THE KALAHARI GROUND WATER PROJECT

AREA NO. 5

THE GROUND WATER OCCURRENCE IN THE MIER SETTLEMENT AREA DISTRICT GORDONIA

GH 3382

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1. INTRODUCTION

At request of the Division of Planning, Department of Water Affairs, the Directorate of Geohydrology carried out a geohydrological survey in the Gordonia, Kuruman, and Postmasburg districts of the Kalahari. The objective of this comprehensive investigation was to evaluate the ground water occurrence with the view to its possible regional utilization. The Kalahari ground water project area amounts to approximately 49 000 km^2 and stretches from about 15 km north of Upington in the south to the Molopo River in the north. The eastern boundary is formed by the Korannaberg-Langeberg Range and the western by the international border of South West Africa/Namibia. The area includes the Mier Coloured Settlement and the Kalahari Gemsbok National Park (Fig. 1).

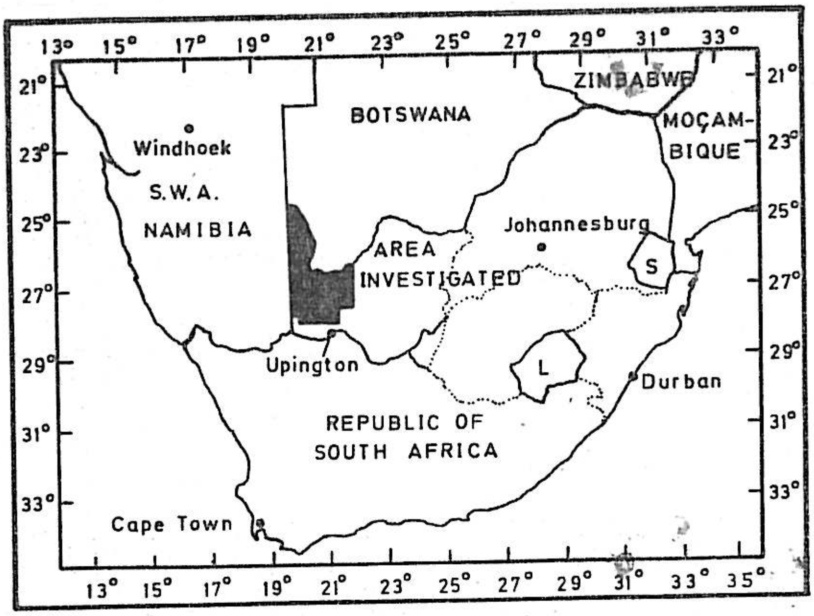

Fig. 1 : Map of area of investigation

As the area is too large for a single report it has been subdivided into 6 smaller portions (Fig. 2). Geohydrological and practical considerations were instrumental in defining these subdivisions. The 6 subdivisions are delineated as follows:

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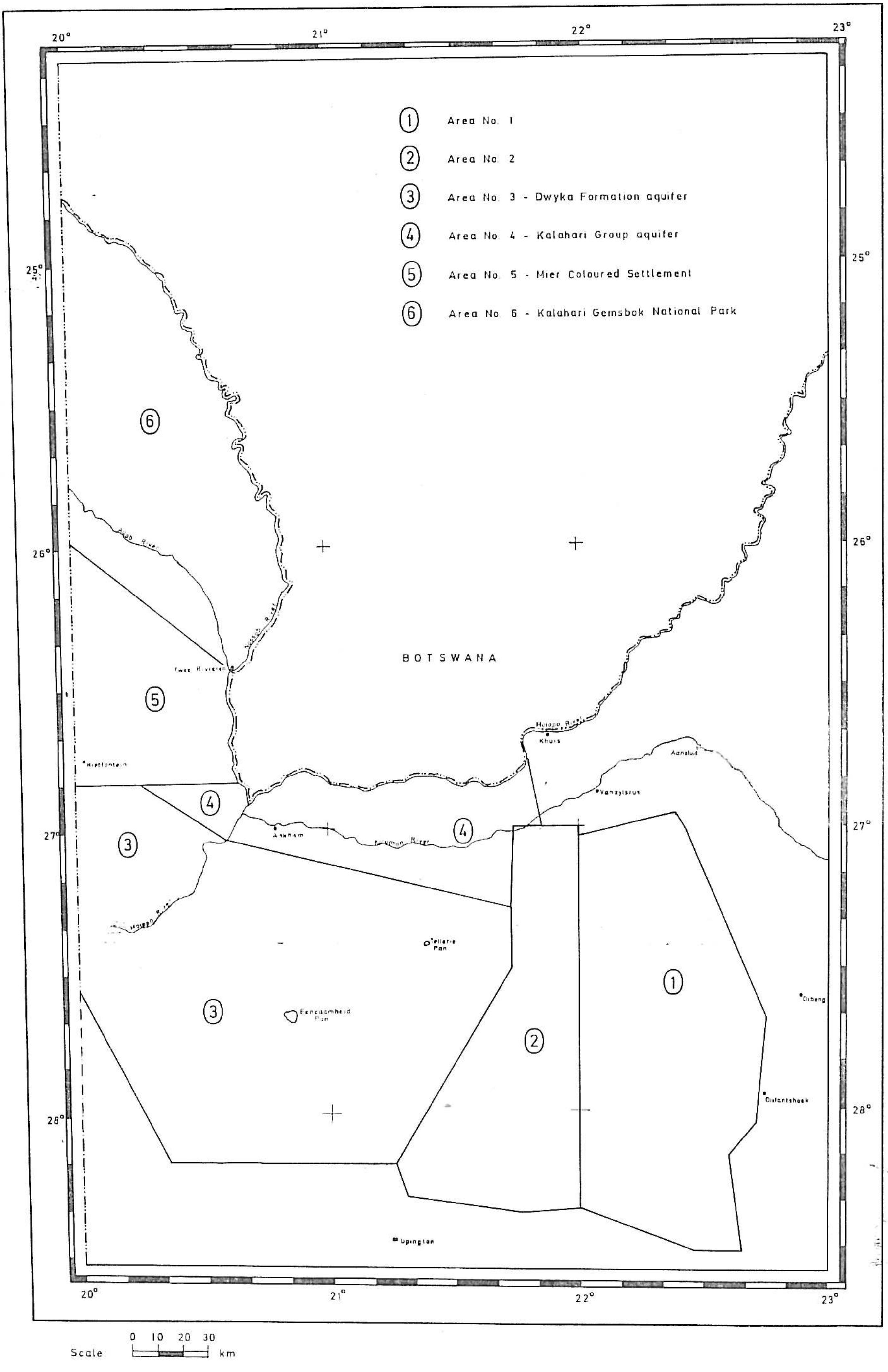

Fig. 2 Map showing subdivisions of the Kalahari Groundwater Project

Area 1: Between the Korranaberg-Langeberg Range and the Kuiepan Hills (The pre-Karoo aquifer).

Area 2: Between the Kuiepan Hills and the eastern suboutcrop of the Dwyka Formation (The pre-Karoo aquifer).

Area 3: The Dwyka Formation aquifer, bounded by area 2 in the east, South West Africa/Namibia in the west, the southern boundary of the Mier Coloured Settlement and a line, some 20 - 25 km south of the Kuruman River in the north, and approximately the 28° latitude in the south.

Area 4: The Kalahari Group aquifer, situated between the northern boundary of area 3 and the Republic of Botswana.

Area 5 The Mier Coloured Settlement.

Area 6: The Kalahari Gemsbok National Park.

Reports on the areas 1, 2 and 3 have been completed and are available from the Directorate of Geohydrology, Pretoria.

This report deals with area 5 and assesses the groundwater occurrence and its agricultural utilization.

In collaboration with the Schonland Research Centre (SRS) for Nuclear Sciences of the University of the Witwatersrand, Johannesburg, ground water samples for environmental isotope investigations were taken from the entire investigation area. The purpose of this specialized investigation was to gain a better understanding of the ground water recharge, underground water movement, mixing,ageing, etc. A separate report will be presented by B. Th. Verhagen of the SRS, later in 1985.

All the borehole and related information is presented in an archives system, consisting of 5 volumes which, together with this report, forms one unit.

1.1 Problems encountered during field survey.

The field survey was carried out between March and July 1984.

(a) As can be seen on the archival record sheet, the collar elevations of nearly all the boreholes were estimated from the 1:50 000 topo cadastral maps on the basis of spot heights. The exceptions were a few boreholes along the Nossob River course which were precisely levelled. In the study area especially, the spot heights are very scarce and the estimated collar elevations can therefore be in error of up to several metres. The contour maps using these elevations (maps 2 and 5) are thus of rather limited accuracy.

(b) Owing to the lack of reference points, the positions of the boreholes are also only approximate. These could be in error of up to approximately 1 km from the true position.

(c) The geological logs were compiled by drillers and the lithological descriptions can only be evaluated with much caution.

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2. PHYSIOGRAPHY

2.1 General:

The investigation area No 5 is part of the vast Southern African Kalahari Basin, and is located at its south-western margin. The basin covers more than 2 500 000 km² of which approximately 1 600 000 km² are occupied by sand (THOMAS, 1982). The Kalahari Basin stretches from the Orange River in the south to the Zaire River watershed in the north and from the Botswana and Zimbabwe highlands in the east to the mountain ranges of central South West Africa/ Namibia and Angola.

2.2 Topography:

The Mier area is approximately 3 300 km² in extent. The elevation above mean sea level ranges from about 950m in the north-west to 780m in the south (Haakskeen Pan). The dominant features are undulating , bright red, longitudinal sand dunes with an average height of 15 to 20 m above the "streets". The overall strike orientation of the dunes is north-west to south-east.

The small region around Rietfontein and Leeu Bos in the south of the investigation area, is the only portion not covered with dunes and here the landscape is virtually flat.

2.3 Climate:

2.3.1 Temperature:

Owing to the semi-arid conditions, the region experiences extreme temperature fluctations. The day and night temperatures vary considerably. The average summer maximum and minimum temperatures are 36°C and 20°C respectively. During the winter months the average maximum temperature is about 20°C and the average minimum temperature varies between 0°C and 5°C. Night frost has been recorded.

2.3.2 Rainfall:

The annual rainfall varies from approximately 170 mm in the south-west (station Rietfontein) to approximately 210 mm in the north-east (station Twee Rivieren). The rain occurs mostly as thunderstorms between February and April.

During the years 1974 - 1976 a noticeably high rainfall was recorded. (See Table 1 below):

Station	1974	1975	1976
Rietfontein	603	212	425
Twee Rivieren	560	303	484

Table 1: High rainfall figures (mm) 1974 - 1976

2.3.3 Evaporation:

The evaporation data are very limited. In order to get an approximate picture of the evaporation, Table 2 was compiled. Here, data from Twee Rivieren in the Kalahari Gemsbok National Park (KGNP) is presented. The average value, based on measurements over 23 years from 1961 to 1983, amounts to 2 739 mm/year. No data concerning the evapotranspiration is available.

2.4 Surface drainage:

The area 5 forms a part of the lower Molopo River subdrainage area (D42). With the exception of the dry Nossob River course in the east, the area lacks surface drainage. The entire rainfall is accumulated within the area where it evaporates, transpires and infiltrates into the sand. For this reason no water reaches the Nossob River which is the main receiving stream. After heavy thunderstorms some water flows in the so-called "streets" between the dunes. Shortly after the rainfal event the main volume of the rainwater has either evaporated or is retained in the sandcover. Only a small fraction under favourable conditions may infiltrate down to the ground water table.

In the Rietfontein area where no dunes are present only a limited surface drainage is developed. The sporadic run-off is collected by the numerous pans.

3. PREVIOUS INVESTIGATIONS

A fairly large number of publications, dealing with the Kalahari semi deset and similar regions, have been published over the last three decades. Since the early seventies, in particular, the southern Kalahari has experienced intensified investigation. Although none of these publications deal with the study area, the investigation results can be extrapolated and applied.

SMIT (1972) discussed the revision of the Dwyka stratigraphy in the Northern Cape and its correlation with South West Africa/ Namibia and Botswana.

In the following years most of the publications on the Kalahari dealt with isotope investigations of the ground water with special reference to the rain recharge problem under arid and semi-arid conditions. Among them are two main opposed theories. VAN STRAATEN (1955), VOGEL & BREDENKAMP (1969) and FORSTER et al. (1982) are of the opinion that rain recharge under the present climatic conditions does not take place in area with a sand cover exceeding 5m. On the other hand MAZOR et al. (1977), VERHAGEN et al. (1979) and VERHAGEN (1983) state that irregular recharge does take place under the above-mentioned conditions.

HEATON (1983),1984) investigated the occurrence and origin of nitrate concentrations adjacent to the South African border in South West Africa/ Namibia. This might indirectly prove the existence of vertical rain recharge.

TABLE 2 : EVAPORATION. STATION: TWEE RIVIEREN, KALAHARI GEMSBOK NATIONAL PARK

Year	Total potential evaporation (mm)
1961	2 317
1962	2 524
1963	1 864
1964	3 319
1965	3 650
1966	3 617
1967	3 358
1968	2 469
1969	2 822
1970	2 922
1971	2 577
1972	2 638
1973	2 917
1974	2 714
1975	2 582
1976	1 895
1977	2 843
1978	2 391
1979	2 872
1980	2 290
1981	2 360
1982	2 690
1983	3 371
23 years	63 002 mm

$\bar{x}$ = 2 739 mm/a

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LANCASTER (1983) and HEINE (1979, 1982) dealt with quaternary climatic changes in the Kalahari with reference to the pan genesis and anomalous water table behaviour. The postulated climatic changes for the area are: approximately 16 000 years B.P. - wet, 8 000 years B.P. - wet, and recent - dry.

STETTLER (1980) presented "A preliminary inter-pretation of the Unions End and Witdraai magnetic maps".

A recent investigation emphasizing the geology of the Kalahari deposits with only a subordinate discussion of geohydrological aspects was carried out by THOMAS (1982).

The stratigraphical subdivision of the study are in this report is based on the South African Committee of Stratigraphy (SACS, 1980).

4. GEOLOGY

The geology of 90% of the study area comprises the sediments of the Kalahari Group. Only a few boreholes have penetrated this succession and intersected Dwyka/ Prince Albert sediments or post Dwyka intrusions At Rietfontein, Dwyka sediments outcrop and Nama sandstone and shales form an elevated anticline just west of the village.

The collation of geological information has been hampered by the lack of borehole data. This can be attributed to the fact that the present field survey is the first to be carried out in the Mier Coloured Settlement.

4.1 Pre-Kalahari geology:

Very little regarding the pre-Kalahari geology (map 8) is known. Those boreholes which penetrated the Kalahari sediments were drilled only a few metres into the underlying formations. It is therefore difficult to make an exact statement about the stratigraphy of the encountered floor strata. The interpretation of the magnetic sheet, Witdraai (2620) by the Geological Survey, distinguishes only between Dwyka shales and tillite, and the dolerite intrusions.

The oldest outcropping rocks of the investigated area are Nama Group sediments, north-west of Rietfontein. According to THOMAS (1982), they belong to the Breckhorn Formation of the Fish River Subgroup and consist of brown and purplish sandstone and subordinate brown micaceous shales with clay-pellet horizons

The Dwyka Formation outcrops around Rietfontein. It consists essentially of a sandy shales , although tillite are also present Northwards from the village the Dwyka sediments comprise coarse, brown, immature conglomerate, cross bedded gritstone and sandstone, and nodules of brown, ferrugineous limestone (THOMAS, 1982).

Map 8 also presents the results of the preliminary interpretation of the Witdraai magnetic map by STETTLER (1980). In general only magnetic intrusions (sills) are distinguished. STETTLER states, "The parts (of the map) not underlain by sills show very gentle changes in the total magnetic field and are only disturbed by near surface dyke intrusions. This suggests that thick sequences of sedimentary rocks occur here and allows conclusions to be drawn about the behaviour of the basement itself."

According to this interpretation the outcropping Dwyka sediments in the south-west of the study area are underlain by dolerite intrusions. At this stage no borehole has intersected the dolerite. It may therefore be concluded that either the sill is deeper than interpreted or there is no dolerite at all. It should be noted, however, that the boreholes in this region are only some 30 - 40 m deep.

On map 5 the pre-Kalahari topography in metres above mean sea level is shown. The contours suggest a north-south orientated, pre-Kalahari drainage trough through farms 110, 109, 106 and continuing in a southerly direction. West and east of this trough only a slightly und rlating surface with a gentle southerly gradient appears to be present.

In the north of the study area, i.e. around farms 11 - 24, 38 - 41, 46 and 60 several hills possibly of dolorite (sill) are present.

4.2 Kalahari Group:

The deposits of the Kalahari Group cover the entire area except around Rietfontein.

The Group consists of sand, calcrete, silcrete, limestone, grit, conglomerate, sandstone, clay and gravel (THOMAS, 1982), and is subdivided into four Formations from the top to the bottom as follows:

(a)	Gordonia		Sand (building dunes)
(b)	Eden	-	Gravel and sand, mostly clayey, locally calcified and silicified
(c)	Budin	-	Clay, gravel
(d)	Wessels	-	Gravel, clayey gravel; sandstone, partly or entirely calcified.

The age of this succession ranges from the late Palaeocene to the upper Pleistocene (SACS, 1980).

Borehole data in the study area confirm the existence of a dominant basal layer with a thickness of several tens of metres. This is locally known as "baksteen", and is a red, slightly consolidated, sandy clay. This basal layer can most probably be correlated with the Budin Formation. The overlying sandy strata most probably represents the Eden Formation.

On map 4, the Kalahari isopachs are constructed. Some doubts exists where the succession was not fully penetrated.

According to the borehole logs the Kalahari Group reaches a maximum thickness of approximately 130m in the north-west of the investigated area. From here south-eastwards to farm No 111 the Kalahari thickness remains constant at about 100m. Towards the south-west, south and further south east, the thickness gradually diminishes. The outcropping Dwyka Formation forms a line stretching from farm No. 97 in the north-west via farms 103 and 105 to farm No 107 in the south-east.

On farm No 11 a low in the thickness occurs. This is possibly caused by a dolerite intrusion elevated above the Dwyka surface.

All the boreholes were drilled in the so-called "streets". These are the depressions between the underlating dunes. As a result the total indicated thickness of the Kalahari Group does not include a large portion of the Gordonia Formation. (The height of the dunes is from 12 to 30m).

5. GEOHYDROLOGY

The ground water in the investigated area occurs in the following four formations:

(1) Sandstone and shale of the Nama Group

(2) Shale and tillite of the Dwyka Formation

(3) Sediments of the Kalahari Group

(4) Weathered magmatic intrusions (sills)

5.1 Ground water in the Nama Group:

Very little information on this aquifer the Nama's water-bearing properties are available. In the limited outcrop areas west and north-west of Rietfontein, ground water of acceptable quality is found at a depth of some 10 metres. Further north and east of Rietfontein the Nama is covered with thick sediments of the Kalahari Group and possibly Dwyka Formation as well.

The ground water level contours in m.a.m.s.l and the ground water flow directions in this aquifer are presented on map 2. The contours are between 880 and 850 m.a.m.s.l When this contour pattern is compared with the pattern further east of the Nama/Dwyka geological contact (also indicated on map 2). it is evident that the Nama aquifer is possibly independent. It could, furthermore, be expected that artesian or subartesian conditions might occur in boreholes drilled north, south and east of the Nama outcrops under the impermeable Dwyka cover.

5.2 Ground water in the Dwyka Formation:

The Dwyka aquifer outcrops south-west of the zero contour line of Kalahari cover (see also map 2). Here, the ground water elevation ranges between 840 and 820 m.a.m.s.l and the ground water level is less than 10m below surface.

According to cross-section A - B this aquifer also occur in the north-eastern part of the study area. Owing to insufficient borehole data no further statement can be made.

5.3 Ground water in the Kalahari Group:

The Kalahari Group is the main aquifer in the investigated area. The water level measurements represent the period from March to July 1984. In additon, the rest water levels, measured where obtainable on borehole completion, were also taken into account. This was done in order to avoid creating local contour lows resulting from subsequent pumping. The year of measurement is appended to those boreholes where more than one ground water level was available. In some cases a capital letter P indicates a pumping level.

The water level contours (map 2) are seen to decline from 890 m.a.m.s.l. in the north-west to 810 m.a.m.s.l. in the south-east. Some local highs occur along the Nossob River course and on the farms 5, 18 and 123. These highs may possibly be the result of a higher Kalahari floor elevation (e.g. dolerite hills) and/or better infiltration and recharge conditions around these localities.

The depth to ground water (map 3) is in the range of from less than 10m down to 80m. A local maximum of 90m below surface occurs on the farms adjacent to farm 79. In general the ground water level shallows from the north-east towards the east, south-east and south. Along the Nossob River course the ground water level is less than 30m below surface, and towards the zero line of the Kalahari cover it is less than 10m below surface.

5.4 Ground water in weathered magmatic intrusions:

These rocks have been encountered in a very few boreholes only. So far no water has been struck in these intrusions-.

5.5 Ground water drainage:

As indicated on map 2 it appears that the ground water flows from the north-western part of the investigated area, possibly recharged by the Auob River, in a south-easterly and southerly direction.

The ground water divide between the Nossob River drainage and the Hakskeenpan extends from the farm Klein Mier No 2 in the south, northwards via farms 123, 124, 73, 58 and 28 and into the KGNP.

Generally, the whole ground water flow pattern fits fairly well with the adjacent north-western portion of area 3 (see report GH3367), which is situated south of the study area.

5.6 Ground water quality:

The ground water quality of area 5 is poor. On map 7 the electrical conductivity (EC) contours are shown. Values higher than 2000 mS/m (or approximately 13 000 mg/ℓ TDS) occur along the boundary with area 6 (KGNP) and along the Nossob River course. This water is not suitable for stock watering. The maximum limit for sheep is 12 000 mg/ℓ TDS or 1 800 mS/m, (DE WET, 1980). The only reasonable water (EC 300 mS/m), which could also be used by humans occurs in the Rietfontein area and along a line stretching north-west from farm 59 via farm 46 to 20.

Four ground water types (referring to JOHNSON'S (1975) ground water cycle) can be distinguished.

(1) HCO_3-type

(2) HCO_3-Cl-type

(3) Cl-SO_4-type

(4) Cl-type

For determining these ground water types the minimum limit of an element to be stated is 20 meq% of the respective water analysis. The dominant elements are mostly in the range of 50- 80%.

This ground water cycle is formulated as follows:

$$Ca/Mg\ (HCO_3)^2 \rightarrow Na\ HCO_3 \rightarrow HCO_3 \rightarrow$$

$$HCO_3 + Cl \rightarrow Cl + HCO_3 \rightarrow Cl + SO_4 \rightarrow Cl$$

The HCO_3-Cℓ-type is the dominant water (map 6). Generaly, this pattern corresponds to that of the EC contours, i.e. where there is an EC/low, the HCO_3 type of waters will be expected.

For the graphical presentation of the water analyses the Piper diagram was used.It can be seen onf Figure 3 the majority of the water samples plot in the lower half of the diamond-shaped diagram. This field represents waters normally found in a dynamic basin environment, and those commonly encountered in hydrology (JOHNSON, 1975). Furthermore the progression from south to east within the diamond represents the direction of concentration and precipitation i.e. from high $NaHCO_3$ concentration (south) to high NaCℓ concentration (east). Generally these waters plotting in the lower half of the Piper diagram are found in the south-west of the study area. The top half of the diamond is more representative of the rest of the investigated area i.e. with a more or less thick Kalahari cover. This field represents static waters and other unusual waters, high in Mg/CaCℓ₂ and Ca/Mg SO_4 (JOHNSON, 1975).

On map 10 the nitrate concentration in ground water is shown. From north to south the concentration of this ion gradually decreases, from 250 mg/ℓ tp less than 45 mg/ℓ.

The origin of the nitrates in concentration up to 250 mg/ℓ NO_3 may be explained by the physical and chemical soil processes when rain water is available. Values higher than this concentration are recorded as pollution derived from livestock waste (HEATON, 1984). The recommended World Health Organisation limit for human consumption is 45 mg/ℓ NO_3.

Special attention should be given to the fluoride concentration (map 9). The maximum limit for potable water is 1,5 mg/ℓ and 3,0 mg/ℓ is the critical limit. A higher concentration than the critical limit causes damage to human health. These concentrations are recommended by the World Health Organisation.

In more than 70 cases the fluoride concentration is far more than 3,0 mg/ℓ. The origin of the high fluoride concentrations in ground water of the Mier area remains unknown. No correlation with the occurrence of dolerite is found (see map 9).

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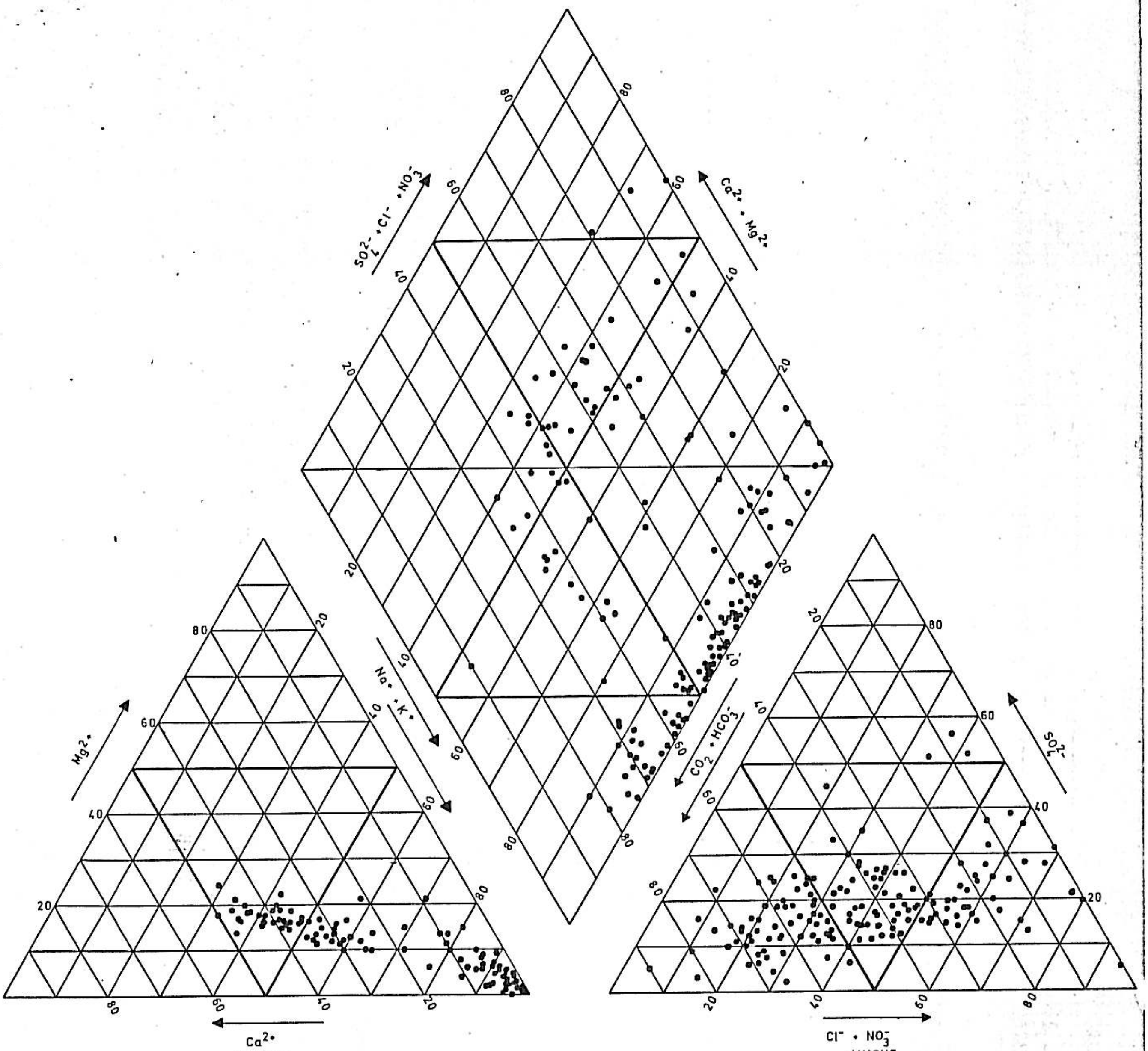

Fig. 3: Piper diagram representing water samples from the entire study area

5.7 Ground water recharge:

No publication exists on ground water recharge in the investigated area. The present survey is the first to shed some light on this phenomenon. It appears, however, that some underground flow of water from the north-west direction (upper course of the Auob River) towards Rietfontein and Haakskeenpan does exist in the area. Some recharge from the river water also occurs along the lower Nossob River course. At Rietfontein, due to the absence of the sandy cover, the Dwyka aquifer appears to receive a substantial rain recharge. This is substantiated by the Piper diagram where these waters plot in the lower half of the diamond where waters of a dynamic basin environment are represented (section 5.6). Although no serious shortage of water supplies has been encountered in this region, no quantitative assessment is possible at this stage.

As several boreholes were sampled for environmental isotope investigations it is hoped that the recharge problem will be elucidated. A separate report on this investigation will be compiled by B.T.H. VERHAGEN possibly early in 1986.

6. CONCLUSIONS AND RECOMMENDATIONS

(1) The ground water bearing formations in the study area are the Nama Group, the Dwyka Formation and the Kalahari Group. Generally, the permeability is very low , explaining low borehole yields (approx. 0,1 ℓ/s to 1.0 ℓ/s).

(2) High fluoride concentrations (up to 52,6 mg/ℓ) occur within the investigated area. The origin remains unknown.

(3) Boreholes with more than 3,0, mg/ℓ F (map 9) should be avoided for human consumption.

(4) High nitrate concentrations ($>$250 mg/ℓ) occur along the northern area boundary and in several patches distributed over the entire study area (map 10).

(5) In order to avoid the drilling of unsuccessful boreholes the following regions should be investigated geophysically:

(a) From farm No 95 in a northerly and westerly direction

(b) On farms 44, 45, 56, 57, 73, 74 and 112

The areas with thin Kalahari cover and those with shallow dolerite sills should, by this means, be delineated and avoided.

(6) It is also recommended that no further boreholes should be drilled in regions where the EC exceeds 2 000 mS/m

(7) The recharge of the ground water in the investigated area cannot be discussed at this stage. As several boreholes for the natural isotope investigations were sampled, however, it is hoped that some aspects of the ground water recharge will soon be better understood. The results of this investigation will be presented in a separate report by B.T.H. VERHAGEN.

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