

PRELIMINARY REPORT ON GEOHYDROLOGICAL

INVESTIGATIONS IN KLEIN SWARTBERG VALLEY,

LAINGSBURG DISTRICT, CAPE PROVINCE

SEPTEMBER 1971 TO AUGUST 1972

by

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## A. INTRODUCTION (Ref. Folder 1)

The geohydrological survey of Klein Swartberg Valley, Laingsburg District, was undertaken by the Geological Survey in response to requests made by the local Farmers' Association to the Minister for Water Affairs to consider the grant of subsidies to assist in the development of water supplies from boreholes for irrigation purposes (Kritzinger, 1971).

In order that these requests might be considered, the Minister of Water Affairs stipulated that it would be necessary to show that groundwater reserves of suitable quality for irrigation do exist at Klein Swartberg Valley in sufficient quantity to provide irrigation water supplies for the foreseeable future. It would therefore be necessary to prove that, after a period of extraction of water from boreholes for irrigation, the groundwater reserves are replenished, that is, that quantities of groundwater sufficient for irrigation purposes can be extracted each summer without serious depletion of the groundwater reserves or deterioration in quality.

The present survey, which included geological mapping, collection of borehole data, measurement of stream flows, measurement of water-levels in boreholes, pumping yields, and salinity, was commenced in September 1971. Routine measurements were done by learner technicians J.C. Kruger (Jnr.) (September 1971 to January 1972) and F.M.K. van der Spuy (February 1972 onwards). Geological mapping was done by J.N. Theron east of Long. 21°15'E in 1968 and by the writer west of that longitude.

Klein Swartberg Valley is situated in Laingsburg District, Cape Province, along the northern foot of the Klein Swartberg Mountains, which, as do most of the mountain and hill ranges in the Little Karoo, trend east-west. The Klein Swartberg Valley occupies the east-west strip, up to 5 km from the foot of the mountains, between Seven Weeks Poort and Buffels Poort, being 45 km in length from east to west.

The occurrence of permanent water supplies from streams flowing northwards from the Klein Swartberg Mountains and from springs in Klein Swartberg Valley has enabled a small but prosperous farming community to develop, centred on the village of Vleiland which is 55 km by road from Laingsburg and 65 km by road from Ladismith.

The Klein Swartberg Valley may be divided into two sections:-

- (i) The Main Valley, comprising the 35 km stretch between Buffels Poort and Rooihogte, at an attitude between 450 and 950 m above mean sea level, drained by the westward flowing Klein Swartberg River, a tributary of the Buffels (Groot) River.
- (ii) The Koueveld, comprising the 10 km east of Rooihogte, at an attitude of 1 000 to 1 200 m above mean sea level, drained by Bosluis Kloof and the upper Huis River both of which flow eastward into the Gamka River. The upper Huis River flows by way of Seven Weeks Poort.

The soil in the valley is fertile and the climate is mild and sunny with low rainfall (average 319 mm per year between 1960 and 1971 inclusive). These factors, together with the availability of permanent water supplies from mountain streams, augmented in recent years by abundant borehole water supplies, have enabled the farmers to develop the valley for cultivation of deciduous fruits (apricots, peaches, plums, pears, apples), vines, and for lucerne and vegetables.

At the time of the investigation (March - April 1972) areas under irrigation were, according to figures supplied by the farmers, as under.

	Vineyards	Orchards	Land (lucerne, vegetables)*	Total
Main Valley	60 ha	260 ha	340 ha	660 ha
Koueveld	None	50 ha	80 ha	130 ha
Total	60 ha	310 ha	420 ha	790 ha

\*Some lucerne is irrigated only at times when sufficient irrigation water is available. During the summer 1971-72, it is understood that there was sufficient water available for irrigation of the complete areas as given.

In addition, crops such as wheat and hay are irrigated when there is water available (about 600 hectares).

The Farmers Association's request to Ministry of Water Affairs (March 1971) gave a total of 1 380 hectares under cultivation and estimated a further 495 hectares which are potentially cultivable. Such areas which could be developed further, if sufficient water is made available, would be in Koueveld and in

the lower part of the Main Valley below Suikerbosfontein.

There are 39 farmers in Klein Swartberg Valley with land under cultivation. Some relevant details of cultivated areas under irrigation and irrigation water supplies are given in Table 1 (Sheets 1 to 39) and Fig. 2 (Sheets 1 to 39).

The ground utilised for cultivation under irrigation is alluvial and colluvial soil in the valley of the Klein Swartberg River, upper Huis River, and their tributary valleys, along the foot of the Swartberg Mountains. On farm Sandrivier, tributary valleys of upper Bosluiskloof are cultivated.

The alluvial/colluvial soils are normally 10 to 15 m deep and cover shales (and, less commonly, sandstones) of the lower Bokkeveld Group (up to and including 4th shale - see section C).

#### B. WATER REQUIREMENTS AND WATER SOURCES

The summary table 2 gives the water requirements for the individual farms for land under permanent irrigation. These requirements are based on estimates given as follows:-

- (i) For fruit trees and vines in the season September to March, the equivalent of 980 mm of rainfall. (Figure given by Fruit and Fruit Technology Research Institute, Stellenbosch).
- (ii) For lucerne and vegetables, the equivalent of 760 mm of rainfall per year. (Figure given for Worcester area by Department of Agriculture, Worcester).

For Koueveld, there could be an over-estimate of water requirements since the climate is cooler there than in the Main Valley.

On the other hand, there could be considerable underestimates of requirements in view of the high permeability of the ground in many parts of Klein Swartberg Valley (see Section D below) especially in the case of the majority of farms where flood irrigation is practised.

According to these figures, the total quantity of water required annually for irrigation in Klein Swartberg Valley is 6 688 000 m<sup>3</sup>.

Sources of irrigation water are:-

- (a) Rainfall
- (b) Mountain Streams
- (c) Dam Storage
- (d) Boreholes

(a) Rainfall

Monthly rainfall recorded at Vleiland and Rietvlei from January 1960 to date, is given in Table 4. The rainfall at these farms may be taken as about average for the whole valley. Farms close to the mountain generally receive higher rainfall than those situated further away. Farm Rooihogte is reported to receive the highest average rainfall which decreases gradually to east and west.

Variation in the rainfall in Klein Swartberg Valley is shown, for Sept. 1971 onwards, on Fig. 3 sheets. These are based on additional rainfall records which have been taken since January 1971 by Messrs. A.W. Emit (Sandrivier) and C.J. Oosthuysen (Suikerbosfontein). Reports of rainfall by individual farmers have also been taken into account (e.g. the rainstorm of 5/6th January 1972 which affected farm Besemfontein only).

Table 2 indicates that during the period September 1971 to August 1972, the Koueveld farms and Rooihogte received 30-35 per cent of their total irrigation water requirements from rainfall

(effect of rainstorm of 5/6.1.72 may be excluded) while farms in the lower Main Valley received as low as 17 per cent of their requirements. The average percentage of irrigation water requirements received from rainfall in Klein Swartberg Valley may be taken as 20 per cent over this period.

The average annual rainfall in Klein Swartberg Valley between 1960 and 1971 inclusive is 318,6 mm (of 185,0 mm between September 1971 and August 1972). Theoretically, this would mean than in an average year, Klein Swartberg Valley would receive 30 to 35 per cent of its irrigation water requirements from rainfall. Table 2 shows, however, that in an average year, only 35 per cent of the total rain falls between October and March, the months during which the most water is required for irrigation of vines and fruit trees.

Even small falls of rain, especially during the months October to March, are highly beneficial to farmers who have irrigation land close to the Swartberg Mountains or those who have storage dams which can be filled from the augmented mountain streams. Farmers in Vleiland and the lower portions of farms Doornkloof, Baartransfontein, Suikerbosfontein, Doornrivier and Avondrus would not so benefit unless rainfall is sufficient to cause the Klein Swartberg River to flow.

#### (b) Mountain Streams

The mountain streams which flow permanently in Klein Swartberg Valley are shown on Folder 1 and their flows are given in Table 3.

The measurements were taken as near as possible to the foot of Swartberg Mountain, usually at the head of furrows or at the end of pipe lines leading from the intakes.

The flow measurements in beginning of October were taken as soon as possible after farmers reported cessation of overflow at the intake. They therefore represent, in most cases, an approximation to the maximum capacity of the furrows or pipe leading from the respective sources.

At the end of December, after two months of low rainfall, the measurements were retaken but since rain fell between January and March, the flows increased and no further significant flow measurement could be taken.

During a dry summer, the flows diminish further and those which flowed at less than  $5,0 \text{ m}^3/\text{h}$  in December 1971 may cease to flow altogether.

Taking the Klein Swartberg Valley as a whole, it may be observed that if the total flow in December 1971, of  $240,16 \text{ m}^3/\text{h}$  is maintained and can be fully developed, the mountain streams alone could provide 12 million  $\text{m}^3$  over a period October-April.

This well exceeds the calculated annual requirement for irrigation. In practise, however, much water is lost by leakage in furrows (lower furrow proprietors receive only a fraction, if any, of the water available at the mountain sources), and much of this water, when stored in dams, is lost by evaporation and underground leakage.

Further, a shortage of water would be experienced on farms Doornkloof, Baartmansfontein, and farms along the lower Klein Swartberg River since the normal summer flow is very small.

Without permanent automatic recording gauges near to intakes on each of the mountain streams, it is not possible to calculate

the potential water supplies from these sources; neither can the quantities of water used from them for irrigation be calculated unless the water led from them, from dams and furrows is measured.

Referring again to Table 2, however, it may be roughly assessed that:-

- (i) farmers in the Main Valley who derived less than 60 per cent of their irrigation water requirements from boreholes;
- (ii) farmers in Koueveld who derived less than 45 per cent of their irrigation water requirements from boreholes.

obtained the greater part of their irrigation water directly from furrows leading from mountain streams or indirectly from them by dam storage.

Rainfall during February and March 1972 was, however, well above average and many farmers thus benefited more from augmented flow of mountain streams than would do so in a normal summer season.

#### (c) Dam Storage

The total dam storage capacity in Klein Swartberg Valley, including concrete tanks, is estimated at 1 100 000 m<sup>3</sup>.

The largest storage dams are situated on the following farms:-

Besemfontein	-	G.F. Nefdt, O.J. le Grange, L.J. van Zyl (under construction)
Buffelsrivier	-	J.P. Ellis, W. Ferreira
Doornkloof	-	N.J. Carstens
Doornrivier	-	G.W. Roux
Willemsrivier	-	C.C. Mellett (in need of repair)

These dams, with the exception of those of G.F. Nefdt and O.J. le Grange (on 3rd shale, Bokkeveld), are situated at the foot of the Swartberg Mountains on 1st or 2nd shale of the Bokkeveld Formation.

While there is no report of excessive loss of water from dams situated under the Swartberg Mountains, some owners of dams situated on 3rd or 4th shale of the Bokkeveld (notably G.F. Nefdt, Besemfontein and J.J. Kritzinger, Rietvlei) have reported a heavy loss of water stored in them.

This may be largely due to evaporation but, for reasons given below (Section D), it is considered that heavy underground leakage may occur due to high permeability of the underlying shale. This high permeability is often indicated by high yielding boreholes in the vicinity of the dams.

Quantities of water obtained for irrigation from dam storage were not measured in the course of the present survey.

#### (d) Boreholes

According to information obtained from farmers in Klein Swartberg Valley, 198 boreholes have been drilled for water. (These include six boreholes drilled in 1971/72 by Dept. of Water Affairs for installation of automatic water-level recorders). Most of these boreholes were drilled on sites selected by water divining or other rough appraisals. 61 per cent have been successful as a result of drilling 40-150 m depth and the average pumping yield of the successful boreholes is 35 m<sup>3</sup>/hour.

Summary borehole statistics are given in Table 5. Further details are given in Table 1 (Sheets 1 to 39), Table 2, Fig. 1, Fig. 2 (Sheets 1 to 39) and Fig. 3 (11 sheets). Borehole positions are given on Folder 1.

With the exception of 11 boreholes, which have been drilled on uppermost quartzites of the Table Mountain Group, all boreholes drilled in the Klein Swartberg Valley are on lower shales and sandstones of the Bokkeveld Group.

Table 5 shows that the most successful boreholes have been drilled, not on the T.M. quartzites and lowest Bokkeveld shales above the 2nd sandstone horizon. Reasons for this are discussed below (Section D).

Referring to Table 2, allowing that on average, the fulfilment of irrigation requirements by rainfall are 20 per cent in the Main Valley and 35 per cent on Koueveld (comparing with Section B (2) above) it may be roughly estimated that the farmers who obtained the greater part of their irrigation water from boreholes during the period September 1971 to August 1972 are those whose percentage of water requirement pumped from boreholes exceeds 80 per cent both in the Main Valley and on Koueveld ( $60 + 20\% = 80\%$ ,  $45 + 35\% = 80\%$ ).

Several farmers pumped irrigation water from boreholes well in excess of their theoretical requirements, in certain cases 180 per cent or more. This is considered to be due to the high permeability of the ground in many parts of Klein Swartberg Valley, which would entail a high loss of water by:-

- (i) ground leakage (and evaporation) from storage dams. This would be largely eliminated where concrete tanks are used for storage;
- (ii) leakage from furrows;
- (iii) high wastage of water by leakage into ground under irrigation where flood irrigation is practised.

This topic is discussed further in Section D below.

During the period September 1971 to August 1972, the farmers who, it is assessed, derived the greater part of their irrigation water from boreholes are:-

- (i) those in the lower valley of the Klein Swartberg River - farms Buffelsfontein (Vleiland), Doornkloof, Baartmansfontein, Suikerbosfontein, and Driefontein;
- (ii) those on farms close to the foot of the Swartberg Mountains who have either meagre mountain stream supplies or small dam storage - N.J. Carstens (Doornkloof), P.J.J. Botes (Withoek), D.J. Swanepoel (Genanendal).

During a year of abnormal drought, many more farmers would be dependant upon boreholes for the greater part, if not their entire, irrigation water supply.

For a precise estimate of the degree to which farmers are dependant on boreholes for irrigation water supplies, it would be necessary to obtain measurements of water supplies available and utilised from mountain streams, to make an up-to-date measurement of dam storage capacities and to keep detailed rainfall records on individual farms.

Referring once again to Table 5, the effect of pumping of water for irrigation from boreholes in Klein Swartberg Valley during the period September 1971 to August 1972 was as follows:-

- (i) 3 710 000 m<sup>3</sup> were pumped from the whole valley.
- (ii) During the pumping season, the average maximum reduction in static water-levels at boreholes being pumped was 7,5 m (usually in February or March 1972). Average recovery was 4,2 m or 56 per cent of the drawdown. The average net drawdown was 3,3 m.

Incomplete recovery is attributed to the following factors:-

- (a) Very low winter rainfall (April to August) - this would mean a very low recovery due directly to rainfall and also that some farmers (notably those in the lower part of the Main Valley) had to continue pumping throughout the winter.
- (b) A few boreholes appear to have been pumped beyond their safe yielding capacity during the period September 1971 to April 1972, e.g. N.J. Carstens, Doornkloof (Fig. 2/24) and certain boreholes on Baartmansfontein belonging to J.A. Nel (Die Meule), B.J.N. van der Westhuizen and P.J.J. Botes (Figs. 2/27, 28, 30).

This topic is discussed further in Section E.

- (iii) During the pumping season October 1971 to March 1972, the average fall off in yield was 9 per cent. The full-off in yield was most pronounced in boreholes near to the Swartberg Mountains drilled below the 2nd Bokkeveld sandstone horizon. Measurements have not yet been made to test whether or not a recovery in pumping yield has taken place. Many boreholes in the Main Valley above the 2nd Bokkeveld sandstone, although pumped heavily, were never pumped to full capacity.

The quality of water pumped for irrigation from boreholes was measured, in many cases at the beginning and end of the pumping season. No significant deterioration in quality was noted. Total

dissolved solids in p.p.m. are given on Table 1 (Sheets 1 to 39).

Water may be classified in three divisions:-

- (i) Fresh water (T.D.S. less than 200 p.p.m.) - derived from boreholes in T.M. quartzite and lower Bokkeveld formations close to the foot of Swartberg Mountains as far west as Rouxpos.
- (ii) Slightly brackish water (T.D.S. 200 to 400 p.p.m.) - derived from boreholes in Bokkeveld shales away from the foot of the Swartberg Mountains as far west as Suikerbosfontein.
- (iii) Brackish water (T.D.S. over 400 p.p.m.) - derived from boreholes in T.M. quartzite and Bokkeveld shales west of Rouxpos and Suikerbosfontein.

In general, the quality of groundwater normally tends to deteriorate.

- (i) northwards away from the Swartberg Mountains;
- (ii) in directions east and west along the foot of the mountains away from the Rooihoogte pass.

Water in high yielding boreholes tends to be of better quality than in low yielding boreholes in the same neighbourhood. With the possible exception of the water pumped from boreholes AJHS 1 and 2 at Driefontein, all water is suitable for irrigation of vines and fruit trees.

### C. GEOLOGY

The geology of the Klein Swartberg Valley is depicted on Folders 1 and 2.

The whole area is underlain by rocks of the Cape System. The strike is east-west and the northerly dip causes progressively higher members of the succession are to be exposed northwards.

Witteberg Group	- Quartzites and shales	Elandsberg
Upper Bokkeveld Group	- Flaggy sandstones and shales	Hills
	4th shale <sup>‡</sup>	
	3rd sandstone	
	3rd shale	
Lower Bokkeveld Group	2nd sandstone	Klein Swartberg
	2nd shale	Valley
	1st sandstone	
	1st shale	
	Top sandstone	
Table Mountain Group	Upper quartzite	North Swartberg escarp-
	Lower quartzite	ment
		High Swartberg Mountains,
		Seven Weeks Poort,
		Buffels Poort

In Klein Swartberg Valley, the "sandstones" of the lower Bokkeveld Group are largely quartzitic, not unlike Table Mountain quartzite in appearance, while the "shales" frequently include beds of impure grey sandstone. The top "sandstone" of the Table Mountain Group is also largely quartzitic and, in many places, cannot be distinguished from the upper quartzite with certainty.

The rocks are further described by Rogers (1925), Rossouw et al. (1964), and by Theron (1972).

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<sup>‡</sup> Top of 4th shale and base of upper Bokkeveld are determined by the base of the first sandstone above the 3rd sandstone.

Structurally, the Klein Swartberg Valley follows the northern limb of the east-west striking synclinorium of the Swartberg Mountains. The rocks of the lower Bokkeveld Group, while generally dipping northwards away from the Swartberg anticlinorium are themselves locally folded into minor anticlines and synclines also trending east-west. In the west, the rocks on the northern limb of the Swartberg anticlinorium are gently dipping and the minor folds are open. Eastwards, the dip of the northern limb steepens and in Koueveld, some of the minor folds are overfolded.

The thickness of the lower Bokkeveld Group appear to vary from 600 m in Koueveld—Rietvlei area to 850 m in the lower part of the Main Valley. This could be attributed to thickening of the incompetent shale members in areas of gentle folding. (See sections, folder 2).

Individual members in the lower Bokkeveld Group vary in thickness. For instance, in the Main Valley between Stelladale and Suikerbosfontein, the 3rd "sandstone" thins to a mere 10 to 20 metres bringing the 3rd and 4th shales into near juxtaposition. (No evidence of strike faulting was observed). This may be hydrogeologically significant as discussed in section D below, since it is in this section of the Main Valley where the greatest concentration of strong yielding water boreholes have been drilled. No evidence of faulting has been observed in the rocks of the Cape System. The superficial deposits include alluvial and colluvial sands, silts and gravels. In the broader valleys of the Klein Swartberg and Upper Huis Rivers, sands and silts predominate but in the upper reaches of tributaries along the foot of the Swartberg Mountains, coarse gravels and talus are deposited. In general, these deposits are not more than 10-20 m in thickness.

#### D. HYDROGEOLOGY

All boreholes which are pumped for irrigation in Klein Swartberg Valley have been drilled to depths of at least 40 m, generally to 60-120 m, and a few to 150 m or more. (Details given in Table 1 Sheets 1 to 39). All of them struck the main water supply in Cape rocks. There are no recorded instances of strong, consistent water supplies having been encountered in superficial deposits.

##### (1) Water-bearing properties of the Cape Formations

The main relevant members of the Cape System will here be briefly considered in turn as potential aquifers.

##### (i) Quartzites of the Table Mountain Group.

Strong, consistent supplies of groundwater of excellent quality have been obtained by drilling into the quartzites of the Table Mountain Group especially where the quartzites are highly fractured or brecciated, - e.g. Caledon, Worcester, Montagu, Ladismith and Uniondale Districts.

Areas where water supplies for irrigation have been located within these districts are, however, somewhat restricted and many boreholes have given disappointingly low yields.

Along the northern escarpment of the Klein Swartberg Mountains, little evidence of intense fracturing or brecciation has been observed.

The formation has the disadvantage of being exceedingly hard, and severe technical difficulties of drilling may ensue.

Boreholes in Klein Swartberg Valley drilled in uppermost Table Mountain quartzites are:-

	Koueveld	- JJH 1	(Table 1/1(c))
		JEN 8	(Table 1/3(c))
		AWS 2	(Table 1/5(a))
	Baartmansfontein	- JAN 2	(Table 1/27)
Main		- PJJB 1, 2, 3, 4	(Table 1/30)
Valley	Suikerbosfontein	- DJS 2	(Table 1/31)
	Driefontein	- HRM 1	(Table 1/38)

In addition J.P. Ellis (Kliprivier, Buffelsrivier) drilled 4 boreholes on uppermost T.M. quartzites which went off-line at shallow depth ( 30 m) and were abandoned.

The boreholes drilled in the Koueveld give comparatively low yields which could at best provide an auxiliary supply of irrigation water. If pumped at more than 10 m<sup>3</sup>/h, the yield decreases with prolonged pumping.

The boreholes in the Main Valley have been more successful. Yields are higher (20 to 50 m<sup>3</sup>/h) but also decrease considerably if pumped for long periods.

(ii) Quartzites and sandstones of the lower Bokkeveld Group.

In general, water bearing properties of the quartzites and sandstones of the lower Bokkeveld formations are similar to those of the associated shales. In many parts of the Cape Province, these rocks are poor aquifers and yield saline water - e.g. Bredasdorp, Swellendam, Riversdale areas. In other areas, e.g. Grabouw Hex River, Ceres, south of Oudtshoorn, strong yields may be obtained but the water is usually brackish to some degree.

In Klein Swartberg Valley, with three exceptions, boreholes drilled on these quartzites and sandstones have given good yields of water of suitable quality for irrigation.

There appears to be no advantage, however, in drilling on the sandstones and quartzites in preference to the shales. In fact the hardness of the sandstones and quartzites may present technical difficulties which would not otherwise be encountered. If these sandstones/quartzites are encountered at depth and the dip is steep, they may cause the borehole to go off line, e.g. borehole ABG 3 (Table 1/14) at Vrede gives a moderately good yield but is only 40 m deep and cannot be deepened. Boreholes AWS 8 (Table 1/5) at Sandrivier, ABN 6 (Table 1/20) at Vleiland GWR 2 (Table 1/32) at Doornrivier encountered hard rock and gave low yields.

Successful boreholes drilled on sandstones/quartzites of the lower Bokkeveld include:-

JMK 4	(Table 1/19)	Vleiland	(3rd sandstone)
NJC 1	(Table 1/24)	Doornkloof	(1st sandstone)
BJNW 3	(Table 1/28)	Baartmansfontein	(2nd sandstone)
BJNW 4, 8	"	"	(3rd sandstone)
CJO 4, 7	(Table 1/32)	Suikerbosfontein	(2nd sandstone)
ACB 1	(Table 1/35)	Avondrust	(1st sandstone)

(iii) Shales of the lower Bokkeveld Group

The water bearing properties of the shales of the lower Bokkeveld Group are similar to those of the sandstones and quartzites described briefly above (subsection ii).

In Klein Swartberg Valley, as Table 1 (Sheets 1 to 39) illustrates, strong yields of slightly brackish water of suitable quality for irrigation can be obtained from these shales.

The shale is soft and easily drilled, but is usually sufficiently cohesive that risk of caving-in of the borehole is small.

A total of 176 boreholes have been drilled on these shales in Klein Swartberg Valley with 60 per cent success. These include all the strongest, most consistently yielding, boreholes in the valley.

(2) Fissuring in rocks of the Cape System.

As mentioned in Section D(1) above, the water bearing properties of the rocks of the Cape System vary greatly from place to place in the Cape Province and there is a similar, but lesser variation within the Klein Swartberg Valley.

Table 5 shows clearly that in the Main Valley, boreholes drilled north of the Bokkeveld 2nd sandstone outcrop are more successful than those drilled south of that horizon. Success percentage, average yield, and average recovery percentage are all higher, while average maximum drawdown and percentage average decrease in yield are all lower, in boreholes drilled north of the 2nd sandstone horizon.

A similar variation is indicated in Koueveld since GFN 1, 2 and 8 are all high yielding boreholes (Table 1/1) but there, insufficient drilling has been done north of the 2nd sandstone horizon to draw definite conclusions in this respect.

The shales and sandstones of the Bokkeveld Group would, in the normal way, be considered a highly infervious formation and a very poor potential aquifer. In certain areas of the Cape Province, of which Klein Swartberg Valley is one, the rocks of the formation are fissured to some degree. Fissuring may be attributed to conditions of low tectonic compression, or even tension (Olivier in press, Whittingham 1971 a, b). The resultant open joints in the formation facilitates the infiltration of meteoric water and the

circulation of groundwater stored therein.

The fissuring is sometimes indicated by the presence, in joints and on rock surfaces, of veins and encrustations of oxides of iron and manganese, and (more prominent in Klein Swartberg Valley) lime. Such material is soluble or colloidal material which has been derived from fissured formations at depth by circulation of water in the fissures. The possible sources of these oxides are:-

Iron and manganese oxides - lowest members of upper quartzites of Table Mountain formation (suggested by Toerien).

Lime<sup>‡</sup> - from pre-Cape formations (e.g. large Limestone).

From this, it would appear that the fissured zones must extend deep into the earth's crust. The longitudinal extent of these zones is not well defined; so far, it can only be stated that, in the Great and Little Karoo, such zones are elongated east-west, parallel to the Cape Fold Belt.

The groundwater potential of the Cape formations would depend on the degree to which the rocks are fissured. In the case of Klein Swartberg Valley, it is suggested that the sequence underlying the 2nd sandstone is fissured, but not to the same degree as the beds which overlie the 2nd sandstone.

From hydrogeological data available, it would appear that the incompetent shale members of the Bokkeveld formation are generally fissured to a greater degree than the sandstone and

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<sup>‡</sup> It is unlikely that lime has been derived from superficial sources. Note has not been made of lime encountered in drilling in Klein Swartberg Valley, but at Kandelaars River, driller Hayes of Oudtshoorn recorded concentrations of lime at 100 m depth or more.

quartzite members. This may account for the concentration of high yielding boreholes in the Main Valley between Middelpaas and Suikerbosfontein where the 3rd sandstone is thin and the 3rd and 4th shales are in near juxtaposition.

An alternative explanation for concentration of groundwater supplies in this section of the Main Valley is the presence of the Klein Swartberg River, which facilitates recharge during rainy periods when the river flows. Water could also be stored in alluvium and infiltrate into the underlying Bokkeveld shales. Although the facilitation of surface recharge in this way is doubtless an important factor to be considered, it does not preclude the hydrogeological theory of fissuring outlined above, for the following reasons:-

- (i) In the valley of the Klein Swartberg River at Driefontein, below where the river transgresses the 2nd sandstone, and in the upper Huis River Valley on farm Besemfontein, conditions during rainy periods should also facilitate recharge, yet the success percentage and yields of successful boreholes are considerably lower than in the Main Valley between Middelpaas and Suikerbosfontein. Even in the Main Valley below Suikerbosfontein immediately above the 2nd sandstone horizon, success percentage and yields of boreholes are lower.
- (ii) On farm Besemfontein, the most successful boreholes (GFN 1, 2 and 8) are on the 3rd shale horizon, in a position where there is no river and recharge from mountain streams is not easily facilitated.

(iii) Along the outcrop of the 4th shale, under natural conditions, spring water flows at  $14 \text{ m}^3/\text{h}$  in the river after the river higher up has ceased to flow, and continues to flow until borehole JAN 1 is pumped. Springs also occur at Nietvoorby and along Bosluiskloof (total flow approximately  $10 \text{ m}^3/\text{h}$ ). Small, but permanent, seepages also occur high on the steep southern flank of Bosluiskloof, to the north of boreholes GFN 1 and 2.

Further evidence in favour of or against the high concentration of fissures along the 3rd and 4th shale outcrop might be gained by drilling on those outcrops on farms Sandrivier and the western portion of Besemfontein. Under the above hypothesis, strong supplies of groundwater can be expected in parts of these farms which are so far undeveloped.

The fissure hypothesis may also explain why several farmers, notably in the main valley between Stelladale and Suikerbosfontein, have to pump in excess of their theoretical water requirement for irrigation purposes. If the water is stored in ground dams or led to the irrigation area by furrows, much of the water will leak back into the ground, both into the alluvium as well as the underlying shale formation which is in fact, highly pervious. Of the water pumped from boreholes and stored in ground dams only a fraction (not determined) reaches the crops under irrigation. The rest is dissipated by recharge and evaporation.

Natural recharge of shale aquifers in Klein Swartberg Valley has been observed by farmers (J.J. Kritzinger and A.B. Gouws) on farms Rietvlei and Vrede. On these farms there are

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points in the bed of the Klein Swartberg River where water, flowing strongly higher up, disappears for a time (until recharge at that point is complete) and after that flows at the original strength below the point of disappearance. This phenomenon occurs at the beginning of a rainy period and has not been observed on the present survey.

#### E. GEOHYDROLOGY

In the Klein Swartberg Valley measurement of water-levels in boreholes and their attitudes above mean sea-level in September 1971 revealed that the groundwater-level in the valleys was at a depth of 0 to 20 m below the surface. At that time, the groundwater-level was undisturbed by pumping, following a winter (March to August) of average rainfall during which boreholes in the valley were not pumped.

The groundwater-level corresponds broadly to the topography. The groundwater gradient, however, while corresponding to the topographical gradient longitudinally along the valley, is less than the topographical gradient laterally across east-west trending ridges. This is illustrated on profiles (Folder 2(a)).

Groundwater-level contours are shown on Folder 1(a).

Charts from water-level recorders show that the groundwater-level is subject to semi-diurnal fluctuations, but these are only of the order 1-2 cm in the equinoxial period (September 1972).

Drawdown in groundwater-level, in boreholes which were pumped, is given in Table 1 (Sheets 1 to 39) and on Fig. 2 (Sheets 1 to 39) and is summarised in Table 5. Drawdown in groundwater-level is also reflected in boreholes fitted with water-level recorders. These records are summarised in Fig. 3 (11 sheets).

On Fig. 3 the fluctuations in groundwater-level are shown together with quantities of water pumped from neighbouring boreholes - the red histogram represents quantities of water pumped from the borehole which appears to have the main effect on the water-level at the recorder borehole; the black histogram represents total quantities of water pumped from all boreholes in the vicinity, which could feasibly affect the groundwater-level.

In general, it may be observed that water-levels at boreholes fitted with recorders respond most strongly to pumping of boreholes situated in an east-west direction from them.

It is significant that boreholes JMK 1 and 4 at Vleiland which are 30 m apart in a north-south direction do not noticeably affect each other when pumped. On the other hand, a seasonal drawdown of 10 m at AWRO 1 (Doornkloof) is reflected by a seasonal drawdown of 10 m at recorder borehole AWRO 6 situated 30 m to the south.

A seasonal recovery of 41 m at borehole AWS 7 (Sandrivier) is reflected by a recovery of 18 m at recorder borehole AWS 9, 200 m to the east, over the same period.

Taking conditions over Klein Swartberg Valley as a whole, (Ref. Fig. 1 and Table 5) it is observed that while between September 1971 and end of March 1972 a total of 3 100 000 m<sup>3</sup> was pumped from boreholes, there was a maximum average drawdown of 7,5 m (in most cases the maximum drawdown occurred between February and April 1972). During this season conditons were complicated by rainfall above average in January and February which enabled some farmers to stop pumping early and an abnormally dry winter which forced other

farmers to continue pumping during the winter months.

Average recovery during the winter months in Klein Swartberg Valley was 4,2 m or 56 per cent. For a normal winter, it may be inferred that a recovery of 90 per cent is more typical, as was observed at Koueveld, where pumping virtually ceased at the end of April 1972.

In observation boreholes (Ref. Figs. 2 and 3) not all directly affected by pumping, the average maximum fall in groundwater-level was 4,9 m with an average recovery of 3,7 m or 75 per cent. It is considered, however, that observation boreholes (31 altogether) are insufficient to draw definite conclusions on the changes in water-level remote from boreholes which are pumped.

Nevertheless, these figures which are available may lead to a closer approximation to the actual mean drawdown in groundwater-level. Taking the mean figures between pumping and observation boreholes, the effect of pumping during the period September 1971 to March 1972 (3 100 000 m<sup>3</sup>) would be as follows:-

Mean drawdown in groundwater-level 6,2 m

Mean recovery in groundwater-level 4,0 m after pumping is reduced or stopped

Mean percentage recovery 65

Mean net drawdown in groundwater-level 2,2 m

Recovery of groundwater-level may be attributed to

two sources:-

- (i) Subterranean recharge - recharge from underground sources consequent upon the cessation of pumping.
- (ii) Meteoric recharge - recharge due either directly to rainfall or surface run-off and storage (infiltration along river courses or in ground dams).

It is not possible to assess accurately the relative importance of subterranean and meteoric recharge. The fact that there was a mean percentage recovery of the order 65 per cent, in spite of abnormally low winter rainfall and that some farmers continued pumping in the winter months, thereby lowering the groundwater-level further, suggests that subterranean recharge is a very important, if not the dominant factor.

An illustration of this may be cited from the W.L. recorder chart for borehole AWS 9 (Sandrivier) for September 1972. At Sandrivier 35,6 mm of rain fell on 20th/21st September. Although rain fell during the remainder of the month, (19 mm) it was sporadic only.

Between 31st August and 20th September, the recovery was uniform at the rate of 7,5 cm per day. Between 20th September and 3rd October, the recovery rate increased to 9,5 cm per day. The increase was most pronounced between 25th September and 1st October. Since the borehole is remote from dams or stream channels, this instance may indicate that even during or following a rainy period, subterranean recharge remains the dominant factor and is of the order 75 per cent.

The year of investigation in Klein Swartberg Valley has been one of abnormal weather and recovery of groundwater-level after the season's pumping, has been incomplete. It is not possible at this stage to determine whether or not complete recovery will occur after a normal winter rain.

So far, there are available only farmer's reports (Kritzinger, 1971) of severe drought conditions in 1968, 1969 and 1970 during which period many new boreholes were drilled to augment water

supplies, pump yields fell due to fall in groundwater-level and many pumps had to be inserted deeper. Even during this period, there are no reports that the quality of water noticeably depreciated.

Following a winter of average rainfall in 1971, with consequent cessation of pumping for a 5 month period, conditons were in September 1971 at the beginning of the present investigation, reported to be similar to conditions prior to 1968, although large quantities of water, probably of the order 15 million m<sup>3</sup>, had been pumped in the meantime. The farmers anticipate that following the next normal winter rainfall there will be a further complete recovery of groundwater-level and strength of water supplies. Geohydrological observations would have to be continued in Klein Swartberg Valley up to the time following the next winter of normal rainfall to test whether or not this is so.

#### F. CONCLUSIONS AND RECOMMENDATIONS

1. The Klein Swartberg Valley is a region which, like others in the Cape Province, is fortunate to have strong and largely, if not fully, replenishable groundwater supplies at its disposal. Future investigations would be necessary to prove whether these reserves are, in fact, wholly or only partially replenishable.
2. Areas of land suitable for cultivation are limited in extent and there is little inducement for over-development of land with respect to water supplies from surface or underground source at its disposal. Further development with adequate water supplies is, in the writer's opinion, possible on the outcrop of the 3rd and 4th shale of the Bokkeveld Group in the northern parts of farms Sandrivier and Besemfontein. The existence of strong underground water supplies there is likely, but has yet to be proved.

3. In the terrain north of the 2nd Bokkeveld sandstone outcrop there is no evidence that any boreholes have been, or are being, pumped in excess of their safe yielding capacity although 2 470 000 m<sup>3</sup> (65 per cent of total) of water have been pumped from these strata during the period of investigation. In the terrain south of the 2nd Bokkeveld sandstone horizon, there are indications that a few farmers in Doornkloof/Baartmansfontein have pumped beyond the safe yielding capacity during that period.

4. Owing to the permeable nature of the ground in many parts of Klein Swartberg Valley, strong underground water supplies are readily available. On the other hand, due to the same reason, much water pumped from the ground appears to be "wasted" in delivery to irrigated areas, especially if ground dam storage is used and flood irrigation is practised. The "wasted" water is not, however, lost, but percolates into the ground to replenish aquifers from which it was pumped, but it would appear that much expense in fuel and depreciation of pumping equipment could be saved if this "wastage" is prevented. This could, in the writer's opinion, best be done by:-

- (i) installation of overhead irrigation equipment which could, wherever possible, be supplied direct from a borehole;
- (ii) erection of concrete tanks for storage of water pumped from boreholes where this is necessary.

5. It is recommended that:-

- (i) the present groundwater survey be continued with a view to testing more conclusively the strength and permanence of the underground water supplies in Klein Swartberg Valley.

- (ii) consideration be given to installation of overhead irrigation equipment and erection of concrete storage tanks as suggested in para. 4 above. Outlay in these items of equipment is here considered to be the means of development to which assistance could most profitably be given;
- (iii) the surface water potential in Klein Swartberg Valley be determined. This would require the installation of permanent gauging weirs with automatic water stage recorders near the intakes on each of the main kloofs. If these supplies prove adequate, improvement of supplies to the lower furrow proprietors by building of storage dams and concrete furrows or pipes could be considered.

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NOTE ON ANOMALOUS RECOVERY AT AWRO 6 DURING OCTOBER 1972

(Ref. Fig. 3/25 and Recorder Charts for October)

During October, 1972, although Bh AWRO1 was pumped heavily so that in the normal way, a drawdown of the order 1-2 m would be expected, there was, instead, a recovery of 2,5 m. (Week-end recovery maxima measured).

Rain fall heavily on 20/21 September which caused the Klein Swartberg River to flow until mid October. (On 2nd October 1972, a flow of about 45 m<sup>3</sup>/h was seen at the bridge west of Vleiland). This enabled Vleiland/Rietvlei farmers to suspend pumping till mid October. According to Mr. A.W.R. Oosthuizen, on Doornkloof, the river does not flow on his farm unless rains are exceptionally heavy. He was obliged to pump from boreholes throughout October. The net recharge of 2,5 m (Gross recharge estimated at 4 m) must have been due to the flow of the river (in river bed as far W as Vleiland, in gravels on Doornkloof).

Below Doornkloof the river resumed flow till mid October on farms Baartmansfontein/Suikerbosfontein but flow was of the order 10 m<sup>3</sup>/h only. On Suikerbosfontein, pumping from boreholes was reduced till mid October but there was no marked recovery at recorder CJO 10.

There was also no recovery, but instead a drawdown, on recorders Vleiland, WF 6 and WPK 4 due to resumed pumping in October.

The foregoing facts suggest that Mr. A.W.R. Oosthuizen's portion of farm Doornkloof is situated on a groundwater sump, of which he takes full advantage for his irrigation!

TABLE 3. - MOUNTAIN STREAM SOURCES KLEIN SWARTBERG  
VALLEY LAINGSBURG DISTRICT, C.P.

Source	Farm	Mountain stream flow in m <sup>3</sup> /h	
		Beginning <sup>#</sup> October 1971	End <sup>+</sup> December 1971
Waterval	Besemfontein	22,9	Dry
Bowaterkloof		No measurement	9,0
Rondefontein	Sandrivier	4,14	2,75
Slootrivier		2,05	0,45
Sandrivier		65,9	38,5
Weskloof		No measurement	1,09
Rooihoogte	Rietvlei	100,0	39,6
Kleinwaterkloof		35,0	13,0
Rooikloof	Vrede	27,4	14,2
Modderrivier	Buffelsrivier	21,3	7,3
Stelladale		26,1	6,0
Kliprivier E		49,1	17,3
Kliprivier W		9,8	2,8
Doornkloof	Doornkloof	12,0	2,96
Baartmansfontein	Baartmansfontein	36,4	2,86
Withoek E	Suikerbosfontein	1,4	Dry
Withoek W		9,9	8,46
Genanendal		11,4	7,96
Rouxpos	Doornrivier	20,5	15,9
Avondrust	Avondrust	12,5	5,14
Willemsrivier	Willemsrivier	No measurement	7,96
Kleinhoek	Driefontein	7,64	11,70
Vergenoeg		2,68	2,91
Damfontein		14,3	15,1
Steenbergsekloof		1,82	3,05
Driefontein		No measurement	4,27
Total summer flow			240,16 m <sup>3</sup> /h

±

Measured in furrows after reports received that overflow at intakes had ceased.

+

In most cases, this represents minimum flow during summer 1971-72 since rain fell between January and March 1972. No significant flow measurements could be taken after beginning of January 1972.

TABLE 4. - MONTHLY RAINFALL (VLEILAND/RIETVLEI)

in millimeters

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
1960	25,5	0	7,7	23,0	70,0	85,2	12,2	0	13,0	6,7	10,7	20,7	274,7
1961	6,2	65,0	6,2	78,5	20,0	89,0	77,0	65,7	46,2	0	22,5	0	496,3
1962	51,2	10,0	0	8,7	13,7	110,0	41,2	19,1	0	35,0	40,0	0	328,9
1963	98,7	0	76,2	74,0	61,2	66,0	110,0	14,0	0	0	12,7	121,0	634,0
1964	16,2	0	35,0	6,2	4,7	89,7	6,2	72,2	33,0	40,0	7,9	35,7	349,8
1965	14,0	30,0	65,5	167,2	24,0	20,0	39,7	15,5	0	126,0	3,2	3,2	508,3
1966	14,0	8,7	4,0	30,0	13,0	15,6	6,0	9,0	17,7	0	6,0	0	124,0
1967	0	20,0	0	147,5	27,0	48,5	16,5	0	6,0	0	18,0	24,0	307,5
1968	0	0	0	0	46,8	0	0	0	0	0	0	0	46,8
1969	0	7,5	23,5	26,5	8,5	15,5	7,5	0	20,9	15,5	0	0	125,4
1970	0	29,5	0	6,5	16,0	9,5	24,5	27,0	0	22,5	0	0	135,5
1971	0	0	21,4	56,5	9,5	3,0	48,5	32,0	0	0	7,0	5,0	182,9
1972	10,5	35,5	56,5	0	38,5	0	0	0	52,1				
Month-ly average (1960-71)	20,7	15,6	21,8	56,8	28,8	50,6	35,2	23,0	12,5	22,5	11,7	19,4	318,6

ES PUMPED FOR IRRIGATION IN KLEIN SWARTBERG VALLEY,  
ICT DURING PERIOD SEPTEMBER 1971 TO AUGUST 1972

MAIN VALLEY			WHOLE OF KLEIN SWARTBERG VALLEY			REMARKS
kke- and- in- g uart-	Above 2nd Bokke- veld sand- stone	All forma- tions	2nd Bokke- veld sand- stone and below, in- cluding T.M. quart- zite	Above 2nd Bokke- veld sand- stone	All forma- tions	
	103	162	86	112	198	No boreholes drilled in upper Bokkeveld or Witteberg formations
	59	88	39	61	100	
	12	16	6	14	20	
	71	104	45	75	120	
	10	17	10	11	21	12 of these are fitted with automatic water-level recorders. Could be used for irrigation if affecting boreholes are not used
	22	41	31	26	57	13 of these have windpumps installed for domestic/livestock use
	32	58	41	37	78	
	69	64	52	67	61	
	39	36	27	39	35	
	1060	1120	1160	1040	1060	Moderate pumping in Rietvlei, Vrede, Buffelsrivier this season
	2450	3520	1240	2470	3710	

MAIN VALLEY			WHOLE OF KLEIN SWARTBERG VALLEY			REMARKS
kke- and- and in- g uart-	Above 2nd Bokke- veld sand- stone	All forma- tions	2nd Bokke- veld sand- stone and below, in- cluding T.M. quart- zite	Above 2nd Bokke- veld sand- stone	All forma- tions	No boreholes drilled in upper Bokkeveld or Witteberg formations
	5,8	6,7	10,2	5,8	7,5	
	2,9	3,1	6,3	2,9	4,2	Low in Main Valley due to (i) Overpumping at Doornkloof (NJC) and Baartmansfontein (below C <sub>2</sub> Q <sub>2</sub> )
	50	46	62	50	56	(ii) Continued pumping in winter at Doornkloof (AWRO) and Suikerbosfontein (JJJO & CJO) (above C <sub>2</sub> Q <sub>2</sub> )
	7	9	14	7	9	
	2,9	3,6	3,9	2,9	3,3	