BATINI RPT55

R2419

WATER QUALITY IN HILLS CATCHMENTS - M.W.S.S. & D.BOARD PERTH

NOTES FOR CONSERVATION AND LAND USE COMMITTEE - 1978

SUMMARY:

The water quality of the metropolitan system is monitored by sanitary survey and continual inspection of the total system plant, the investigation of consumer complaints particularly as regards colour, taste etc., and a system of bacteriological testing. The tests are made on samples taken from catchments, streams, storages and through the system to the consumer. These notes review the significance of the bacteriological test which may convey a danger signal calling for a need to identify an existing source of pollution. Guidelines and their relationship to public health are quoted. The notes set out a record of the bacteriological results obtained over recent years by regular sampling in the catchments These relate to four principal categories namely those taken from streams within virgin catchments, from within storages with a lengthy detention time, from those with a short detention time and finally samples taken in the vicinity of defined picnic sites. It concludes on a cautionary note.

1. The significance of the bacteriological test

Contamination by human excrement is the greatest danger associated with drinking water. If such contamination has occurred recently and if among the contributors there are cases or carriers of such infectious diseases as typhoid or dysentry, the water may contain the living micro-organisms which cause these diseases and the drinking of such water may result in fresh cases. Sewage polluted water may also contain the viruses of poliomylitis, of infectious hepatitis etc. Animals and birds may also carry human intestinal organisms pathogenic to man.

For many reasons the direct search for the persons of specific pathogenic bacteria or viruses in water is impracticable for routine trial purposes. As noted by Mara(1) "safety in a bacteriological context means freedom fr[om] those organisms which cause disease (pathogens)". Pathogenic bacteria belong to various groups whose cultural requirements are often complex and totally different. For this reason and since non-pathogenic bacteria vastly outnumber the pathogens in a water sample it is impossible to examine as routine all samples with a presence or absence of all pathogens. Not only is it difficult but it is unnecessary as well since a water which contains pathogens will also contain much larger numbers of non-pathogenic bacteria which are the normal inhabitants of man and animals. These commensal bacteria

but is the corollary true?

Contd/-

are always shed in faeces together with any pathogens present. The presence of these bacteria in a water implies beyond doubt that the water has been contaminated and may therefore contain pathogens as well. The water is always condemned on this possibility alone.

E.Coli is the most frequent type of coliform organism present in human and animal intestine being found in numbers up to 100 million or even 1000 million per gram of fresh faeces. Apart from excretal contamination it is rarely found in soil, vegetation or water. Coliform organisms other than E.Coli also occur in the intestinal canal but their combined numbers seldom exceed 1 million organisms per gram. Outside the body these have much greater powers of survival and do not appear to be limited to faecally polluted sites. They can also be found in soil which appears to be unpolluted and which, on examination is found to be free of E.Coli. High counts of E.Coli in a water sample equate to heavy and recent pollution, low counts equate to slight or relatively low pollution. One cannot distinguish whether these counts are of human or animal origin. In any case, there is evidence that faeces of birds, rodents and domestic animals may contain organisms of the salmonella group.

heavy?

The presence of other coliforms in the absence of E.Coli in a sample may indicate past excretal contamination; herald the onset of more dangerous pollution and yet the source may be decaying vegetation. Any coliform in a chlorinated water indicates inadequate treatment or the excess of undesirable materials after treatment.

A rationale[(2)] for the adoption of the standard for the level of coliform organisms has been reproduced at Appendix A.

2. Bacteriological criteria for domestic water supplies and raw water quality

In Australia as in Great Britain, no criteria for water quality has the force of law. Table 1 has been reproduced from Australian Water Resources Council Technical Paper No.7[(3)]. As a guideline criteria are set out therein for drinking and raw water. The criteria are essentially those of the World Health Organization. It is to be noted that the specified criteria for drinking water apply following treatment of the water, i.e., disinfection or alternatively, coagulation, sedimentation, filtration and disinfection. The criteria given for raw water indicate the threshold level applicable either to disinfection (Type 1) or complete treatment (Type 2).

Contd-

3. Bacteriological samples taken from MWB catchments

Figs. 1 - 15 attached record the results of recent bacteriological sampling in MWB catchments for total and faecal coliform counts (MPN). On each figure a site description of the sampling point is given and the location of each of the sites is also contained on the map on fig.16. The figures fall into the following 5 categories:

3.1 Figs. 1, 2 & 3 relate to samples from streams in virgin catchments i.e. prior to storage. They provide a sample of the pollutional level of tributary streams.

3.2 Figs. 4, 5 & 6 relate to samples taken in storages with a long detention time, the samples are taken prior to release from the storage and disinfection.

3.3 Figs. 7, 8, 9 & 10 show a much higher level of contamination, particularly in faecal coliforms. The Gooralong Catchment is approximately 10% alienated and farmed. The samples taken from the Canning Catchment disclose an undesirable level of pollution in these tributaries.

3.4 Fig.11 relates to Dirk Brook Catchment Site No.2 downstream of the Karnet Prison farm. At this point salmonella has been detected. The stream is not presently being used for public supply downstream of the Karnet Prison farm. The figure shows a high level of pollution.

3.5 Figs. 12 - 15 relate to sampling points in each of the two catchments. From each one sample is taken from the relatively short period storage and the second from a tributary.

4. Water quality in the metropolitan system

Over a long time the quality of water of the system has been reviewed regularly by an Advisory Committee for the Purity of Water. This committee has representation on the departments of Health, Mines (Chemical Laboratories) Agriculture, Forests, in addition to representation from the water authorities. The intervals between successive routine examinations and the number of samples have been selected to conform with the criteria of the Bacteriologica Examination of Water Supplies[4]. The total number of chlorinated samples taken throughout the system to include trunk mains, service reservoirs and the reticulation would be in the order of 400 per month. The integrity of the system plant is ensured by adequate maintenance. It has been found necessary to chlorinate the supply not relationship of E coli counts from one to the other?

only as it is released from headworks, but again when it is drawn from unroofed service reservoirs. Despite such measures the Board, like other Australian authorities, has been unable to comply with the standards for treated water as specified in Table 1.

5. Future development of the system

Proposals to develop water resources for the Perth system include the provision of pump back schemes from sites below existing dams such as presently exists on the Helena River. In particular early consideration will be given to such developments below the Serpentine Dams and the Canning Dam. These will not be supplied from virgin catchments and the means of obtaining adequate detention will be necessary. These waters which will be drawn from the higher rainfall areas will have low total dissolved solids content.

The University of Western Australia is undertaking research into the questions of reservoir dynamics. In the first instance the Canning reservoir will be studied as a further step from the works undertaken at the Wellington Dam.

6. Conclusion

It is noted the Department of Conservation and Environment will ask the Commissioner for Public Health to provide technical advice on the reasons for prohibition of recreation in catchment areas.

In the present state of understanding of catchment pollutional problems the Board's approach is well expressed in the following extract from "Drinking Water and Health 1977" -

> "Good engineering and public health practices emphasise the need for using raw water of the highest possible quality . Bacteriological testing, or the imposition of bacteriological standards are adjunct to, not substitutes for, good raw water, proper water treatment, and the integrity of the distribution system".

will chlorination kill pathogenic bacteria? statistical treatment of data.

Ta[illegible] 1

BACTERIOLOGICAL CRITERIA FOR DOMESTIC WATER SUPPLIES

		Coliform Organisms (organisms/100 ml)	Faecal Coliforms (organisms/100 ml)	Remarks
Health or Aesthetic Effect		Indicator of possible contamination of water with pathogens	Indicator of recent faecal pollution. Indicator of possible contamination of water with pathogens	
Drinking Water:				
1. Treated Supplies	Derived Working Level	1) No coliform in at least 95% of samples for the year 2) No sample should contain more than 10 coliform organisms per 100 ml 3) Coliforms should not be detected in any two consecutive 100ml samples	No faecal coliforms (or *E. coli*) in any 100ml sample	1) If any coliforms are found, the minimum action is immediat[e] re-sampling. 2) If 1 to 10 coliform organis[ms] per 100 ml are repeatedly foun[d] measures should be taken at once to discover and if possib[le] remove the source of pollution.
	Objective Level	No coliforms per 100 ml	No faecal coliforms per 100 ml	
2. Untreated Supplies		3 3 to 10 10	0 1 1	Satisfactory Suspicious Unsatisfactory A sanitary survey of the catch-area should be conducted to reveal any potential source of contamination
Raw Water				
Type 1 Treatment (chlorinate)		100	10	Limits not to be exceeded by more than 5% of sample
Type 2 Treatment (full treatment)		5 000	100	Limits not to be exceeded by more than 10% of samples

REFERENCES

1. "Bacteriology for Sanitary Engineers" - Author D.D. Mara

2. "Drinking Water and Health" - National Research Council (USA)

3. "A Compilation of Australian Water Quality Criteria" - Australian Water Resources Council Technical Paper No.7

4. The Bacteriological Examination of Water Supplies Reports on Public Health & Medical Subjects No.71 London H.M.S.O.

The Health Significance of the Coliform Test

Several pathogens, notably those in the genus *Shigella*, are able to initiate infection in humans even when introduced in very low numbers. Because it is not feasible to assay for bacterial pathogens directly in water, it is important to consider the utility of the coliform test in ensuring the bacteriologic safety of drinking water.

A direct approach to assessing the significance of the coliform count would be to obtain evidence of a correlation between numbers of coliforms and numbers of pathogenic bacteria (e.g., salmonellae or shigellae). One attempt to seek such a correlation was the study of Kehr and Butterfield (1943). Although imperfect, this is the only study found that attempts to relate the coliform count directly to disease incidence. In the discussion below, this study is analyzed in some detail in order to present a picture of the approach necessary to place the coliform standard on a firmer scientific basis. (It is perhaps of historical interest that the motivation for their study was an adverse decision by the Illinois Supreme Court as to the value of the coliform count in indicating that water is unsafe.)

The approach used by Kehr and Butterfield involved two aspects. First, data on the relative proportions of *Salmonella typhosa* and coliforms in various types of water (such as river, sewage, and sludge) were obtained from the literature, and the numbers of *S. typhosa* per 10^6 coliforms were calculated. These data, obtained from cities throughout the world, were then plotted on the ordinate on log-log paper, with typhoid fever morbidity on the abscissa (Fig. III-2). An approximately straight line was obtained. The point here was that the excretion rate of coliforms would be the same in a healthy as in a sick population, but that the latter would also excrete typhoid bacteria. Kehr and Butterfield then considered the stability of the *E. coli*-*S. typhosa* ratio and showed that *S. typhosa* and coliforms died off at approximately the same rate during sewage treatment, during self-purification in streams and lakes, and during drinking-water purification. The stability of this ratio is not surprising, when it is considered that S. typhosa and coliforms are members of the same group of bacteria and are likely to show similar tolerance and sensitivities to environmental influences.

From the data in Figure III-2 and from recorded waterborne outbreaks of typhoid fever, Kehr and Butterfield estimated a minimal infecting dose of S. typhosa for the general population and the percentage of persons infected by that dose. In doing this, these workers considered only epidemics of typhoid fever of a diffuse nature, i.e., characterized by a low attack rate but spread over a fairly large population. Kehr and Butterfield wrote that such epidemics were common at the time. Outbreaks with high attack rates, in which infection could arise more or less directly from carrier or patient discharge, were not considered, in order to avoid situations not likely to involve drinking water. In the diffuse typhoid epidemics, a common observation is the additional widespread occurrence of non-typhoid gastrointestinal disturbances. Considering the frequency of occurrence of the diffuse pattern of epidemics, and the data on concentrations of S. typhosa found in sewage and polluted waters, (as given in Figure III-2) Kehr and Butterfield concluded that it would be unlikely in such an outbreak for a person to drink more than a single typhoid bacterium or at most only a few, and that a single typhoid organism could produce infection in a small percentage of the general population. This conclusion is consistent with studies in experimental animals, which have shown that infection can be initiated by single bacterial cells (Meynell, 1961; Meynell and Meynell, 1965).

But this conclusion is not unequivocal. Populations of bacteria, even if derived from the same clone, can have a range of infectivities, and populations of humans have a range of susceptibilities. Thus, although a single cell may initiate an infection, not every cell-host contact will lead to infection. When the pathogenic bacterial population is diluted by a large volume of drinking water and spread over a large population of people, there is a non-zero probability that an appropriately virulent cell will reach a susceptible person. This is the situation that Kehr and Butterfield considered in their analysis of diffuse waterborne typhoid epidemics.

If the hypothesis that a single typhoid bacterium is infective can be accepted, then it is possible to consider the significance of the typhi:coliform ratio in drinking water. Assume that a water plant is treating source water with a typhi:coliform ratio of $10:10^6$, corresponding roughly to the ratio found in many polluted surface waters. Assuming equal destruction of typhoid bacteria and coliforms during treatment,

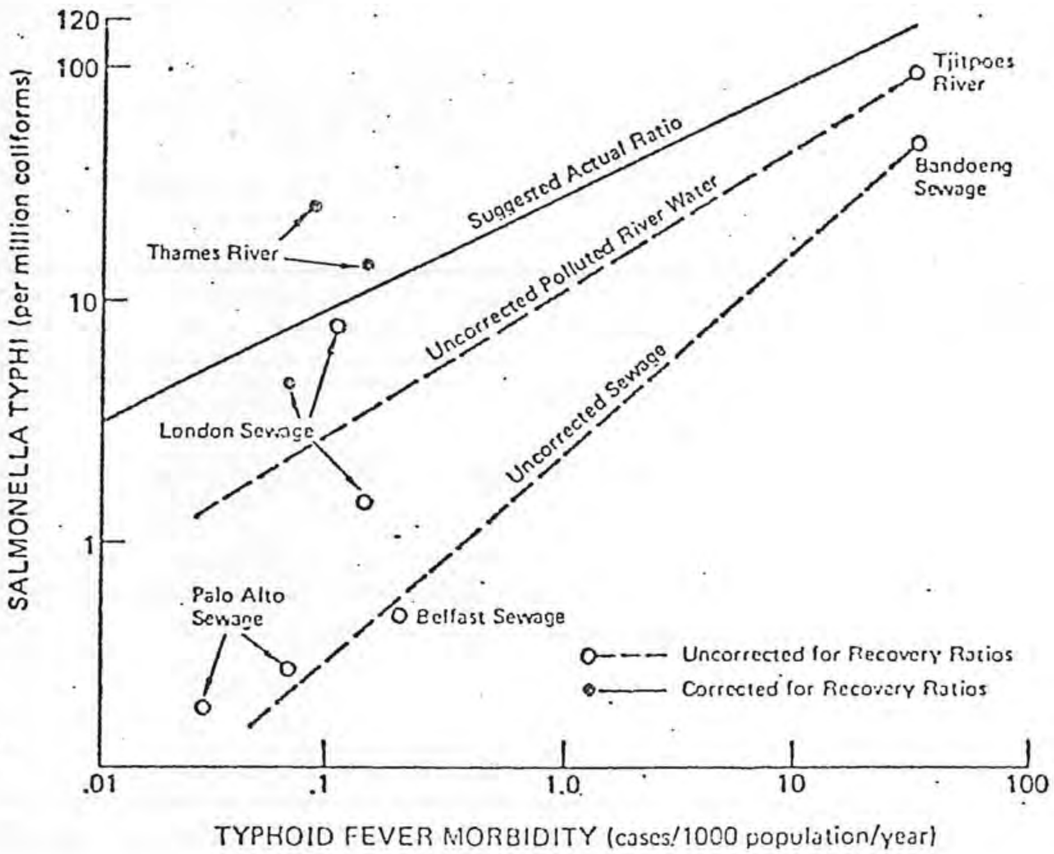


Figure III-2. Ratio of Salmonella typhi per million coliforms for varying typhoid fever morbidity rates. From: Kehr and Butterfield (1943).

if the finished water contained one coliform/100 ml (a reasonable possibility, even in many well-run plants), then the probability of consuming one typhoid bacterium when drinking a liter of water would be 10^{-5}; or, put another way, 10 people in a population of 1,000,000 could be infected. In an attempt to verify this, Kehr and Butterfield analyzed a number of epidemics of waterborne disease of the diffuse type, and concluded that the observed incidence of infection was consistent with this hypothesis. Thus, it was concluded that water which does not meet the coliform standard (one coliform/100 ml) can be responsible for waterborne disease, both gastroenteritis and typhoid fever.

Even more important, this analysis raises the question of whether water that meets the standard might bear disease-causing organisms. It is a simple exercise in arithmetic to convince oneself that this could be the case, inasmuch as drinking water with less than one coliform/100 ml, thus meeting the standards, could well have pathogenic organisms. Suppose that, instead of analyzing 100 ml of water, 1 liter were analyzed, and one coliform was found. This would be a coliform count of 0.1/100 ml, equivalent to one typhoid infection per 1,000,000 people (assuming the same typhi: coliform ratio as in the previous paragraph). Since the incidence of nonspecific gastroenteritis can be expected to be higher than that of typhoid, water that meets the present coliform standard may be the bearer of disease. However, existing epidemiologic data and reporting systems would not permit detection of such waterborne incidents, because the number of organisms would be below the detection limits of current surveillance methods. Although it is recognized that the above analysis is imperfect, it is the only one that has been done that this Committee is aware of.

The epidemiologic work of Stevenson (1953) added much weight to the rationale of establishing a coliform standard for drinking-water sources. His analyses showed that if raw water has fewer than 1,000 coliforms/100 ml, then it would be likely that salmonellae in finished water would be below infective levels.

Gallagher and Spino (1968) challenged the validity of the standards and stated that "summarized data from several stream surveys over the past few years showed little apparent correlation between quantities of total or fecal coliforms and the probable isolation of salmonellae." Geldreich (1970a) challenged their conclusion, on the basis of fecal coliform detections that showed a correlation between coliform numbers and salmonela isolations. He showed from numerous previous studies that, when fecal coliforms were 200/100 ml or more, there was a finite probability of isolating salmonellae. Smith and Twedt (1971) corroborated these data in a study of two Michigan rivers.

There are well-known epidemiologic histories of the presence of bacterial pathogens when the coliform index was low. Boring et al. (1971) reported that *Salmonella typhimurium* outnumbered coliforms by a factor of 10 in the Riverside, California outbreak. Similarly, a report by Seligmann and Reitter (1965) showed that index organisms can be low in the presence of pathogens. These sporadic reports of the failure of the index-organism concept emphasize the need for more research on pathogen detection.

Indicator Organisms

The term "indicator organism," as used in water microbiology, means: a microorganism whose presence is evidence that pollution (associated with fecal contamination from man or other warm-blooded animals) has occurred. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

As noted above, pathogens are usually more difficult to grow, isolate, and identify than indicator organisms, and often require special media and procedures. Indicator organisms, rather than the actual pathogens, are used to assess water quality because their detection is more reliable and less time-consuming. Pathogens appear in smaller numbers than indicator organisms and are therefore less likely to be isolated. An indicator organism should have the following characteristics:

- Applicable to all types of water.
- Present in sewage and polluted waters when pathogens are present.
- Number is correlated with the amount of pollution.
- Present in greater numbers than pathogens.
- No aftergrowth in water.
- Greater survival time than pathogens.
- Absent from unpolluted waters.
- Easily detected by simple laboratory tests in the shortest time consistent with accurate results.
- Has constant characteristics.
- Harmless to man and animal.

No organism or group of organisms meets all these criteria, but the "coliform group" of organisms fulfills most of them.

NOTES FOR CHIEF ENGINEER

PREPARED BY G. LOWE

BACTERIOLOGICAL QUALITY OF WATER COLLECTED ON HILLS CATCHMENTS

METROPOLITAN WATER BOARD, PERTH

RESULTS FROM BOARD'S SAMPLING

This paper presents evidence that the bacteriological quality of water being collected from the Metropolitan Water Board's Hills Catchments is susceptible to pollution of Public health significance from human activity.

A series of 15 sets of results are appended (figure 1 - 15) which present in graph form the results of bacteriological sampling at some of the 500 monitoring sites (see figure 16) on Catchments and in Dams. It is appreciated that these records have some short comings as to their length (2½ years) and frequency of sampling (once per month) but they do show a picture of concern to the Board.

For presentation purposes the graphs are divided into 4 groups:

1. Figures 1 - 3 which show, in areas where little human or animal activity is known, that the water quality is of a certain standard. None of the examples, and they are by no means the worst sites, meets the Australian Water Resources criteria for *Type 1 treatment.

2. Figures 4 to 6 which show that the quality of surface water near the dam wall in the three main reservoirs has, by natural purification processes in the water body, reached acceptable standards for use with disinfection alone. Actually South Dandalup is marginally sub-standard and this is thought to be due to the illegal activities of marron fishermen and other illegal recreation.

   It is clear from these graphs that the bacteriological quality of the streamwater is by no means perfect and that to allow activities which would cause further degradation would be most foolhardy.

3. Figures 7 to 11 which show that human activities in the vicinity of streams can cause a serious degradation in their bacteriological quality. In some cases, as noted

*Type 1 treatment - involves only disinfection to upgrade the biological quality of the raw water. Screening to remove floating debri and coarse suspended matter may also be incorporated after this the treated water will have almost the same quality as the source except in microbiological and perhaps colour, odour and taste characteristics.

Bacteriological Criteria for Type 1 Treatment

Coliform Organisms/100mℓ	Faecal Coliforms/100mℓ	Remarks
100	10	Limits not to be exce by more than 5% of samp

Quoted From "A compilation of Australian Water Quality Criteria" Australian Water Resources Council Technical Paper No. 7 1974.

on the relevant figures, salmonella have been isolated from "moore swabs" placed in the streams at these sites. Generally the sero types isolated are of low public health significance. There are however exceptions, for example Salmonella Derby which has high public health significance was detected at Dirk Brook Site 2 (figure 11.).

4. Figures 12 - 15 which show that where reservoirs have relatively short retention times and a polluted stream flow input that the quality of water at the dam wall near the offtake frequently does not meet the criteria for Type 1 treatment.

The nominal retention times quoted on the figures are defined as the average volume of the dam during 1976/77 divided by the maximum monthly draw off rate.

too simplistic? ?

Both Victoria and Churchman's Brook Dams have relatively short nominal retention times of 18 and 31 days respectively when compared with the large retention times of the main Dams. (Canning Dam 130 days, Serpentine 220 days).

THE QUALITY OF WATER AFTER DISINFECTION

The Board has as its bacteriological quality objective for supplied water the World Health Organisation (1971) standard but various practical constraints prevent achievement of the very high standards which briefly are as follows:

- throughout any year 95% of samples should not contain an coliform organisms in 100mℓ.
- no sample should contain E-coli in a 100mℓ.
- no sample should contain more than 10 coliform organisms per 100mℓ.
- coliform organisms should not be detectable in a 100mℓ of any 2 consecutive samples.

data

For the year 1977/78 the water in the distribution systems after disinfection at the hills sources did not meet the standards. The reason for this state of affairs can in part be attributed to the bacteriological quality of the raw water in the dams. It is evident that further loss in quality of water stored in the dams cannot be tolerated, on the contrary the Board would like to press for improvement.

what else

HEALTH SIGNIFICANCE OF COLIFORMS AND FAECAL COLIFORMS

The basis for the adoption of coliforms and faecal coliforms as indicator organisms of the potential existence of pathogenic bacteria in water is well established elsewhere. Briefly however the rationale is that several pathogens notably those in the genus Shigella are able to initiate infection in humans even when introduced in very low numbers. It is however not feasable to assay for bacteriological pathogens directly in water and thus it has been found more practicable to monitor

the existence of non-pathogenic bacteria with similar characterist
(for a more complete definition of indicator organisms see Appendix 2)

A rationale for the adoption of stringent standards for the level of coliform organisms is given in a recent publication under the auspices of the American Environmental Protection Agency entitled Drinking Water and Health (1977) and the relevant section is quoted in the Appendix. Briefly it reasons that water that does not meet the standard of one coliform per 100mℓ can be responsible for water borne disease both gastroenteritis and typhoid.

CONCLUSIONS

? The evidence presented in this paper while not conclusive suggests the following conclusions may be made. However more raw data is necessary to be collected and more analysis is required before these conclusions can be finally confirmed or reject although they are consistent with a body of world experience in these matters.

- Human activity on Catchments has a detrimental effect on the bacteriological quality of water flowing in streams.

- The quality of water stored in a reservoir is influenced by the quality of stream inflow. The quality of water available for draw off is dependant on two factors

  (a) the length of retention time and

  (b) the quality of inflow.

- There is strong indication that short residence times, such as those existing in Victoria and Churchman's Brook are insufficient to provide the necessary purification for polluted stream water inflow. Conversely it appears that long residence times have a significant self purifying effect on polluted inflows for example Canning, Serpentine and South Dandalup. This statement should not be regarded as accepting that there is sufficient self purification in the large dams to provide raw water acceptable for water supply after disinfection only.

- The water in the large transmission mains after disinfection does not meet World Health Organisation 1971 standards for bacteriological quality and this is in part due to the quality of water stored in the reservoirs. water in other parts of system

- The current legislation which seeks to restrict human activity on Catchments needs to be enforced more competently.

In conclusion it is appropriate to quote from the National Research Council's paper entitled Drinking Water and Health (1977) page (iii) - 65.

> "Good engineering and public health practices emphasise the need for using raw water of the highest possible

quality. Bacteriological testing, or the imposition of bacteriological standards are adjunct to, not substitutes for, good raw water, proper water treatment, and the integrity of the distribution system".

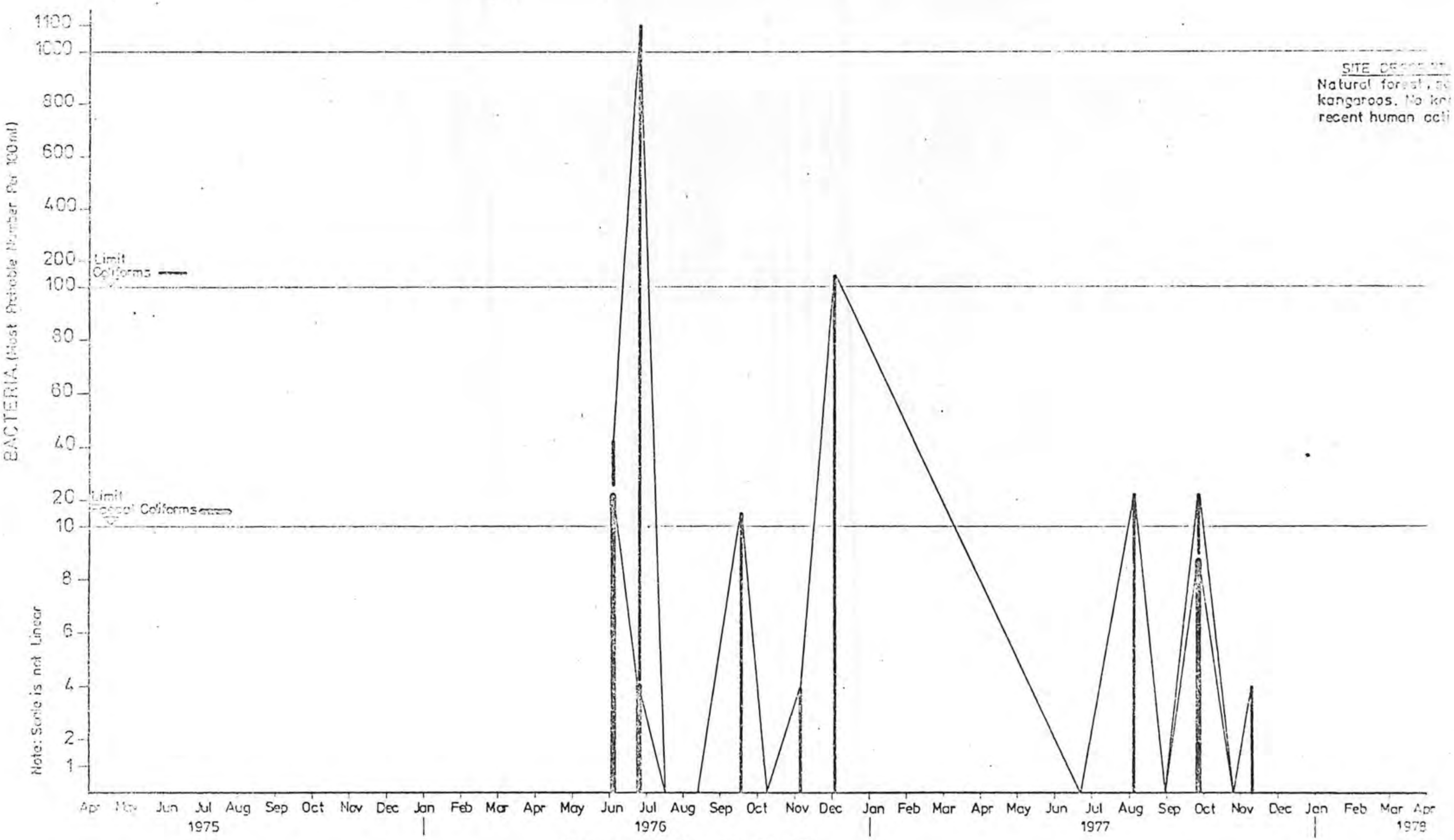
G P W LOWE
CATCHMENT ENGINEER

November 16, 1978 :DF

FIGURE 1, 2, & 3

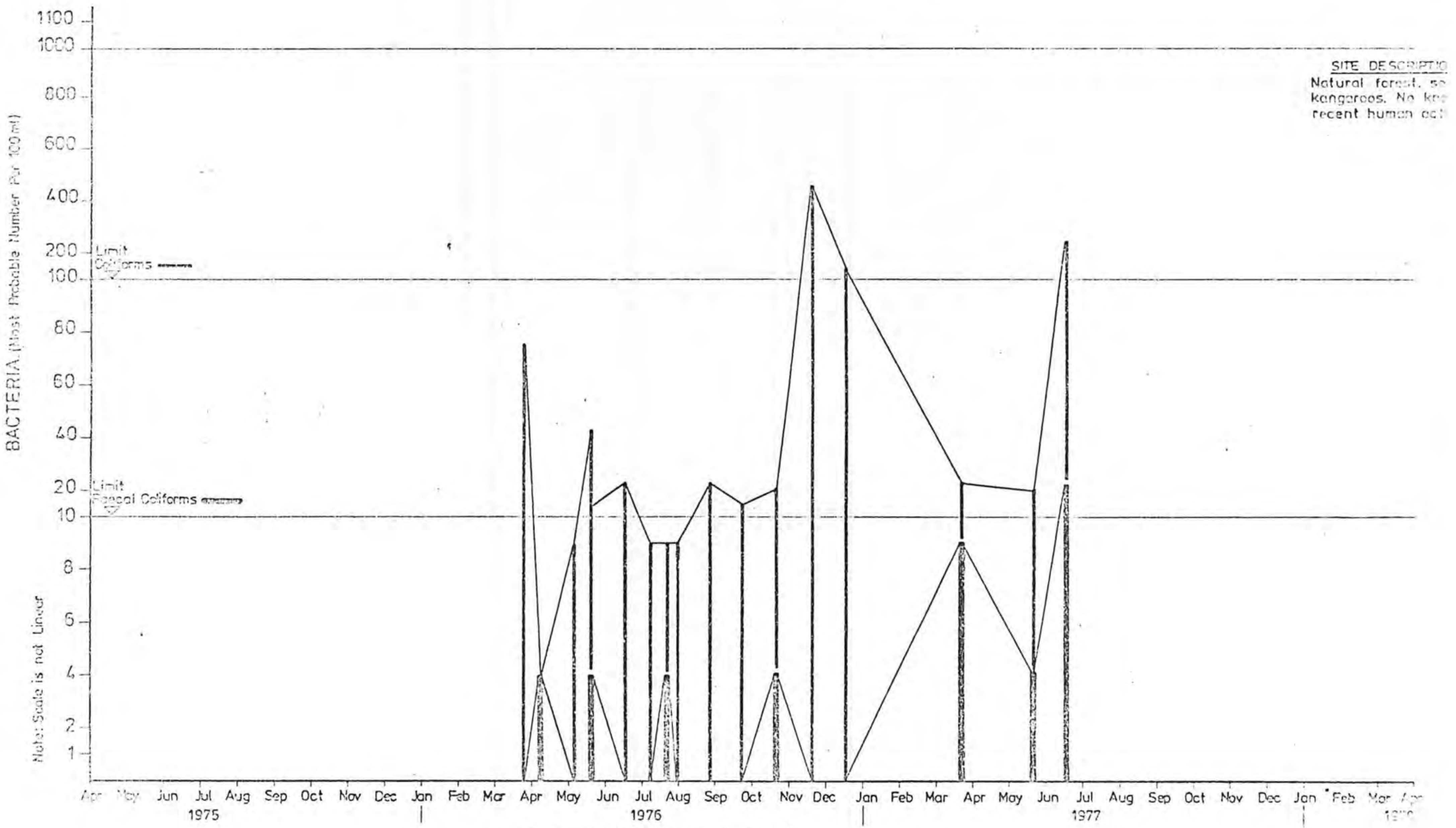
BACTERIOLOGICAL SAMPLING RESULTS

From sites on Catchment where there is little or no human activity.



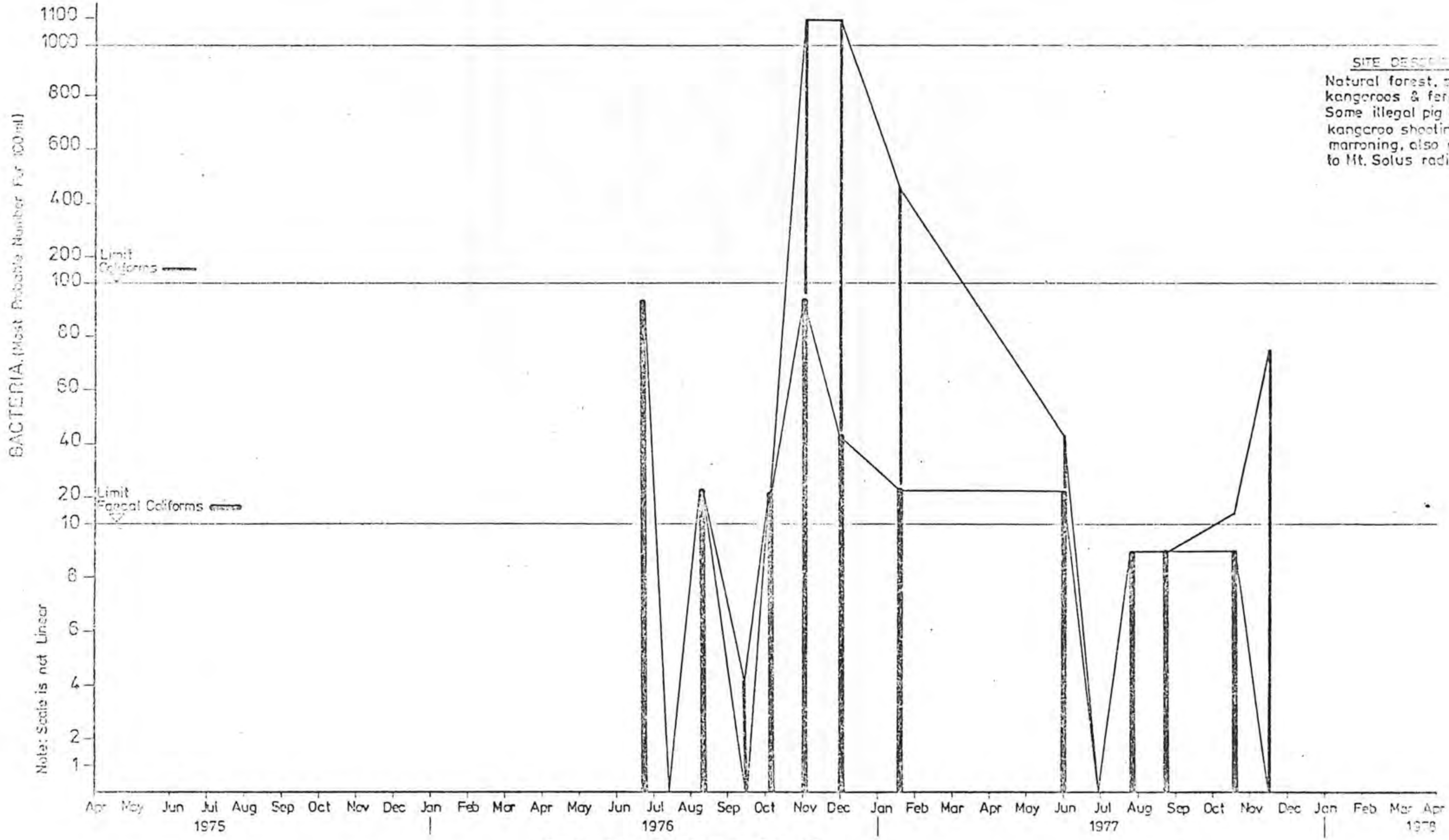
Canning Catchment Site 52

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.



Little Dandalup Catchment Site 6

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.



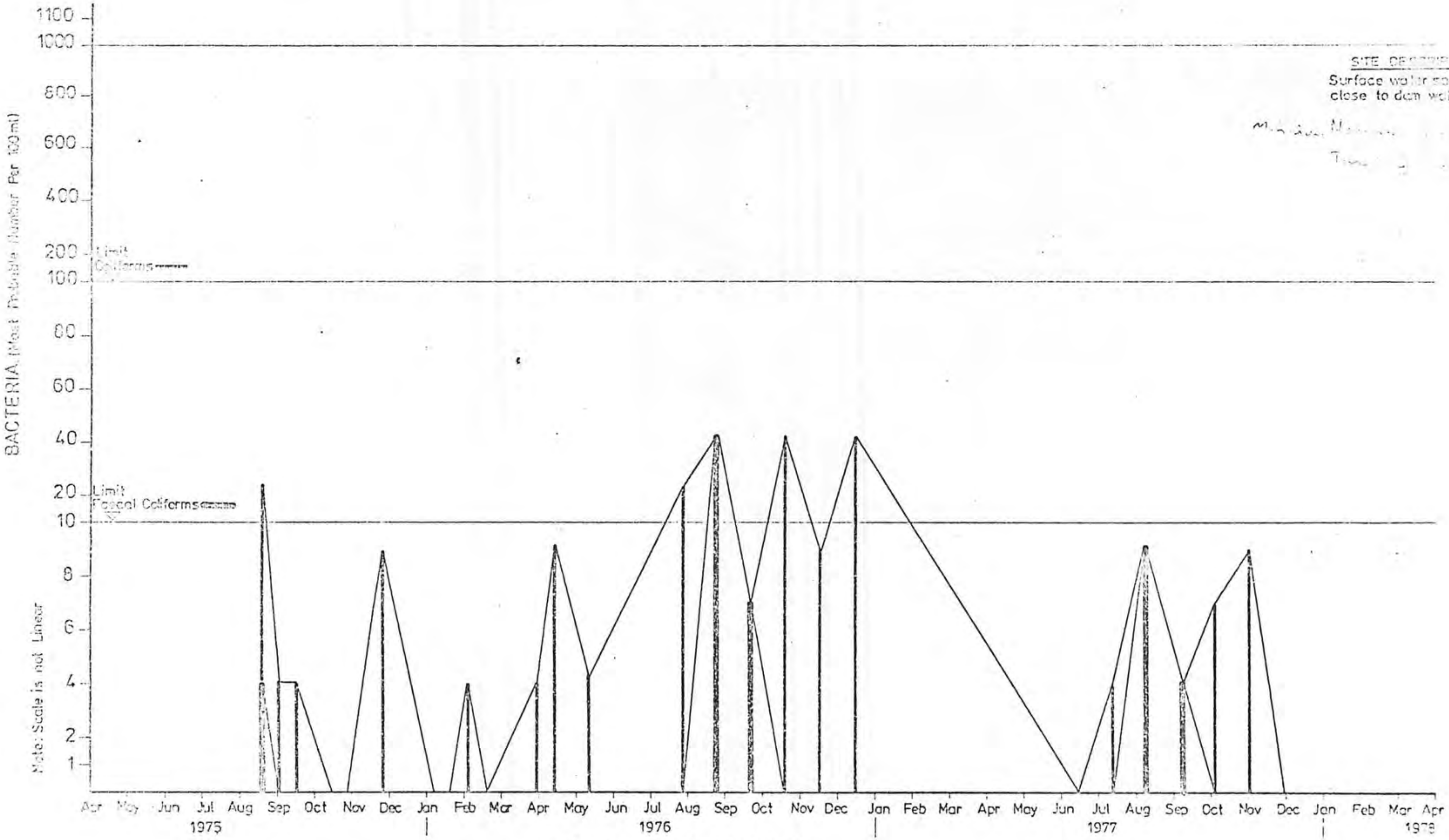
Serpentine Catchment Site 45

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.

FIGURES 4, 5 & 6

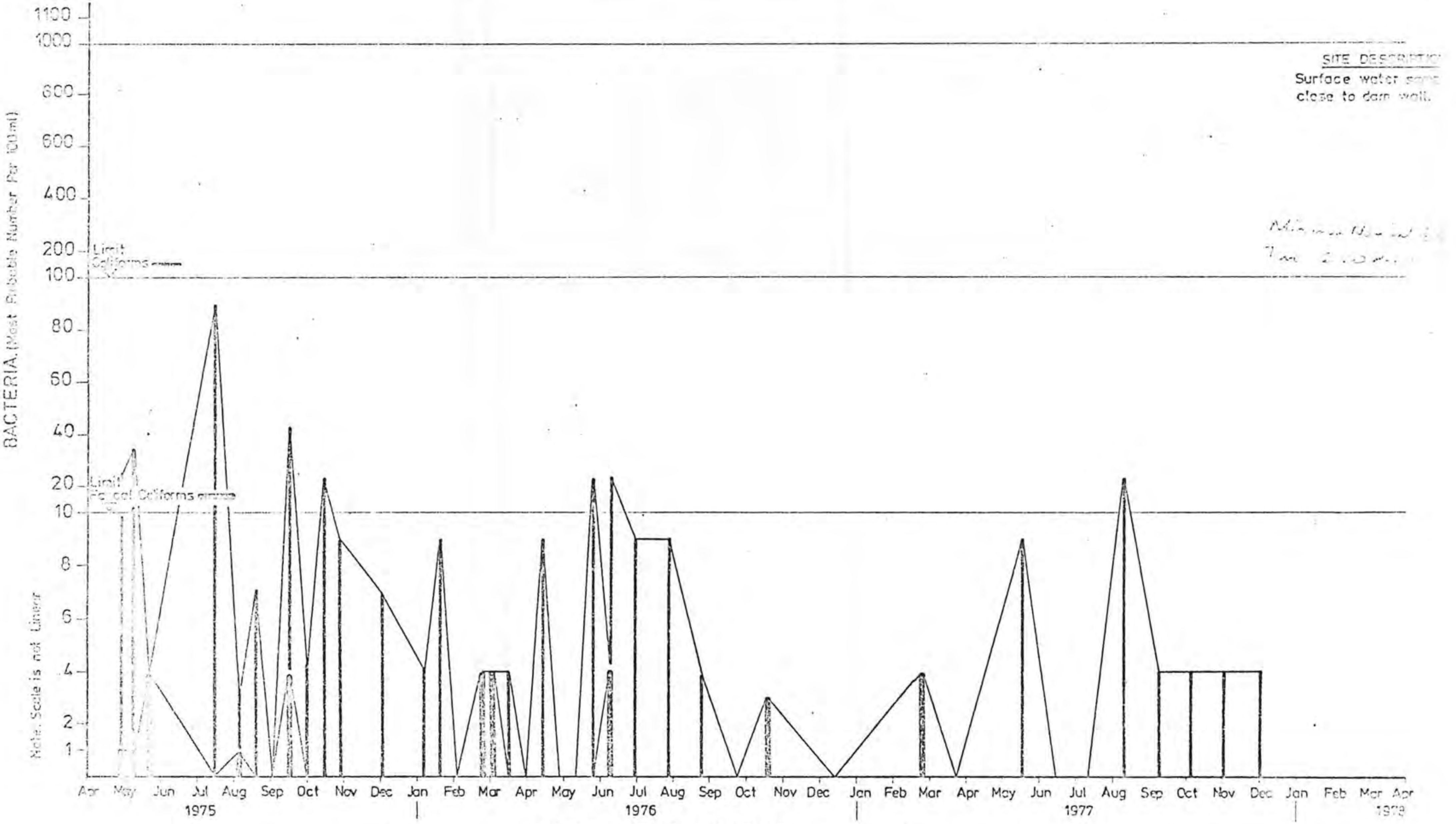
BACTERIOLOGICAL SAMPLING RESULTS

From sites in the reservoirs close to the Dam Wall for Canning, Serpentine and South Dandalup Dams.



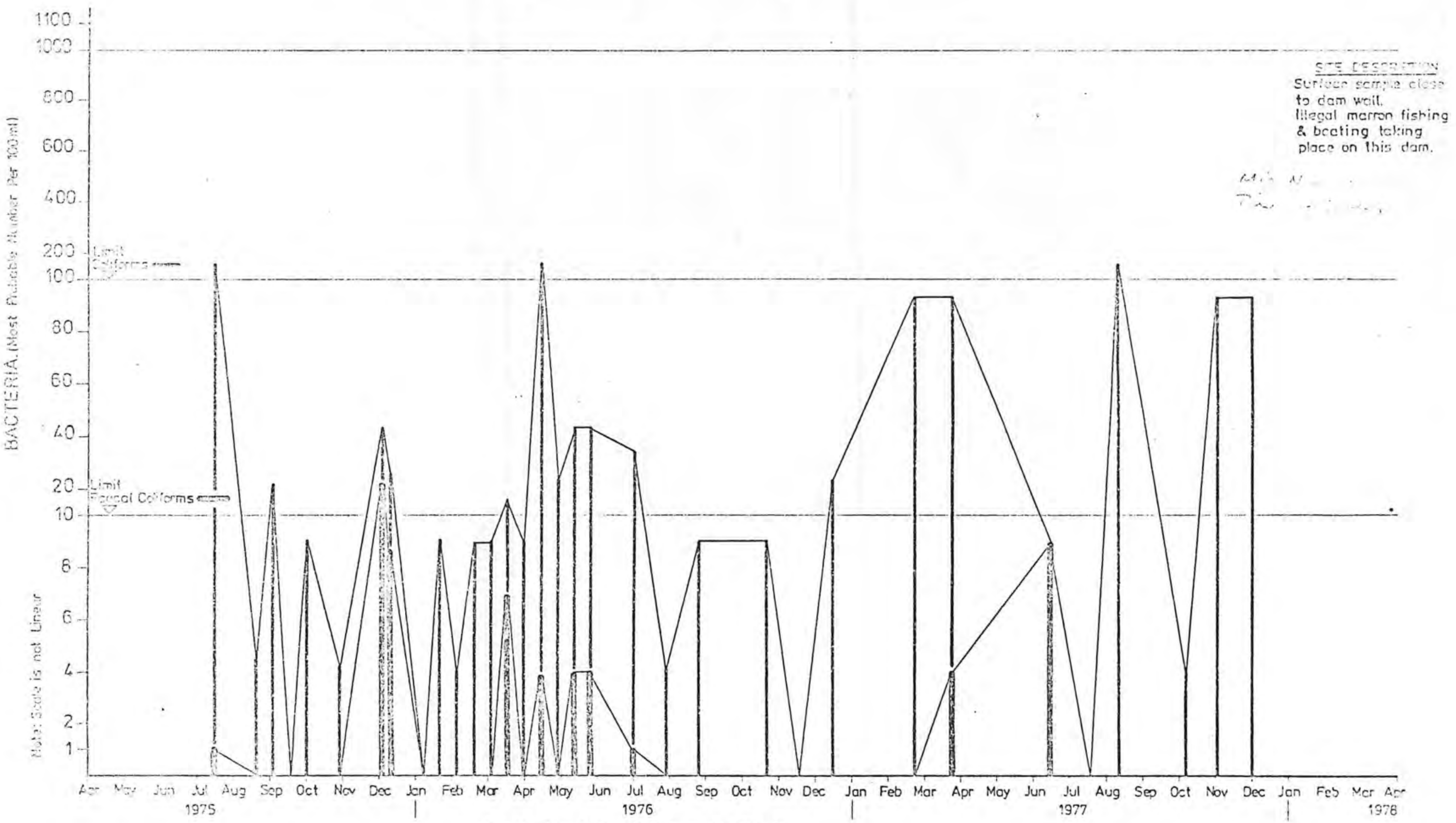
Canning Catchment Site 1

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.



Serpentine Catchment Site 1

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.



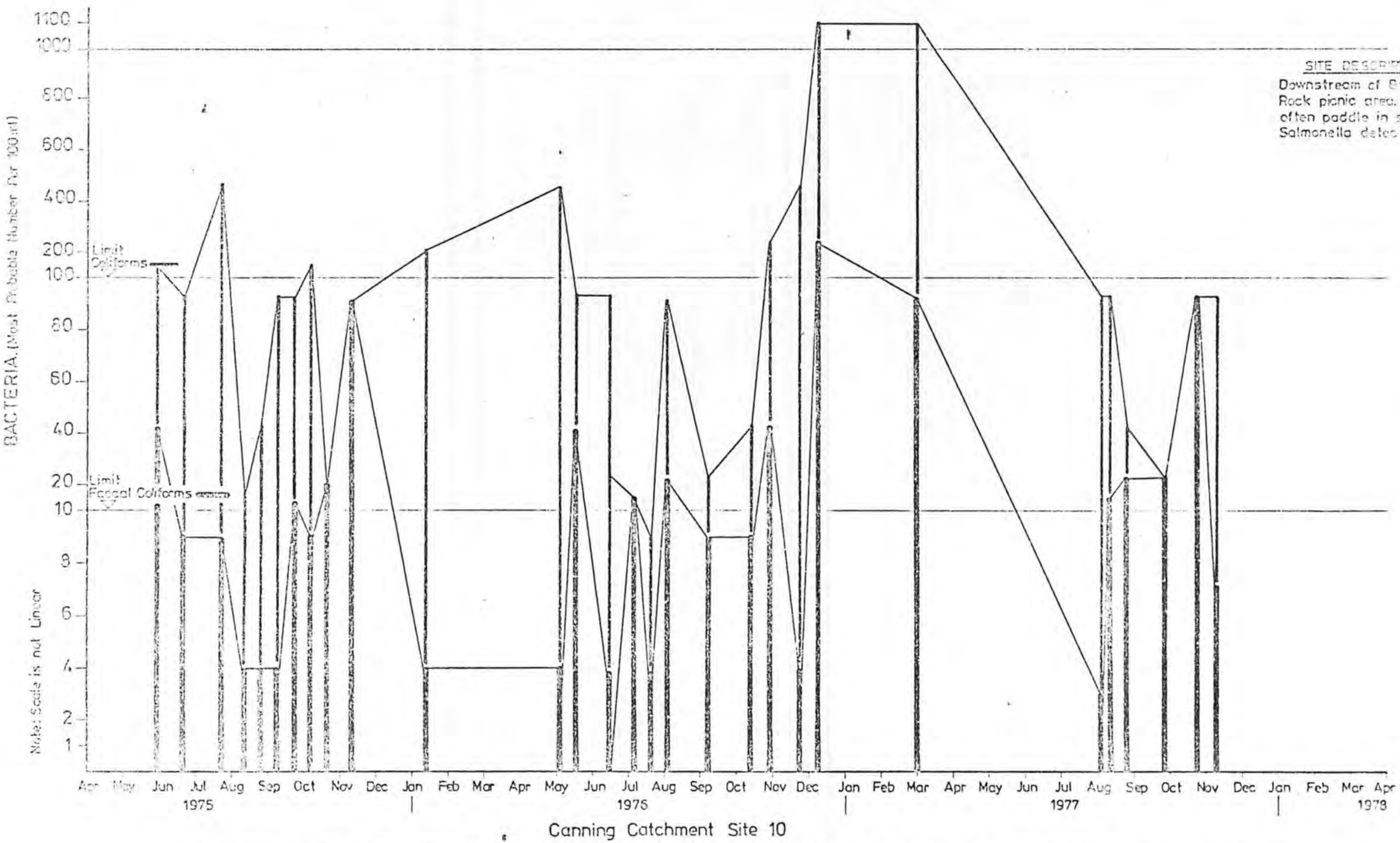
South Dandalup Catchment Site 1

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.

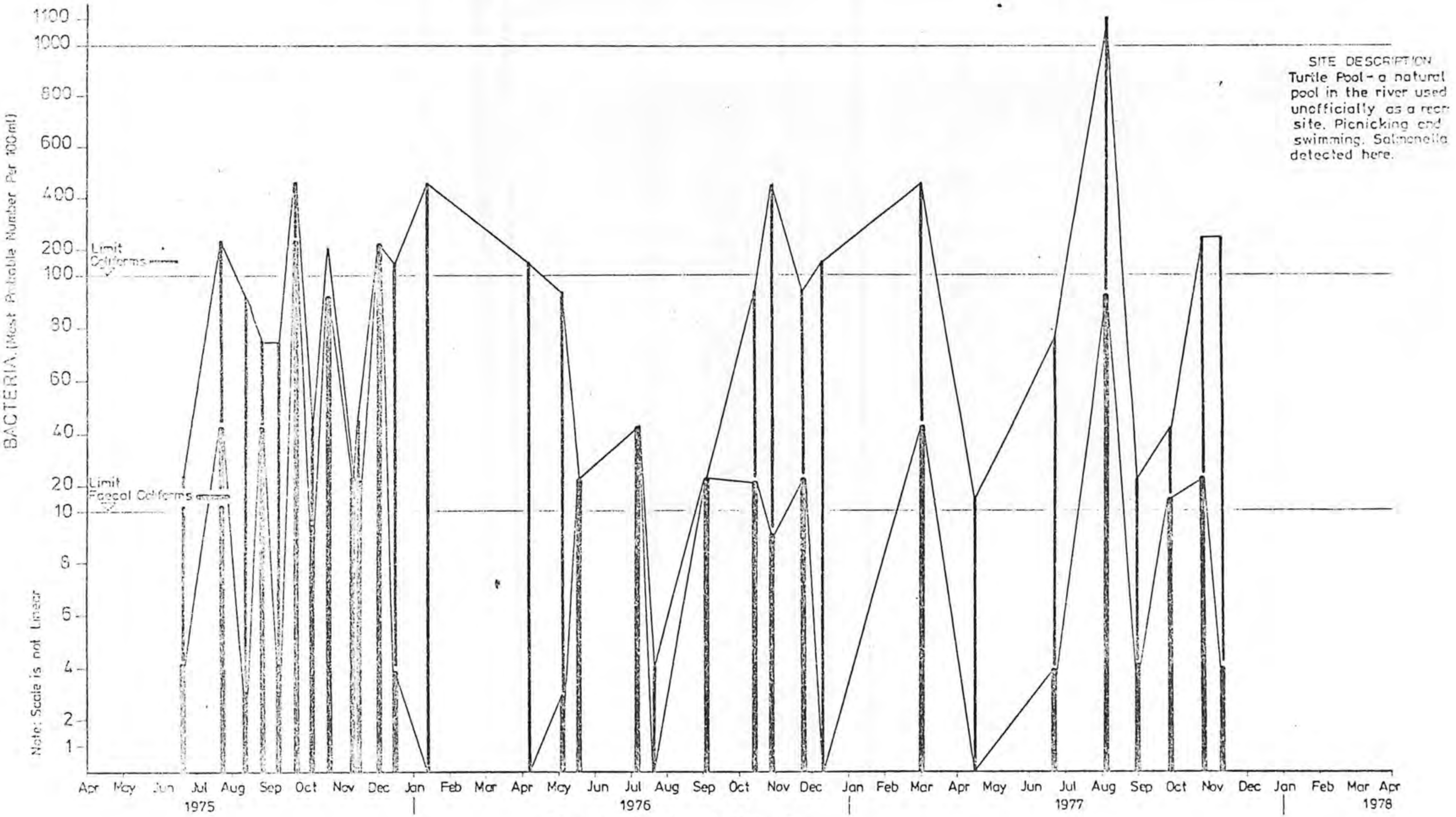
FIGURES 7, 8, 9, 10 & 11

BACTERIOLOGICAL SAMPLING RESULTS

From sites on Catchment in the vicinity of known human activity.

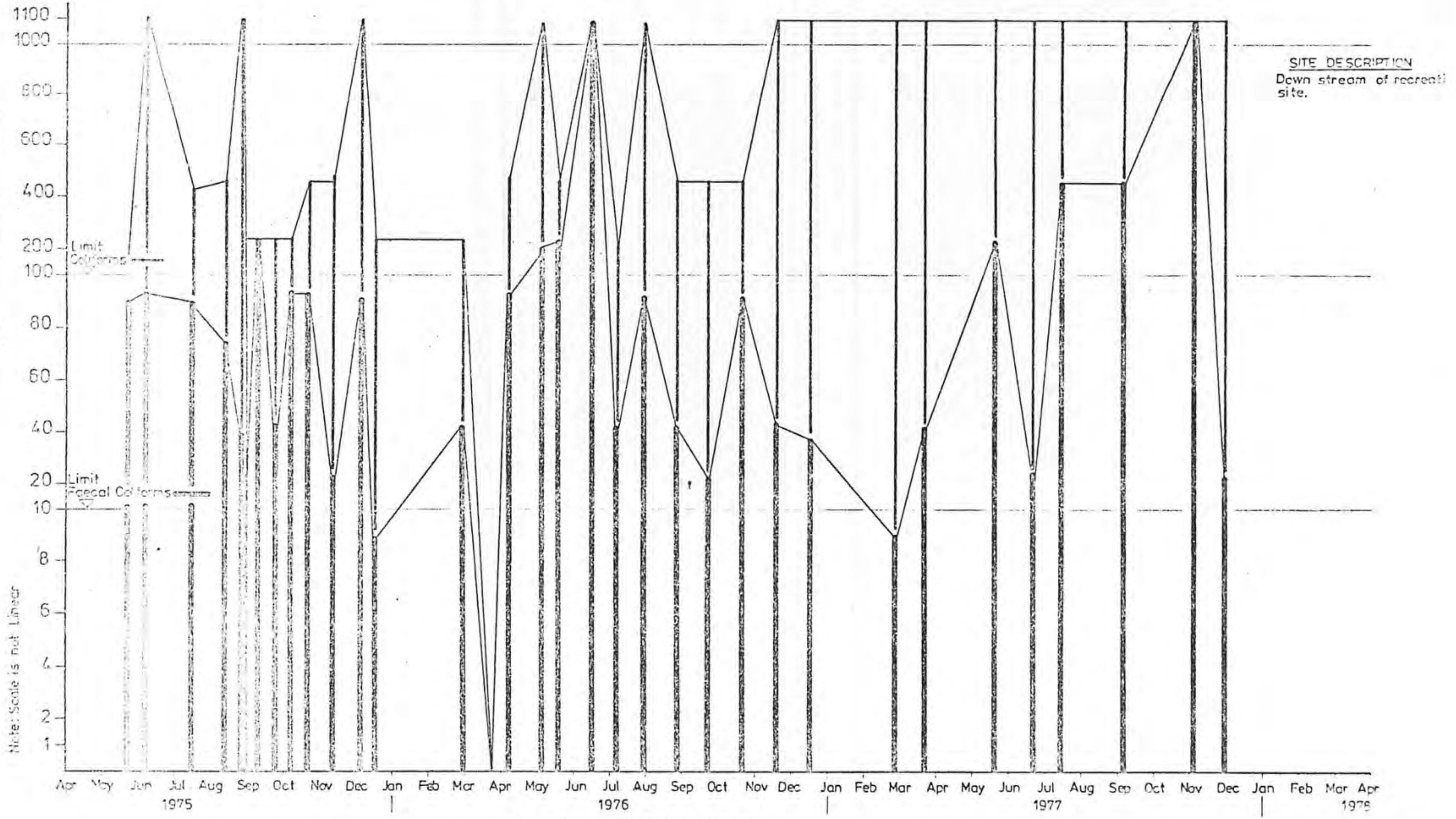


Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.



Canning Catchment Site 49

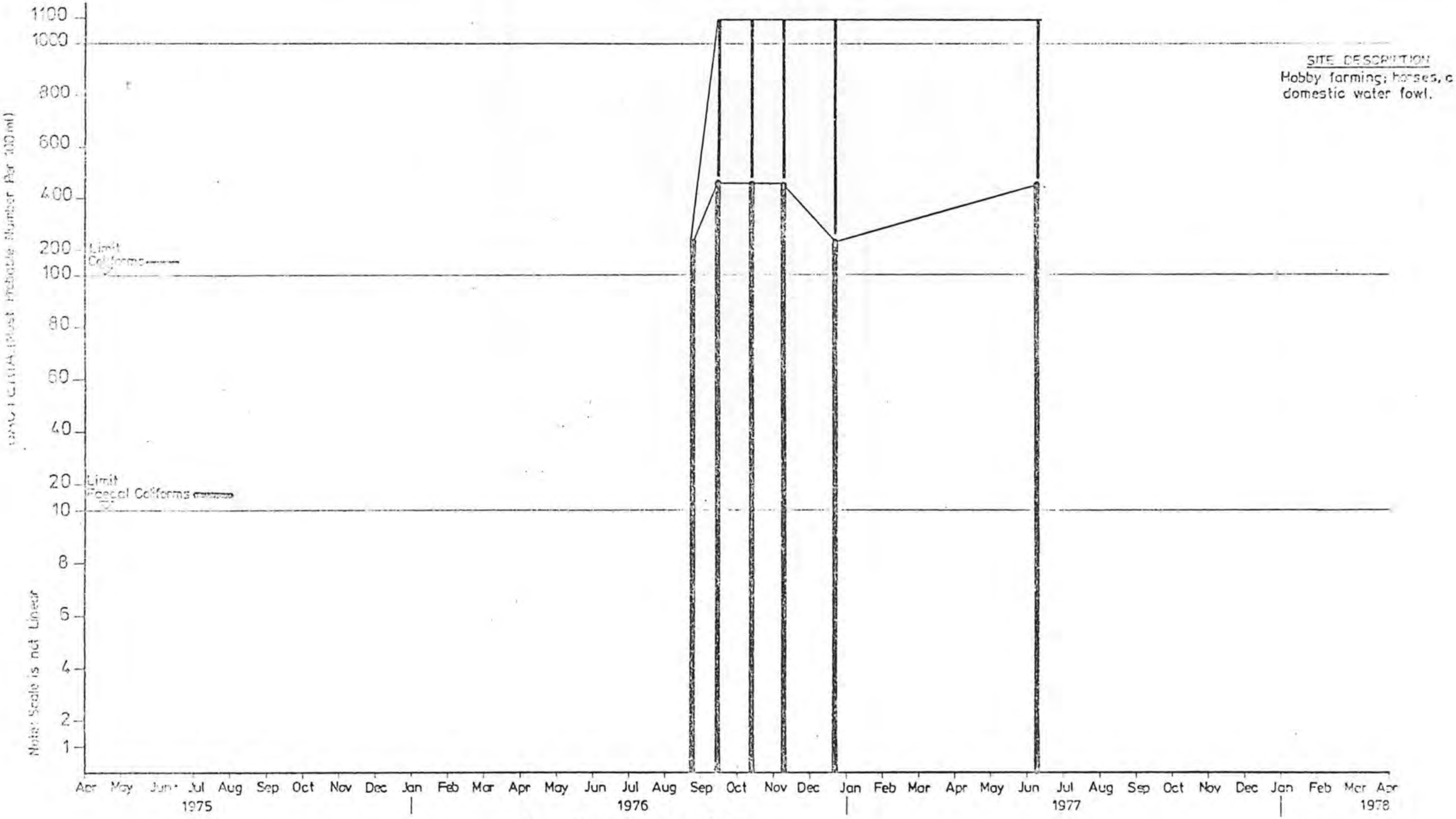
Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.



Gooralong Catchment Site 4

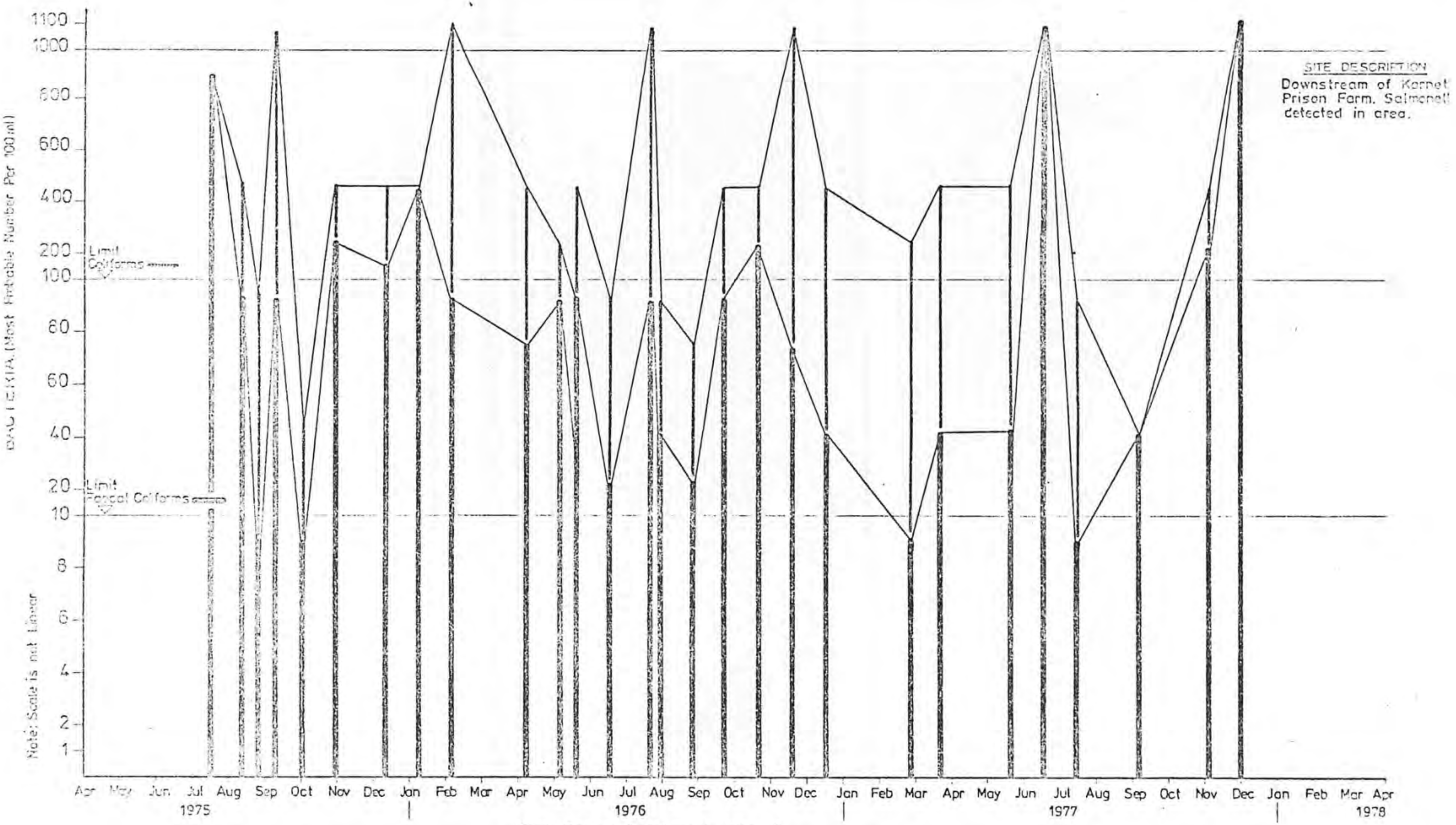
Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.

FIGURE 9



Jane Brook Catchment Site

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.



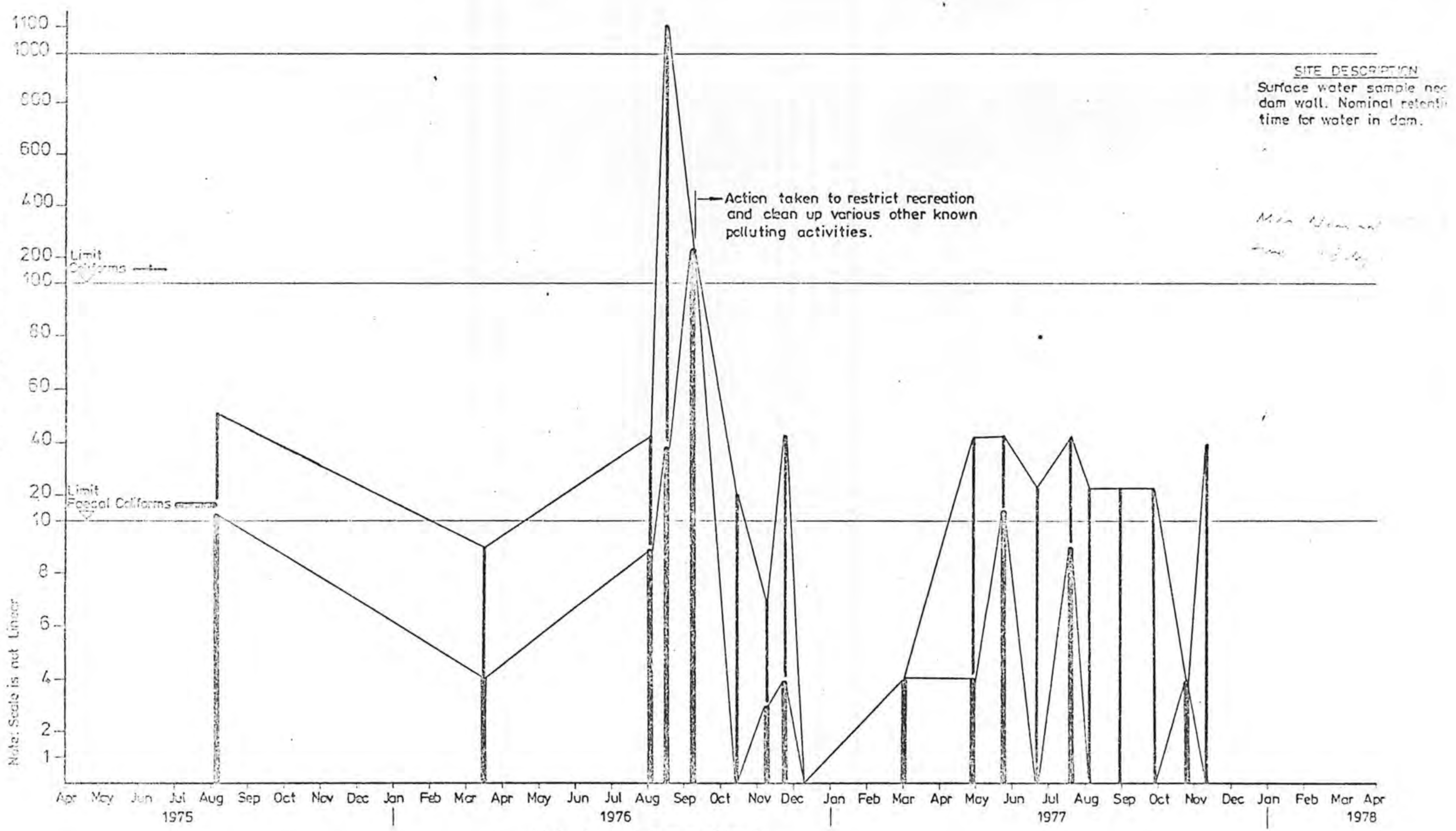
Dirk Brook Catchment Site 2

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time

FIGURES 12, 13, 14 & 15

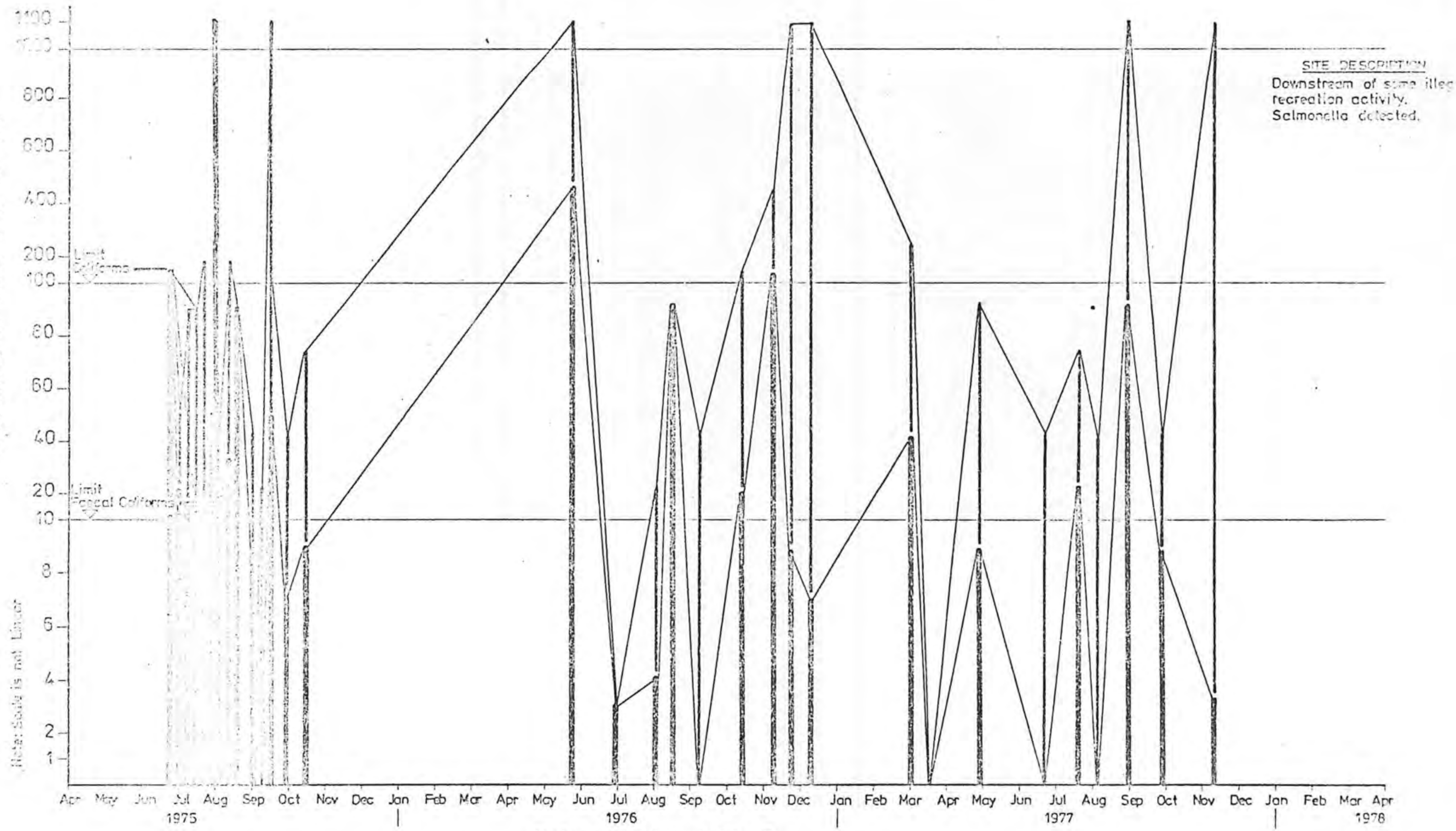
BACTERIOLOGICAL SAMPLING RESULTS

From two small Dams indicating an increase in health hazard resulting from pollution (suspected to be human) of streams flowing into Dams with relative low nominal retention time.



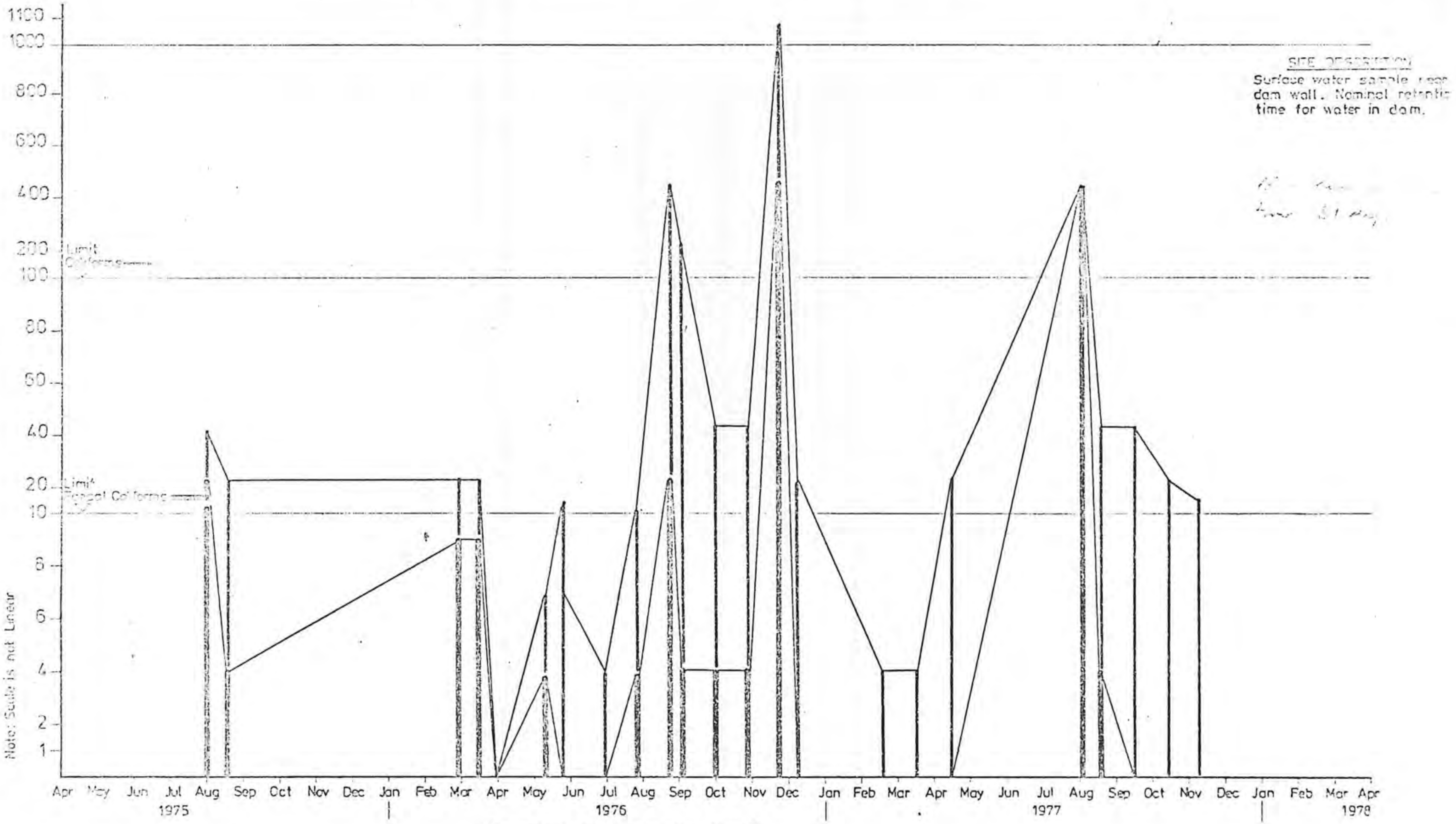
Victoria Catchment Site 1

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.



Victoria Catchment Site 2

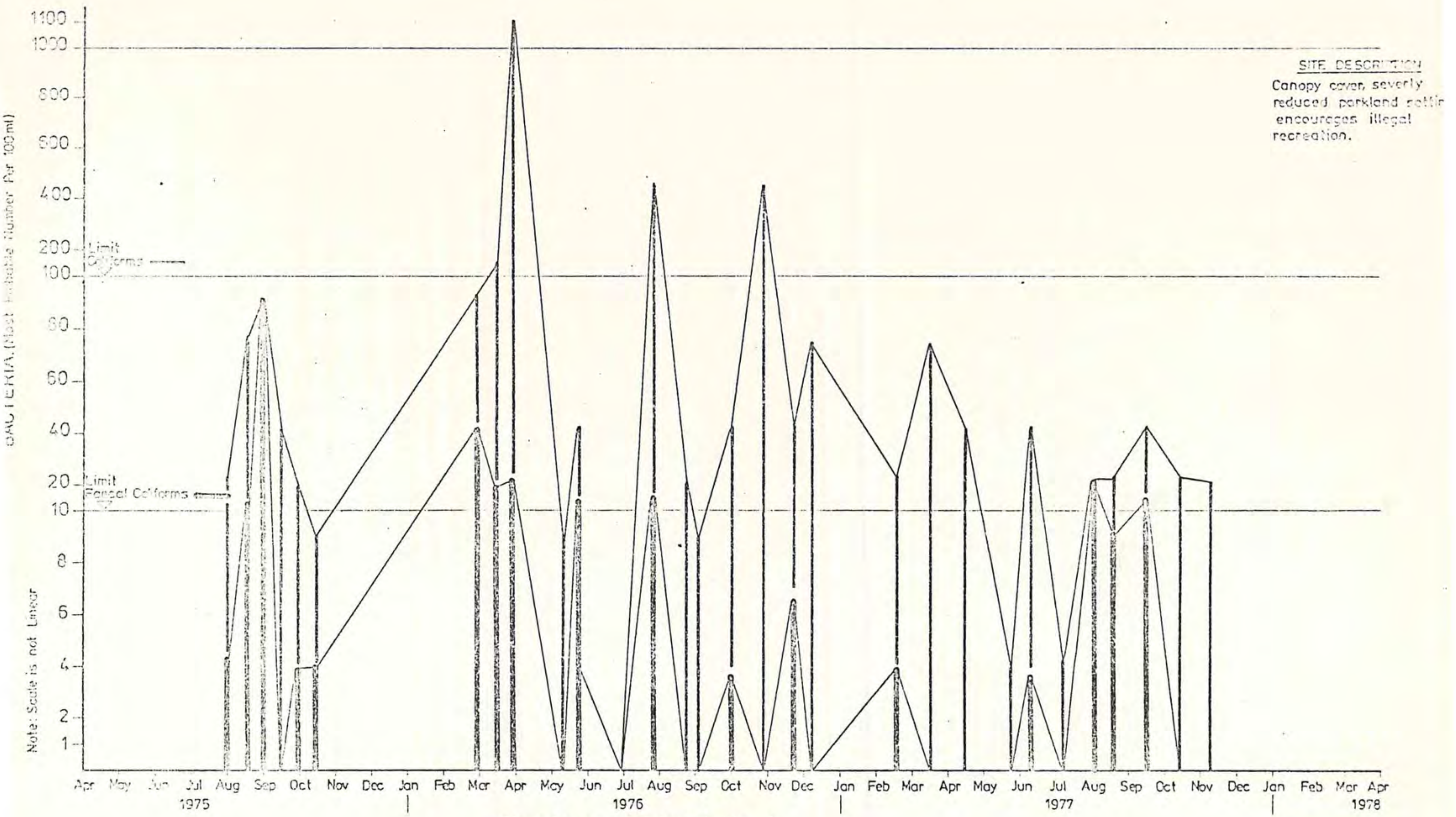
Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time



Churchmans Catchment Site 1

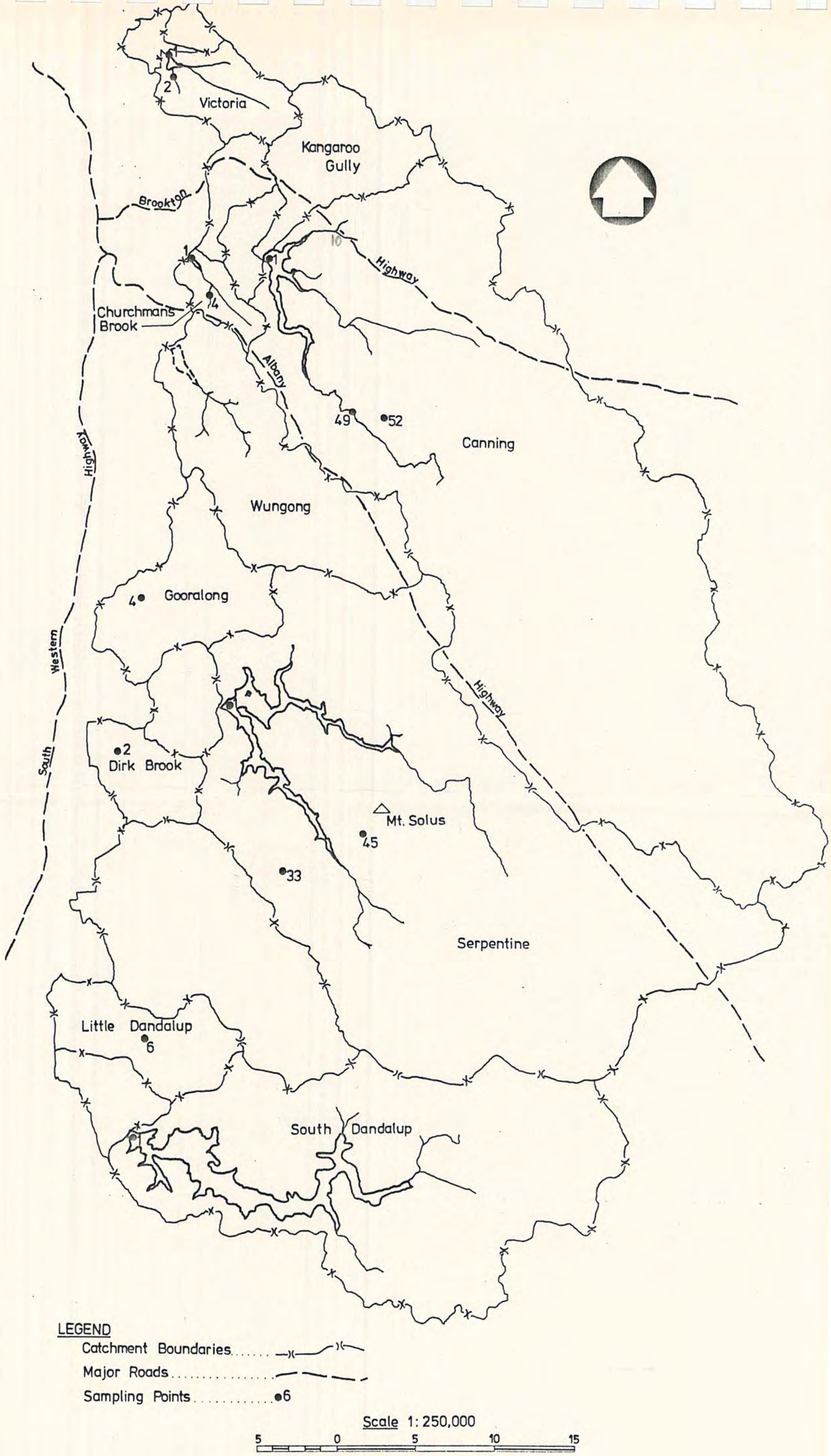
Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.

FIGURE 14



Churchmans Catchment Site 4

Results of Monthly Bacterological Sampling on M.W.B. Catchments Showing Variation in Total and Faecal Coliform Counts (MPN) with Time.



Location of some Water Quality Sampling Points on Metropolitan Water Board Catchments and Dams.