WATER RESOURCES
INFORMATION NOTE

INVESTIGATIONS OF THE WHITTINGTON INTERCEPTOR SYSTEM OF SALINITY CONTROL

PROGRESS REPORT
MAY 1979

WATER RESOURCES SECTION
PLANNING DESIGN AND INVESTIGATION BRANCH
PUBLIC WORKS DEPARTMENT
WESTERN AUSTRALIA

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SUMMARY

In July 1977 the Public Works Department commenced a trial with the co-operation of Mr H.S. Whittington to investigate the effects of the interceptor bank system on the quality of water discharging from the small catchment of Batalling Creek which is a tributary of the Collie River in the Wellington Dam catchment area.

This report collates the information obtained from the first year of the trial and discusses the results. It is stressed that the trial has been running for only one year, and that observations need to be made over a longer period of time before any fully reliable conclusion can be reached. Nevertheless, based on the conditions that applied during 1978 the results presented in this interim report are indicative of the salt and water balances that exist.

The decision to proceed with this trial was taken after representations had been made to the Minister for Works and Water Supplies suggesting that the Whittington interceptor banks could be used to effectively control stream salinity on the Wellington Dam catchment. Mr Whittington had constructed a system of interceptor banks on his Springhill property at Brookton to control water logging and subsequent soil salination. Such a system has been claimed to have been successful in controlling water logging and land salinity on other farms, but its influence on water quality in streams has yet to be evaluated.

The prime objective of the trial at Batalling Creek is to study the effect of the interceptor bank system on stream salinity. To do this, a site was required where the removal of the native vegetation had caused a stream salinity problem. It was also necessary to be able to measure the quantity of salt and water moving through the shallow subsurface soil, the surface runoff and the movement of the deep groundwater.

A site was selected in December 1977 which was satisfactory to Mr Whittington and the Public Works Department. Interceptor banks were constructed during January 1978 under the direction of Mr Whittington. These banks were graded so that the water collected behind the banks is channelled into Batalling Creek. The site selected was upstream from an existing stream gauging station

which measures the quantity and quality of water from the 1660 hectare catchment. The station has been in operation since 1976. Clearing on the catchment had been commenced in the early 1950's and, following extensive clearing in the 1960's, some 53% of the catchment is now cleared. Salt affected land has developed along much of the stream line with an extensive 16 hectare area in the lower section of the valley.

By May 1978 a monitoring system had been installed to measure the quantity and quality of the shallow subsurface seepage collected behind one of the interceptor banks, and a series of eleven piezometers had been installed above and below the interceptor banks to measure the gradients and salinities of the shallow, intermediate and deep groundwater.

The measurements obtained of the shallow subsurface flows from the 10.09 hectares of catchment behind one interceptor bank have been scaled up, to provide a realistic estimate of the quantity and quality of the shallow subsurface flow emanating from the total catchment. Three different methods have been used to derive scaling factors, these are:

(a) the ratio of total catchment area to drain catchment area,

(b) the ratio of cleared catchment area to drain catchment area and,

(c) two estimates of the ratio of the length of likely seepage into the total valley system relative to the length of the monitored drain.

Over 500 water samples have been collected, analysed and processed to determine reliable chloride concentrations for the surface and groundwater flows. Tables 1 to 6 in the report summarise this information. It should be noted that water quality is measured in chloride ions which is approximately 50% to 60% of the total dissolved solids (T.D.S.).

The results show that 40 700 kg of chlorides were deposited on the catchment from rainfall during 1978, whereas the stream flow at the gauging station discharged 1 176 000 kg of chlorides giving a nett outflow of chlorides of 1 135 000 kg. On the other hand the calculated amount of chlorides carried in the shallow subsurface flow controlled by the interceptor banks was between 41 000 kg and 78 000 kg depending upon the scaling factor used. That is only between 4% and 7% of the total chloride discharged from soil storage came from the shallow subsurface seepage. It is of interest to note that the quantity of salts carried down Batalling Creek in 1978 was equivalent to some 2300 kg T.D.S. from each hectare of cleared land.

The information obtained from the piezometers clearly show that the groundwater has the potential to rise above the natural surface of the valley floor and contribute deep saline water to Batalling Creek. Vertical movement of this highly saline water (10 000 mg/l chloride) was observed in a backhoe excavation. Some 70 years of accumulation of salts from the shallow seepage would have had to occur in the valley to explain the discharge of salts from Batalling Creek over the last three years. As clearing of the catchment only commenced 20 - 25 years ago such a build up is not feasible. The analysis of the information collected in 1978 indicates that the main source of stream salinity at Batalling Creek is from the deep groundwater.

It is interesting to note from Table 4 that almost 10% of the rainfall is discharged by shallow subsurface seepage compared to less than 2% through the deep groundwater. Whereas the quantities of chloride discharged through the shallow surface profile is only one nineteenth of that transported by the deep groundwater. The information presented in the report, and in Table 5 in particular, shows that if all the water entering Batalling Creek from the shallow subsurface flows was cut off by interceptor banks and no action is taken to control the deep groundwater flow, high stream salinities could be expected for at least the next 300 years. Figure 7 clearly shows that a very small percentage of salts are stored in the shallow subsurface soils, in fact less than 0.3% in the top 1.2 metres.

Within the limits of reliability that can be expected from the results of a one year trial this interim report indicates that:

(a) less than 10% of the salts being discharged into Batalling Creek comes from the shallow subsurface soils,

(b) deep groundwater is the major source of salts causing stream salinity,

(c) the quantity of water moving through the shallow subsurface soils is much greater than the deep groundwater flow,

1. INTRODUCTION

As a part of a continuing programme of research into important aspects of the salinity problems in Western Australia, the Public Works Department commenced a co-operative trial with Mr H.S. Whittington in July 1977 to investigate the effects of his interceptor bank treatment on the quality of water discharging from a small catchment.

From his experience at Springhill, Mr Whittington developed a system of interceptor banks for controlling water logging and subsequent soil salination. The treatment is based on the premise that shallow, subsurface water flow is the prime cause of salinity problems following clearing; and the banks are designed to intercept this flow, and any surface runoff, then either divert the held water directly to a stream channel or infiltrate it to the deeper groundwater bodies. Such treatment has been claimed successful in controlling waterlogging and land salting on some farms, but its effects on the water quality in streams has yet to be evaluated.

Research to date has shown that there are large stores of soluble salts in the deeper pallid zone soils; that deep groundwater levels rise after clearing of natural vegetation; and that movement of saline water towards the surface in salt affected valleys can be inferred from the groundwater pressure gradients. The object of the current trial is to quantify the magnitude of water and salt movement into the streams from shallow, subsurface seepage, and compare this with deep groundwater measurements in a similar landscape. This report summarises the results of the first year of observation.

2. MONITORING PROGRAMME AND APPROACH TO ANALYSIS

After consideration of numerous alternatives by Mr Whittington and Departmental officers a site on Batalling Creek was selected in December 1977. Interceptor banks to control an extensive (16 ha) salt affected area upstream from an existing gauging station were constructed under Mr Whittington's direction in January 1978. Monitoring equipment to continuously measure the flows and salt loads in one representative drain were installed during April and were operational by May 1978.

These provide a direct estimate of the salt and water seepage from the shallow subsurface soils of the hillside after the effect of surface runoff has been separated. Piezometers to monitor deep groundwater gradients and salinities beneath the drain were also constructed and have been regularly monitored since June 1978. These provide the basic data which, together with other information on the hydraulic conductivity properties of the soil, enable assessment of the salt and water discharges from the deep groundwater system.

The existing monitoring on Batalling Creek provides a measure of the salt and water input through rainfall and output through streamflow for the total catchment. Instrumentation on the Batalling Creek gauging station was upgraded through 1977 to provide better definition of the streamflow salinity and therefore the total catchment salt discharge. Both daily sampling and continuous conductivity measurement were carried out in 1978. The input of salt was estimated from measured rainfall volumes and average concentrations of salts in rainfall as determined by Hingston and Gailitis (1976).

The quantities of salt discharged from the catchment in one year minus that salt which falls on the catchment (through rainfall or dry fallout) in the same year provides an estimate of discharge from soil storage within the catchment.

The quantity of salts discharged from total soil storage minus the salts discharged from the shallow subsurface soils (obtained by scaling up the results of the interceptor drain) represents an estimate of the salts discharged from the deeper soils and associated groundwater system on the catchment scale.

The monitoring programme therefore enabled two essentially independent estimates of the relative magnitude of the salts discharged from the shallow and deep groundwater systems to be made; the first using data from the groundwater bores to estimate the deep groundwater discharge from the hillside and the second using Batalling Creek gauging station data to estimate deep groundwater discharge on the catchment scale. These approaches are shown diagrammatically in Figures 1 and 2.

During installation of the groundwater piezometers, three cored holes were drilled to bedrock and additional shallow holes sampled so that the variation of salt storage with depth could be determined. By comparing the figures for salt storage and salt discharge for both of the soil zones (i.e. shallow and deep) an estimate of the time taken to leach half the current salt storage from each of the zones was determined.

3. RESULTS

Over 500 water samples have been collected, analysed and processed during 1978 to determine reliable averaged chloride concentrations for the surface and groundwater flows. Figures 4 to 6 show the variations of flow rate, chloride ion concentration and rainfall over the year. Figure 7 shows the distribution of salts stored in the soil profile while figures 8, 9 and 10 show the groundwater pressure levels at different depths beneath the monitored hillside. Chloride ion concentration and volumes of flow and rainfall for both the drain and Batalling Creek are summarised in Tables 1 and 2.

As outlined in the previous section data from Tables 1 and 2 can be used to estimate salts leaching from both the shallow and deep groundwater system for the total Batalling Creek catchment assuming that measurements of seepage flow from the monitored hillside are reasonably typical of those from the remainder of the catchment. Three estimates of the shallow subsurface salt discharge from the catchment were determined from Table 2 using the following scaling factors:

(i) the ratio of total catchment area to drain catchment area

(ii) the ratio of cleared catchment area to drain catchment area, and

(iii) two estimates of the ratio of the length of likely seepage into the total valley system relative to the length of the monitored drain.

Table 3 summarises the resultant chloride inputs to and outputs from the total catchment and associated soil zones. The table shows that the difference between the salts discharging from streamflow and coming through rainfall was 1.14 x 10^6kg (chloride ion) or 684 kg/ha over the total catchment. As only 53% of the catchment is cleared the quantity discharged per unit cleared area is approximately 1290 kg/ha. Table 3 also shows that between 40 and 80 x 10^3kg (chloride ion) or between 4% and 7% of the total chloride quantity discharged from soil storage came from the shallow subsurface seepage. Thus, by difference some 93% of the discharging salts (or 1.10 x 10^6kg of chloride) were estimated to be discharged from the deep groundwater system during 1978.

Table 4 lists the quantities of chloride and water falling on and discharging from the monitored hillside and includes an independent estimate of the chloride discharge from the deep groundwater system based on direct groundwater monitoring (see previous section).

Two points should be noted from Table 4. Firstly, the estimtes of the shallow subsurface seepage relative to the deep groundwater flow indicate that considerable amounts of moisture (10% of rainfall) move through the shallow soil profile. Secondly, the quantities of chloride which are transported by this shallow subsurface flow are only one nineteenth (5.2%) of those transported by the deep groundwater system.

It should be stressed that the estimates of groundwater seepage are only approximate, particularly since determination of transmissivities and hydraulic conductivities have not been determined at the site. However the deep groundwater discharge of chloride from the hillslope is of the same order as the estimated chloride discharge from the deep soil profile of cleared areas on the Batalling Creek catchment (0.091 and 0.124 kg/m^2 respectively - Table 5).

Groundwater monitoring in the valley flat has shown pressure heads above the ground surface indicating a potential for vertical movement of deep groundwater towards the soil surface (Figures 9 and 10). Thus there is a mechanism by which the deep groundwater salinities can be discharged to the surface stream system.

Three deep holes were drilled and cored to bedrock as shown in Figure 7. The total quantities of soil salt storage were calculated and the distribution of salts above and below the water tables were determined. Additional samples were taken in the shallow soils to obtain a better comparison between the shallow and deep soil salt storage. The storage results are summarised in Table 5. The storage of 164 kg/m^2 of total soluble salts for the full profile represents the highest storage encountered to date in all drilling programmes throughout the Darling Range. In contrast, the quantities of salts stored in the top 1.2 metres at sites unaffected by deep groundwater are very small, being only 0.3% of the total soil storage (holes 6129051 and 6129048 - Figure 7).

Calculations of the proportion of salts held in storage above and below the current groundwater levels have been made at Batalling Creek and compared with similar proportions at other cleared and uncleared sites. From studies in the woodchipping, bauxite mining and Collie research catchment areas soil coring has consistently shown that between 70% and 80% of the salts from forested sites are held above the saturated groundwater level (Colin Johnston, pers. comm). In comparison, drilling in the cleared areas at Batalling Creek showed that only some 1% of the salts were held above the estimated saturated level; the implication being that substantial increases in the groundwater level have occurred since clearing.

Table 5 also compares the quantities of chloride discharged from soil storage in 1978 relative to the quantities stored in the soil profile of both the shallow and deep groundwater system.

Table 5 and Figure 7 clearly show that only a very small proportion of salts are stored in the shallow subsurface soils (less than 0.3% in the top 1.2 metres). However the rate of discharge of salts from the shallow soils is also very much less than from the deeper soil profile. Division of the current soil storage by the current annual discharge rate gives a measure of the time required for the leaching process to reduce the salt storage to half its current level. Estimates of these soil storage half lives are summarised in Table 5. It is clear that, regardless of the different estimates of soil storage and deep groundwater discharge used, the time scale for leaching the salts held in the deep soils is very long (at least 300 years) relative to the shallow subsurface soils (only 25 years). That is, significant salt discharge from the deep groundwater system can be expected to persist for at least 300 years.

Table 6 lists the annual rainfalls, flows and chloride ion concentrations at Batalling Creek for all years of available record. Major variations occur in both the flow rates and chloride ion concentrations between years. Possible causes of these variations include variations in the seasonal response, possible time trends in the salinity data, and differences in the frequency of the sampling programme, in addition to the changes that may be brought about by the construction of the interceptor banks. At this stage no worthwhile attempt can be made to identify the effect of the interceptor banks on the salinity of Batalling Creek streamflow. A number of additional years of detailed sampling will be necessary before conclusions about the direct effect of the banks on the creek will be possible. Even then, only large changes are likely to be identified.

4. DISCUSSION

The data presented in Tables 3 and 4 clearly emphasises the dominant role that salt discharge from deep groundwater systems plays in the transport of salts from soil storage. The contribution of salts from the shallow subsurface soils range between 4% and 7% of the total leaching from the landscape. These proportions are based on two independent estimates of the deep groundwater discharge and a range of factors used to scale up the seepage flow from the monitored hillside to the catchment scale. Because the percentages of shallow subsurface salt discharge are so small, the assumptions of scaling, of the hydraulic properties of the deep groundwater system, of the representativeness of the hillside and the fact that only one year's data are available are unlikely to be so restricting as to change this overall conclusion.

It may be argued, however, that the salts in excess of those from the surface and shallow subsurface soils which discharged from Batalling Creek in 1978 (Table 3) did not come from deep groundwater seepage but came from an accumulation of salts in the valley from the shallow subsoils prior to construction of the interceptor banks. However estimates of groundwater discharge into the valley flat beneath the drain (Table 4) clearly indicate that deep groundwater seepage is contributing roughly the same quantity of salts into the valley as are being discharged down the river system (see previous section).

Moreover groundwater pressure gradients within the valley flat are above the soil surface (Figure (9) and are contributing both water and salts from depth to the soil surface. This vertical movement of highly saline groundwater (10 000 mg/l chloride) from below the shallow subsurface soils has been observed directly during backhoe excavation.

Batalling Creek has been discharging salts in excess of inputs from rainfall since at least 1976 (see Table 6). Some 70 years of 100% accumulation at the current rate of shallow subsurface salt discharge from cleared areas would be necessary to explain the discharge of salts from Batalling Creek over the last three years. As clearing on the catchment only commenced in the mid 1950's some 20 to 25 years ago, accumulation of salts from the shallow soils cannot explain the current salt discharges.

While the quantity of chloride discharged from the shallow soils is minor relative to the deep groundwater chloride flow, the quantity of water seeping through the shallow soils is relatively large. This seepage presumably accumulated in the low lying areas immediately following clearing and in part infiltrated to the deep groundwater, increasing the rate of the groundwater rise. Following the rise of the groundwaters to the soil surface, the seepage flows have presumably contributed to the quantity of water lying in valley areas during winter and spring periods. The interception of these flows and their discharge away from low lying areas may therefore delay the onset of saline seeps following clearing and reduce the degree of associated water logging once salinity problems have developed.

However this approach is unlikely to significantly affect stream salinities simply because the quantities of salts carried by these seepage flows are such a small percentage of the total salts being discharged from the landscape following clearing. It is clear from Table 5 that if all the salts from shallow subsurface sources were stopped from entering the stream system and no action was taken to control the groundwater discharges, high stream salinities could be expected for the next 300 years. The strategy for long term stream salinity rehabilitation must therefore concentrate on reducing the discharge of salts from the major source in the landscape; that is, from the deep groundwater system.

It is also apparent that construction of banks further upslope in the landscape could easily increase the salinity problem in the Batalling Creek case. If banks upslope from bore hole 6129046 (see Figure 8) directed surface and shallow subsurface flow into the deeper groundwater the hydraulic gradient and therefore the deep groundwater flows into the valley would increase. As this flow is the major vector of salt movement in the landscape, increases in the discharge of salts to the stream system must be expected.

5. CONCLUSIONS

The analysis of data from the Batalling Creek trial described above has concentrated on assessing the relative proportions of salts and water from the shallow and deep groundwater systems on both the hillside scale and the total catchment scale. Using different scaling factors and estimates of the deep groundwater seepage it has been estimated that less than 10 percent of the salts being discharged from Batalling Creek come from the shallow subsurface soils.

It would therefore appear that solutions to the long term discharge of salts down the surface stream system will need to concentrate on controlling discharge from deep groundwater; the major source of the salts causing stream salinity problems.

In contrast, the quantities of water moving through the shallow soils of the monitored hillside are much larger than the deep groundwater underflow.

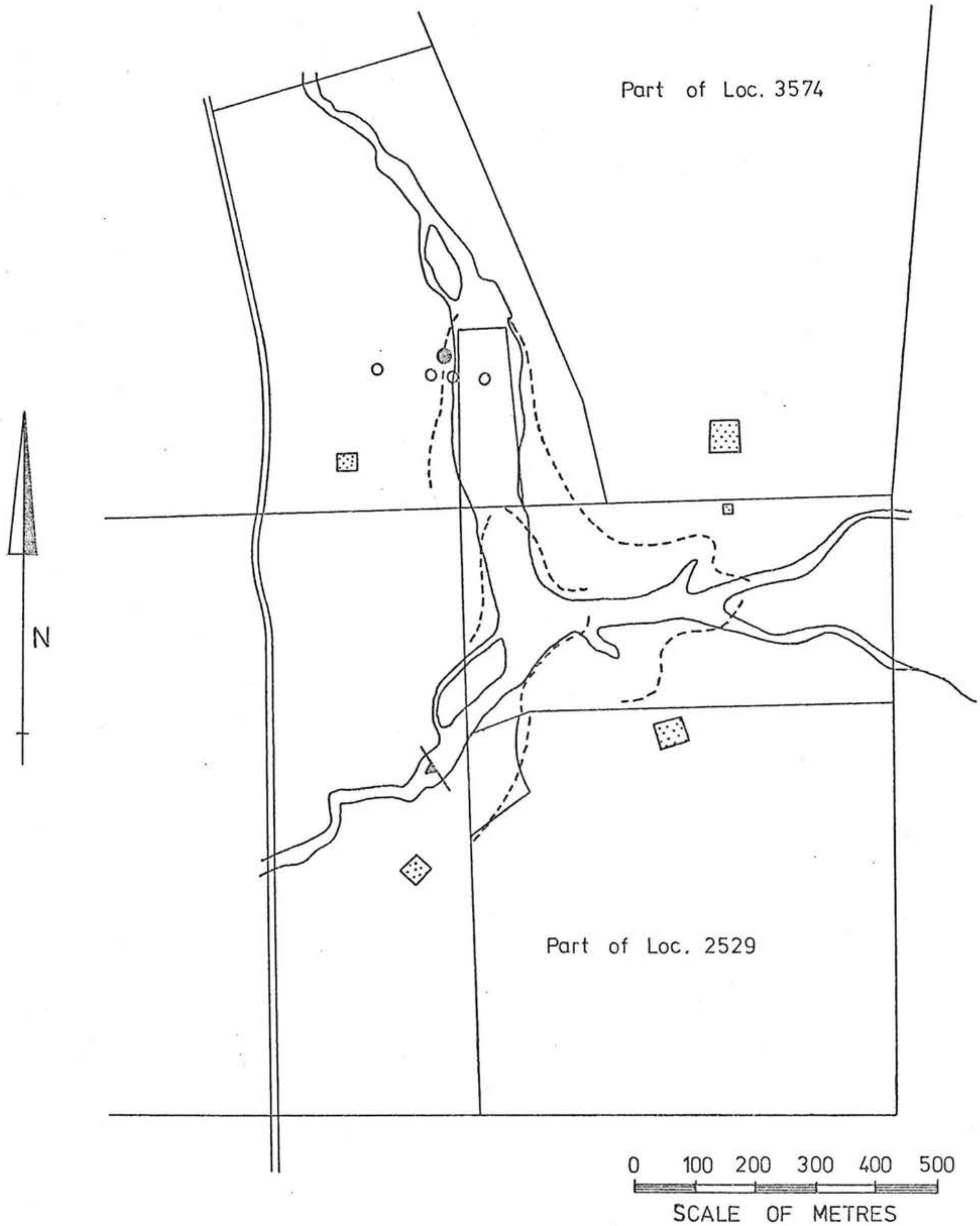
This shallow subsurface water, however, does not carry significant quantities of salts, and it is therefore unlikely that its interception and diversion will cause a significant reduction in stream salinity.

Additional years of monitoring are required to confirm the magnitude of the salt and water balances calculated from the 1978 data. While long term monitoring of the discharge of salts from the total catchment is the only way to provide final evidence of the success or failure of the interceptor concept, the monitoring of one of the interceptor drains has enabled considerable knowledge about the processes causing the problem to be developed and by inference the likely success of the trial.

6. REFERENCES

Hingston, F.J. and Gailitis, V., 1977. Salts in Rainfall in Western Australia (1973 - 1974). CSIRO Division of Land Resources Management Technical Memorandum - 7/1.

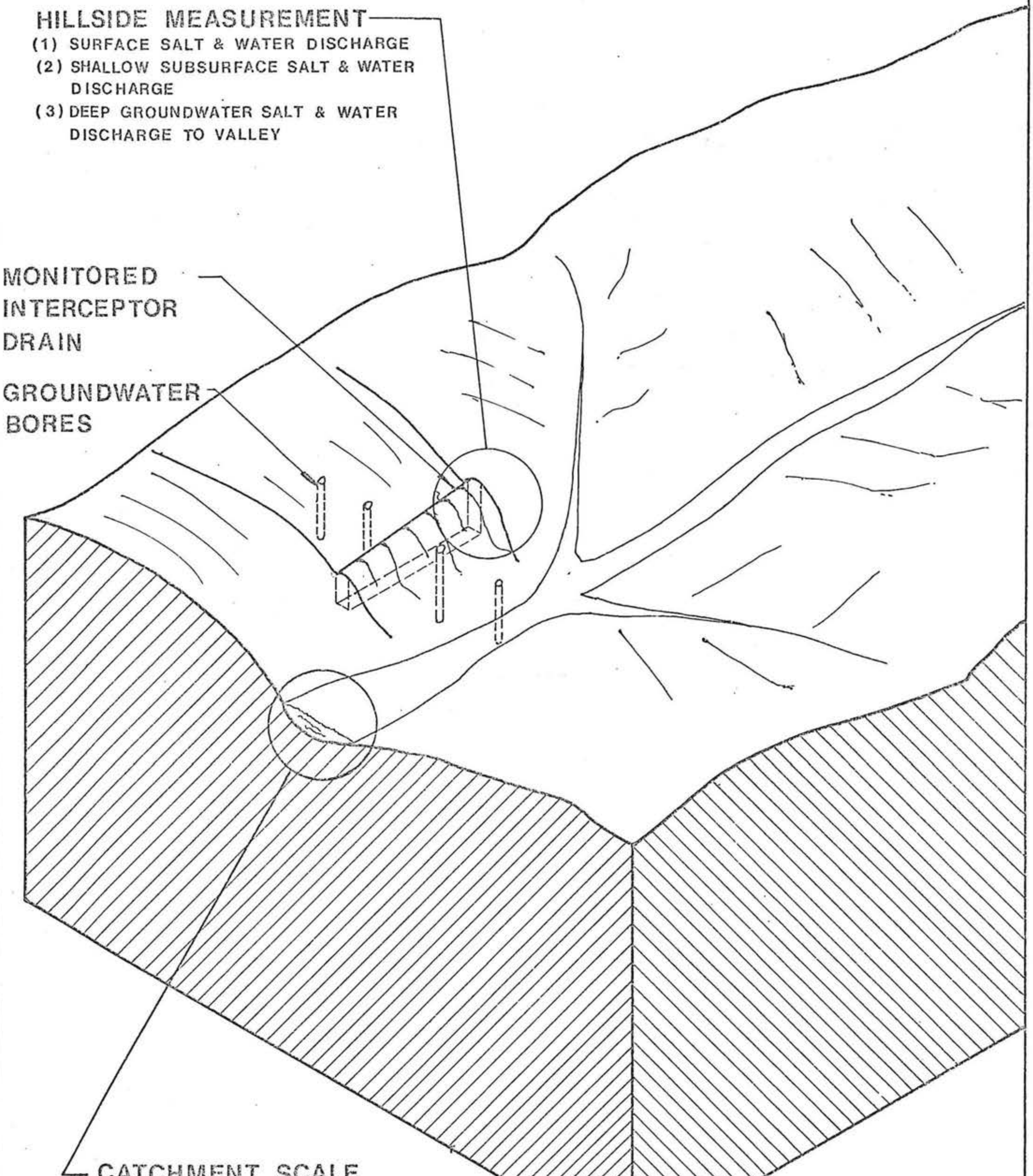
LAYOUT OF INTERCEPTOR DRAINS – BATALLING CREEK



LEGEND

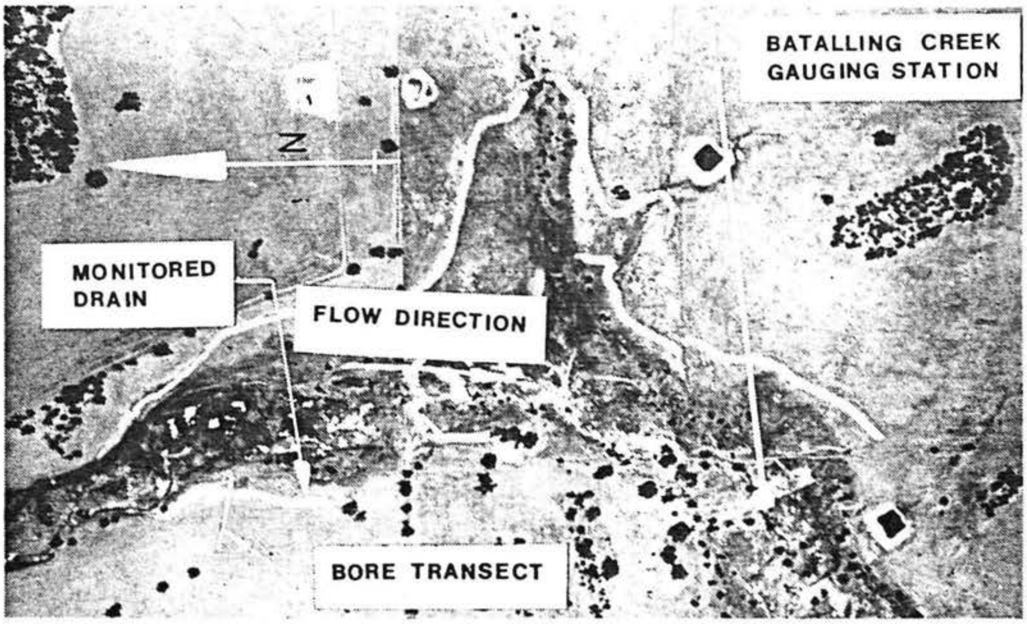
- EXISTING GAUGING STATION
- FARM DAMS
- INTERCEPTOR DRAINS
- DRAINAGE LINES
- BOREHOLE LOCATIONS
- INTERCEPTOR DRAIN GAUGING STATION

FIGURE 1

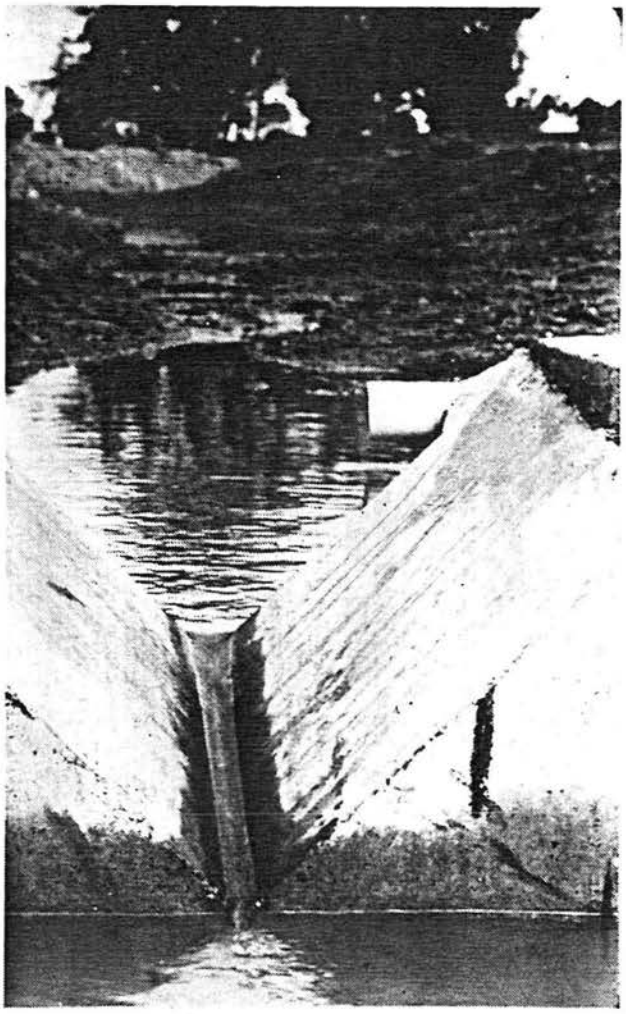


BATALLING CREEK TRIAL

FIGURE 2

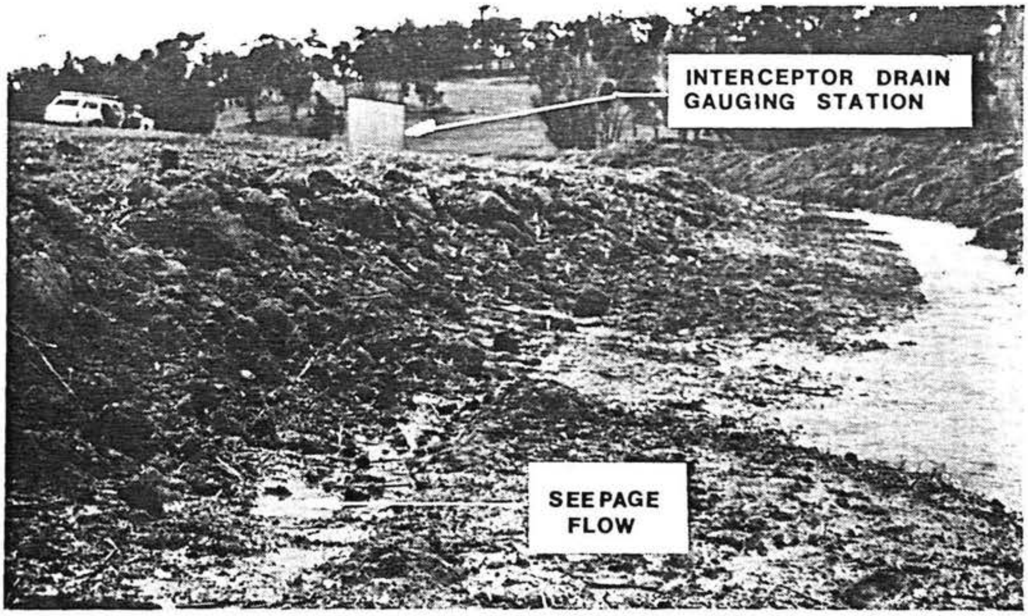


AERIAL VIEW OF INTERCEPTOR BANK LAYOUT

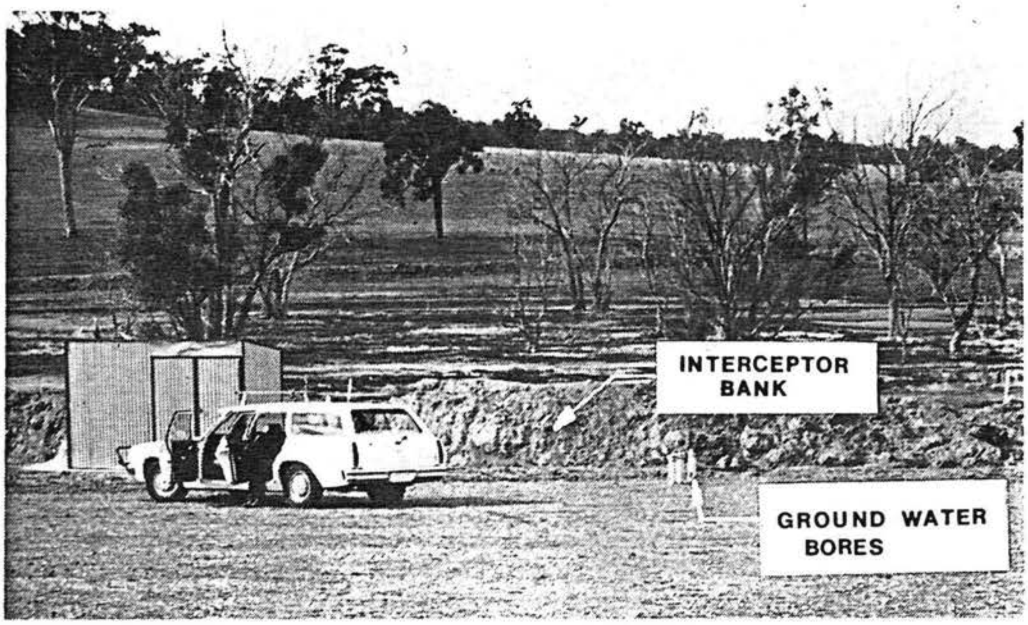


SEEPAGE FLOW BEING MEASURED THROUGH V—NOTCH

FIGURE 3a



VIEW OF MONITORED DRAIN



VIEW OF BORE TRANSECT

FIGURE 3b

BATALLING CREEK DAILY RAINFALLS FOR 1978

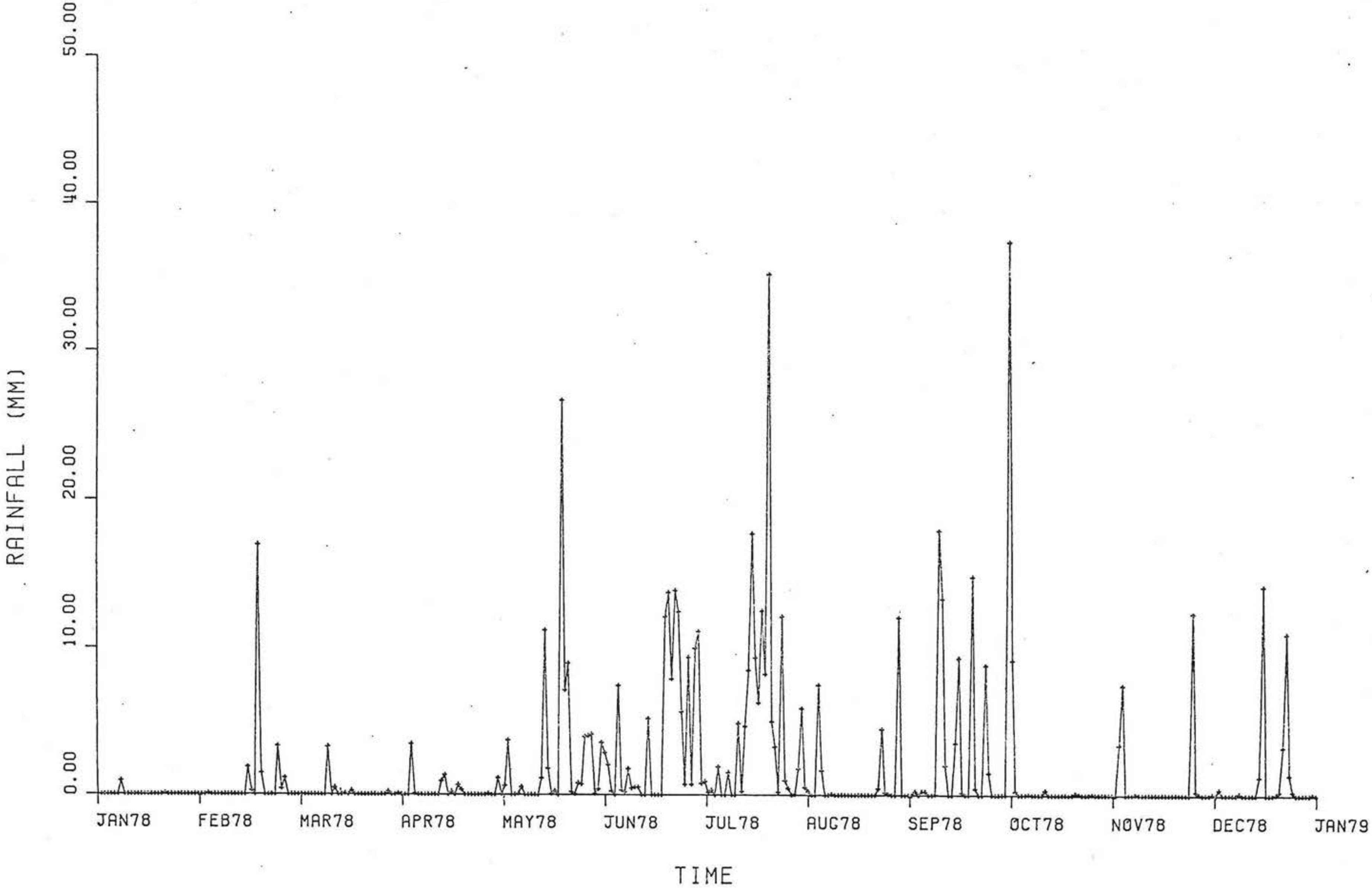


FIGURE 4

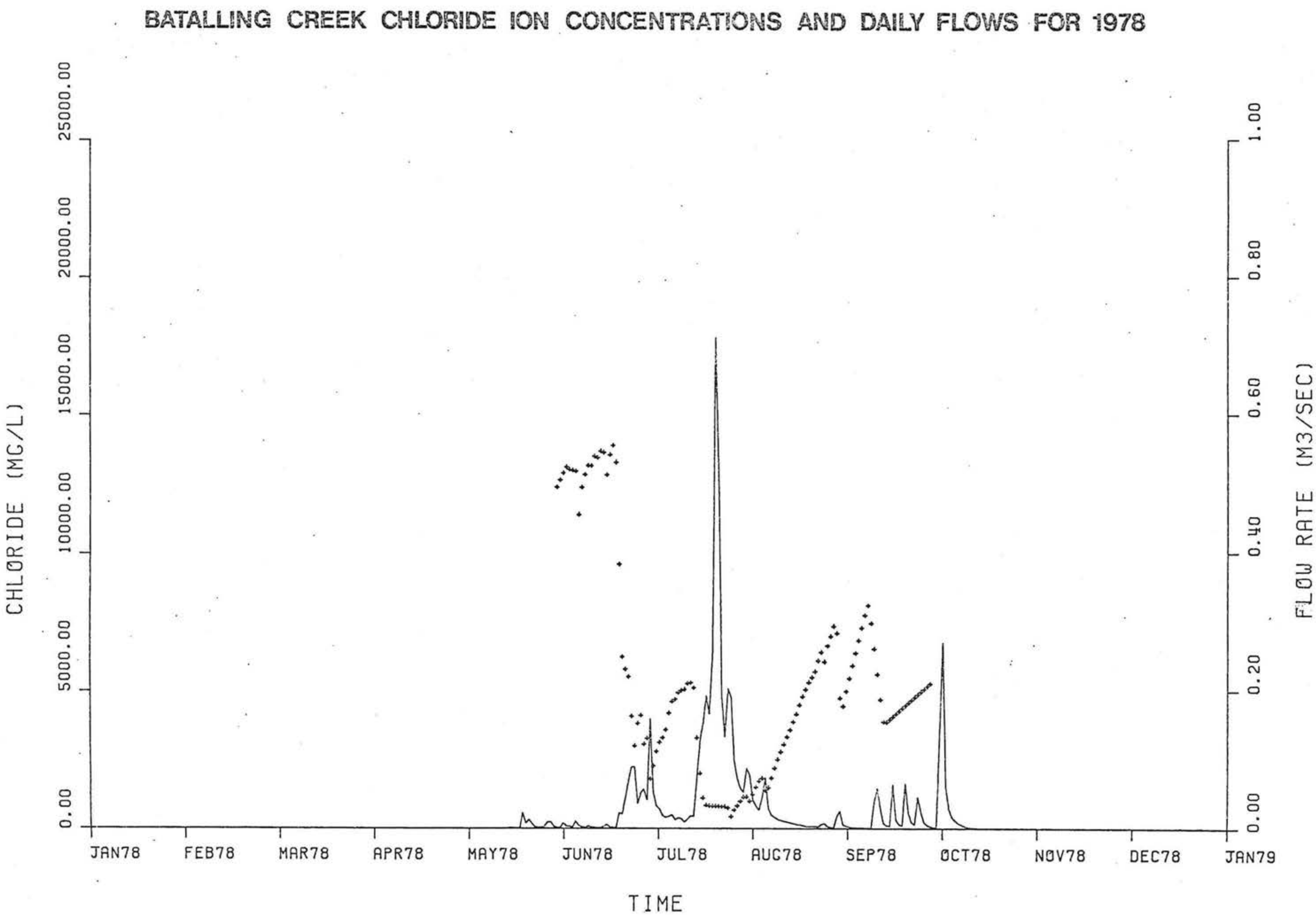

BATALLING CREEK CHLORIDE ION CONCENTRATIONS AND DAILY FLOWS FOR 1978
CHLORIDE (MG/L)
0.00
5000.00
10000.00
15000.00
20000.00
25000.00
FLOW RATE (M3/SEC)
0.00
0.20
0.40
0.60
0.80
1.00
JAN78
FEB78
MAR78
APR78
MAY78
JUN78
JUL78
AUG78
SEP78
OCT78
NOV78
DEC78
JAN79
TIME

FIGURE 5

INTERCEPTOR DRAIN CHLORIDE ION CONCENTRATIONS AND DAILY FLOWS FOR 1978

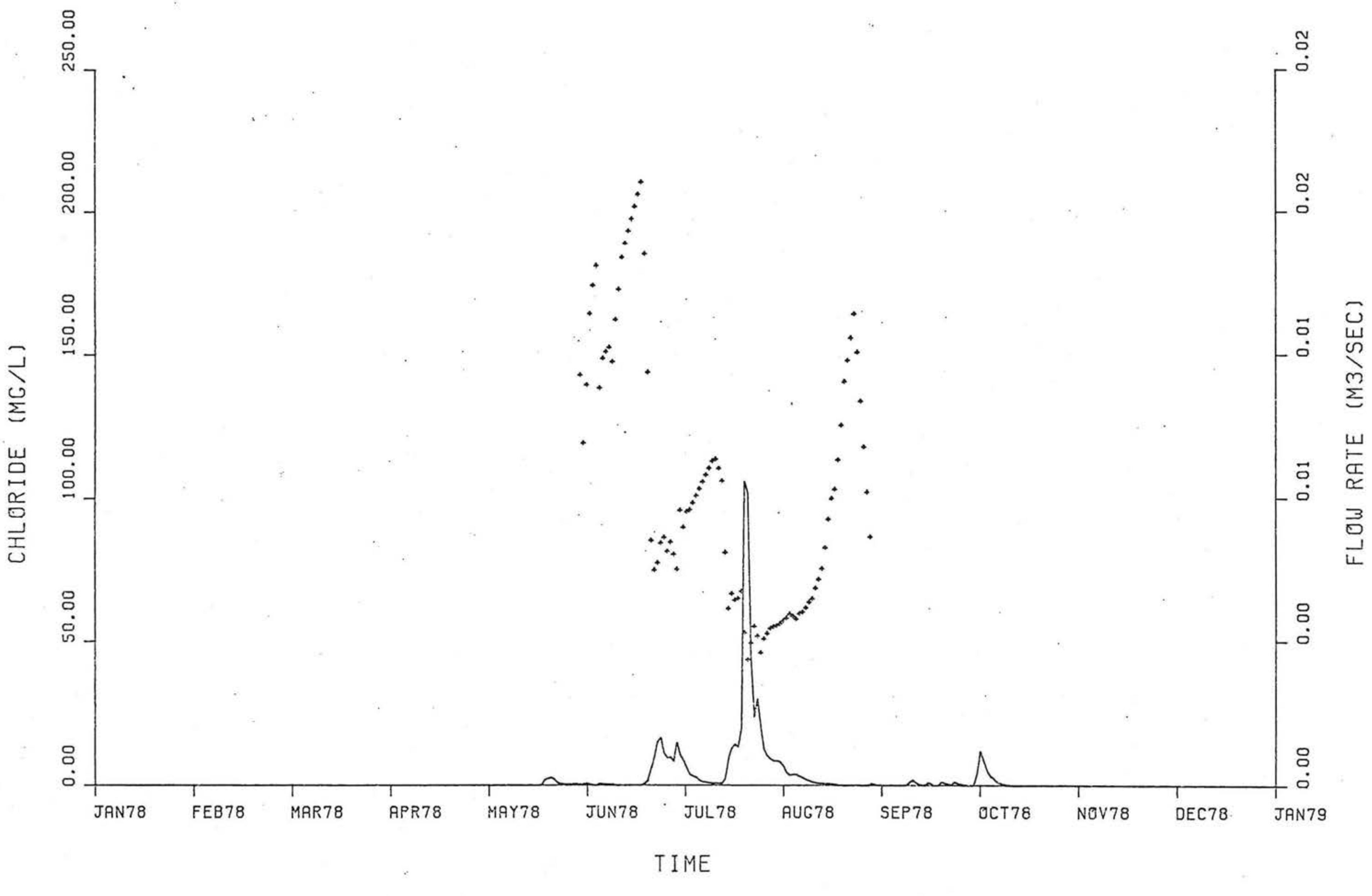


FIGURE 6

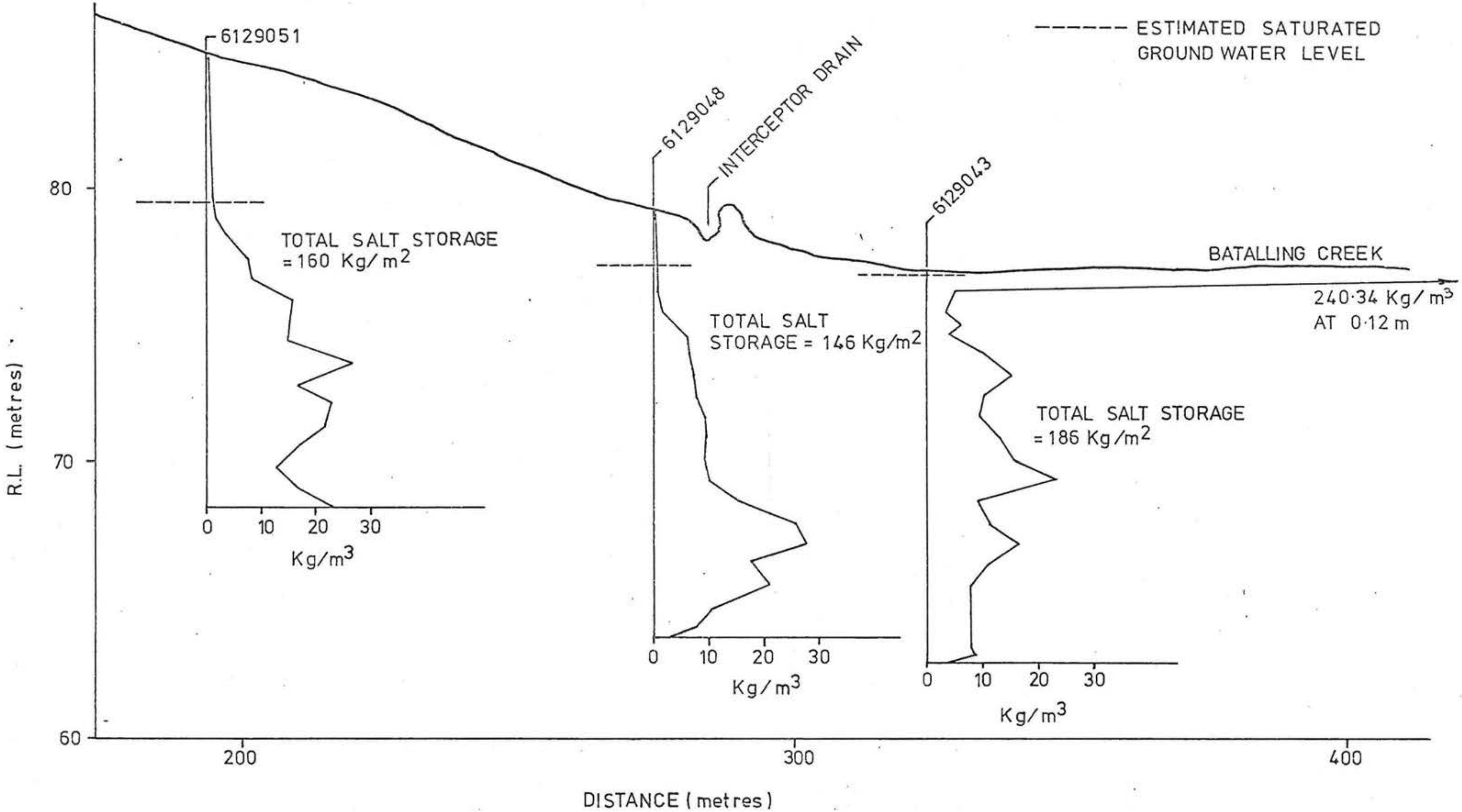
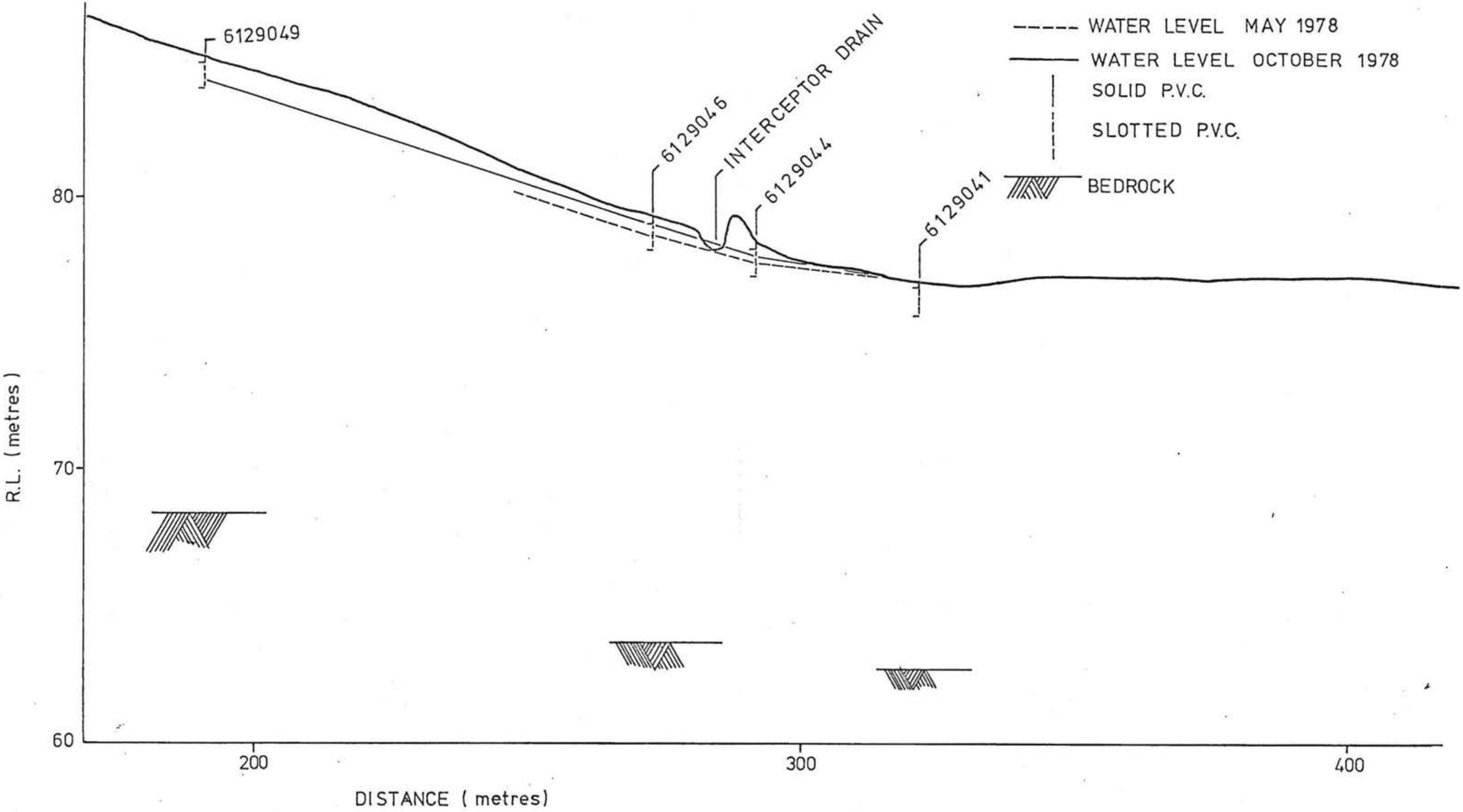


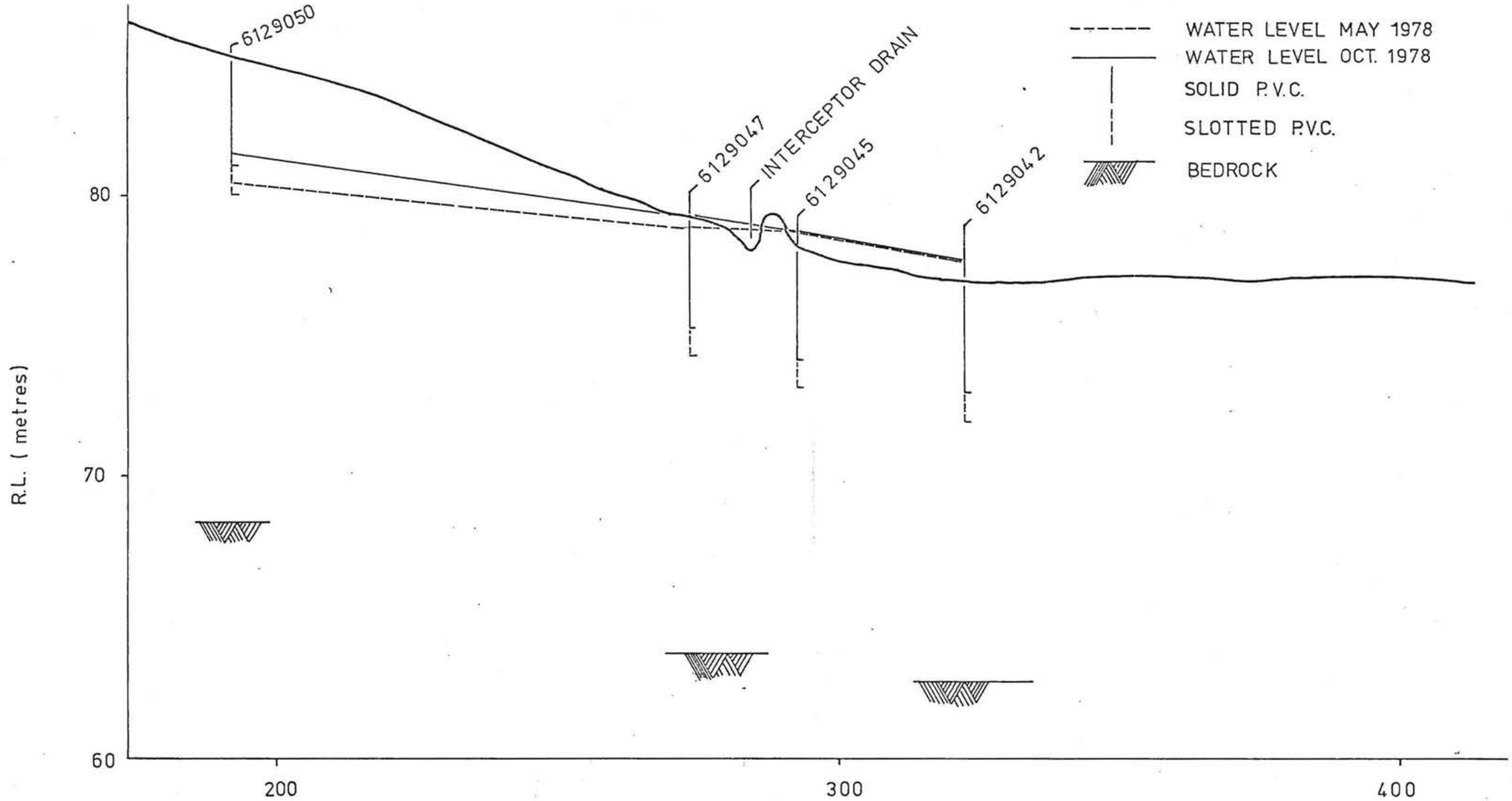
FIGURE 7

BATALLING CREEK
VARIATION OF SOIL SALT CONCENTRATION



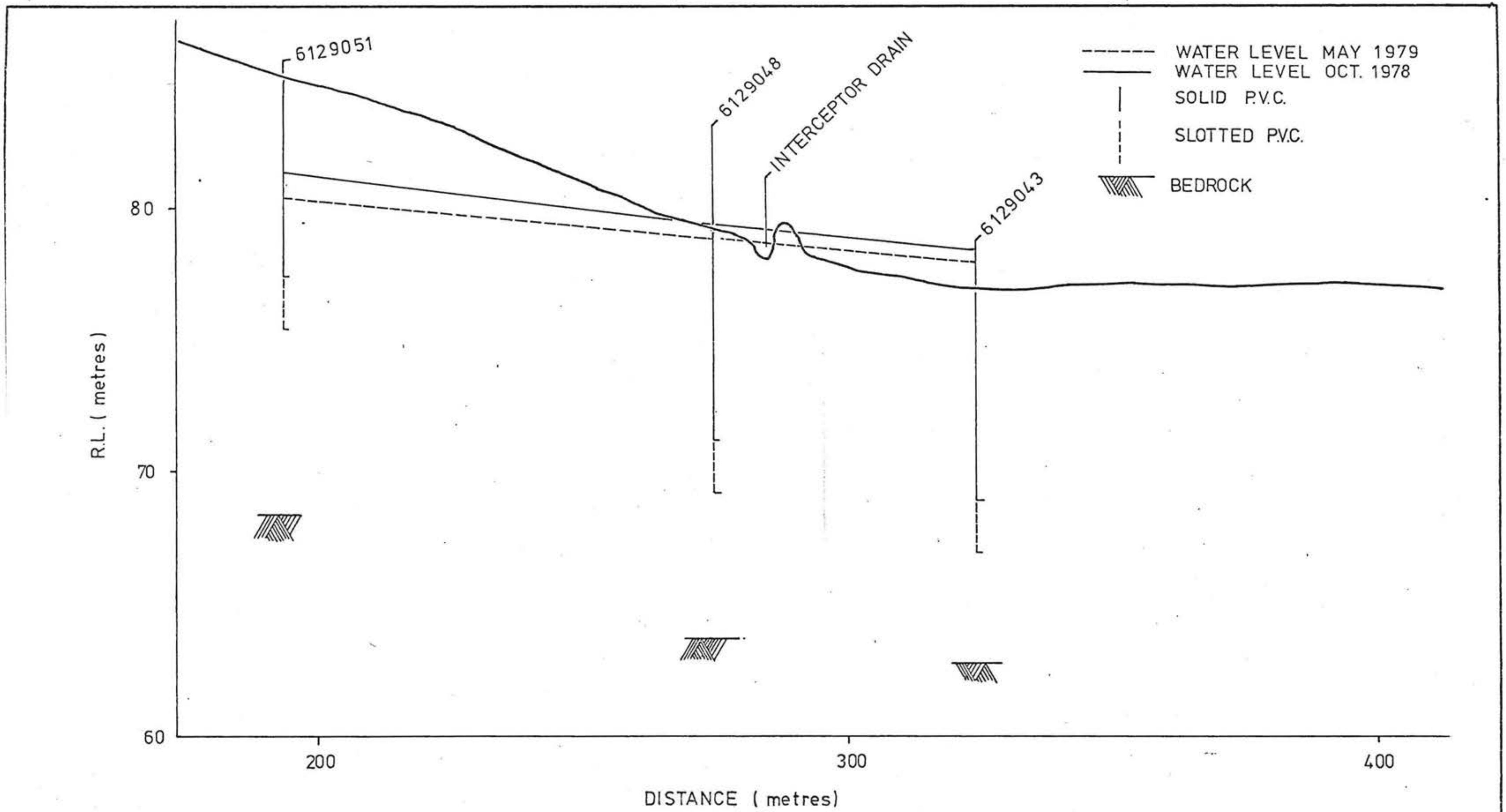
BATALLING CREEK
SHALLOW BORES - CROSS SECTION

FIGURE 8



BATALLING CREEK
INTERMEDIATE BORES - CROSS SECTION

FIGURE 9



BATALLING CREEK
DEEP BORES - CROSS SECTION

FIGURE 10

TABLE 1

DATA FOR ESTIMATING THE ANNUAL CHLORIDE AND WATER FLUXES OF BATALLING CREEK CATCHMENT (1)

Year	Rainfall			Streamflow		Chloride Load	
	Depth mm	Volume 10^3m^3	Chloride Concentration mg/l (2)	Volume 10^3m^3	Chloride Concentration mg/l (3)	Input 10^3kg	Output 10^3kg
1978	584	9690	4.2	513	2290	40.7	1175

(1) Batalling Creek Catchment Area - 16.6 km^2

Length of side slopes contributing seepage to the streamline - 20 km

Percentage of Catchment Area Cleared - 53%

(2) Based on chloride ion measurements of rainfall analysed by C.S.I.R.O. in 1973.

(3) Flow weighted chloride ion concentration calculated from hourly integration of flow and chloride data. The chloride data was estimated from 202 water samples collected to September 1978.

TABLE 2

DATA FOR ESTIMATING THE ANNUAL SURFACE AND SUBSURFACE CHLORIDE AND WATER FLUXES THROUGH THE INTERCEPTOR DRAIN (1)

Year	Total Drain m^3	Sub Surface Seepage Flow (2) m^3	Chloride Concentration of Total Flow (3) mg/l	Total Chloride Discharge kg	Sub Surface Seepage Chloride Discharge kg
1978	6029	4818	98.6	594	475

(1) Total Drain Catchment - 10.09 ha
Total Drain Length - 200 m
Effective Drain Length - 136 m

(2) Estimated from Base flow separation of the hydrographs of specific rainfall events.

(3) The chloride ion concentration is based on hourly integration of flow and chloride data. The chloride data was based on 140 water samples collected up to September 1978.

TABLE 3

CHLORIDE BALANCES FOR BATALLING CREEK

CATCHMENT IN 1978

(a) Chloride Inputs and Outputs	Scaling Based On							
	Drain Area *Divided by* Catchment Area		Drain Area *Divided by* Cleared catchment Area		Drain Length *Divided by* Length of hillside seepage		Effective Drain Length / Length of hillside seepage	
	10^3kg	kg/ha	10^3kg	kg/ha	10^3kg	kg/ha	10^3kg	kg/ha
Total Input from Rainfall	40.7	24.5	40.7	24.5	40.7	24.5	40.7	24.5
Shallow Subsurface Output	78.2	47.1	41.4	25.0	47.5	28.6	69.7	42.0
Total Streamflow Output	1176	708	1176	708	1176	708	1176	708
Nett Output from Total Soil Storage	1135	684	1135	684	1135	684	1135	684
Estimated Discharge from Deep Ground-water storage	1057	637 (1202)	1094	659 (1243)	1088	655 (1236)	1065	642 (1211)

Note: Figures in brackets are estimates of the chloride discharge from the deep soil profile per unit of cleared area.

(b) Ratios of Inputs and Outputs	Scaling Based On			
	Drain Area *Divided by* Catchment Area	Drain Area *Divided by* Cleared catchment area	Drain Length *Divided by* Length of hillside seepage	Effective Drain Length / Length of hillside seepage
Total Output / Total Input	28.9	28.9	28.9	28.9
Shallow Subsurface Output / Nett Output from Soil Storage	0.069	0.036	0.042	0.061

TABLE 4

INPUTS AND OUTPUTS OF CHLORIDE AND WATER FROM THE MONITORED HILLSIDE DURING 1978

Item	WATER			CHLORIDE		
	$10^3 m^3$	mm	%of Rainfall	kg	As ratio of chloride in rainfall	As ratio of chloride in shallow sub-surface flow
Rainfall	58.9	584	100	247	1.00	0.52
Surface Runoff	1.21	12.0	2.1	119	0.48	0.25
Shallow Subsurface Seepage	4.82	47.8	8.2	475	1.92	1.00
Deep (1) Groundwater Seepage	1.02	10.11	1.7	9200	37.25	19.37

(1) The groundwater seepage is based on:

(a) hydraulic gradient - 2.4%

(b) average groundwater concentration - 9020 mg/l chloride

(c) depth of flow - 14.6 m

(d) hydraulic conductivity - 4 x 10^{-2} m/day

TABLE 5

SHALLOW AND DEEP SOIL SOLUTE DISCHARGE

RELATIVE TO SOIL SOLUTE STORAGE

	Soil Storage TSS	Soil Storage Chloride (1)		1978 Chloride Discharge from Soil Storage		Soil Storage (2) Half Life
	kg/m^2	kg/m^2	$10^3 kg$	kg/m^2	$10^3 kg$	Years
Shallow Subsurface Soils (to 1.2 metres depth)	.192 (3)	.115	12	.0045	.456	25
Deep Soils (below 1.2 metres depth)	164 (4)	98.4	9900	.091 (6) .123 (7)	9.20 12.4	1080 798
	75 (5)	45	4540	.091 (6) .123 (7)	9.4 12.4	490 366

(1) Chloride soil storages have been taken as 60% of Total Soluble Solute storage.

(2) Soil storage Half Life is the time for the current soil storage to reduce by 50%.

(3) Estimated from 17 samples taken in the shallow subsurface soils unaffected by deep groundwater leakage or evaporation.

(4) Soil Storage estimated from 3 cored holes at Batalling Creek.

(5) Based on expected average salt storage for a rainfall of 690 mm per annum.

(6) Deep groundwater discharge based on estimates of groundwater flux beneath the drain (from Table 4).

(7) Deep groundwater discharge estimated from the salts discharged from Batalling Creek catchment in excess of that which comes from rainfall and shallow subsurface seepage (Table 3).

TABLE 6

BATALLING CREEK ANNUAL FLOWS AND

CHLORIDE ION CONCENTRATIONS

Year	Annual Rainfall mm	Annual Flow 10^3m^3	Chloride Concentration: Flow Weighted Mean mg/l	Chloride Concentration: Arithmetic Mean mg/l	Chloride Concentration: No. of Samples Taken
1974	781	-	499	2060	37
1976	530	169	3660	8860	22
1977	541	241	3300	6290	17
1978	584	513	2290	6530	202

Note: The 1974 data is based on a salinity sampling programme before continuous streamflow measurement was undertaken in 1976.