Technical Report GH 3837

DE AAR - DEVELOPMENT AND MANAGEMENT OF AVAILABLE GROUNDWATER RESOURCES

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ABSTRACT

The Department of Water Affairs and Forestry was requested to aid the De Aar Municipality in developing and implementing a groundwater management plan to ensure the optimal utilisation of their groundwater resources. The Department proposed a three phase programme of action. This report deals with the initial phase, providing a foundation upon which future work could be based.

De Aar's existing production boreholes are not capable of meeting the town's short-term water requirements of 2.4 - 2.9 x 10^6 m^3 per annum. To make up for this shortfall, it is recommended that the South-Eastern and Burgerville areas are fully developed.

A development scenario is proposed which could meet De Aar's water requirements until the year 2010, both in terms of the water quality and quantity, based on a simple optimisation study.

Monitoring requirements are also discussed. This information is crucial to the overall success of the proposed water resources management plan.

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1 INTRODUCTION

The Department of Water Affairs and Forestry (DWAF) was requested to aid the De Aar Municipality in developing and implementing a groundwater management plan to ensure the optimal utilisation of their groundwater resources. In 1993, the Directorate : Geohydrology proposed a three phased approach to the implementation of a management plan, namely:

Phase 1: Basic Programme - Existing Wellfields Only

This phase will be designed to rapidly implement a practical and simple management plan which will give the Municipality some degree of control over their water resources. A short report will be produced giving guidelines and recommendations. A computer database (Munibase or a commercial spreadsheet) will be installed on the Municipality's PC, which will allow for the visual analysis of trends in waterlevels, abstraction, rainfall and water quality in an individual borehole or an entire wellfields.

Phase 2: Basic Programme - All Wellfields

A summary report will be produced as above, but will consider unused wellfields, as well as the possibilities for further groundwater development within the respective groundwater units.

Phase 3: A management Programme encompassing Phase 1 and 2, incorporating optimisation models (long term)

The information gathered during phases 1 and 2 will be evaluated and used to upgrade the existing management plan, using groundwater modelling and optimisation methods. This work should be conducted by a suitable consultant, approximately one year after the implementation of Phase 1.

This report deals with phases 1 and 2 above, but only considers existing municipal production boreholes and unused boreholes of production status. The report draws it's information from a number of departmental documents and does not include any major reworking of the original data. The report draws heavily upon information from reports GH3710 and GH3775 by Vegter (1990 and 1992).

2 MUNICIPAL WATER REQUIREMENTS

During 1990, De Aar's water consumption was 2.44 x 10^6 m^3 per annum. Stewart, Sviridov & Oliver (1990) estimated that the town's consumption would rise to 3.89 x 10^6 m^3 by the year 2010 (Table 1), which is somewhat lower than the estimate of 4.93 x 10^6 m^3 by Ninham Shand (1987). These figures include industry, Spoornet and the SADF's water requirements.

TABLE 1: DE AAR - FUTURE WATER DEMAND

YEAR	ESTIMATED WATER CONSUMPTION (x10^6 m3)
1995	2.900
1997	3.000
1998	3.040
2002	3.280
2005	3.500
2010	3.890

3 GROUNDWATER RESOURCES

After 1927, De Aar obtained its water mainly from springs and boreholes in the so-called "Burgerville-Zewefontein area", hereafter referred to as the **Burgerville** area. At this time, the Cape Government Railways obtained water from springs and wells on the farm **Caroluspoort** (Figure 1).

During 1971-75, the Geological Survey conducted an extensive groundwater exploration program to locate additional water supplies for De Aar. Three new potential groundwater resources were located, the so-called "**South-Eastern, South-Western** and **Northern areas**". In September 1978, eight boreholes were commissioned in the South-Western scheme, with an additional four boreholes being added in February 1978. Production boreholes on the farm **Brandfontein** were not connected to the scheme (Figure 1).

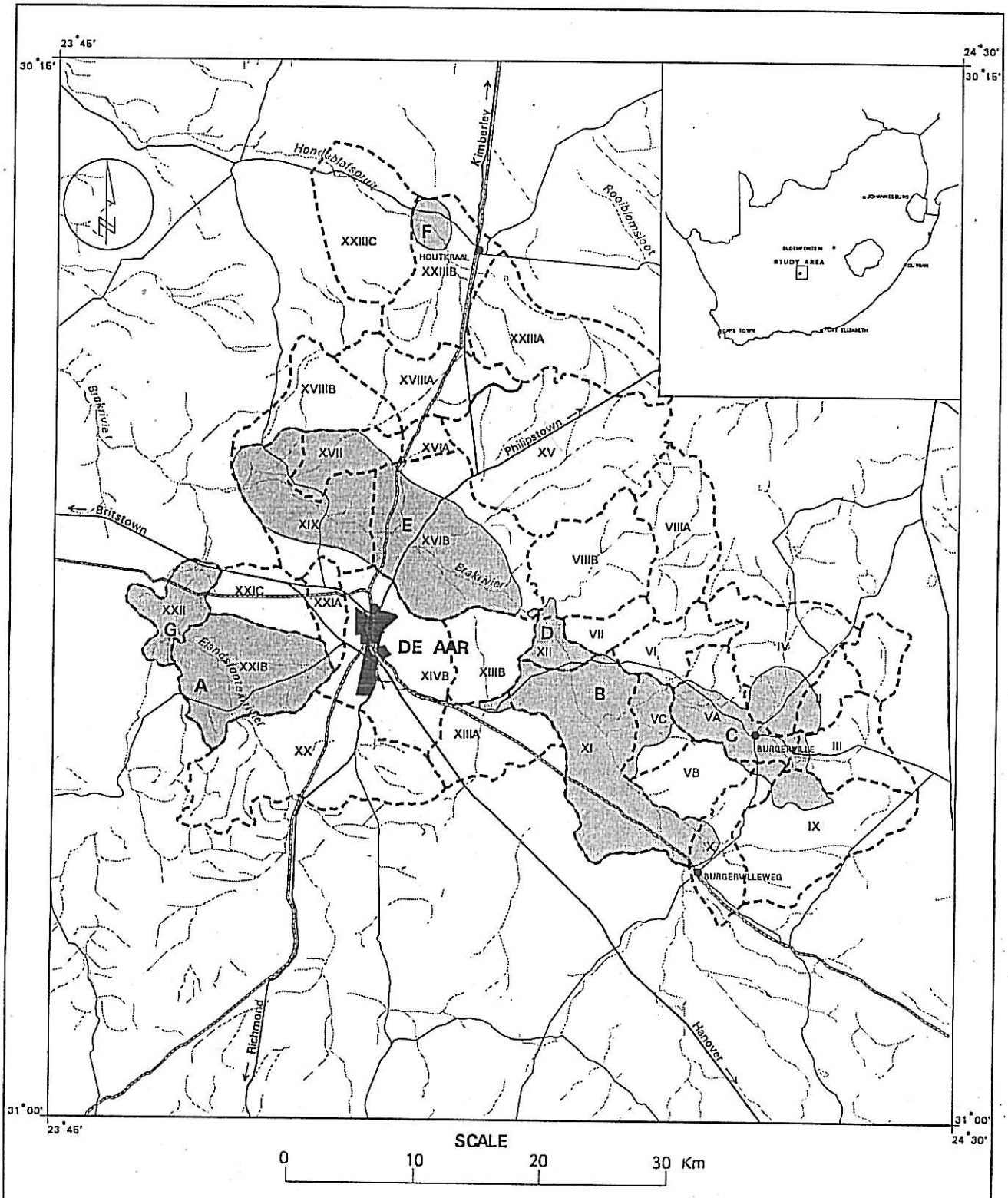

FIGURE 1 : *DE AAR - LOCATION OF GROUNDWATER RESOURCES*

In 1981, a single borehole was developed in the South-Eastern area, whereafter in 1985 a further six production boreholes were commissioned. The South-Eastern area was not developed to the extent that had been envisaged by the 1971-75 groundwater investigations (Smit, 1975).

In order to meet the expected rise in consumption for the next decade or two, the Department embarked on further groundwater investigations over the period 1987 to 1989. This comprised exploratory drilling, test-pumping and establishment of additional production boreholes in the South-Eastern and Burgerville areas, the re-drilling and/or test-pumping of the 1971-75 proposed production boreholes in the Northern and Brandfontein areas, and the investigation of farm Hennopskraal in the so-called "**Far Northern area**" (Van Wyk, 1989, Woodford, 1989, 1990a, 1990b).

Vegter (1990) subdivided these geographical areas into groundwater units (Figure 1) and estimated the exploitation potential of each unit (Table 2). This report deals only with boreholes that are either presently in use or have been positively identified as possible production boreholes within each of the **geographical areas**. For simplicity, the boreholes are discussed according to the geographical area within which they occur and the area names used by the Municipality are adopted.

Details on the possibility of obtaining additional groundwater resources (Table 2 - Undeveloped Potential), within the groundwater units are discussed by Vegter (1990).

3.1 DEVELOPED GROUNDWATER RESOURCES

De Aar's existing production boreholes and fountains are capable of delivering 2.1-2.5 million m^3 per annum (Haasbroek, 1991). The groundwater is abstracted from four main geographical areas, namely the Burgerville, Caroluspoort, South Eastern and South Western Areas.

TABLE 2 : ESTIMATES OF SUPPLIES AVAILABLE FOR URBAN USE FROM DIFFERENT GROUNDWATER UNITS DE AAR
(After Vegter, 1992)

GROUND WATER UNIT	AREA Km^2	STEADY YIELD x 10^6 m^3		FARM USE	URBAN USE	UNDEVELOPED POTENTIAL
		MIN[A]	MAX[B]	x10^6m^3	x10^6m^3	x 10^6 m^3
I	21.8	0.157	0.187	0.002	-	0.185
II	18.0	0.130	0.155	0.002	-	0.153
III	46.4	0.334	0.399	0.095+	0.150	0.154
IV	63.3	0.519	0.601	0.056	0.340	0.204
VA	48.9	0.352	0.421	0.005	0.350	0.069
VB	41.0	0.282	-	-	-	-
VI	39.0	0.282	0.337	0.044	-	0.293
VII	17.7	0.127	0.152	0.002	-	0.150
VIIIB	72.3	0.593	0.687	0.007	0.280	0.400
IX	92.1	0.663	0.792	0.079+	0.050	0.663
X	37.7	0.271	0.324	0.004	0.150	0.175
XI	122.5	1.005	1.164	0.362+	0.600	0.202
XII	14.8	0.121	0.141	0.001	0.120	0.000
XIIIB	47.2	0.340	0.406	0.005	0.060	0.341
XIVA	39.9	0.287	0.343	0.004	-	0.339
XIVB	117.6	-	-	-	-	-
XV	151.0	-	-	-	-	-
XVIA	13.1	-	-	-	-	-
XVIB	123.7	1.014	1.175	0.362	0.280	0.538
XVII	29.6	0.213	0.255	0.153	0.060	
XVIIIA	56.3	-	-	-	-	0.000
XVIIIB	32.9	0.237	0.283	0.083	0.060	0.145
XIX	78.3	0.642	0.744	0.048	0.530	0.171
XX	126.9	1.041	1.206	0.013	0.300	0.893
XXIA	22.2	-	-	-	-	-
XXIB	81.7	0.670	0.776	0.133	0.440	0.213
XXIC	40.2	-	-	-	-	-
XXII	30.3	0.248	0.288	0.133	0.120	0.000
XXIIIA	±80.0	-	-	-	-	-
XXIIIB	75.0	0.615	0.712	0.238+	0.370	0.101
XXIIIC	±60.0	-	-	-	-	-

NOTE: A - Recharge rate based on rainfall >= 15mm
B - Recharge rate based on rainfall >= 10mm assuming zero effluent seepage/evaporation.

Explain

3.1.1 SOUTH WESTERN AREA

Smit (1975) recommended 11 production boreholes on the farms Rhenosterpoort, Vaalbank and Zwartkopjes. At present 12 production boreholes are in use (Table 3, Figure 2).

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Boreholes G27707, G27704, G27715G, G23204D, G27702G and G27703 should be pumped "out-of-phase" from the remaining production boreholes.

The average total dissolved solids (TDS) of the water abstracted from the South Western area, according to the 1993/94 abstraction rates, is in the order of 1370 mg/l. If the boreholes were pumped according to the schedule recommended in Table 3 the TDS would be approximately 1300 mg/l (Appendix A).

3.1.2 SOUTH EASTERN AREA

Smit (1975) recommended 12 production boreholes, but for various reasons only 7 of these boreholes were eventually commissioned in 1985 (Figure 2). These boreholes are listed in Table 4.

The bulk TDS of the water abstracted from the production boreholes, according to the pumping schedule recommended in Table 4, will be in the order of 2380 mg/l. This water does not meet the water quality standards (Appendix A).

3.1.3 BURGERVILLE AREA

During the early 1900's, De Aar was supplied mainly from fountains in the Burgerville area. Later, boreholes were drilled in the area to augment supplies as the town's water demand rose. The private production boreholes on the farm Kaffirsdam have been included under this section.

The boreholes in production are listed in Table 5 and their location indicated in Figure 2. Boreholes CF39 (Municipal No. 5) and CF31 (Municipal No. 1) are replaced by G39024 and G39025, respectively (see Section 3.2.3). Production borehole CF38 (Municipal No. 4) has been scrapped.

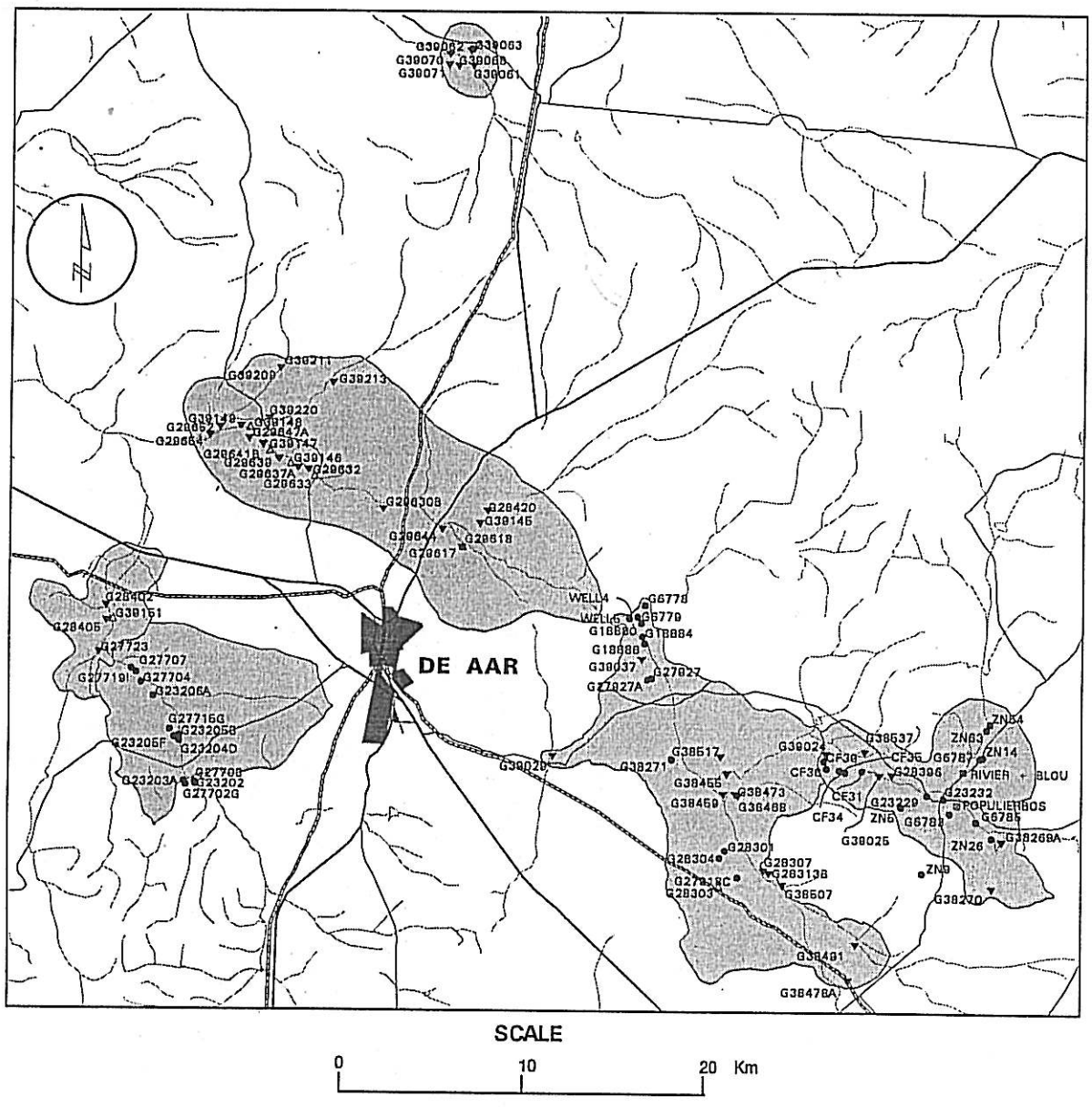


FIGURE 2 :*DE AAR - EXISTING AND RECOMMENDED PRODUCTION BOREHOLES*

TABLE 3 : SOUTH-WESTERN AREA – DEVELOPED PRODUCTION BOREHOLE AND ABSTRACTION SPECIFICATIONS

BOREHOLE NUMBER	GROUND-WATER UNIT	DEPTH (m)	PUMP INTAKE (m)	PUMP RATE (l/s)	MAXIMUM MONTHLY ABSTRACTION (m^3)	MAXIMUM * PERMISSIBLE DRAWDOWN (m) BELOW COLLAR
RHENOSTER-POORT						
G27707 (1)	XXI B	29.0	23.0	6.0	5 000	8.0
G27719I (2)	XXI B	42.4	27.5	7.0	5 800	10.0
G27704 (3)	XXI B	45.7	18.0	8.0	5 800	8.5
G23206A (4)	XXI B	22.8	15.0	3.5	3 400	8.0
VAALBANK						
G27715G (5)	XXI B	A15.5	16.0	3.5	3 400	10.0
G23205B (6)	XXI B	21.6	15.0	5.0	5 000	7.5
G23205F (7)	XXI B	22.8	18.0	4.0	4 500	10.0
G23204D (8)	XXI B	22.9	16.0	7.0	3 400	9.0
ZWARTKOPJES						
G23203A (9)	XX	22.8	16.0	4.5	5 000	10.0
G27702G (10)	XX	26.4	16.0	4.5	5 000	9.0
G27703 (11)	XX	22.8	12.0	6.0	7 000	8.0
G23202 (12)	XX	19.8	12.0	4.5	5 000	8.0
			TOTAL		700 000 m^3/year	

(Adapted from Vegter, 1990)

NOTES:

* – Waterlevel prior to switch-on of pump (i.e. after a period of at least 8 hours rest).

A – Old pump cylinder stuck in borehole. Original depth = 24.4m.

G23206A – Production borehole in use, but not recommended by Smit in 1975.

TABLE 4 : SOUTH-EASTERN AREA - DEVELOPED PRODUCTION BOREHOLE AND ABSTRACTION SPECIFICATIONS

BOREHOLE NUMBER	GROUND-WATER UNIT	DEPTH (m)	PUMP INTAKE (m)	PUMP RATE (l/s)	MAXIMUM MONTHLY ABSTRACTION (m^3)	MAXIMUM * PERMISSIBLE DRAWDOWN (m) BELOW COLLAR
WAG - N - BIETJIE						
G27927 (8)	XII	22.1	19.0	6.0	3 000	7.0
G27927A (9)	XII	19.2	16.0	6.0	4 000	7.0
RIET	XI					
G38271 (7)	XI	36.0	25.0	12.0	10 000	13.0
RIETFONTEIN						
G27918C (3)	XI	24.4	22.0	15.0	13 000	11.0
G28303 (4)	XI	21.3	16.0	5.0	-	10.0
G28304 (5)	XI	90.0	30.0	6.0	3 000	10.0
G28301 (6)	XI	24.4	16.0	6.0	3 000	8.0
				TOTAL	430 000	m^3/year

(Adapted from Vegter, 1990)

NOTE:

* - Waterlevel prior to switch-on of pump (i.e. after a period of at least 8 hours rest).

- G28303 should only be used as a standby for G27918C. Abstraction from G28303 should not exceed 3500 m^3/month.
- G38271 replaces G27917E

In 1987, the pump operator reported that borehole G6787 was only 12.4m deep and that the pump inlet was set at 9.6m, while the rest-waterlevel was 8.16m. The original depth of the borehole was 26m and water was intercepted at 12-14m and 24m. Obviously, under these conditions the borehole will appear to "dry-up" during a drought. This borehole should be cleaned and properly cased to 26m. This case raises the question as to the condition of the other older boreholes in the area. The physical condition of production boreholes has to be checked and the boreholes maintained on a regularly basis.

Borehole G28396 (Figure 2) was used by the SADF for domestic and stock water purposes, this borehole should be cleaned and re-tested for possible inclusion into the municipal supply scheme.

The yield of the "Populierbos" spring (Figure 2) varies widely depending on variations in the rainfall regime. In 1988, following heavy rains and filling of the dam upstream from the fountain, the flow was estimated at approximately 25 l/s (EC 47 mS/m). This rate of flow is maintained whilst there is water in the dam and thereafter it decreases rapidly. The flow was estimated to be approximately 3-5 l/s (EC 77 mS/m), during the drought of 1987. The average volume of water supplied by the spring is approximately 94 000 m^3 per annum, assuming a continuous rate of flow of 3 l/s.

In 1987 and 1989, the combined yield of the "Rivier" and "Blou" springs (Figure 2) were estimated at 1.6 (EC 76 mS/m) and 3 l/s (EC 78 mS/m), respectively. This would suggest that the average volume available from these springs is in the order of 145 000 m^3 per annum.

If the abstraction rates recommended in Table 5 are adhered to, then the bulk TDS of the borehole water will be in the order of 665 mg/l. The average TDS drops to 590 mg/l if the fountain water is also considered (Appendix A).

3.1.4 CAROLUSPOORT AREA

The SA Railways obtained water for the locomotives from Caroluspoort from the early 1900's up until 1988, whereafter the property was purchased by the De Aar municipality. To date the Municipality have not incorporated all the original production boreholes into the supply scheme. Table 6 shows the recommended production boreholes (Figure 2).

TABLE 5 : BURGERVILLE AREA – DEVELOPED PRODUCTION BOREHOLE AND ABSTRACTION SPECIFICATIONS

BOREHOLE NUMBER	GROUND-WATER UNIT	DEPTH (m)	PUMP INTAKE (m)	PUMP RATE (l/s)	MAXIMUM MONTHLY ABSTRACTION (m^3)	MAXIMUM * PERMISSIBLE DRAWDOWN (m) BELOW COLLAR
BURGERVILLE						
G6783 [B] (0)	V A	55.0	–	3.0	1 900	–
G6785 [C] (0)	V A	42.0	–	3.0	1 900	16.0
G23229 [D] (0)	V A	47.6	–	3.0	1 900	–
G23232 [E] (0)	V A	72.5	–	4.0	2 500	–
ZN 5 [F] (0)	V A	172.0	81.0	3.0	1 250	–
G28396 [G] (0)	V A	–	24.0	–	–	–
ZN 9 [H] (0)	X	–	–	3.0	2 000	–
ZN 26 [I] (1)	III	30.0	21.0	6.0	5 000	15.0
ZEWEFONTEIN						
G6787 [K] (0)	IV	26.0	23.0	3.0	2 500	15.0
ZN 14 [L] (0)	IV	–	–	4.0	3 200	–
ZN 63 [M] (0)	IV	–	–	6.0	11 000	–
ZN 54 [N] (1)	IV	24.0	18.0	6.0	11 000	14.0
KAFFIRSDAM						
CF 31 [O] (1)	V A	–	–	–	–	–
CF 34 [P] (1)	V A	45.9	36.0	4.0	3 000	22.0
CF 35 [Q] (1)	V A	45.9	41.0	4.0	2 500	22.0
CF 36 [R] (1)	V A	–	–	–	–	–
CF 39 [S] (1)	V A	–	–	–	–	–
				TOTAL	580 000	m^3/year

(Adapted from Vegter, 1990)

NOTE:

Ownership – (0) Municipal (1) Private

* – Waterlevel prior to switch-on of pump (i.e. after a period of at least 8 hours rest).

A – "Populierbos" spring
B – Municipal Name "Lekkerwater"
C – Municipal Name "Beilergat"
D – Municipal Name "No. 2B"
E – Municipal Name "No. 2A"
F – Municipal Name "No. 36"
G – Municipal Name "Teelplaas" or "ZN 1"
H – Municipal Name "Ou kraal or Klipkraal"
I – Municipal Name "Si6" on the farm Sipreshof.
J – Bloufontein and Rivierfontein springs
K – Municipal Name "Op-die-Wal" or "In-die-Dam"
L – Municipal Name "Miergat".
M – Municipal Name "Anderkant-die-Sloot".
N – Municipal Name "De Kock Borehole" on the farm Leeufontein.
O – Municipal Name "No. 1"
P – Municipal Name "No. 3
Q – Municipal Name "No. 2
R – Municipal Name "No. 4
S – Municipal Name "No. 5

3.2 UNDEVELOPED GROUNDWATER RESOURCES

3.2.1 SOUTH-WESTERN AREA

Fully utilised and no further development is recommended.

3.2.2 SOUTH-EASTERN AREA

A number of production boreholes recommended by Smit (1975) and new production boreholes located during the 1987-89 investigations are recommended in Table 7. During the 1987-89 drilling program the production boreholes were located so as to provide a greater spread of abstraction points in the South-Eastern area and thereby optimise the utilisation of the aquifer (Figure 2).

The bulk TDS of the blended groundwater obtained from the production boreholes as recommended in Tables 4 and 7 would be ±1810 mg/l. If borehole G39037 is excluded from the system then the TDS of the water would drop to ±1560 mg/l. It is therefore recommended that borehole G39037 be equipped for standby purposes only or to make up any peak supply shortfalls. This represents a marked improvement in the overall groundwater quality from this area, considering that the present boreholes (Section 3.1.2 and Table 3) deliver water with a bulk TDS of 2379 mg/l.

3.2.3 BURGERVILLE AREA

The boreholes discussed in this section are mainly replacement boreholes, which are better constructed and/or more optimally sited on a particular geohydrological structure. Boreholes G38537 and G38270 are new production boreholes (Table 8).

Boreholes CF39 (Municipal No. 5) and CF31 (Municipal No. 1) are replaced by G39024 and G39025, respectively.

The bulk TDS of the blended groundwater obtained from the production boreholes recommended in Tables 5+8 and the fountains would be approximately 590 mg/l, which is the same as that estimated in Section 3.1.3.

TABLE 6 : CAROLUSPOORT AREA - DEVELOPED PRODUCTION BOREHOLE AND ABSTRACTION SPECIFICATIONS

WELL NUMBER	GROUND-WATER UNIT	DEPTH (m)	PUMP INTAKE (m)	PUMP RATE (l/s)	MAXIMUM MONTHLY ABSTRACTION (m^3)	MAXIMUM * PERMISSIBLE DRAWDOWN (m) BELOW COLLAR
W 4	VIII B	10-15	-	4	3 300	-
W 5	VIII B	10-15	-	4	4 200	-
W 2 G6779	VIII B	10-15	-	5	5 000	-
W 3 G6778	VIII B	10-15	-	4	4 200	-
W 6 G18880	VIII B	10-15	-	4	6 500	-
W G18884	XII	?	-	5	5 000	-
W G18886	XII	?	-	3	2 500	-
				TOTAL	368 000	m^3/year

NOTES (Adapted from Vegter, 1990)

* - Waterlevel prior to switch-on of pump (i.e. after a period of at least 8 hours rest).

TABLE 7 : SOUTH EASTERN AREA - UNDEVELOPED PRODUCTION BOREHOLE AND ABSTRACTION SPECIFICATIONS

BOREHOLE NUMBER	GROUND-WATER UNIT	DEPTH (m)	PUMP INTAKE (m)	PUMP RATE (l/s)	MAXIMUM MONTHLY ABSTRACTION (m^3)	MAXIMUM * PERMISSIBLE DRAWDOWN (m) BELOW COLLAR
WAG - N - BIETJIE						
G39029	XIV A	48.0	27.0	5.0	5 000	8.0
G39037	XII	18.0	7.5	6.0	4 000	7.0
RIETFONTEIN						
G38517	XI	36.0	24.0	3.0	2 500	13.0
G38455	XI	30.0	18.0	3.5	3 000	12.0
G38459	XI	36.0	25.0	4.0	3 500	16.0
G38468	XI	48.0	35.0	3.0	2 000	18.0
G38473	XI	24.0	17.0	4.0	2 000	12.0
G28307	XI	22.5	16.0	4.5	5 000	7.5
G28313B	XI	21.4	16.0	3.0	3 000	9.5
ROODE KRAAL						
G38507	XI	42.0	30.0	10.0	6 000	17.0
LEUWEFONTEIN						
G38491	X	42.0	25.0	5.5	4 500	15.0
G38478A	X	60.0	50.0	7.0	6 000	16.0
				TOTAL	550 000	m^3/year

NOTES (Adapted from Vegter, 1990)

* - Waterlevel prior to switch-on of pump (i.e. after a period of at least 8 hours rest).
- G28307 and G28313B were drilled during the 1971-75 investigation and were cleaned and pump-tested in 1989.

TABLE 8 : BURGERVILLE AREA - UNDEVELOPED PRODUCTION BOREHOLE AND ABSTRACTION SPECIFICATIONS

BOREHOLE NUMBER	GROUND-WATER UNIT	DEPTH (m)	PUMP INTAKE (m)	PUMP RATE (l/s)	MAXIMUM MONTHLY ABSTRACTION (m^3)	MAXIMUM * PERMISSIBLE DRAWDOWN (m) BELOW COLLAR
SIPRESHOF						
G38270	IX O	48.0	25.0	4.0	4 200	14.0
G38269A	III O	48.0	30.0	10.0	7 500	20.0
KAFFIRSDAM						
G39025	V A O	72.0	20.0	4.5	3 000	13.0
G39024	V A O	36.0	30.0	10.0	6 000	18.0
G38537	V A O	66.0	24.0	4.0	2 500	10.0
				TOTAL	278 000	m^3/year

NOTE: (Adapted from Vegter, 1990)

* - Waterlevel prior to switch-on of pump (i.e. after a period of at least 8 hours rest).

- Ownership - (O) Municipal (1) Private

3.2.4 NORTHERN AREA

Seventeen production boreholes are recommended in Table 9 (Figure 2). The original exploration and drilling of these boreholes are discussed by Smit (1975). Van Wyk (1989) discusses the re-drilling/construction and pump-testing of many of these boreholes. Woodford (1990) recommends boreholes G38537 and G38270 for production purposes in the so-called "Extended-Northern Area".

The bulk TDS of the blended groundwater obtained from the production boreholes (P) in Table 8 would be in the order of 1140 mg/l (Appendix A).

3.2.5 FAR NORTHERN AREA

During 1988, a number of production boreholes were located on the farm Hennopskraal (Table 10, Figure 2).

The bulk TDS of the groundwater obtained from the production boreholes recommended in Table 10 would be ± 865 mg/l (Appendix A).

3.2.6 BRANDFONTEIN AREA

During 1974-1975, a number of production boreholes were located on the farm Brandfontein (Table 11, Figure 2).

The bulk TDS of groundwater obtained from the recommended production boreholes (P) in Table 11 would be in the order of 1690 mg/l (Appendix A).

Prior to incorporation of these boreholes into the municipal supply scheme, further borehole development is required, failing which further exploration will have to be carried out to locate coarser/cleaner alluvial deposits to facilitate the development process.

TABLE 9 : NORTHERN AREA – UNDEVELOPED PRODUCTION BOREHOLE AND ABSTRACTION SPECIFICATIONS

BOREHOLE NUMBER		GROUND-WATER UNIT	DEPTH (m)	PUMP INTAKE (m)	PUMP RATE (l/s)	MAXIMUM MONTHLY ABSTRACTION (m^3)	MAXIMUM * PERMISSIBLE DRAWDOWN (m) BELOW COLLAR
KAPPOKPOORT							
G39211	P	XVII	24.0	20.0	4.0	2 700	14.0
G39220	P	XVII	36.0	25.0	5.5	3 700	9.0
G39213	P	XVII	36.0	16.0	3.0	2 000	10.0
G39209	P	XVIIIB	30.0	25.0	7.0	5 000	13.0
KALKFONTEIN							
G29654	P	XIX	34.0	12.0	7.0	2 900	6.5
G29652	P	XIX	22.0	12.0	11.0	5 400	7.0
G39149	P	XIX	25.0	12.0	11.0	5 800	8.0
G39148	S	XIX	35.0	16.0	6.0	3 300	9.0
G29647A	P	XIX	22.0	16.0	10.0	5 400	7.0
BLAUUWKRANS							
G39147	P	XIX	22.0	16.0	10.0	3 300	7.0
G29641B	S	XIX	60.0	16.0	10.0	5 400	8.0
G29639	P	XIX	22.0	16.0	12.0	4 200	7.0
G39146	S	XIX	34.0	16.0	12.0	5 800	8.0
G29637A	P	XIX	40.0	30.0	10.0	3 000	8.0
G29632	P	XIX	25.0	12.0	10.0	3 300	7.0
G29633	S	XIX	22.0	16.0	8.0	3 300	7.0
G29630B	P	XIX	34.0	30.0	5.0	3 800	18.0
PAARDEVLEI							
G29644	P	XVI B	40.0	30.0	5.0	2 900	15.0
G29617	P	XVI B	22.0	18.0	8.0	7 900	15.0
G29618	S	XVI B	17.5	12.0	5.0	2 900	10.0
G39145	P	XVI B	22.0	15.0	8.0	7 100	13.0
G28420	P	XVI B	22.0	20.0	7.0	5 000	15.0
					TOTAL	880 800	m^3/year

(Adapted from Vegter, 1990)

NOTE:

- P = Production Borehole S = Standby Production Borehole.

* - Waterlevel prior to switch-on of pump (i.e. after a period of at least 8 hours rest).

- G39150 replaces G29649 as standby borehole for production borehole G29652.
- G39149 replaces G29650 as production borehole.
- G39148 is a standby production borehole for G39149 or G29647, and replaces G29648.
- G39147 replaces G29642 as production borehole.
- G29641B is a standby production borehole for G39147 or G29639.
- G29618 is a standby production borehole for G29617.
- G39146 is a standby production borehole for G29639 or G29637A, and replaces G29636.
- G29633 is a standby production borehole for G29632.
- G39145 replaces G29619 as production borehole.

TABLE 10 : FAR NORTHERN AREA - UNDEVELOPED PRODUCTION BOREHOLE AND ABSTRACTION SPECIFICATIONS

BOREHOLE NUMBER		GROUND-WATER UNIT	DEPTH (m)	PUMP INTAKE (m)	PUMP RATE (l/s)	MAXIMUM MONTHLY ABSTRACTION (m^3)	MAXIMUM * PERMISSIBLE DRAWDOWN (m) BELOW COLLAR
G39061	P	XXIIIB	48.0	25.0	6.0	6 250	15.0
G39062	P	XXIIIB	54.0	36.0	5.0	5 200	15.0
G39063	P	XXIIIB	54.0	36.0	5.0	5 200	15.0
G39070	P	XXIIIB	48.0	15.0	5.0	5 200	10.0
G39071	P	XXIIIB	54.0	15.0	5.0	5 200	7.5
G39068	P	XXIIIB	18.0	15.0	4.0	4 200	10.5
					TOTAL	375 000	m^3/year

(Adapted from Vegter, 1990)

NOTE:
- P = Production Borehole S = Standby Production Borehole.
* - Waterlevel prior to switch-on of pump (i.e. after a period of at least 8 hours rest).

TABLE 11 : BRANDFONTEIN AREA - UNDEVELOPED PRODUCTION BOREHOLE AND ABSTRACTION SPECIFICATIONS

BOREHOLE NUMBER		GROUND-WATER UNIT	DEPTH (m)	PUMP INTAKE (m)	PUMP RATE (l/s)	MAXIMUM MONTHLY ABSTRACTION (m^3)	MAXIMUM * PERMISSIBLE DRAWDOWN (m) BELOW COLLAR
G27723	P	XXII	40.8	18.0	5.0	5 400	9.0
G28405	P	XXII	15.3	12.0	5.0	5 400	8.0
G28402	P	XXII	19.2	16.0	5.0	5 400	9.0
G39151	S	XXII	19.2	16.0	6.0	5 400	10.0
					TOTAL	195 000	m^3/year

(Adapted from Vegter, 1990)

NOTE:
- P = Production Borehole S = Standby Production Borehole.
* - Waterlevel prior to switch-on of pump (i.e. after a period of at least 8 hours rest).
- G39151 is an alternative for G28405.

3.3 SUMMARY OF AVAILABLE GROUNDWATER RESOURCES

The groundwater resources available to De Aar, as discussed in Sections 3.1 and 3.2, are summarised in Table 12.

At present De Aar's existing production boreholes are capable of delivering approximately 2.22 x 10^6 m^3 of groundwater, with an average bulk TDS of 1266 mg/l and a total hardness ($CaCO_3$) of 546 mg/l (Appendix C). The chemical constituents are estimated assuming complete and simultaneous mixing of all the borehole water according to the recommended **maximum monthly abstractions.** Theoretically, blending results in a bulk water which is within the drinking standards, but it alone will **not** solve the hardness problem, which will require some form of water-softening treatment.

The production boreholes recommended in this report are capable of delivering 4.4 x 10^6 m^3/year of groundwater, with an bulk TDS of 1140 mg/l and a total hardness ($CacO_3$) of 493 mg/l (Table 12).

4 IMPROVEMENT OF GROUNDWATER QUALITY

In 1990, Stewart, Sviridov & Oliver were appointed by the Department of Water Affairs to provide technical and cost information regarding the supply and treatment of water of acceptable quality to De Aar from groundwater resources in the area.

Stewart, Sviridov & Oliver (1990) state that the temporary hardness of the water is high, resulting in problems such as scale formation in hot water systems, poor soap lathering etc. They concluded that by judicious blending of water it could be possible to achieve an untreated water with a TDS of about 1200 mg/l, which would be reduced to between 1000-1100 mg/l after water-softening treatment. Stewart et al (1990) estimated that the unit cost of the water-softening process would be approximately 30.3 c/m^3 at a delivery rate of 9000 m^3/day.

TABLE 12 : DE AAR - SUMMARY OF AVAILABLE GROUNDWATER RESOURCES

AREA	USE OPTION	RECOMMENDED ABSTRACTION (m^3/year)	AVERAGE BULK TDS (mg/l)	TOTAL HARDNESS (mg/l)
South West	D	700 000	1303	421
Brandfontein	U	195 000	1688	551
Burgerville	P D	725 000 1 003 000	590 590	277 274
South Eastern	P D	430 000 980 000	2379 1813	1171 727
Caroluspoort	D	368 000	1228	582
Northern	U	816 000	1137	488
Far Northern	U	375 000	865	351
FULLY DEVELOPED (D) TOTAL **4 437 000**			1140	493

NOTES:

- Total Hardness as $CaCO_3$. A hardness > 300 mg/l is referred to as "Very Hard" in SA Water Quality Guidelines for domestic use (DWA&F, 1993)
- Burgerville/Zewefontein delivery assumes a combined average fountain flow of 145 000 m^3 per annum.

D - All of the available production boreholes are fully developed.
U - None of the available production boreholes are developed.
P - Some of the available production boreholes are developed.

In theory, blending of water from the various wellfields will provide De Aar with a reasonable quality water, but in practice there will be a number of difficulties. The main problem lies with the reticulation/storage system, i.e. groundwater from the South-Western area is piped directly into the "old" reservoir and gravity-fed to the residential area to the west of the railway line; while the water from Caroluspoort, Burgerville and the South-Eastern areas are pumped into the "new" reservoir, which gravity feeds the location, business and industrial areas (Appendix D). The two reservoirs are gravity linked to one another so that a constant damlevel can be maintained, but according to the Town Engineer (Taljaard Pers. Comm, 1994), this system is not functioning correctly. If this is the situation then the "old" and "new" reservoirs will deliver water with a TDS of 1303 and 1092 mg/l, respectively (Appendix C).

5 OPTIMAL UTILISATION AND DEVELOPMENT OF WATER RESOURCES

The developed groundwater resources of 2.2×10^6 m^3 (Appendix C - Scenario A), are not capable of meeting De Aar's present water requirements of 2.44×10^6 m^3 per annum.

A simple optimisation study was conducted with the goal of supplying De Aar with groundwater of an acceptable quantity and quality (TDS < 1200 mg/l) at minimum costs.

Haasbroek (1991) calculated the unit cost of developing water from the Far-Northern area at R1.32/m^3. The developmental costs quoted in Appendix B are estimated using Haasbroek's unit cost (R1.32÷30km = R0.044/km) and the average length of pipeline required to develop a particular area, assuming that a direct relationship exists between the distance and the cost of developing a cubic metre of water.

A summary of the optimisation results is contained in Appendix B.

Figure 3 indicates the results of minimising bulk water quality in an ideal situation where all the groundwater resources are in full production and therefore no developmental costs are involved. The present water requirements (1990-1995) would enable provision of "good" quality water (TDS 879-951 mg/l). Notice that the maximum quotas of groundwater are consistently drawn from the Burgerville, Northern and Far-Northern areas, with increasing volumes being required from South-Western and South-Eastern areas to meet the rising water demand. The Brandfontein area is totally ignored.

Figure 4 shows the results of minimising the costs of development, while maintaining a reasonable quality (TDS < 1200 mg/l) water. In this case, the Burgerville, South-Western, Brandfontein and Caroluspoort areas are consistently utilised to their maximum capacity. The South-Eastern and Northern areas are gradually included as the water consumption increases, while the Far-Northern area is totally excluded.

The above two scenarios appear to represent the opposite ends of the development spectrum, indicating the conflict between cost of development and the required water quality. One consistent factor appears, however, in both of the scenarios, namely that the Burgerville water is always utilised to its maximum capacity. The Burgerville water is crucial to De Aar's water supply scheme in terms of minimising costs, maintaining a reasonable quality of water and maximising yield from the system.

In a similar study, Dziembowski and Van Rensburg (1993), concluded that a "better" solution could be obtained by minimising quality instead of costs, as the average cost of the water in the former case is only about 20c/m^3 more than that of the latter case, while the purifying costs are estimated at 30 c/m^3 (Section 4).

A compromise was obtained by "fudging" a more realistic situation with regard to areas that are already developed and those that are more likely to be developed (**Figure 5**). De Aar's short-term water requirements of 2.4-2.9 x 10^6 m^3/yr could be met by fully utilising the areas already in production (Table 13), while still maintaining a reasonable quality (TDS 1037-1126 mg/l) of water. Within this scenario the water quality deteriorates as the demand increases, because greater volumes of poorer quality groundwater is abstracted to satisfy demand.

FIG 3 : DE AAR- GROUNDWATER ABSTRACTION
PER GEOGRAPHICAL AREA (1990 - 2010)

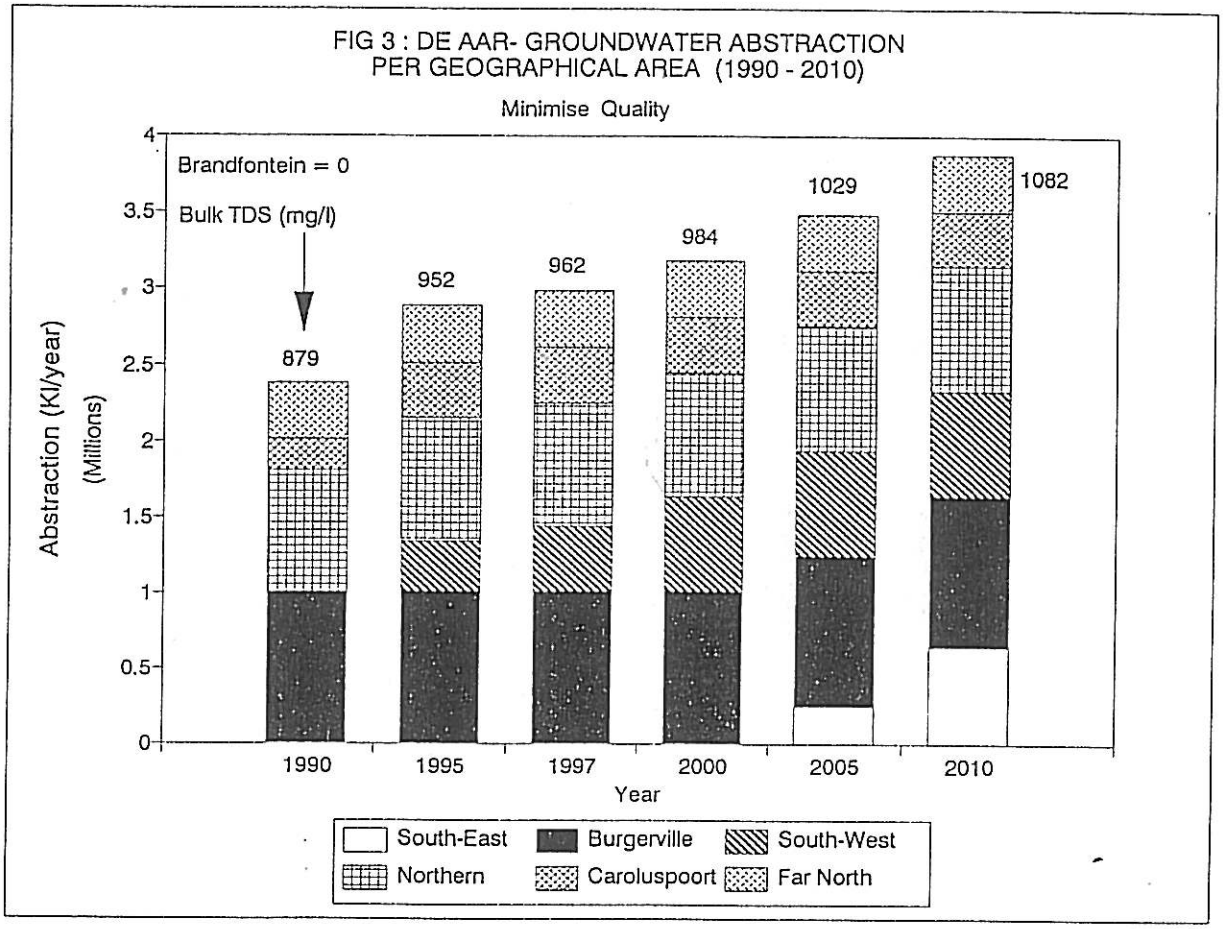


FIG 4 : DE AAR- GROUNDWATER ABSTRACTION
PER GEOGRAPHICAL AREA (1990 - 2010)

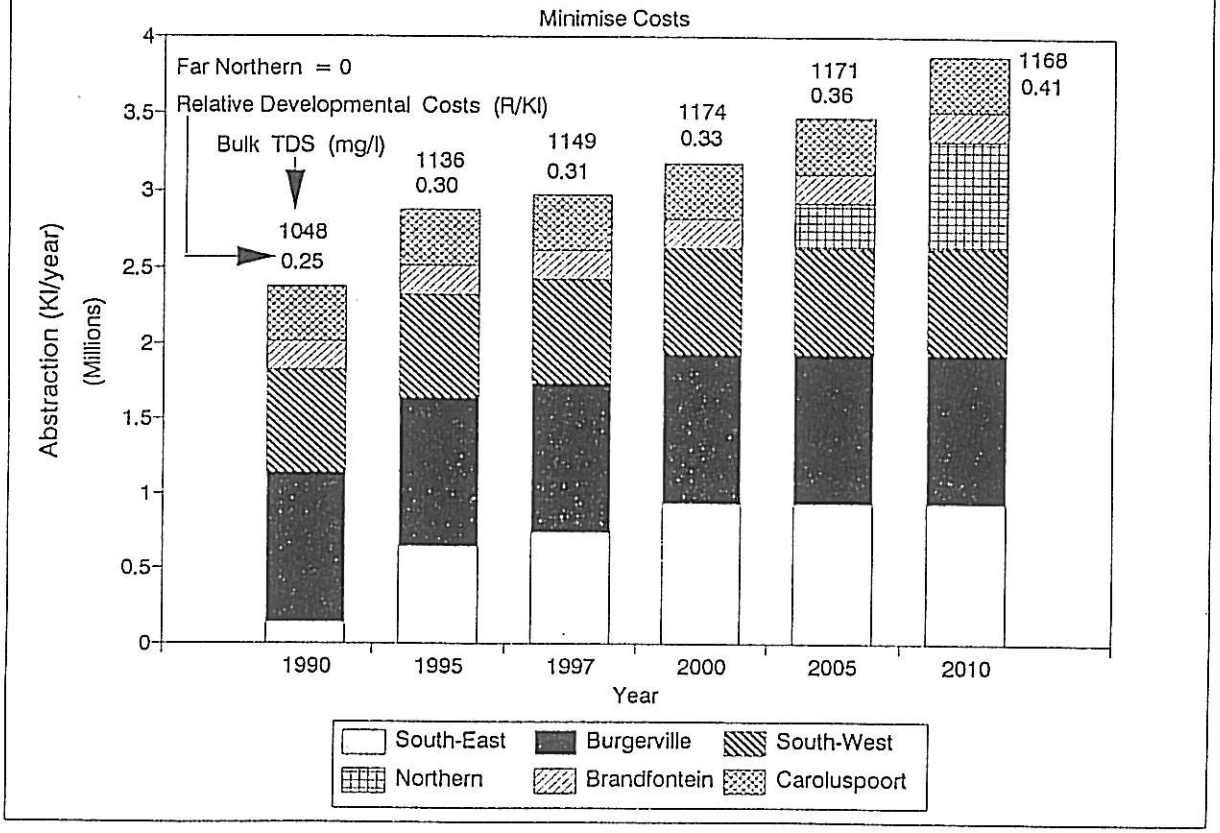
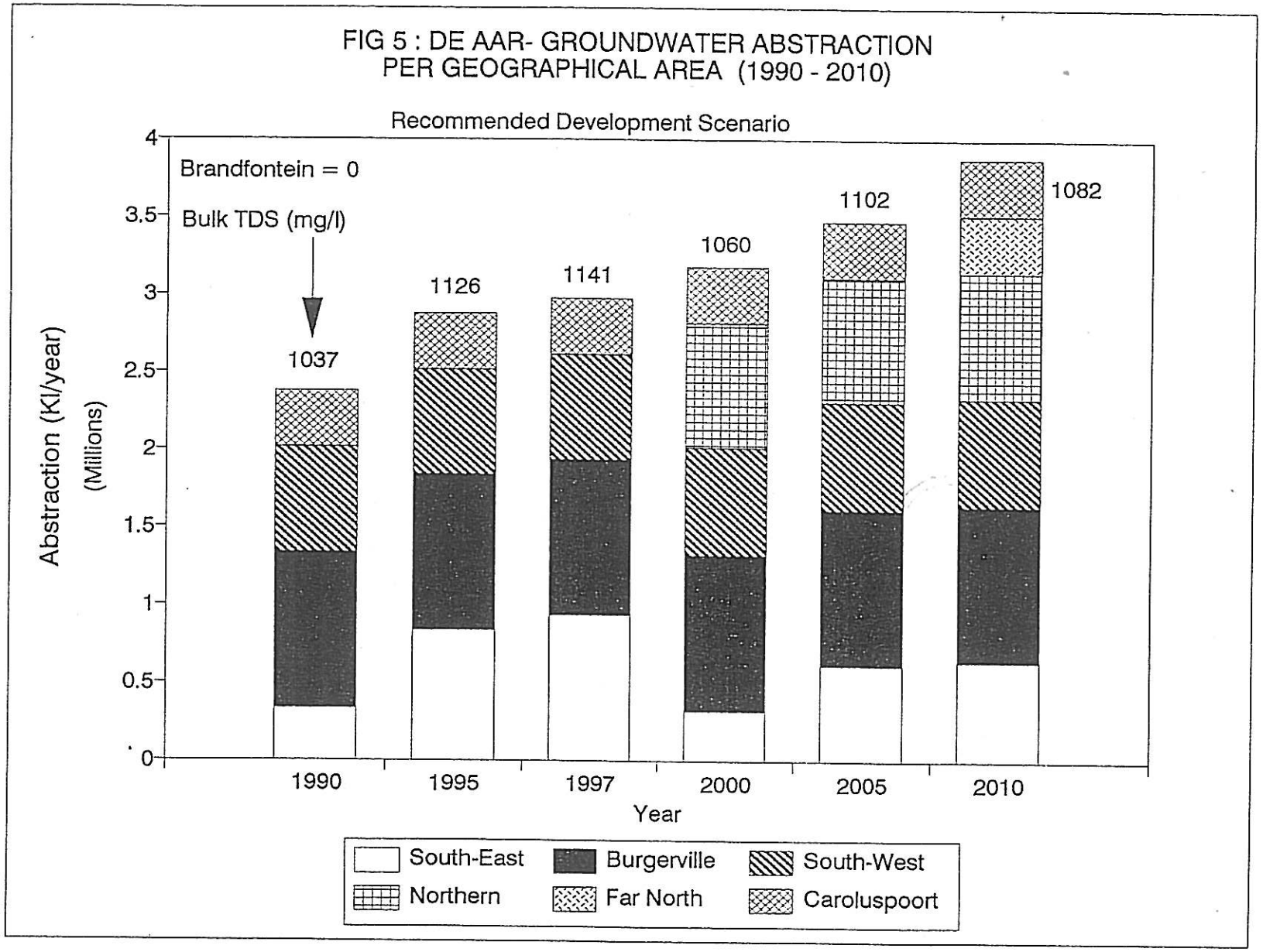


FIG 5 : DE AAR- GROUNDWATER ABSTRACTION
PER GEOGRAPHICAL AREA (1990 - 2010)



After 1997, the Northern area should be gradually phased into the supply scheme which, when fully developed, will produce an improvement in the overall water quality. The quality of the water will decrease as the demand for water rises. The Brandfontein area is not considered for development at this stage, although relatively easily linked into the South-Western scheme, given the poor quality of the water and relatively low yield of the wellfield, coupled with the need for further developmental/exploratory work.

De Aar will need to develop further groundwater resources before the year 2010. In this scenario, the Far Northern area is selected by the optimisation model due to it's good groundwater quality only.

At this stage, De Aar's water requirements should be re-evaluated and various groundwater development options re-assessed. It may be more feasible to investigate and develop certain of the unexplored areas as outlined by Vegter (1990), in favour of the Far-Northern area. The addition of the Brandfontein boreholes to the existing **fully** developed scheme (Appendix C - Scenario D) will only increase the bulk TDS from 1140 mg/l to 1170 mg/l (Appendix C - Scenario E), whereas groundwater from the Far-Northern area would result in a decrease in the bulk TDS to 1082 mg/l. In the final analysis, however, the quality of the potential water resource, rather than the quantity, will always remain the crucial issue.

The groundwater obtained from the Burgerville area is crucial to De Aar's water supply scheme both in terms of quantity and quality. There has been a tendency to under-utilise this supply for a number of reasons which are more of a political nature.

TABLE 13 : POSSIBLE GROUNDWATER DEVELOPMENT SCENARIO

YEAR	VOLUME GROUNDWATER ABSTRACTED ($x10^3$ m^3/yr)							BULK TDS mg/l
	SOUTH-EAST	BURGER-VILLE	SOUTH-WEST	NORTH	FNORTH	CAROL-USPRT	TOTAL	
1990	329	1003	700	0	0	368	2.400	1037
1995	829	1003	700	0	0	368	2.900	1126
1997	929	1003	700	0	0	368	3.000	1141
2000	313	1003	700	816	0	368	3.200	1060
2005	613	1003	700	816	0	368	3.500	1103
2010	638	1003	700	816	375	368	3.900	1082
MAX:	932	1003	700	816	375	368	4.194	1140

6 MONITORING

Successful management of any groundwater scheme will depend on the implementation of an efficient monitoring programme.

At present DWAF is responsible for the monthly servicing and maintenance of 49 waterlevel stations. Total monthly abstraction and rainfall data are also assimilated.

Implementation of a groundwater management programme must involve the simultaneous transfer of all the monitoring responsibilities to the Municipality or their appointed groundwater consultant.

6.1 GROUND-WATERLEVELS

Proper management of the various groundwater units will require the installation of a number of waterlevel monitoring stations, which record various aspects of the aquifer's response to abstraction, i.e. waterlevel response of an individual borehole or cluster of boreholes (local) as opposed to the ambient (regional) waterlevel response of the aquifer to abstraction.

Establishment of local monitoring stations in the priority areas for groundwater development, the South-Eastern and Burgerville areas, will be discussed in this report. The final design of the entire monitoring network should be addressed by the groundwater consultant who will eventually manage the abstraction scheme.

Waterlevels should be measured on a monthly basis in all the production boreholes, where a "pumping" and "static" reading should be taken, i.e. towards the end of the daily pumping cycle and just prior to pump start-up on the following pumping cycle.

6.1.1 EXISTING WATERLEVEL MONITORING STATIONS

The boreholes which are currently equipped with autographic waterlevel recorders are listed in Table 14. The National Groundwater Database (NGDB) site-identification number is a unique code which is allocated to each borehole stored on the Department's mainframe computer.

Two specialised monitoring sites were established in 1990 at Wag-n-Bietjie (South-East) and Vaalbank (South-West), to observe the effect of river-flow on recharge to the composite aquifer. The relevant boreholes equipped with autographic waterlevel recorders are tabulated in Table 15.

The position of these boreholes is indicated on Figure 6.

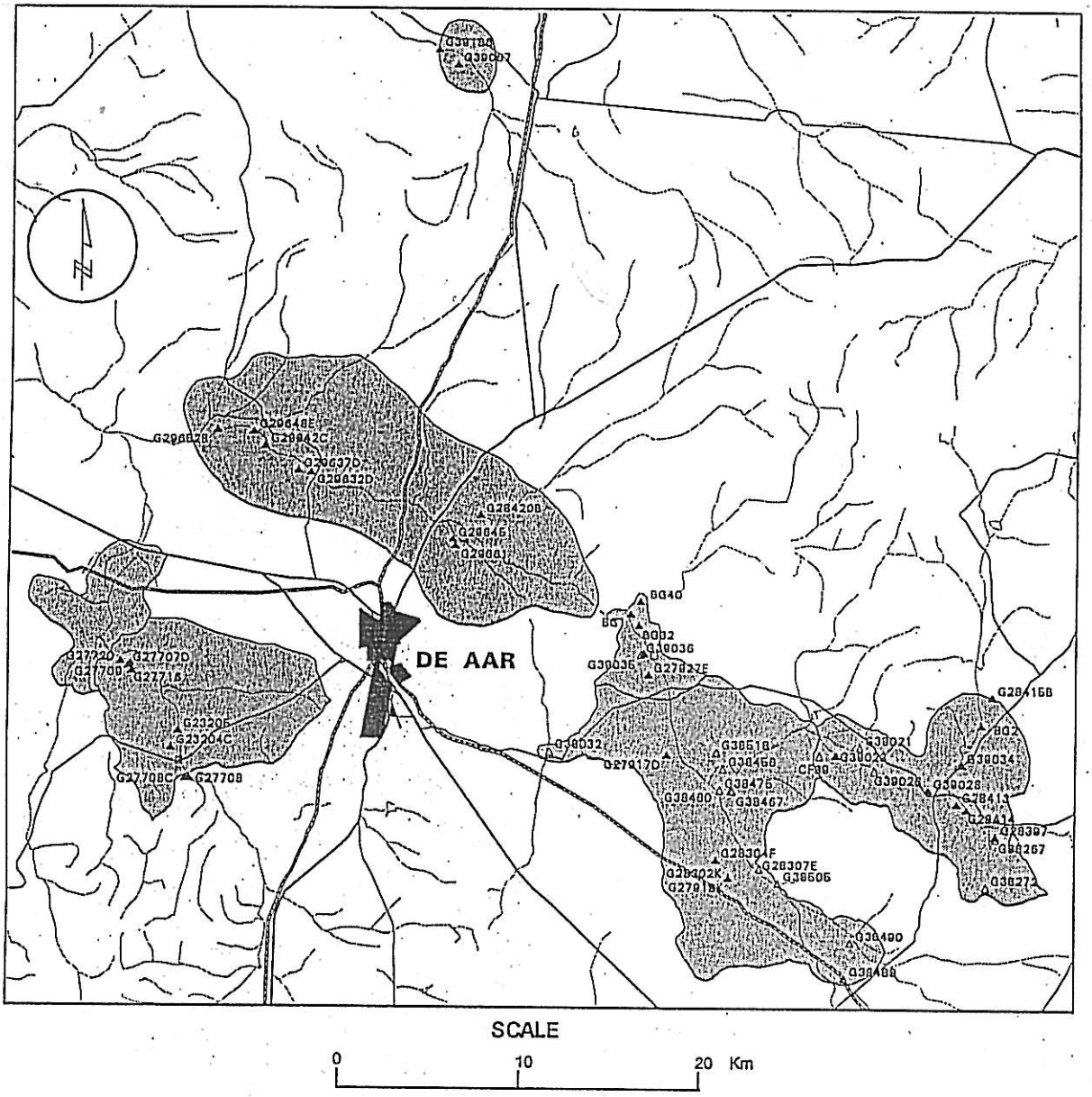


FIGURE 6 : *DE AAR - EXISTING AND RECOMMENDED MONITORING BOREHOLES*

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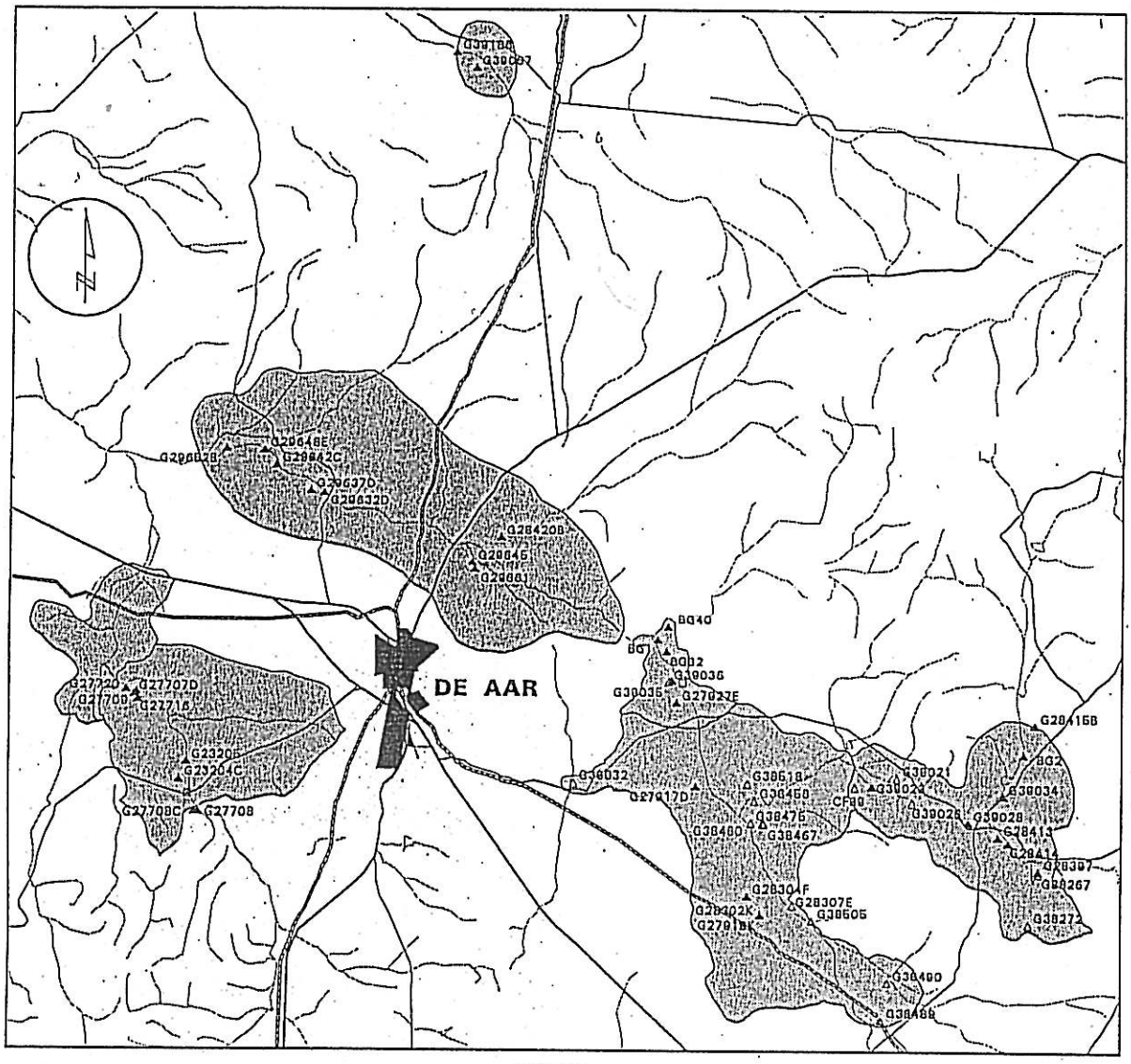

SCALE

0 10 20 Km

▲ *EXISTING MONITORING BOREHOLES*

△ *RECOMMENDED MONITORING BOREHOLES*

□ *SOUTH EASTERN RIVER STATION*

▣ *SOUTH WESTERN RIVER STATION*

FIGURE 6 :*DE AAR - EXISTING AND RECOMMENDED MONITORING BOREHOLES*

TABLE 14: DE AAR - EXISTING AUTOGRAPHIC WATERLEVEL MONITORING STATIONS

BOREHOLE NUMBER	DRAINAGE NUMBER	NGDB SITE NUMBER	TYPE	LOCAL FARM NAME
SOUTH WESTERN AREA				
G27716	D6N519	3023DB00054	R	Renosterpoort
G27720	D6N517	3023DB00374	R	Renosterpoort
G27707D	D6N518	3023DB00428	R	Renosterpoort
G27709	D6N520	3023DB00071	R	Vaalbank
G23205	D6N521	3023DB00080	R	Vaalbank
G27708C	D6N551	3023DB00114	R	Vaalbank
G27708	D6N550	3023DB00124	R	Vaalbank
G23204C	D6N522	3023DB00235	R	Vaalbank
SOUTH EASTERN AREA + CAROLUSPOORT				
G27927E	D6N537	3024CA00115	R	Wag-n-Bietjie
G27917D	D6N538	3024CA00324	R	Riet
G28302K	D6N540	3024CA00238	R	Rietfontein
G28304F	D6N539	3024CC00007	R	Rietfontein
G39035	-	3024CA00331	R	Caroluspoort
BG1	D6N500	3024CA00328	R	Caroluspoort
BG32	D6N507	3024CA00329	R	Caroluspoort
BG40	D6N508	3024CA00330	R	Caroluspoort
BURGERVILLE / ZEWEFONTEIN AREA				
BG2	D6N501	3024CB00067	R	Zewefontein
G39034	D6N562	3024CB00087	R	Zewefontein
G39028	D6N563	3024CB00088	R	Zewefontein
G28413	D6N543	3024CB00073	R	Burgerville
G28414	D6N545	3024CB00075	R	Burgerville
G28397	D6N546	3024CB00076	R	Burgerville
G39023	D6N564	3024CB00085	R	Cyfferkuil
G28415B	-	3024CB00035	R	Zewefontein
NORTHERN AREA				
G29648E	D6N526	3023DB00412	R	Kappokpoort
G29652B	D6N525	3023DB00423	R	Kalkfontein
G29632D	D6N529	3023DB00424	R	Blaauwkrans
G29637D	D6N528	3023DB00425	R	Blaauwkrans
G29642C	D6N527	3023DB00527	R	Blaauwkrans
G28420B	D6N530	3024CA00318	R	Paardevlei
G29645	D6N531	3024CA00319	R	Du Plessisdam
G29661	D6N532	3024CA00320	R	Du Plessisdam
FAR NORTHERN AREA				
G39067	-	3024AC00004	R	Hennopskraal
G39186	-	3024AC00005	R	Hennopskraal

NOTES: R - Autographic Recorder
NGDB - DWAF's National Groundwater Databank

TABLE 15: DE AAR - SPECIALISED WATERLEVEL MONITORING STATIONS

BOREHOLE NUMBER	DRAINAGE NUMBER	NGDB SITE NUMBER	TYPE	LOCAL FARM NAME
SOUTH WESTERN AREA				
G39230	-	3023DB00436	R	Vaalbank
G39229	-	3023DB00435	R	Vaalbank
G39228	-	3023DB00434	R	Vaalbank
G39227	-	3023DB00433	R	Vaalbank
G39226	-	3023DB00432	R	Vaalbank
G39225	-	3023DB00431	R	Vaalbank
G39224	-	3023DB00356	R	Vaalbank
G39231	-	3023DB00437	R	Vaalbank
RIVER	-	3023DB00438	R	Vaalbank
SOUTH EASTERN AREA				
G39035	-	3024CA00331	R	Wag-n-Bietjie
G39223	-	3024CA00335	R	Wag-n-Bietjie
G39222	-	3024CA00334	R	Wag-n-Bietjie
G39221	-	3024CC00333	R	Wag-n-Bietjie
G39039	-	3024CC00332	R	Wag-n-Bietjie
RIVER	-	3024CA00336	R	Wag-n-Bietjie

NOTES: R - Autographic Recorder
NGDB - DWAF's National Groundwater Databank

6.1.2 ADDITIONAL WATERLEVEL MONITORING STATIONS

The status of existing waterlevel monitoring stations should be carefully examined and upgraded as part of the developmental phase of any new wellfields.

Table 16 contains a list of boreholes considered to be adequate for monitoring the local response of the aquifer to abstraction from the new boreholes in the South-Eastern and Burgerville areas. The position of these boreholes are indicated in Figure 6. These boreholes should be equipped with autographic waterlevel recorders prior to the commissioning of the production boreholes. Monitoring of the regional waterlevels in these areas will require drilling of additional boreholes, which is beyond the scope of this report.

TABLE 16: RECOMMENDED ADDITIONAL MONITORING STATIONS IN THE SOUTH-EASTERN AND BURGERVILLE AREAS

LOCAL FARM NAME	GROUND-WATER UNIT	PRODUCTION BOREHOLE OR SITE	RECOMMENDED MONITORING BOREHOLE
SOUTH-EASTERN			
Wag-n-Bietjie	XIV A	G39029	G39032
Wag-n-Bietjie	XII	G39037	G39036
Rietfontein	XI	G38517	G38518
Rietfontein	XI	G38455	G38456
Rietfontein	XI	G38459	G38460
Rietfontein	XI	G38468	G38467
Rietfontein	XI	G38473	G38475
Rietfontein	XI	G28307	G28307E
Rietfontein	XI	G28313B	G28307E
Roodekraal	XI	G38507	G38505
Leeufontein	X	G38491	G38490
Leeufontein	X	G38478A	G38489
BURGERVILLE			
Sipreshof	IX	G38270	G38272
Sipreshof	III	G38269A	G38267
Kaffirsdam	V A	G39025	G39026
Kaffirsdam	V A	G39024	CF39
Kaffirsdam	V A	G38537	G39021

6.2 GROUNDWATER ABSTRACTION

Accurate records should be maintained of the monthly volumes of groundwater abstracted from each production borehole, by means of flowmeters. Record should be kept of the bulk volumes of water passing various collection points where they reflect the volumes pumped from the different geohydrological units, i.e. total abstraction from the South-Western Area could be measured at the inflow to the "old" reservoir (Appendix D). This will provide a method of infilling missing data from individual boreholes with faulty flowmeters and to keep a check on system losses.

The of rate of flow of the Populierbos and combined flow of the Rivierfontein / Bloufontein springs must be recorded at the Burgerville and Zewefontein collection tanks, respectively (Appendix D). The Department provided the Municipality with a design for such a system in 1989, but it was never implemented.

6.3 GROUNDWATER QUALITY

Maintaining a reasonable water quality is crucial to the success of De Aar's supply scheme and therefore should form a key component of the monitoring programme.

The groundwater from each production borehole should be tested on an annual basis for at least the following major chemical components:

(a) Total Dissolved Solids (TDS)
(b) Electrical Conductivity (EC)
(c) Total Alkalinity (TAL)
(d) Sodium (Na)
(e) Calcium (Ca)
(f) Magnesium (Mg)
(g) Chloride (Cl)
(h) Sulfate (SO_4)
(i) Fluoride (F)
(j) Nitrates (NO_3)

The EC of the water should be measured on a monthly basis in all the production boreholes, springs and bulk monitoring points as discussed under Section 6.2.

Groundwater sampling procedures should be carried out in accordance with the procedures outlined in "Groundwater Sampling" by Weaver (1992).

6.4 RAINFALL

Rainfall stations should ideally be installed in each of the exploited groundwater units or a least one per geographic area. Monthly data will suffice for the purposes of aquifer management, but daily rainfall data would provide scope for more detailed studies of aquifer recharge.

6.5 MISCELLANEOUS

The monitoring program should include the following:

* Qualitative information on river flow, i.e. maximum stage, duration and dam levels in the exploited groundwater units.

* Annual estimates of agricultural usage of groundwater within groundwater units being exploited by the Municipality, especially in areas of intensive irrigation. Intensive irrigation should be avoided in areas where municipal abstraction takes place, as this will cause conflict between groundwater users, especially in droughts.

The monitoring information should be compiled and stored on a personal-computer database. In this connection the program "Munibase" developed by the Institute for Groundwater Studies at the University of the Orange Free State is recommended.

7 CONCLUSION

De Aar's existing production boreholes are not capable of meeting its short-term water requirements of 2.4 - 2.9 x 10^6 m^3 per annum. This will necessitate the full development of the South-Eastern and Burgerville areas.

A development scenario is recommended based on a simplistic optimisation study where developmental costs and groundwater quality were minimised. The Northern area should be gradually phased into the supply scheme between the years 1997 and 2005. De Aar will require additional water by the year 2010 and a cost-benefit-risk assessment should be conducted to reassess all the available groundwater development options. Continuity in the planning and development of De Aar's groundwater resources is essential if problems of poor water quality and supply shortfalls are to be overcome.

The geohydrological aspects of developing and managing De Aar's groundwater resources are considered in this report, while a number of equally important issues have been omitted, i.e. water conservation, water pricing, impact of abstraction on the environment, education of water users etc.

The report lays a foundation upon which De Aar's groundwater resources could be developed and managed on a sustainable basis. A groundwater consultant should be employed to undertake the next phases in implementing a fully functional groundwater management scheme, where integrated groundwater- and optimisation-modelling will ensure adequate and potable water for De Aar at minimum risk and cost. Insufficient data and knowledge place the development of such predictive models beyond reach at this stage. It is therefore imperative that De Aar fully implement and maintain a monitoring programme that will ensure that this type of information is collected.

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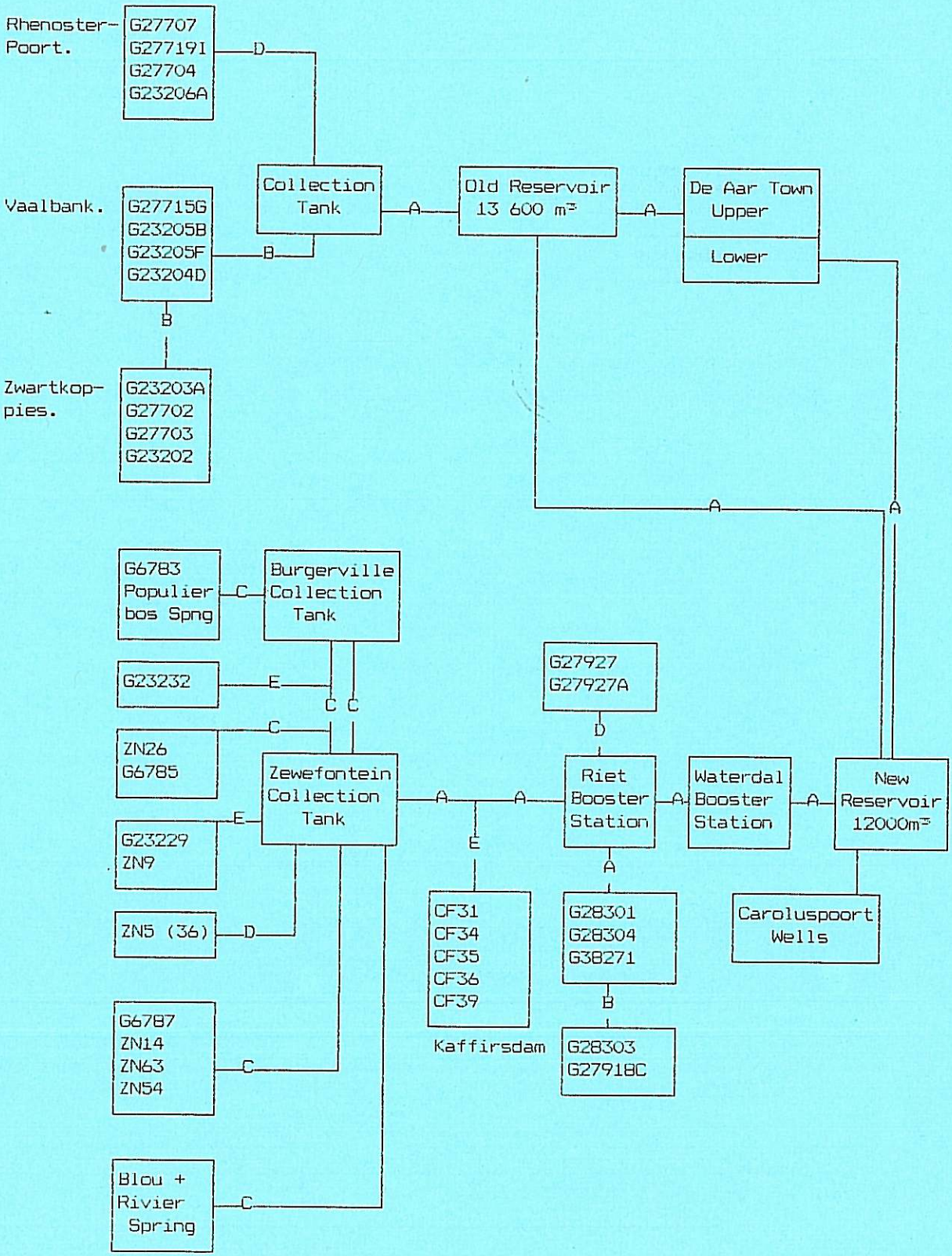
SCHEMATIC DIAGRAM INDICATING DE AAR'S GROUNDWATER RETICULATION SYSTEM

Diameter Code: A-300mm B-200mm C=175mm D-150mm E-100mm



APPENDIX A

HYDROCHEMICAL DATA

ESTIMATED AVERAGE GROUNDWATER QUALITY	pH	EC mS/m	TDS TAL (mg/l)	Na	Ca	Mg	Si	K	Cl	SO_4	F	NH_4	NO_3+ NO_2	P
								(mg / l)						
Domestic*Max. Limit	5.5-9.5	300	2000 650	400	200	100	25	800	600	600	1.5	2	10	0.2
SOUTH WESTERN[1]	8.0	201	1370 342	278	60	67	22	2	293	241	0.9	0	3	0.0
SOUTH WESTERN[2]	8.0	190	1303 335	255	62	65	22	2	271	225	0.8	0	3	0.0
SOUTH EASTERN[3]	7.7	372	2379 232	360	201	163	15	5	795	540	1.0	0	5	0.0
SOUTH EASTERN[4]	7.6	266	1813 263	298	127	118	13	5	524	400	1.2	0	4	0.0
SOUTH EASTERN[5]	7.6	232	1556 249	236	125	101	13	5	444	320	1.3	0	5	0.0
CAROLUSPOORT	7.7	187	1228 282	173	95	84	22	1	293	233	0.9	0	1	0.0
BURGERVILLE[6]	8.0	77	590 241	62	55	34	14	1	46	68	0.9	0	4	0.0
BURGERVILLE[7]	7.8	88	665 268	71	61	39	15	2	55	87	0.8	0	4	0.0
BURGERVILLE[8]	7.9	78	590 242	63	54	34	14	2	46	68	0.9	0	4	0.0
BURGERVILLE[9]	7.4	88	643 262	74	56	37	13	3	54	79	0.9	0	3	0.0
NORTHERN AREA	7.8	168	1137 260	181	74	74	16	2	288	187	1.2	0	3	0.1
FAR NORTHERN AREA	8.0	107	865 327	118	50	55	22	1	129	78	0.9	0	3	0.0
BRANDFONTEIN AREA	7.9	256	1688 347	356	48	105	25	1	458	284	1.8	0	2	0.0

After SA WATER QUALITY GUIDELINES (1993) and Aucamp & Vivier (1990).

NOTES:

1 - Water quality of existing production boreholes under present pumping regime.
2 - Water quality of existing production boreholes under recommended pumping regime (Table 2).
3 - Water quality of existing production boreholes under recommended pumping regime (Table 3).
4 - Water quality of existing production boreholes under recommended pumping regime (Table 3+6).
5 - Water quality of existing production boreholes under recommended pumping regime (Table 3+6), excluding G39037.
6 - Water quality of existing production boreholes under recommended pumping regime (Table 4), including springs.
7 - Water quality of existing production boreholes under recommended pumping regime (Table 4), excluding springs.
8 - Water quality of existing production boreholes under recommended pumping regime (Table 4+7), including springs.
9 - Water quality of existing production boreholes under recommended pumping regime (Table 4+7), excluding springs.

APPENDIX B

SUMMARY OF OPTIMISATION RESULTS
(Simplex Linear Programming)

YEAR	ESTIMATED WATER CONSUMP-TION $\times 10^6 m^3$	AREA IN PRODUCTION	MAXIMUM YIELD $\times 10^6 m^3$	BULK TDS mg/l	MINIMISE COSTS ** Relative Develop Costs R/m^3	Optimal Volume $\times 10^6 m^3$	Result	MINIMISE QUALITY*** Optimal Volume $\times 10^6 m^3$	Result
1990	2.400	South East	0.932*	1556	0.55	0.329	TDS mg/l	0.329	
		Burgervlle	1.003	590	0.44	1.003	1037	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.700	1037
		Carolusprt	0.368	1228	0.04	0.368	Cost	0.368	
		TOTAL	3.003			2.400	R0.28/m^3	2.400	
1990	2.400	South East	0.932*	1556	0.55	0.134	TDS mg/l	0.000	
		Burgervlle	1.003	590	0.44	1.003	1048	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.000	879
		North	0.816	1137	0.77	0.000		0.816	
		FNorth	0.375	865	1.32	0.000	Cost	0.375	
		Brandftn	0.195	1688	0.22	0.195	R0.25/m^3	0.000	
		Carolusprt	0.368	1228	0.04	0.368		0.206	
		TOTAL	4.389			2.400		2.400	
1995	2.900	South East	0.932*	1556	0.55	0.829	TDS mg/l	0.829	
		Burgervlle	1.003	590	0.44	1.003	1127	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.700	1126
		Carolusprt	0.368	1228	0.04	0.368	Cost	0.368	
		TOTAL	3.003			2.900	R0.32/m^3	2.900	
1995	2.900	South East	0.932*	1556	0.55	0.634	TDS mg/l	0.000	
		Burgervlle	1.003	590	0.44	1.003	1136	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.338	951
		North	0.816	1137	0.77	0.000		0.816	
		FNorth	0.375	865	1.32	0.000	Cost	0.375	
		Brandftn	0.195	1688	0.22	0.195	R0.30/m^3	0.000	
		Carolusprt	0.368	1228	0.04	0.368		0.368	
		TOTAL	4.389			2.900		2.900	
1997	3.000	South East	0.932*	1556	0.55	0.929	TDS mg/l	0.929	
		Burgervlle	1.003	590	0.44	1.003	1141	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.700	1141
		Carolusprt	0.368	1228	0.04	0.368	Cost	0.368	
		TOTAL	3.003			3.000	R0.33/m^3	3.000	
1997	3.000	South East	0.932*	1556	0.55	0.734	TDS mg/l	0.000	
		Burgervlle	1.003	590	0.44	1.003	1149	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.438	962
		North	0.816	1137	0.77	0.000		0.816	
		FNorth	0.375	865	1.32	0.000	Cost	0.375	
		Brandftn	0.195	1688	0.22	0.195	R0.31/m^3	0.000	
		Carolusprt	0.368	1228	0.04	0.368		0.368	
		TOTAL	4.389			3.000		3.000	

YEAR	ESTIMATED WATER CONSUMP-TION $x10^6m^3$	AREA IN PRODUCTION	MAXIMUM YIELD $x10^6m^3$	BULK TDS mg/l	MINIMISE COSTS**			MINIMISE QUALITY***	
					Relative Develop Costs R/m^3	Optimal Volume $x10^6m^3$	Result	Optimal Volume $x10^6m^3$	Result
2000	3.200	South East	0.932*	1556	0.55	0.932	TDS mg/l	0.313	
		Burgervlle	1.003	590	0.44	1.003	1141	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.700	1060
		North	0.816	1137	0.77	0.197		0.816	
		Carolusprt	0.368	1228	0.04	0.368	Cost	0.368	
		TOTAL	3.819			3.200	R0.36/m^3	3.200	
2000	3.200	South East	0.932*	1556	0.55	0.932	TDS mg/l	0.000	
		Burgervlle	1.003	590	0.44	1.003	1174	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.638	984
		North	0.816	1137	0.77	0.002		0.816	
		FNorth	0.375	865	1.32	0.000	Cost	0.375	
		Brandftn	0.195	1688	0.22	0.195	R0.33/m^3	0.000	
		Carolusprt	0.368	1228	0.04	0.368		0.368	
		TOTAL	4.389			3.200		3.200	
2005	3.500	South East	0.932*	1556	0.55	0.932	TDS mg/l	0.613	
		Burgervlle	1.003	590	0.44	1.003	1141	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.700	1102
		North	0.816	1137	0.77	0.497		0.816	
		Carolusprt	0.368	1228	0.04	0.368	Cost	0.368	
		TOTAL	3.819			3.200	R0.39/m^3	3.200	
2005	3.500	South East	0.932*	1556	0.55	0.932	TDS mg/l	0.238	
		Burgervlle	1.003	590	0.44	1.003	1171	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.700	1029
		North	0.816	1137	0.77	0.302		0.816	
		FNorth	0.375	865	1.32	0.000	Cost	0.375	
		Brandftn	0.195	1688	0.22	0.195	R0.36/m^3	0.000	
		Carolusprt	0.368	1228	0.04	0.368		0.368	
		TOTAL	4.389			3.200		3.200	
2010	3.900	South East	0.932*	1556	0.55	0.932	TDS mg/l	0.638	
		Burgervlle	1.003	590	0.44	1.003	1168	1.003	TDS mg/l
		South West	0.700	1303	0.04	0.700		0.700	1082
		North	0.816	1137	0.77	0.702		0.816	
		FNorth	0.375	865	1.32	0.000	Cost	0.375	
		Brandftn	0.195	1688	0.22	0.195	R0.41/m^3	0.000	
		Carolusprt	0.368	1228	0.04	0.368		0.368	
		TOTAL	4.389			3.900		3.900	

NOTES

* - South-East yield excluding boreholes G39037.

** - Minimise Costs: Goal Function

F_{min} = 0.549(South-East) + 0.444(Burger) + 0.768(North) + 1.317(FNorth) + 0.220(Brand) + 0.044(South-West) + 0.044(Carol)

While maintaining a bulk TDS < 1200 mg/l.

*** - Minimise Quality: Goal Function

F_{min} = 1556(South-East) + 590(Burger) + 1137(North) + 865(FNorth) + 1688(Brand) + 1303(South-West) + 1228(Carol)

APPENDIX C

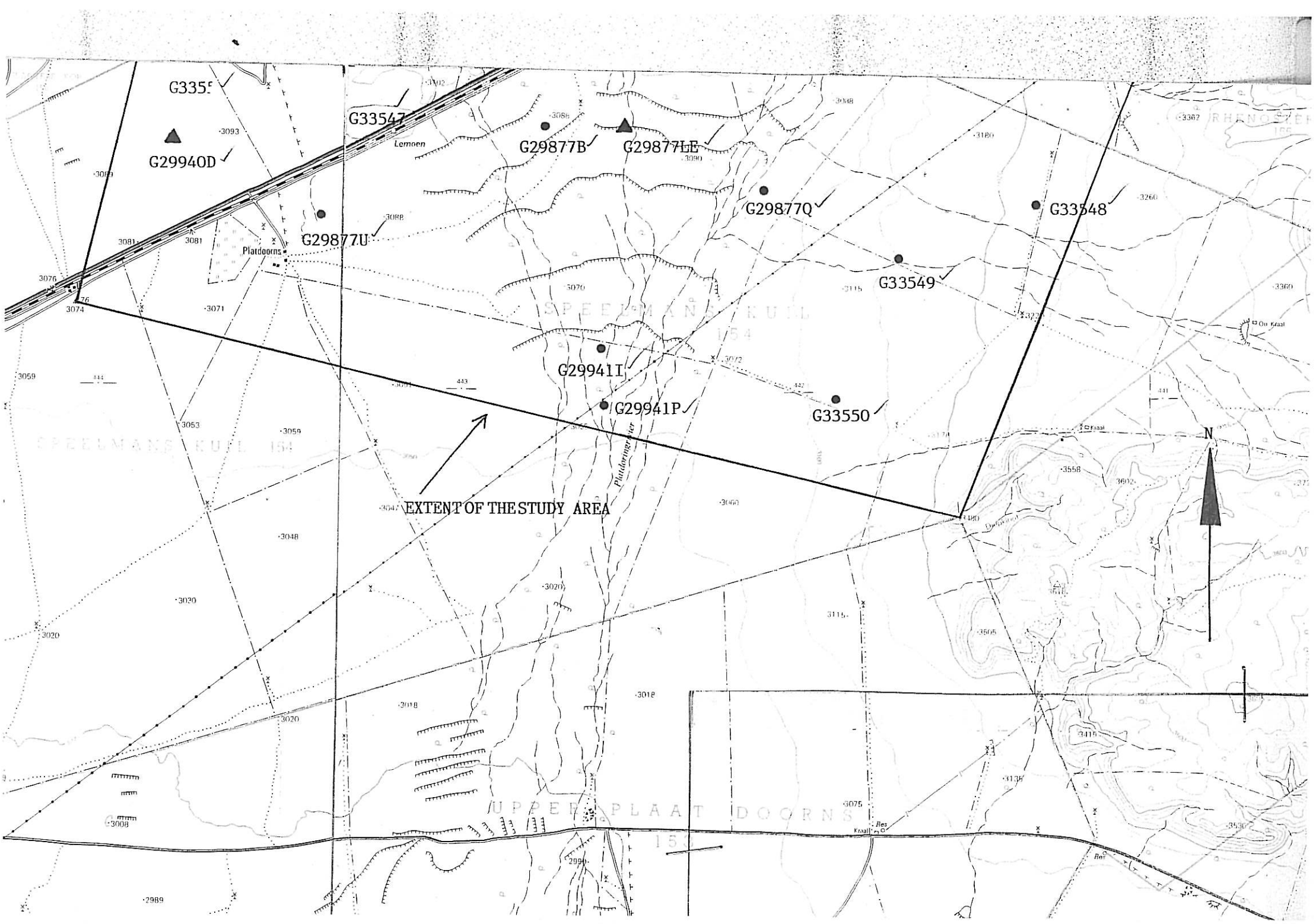
ESTIMATED YIELD AND QUALITY OF GROUNDWATER

APPENDIX D

DE AAR'S GROUNDWATER RETICULATION SYSTEM

DEVELOPMENT SCENARIO	YIELD (m^3/yr)	MAJOR CHEMICAL CONSTITUENTS (mg/l) TDS	TAL	Na	Ca	Mg	Cl	SO^4	F
(A) Existing Production Boreholes	2 223 000	1266	276	199	92	77	303	236	0.9
(B) (A) + New Bores in South Eastern + Burgerville Areas	3 051 000	1223	275	196	84	74	281	231	1.0
(C) (B) but excluding bore G39037	3 047 000	1140	270	176	84	69	255	205	1.0
(D) (C) + Northern Area Boreholes	3 863 000	1140	268	177	82	70	262	201	1.0
(E) (D) + Brandfontein Boreholes	4 058 000	1166	272	186	80	71	271	205	1.1
(F) (E) + Far Northern Area Borehole	4 433 000	1140	277	180	77	80	259	194	1.1
(G) South West + Brandfontein Boreholes only	895 000	1387	338	277	59	74	312	238	1.0
(H) Full Development of Carolus-poort, South East + Burgerville Areas	2 347 000	1092	251	152	90	70	250	199	1.1

ESTIMATED YIELD AND QUALITY OF GROUNDWATER ACCORDING TO VARIOUS DEVELOPMENT SCENARIOS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G33550
EXTENT OF THE STUDY AREA
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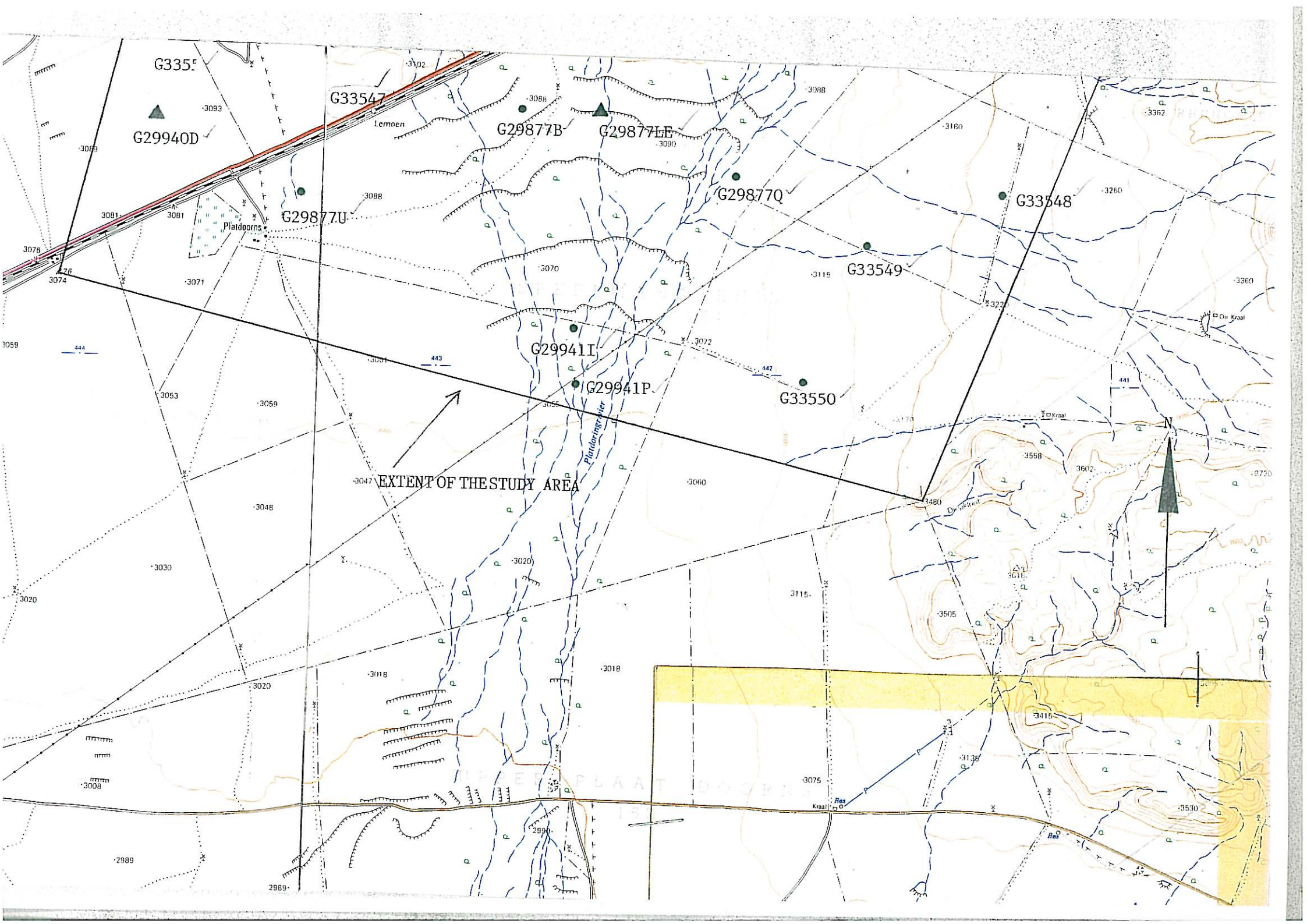
Platdoorns
Lemoen
Platdoringspruit
SPEELMANSKUIL 154
UPPER PLAAT DOORNS 152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G33550
EXTENT OF THE STUDY AREA
Platdoorns
Platdoring River
Lemoen
N

TITLE : De Aar - Development and Management of available Groundwater Resources.

REPORT: GH3837

AUTHOR/AFFILIATION : AC Woodford (DWAF)

LOCALITY : De Aar 3024CA
(Refer to 1 : 50 000 and 1 : 250 000 maps)

DRAINAGE : D60

GH-PLANS : None

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

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AUTHOR : AC Woodford

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