

A GROUNDWATER INVESTIGATION OF THE  
DINOKANA AREA - BOPHUTHATSWANA.

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PRETORIA

CONTENTS:

I INTRODUCTION

- II General
- II2 Investigation area
- II3 Investigation Program

II GEOLOGY OF THE DINCKANA AREA

- III1 Introduction
- III2 Black Reef Series
- III3 Dolomite Series
  - III3A Dolomite
  - III3B Banded Ironstone
- III4 Pretoria Series
  - III4A Timeball Hill Stage
  - III4B Daspoort Stage
- III5 Alluvium
- III6 Structural Geology

III BOREHOLESURVEY, EXPLORATION DRILLING AND PUMPING TESTS,  
SPRINGFLOW ANALYSES:

- III1 Existing Boreholes
- III2 Exploration drilling
- III3 Hydrological pumptests and yield tests
  - III3A Waterlevel variations prior to the tests
  - III3B Execution of the tests
  - III3C Results of the tests
  - III3D Waterquality during tests
- III4 Springs
  - III4A Location
  - III4B Springflow

- III4B1 Dinokana springs
- III4B2 Manwane spring
- III4B3 Tweefontein springs

#### IV GEOHYDROLOGICAL INTERPRETATION

- IV1 Streams
- IV2 Geohydrological classification

- IV2A Good Aquifers
- IV2B Reasonable Aquifers
- IV2C Poor Aquifers

- IV3 Rainfall
- IV4 Replenishment
- IV5 Groundwaterflow

#### V "SUPPLY AND DEMAND" OF WATER

- V1 Supply from the Dinokana springs
- V2 Supply from exploration boreholes
- V3 Present groundwater use and future demands
- V4 Conclusion

#### VI SUMMARY

- VI1 Geology
- VI2 Existing boreholes
- VI3 Exploration boreholes
- VI4 Supply and demand

LIST OF MAPS, PROFILES AND SUPPLEMENTS:

Map No. 1	Borehole locations - scale 1:50 000
Map no. 2	Geological map - scale 1:50 000
Map no. 3	Geohydrological map - scale 1:50 000
Profiles	Geo (hydro) logical
Supplement no. 1	Borehole logs
Supplement no. 2	Magnetometer profiles
Supplement no. 3	Table of waterlevels, borehole depths and borehole-yields
Supplement no. 4	Waterlevel variations
Supplement no. 5	Location plan and profiles of boreholes MWL 10, 12, 20, 20a and 20c.
Supplement no. 6	Drawdown recovery curves of pumping test in borehole MWL 12
Supplement no. 6a	Drawdown recovery curves of hydrological pump test in borehole MWL 20
Supplement no. 7	Springflows
Supplement no. 8	Yearly rainfall at the Dinokana weather station
Supplement no. 9	Pumpage from Dinokana's Upper Spring.

LITERATURE:

- |   |      |   |
|---|------|---|
| Alex du Toit                                | 1956 | Geology of South Africa   |
| Davis de Wiest                              | 1966 | Hydrogeology  |
| J.F. Enslin                                 | 1970 | "Die grondwaterpotensiaal van Suid-Afrika   |
| "Waterbeplanningskomitee vir Wes Transvaal" | 1975 | "Vraag na en aanbod van water in die Wes Transvaal en Postmasburg - Mafeking gebied tot die jaartal 2000" |
| M.P. Mulder                                 | 1974 | Bo-Molopo ondergrondse waterbeheergebied, Departement van Waterwese                                       |

## I. INTRODUCTION:

### I 1. GENERAL:

The groundwater investigation was carried out at the request (Original correspondence could not be traced) of the Department of Bantu Administration and Development to assess the groundwater potential of the area surrounding the proposed capital Leherutshe of Bophuthatswana, approximately 10 km east of Dinokana. Groundwater it is anticipated would be the main source of the capital's water supply.

According to the report of the "Waterbeplanningskomitee vir Wes-Transvaal", the projected population of "Leherutshe" will be 21000 in 1985 and 45 500 at the turn of the century. The report also estimates that in 1985 the per capita water consumption by the "urban Bantu" will be 185 l/day and will increase to 227 l/day in 2000. It then follows that in 1985 Leherutshe's water consumption will be  $1,42 \times 10^6 \text{ m}^3$  (44 l/s), while the consumption around 2000 will be in the order of  $3,7 \times 10^6 \text{ m}^3$  (120 l/s).

The "Beplanningskomitee" also makes the suggestion that part of Leherutshe's watersupply should be derived from the spring at Dinokana (map no. 3). Quoting the report : "n Pyplynskema sal ook aangebring moet word om water van die dolomitiese fonteine by Dinokana na die nuwe dorp Leherutshe te voer waar dit vir huishoudelike gebruik en vir nywerheidsdoeleindes aangewend sal word".

### I 2. INVESTIGATION AREA:

In the groundwater investigation particular attention was given to the dolomite and the quartzites of the Pretoria Series, lying respectively west and east of Dinokana. From previous experience it was known that better aquifers could be expected to be contained in these formations. The geology of the area therefore determined predominantly the area of investigation.

The investigated area extends roughly from the Bophuthatswana border with South Africa in the south to the Botswana border post at "Skilpadhek" in the north. Westward the area is approximately bounded by the Botswana border and in a north-easterly direction the investigation area stretches out as far as a 10-15 km from Dinokana (map no. 1). The total area covers approximately 750 km<sup>2</sup> (see map no. 1).

I 3. INVESTIGATION PROGRAM:

The investigation was carried out from August 1976 until March 1977. The main topics of the program were the following:

- (i) A preliminary study of aerial photographs. The results of which were compared with a previously compiled provisional geological map (1:50 000) of the geological survey covering part of the area under investigation.
- (ii) A geological field study which also included a borehole survey and magnetometer work. Waterlevels were measured in the boreholes scattered throughout the area.
- (iii) Drilling was undertaken by the Boring Sub Division. The objectives were to establish the geology and to locate water-yielding geological formations. Use was made of a rotary air drill and a percussion drill.
- (iv) Pumping tests were carried out to estimate the transmissivity and the storage coefficient of suitable aquifers and the yield on selected boreholes.

In addition some minor programmes were carried out:

- (a) Visits at the farm Rhenosterfontein and farmers around Zeerust and the Fluorspar mine. Information was collected about their water wells. Locations of borehole sites could then be determined in the Dinokana.

area because of the geological similarity between this area and the region around Zeerust.

- (b) Flow measurements were taken in the field and spring flow data collected at the Department of Water Affairs.
- (c) Geological data and information on groundwater yields of existing boreholes were obtained from the Department of Agricultural and Technical Services, and the Department of Bantu Administration and Development.
- (d) Rainfall data over a period of 40 years at Dinokana were collected at the Weather Bureau in Pretoria.
- (e) Elevations of all the exploration boreholes and some of the existing boreholes were surveyed.

## II GEOLOGY OF THE DINOKANA AREA:

### II 1. INTRODUCTION:

The area is underlain by the Black Reef, Dolomite and Pretoria Series of the Transvaal System. The most common rock types are shales, quartzites and dolomites which dip slightly to the north-east.

### II 2. BLACK REEF SERIES:

The quartzite in the west (map no. 2) was observed as a light coloured, reasonably coarse rock. The easterly dip was estimated in the order of 20° to 30°. The outcrop zone is rather thin from a 100m to 400m. It is bounded on the westside by sediments and volcanics of the Zoetlief formation and Ventersdorp System. The contact with the dolomite on the west is gradational with alternating bands of dolomite, quartzite and shale.

### II 3. DOLOMITE SERIES:

#### II 3A Dolomite:

A typical sample of dolomite can best be described as having a blue greyish colour and being mostly of a compact nature though millimeter-sized openings can regularly be observed, filled with secondary quartz. The individual beds can range in thickness from 0.1 to more than 1m. The strike and dip are difficult to determine, but when so a 5° to 20° dip in north-easterly direction is most common. The total thickness of the dolomite varies from approximately 1500m in the south to only 400m in the north. The reason for the apparant thinning of the Dolomite Series has not been adequately explained; most likely it is due to stratigraphic wedging out of the dolomite basin in a north-westerly direction.

Locally one may find different rock types and minerals within the dolomite. It was observed that in the dolomite, layers of shales of variable thicknesses (map no. 2) occur. For example in boreholes MWL 2, 13, 14, 16, and 17 (supplement no. 1) shalebands were found. Also just on top of the Dolomite Series a thin band (2 - 10m) of shale, a grey soft rock was encountered (borehole MWL 16). Pyrite occurs in the top layers of the dolomite as well as in this formation of greyish shales. Actinolite also is a very common mineral in the upper part of the dolomite.

Another geological feature in the dolomite is the vertical or steeply dipping quartz vein. The width is not more than a few meters. In the southern part of the area (map no. 2) these veins run in a northsouth or even southwest-northeast direction while in the northern part the veins have a predominant southeast-northwest strike.

Chert is common, especially near the top of the Dolomite Series where it forms low ridges. Quartz veins intersecting the chert ridges cannot be clearly traced within the chert. At those places the rock gives the impression of chert impregnated with quartz.

A number of dolerite dykes traverse the dolomite in a west to east direction (map 2). The top part of this green-bluish rather fine-grained rock is in most places weathered into a tough clay and therefore was located magnetically. (Supplement No. 2 map no. 2). It could be concluded that the widths of the dykes varies between 10m and 30m. At the location of boreholes MWL 1, 2 and 6 (map no. 2) two dolerite dykes apparantly cross each other. The north-south dyke could however not be traced and it might be a local extrusion of the east-west running dyke, in this particular place. Quartzveins might in places be conductors of groundwater and where they intersect dolerite dykes - which are groundwaterbarriers - the question arises of relative age; which crosses which? Magnetometer profiles (supplement no. 2 M24, M26) suggest that the dolerite dykes are continuous.

II 3 A. BANDED IRONSTONE:

On top of the dolomite a formation of Banded Ironstone is exposed. It consists of thin layers (1 - 10mm) of ferruginous rock combined in thicker layers up to 0 - 5m thick. The total thickness of the formation varies considerably. Owing to the well bedded nature of the rock, the strike and dip are easily to determine. The average dip varies between 10 and 20° while the strike direction is northwest-southeast. According to du Toit's Geology of South Africa one finds on top of the Banded Ironstone a basal conglomerate. It is exposed at the Manwane spring. Here, though more breccia-like the rock can be described as very hard and consisting of fragments of chert in a brownish groundmass.

Another conglomerate occurs in places on top of the Banded Ironstone. This conglomerate is of limited thickness (less than 10m in most places) and can be found in the valleys east of the dolomite plateau (map no. 2). It is a brittle rock with more or less rounded grains of limonite, chert, quartz and banded ironstone in a brownish to darkgrey groundmass.

II 4. PRETORIA SERIES:

II 4 A. TIMEBALL HILL STAGE:

On top of the basal conglomerate one passes into the rather weathered and colourful shales of the Pretoria Series (Timeball Hill Stage) Brown, red to purple coloured on the outside and with a more greyish fresh colour the beds dip an estimated 10 - 20° in a north-easterly direction. Fine layering is often absent in the harder shales but is clearly visible where this rock is soft.

At the base of the Timeball Hill Stage a thin quartzite band is locally developed - only south of Dinokana - known as the polo ground quartzite. White, red and even bluish coloured, this rather coarse grained rock dips 30 - 40° to the north-east.

The top of the mountain range bordering the north-east side of the

'Dinokana Valley' consists of a fine to coarse grained, white to reddish quartzite (map no. 2. Timeball Hill Quartzites). Close to borehole MWL 20 the strike was measured as  $320^{\circ}$  and the dip  $20^{\circ}$  northeast. Fracture lineations have main directions of  $30^{\circ}$  and  $110^{\circ}$ . A zone of "broken" quartzite (thickness  $\pm 1m$ ) separates white to red quartzite from a dark coloured variety that does not outcrop. It was struck in boreholes MWL 20 and MWL 21 where this quartzites had a thickness of respectively 32 and more than 57m. At some levels within the dark quartzite shale was found, while pyrite is common.

#### II 4 B. DASPOORT STAGE:

The contact of the Timeball Hill quartzites and the overlying Daspoort shale is obscured by alluvial deposits. Further northeast (map no. 2) outcrops of this micaceous grey soft shale, were found on the slopes of the hills.

Resting on the shale one finds a breccia with a thickness between 5m and 20m and consisting of particles of quartzite embedded in a dark groundmass; the whole of which is quartzified. Beds are sloping towards the northeast with a dip of  $15^{\circ}$ .

Igneous rocks are directly overlying this breccia and presumably can be classified as the Ongeluk Volcanics. However the normal volcanic character of these igneous rocks could not be seen in the field. What was observed was a bluish rock weathered brown of which the mineral composition closely resembled dolerite.

#### II 5. ALLUVIUM:

Extensive alluvial formations have been deposited in the valley south-east of Dinokana overlying the Timeball Hill Shale and also farther east overlying the Timeball Hill Quartzites and Daspoort Shales, (map no. 2). There is not much information known, about the thickness of this alluvium. Only in boreholes MWL 20

and MWL 21 (supplement no. 1) respectively 15m and 30m of unconsolidated material was found upon a basement of quartzite.

II 6.        STRUCTURAL GEOLOGY:

Although only limited information on dips and strikes is available a picture can be built up of the most important structural features.

Over the whole area beds are generally dipping  $5^{\circ}$  to  $25^{\circ}$  towards the north-east, an exception being the quartzites (polo ground quartzites) south-east of Dinokana (map no. 2). As already mentioned their dip appears to be in the order of  $30 - 40^{\circ}$ . Another exception to the general trend are the practical horizontal beds of dolomite exposed underneath the banded ironstone just west and south of Dinokana (map no. 2). This might indicate some sort of an anticline of which the axis runs in a south-east north-west direction. Synclinal folding to the south-west of this possible anticline has not been observed except for a rather small south-north-west running syncline in the banded ironstone ridge around 8 km south-south-east of Dinokana (map no. 2).

In the banded ironstone ridge minor folding was observed with the axis running in a southwest-northeast direction.

When one draws a line on map no. 2 through Dinokana in a west south-west to east north-east direction one notices a different faulting pattern on each side of this line. On the south side faulting is more limited and trends about north to the south, whereas north of this line, and also close to Dinokana, faulting is more extensive. There the faulting direction is perpendicular or parallel to 'the strike' direction of the bedding planes. The localisation of the faults has been determined in most cases with the aid of aerial photographs. Especially in dolomite, faults are difficult to trace in the field.

III BOREHOLE SURVEY EXPLORATION DRILLING AND PUMPING  
TESTS, SPRINGFLOW ANALYSIS:

III 1. EXISTING BOREHOLES:

A number of windpumps have been installed to supply groundwater for cattle watering. During the period September - December 1976 most of the (windpump) boreholes in the area were surveyed. Locations were plotted and the depths to the waterlevels were measured with an electric sounder. Most collarheights were established with accurate levelling from Tr 19 beacons (chapter 1) and the more outlying boreholes were measured with an aneroid barometer (supplement no. 3). An error in borehole elevation of 2m to 3m with this last-mentioned method is possible. The watertables were then calculated in meters above sealevel.

Information on borehole depths and yields was obtained from the Department of Bantu-administration and Development. The yields were determined by the usual 9-hour pumping test. During the nine hours of this test in which normally a mono pump (maximum capacity of 3 to 5 l/s) is used the pumping rate is measured every hour. The yield of the borehole then is defined as the pumping rate which can be maintained throughout the test.

In supplement no. 3 are shown the depths and the yields of the boreholes and the water levels. The heights of the water levels are shown on map no. 3 together with the yields.

Supplement no. 3 shows, that depths to water levels in the various boreholes range from 0,9m to 30m. The yields of the boreholes vary between 0,37 l/s and 3,75 l/s.

III 2. EXPLORATION DRILLING:

The actual boring program started in October 1976 and lasted until February 1977. Altogether 24 holes have been drilled at carefully selected locations. The geology has played the most important role in determining the drilling sites, with consideration

of groundwater flow direction and the extent of the groundwater catchment areas. Boreholes MWL 1, 2, 5 and 16, were drilled in the metamorphic contact zones of dolerite dykes in the dolomite. Other drilling sites in the dolomite were selected on quartzveins : boreholes MWL 1, 2, 3, 5, 6, 9, 10, 11 and 12); on faulting zones : boreholes MWL 3, 12, 18 and 19, in weathered zones : boreholes MWL 7, 8, 13, and 14, on the edge of a sinkhole : borehole MWL 4 or at the outlets of alluvial filled valleys south of Dinokana : boreholes MWL 15, 16 and 17.

The boreholes were drilled to depths varying from 15 to 97m. In every borehole samples were taken at one meter intervals. The logs are shown in supplement 1. Dry boreholes (11) and boreholes with insufficient water (5 holes,  $< 0,25$  l/s) have been abandoned. The other boreholes were prepared for pumping tests later on (8). For this purpose the casings were retained inside the borehole.

The borehole logs (supplement no.,. 1) show also the depths at which water was struck; together with the 'static' waterlevels (see also supplement no. 3). It is noticed that in boreholes MWL 3, 10 and 12 the waterlevels are very shallow, from 2m to 4m below groundsurface. In boreholes MWL 20 A, B and C the waterlevels are from 7m to 10m and in boreholes MWL 5, 13, 21 the waterlevels are respectively at about 11, 19 and 16m below groundsurface.

### III 3. HYDROLOGICAL PUMPTESTS AND YIELD TESTS:

#### III 3 A. WATERLEVEL VARIATIONS PRIOR TO THE TESTS:

From Jan. 1977 to March 1977 the variations in waterlevel in the exploration boreholes were measured from time to time. They are presented in supplement no. 4. Here the main conclusion should be that waterlevels varied only slightly during the 3 months observation period. The natural variations in boreholes MWL 20, 20A, B, C, 10 and 12 were less than 0,10m while the waterlevels in boreholes MWL 21, 5, and 3 dropped not more than

0,25m. The major irregularities of the waterlevels at the beginning of the observation period in boreholes MWL 20, 20a, b, c and 21 were due to drilling activities. The excessive lowerings of the waterlevels in boreholes MWL 20 and 20a, b, c on the 3rd of February were caused by a 4-hour pumping test in borehole MWL 20 during the previous night.

### III 3 B. EXECUTION OF THE TESTS:

A hydrological pumptest was carried out in borehole MWL 20 and yield tests on borehole MWL 3, 5 and 21. A combined hydrological pumptest and yield test was done in borehole MWL 12. Though borehole MWL 13 had been prepared for a (yield) test no such a test was carried out due to the expected low yield ( $< 0,6$  l/s).

The test on borehole MWL 12 was carried out with observation holes MWL 10 and W 18. The test on borehole MWL 20 with observation holes MWL 20a, b and c.

The tests were carried out with a turbine pump with approximately 30 l/s capacity set at about 1m from the borehole bottom. The water was led away from the pumped hole to a calibrated tank so that the pumping rate could be determined.

The pumped water was diverted in such a way that no infiltration into the watersupplying geological formations could take place. From borehole MWL 20 the pumped water was conducted to a nearby stream; from borehole MWL 3 the water entered a waterlogged pan with a clay-sealed bottom and at boreholes MWL 5 and 12 the pumped water was discharged across an impermeable dolerite dyke. At borehole MWL 21 pumped water may have infiltrated into the sandy upper layers but the rather impervious quartzite layers underneath most likely prevented the water from entering the aquifer at a depth of 42m.

The first (hydrological pump) test was done in borehole MWL 20 from 15 February, 17h00 until 19 February 1977, 13h00. During the first 41 hours of the test the pumping rate was held constant at around 12 l/s. Thereafter the pump was stopped for a recovery period of 10 hours. The last 41 hours of the test the borehole again was pumped; this time at a rate of about 20 l/s.

On the 1, 2 and 3rd day of March 1977 yield tests were carried out respectively in boreholes MWL 3, 21 and 5. The tests lasted from 06h00 until 18h00. At boreholes MWL 5 and 21 the pumping rate could not be kept constant; at MWL 5 the rate dropped from 2,37 to 1,93 l/s and in MWL 21 from 1,25 to 1,01 l/s during the 12 hour test. In borehole MWL 3 the rate at which water was pumped was a constant 21,8 l/s until 16h00. From 16h00 until 18h00 the pumping rate was 28,25 l/s.

Borehole MWL 12 was tested the 9th of March from 6h00 until 20h00. The pumping rates were 14.12 l/s from 06h00 to 12h00, 25.22 l/s from 12h00 to 16h00 and 30.77 l/s from 16h00 to 20h00.

### III 3 C. RESULTS OF THE TESTS:

The pumping data and the values of the calculated transmissivities and storage coefficient can be listed as follows:

BOREHOLE NUMBER	AQUIFER	PUMPING RATE $\bar{x}$	DRAWDOWN $\bar{x}1$	TRANS-MISSIVITY	STORAGE COEFFICIENT
WL 3	Dolomite	28,25 l/s	-	-	-
WL 5	Dolomite	1,93 l/s	16,31 m	-	-
WL 12 <sup>* 2</sup>	Dolomite	30,77 l/s	1,27 m	$\pm 5300 \text{ m}^2/\text{day}$	-
WL 20 <sup>* 3</sup>	Quartzite	20,18 l/s	$\pm 33 \text{ m}$	23 $\text{m}^2/\text{day}$	0,0006
WL 21	Quartzite	1,01 l/s	-	-	-

\* 1

The pumping rates and drawdowns in the list above for boreholes MWL 5, 12 and 20 refer to pumping rates and drawdowns at the end of the tests when waterlevels remained static, and stabilisation was reached. Unfortunately no water levels could be measured in boreholes MWL 3, and 21 during their tests; hence it is not known whether waterlevels stabilised or did not stabilise at the end of the test.

\* 2

Drawdowns in borehole MWL 12 were plotted against the log of lapsed time (supplement no. 6) and calculations were made by Jacob's method. The two observation holes showed a highly irregular drawdown pattern indicating a multiple aquifer system with a variable interrelationship and could therefore not be used for the calculation of hydrological parameters. The transmissivity was calculated using Jacob's simplified formula :  
 $T = 0,183 Q / \Delta S$ . For the pumped part the first 5 hours of the test were used for calculation purposes (see supplement 6) :  
 $Q = 1220 \text{ m}^3/\text{day}$ ,  $\Delta S$  per logcycle of time :  $0,05\text{m}$ .  $T$  then is  $44 \text{ } 65 \text{ m}^2/\text{day}$ . For the recovery part the pumping rate  $Q$  should be taken as  $26 \text{ } 58 \text{ m}^3/\text{day}$  and the slope  $\Delta S$  per logcycle of time as  $0,08\text{m}$ . The transmissivity  $T$  then is  $60 \text{ } 80 \text{ m}^2/\text{day}$ . The transmissivity values so found are in reasonable accordance with values found elsewhere in dolomite.

\* 3

The transmissivity and storage coefficient for the quartzite at borehole MWL 20 have been calculated by using a computer program. The program plotted the drawdown against the log of time (see supplement no. 6A). Data of the first part of the test when the average pumping rate was  $10 \text{ } 51 \text{ m}^3/\text{day}$  ( $\pm 12 \text{ l/s}$ ) and the recovery period hereafter have been used in the program. The waterlevel data in the three observationholes MWL 20 A, B and C at respectively 45, 24 and 96m from the pumped hole MWL 20 were utilized for computation. With Jacobs formulae the following calculated values were obtained for the transmissivity and storage coefficient:

Transmissivity:

<u>OBSERVATION HOLE</u>	<u>DRAWDOWN TEST</u>	<u>RECOVERY TEST</u>
MWL 20C	24.04 m <sup>2</sup> /day	36.29 m <sup>2</sup> /day
MWL 20A	18.86 m <sup>2</sup> /day	23.46 m <sup>2</sup> /day
MWL 20B	17.65 m <sup>2</sup> /day	19.23 m <sup>2</sup> /day

Storage coefficient:

MWL 20C	1.75x10 <sup>-4</sup>	2.34x10 <sup>-4</sup>
MWL 20A	5.24x10 <sup>-4</sup>	5.61x10 <sup>-4</sup>
MWL 20B	10.05x10 <sup>-4</sup>	10.95x10 <sup>-4</sup>

The differences in transmissivity and storage coefficient obtained from the data of the three observationholes can be explained by the varying hydraulic properties of the aquifer in different directions.

III 3 D. WATERQUALITY DURING TESTS:

During the pumping tests in boreholes MWL 12 and MWL 20, water samples were taken. Chemical analyses were carried out at the Hydrological Research Institute (Department of Water Affairs) and gave the following results (cations and anions in ppm; electrical conductivity in micro Siemens per cm<sup>3</sup>):

	F <sup>-</sup>	PO <sup>3-</sup> / <sub>4</sub>	CL <sup>-</sup>	SO <sup>2-</sup> / <sub>4</sub>	HCO <sup>-</sup> / <sub>3</sub>	NO <sup>-</sup> / <sub>3</sub>
MWL 12	0,17	0,03	1,7	1,7	337,5	2,4
MWL 20 (after 41h)	0,85	0,93	5	5	156,2	0,25
MWL 20 (after 92 hours)	1,56	0,03	5	5	156,3	0,5

	Fe <sup>3+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>1</sup>	Si	NH <sub>4</sub> <sup>+</sup>
MWL 12	-	72,0	40,0	3,5	0,6	7,0	0,2
MWL 20 (41)	0,18	30,6	5,2	14	0,1	13,02	0,03
MWL 20 (92)	0,02	30,6	6,24	15	0,1	12,40	0,03

	<u>E.C.</u>	<u>PH</u>
MWL 12	534	8,15
MWL 20 (41)	278	6,6
MWL 20 (92)	288	6,7

The groundwater is of good quality and suitable for domestic use. The fluor content of MWL 20, near Leherutshe was however, rather high at the end of the 92 hours test, but within acceptable limits.

III 4. SPRINGS:

III 4 A LOCATION:

In the investigated area are a number of springs near the upper-contact of the Dolomite Series. They are located in the hills west of the main road from Zeerust to the Botswana border (map no. 3). Regular flow measurements are made by the Department of Water Affairs at five springs:

Manwane (Skilpadoog)	A <sub>1</sub> MO5	3/1970
Dinokana Upper Spring	A <sub>1</sub> MO1	4/1960 recorder 6/1972
Dinokana Lower Spring	A <sub>1</sub> MO2	4/1960
Tweefontein Upper Spring	A <sub>1</sub> MO3	1/1961
Tweefontein Lower Spring	A <sub>1</sub> MO4	1/1961

Springflows are measured once a week except Dinokana's Upper Spring with a self registering recorder, installed in June 1972. The average and minimum monthly flows are given in supplement 7.

III 4 B. SPRINGFLOW:

III 4 B 1. DINOKANA SPRINGS:

The average monthly flow from the Dinokana Upper Spring dropped from 100 l/s to 65 l/s during the years 1960 - 1967 but increased to 100 l/s in 1967 and more than 130 l/s in 1970, 1971, 1972. In 1975 the flow was down to just over 100 l/s. The variation in the flow of Dinokana's Upper Spring more or less reflects the variations in rainfall (supplement no. 8). It is clear that rainfall was below average from 1960 - 1967 and reached peaks in 1967 and 1975 with respectively 1000 and 850mm. It would appear that there is little seasonal variation of the spring flow, probably resulting from the large storage capacity of the source aquifer.

A similar average monthly flow pattern can be observed in Dinokana's Lower Spring. On the whole however the average monthly flow of the Lower Spring was less and ranged between 20 and 35 l/s. The minimum monthly flows of the Upper and Lower Dinokana Springs differed only slightly from the average monthly values.

III 4 B2. MANWANE SPRING:

The flow from the Manwane Spring is limited and appears to be rather constant ranging between 1,5 l/s and 4 l/s.

III 4 B3. TWEEFONTEIN SPRINGS (IN COMPARISON WITH THE DINOKANA SPRINGS):

On one hand the flow of the Tweefontein Springs is similar to the Dinokana Springs: A decrease in flow during the period 1961 - 1967, from 10 l/s to less than 2 l/s at the beginning of 1966. A rapid increase of flow after December 1966 following the abundant rainfall of the 1966/1967 season and again in 1968 a flow in both Tweefontein springs exceeding 30 l/s. Peak flows at the Dinokana springs coincided with the peak flows of the Tweefontein Upper and Lower Spring. Unfortunately the record of Tweefontein springs is not altogether reliable due to flooding of the gaging weir and collapse of the canal sides upstream of the measuring point.

On the other hand some differences between the Dinokana and 'Tweefontein' spring flows are significant. For instance the long term variation in the average monthly flow during the observation years was far more pronounced at the 'Tweefontein' than at the Dinokana Springs. Another difference between the springs is the influence of the seasonal rains. This influence could clearly be noticed (supplement no. 7) at the 'Tweefontein' Springs, during the 1969 to 1975 period and could not be noticed as mentioned above at the Dinokana Springs. Another difference between the springs is the time delay of the reaction of flow to rainfall. At 'Tweefontein' this time interval is less than two months; at Dinokana more than four months. The more pronounced variation in the flow and the influence and time delay of the seasons at the 'Tweefontein' springs could then lead to the conclusion that the flow of this spring is supplied by an aquifer with considerable less available storage capacity than the aquifer from which the Dinokana Springs are supplied.

IV GEOHYDROLOGICAL INTERPRETATION:

IV 1. STREAMS:

During most part of the year there is no runoff in the majority of watercourses in the investigated area. (map no. 3). Only three streams fed by the Mamvane, Dinokana and 'Tweefontein' springs are perennial. The three streams are part of the Nokwani River drainage area (A 110), which is part of the Limpopo River catchment. Only the south-western part of the investigated area (map no. 2) should be placed within the drainage area of the Molopo river (D 441).

The two main streams in the area originate as mentioned from the 'Tweefontein' and Dinokana springs. The 'Tweefontein' stream rather varied in flow along its course from around 150 l/s at the road from Zeerust to Dinokana down to 44 l/s where it entered the alluvial valley at the east side of the Upper Timeball Hill Quartzites. Finally it had a discharge of around 300 l/s where it joined the stream supplied by the Dinokana Springs (map no. 3). The discharge of the latter stream at this location also was in the order of 300 l/s. The flows were measured in November 1976.

IV 2. GEOHYDROLOGICAL CLASSIFICATION:

An attempt has been made to classify the geological formations in the area under investigation on a basis of their geohydrological properties (map no. 3). Consideration about the outcrop area, the transmissivity, the storage coefficient and the saturated thickness of the formation led to this classification. The geological formations in the area have been classified as good, reasonably good or poor aquifers.

IV 2 A. GOOD AQUIFERS:

DOLomite:

The dolomite has been classified as a good aquifer; though it should be added that this is only locally the case. Normally solution cavities throughout the dolomite are no guarantee for a high transmissivity. Boreholes drilled through solution holes (boreholes MWL 2, 4, 6, 7, 18 and 19) and below the watertable proved to supply no water. High transmissivities and storage coefficients of the dolomite and a good yield of groundwater can only be noticed at certain locations. Such locations are the quartzveins (boreholes MWL 3, 5, 10, and 12) and then especially where these are fractured and broken (borehole MWL 3 and 12) Here the transmissivities and the storage coefficients are high and so are the groundwateryields. (see chapter III).

Weathered and decomposed dolomite proved to be a relatively poor aquifer (boreholes MWL 5, 8 and 13), with yields rarely exceeding 0,6 l/s .

The boreholes which were drilled along fault zones (borehole MWL 18 and 19), along dolerite dykes (boreholes MWL 1 and 2) and in valley bottoms (boreholes MWL 14, 16, 17, 18 and 19) did not produce any significant amount of water.

Because of their limited thicknesses the chert formation within the dolomite and the alluvial debris on top of the dolomite in the east, where they cover the western slope of the mountain ridge (map no. 2) are not considered to be good aquifers. They have been omitted from map no. 3.

#### IV 2 B. REASONABLE AQUIFERS:

##### TIMEBALL HILL QUARTZITES:

The Timeball Hill Quartzites (map no. 2) are considered to be reasonable aquifers, mainly due to zones where the quartzite

is fractured (borehole MWL 21, at 40 and 66m; MWL 20, at 42 and 59m) and proved to have a high transmissivity. The yields can be considerable (chapter III). The fractured zones are of a limited thickness (1 - 2m) and presumably run parallel the stratification. It is not known whether these fractured zones in the dark Timeball Hill Quartzites persist throughout the investigated area.

#### ALLUVIUM:

The larger alluvial deposits around Dinokana and in the valley towards the north-east can be divided into a more clayey and a more sandy part (map no. 3). Sandy deposits have been developed upon the Timeball Hill Quartzites and clayey alluvium was formed on top of the Timeball Hill and Daspoort Shales.

Though hardly any water was encountered in the 16m and 30m thick sandy deposits in boreholes MWL 20 and 21, it is not unlikely that at other places where the deposits are thicker and groundwaterflow is more favourable better yields can be expected. Together with its supposed good transmissivity those are the reasons why the sandy deposits are classified as reasonable aquifers.

#### IV 2 C. POOR AQUIFERS:

##### POLOGROUND QUARTZITE:

Two boreholes drilled prior to the investigation period were in the pologround quartzite (map no. 2). They are T 7825 and T 7826 (map no. 1). Their yields are low, respectively 0,5 l/s and 0,75 l/s (supplement no. 3) and therefore this quartzite can be classified as a poor aquifer.

##### BLACKREEF QUARTZITE:

Presumably also the Black Reef Quartzite should be classified

as a poor aquifer. The rock itself is dense and it is doubtful whether fractured zones are present that can supply any reasonable amount of groundwater.

#### TIMEBALL HILL AND DASPOORT SHALES:

The shales in the area should be classified as poor aquifers. It is not likely that the finely grained and locally hard rocks have a high transmissivity.

However, it appears that transmissivity is still high enough to supply some water to boreholes that were drilled previously to the investigation period (supplement no. 3, T7855 : 0,25 l/s and T7843 : 0,17 l/s). It is not unlikely that fracturing of the rock accounts for the necessary transmissivity. That this fracturing could even be considerably in places might be deducted from the results of a 9 hour yield test in borehole T 7853; a yield of 3,65 l/s could be maintained.

#### OTHER FORMATIONS:

The Banded Ironstone forms a rather thin, fine-grained and dense rock and has a low permeability and storage coefficient. Therefore the Banded Ironstone is classified as a poor aquifer,

Considered also as a poor aquifer is the deposit of brownish loose conglomerate overlying in some places the banded ironstone (map no. 2). The reason for this classification is the conglomerates limited thickness (estimated in most places at less than 5m) and its position above most water tables. Perhaps only at Dinokana its thickness and its position in relation to the local water table are such that there is a supply of groundwater to wells (for instance : Dinokana School, T 7824; 1,35 l/s).

The Ongeluk Lavas as well are classified as a poor aquifer. The rock is hard and has a low porosity. Fracturing of the rock is limited.

Apart from the alluvial sands east and south-east of Dinokana

(see IV 2B), the recent deposits are mainly poor aquifers. Such as the alluvium in the north-west (map no. 3) which contains little or no water because of its limited thickness (estimated at less than 20m). Any supplies to wells in this formation will soon be exhausted. Another poor aquifer is the fill in the valleys of the mountain ridge just west and south of Dinokana (map no. 3). Here the fill material is unsorted to such an extent that reasonable values for the transmissivity cannot be expected; hence well yields will be low (borehole MWL 13) or there will be no yield at all (borehole MWL 14, 17, 18 and 19). It is assumed that the clayey deposits on top of the Timeball and Daspoort Shales east of Dinokana have a low transmissivity. No field evidence unfortunately is available to prove this assumption. The clays have been classified as a poor aquifer.

#### IV 3. RAINFALL:

A 48-year record of rainfall data from station 545/626 at Dinokana (Latitude 25°27', Longitude 25°51') shows that the average yearly rainfall is 600mm (supplement no. 8). One would be inclined to conclude from the rainfall record (supplement no. 8) that a period of dry years is followed by a period of wet years. Dry and wet periods could last as long as 7 to 11 years and their average yearly rainfall could be taken as 500 and 750mm respectively.

#### IV 4. REPLENISHMENT:

##### DOLOMITE:

It is not easy to make an estimation of that part of the rainfall that will infiltrate and be added to the dolomite aquifer. However dr. Enslin in his publication. "Die grondwaterpotensiaal van Suid-Afrika" (convention : Water for the future : Pretoria 1970) presented a graph (supplement no. 9) of percentage

replenishment against average annual rainfall for dolomitic and other groundwater catchments. For dolomite a range of 3% to 13% was indicated for annual rainfalls between 550mm and 670mm. In the more recent investigations of the Grootfontein Compartment in the Bo-Molopo Subterranean Water Control Area - of which Dinokana forms a part - replenishment was found to vary between 5% and 8,3% with a maximum of 17% (Report of van Wyk and Mulder, 28.2.1975 on file 348/1/5, Department of Water Affairs).

In the investigated area the hydrological data are insufficient and of too short a duration to come to meaningful values, for the rate replenishment. Based on the results mentioned above the recharge of the dolomitic aquifers can be taken as between 5% and 10%. For a dolomitic surface of 236 km<sup>2</sup> and with an average rainfall of 600 mm this would give an annual recharge of between 7,1 and 14,2 million m<sup>3</sup> (228 and 427 l/s).

#### PRETORIA SERIES:

The recharge rate is assumed to be 6% based on dr. Enslin's publication before mentioned. The alluvial filled valley north and south of Dinokana has a total area of 65km<sup>2</sup>. The hills (Timeball Hill Quartzites) and adjoining plain eastwards near Leherutshe has an area of 50km<sup>2</sup>. Recharge is estimated as respectively 2,3 and 1,8 million m<sup>3</sup> per year (73 l/s and 59 l/s).

#### IV 5. GROUNDWATERFLOW:

Groundwater in the dolomite flows in a northerly direction (see map no. 3) except for a flow eastwards immediately above Dinokana and Tweefontein Springs. Normal groundwater gradients in dolomite are in the order of 0,002. Dolerite dykes in dolomite often act as an impedance to groundwater flow. Not enough data were available to prove whether also in the investigated

area the dolerite dykes are impermeable.

The groundwater flow in the alluvium and Timeball Hill Quartzites south-east and east of Dinokana takes place in a north-westerly and northely direction. This should be concluded from the topography and the heights of the groundwater levels in this area.

V SUPPLY AND DEMAND OF WATER:

V 1. SUPPLY FROM DINOKANA SPRINGS:

The average monthly flow for the period 1960 - 1975 of the Upper and Lower Spring at Dinokana was respectively 92 and 23 l/s with a minimum in 1965 of respectively 65 l/s and 20 l/s.

The rainfall at station 545/626 (Dinokana) is observed since 1929 and averages 600 mm. From 1959 to 1965 was the longest period of sub-normal rainfall (average 500 mm). The low flows in (November)1965 can safely be assumed to have been the lowest flows during the period of rainfall observations.

Part of the flow from Dinokana's Upper Spring will infiltrate and contribute to the flow of the Lower Spring. Assuming a drop of 50% in the flow of the Lower Spring if all the water of the Upper Spring is utilized the average total combined available flow would be 103.5 l/ with a minimum of 75 l/s.

V 2. SUPPLY FROM EXPLORATION BOREHOLES:

a. DOLOMITE:

During their yield tests the boreholes MWL 3 and MWL 2 in the dolomite (map no. 1) supplied respectively 28.25 l/s and 30.77 l/s.

Both boreholes were approximately pumped at maximum pump capacity. The lowering of the watertable in borehole MWL 12 during the test was only 1.27m, and stabilisation was reached. Abstractions of 28 l/s and 31 l/s can be taken as the "safe yields" for respectively borehole MWL 3 and MWL 12.

b. TIMEBALL HILL QUARTZITE:

The pumping rate of the quartzite borehole MWL 20 during the hydrological pump test was 20.18 l/s with a drawdown of 33m and stabilisation was reached. The borehole was pumped at maximum (pump) capacity and the maximum borehole yield could possibly be higher, but in view of the considerable drawdown a "safe yield" of 20 l/s is accepted.

V 3. PRESENT GROUNDWATER USE AND FUTURE WATERDEMANDS:

It is not an easy task to estimate the present groundwater withdrawals in the area. However, it appeared that:

1. The groundwater withdrawals in 1975 from the Dinokana Upper Spring, for use in the recently built township of Welbedacht (map no. 1) were in the order of 260 m<sup>3</sup>/day. (supplement no. 10).
2. There were no groundwater withdrawals for irrigation purposes in the area during the investigation period (August 1976 - March 1977).
3. The "Waterbeplanningskomitee vir Wes Transvaal" estimated the Dinokana water consumption for the year 1970 at 795 m<sup>3</sup>/day; possibly based on number of population and an assumed consumption per capita.
4. Groundwater withdrawals by windpumps are very small; a rough estimation indicates that a maximum of 140 m<sup>3</sup>/day is abstracted from a total of around 25 windpumps in working condition.

The waterconsumption by the year 2000 is therefore estimated at 10360 (see chapter 1) + 795 + 260 + 140 = 11555 m<sup>3</sup>/day, assuming that no further increase takes place in domestic use or cattle watering other than the consumption increase for the planned capital of Lehurutshe.

V 4. CONCLUSION:

The exploration boreholes (MWL 3, 12 and 20) in dolomite and Timeball Hill Quartzite in combination with the dolomitic spring at Dinokana are able to supply 15768 m<sup>3</sup>/day (182,5 l/s). A minimum supply of 13306 m<sup>3</sup>/day (154 l/s) can be expected in dry years when the flow from the Dinokana Springs decreases. The amounts exceed the mentioned waterdemand of 11555 m<sup>3</sup>/day (140 l/s) for the year 2000.

The dolomite will supply 14040 m<sup>3</sup>/day (162 l/s) and the Timeball Hill Quartzite 1728 m<sup>3</sup>/day (20 l/s). The figures above do not exceed the long-term replenishments into the aquifers; which have been estimated between 19700 m<sup>3</sup>/day (228 l/s) and 39480 m<sup>3</sup>/day (457 l/s) for the dolomite and 5100 m<sup>3</sup>/day (59 l/s) for the Timeball Hill Quartzite (Chapter IV).

VI. SUMMARY:

VI 1. GEOLOGY:

The area is underlain by dolomite, banded ironstone shale and quartzite of the Transvaal System. The beds dip slightly to the north-east. In places they are overlain by rather thin alluvial deposits. A number of dykes intersect all formations in a predominant east-west direction. There are no major displacements.

VI 2. EXISTING BOREHOLES:

Yield tests in the boreholes drilled prior to the investigation period gave relatively low yields. The highest yields were between 2.5 and 3.8 l/s.

VI 3. EXPLORATION BOREHOLES:

Twenty one exploration boreholes and 3 observation boreholes were drilled during the investigation period. Twelve hour yield tests were undertaken on 4 boreholes of which 3 were in dolomite with yields of 28.2 l/s (MWL 3), 1,9 l/s (MWL 5) and 30,8 l/s (MWL 12) and one in the Timeball Hill Quartzite : 1 l/s (MWL 21). A 92 hour hydrological pump test was carried out on a borehole MWL 20 in Timeball Hill Quartzite with a constant yield of 20.2 l/s at the end of the test. A short hydrological pump test was carried out on borehole MWL 12 in combination with the 12 hour yield test.

The quality of the boreholewater was found to be good and suitable for domestic use.

VI 4. SUPPLY AND DEMAND:

The estimated waterdemand around 2000 (11555 m<sup>3</sup>/day) can be supplied from the dolomitic springs at Dinokana (8942 m<sup>3</sup>/day with a minimum of 6480 m<sup>3</sup>/day) and the exploration boreholes MWL 3 and 12 (5098 m<sup>3</sup>/day) on the dolomite plateau west of Dinokana and MWL 20 (1728 m<sup>3</sup>/day) in the Timeball Hill Quartzite east of Dinokana.

The mentioned groundwater extractions do not exceed the long-term replenishments into the dolomite and Timeball Hill Quartzite aquifers.

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