Where :

E = the soil loss in tons/hectare

R = an erosivity index = $\frac{EI_{30}}{100}$

E = Kinetic Energy of rainfall

I_{30} = Rainfall intensity of a 30 minute storm

K = erodibility index

L = Slope length

S = slope gradient in per cent

C = cropping management factor

P = erosion control factor

The equation has been developed by soil conservationists purely through observational data, regression and statistical analysis of plots over many years and the equation has been developed and modified according to the area in question, whether it be temperate, tropical or sub-tropical. The equation takes into account grain size, bulk density of material, slope length, slope angle, permeability and, most importantly, the rainfall characteristics.

In trying to analyse the erosion of slimes it became necessary to modify existing parameters suitable to the particular area and conditions.

Wischmeier and Smith[9] carried out the most significant work on rainfall based on 22m plots on a 5 degree slope throughout America and developed a kinetic energy equation based on rainfall intensity.

$$KE = 1{,}213 + 0{,}890 \log_{10} I$$

where KE = kinetic energy in kg m/m^2

and I = rainfall intensity in mm/hr

Hudson[10] observed $KE = 29{,}8 - \frac{127{,}5}{I}$ for tropical rainfall in Zimbabwe. The Kinetic Energy is based on the summation of intensities of rainfall for different storm times. However the measurement and recording of the storms is beyond the scope of this report and it is hoped to show that a prediction can be made by back analysis of the results obtained for the erositivity index R.

K is described as the erodibility index and assumes that different soils erode at different rates based on the soil grading analysis, permeability and organic content. The nomograph shown in table 4.8 had been developed to cover differing types of soils in America and many locations world wide and is considered a valid nomograph for general soil erodibility.

LENGTH AND GRADIENT

The effect of slope length and gradient are represented by L and S but are often evaluated together as LS. L is defined as the distance of the point of origin of the flow of water to the point of deposition and slope gradient is expressed as a percentage. Wischmeier and Smith defined the factor.

$$LS = \left(\frac{x}{22{,}13}\right)^m (0{,}065 + 0{,}045S + 0{,}0065S^2)$$

where x is the slope length and m varies and is dependent on slope angle but is equal to 0,5 for slopes greater than 5 per cent. Morgan [11] refined this to more manageable terms.

$$LS = \sqrt{\frac{L}{100}} \quad (0,136 + 0,097S + 0,0139S^2)$$

The equation has been developed for angles of up to 25° therefore it is with caution that this equation must be used for angles greater than this as no previous research has indicated the equation valid above 25°. It is intended to show that the equation is valid to an angle of 35° thereafter other factors should be taken into account in the prediction. Wischmeier and Mayer warned that beyond some critical steepness the formula would probably overpredict soil loss.

C AND P

The cropping management factor C and erosion control factor P represent the soil loss from a specific cover condition eg. crops or grass and the soil loss due to specific practices such as contouring or furrowing. The factors do not apply to the case of slimes dam slopes except perhaps for benching of slimes but the factors have been taken to be 1 for each slimes dam.

The literature survey of articles from 1981 onwards tended to reiterate the views of earlier articles or were found not to be directly relevant to the problem addressed.

3.0 FIELD W(

3.1 INTRODUCTION

The theory behind the development of E T C O M was that as the flow of water over the surface has a shearing effect on the surface particles, the shearing effect should be a measurable item and is directly related to the rate of loss of soil from the slopes. If this shearing effect could be simulated and measured then a relationship could be established between E T C O M reading and rate of soil loss.

3.2 E T C O M

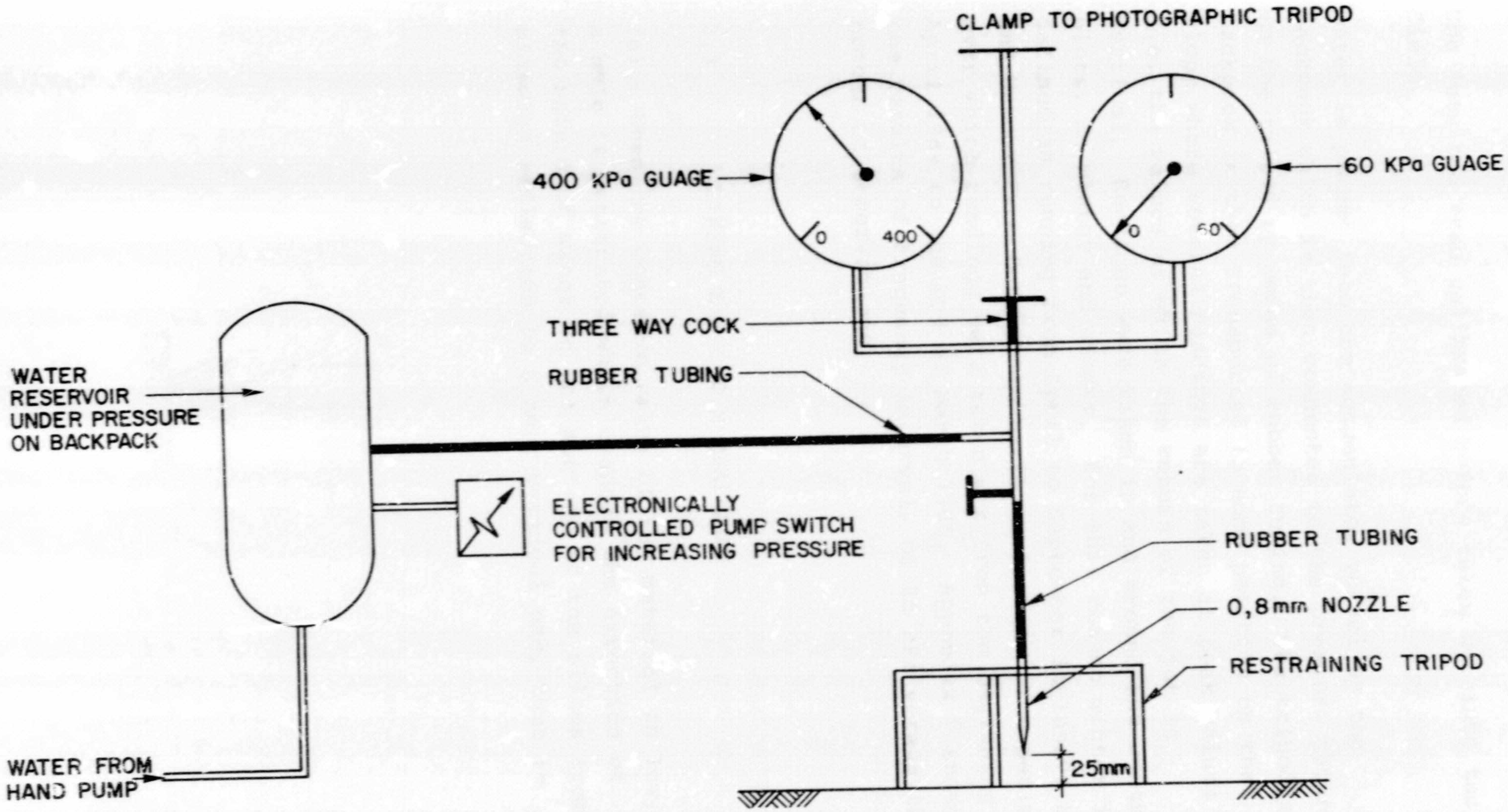
Fig. 3.0 shows a diagram of the layout of E T C O M and its appurtenances. They consist of :

(a) A portable pump with pressure gauge reading to 2500 kPa.

(b) A backpack with accumulator, and electronic pump regulator. Water is pumped into the accumulator to a pressure of 2000 kPa.

(c) Low and high pressure gauges on adjustable tripod.

(d) Fixed tripod with 0,8mm nozzle clamped 25,4mm above surface.



DIAGRAMMATIC OUTLAY OF EROSION TESTER CHAMBER OF MINES E.T.C.O.M.

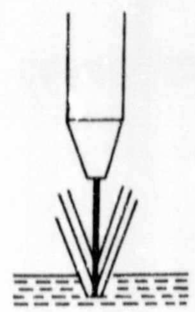
FIG. 3,0

The jets had been calibrated before taken out into the field.

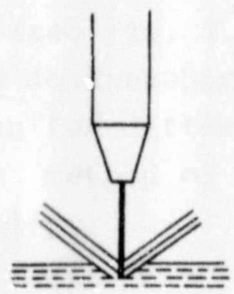
Water is pumped into the accumulator vessel on the backpack which is then connected to the pressure gauges on the tripod by means of rubber tubing. The tripod and backpack is then transported to some position on the slope where several readings are taken at peak values i.e. the values at which the return of the jet is vertical. Readings were taken in and around the control plots, in winter and summer. For this reason winter is defined as running from April to September inclusive and and summer from October to March inclusive. The period over which readings were taken was from the beginning of April 1984 to the end of March 1985. Appendix B shows the results of frequency intervals of 25 kPa versus the number of observations.

3.3 TAKING E T C O M READINGS

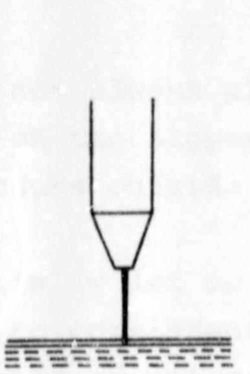
(a) When the cohesive value of the material is low, a hole is penetrated which changes the direction of the return of water on the surface of the slimes from a sideways reflection to a near vertical one, thus :-



(b) As the cohesive value increases, the surface particles are seen to become dislodged without the marked drilling of a hole as in (a) and the direction of the return of water lifts at a more gentle angle than previously shown :-



(c) When the cohesive value is above the maximum dislodging force of E T C O M (400 kPa), the return of water hugs the surface of the slimes :-



3.4 FIELD MEASUREMENTS

3.4.1 THE PLOTS

A series of ten plots were chosen on seven slimes dams each measuring 9m by 9m (see Fig. 3.1 and 3.2 for location) within the Johannesburg / Germiston area. The plots were chosen for differing aspect, slope length, and angle and method of deposition (eg. benched or uniform slope).

8mm diameter mild steel pegs, one metre in length were driven normal to the slope at three metre intervals giving a 4 x 4 peg plot of 16 pegs in total. 250mm of each peg, accurately measured, was left proud of the ground. The positioning of the plot is critical assuming an averaging of results, so plots were positioned approximately in the middle of the slope length. It is assumed that erosion is least at the top of the slope and most at the bottom. Therefore an averaging value should be obtained at the centre of the slope.

Similarly pegs were not always placed in the small gulleys or rills that occur on the slopes, as it is presumed that some erosion occurs outside of these areas.

Rain gauges were intially set up on five of the seven slimes dams but due to consistent vandalism, only two, with the exception of one month on dam 4L37, were found to be recording throughout the whole of the period.

The two were on dams 3L37 (Meyer and Charlton) and 4L37. It was felt that due to the fairly close proximity of the plots that the two gauges as well as readings received from the Metrological Office at Rand Airport in Germiston would suffice.

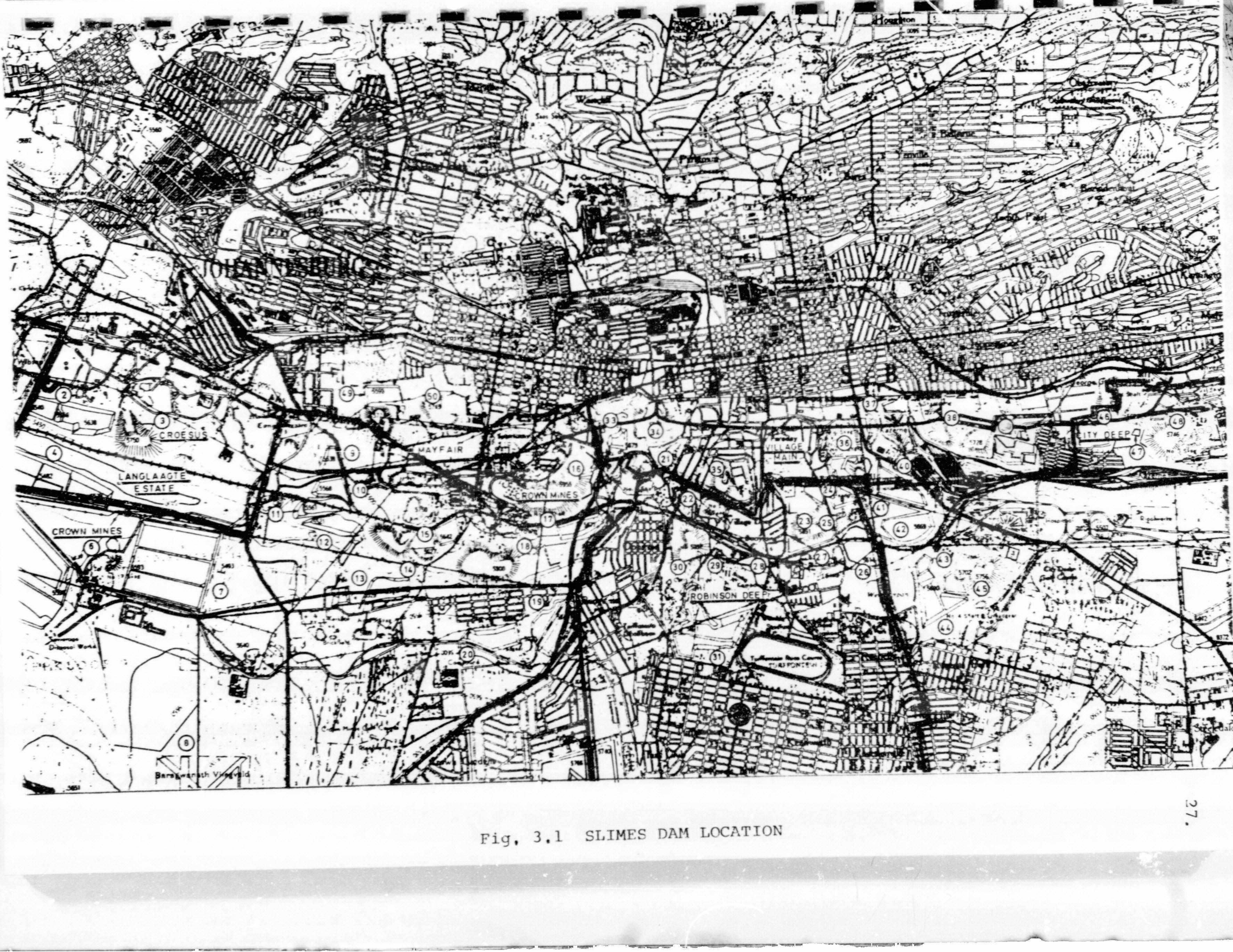


Fig. 3.1 SLIMES DAM LOCATION

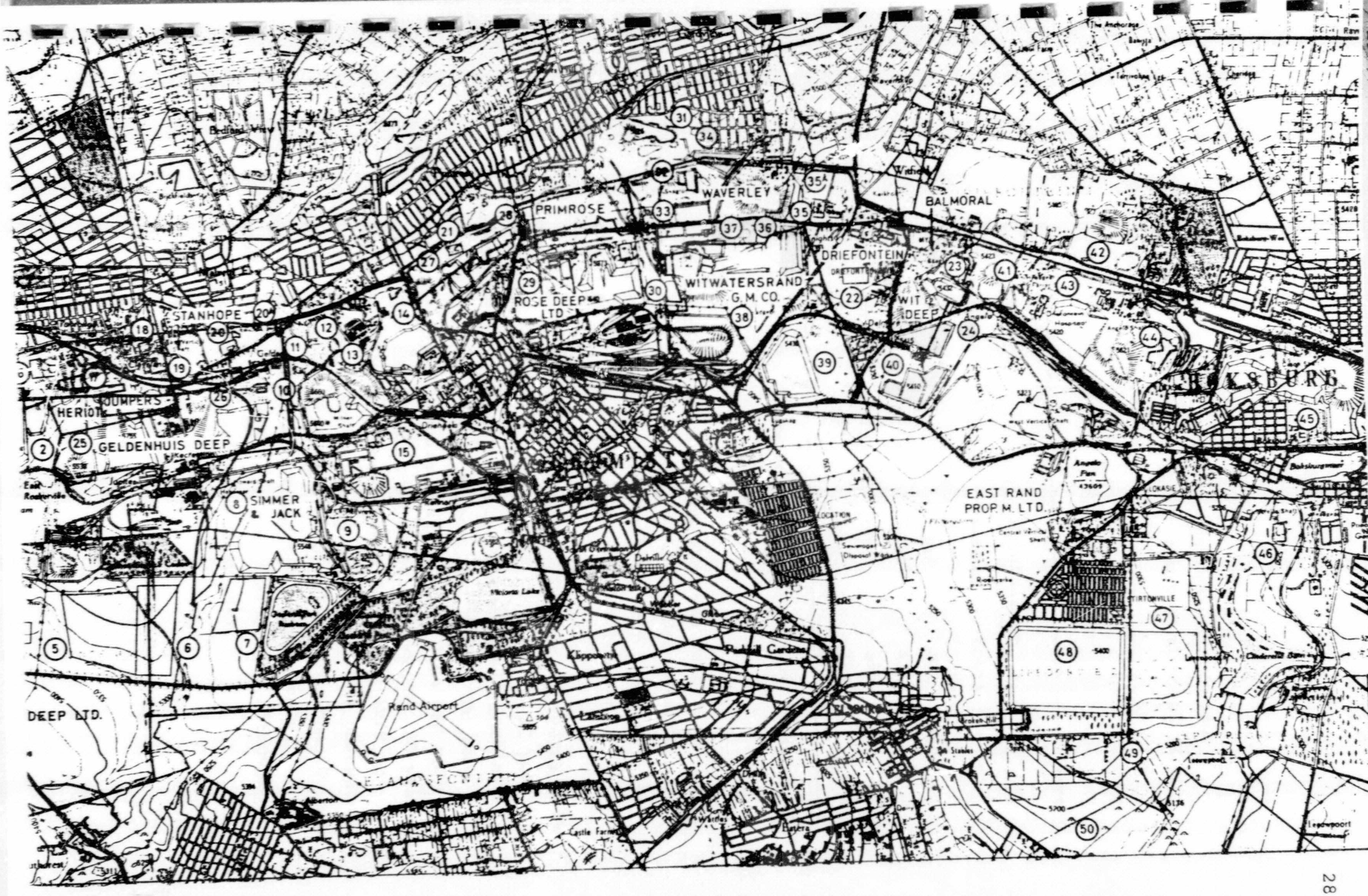


Fig. 3.2 SLIMES DAM LOCATION

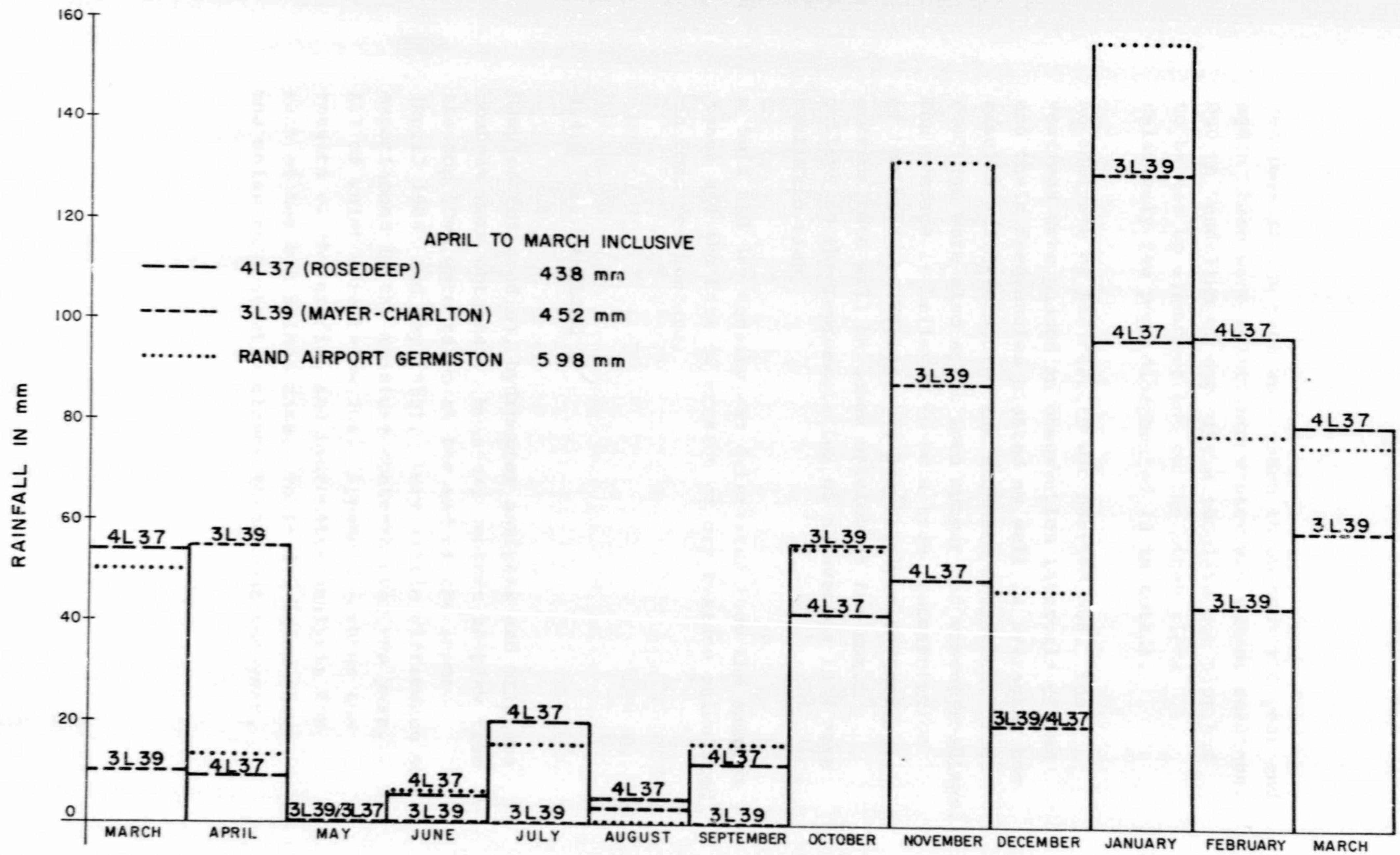
The readings for each rain gauge are shown below (with winter readings given for the period April to September).

		Rainfall mm	
Data Source	Winter	Summer	Total
4L37	47	386	433
3L39	54	397	451
Rand Airport	53	545	598
$\bar{\bar{x}}$	51	443	494

Table 3.0 Rain Gauge Readings - April 1984 - March 1985

In January the rain gauage on 4L37 was vandalised and replaced. An average reading of the Rand Airport, 3L39 and two other nearby stations were taken and this is shown on the graph in Fig. 3.3 for the year.

Appendix 3 shows rainfall statistics for the years 1979 to 1984 inclusive as well as the 25 year and 30 year average at Jan Smuts Airport. The rainfall for the period recorded at Rand Airport is 598mm. No long term data exists at this station since data has only been recorded for the past three years. Hence the 30 year average of 726mm and the average for years 1979 to 1984 of 644mm at Jan Smuts is recorded. The percentage comparison of Rand Airport to Jan Smuts for the 30 year and 6 year average is 82% and 93% respectively. Therefore the rainfall for the test period although lower does not appear to be abnormal.



RAINFALL JOHANNESBURG/GERMISTON

MARCH 1984 TO MARCH 1985

FIG. 3.3

Readings at the pegs were taken throughout the year and again these were split into winter and summer readings. Due to vandalism of one site a complete new plot had to be set up elsewhere but on the other plots relatively few pegs disappeared (3 in total).

An analysis of the results was carried out. The readings were placed in observation intervals of 5mm and their frequencies plotted as well as averaging the results and determining the standard deviation. The readings were also split into summer and winter readings. The average is believed to be a true representation of the rate of erosion. As previously discussed erosion rate will be lower outside of the small gulleys so the representation of an average is a more realistic view.

A bulk and dry density was determined from the samples taken and the rate of erosion of dry residue calculated in tons per hectare.

3.4.2 SAMPLING

Samples for grading, hydrometer analyses and moisture content were obtained. Moisture content samples from the top 50mm were taken at the end of the summer (April 1984 and May 1985). Very little difference was experienced in the moisture contents over the year. All of which were below 20%. Appendix A shows the results of the grading and hydrometer analysis for each of the six slimes dams. Table 3.1 below shows the moisture content variance throughout the year.

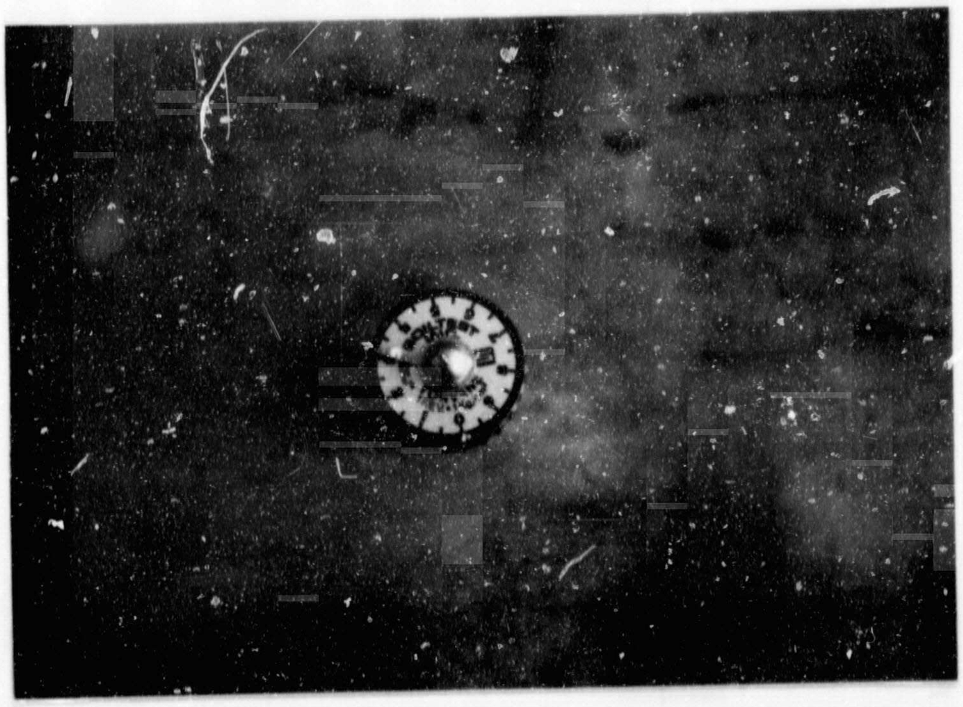
	3L39	4L34	Balmoral	4L37	4L36	4L24	4L40
April 84	-	9,8	18,4	5,5	6,6	7,5	4,6
May 85	14,2	9,8	18,0	7,6	7,8	12,9	7,8

Table 3.1 % Moisture Content at the Surface of Slimes

3L39 was not sampled in 1984 and it is assumed that there is little difference in moisture content throughout the year.

3.4.3 SHEAR VANE READINGS

The shear strength of the surface of the slimes was determined using the 'TORVANE' shown in Fig. 3.11, a miniature shear vane with a vane height of 5mm. A minimum of six readings were obtained per plot on each slimes dam. Pre-soaking of the area was carried out before the shear vane test to eliminate capillary stresses that would have shown an unrealistically high shear strength. The results are shown in table 3.2.. N, E, S and W refer to the aspect of the slope.



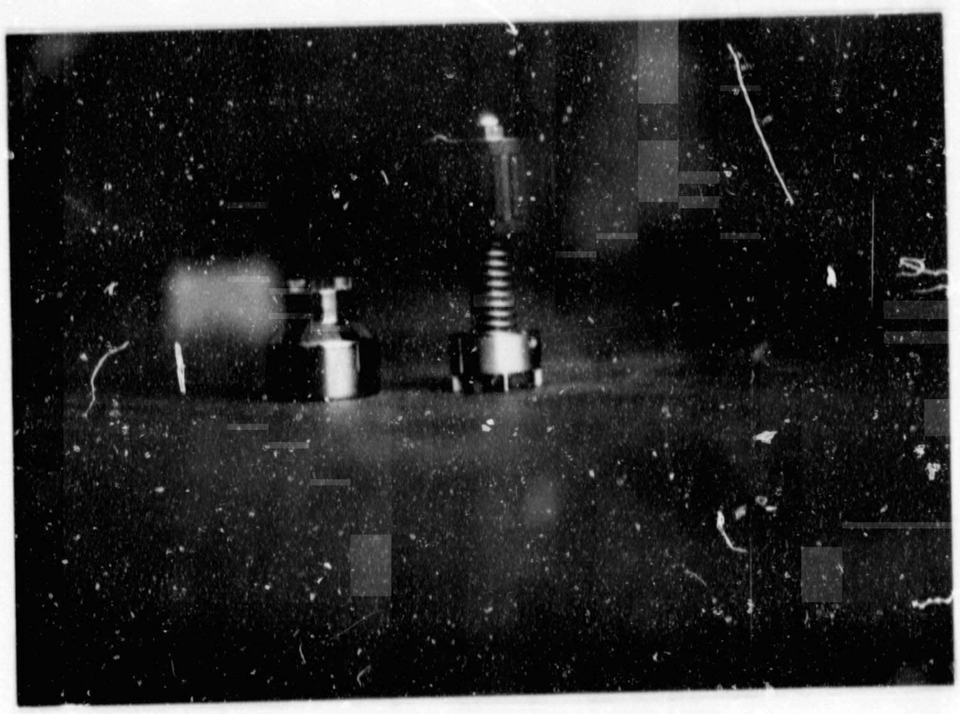


Fig. 3.4 'Torvane' Shear Vane - Vane Height 5mm