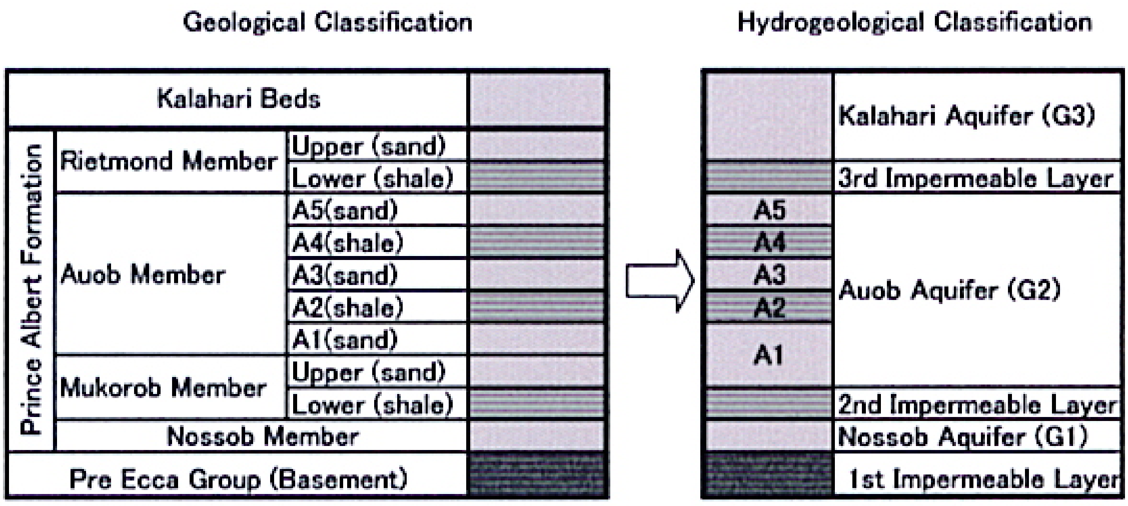
3. HYDROGEOLOGY

3.1 Definition of Aquifer

In this study, new definitions were given to the Kalahari Aquifer and Auob Aquifer based on the classification below.



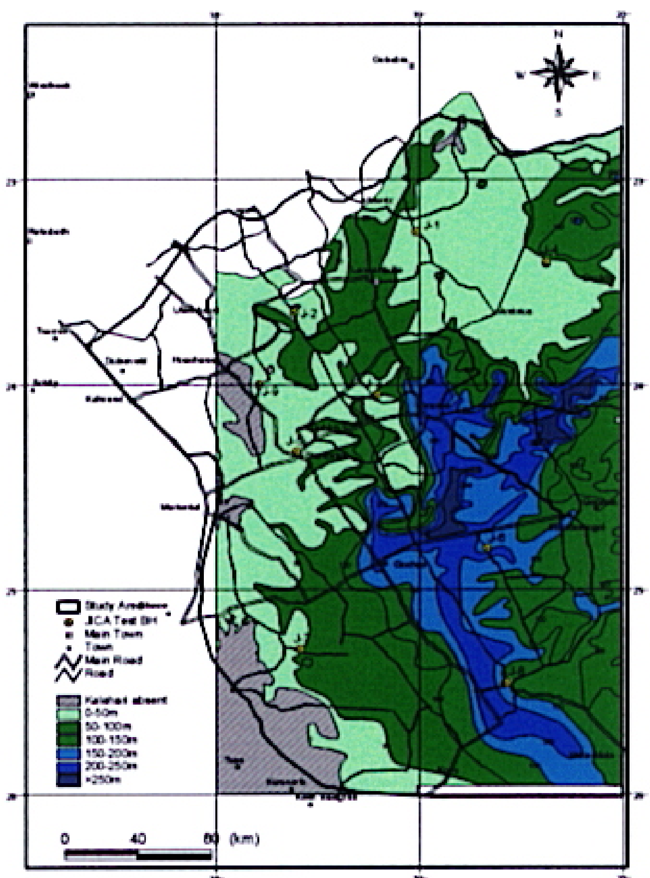
< Fig. 3-1 Reclassification of Aquifers >

3-2 General Feature of Aquifer

(1) Kalahari Aquifer

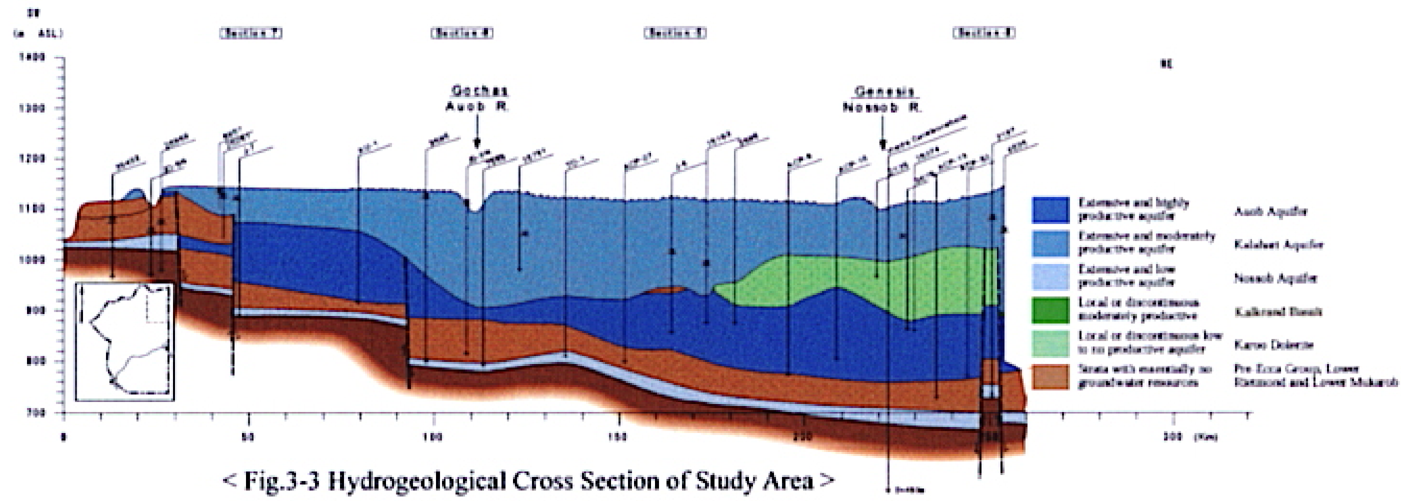
Although most of the study area is covered by the Kalahari Beds, the area around Hoachanas, northwest from Stampriet, consists predominantly of the Kalkrand Basalt. Pans and sinkholes are the two kinds of depressions observed on the surface of the Kalahari Aquifer.

The Kalahari Aquifer is the most intensively used aquifer in the study area. Approximately 4,500 boreholes, (more than 80% of total boreholes), were drilled into the Kalahari Aquifer and 9.8 x 10^6 m^3/year of groundwater is abstracted from it annually, which reperesents 65 % of the total extraction within the study area.



< Fig.3-2 Isopachs of Kalahari Aquifer >

A pre-Kalahari surface of the Kalahari Aquifer is shown in Fig.3-2, which indicates an erosional surface before sedimentation of the Kalahari Beds occurred known as the "African Surface". It shows that the Pre-Kalahari Valley was deeply eroded and the cross section (Fig.3-3) indicates that the erosion reached the Auob Aquifer as shown in Fig.3-3.

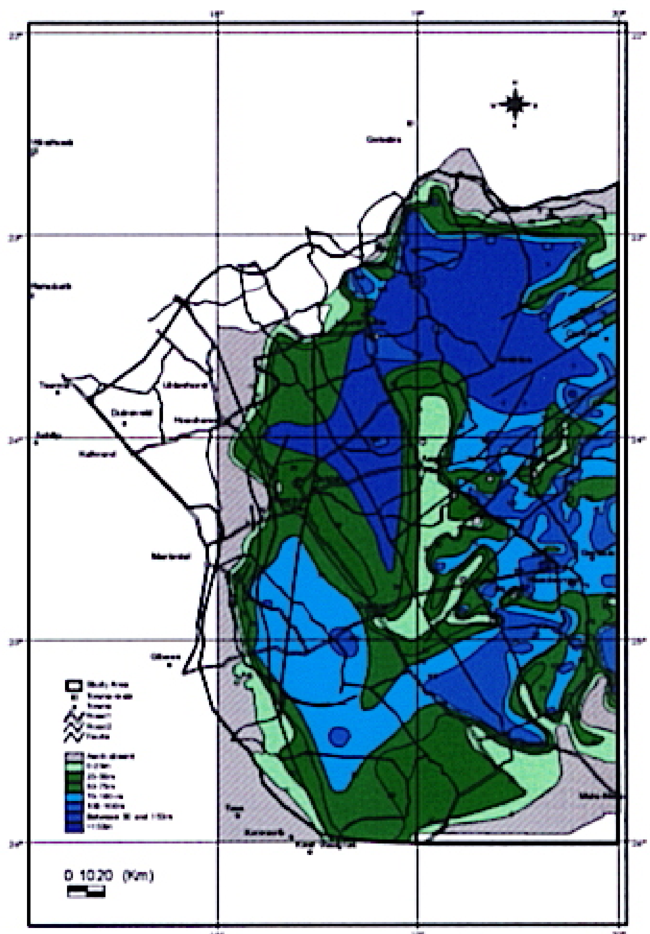


< Fig.3-3 Hydrogeological Cross Section of Study Area >

(2) Auob Aquifer

Since the Auob Aquifer is a confined aquifer and contains good water, local people used to utilize it for along time. Total production volume; which is round 4.97 x 10^6 m^3/year, is about 33 % of the total extraction in the study area. The withdrawal is higher in the western part of the basin; around Stampriet and Aranos where the depth of the aquifer is relatively shallower than in the east.

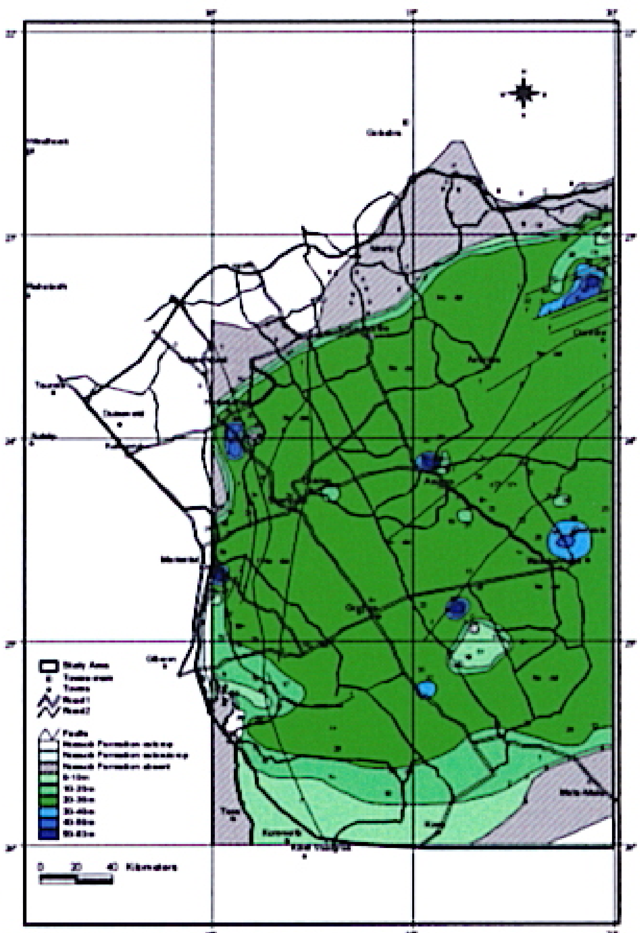
An isopach map of the Auob Aquifer is illustrated in Fig.3-4. It implies that the major distribution extends from south of Aminius to the east of Aranos. In this part, the thickness of the aquifer ranges from 100 meters to 150 meters and exceeds 150 meters in several places. On the other hand, it becomes thinner immediately close to the marginal area of the basin.



< Fig. 3-4 Isopach of Auob Aquifer >

(3) Nossob Aquifer

Although the Nossob aquifer has the highest piezometric head of all the aquifers, reaching more than 20 m above the ground surface, the total groundwater abstruction from this aquifer is only 0.2 million m^3/year which is about 1.3 % of the total extraction in the study area. This is mainly due to the thin nature excess depth and the frequent inferior water quality of the aquifer.



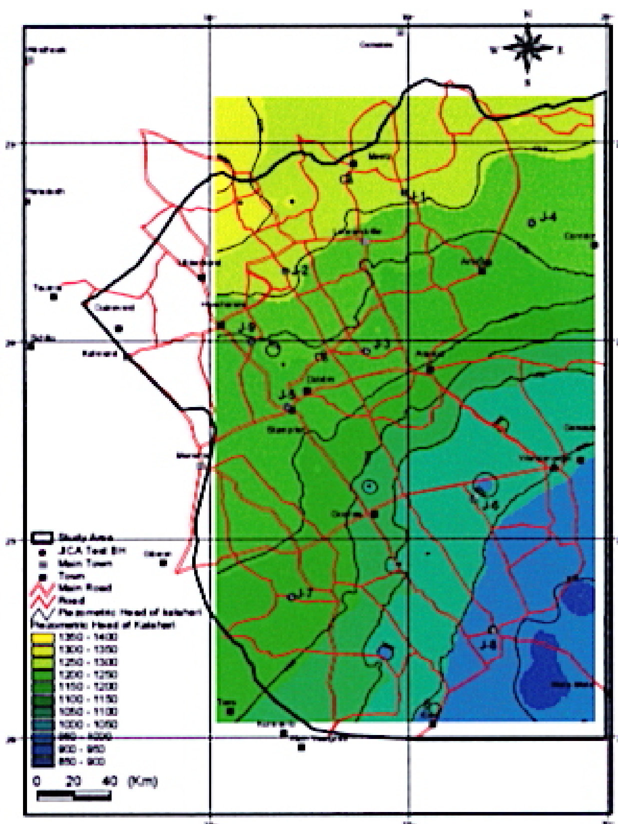
< Fig. 3-5 Isopach of Nossob Aquifer >

The thickness of the Nossob Aquifer is presented in the isopach map in Fig.3-5. It indicates that the thickness of aquifer tends to increase toward the center of the basin, although there is no distribution on the margin of the basin. An average thickness of the aquifer is estimated at approximately 25 meters. However, there are thicker parts of the aquifer in some places. The maximum thickness is reported to be 94 meters in the petroleum core holes, drilled in the farm Vreda during 1963 and 1994.

3-3 Piezometric Head

(1) Present Piezometric Head

The rest water level of the Kalahari Aquifer is shown in Fig.3-6. Groundwater is flowing from the northwest to the southeast harmonizing with hydrogeological conditions. The gradient of the groundwater table becomes steeper in Aranos / Gochas area but then flattens toward the Salt Block. (Refer to



< Fig.3-6 Water Level of Kalahari Aquifer >

flattens toward the Salt Block. (Refer to Fig.3.8)

Groundwater flow of the Auob Aquifer as a whole is similar to the Kalahari Aquifer. The general direction of groundwater flow in the Nossob Aquifer is also from the NW to the SE. However, the average of piezometric head is gentle as being around 1/1000.

(2) Long-term Variation of Piezometric Head

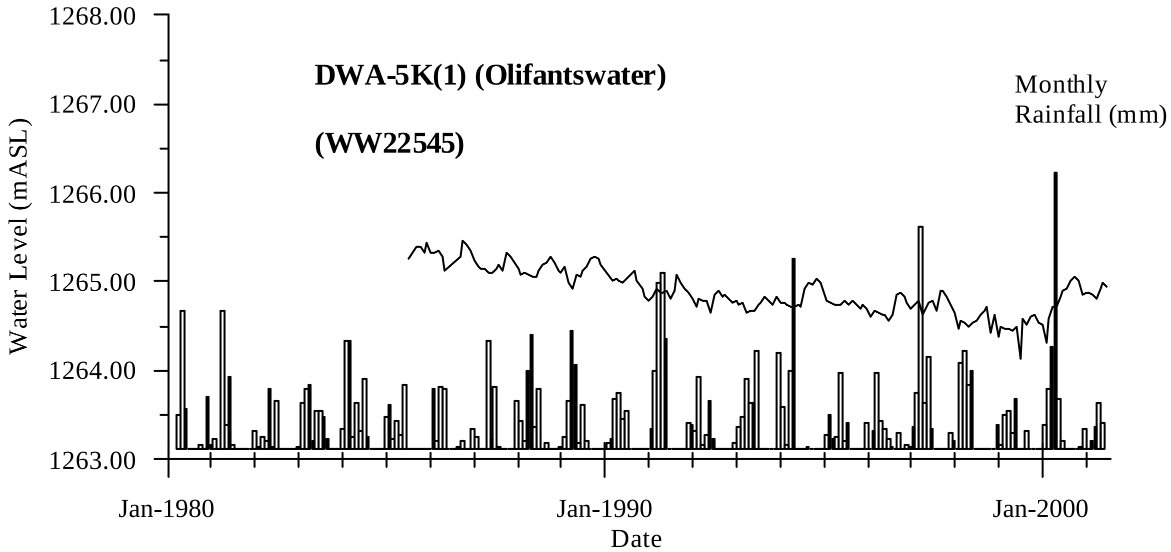
The variation of the groundwater level in the Kalahari Aquifer at Olifantswater West is shown in Fig.3-7. It is clear that the water levels have been decreasing constantly with a periodic fluctuation of approximately 5 cm/year on average since 1986. This pattern was however altered after the heavy rains from 1999 to 2000. (hereinafter referred to as '99-'00 rainy season) As for the Auob and Nossob Aquifer, reliable data from JICA test boreholes should be monitored over the long term.

3-4 Groundwater Quality (TDS)

A distribution of TDS concentration in each aquifer is shown in Fig.3-8.

(1) Kalahari Aquifer

It is obvious that the high concentration area of TDS is located in the southeastern part of the study area, especially around J-6. This area mostly coincides with the Pre-Kalahari Valley or



< Fig.3-7 Water Level Variation of Kalahari Aquifer >

"Salt Block". The maximum concentration of TDS 14,874 mg/l was recorded at J-6. According to WHO's Standards for Drinking Water, TDS should be less than 1,000 mg/l.

(2) Auob Aquifer

A high concentration area of TDS is recognized around J-8. The existence of the Salt Block is poorly appeared. The maximum value of the Auob Aquifer is 6,754 mg/l at J-8. Water quality in the northeastern half of the study area is better than the standard, and is likewise for the Kalahari Aquifer.

(3) Nossob Aquifer

A high concentration area of TDS is also distributed around J-8 (33,500mg/l). The water quality of the Nossob Aquifer is the worst of the three aquifers.

<u>3-5 Isotope Analysis</u>

(1) Age of Groundwater by ^{14}C

The ^{14}C ages in the unconfined aquifer system are overall high, despite the fact that the aquifer system can be recharged virtually everywhere in the basin. Nevertheless, it is important to note that younger water occurs in the northwestern part of the basin or near the Kalkrand Basalt. Younger water (< 2000 a) also occurs along the lower reaches of the Nossob River, which confirms recharge from the riverbed during periods of flood. Younger water (< 5000 a) of good quality also occurs along the lower reaches of the Auob River at borehole J8K, confirming the importance of floodwater recharge in the basin.On the other hand, the groundwater in the Auob Aquifer and the Nossob Aquifer is generally old or very old even close to the northern and western edge of the basin. (refer to Fig. 3-9)

Considering the high ^{14}C ages, very low tritium values can be expected in both of them. Nevertheless, it is an important confirmation that natural recharge is a very slow process. The trace amounts of tritium in a few boreholes within the unconfined aquifer and also in one borehole in the Auob aquifer could indicate that younger water may be blended into the aquifer and that a mixture of very old and younger water is abstracted in places.

(3) Nitrogen Isotope Ratio

According to the results of the nitrogen isotope ratio ($^{15}N/^{14}N$), most of the ratios are low but some of them are high enough to indicate a potential pollution source by livestocks. Fortunately, there is no indication of pollution by chemical fertilizer.