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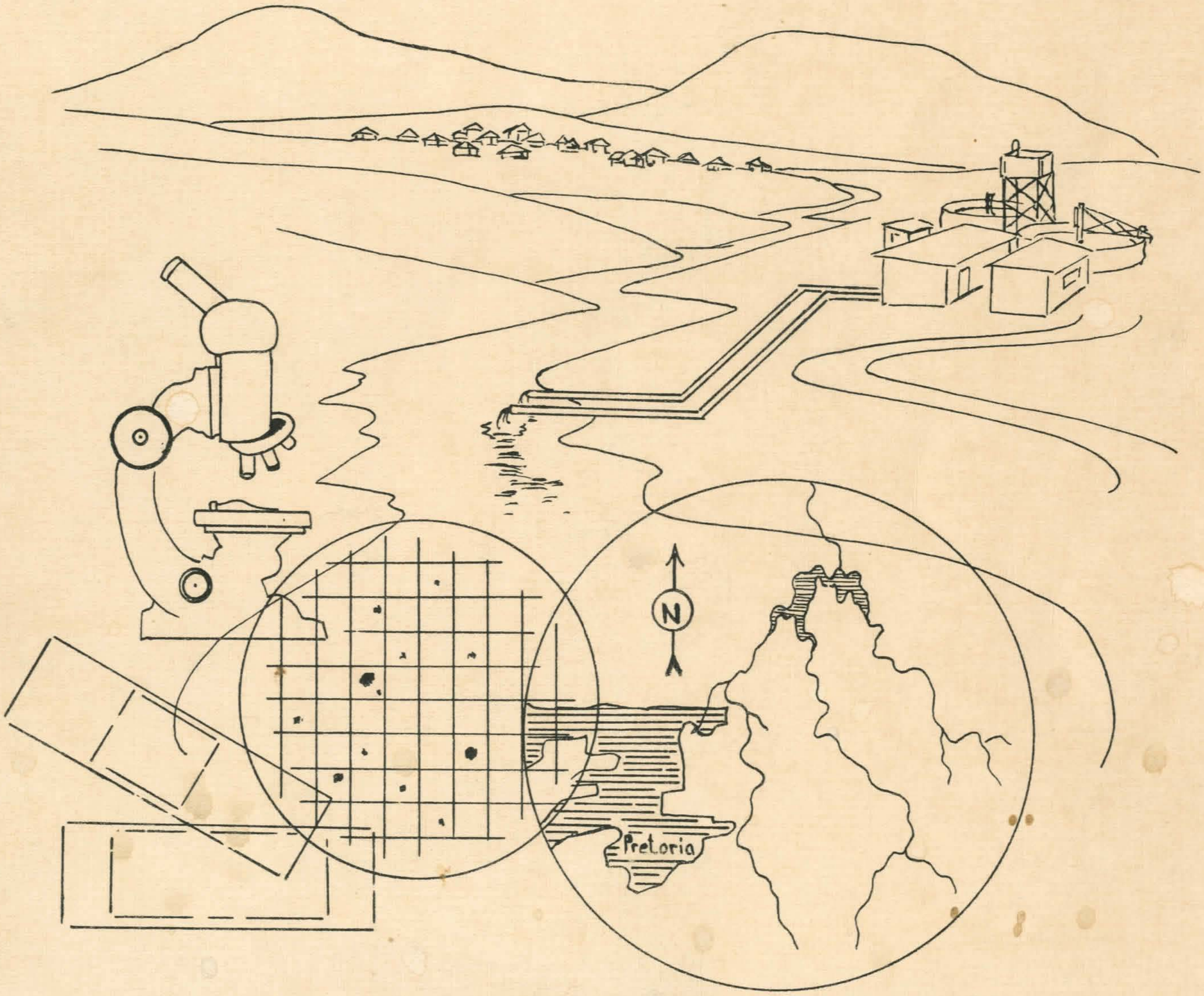
DEPARTMENT OF WATER AFFAIRS, FORESTRY AND ENVIRONMENTAL CONSERVATION

Bacteriological quality of the river waters of the Roodeplaat Dam catchment

D.P. Sartory



DEPARTMENT OF WATER AFFAIRS, FORESTRY AND ENVIRONMENTAL CONSERVATION

Hydrological Research Institute

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BACTERIOLOGICAL QUALITY OF THE RIVER WATERS OF THE ROODEPLAAT DAM CATCHMENT

by D.P. SARTORY

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DEPARTMENT OF WATER AFFAIRS, FORESTRY AND ENVIRONMENTAL CONSERVATION
Private Bag X313
PRETORIA
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ABSTRACT

The rivers of the Roodeplaat Dam catchment area were monitored bacteriologically for a period of six months. The results show that the Pienaars River and the Hartbeesspruit/Moretelespruit system received extensive runoff pollution. Chlorination of the sewage effluent from Baviaanspoort resulted in a 1 000 fold decrease in indicator bacteria numbers with a consequent improvement in river water quality. During the rainy season, however, this was abrogated by extensive runoff pollution. The type of pollution for the Hartbeesspruit/Moretelespruit system was constant during both wet and dry seasons. The water leaving Roodeplaat Dam for agricultural purposes was of very high quality.

Chlorination of the sewage effluent resulted in a marked change in FC/FS ratios, opening to question the validity of using these ratios to predict pollution type.

BACTERIOLOGICAL QUALITY OF THE RIVER WATERS OF THE RODEPLAAT DAM CATCHMENT

1. INTRODUCTION

Over a period of six months (05-06-79 to 27-11-79) the rivers of the Roodeplaat Dam catchment area were routinely monitored on a weekly basis for bacteriological and chemical parameters. This report contains the analysis of the bacteriological data and reflects on the types of pollution affecting the water quality of the rivers. The data was collated in two groups. This was done for two reasons. Firstly, the first period (05-06-1979 to 02-10-1979) is representative of the dry season and the second period (16-10-1979 to 27-11-1979) is representative of the wet season (Figure 1). During the first period rain was recorded on 11 out of 124 days. The total fall was 72,3 mm, of which 41 mm fell on one day (28-08-1979). During the second period rain was recorded on 17 out of 47 days with a total rainfall of 252,2 mm. Rainfall of greater than 15 mm a day was recorded on 8 days during this period. Secondly, the final effluent being emptied into the Pienaars River by the Baviaanspoort sewage works was not chlorinated during the first period. Chlorination of the effluent began on 12-10-1979 and thus the second period contains data of the effect of chlorination on improvement of water quality.

2. MATERIALS AND METHODS

2.1 Sampling sites

Sixteen sampling stations were set up on the Pienaars River, the Edendalespruit, the Moretelespruit* and the Hartbeesspruit. A map of the sampling sites is shown in Fig. 2. The sites were as follows:-

Pienaars River

PRS01 : 10 km from the source of the Pienaars River. Situated near a main road in agricultural land. Map reference : 25°52'30"S, 28°25'30"E.

SPS01 : Swawelpoortspruit, 2 km before its confluence with the Pienaars River (21 km downstream of PRS01). Situated in agricultural land, used for watering of cattle. Map reference : 25°48'30"S, 28°24'30"E.

PRS02 : 25 km from the source of the Pienaars River (4 km after the confluence of the Swawelpoortspruit). Situated at a ford over the river in agricultural grazing land. Map reference : 25°46'40"S, 28°24'25"E.

* Commonly known as the Moreletaspruit. The name was changed by the Place Names Committee, minutes 12, January 1963, page 43. The matter is, however, receiving new attention.

PRM27 : 29,5 km from the source of the Pienaars River, after the river has passed under a motorway, a main trunk road and through agricultural land. Areas near the site have been used as unofficial rubbish dumps by the public. Map reference : 25°45'15"S, 28°22'50"E.

The Pienaars River continues for 4,25 km where it then passes through the black township of Mamelodi for 4 km. One kilometre downstream is the outfall of the Baviaanspoort Sewage Works (Map reference : 25°40'15"S, 28°21'50"E), 40,75 km from the source of the river.

PR1BB : 150 m upstream of the outfall of the sewage works.

BSWFE : The final effluent of Baviaanspoort sewage works at the point where it pours into the river, but before any river water contaminates it.

PR2AB : 150 m downstream of the outfall of the sewage works after the effluent had mixed with the river water. The site was on the river edge of a reed bed and the water was turbulent.

PR165 : 42,4 km from the source of the river (1,65 km downstream of the sewage works outfall). The site was situated downstream of a main road. Map reference : 25°40'50"S, 28°21'40"E.

A2M27 : A Department of Water Affairs gauging weir located 45,3 km from the source of the river and 1 km before the river enters Roodeplaat Dam. Map reference : 25°39'45"S, 28°21'15"E.

Edendalespruit

The Edendalespruit flows for 24 km through agricultural land before entering Roodeplaat Dam.

A2M29 : A Department of Water Affairs gauging weir located 300 m before the river enters the dam. Map reference : 25°39'00"S, 28°23'30"E.

Hartbeesspruit/Moretelespruit

The Moretelespruit originates in open land (rapidly being urbanised) and flows through urban/industrial areas before its confluence with the Hartbeesspruit.

MSS01 : The Moretelespruit 7,5 km from its source. The site was near a main road just after the river enters the urban area. Up to this point the river flowed through agricultural holdings. Map reference : 25°46'15"S, 28°17'20"E.

MSS02 : 5,5 km downstream of MSS01 (13,0 km from source) after the river has passed through urban development. The site is upstream of a busy main road. Nearby a hotel and an open air museum discharged runoff. Map reference : 25°43'55"S, 28°18'30"E.

MSS03 : 6,0 km downstream of MSS02 (19 km from source) after the river has passed through an industrial area. The site had been used as a dump by the public. Waste found there included pharmaceuticals and old poultry carcasses. Map reference : 25°41'35"S, 28°17'30"E.

After 1,5 km the Moretelespruit empties into the Hartbeesspruit. The Hartbeesspruit originates in urban Pretoria.

HBS01 : 9 km from the source of the Hartbeesspruit as it leaves urban Pretoria. The site is downstream from a motorway and a gravel quarry (which pumps excess runoff into the river) in a sandy area. Map reference : 25°41'50"S, 28°16'55"E.

After 1,75 km the Hartbeesspruit and the Moretelespruit converge.

A2M28 : A Department of Water Affairs gauging weir on the Hartbeesspruit, 5,5 km downstream of the joining of the two rivers and 1 km before the river enters Roodeplaat Dam. Map reference : 25°39'00"S, 28°19'15"E.

The final sampling station was RD101. This was an irrigation canal below the dam wall.

2.2 Collection of samples

Bacteriological samples were collected in sterile 500 cm^3 glass bottles. After the sewage works started chlorinating their effluent the samples from BSWFE and PR2AB were treated with 5 cm^3 of a sterile solution of 10 g dm^{-3} sodium thiosulphate. All the samples were stored in cool bags with "ice bricks" and then returned to the laboratory and processed within 6 h of collection.

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2.3 Bacteriological analysis

All the samples were analysed for total coliform count, faecal coliform count and faecal streptococcus count. When dilutions were prepared, sterile quarter strength Ringer solution was used.

2.3.1 Total coliform count

Total coliforms were enumerated using the membrane filtration method according to Standard Methods (1975), using M-Endo broth (Merck Chemicals). The plates were incubated for 20 to 24 hours at $35,5^{\circ}C \pm 0,5^{\circ}C$.

2.3.2. Faecal coliform count

Faecal coliforms were enumerated using the membrane filtration method according to Standard Methods (1975), but using M-FC broth (Difco) without rosolic acid (Presswood and Strong, 1978; Sartory, 1980). The plates were incubated for 20 to 24 h at $44,5^{\circ}C \pm 0,2^{\circ}C$.

2.3.3 Faecal streptococcus count

Faecal streptococci were enumerated using the membrane filtration method according to Standard Methods (1975), using Slanetz and Bartley m-Enterococcus agar (Oxoid). The plates were incubated for 48 h at $35,5^{\circ}C \pm 0,5^{\circ}C$.

Throughout the study Millipore HC membrane filters were used.

3. RESULTS AND DISCUSSION

3.1 Pienaars river

The results of the bacteriological analyses on the Pienaars River before Baviaanspoort sewage works, and the Swawelspoortspruit (SPS01) are represented in Figure 3. The results for Baviaanspoort Sewage Works final effluent and stations on the Pienaars River downstream of the outfall are represented in Figure 4. The geometric means of the counts for all stations are laid out in Table 1. The counts for the 4 stations of the upper reaches (PRS01, SPS01, PRS02 and PRM72) of the Pienaars River system never exceeded 10^4 per 100 cm^3 and rarely exceeded 10^3 per 100 cm^3, even in periods of high rainfall (and thus high runoff). The results for the first station on the Pienaars River (PRS01) were unexpectedly higher than those of three other downstream stations, indicating a point source of pollution near the sampling site. The type of pollution for this point source appears to be of human origin as indicated by a mean faecal coliform/faecal streptococci ratio (FC/FS ratio) of 9,04 (range : 1,44 to 62,86) during the dry season (Table 2). A ratio equal to or less than 0,6 is indicative of animal faecal or farm waste pollution and greater than 4 is indicative of human faecal pollution (Geldreich, 1976). During the wet season the FC/FS ratios decreased and for the sites SPS01, PRS02 and PRM72 dropped to 0,65 or below, typical of agricultural runoff (Table 2).

The results for the station immediately before Baviaanspoort sewage works outfall (PR1BB) show the effect of the black township of Mamelodi on the water quality, with significant increases in bacterial counts (10-fold for total coliform (TC) and faecal coliforms (FC) and 100-fold for faecal streptococci (FS)). The mean FC/FS ratios are not strongly indicative of any type of pollution although during the rainy season the mean FC/FS ratio of 0,79 tends to indicate stormwater pollution, as would be expected for this period.

The results for the Baviaanspoort sewage works final effluent (BSWFE) amply show the beneficial effect, bacteriologically, of effluent chlorination. Chlorination results in a 1 000-fold improvement in bacterial counts. This improvement has been maintained since this survey was completed. One interesting fact arising out of the chlorination of the effluent is that the non-chlorinated effluent had a mean FC/FS ratio of 15,71 typically indicating human faecal pollution, while the chlorinated effluent had a mean FC/FS ratio of 2,25 indicating neither human nor animal faecal pollution (Table 2). On occasion FC/FS ratios below 0,6 were recorded and, had one not known that the samples came from a sewage works handling human waste, agricultural pollution may have been assumed. It is generally accepted that faecal streptococci are more resistant to chlorination, and doses sufficient to kill faecal coliforms may not completely destroy the faecal streptococci (Mead, 1969). As yet this large change in FC/FS ratios brought about by the introduction has not been studied in detail. Lin (1974) reported some preliminary results where on 18 unchlorinated effluent samples a mean FC/FS ratio of 11,2 was found and on 63 chlorinated effluent samples a mean FC/FS ratio of 0,72 was recorded. These results and those of this study embolden the view that faecal streptococci are more resistant to chlorination than faecal coliforms. If this low FC/FS ratio for chlorinated effluents is common, however, then the application of the FC/FS ratio, in this day of chlorination of effluents, as an indicator of the type of faecal pollution present, becomes questionable.

The results for the three stations downstream of the sewage works (PR2AB, PR165 and A2M27) show that before chlorination began (i.e. during the dry season) the effluent had a profound effect on the river water quality with station PR2AB (150 m downstream of the outfall) mirroring the effluent results very closely. The bacterial counts decreased downstream and at A2M27 a 10-fold decrease was observed in all three groups of bacteria. During the wet season the counts for these stations were still high despite the reduced bacterial load from the sewage works indicating extensive runoff pollution and possibly other point sources as yet unidentified. The results from PR2AB for this period are 10-fold lower than those of PR1BB, PR165 and A2M27 showing the dilution effect of the sewage works effluent.

The FC/FS ratios for these stations copy those of the sewage works effluent (Table 2), giving typically human faecal pollution indications before chlorination and very low ratios after chlorination. These low ratios are compounded by the fact that they occurred during the wet season, when ratios are expected to be reduced due to the increase in runoff pollution.

From these results the following conclusions are made in regard to the bacteriological water quality of the Pienaars River system.

1. The background bacterial numbers as indicated by the first 4 stations are of the order 100 to 1 000 per 100 cm^3 showing that the river is mildly polluted before it reaches Mamelodi and Baviaanspoort sewage works.
2. The first part of the river receives agricultural pollution but at one site (PRS01) human faecal pollution is indicated.
3. The chlorination of the sewage effluent dramatically reduces the bacterial numbers in the effluent with the consequent improvement of river water quality. The chlorination of the sewage effluent also causes a marked change in FC/FS ratios opening to question the application of these ratios in assessing the type of pollution.
4. The normal bacterial counts of the lower reaches of the river during the rainy season is in the order of 10^4 per 100 cm^3. During the dry season, with effluent

chlorination, the counts may be expected to be reduced 10-fold.

5. The lower reaches of the river receive extensive pollution, other than from the sewage works, from runoff and possibly point sources.

3.2 Edendalespruit

The water quality of the Edendalespruit was relatively clean with counts rarely exceeding 10^3 per 100 cm^3. The geometric means of the counts per 100 cm^3 were TC = 90, FC = 40 and FS = 53, although during the wet season these increased to 290, 130 and 250 respectively. The mean FC/FS ratio was 1,68. This river receives only agricultural pollution but the dry season FC/FS ratio of 2,13 does not give a strong indication of this. The ratio characteristically dropped during the wet season to 0,72.

3.3 Hartbeesspruit/Moretelespruit

The results of the bacteriological analysis on the Hartbeesspruit/Moretelespruit river system are represented in Figure 5, and the geometric means of these results and mean FC/FS ratios are laid out in Table 3.

The results for the urban sited stations of this system were lower than expected with a geometric mean TC count ranging from $1,9 \times 10^3$ to $2,5 \times 10^3$ and FC counts from 570 to 920. The bacteriological quality of the Moretelespruit does not change much during its passage through urban and industrial Pretoria (stations MSS01 and MSS02), although chemically there is a significant effect particularly with respect to alkalinity, conductivity, chloride, sulphate and sodium (Walmsley and Toerien, 1978; Sartory, 1979 - unpublished data). The counts for all three groups of bacteria increased during the wet season but never reached a level expected of urban runoff. This may be due to a dilution effect as most of the samples were taken long after the beginning of a storm. Davis, Casserly and Moore (1971) showed that peak indicator bacterial counts occurred before peak flooding occurred, due to first flushing of loose ground material before peak runoff. Thus the counts for these stations could have been much higher during the early stages of a storm. The dilution effect is much more dramatic for the chemical water quality (Sartory, 1979 - unpublished data). The mean FC/FS ratios tend to indicate stormwater runoff type pollution, particularly during the wet season, although the ratio values do not differ significantly from those of the dry season (Table 3). This indicates that, bacteriologically, the type of pollution for this system is constant. The results for the

Hartbeesspruit (HBS01) did not differ significantly ($p = 0,05$) from the three Moretelespruit sites. The mean FC/FS ratios for HBS01 did not differ from dry season to wet season (0,74 and 0,71 respectively) indicating a very stable pollution type.

The results for A2M28 show that during the wet season the quality did not change significantly between Pretoria and Roodeplaat Dam. However, during the dry season the quality improved 10-fold for all three parameters, indicating a self purification process during periods of low rainfall.

From these results the following conclusions are drawn for the Hartbeesspruit/Moretelespruit system.

1. The system receives urban runoff pollution. The quality of the Moretelespruit does not deteriorate significantly ($p = 0,05$) during its passage through urban and industrial areas indicating consistent runoff pollution along this stretch of river and not intermittent point source pollution

2. Under low flow conditions there is a self purification process occurring between the confluences of the two rivers and A2M28.

3.4 Roodeplaat Dam outflow

The quality of the water leaving Roodeplaat Dam via the irrigation canal from the dam wall was also monitored (RD101). The water for this canal is drawn from a point below the surface of the dam in the hypolimnion and thus the results must not be taken to represent the quality of the surface water of the dam. The results are laid out in Table 4.

The quality of the water leaving the dam via the irrigation canal is, for agricultural purposes, exceptionally good. A mean total coliform count of 10 per 100 cm^3 with a maximum count of 41 (an exceptional case) underlines this point. Generally counts for all three groups were below 10 bacteria per 100 cm^3.

4. CONCLUSIONS

The bacteriological results of the waters feeding Roodeplaat Dam show that the two main rivers receive extensive runoff pollution, both urban and agricultural. The chlorination of the effluent of the Baviaanspoort sewage works has resulted in improvement in effluent quality. There was, however, only a 10-fold decrease in bacterial numbers for the lower reaches of the Pienaars River during the wet season, despite effluent chlorination, underlining the extent of runoff pollution. The wet season counts for the Hartbeesspruit/Moretelespruit system are 10- to 100-fold greater than those of the dry season period, again underlining the effects of runoff pollution. The water leaving the dam for irrigation purposes is of exceptionally good quality.

Chlorination of the sewage effluent resulted in FC/FS ratios dropping from levels typically indicating human faecal wastes, to levels where, on occasion, animal faecal wastes would have been assumed. Since this change is solely due to chlorination, the usefulness of using these ratios to predict the type of pollution is questionable.

5. ACKNOWLEDGEMENTS

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TABLE 1 : Geometric means of bacteriological results for the Pienaars River, Swawelpoortspruit and the Baviaanspoort sewage works final effluent.

STATION	TOTAL PERIOD (22 Samples)	DRY SEASON (15 samples)	WET SEASON (7 samples)
(a) Total coliforms			
*PRS01	$1,0 \times 10^3$	940	$1,2 \times 10^3$
SPS01	240	210	350
PRS02	81	53	200
PRM72	320	220	690
PR1BB	$2,6 \times 10^3$	$1,0 \times 10^3$	$2,0 \times 10^4$
BSWFE	$9,0 \times 10^4$	$7,6 \times 10^5$	930
PR2AB	$8,7 \times 10^4$	$3,8 \times 10^5$	$3,7 \times 10^3$
PR165	$6,1 \times 10^4$	$1,1 \times 10^5$	$1,6 \times 10^4$
A2M27	$1,6 \times 10^4$	$1,7 \times 10^4$	$1,2 \times 10^4$
(b) Faecal coliforms			
PRS01	560	540	600
SPS01	68	50	130
PRS02	28	16	100
PRM72	140	89	330
PR1BB	420	160	$3,2 \times 10^3$
BSWFE	$2,3 \times 10^4$	$1,5 \times 10^5$	440
PR2AB	$2,3 \times 10^4$	$8,7 \times 10^4$	$1,3 \times 10^3$
PR165	$2,0 \times 10^4$	$4,1 \times 10^4$	$4,5 \times 10^3$
A2M27	$4,7 \times 10^4$	$5,2 \times 10^3$	$3,9 \times 10^3$
(c) Faecal Streptococci			
PRS01	170	120	360
SPS01	60	36	250
PRS02	41	14	390
PRM72	210	110	830
PR1BB	380	92	$1,8 \times 10^3$
BSWFE	$5,0 \times 10^3$	$2,1 \times 10^4$	240
PR2AB	$7,3 \times 10^3$	$1,7 \times 10^3$	$1,2 \times 10^3$
PR165	$2,8 \times 10^3$	$2,8 \times 10^3$	$3,0 \times 10^3$
A2M27	680	330	$3,2 \times 10^3$

*See text for description of sampling sites.

TABLE 2 : Mean FC/FS ratios for the Pienaars River, Swawelpoortspruit and the Baviaanspoort Sewage Works final effluent

STATION	TOTAL PERIOD	DRY SEASON	WET SEASON
PRS01	6,81	9,04	2,04
SPS01	1,73	2,23	0,65
PRS02	1,25	1,68	0,33
PRM72	0,91	1,07	0,57
PR1BB	2,04	2,63	0,79
BSWFE	11,43	15,71	2,25
PR2AB	10,65	14,97	1,38
PR165	27,01	38,58	2,22
A2M27	18,07	25,48	2,21

TABLE 3 : Geometric means of bacteriological results and mean FC/FS ratios for Hartbeesspruit/ Moretelespruit system

STATION	TOTAL PERIOD (22 samples)	DRY SEASON (15 samples)	WET SEASON (7 samples)
(a) Total coliforms			
*MSS01	760	460	$2,2 \times 10^3$
MSS02	$2,0 \times 10^3$	$1,2 \times 10^3$	$5,4 \times 10^3$
MSS03	$2,5 \times 10^3$	$1,4 \times 10^3$	$8,9 \times 10^3$
HBS01	$1,9 \times 10^3$	$1,1 \times 10^3$	$5,1 \times 10^3$
A2M28	640	250	$4,7 \times 10^3$
(b) Faecal Coliforms			
MSS01	220	100	$1,2 \times 10^3$
MSS02	570	290	$2,5 \times 10^3$
MSS03	920	520	$3,2 \times 10^3$
HBS01	640	380	$2,0 \times 10^3$
A2M28	160	56	$1,6 \times 10^3$
(c) Faecal Streptococci			
MSS01	280	100	$2,4 \times 10^3$
MSS02	820	400	$3,8 \times 10^3$
MSS03	880	460	$3,5 \times 10^3$
HBS01	$1,1 \times 10^3$	700	$3,3 \times 10^3$
A2M28	230	79	$2,2 \times 10^3$
(d) FC/FS ratios			
MSS01	1,45	1,82	0,65
MSS02	1,01	1,07	0,88
MSS03	1,72	2,06	1,00
HBS01	0,73	0,74	0,71
A2M28	1,07	1,09	1,01

*See text for description of sampling sites.

TABLE 4 : Bacteriological results for the irrigation canal leaving Roodeplaat Dam (RD101). Counts per 100 cm^3.

Date 1979	Total Coliform	Faecal Coliform	Faecal Streptococci
05/06	16	3	0
19/06	23	1	1
26/06	12	0	3
03/07	0	0	9
10/07	4	3	2
17/07	1	1	1
14/07	26	0	6
31/07	3	2	4
07/08	2	0	4
14/08	0	0	7
21/08	5	2	4
28/08	9	5	7
18/09	1	1	1
15/09	2	0	0
02/10	2	1	1
16/10	4	0	1
23/10	2	2	1
30/10	9	1	4
06/11	16	6	0
13/11	41	7	10
20/11	19	11	23
27/11	23	4	7
Arithmetic Mean	10,0	2,3	4,4
Maximum	41	11	23
Minimum	0	0	0

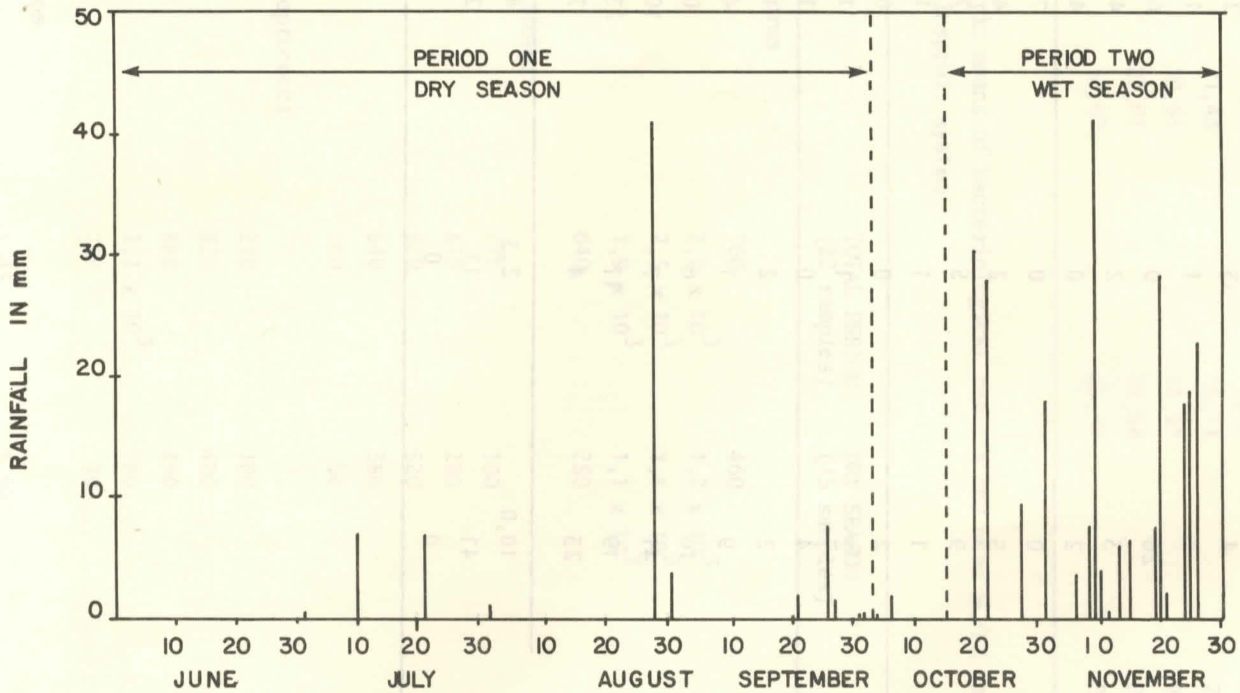

FIGURE 1: DAILY RAINFALL AT ROODEPLAAT DAM WEATHER STATION AT THE HYDROLOGICAL RESEARCH INSTITUTE FOR JUNE TO NOVEMBER 1979

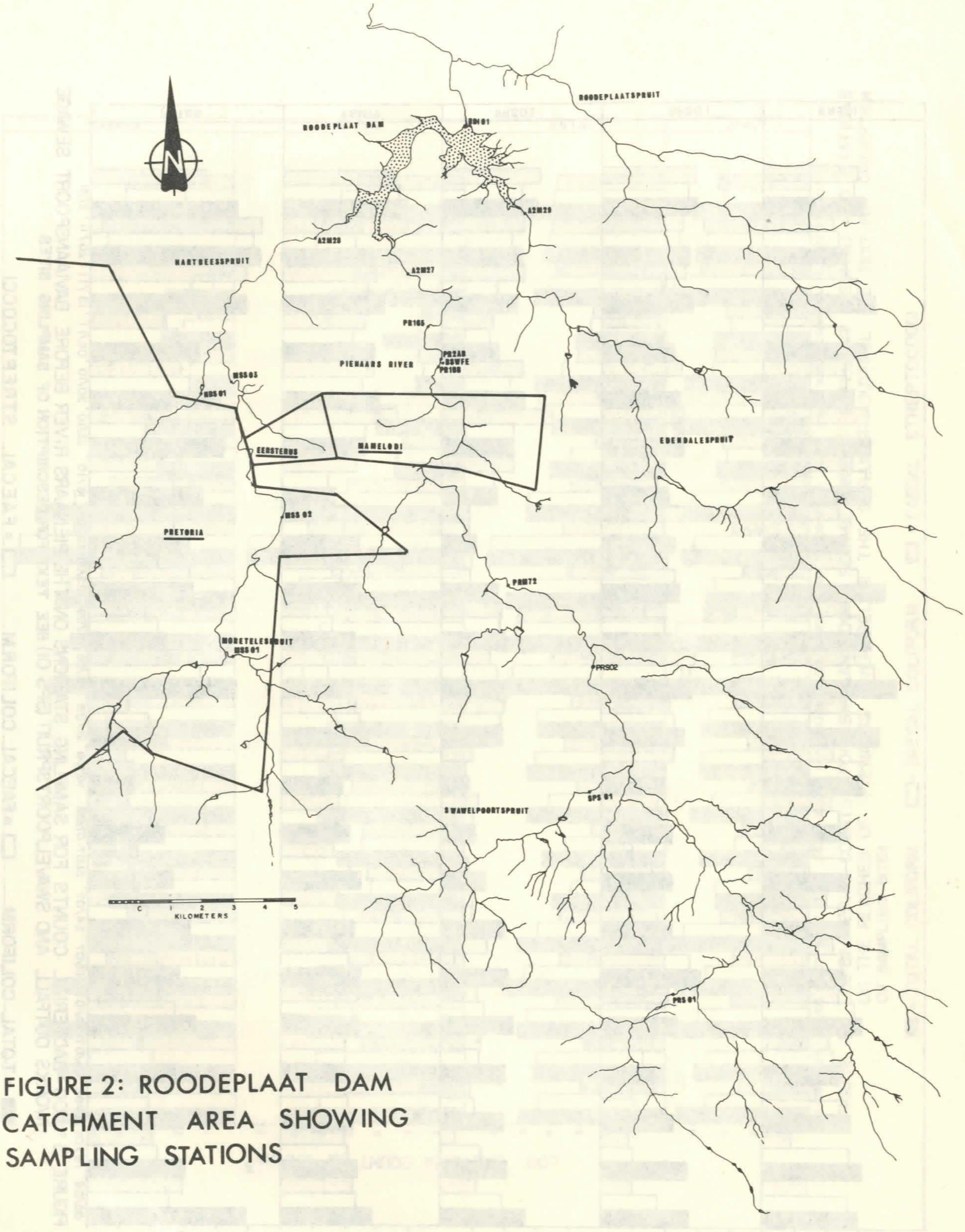

FIGURE 2: ROODEPLAAT DAM CATCHMENT AREA SHOWING SAMPLING STATIONS

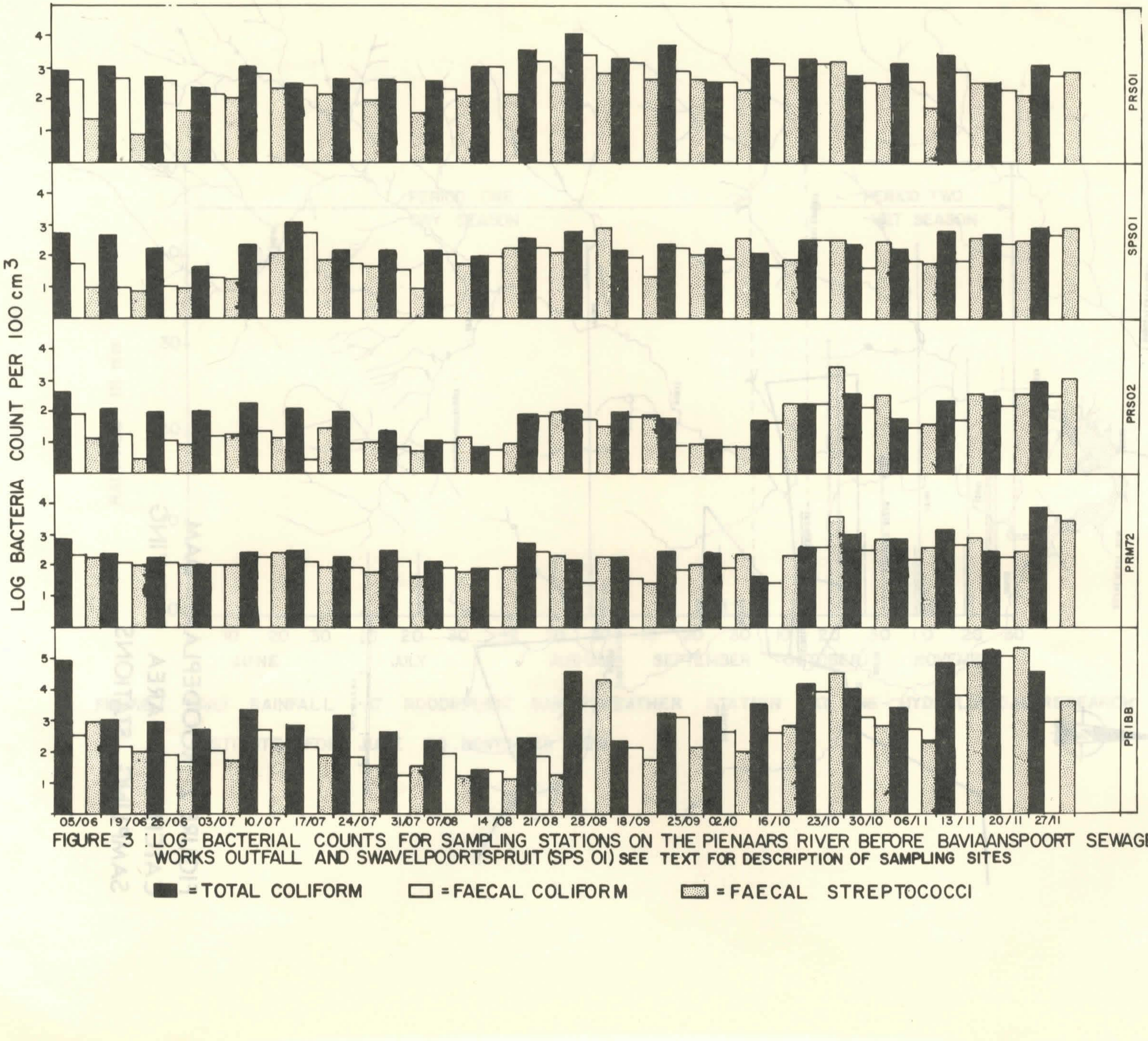

FIGURE 3 : LOG BACTERIAL COUNTS FOR SAMPLING STATIONS ON THE PIENAARS RIVER BEFORE BAVIAANSPOORT SEWAGE WORKS OUTFALL AND SWAVELPOORTSPRUIT (SPS 01) SEE TEXT FOR DESCRIPTION OF SAMPLING SITES

■ = TOTAL COLIFORM   □ = FAECAL COLIFORM   ▨ = FAECAL STREPTOCOCCI

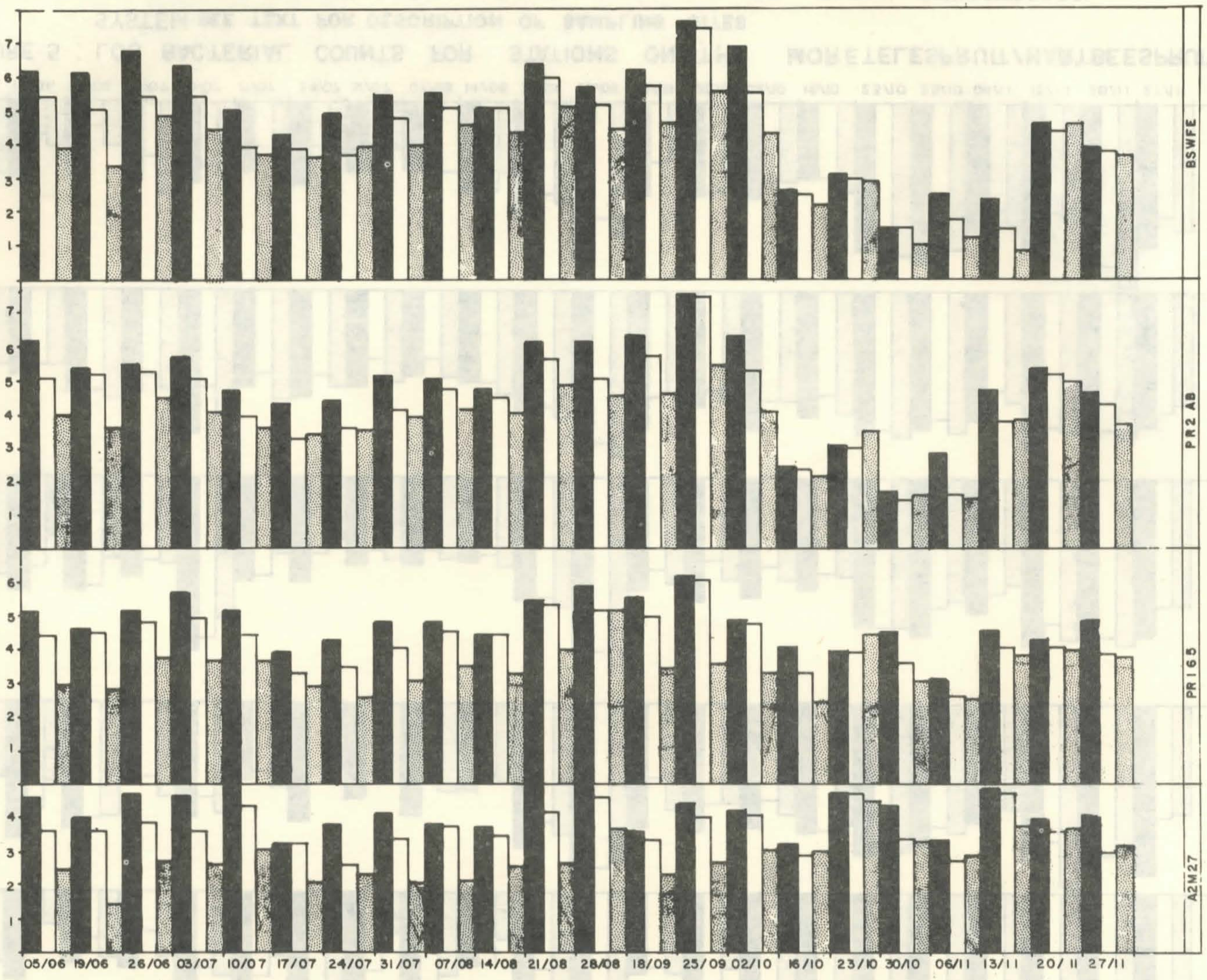

FIGURE 4 : LOG BACTERIAL COUNTS FOR BAVIAANSPOORT SEWAGE WORKS EFFLUENT (BSWFE) AND STATIONS ON THE REACHES OF PIENAARS RIVER BELOW THE EFFLUENT OUTFALL SEE TEXT FOR DISCRIPTION OF SAMPLING SITES

■ = TOTAL COLIFORM □ = FAECAL COLIFORM ▨ = FAECAL STREPTOCOCCI

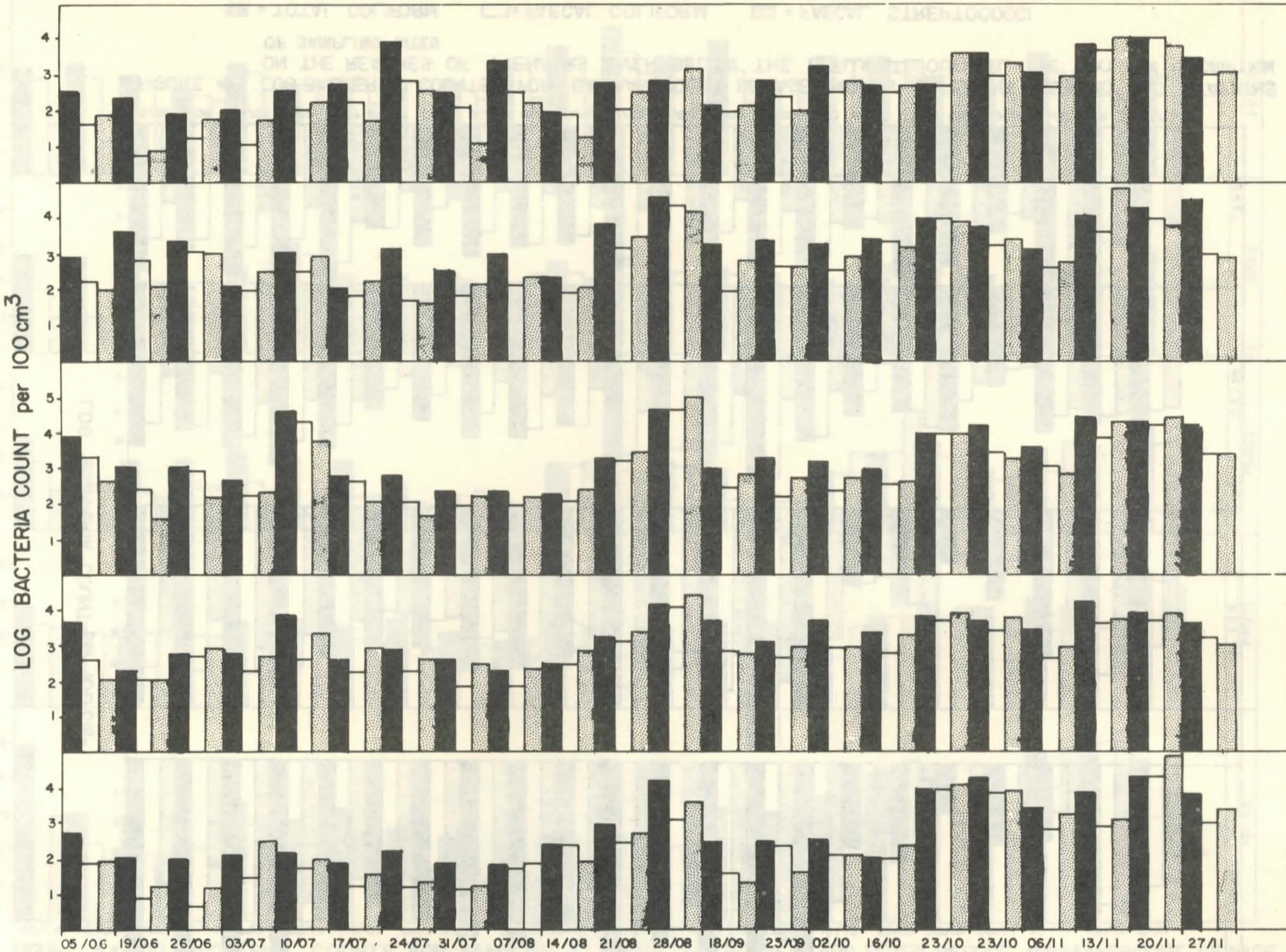

FIGURE 5 : LOG BACTERIAL COUNTS FOR STATIONS ON THE MORETELESPRUIT/HARTBEESPRUIT SYSTEM. SEE TEXT FOR DESCRIPTION OF SAMPLING SITES

■ = TOTAL COLIFORM □ FAECAL COLIFORM ▒ FAECAL STREPTOCOCCI