GH 3866

Hydrological Evaluation of the West Rand dolomitic compartments: Zuurbekom, Gemsbokfontein East and Gemsbokfontein West

May 1993

D.B. Bredenkamp

Western Areas:

Introduction

The West Rand dolomitic compartments, Zuurbekom, Gemsbokfontein East and Gemsbokfontein West which are shown in Fig.1, have been studied quite extensively in order to determine:

1) the natural groundwater recharge (Re);
2) the storativity of the dolomite aquifer for each of the compartments (S);
3) the occurrence of leakage between the compartments;
4) the rate of dewatering of the compartments in relation to the large abstraction of groundwater by the Western Areas mine.

From a geohydrological point of view the large abstraction by the mine puts the aquifers under a great deal of stress which is essential for the characteristics (S and Re) to be determined.

The Bekkersdal compartment, which is separated from the Gemsbokfontein West compartment by the Panvlakte dyke, is not considered part of the other three compartments, mainly because the water level shows no significant change that could be related to the pumpage by the mine.

The Eastern Gemsbokfontein compartment (GBFE) is of importance because of the leakage occurring through the Magazine dyke which has caused the water level in the Gemsbokfontein East compartment to decline to levels that could be conducive to sinkhole formation. For this reason artificial replenishment (rewatering) of the Gemsbokfontein East compartment was started to restore the natural water levels that had prevailed before the pumpage started.

The Zuurbekom compartment is at issue because of the pumpage by the Rand Water Board and claims that their compartment is being affected by the pumping of the mine.

The possibility of leakage occurring through the Panvlakte dyke, was investigated by means of a pumping test that was carried out in August 1990. Borehole ZM30 in the Gemsbokfontein East compartment was pumped for 16 days and the affect on the water levels on both sides of the dykes was monitored. No evidence of a leak could however be found.

Subsequent drilling has revealed that the leak from Gemsbokfontein East compartment probably occurs to the south, towards WD10. A highly permeable conduit (fracture) probably extends from this area to the east west fault zone which conveys the water to the mining area. The travel time for water to leak from the Gemsbokfontein East compartment to the mine area can only be inferred from a tracer test which at this stage is too costly and it is still uncertain whether a conclusive result will be obtained.
The pumping test however revealed that water levels react over great distances because of highly transmissive zones which could indicate rapid movement of water along the zones to the mine area.

Water Balance Approach

A water balance approach was followed to determine for each of Gemsbokfontein East, Zuurbekom and Gemsbokfontein West compartments the recharge and aquifer storativity. The saturated volume fluctuation method was applied, which essentially boils down to a lumped (integrated) water balance. The method involves determining the rate of change of water levels as a result of the abstraction.

Zuurbekom Compartment

The Zuurbekom compartment, comprising 70 sq. km. is being pumped by the Rand Water Board. The rate of the groundwater decline (SVF) in relation to the abstraction by the Rand Water Board production pumps, is shown in Fig. 2. This shows a consistent rate of decline which indicate uniform storativity. The average groundwater recharge is estimated at 111 mm/a (15,8 % of 700 mm rainfall) and S = 0,016.

Leakage from this compartment to the Gemsbokfontein East compartment or directly to Gemsbokfontein West probably occurs according to a water quality model (Simonic 1992), but at a maximum rate of 2,5 Ml per day which is only 13 % of the total leakage from Gemsbokfontein East. As the water level of the Gemsbokfontein East compartment increases, this leak should reduce.

The effect of the flow between the different compartments can only be properly addressed by means of a dynamic model of the three compartments which is not part of the present analysis of the systems.

Gemsbokfontein East Compartment (GFE)

An analysis of the Eastern Gemsbokfontein compartment was also carried out. This system had not only been stressed by pumpage and the leakage from it, but the artificial rewatering allowed a further controlled manipulation of the system.

To balance the different abstraction scenarios so that they yield the same S value for the system, the leakage and recharge had to be adjusted until all portions in Fig. 3 yielded a consistent S value. As can be seen from the Figure 4, a uniform S value of 0,048 was obtained with Re =0,20 rainfall and recharge 17,7 Ml/d. Despite the rewatering, its rate initially was not sufficient to let the water level recover but a reduced rate of depletion continued.

The effect of the increased rate of replenishment can be seen at the end of the period.

The storativity (S) which is denoted by the rate of change of the saturated volume was the same for all portions if the nett outflow was 6,5 x 10^6 m^3/year ie. 17,7 ml/d which is partly balanced by the high recharge in the eastern compartment. Only when the rate of replenishment is around 12 - 18 Ml/d would the water levels in the eastern compartment rise significantly.

Gemsbokfontein West Compartment (GFW)

The Gemsbokfontein West compartment, if analyzed on its own, yield a drawdown rate as is depicted in Fig. 5 on a 12 monthly basis. From it the recharge is estimated at:

Re = 250 mm = 36 % of rainfall

S = 0,02

The high recharge compared to Zuurbekom and Gemsbokfontein East is partly due to the leakage from Gemsbokfontein East which is 17,7 Ml/d i.e. 6,5 x 10^6 m^3/a. If this is subtracted from the 70 Ml/d recharge the rainfall recharge is 189 mm/a on 27 % of the average rainfall.

There is still a possibility that of this recharge, some is leakage from the Bekkersdal compartment and even from the Transvaal system to the south, so that the average rainfall recharge of the compartment could eventually come closer to 20 % of the average rainfall. It is also possible that the size of the Gemsbokfontein West compartment is larger than its present delineation (extending to the south) so that the percentage recharge would automatically reduce in the same proportion.

At first it was attempted to solve the groundwater balance for each of the following compartments Zuurbekom Gemsbokfontein East Gemsbokfontein West , but the leakage that could occur between them, posed a problem.
Hence it was decided to apply the SVF method to the total system i.e. the three compartments combined and estimate the recharge and storativity of this lumped system. In this way the effect internal recharge of water is automatically incorporated in the overall water balance, and does not have to be known for the individual compartments.

SVF Water balance:

Fig. 6 denotes the excellent linear relationship that was obtained between

Q_{total} and SVF_{total}

where: $Q_{total} = Q_{GFW} + Q_{Zuurbekom} + Q_{GFE}$ (Rewatering not seperated)

where: $Q_{GFE} = Q_{CORROBRICK} + Q_{RWB}$ (Rewatering not separated) and $\Delta SVF_{total} = \Delta SVF_{GFW} + \Delta SVF_{Zuurbekom} + \Delta SVF_{GFE}$

The Bekkersdal compartment was not regarded to be part of the analyzed system i.e. the Panvlakte dyke is assumed to be impermeable along its boundary between Bekkersdal and Gemsbokfontein West.

Results of SVF analysis

Fig. 6 depicts the linear relationship between Q_{total} and ΔSVF_{total} from which the average recharge Re and storativity S of the total aquifer were determined as:

$S = 0,0225$

$R = 175$ mm/a

$= 24$ % of Rf_{av}

The S value incidently is virtually the same as that derived for the Grootfontein aquifer ($S_{gf} = 0,0225$) which is reassuring insofar that it indicates that the dolomite which is of the same age and hydrological evolution has undergone the same leaching over geological times.

The recharge (Re) which is about 24 % of the average rainfall is much higher than previous estimates and it is also higher than the estimates for the Grootfontein aquifer. Chloride profile studies have however indicated that a recharge of 25 % of the rainfall is quite possible. There is definite indications that the total dolomite system is probably continuously draining water to lower lying areas, so that the total system is in dynamic equilibrium. This equilibrium is maintained by rainfall largely above average which restores the losses that is caused by drainage and/or evapotranspiration. On the other hand the equillibrium is affected by abstraction.

The recharge component (Re) could incorporate inflow from the Bekkersdal compartment, but if so this cannot be established. If some inherent leakage does exist, the average recharge would be proportionally smaller.

Further extension of the study:

The leakage from the Gemsbokfontein East compartment to Gemsbokfontein West is probably occurring along fractures that can not be defined. A significant portion of the outflow could be southwards and then via the fault zone to the mining area and part could flow through the Magazine dyke.

There is a possibility of upwelling of groundwater from depth along fissures or contact zones. Such leaks would be directly dependent on the hydraulic gradient applying along such a conduit.

The future reactions of the water level in the mine area could be predicted if the total system of 3 compartments is simulated by means of a dynamic model. From the present data it would seem that a constant rate of decline is being approached and according to Fig. 7 the rate of decline would from now on would be 0,375m per month. This equilibrium would however be affected by rate of recharge from rainfall, which has been low over the past few years and for this reason a slight increase in pumpage might be required to maintain the present levels.

A substantial degree of recirculation of the water being replenished in the Gemsbokfontein East compartment is inevitable if the water levels in the eastern compartment are to be maintained. It should be pointed out that the water balance is affected by the natural recharge which seemingly can be about 24 % of the average rainfall over the preceding 12 months.

The water quality study of the Zuurbekom compartment indicates that leakage is probably taking place from Zuurbekom but this can only be clarified by a dynamic model which is not part of the present study. Further drilling and pumping tests may help to locate the leak if it occurs as a point source.

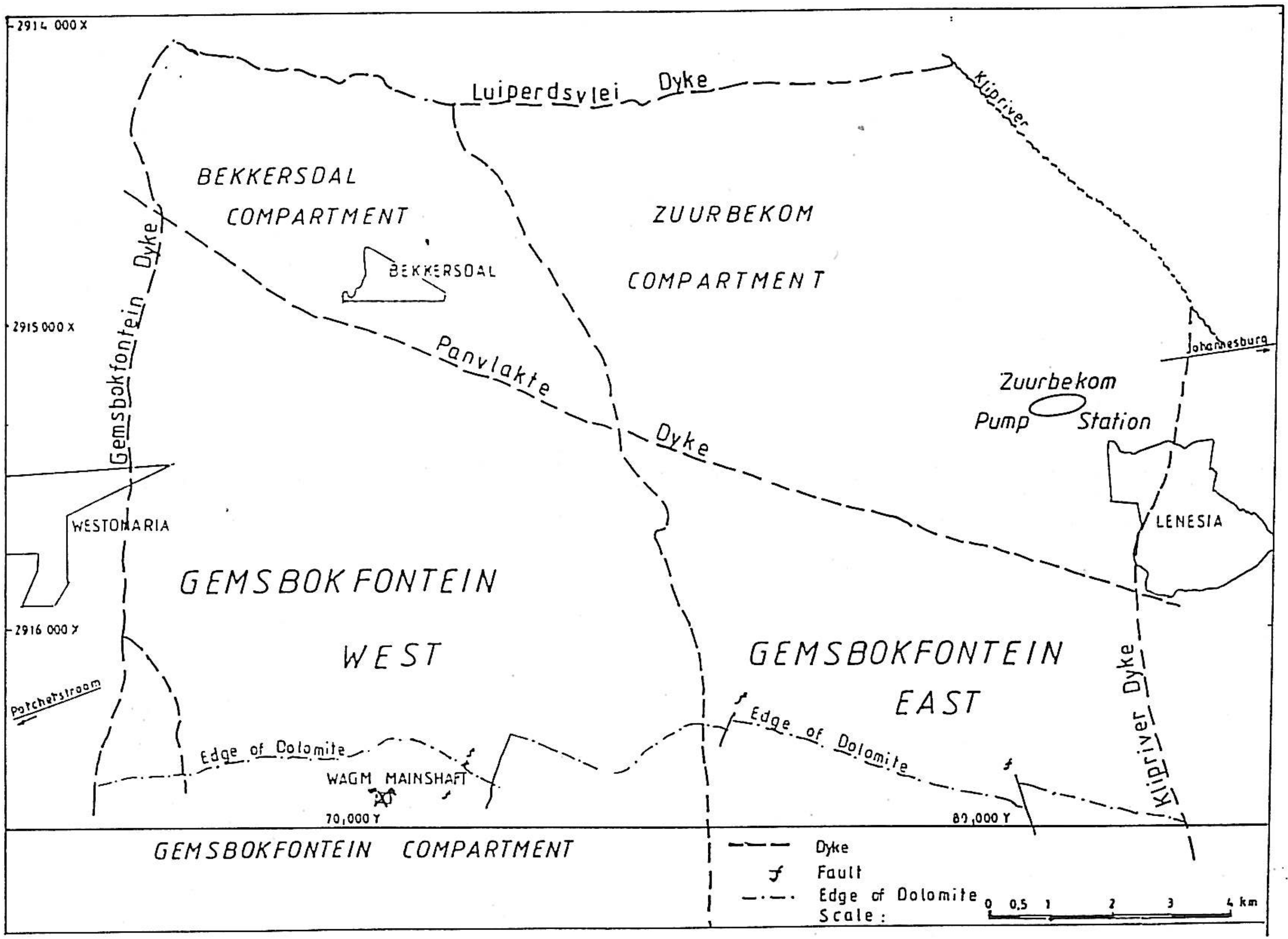

Fig. 1. Locality map of the dolomitic compartments in the Western Areas region.

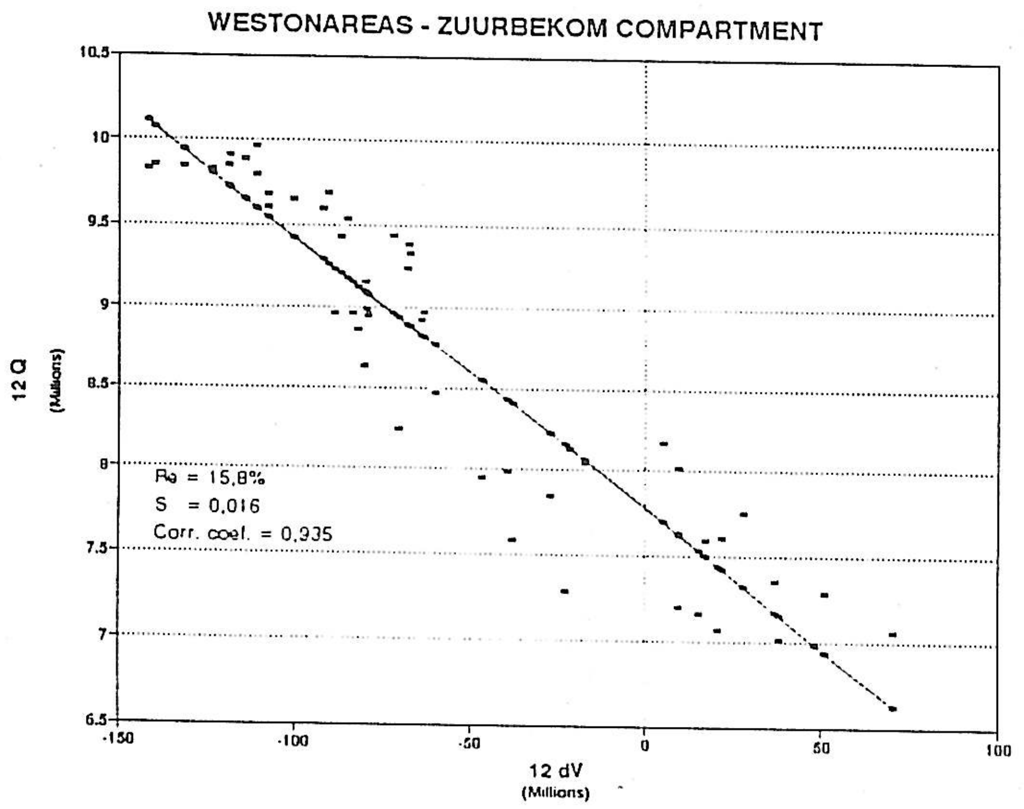

Fig. 2. Derivation of the recharge and storativity of the Zuurbekom compartment.

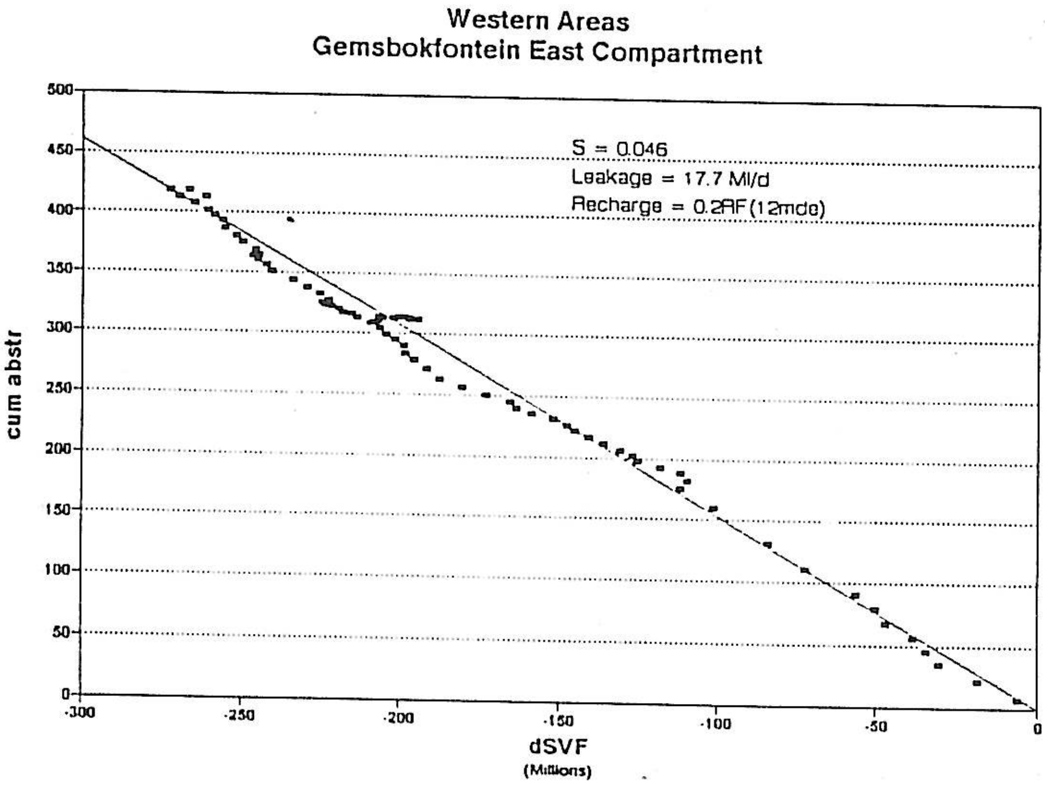

Fig. 3. Determination of the storativity of the Gemsbokfontein east compartment based on the change in storage due to pumpage, recharge and artificial replenishment of water.

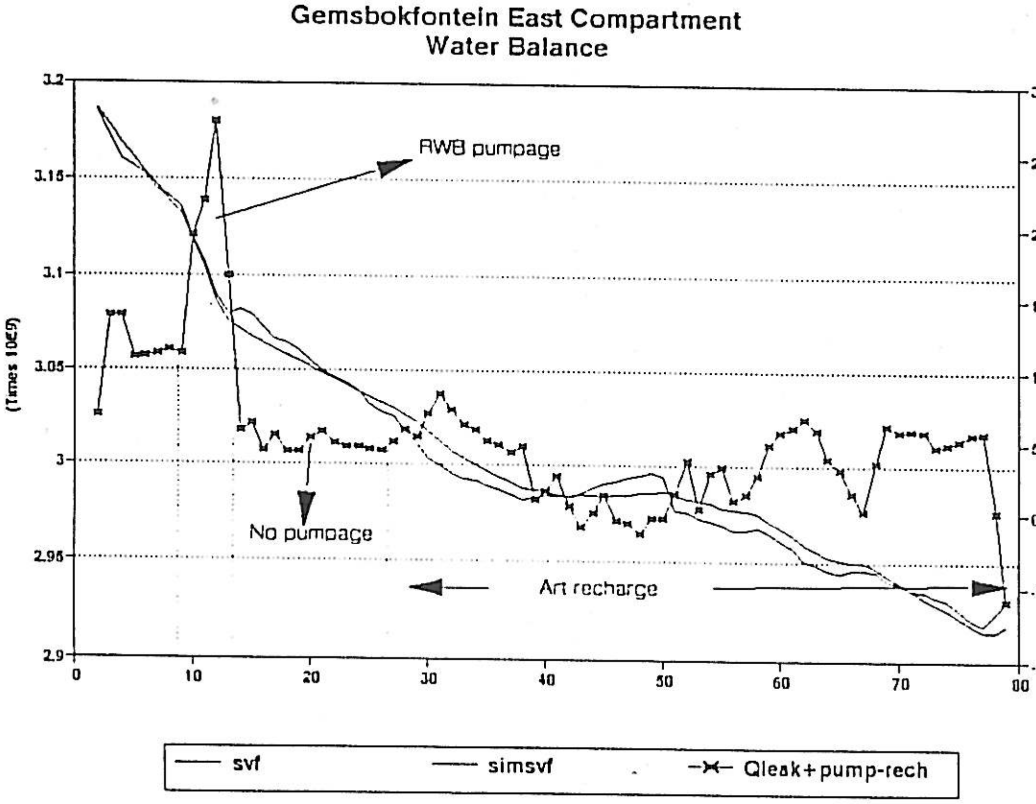

Fig. 4. Simulation of the water level response in the Gemsbokfontein east compartment due to pumpage and recharge.

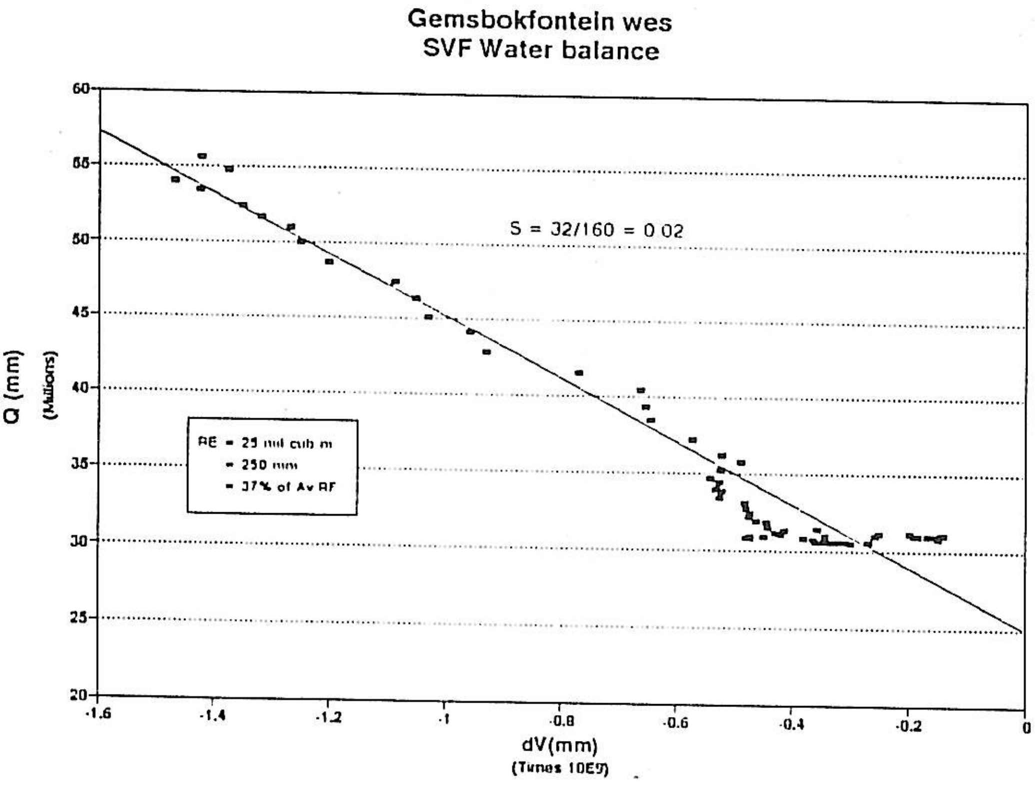

Fig. 5. Water balance estimation of the storativity S and recharge of the Gemsbokfontein west compartment.

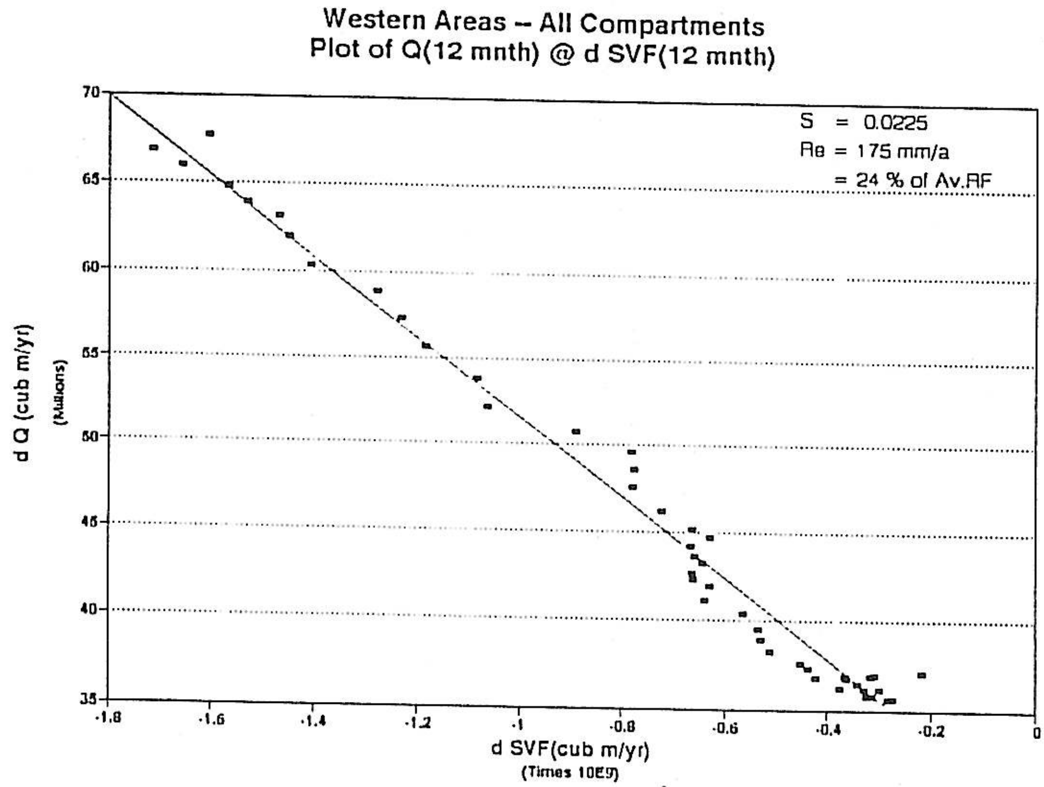

Fig. 6. Water balance estimation of recharge and storativity of the three compartments combined. The high recharge value is partly due to the leakage from the eastern sub compartment, but could also be too high because of leakage from the Bekkersdal compartment and the Transvaal system to the south of the compartment.

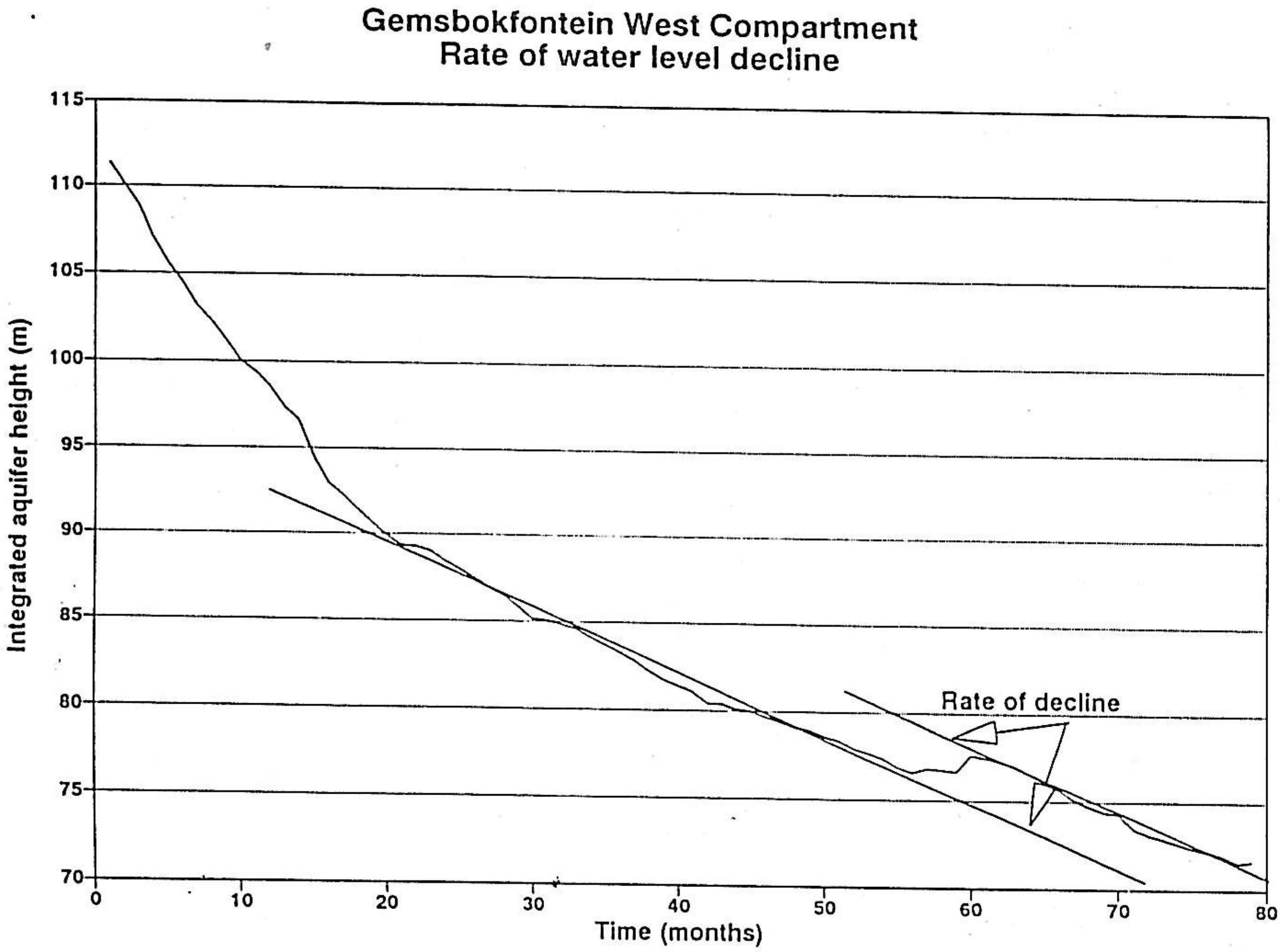

Fig. 7. Decline of water levels with time.