research Station (1977-1991). The data is contained in Appendix B and the position of the stations, marked on Figure 8. Further rainfall data was available from two Weather Bureau stations - Graafwater and Eland's Bay. The graphs of rainfall, evaporation and temperature (Figure 2) show the Nortier station (6 km NNE of Lambert's Bay) to have a lower range in temperature and evaporation figures - an effect of the cooling influence of the cold Benguella ocean current. In comparing the long term rainfall data from the Weather Bureau station to the Agrometeoric station (both in Graafwater), the average from the longer period is lower (277mm as compared to 230 mm). The average yearly rainfall for the GSGWCA, based on both the inland and the coastal long term records is 228 mm/year.

2.4 Geology

During the Cretaceous and Tertiary Periods, Southern Africa separated from the rest of Gondwanalanad. During this period the interior of the continent was subjected to erosion, with sedimentation taking place along the continental margins and adjacent ocean basins. During the Cenozoic, up until the Middle Miocene, tectonically controlled eustatic sea-level changes controlled deposition along the coastal margins (Hendey, 1983). Thereafter the major controls on sea-level changes were marine regressions and transgressions caused by variations in the volume of the polar caps. These sea-level

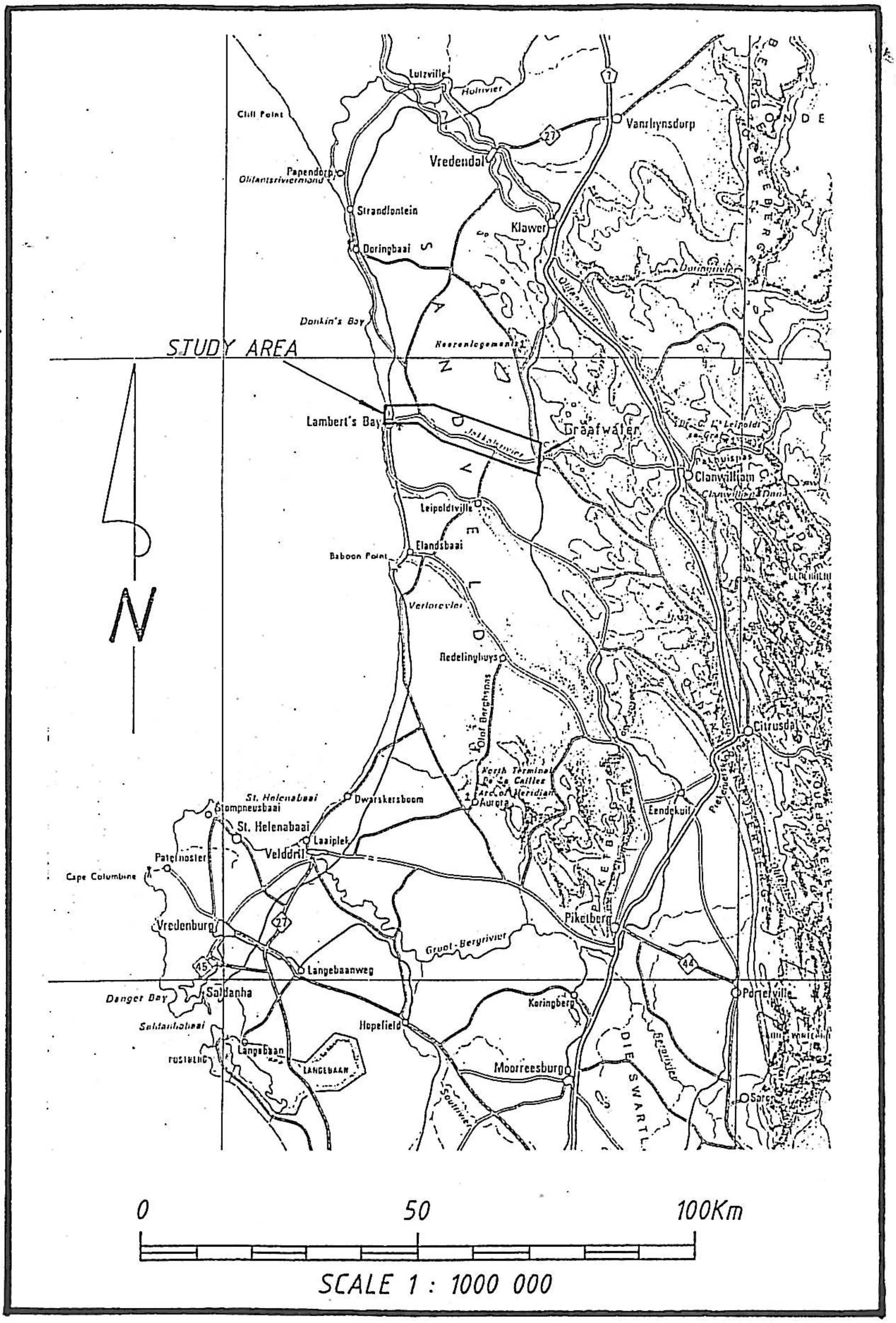
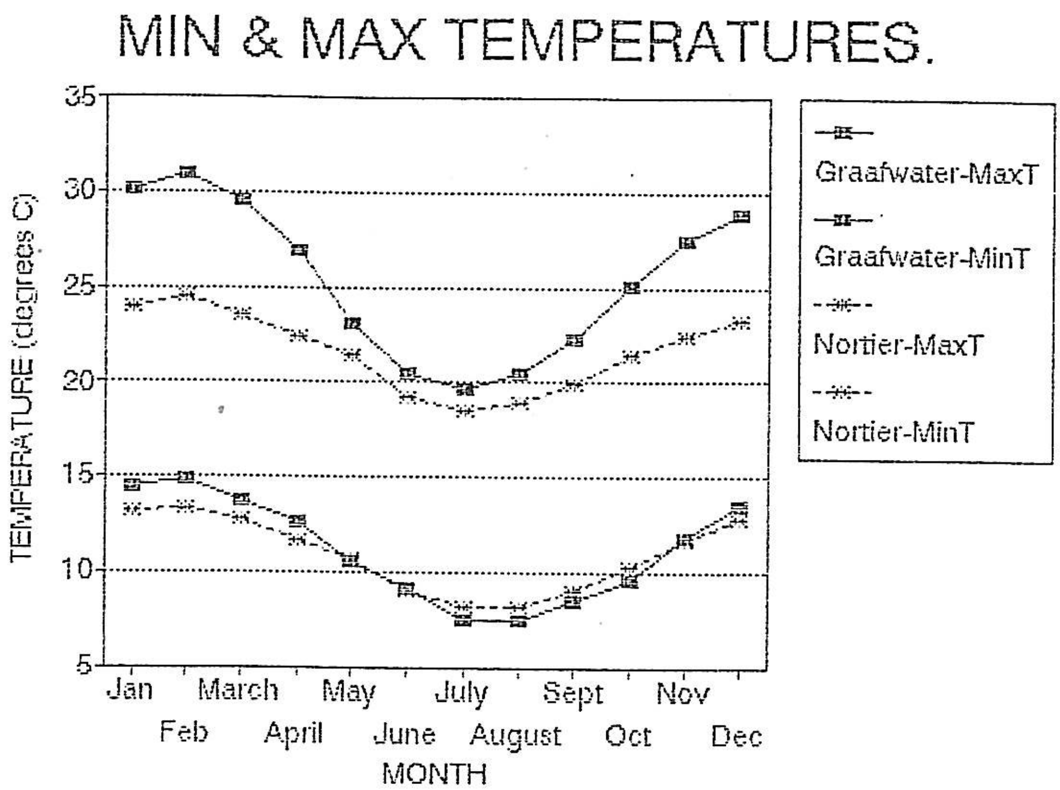


FIG I : LOCATION OF THE STUDY AREA.



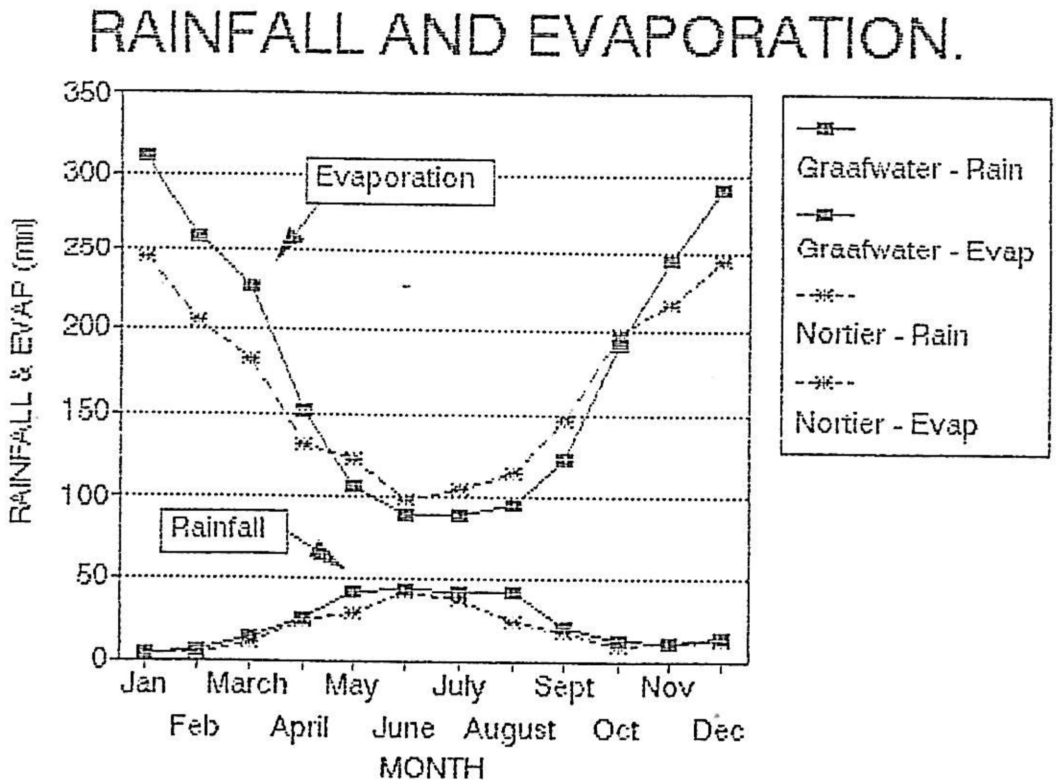


FIGURE 2 : AVERAGE MONTHLY CLIMATOLOGICAL DATA.

changes had major effects on the depositional and erosional processes along the coastline. Vail et al (1977) believed that regressions were more dramatic than transgressions and had a greater effect on sediments previously deposited. Erosion during the extreme low sea-levels experienced during the Oligocene was severe - rivers were deeply incised into their valleys, and most of the existing deposits were eroded away. During the quieter transgressional periods the geological processes involved the regrading of rivers through the build up of channel sediments, followed by the deposition of marine sediments on those areas inundated by the sea. Peats were normally formed during the transgressive stages.

The stratigraphy of the Cenozoic deposits along the South African coastline, especially along the West Coast is still undergoing revision. Along the East and Southern Cape coastlines the stratigraphy of the Algoa and Bredasdorp Groups has been clearly defined. The stratigraphic subdivisions of these two groups is contained in Table 1. The West Coast was probably more unstable than the Southern Cape coast during the Cenozoic era. The shelf break along the continental margin of the West Coast is one of the deepest in the world (Tankard, 1976). A further difference between the South and West Coast depositional histories is explained by an axis or "hinge line" (Tankard, 1976) trending NNW from Cape Agulhas up the West Coast. Tilting and warping along this axis, resulted in different depositional environments, and has also displaced certain units relative to the coastline, compared to the Southern Cape. The stratigraphic subdivisions of the Bredasdorp Group in the Southern Cape are not suitable for use on the West Coast. The Western Cape members of the former Bredasdorp Formation have now been upgraded to Formations. In addition SACS have proposed that the entire Western Cape Cenozoic succession be termed the Sandveld Group. Existing formations occurring between Cape Town and Elands Bay are :

- Elandsfontyn Fm: fluvatile - Miocene age
- Saldanha Fm : littoral - Miocene age
- Varswater Fm : shallow marine/ estuarine - Pliocene age.
- Springfontyn Fm: aeolian - Early Pleistocene
- Velddrif Fm : littoral - estuarine - Late Pleistocene
- Langebaan Fm : aeolian - Late Pleistocene
- Witzand Fm : aeolian - Holocene age.

Further up the West Coast, at Hondeklip baai, Pether (1986) has subdivided the geology into three "packages" dependant on their elevation above present sea-level. It is, however, difficult to correlate these packages with the stratigraphy of the South-western Cape.

TERTIARY					QUARTERNARY			
Paleo-cene	Eocene	Oligio-cene	Mio-cene	Plio-cene	Pleistocene Early	Pleistocene Middle	Pleistocene Late	Holo-cene
		------------------ALGOA GROUP---------------						
						--Schelm Hoek Fm-		
						-Nahoon Fm-		
					----Salnova Fm---			
				---Nanaga Fm-----				
			---Alexandria Fm---------					
	-------Bathurst Fm---							
				------BREDASDORP GROUP-------				
						--Strandveld Fm--		
					-Waenhuiskrans Fm-			
				--Klein Brak Fm-----				
		---Wankoe Fm----------						
		----De Hoovlei Fm-						

TABLE 1 : STRATIGRAPHY OF THE ALGOA AND BREDASDORP GROUPS

The hard rock basement underlying the Cenozoic sands consists of Table Mountain Group rocks - in the east the Graafwater Formation, and in the west the Piekenierskloof Formation.

2.5 Previous Geohydrological Investigations

2.5.1 Introduction

Groundwater investigations in the area have involved both the CSIR and Water Affairs, dating back to 1979.

2.5.2 Schreuder (Gh 3074, 1979)

Schreuder undertook a hydrocensus of the area surrounding Lambert's Bay, with the aim of identifying sources of supply for the town. The springs at Wadrif were suggested as being the most promising supplies. An area with considerable thicknesses of unconsolidated sands between the town and Nortier Agricultural Research Station was also mentioned as an area which could warrant further study - this area appeared however to be limited by low yields.

2.5.3 Meyer et al (1983)

The National Physical Research Laboratory (NPRL) of the CSIR was involved in a major geophysical investigation on the unconsolidated deposits of the Elands Bay / Lambert's Bay/Graafwater area. The aim of the study was to identify the most suitable geological conditions for groundwater storage. Numerous resistivity traverses were undertaken, identifying zones of sediment accumulation - in some of the areas boreholes were drilled to calibrate the geophysics, although little geohydrological data was collected.

2.5.4 Timmerman (Gh 3471, 1985)

Six exploration boreholes were drilled north-west of Graafwater to test the geophysics undertaken by the CSIR. An east-west trending palaeovalley was identified with sediment thicknesses of over 90m. The sediments formed an aquifer with average k values of 2.5 m/day. Based on this k value borehole yields of 5 l/s could be expected. The western part of the aquifer had good quality groundwater (< 100 mS/m). The exploitation potential of the aquifer was estimated at 1×10^6 m^3 per annum.

2.5.5 Jolly (Gh 3703, 1990)

Exploratory drilling, borehole development and aquifer testing culminated in the completion of two production boreholes situated in the palaeovalley identified by Timmerman. The holes (to be used alternately) could be pumped at a rate of 864 m^3/day, delivering groundwater with a quality of 42 mS/m. These boreholes were taken into use by the town during early 1992.

3. FIELDWORK

3.1 Introduction.

The previous work by Jolly (1990) concentrated on the development of a wellfield to supply Graafwater with water. The work had not investigated the relationship of the wellfield to the rest of the aquifer. The follow-up investigation was to delineate the extent of the whole aquifer, estimate it's supply potential, and recommend allocation rates to the property owners in the GSGWCA. In order to undertake this a hydrocensus was undertaken, a geophysical survey was carried out, boreholes were drilled and aquifer tests were carried out.

3.2 Hydrocensus

Dyason (1990) undertook a hydrocensus of the GSGWCA, using present and historical data to compile maps on :- the sediment thickness of the palaeovalley, groundwater level contours and groundwater quality variations (Figures 3, 4 and 5 contained in the map pockets). The groundwater use in the control area is limited mostly to domestic and stock water. Only 17 ha are under irrigation - total yearly abstraction for irrigation being 76603 m^3. The data collected during the hydrocensus is contained in Appendix C.

3.3 Geophysics

3.3.1 Aeromagnetics

Aeromagnetic maps were of little help in delineating the palaeovalley - they do however indicate a magnetic anomaly between the Lambert's Bay/Vredendal road and the coastline (Figure 6). It is theorized that this is caused by Pre - Cape (Nama/Malmesbury) rocks found at a shallow depth below the TMS.

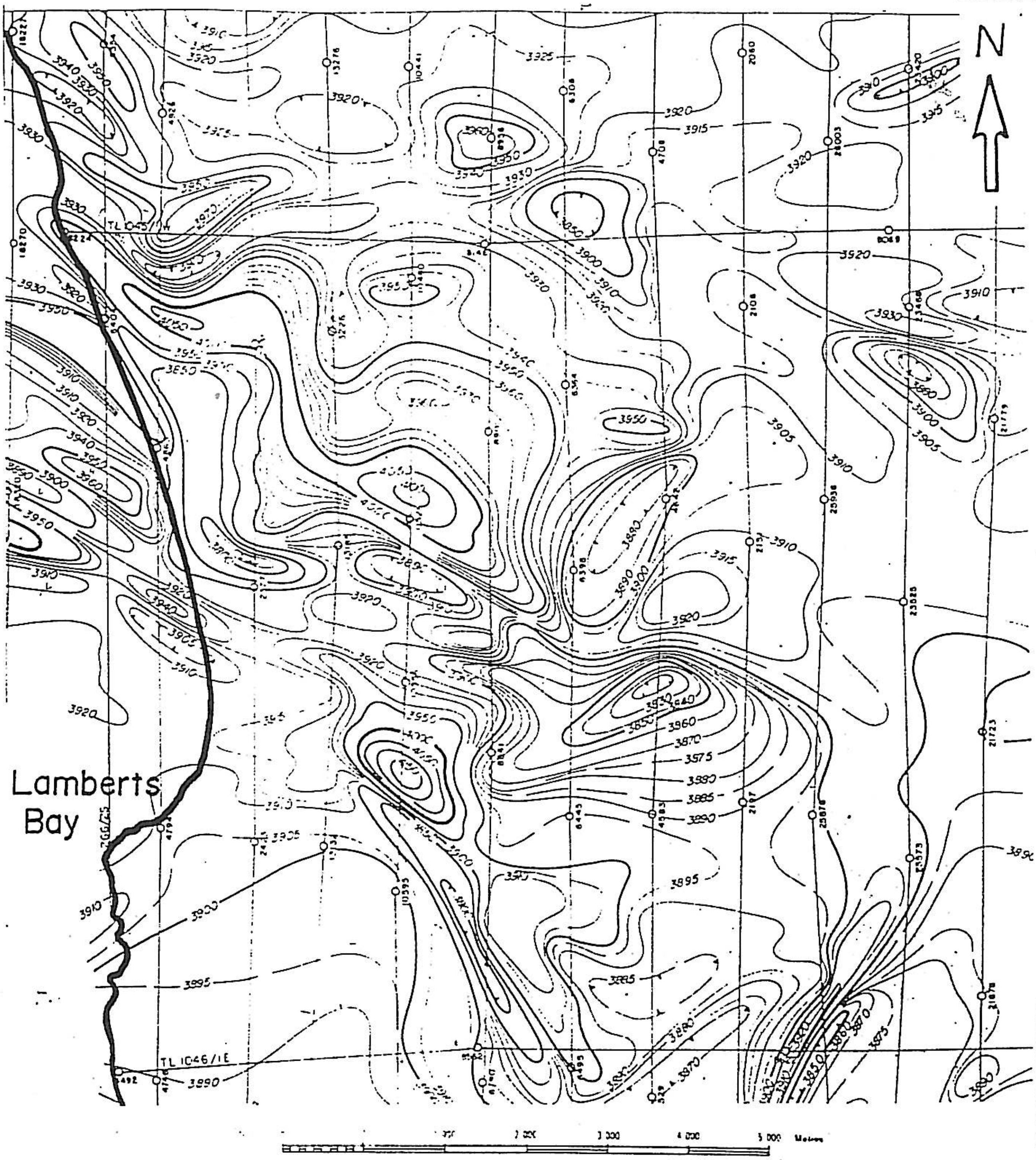
3.3.2 Resistivity

The resistivity work undertaken by Meyer et al (1983) has already been discussed (Section 2.5.3). Resistivity in the Sandveld appears to have its problems:

- the high contact resistance caused by dry surface sands made fieldwork difficult,
- clay horizons within the unconsolidated deposits masked deeper formations
- the limited conductivity differences between the sands and the underlying weathered TMS rocks made it difficult to interpret the depth of the contact zone.

3.3.3 Electromagnetics

A limited investigation was undertaken using a Geonics 34-3 electromagnetic system. The system is a conductivity measuring apparatus which operates in the frequency domain, having a maximum penetration depth, in the study area, of 40m.



REFERENCE

Flight Line

Ground clearance 100 ± 15 m positioning accuracy within 150 m

Ground clearance not 100 ± 15 m

Positioning accuracy not necessarily within 150 m

2640 Fiducial point

Aeromagnetic

Magnetic induction contours

1000 nT

250 nT

50 nT

10 nT

5 nT

FIGURE 6 : AEROMAGNETIC MAP.

The depth factor was unfortunately limiting. A traverse was undertaken NS across the palaeovalley through the Graafwater Wellfield. The interpreted geo-electrical results (Figure 7) only identified two layers - a surface layer (10-20m thick) with a resistivity of 1500 to 3000 ohm.m, and a lower layer with a resistivity between 120 and 10 ohm.m. The contact between these two layers coincides with the water level. Only on the northern edge of the palaeovalley where the bedrock is shallower than 40m was the basement detected. Any layer below a depth of 40m could not be detected. The results obtained show that the Geonics EM system can be useful, but is limited by depth of penetration. Future investigations could assess the use of the Genie system which has a greater depth penetration.

3.3.4 Gravity
A gravity survey was undertaken as part of the Graafwater/Lamberts Bay investigation (De Klerk, Gh 3730, 1991). The aim of the gravity work was to characterize the boundaries of the primary aquifer. The high density contrast between the Table Mountain Group basement rocks and the overlying sands were perfect conditions for a gravity investigation. Maps of the depth to bedrock (Map Ghp No. 6974), and the bedrock elevation (Map Ghp No. 6973) show the boundaries of the unconsolidated formations, and the position of the palaeovalley (Maps in the map pocket).

3.4 Drilling
During Timmerman's study in 1985, 6 boreholes were drilled north-west of Graafwater. In order to evaluate the Graafwater Wellfield fully a further 31 boreholes were drilled (Jolly, 1990). To calibrate the geophysics and to find out more about the entire GSGWCA a further 16 boreholes were drilled. All of these holes are shown on Figure 8. During the final drilling phase all but two of the holes drilled were exploration holes. The remaining two were test holes. Details of all the Government boreholes drilled are contained in Appendix D.

3.5 Constant Head Permeability Tests.
During previous investigations at Elands Bay slug tests were undertaken in order to evaluate the hydraulic conductivities of the formations penetrated. However the results obtained led one to question whether the tests were not merely evaluating the gravel pack surrounding the borehole. The water displaced by the small slug introduced moves along the most permeable route available - up the gravel pack. During this investigation constant head permeability (chp) tests were undertaken and were found to be vastly superior to slug test.

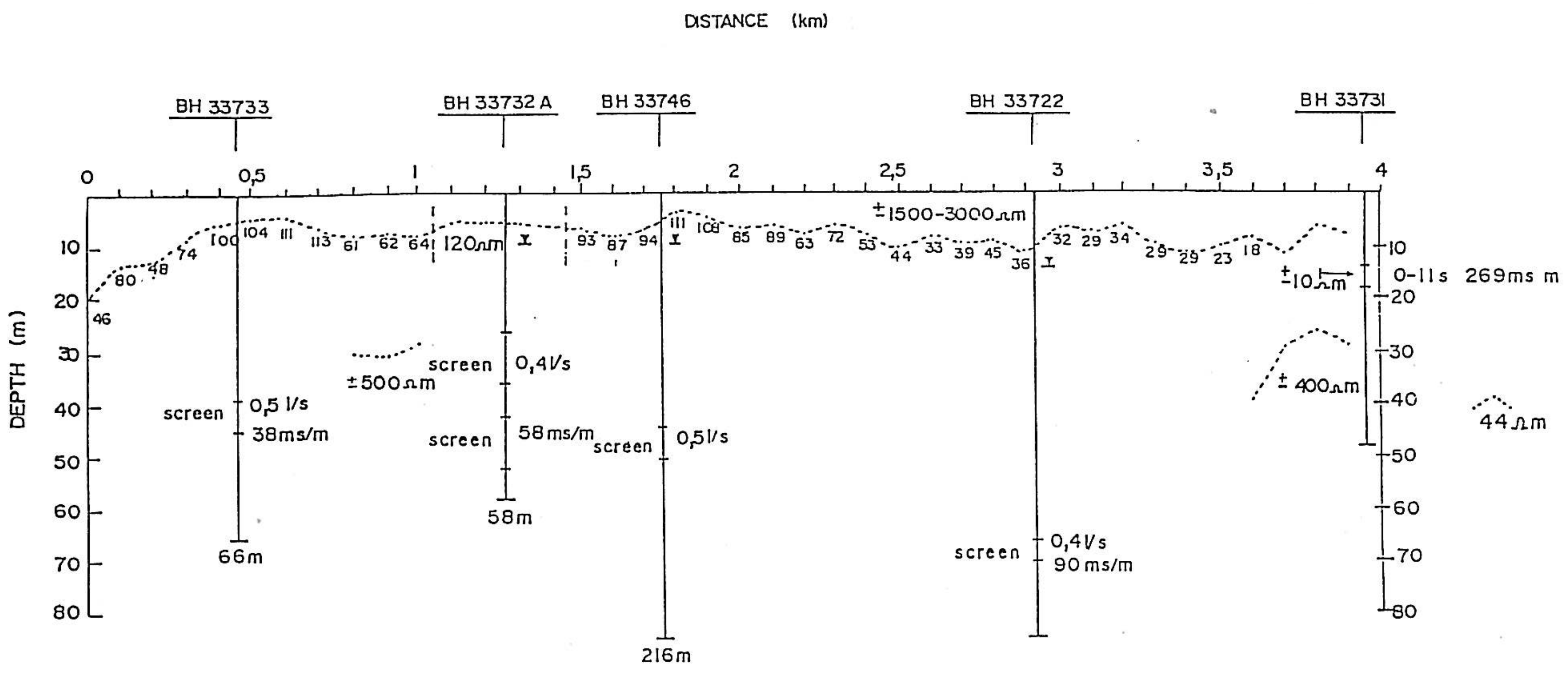


FIGURE 7 : GEO-ELECTRICAL SECTION.

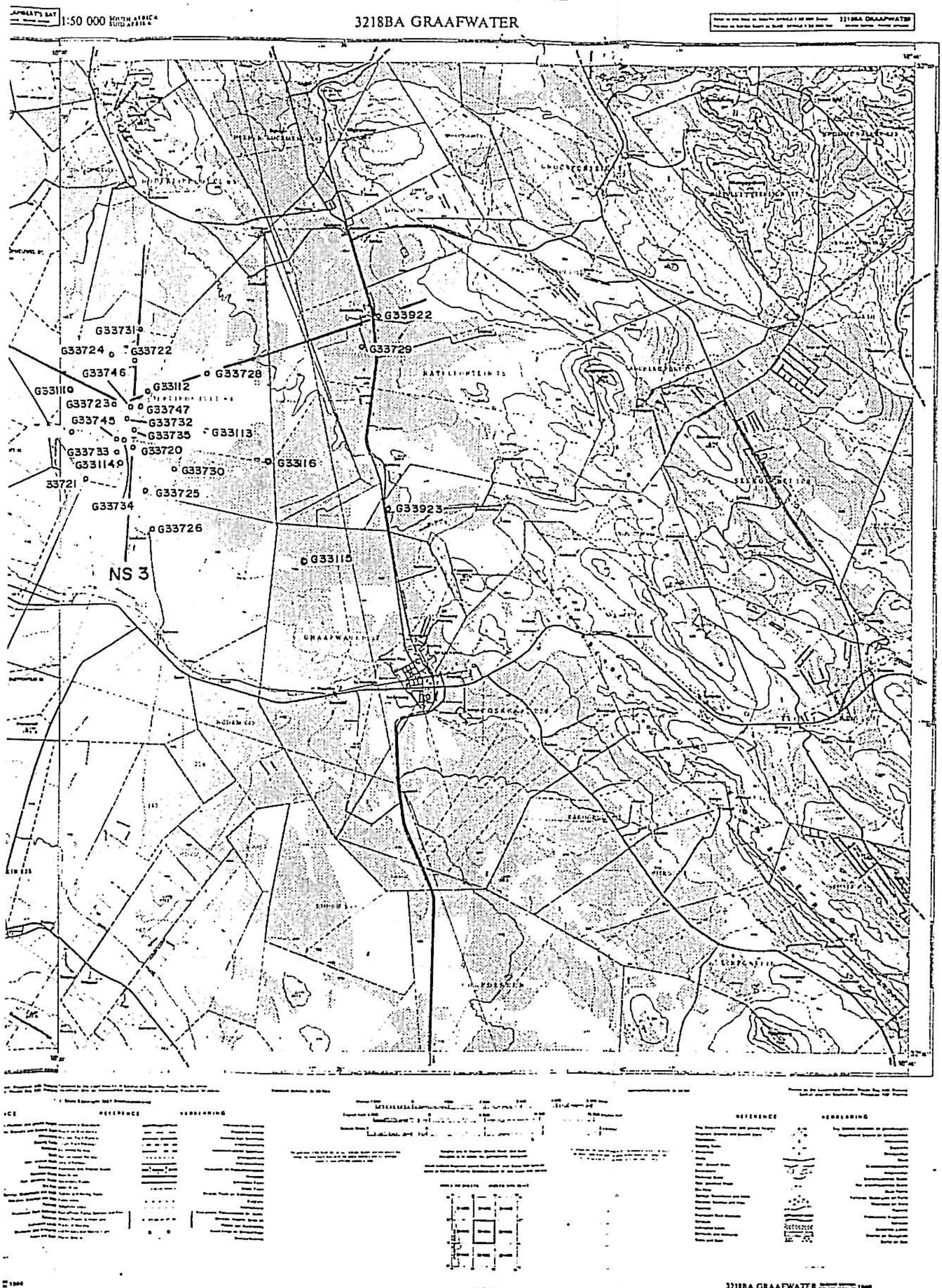

1:50 000
3218BA GRAAFWATER
G33922
G33729
G33731
G33724
G33722
G33746
G33728
G33110
G33112
G33723
G33747
G33745
G33732
G33735
G33113
G33733
G33720
G33114
G33116
G33730
33721
G33725
G33734
G33923
G33726
G33115
NS 3
3218BA GRAAFWATER

FIG 8

The procedure was as follows :- water was fed into a borehole at a constant rate for 10 -15 minutes. The rise in water level was monitored throughout - once the rising water level had stabilized for at least five minutes the water level was measured and the test curtailed. All of the following information was known - rest water level, equilibrium water level, head of water, diameter of screens/casing, diameter of drilled hole, length of screens, and constant yield fed into the borehole. The hydraulic permeability (k) was calculated using the following formula for partially penetrating boreholes in semi-confined sand aquifers:-

$$k = \frac{(Q)}{5.5\ r\ h}$$

where Q = rate of water flow into the borehole
h = the head of water above the rest water level
r = the radius of the screens.

Tests were undertaken at 38 boreholes. Results are contained in Table 2. Hydraulic conductivities ranged from <0.1 m/day in those boreholes which penetrated weathered Graafwater Fm shales, to 67.8 m/day in some of the coarser grained sand horizons. The permeabilities (m/day) of the different aquifers vary as follows:-

Upper Bredasdorp Fm Aquifer	: 2.8 - 29,8, av = 12 m/day
Lower Elandsfontyn Fm Aquifer	: 1.5 - 67,8, av = 18 m/day

The Bredasdorp Fm is much more uniform in permeability, than the Elandsfontyn Fm. This is a reflection on the environment of deposition. The Elandsfontyn, being fluvial consists of interbedded sediment horizons varying from clays to lenses of coarse grained sand and gravel, while the Bredasdorp Fm is a more homogeneous aeolian deposit.

The Hazen formula can also be used to calculate the hydraulic conductivities of the two different aquifers. The formula states :

$$k\ (m/day) = 864\ (d_{10})^2$$

where d_{10} is the diameter of the grains such that 10% of the sample has a smaller grain size. The calculated hydraulic conductivities are based on the grain size analyses presented in Table 3 :-

Upper aquifer (d_{10} = 0.15mm) = 19 m/day
Lower aquifer (d_{10} = 0.25mm) = 54 m/day

However it must be borne in mind that the Elandsfontyn samples sieved were the coarsest samples obtained during drilling - samples from the finer lenses and clay horizons which also exist were not analysed. Also, the samples obtained by mud rotary drilling had been stripped of the very fine fraction

TABLE 2 : CONSTANT HEAD PERMEABILITY TESTS: GRAAFWATER

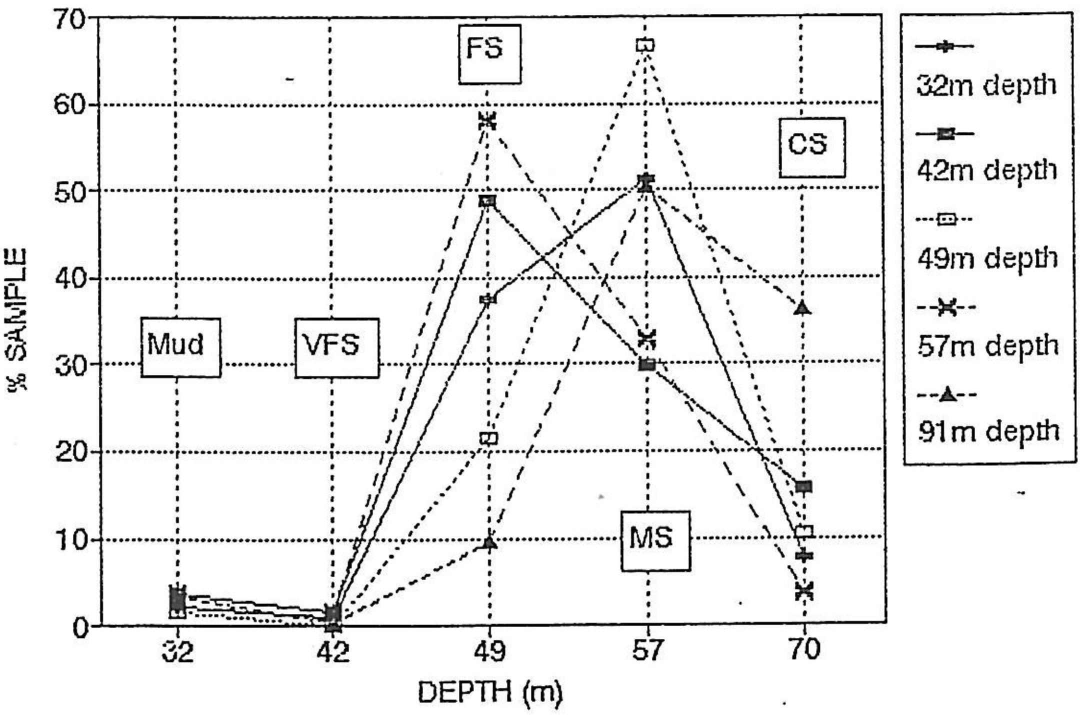
Borehole number	Rest water level (m)	Casing diameter (m)	Screen length (m)	Final Water level(m)	Head (m)	Yield (l/s)	Yield (m3/day)	k (m/day)
G33720	10.65	0.09	4.00	0.00	10.65	0.16	13.82	2.62
G33720A	10.50	0.26	0.50	0.00	10.50	0.01	0.86	0.06
G33721	10.45	0.17	0.50	0.00	10.45	0.04	3.46	0.35
G33722	13.58	0.09	4.00	7.50	6.08	1.04	89.86	29.86
G33723	14.89	0.09	4.00	0.00	14.89	0.46	39.74	5.39
G33724	13.41	0.09	4.00	0.00	13.41	0.11	9.50	1.43
G33725	9.68	0.09	3.00	0.00	9.68	0.45	38.88	8.11
G33726	5.11	0.09	1.00	0.00	5.11	0.92	79.49	31.43
G33727	15.30	0.09	4.00	0.00	15.30	0.06	5.18	0.68
G33728	13.40	0.09	4.00	4.00	9.40	0.93	80.35	17.27
G33729	17.71	0.09	4.00	9.00	8.71	1.03	88.99	20.64
G33730	11.50	0.09	2.00	0.00	11.50	0.42	36.29	6.37
G33731	13.55	0.09	4.00	0.00	13.55	0.55	47.52	7.08
G33732	10.85	0.09	7.00	0.00	10.85	0.42	36.29	6.76
G33732A	10.50	0.20	20.00	0.00	10.50	0.74	63.94	5.54
G33732B	11.35	0.20	23.00	0.00	11.35	0.54	46.66	3.74
G33733	9.29	0.09	6.00	0.00	9.29	0.36	31.10	6.76
G33733A	9.00	0.20	21.00	0.00	9.00	0.42	36.29	3.67
G33734	9.67	0.09	5.00	0.00	9.67	0.70	60.48	12.64
G33734A	9.71	0.20	30.00	7.00	2.71	0.68	58.75	19.71
G33735	10.08	0.09	5.00	0.00	10.08	0.27	23.33	4.68
G33745	9.88	0.09	6.00	0.00	9.88	0.51	44.06	9.01
G33745A	9.98	0.20	15.00	2.00	7.98	0.76	65.66	7.48
G33746	12.46	0.09	6.00	0.00	12.46	0.34	29.38	4.76
G33746A	11.76	0.20	15.00	0.00	11.76	0.01	0.86	0.07
G33746C	13.38	0.09	6.00	0.00	13.38	0.08	6.91	1.04
G33746D	13.57	0.09	0.50	0.00	13.57	0.06	5.18	0.77
G33747	15.52	0.09	6.00	13.00	2.52	0.98	84.67	67.88
G33748	47.10	0.09	3.00	0.00	47.10	1.85	159.84	6.86
G33749	3.66	0.09	6.00	0.00	3.66	0.10	8.64	4.77
G33920	17.00	0.09	6.00	0.00	17.00	1.56	134.78	16.02
"	17.00	0.09	6.00	5.90	11.10	0.76	65.66	11.95
G33921	17.24	0.09	6.00	7.00	10.24	1.92	165.89	32.73
G33924	11.39	0.09	6.00	0.00	11.39	0.06	5.18	0.92
G33925A	13.06	0.09	8.00	0.00	13.06	0.29	25.06	3.88
G33926	14.85	0.09	10.00	0.00	14.85	0.60	51.84	7.05
"	14.85	0.09	10.00	5.00	9.85	0.28	24.19	4.96
G33928	16.59	0.09	6.00	0.00	16.59	0.50	43.20	5.26
"	16.59	0.09	6.00	4.00	12.59	0.29	25.06	4.02
G33929	26.32	0.09	6.00	0.00	26.32	0.29	25.06	1.92
"	26.32	0.09	6.00	12.00	14.32	0.32	27.65	3.90
G33931	21.06	0.09	6.00	4.00	17.06	2.94	254.02	30.08
"	21.07	0.09	6.00	10.30	10.77	1.43	123.55	23.18

$k=Q/(5.5*r*H)$

TABLE 3A : GRAIN SIZE ANALYSES - BOREHOLE G33746A					
Depth (m)	% Mud < 0.0625 mm	% VFS 0.0625 - 0.0125 mm	%FS 0.0125 - 0.25 mm	%MS 0.25 - 0.5 mm	% CS 0.5 - 1.0 mm
32	2.24	1.04	37.49	51.30	7.93
42	3.85	1.69	48.86	29.89	15.72
49	1.54	0.17	21.38	66.51	10.39
57	3.70	1.49	58.26	32.76	3.70
70	6.00	0.01	1.47	28.66	63.87
91	3.42	0.30	9.61	50.49	36.18

VFS = Very Fine Sand, FS = Fine Sand, MS = Medium Sand, CS = Coarse Sand

TABLE 3B : GRAIN SIZE ANALYSES



which was carried away by the drilling mud. The k values calculated using the Hazen formula is too high, not taking into account inhomogeneities within the sediments, or the loss of the finer fraction during drilling.

3.6 Aquifer Tests.

Six boreholes were tested during the 1989/90 study (G33732A, G33733A, G33747B, G33746B, G33734A and G33745A), with a further two holes (G33921A and G33925B) being tested during the latest investigation. The results from these tests are contained in Appendix E and summarized below.

Table 4 : Aquifer test results - GSGWCA

Aquifer	Boreholes tested	Results
Upper Aquifer Bredasdorp Fm	G33732A, G33733A, G33734A, G33745A	T from 0.17 - 22 m^2/day Leakage occurs -aquifer is unconfined with delayed yield.
Lower Aquifer Elandsfontyn Fm.	G33746B, G33747B G33921A, G33925B G33925A, G33921A	T from 26 - 169 m^2/day Little leakage -aquifer is nearly confined.

The Upper Bredasdorp aquifer has a transmissivity averaging $10m^2$/day - this translates to a k value of approximately 0.3 m/day. A storativity value of 18% was calculated using the Walton method.

The lower Elandsfontyn aquifer showed little signs of leakage during three day tests - leakage could occur at a later stage. The aquifer appeared to be nearly confined, storativity values between 0.067 and 4×10^{-5}. Transmissivities averaged 95 m^2/day, in other words, nearly ten times more permeable than the overlying Bredasdorp sands. Permeabilities (k) averaged 3 m/day.

4. RESULTS

4.1 Aquifer characterization.

4.1.1 Introduction.

The geophysics helped to identify the position of the palaeovalley between Graafwater and the coast - the drilling data produced a clearer picture of the geohydrology of the palaeovalley. Although the palaeovalley reaches down to the coast (and further out to see ?) the nature of the sediment inland varies considerably from that along the coast. The sediments closest to the coast are finer grained (clayey), while the coarse grained sediments only occur further inland. To explain this change, a model for the depositional history was formulated.

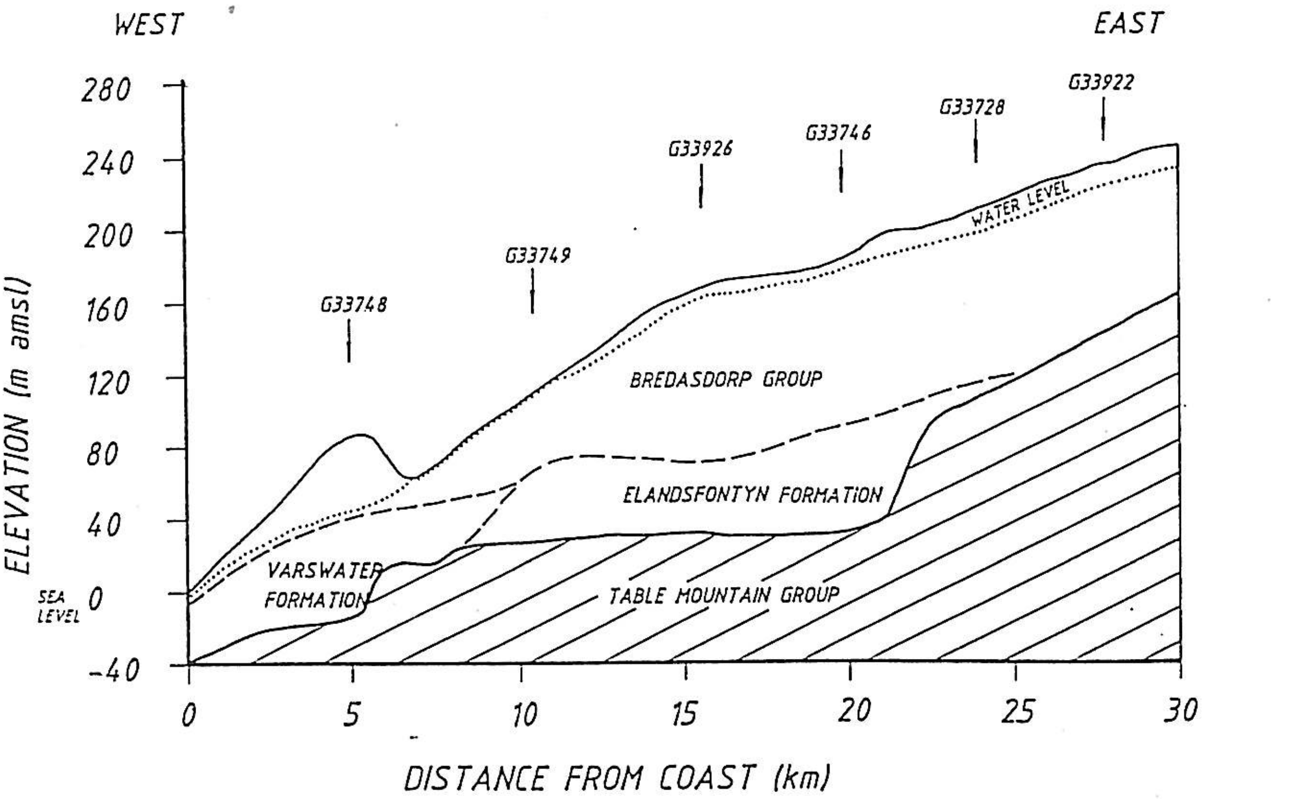
4.1.2 Depositional Model.

The first assumption is that the palaeochannel was incised during the major regression in the Oligocene - the only sediment deposited was river alluvium. With the next transgression the river would have regraded, causing a further build up of river alluvium, including peats (Elandsfontyn Fm). As the sea-level continued to rise, existing river alluvium would be reworked and replaced by littoral, estuarine and off shore deposits (Varswater Fm - Bookram Member ?). It is then postulated than a backshore lagoonal environment developed in which alternations of well sorted, well rounded sands were mixed with poorly sorted silts (Papkuils Fm of the Bredasdorp Group). At some stage the river must have changed its course, leaving the palaeovalley, and flowing down its existing course of the Jakkals river. Once this occurred the palaeovalley was covered with wind blown sands (Recent aeolianites) to produce the existing topography seen today.

The geological cross-section produced by the above scenario is shown in Figure 9, stretching from the coast inland to the Graafwater/Vredandal gravel road. A further three cross-sections (N-S) are shown in Figures 10, 11 and 12 (Positions marked on Figure 8). The sediment thicknesses, and thus the position of the palaeovalley, are shown on Figure 13. The bedrock elevations are shown on Figure 14.

4.1.3 Yield Potential.

The deposits of the Elandsfontyn Fm make up the main aquifer in the palaeovalley. Within these deposits, horizons of medium to coarse grained sands exists - these sands can yield up to 20 l/s. The Bredasdorp Group sands overlying these deposits are much finer grained and, although saturated, do not appear to have the potential to yield above 3 l/s. The Varswater Fm deposits are even finer grained (clayey) and does not appear to be a potential aquifer at all.



GEOHYDROLOGICAL CROSS-SECTION E-W

FIG 9

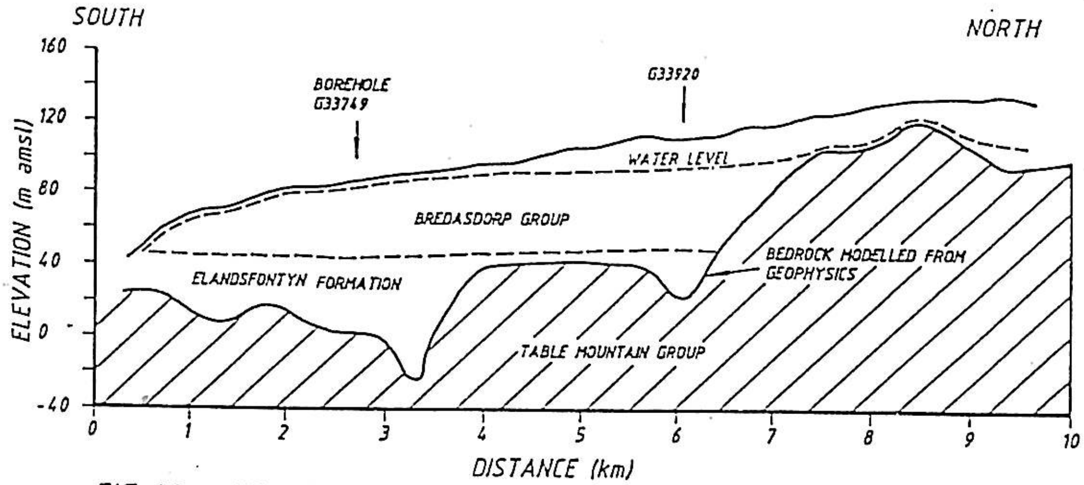


FIG. 10 GEOHYDROLOGICAL CROSS-SECTION N-S(1)

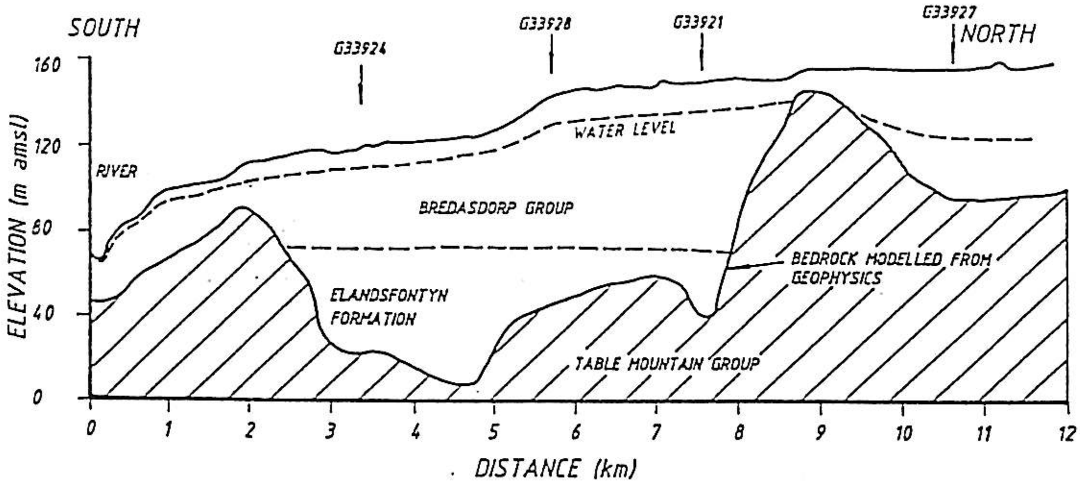


FIG. 11 GEOHYDROLOGICAL CROSS-SECTION N-S(2)

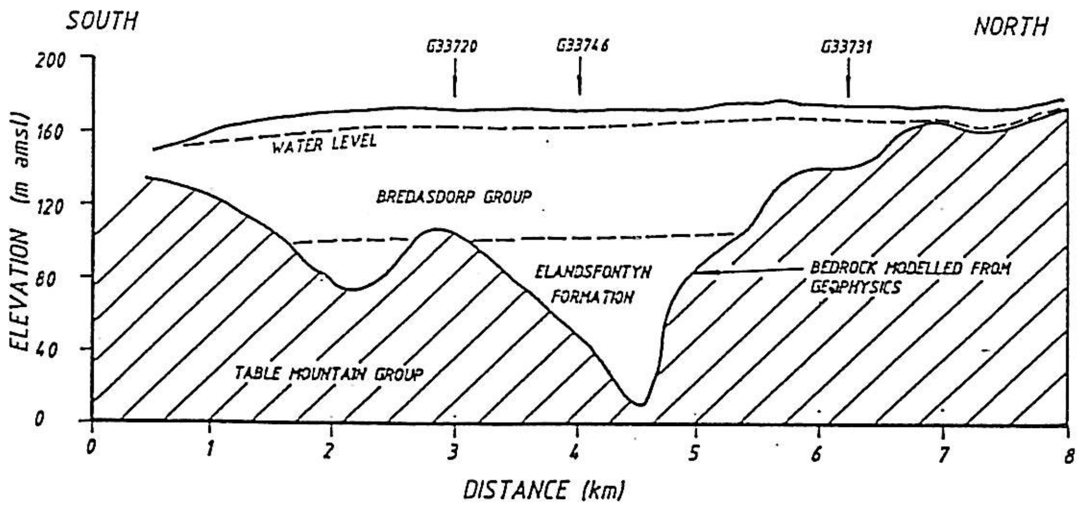


FIG. 12 GEOHYDROLOGICAL CROSS-SECTION N-S(3)

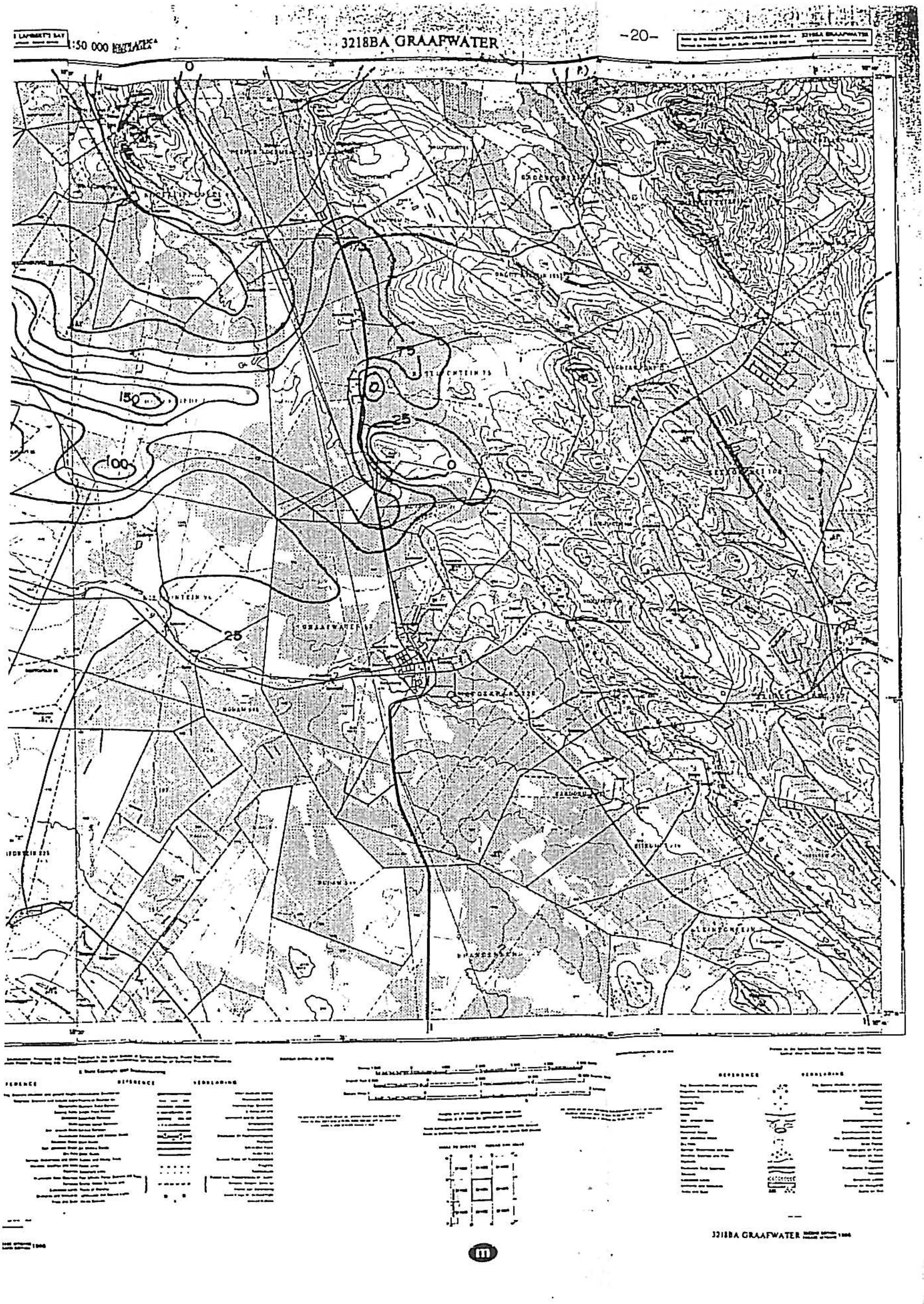
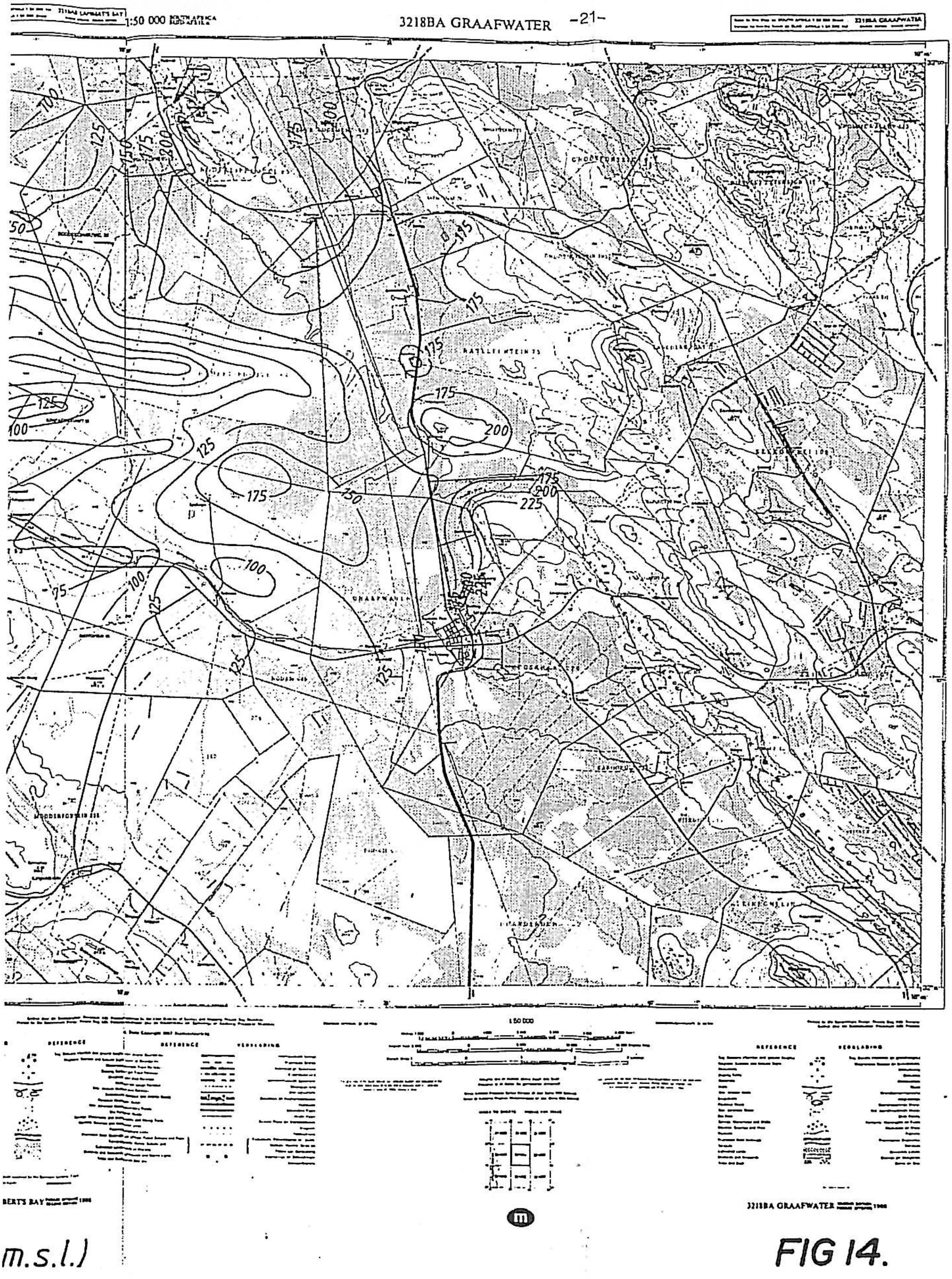

3218BA GRAAFWATER
1:50 000
0
75
0
25
0
150
100
25
3218BA GRAAFWATER

FIG 13



m.s.l.)

FIG 14.

Within 6km of the coastline the unconsolidated deposits are below sea-level, so large scale abstraction (if it was possible in these silts and clays) would not be advisable because of the threat of salt water intrusion.

4.2 Storage volumes.

The storage volumes are directly related to the specific yields of the sands deposits, in turn related to the grain size and degree of sorting of the deposit. The Geological Survey undertook full grain size analyses of borehole G33746A (Table 3A). The table shows that the coarsest sands are below 70m. The upper sands (Bredasdorp Fm aquifer) are predominantly fine to medium grained sands, while the underlying sands (Elandsfontyn Fm aquifer) are medium to coarse grained. From Johnson (1976) the specific yield of the upper and lower sands would be 23% and 26% respectively. These figure are however too high, for reasons explained in Section 3.5. During the aquifer tests the storativity of the Upper aquifer was calculated at 18%. If the storativity of the underlying sands is adjusted by a similar margin, a figure of 21% would appear more feasible.
The volume of water stored in the two aquifers would be :

Upper aquifer : Sediment volume x 18%
$= 5055 \times 10^6 \, m^3 \times 18\%$
$= 910 \times 10^6 \, m^3$

Lower aquifer : Sediment volume x 21%
$= 1290 \times 10^6 \, m^3 \times 21\%$
$= 270 \times 10^6 \, m^3$

In total about 1180 million cubic meters of groundwater is contained in the GSGWCA. Twenty-three percent of the groundwater is contained in the coarser, underlying Elandsfontyn aquifer. This aquifer is fed by slow downward percolation from the large overlying Bredasdorp Group aquifer.

4.3 Groundwater Chemistry.

The conductivity of the groundwater was measured at each of the boreholes surveyed during Dyason's hydrocensus (see Appendix C). Further to this more detailed chemical analyses were undertaken at the 13 boreholes (Appendix F). The results are summarised in Table 5.

Table 5 : Groundwater chemistry - GSGWCA.

Macro Elements (mg/l)		Micro Elements (mg/l)	
K	1.3 -4.3	Fe	1.5 - 80
Na	56 - 214	Mn	<0.02 - 0.56
Ca	4.7 - 13.5	Al	<0.01 - 1.32
Mg	9.8 - 16.9	Pb	<0.02 - 0.12
N	<0.05	Cu	<0.01 - 0.03
SO_4	19 - 44	Zn	<0.02 - 1.4
Cl	97 - 319		
CaCO3	12 - 68		
Hardness	54 - 72	pH	6.3 - 6.8
TDS	266 - 826	EC(mS/m)	42 - 129

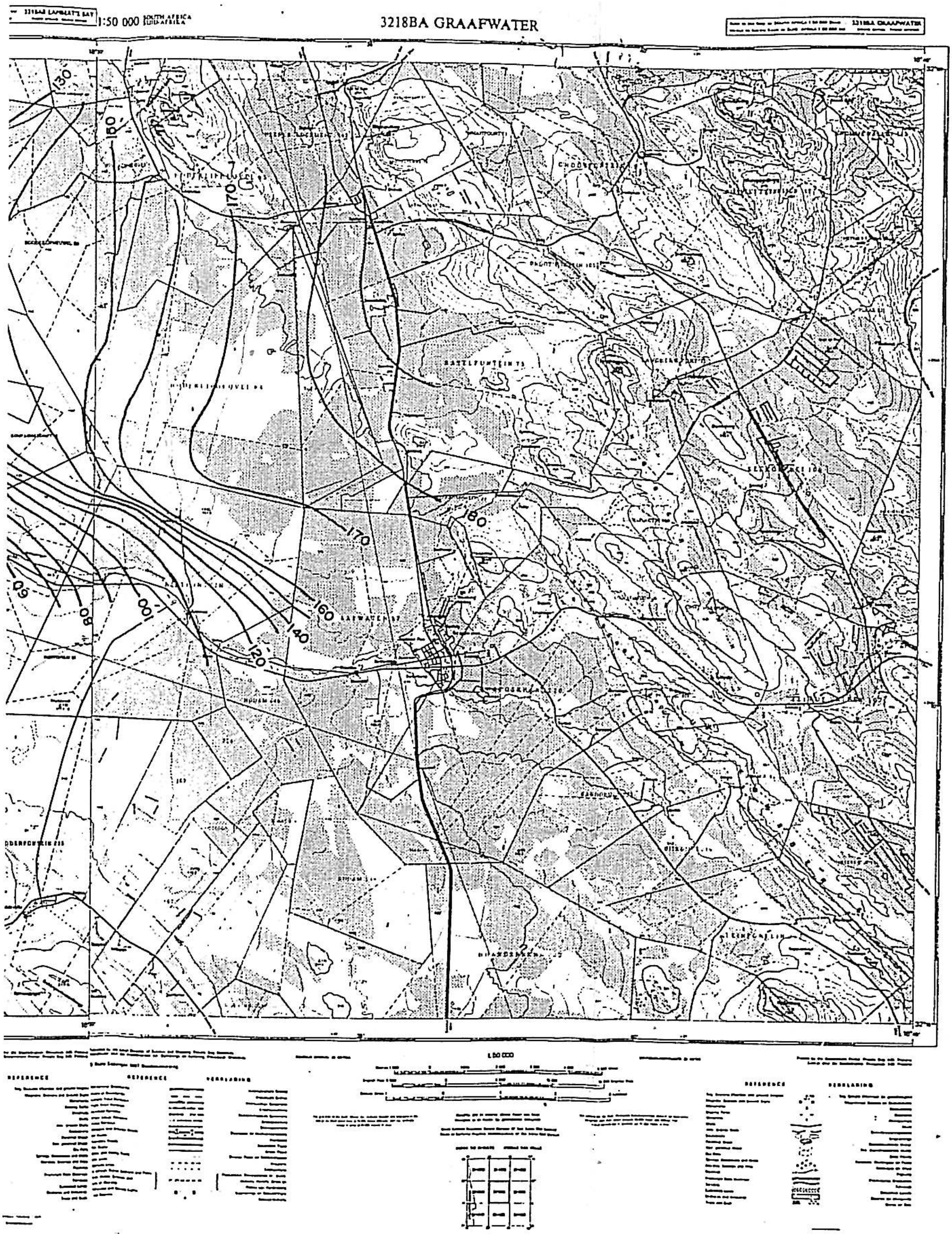
There appears to be limited difference in groundwater quality between the upper and lower aquifers - both have conductivities below 200 mS/m (in most circumstances conductivities vary between 50 - 75 mS/m). The poorer quality groundwater is associated with the underlying bedrock. Boreholes penetrating the Graafwater Fm shales generally have groundwater with a conductivity of above 150 mS/m, but conductivities were measured as high as 400 mS/m. The poorer quality water is found usually in the areas with shallower sediment, especially to the north of the palaeovalley.

The groundwater in the sand aquifer is generally of good quality, being acceptable for human consumption. The only problem associated with the groundwater is a high iron content (up to 24 mg/l), which appears to be associated with seepage/recharge derived either from the TMS formations, or from iron reducing bacteria associated with iron sulfides found in the more peaty horizons. Any groundwater with Fe concentrations above 0.1 mg/l must be treated to conform to SABS recommended limits.

<u>4.4 Piezometry.</u>

The map of water level contours (Figure 15) shows a groundwater flow from east to west. The gradient is fairly uniform and gentle, becoming steeper to the west of the 130m isobath. The following flow model is hypothesized :-

The major aquifer is east of the 130m isobath (east of the power lines). Rainfall recharge over this area coupled with inflow from the mountains results in a flow towards the coast. From the powerlines westwards, the more transmissive Elandsfontein Fm pinches out. Flow becomes restricted - thus to relieve the pressure flow occurs towards the Jakkals river, with the remaining groundwater flowing


1:50 000 SOUTH AFRICA
3218BA GRAAFWATER
130
150
170
180
170
160
140
120
100
80
60
3218BA GRAAFWATER

m a.m.s.l.)

FIG 15

coastwards through the Bredasdorp Group sands. Since these sands are less transmissive than the Elandsfontyn Fm, the flow gradient increases towards the coast. The situation is analogous to a wide river suddenly becoming narrower - the rate of flow must increase, or it must overflow on the sides.

4.5 Exploitation Potential.

The exploitation potential of an aquifer is dictated by the recharge occurring, and not by the volume of water in storage in the aquifer. The calculation of aquifer recharge is difficult. In order to understand the difficulties it is necessary to delve into the history of recharge estimates along the West Coast.

All the initial research was undertaken in the Atlantis area. Vandoolaeghe and Bertram (Gh 3222, 1982) used the water balance method to calculate a recharge rate of 26% of the rainfall (380mm/a). Vandoolaeghe and Bredenkamp (Gh 3227, 1982) calculated a recharge rate of 25% (rainfall of 380mm pa) also using a water balance method. They felt that a rate of 30 - 35% was not impossible.
Bredenkamp (Gh 3233) modeled conditions at Atlantis and came up with a recharge rate of 21% of a total rainfall of 350mm pa. Fleisher (pers comm) in the latest work at Atlantis states that recharge is probably in the order of 17 - 20% of the annual rainfall (350mm).
Timmerman (Gh 3370, 1985) working between the Berg River and Eland's Bay guestimated a recharge rate of 15% in an area where the rainfall varies between 200 and 316mm pa. While investigating the Lower Berg River area (Gh 3374, 1985) Timmerman once again suggested 15% as the recharge rate (rainfall varies between 200 and 380 mm pa). In the Graafwater area (rainfall of 250mm pa) Timmerman (Gh3471) assumed a "conservative" recharge rate of 8%. In the investigation at Strandfontein (Gh 3511, 1988) Timmerman and Vandoolaeghe adopted a different approach - they stated that rainfall would not occur on a yearly basis, but only sporadically. They suggested that recharge might only occur ever 10 years, although a figure of 20 years would not be impossible.

Gerber (1980) modelled the water balance on the Cape Flats aquifer (rainfall of between 600 and 750mm/a) and came up with a recharge figure of 40 % for the dune area, although he did concede that this value did not take into account evapotranspiration of water that had already reached the groundwater level. Vandoolaeghe (Gh 3655, 1989) used a modelling exercise to calculate the exploitation potential of a hypothetical wellfield on the Cape Flats. During this exercise recharge was found to vary between 15 and 35% of rainfall.

Timmerman (Gh3372, 1985), working on the Grootwater Aquifer at Yzerfontein (rainfall of 340mm/a) felt that 15% was the bottom limit for recharge to the aquifer. Baron (Gh 3715, 1990) working on the same area selected a much more conservative figure of 10%.

Bredenkamp, in his document on groundwater recharge (Gh 3572, 1988) investigated a linear relationship between rainfall and recharge. Although his data is from secondary and dolomitic aquifers, he postulated that recharge only occurs above a certain minimum yearly rainfall (313 mm pa.) and then at a rate of 30% of the "excess" rainfall.
Foster et al (1982) working on Ecca sandstone aquifers in the Kalahari (Botswana) were even more extreme. They calculated that during average rainfall years (450mm/a) no groundwater recharge would occur in areas where the soil/sand cover was deeper that 4m. The rainfall would be stored in the sands and then evapotranspirated. Recharge would only occur in areas where the soil cover was thin or non existent. Working in the same area Mazor (1982) however, refutes Foster et al. Mazor maintains that water level measurements, and elevated tritium values prove that recharge does take place, although he ascertains that this is only in above-average rainfall years. He felt that preferential recharge zones exist within the sand cover, and recharge would occur, but with a time lag of up to 4 months, dependant on the sand thickness.

At Eland's Bay (rainfall of 196mm/a) groundwater abstraction has been carefully monitored for the last 2.5 years (late 1989 to present). During this period water levels have not dropped at all. Abstraction must therefore equal recharge. Calculations suggest a recharge rate of 12% per annum. This figure includes some horizontal inflow, although how much is conjecture.

Having presented all the above information it would appear that a recharge figure of 8% is conservative. However it is suggested that this figure is used until abstraction data, coupled with water level monitoring, provides more suitable data for evaluation.

Using the 8% figure the recharge to the aquifer is :

$$\begin{aligned}\text{Recharge} &= 8\% \times \text{Rainfall (228mm/year)} \times \text{aquifer area}\\ &= 0.08 \times 0.228\text{m} \times 123510000\\ &= 2.25 \text{ Million m}^3\text{/year}\end{aligned}$$

This figure is for recharge from rainfall onto the aquifer only - further recharge would occur by subsurface inflow from areas bordering the aquifer, especially runoff during high rainfall events on the mountains to the west .

5. DISCUSSION.

5.1 GSGWCA boundaries.

The original boundaries of the GSGWCA were over conservative, and emplaced before the actual position of the palaeovalley was known. Having undertaken the fieldwork, the boundaries of the control area can now be changed to the smallest area necessary to protect the aquifer. The "new" boundaries are shown in Figure 16 and the farm names listed in the Government Gazette No. 13998 of the 29th of May 1992 (Appendix G).

5.2 Groundwater abstraction allocations.

Within the control area the Minister of Water Affairs can, at his discretion, make an abstraction allocation to each of the properties. In the control area the allocation made to each farm was based on the following factors :-

1) All existing groundwater abstraction which took place before the proclamation of the control area was recognized.

2) Abstraction allowed for household use - calculated at 3500 m^3 per year.

3) Stock watering - water requirements calculated at 32.9 m^3/year per large stock unit (LSU), with the carrying capacity for one LSU in this area being 30 ha. The amount of water made available (m^3) for stock water is therefore calculated from :

$$\frac{\text{Farm area (ha)} \times 32.9}{30}$$

4) Irrigation for stock fodder - an allocation was made based on : the area of the farm overlying the aquifer (a reflection of that farm's contribution to the total recharge area overlying the aquifer), an allowed irrigation requirement of 10 000 m^3/ha/year and an irrigation area of 1,5 ha for every 100 ha unit on the farm. The irrigation allocation (m^3/year) was therefore calculated as follows :

$$\text{Farm area} \times \%\ \text{area underlain by the aquifer} \times \frac{1,5}{100} \times 10^3\ m^3$$

5) The total allocation consisted of either :
- the sum of 2), 3) and 4).
- the initial use, if this was larger than the summation above.
- the recharge per farm. Based on an 8% recharge rate the recharge per hectare per year would be 182 m^3. If the total recharge for the area of the farm overlying the aquifer was smaller than the allocation calculated above, the recharge volume was the limiting factor. The allocations are contained in Appendix G.

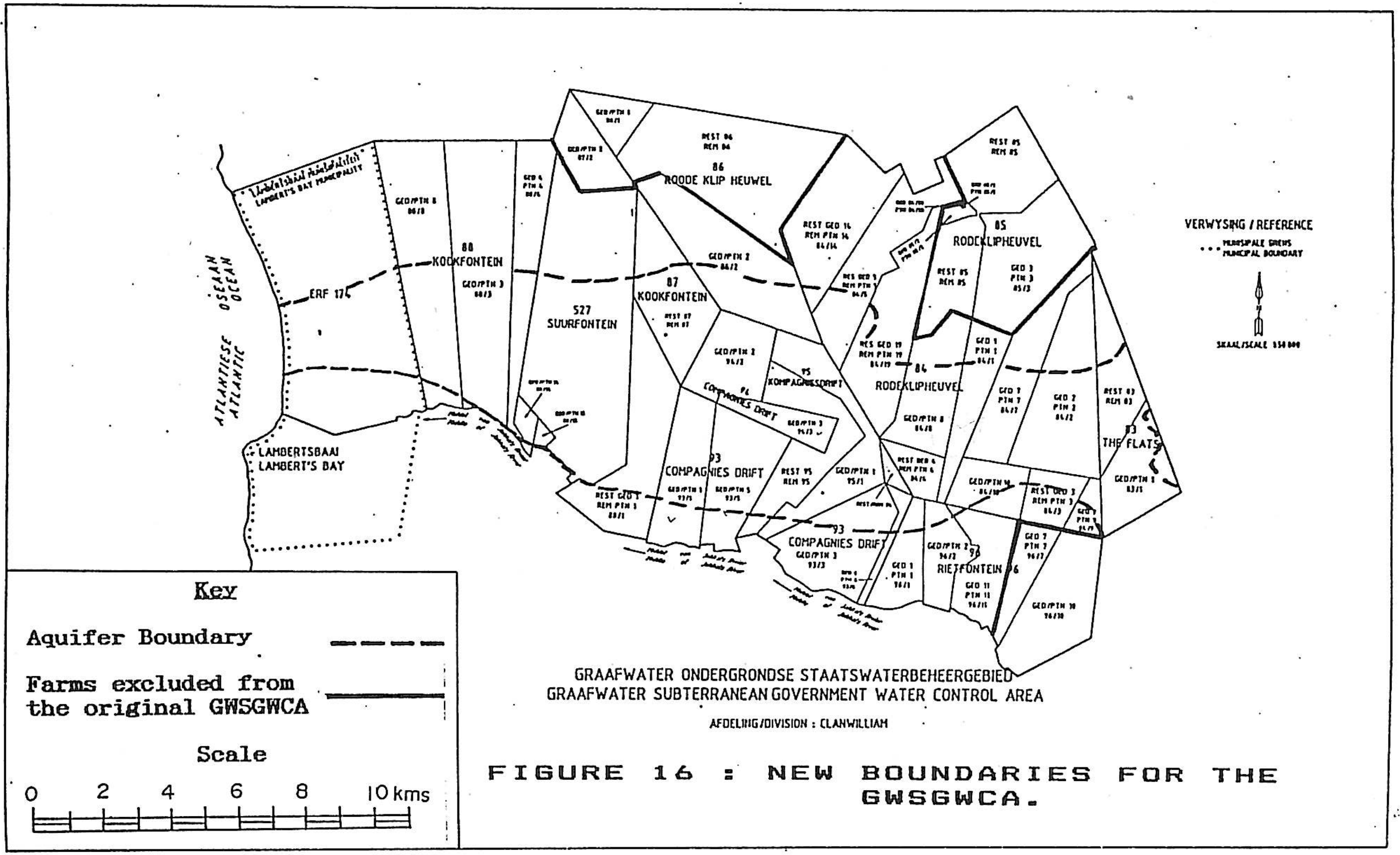


FIGURE 16 : NEW BOUNDARIES FOR THE GWSGWCA.

5.3 Management recommendations

At present monthly water level monitoring is being undertaken by the Directorate of Geohydrology (Western Cape) at the following boreholes :- G33112, G33113, G33720A, G33721, G33722, G33723, G33725, G33726, G33727, G33728, G33729, G33730, G33731, G33732A, G33733A, G33734A, G33735, G33745A and G31260 (Research Station). The data from the water level monitoring throughout the GSGWCA must be used to assess the effect of abstraction on water levels in the aquifer. If the allocations made are found to be overly conservative then the allocations can be altered accordingly. It is suggested that the allocations should be reviewed by the end of 1993, and the monitoring network should be reduced as necessary.

It has also been written into the contract between Water Affairs and the Graafwater Municipality that monitoring of the water levels at boreholes G33747B, G33746D and G33746E must take place on a monthly basis, while the conductivity of the production hole being used must also be monitored on a monthly basis. Full chemical analyses from the production borehole should be undertaken quarterly. The collation of this data is essential, and must be supplied to the Directorate of Geohydrology on a regular basis. Geohydrology has supplied the Graafwater Municipality with water-level meters, forms and graphs so that they can monitor the situation at the wellfield. It must be emphasized that this supply has been handed over to the Municipality - although Geohydrology can offer advice and guidance, the final management of the Graafwater Wellfield lies with the Municipality. If the Municipality notices that a trend of falling water levels, or deteriorating qualities occurs, then they must contact the Regional Office of Water Affairs immediately for advice.

6. CONCLUSIONS.

An east-west trending palaeovalley exists between Graafwater and Lamberts Bay. The palaeovalley contains saturated unconsolidated deposits reaching a maximum thickness of 150m. The aquifer consists of fine grained upper silts (Bredasdorp Group), underlain by medium - coarse grained sands (Elandsfontein Fm). The coarser grained sands comprise the major aquifer. The geohydrological characteristics of the two aquifers are contained in the table below.

Table 6 Summary of Aquifer Characteristics.

Aquifer	Thickness (m)	Yields (l/sec)	T (m2/day)	Storage (M m^3)	Quality (mS/m)
Bredasdorp	80	< 3	0.17 - 22	910	50-75
Elands-fontein	40	10 - 20	26 -169	270	50-75

The average yearly recharge volume for the GSGWCA (derived as 8% of rainfall) is 2.25 milion m^3/year - this is the sustainable yield for the aquifer, without causing detrimental lowering of the groundwater level.

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APPENDIX A

FARMS IN THE ORIGINAL
GRAAFWATER GSWCA

(b) Die volgende gedeeltes van die aangeduide plase:

Compagnies Drift 93
Gedeelte 5.
Compagnies Drift 94
Resterende Gedeelte.
Gedeelte 2.
Gedeelte 3.
Kompagniesdrift 95
Resterende Gedeelte.
Gedeelte 1.
Kookfontein 87
Resterende Gedeelte.
Gedeelte 2.
Kookfontein 88
Resterende Gedeelte van Gedeelte 1.
Gedeelte 15.
Rietfontein 96
Gedeelte 2.
Gedeelte 7.
Roode Klip Heuwel 86
Resterende Gedeelte.
Gedeelte 1.
Gedeelte 2.
Rodeklipheuvel 84
Gedeelte 1.
Gedeelte 2.
Resterende Gedeelte van Gedeelte 3.
Resterende Gedeelte van Gedeelte 4.
Resterende Gedeelte van Gedeelte 5.
Gedeelte 7.
Gedeelte 8.
Gedeelte 9.
Gedeelte 10.
Resterende Gedeelte van Gedeelte 14.
Resterende Gedeelte van Gedeelte 19.
Resterende Gedeelte van Gedeelte 20.
Rodeklipheuvel 85
Resterende Gedeelte.
Gedeelte 1.
Gedeelte 2.
Gedeelte 3.
The Flats 83
Resterende Gedeelte.
Gedeelte 1.

(c) Die volgende gedeeltes van die aangeduide plase vir sover hul noord van die Jakkalsrivier geleë is:

Compagnies Drift 93
Gedeelte 1.
Gedeelte 3.
Gedeelte 6.
Kookfontein 88
Gedeelte 3.
Gedeelte 4.
Gedeelte 8.
Gedeelte 14.

(b) The following portions of the farms indicated:

Compagnies Drift 93
Portion 5.
Compagnies Drift 94
Remaining Extent.
Portion 2.
Portion 3.
Kompagniesdrift 95
Remaining Extent.
Portion 1.
Kookfontein 87
Remaining Extent.
Portion 2.
Kookfontein 88
Remaining Extent of Portion 1.
Portion 15.
Rietfontein 96
Portion 2.
Portion 7.
Roode Klip Heuwel 86
Remaining Extent.
Portion 1.
Portion 2.
Rodeklipheuvel 84
Portion 1.
Portion 2.
Remaining Extent of Portion 3.
Remaining Extent of Portion 4.
Remaining Extent of Portion 5.
Portion 7.
Portion 8.
Portion 9.
Portion 10.
Remaining Extent of Portion 14.
Remaining Extent of Portion 19.
Remaining Extent of Portion 20.
Rodeklipheuvel 85
Remaining Extent.
Portion 1.
Portion 2.
Portion 3.
The Flats 83
Remaining Extent.
Portion 1.

(c) The following portions of the farms indicated, in so far as they are situated north of the Jakkals River:

Compagnies Drift 93
Portion 1.
Portion 3.
Portion 6.
Kookfontein 88
Portion 3.
Portion 4.
Portion 8.
Portion 14.

Rietfontein 96

Gedeelte 1.

Gedeelte 10.

Gedeelte 11.

(d) Die volgende eiendom binne die Lambertsbaai munisipale gebied:

Erf 174.

Rietfontein 96

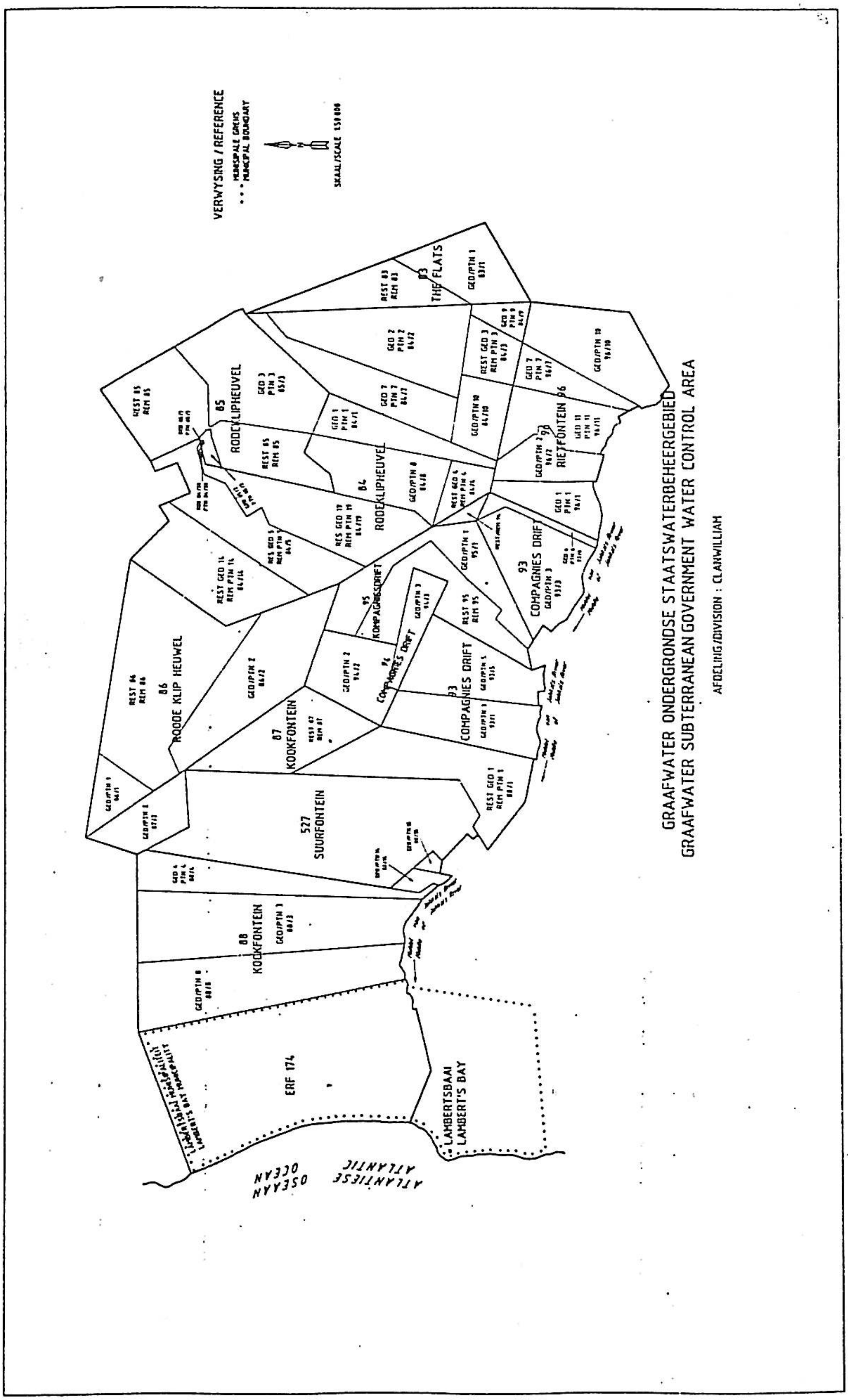
Portion 1.

Portion 10.

Portion 11.

(d) The following property situated in the municipal area of Lamberts Bay:

Erf 174.


GRAAFWATER ONDERGRONDSE STAATSWATERBEHEERGEBIED
GRAAFWATER SUBTERRANEAN GOVERNMENT WATER CONTROL AREA
AFDELING/DIVISION : CLANWILLIAM
VERWYSING / REFERENCE
THE FLATS
RODEKLIPHEUVEL
RIETFONTEIN
COMPAGNIES DRIFT
RODDE KLIP HEUVEL
KOOKFONTEIN
527 SUURFONTEIN
ERF 174
LAMBERTSBAAI
LAMBERT'S BAY
ATLANTIESE OSEAAN
ATLANTIC OCEAN

AVERAGE MONTHLY CLIMATOLOGICAL DATA

GRAAFWATER

Month	MAXT (Deg C)	MINT (Deg C)	RAIN (mm)	EVAP (mm)	SUN DAYS (hrs/month)	WIND (km/day)	MAXH (%)	MINH (%)
Jan	30.1	14.4	4.7	311.1	332.1	113.1	86.0	32.3
Feb	31.0	14.9	5.6	258.0	288.8	101.0	84.9	32.2
March	29.5	13.8	13.2	227.2	285.2	87.7	84.4	32.6
April	26.9	12.6	26.1	151.1	239.2	80.2	83.7	35.4
May	23.1	10.5	42.7	107.3	214.4	91.4	84.7	39.2
June	20.4	9.1	43.4	88.1	201.8	100.0	83.0	39.9
July	19.6	7.5	41.3	88.5	209.1	97.6	86.2	40.3
August	20.4	7.5	42.3	96.1	222.4	93.6	88.6	38.9
Sept	22.3	8.5	21.4	123.0	234.2	87.7	87.2	34.7
Oct	25.1	9.6	11.9	191.6	275.8	97.1	84.2	30.3
Nov	27.5	11.8	11.1	244.3	294.3	106.1	83.9	30.0
Dec	28.9	13.5	14.0	291.9	322.8	103.3	86.2	32.6

NORTIER RESEARCH STATION

Month	MAXT (Deg C)	MINT (Deg C)	RAIN (mm)	EVAP (mm)			MAXH (%)	MINH (%)
Jan	24.0	13.2	4.4	244.6			91.1	48.1
Feb	24.5	13.4	4.3	205.3			90.0	47.3
March	23.6	12.8	9.8	182.8			88.4	48.4
April	22.5	11.7	24.4	131.9			86.9	47.3
May	21.5	10.7	28.8	123.6			81.7	43.8
June	19.2	9.0	41.4	99.8			82.0	45.4
July	18.5	8.2	36.4	105.2			86.3	47.6
August	19.0	8.2	23.6	114.5			88.4	48.0
Sept	19.9	9.0	17.6	146.2			89.4	46.6
Oct	21.4	10.2	8.6	198.5			82.3	41.6
Nov	22.4	11.6	11.3	217.5			89.0	45.7
Dec	23.3	12.8	11.8	244.0			91.1	48.6

APPENDIX C

HYDROCENSUS DATA

KEY

COORDINATES

(D,M,S) - Degrees, minutes, seconds

SITE TYPE

B - Borehole
D - Dugwell
F - Fountain

EQUIPMENT

W - Windpump
M - Monopump
G - Gravity suction
N - None/Open borehole
R - Automatic waterlevel recorder

APPLICATION

D - Domestic
G - Garden
S - Stock watering
I - Irrigation
DWA - Department of Water Affairs

ELEVATION

All the groundwater sources elevations were interpolated from the 1:50 000 topographical map, except boreholes G33112 - G33116, G33720A - G33722, G33725 - G33735 and G33745A - G33747 that were surveyed..

APPENDIX 4 : Private groundwater sources data.

Borehole number	Farm name	Coördinates Longitude (D,M,S)	Coördinates Latitude (D,M,S)	Site type	Depth (m)	Depth to bedrock	Water level below collar height	Collar height above ground level	Water level below ground level	Elevation (mamsl)	Water level (mamsl)	E.C. (mS/m)	Equip-ment	Yield (l/s)	Application/ remarks
CT1	Compagnies Drift 93	182529	320656	B	52	30	28.73	0.30	28.43	74.00	45.57	83	W	0.3	Stock watering
CT2	Compagnies Drift 93	182556	320657	B	24		1.72	0.30	1.42	72.00	70.58	75	W	0.6	Garden
CT3	Compagnies Drift 93	182637	320547	B	58	56	26.12	0.25	25.87	119.00	93.13	60	W	0.3	Stock watering
CT4F	Compagnies Drift 93	182557	320650	F					0.00		0.00	84	G	0.1	Garden
CT5	Compagnies Drift 93	182944	320632	B			10.31	0.40	9.91	152.00	142.09		W		Stock watering
CT6	Compagnies Drift 93	182750	320549	B			16.03	0.70	15.33	136.00	120.67	73	W		Stock watering
CT7	Compagnies Drift 93	182706	320534	B			6.95	0.50	6.45	127.00	120.55	200	W		Stock watering
HN1	Harde Vlakte Kliph. ext.	182258	320044	B	90				0.00		0.00	320	W		Stock watering
KN1	Kookfontein 88	182226	320456	D	7		6.30	0.00	6.30	40.00	33.70		W		Domestic
KN2F	Kookfontein 88	182224	320456	F					0.00		0.00	117	N		Domestic
KN3F	Kookfontein 88	182219	320455	F					0.00		0.00	85	W		Domestic
KN4F	Kookfontein 88	182219	320453	F					0.00		0.00	84	N		Domestic
KN5F	Kookfontein 88	182220	320452	F					0.00		0.00	.	N		Domestic
KN6	Kookfontein 88	182214	320450	B	110	30	6.56	0.30	6.26	58.00	51.74		N	0.9	Unused
KN7	Kookfontein 88	182345	320525	B	42	30	0.00	0.00	0.00	85.00	85.00		G		D,G,S,I
KN8	Kookfontein 88	182346	320525	B	35	34	0.00	0.00	0.00	85.00	85.00	78	G	2.3	D,G,S,I
KN9	Kookfontein 88	182326	320527	F	130	7	0.00	0.00	0.00	50.00	50.00	72	N	1.9	D,G,S,I
KN10F	Kookfontein 88	182317	320538	B					0.00		0.00		W	0.4	Domestic
KN11	Kookfontein 88	182433	320624	B	30		7.00	0.70	6.30	63.00	56.70	64	W		D,S
KN12	Kookfontein 87	182605	320234	B	30		21.36	0.60	20.76	154.00	133.24	145	W		Stock watering
KN13	Kookfontein 87	182414	320131	B			48.18	0.50	47.68	151.00	103.32	360	W		Stock watering
KN14	Kookfontein 88	182244	320219	B	123				0.00		0.00		N		Unused, (bees)
KN15	Kookfontein 88	182141	320503	B	82	0	0.00	0.00	0.00		0.00	498	N	0.4	Unused

Borehole number	Farm name	Coördinates Longitude (D,M,S)	Coördinates Latitude (D,M,S)	Site type	Depth (m)	Depth to bedrock	Water level below collar height	Collar height above ground level	Water level below ground level	Elevation (mamsl)	Water level (mamsl)	E.C. (mS/m)	Equip-ment	Yield (l/s)	Application/ remarks
KN16F	Kookfontein 88	182141	320502	F			1.15	0.00	1.15	20.00	18.85	142	N		Unused
KN17	Kookfontein 88	182140	320501	B	113	6	1.24	0.10	1.14	23.00	21.86	79	N	3.0	Unused
KN18	Kookfontein 88	182144	320500	B	46		3.33	0.10	3.23	26.00	22.77	118	N	0.3	Unused
KN19	Kookfontein 88	182138	320459	B	130	4	6.00	0.15	5.85	30.00	24.15	90	W	2.0	Domestic
KN20	Kookfontein 88	182147	320458	B	122	4			0.00		0.00	284	N	12.1	Irrigation
KN21	Kookfontein 88	182133	320501	B	110				0.00		0.00		M	3.5	D,S,I
KN22	Kookfontein 88	182206	320459	B	50	7			0.00		0.00		W	2.3	Domestic
KT1	Kompagniesdrift 95	182839	320613	B	20		11.13	0.40	10.73	144.00	133.27		N		Unused
KT2	Kompagniesdrift 95	182826	320608	B					0.00		0.00		W		Stock watering
FP1	Nortier experimental farm	182005	320200	B					0.00		0.00		N		Dry (bees)
FP2	Nortier experimental farm	182044	320154	B					0.00		0.00		N		Unused (bees)
FP3	Nortier experimental farm	182035	320309	B	70				0.00		0.00		N	0.8	Sealed (bees)
FP4	Nortier experimental farm	182036	320308	B	75				0.00		0.00		N	1.2	Destroyed
FP5	Nortier experimental farm	182101	320304	B	134				0.00		0.00		N		Sealed
FP6	Nortier experimental farm	182059	320308	B	134				0.00		0.00		N	0.4	Sealed
FP7	Nortier experimental farm	181906	320153	B					0.00		0.00		N		Unused (bees)
FP9	Nortier experimental farm	181909	320338	D					0.00		0.00		N		Unused
FP10	Nortier experimental farm	181911	320337	D			5.51	0.00	5.51	9.00	3.49		N		Unused
RH1	Roode Klip Heuvel 86	182729	320116	B	125		37.61	0.20	37.41	162.00	124.59	311	N	0.2	Stock watering
RH2	Roode Klip Heuvel 86	182559	320125	B	65		35.92	0.60	35.32	157.00	121.68		N		Unused
RH3	Roode Klip Heuvel 86	182523	320128	B	120				0.00		0.00	94	W	0.9	Stock watering
RH4	Roode Klip Heuvel 86	182522	320130	B	65		36.70	0.70	36.00	155.00	119.00		N		Unused
RH5	Roode Klip Heuvel 86	182555	320127	B	76	28			0.00		0.00	90	W	0.4	Stock watering
RH6	Roode Klip Heuvel 86	182616	320232	B			22.44	0.40	22.04	155.00	132.96	83	W	0.2	Stock watering

Borehole number	Farm name	Coördinates Longitude (D,M,S)	Coördinates Latitude (D,M,S)	Site type	Depth (m)	Depth to bedrock	Water level below collar height	Collar height above ground level	Water level below ground level	Elevation (mamsl)	Water level (mamsl)	E.C. (mS/m)	Equipment	Yield (l/s)	Application/ remarks
RK1	Roodeklipheuvel 84	192816	320305	B	55		31.52	0.55	30.97	160.00	129.03	300	W	0.2	Stock watering
RK2	Roodeklipheuvel 84	182956	320359	B	64	18	15.47	0.40	15.07	162.00	146.93	306	W	1.9	Stock watering
RK3	Roodeklipheuvel 85	183122	320154	B	80	6			0.00		0.00	157	W		D,S
RK4	Roodeklipheuvel 85	183121	320156	B	85	30	28.41	0.45	27.96	185.00	157.04	157	W	0.1	D,S
RK5	Roodeklipheuvel 84	182857	320316	B			13.74	0.45	13.29	162.00	148.71	400	W		Stock watering
RK6	Roodeklipheuvel 85	183240	320150	B	60				0.00		0.00		W		Stock watering
RK7	Roodeklipheuvel 85	183209	320219	B	90				0.00		0.00		N		Dry
RK8	Roodeklipheuvel 85	183212	320342	B	45				0.00		0.00	500	W		Stock watering
RK9	Roodeklipheuvel 84	183236	320431	D	18		12.44	0.50	11.94	190.00	178.06	330	W		Stock watering
RK10	Roodeklipheuvel 84	183119	320402	D					0.00		0.00		N		Stock watering
RN1	Rietfontein 96	193010	320717	B	80	12	24.65	0.10	24.55	130.00	105.45	82	W	0.3	Domestic
RN2	Rietfontein 96	183032	320715	B	52		25.51	0.10	25.41	138.00	112.59	70	W		Garden
RN3F	Rietfontein 96.	193018	320759	F					0.00		0.00		W		Unused
RN4F	Rietfontein 96	183015	320759	F					0.00		0.00		N		Unused
RN5F	Rietfontein 96	183126	320704	F					0.00		0.00	50	W		D,S
RN6	Rietfontein 96	183317	320751	D	15		14.00	0.00	14.00	178.00	164.00	-	W		Stock watering
RN7	Rietfontein 96	183150	320840	D	10		0.50	0.40	0.10	115.00	114.90	190	W		Domestic
SF1	Suurfontein 527	182413	320140	B	82				0.00		0.00		N		Unused
SF2	Suurfontein 527	182351	320248	B	82		52.55	0.70	51.85	114.00	62.15	316	W	0.3	Stock watering
SF3	Suurfontein 527	182456	320159	B	82	42	62.67	0.50	62.17	152.00	89.83	231	W		Stock watering
SF4	Suurfontein 527	182416	320333	B					0.00		0.00		N		Destroyed
SF5	Suurfontein 527	182345	320534	B	132	9	28.21	0.20	28.01	78.00	49.99		N		Unused
SF6	Suurfontein 527	182346	320530	B	50	18	1.55	0.40	1.15	81.00	79.85		N	1.5	Unused
SF7F	Suurfontein 527	182405	320550	F					0.00		0.00	90	N		Garden
SF8	Suurfontein 527	182413	320550	D	4		1.30	0.35	0.95	77.00	76.05	110	W		Garden
SF9	Suurfontein 527	182410	320556	D	6		1.84	0.00	1.84	66.00	64.16	279	W		Garden

APPENDIX B : 6 - boreholes data.

Borehole number	Farm name	Coördinates Longitude (D,M,S)	Coördinates Latitude (D,M,S)	Site type	Depth (m)	Depth to bedrock	Water level below collar height	Collar height above ground level	Water level below ground level	Elevation (mamsl)	Water level (mamsl)	E.C. (mS/m)	Equipment	Yield (l/s)	Application/ remarks
630989	Kookfontein 88	182051	320203	B	100	43			0.00		0.00		N		Destroyed
630990	Kookfontein 88	182321	320542	B	88	5	1.17	0.30	0.87	41.00	40.13		N		Unused
630994	Nortier experimental farm	181857	320339	B	119	59			0.00		0.00		N		Dry
630995	Nortier experimental farm	181918	320427	B	100	42			0.00		0.00		N		Destroyed
631002	Nortier experimental farm	182005	320352	B	60	42			0.00		0.00		N		Unused (standby)
631007	Nortier experimental farm	181916	320222	B	124	47	36.34	0.13	36.21	45.00	8.79		N		Unused
631016	Nortier experimental farm	181653	320225	B	83	7			0.00		0.00		N		Unused
631260	Nortier experimental farm	182005	320350	B	43		11.15	0.40	10.75	15.00	4.25		N		Observasion-DWA
631261	Nortier experimental farm	181918	320431	B	81	45			0.00		0.00		N		Dry
631274	Suurfontein 527	182357	320513	B					0.00		0.00		N		Destroyed
632997	Nortier experimental farm	182005	320351	B	37	32			0.00		0.00		N		D,S,I
633111	Roodeklipheuvel 84	183010	320455	B	112	112			0.00		0.00		N		Unused
633112	Roodeklipheuvel 84	183140	320453	B	112	>110	15.40		15.40	178.77	163.37	98	N		Observasion-DWA
633113	Roodeklipheuvel 84	183313	320512	B	99	>99	10.49		10.49	187.44	176.95	164	R	0.2	Observasion-DWA
633114	Roodeklipheuvel 84	183109	320610	B	69	42	14.42		14.42	178.01	163.59	39	R	0.1	Observasion-DWA
633115	Graafwater 97	183436	320740	B	33	30			0.00	186.95	186.95	355	N		Unused
633116	Roodeklipheuvel 84	183346	320600	B	88	87	16.30		16.30	192.63	176.33	269	N		Observasion-DWA
633720A	Roodeklipheuvel 84	183119	320547	B	102	71	10.72	0.50	10.22	179.18	168.96	87	N	0.1	Observasion-DWA
633721	Roodeklipheuvel 84	183141	320620	B	102	23	10.53		10.53	171.94	161.41	65	N	0.1	Observasion-DWA
633722	Roodeklipheuvel 84	183122	320438	B	85	>85	14.77		14.77	177.91	163.14	90	N	0.4	Observasion-DWA
633723	Roodeklipheuvel 84	183100	320514	B	138	97			0.00		0.00	192	N	0.1	Unused

Borehole number	Farm name	Coördinates Longitude (D,M,S)	Coördinates Latitude (D,M,S)	Site type	Depth (m)	Depth to bedrock	Water level below collar height	Collar height above ground level	Water level below ground level	Elevation (mamsl)	Water level (mamsl)	E.C. (mS/m)	Equip-ment	Yield (l/s)	Application/ remarks
633724	Roodeklipheuvel 84	183306	320440	B	94	79			0.00		0.00	77	N	0.2	Observasion-DWA
633725	Roodeklipheuvel 84	183131	320627	B	40	30	9.82		9.82	177.58	167.76	55	N	0.5	Observasion-DWA
633726	Rietfontein 96	183139	320704	B	18	9	5.11		5.11	167.51	162.40		N	0.0	Observasion-DWA
633727	Roodeklipheuvel 84	183007	320532	B	77	>102	15.37		15.37	173.60	158.23	142	N	0.1	Observasion-DWA
633728	Roodeklipheuvel 84	183242	320447	B	103	62	13.27		13.27	188.16	174.89	125	N	1.0	Observasion-DWA
633729	Ratelfontein 76	183523	320416	B	78	21	17.63		17.63	213.16	195.53	179	N	0.2	Observasion-DWA
633730	Roodeklipheuvel 84	183209	320607	B	36	34	11.71		11.71	185.47	173.76	164	N	0.2	Observasion-DWA
633731	Roodeklipheuvel 84	183124	320403	B	46	33	14.06		14.06	178.05	163.99	269	N	0.1	Observasion-DWA
633732A	Roodeklipheuvel 84	183112	320531	B	58	>57	10.52	0.32	10.20	177.10	166.90	92	N		Observasion-DWA
633733A	Roodeklipheuvel 84	183105	320557	B	60	>60	9.30	0.22	9.08	177.02	167.94	72	N		Observasion-DWA
633734A	Roodeklipheuvel 84	183110	320544	B	65	>69	9.80	0.17	9.63	177.63	168.00	38	N		Observasion-DWA
633735	Roodeklipheuvel 84	183118	320540	B	66		10.16	0.09	10.07	178.30	168.23	48	N	0.5	Observasion-DWA
633745A	Roodeklipheuvel 84	183103	320547	B	50		10.06	0.30	9.76	177.34	167.58		N	2.0	Observasion-DWA
633746D	Roodeklipheuvel 84	183119	320513	B	102	128	13.47	0.23	13.24	176.97	163.73	38	N	0.5	Observasion-DWA
633747	Roodeklipheuvel 84	183129	320513	B	102	128	14.86	0.22	14.64	177.21	162.57	38	N	5.0	Observasion-DWA
633748	Kookfontein 88	182215	320408	B	148	121	47.80	0.00	47.80	93.00	45.20		N	0.1	Unused
633749	Suurfontein 527	182510	320519	B	84	73	3.52		3.52	95.00	91.48	64	N	0.1	Unused
633920	Suurfontein 527	182516	320431	B	90	88			0.00		0.00	84	N	1.0	Unused
633921	Kookfontein 87	182626	320306	B	102	94			0.00		0.00		N		Unused

APPENDIX D

DATA FROM GOVERNMENT BOREHOLES

	Borehole Number	Borehole Type	Drilling Details	Casing Details	Screen Details	Yield (l/s)	Aquifer test data	Quality (mS/m)	Water level (m)	Elevation (m amsl)	W-level (m amsl)	Co - ordinates Y	Co - ordinates X
3218BA359	G33111	Exploration	0 - 112 m x 165 mm MR	0 - 112 m x 90 mm PVC	None	Dry	-	95	14.325	172.060	157.735	+46965.79	+3550855.11
3218BA12	G33112	Exploration	0 - 112 m x 165 mm MR	0 - 96 m x 90 mm PVC	87 - 90 m Preussag K80	<0.1	-	98	15.623	178.770	163.147	+44600.96	+3550933.21
3218BA6	G33113	Exploration	0 - 99 m x 165 mm MR	0 - 75 m x 90 mm PVC	34 - 36 m Preussag K80	0.2	Slug test:k from 0.76-0.96 m/day	164	14.762	187.440	172.678	+42920.02	+3551683.17
3218BA358	G33114	Exploration	0 - 69 m x 165 mm MR	0 - 44 m x 90 mm PVC	34 - 38 m Preussag K80	0.1	Slug test:k from 0.24-0.57 m/day	39	10.474	178.010	167.536	+45448.29	+3553094.64
3218BA357	G33115	Exploration	0 - 33 m x 165 mm MR	0 - 31 m x 90 mm PVC	21 - 24 m Preussag KK80	0.1	Slug test:k from 10.1-9.04 m/day	355	13.620	188.490	174.870	+40269.68	+3555577.99
3218BA11	G33116	Exploration	0 - 88 m x 165 mm MR	0 - 62 m x 90 mm PVC	52 - 54 m Preussag K80 54 - 56 m Preussag KK80	<0.1	Slug test:k from 0.14-0.59 m/day	269	16.330	192.630	176.300	+41188.39	+3552662.52
—	G33720	Exploration	0 - 64 m x 195 mm MR 64 - 100 m x 165 mm MR	0 - 64 m x 165 mm Steel	None	<0.1	-	262	11.045	179.180	168.135	+45139.43	+3552364.36
3218BA36	G33720A	Exploration	0 - 102 m x 195 mm MR	0 - 102 m x 90 mm PVC	42 - 46 m Preussag KK80	0.1	-	87	10.685	179.230	168.545	+45130.56	+3552361.3
3218BA37	G33721	Exploration	0 - 40 m x 195 mm MR 40 - 102 m x 165 mm AP	0 - 40 m x 165 mm Steel	None	<0.1	-	65	10.767	176.070	165.303	+44534.06	+3553374.4
3218BA38	G33722	Exploration	0 - 85 m x 195 mm MR	0 - 84 m x 90 mm PVC	66 - 70 m Preussag K80	0.4	-	90	14.577	177.910	163.333	+45061.73	+3550245.22
3218BA356	G33723	Exploration	0 - 93 m x 195 mm MR 93 - 138 m x 165 mm AP	0 - 73 m x 165 mm Steel 0 - 138 m x 90 mm PVC	84 - 88 m Preussag K80	0.1	-	192	14.900	176.070	161.170	+45625.77	+3551348.39
3218BA40	G33724	Exploration	0 - 94 m x 195 mm MR	0 - 94 m x 90 mm PVC	52 - 56 m Preussag KK80	0.2	-	77	13.538	173.670	160.132	+46103.68	+3550302.3
3218BA355	G33725	Exploration	0 - 40 m x 195 mm MR	0 - 40 m x 90 mm PVC	29 - 32 m Preussag KK80	0.5	-	55	10.096	177.580	167.484	+44818.77	+3553608.2
3218BA42	G33726	Exploration	0 - 18 m x 195 mm MR	0 - 18 m x 90 mm PVC	4 - 5 m Preussag KK80	<0.1	-	-	5.207	167.510	162.303	+44627.75	+3554726.01
3218BA43	G33727	Exploration	0 - 102 m x 195 mm MR	0 - 78 m x 90 mm PVC	68 - 72 m Preussag KK80	0.1	-	142	15.265	173.600	158.335	+47004.43	+3551923.0

	Borehole Number	Borehole Type	Drilling Details	Casing Details	Screen Details	Yield (l/s)	Aquifer test data	Quality (mS/m)	Water level (m)	Elevation (m amsl)	W-level (m amsl)	Co - ordinates Y	X
3218BA44	G33728	Exploration	0 - 102 m x 195 mm MR	0 - 102 m x 90 mm PVC	29 - 33 m Preussag KK80	1.0	-	125	10.678	188.160	177.482	+42966.97	+3550525.39
3218BA35A	G33729	Exploration	0 - 78 m x 195 mm MR	0 - 78 m x 90 mm PVC	42 - 46 m Preussag KK80	0.2	-	179	17.763	213.160	195.397	+38747.00	+3549527.00
3218BA35B	G33730	Exploration	0 - 36 m x 195 mm MR	0 - 36 m x 90 mm PVC	26 - 28 m Preussag KK80	0.2	-	164	11.927	185.470	173.543	+43816.07	+3552990.62
3218BA47	G33731	Exploration	0 - 48 m x 195 mm MR	0 - 46 m x 90 mm PVC	14 - 18 m Preussag K80	0.1	-	269	14.266	178.050	163.784	+45011.10	+3549175.43
427	G33732	Exploration	0 - 72 m x 195 mm MR	0 - 71 m x 90 mm PVC	43 - 50 m Preussag KK80	0.4	-	92	11.142	177.180	166.038	+45328.22	+3551858.56
3218BA48	G33732A	Production	0 - 58 m x 300 mm MR	0 - 58 m x 200 mm PVC	26 - 36 m Preussag KK200 42 - 52 m Preussag KK200	1.4 P	-	78	10.619	177.420	166.801	+45316.58	+3551867.82
428	G33732B	Production	0 - 83 m x 300 mm MR	0 - 83 m x 200 mm PVC	57 - 81 m Johnson 200mm #20	1.0 P	-	40	11.523	177.310	165.787	+45317.70	+3551854.62
	G33733	Exploration	0 - 66 m x 195 mm MR	0 - 60 m x 90 mm PVC	39 - 45 m Preussag KK80	0.5	-	38	9.662	177.260	167.598	+45507.58	+3552656.75
3218BA49	G33733A	Production	0 - 60 m x 300 mm MR	0 - 60 m x 200 mm PVC	33 - 54 m Houston 200mm #10	0.5 P	-	38	9.295	177.240	167.945	+45501.06	+3552670.18
	G33734	Exploration	0 - 69 m x 195 mm MR	0 - 68 m x 90 mm PVC	49 - 54 m Preussag KK80	1.3	-	38	9.778	177.680	167.902	+45368.62	+3552283.25
3218BA50	G33734A	Production	0 - 65 m x 300 mm MR	0 - 65 m x 200 mm PVC	29 - 59 m Houston 200mm #10	4.2 P	-	38	9.842	177.800	167.958	+45357.75	+3552293.30
3218BA352	G33735	Exploration	0 - 66 m x 195 mm MR	0 - 64 m x 90 mm PVC	47 - 52 m Preussag KK80	0.5	-	48	10.432	178.390	167.958		
429	G33745	Exploration	0 - 60 m x 195 mm MR	0 - 58 m x 90 mm PVC	34 - 37 m Preussag KK80 52 - 55 m Preussag KK80	0.5	-	37	10.185	177.510	167.325	+45556.44	+3552348.70
3218BA52	G33745A	Production	0 - 50 m x 300 mm MR	0 - 49 m x 200 mm PVC	28 - 43 m Unique Engineerin	1.3 B	-	37	10.227	177.640	167.413	+45557.80	+3552363.26

	Borehole Number	Borehole Type	Drilling Details	Casing Details	Screen Details	Yield (l/s)	Aquifer test data	Quality (mS/m)	Water level (m)	Elevation (m amsl)	W-level (m amsl)	Co - ordinates Y	X
3218BA101	G33746	Exploration	0 - 76 m x 195 mm MR	0 - 76 m x 90 mm PVC	44 - 50 m Preussag KK80	0.5		38	12.437	177.550	165.113	+45152.31	+3551387.37
3218BA96	G33746A	Exploration	0 - 123 m x 305 mm MR 123- 216 m x 165 mm AP	17 - 123 m x 305 mm Steel 0 - 128.5m x 254 mm Stee	None	<0.1	-	42	15.753	177.540	161.787	+45138.06	+3551375.20
3218BA102	G33746B	Production	0 - 102 m x 305 mm MR	0 - 98 m x 204 mm PVC	92 - 62 m Johnson 200mm #30	>16.0	T : 116-179 S : 0.033-0.067	38	15.370	177.550	162.180	+45146.70	+3557373.10
3218BA99	G33746C	Observation	0 - 126 m x 165 mm MR	0 - 126 m x 90 mm PVC	70 - 76 m Preussag KK80	0.1	-	38	13.437	177.660	164.223	+45143.11	+3551392.50
3218BA53	G33746D	Observation	0 - 102 m x 165 mm MR	0 - 101 m x 90 mm PVC	70 - 73 m Preussag KK80	0.5	-	38	13.478	177.210	163.732	+45141.26	+3551333.27
3218BA109	G33747	Exploration	0 - 102 m x 165 mm MR	0 - 102 m x 90mm PVC	87 - 93 m Preussag KK80	5.0	-	38	15.185	177.430	162.245	+44881.49	+3551327.86
3218BA97	G33747A	Production	0 - 102 m x 305 mm MR	0 - 99 m x 204 mm PVC	63 - 93 m Johnson 200mm #30	10.0 B	-	36	15.000	177.460	162.460	+44880.46	+3551313.22
3218BA54	G33747B	Production	0 - 102 m x 305 mm MR	0 - 99 m x 204 mm PVC	63 - 93 m Johnson 200mm #30	16.0 P	-	36	15.215	177.280	162.065	+44869.34	+3551336.40

Borehole Number	Borehole Type	Drilling Details	Casing Details	Screen Details	Yield (l/s)	Aquifer test data	Quality (mS/m)	Water level (m)	Elevation (m amsl)	W-level (m amsl)	Co-ordinates Latitude	Co-ordinates Longitude
3218BA106 G33748	Exploration	0 - 148 m x 200 mm MR	0 - 100 m x 90 mm PVC	72 - 74 m Preussag KK80 78 - 82 m Preussag KK80	0.1			47.810	90.000	42.190	32.06892	18.37083
3218BA197 G33749	Exploration	0 - 84 m x 200 mm MR	0 - 83 m x 90 mm PVC	57 - 73 m Preussag KK80	0.1		64	3.52	100	96.460	32.00886	18.41944
3218AB191 G33920	Exploration	0 - 90 m x 200 mm MR	0 - 90 m x 90 mm PVC	70 - 76 m Preussag KK80	1.0		84		130	130.000	32.07528	18.42111
3218AB190 G33921	Exploration	0 - 102 m x 200 mm MR	0 - 100 m x 90 mm PVC	87 - 93 m Preussag KK80	0.1			17.23	155	137.770	32.05225	18.44028
G33921A	Test	0 - 100 m x 300 mm MR	0 - 100 m x 200 mm PVC	86 - 94 m Soloflow (0.5mm)	5.2	T = 26 m2/day s = 1.5E-03	103		155	155.000	32.05230	18.44033
3218BA314 G33922	Exploration	0 - 84 m x 165 mm MR	0 - 82 m x 90 mm PVC	42 - 46 m Preussag KK80 70 - 72 m Preussag KK80	1.3		201	13.55	215	201.450	32.0626	18.59193
3218BA117 G33923	Exploration	0 - 102 m x 165 mm MR	0 - 100 m x 90 mm PVC	54 - 60 m Preussag KK80	1.3		261	14.85	195	180.150	32.11261	18.59569
G33924	Exploration	0 - 112 m x 165 mm MR	0 - 100 m x 90 mm PVC	44 - 50 m Preussag KK80	0.2		50	11.48	110	98.520	32.09308	18.04422
G33925A	Exploration	0 - 108 m x 165 mm MR	0 - 108 m x 90 mm PVC	78 - 86 m Preussag KK80	4.0		54	13.8	110	96.200	32.10856	18.45073
G33925B	Test	0 - 91 m x 300 mm MR	0 - 91 m x 200 mm PVC	75 - 85 m Soloflow (0.5mm)	7.0	T = 40 m2/day s = 4.24E-05	54	13.68	110	96.320	32.10850	18.45076
G33926	Exploration	0 - 143 m x 165 mm MR	0 - 135 m x 90 mm PVC	125 - 135 m Preussag KK80	0.26		106	14.86	160	145.140	32.06750	18.49333
G33927	Exploration	0 - 84 m x 165 mm MR	None		<0.1			32.36	150	117.640	32.023250	18.43583
G33928	Exploration	0 - 107 m x 165 mm MR	0 - 106 m x 90 mm PVC	79 - 85 m Preussag KK80	1.0		65	16.56	145	128.440	32.06805	18.44055
G33929	Exploration	0 - 78 m x 165 mm MR	0 - 78 m x 90 mm PVC	44 - 50 m Preussag KK80	0.22		557	26.33	40	13.670	32.03611	18.31527
G33930	Exploration	0 - 28 m x 165 mm MR	None					dry	20		32.0825	18.32973
G33931	Exploration	0 - 58 m x 165 mm MR	0 - 57 m x 90 mm PVC	21 - 27 m Preussag KK80	0.1			16.33	18	1.670	32.05277	18.31388

APPENDIX E

AQUIFER TEST RESULTS

GRAAFWATER WELL-FIELD : AQUIFER TEST RESULTS

BOREHOLE PUMPED	TYPE OF TEST	DATE EXECUTED	PUMPING RATE(S)	BOREHOLE ANALYSED	METHOD OF ANALYSIS	AQUIFER PARAMETER T	k	S	COMMENTS
G33732A	Step	14/09/89	0.5,1.0,1.1	None					Borehole pumped dry at 1,1 l/s.
G33733A	Step	04/10/89	0.4,0.5,0.6	None					Borehole pumped dry at 0,6 l/s,
G33734A	Step	28/08/89	2.3,3.4,4.0,4.3	G33734A	Bierschenk-Wilson Logan	18.65	0.5		Points not on a straight line. Analysis of first step.
G33734A	Constant rate	29/08/89	4.5	None					Borehole sucking air after 350 mins.
G33734A	Constant rate	30/08/89	3.3	G33734	Jacob Jacob Boulton Walton	60.68 21.94 18.00 13.80		0.00116 0.00116 0.085 0.186	Calculated from first 12 mins data. Calculated from last data. S = Sa(early time co-eff of storage) L = 75m and c = 407 days.
G33734A	Recovery	01/09/89	-	G33734 G33734A	Jacob Jacob	19.33 18.37			
G33734A	Step	12/09/89	2.0,3.1,4.4,5.0	G33734A	Bierschenk-Wilson Logan	19.27			Points not on a straight line.
G33745A	Step	16/11/89	0.3,0.5,0.6,0.8	G33745A	Bierschenk-Wilson Logan	6.76			Eff. = 90%, 83%, 80% and 75%.
G33745A	Step	05/12/89	0.2,0.5,1.0	G33475A	Bierschenk-Wilson Logan	6.75	0.19		Only three steps undertaken - pump too small.

BOREHOLE PUMPED	TYPE OF TEST	DATE EXECUTED	PUMPING RATE(S)	BOREHOLE ANALYSED	METHOD OF ANALYSIS	AQUIFER PARAMETER T	k	S	COMMENTS
G33746B	Step	07/02/90	2.5,3.7,5.3,7.8	G33746B	Bierschenk-Wilson				Eff. = 91%, 87%, 82%, and 75%.
					Logan	79.06			
G33746B	Step	20/02/90	6.0,8.4,16,2	G33746B	Bierschenk-Wilson				Eff. = 80%, 74%, and 61%.
					Logan	78.99			
G33746B	Constant rate	21/02/90	15.5	G33746C	Walton	67.00		0.067	L = 32.8 m and c = 16.06 days. (Both values too low)
				G33746D	Hantush I	116.79	2.65	0.033	
				G33746D	Walton	135.80		0.035	c = 3016624 days.
G33746B	Recovery	23/02/90	-	G33746B	Jacob	127.20	2.89		
				G33746C	Jacob	169.04	3.84		
				G33746D	Jacob	179.00	4.08		
G33747B	Step	10/04/90	1.3,4.5,7.8,11.1		Logan	53.58			Borehole developing with time during pumping.
G33747B	Constant rate	23/04/90	10.00	747+747A	Hantush-Jacob	45.00			c = 7194 days (19 years) Observation boreholes nearly fit a Theis curve ie L and c are very high and the aquifer is nearly confined. (L ≈ 4400 days)
				747+747A	Walton				
				G33747B	Jacob	137.50		0.0002	
G33747B	Recovery	29/04/90	-	G33747	Jacob	166.00			
				G33747A	Jacob	166.00			

BOREHOLE PUMPED	TYPE OF TEST	DATE EXECUTED	PUMPING RATE(S)	BOREHOLE ANALYSED	METHOD OF ANALYSIS	AQUIFER PARAMETE			COMMENTS
						T	k	S	
G339258	Step	17/04/91	3.2,3.7,7.8,10.9	G339258	Bierschenk-Wilson Logan	42.6			Eff. = 92%, 91%, 83%, and 78%.
G339258	Constant Rate	15/05/91	6.0	G339258A	Jacob	40.4		4.2E-05	
G339258	Recovery	18/05/91	-	G339258A	Jacob	59.0			
G33921A	Yield	21/05/91	5.2						Maximum yield of 5.2 l/sec.
G33921A	Constant rate	22/05/91	2.4	G33921	Jacob	26.1		1.6E-3	
G33921A	Recovery	24/05/91		G33921	Jacob	26.0			

APPENDIX F

DETAILED CHEMICAL ANALYSES

Borehole	G33734A	G33746B	G33747A	SABS
Date sampled	(01/09/89)	(22/05/90)	(28/05/90)	Recommended limits
Major element concentrations (mg/l)				
Na	63	52	60	100
Ca	4.7	10.0	13.0	-
Mg	10.2	6.0	7.0	70
N	<0.05	<0.05	<0.05	6
SO4	28	12	16	200
Cl	108	96	121	250
CaCO3	10	26	13	20
Hardness	54	52	60	20
T.D.S	301	192	236	448
pH	6.6	6.5	6.1	6.0-9.0
E.C.	47	39	47	70

Borehole	Date sampled	Trace element concentrations (mg/l)					
		Mn	Fe	Pb	Cu	Zn	Al
G33733A	(21/03/90)	0.06	5.57	0.14	0.11	0.44	0.82
G33734A	(21/03/90)	0.03	2.58	0.28	0.06	0.33	0.48
G33746B	(22/05/90)	<0.05	1.5	<0.25	<0.03	<0.02	<0.5
G33747A	(28/05/90)	<0.05	1.8	<0.25	<0.03	<0.02	<0.5
G33720	(01/06/90)	0.50	80.87	0.12	0.03	1.40	1.32
G33724	(01/06/90)	0.29	26.16	0.03	<0.01	0.39	0.39
G33725	(01/06/90)	0.43	13.19	0.05	0.02	0.54	0.79
G33728	(01/06/90)	0.30	5.62	0.03	0.02	0.12	0.16
G33731	(01/06/90)	0.56	12.14	0.08	0.03	0.38	5.53
G33733A	(01/06/90)	0.03	6.69	0.02	0.02	0.14	1.20
G33734A	(01/06/90)	0.01	3.89	0.02	0.01	0.02	0.71
G33735	(01/06/90)	0.04	4.11	0.07	0.02	0.21	0.20
G33746B	(01/06/90)	0.02	1.76	0.02	0.01	0.03	0.43
G33745A	(01/06/90)	0.03	4.59	0.02	0.03	0.05	2.04
G33747A	(01/06/90)	0.03	1.97	0.02	0.01	<0.01	0.06
SABS Recommended Limits		0.05	0.1	0.05	0.5	1.0	0.5 *

* No SABS limits for Aluminium - obtained from Kempster et al (1982)

BYLAE • ANNEXURE

GRAAFWATER ONDERGRONDSE STAATSWATERBEHEERGEBIED, AFDELING CLANWILLIAM
GRAAFWATER SUBTERRANEAN GOVERNMENT WATER CONTROL AREA, DIVISION CLANWILLIAM

Lys van toekennings van ondergrondse water kragtens artikel 32B (1) (b) van die Waterwet, 1956, aan stukke grond soos geregistreer in die Kantoor van die Registrateur van Aktes, op die datum van insluiting in bogenoemde Ondergrondse Staatswaterbeheergebied.

Schedule of allocations of subterranean water in terms of section 32B (1) (b) of the Water Act, 1956, to pieces of land as registered in the Office of the Registrar of Deeds on the date of inclusion in the above-mentioned Subterranean Government Water Control Area.

Item No.	Beskrywing van stuk grond Description of piece of land	Grootte Extent (ha)	Naam en geboortedatum van geregistreerde eienaar Name and date of birth of registered owner	Aandeel Share	Bestaande onttrekking (m³/p/j) Existing abstraction (m³/p/a) Huishoudelike gebruik en veesuiping Domestic use and watering of stock	Bestaande onttrekking (m³/p/j) Existing abstraction (m³/p/a) Besproeiing Irrigation	Totale jaarlikse watertoekenning vir huishoudelike gebruik, veesuiping en besproeiing Total annual water allocation for domestic use, watering of stock and irrigation (m³)
	COMPAGNIES DRIFT 93						
1	Ged. 1/Ptn 1	1421,8431	Bester, Andries Nicolaas Everhardus; 28-11-29 Bester, Jacobus Andreas; 25-02-03	3/4 1/4	6 640	Nul/Nil	68 100
2	Rest. Ged. 3/Rem. Ptn 3	856,8175	De Waal, Arend Johan Frederik; 42-11-29	Vol/Full	5 380	Nul/Nil	38 400
3	Ged. 5/Ptn 5	701,0715	De Milander, Jacobus Petrus; 39-01-13	Vol/Full	4 660	Nul/Nil	83 000
4	Ged. 6/Ptn 6	343,0097	Visser, Dirk Jacobus; 18-04-04 Visser, Magdalena Francina; 24-09-12	1/2 1/2	4 260	Nul/Nil	19 300
	COMPAGNIES DRIFT 94						
5	Rest. Ged./Rem. Ext	50,45	Slabber, Martinus Jacobus; 13-10-06 Engelbrecht, Johannes Arnoldus Slabber, Hermias Cornelius; 11-07-24	1/4 1/2 1/4	Nul/Nil	Nul/Nil	18 000
6	Ged. 2/Ptn 2	467,2996	Engelbrecht, Johan de Villiers; 46-05-14	Vol/Full	860	Nul/Nil	73 600
7	Ged. 3/Ptn 3	234,9553	De Milander, Jacobus Petrus; 39-01-13	Vol/Full	400	Nul/Nil	38 400
	KOMPAGNIESDRIFT 95						
8	Rest. Ged./Rem. Ext	595,6104	De Milander, Jacobus Petrus; 39-01-13	Vol/Full	990	Nul/Nil	82 800
9	Ged. 1/Ptn 1	607,8469	De Milander, Jacobus Petrus; 39-01-13	Vol/Full	4 490	Nul/Nil	92 000
	KOOKFONTEIN 87						
10	Rest. Ged./Rem Ext	687,0429	Engelbrecht, Johan de Villiers; 46-05-14	Vol/Full	1 320	Nul/Nil	79 000
11	Ged. 2/Ptn 2	346,4829	Engelbrecht, Johan Frederik; 55-01-28	Vol/Full	1 760	Nul/Nil	68 500
	KOOKFONTEIN 88						
12	Rest. Ged. 1/Rem. Ptn 1	837,8025	Engelbrecht, Johan de Villiers; 46-05-14	Vol/Full	5 080	Nul/Nil	98 100
13	Ged. 3/Ptn 3	1387,5	Engelbrecht, Josias Andreas; 23-05-25 Engelbrecht, Ernst Hendrik; 27-12-23 Engelbrecht, Christiaan Lodewyk; 34-03-01	1/4 1/2 1/4	8 670	Nul/Nil	106 700
14	Ged. 4/Ptn 4	1438,1172	Engelbrecht, Johan Frederik; 55-01-28	Vol/Full	6 250	Nul/Nil	43 300
15	Ged. 8/Ptn 8	1173,81	Engelbrecht, Hester Elizabeth Van Zyl; 14-10-04	Vol/Full	5 810	Nul/Nil	80 900
16	Ged. 14/Ptn 14	883,1236	Engelbrecht, Sybrand Abraham; 36-09-03	Vol/Full	3 500		24 000
17	Ged. 15/Ptn 15	29,2901	Engelbrecht, Sybrand Abraham; 36-09-03	Vol/Full	3 000	40 000	43,000

Item No.	Beskrywing van stuk grond / Description of piece of land	Grootte / Extent (ha)	Naam en geboortedatum van geregistreerde eienaar / Name and date of birth of registered owner	Aandeel / Share	Bestaande onttrekking ($m^3/p/j$) / Existing abstraction ($m^3/p/a$): Huishoudelike gebruik en veesuiping / Domestic use and watering of stock	Bestaande onttrekking: Besproeiing / Irrigation	Totale jaarlikse watertoekenning vir huishoudelike gebruik, veesuiping en besproeiing / Total annual water allocation for domestic use, watering of stock and irrigation (m^3)
	LAMBERTSBAAI MUNISIPALE GEBIED/LAMBERTS BAY MUNICIPAL AREA						
18	Erf 174/Erf 174	2926,8035	RSA	Vol/Full	7 700	Nul/Nil	144 700
	RIETFONTEIN 96						
19	Ged. 1/Ptn 1	671,2356	Visser, Dirk Jacobus; 18-04-04 Visser, Magdalena Francina; 24-09-12	1/2 1/2	4 990	Nul/Nil	20 000
20	Ged. 2/Ptn 2	314,3472	Eygelaar, Theunis Johannes; 53-04-30	Vol/Full	4 190	Nul/Nil	19 200
21	Ged. 11/Ptn 11	1137,1298	Burger, Frederik Johannes; 51-06-24 Coetzee, Gerhardus Johannes; 27-10-03 Burger, Johan Frederick; 60-06-02	1/4 1/2 1/4	6 270	Nul/Nil	21 300
	RODEKLIPHEUWEL 84						
22	Ged. 1/Ptn 1	385,5136	Eygelaar, Theunis Johannes; 53-04-30	Vol/Full	4 360	Nul/Nil	44 400
23	Ged. 2/Ptn 2	896,3965	Visser, Arend Egbertus; 19-11-14 Visser, Jacobus Hendrik; 26-04-03	1/2 1/2	Nul/Nil	Nul/Nil	94 000
24	Rest. Ged. 3/Rem. Ptn 3	233,4636	Burger, Frederik Johannes; 51-06-24 Coetzee, Gerhardus Johannes; 27-10-03 Burger, Johan Frederick; 60-06-02	1/4 1/2 1/4	590	Nul/Nil	20 400
25	Rest. Ged. 4/Rem. Ptn 4	175,2264	Visser, Dirk Jacobus; 18-04-04 Visser, Magdalena Francina; 24-09-12	1/2 1/2	3 900	Nul/Nil	30 000
26	Rest. Ged. 5/Rem. Ptn 5	731,5993	Van der Westhuizen, Francois Gysbert Johannes; 51-06-29	Vol/Full	6 910	Nul/Nil	40 000
27	Ged. 7/Ptn 7	591,0671	Visser, Arend Egbertus; 19-11-14 Visser, Jacobus Hendrik; 26-04-03	1/2 1/2	4 400	Nul/Nil	52 500
28	Ged. 8/Ptn 8	595,8236	Van der Westhuizen, Francois Gysbert Johannes; 51-06-29	Vol/Full	1 760	Nul/Nil	63 800
29	Ged. 9/Ptn 9	118,6823	Burger, Frederik Johannes Petrus; 46-11-06 Burger, Anna Elizabeth Christina; 42-06-11 Burger, Dirk Jacobus Johan; 49-03-01	1/4 1/2 1/4	390	Nul/Nil	18 000
30	Ged. 10/Ptn 10	308,7699	Burger, Frederik Johannes; 51-06-24 Coetzee, Gerhardus Johannes; 27-10-03 Burger, Johan Frederick; 60-06-02	1/4 1/2 1/4	730	Nul/Nil	35 400
31	Rest. Ged. 14/Rem. Ptn 14	826,6601	J. C. de Jongh Trust	Vol/Full	1 350	Nul/Nil	19 000
32	Rest. Ged. 19/Rem. Ptn 19	804,1437	Koegelenberg, Johannes Josias Albertus; 42-01-24	Vol/Full	2 900	Nul/Nil	58 000
	SUURFONTEIN 527						
33	Die Plaas/The Farm	2268,7250	Engelbrecht, Johannes Arnoldus; 27-12-06 Engelbrecht, Josias Andreas; 33-08-28	1/2 1/2	9 220	20 000	248 300
	THE FLATS 83						
34	Rest. Ged./RemExt	463,91	Walters, Zacharias Andries; 29-08-13 Walters, Hendrik Cornelius; 27-08-31	1/2 1/2	4 500	Nul/Nil	50 500
35	Ged. 1/Ptn 1	495,7950	Koegelenberg, Johannes Josias Albertus; 42-01-24	Vol/Full	1 780	Nul/Nil	69 600

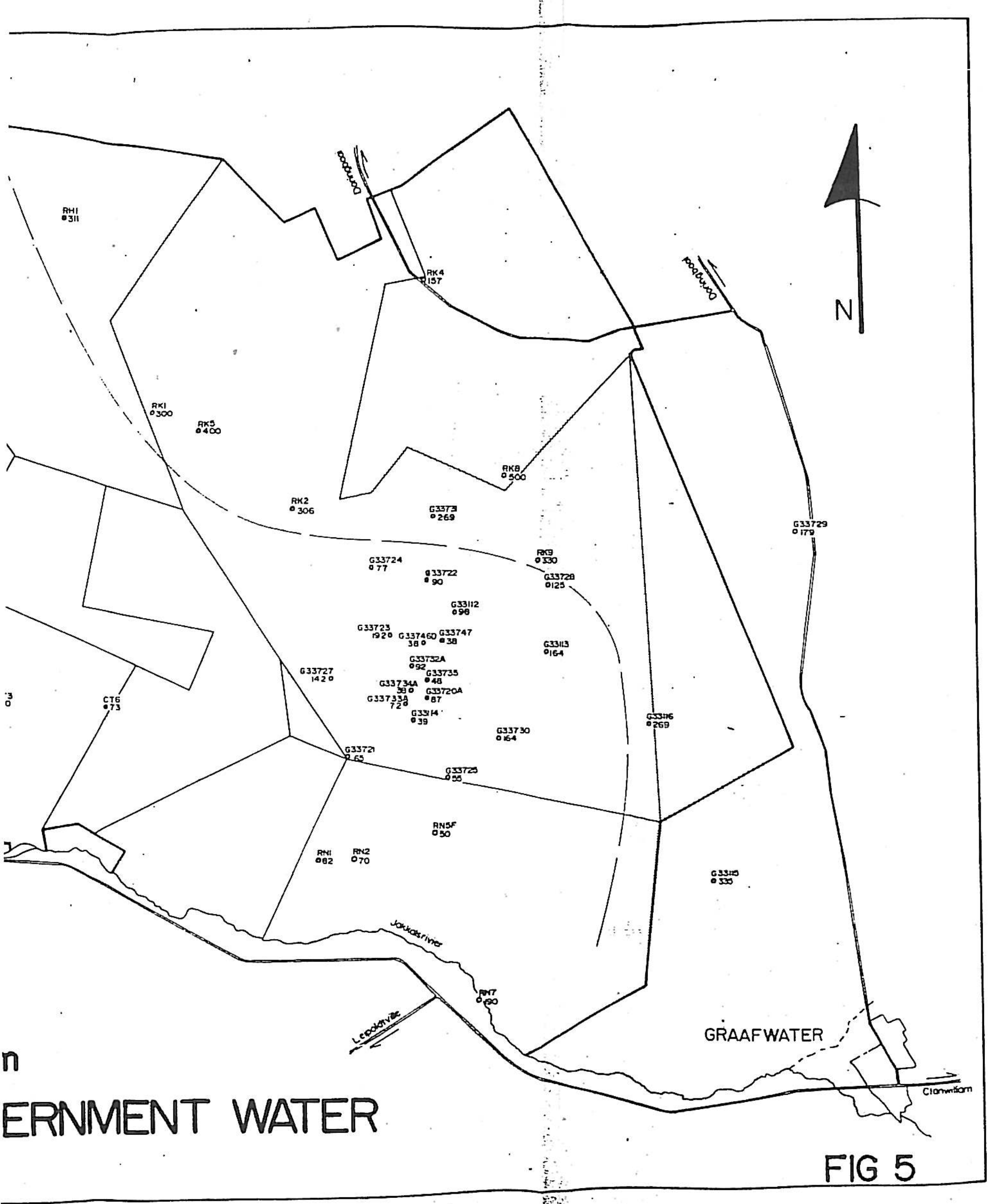


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FIG 5

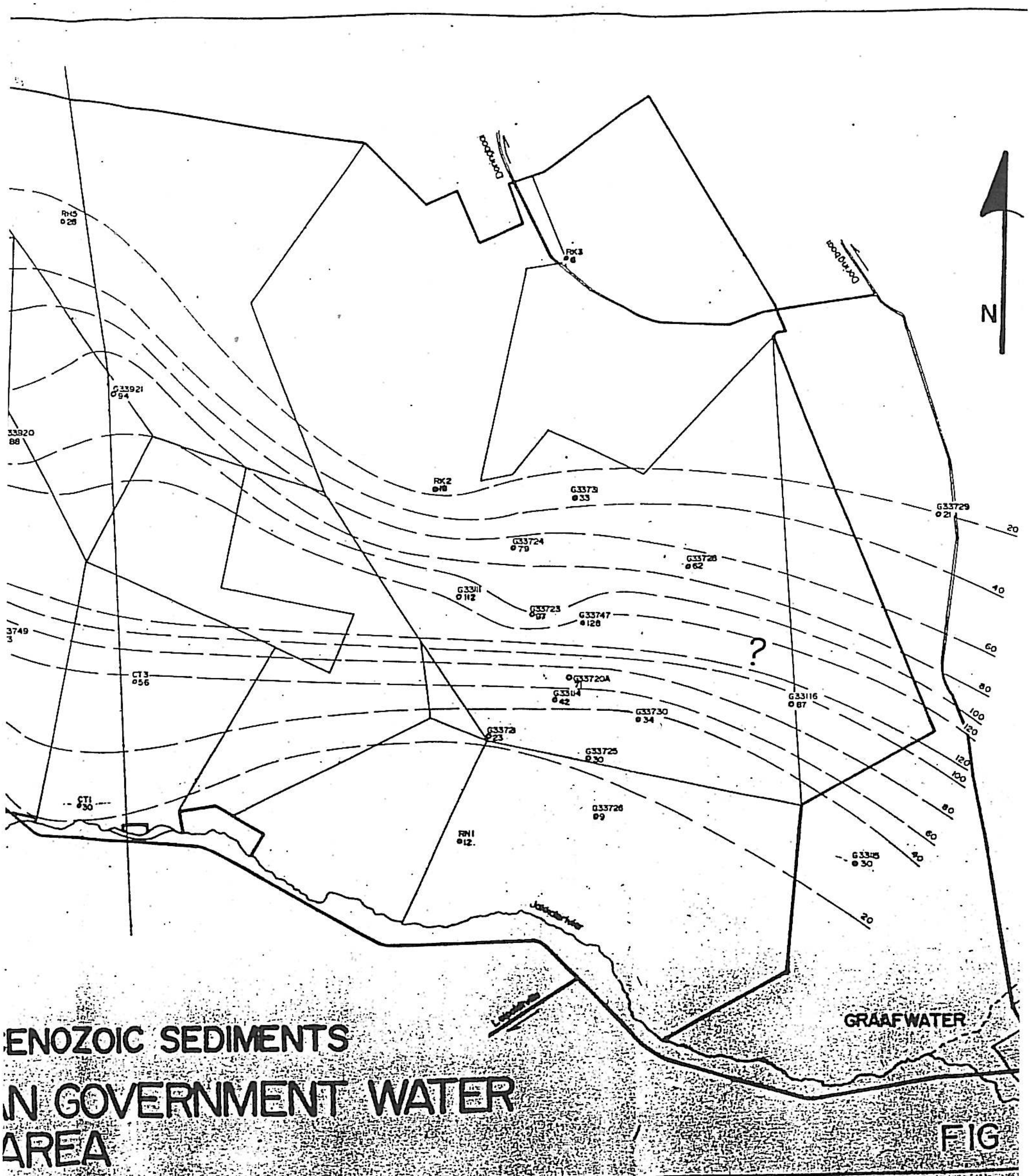

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FIG

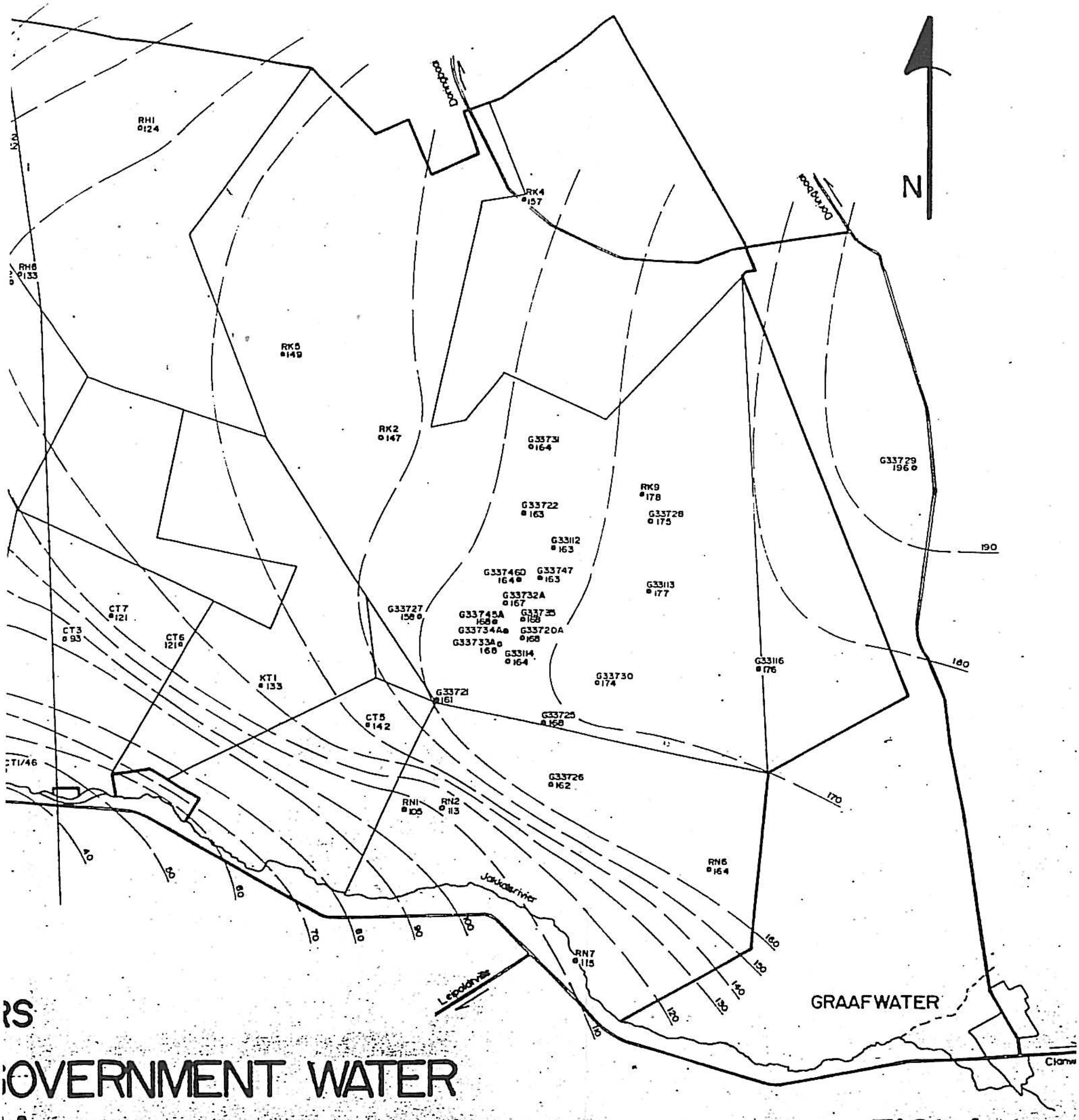

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FIG 4.