NRA Thames 224

Sniffer

SCOTLAND & NORTHERN IRELAND FORUM
FOR ENVIRONMENTAL RESEARCH

NRA

MEASURES FOR PROTECTING UPLAND WATER QUALITY (FORESTRY)

Progress report for 1991/92

SR 3052

AUGUST 1992

NRA Project 230

R&D Ref 230/4/W

MEASURES FOR PROTECTING UPLAND WATER QUALITY (FORESTRY)

Progress report for 1991/92

SR 3052

AUGUST 1992

National Rivers Authority
Rivers House
Waterside Drive
Almondsbury
Bristol BS12 4UD

Tel: 0454 624400
Fax: 0454 624409

Dissemination Status
Internal: Limited release
External: Restricted

MEASURES FOR PROTECTING UPLAND WATER QUALITY (FORESTRY)

Progress report for 1991/92

Report No: SR 3052

August 1992

Authors: D W Swift and R L Norton

Contract Manager: R L Norton

Contract No: 4202/2408

Client's Reference No: 1.1.3a

SNIFFER Project Leader

The SNIFFER Project Leader is:
R Arnott - SOEnD

NRA Project Leader

The NRA's Project Leader for R&D Contract 230:
N Reynolds - Welsh Region

NRA Report No: 230/4/W

Any enquiries relating to this report should be referred to the author at the following address:

WRc plc, Henley Road, Medmenham, PO Box 16, Marlow, Buckinghamshire SL7 2HD. Telephone: Henley (0491) 571531

CONTENTS

CONTENTS continued

CONTENTS continued

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES continued

EXECUTIVE SUMMARY

The objectives of this study are to investigate the effectiveness of buffer strips for the protection of receiving waters from water quality deterioration following forestry practices, and to make recommendations and derive practical guidelines concerning optimum buffer strip width, for use by water and forestry staff.

This second progress report describes and summarises the findings from the second year of the study, but with emphasis on the period following aerial fertilization. A number of interim conclusions have been made.

Early in the year, a 90 percent attenuation of solids loads by the strip was indicated but this performance was not sustained. There is evidence that the performance of the buffer strip diminishes with time, possibly as a result of progressive flattening of vegetation by the flow of water. Additionally, the effectiveness of the strip appears to be related to runoff flow rate. As might be expected, those determinands present in an insoluble form tend to follow a similar pattern to suspended solids. Increases in concentration of phosphorus, potassium, calcium and chloride in the drainage waters were noted following fertilization.

KEY WORDS

Forestry, afforestation, ploughing, buffer, water quality, runoff, fertilization.

1. INTRODUCTION

Afforestation of upland areas of Britain has shown a progressive increase over the past 60 years and, despite the present ban on upland afforestation in England, this trend is likely to continue elsewhere for a considerable time to come. Upland soils are generally poorly drained and peaty and are considered to require ploughing and draining prior to planting. Studies (reviewed by Swift *et al* 1990) have demonstrated that such activities and others associated with afforestation such as fertilization can have a marked deleterious effect on water quality. As a result, interest has focused on the development of methods for protecting waterbodies from these adverse effects.

Early forestry practices frequently involved ploughing close to water courses and waterbodies prior to planting. This can have severe adverse effects on water quality and biota (Maitland *et al* 1990) and the "Forests and Water Guidelines" (Forestry Commission, 1990, revised 1991) recommend that furrows and ditches stop well short of water courses and waterbodies. The effectiveness of buffer strips between the planted zone and the waterbody/water course (in combination with good ploughing and land preparation techniques) to control sediment and solute transport is recognised in the guidelines, but no firm data are available on which to base recommendations for buffer strip width. Results from studies at Balquhidder, as yet unpublished, have shown that where 20 m buffer strips were used, large amounts of sediment still entered the waterbodies. However, some of the strips were not completely intact and although sediment entered the burn this appeared to have little effect on the biota. Nevertheless, the minimum effective width of a buffer strip is likely to be in excess of 20 m, especially where gradients are steep. Evidence for minimum effective buffer strip width should reduce conflict between the forestry industry and regulatory authorities responsible for water quality protection.

This study, which is jointly funded by the National Rivers Authority and the Scotland and Northern Ireland Forum for Environmental Research, is intended to address this issue and is being undertaken in full collaboration with the Forestry Commission.

2. PROJECT DESCRIPTION

The objectives of the study are:

- to investigate, by field experiment, the effectiveness of buffer strips of differing widths in the protection of receiving waters from water quality deterioration resulting from ground preparation for afforestation, with particular reference to the transport of suspended solids, colour, nutrients, and the metals iron, aluminium and manganese; and

- to make recommendations and derive practical guidelines concerning optimum buffer strip width for use by water and forestry industry staff.

In general terms, the procedures adopted, which are described in detail in the first interim report (Swift *et al* 1991), were to monitor water quality and sedimentation at intervals of 10 m from the end of the cross-drains down the buffer strips (Figure 2.1). Two sites were selected which have become known as 'east' (E) and 'west' (W). These sites differ in that the soils at the 'east' site are predominantly peaty, while those at the 'west' site are of a more mineral nature, with a thin peaty topsoil.

The interim conclusions for the first year of the study were that "the water qualities of the runoff at the the two test sites at Dalmellington, Ayrshire, are consistent with the different soil types" and that "visual examination of the buffer strips revealed that, at the 'west' site, a considerable quantity of material has settled out, especially at the margins of water flow. However, an initial examination of the water quality data suggested that improvements in water quality during its passage through the buffer strip were small. More intensive sampling, particularly for suspended solids (SS), is indicated".

This interim report summarises the results for the second year of the study, with particular emphasis on the period following aerial fertilization.

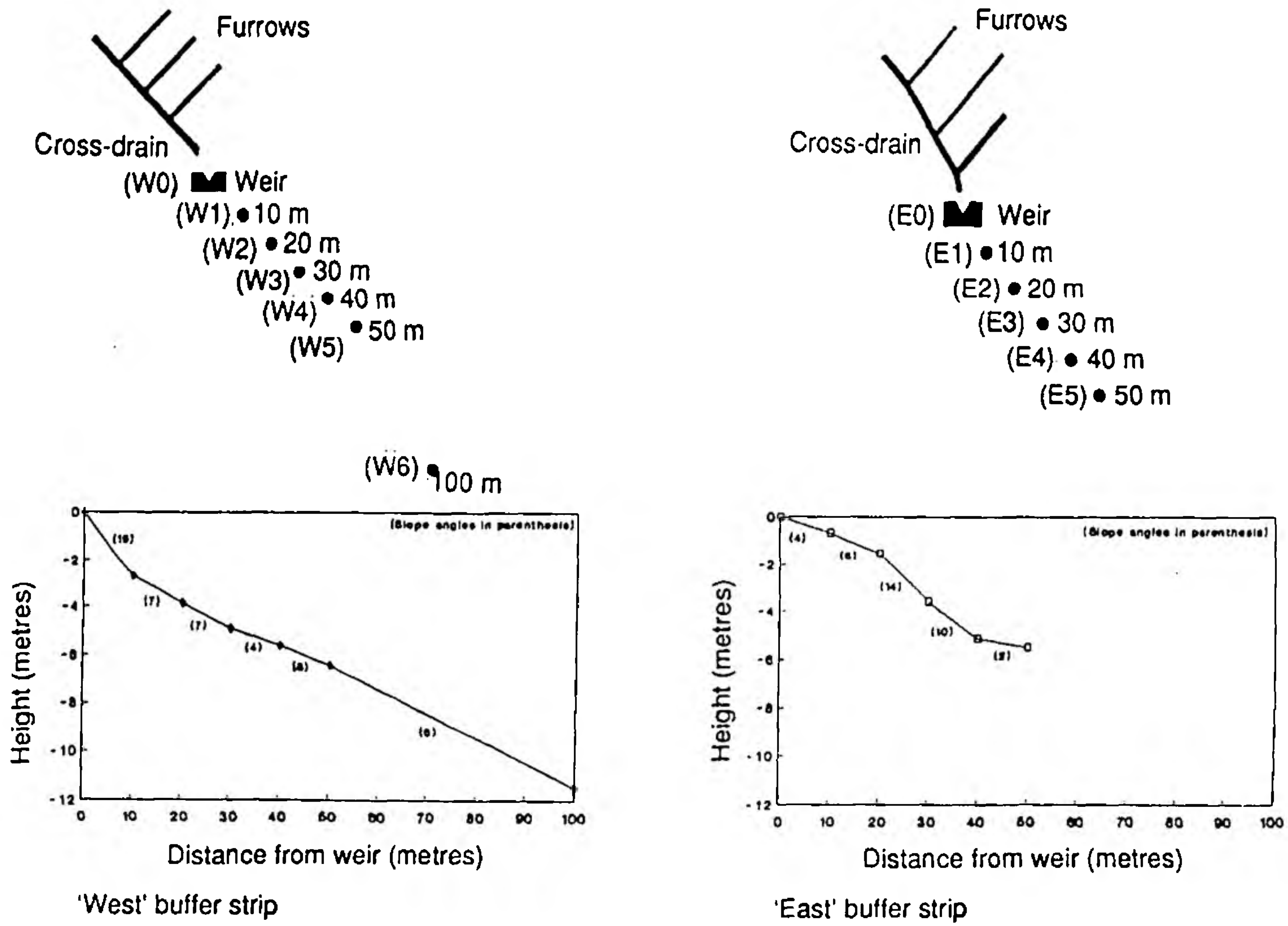


Figure 2.1 Schematic diagram of buffer strips and their slopes

3. WORK PROGRAMME FOR 1991/2

This was based on the recommendations made in the first interim report and was as follows:

1. Monitoring should continue, with an emphasis on the 'west' site. Here, it is recommended that Partech continuous suspended solids monitors be installed at 'W0' and 'W6' so that runoff events can be examined in closer detail. In particular, this means that any periods of especially high suspended solids concentration (e.g. on the rising limb of a hydrograph) should be observed, and it should be possible to quantify the solids load entering and leaving the buffer strip.

2. The quantity of accumulated sediment should be measured and this compared with an estimate of the quantity of solids that have entered the buffer strip - based on the general relationship between suspended solids concentration and flow for the 'west' site.

3. Graduated rods or a similar device should be inserted at various points in the accumulated sediment to monitor any continuing accumulation.

4. A more detailed analysis of the data should be carried out, in particular to examine the importance of initial water quality and the influence of flow rate.

5. The frequency with which soluble reactive phosphorus is determined should be increased in order to assess runoff characteristics following aerial fertilizer application planned for July/August.

6. A more detailed survey of soils should be carried out at the 'west' site.

During the course of this year's work, it became apparent that further work items should be added to the programme, some of which would not be completed until the third and final year of the study. These were as follows:

1. Take sediment samples from the edge and centre of the flow path for particle size analysis and attempt to relate particle size distribution with distance down the buffer strip.

2. Keep a record of the "flattening-down" of vegetation since this appears to have had a marked effect on sedimentation during the second year.

3. Make a visual assessment of bed load (pebbles and rocks) which has been transported down the strip.

4. With the permission of Clyde RPB, undertake a dye tracing test to establish the velocity of flow at the 'west' site under conditions of high flow.

4. EXPERIMENTAL PROCEDURES

4.1 Manual sampling

Spot samples were taken manually from the same points as in the previous year (Figure 2.1): the gauging weirs at the top of the buffer strips (E0 and W0) and at 10 m intervals down the strip to 50 m (E1 and W1 to E5 and W5 respectively), with an additional sample at 100 m on the 'west' site (W6).

Samples were analysed by the methods described in last year's report.

4.2 Continuous measurement of suspended solids

In assessing last year's results it was apparent that the manual sampling programme had missed many rainfall events, including perhaps the most severe ones. It was also recognised that taking samples along the buffer strips at approximately the same time - even taking them in sequence with the direction of flow - has certain shortcomings. There is a flow rate dependent time taken for the water to travel down the buffer strip; the water itself will be attenuated with varying amounts of transverse and longitudinal mixing, and the solids load may be attenuated even more.

In an attempt to overcome some of the shortcomings of the manual sampling programme it was decided to install continuous suspended solids monitors at the top (W0) and bottom (W6) of the 'west' buffer strip. Partech IR40C sensors have been used in conjunction with Newlog interfaces and loggers so that the data can be downloaded using a Psion Organiser in the same way as the rainfall and flow data.

Before installation the sensors were calibrated (measuring current (mA) against suspended solids concentration) with a range of samples taken from W0 during a major runoff event, the suspended solids concentrations ranging to nearly 1000 mg l^{-1}. Since installation, the performance of the sensors has been monitored by comparing the suspended solids concentration of manual samples (taken at W0 and W6) with the corresponding record from the sensors. Unfortunately, early results showed a very large discrepancy from the initial calibration. Consequently, the sensors were re-calibrated against a range of standard kaolinite suspensions, and have been checked regularly since then against a standard of 400 mg l^{-1}. Also, to enable a closer comparison between manual samples and the Partech results, the frequency of recording by the sensors was increased to every 5 minutes and the times of taking the W0 and W6 samples noted with greater accuracy.

Following these changes, on 12 February 1992 seven samples were taken from both W0 and W6 throughout a hydrograph, including suspended solids concentrations up to 500 mg l^{-1}, and all 14 results agreed almost exactly with the kaolinite calibration. However, for further samples taken on 24 April, the results do not agree so well.

The results from the various calibrations and check samples are presented in Figure 4.1. The results with kaolinite are shown by a filled square, the initial calibration by a diamond, and check samples by the appropriate identifying letter used in the results (Appendix A and B). It is suggested that much of the disparity may be due to the gritty nature of some of the solids, making them settle very rapidly. For example, the deviation of the initial calibration at high concentrations may have been due to inadequate suspension of the larger solids (which is not a problem with *in situ* readings); and the suspended solids analyses may be susceptible to rapidly-settling solids being missed in sub-sampling.

Based on the kaolinite calibrations, the response of the Partech sensors has been described by the following equation:

$$mA = 0.1577 + 0.001912SS + 0.0000045SS^2$$

where mA = current (mA), and
SS = suspended solids concentration (mg l^{-1}).

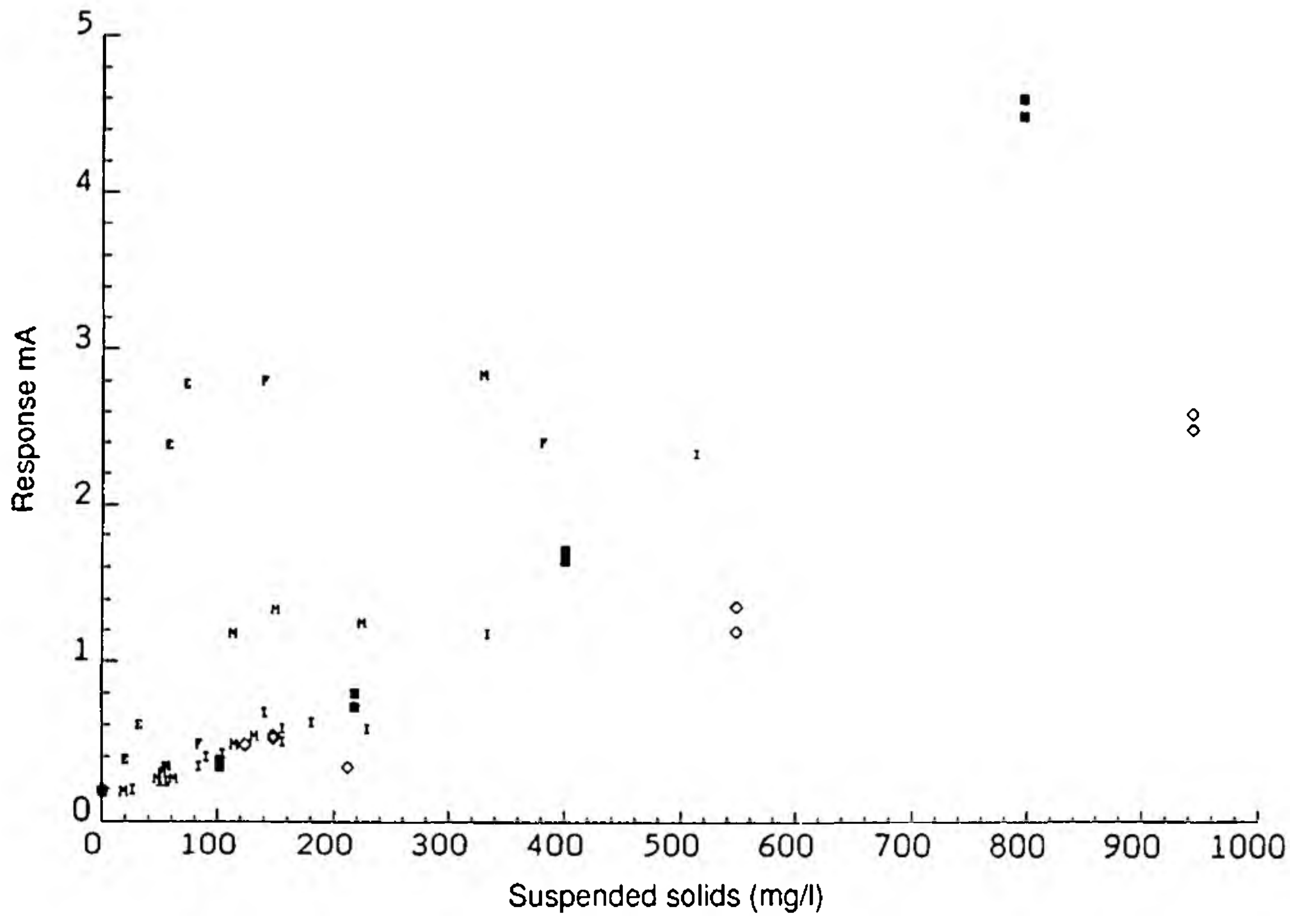


Figure 4.1 Calibration of Partech IR40C suspended solids sensors

Exact correspondence between real samples and kaolinite is not to be expected because the transmission of a light beam is dependent on the size of intervening particles as well as their concentration: for a given concentration (in terms of total mass of solids per volume) smaller particles will interrupt the light beam more than larger ones. The kaolinite used for the standard suspensions is thought to be significantly finer than many of the suspended solids in the actual samples. However, kaolinite has the advantage that standards can be reproduced with confidence.

Although there remains some doubt about the consistency of the sensors' performance (the regular checks against 400 mg l^{-1} kaolinite suggest there may be some drift at the end of battery life), on each occasion the two instruments have given almost identical responses (and batteries are always changed on the same day). This gives reasonable confidence in a comparison of the results from the top and bottom of the buffer strip, even if there is some doubt as to the absolute values. As a further check on the reliability of the Partech readings, the instruments were interchanged on 16 December: for both W0 and W6 the records continue without any apparent shift.

4.3 Fertilization

Aerial application of "PK" fertilizer (67% rock phosphate, 33% potassium chloride) was undertaken by contractors for the Forestry Commission on 21 and 22 August 1991. The weather was dry, with no flow at all at the 'west' site and only a trickle at the 'east'. Application had to be stopped early on the first day due to the possibility of strong winds causing excessive scatter of the fertilizer, after doing all of the 'east' site and part of the 'west'. There was some light rain overnight before completing application to the 'west' site on the following day.

The method of application - scattering the fertilizer in a circular pattern beneath the helicopter - results in a striped distribution on the ground, with highest application rates immediately below the helicopter and decreasing either side. This is reflected in the results from the collection bags ('traps'), with an opening of 1 m^2, set out across the whole area being fertilised (though none actually in the catchments of interest) by the Forestry Commission to check the application rate. They indicated an average application rate of 679 kg ha^{-1} (giving 113 kg K and 56 kg P), with a standard deviation of 263 kg ha^{-1}, and a range from 218 kg ha^{-1} to 1273 kg ha^{-1}. It is likely that the same sort of variation occurred in the two experimental catchments. A number of trays were placed in the relevant catchment areas and these indicate the application rate was much lower; but these are probably underestimates because of the trays being shallow and some fertilizer bouncing out.

Observation of the application showed that care was taken to spread the fertilizer to only the ploughed areas. This was confirmed by having a tray at each site about 10 m down from the weir and into the buffer strip: at the 'east' site no fertilizer was found in this tray, and only a small amount in the one on the 'west'.

4.4 Sediment studies

Last year's report commented on the apparent anomaly that, despite only modest observed improvements in the quality of water as it flowed through the buffer strip, at the 'west' site there was clearly a significant deposition (typically 25 to 50 mm) of sediment along the channel taken by the water. To keep a closer watch on the accumulation of sediment within the buffer strip, short plastic rulers have been inserted at approximately the 10 m sampling points, and these are read when opportunity arises.

During the dry summer period the opportunity was taken to estimate the quantity of sediment. This was done by measuring the depth of sediment along a transect, perpendicular to the line of flow, at each 10 m interval corresponding to a sampling point; it was hoped that this would give a reasonably representative picture. However it became apparent that there is a lot of variation in the build up of sediment - partly due to the irregularities of the original soil surface, and partly to the sediment itself forming mounds and channels. A further difficulty is that the interface between the underlying soil and overlying sediment is not always clear.

During the summer dry period sediment samples were taken at 10 m intervals down the buffer strip, from the centre and side of the watercourse. A sample was also taken from the side-stream of sediment corresponding to the route taken by high flows leaving the main channel at 35 m on the 'west' site. These samples were analysed for particle size distribution using the sedimentation rate test.

5. RESULTS AND OBSERVATIONS - 'WEST' SITE

5.1 Catchment re-vegetation

Re-vegetation of the ploughed areas of the catchment has been variable - ranging from very little where the soil is substantially peaty to perhaps 20% on the brown earths (mainly in the higher parts of the catchment). It is estimated that overall about 5 to 10% re-vegetation has taken place.

5.2 Vegetation of the buffer strip

5.2.1 1990-1991

In autumn of 1990, there was a period of at least a month between ploughing of the catchments and cutting of the cross-drains, during which time there was substantial rainfall and the furrows collected a large amount of water. Hence, when the cross-drains were cut, especially as it was raining quite heavily at the time, they were immediately filled with a large quantity of water. This initial deluge completely flattened the vegetation (mainly grass and juncus) along the line taken by the drainage water through the buffer zone. The vegetation remained flattened throughout the winter of 1990/91, during all the sampling events reported previously in the 1991 interim report.

5.2.2 1991-1992

Re-growth began in the late spring of 1991, and by June/July it was clear that the vegetation along the line taken by the drainage water was of a much darker green and possibly denser and taller than the surrounding vegetation. This is attributed to the extra nutrients carried down in the drainage water, and perhaps to some irrigation value. There was no large rainfall event, such as to produce a high runoff, between mid-April and October. During this time and the early part of the following autumn, throughout the length of the buffer strip the drainage water flowed between the stems of the vegetation.

Over the next three months, successive large rainfall events resulted in the vegetation being flattened by the runoff, progressively extending further down the buffer strip (to 10 m by the end of October, 30 m by mid-November, about 45 m by early January 1992, and reaching a maximum of 60-70 m by March). The vegetation was flattened to 30 m for quite a long time; during this period when high flows occurred, a proportion of the runoff left the main channel at this point; once the vegetation had flattened, further high flows spilled over at 35 m, as had been the case during the previous winter. By the end of March 1992, the appearance of the buffer strip resembled that of the first winter, in particular with the water flowing over the flattened vegetation, rather than through it, even at low flows.

5.3 <u>Water quality at the weir</u>

Data from samples taken since the last report but preceding aerial fertilization of the catchments in August 1991 are listed in Appendix A. No high flows were sampled in this time, so initial water quality was good and the data are consistent with those reported previously, so no further comment is made here. To aid comparison with the post-fertilization data, Table 5.1 summarises the pre-fertilization water quality at the weir.

The post-fertilization results are presented in Appendix B, and discussed here. In the Appendix and in the figures, each sampling event is identified by a letter.

5.3.1 Suspended solids

It was noted in last year's report that, as expected, suspended solids concentration generally increased with flow rate, and that this general relationship appeared to remain substantially the same throughout the winter, although noting that the highest concentrations occurred soon after ploughing.

Table 5.1 Summary of pre-fertilization water quality at the 'west' weir

For many determinands, the concentration appeared to vary with flow rate; for these, typical low-flow and high-flow values are as follows:

	Low flows	High flows (>10 l s^{-1})
Suspended solids	<10 mg l^{-1}	400 mg l^{-1}
Chloride	10 mg l^{-1}	5 mg l^{-1}
Total phosphorus	0.04 mg l^{-1}	0.3 mg l^{-1}
Nitrate	0.05 mg l^{-1}	0.5 mg l^{-1}
pH	5.7	5.1
Alkalinity	10 mg l^{-1}	5 mg l^{-1}
Calcium	6 mg l^{-1}	5 mg l^{-1}
Potassium	0.3 mg l^{-1}	0.7 mg l^{-1}
Aluminium	0.3 mg l^{-1}	10 mg l^{-1}
Iron	0.5 mg l^{-1}	5 mg l^{-1}

Typical values for determinands which did not appear to be related to flow are as follows:

Colour	5 AU/m,
Sulphate	5-10 mg l^{-1}
Soluble reactive P	<0.003 mg l^{-1}
Ammonia	0.05-0.25 mg l^{-1}
Manganese	0.1 mg l^{-1}

The results for this year from manual samples, plotted in Figure 5.1, show a similar pattern. The suspended solids concentration is, of course, influenced by factors other than flow, such as rising or falling stage, rainfall intensity, and the availability of erodable material within the catchment. It is not surprising, therefore, that there is substantial variation in the relationship, but interesting that the relationship is generally more consistent on any given day. The few samples at the highest flows have relatively low suspended solids concentrations, which may be due to dilution, but doubts have already been expressed about these results in the context of calibration of the Partech sensors. The preponderance of the data indicate that from virtually nil suspended solids at low flows (<2 l s^{-1}) the concentration rises to around 300 mg l^{-1} or higher by 5 to 10 l s^{-1}. This is very similar to that found last year.

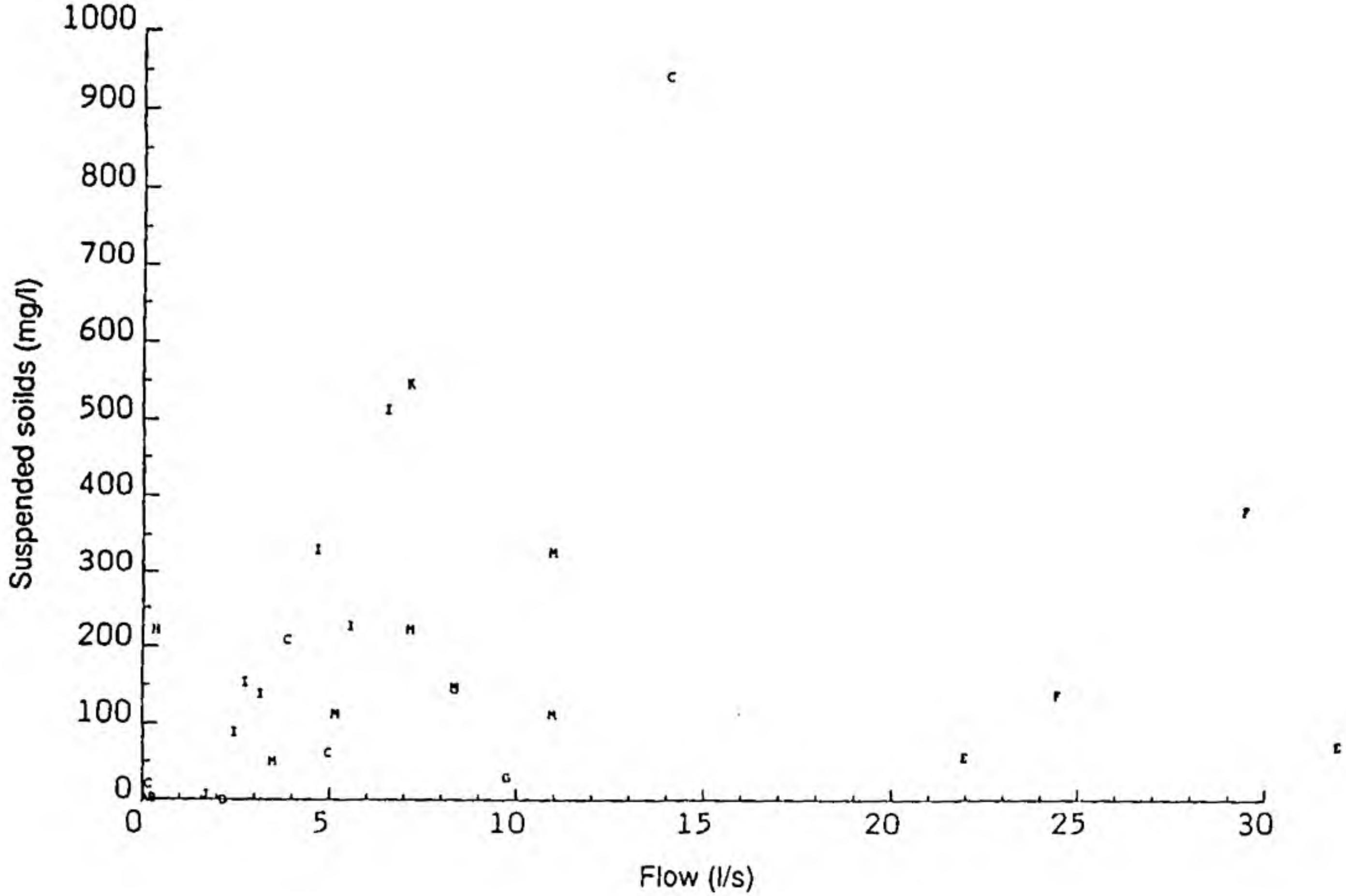


Figure 5.1 West site: relationship between suspended solids and flow

5.3.2 Colour

Colour has been comparable with that found last year, most values being between 3 and 10 AU/m with little relationship to flow. Of particular interest is that there is some evidence of colour increasing throughout the winter (see Figure 5.2), particularly high values occurring in April 1992.

5.3.3 Phosphorus

Last year the maximum total phosphorus (TP) concentrations never reached 1 mg l^{-1} and were usually much less than this. By comparison, in the first major (sampled) rainfall event after fertilization total phosphorus was nearly 5 mg l^{-1}. (Bearing in mind that here 100% of the drained catchment was fertilized, this is in line with the total phosphorus concentration of 1 mg l^{-1} found elsewhere (Swift, 1987) shortly after applying fertilizer to about 30% of a catchment.) Total phosphorus concentrations declined subsequently, but were close to 1 mg l^{-1} during high flows on 31 March. The results for total phosphorus are shown in Figure 5.3. It is apparent that, superimposed on the gradual decline of phosphorus concentrations, total phosphorus is also affected by flow, as found for last year's data.

The results indicate that over a wide range of concentrations, the soluble reactive phosphorus (SRP) concentration is often as much as 30% of the total phosphorus and usually between 0.03 mg l^{-1} and 0.1 mg l^{-1} even in the spring of 1992. This is much higher than before fertilization when soluble reactive phosphorus was usually below the detection limit of 0.003 mg l^{-1}.

5.3.4 Potassium and calcium

Shortly after fertilization, the concentrations of these elements were at least 10 times higher than before, both exceeding 50 mg l^{-1}. During the following months there was a steady decrease, illustrated in Figure 5.4 for potassium, such that by April 1992 the concentrations were around 5 mg l^{-1} and 1.5 mg l^{-1} respectively for potassium and calcium - similar to those found last year.

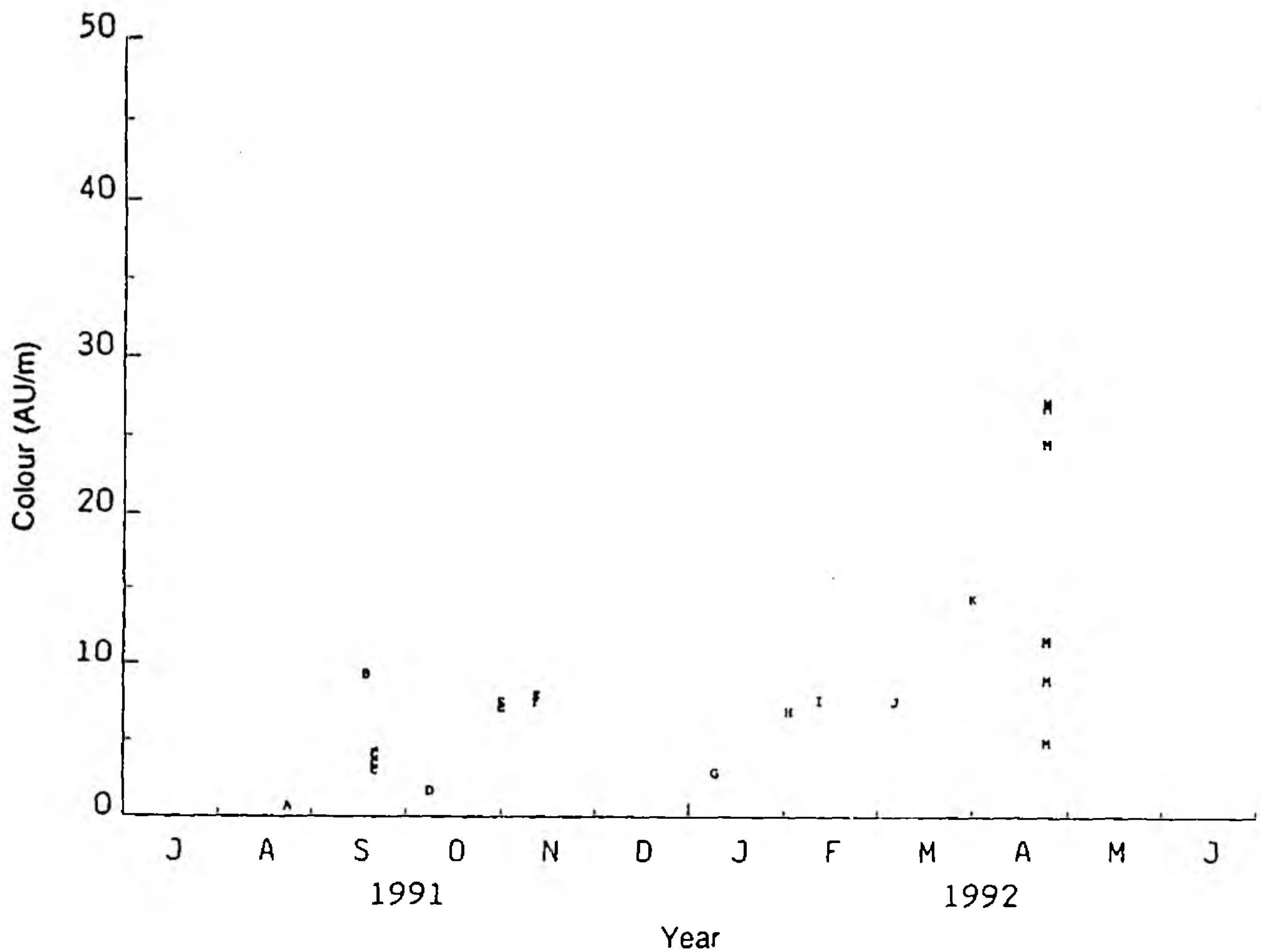


Figure 5.2 West site: relationship between colour and time

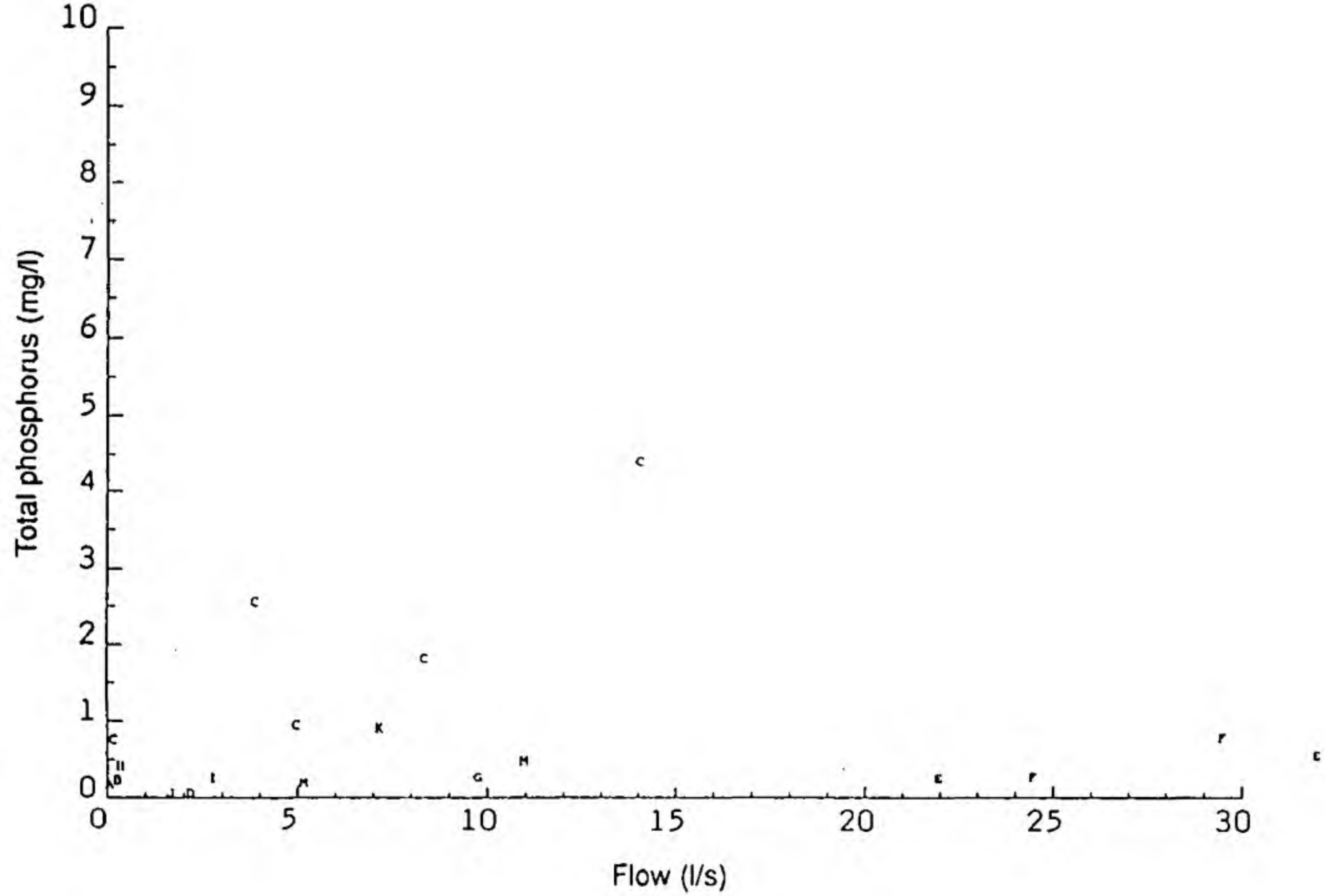


Figure 5.3 West site: relationship between total phosphorus and flow

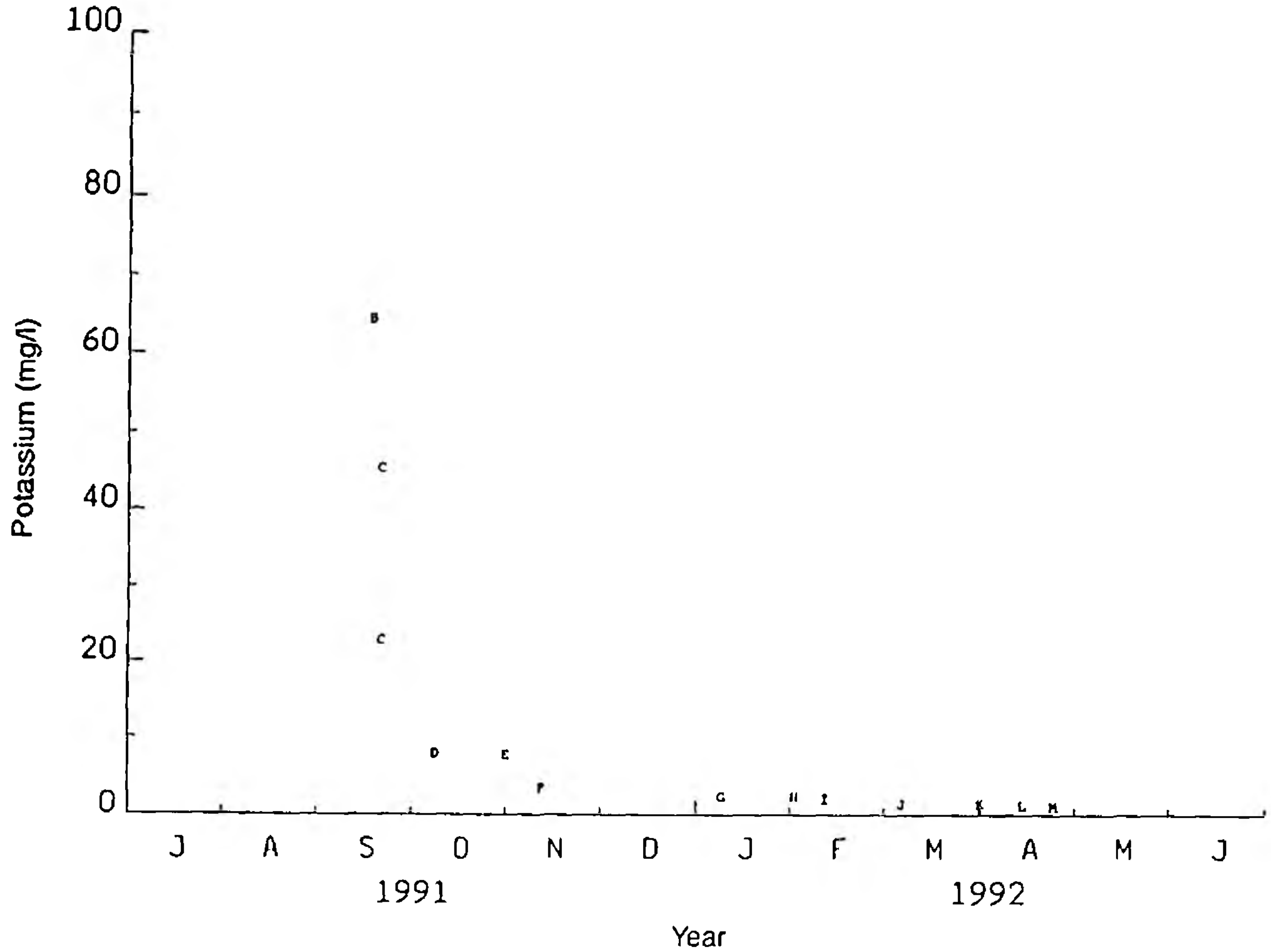


Figure 5.4 West site: relationship between potassium and time

5.3.5 Chloride

Samples were analysed for chloride during a major rainfall event about two months after applying fertilizer. The concentrations were greater than 30 mg l^{-1} - at least three times those seen before fertilization - no doubt reflecting the addition of chloride with the potassium. Further analyses in spring 1992 were consistent with a progressive decrease in the chloride concentration, comparable with that found for potassium and calcium and, by comparison with those results, it seems likely that the chloride concentration had been even higher soon after fertilization.

This change in chloride concentration over time contrasts with the results from last year which demonstrated primarily a flow-related variation - about 10 mg l^{-1} at low flows, falling to 5 mg l^{-1} at high flows.

5.3.6 Nitrogen

Samples from the event on 31 October 1991 were analysed for ammonia and nitrate and, at approximately 1 mg l^{-1} and 3 mg l^{-1} respectively, found to be about 2 to 3 times higher than before fertilization. There is no ready explanation for this; the Forestry Commission do not think that contamination of the fertilizer with urea is particularly likely. Subsequent analyses for nitrate showed a progressive decrease to 1.3 mg l^{-1} on 31 March 1992 and then 0.3 mg l^{-1} on 24 April 1992 which is comparable with the previous year's values.

5.3.7 Alkalinity and pH

Alkalinity and pH were similar to values before fertilization at about 3 mg l^{-1} and pH 5 respectively.

5.3.8 Sulphate

Sulphate was examined on only two occasions, giving concentrations of 13 mg l^{-1} and 6 mg l^{-1} which are similar to those found before fertilization.

5.3.9 Aluminium and iron

In general, aluminium and iron concentrations rose from 0.5 mg l^{-1} at low flows to about 2 mg l^{-1} at flows above 5 l s^{-1}, though with some values as high as 5 mg l^{-1} and 7.5 mg l^{-1} respectively. These levels are similar to those occurring before fertilization. The higher values tended to be in the first samples after fertilization, including one sample for which the concentrations of aluminium and iron were 21 mg l^{-1} but which also had particularly high suspended solids.

5.3.10 Manganese

Most manganese concentrations were within the range 0.5 to 1.5 mg l^{-1}, perhaps with a tendency for the higher concentrations to be at higher flows, which is comparable to before fertilization.

5.4 <u>Effect of the buffer strip</u>

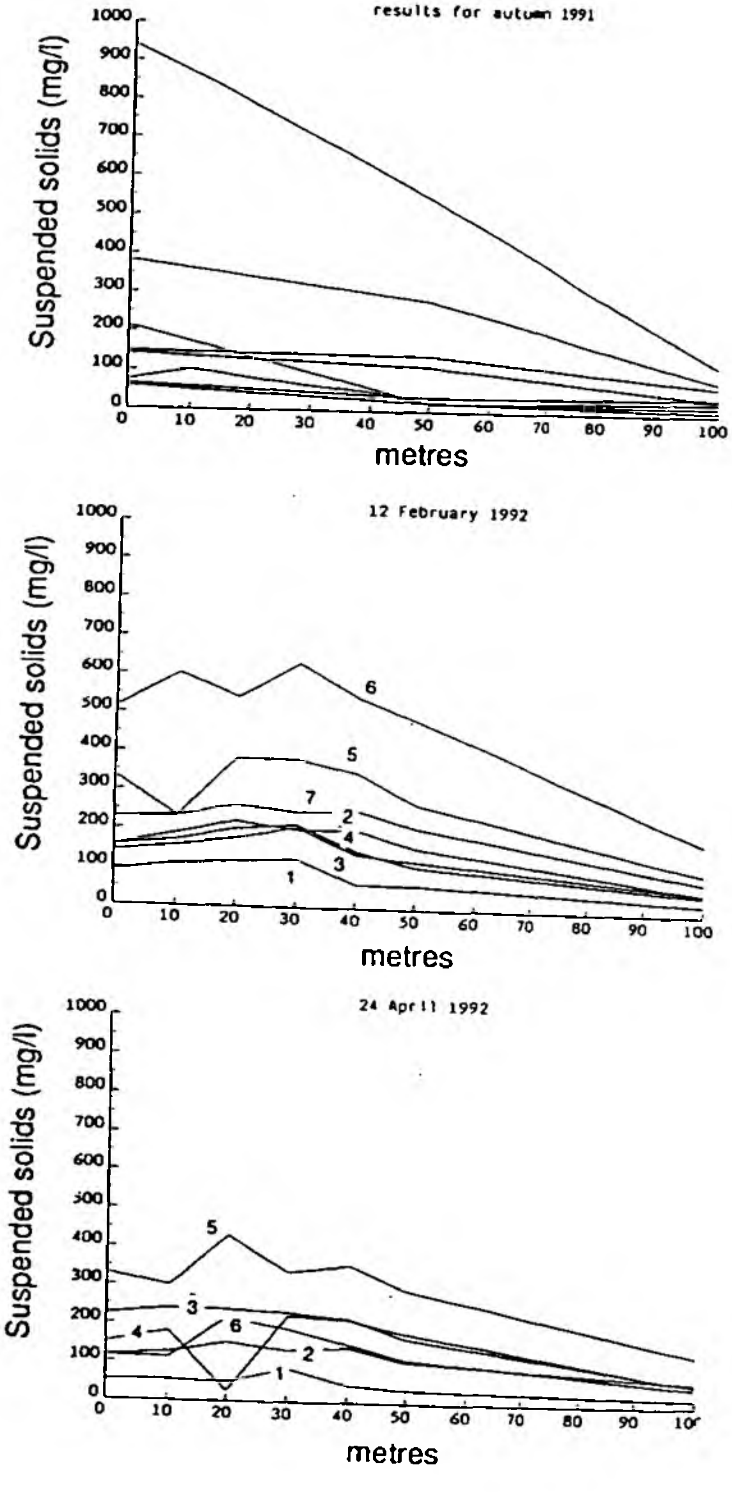
5.4.1 Suspended solids

Manual samples

The overall pattern of results is broadly similar to that seen last year, with a modest decline in suspended solids between W0 and W5, and a more substantial reduction by W6. However, examination of the data for different times throughout the winter period indicates some changes in the performance of the buffer strip. The suspended solids concentrations from manual samples taken at the sampling points down the buffer strip are illustrated by Figure 5.5 which shows the data for autumn 1991, 12 February 1992 and 24 April 1992 respectively.

Figure 5.5 shows that, at least on some occasions during the autumn, there was a substantial reduction of suspended solids within the first 50 m as well as beyond that. Unfortunately, due to the absence of a perceived effect in the first 50 m last year, it had been decided to take fewer intermediate samples, so it is not possible to say whether the improvement in water quality occurred uniformly throughout the strip or from some intermediate point. The results for 12 February show that the suspended solids concentration decreased fairly consistently after about 30 m, and on 24 April after 40 m. A typical reduction of suspended solids on these latter occasions would appear to be about 50%.

The five sets of samples taken on 21 September 1991, following a prolonged dry period, clearly illustrate some of the difficulties of interpreting the data, especially based on manual samples. There was no flow before the onset of rain, and when the first sample was taken from W0 there was still no flow emerging at W6. Fifteen minutes later the flow at W0 had reached about 4 $l\ s^{-1}$ but there was only a small flow at W6. At this time the suspended solids concentration at W0 was 212 $mg\ l^{-1}$ and only 10 $mg\ l^{-1}$ at W6, but it would be misleading to conclude that this represents a 95% reduction in the solids load as clearly there is a substantial delay in the water passing over the weir and reaching W6. A further 15 minutes later, the suspended solids at W0 had reached 943 $mg\ l^{-1}$ and 124 $mg\ l^{-1}$ at W6, but it is not possible to determine how much of this reduction is due to retention of solids in the buffer strip and how much to the retention time of the water. Conversely, in the declining phase of the hydrograph, the data indicate a solids reduction of 50% or less, but this could be pessimistic if the difference in time between sampling at W0 and W6 was substantially different from the time taken for water to travel from W0 to W6.



Numbers indicate sampling sequence

Figure 5.5 West site: attenuation of suspended solids

Continuous monitoring

The data from 21 September emphasise the value of continuous monitoring, which has been achieved using the Partech suspended solids sensors. The results for October 1991 to April 1992 are shown in Figures 5.6 to 5.12, in which the suspended solids concentration is based on the kaolinite calibration of the Partech sensors as described in Section 4.2. As mentioned there, even if the calibration is biased so that the actual suspended solids concentration was different to that presented in the figures, it is thought that the two sensors respond sufficiently similarly for a comparison between the two to be valid. Figures 5.6 to 5.12 include the corresponding flow rate at the 'east' site as an indication of the relative magnitude of the flows at the 'west' site in the absence of an actual 'west' flow record.

Inspection of these figures reveals two important features that affect the performance of the buffer strip: The first is time through the winter season - attributed to the state of the vegetation, and the second is flow rate. Data for individual events referred to in the following paragraphs are shown in Figures 5.13 and 5.14. It should be noted that these figures do not represent solids load (flow rates are not available at the 'west' site), and neither can it be assumed that the instantaneous flow rates at W0 and W6 are the same.

Time/vegetation effects

The effect of time is seen most clearly by the major rainfall events - when flow rate at the 'east' site was 20 l s^{-1} or more.

The first major event was on 31 October (Figure 5.13) when the vegetation in the buffer strip was substantially intact. Although there is no flow record for this day, the rainfall event was sampled and manual measurement of the flow at the 'west' site showed a maximum of about 30 l s^{-1}. The Partech sensor record indicates that suspended solids concentration at the weir peaked at over 700 mg l^{-1} and remained above 500 mg l^{-1} for four hours; it was two hours before the suspended solids at W6 rose substantially, reaching 200 mg l^{-1}.

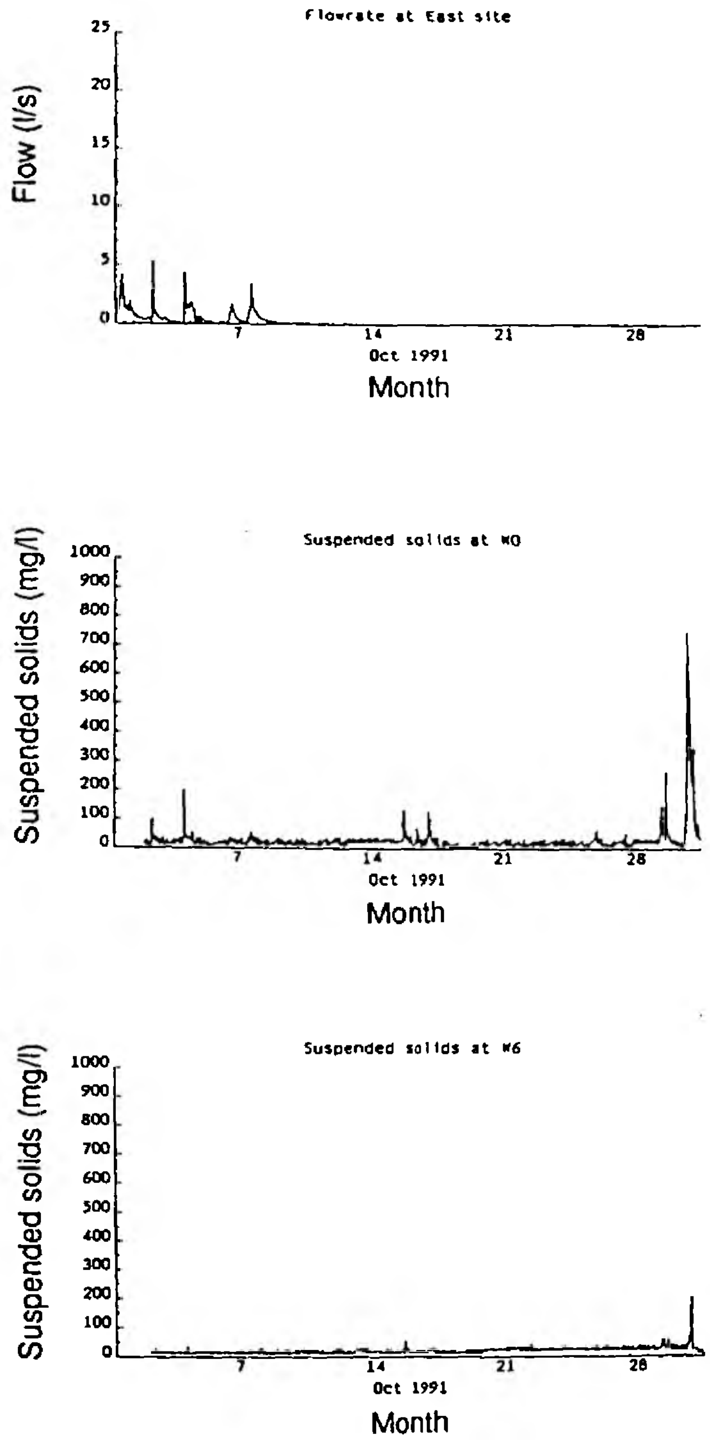


Figure 5.6 Records of flow rate at the 'east' weir and suspended solids at W0 and W6, October 1991

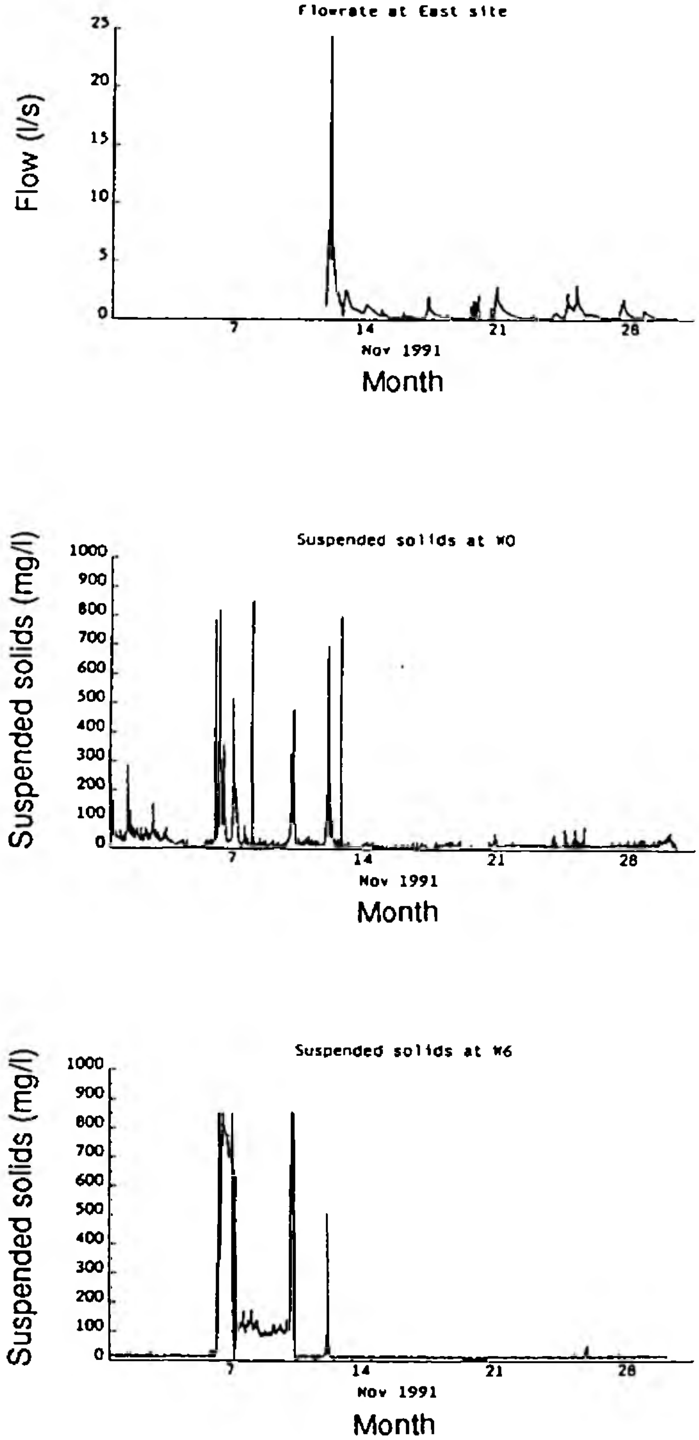


Figure 5.7 **Records of flow rate at the 'east' weir and suspended solids at W0 and W6, November 1991**

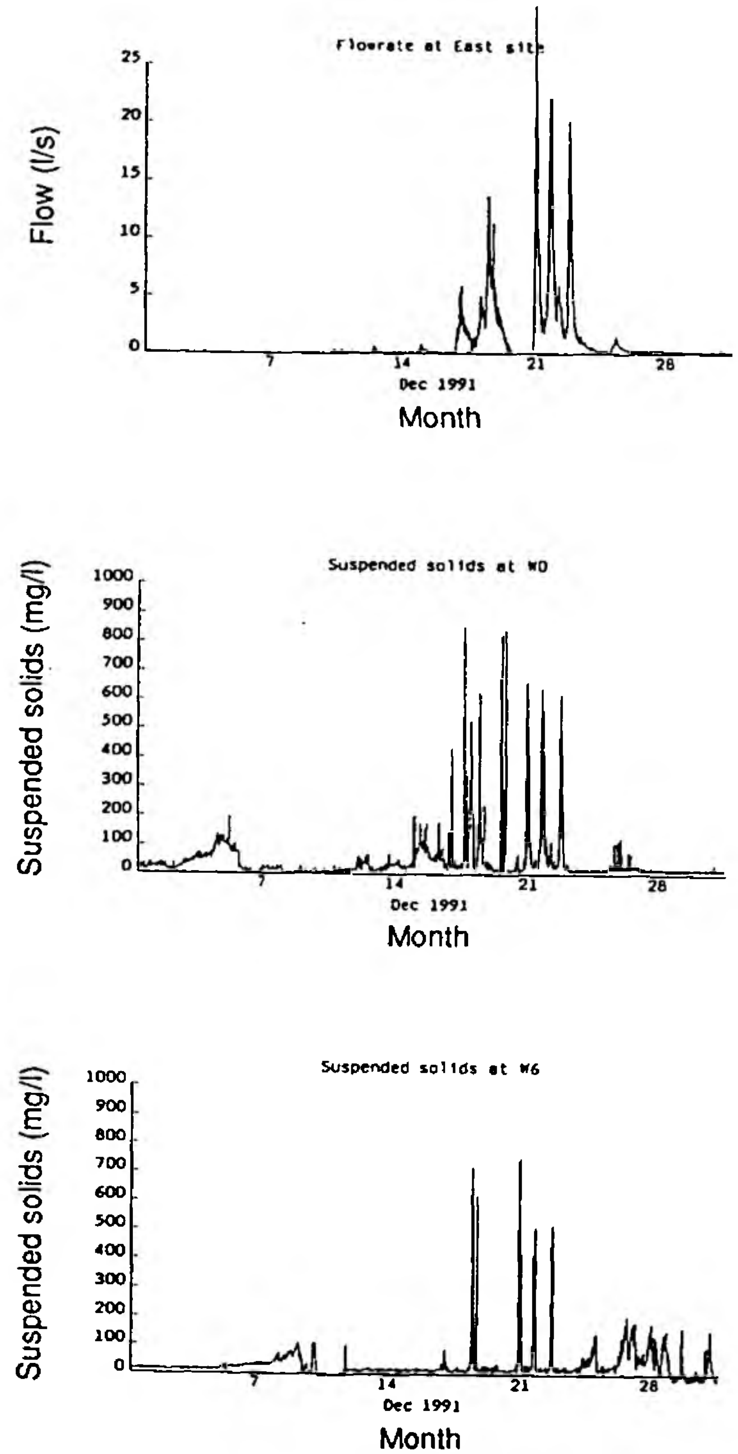
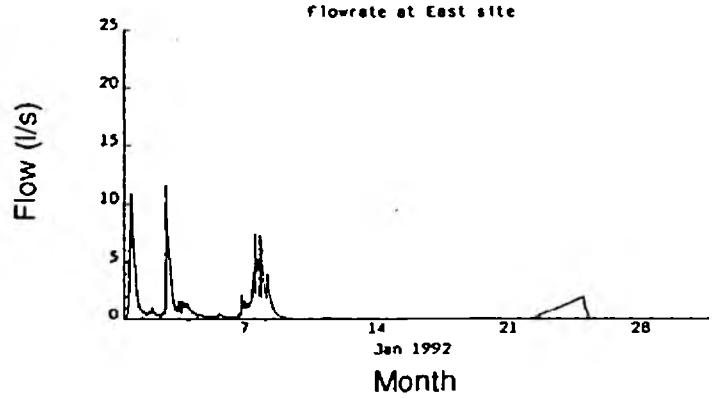
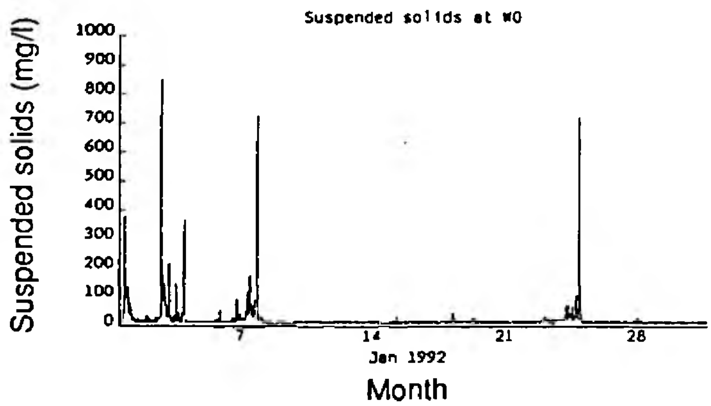


Figure 5.8 **Records of flow rate at the 'east' weir and suspended solids at W0 and W6, December 1991**





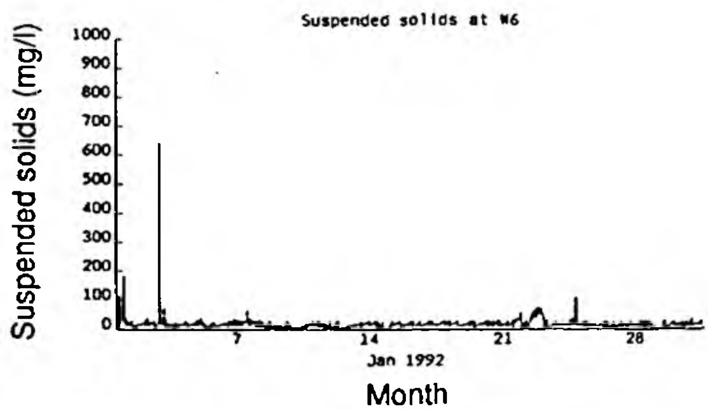


Figure 5.9 Records of flow rate at the 'east' weir and suspended solids at W0 and W6, January 1992

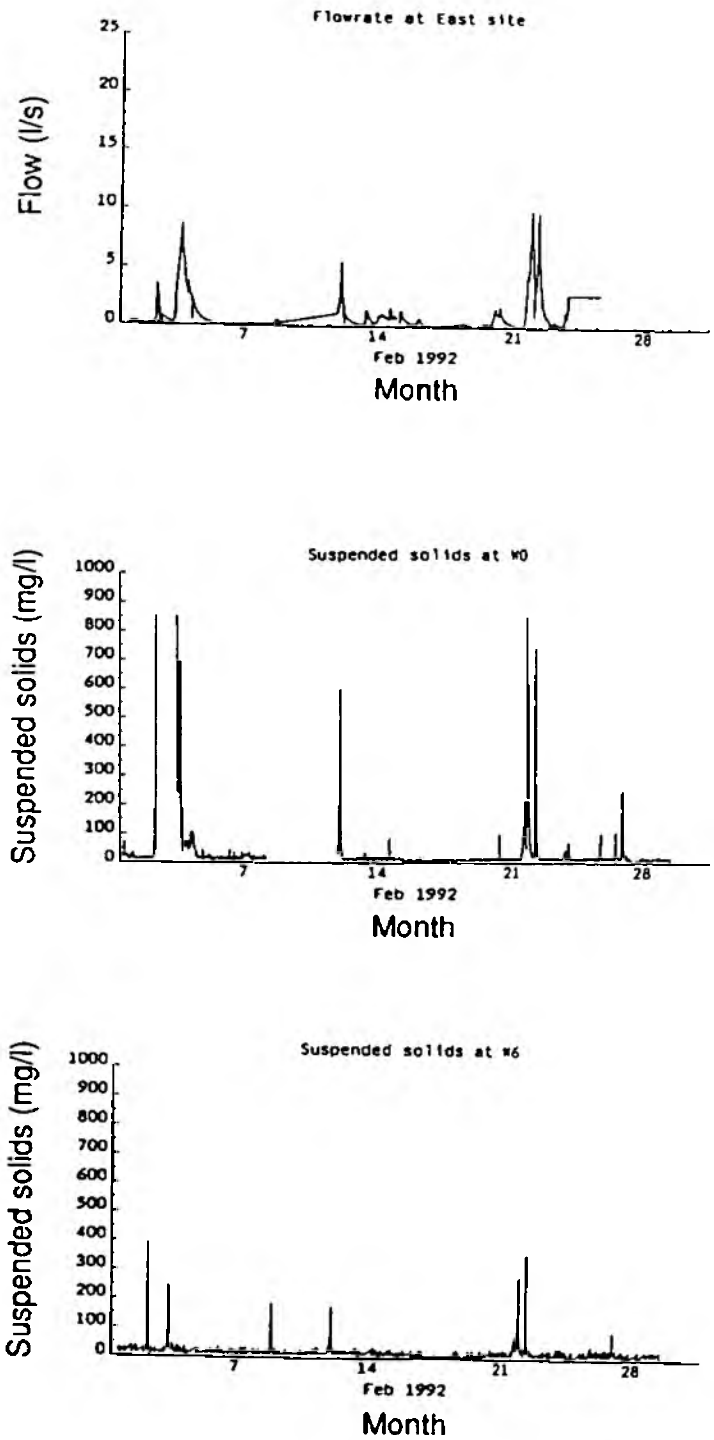


Figure 5.10 **Records of flow rate at the 'east' weir and suspended solids at W0 and W6, February 1992**

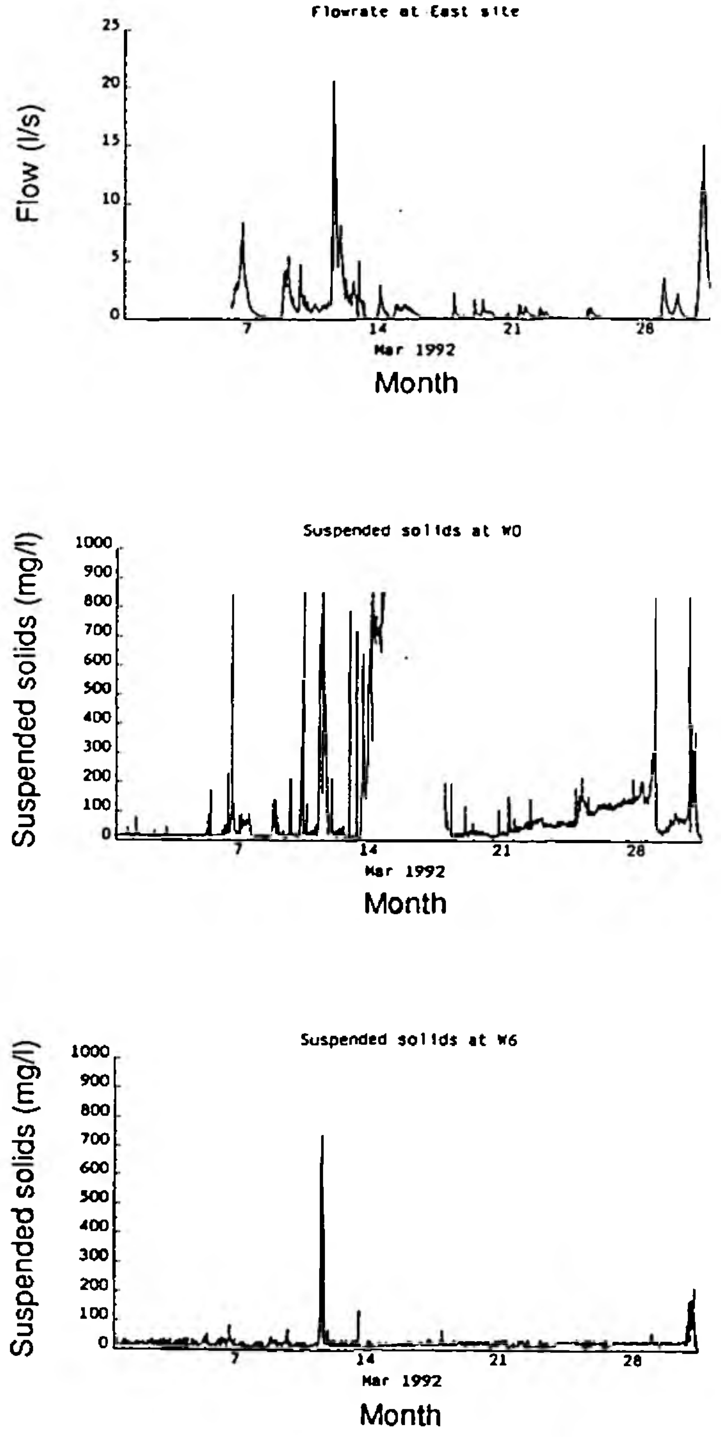


Figure 5.11 Records of flow rate at the 'east' weir and suspended solids at W0 and W6, March 1992

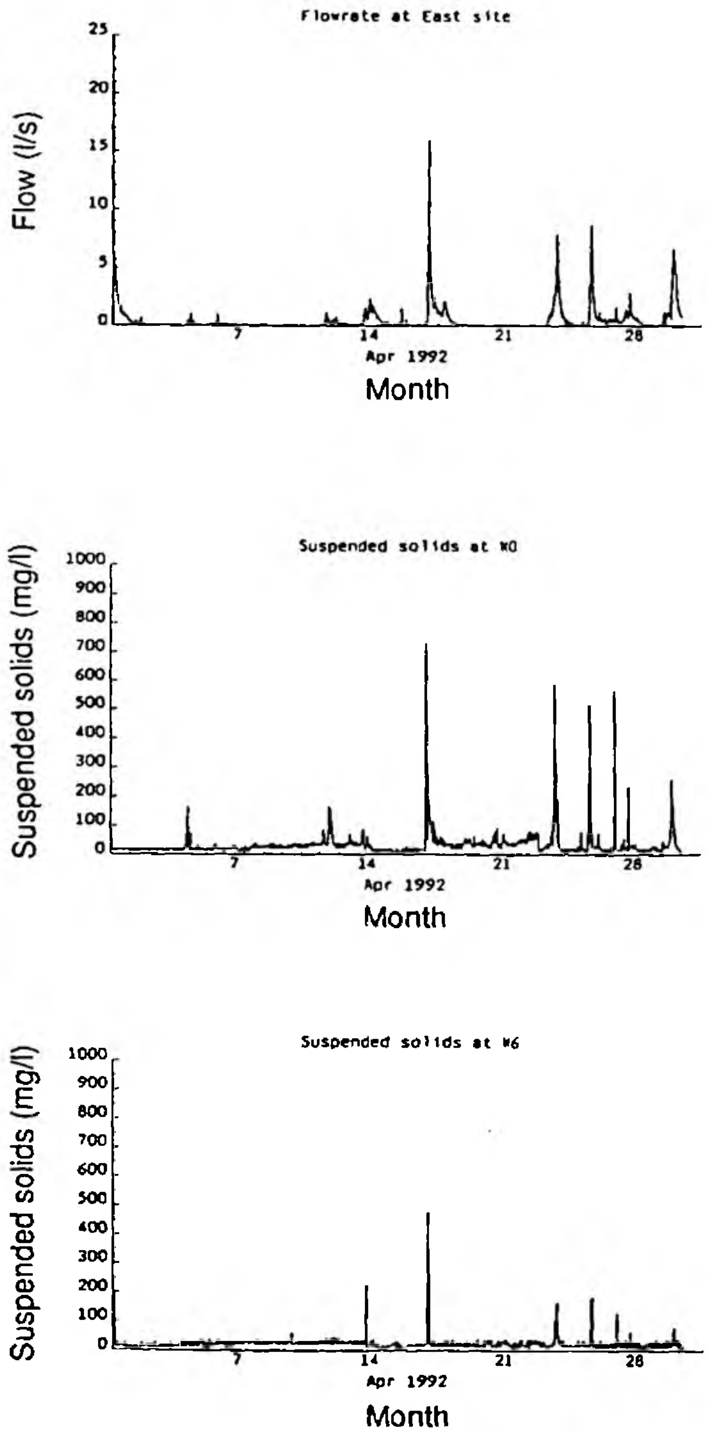


Figure 5.12 Records of flow rate at the 'east' weir and suspended solids at W0 and W6, April 1992

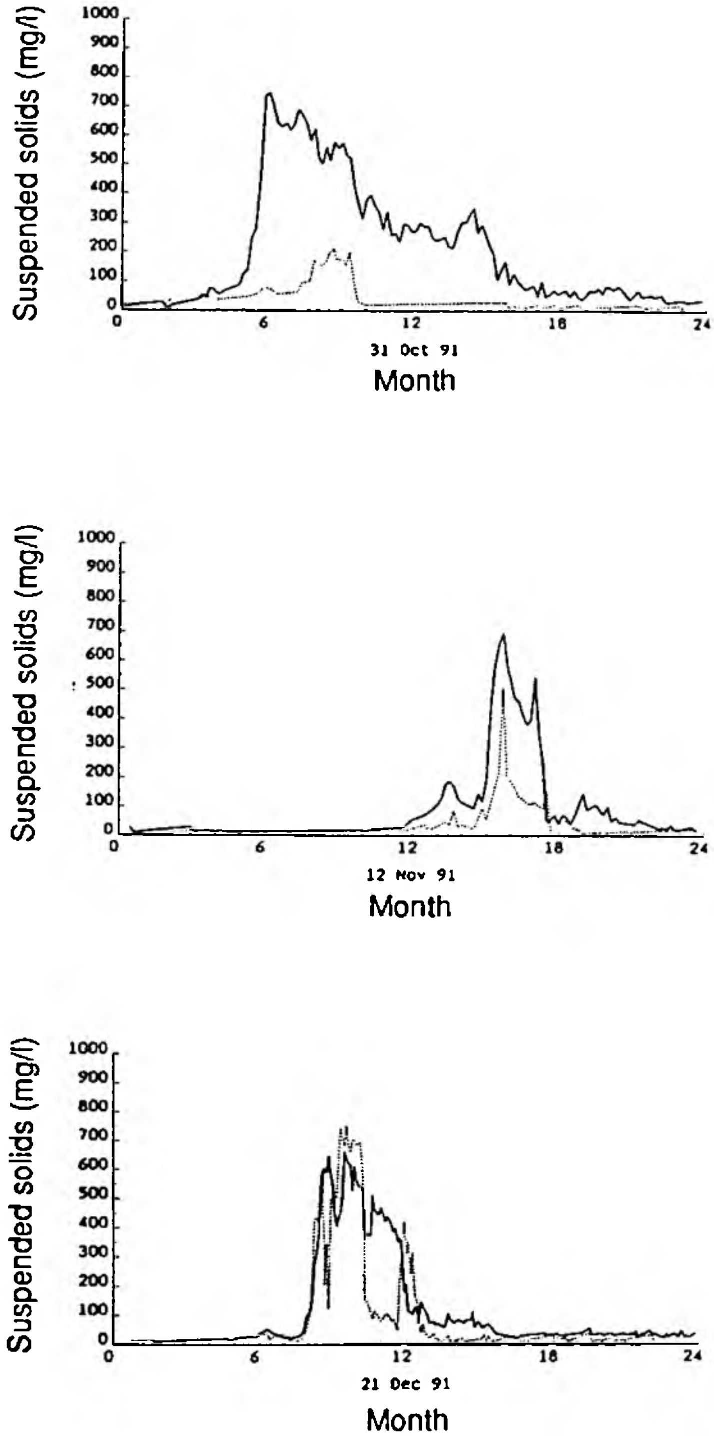


Figure 5.13 Detailed records of suspended solids at W0 and W6

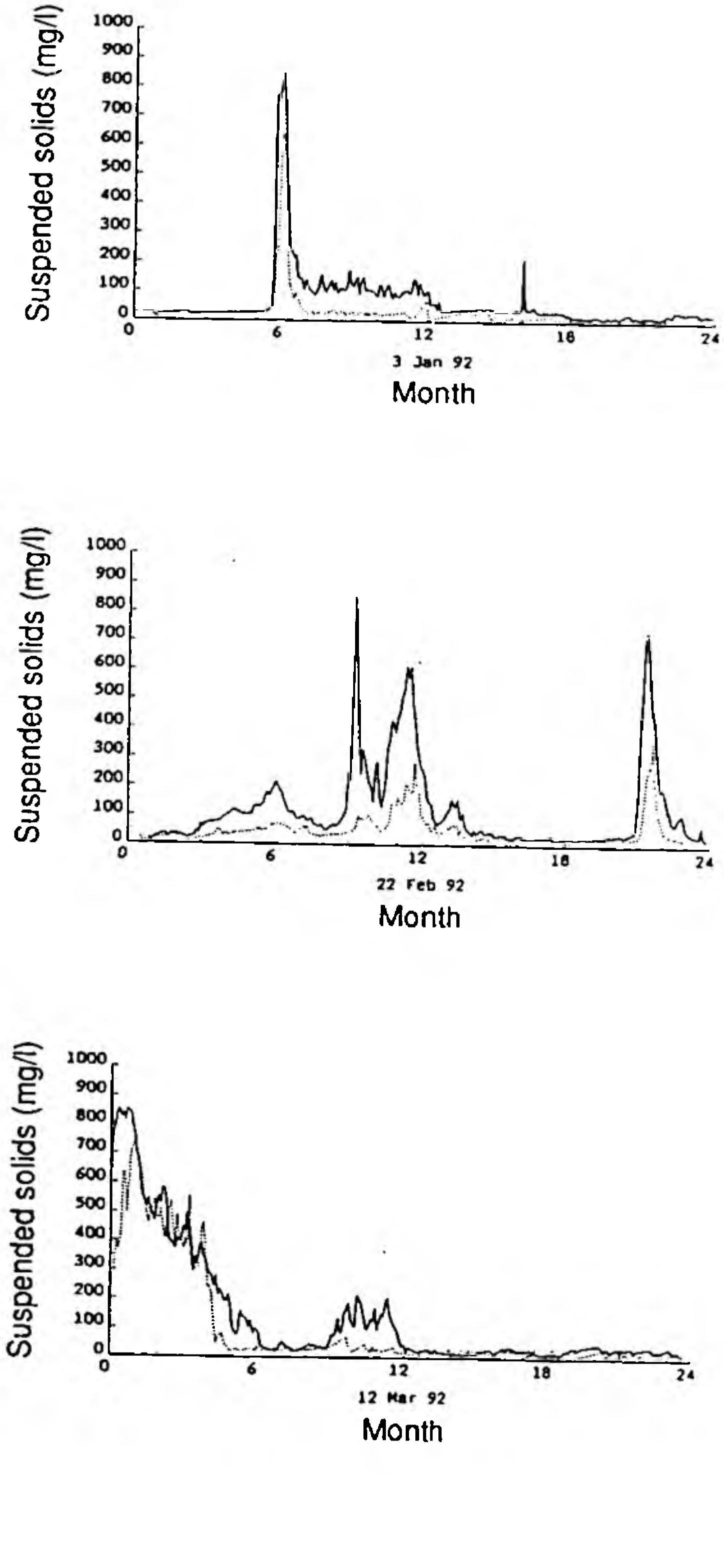


Figure 5.14 Detailed records of suspended solids at W0 and W6

Also it is clear from the results that most of the solids must have been retained within the buffer strip. Figure 5.13 also shows a clear delay between W0 and W6 in the rise and fall of suspended solids.

During the next two weeks the grass was flattened to about 20 m. On 12 November there was a further major event and Figure 5.13 shows that the smaller reduction in suspended solids throughout the event, with the peak concentration of 700 mg l^{-1} at W0 falling to 500 mg l^{-1} at W6.

On 21 December (Figure 5.13), by which time the vegetation was flattened to 30 m, the suspended solids at W0 and W6 were comparable, peaking at about 650 mg l^{-1}, throughout much of a 4-hour event.

By 12 March (Figure 5.14), when the vegetation was flattened beyond 50 m, the peak suspended solids at W0 of 850 mg l^{-1} was reduced to 750 mg l^{-1} at W6, and then W0 and W6 were much the same for 4 hours during the declining phase.

It is evident from this sequence of events that during the autumn there was a progressive reduction in the effect of the buffer strip, with the effect persisting into the spring. Also, the performance of the buffer strip corresponds well with the changes in the appearance of the vegetation in the strip during this time.

Effects of flow rate

The event on 21 December has already been mentioned. There were further significant events (Figure 5.8) on the following two days, but with lower flow rates, and although the peak suspended solids at W0 were similar on each occasion, it can be seen that the suspended solids at W6 were much less.

Throughout January and February, when the vegetation within the buffer strip was flattened beyond 40 m, there were several events when the suspended solids at W0 reached about 700 mg l^{-1} but peaked around 200 mg l^{-1} at W6. However, for each of these events the flow rate was only about 10 l s^{-1} or less.

Figure 5.14 shows two typical events which occurred on 22 February. The only event when flow exceeded 10 l s^{-1} (on 3 January) coincided with when suspended solids at w6 reached 600 mg l^{-1}.

5.4.2 Other insoluble determinands

As might be expected, insoluble determinands showed a similar response to the suspended solids, namely aluminium, iron and manganese, and total phosphorus which is illustrated in Figure 5.15.

5.4.3 Potassium, calcium and chloride

These three elements showed a tendency to decrease slightly down the buffer strip (up to 10%, especially for the earlier samples), which could indicate that they are present, at least in part, in particulate form. For potassium and calcium there were two samples about a month after fertilization which showed a large increase from W0 to W5; both were during low flow rates and it is suggested that the anomaly is due to sampling not being in phase with the flow of water.

5.4.4 Alkalinity and pH

There was a small increase in pH and alkalinity, and perhaps this was due continued dissolution of particulate calcium.

5.4.5 Soluble determinands

Somewhat surprisingly there was a small (about 15%) but fairly consistent decline in the concentrations of the soluble determinands (colour, soluble reactive phosphorus, ammonia, nitrate and sulphate) between W5 and W6. It is thought that the most likely cause of this is dilution of the drainage water by less contaminated surface water. The results for colour are shown in Figure 5.15.

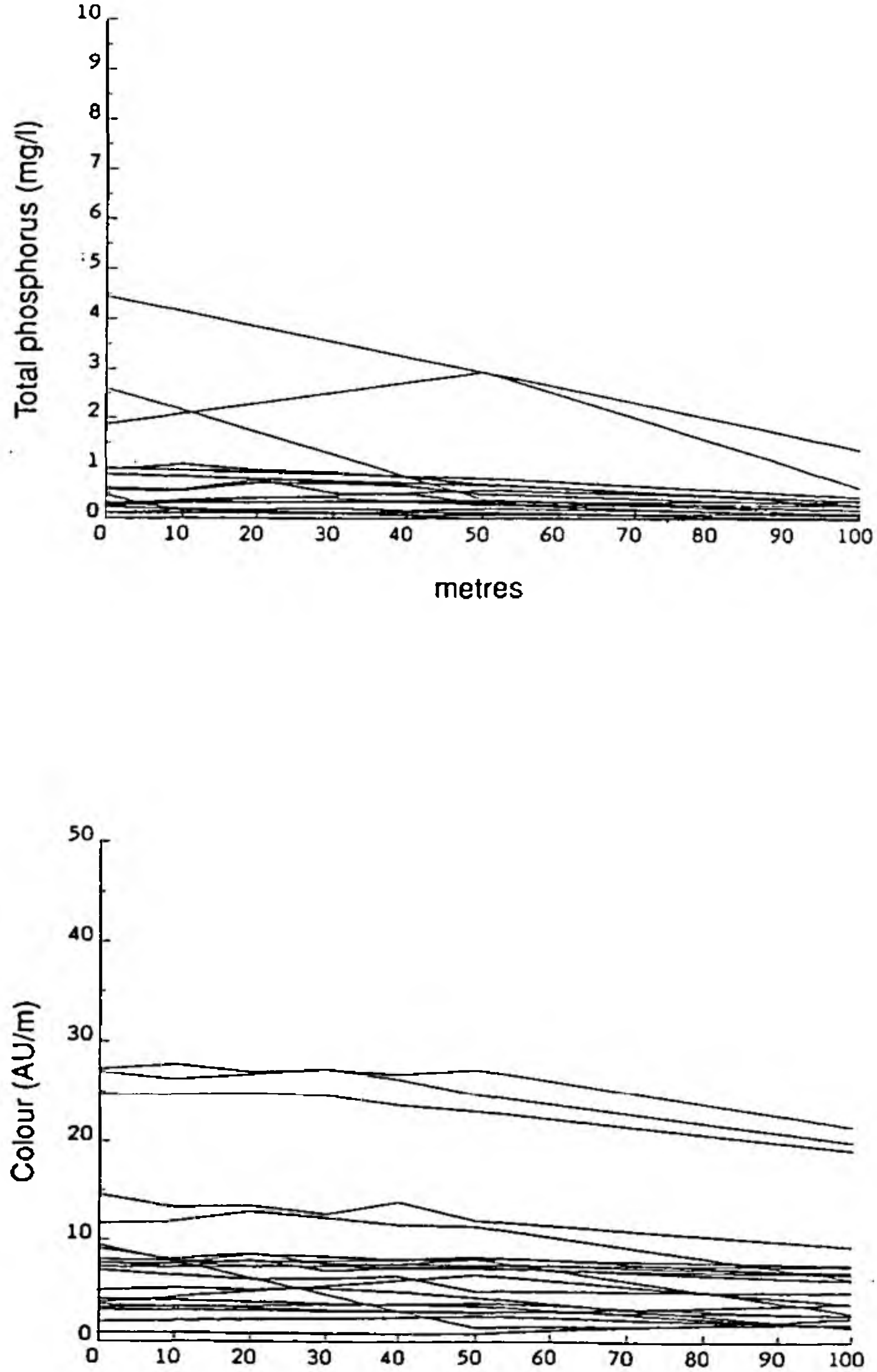


Figure 5.15 West site: total phosphorus and colour behaviour along the buffer strip

6. RESULTS AND OBSERVATION - 'EAST'

6.1 Catchment vegetation

There has been very little re-vegetation of the furrows within the catchment.

6.2 Vegetation of the buffer strip

As at the 'west' site, vegetation along the line of flow within the buffer strip was flattened by the initial deluge of drainage water when the cross drains were cut.

Substantial re-growth of vegetation occurred during the early summer which, like the 'west' site, was clearly darker than the surrounding vegetation. Through the autumn, about the first 30 m of vegetation was progressively flattened by successive runoff events. Vegetation in the last 10 to 15 m has remained substantially intact. The route taken by the drainage water between 20 m and 40 m has been about 5 m to one side (further north) of that in the previous winter.

6.3 Water quality at the weir

Results of samples taken before fertilization but not reported previously are listed in Appendix A. Table 6.1 provides a summary of all the pre-fertilization data.

The post-fertilization results are discussed below. It should be noted that due to the generally better initial water quality at the 'east' site, and the consequent greater interest in the 'west' site, fewer samples were taken from here.

Table 6.1 Summary of pre-fertilization water quality at the 'east' weir

For many determinands, the concentration appeared to vary with flow rate; for these, typical low-flow and high-flow values are as follows:

	Low flows	High flows (>10 $l\ s^{-1}$)
Suspended solids	<10 mg l^{-1}	200 mg l^{-1}
Colour	20 au/m	15 au/m
Chloride	10 mg l^{-1}	5 mg l^{-1}
Sulphate	5-15 mg l^{-1}	15-20 mg l^{-1}
Total phosphorus	0.06 mg l^{-1}	0.16 mg l^{-1}
Calcium	1 mg l^{-1}	0.8 mg l^{-1}
Potassium	0.3 mg l^{-1}	0.7 mg l^{-1}
Aluminium	0.1 mg l^{-1}	0.5 mg l^{-1}

Typical values for determinands which did not appear to be related to flow are as follows:

Sulphate	between 5 and 10 mg l^{-1}
Soluble reactive p	<0.003 mg l^{-1}
Ammonia	0.05-0.25 mg l^{-1}
Nitrate	<0.1 mg l^{-1}
Alkalinity	nil
pH	4
Iron	0.5 mg l^{-1}
Manganese	0.05 mg l^{-1}

6.3.1 Suspended solids

By the spring of 1991 there had been a substantial reduction in the quantity of suspended solids leaving the 'east' site, with concentrations being well below 100 mg l^{-1} even at high flows. It can be seen from Figure 6.1 that this situation has continued in the samples collected during this year, with all but one of the samples being below 50 mg l^{-1}.

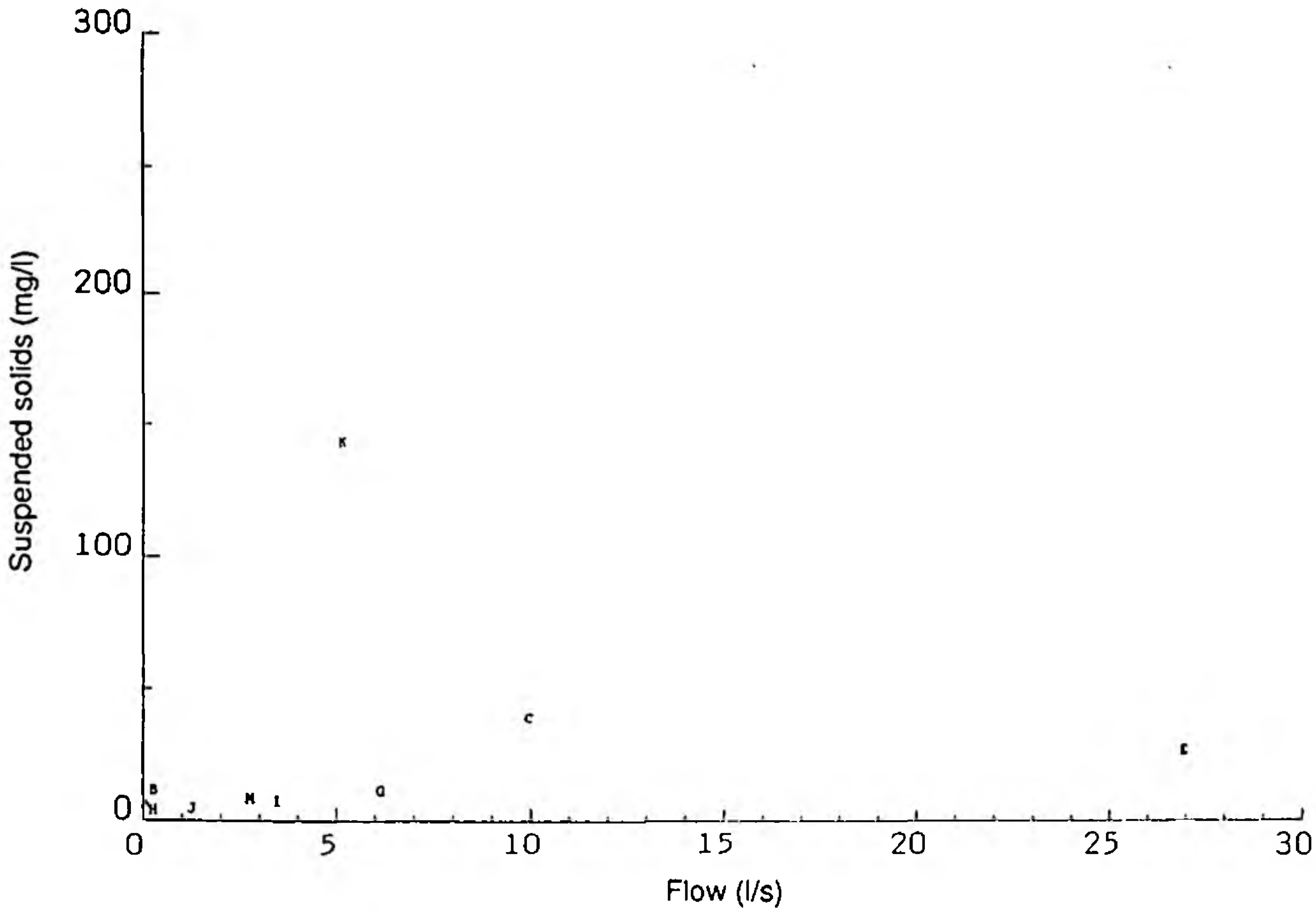


Figure 6.1 East site: relationship between suspended solids and flow

6.3.2 Colour

Figure 6.2 shows this year's colour results plotted against time. It can be seen that in the autumn of 1991 colour was usually around 10 AU/m which is consistent with the lower values found last year. However, in the first months of 1992 there has been a substantial, and apparently progressive, increase in colour, reaching 36 AU/m by April. A smaller increase was observed at the 'west' site (see Section 5.3.2).

6.3.3 Phosphorus

As with the 'west' site, there was a very large increase in the levels of phosphorus following fertilization with a maximum observed concentration of nearly 10 mg l^{-1} which is about twice that found at the 'west' site. There was a progressive decline in the succeeding months to about 1 mg l^{-1}, but this is still 10 times higher than pre-fertilization values. The results are plotted against time in Figure 6.3.

A significant difference from the 'west' site is that at the 'east' it would seem that almost all of the total phosphorus is soluble.

6.3.4 Potassium and calcium

Very large increases in potassium and calcium levels occurred shortly after fertilization, values of nearly 50 mg l^{-1} and 20 mg l^{-1} respectively being found, and then falling to about 2 or 3 mg l^{-1} respectively by spring 1992 (Figure 6.4). Pre-fertilization values were about 1 mg l^{-1} or less for each of these elements.

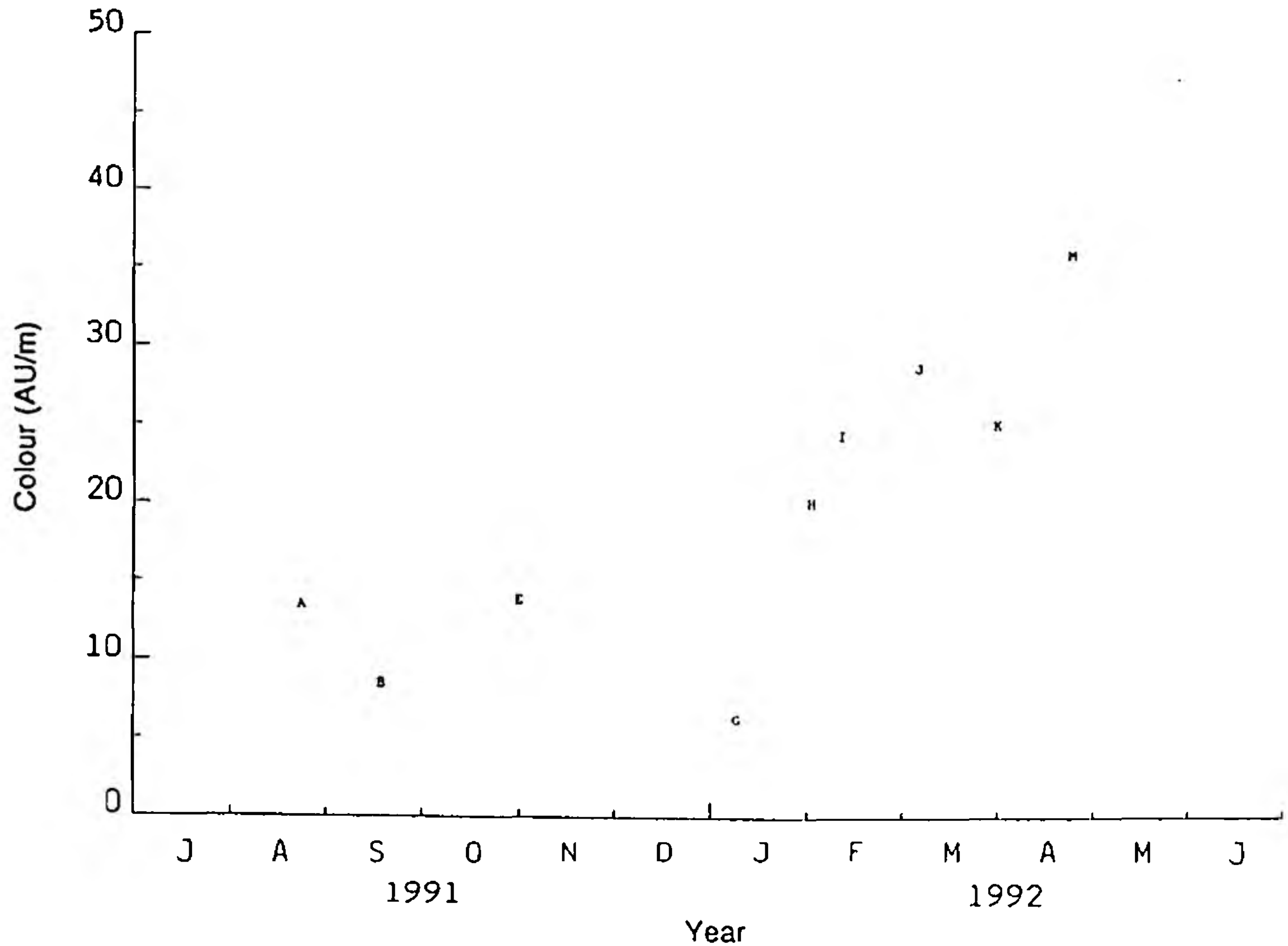


Figure 6.2 East site: relationship between colour and time

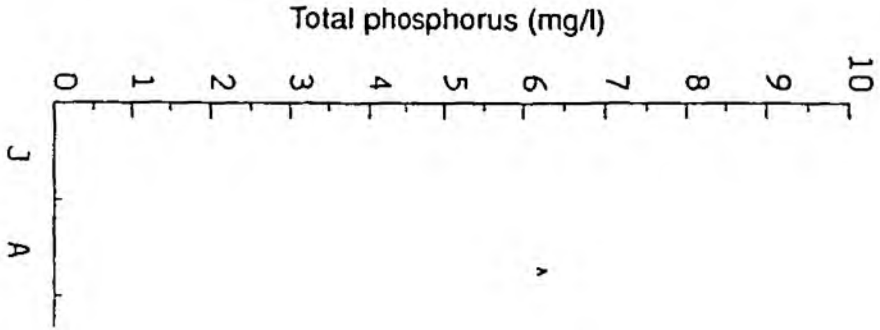
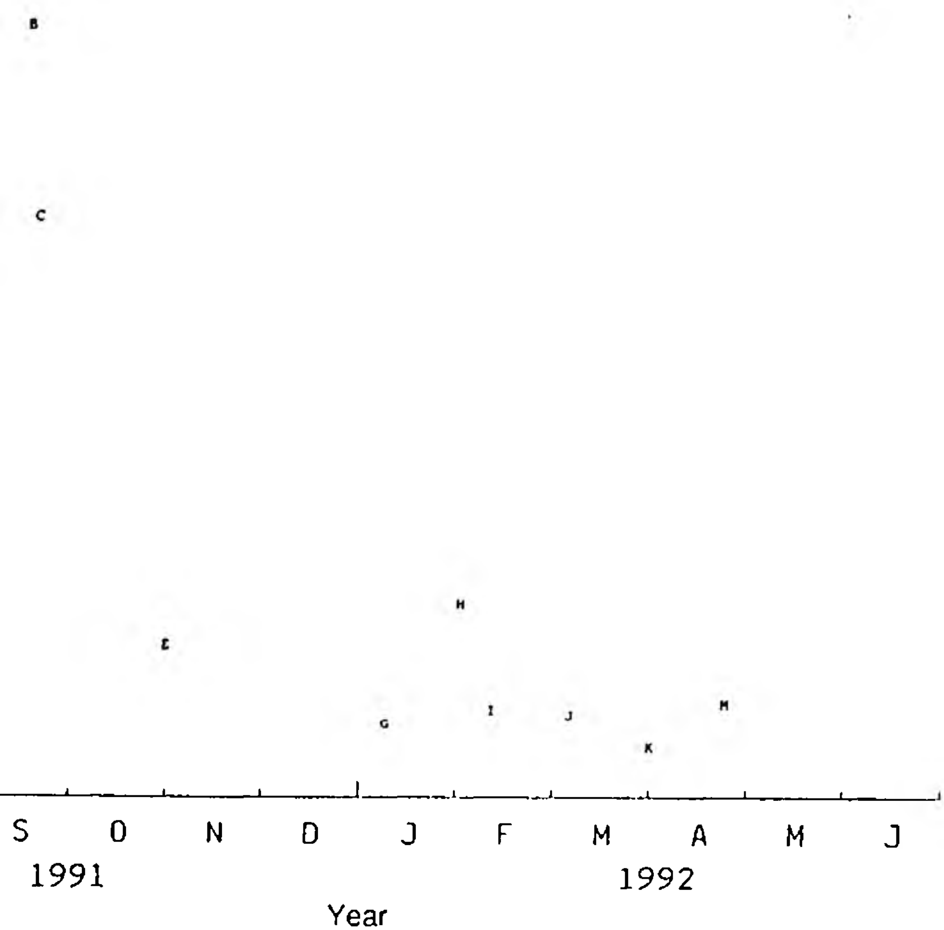


Figure 6.3



East site: relationship between total phosphorus and time

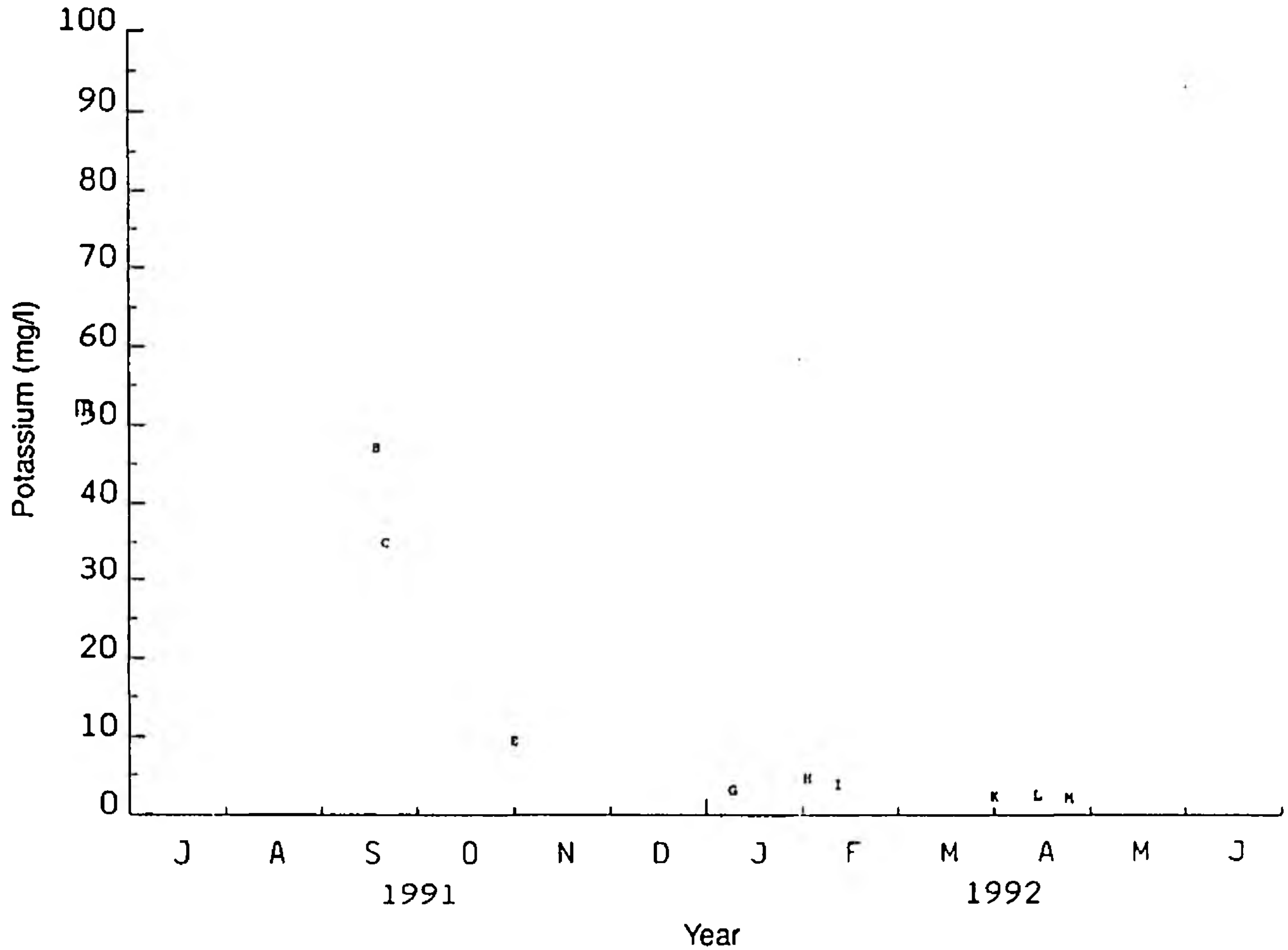


Figure 6.4 East site: relationship between potassium and time

6.3.5 Chloride

Although only a few samples were analysed for chloride, it is clear that chloride concentrations followed a similar pattern to those at the 'west' site: greater than 30 mg l^{-1} soon after fertilizer application and falling by spring 1992 to 5 mg l^{-1} which is comparable to pre-fertilization levels.

6.3.6 Nitrogen

As with the 'west' site, immediately after fertilization there was a small increase in both ammonia and nitrate at the 'east' site. In spring 1992 only nitrate was determined but the results show a return to pre-fertilization levels.

6.3.7 Alkalinity and pH

Alkalinity and pH have been substantially the same as before fertilization, being nil and about pH 4 respectively.

6.3.8 Sulphate

Only two samples were analysed for sulphate, and found to have concentrations of 10 mg l^{-1} and 3 mg l^{-1} which are within the range of values observed before fertilization.

6.3.9 Aluminium, iron and manganese

There were no substantial changes in the concentrations of these elements from those before fertilization, usually being about 0.2 mg l^{-1}, 0.5 mg l^{-1} and 0.005 mg l^{-1} respectively. However, there is some indication that there was a small increase, most pronounced for manganese, immediately after fertilization.

6.4 Effect of the buffer strip

6.4.1 Suspended solids

The results, plotted in Figure 6.5, show a definite decrease (around 25%) in suspended solids concentration down the buffer strip, from early on in the autumn right through into spring 1992. The temporal changes observed at the 'west' site are not clearly evident; but this is not surprising in view of the lower solids concentration at the weir, fewer samples being taken at the 'east' site, and no continuous solids monitoring. On one occasion a very large fall in suspended solids occurred between E3 and E4; this corresponds with the flattening of the vegetation (see Section 6.1), but could be due to the timing of sampling in relation to the changes in water quality.

6.4.2 Phosphorus

The results for total phosphorus are shown in Figure 6.5. Samples taken soon after fertilization, when the phosphorus concentrations were relatively high and flows low, show a substantial reduction down the buffer strip. However, in most cases there was no change, consistent with the phosphorus being substantially dissolved.

6.4.3 Calcium, potassium and chloride

Results for potassium are illustrated in Figure 6.5. Samples taken soon after fertilization and early in the autumn had the largest initial concentrations and show the greatest reduction in calcium and potassium down the buffer strip. Later on, the initial concentrations are much lower and there is hardly any reduction. It seems likely that the difference in response is due to the presence of insoluble fertilizer early on, but only dissolved elements later.

It is suspected that chloride would have behaved similarly but too few results are available immediately after fertilization to demonstrate this.

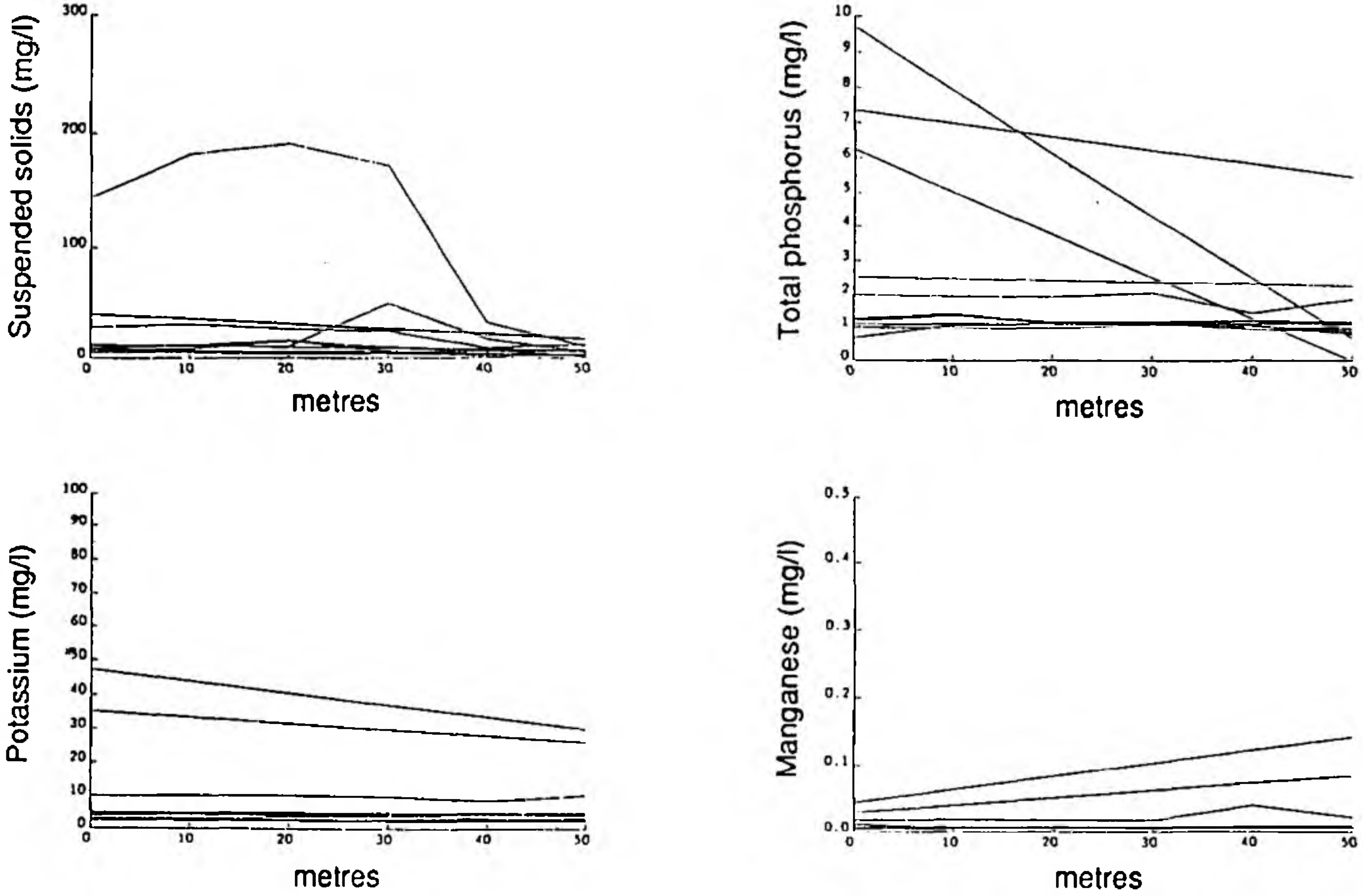


Figure 6.5 East site: behaviour of selected determinands along the buffer strip

6.4.4 Soluble determinands

Colour, sulphate, nitrate and pH show no significant change down the buffer strip but a small decline may be indicated for ammonia.

6.4.5 Aluminium, iron and manganese

As expected, aluminium and iron show a small decrease in line with suspended solids. However, for the first three sampling occasions there is a definite rise in manganese concentration down the buffer strip (Figure 6.5). A possible explanation for this is that some manganese is solubilised in the stagnant summer conditions and is leached out of the peat in the early rainfall events.

7. SEDIMENT

7.1 Quantity

Sketches of the sampling transects are shown in Figure 7.1, which illustrates the variation in terms of width and depth of the sediment, and gives the overall vertical cross-sectional area of each. Taking each transect as representative of the preceding 10 m gives the total volume of sediment to be about 1 m^3, with a mass estimated to be around 2000 kg.

It has been mentioned that, during the 1990/91 winter, high flows spilled over from the main channel at about 35 m from the weir. There is clear evidence of sediment extending away from the main channel at this point: it is quite extensive but relatively shallow, and estimated to contain perhaps a further 400 kg. This gives an estimate for the total sediment in the buffer strip of 2400 kg.

There is no doubt that the drainage water is still carrying an appreciable amount of solids: The Aquatrac sensor at the 'west' weir is completely re-covered with sediment after almost every significant runoff event, and during this autumn some accumulations of sediment have been seen within the buffer strip. By early January there had been a further accumulation of 20 mm at the 10 m and 20 m rulers, but these were clearly in localised mounds and the sediment did not extend across or along the channel. There were accumulations of about 10 mm at the 30 m and 40 m rulers, but again this depth was not uniform. On the particular visit when the measurements were taken, the flattening of the vegetation had just reached the 40 m mark and there was quite a large amount of sediment supported on partly knocked down juncus, above the level of the ruler; this sediment had been washed away just four days later. No increase in sediment has been noted at the 50 m ruler or on one placed downstream of W6.

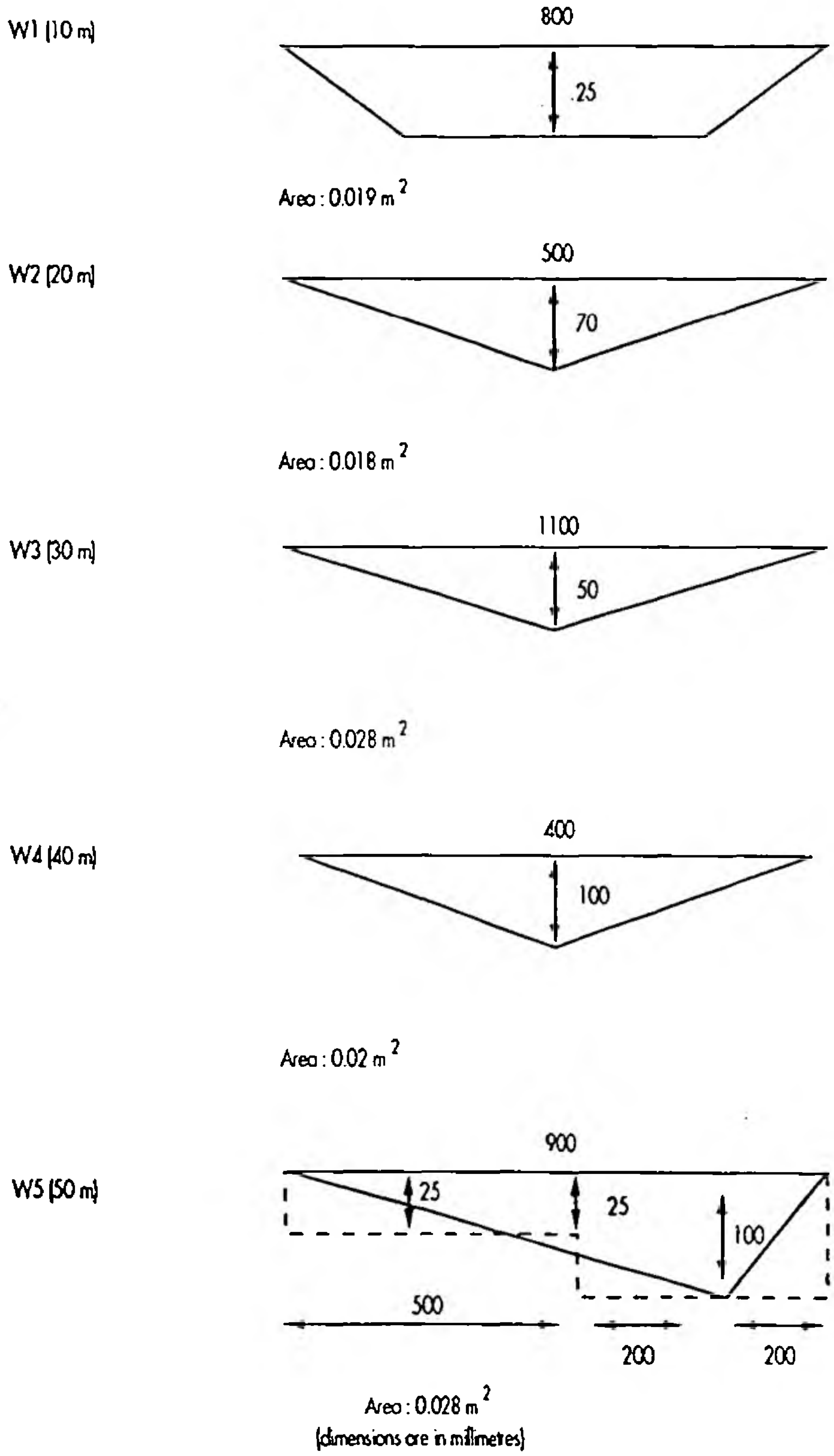


Figure 7.1 Sediment sampling transects, 21 August 1991

7.2 Waterborne solids load

Obviously it is important to put the amount of sediment in the context of the solids load entering the buffer strip, so an attempt has been made to estimate this solids load during the 1990/1 winter. This was based on a simple rating curve, although it is recognised that this approach can have significant shortcomings.

The rating curve, relating suspended solids concentration to flow rate for the 'west' site, was based on analyses of manual samples and the manual measurements of depth of flow which are always made at the time of taking samples (i.e. this does not rely on the operation of the 'west' Aquatrac). A simple linear regression, forced through the origin, indicated a relationship of:

$SS(mg\ l^{-1}) = 33.6 \times flow(l\ s^{-1})$.

Clearly this will be an over-simplification, particularly in not distinguishing between rising and falling stage and, because of the absence of data for the highest flows, relies on extrapolation (rather than interpolation) for predicting high flow values.

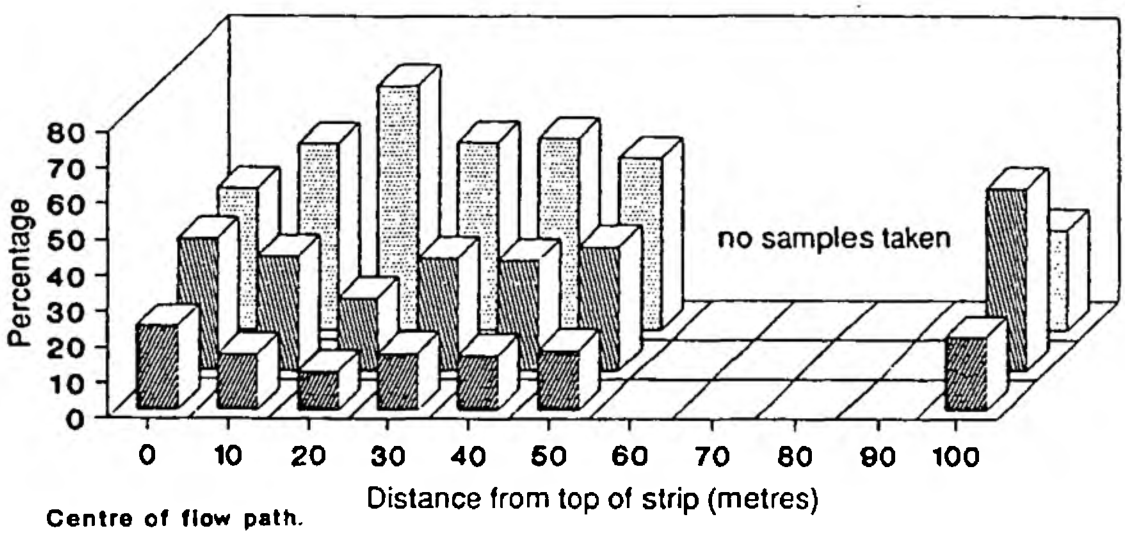
Because of the bed load carried down the 'west' cross-drain, the Aquatrac sensor there becomes buried under sediment after almost every significant rainfall event. The flow record from the 'west' site is therefore scanty, with an almost complete absence of data for the high flows which are of most relevance here. For this reason it has been necessary to estimate the flow at the 'west' site from that at the 'east' for which the record is substantially complete. The relationship between the two flows has been based on a comparison of measured flows at sampling times during the 1990/1 winter. Although the samples were not taken simultaneously, but usually about half an hour apart, there seems to be a reasonable correspondence between the flows, with 'west' flow being approximately 1.25 times the 'east' flow.

Based on the estimated 'west' flow and the rating curve for the 'west' site, the suspended solids concentration, and hence the solids load, has been estimated at 15 minute intervals throughout the autumn to spring period of 1990/1. The total load is estimated to be about 1700 kg. The flow record is not quite complete, and a comparison with the rainfall record suggests that perhaps 10% of the rainfall was missed, so the estimate of load should be increased by about 10%. In addition, it is reckoned that repeated clearing of sediment from the Aquatrac - and moving it to just downstream of the weir - could have added about a further 100 kg. This indicates that the total solids load may have been around 2000 kg.

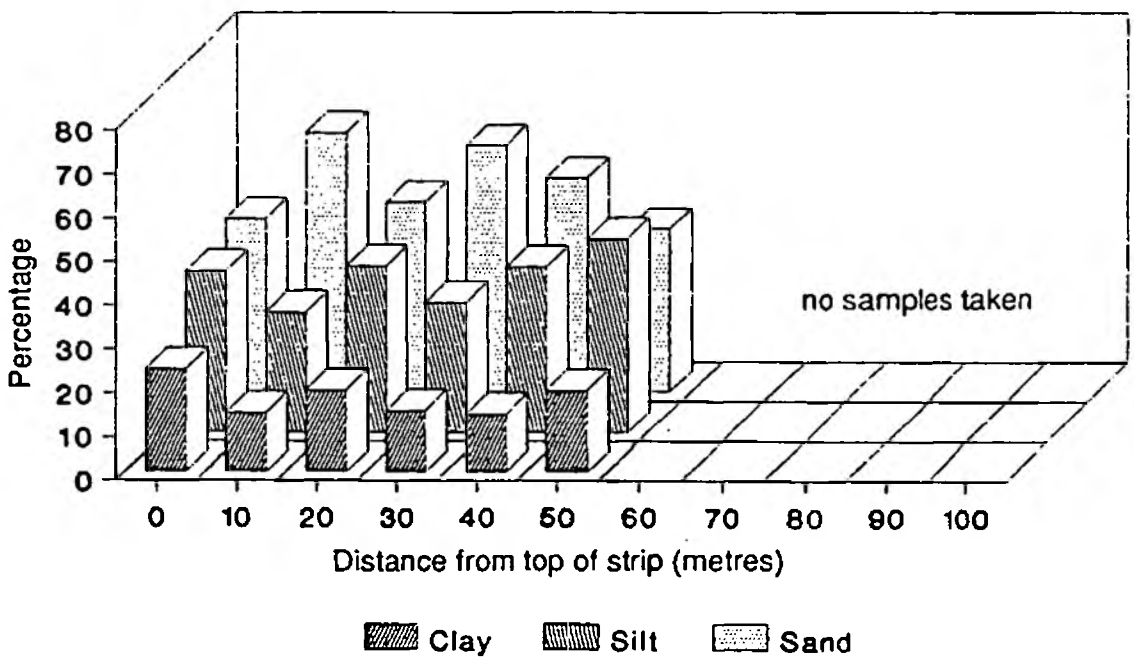
7.3 Particle size analysis

Samples of sediment were taken during late August 1991. All of the samples taken from the 'east' site were found to be 100% organic (peat) so no particle size analysis could be carried out. The results for the 'west' samples are presented in Table 7.1 and in a simplified form as clay, silt and sand in Figure 7.2.

There is one exceptional sample: that from the centre of the channel at 20 m has an unusually high proportion of sand. Apart from this, all of the samples from the centre of the channel are substantially similar to corresponding ones at the side. Also, the data are consistent with a gradual decline in the amount of sand content - which could be accounted for by depletion of the suspended material - and a corresponding increase in the proportion of finer particles. Finally, the quality of sediment from the side stream is comparable with that from the 50 m sample.



Centre of flow path.



Edge of flow path

Figure 7.2 Particle size analysis of sediment deposited on the buffer strip

Table 7.1 Particle Size Analysis of Sediment from 'West' Site

	Particle size distribution % in each size (micron) fraction					
Sample Identity	Sand 2000-600	Sand 600-212	Sand 212-63	Total sand 2000-63	Silt 63-2	Clay
Centre of flow-path						
W0, Weir pool	17.0	6.5	16.2	39.7	36.8	23.5
W1, 10 m	8.7	17.1	26.6	52.4	32.0	15.6
W2, 20 m	25.2	29.0	14.6	68.8	20.4	10.8
W3, 30 m	11.8	24.5	16.4	52.7	31.4	15.9
W4, 40 m	6.2	20.9	26.8	53.9	30.9	15.2
W5, 50 m	2.5	18.3	27.6	48.4	34.8	16.8
W6, 100 m	2.2	1.9	24.2	28.3	51.2	20.5
'Side stream'	0.2	10.2	31.4	41.8	40.9	17.3
Edge of flow-path						
W1, 10 m	13.2	21.9	24.1	59.2	27.4	13.4
W2, 20 m	3.3	17.0	23.1	43.4	37.9	18.7
W3, 30 m	3.0	18.5	34.9	56.4	29.6	14.0
W4, 40 m	2.4	14.7	31.9	49.0	37.7	13.3
W5, 50 m	1.5	9.7	26.1	37.3	44.1	18.6

8. DISCUSSION OF RESULTS

Concentrations of calcium and potassium immediately following fertilization in the runoff at the weirs were considerably greater by a factor of 10 at the 'west' site and higher at the 'east' site. Concentrations have subsequently declined to near pre-fertilization levels. There is little data for chloride but similar trends are indicated.

Total phosphorus levels at the 'west' site were some 5-fold higher after fertilization, with as much as 30 per cent present in the soluble reactive form. In contrast, concentrations of total phosphorus approached 10 mg P l^{-1} at the 'east' site and are still 10 times greater than prior to fertilization. Furthermore it is present almost entirely in the soluble reactive form. These differences in behaviour between the sites are almost certain to be soil-related.

Colour levels also increased at both sites, but particularly at the 'east'. There do not appear to be any ready explanations for this but it could be a result of fertilization; calcium ion interaction with the coloured humic substances enhances their mobility. Alternatively, it may be due to the unusually mild and wet Spring of 1992.

The results indicate that there was a progressive reduction in the effect of the buffer strip during Autumn which persisted well into the Spring. As time progressed it was evident that a progressively larger stretch of the upper part of the buffer strip had negligible impact on water quality. This ties in well with the progressive flattening of the vegetation, and was not apparent in last year's results when all of the vegetation was flattened throughout the winter. However, the smaller effect of the buffer strip for the first 30 m could also be due to the slope being steeper.

In addition to the vegetation-related effects, runoff flow rate also appears to be important, with substantial attenuation in suspended solids at moderate flows, regardless of the state of the vegetation.

Similar improvements in water quality during its passage over the 'east' site are less evident than at the 'west' site. There are several possible reasons: the runoff quality is relatively better, the slope of the strip tends to be steeper and the vegetation is not as substantial.

Particle size analysis indicates that the coarser particles tend to settle out in the upper parts of the strip and that the fine material tends to be carried though the strip as expected.

Studies indicate that the quantity of sediment at the 'west' site is of the same order as the solids load - a conclusion which is quite inconsistent with the only modest improvement in water quality observed between the top and bottom of the buffer strip. Some possible explanations are discussed here.

Firstly, it is recognised that the estimate of the amount of sediment is not very accurate and could possibly be overestimated by as much as 50%, but probably not more than this, so this alone is not adequate explanation. Secondly, it is obvious that the estimation of the solids load involves certain assumptions which could introduce error. Also, the possibility of unrepresentative sampling cannot be ruled out.

The most likely explanation seems to be that much of the sedimented material entered the buffer strip area when and immediately after the drains were cut. There was a lot of loose soil in the furrows because of the ploughing and it has already been mentioned that it was wet before and during the cutting of the drains. So when the drains were cut they were filled immediately with a large quantity of very dirty water which spilled out over the buffer strip area. There is little doubt that the quantity of soil debris from the ploughing could easily amount to the 1 m^3 of sediment found in the buffer strip.

Some circumstantial evidence to support this explanation emerged during the autumn of 1991: the build-up of sediment in the buffer strip seems to be much less than last year. Also, for a few weeks flow left the main channel at 30 m, and there was a clear build-up of solids in the area, but again this is considerably less than the extensive accumulations that occurred from the 35 m point last winter.

9. CONCLUSIONS

9.1 Buffer strips vegetation

During the summer there was prolific growth of vegetation, which was particularly noticeable at the 'west' site, along the routes taken by the drainage water through the buffer strips. This has progressively been flattened by successive high flows occurring in the autumn and winter.

9.2 Water quality at the weirs

Suspended solids remain low at the 'east' site, and some decline is probable at the 'west' but the extent of this is uncertain.

At both sites there were large increases in phosphorus, potassium, calcium and chloride immediately following fertilization with a progressive decline in the months since then.

Throughout the winter there was a large and progressive increase in colour at the 'east' site and a small increase at the 'west' site. There is no obvious explanation for this.

9.3 Effect of the buffer strips

Evidence from both spot samples and continuous suspended solids monitors indicates that there has been a gradual change in the performance of the buffer strips, in line with the flattening of the vegetation. For major runoff events (>20 $l\ s^{-1}$ for the 'west' site), early in the autumn there appeared to be a 90% reduction in the peak suspended solids concentration between the top and bottom of the buffer strip, by the end of 1991 and continuing into the spring of 1992 the peak concentrations were similar but probably still a reduction in the overall solids load.

The continuous monitoring data also show that the performance of the buffer strip depends on flow rate. Even after the vegetation had been flattened there was a large reduction in suspended solids carried by relatively smaller (<10 l s^{-1} for the 'west' site) runoff events.

There were similar effects on the concentrations of other insoluble determinands.

Small reductions in soluble determinands between 50 m and 100 m at the 'west' site are attributed to dilution rather than removal.

9.4 Sediment

Crude measurements of the sediment within the buffer strip exceed the estimated amount of suspended solids carried in the drainage water. It is suggested that the most likely explanation is that much of the sediment entered immediately after the cross drains were cut - carrying the soil debris arising from ploughing, rather than solids from continued erosion since then.

10. RECOMMENDATIONS

The work programme identified in Section 3 was intended to continue into 1992/93, when it is to be expected that contaminant loads will decline as the catchment becomes re-vegetated. It is recommended that the following work programme be completed:

1. Review the desirability of revising the summer work programme with a view to the transfer of funds to 1993/94 so that the final report could be written and issued during April to June 1993. This would enable monitoring throughout the wet winter period when the vegetation becomes progressively flattened.

2. Continue to sample manually under medium to high flow conditions at both 'east' and 'west' sites, with an emphasis on the latter. Samples shall be analysed for suspended solids, total phosphorus, iron, aluminium and manganese, plus colour at the 'east' site. About a third of the samples will be analysed for soluble reactive phosphorus. Nitrate, sulphate, chloride, calcium and potassium will be included from time to time.

3. Continue to monitor suspended solids at the 'west' site using the Partech sensors installed at the weir (W0) and at 100 m (W6). Regularly check that the sensors maintain calibration using kaolinite control standards. Undertake a thorough comparison of results against those obtained by gravimetric analysis.

4. Under suitable conditions, re-assess the build-up of sediment at the marker rods. Make a further assessment of the quantity of accumulated sediment and make a visual assessment of the quantity of bed load (pebbles, stones, etc.) which have been transported down the strip.

5. Under medium and high flow conditions, take samples from the weir (W0) for the determination of particle size distribution.

6. Keep a record of the "flattening-down" of vegetation.

7. Undertake a dye tracing test (with the permission of Clyde RPB) to establish the velocity of flow at the 'west' site under conditions of high flow.

8. Collate and evaluate the data set, draw conclusions from the study and derive protocols for buffer strip design.

9. Write the final study report.

10. Decommission the study site.

REFERENCES

Forestry Commission (1991) Forests and Water Guidelines.

Maitland, R.S., Newson, M.D. and Best, G.A. (1990) The impact of afforestation and forestry practice on freshwater habitats. Nature Conservancy Council, Northminster House, Peterborough, PE1 1UA. ISBN 0 86139 6111.

Swift, D.W. (1987) Phosphorus run-off from Glenorchy forest: the impact of aerial application of rock phosphate fertilizer. WRc Report PRU 1699-M.

Swift, D.W., Parr, W. and Clarke, S. (1990) A review of the effects of afforestation and forestry activities on upland water quality. WRc Report No. PRS 2422-M/1, 56pp.

Swift, D.W., Clarke, S.J. and Norton, R.L. (1991) Measures for protecting upland water quality. WRc Report No. SR 2809. 70pp.

APPENDIX A

PRE-FERTILIZATION WATER QUALITY DATA

Pre-fertilisation data for Dalmellington WEST site (not previously reported):

Date		Time	l/s		SS	Hz	Cl	SO_4	TP	SRP	NH_4	NO_3	pH	ALK	Ca	K	Al	Fe	Mn
13 05 91	1	10.00	0.1	W0	6.0	2.65	6.74	8.40	0.02		<0.05	0.55	5.30	5.00	4.2	0.4	0.69	0.602	0.052
				W1	7.0	3.18	9.00	7.54	0.02		<0.05	0.39	5.10	7.70	4.1	0.4	0.6	0.422	0.032
				W2	2.0	3.53	9.13	6.46	0.01		<0.05	0.30	5.40	11.50	5.0	0.5	0.45	0.947	0.291
				W3	2.5	5.03	8.61	5.38	0.01		<0.05	0.19	5.50	20.30	5.8	0.4	0.33	0.606	0.989
				W4	11.5	8.78	7.95	3.88	0.01		<0.05	0.13	5.60	28.80	6.4	0.5	0.30	2.110	2.220
				W5	23.0	4.28	6.35	4.20	0.01		<0.05	0.12	5.60	31.70	7.5	0.5	0.23	0.666	1.880
				W6	2.0	3.80	6.39	3.77	<0.01		<0.05	<0.10	5.60	16.50	4.9	0.3	0.24	0.203	0.098
23 06 91	1	13.00	0.1	W0	37.0	4.95	8.16	13.80	0.14		0.14	0.47	5.00	3.80	3.5	0.6	2.10	1.760	0.104
				W1	81.0	4.78	9.29	15.60	0.13		<0.05	0.36	5.10	3.70	4.3	0.6	2.23	2.230	0.098
				W2	44.0	5.30	8.02	20.80	0.14		0.08	0.44	5.20	4.80	4.8	0.6	1.46	1.350	0.071
				W3	28.0	5.03	7.94	12.40	0.12		<0.05	0.50	5.30	5.50	5.2	0.7	0.87	0.425	0.136
				W4	27.1	5.05	7.78	12.10	0.12		<0.05	0.55	5.30	8.20	5.4	0.6	1.05	1.260	0.422
				W5	25.7	5.05	7.37	11.70	0.09		<0.05	0.53	5.40	12.80	6.2	0.7	1.12	2.350	0.990
				W6	25.0	6.10	3.66	6.35	0.09		<0.05	<0.10	6.00	26.10	7.1	0.5	0.67	0.880	0.490
09 08 91	1	5.30	2.5	W0	16.3	5.53	4.30	10.10	0.08		0.34	1.75	4.80	3.90					
				W5	7.3	7.20	4.00	11.10	0.04		0.59	1.59	6.60	3.20					
				W6	12.5	7.58	4.20	10.40	0.03		0.33	1.32	4.90	5.50					
	2	6.00	2.3	W0	12.4	6.08	4.40	10.10	0.06		0.58	1.79	4.70	2.90					
				W5	7.5	6.93	4.20	11.70	0.04		<0.20	1.65	4.80	3.90					
				W6	9.5	6.83	4.30	10.60	0.04		0.39	1.41	5.10	4.90					
	3	6.30	2.0	W0	14.8	6.25	4.70	12.40	0.06		0.33	1.88	4.70	2.90					
				W5	5.5	7.13	4.30	11.70	0.04		0.45	1.72	4.70	4.40					
				W6	8.8	6.70	4.20	11.40	0.04		0.20	1.40	4.80	6.00					
	4	7.0	1.5	W0	10.0	7.50	4.70	14.90	0.05		0.49	1.85	4.60	2.50					
				W5	5.3	6.83	4.60	14.60	0.04		0.59	1.74	4.90	3.90					
				W6	5.8	6.45	4.10	11.70	0.03		0.17	1.36	5.00	6.10					
	5	7.30	1.5	W0	8.8	5.88	4.80	13.90	0.05		0.68	1.84	4.70	3.00					
				W5	9.3	7.28	4.50	12.90	0.04		0.57	1.69	4.70	3.90					
				W6	9.5	6.60	4.20	12.00	0.03		<0.10	1.36	5.00	5.80					
	6	8.00	1.1	W0	5.4	10.00	5.30	15.40	0.04		0.31	1.87	4.70	3.20					
				W5	5.5	6.85	4.60	14.70	0.03		0.46	1.70	4.70	4.30					
				W6	5.5	5.63	4.20	12.40	0.03		<0.10	1.24	4.90	6.50					
	7	8.30	1.0	W0	5.3	5.48	4.90	15.20	0.05		<0.20	1.84	4.70	3.00	4.3	0.5	0.67	0.432	0.046
				W1	7.3	8.05	4.90	15.40	0.05		<0.20	1.85	4.80	3.40	4.3	0.4	0.70	0.486	0.055
				W2	11.3	5.83	4.90	15.20	0.18		0.39	1.81	4.80	3.60	4.6	0.6	0.87	0.697	0.064
				W3	11.3	6.45	4.80	15.30	0.17		<0.20	1.79	4.80	4.00	4.6	0.5	0.75	0.629	0.060
				W4	8.3	7.10	4.70	15.40	0.05		<0.20	1.82	4.90	3.50	5.1	0.4	0.67	0.529	0.052
				W5	11.3	7.28	4.40	13.20	0.05		<0.10	1.83	5.00	4.20	5.7	0.4	0.57	0.418	0.060
				W6	6.5	6.80	4.10	12.20	0.03		<0.10	1.28	4.90	5.80	5.2	0.3	0.45	0.437	0.163

Pre-fertilisation data for Dalmellington EAST site (not reported previously):

Date		Time	l/s		SS	AU	Cl	SO_4	TP	SRP	NH_4	NO_3	pH	ALK	Ca	K	Al	Fe	Mn
13 05 91	1	10.30	0.1	E0	8.0	17.90	6.74	4.09	0.01		<0.05	<0.10	4.2		0.9	0.1	0.10	0.277	0.007
23 07 91	1	12.30	0.1	E0	<0.1	14.63	7.17	7.22	0.14		<0.05	<0.10	4.2		1.1	0.2	0.08	0.272	0.009
				E1	<0.1	16.80	7.23	7.65	0.13		0.06	<0.10	4.2		1.0	0.2	0.08	0.281	0.009
				E2	<0.1	18.13	7.02	7.24	0.12		<0.05	<0.10	4.1		0.8	0.3	0.08	0.269	0.008
				E3	<0.1	28.40	7.81	7.86	0.17		0.25	<0.10	4.0		0.7	0.6	0.15	0.682	0.011
				E4	3.0	25.78	7.58	8.83	0.19		0.25	<0.10	4.1		0.8	0.6	0.16	0.813	0.014
				E5	2.0	25.50	7.42	8.40	0.22		0.23	<0.10	4.0		0.8	0.6	0.15	0.827	0.015
09 08 91	1	7.45	1.3	E0	9.7	22.68	5.00	19.90	0.09		0.64	0.17	4.1	0.0	1.2	0.6	0.12	0.303	0.007
				E1	10.0	24.70	5.10	19.80	0.07		0.67	0.18	4.0	0.0	1.7	0.7	0.13	0.335	0.008
				E2	10.5	26.60	5.00	19.00	0.07		0.68	0.16	3.9	0.0	0.9	0.6	0.11	0.317	0.007
				E3	11.5	24.93	4.80	18.50	0.09		0.76	0.15	3.9	0.0	1.1	0.6	0.14	0.368	0.009
				E4	10.5	24.58	4.70	19.20	0.07		0.71	0.12	3.9	0.0	0.9	0.4	0.11	0.493	0.010
				E5	5.5	24.18	4.60	18.50	0.05		0.55	0.12	3.9	0.0	0.9	0.5	0.13	0.514	0.012

APPENDIX B

POST-FERTILIZATION WATER QUALITY DATA

Post-fertilisation data for Dalmellington WEST site:

	Date		Time	l/s		SS	Hz	Cl	SO_4	TP	SRP	NH_4	NO_3	pH	ALK	Ca	K	Al	Fe	Mn
A	23 08 91	1	18.00	0.1	W0	5.0	0.88			0.22										
					W5	10.3	0.80			<0.01										
					W6	5.9	2.38			0.03										
B	18 09 91	1	6.00	0.3	W0	5.0	9.50			0.28	0.100					31.4	64.6	7.46	0.131	0.641
					W5	9.0	1.40			0.57	0.010					50.2	63.3	1.13	0.098	0.792
					W6	3.0	1.80			0.38	0.002					40.6	10.1	0.09	0.029	0.281
C	21 09 91	1	14.30	0.2	W0	24.0	4.40			0.79										
		2	14.45	3.9	W0	212.0	4.20			2.60						16.2	45.6	7.60	2.810	0.621
					W5	22.0	3.50			0.39						26.7	56.4	3.15	0.478	0.776
					W6	10.0	1.50			0.11						22.9	5.5	0.28	0.700	0.411
		3	15.00	14.1	W0	943.0	3.80			4.45	0.75					21.7	23.0	21.00	21.600	0.493
					W5	548.0	6.60			2.94	0.76					17.4	26.4	9.53	10.6	0.383
					W6	124.0	3.80			1.38	0.47					16.3	24.2	4.87	5.73	0.387
		4	15.15	8.4	W0	148.0	3.60			1.87										
					W5	143.0	2.80			2.94										
					W6	72.0	3.80			0.62										
		5	15.45	5.0	W0	65.0	3.30			0.99										
					W5	37.0	3.80			0.80										
					W6	43.0	2.60			0.45										
D	08 10 91	1	9.25	2.2	W0	2.7	1.93			0.10						12.9	8.2	0.78	0.128	0.111
					W5	4.0	2.50			0.08						12.2	7.7	0.68	0.175	0.126
					W6	1.8	1.73			0.04						11.8	6.7	0.50	0.129	0.115
E	31 10 91	1	8.00	32.0	W0	74.0	7.33	33.9	12.6	0.61	0.22	1.70	2.91	4.8	3.0	10.3	8.0	2.59	2.650	0.148
					W1	103.0	7.28	34.4	12.8	0.57	0.20	1.45	3.08	4.8	2.7	11.3	8.1	3.97	4.670	0.177
					W2	83.0	7.33	33.8	13.1	0.77	0.20	1.53	2.89	4.6	2.7	11.8	8.1	2.11	1.790	0.146
					W3	65.0	7.43	33.3	12.4	0.51	0.18	1.47	2.87	4.6	2.0	10.0	7.9	2.33	2.310	0.145
					W4	51.0	7.60	33.6	12.4	0.49	0.15	1.28	2.61	4.8	3.3	9.9	7.7	1.46	0.914	0.132
					W5	22.0	7.58	35.0	13.2	0.33	0.16	1.40	2.87	4.7	3.3	10.7	7.9	0.87	0.469	0.123
					W6	33.0	7.50	32.6	12.2	0.36	0.10	0.68	2.31	4.9	2.8	8.6	7.2	1.16	0.972	0.145
		2	9.30	22.0	W0	59.0	7.65	33.5	13.2	0.30		1.23	3.26	4.6	2.6	10.3	8.0	1.73	1.200	0.135
					W5	23.0	8.18	34.0	12.6	0.34		1.28	3.08	4.9	3.0	10.0	7.5	1.05	0.758	0.120
					W6	21.0	7.68	31.9	12.3	0.27		0.94	2.65	5.0	3.2	9.2	7.2	0.91	0.648	0.123
F	12 11 91	1	15.15	24.5	W0	142.0	7.68			0.31										
					W5	115.0	7.20			0.37										
					W6	40.0	6.75			0.20										
		2	16.00	29.5	W0	383.0	8.08			0.87	0.06					6.4	3.8	2.04	1.240	0.069
					W5	284.0	7.55			0.67	0.03					5.9	3.5	1.68	1.310	0.067
					W6	85.0	6.98			0.37	<0.01					5.6	3.4	0.78	0.436	0.060
G	09 01 92	1	9.30	9.8	W0	32.8	3.08			0.33	0.03					5.3	2.7	0.88	0.541	0.044
					W1	43.7	3.08			0.19	0.02					5.5	2.7	0.91	0.475	0.046
					W2	41.5	3.05			0.19	0.03					5.3	2.7	0.85	0.437	0.045
					W3	55.7	2.98			0.20	0.02					6.1	2.7	1.10	0.643	0.056
					W4	49.3	3.08			0.17	0.03					6.1	2.8	1.08	0.493	0.053
					W5	56.0	2.98			0.20	0.01					5.7	2.7	0.93	0.553	0.048
					W6	15.2	2.75			0.11	0.03					5.5	2.5	0.59	0.389	0.038

Post-fertilisation data for Dalmellington WEST site - Continued

	Date		Time	l/s		SS	Hz	Cl	SO_4	TP	SRP	NH_4	NO_3	pH	ALK	Ca	K	Al	Fe	Mn
H	02 02 92	1	18.15	0.4	W0	225.0	7.05			0.46	0.01					6.3	2.7	1.05	0.178	0.079
					W1	55.5	6.55			0.14	0.01					6.4	2.7	1.00	0.412	0.080
					W2	23.5	6.15			0.13	0.01					6.5	2.7	0.81	0.371	0.073
					W3	27.5	6.20			0.13	0.01					6.5	2.6	0.85	0.485	0.079
					W4	9.2	6.48			0.06	0.01					6.7	2.7	0.61	0.340	0.062
					W5	15.8	4.98			0.07	0.01					9.0	2.4	0.49	0.283	0.116
					W6	19.4	4.93			0.13	0.01					6.3	2.2	0.54	0.506	0.138
I	12 02 92	1	12.00	2.5	W0	91.9														
					W1	112.0														
					W2															
					W3	126.0														
					W4	62.8														
					W5	62.4														
					W6	28.3														
		2	12.30	2.8	W0	157.0	7.80			0.31	0.08					6.5	2.5	1.77	1.060	0.059
					W1	190.0	7.60			0.37	0.06					6.1	2.6	1.46	0.686	0.066
					W2	222.0	8.60			0.42	0.10					6.7	2.5	2.54	1.560	0.087
					W3	201.0	8.40			0.41	0.07					6.4	2.5	2.47	1.300	0.087
					W4	202.0	8.15			0.35	0.07					5.9	2.4	2.03	0.931	0.075
					W5	159.0	8.40			0.27	0.05					6.6	2.4	1.90	1.240	0.073
					W6	56.8	6.70			0.11	0.03					7.9	2.3	0.92	0.438	0.066
		3	13.00	2.8	W0	157.0														
					W1	173.0														
					W2	203.0														
					W3	214.0														
					W4	149.0														
					W5	110.0														
					W6	51.3														
		4	13.30	3.2	W0	142.0										5.4	2.3	1.99	1.400	0.059
					W1	159.0										5.6	2.3	2.03	1.360	0.066
					W2	179.0														
					W3	207.0										6.5	2.4	1.86	0.660	0.069
					W4	140.0										5.9	2.3	1.61	0.880	0.059
					W5	124.0										6.6	2.4	1.45	0.566	0.059
					W6	56.8										5.4	2.2	0.90	0.567	0.049
		5	14.00	4.7	W0	335.0														
					W1	235.0														
					W2	384.0														
					W3	382.0														
					W4	349.0														
					W5	270.0														
					W6	106.0														
		6	14.30	6.6	W0	515.0										6.3	2.4	4.57	2.850	0.096
					W1	603.0										6.4	2.4	4.53	1.910	0.109
					W2	543.0										7.5	2.4	4.88	2.520	0.108
					W3	630.0										6.7	2.4	5.67	3.920	0.131
					W4	544.0										7.2	2.4	5.10	3.460	0.119
					W5	487.0										6.5	2.3	3.62	2.370	0.087
					W6	182.0										5.0	2.5	2.05	1.410	0.077

Post-fertilisation data for Dalmellington WEST site - Continued

	Date		Time	l/s		SS	Hz	Cl	SO_4	TP	SRP	NH_4	NO_3	pH	ALK	Ca	K	Al	Fe	Mn
		7	15.00	5	W0	230.0														
					W1	235.0														
					W2	264.0														
					W3	247.0														
					W4	252.0														
					W5	210.0														
					W6	85.0														
J	06 03 92	1	18.00	1.7	W0	10.8	7.73	13.2		0.10						5.6	1.8	0.68	0.392	0.043
					W1	14.4	7.30	13.0		0.16						5.6	1.8	0.70	0.470	0.048
					W2	41.0	8.08	13.4		0.16						5.8	1.9	0.85	0.591	0.050
					W3	20.6	6.98	12.8		0.12						6.8	1.9	0.82	0.690	0.051
					W4	19.2	7.28	12.7		0.13						6.1	1.7	0.58	0.376	0.042
					W5	8.2	7.33	12.6		0.12						5.8	1.8	0.68	0.475	0.069
					W6	5.8	6.13	11.8		0.08						5.4	1.6	0.44	0.281	0.032
K	31 03 92	1	10.00	7.2	W0	548.0	14.55	6.3	5.82	0.96	0.03		1.32			7.3	1.8	6.36	5.330	0.117
					W1	655.0	13.28	6.3	6.01	1.07	0.02		2.15			7.1	1.8	3.71	0.525	0.101
					W2	561.0	13.43	6.4	5.80	0.96	0.03		1.42			7.2	1.8	6.01	4.500	0.122
					W3	505.0	12.58	6.3	5.78	0.92	0.05		1.09			7.0	1.7	4.82	2.520	0.110
					W4	499.0	13.80	6.5	5.74	0.82	0.05		1.03			7.0	1.7	4.66	3.760	0.118
					W5	400.0	11.98	6.5	5.74	0.69	0.03		1.09			6.3	1.7	4.32	3.740	0.105
					W6	127.0	9.48	6.5	5.54	0.30	0.04		0.55			4.8	1.6	1.55	0.977	0.088
L	14 04 92	1	7.30	1.7	W0											4.6	1.6	0.94	0.609	0.044
					W1											4.4	1.6	0.95	0.625	0.048
					W2											5.8	1.5	1.03	0.672	0.052
					W3											5.4	1.6	1.08	0.753	0.055
					W4											4.7	1.5	0.83	0.561	0.048
					W5											5.5	1.5	0.84	0.586	0.052
					W6											5.7	1.2	0.59	0.389	0.037
M	24 04 92	1	7.30	3.5	W0	53.5	24.70													
					W1	55.0	24.70													
					W2	50.0	24.88													
					W3	86.0	24.65													
					W4	45.0	23.68													
					W5	35.1	23.08													
					W6	20.0	19.20													
		2	9.30	5.2	W0	116.0	11.65	5.30		0.25	0.09		0.26			4.4	1.4	1.26	0.829	0.040
					W1	127.0	11.85	5.30		0.30	0.08		0.27			5.2	1.4	1.43	0.823	0.048
					W2	153.0	12.88	5.12		0.31	0.08		0.35			4.3	1.4	1.47	0.869	0.058
					W3	133.0	12.20	5.30		0.33	0.09		0.32			4.0	1.4	1.55	1.080	0.052
					W4	142.0	11.55	5.18		0.32	0.09		0.34			5.8	1.5	1.56	1.020	0.061
					W5	107.0	11.38	5.15		0.30	0.08		0.30			4.3	1.4	1.70	1.200	0.060
					W6	63.3	6.28	5.36		0.19	0.07		0.11			3.9	1.2	0.79	0.587	0.047
		3	10.00	7.2	W0	225.0	27.00													
					W1	240.0	26.25													
					W2	238.0	26.75													
					W3	231.0	27.25													
					W4	217.0	26.25													

[redacted]

Post-fertilisation data for Dalmellington WEST site - Continued

Date	Time	l/s		SS	Hz	Cl	SO_4	TP	SRP	NH_4	NO_3	pH	ALK	Ca	K	Al	Fe	Mn
4	10.45	8.4	W0	151.0	27.25													
			W1	181.0	27.75													
			W2	26.1	27.00													
			W3	222.0	27.25													
			W4	214.0	26.75													
			W5	180.0	27.25													
			W6	55.5	21.58													
5	11.15	11.0	W0	331.0	9.13			0.56						6.0	1.5	2.22	0.772	0.063
			W1	301.0	8.15			0.54						6.1	1.5	3.08	2.320	0.064
			W2	430.0	8.73			0.71						4.5	1.5	3.36	1.840	0.092
			W3	337.0	7.60			0.70						5.1	1.5	2.62	1.070	0.072
			W4	357.0	7.68			0.65						4.9	1.5	2.57	0.945	0.075
			W5	292.0	8.15			0.49						5.3	1.4	1.62	1.400	0.074
			W6	133.0	2.88			0.29						3.7	1.3	1.53	0.699	0.062
6	12.00	11.0	W0	115.0	5.05													
			W1	113.0	5.30													
			W2	217.0	5.10													
			W3	188.0	5.25													
			W4	151.0	4.93													
			W5	113.0	4.35													

Post-fertilisation data for Dalmellington EAST site:

	Date		Time	l/s		SS	AU	Cl	SO_4	TP	SRP	NH_4	NO_3	pH	ALK	Ca	K	Al	Fe	Mn
A	23 08 91	1	18.30	0.1	E0	7.2	13.68			6.25										
					E5	3.1	12.48			<0.01										
B	18 09 91	1	6.30	0.3	E0	12.0	8.70			9.72	9.300					18.2	47.3	0.95	0.284	0.044
					E5	7.0	7.50			0.67	0.760					9.6	30.3	0.50	0.294	0.143
C	21 09 91	1	15.30	10.0	E0	40.0				7.36	7.450					12.7	35.2	0.62	0.363	0.029
					E5	17.0				5.46	5.300					7.1	26.4	0.55	0.311	0.084
E	31 10 91	1	8.30	27.0	E0	28.0	14.00	28.90	10.60	1.96	1.730	2.47	0.53	4.0	0.0	3.3	9.8	0.22	0.299	0.018
					E1	30.0	13.40	28.40	11.10	1.93	1.740	1.70	0.53	3.9	0.0	3.3	10.0	0.20	0.333	0.019
					E2	26.0	13.25	27.60	12.00	1.91	1.750	2.43	0.52	3.9	0.0	3.7	10.0	0.21	0.199	0.018
					E3	24.0	13.73	28.20	10.90	2.04	1.740	2.21	0.52	3.9	0.0	3.3	9.8	0.22	0.299	0.018
					E4	9.0	11.50	24.60	9.00	1.43	1.520	1.49	0.41	3.9	0.0	2.7	8.5	0.20	0.292	0.039
					E5	12.0	13.40	30.90	11.00	1.85	1.740	1.53		3.9	0.0	3.5	10.3	0.19	0.240	0.022
G	09 01 92	1	10.00	6.2	E0	11.7	6.33			0.98	0.740					1.3	3.3	0.12	0.263	0.004
					E1	10.7	6.35			0.97	0.780					3.3	3.3	0.08	0.265	0.005
					E2	10.3	6.48			0.97	0.770					2.2	3.4	0.15	0.280	0.005
					E3	49.5	6.35			1.08	0.780					1.4	3.4	0.17	0.400	0.008
					E4	16.7	6.30			1.00	0.770					2.3	3.4	0.16	0.488	0.007
					E5	5.6	6.33			0.97	0.760					2.2	3.2	0.12	0.324	0.005
H	02 02 92	1	18.30	0.3	E0	4.8	20.08			2.50	2.250					1.6	4.8	0.20	0.254	0.006
					E5	2.8	19.38			2.26	1.900					1.7	4.8	0.21	0.496	0.009
I	12 02 92	1	15.30	3.5	E0	8.0	24.40			1.17	1.480					2.4	4.0	0.18	0.282	0.006
					E1	8.0	24.70			1.35	1.490					2.0	4.2	0.17	0.259	0.006
					E2	15.5	25.00			1.15	1.490					3.2	4.1	0.19	0.284	0.007
					E3	6.0	24.50			1.18	1.510					3.3	4.1	0.17	0.308	0.006
					E4	1.3	24.90			1.19	1.540					1.9	4.3	0.18	0.363	0.007
					E5	3.0	24.60			1.16	1.480					1.9	4.2	0.18	0.391	0.008
J	06 03 92	1	18.30	1.3	E0	5.4	28.75	19.10		1.09										
					E5	6.0	27.50	14.70		1.11										
K	31 03 92	1	11.00	5.2	E0	144.0	25.13	5.69	2.82	0.67	0.740		0.15			1.9	2.5	0.26	0.598	0.011
					E1	182.0	26.48	5.93	3.20	1.05	0.750		0.14			2.4	2.4	0.27	0.698	0.006
					E2	191.0	26.13	5.87	3.48	1.12	0.760		0.15			1.6	2.4	0.30	0.769	0.008
					E3	172.0	25.43	5.74	3.64	1.12	0.760		0.14			1.6	2.5	0.23	0.689	0.007
					E4	31.5	23.68	5.88	3.93	0.93	0.760		0.14			1.2	2.4	0.15	0.336	0.005
					E5	10.7	23.55	5.90	4.16	0.88	0.770		0.14			1.1	2.4	0.11	0.309	0.005
L	14 04 92	1	9.00	9.3	E0											1.8	2.7	0.18	0.255	0.005
					E1											1.7	2.7	0.18	0.261	0.005
					E2											2.2	2.7	0.19	0.300	0.006
					E3											1.4	2.7	0.17	0.285	0.005
					E4											1.3	2.8	0.18	0.414	0.005
					E5											1.4	2.7	0.18	0.448	0.007
M	24 04 92	1	9.00	2.8	E0	9.0	36.00	5.89		1.24	<0.01		<0.10			1.2	2.3	0.18	0.291	0.005
					E1	11.5	35.50	5.95		1.40	<0.01		<0.10			1.3	2.3	0.16	0.300	0.005
					E2	15.5	35.75	6.01		1.12	<0.01		<0.10			1.9	2.3	0.15	0.322	0.005
					E3	9.6	35.75	5.89		1.18	<0.01		<0.10			2.9	2.3	0.15	0.316	0.005
					E4	6.8	36.25	5.83		1.06	<0.01		<0.10			1.5	2.3	0.17	0.401	0.005
					E5	1.5	35.25	6.07		0.80	<0.01		<0.10			1.5	2.2	0.16	0.429	0.006