Project 208

The Disposal of Sheep Dip Waste
Effects on Water Quality

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SCOTLAND & NORTHERN IRELAND FORUM FOR ENVIRONMENTAL RESEARCH

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R&D Report 11

The Disposal of Sheep Dip Waste

Effects on Water Quality

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This document contains information on the current state of knowledge concerning the effect of disposing of sheep dip chemicals on ground and surface water quality. It indicates options for the future and outlines further potential for research. It is intended for information only.

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FOREWORD

The dipping of sheep is carried out for the welfare of these animals. That is why the chemicals used are classified as veterinary medicines. No-one should question the need to control ectoparasitic infection of sheep; although if alternative methods to sheep dipping could be found, then this would be very welcome. Sheep dipping is nevertheless a practice which results in a waste product which is potentially harmful to the environment, and thus equally no-one should challenge the need to ensure that such waste is disposed of in such a manner that environmental harm does not result. It is also a practice with the potential to contaminate ground and surface waters from a multitude of sources which are difficult to control. The NRA has already expended considerable effort in developing policies and practices to protect groundwater. It has similarly attempted to reduce the impact of diffusely distributed sources of pollution, particularly those arising from agricultural practices. In order to strengthen even further its ability to safeguard the quality of waters under its control, the NRA has therefore funded research and development work to examine the effects of sheep dip waste disposal on the aquatic environment. This report draws together the findings of this research, which will be used to develop future policy and produce guidelines.

It is, however, clear that the use of soakaways is no longer an acceptable disposal method and that other methods - such as collection, treatment, or disposal in suitable areas by suitable means - must be further explored. It will also be necessary to consider further how best to get the message across to the farming community, and as to what areas of research need further to be explored.

DR R J PENTREATH
Chief Scientist and Director of Water Quality

January 1994

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GLOSSARY

Active ingredient	The insecticide used in a dip formulation.
Bactericide	Phenolic compounds used to prevent bacterial growth in the dipper.
Dip concentrate	The product as supplied to farmers before dilution.
Dipper	The bath in which sheep are immersed.
Organochlorine pesticides	Family of active ingredients no longer permitted in dip.
Organophosphorous pesticides	Family of active ingredients currently most widely used in dip.
Regulatory water organisations	The NRA for England and Wales; the River Purification Boards for Scotland; the Environmental Protection Division of DoE Northern Ireland.
Sheep dip	A solution containing bactericide and pesticide in which sheep must be totally immersed to control ectoparasites.
Sheep dip waste	The liquid remaining in the dipper after dipping.
Stripping	The removal of the active ingredient from dip by adsorption onto sheep's fleece. This is how organophosphorous pesticides work, but does not happen with pyrethroids.
Synthetic pyrethroids	Family of active ingredients sometimes used in dip. Currently only flumethrin is scab-approved.
U100	100-mm diameter core recovered by percussion drilling, about 450mm long.

NOTATION

gal	gallon
ha	hectare
kg	kilogram
l	litre
$l\ m^{-2}$	litres per square metre
m	metre
m^3/s	cubic metres per second
$mg\ kg^{-1}$	milligrams per kilogram
$mg\ l^{-1}$	milligrams per litre
Ml	megalitre (10^6 l)
ml	millilitre
mm	millmetre
$ng\ l^{-1}$	nanograms per litre
$\mu g\ l^{-1}$	micrograms per litre
V	Volt

SUMMARY

This report was prepared for the National Rivers Authority under Project 208 of the National R&D Programme, and for the Scotland and Northern Ireland Forum for Environmental Research.

The aims of the project were to investigate the impact of the disposal of sheep dip waste, principally on groundwater quality, but also with regard to disposal onto shallow soils overlying impermeable bedrock. In the latter situation, typical of much of the sheep farming land of northern Great Britain, the perceived threat was to surface water quality because of lateral migration of polluted water along the rock/soil boundary.

A national survey of sheep farming and dipping practices was carried out and presented as a separate report (R&D Interim Report 208/7/N) in 1991, a summary of which is included in this report. A number of catchment-based studies was carried out in Devon, Sussex, Northern Ireland and Scotland. A total of six dip disposal sites in these areas was investigated.

Questionnaires were circulated to farmers in catchments in Devon and Sussex to determine background information on dipping and dip disposal. Alternative disposal methods for waste dip are reviewed.

Evidence was found of pollution of the unsaturated zone, and groundwater at sites on aquifers where dip was disposed of at high loading rates. Pollution of surface water and soil contamination is likely at sites on shallow soils and impermeable bedrock where disposal is to soakaway. However, surface water pollution may be limited by the high dilution rates involved. Determining peak stream concentrations is difficult with routine chemical sampling; biological monitoring of macroinvertebrates is a useful tool when monitoring for dip pollution.

Recommendations aimed at controlling and preventing the pollution of surface and groundwaters by sheep dip waste are given in Chapter 8 (page 40).

KEY WORDS

Sheep dip, Groundwater pollution, Freshwater pollution, Organophosphorus pesticide, Organochlorine pesticide, Synthetic pyrethroid, Soakaway

1. INTRODUCTION

As a result of concerns expressed by the National Rivers Authority (NRA) and SNIFFER[1], a two-year research contract has been carried out by WRc to investigate the effects of the disposal of sheep dip waste on water quality. This is the final report of that contract (Project 208 of the NRA's National Research and Development Programme). Originally the project was to concentrate on the impact of disposal of sheep dip waste to soakaway on groundwater quality, but the aims were expanded to include the effects on surface waters in the upland sheep farming catchments typical of Scotland and Northern Ireland.

The project falls into four main sections:

- a survey of sheep rearing and sheep dip usage in the UK;
- studies of four catchments in which sheep farming is important;
- site investigations in each of the these catchments; and
- identification of possible alternative routes of disposal.

A survey of national sheep populations and sheep dip formulations was carried out in 1990 and 1991. This has been presented separately to SNIFFER and the NRA (Bascombe and Clark 1991); a summary of these findings appears in this report.

This R&D Report presents the principal findings of the work carried out. Full details of the methods used and results obtained are given in the associated output, R&D Project Record 208/10/N.

[1] The Scotland and Northern Ireland Forum For Environmental Research (SNIFFER) administers funds for common interest research with WRc on behalf of the Department of Environment for Northern Ireland (Environmental Protection Division), the Scottish Regional Councils and the Scottish River Purification Boards.

2. BACKGROUND

2.1 Project History

The disposal of sheep dip waste has been identified as a threat to the quality of groundwater resources by the UK water industry for a number of reasons:

- actual pollution incidents due to sheep dip;
- the general problems of pesticide use and disposal on aquifers;
- worries about the widespread use of soakaways on aquifers; and
- the toxicity of the active ingredients used in dip.

A wide range of guidelines to farmers on sheep dip disposal has been issued in the past by a number of organisations. These have included the NRA (and by the Water Authorities before 1989), the Department of the Environment for Northern Ireland (DoE NI), the Scottish River Purification Boards (RPBs), the Ministry of Agriculture, Fisheries and Food (MAFF) and its agencies, and dip concentrate manufacturers. Although there has been liaison between some of these groups in the past, the guidelines issued were not consistent. In particular, the advice by some organisations to dispose of the waste dip to soakaway seemed to be concentrating on the protection of surface water resources at the expense of groundwater. Given that groundwater makes up 35% of the total public supply in England and Wales, this situation clearly required review. In fact, the active ingredients used in sheep dip both at present and in the past are classed as List I substances by the EC Directive on the Protection of Groundwater (CEC 1980), the implementation of which under UK law makes uncontrolled discharge of these substances to an aquifer an offence.

Figure 2.1 (page 15) shows the distribution of major UK aquifers and this can be compared to Figure 2.2 showing the intensity of sheep farming in the UK. Fortunately, the major sources of groundwater supply tend to be away from intensive sheep farming areas. However, the Chalk Downs of south-east England are quite intensively farmed and also form a major source of groundwater, and sheep farming takes place on most aquifers to some extent. The pollution risk to surface waters from sheep dipping is shown on page 16 in Figure 2.3 (NRA and MAFF 1992).

This project was designed to provide information about the scale and nature of the problem of waste dip disposal to soakaway and to assist the NRA in reviewing existing guidelines on disposal, in consultation with MAFF and other interested parties. The project was equally supported by SNIFFER whose principal interests were in the effects of dip disposal in upland hard rock areas with shallow soils. This situation is typical of many of the most intensive sheep farming areas in the UK, and it was felt that lateral movement of dip waste along the rock head could pose a threat to surface water courses.

Figures 2.4 to 2.7 (pages 17 and 18) show examples of sheep dips and dip disposal sites encountered during this project.

2.2 Related WRc Work

2.2.1 Proposed Environmental Quality Standards for sheep dip chemicals in water

In 1991, WRc undertook an assessment of suitable Environmental Quality Standards (EQSs) for a number of pesticide compounds. Note that this is only a summary; for full background to the derivation and selection of EQSs, reference should be made to the original report (R&D Note 216). This earlier report proposed EQSs pertaining to the protection of aquatic life, for the principal pesticides in use in sheep dip preparations in the UK. These pesticides are chlorfenvinphos, coumaphos, diazinon, fenchlorphos and propetamphos (organophosphorus) and flumethrin (synthetic pyrethroid). The report reviewed their properties and uses, physical chemistry, fate in the environment and environmental concentrations, and critically assessed available data on their aquatic toxicity and bioaccumulation. This information was used to derive tentative EQSs for the protection of freshwater and saltwater life.

The standards derived (Table 2.1) were based on the limited aquatic toxicity data available, and where insufficient data were available, no EQS was proposed (e.g. flumethrin).

Because sheep dipping is carried out intermittently and the active ingredients are more likely to enter watercourses during dipping periods, both short-term and long-term EQSs have been proposed. The short-term EQSs (maximum allowable concentrations, MACs) were designed to afford protection against relatively transient exposure to high levels of dip pesticides, while the long-term EQSs (annual average concentrations, AAs) should permit healthy aquatic communities to

Table 2.1 Environmental Quality Standards proposed for sheep dip chemicals in water (Lewis *et al.* 1991)

Sheep dip chemical	Environmental Quality Standard (EQS)[a] Freshwaters (ng l^{-1})	Saltwaters (ng l^{-1})
Chlorfenvinphos	100 MAC[b]	-[c]
	10 AA[b]	-[c]
Coumaphos	100 MAC[b]	400 MAC
	10 AA[b]	40 AA
Diazinon	100 MAC	150 MAC
	10 AA	15 AA
Fenchlorphos	100 MAC[b]	-[c]
	10 AA	-[c]
Flumethrin	-	-
	-	-
Propetamphos	100 MAC[b]	-[c]
	10 AA[b]	-[c]

MAC Maximum allowable concentration
AA Annual average concentration
- Insufficient data to propose an EQS
[a] EQS proposed for the protection of aquatic life
[b] EQS based on EQS proposed for diazinon in freshwater
[c] Interim EQS could be based on EQS proposed for freshwater

The use of these chemicals is not exclusive to sheep dip formulations; some are also used in agriculture and other areas where insect control is needed. Except for diazinon there are only limited data in the literature on the amounts of compounds used for sheep dipping, their environmental fate and their toxicity to aquatic organisms. Additional information was requested from the major dip manufacturers and distributors but has, in the majority of cases, not been provided. A move towards greater co-operation between dip manufacturers and

survive and persist during longer periods of exposure to lower concentrations.

2.2.2 A national survey of sheep stocking densities and dip types

A survey was undertaken early in the project (R&D Interim Report 208/7/N) to study distributions of sheep in the UK, identify regional dipping and dip disposal practices, list and assess chemicals used in dip and identify areas of the UK where surface and groundwaters may be affected by sheep dip disposal. The survey forms an important part of the overall project, and is summarised here.

Data collection

The survey was necessarily broad in scope as the whole of the UK was reviewed in terms of sheep stocking density and dip usage. The very wide range of dip types, each often marketed under a considerable number of different trade names, did not facilitate a detailed assessment of each dip. This was complicated still further when a formulation of dip had changed but retained the same manufacturer's and trade names. Deosan Ltd, for instance, while retaining the old product names, changed the active component of their Traditional and Regional Dips from 3.5% lindane to 50% diazinon following the ban on lindane. Also, despite assurances of confidentiality, there appeared to be a reluctance among both manufacturers and suppliers to divulging qualitative information concerning dip formulations and, more especially, quantitative information, which inevitably reflects sales figures. As mentioned in Section 2.2.1, this reluctance to divulge information proved to be a major hindrance to attempts to address the problems of pollution from sheep dip. Greater collaboration between all interested parties would be extremely useful.

The survey findings were therefore founded on a considerably smaller database than had originally been hoped, and specific aspects of the study, in particular quantitative assessments of dip usage, must necessarily be considered with caution. It was not possible to provide a regional breakdown of use split into the different formulations on the market. Nevertheless, the combination of information published in different sources enabled a fairly broad database to be compiled concerning the past and present formulations of the most commonly occurring sheep dips.

Owing to the perceived need for confidentiality by the Trading Standards Officers (TSOs) of local councils, it was not possible to obtain detailed information on dip locations; such information would have been invaluable in assessing pollution risk. TSOs were responsible for enforcing the Sheep Scab Orders and as such held comprehensive databases on dip locations within their regions. Similarly, although TSOs may have had information on the prevalence of mobile or fixed dippers, it is not readily available. With the move away from compulsory dipping, such records that do exist may be lost or become out of date, and controls on dipping will be reduced.

Agricultural census data readily available from MAFF, the Scottish Office Agriculture and Fisheries Department (SOAFD) and the Department of Agriculture for Northern Ireland (DANI) enabled maps of sheep stocking density to be prepared. This information was also incorporated into a geographical information system (GIS) under NRA project 001 on Sources, Impact and Detection of Farm Pollution for further analysis in relation to risk-determining factors such as soil type, rainfall and slope (see Figure 2.3). Due to the large-scale nature of the assessment, site-specific pollution risk factors (such as proximity of dipper to watercourse, environmental half-life[1] of active ingredient, etc.) could not be accommodated as they could be in a smaller-scale study.

A computer literature search on the AQUALINE and DIALOG databases was carried out to identify relevant literature on sheep dip usage, supplemented by literature gathered from personal contacts. Of 83 references identified, only 15 were of direct relevance to the water quality effects of the active components considered. Many of the references found centred on the toxicological effects of the active ingredients and have been considered elsewhere (R&D Project Record 053/7/HO).

A list of the names and addresses of the suppliers and manufacturers of sheep dip concentrates was compiled; this is included as an Appendix to the R&D Project Record 208/10/N. This was done through contacts within the water industry, the KOMPASS directory (KOMPASS 1989), the BASIS list of registered properties, MAFF, DAFS and TSOs.

Details of stock density were gathered from the respective agricultural census branches of MAFF, DAFS and DANI. These data were collated on a spreadsheet and finally processed into graphical form as a map of the UK (Figure 2.2). Broad estimates of the quantities of toxic components posing a risk to water resources were made based on general figures for quantities of dip concentrate used and the diluted volumes produced. Assuming two dips per year and five litres (l) of diluted dip solution per sheep per dip (Robertson, S., pers comm, 30.12.1991), about 400 million litres (Ml) of diluted dip are used annually (40 million sheep in the UK in 1988). At an average dilution rate of 1:200, this means that 2 Ml of dip concentrate are sold annually, of which a very variable proportion is active ingredient. However, assuming 75% to be organophosphorus-based (5-60% active ingredient) and 25% pyrethroid (2.5-6.0% active ingredient), the annual UK sheep dip consumption is of the order of 75 000-900 000 l of organophosphorus (mostly diazinon, propetamphos and chlorfenvinphos) and 12 500-30 000 l of pyrethroid (flumethrin).

Ectoparasites

The report gave details of the main ectoparasites of sheep for which they may be dipped:

Sheep scab: Considered to be the most debilitating mange of sheep, active all year round. Outbreaks in recent years peaked in 1983 (160), although the number of outbreaks is thought to be on the increase again (Good, E.A.M., pers comm, 30.12.91).

Blowfly and headfly: Fly larvae attack the fleece, causing it to be shed around the infested area. Also a very serious condition.

[1] The half life is the average time taken (in seconds) for the number of radioactive atoms present to be reduced by half.

Ticks: Severe infestations may occur in spring and autumn. Young lambs need to be dipped in spring to prevent infestation.

Lice: Often a major problem when over-wintering sheep indoors. Controlled by winter dip.

Keds: Similar to lice and treatment similar.

Pour-on or spray-on preparations may usually be used to control all but scab. However, because dipping for scab has been compulsory in the past, most farmers use dipping for the other treatments as well.

The nature of sheep dips

As recently as 1984, lindane, dieldrin and DDT (organochlorine pesticides) were the principal active ingredients in sheep dip. These compounds have all been withdrawn from use as sheep dips, and all but lindane are banned altogether in the UK, because of their toxicity, persistence and tendency to accumulate in the food chain. As a result, in the early 'eighties, the dip manufacturers began to look for alternatives, resulting in the development of new dips based on the organophosphorus pesticides coumaphos, iodofenphos, chlorpyrifos, fenchlorphos, carbophenothion, propetamphos, diazinon and chlorfenvinphos. Partly as a result of worries about the effects of the organophosphorus pesticides on the health of farmers carrying out dipping, synthetic pyrethroid pesticides such as flumethrin, cypermethrin and deltamethrin were also incorporated into dip formulations. All of these new groups of pesticide are purported to be less persistent in the environment than the organochlorines, although compounds in both of the new groups are toxic to mammals and fish. Dips also contain an oily solvent and a bactericide based on phenolic compounds; occasionally inorganic compounds such as copper and aluminium sulphate are found in dips.

Currently, dip formulations are most likely to contain diazinon, propetamphos, flumethrin or chlorfenvinphos. The first three of these are approved by MAFF for the control of sheep scab. In the past the dip concentrate used by farmers during the statutory dip period had to contain one of these three as the active ingredient. Although List I substances under the EC Groundwater Directive, the organophosphorus pesticides have yet to become routinely incorporated into the analytical suites used by the Regulatory Water Authorities for either groundwater or surface water.

The majority of samples for this project was analysed only for chlorfenvinphos, diazinon and propetamphos; analysis for flumethrin would have doubled analytical costs, and is the least widely used of the current active ingredients. The relative properties of the three organophosphorus pesticides considered are summarised below:

Solubility in water (20° C)
Source: Lewis *et al.* (1991)

chlorfenvinphos	>	propetamphos	>	diazinon
145 mg l^{-1}		110 mg l^{-1}		40 mg l^{-1}

Mammalian toxicity (LD50[1])
Source: British Greyhound (1991)

chlorfenvinphos	>	propetamphos	>	diazinon
25 mg kg^{-1}		75 mg kg^{-1}		300 mg kg^{-1}

Degradation rate
Source: Rammell *et al.* (1988) and Rammell and Bentley (1989)

diazinon	>	propetamphos	>	chlorfenvinphos

Regional pattern

The regional pattern of sheep farming was assessed and the results plotted as a map showing numbers of sheep per hectare of grazing land (Figure 2.2). In addition, all the NRA Regions, the Scottish RPBs and the Environmental Protection Division (EPD) of DoE NI were contacted to discover how much of a threat sheep dipping activities were perceived to be to water quality in their area. Awareness of the problem was widespread, but perhaps best appreciated, not surprisingly, in areas such as Scotland and Wales with high sheep populations. The number of reported pollution incidents was widely thought to be only 'the tip of the iceberg', because little routine monitoring has been carried out for dip pesticides and the effects of dip pollution, particularly on groundwater, are not nearly as obvious as, for instance, those of slurry or silage.

[1] The LD50 is the dose required to kill 50% of the test organism.

3. THE CURRENT SITUATION

3.1 Sheep Farming and Dipping

Dipping is carried out to control a number of ectoparasitic infestations of sheep for a combination of economic, cosmetic and animal welfare reasons. Sheep scab, caused by the mites *Psoroptes ovis* or *Sarcoptes scabiei. P. ovis*, is perhaps the most serious condition caused by such ectoparasites, and can result in serious discomfort to the sheep, or even death if left untreated (Kirkwood 1986). However, the condition is readily cured by dipping using a dip with a suitable active ingredient (insecticide).

Because of its seriousness, sheep scab has been treated in the past as a notifiable disease, and preventative dipping of all sheep in the UK was compulsory during periods designated by the government, once or twice per year. In addition, sheep are dipped as necessary at other times to control any ectoparasitic infestations which occur. However, all conditions caused by ectoparasites on sheep can be controlled by methods other than dipping, except for scab. In 1992, no compulsory Scab Order was issued for England, Wales or Scotland, while the matter is currently under review in Northern Ireland. The reason stated for this change of policy was that outbreaks of scab are relatively uncommon (1500 outbreaks between 1973 and 1991, and 116 flocks out of 105 000 in Great Britain affected in 1991) and consequently the best way to prevent unnecessary use of dipping was thought to be the control of outbreaks as they occur. Consequently, there will be no statutory monitoring of dipping in Great Britain in future.

Dipping sheep entails total submersion of the animal in a bath containing a solution made up with dip concentrate which contains an active ingredient to control the ectoparasite and a phenol-based bactericide to prevent bacterial growth in the dipper. Of these compounds, the active ingredient has the greatest potential for harming mammals and fish, and consequently analysis for this project has been confined to these compounds. In the past, active ingredients have included lindane, DDT and dieldrin, but all have been withdrawn because of their persistence in the environment and toxicity to aquatic life.

Currently most dips contain an organophosphorus pesticide or a synthetic pyrethroid. These are supposed to be more amenable to biodegradation in the environment than the organochlorine pesticides, and are not readily soluble in water. The principal pesticides in use are flumethrin (a synthetic pyrethroid), diazinon, propetamphos, coumaphos and chlorfenvinphos. The organophosphorus pesticides can attack the nervous system of mammals and fish by suppressing acetylcholinesterase function. The synthetic pyrethroid pesticides are thought to be less toxic. Sheep may sometimes be treated with a 'polishing' dip, which contains no active ingredient and merely improves the appearance of the sheep.

Methods of waste dip disposal vary, but a 1981 MAFF survey indicated the following distribution (Good, E.A.M., pers comm, 30.12.91):

soakaway	60%
directly onto nearby land	23%
cesspool	8%
sprayed on fields	5%
not known	4%

The apparent predominance of the use of soakaways, which effectively inject the pollutant into the aquifer or subsurface, by-passing any attenuating effect that the soil might provide, is of some concern.

3.2 Groundwater Monitoring for Organophosphorus Pesticides

To obtain a broader picture of the effects of sheep dip disposal on groundwater quality than that provided by the site investigations, all ten[1] Regions of the NRA were asked about any monitoring that they might have carried out for the organophosphorus pesticides.

All the NRA Regions are still at the planning stage of their routine groundwater monitoring programmes, although some are close to implementing these plans. Consequently, several of the regions referred to data supplied by the corresponding Water Utility, while the remainder had only limited data to consult.

Only two Regions, Yorkshire and Welsh, had any records of monitoring for organophosphorus pesticides in groundwater. The data from Yorkshire NRA related to work carried out by the then Yorkshire Water Authority (YWA) (YWA Interim Report 1988) looking specifically at the problems of the disposal of sheep dip waste to groundwater. Two public supply boreholes in sheep farming areas were sampled and no organophosphorus (OP) or organochlorine pesticides

[1] Since this work was completed the number of NRA Operational Regions has been reduced to eight by merging Northumbria with Yorkshire and South West with Wessex.

were detected; details of the extent of the sampling were not known. Welsh NRA knew of only one spring which had been sampled for OP pesticides, and again none were detected.

Only NRA Northumbria Region stated that it would definitely be including the OP pesticides in its groundwater analytical suite. The other Regions would analyse only where they had reason to suspect pollution from sheep dip waste, and a number thought there was insufficient sheep farming in their region for a problem to arise.

3.3 Surface Water Monitoring for Organophosphorus Pesticides

The monitoring of surface waters for organophosphorus pesticides has tended to be limited, and often related to specific pollution events. Analytical methods are being developed, and analyses for these pesticides will probably increase in future. However, a small number of studies aimed specifically at monitoring the effects of dip pesticides on surface water have already been carried out, for instance those reported by Littlejohn and Melvin (1989,1991) in the Grampian Region and in the Tweed RPB area (Currie 1992).

4. FIELDWORK

A major part of this project consisted of a number of fieldwork-based surveys of the effects of the disposal of sheep dip waste on the quality of surface and groundwater. These were carried out in four different catchments, one each in Devon, Sussex, Scotland and Northern Ireland, to cover as wide a range of sheep dipping and dip disposal practices as possible.

4.1 Work Programme

Background information was gathered for each catchment on dipping and dip disposal, and six dipping sites were examined in more detail, with sampling being carried out to determine the extent of migration of pesticides from the dip disposal area. The catchment areas chosen for study were:

- the River Rother, West Sussex;
- two sub-catchments of the River Taw, Devon;
- Wooplaw Burn, Borders Region, Scotland; and
- three tributaries of the River Bann, County Down, Northern Ireland.

4.2 The River Rother Catchment, West Sussex

The catchment of the River Rother lies to the north of Chichester in West Sussex. The catchment and its underlying geology are shown in Figure 4.1. The South Downs form a southern boundary to the catchment, resulting in a west-to-east flow direction of the river for much of its course.

The strata exposed in the Rother catchment are entirely of the Cretaceous period and range from the oldest, Weald Clay, through Lower Greensand, Gault and Upper Greensand to the youngest, Chalk.

The presence of the Greensand and Chalk aquifers in the catchment area, combined with relatively intensive sheep farming for south-east England were major factors in choosing this catchment. The two sites chosen for more detailed investigation were situated on the Greensand and Chalk aquifers, and were both locations where waste dip was drained out onto the same small area of pasture every time dipping took place. At each site, two 20-metre (m) boreholes were drilled to recover U100 core samples, or bagged samples where coring failed. One borehole penetrated the dip disposal area, while the second was located about 20 m away to detect

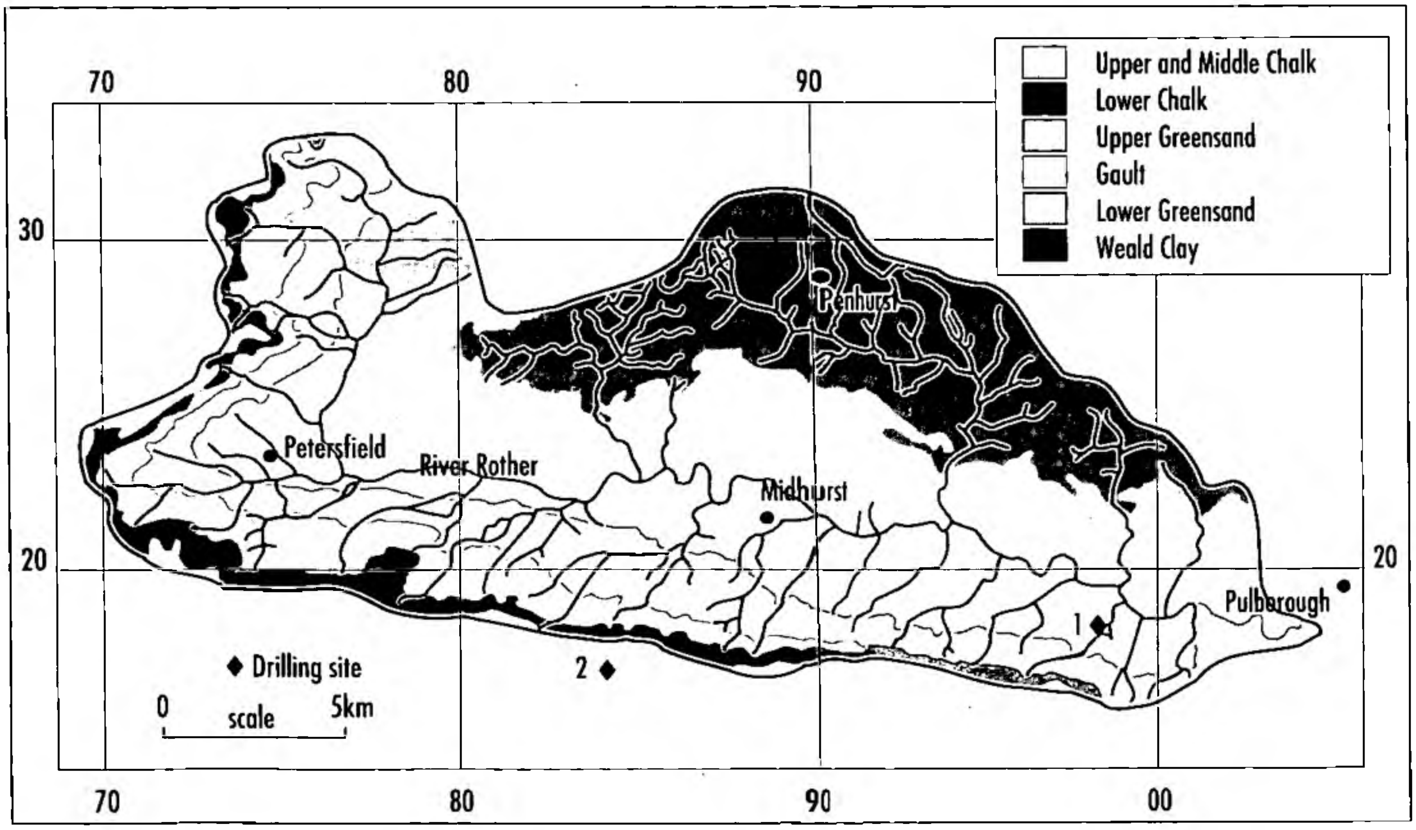

Figure 4.1 The River Rother catchment: Geology

lateral movement of the waste dip. The design specified for all complete boreholes is shown in Figure 4.2.

The Greensand site was located on a medium-sized farm near Petworth, which was managed as part of a larger estate. A plan of the site is shown in Figure 4.3.

Dipping was carried out using an 1100-l (240-gal) mobile dipper , which was parked in the farmyard. Spent dip was pumped out into large plastic tanks, which were then emptied out onto the same area of pasture every year, the waste dip soaking away almost immediately. About 1300 sheep were held at any one time, these being dipped between one and three times per year. Each dipping session required two full dipper volumes, resulting in 2200 l of waste dip for disposal. The usual brand of dip used was Ciba-Geigy Topclip Gold Shield, containing 60% w/w (weight in weight) diazinon. The waste dip drained through a thin, sandy soil into the Cretaceous Folkestone Beds of the Lower Greensand Formation, the latter consisting of coarse to medium sands with occasional clay lenses. The loading

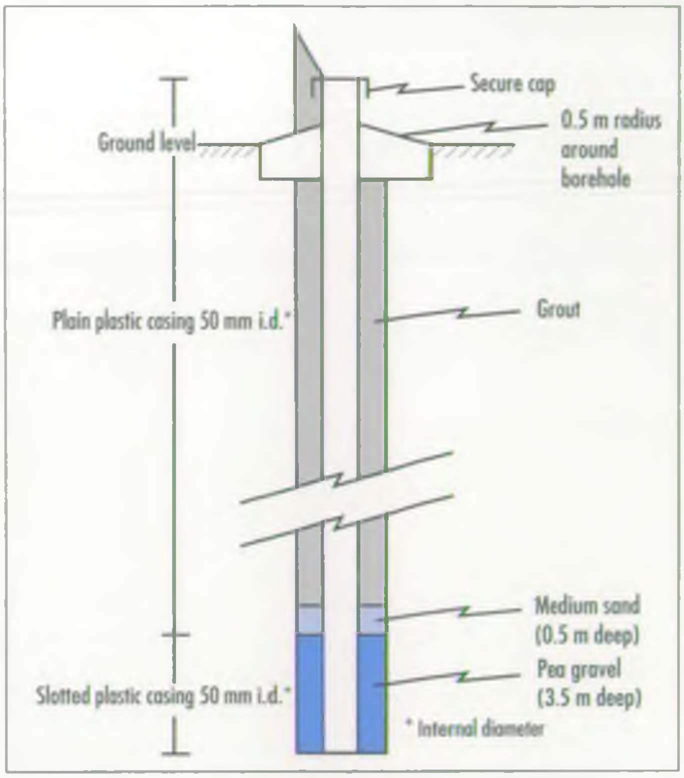

Figure 4.2 Design for groundwater sampling boreholes

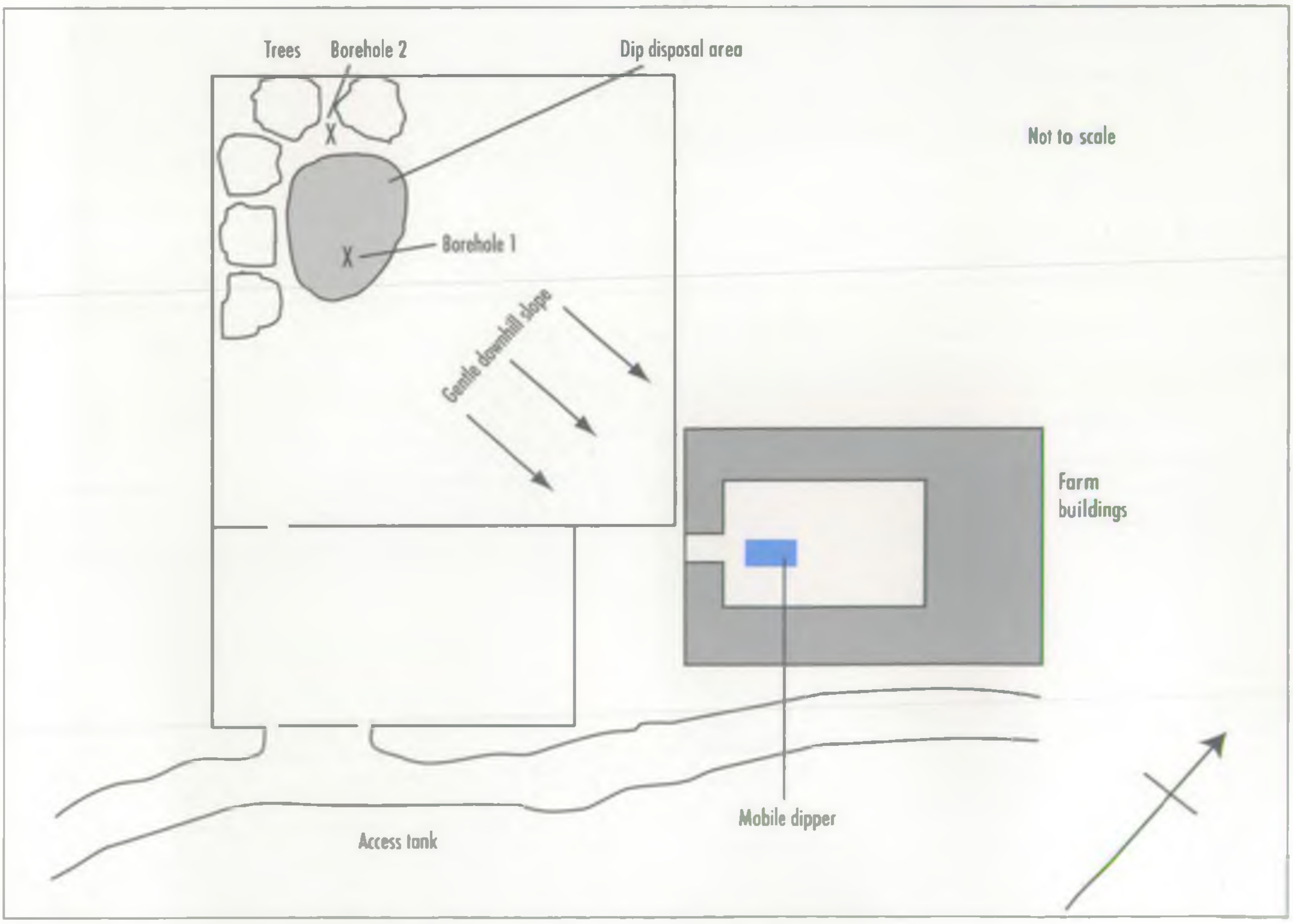

Figure 4.3 Site plan of dipping and dip disposal site on the Greensand, West Sussex

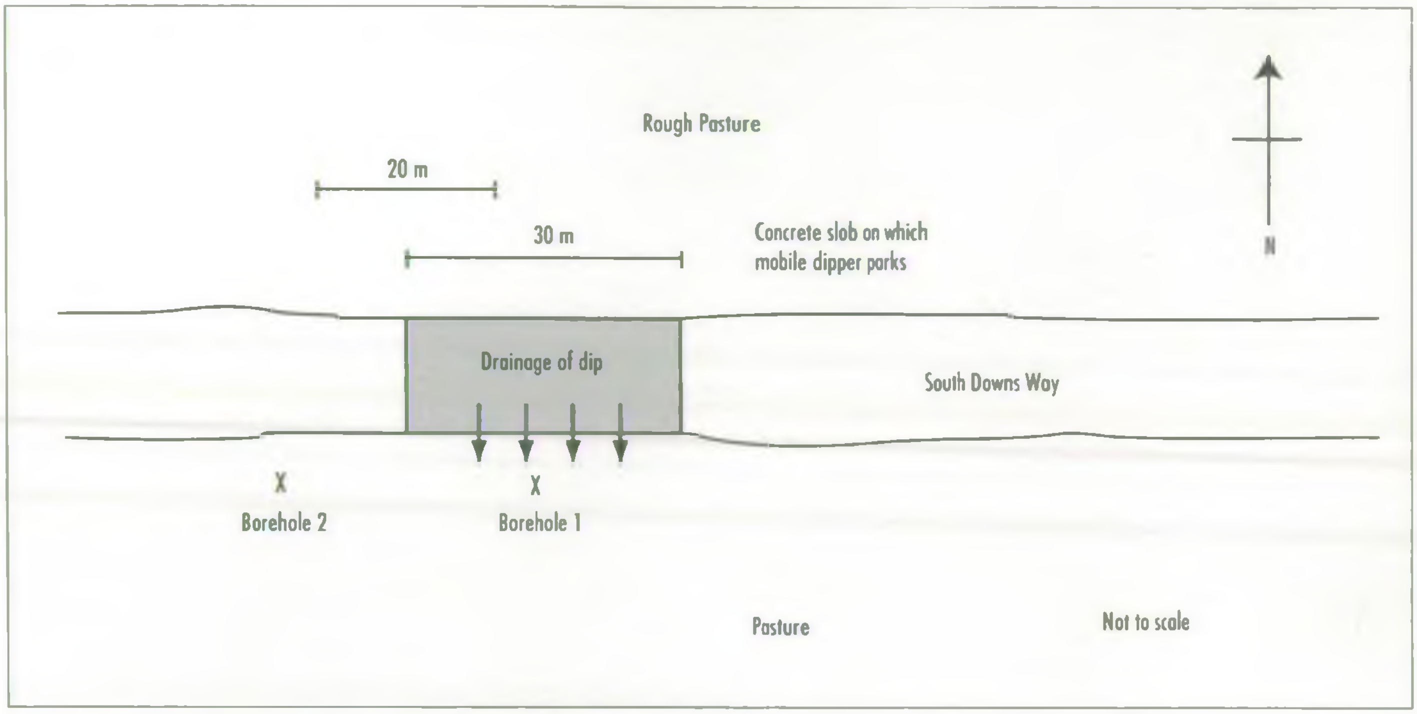

Figure 4.4 Site plan of dipping site on the Chalk, West Sussex

rate used here was probably of the order of 100 l m^{-2}, well in excess of the current guidelines (e.g. 0.5 l m^{-2} - the National Office of Animal Health (NOAH) and MAFF).

The Chalk site was situated at about 200 m AOD[1] on the South Downs Way, near Midhurst. A plan of the site is shown in Figure 4.4. Dipping was carried out using a 1600-l (350-gal) mobile dipper which was parked on a concrete slab as indicated in the site plan. Drainage of the waste dip was directly onto the slab, from where the liquid drained onto pasture, soaking in rapidly. The site had been in use for at least six years before drilling took place, with one or two dips per year. In total, about 2500 sheep were dipped on each occasion, usually using Ciba-Geigy Topclip Gold Shield (60% w/w diazinon). The dip waste drained through a very thin silty topsoil into the Upper Chalk. The Chalk is the major aquifer of the region, and is composed of soft, white, fine-grained limestone with flints and some marl bands in its lower part.

4.3 The Taw Catchment, Devon

The Taw catchment was identified as suitable for study because there had been instances of surface water pollution from sheep dip documented in the catchment in the past (South West Water 1984a and 1984b). Although the area does not include any major aquifers, there is some exploitation of groundwater for domestic supplies and the catchment also includes examples of upland sheep farming (Dartmoor and Exmoor), which could provide results applicable to the particular problems in SNIFFER's area.

After initial discussion, the Upper Taw and River Bray catchments were chosen for more detailed study, as the whole Taw catchment was considered too extensive. The geology of the area and the two catchments are marked on Figure 4.5.

The headwaters of the Upper Taw rise in the peat bogs of northern Dartmoor which overlie the granite intrusion (Figure 4.5). The river flows north across a mixture of metamorphosed rocks of the Carboniferous Limestone Series and intrusive igneous strata near Belstone. The River Bray rises on high ground at the southern edge of Exmoor, passing over progressively younger strata as the river flows southwards. No formation in either catchment is a significant source for groundwater supply.

One of the sites chosen for detailed investigation was located in the Bray catchment near South Molton, on the Bude Formation (or Culm Measures), a sequence of sandstones and shales, with local exploitation of the sandstone for water supplies, mostly to farms. The second site was in the Upper Taw catchment on Dartmoor, adjacent to the river.

The Bude Formation site (Figure 4.6) was situated on a farm close to South Molton, which allowed other farms to use its dipper, although no sheep had been kept on

[1] Above Ordnance Datum; ie above sea level based on a point at Newlyn in Cornwall.

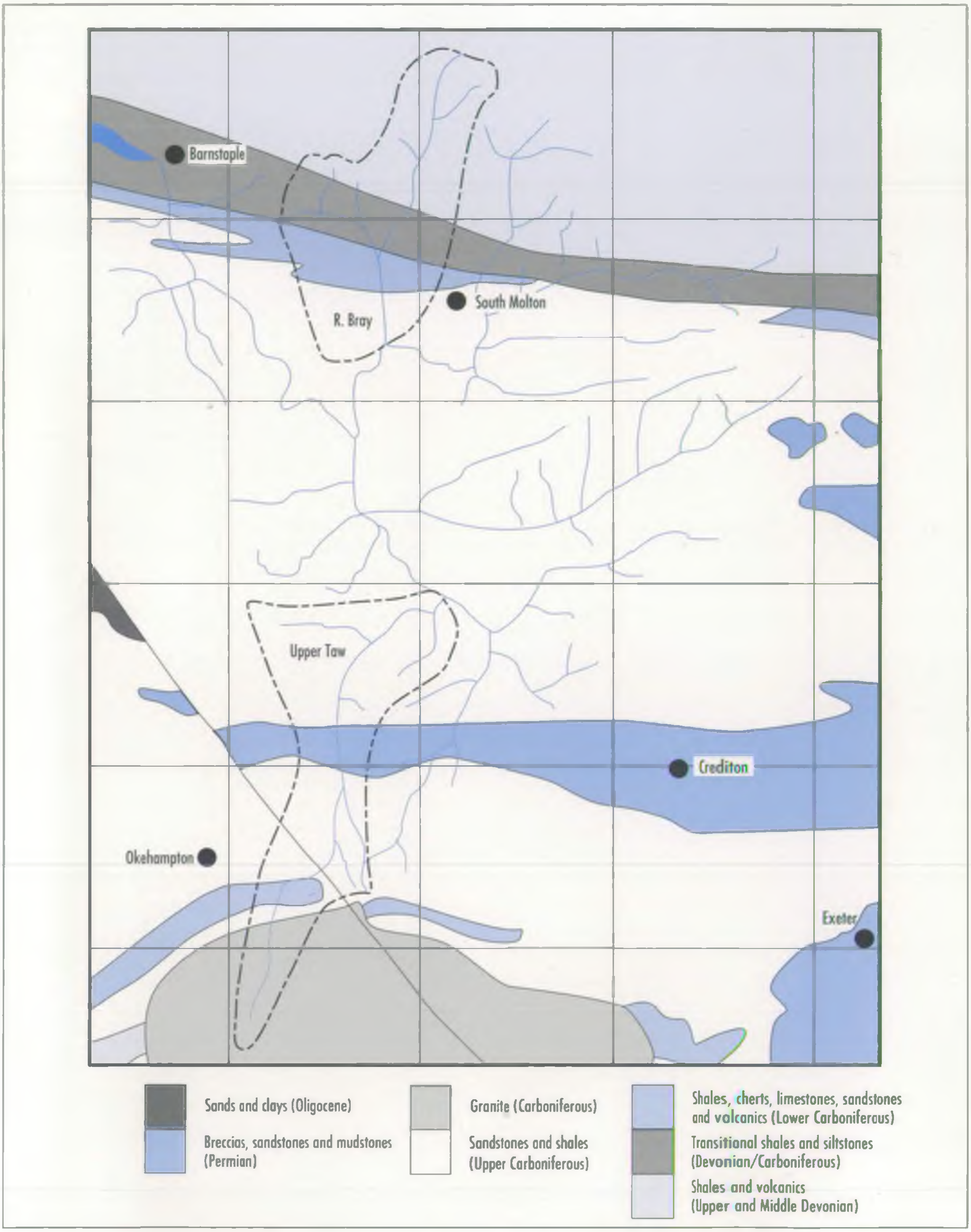

Figure 4.5 The Taw catchment: Geology

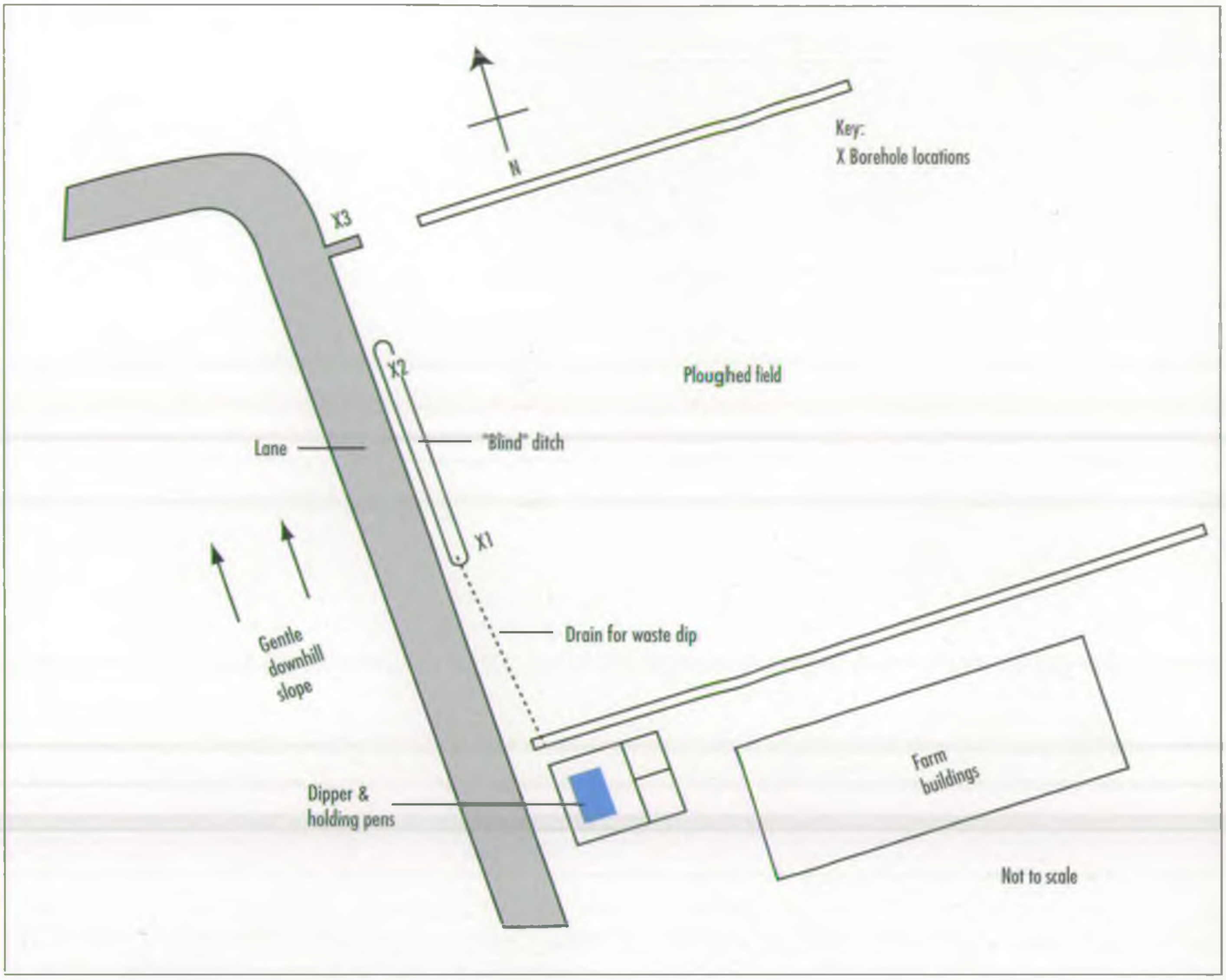

Figure 4.6 Site plan of the dipping site on the Bude Formation, Devon

the farm for over two years. The dipper, in use for over ten years, was used perhaps twice each year in recent years to dip 500 sheep at a time. The volume of the dipper was estimated as about 1800 l (400 gals). Records showed that Ciba-Geigy Topclip Gold Shield (diazinon-based), Young's Ectomort (propetamphos-based) and ICI Gamma-HCH (γ-HCH-based) had been used in recent years.

The dip was emptied via a drain from the bottom which ran for about 50 m downhill underground, emerging at the top of a blind ditch along the edge of a field used for growing potatoes. The waste dip rapidly soaked into the ground within several metres of the point of emergence, draining through a shallow soil into heavily vertically fractured shales, and then into fractured, hard, granular sandstone.

The drilling at this site was more complex than that in Sussex because of the hardness and variety of rock types encountered. A percussion rig was used to drill as far as possible, recovering U100 cores. When percussion drilling became impossible, a rotary 'pendant' attachment was used to continue coring to the full depth, recovering 54-mm diameter cores.

Three boreholes were drilled at this site. Borehole No. 1 was to 20 m depth, at the point where waste dip emerged into the ditch. Boreholes No. 2 and 3 were 10 m deep, located in line down the edge of the field. Groundwater samples were taken from each borehole using a 12-V submersible pump.

The plan of the Dartmoor site is shown in Figure 4.7. A fixed dip, about 2300 l (500 gals) in volume, was allowed to drain into a soakaway built in the shallow sand overlying the Dartmoor Granite. The soakaway comprised 2-m diameter concrete rings sunk to about 6 m below ground and backfilled with boulders and sand. The spent dip was allowed to remain in the dipper

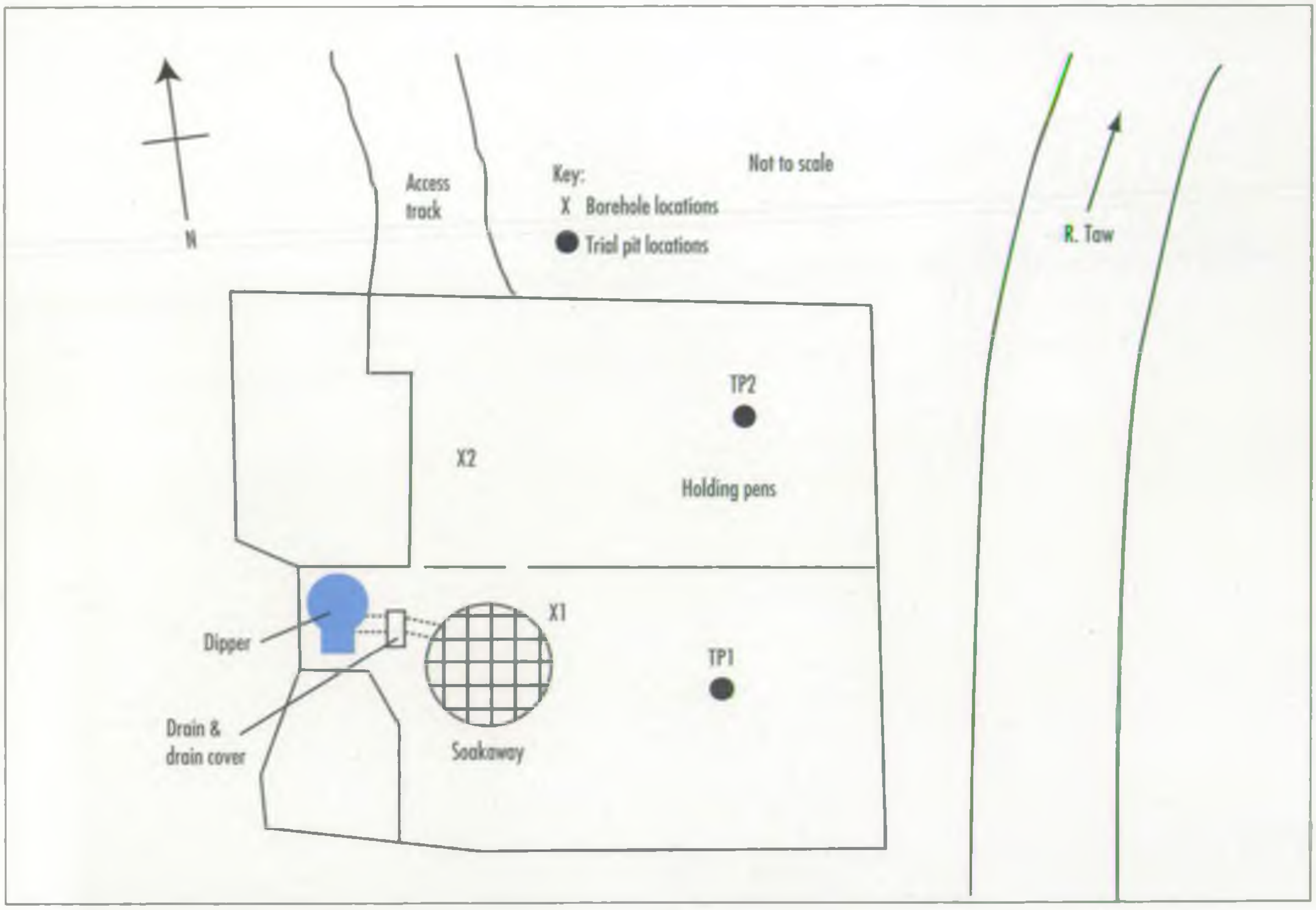

Figure 4.7 Site plan of the Dartmoor dipping site, Devon

until the next time it was required, before draining into the soakaway. Behind the dip, away from the River Taw, a large collection of empty dip concentrate cans had accumulated.

A flock of 1000 sheep was dipped in batches of 500 three times per year, and the dipper had been in the same location since the last century. No records were available of the types of dip used, but the cans behind the dipper indicated the use of a wide range of brands containing chlorfenvinphos, propetamphos and diazinon. Many of the cans were not identifiable due to corrosion.

The sands which surrounded the dipper did not appear to be hydraulically connected to the River Taw; drainage was either by overland flow through the gate and over some marshy ground to the river (this was observed during very heavy rainfall) or through a small spring which emerged into the river at the downstream corner of the holding pens.

Because of the presence of granite boulders in a sandy matrix, drilling to recover U100 cores was not possible. Instead, two trial pits were excavated to about 3 m depth to recover disturbed samples, while rotary drilling was used to recover samples from the weathered zone of the granite bedrock to 10 m below ground. Samples were taken of river and spring water, as well as pumped groundwater samples from the boreholes and baled water samples from the trial pits.

4.4 Wooplaw dipper, Borders Region

Wooplaw Burn, a tributary of the Tweed, drains a catchment area of about one square kilometre on the border between Scotland and England, south of Jedburgh. The site was chosen because it is in an area of intensive sheep farming, with impermeable drift cover meaning that dip disposal was likely to be a threat to surface water, not groundwater, quality. In addition, the whole catchment of this small burn fell within the land owned by the farmer operating the dipper, and the dipper was the only one in the catchment. Invaluable co-operation was provided by staff of Tweed RPB and by the farmer himself.

The location of the dipper is shown in Figure 4.8. The dipper holds about 1200 l (250 gals) of dip, and has been in use for over 30 years. The flock size has varied little in

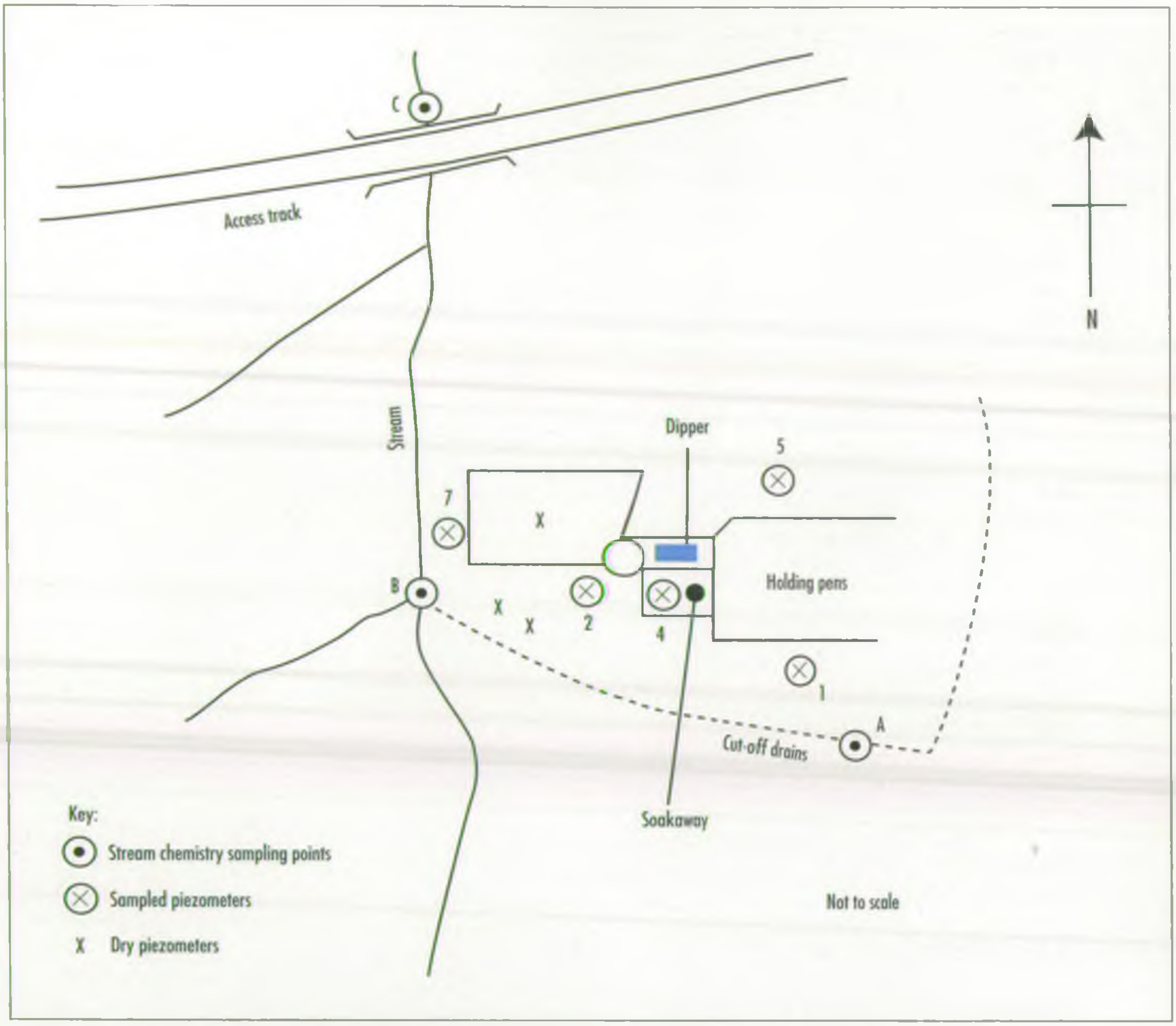

Figure 4.8 Site plan of the Wooplaw dipper, Borders Region, Scotland

this time and currently stands at about 800 ewes and 1000 lambs. The number of annual dips ranges from one to three, but in 1991 it was three, the brands in use being Young's Tick and Fly Dip and Young's Ectomort (both propetamphos-based). Previous types used included Young's Jason (propetamphos), Cooper's Border Winter and Summer Dips (chlorfenvinphos and diazinon) and dip based on γ-HCH. A 23-l (5-gal) drum of concentrate is used for each dipping session, simply topping up with water and dip concentrate as necessary. Because of water removed on the sheep's fleeces, only about 650 l of dip remain for disposal. This drains into a soakaway next to the dipper, via a short length of pipe. The soakaway currently in use was dug in 1991, to about 2.5 m depth and about 2.5 m diameter, backfilled with boulders. The soakaway is usually saturated because of the impermeable nature of the soil.

Between 9 July 1991 and 6 January 1992, regular weekly or fortnightly stream samples were taken upstream and downstream of the dipper. More frequent monitoring was carried out to coincide with dipping in October. In addition to the stream sampling, a number of piezometers were installed to 2 m below ground level to sample the soil water. Routine samples were analysed for organophosphorus pesticides, while during intensive sampling, analysis was also carried out for organochlorine pesticides.

In addition to the chemical monitoring, invertebrate

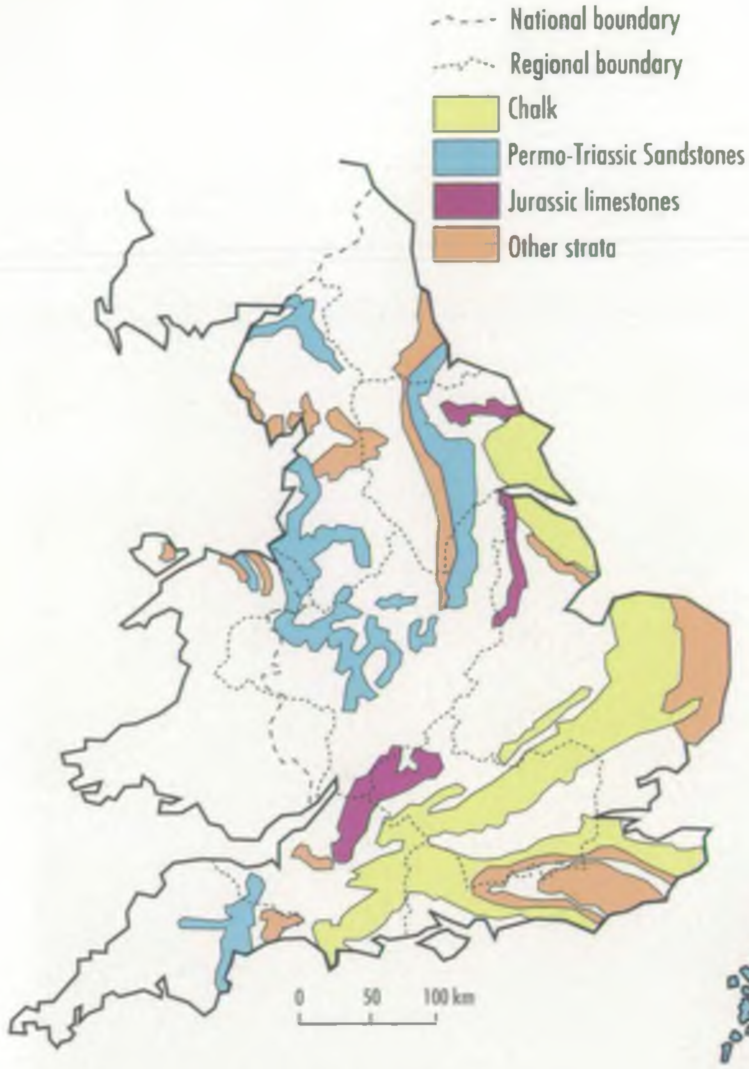

Figure 2.1 Major aquifers in England and Wales

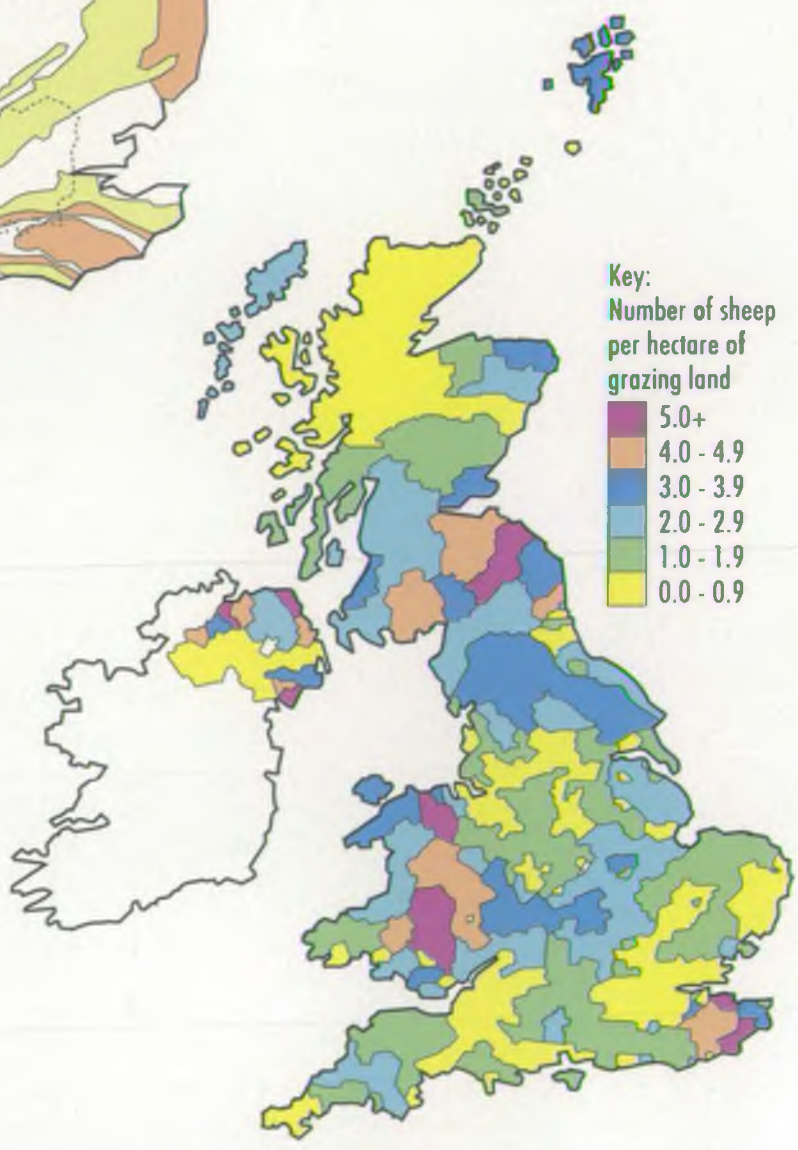

Figure 2.2 Map of UK showing the intensity of sheep farming operations

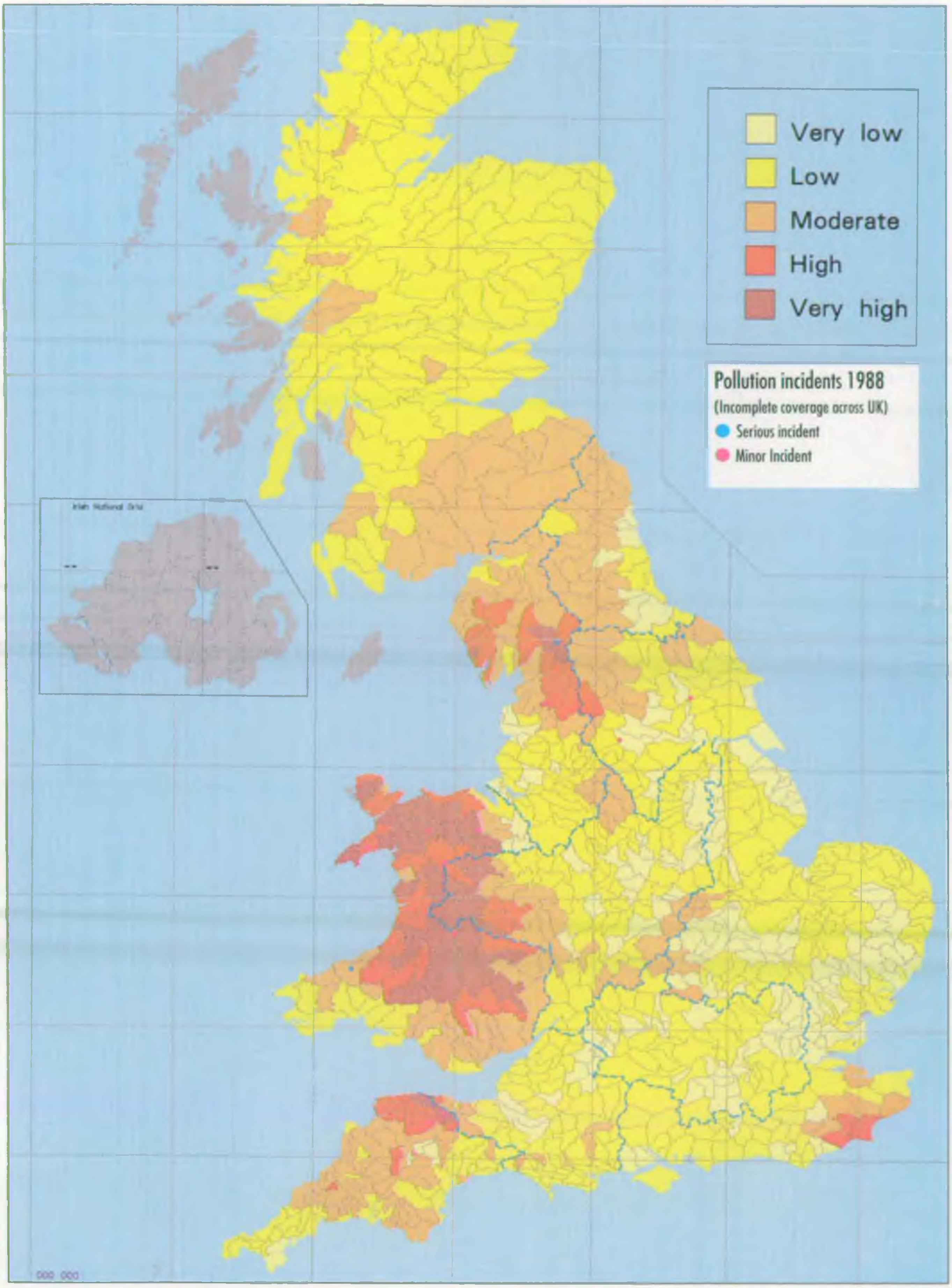

Figure 2.3 Map showing the pollution risk to surface waters from waste sheep dip

Figure 2.4 A typical sheep dipping operation (Scotland)

Figure 2.5 View from a dipper to dip disposal area (Northern Ireland)

Figure 2.6 Dipper on Dartmoor showing disposal of old cans, with rotary drilling rig in background

Figure 2.7 General view of typical dipper and holding pens, Dartmoor

sampling was carried out regularly by Tweed RPB staff, upstream and downstream of the dipper. The upstream site was approximately 100 m above the dipper, where the stream was almost totally overgrown by dense foliage. The substrate varied greatly from bedrock through to deep sediments. Upstream samples contained large amounts of vegetable detritus. The downstream site was located approximately 400 m below the dipper, where the stream was open and samples were almost free of vegetable detritus. However, the substrate still varied from bedrock to sediments. Samples were taken using a standard hand net and three minutes of sampling. Samples were fixed in 4% formaldehyde for subsequent analysis.

4.5 The Rocky River, Shanky's River and Leitrim River Catchments, County Down

Fieldwork studies in Northern Ireland were based on three adjacent catchment areas which are all tributaries of the River Bann. Rocky River, Shanky's River and Leitrim River all drain from the north-western flanks of the Mourne Mountains (Figures 4.9 and 4.10). No flow data were readily available for these rivers, but an average flow rate was estimated as of the order of 2 m^3/s for each, although because of the 'flashy' nature of the catchments, wide flow variations were observed.

These river catchments were chosen in conjunction with staff of the EPD of DoE Northern Ireland, partly because the locations of almost all dippers, and the dip disposal method, were known. These are shown in Table 4.1 and marked on Figures 4.9 and 4.10. As can be seen, the Shanky's and Rocky River catchments contained only one known dipper each. Between 10 July and 20 December 1991, weekly or fortnightly samples were taken from upstream (A) and downstream (B) of the Rocky River dip, and from the Leitrim River (E) at Leitrim Bridge. From 29 October, samples were also taken from upstream (C) and downstream (D) of the Shanky's River dip. More intensive stream sampling at all five sites was timed to coincide with the compulsory dipping period for Northern Ireland (1 October to 11 November).

Samples taken were analysed for organophosphorus pesticides, and for organochlorine pesticides during the intensive sampling period.

In addition to surface water samples, six soil samples were taken from the area around the Rocky River dip on 31 October to check for build-up of pesticides in the soil, and their possible migration to the river. A plan of the Rocky River site is shown in Figure 4.11, along with the soil sampling points. The waste dip drained straight into a ditch running away towards the river. However, after only about 10 m the ditch fanned out into a broad area of peaty soil. This area had a noticeably greener crop of grass than the surrounding moorland. Between this area and the river there were two steep slopes, followed by flatter, marshy terrain, with a total distance

Table 4.1 Details of dippers in the Leitrim, Rocky and Shanky's Rivers catchments, Northern Ireland

Number*	Catchment	Method of disposal	Brands of dip in use
1	Leitrim River	Via manhole to soakaway	Young's Scab Approved Dip and Cooper's Winter Dip 200 (diazinon & propetamphos-based respectively) (all dippers)
2 A&B	Leitrim River	Sprayed onto land	
3	Leitrim River	Drains directly onto field	
4	Leitrim River	Sprayed on land	
5	Leitrim River	Drains directly onto field	
6	Leitrim River	Emptied by bucket onto paddock	
7	Shanky's River	Held in tank then sprayed onto forestry	
8	Rocky River	Drains directly onto moorland	

* See Figures 4.9 and 4.10

from dip to river of perhaps 150 m and a vertical difference of about 20 m.

Soil samples were taken along a line down the steepest slope, and hence most likely drainage path, between the dip and the river. Samples 1, 2, 3 and 4 were from the dip outwash area at increasing distances from the dip. Samples 6 and 7 came from the marshy ground below the second slope, close to the river. Sample 10 was from close to the sheep holding pens (see Figure 4.11) Samples of about 2 kg of soil were taken with a 100-mm hand auger, taking material from the surface to depths of between 300 and 500 mm. The sampling depth was governed by the point at which the underlying granite was reached; this could not be penetrated by the hand auger and examination of exposed soil profiles elsewhere suggested that water was trapped in the organic rich peaty soil either by the impermeability of the granite, or by a well developed iron-pan at about 300-500 mm below the surface.

In addition to the soil samples, a sample of water was taken from one of a number of water-filled rectangular pits, about 1 m x 0.75 m in plan and perhaps 0.5 m deep, which dotted the area. The pit sampled lay between soil sampling points 2 and 3. This unpreserved sample was sent with the subsequent batch of river water samples for analysis for the organophosphorus pesticides. This was sample P1.

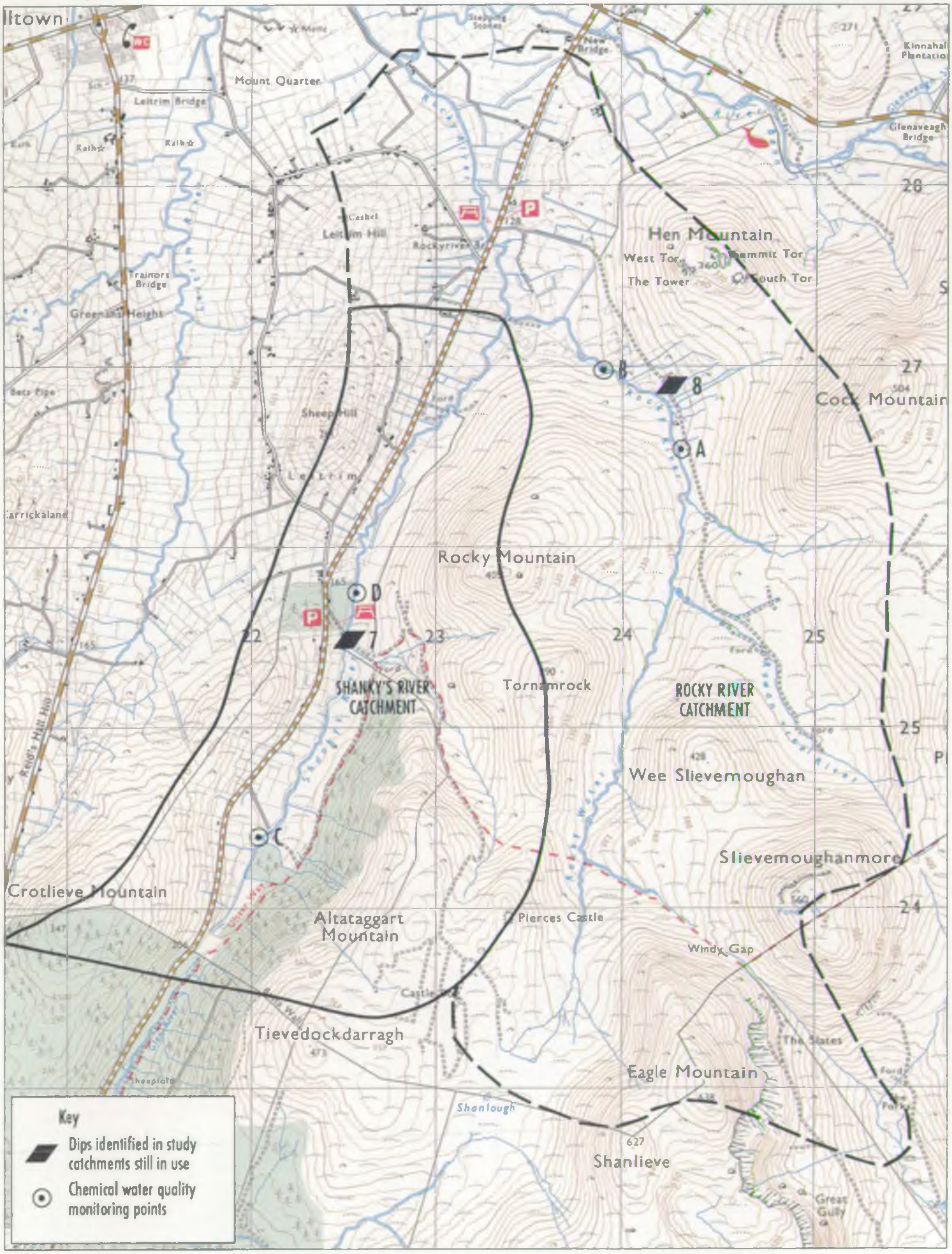

Figure 4.9 Map shawing the Rocky River and Shanky's River catchments in the Mourne Mountains, Northern Ireland

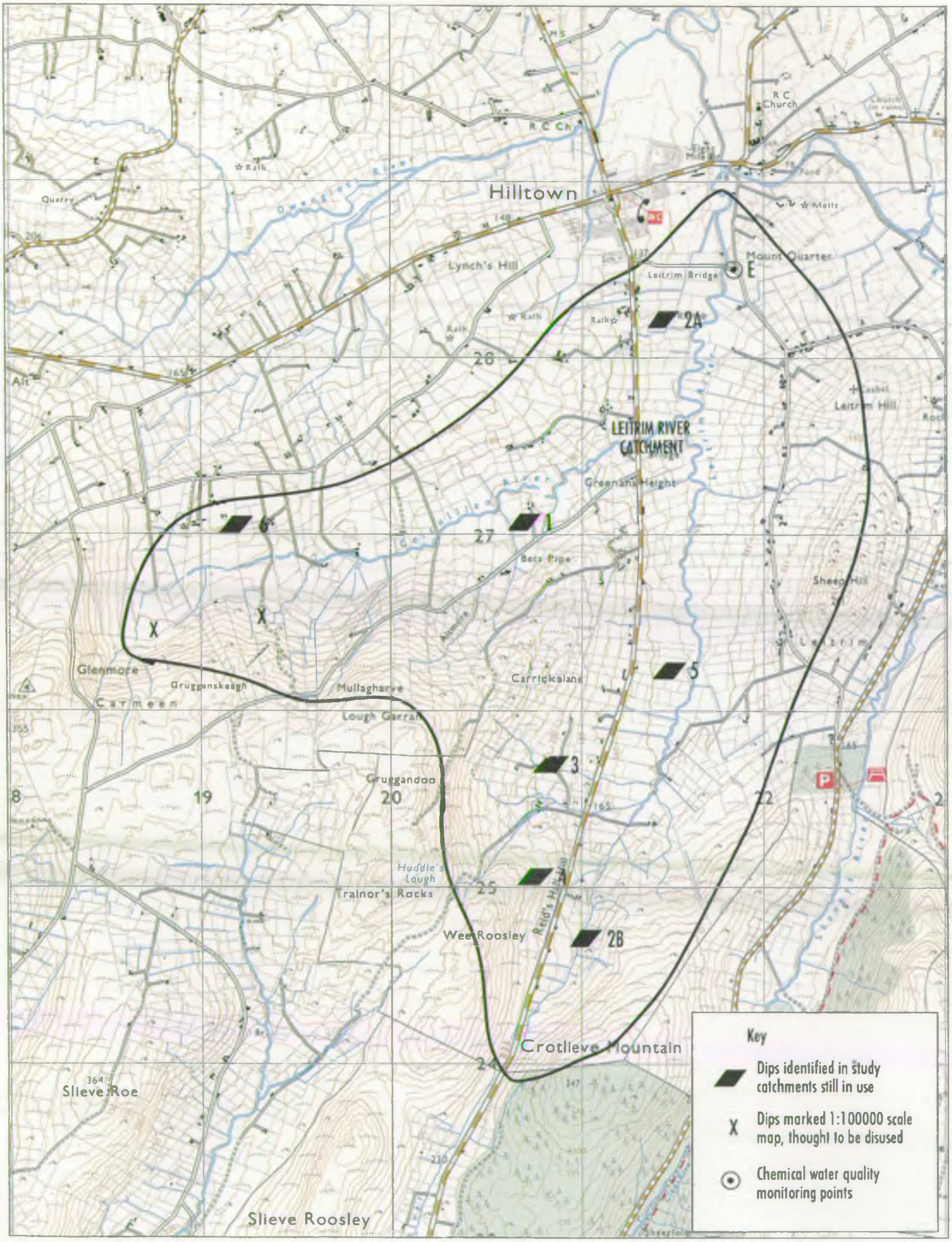

Figure 4.10 Map showing the Leitrim River catchment in the Mourne Mountains, Northern Ireland

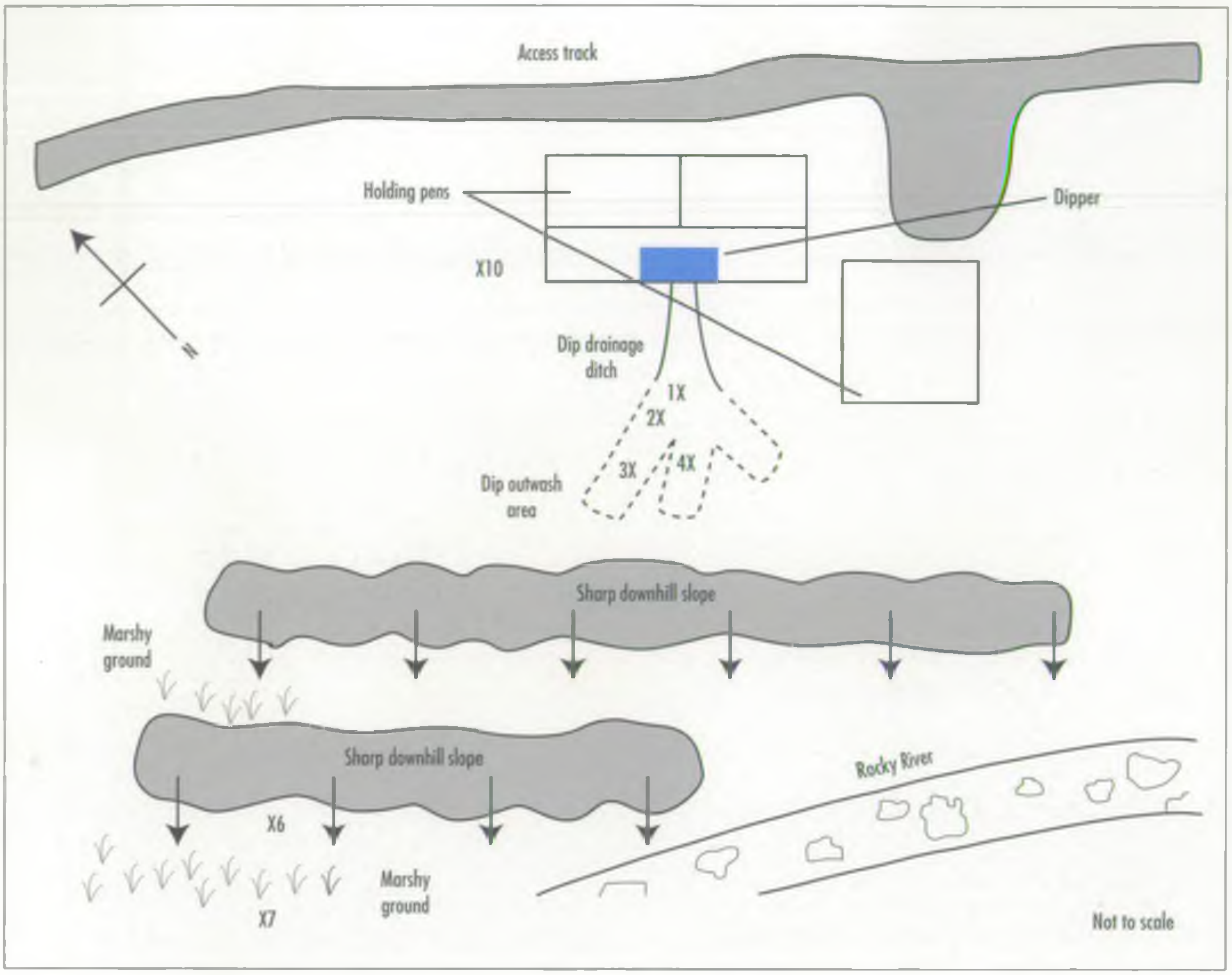

Figure 4.11 Soil sampling points at the Rocky River site, Mourne Mountains

5. RESULTS

The results of the fieldwork exercises carried out in Sussex, Devon, Scotland and Northern Ireland are presented in this section. It should be noted that all solid samples recovered, including cores, bagged samples and soil samples were processed using a leaching technique developed for this project. Full details and validation of this method appear in the Project Record. However, the basis of the method was the leaching of 1-kg samples on an orbital shaker table with about 1 l of pesticide-free water for two hours. The resulting liquid was decanted, filtered, and if necessary some of the solid residue centrifuged to provide a full 1 l for analysis. The original soil water or pore water concentration was back-calculated from the analytical result using the result of moisture content determinations carried out on each sample. The results discussed below for solid samples always refer to the back-calculated figure in the pore water or soil water. Because of the dilution effect of the leaching water, detection limits were raised, by a variable amount dependent on the sample moisture content.

Analyses for this project were carried out using WRc's Organic Analysis Group, Tweed RPB's Laboratory or Severn-Trent Laboratories (Coventry). Most samples were analysed for the organophosphorus pesticides diazinon, propetamphos and chlorfenvinphos only, but some samples were also submitted for lindane, dieldrin and DDT, which are all organochlorine pesticides, to check for residues from the time when these compounds were licensed for use in sheep dip. Details of the analytical methods used are given in the Project Record.

5.1 The River Rother Catchment, West Sussex

Nine samples from Greensand borehole No. 1 and ten samples from borehole No. 2 were processed and analysed. The results of these analyses are shown in Figure 5.1. The only organophosphorus pesticide detected in any of the samples was diazinon, with peak concentrations observed at 11-12 m below ground in borehole No. 1 (870 ng l^{-1}) and at 18-19 m below ground in borehole No. 2 (930 ng l^{-1}). Diazinon was detected in five out of eight samples from borehole No. 1 and three out of nine samples from borehole No. 2. These results indicate significant vertical and lateral movement of pesticides from the disposal site.

The results of sampling at the Chalk site on the South Downs are shown in Figure 5.2. A total of 15 samples from borehole No. 1 and 22 samples from borehole No. 2 were processed, but only four samples contained detectable levels of any of the three organophosphorus pesticides analysed. The reason why such a large number of these cores was processed is that they were run first and some were used for method development work.

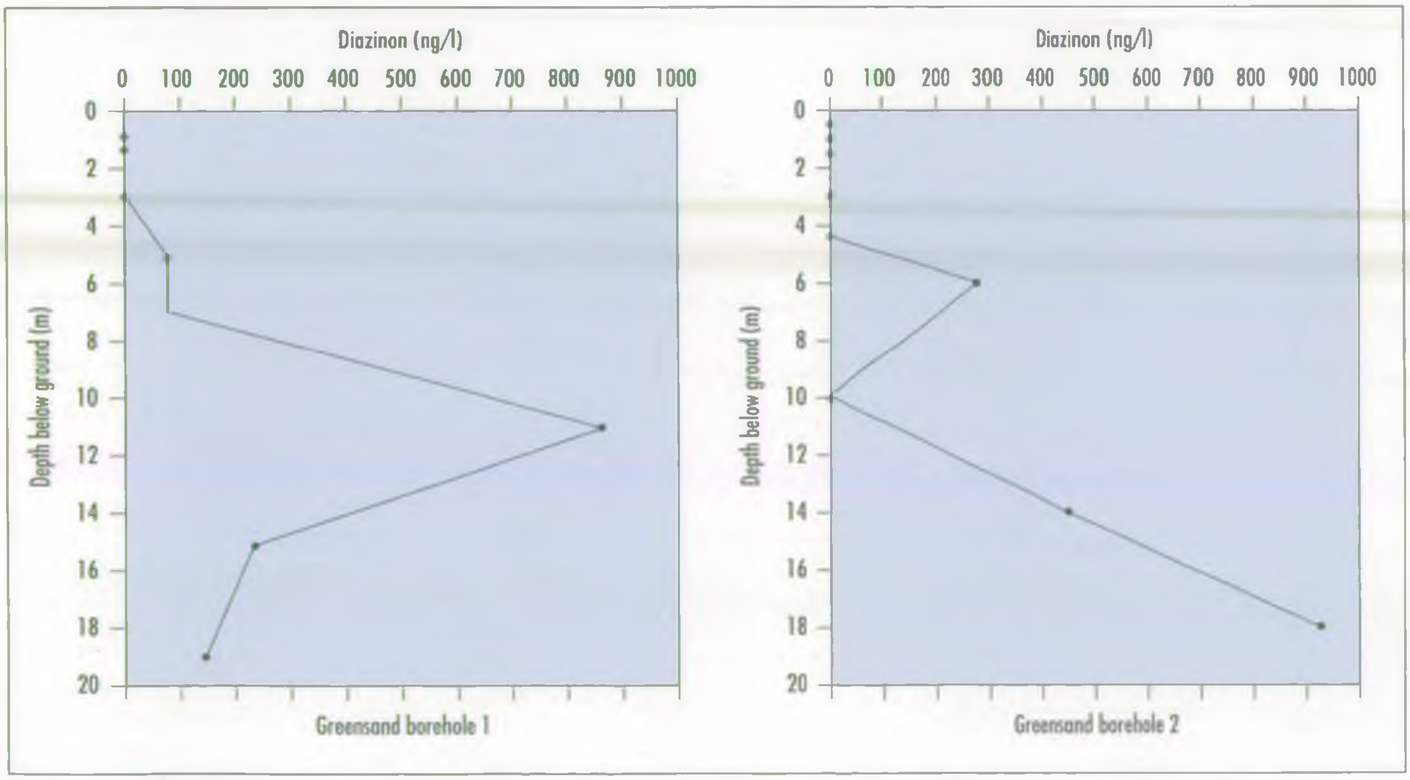

Figure 5.1 Diazinon concentrations in cores from Greensand boreholes 1 & 2

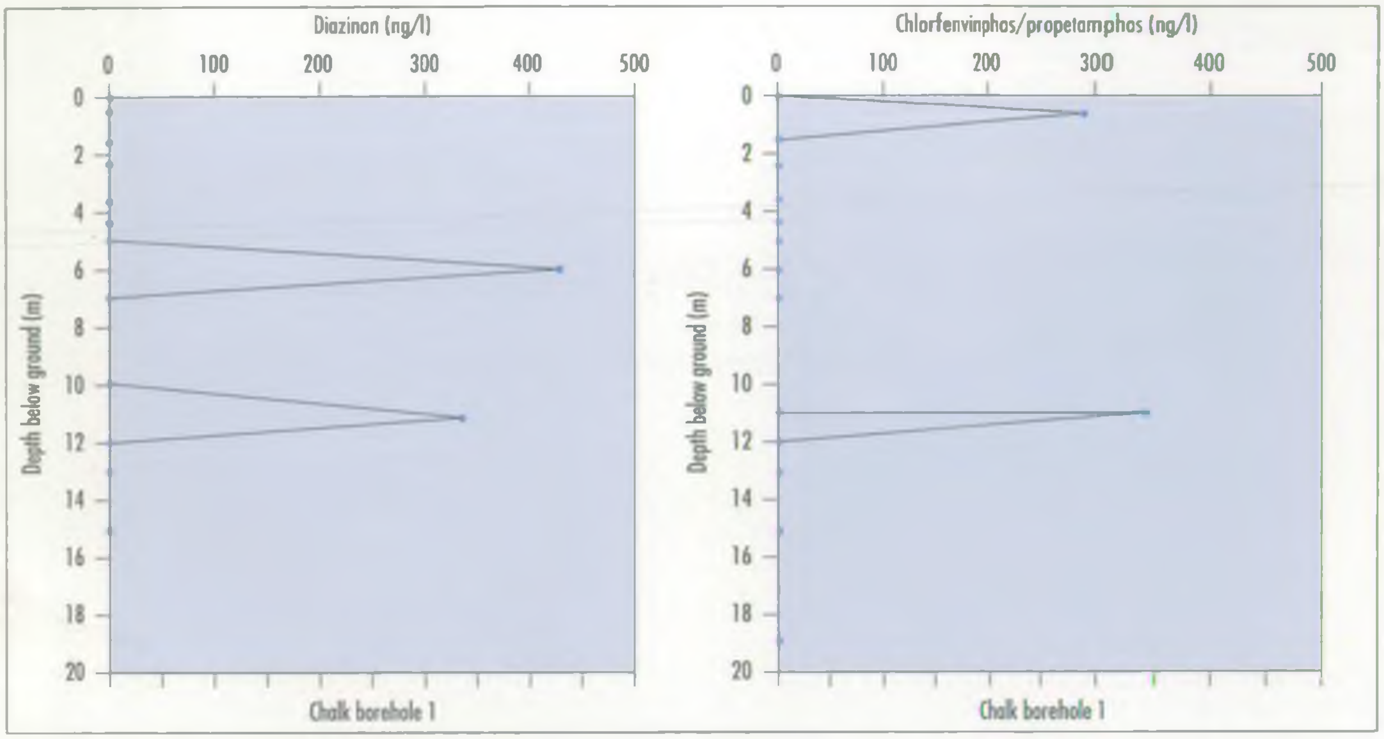

Figure 5.2 Pesticide concentrations in cores from Chalk borehole number 1

Of the positive results obtained, one was the very top sample from borehole No. 2, which contained diazinon at the limit of detection. This was a sample of the topsoil and it is possible that the presence of diazinon is due to drainage from the fleeces of dipped sheep. The three other samples containing pesticides were from borehole No. 1, and these results are shown in Figure 5.2. Detected concentrations of chlorfenvinphos and propetamphos were the same in both the sample from 0.5-1.0 m and that from 11.0-12.0 m (346 ng l^{-1}). Diazinon was also detected at 6.0-7.0 m and 11.0-12.0 m. The highest concentration of all was that of diazinon at 6.0-7.0 m which was 439 ng l^{-1}. The results at this site indicate significant vertical penetration of pesticides into the Chalk, but only limited lateral movement.

5.2 The River Taw Catchment, Devon

The results of drilling and groundwater sampling at the site on the Bude Formation (Culm Measures) in Devon are shown in Figures 5.3 and 5.4. Figure 5.3 shows a rough cross section through the site sampled showing the inter-relationship between the boreholes, the geology, the water table and the ground surface. Figure 5.4 presents the pesticide concentrations from the three boreholes; only chlorfenvinphos and propetamphos were detected in the pore waters, although very low levels of diazinon were found in the groundwater. Seven samples were analysed from each of boreholes No. 1 and No. 2, while five were analysed from borehole No. 3. The concentrations detected in these samples were all relatively high, but were detected in only five samples altogether. Highest concentrations were detected in borehole No. 2, with 5000 ng l^{-1} chlorfenvinphos in the pore water at 4.0-4.5 m below ground and 2300 ng l^{-1} in the groundwater. At this site, pesticide movement was found to be both vertical and lateral, with groundwater contamination identified as well.

The results of the site investigation carried out at the dipper on Dartmoor are shown in Figures 5.5 and 5.6. A wide range of samples was taken from this site, including bagged samples excavated by JCB backhoe, rotary cores, river waters and pumped water samples from the granite sands. The figures given in the results table and plotted in Figure 5.5 show that the pesticide concentrations in the sands overlying the granite were very high, to a maximum of 68 000 ng l^{-1} chlorfenvinphos at 1.5-2.0 m in trial pit 2, which was the further of the two from the soakaway. The higher concentrations were detected in the trial pit samples, with none detected in the weathered zone of the granite. Concentrations of both chlorfenvinphos and the organochlorine pesticide lindane in water samples are shown in Figure 5.6. Concentrations of both decrease with increasing distance from the soakaway, to almost below detection limits in the River Taw. The results at this site indicate a potentially serious build-up of pesticides in the pore waters around the dip; insufficient surface water sampling was carried out here to measure the effects of the dip on the River Taw.

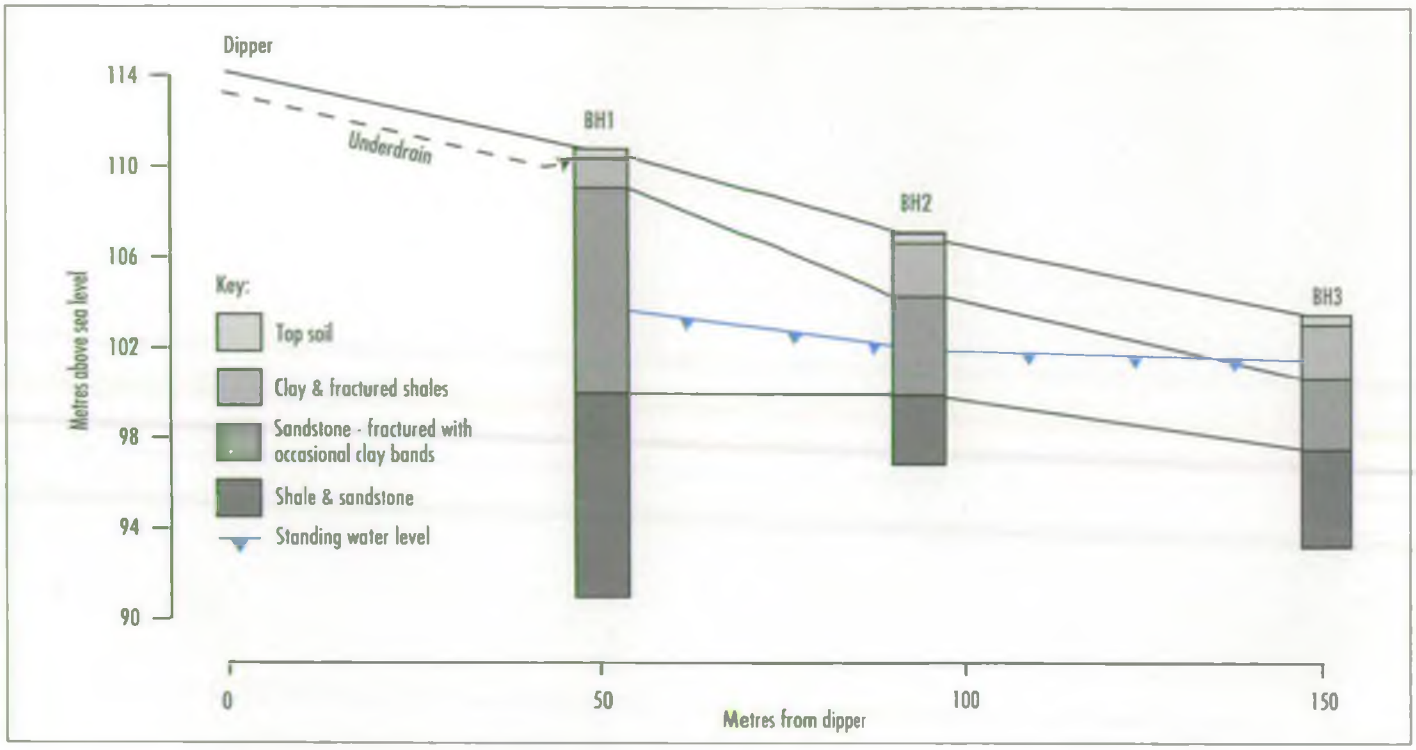

Figure 5.3 Details of boreholes in Bude Formation, Devon

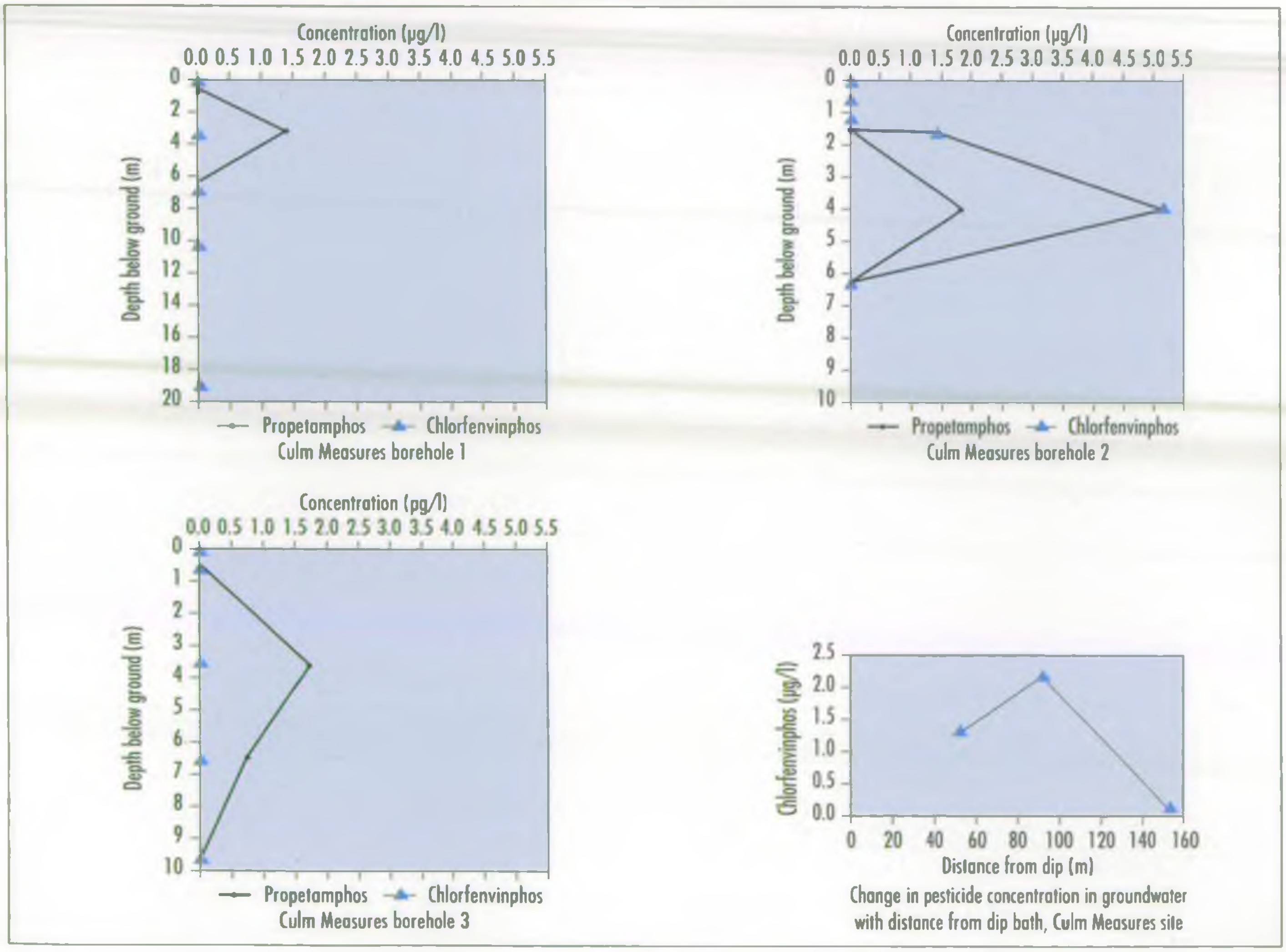

Figure 5.4 Pesticide concentrations in samples from Culm Measures, Devon

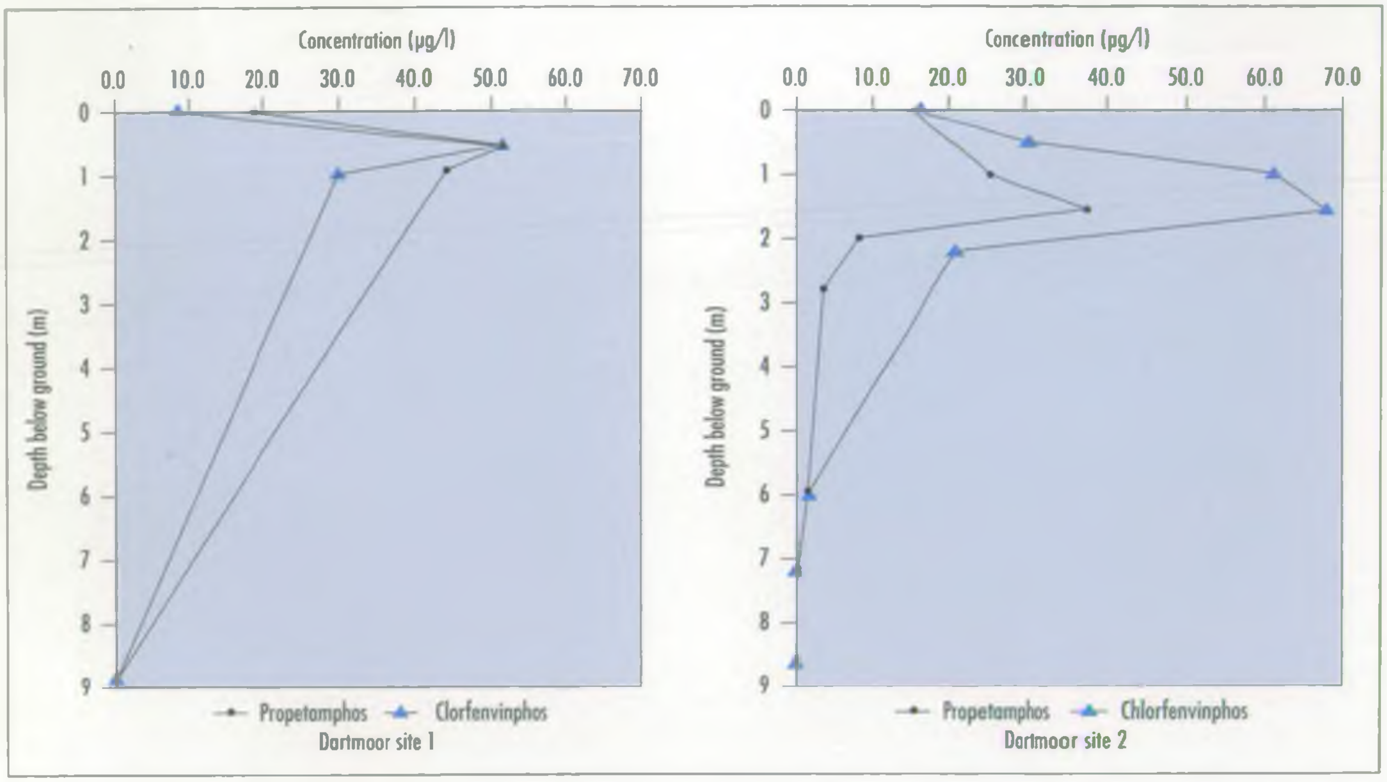

Figure 5.5 Results of sampling at dip site on Dartmoor, Devon

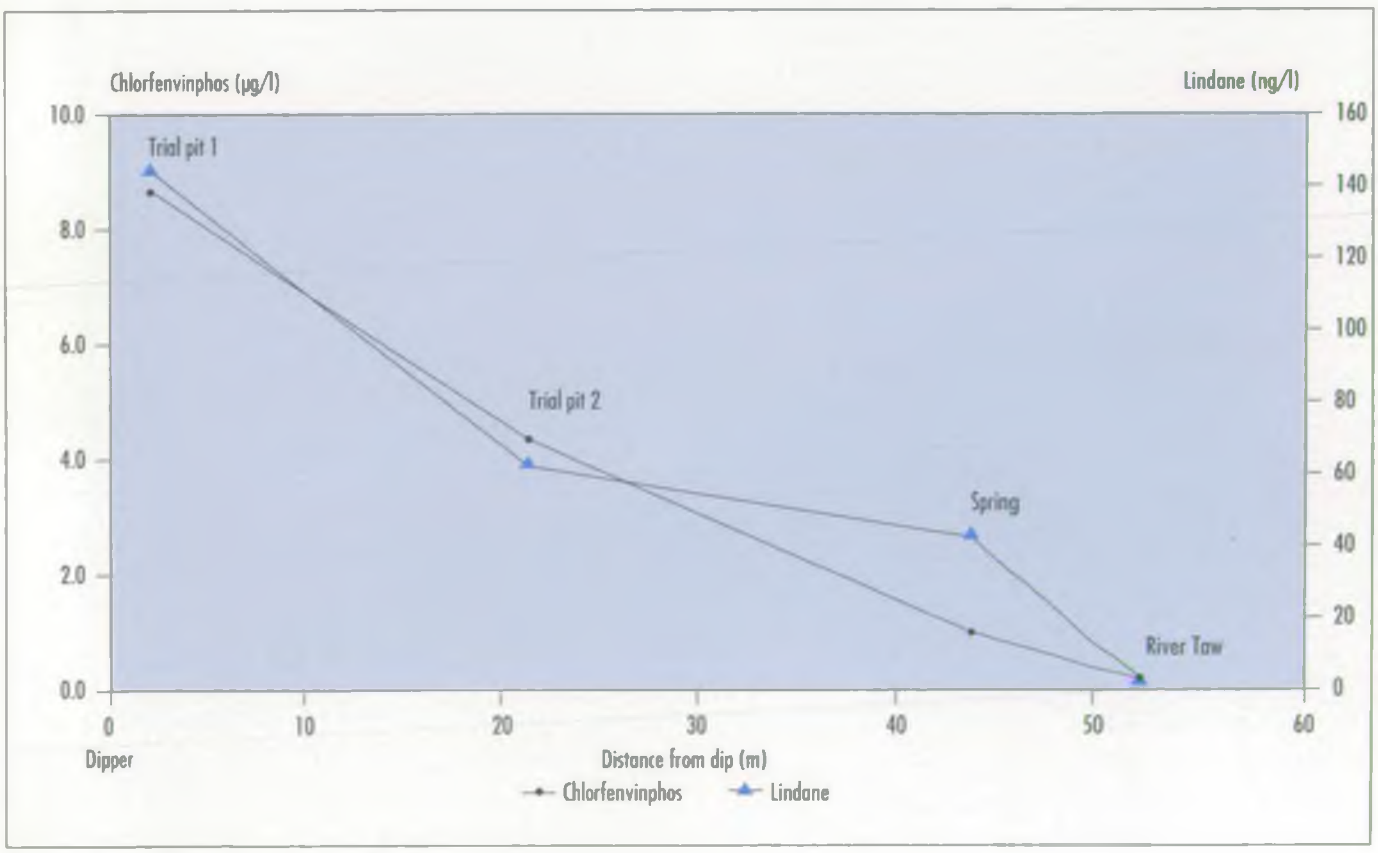

Figure 5.6 Results of sampling at dip site on Dartmoor, Devon

5.3 Wooplaw Dipper, Borders Region

Daily rainfall totals and the results of the stream sampling from the Wooplaw site are shown in Figures 5.7 to 5.10. Rainfall for 1991 was below average, although there were some intense storms just after dipping took place. Concentrations of the organophosphorus pesticides were generally less than 100 ng l^{-1} in the stream waters, with only one set of samples showing any major peak: chlorfenvinphos (4660 ng l^{-1}) and propetamphos (1080 ng l^{-1}) were detected on 22 October. Samples taken during the dipping period were also analysed for the organochlorine group of pesticides, but only two stream samples contained detectable concentrations (of PP-DDT), one at 21 ng l^{-1} on 22 October at the most upstream sampling point and one at 180 ng l^{-1} on 24 October at the intermediate sampling point.

Sampling with piezometers was only carried out during the dipping period, the samples taken being analysed for organophosphorus and organochlorine pesticides.

No clear temporal trend was discernible in the results from the piezometers, but pesticides were detected in all piezometers on at least one of the three sampling dates (23 and 24 October and 6 November). In particular, dieldrin was present (30 000 ng l^{-1} in piezometer 2) in all but piezometer 1, and PP-DDT was present (97 000 ng l^{-1} in piezometer 4) in all piezometers. The presence of organophosphorus pesticide carbophenothion was reported by Severn-Trent Laboratories in some samples, and on 24 October, this pesticide was detected in samples from three of the four piezometers; this pesticide has been used in sheep dip in the past but is no longer in use. The highest concentration of this pesticide was found in piezometer 2 (43 000 ng l^{-1}). The only other organophosphorus pesticide detected in the piezometers was chlorfenvinphos; this was detected at 11 600 ng l^{-1} and 3500 ng l^{-1} in piezometer 2, but at only 200 ng l^{-1} in any of the other piezometers.

The results of Tweed RPB's biological monitoring at Wooplaw are shown in Figure 5.11, reported as BMWP (Biological Monitoring Working Party) scores. The differences in substrate between the upstream and downstream sites are reflected in the relatively poorer diversity upstream compared to the downstream site. Perhaps the most noticeable feature of these results is the perturbation of the macroinvertebrate communities, both upstream and downstream of the dipper in late October (the compulsory dipping period).

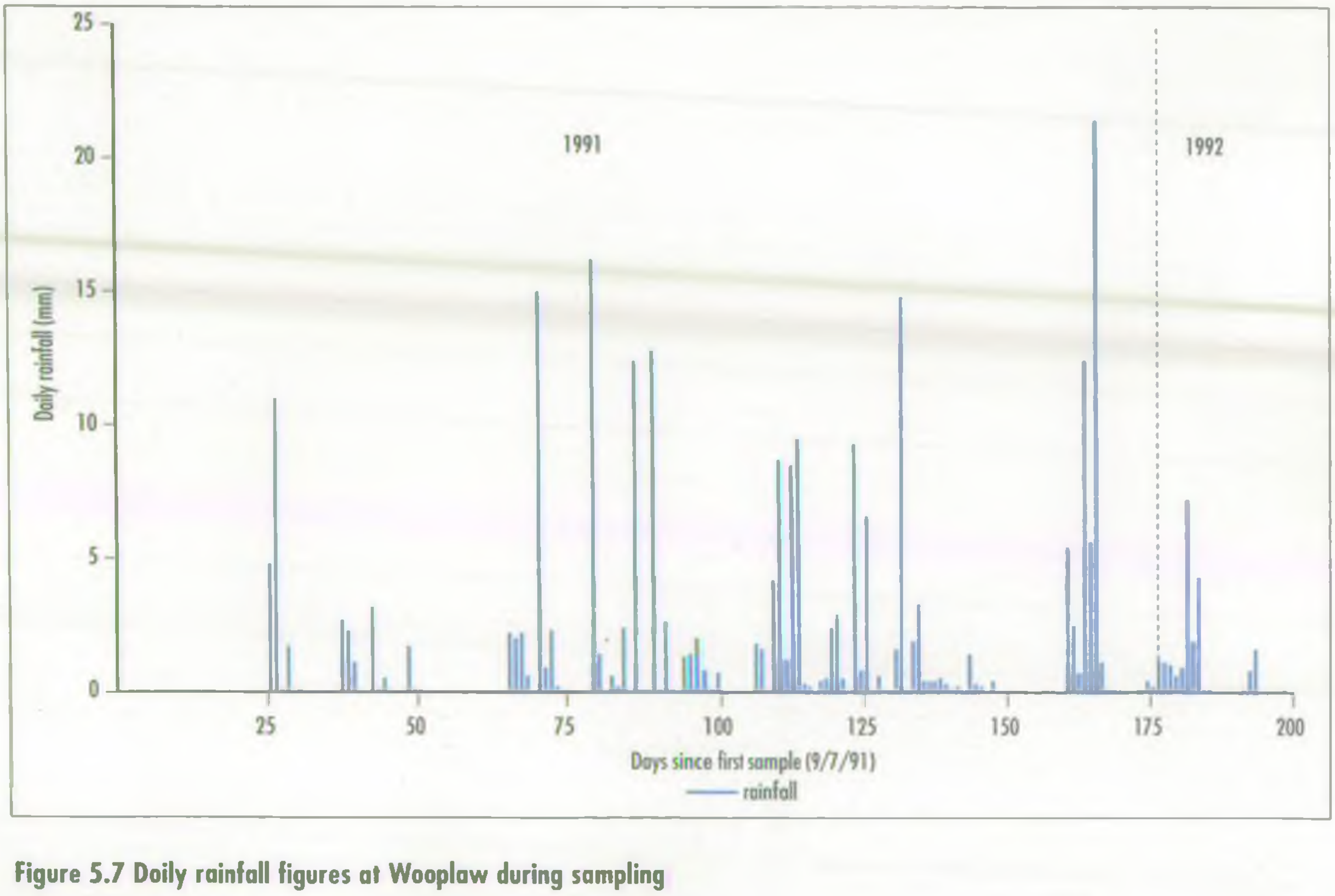

Figure 5.7 Daily rainfall figures at Wooplaw during sampling

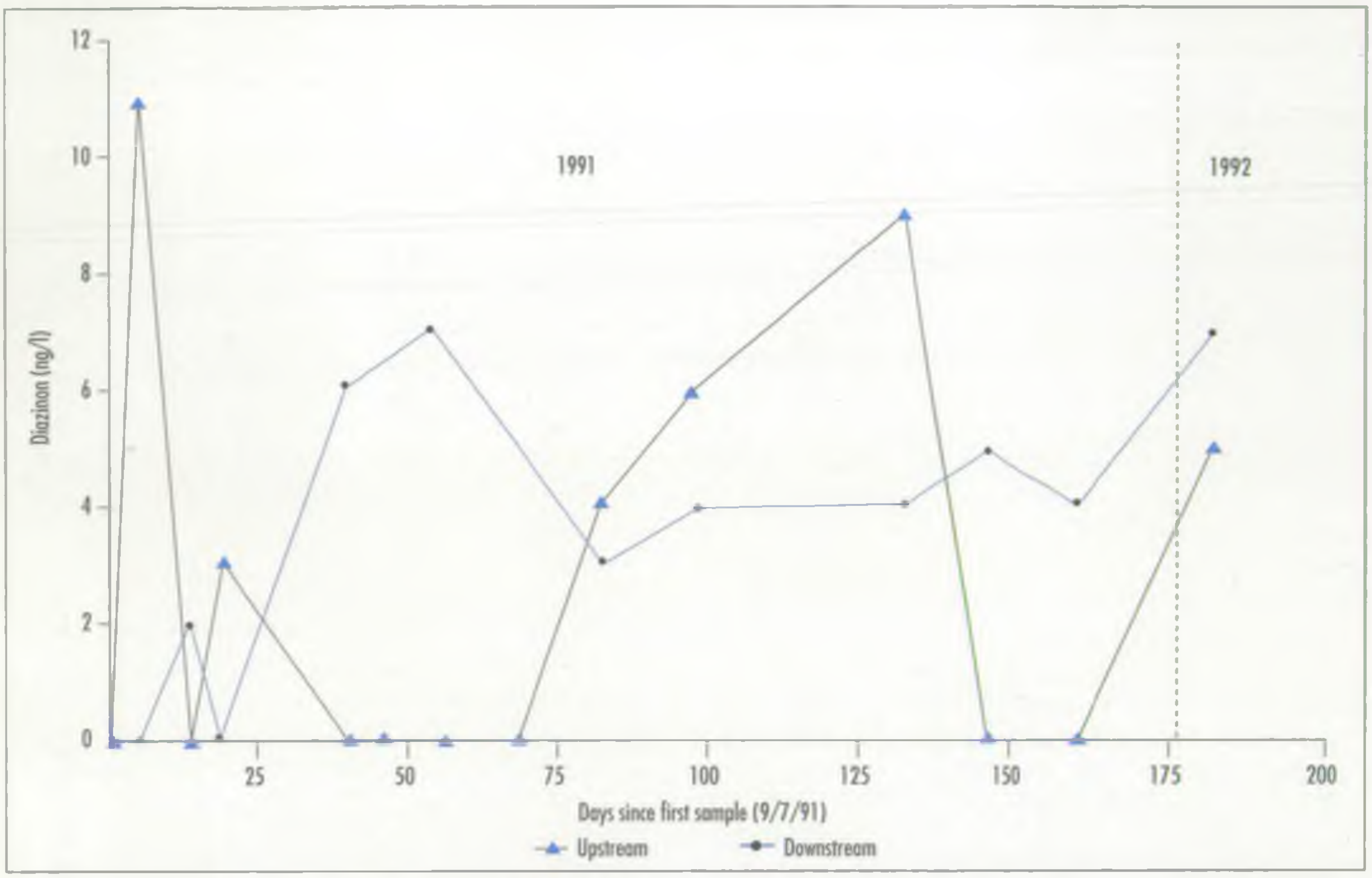

Figure 5.8 Diazinon concentrations in stream at Wooplaw

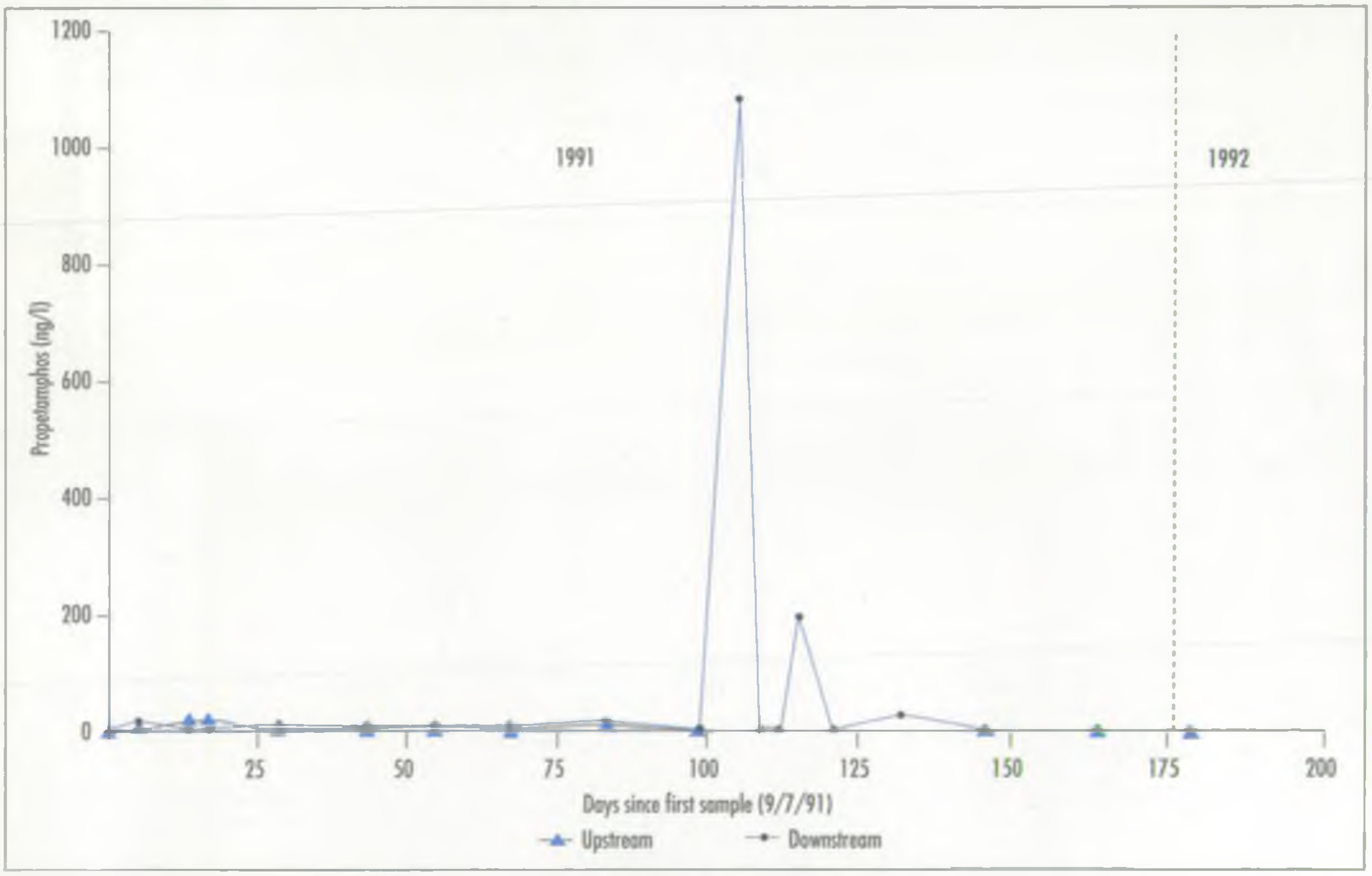

Figure 5.9 Propetamphos concentrations in stream at Wooplaw

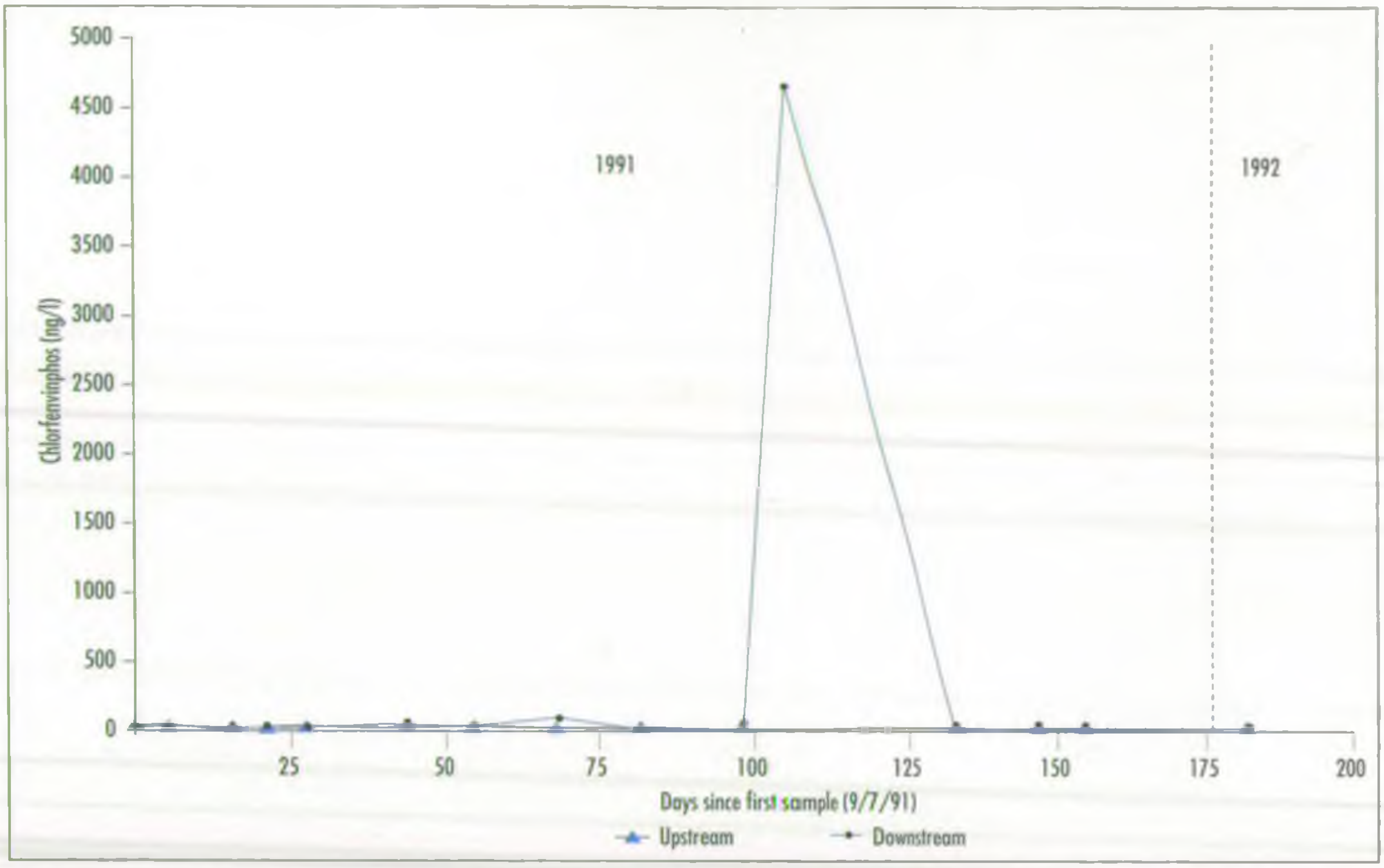

Figure 5.10 Chlorfenvinphos concentrations in stream at Wooplaw

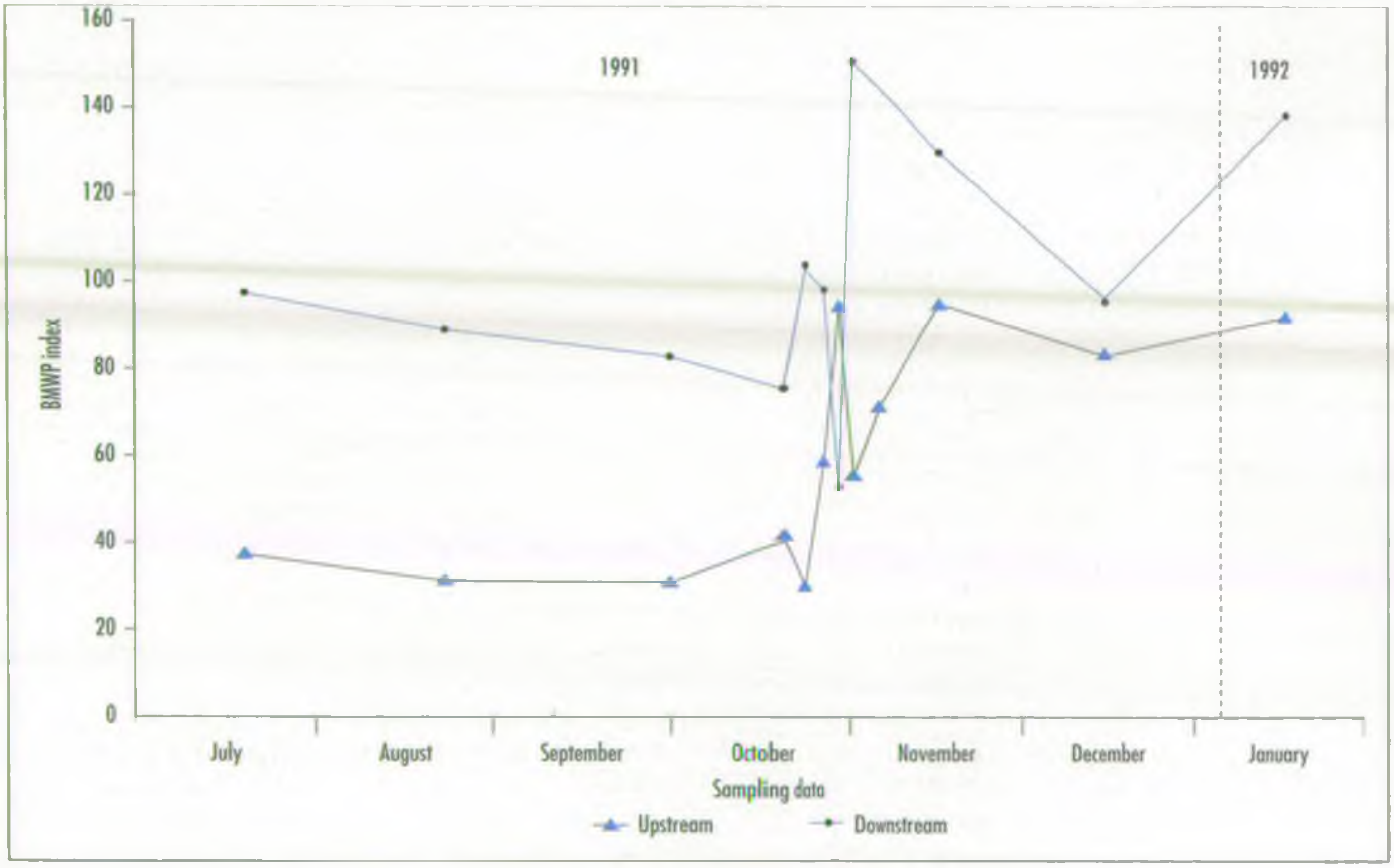

Figure 5.11 Results of invertebrate surveys at Wooplaw dipper (work carried out by Tweed RPB)

Initially, the information given to WRc was that the dipping took place on 22, 23 and 24 October, with the dipper being emptied to soakaway on the 25th. However, it was later reported by Tweed RPB staff that the dipper was emptied on 28 October, following the dipping of stragglers.

It is surprising, given the high levels of propetamphos (1080 mg l^{-1}) and chlorofenvinphos (4660 mg l^{-1}) detected on 22 October downstream of the dipper, that the biological survey showed no decline in downstream invertebrate diversity until 30 October (although it does appear the that stream's macroinvertebrate ecosystem was disturbed in some way before this). It is difficult to explain these high pesticide levels; however there is no reason to doubt their validity. Trip blank results from the sampling programme showed either no detectable concentrations of pesticides or very low (maximum 12 ng l^{-1}) concentrations. The reason for pesticide concentrations reaching a peak before dipping is unclear. However, the standing water in the dip may have been baled out, prior to making up the dip solution, and disposal of this to the soakaway could have displaced contaminated water into the stream.

Chemical monitoring carried out by the Tweed RPB during the dipping period also raised some queries. Samples taken on 21 October (the day before dipping commenced) and 28 October (before the dipper was emptied to soakaway in the afternoon) showed only background levels of propetamphos (3-6 ng l^{-1}) below the dipper. The next set of samples was taken on 4 November (one week after the dipper was emptied and following high river levels) when a peak in propetamphos levels was recorded (94-97 ng l^{-1}) and levels were still elevated against background a further fortnight later (25-27 ng l^{-1}). Given the time that the dipper was actually emptied (21 October) and the high river levels that followed on 29-30 October, it is probable that the levels of pesticides in the burn below the dipper reached much higher levels that those recorded on 4 November. The macroinvertebrate suppression seen on 30 October below the dipper would also support this theory. If the high levels of active ingredients recorded below the dipper on 22 October were correct, then the fact that these appeared to cause no invertebrate suppression would suggest that the suppression seen on 30 October would have been caused by much higher levels of active ingredients than those recorded on the first day of dipping. In fact, increasing levels of propetamphos were recorded over the period of 25 October - 1 November but nothing approaching the level recorded on 22 October. During the four sampling surveys undertaken by the Tweed RPB between 21 October and 18 November, no chlorfenvinphos was recorded in the burn above or below the dipper.

Although the work at Wooplaw has raised some problems of interpretation, there is sufficient evidence to suggest that contamination of the stream was occurring as a result of dipping operations, and that peak concentrations probably exceeded those detected by chemical sampling.

5.4 The Rocky River, Shanky's River and Leitrim River, County Down

No pesticides were found in the samples from Rocky River upstream and Shanky's River upstream or downstream. Only one sample from Rocky River downstream was reported as containing any pesticide; this was 200 ng l^{-1} propetamphos on 23 July, the same date as an identical concentration was reported for Leitrim Bridge. In fact, this is most likely an error in reporting, as duplicate samples were submitted for downstream Rocky River and Leitrim Bridge and only one sample in each case was reported as having this concentration. The subsequent samples on 26 July were negative at downstream Rocky River and positive (70 ng l^{-1} propetamphos) at Leitrim Bridge. It would therefore seem that no pesticides were detected in the Rocky River, whereas they were present in the Leitrim River, which has a similar flow rate but six times as many dippers. Propetamphos was again reported (170 ng l^{-1}) in the Leitrim on 30 October and lindane was detected at 8 ng l^{-1} on 29 October.

Selected soil sampling results have been plotted in Figure 5.12 to show the change in concentration of the organophosphorus pesticides with increasing distance from the dipper. Note that the horizontal axis is not to scale. Concentrations were lowest adjacent to the holding pens and to the Rocky River itself. However, the intermediate samples from the area of outwash from the dipper's drain all contained high concentrations of diazinon, propetamphos and chlorfenvinphos. These soil water concentrations ranged from 890 ng l^{-1} chlorfenvinphos to 13 800 ng l^{-1} diazinon. Sample P1, standing water from a pit between soil samples 2 and 3, also contained high levels of pesticide (810 ng l^{-1} diazinon, 51 800 ng l^{-1} propetamphos and 190 ng l^{-1} chlorfenvinphos).

Although the routine surface water sampling provided no evidence of pesticide contamination of the Rocky or Shanky's Rivers, samples from the larger Leitrim River catchment did indicate the presence of low concentrations of dip chemicals. Monitoring of the invertebrate populations of rivers in the Mournes,

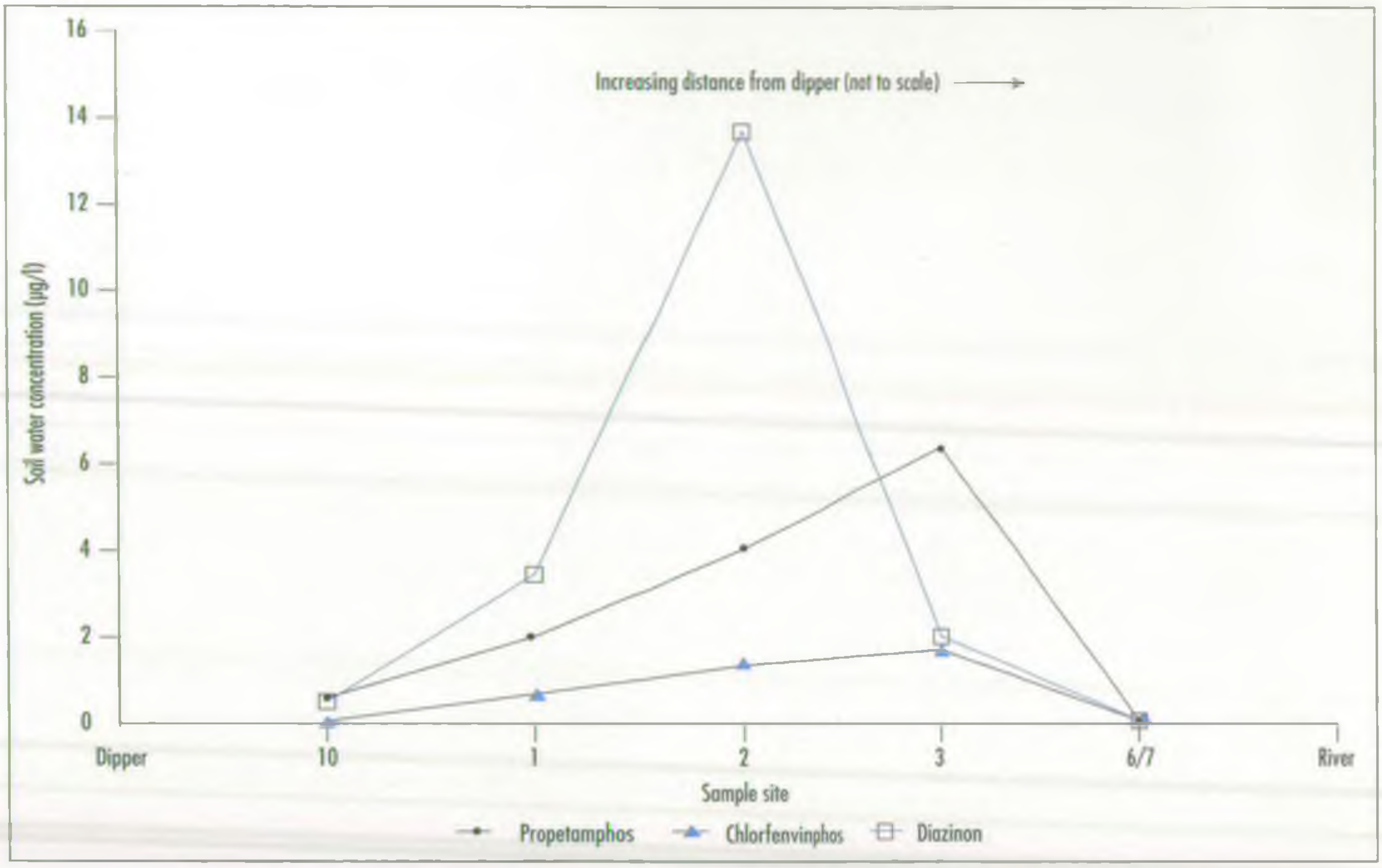

Figure 5.12 Soil water pesticide concentrations, Rocky River dip site

including those studied by WRc, has been carried out by DANI with specific reference to the effects of sheep dip disposal. This work has not been formally published, but preliminary assessment of the results indicate that biological monitoring can detect the effects of transient sheep dip pollution peaks which may be missed by routine chemical sampling.

6. ALTERNATIVE DISPOSAL METHODS

Although disposal of dip waste to soakaway is, in many areas, the principal route, a number of alternative disposal methods exists. A knowledge of the likely costs and technical feasibility of these alternatives would be useful in drawing up guidelines on disposal. The principal options are reviewed here.

6.1 On-Site Treatment

One of the objectives of this project was to assess the viability of a treatment plant being developed by E Allman and Company Ltd of Chichester. The Sentinel plant had been produced to treat dilute pesticide sprayer washings and other small volumes of waste water containing organic compounds using the ICI Carbo-Flo process. Following the commercial success of this plant, at least outside the UK, Allman and Co. set about developing new applications of the same process, and the treatment of waste sheep dip was identified as a suitable area for development work.

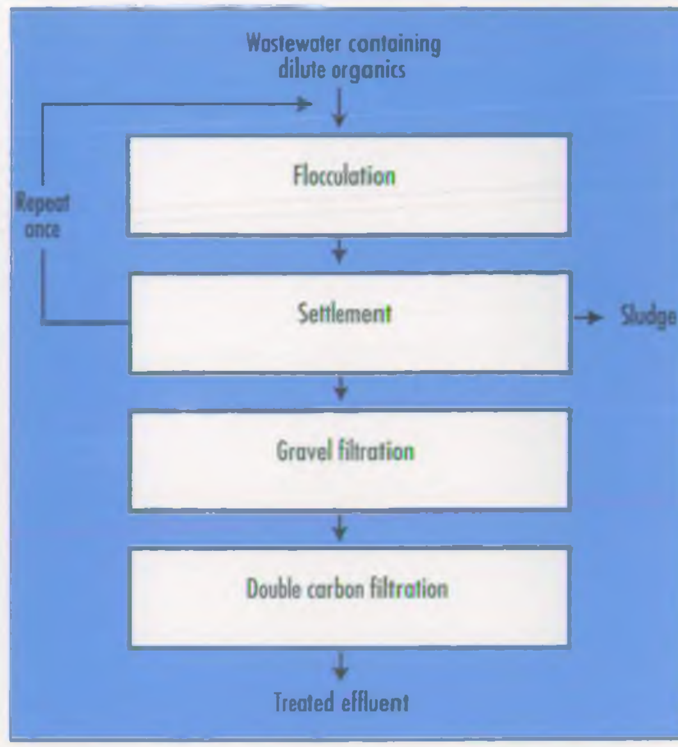

Figure 6.1 Treatment process used in Sentinel plant

The basic Carbo-Flo process is shown in Figure 6.1. Chemical coagulation in the main tank allows the solids to be collected as a sludge, while the remaining liquid is passed through a gravel filter and two activated carbon filters to remove any remaining solids and organic compounds. The sludge must be collected by a waste disposal contractor. A dye is added at the first stage to monitor the condition of the carbon filters; when the filters are exhausted, the dye will colour the effluent. The method of disposal of the final effluent must be agreed with the relevant Regulatory Authority.

However, the process was found to be unsuitable for the treatment of sheep dip waste, because of the high solids content of the dip waste and also because of the presence of lanolin from the sheep's fleeces. During 1991 and 1992 development work was carried out by Allman and Co. which concentrated on modifying the chemical dose added at the primary stage to remove these additional contaminants. Experiments with a range of dip samples showed that it was necessary to dilute most waste dip with an equal volume of water before treatment, use more complicated multiple additions of chemicals and to use two phases of chemical addition and sludge removal to produce successful treatment. It was found that the treatment of waste from larger dip baths was more effective, perhaps because of the greater dilution of the solids and lanolin.

Results from the treatment of two samples of sheep dip waste are shown in Table 6.1. Both dip wastes came from 1200-l (250-gal) dippers in which Ciba-Geigy Topclip Gold Shield was used. Eight hundred sheep were dipped in Dip A one week before treatment, while 580 sheep passed through Dip B three-and-a-half weeks before treatment. Both were diluted 50:50 with clean

Table 6.1 Treatment plant performance data

	50:50 dilution		Intermediate		Final Effluent	
	Diazinon ($\mu g\ l^{-1}$)	Propetamphos ($\mu g\ l^{-1}$)	Diazinon ($\mu g\ l^{-1}$)	Propetamphos ($\mu g\ l^{-1}$)	Diazinon ($\mu g\ l^{-1}$)	Propetamphos ($\mu g\ l^{-1}$)
Dip A	8.0*	71.0*	26.0	1 81	4.0	33.0
Dip B	88.0	560	2.7	112	2.0	34.0

* low results due to difficulties with analysis of dip

water before treatment started. Samples taken by WRc and analysed by the NRA Northumbria Region laboratories for organophosphorus pesticides indicated that the plant removed all the suspended matter and 94% of the pesticide from Dip B. No comparable figure is available for Dip A because it appeared that lanolin in the sample adsorbed much of the pesticide. A higher result might have been obtained had a hot extraction technique been used prior to analysis.

The cost of treating the dip waste on site using this system was estimated as being about 10p l^{-1}. This figure assumes that 50% of the cost of the plant would be met by the Agricultural Development Advisory Service (ADAS) grants, as was the case for the standard Sentinel plant.

In spite of the apparent success of the modified Sentinel plant in treating dip waste, the manufacturers have suspended further development work. A number of factors influenced their decision:

- no guarantee of a market for the plant unless farmers are compelled to find alternative disposal routes for dip waste;
- lack of external funding for development work; and
- the high cost to the farmer of approximately £200 per dip for a medium-sized flock (2000 l of waste dip).

However, Allman and Co. have shown the technical feasibility of on-site treatment, and could develop the plant commercially in the future if legislation on dip disposal was tightened up.

6.2 Disposal to Landfill or Incineration

Six of the major waste disposal firms were approached to find out approximate costs of disposal for dip waste and also to find out the distribution of facilities able to accept the waste, as transport could be a major component of the overall cost.

Of the companies approached, only two were prepared to provide the information requested, and both asked not to be named in case the costs quoted were of help to competitors.

The first company to respond indicated that incineration was unlikely to be a cost-effective option because of the high water content of the dip. The cost for incinerating 2000 l was estimated as being more than £500. The company estimated that perhaps ten landfill sites nation-wide would be licensed to accept waste dip; their licence would have to include liquid wastes and organophosphorus pesticides. To dispose of 2000 l of tankered waste would cost about £100-200. However, for both incineration and landfilling, transport would increase the overall cost.

The second company took the view that incineration was the best disposal option, but in conjunction with pre-treatment to reduce the water content.

Both companies are currently considering setting up 15-20 regional treatment centres for wastes, with some of these being in predominantly agricultural areas to deal with animal carcasses and other farm wastes. The dip waste could be collected from a wide area and treated in a plant similar to that developed by Allman and Co., with the sludge being incinerated. The centralisation of the treatment would reduce costs, and the wide distribution of the treatment centres would reduce transport costs.

6.3 *In Situ* Biodegradation

The organophosphorus pesticides have been shown to be much more readily biodegradable, at least under laboratory conditions and in aqueous solution, than the organochlorine pesticides previously used in sheep dip. If conditions within the dipper could be optimised, then in situ biodegradation of the pesticides could be encouraged. Work done in the United States of America (Shelton and Hapeman-Somich 1991) has shown that coumaphos, an organophosphorus pesticide used in cattle dips on the US-Mexican border, is susceptible to such biological treatment. Between 97.4% and 99.9% removal was achieved in laboratory experiments using bacterial cultures isolated from a dip bath. Work on in situ biodegradation of sheep dip pesticides has been carried out at the Scottish Agricultural College in Aberdeen by Dr N Stephen, but is still at a preliminary stage.

6.4 Disposal with Cattle Slurry

The use of cattle slurry lagoons for the disposal of dip waste on farms where sheep and cattle are kept would seem to have two principal advantages:

- increased potential for biodegradation in the biologically active lagoon; and
- dilution of the dip pesticides.

In addition to these benefits, when the slurry is eventually sprayed onto the land, it will be dispersed over a far greater area than would usually be the case when dip is disposed of to soakaway or directly to land.

However, conflicting guidelines have been available to farmers on the disposal of dip waste with slurry. The National Office of Animal Health, an organisation representing the manufacturers of veterinary medicines, have issued guidelines indicating that 'spent dipwash can also be mixed with slurry before disposal' (NOAH undated). Disposal advice from some NRA Regions has also cited disposal into a slurry lagoon as acceptable (NRA North West Region, undated). This is directly contradicted by the most recent advisory notes (1991) for farmers from the Veterinary Medicines Directorate of MAFF. This document indicates that mixing dip waste with slurry before disposal can lead to the evolution of gases (presumably hydrogen sulphide) which may be lethal to livestock and humans and that, because slurry is a major cause of water pollution in its own right, mixing it with dip merely complicates any attempt at clean-up. The NRA document on groundwater protection (NRA 1992) seems to indicate that disposal of slurry and dip waste to land would be discouraged, stating that 'sludge applications to land should be beneficial for agricultural use and should not be used primarily for waste disposal'.

To try to resolve some of the confusion surrounding this aspect of dip waste disposal, two experiments were carried out by WRc. These were very simple tests to determine:

1. the rate and extent of dip degradation when disposed of to a slurry lagoon; and

2. the extent of pesticide leaching from soils treated with the slurry/dip mixture using a lysimeter.

For the first stage of the experiment, samples of dip waste (60 l) and slurry from a weeping wall system (180 l) were mixed together, after sub-samples of the dip and slurry had been taken for analysis. Over the next four weeks, a number of samples of the mixture were taken for analysis. Before each sample was taken, the mixture was stirred thoroughly. The results are shown in Table 6.2 and Figure 6.2.

The results, in Figure 6.2, show that the amount of degradation of diazinon in the artificial slurry lagoon was high in the first couple of days, being reduced by over one third. However, a temporary decrease in the rate of degradation was observed after this, perhaps due to the low ambient temperatures at the time, which resulted in ice formation on the surface of the mixture on a number of occasions. Once ambient temperatures rose above freezing, degradation resumed achieving 87% removal of diazinon after 18 days.

The second experiment used four lysimeters to investigate the potential for leaching of the organophosphorus pesticides when applied to pasture land with slurry. The lysimeters were set up as shown in Figure 6.3, with lagging and heating cable around the outside to prevent freezing of the columns. One of the lysimeters was used as a control, with no slurry being

Table 6.2 Changes in pesticide concentration with time in slurry mixture

Date	Sample code	Comments	Diazinon ($\mu g\ l^{-1}$)
22/11/91	SL/1	waste dip only	3790
22/11/91	SL/2	slurry only	1200
22/11/91	SL/3	mixed dip and slurry	1580
25/11/91	SL/4	mixed dip and slurry	1150
03/12/91	SL/5	mixed dip and slurry	1200
03/12/91	SL/6	mixed dip and slurry	940
09/12/91	SL/7	mixed dip and slurry	1080
09/12/91	SL/8	mixed dip and slurry	980
18/12/91	SL/9	mixed dip and slurry	210
18/12/91	SL/10	mixed dip and slurry	190

The samples were all analysed for diazinon, chlorfenvinphos and propetamphos, but only diazinon was detected in any of the samples. It was known that the dip used was Ciba-Geigy Topclip Gold Shield, which is diazinon-based. When the slurry was collected, the staff stated that no dip waste had been added for several years. It is therefore surprising to note that the slurry also contained diazinon.

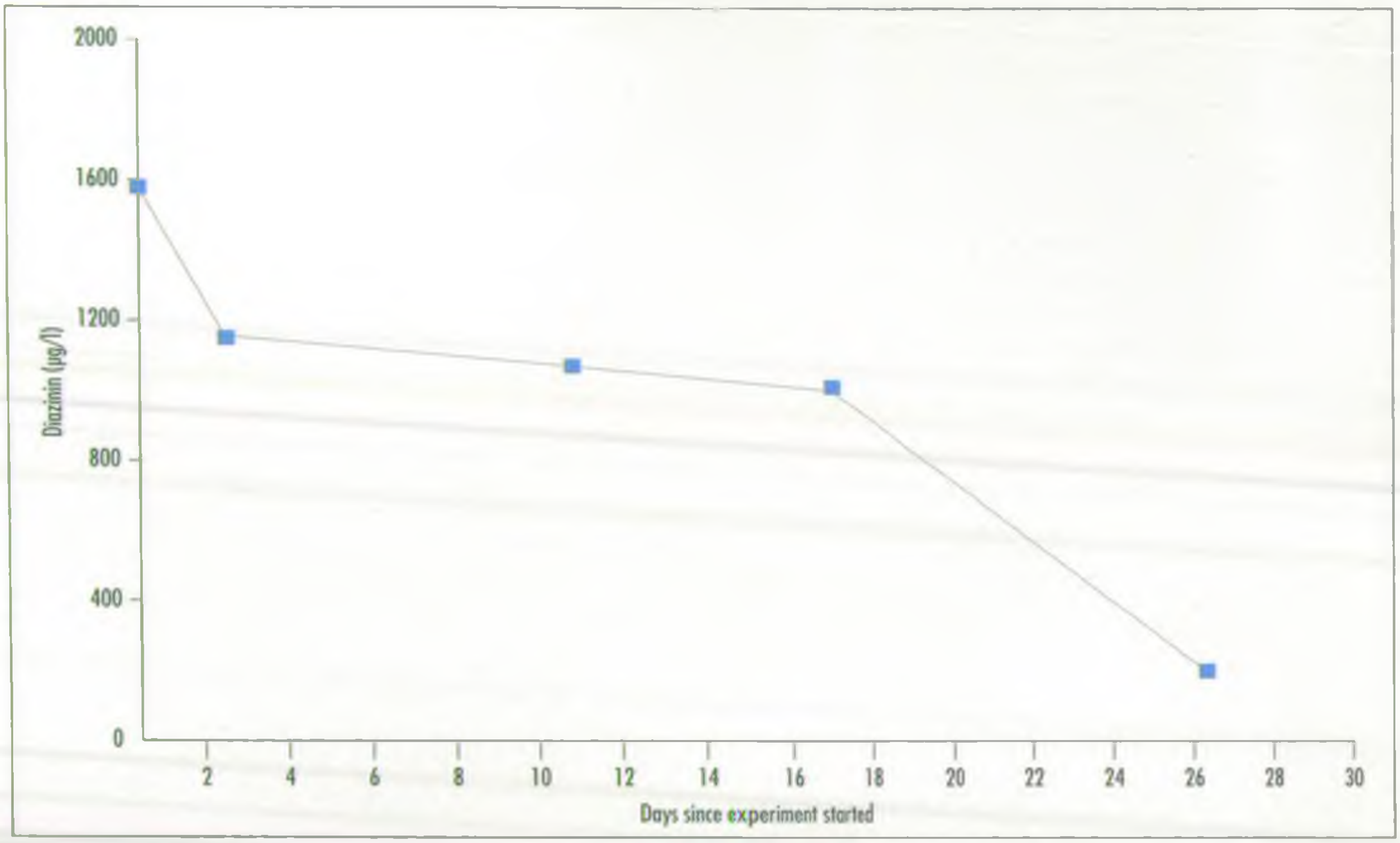

Figure 6.2 Concentration of diazinon in slurry lagoon

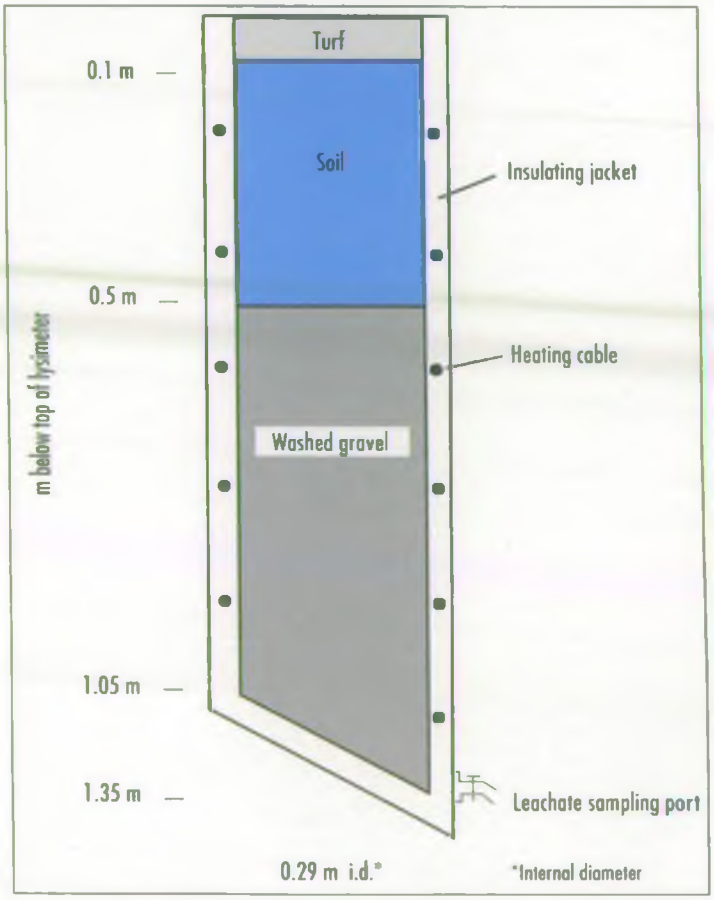

Figure 6.3 Lysimeter design for slurry and dip disposal experiments

applied, but otherwise being treated in exactly the same way as the others. To the remaining three lysimeters, different loadings of slurry were applied. The recommended loading rate cited both by the Veterinary Medicines Directorate of MAFF and NOAH when disposing of sheep dip waste with slurry is 0.5 l m^{-2}. The loading rates used for this experiment were 0.4 l m^{-2}, 0.8 l m^{-2} and 8.0 l m^{-2} to give a realistic range.

The mixture of slurry and dip was spiked with all three main organophosphorus pesticides before it was added to the lysimeters; the nominal initial concentrations were 66.0 mg l^{-1} diazinon, 124.7 mg l^{-1} chlorfenvinphos and 8.4 mg l^{-1} propetamphos.

Before beginning the experiment, all the lysimeters were saturated with water, and then allowed to drain to field capacity. To simulate a high rainfall onto the disposal sites, 500 ml of water was added to each lysimeter every weekday, which would represent a site in one of the wettest areas of the UK. It was felt that this was valid to provide a 'worst case' scenario.

Samples were taken of the initial dip/slurry mix and of the added water used for saturating the lysimeters initially and the simulated rainfall. In addition, samples were taken weekly from the port at the base of each lysimeter, with a quality control sample being submitted with each batch. Results show that after 18 days, no traces of the organophosphorus pesticides were picked up from any of the lysimeters. However, further research would be required to validate these findings over a greater time period.

6.5 Disposal to Sewer

The disposal of waste sheep dip to sewer would require consent from the relevant water undertaking, and possibly Her Majesty's Inspectorate of Pollution (HMIP). This is unlikely to be acceptable as a disposal route because of the potential damage that might occur to the biomass in the sewage treatment works, and the possibility that the pesticides could be discharged untreated in the sewage works effluent. A recent case (ENDS 1992) highlighted a similar problem, when North West Water was prosecuted by the NRA for discharging an organic pollutant from a sewage works, which was being discharged to sewer by an industrial unit. This could lead to more stringent controls on permitted discharges to the sewerage system.

7. CONCLUSIONS

The following conclusions are based not only on the interpretation of the results, but also on the literature relating to the subject and discussions with a wide range of interested parties. Results of the drilling exercises on the Chalk, Greensand and Culm Measures show that disposal of sheep dip waste to soakaway or at high loading rates onto land can contaminate the unsaturated zone of that aquifer, and there is some evidence to suggest that this can lead to contamination of the groundwater. The maximum depth below ground level at which organophosphorus pesticides were detected was 19 m, in the Greensand, but the maximum depth sampled was 20 m. Organophosphorus pesticides were found in the groundwater in a sandstone horizon of the Culm Measures at a maximum concentration of 2300 ng l^{-1}.

The concentrations detected both in interstitial pore waters and groundwater samples were several orders of magnitude less than the expected concentrations for the waste dip (Littlejohn and Melvin 1989). This indicates that considerable attenuation does take place in the soil and/or upper aquifer. The exact mechanisms for this attenuation have not been researched for this project, but the literature indicates that biodegradation of the pesticides occurs in the soil horizon (Henderson 1988, Getzin and Rosefield 1966, Bowman 1991, Inch *et al.* 1972, Lopez-Avila *et al.* 1986, Leistra *et al.* 1984). However, given that the limit for pesticides in drinking water is set at 100 ng l^{-1} for any individual pesticide and 500 ng l^{-1} for total pesticides, this attenuation effect is still not sufficient in highly permeable aquifers where high loading rates are applied repeatedly to the same area.

Waste sheep dip disposal, and to some extent the dipping operation in general, on shallow soils or drift overlying impermeable strata will lead to the build-up of a reservoir of pesticides in the overburden. The amount of risk this poses to water quality depends upon a number of factors, such as rainfall, ground slope, proximity of dipping and dip disposal sites to water courses and whether or not the contaminated soil is likely to be disturbed. There has been at least one instance, where a dip disposal site was disturbed to install drainage pipes, which resulted in significant pollution of a river (South West Water 1984). Three sites investigated for this project contained considerable concentrations of sheep dip pesticides in soil overlying impermeable bedrock.

At sites on impermeable bedrock with shallow soils or drift cover which are close to surface water courses, some pollution is likely. Dilution by stream flow will often mask this, but peaks may occur around dipping time which are difficult to pick up through routine monitoring.

Since 1992 onwards in Great Britain, dipping for sheep has not beeen compulsory; rather it is left to farmers to treat scab outbreaks as they occur, as they currently do with other ectoparasitic infestations. The situation is currently under review in Northern Ireland. However, the problems of dipping and dip waste disposal are likely to continue for some time to come. It is unclear how quickly an alternative for dipping to treat scab will emerge, but alternatives such as spray-on or pour-on treatments will still require the handling and disposal of pesticides.

Disposal to landfill or incineration of sheep dip waste is likely to be prohibitively expensive for most farmers, not least because of the transport costs. Treatment of dip waste along the lines of the Allman's Sentinel plant is technically feasible, but further investment would be required to develop it commercially. Allman's would not be prepared to invest further capital in the plant unless they were more certain of the future of dipping, and hence their market. In any case, such treatment would be prohibitively expensive for most average-sized farms. More realistically, a larger version, situated within easy reach of a number of farms would be needed. Without legislation preventing current disposal options available to farmers, this will not be possible.

Results from preliminary experiments carried out by WRc suggest that disposal by spreading to land, possibly mixed with cattle slurry, at low loading rates, poses less risk of pollution than disposal to soakaway or disposal of large volumes onto small areas. However, there are some reservations about this technique, because of the problems of diluting the dip waste and producing a larger volume for disposal, the pollution risk of cattle slurry being worsened by adding pesticides and the possibility of changing a point-source pollution risk into a diffuse pollution risk.

The results of this project indicate that some pollution of water resources is likely to occur in intensive sheep farming areas as a result of sheep dipping and dip disposal operations. The actual risk this poses to the water consumer is unclear, as the limit of 100 ng l^{-1} set for individual pesticides in drinking water is not based on the toxicological data, but was set as a surrogate zero in the 1970s when this was the best detection limit. The organophosphorus pesticides are certainly toxic to mammals in acute doses, but the effects of exposure to low concentrations ingested in drinking water over long periods are less clear. The provisional EQS values proposed for the organophosphorus group are 100 ng l^{-1} as a maximum allowable concentration and 10 ng l^{-1} annual average. It should be noted that these EQS values are proposed for the protection of aquatic life and are not based on mammalian toxicity.

To put these findings in perspective, the risk to water consumers is considerably less than that faced by the persons carrying out the dipping. They inevitably become soaked in dip solution at tens of milligrams per litre concentrations, and the wearing of protective clothing is made impractical by the arduous nature of the work, which can last for several days at a time. Research is being carried out into the long-term health effects on the farmers, which media reports indicate are severe (Bartle 1991; Watts and Prestage 1991). It may be that changes to sheep dipping and dip disposal practice will not be driven by concerns over water pollution, but rather by the need to legislate to protect the health of the farmers.

8. RECOMMENDATIONS

1. The disposal of sheep dip waste needs to be under the legislative control of the Regulatory Water Organisations including the NRA. At present it must be proven that pollution has occurred before a farmer can be compelled to change established practice.

2. For the Regulatory Water Organisations to prevent pollution from dippers and dip disposal, there should be greater co-operation between the various organisations involved in sheep dipping. In particular, the NRA should seek the support of Trading Standards Officers (TSOs) in identifying dip location and other details currently held. This is of particular importance now that the compulsory scab dip will no longer be enforced by TSOs.

3. Information held by dip manufacturers on their products should be provided to the NRA who would respect its commercial sensitivity, including toxicity, degradation rates, etc. The National Office for Animal Health Ltd (NOAH) has identified its Compendium of Data Sheets for Veterinary Products as a useful document in this respect.

4. Disposal of sheep dip waste to soakaway or at high loading rates to land should be banned, including the existing sites where these practices are currently used safely.

5. The disposal of sheep dip waste has been included in the scope of the work of the MAFF Pesticides Disposal Working Group, although technically sheep dip is a veterinary medicine, not a pesticide. This group provides an important link between the interested groups such as the Veterinary Medicines Directorate of MAFF, the National Farmers Union, the NRA, NOAH and the Health and Safety Executive and, as such, sheep dip should continue to be covered by the group.

6. The siting of new dips and the associated plans for dip disposal should be subject to planning controls, with the Regulatory Water Organisations as statutory consultees. In the longer term, consideration should be given to the need to register sheep dippers.

7. Greater efforts should be made to make sheep farmers aware of the risks of pollution that their dipping operations may cause; most can appreciate that surface water is at risk, but there seems to be a widespread lack of understanding about the possibilities of groundwater contamination.

8. Surface water sampling programmes to monitor for pollution from sheep dips and dip waste disposal must be designed carefully to detect maximum concentrations of pesticides. The use of biological monitoring may be helpful, but must be backed up by chemical monitoring.

9. Research into the alternative to dipping by manufacturers of veterinary medicines and the relevant government bodies is recommended. This, combined with the decision to end the use of compulsory dipping periods in Great Britain, is likely to lead to a move away from the use of dipping in the long term. However, it is likely that dipping will still be the most effective control for scab in the near future.

10. The recommended options for dip waste disposal, which are now included in guidelines issued by the government (e.g. Code of Good Agricultural Practice for Protection of Water; the PEPFAA Code for Scotland (SOAFD 1992)), are:

    - no spreading on land identified as not suitable or very high risk or high risk categories in respect of spreading of animal manures as indicated in the Code of Good Agricultural Practice for Protection of Water;
    - spreading to suitable areas of land at loading rates of less than 5 m^3 per hectare of dilute used dip fluid (not the concentrate); and
    - collection of the waste for treatment and off-site disposal at a properly licensed/approved site.

    Cattle slurry may be an aid to biodegradation of dip pesticides, but disposal direct to slurry lagoons is not recommended. Addition of slurry to the waste dip before disposal to land would be more acceptable. It is recommended that research into the efficiency of these options is continued by MAFF, industry and the NRA.

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