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The Impact of Destocking on the Microbiological Quality of Rivers in the Caldew Catchment - Volumes 1 & 2

Science Report SC020045/SR

Environment Agency

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Statement of Use:
This technical report contains the results of a study to describe the impact of changes in stocking density on the microbiological water quality of the Caldew Catchment in Cumbria, which was heavily affected by foot and mouth disease (FMD). The information in this document is for use by Environment Agency staff and others involved in the regulation of diffuse microbial pollution.

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Professor Mike Depledge Head of Science

Executive Summary

Objectives and design

This project monitored and described the impact of changes in stocking density on the microbiological water quality of the Caldew Catchment in Cumbria, which was heavily affected by foot and mouth disease (FMD).

To characterize the catchment in agricultural terms, manure production and farm management practices were monitored through the integration of Department of Environment, Food and Rural Affairs (Defra) agricultural census data and livestock movement statistics, by a field survey of representative farms and by the seasonal modelling of manure management using the results of national and regional stratified surveys of farm practices.

Twenty-five farms, selected as typical of the catchment, were recruited for detailed survey. The farms represented 23% of the total farmed area in the catchment and accounted for 26% of the total cattle population and 14% of the total sheep population. At the start of the project, they were surveyed using a questionnaire and farm map for livestock and land-use practices both prior to and following the FMD outbreak. The farm locations were distributed evenly across the subcatchments. Monthly log sheets, which provided information on farming activities during the project, were completed by each of the 25 farmers from December 2002 to December 2003.

The timing of animal grazing is of special importance in assessing the risk of faecal indicator delivery to watercourses, as fresh excreta voided directly onto fields is not subject to die-off in storage. For the water-quality data analysis the study was divided into 'summer' periods, when virtually all cattle are out in the fields, and 'winter' periods, when the majority of the cattle are indoors, defined as follows:

- October 2001-April 2002: restocking winter;
- May-September 2002: mostly stocked summer;
- October 2002-April 2003: restocked post-FMD winter;
- May-September 2003: restocked post-FMD summer.

Fifteen sites, selected for their particular catchment characteristics of topography, potential land-use, stocking densities and management practices, were sampled for total coliforms, faecal coliforms and enterococci between December 2001 and January 2004. Discharge ($m^3\ s^{-1}$) was estimated for each site based on data from Environment Agency flow-monitoring stations, flow modelling and/or hydrometric survey.

The impact of foot and mouth disease on stock levels and manure management

The catchment is predominantly a productive grass-growing area with mainly dairy and stock-rearing farms. Most are family farms of medium size, although there are a substantial number of fairly large livestock holdings. 330 individual holdings were located within the Caldew Catchment, of which half accounted for 90% of grazed livestock.

The catchment was heavily affected by FMD, with a total of 175 infected premises (IPs) and dangerous contacts (DCs) where stock was culled, the majority between April and May 2001. Approximately 80% of cattle and 90% of sheep in the catchment were culled. The majority of stock was culled during April and May 2001. By mid-2002 stock numbers increased rapidly (i.e. to 75% of cattle and 52% of sheep numbers prior to FMD), but this rate of increase has not been sustained and the most recent available census statistics for June 2003 show only 79% and 59% of pre-FMD numbers, respectively (*Figure S1*). Stock densities may never reach pre-FMD levels because of Common Agricultural Policy (CAP) reforms and de-coupling of farm subsidies.

Monthly stock records from the surveyed farms and records of restocking during 2002 were used to identify stock numbers within the catchment from September 2001 to June 2003. It was assumed that no farm began restocking until September 2001. The restocking of cattle, many of which were in calf, occurred between January and March 2002 at a time when animals were normally housed. Therefore, by the time the newly introduced animals were out grazing and presented the greatest risk of faecal indicator organism pollution of streams, the estimated excreta load was already at 70% of pre-FMD levels. Sheep were restocked in two phases over the winters of 2001/02 and 2002/03, although some evidence suggests that some farms abandoned sheep rearing.

Faecal indicator organism concentrations and flux

Generally, there was an increase in microbial concentrations downstream under both base-flow and high-flow conditions. Geometric mean (GM) concentrations were lowest in the headwater, fell and areas of the upper Caldew Catchment during all four study periods. In contrast, the concentrations in the predominantly improved pasture headwaters of the Roe Beck Catchment were greater. Overall, concentrations within the Roe Beck and River Ive Catchment upstream of its confluence with the River Caldew were greater than those within the upper and middle Caldew Catchment.

These differences in water quality may be explained by the variation in land use within each subcatchment, with a greater proportion of improved pasture and lower proportion of rough grazing in the Roe Beck and River Ive Catchment compared to the Caldew Catchment.

The subcatchment delivery of faecal indicators exhibits strong seasonality – summer concentrations exceeded winter concentrations at all sites (*Figure S2*). This seasonality is significant to the design of future studies of diffuse pollution remediation strategies. High-flow periods exhibited the highest concentrations and dominated faecal indicator fluxes from the catchments. This characteristic was further exacerbated after restocking (*Figure S2*). Low-flow concentrations did not exhibit any particular pattern, which suggests the acquisition of low-flow survey data is of limited value in studies of faecal indicator flux and of the evaluation of diffuse pollution-remediation strategies where there are few point-source inputs.

Modelling the relationships of land cover, stock numbers and manure quantities with faecal indicator organisms

Multiple regression was used to model the relationships between GM faecal indicator organism concentrations and percentage land use, livestock numbers and animal waste volumes within subcatchments. In the majority of cases, the best predictor of faecal indicator organism concentrations was the proportion of improved pasture. Land-use variables produced the most significant relationships when compared to the stocking number and manure input variables. This reflects the potential sources of faecal indicator organisms associated with this land-use type (i.e. grazing animals and spreading of animal wastes).

A generic model able to predict water quality using land-cover data and developed by the Centre for Research into Environment and Health (CREH) was used to predict summer faecal indicator organism concentrations at the sampling sites assuming a condition of 100% pre-FMD stock levels. An analysis of the residuals (i.e. observed minus predicted concentrations) indicated that concentrations in the Caldew Catchment had not reached the modelled concentrations by the summer of 2003 (restocked post-FMD summer). Furthermore, greater residuals were evident during the summer of 2002 (mostly restocked summer), which indicates that the increase in animal numbers between the 2 years has resulted in concentrations moving towards the modelled levels. Land-use data are more readily available than the remaining variables considered here and the further development of the land-use-water quality models on this basis would be possible. The similarity of the most significant predictor variables to previous CREH modelling exercises suggests that this approach would be portable to other catchments.

Tentative relationships between stock density expressed in livestock units and GM high-flow faecal indicator organism concentrations were developed. These relationships may be used to relate stock density to estimated water quality, although the confidence intervals of the relationships are currently quite large and the GM concentrations upon which the relationships are based are poorly characterized. However, further research into consolidating these relationships could produce a useful management tool to inform estimates of the impact of agricultural practices on diffuse pollution generation.

Reforms to the CAP are likely to have a significant impact on the Caldew Catchment, in terms of changes to stock numbers, which are likely to result in further changes to water quality. An ideal opportunity therefore exists to characterize the impacts of CAP reform on both stock numbers and water quality, and the relationships between the two, through further study of this catchment. Such a study would also present an opportunity to collect further data of the type necessary to improve the functions that describe the relationships between stock density and water quality.

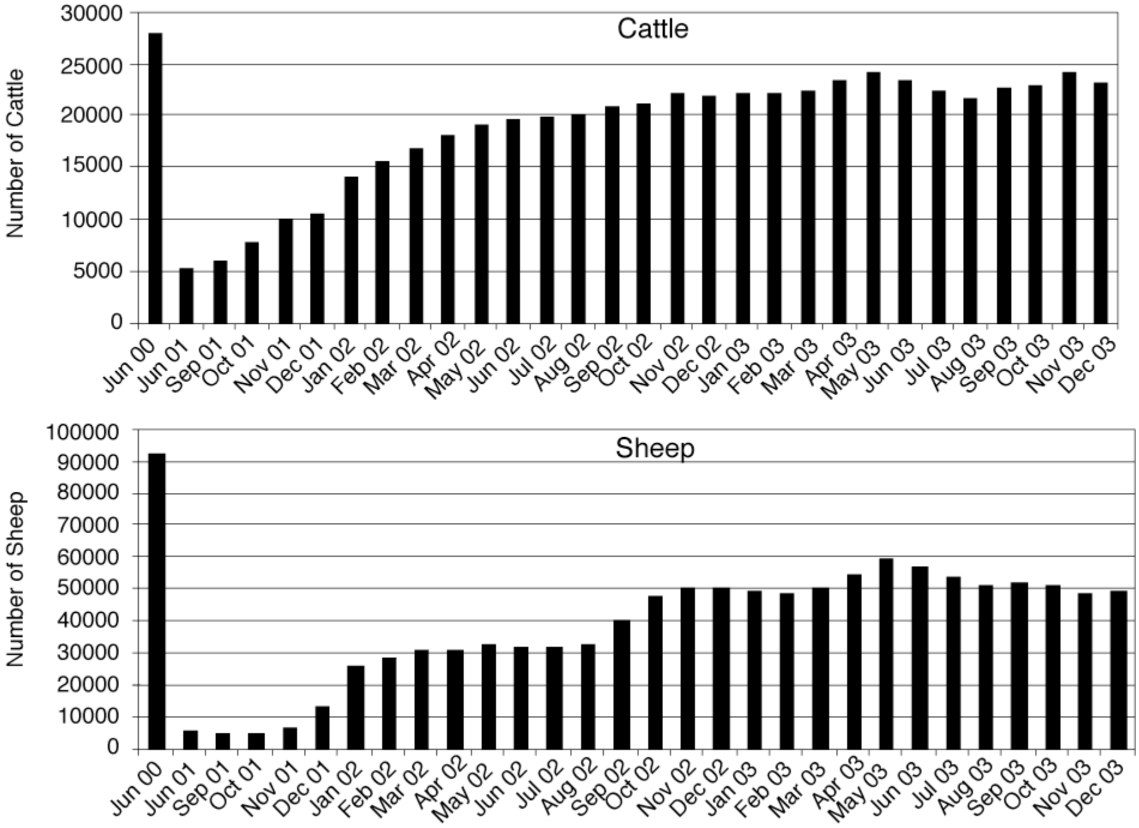

Figure S1: **Calculated total numbers of cattle (top) and sheep (bottom) in the Caldew catchment, between June 2000 and December 2003.**

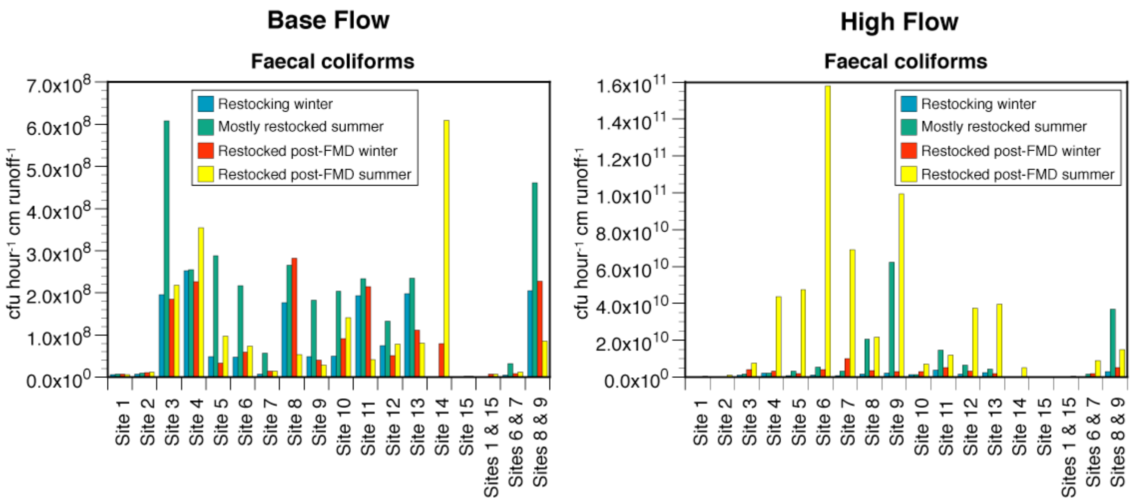

Figure S2: **Base flow and high flow faecal coliform export coefficient (cfu hr^{-1} cm $runoff^{-1}$) during the restocking winter (October 2001 to April 2002), mostly stocked summer (May to September 2002) restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).**

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1. INTRODUCTION

The delivery of diffuse bacterial pollution derived from agricultural activities within catchments is a contributor to the non-compliance of some UK bathing water locations. This pollution loading is highly episodic and driven by catchment hydrological processes that produce a short-term flush of faecal pollution early in the hydrograph event. Remediation of this diffuse pollution loading requires the type of upstream catchment management and control noted in the Council of the European Communities (CEC) Draft Bathing Water Directive (2002) preamble, which suggest the implementation of Water Framework Directive (2000) principles in the management of complex pollution sources.

Faecal indicator organisms in the estuarine and coastal environment could derive from human or animal sources (Booth *et al.,* 2003). The former could be effluents discharged to rivers, estuaries or the sea and spills from combined sewer overflows (CSOs) and/or storm tanks. The latter could be diffuse sources in riverine catchments related to agricultural activities. Previous Centre for Research into Environment and Health (CREH) work for the Environment Agency, Scottish Environment Protection Agency (SEPA), Scottish Executive and water companies suggests a highly episodic and complex input pattern dominated by flushes after rainfall (Fewtrell *et al.,* 1998; Stapleton *et al.,* 1999, 2000a,b, 2002; Wyer *et al.,* 1995, 1998a,b,c, 1999a,b, 2000, 2001, 2003; Wyer and Kay, 2000).

This opportunistic project was initiated by the Environment Agency (North West Region) to quantify the contribution of farm livestock to faecal indicator loadings in streams that drain the Caldew Catchment in Cumbria. Some subcatchments of the Caldew were almost entirely de-stocked following the outbreak of foot and mouth disease (FMD) in 2001-2002. Water-sampling programmes were undertaken by Environment Agency field officers to quantify the effects of destocked and restocked conditions within the Caldew Catchment. Detailed subcatchment data that described land use were acquired by ADAS Consulting and CREH analysed the resultant data to provide a longitudinal comparison of water-quality changes within the sampled subcatchments. The Caldew case-study provides a unique illustration of faecal indicator delivery from a principally grassland catchment in which the major sources of faecal indicators were wildlife and small sewage systems, such as septic tanks and soakaways, during the destocked FMD period.

1.1 Objectives of the project

- To design a programme of sampling and data collection implemented by Environment Agency staff to investigate the possible relationships between stocking density and microbiological quality of water in a catchment affected by FMD cull.

- To produce a reasoned description of the impact of destocking on microbiological quality in the catchment, taking into account catchment topography, land use, manure management and stock-management practices, and possibly other factors found during the study to affect water quality.

- To investigate the potential for design and application of a predictive tool that links stock density, stock and manure management practices, topography and precipitation with the microbiological quality of the watercourse.

2. SAMPLING AND DATA COLLECTION

2.1 Farm questionnaire, map and monthly log sheets

As part of this project, 25 farms within the catchment were recruited by ADAS. These were selected, as typical of the catchment, in discussion with the local Environment Agency pollution control team and were known to both ADAS and the Environment Agency. The National Farmers Union (NFU) and Country Land and Business Association (CLA) were both kept informed during the recruitment process and were supportive. The farms were surveyed, by standard questionnaire and log sheet (Appendix I), for livestock and land-use practices prior to and after the FMD outbreak. The farm locations were distributed across the subcatchments to enable representative statistics to be calculated.

A questionnaire (Appendix I) was designed to collect information on aspects of the farming system that may effect water quality. The following data were collected from the farmer, on the farm:

- Cropping and stocking rates, both current and pre-FMD.
- Impact of FMD on stocking and timing of restocking to support British Cattle Movement Service (BCMS) data.
- Manure management, including type, age at spreading and quantities of waste, slurry storage capacity and spreading details.
- Spring turn-out dates and autumn housing dates for cattle.
- Imported or exported wastes.
- Soil types.
- Areas of yards, hardstandings and building roofs.
- Out-wintering of cattle.

A base map was provided by the Environment Agency for each farm at 1:7500 or 1:10,000 scale, showing field boundaries and watercourses, etc. The following information was given by the farmer and marked on the map:

- Farm boundary;
- Fields or part-field areas where wastes are normally spread;
- Fields or part-field areas where effective land drains are present;
- Streams, ditches and freshwater ponds that cattle can walk into or through;
- Current field use;
- Fields used for out-wintering cattle.

The log sheets were completed, each month, by each of the 25 farmers from December 2002 to December 2003. They were designed to give detailed information on farming activities during the project. While the log sheets only cover a sample of farms in the catchment, they represent 23% of the total land area and therefore provide an indication of the typical farming practices that take place on a monthly basis, in particular:

- Grazing practices and stocking rates.
- Spring turn-out dates and autumn turn-in dates for cattle.
- Quantity of wastes spread, application rates and age of wastes when spread.

As part of the farm survey, a risk characterization was carried out to enumerate the numbers of fields to which manure is spread, fields in which grazing livestock have access to flowing water and field that have artificial drainage. For each of the 25 survey farms, the manager was interviewed by a farm consultant and guided through the process of marking on a detailed farm map (1:10,000) of individual fields the normal field management. The same maps were used by a geographical information systems (GIS) consultant to identify those fields in which mapped drainage features (streams and ditches) either passed through the field or marked the field boundary. Those directly accessible for grazing livestock were identified again in consultation with the farm manager.

2.2 Land-cover mapping

To determine the applications of excreta and managed manure to land within the catchment, and to provide land cover data for the modelling exercise, it was necessary to map the distribution of agricultural land types and the distribution of livestock. This included differentiating between arable and grassland, and also of types of arable cropping, as this impacts on the likelihood and timing of managed manure applications. The distribution of holdings does not provide sufficient information for this as the land managed by each farm office is frequently some distance away.

For this work, we employed the ADAS National Land Use Map (Lord and Anthony, 2000). This is a dataset that provides statistical information on the numbers of livestock and areas of crops within each cell of 1 km^2. The dataset has been constructed through the application of algorithms that integrate Department of Environment, Food and Rural Affairs (Defra) holding-level statistics data with remotely sensed and cartographic vector map products that identify areas potentially under agricultural use (i.e. the CEH 1990 land-cover map (Fuller *et al*., 1994) and the Ordnance Survey Strategi™ dataset (Ordnance Survey, 2004). The algorithms are designed so that the mapped land use (in a GIS) agrees exactly with tabular returns from the census.

2.3 Sample site selection

Initially, 13 sites along the River Caldew and on some of its tributaries were identified for water-quality monitoring (Sites 1-13, *Table 2.1*, *Figure 2.1*). These are particularly concentrated in the upper catchment and define relatively small subcatchments selected for their particular characteristics of topography, potential land-use, stocking densities and management practices. This was undertaken after a preliminary survey of the catchment and in liaison with local Environment Agency and ADAS staff. A further two sites (Sites 14 and 15, *Table 2.1*, *Figure 2.1*) were added early in 2003 when it became apparent that Common Grazing Agreements under The Lakes Environmentally Sensitive Area (ESA) Scheme had restricted the level of stocking and allowed further quantification of water quality from destocked areas. One of these sites (site 14, River Glenderamackin at Mungrisdale) was outside the Caldew Catchment, although its proximity to the catchment and its similar land use merited its inclusion.

2.4 Estimation of river discharge

The Environment Agency hydrological monitoring network includes two discharge ($m^3 s^{-1}$) monitoring stations within the catchment at Stockdalewath (NGR: NY 38745 45009) on Roe Beck (confluent with the River Caldew in the middle catchment) and Cummersdale (NGR: NY 39489 52727) on the River Caldew in its lower reaches

(*Table 2.2*, *Figure 2.1*). Discharge time series data at 15 minute intervals were obtained from the two gauges throughout the entire study and sampling periods (i.e. 1st October 2001 to 1/2/04). Sequences of mean hourly discharge were calculated for each catchment. These flow records were used to estimate discharge for the sampling sites proximal to the gauges: sites 8, 9 and 11 utilized data from Stockdalewath, while sites 12 and 13 utilized data from Cummersdale (*Table 2.1*). For each sampling location, the flow record was scaled by the catchment area, derived from a digital elevation model (DEM; *Table 2.1*) on the assumption that runoff is equal across the area. A time lag was also applied to the record to allow for travel times through the catchment. This was estimated by comparing the travel times of hydrograph peaks between sites with monitored and/or modelled flow records (i.e. the Environment Agency gauges and those monitored or modelled as described below).

In addition barometric-level recorders were installed in the streambed at eight sites (*Table 2.1*), together with two 'compensation' units deployed to record atmospheric pressure. These provided a measure of stream depth every 15 minutes that can be linked to stage boards to provide an indication of the provenance of each water-quality sample. Flow-velocity profiles were also taken at four sites that covered headwater catchments to derive stage–discharge relationships. These were applied to the continuous stage traces, thus providing discharge estimates for the relevant catchments: two covered upland fell catchments at sites 5 (Parkend Beck at Parkend) and 15 (Carrock Beck); and two covered lowland catchments at sites 6 (Peel Gill) and 7 (Roe Beck at Crown Point; *Table 2.1*).

The field methods applied in the hydrological measurement component of this project followed Chapter 4 *Instantaneous Flow Measurement* in the *Environment Agency Hydrometric Manual* (Environment Agency, 2003, Draft). Both moving element (AOTT C31) and electromagnetic (SENSA RC-2) flow meters were available at each site. The former is more appropriate to larger channels, while the latter offers a more appropriate approach to velocity measurement in shallow or vegetated environments. Manufacturers' calibration records for both meters are available.

The 'Mean Section Method' was used for discharge calculation, but the 'Mid Section Method' was also utilized as a further check. Checks were also implemented to ensure the best possible stage–discharge relationships within the time available. First, supplementary analysis was undertaken, based on rainfall volume and catchment area, as a check on the top-end discharges suggested by the power function calculated for each site. Second, a rainfall-runoff model was employed following the approach of Littlewood and Jakeman (1992), again to check the upper end of the stage–discharge relationship.

The installation of the barometric level recorders was not initiated until December 2002, and thus a period of approximately 14 months exists within the study period for which there is no continuous stage record at the sites not monitored by the Environment Agency. Furthermore, no stage–discharge relationships were available for six sites (sites 1 to 4, 10 and 14; *Table 2.1*). For these sites it was necessary to model flows utilizing the stage records where available, as described in Section 2.4.1.

2.4.1 Flow modelling

Flow modelling was based on a lumped conceptual model, IHACRES (Identification of unit hydrographs and component flows from rainfall, evaporation and streamflow data; Jakeman *et al.*, 1990; Littlewood and Jakeman, 1992). Rainfall data utilized by the model was derived from Environment Agency gauges (Section 2.4.3). Rainfall was taken from the Mosedale, Calebreck Hall and Skelton rain gauges. The variation of the vicinity of the gauges with respect to the different stream sampling sites required simple assumptions to be made about which gauge or combination of gauges was likely to be most relevant to which site. For sites 1 and 2, rainfall at Mosedale was used, while for sites 3 and 4 Calebreck Hall was used. Site 5 had approximately equal proximity to Calebreck Hall and Mosedale and the average of the two sets of data was used. Rainfall at Skelton was used for sites 7 and 10. Site 6 was anomalous in that, although its' catchment was closest to the Skelton rain gauge, the peaks and troughs in flow were found to be best matched by rainfall at Mosedale.

2.4.2 High-flow separation

The hourly discharge records are split into two components: (i) base flow and (ii) high flow (Wyer *et al*., 1996). This was achieved using a combination of computer programs (Pascal) and visual inspection of individual events. The computer programs apply smoothing to the time series and examine the change in the smoothed values at each time step to define the start and peak of events above a defined threshold. The event end, or cut off, was set at a decay to 56% of the event peak. This value was derived from an analysis of over 100 events separated manually in previous CREH catchment investigations. While this process worked well for larger events, a degree of manual intervention was required for smaller events and some event sequences. The final separation was applied to the un-smoothed hourly time series. Each water-quality sample was then assigned either to base-flow or high-flow categories according to flow conditions at the time of sampling.

2.4.3 Rainfall

Rainfall (mm) within the Caldew Catchment was monitored by the Environment Agency at six locations (*Table 2.3*, *Figure 2.1*). However, hourly records were available at four of these gauges (*Table 2.3*). The hourly rainfall records were used within the flow models described in Section 2.4.1 and to aid the high-flow separation process.

2.5 Water-quality monitoring

Sites were sampled on a once weekly basis for the faecal indicator organisms total coliforms, faecal coliforms and intestinal enterococci (faecal streptococci), and a suite of physicochemical parameters, including turbidity, suspended solids and nutrients. In addition, during one week in each month, more intensive daily sampling was undertaken to characterize water quality during a number of 'high flow' events, on the premise that microbial water quality deteriorates during periods of rainfall-induced increased flows (Wyer *et al*., 1997, 1998a). Sampling encompassed the months of December through to June for 2001-02 and 2002-03. A further period of targeted sampling during high-flow periods from June 2003 to January 2004 was undertaken once it became apparent that the number of high-flow samples for the period December 2002 to June 2003 was low.

Microbiological analyses were undertaken by the Environment Agency at accredited laboratories using standard methods outlined in Environment Agency (2000).

2.6 Statistical analysis

For statistical analyses, samples in which no organisms were detected were recorded as the detection-limit value. The distribution of microbial concentrations found in stream samples, taken under base-flow and high-flow conditions, showed a closer approximation to normality when $\log_{10}$ transformed. All microbial concentration data were, therefore, $\log_{10}$ transformed prior to statistical analysis. The MINITAB (1995; Ryan and Joiner, 1994) and SPSS (1999; Pallant, 2001) packages were used for statistical analyses.

Water-quality samples were assigned to either base-flow or high-flow categories according to their time of sampling using the separated hourly flow records (Section 2.4.2). Descriptive statistics were used to characterize the distribution of bacterial concentrations at each sampling location. These statistics include the geometric mean (GM), calculated as the antilog of the mean of $\log_{10}$ transformed concentrations, the standard deviation (SD) of $\log_{10}$ transformed concentrations, the 95% confidence interval for the mean and the range of values at each site. The significance of differences between GM concentrations was examined using Student's t-test to compare the means of $\log_{10}$ transformed concentrations. The methodology included Levene's test for equality of variances to determine whether or not the t-test applied should assume equal variances, with the hypothesis of equal variance being rejected at $p < 0.05$ (Pallant, 2001).

All statistical tests were assessed at $\alpha = 0.05$ (i.e. 95% confidence level or 5% significance level) by comparing p, the calculated probability at which the null hypothesis for a particular test is accepted, to α. Rejection of the null hypothesis (e.g. that two means are not different from each other or that a regression line slope is not different from zero) and acceptance of the alternative hypothesis (e.g. that two means are different from each other or that a regression line slope is different from zero) occurs when $p < \alpha$ (i.e. $p < 0.05$).

2.7 Faecal indicator organism load estimates

Faecal indicator organism load estimates were made for each sample site over the selected periods (see Section 3.4) to examine the faecal indicator organism inputs from each subcatchment. The faecal indicator organism loads were calculated as follows:

(i) The load, L (organisms), of each indicator organism was calculated for each source (i) for base flow (b) and high flow (h) discharge components during the study period:

$$L_{ib} = Q_{ib} \times C_{ib} \quad \textbf{(2.1)}$$
$$L_{ih} = Q_{ih} \times C_{ih} \quad \textbf{(2.2)}$$

where:
Q = flow (m^3) during the study period;
C = GM concentration (per m^3).

(ii) Total load, L_{it} (organisms), from each source was calculated as:

$$L_{it} = L_{ib} + L_{ih} \quad \textbf{(2.3)}$$

(iii) The total load, L_s (organisms), from all sources is given by:

$$L_s = \Sigma L_{it}. \quad \textbf{(2.4)}$$

(iv) Proportional contributions, PC_{ix} (%), from each source, i, associated with each flow component, x (base flow, high flow or total flow) for each site and/or group of sites were finally calculated as:

$$PC_{ix} = (L_{ix}/L_s) \text{ x } 100 \quad \textbf{(2.5)}$$

Similar proportional contributions were calculated for base flow, high flow and total discharge estimates.

3. FARM CHARACTERISTICS

The objective of this part of the work was to characterize manure production and management practices within the catchment of the River Caldew above the monitoring station at Holmehead (NY 397 545; 254.6 km^2) and to chart the changes in animal numbers during the period of restocking after the catchment-wide FMD cull. This was achieved through the integration of official agricultural census and livestock movement statistics, by a field survey of representative farms and by the seasonal modelling of manure management using the results of national and regional stratified surveys of farm practices.

The catchment of the River Caldew above the sample site at Holmehead drains an area of 254.6 km^2. Average annual rainfall is in the range 830 to 2190 mm (average of 1300 mm), increasing with altitude from 10 m at Carlisle to 900 m on Mungrisdale Common (MC) and the Skiddaw Forest. The river rises on impervious Skiddaw Slates and flows north over carboniferous limestone in the headwaters. Hill peat and boulder clay are extensive below 200 m. Topography is predominantly gently sloping or level land at the catchment mouth, becoming more undulating further up the catchment. Moderate- and steep-sloping fields become more common nearer to the fells, although such slopes can also be found in some areas of the middle and lower parts of the catchment. The catchment is rural, with heath and moorland in the headwaters, and mixed dairy farming confined to the lower reaches. The dominant soil series are the eriophum and sphagnum peat Winter Hill on the hillsides and summit plateaux, the clayey drift Hallsworth at the foot of the hills and the light loamy drift Quorndon over the lowlands. The Quorndon series is described as rapidly permeable with groundwater at shallow depth (60 cm). All soils require drainage for agriculture to prevent surface runoff.

Land cover in the catchment is dominated by improved pasture (52.3%) and rough grazing on common land (29.6%). Arable cropping (5.7%) and woodland (5.8%) make only minor contributions. Land cover varies geographically, providing a continuum of agricultural intensity between the headwaters and mouth of the catchment (*Table 3.1*; *Figure 3.1*).

3.1 Farm characteristics

The catchment is predominantly a productive grass-growing area with mainly dairy and stock-rearing farms. Most are family farms of medium size, although there are a substantial number of fairly large livestock holdings, including a small number of intensive pig and poultry units towards the lower end of the catchment. Defra annual agricultural census statistics for 2000 to 2003 identify 330 individual holdings located within the Caldew Catchment (*Figure 3.2*). Of these, 165 are below the gross margin threshold for a commercially viable farm to provide full-time work for one person (i.e. they are part-time farms within the accepted definition – less than 16 European Currency Units, equivalent to about £20,000 per year). The larger enterprises account for more than 90% of the total cattle, sheep and pigs within the catchment, and for 45% of the poultry (*Table 3.2*). The majority are classified by income source as dairy farms or mixed cattle and sheep farms (*Table 3.3*, *Figure 3.3*). The dairy farms predominate in the lower and middle parts of the catchment, including the Roe and Ive subcatchments. Pre-FMD, these farms typically had fairly high stocking rates and almost all also kept some sheep. On higher and more marginal land towards the upper end of the catchment, beef cattle and upland sheep systems become most common where stocking rates are generally lower. Prior to the FMD outbreak, the Defra June 2000 agricultural census reported 29,500 cattle and 96,500 sheep associated with farms located within the catchment[1].

The 25 survey farms were representative of the dairy, and mixed beef and sheep farms within the study catchment. The total land area managed by the farms is 8200 ha, including 4800 ha of sheep fell-grazing rights, which represents 23% of the total farmed area in the catchment (*Table 3.4*). The survey farms were targeted to the livestock enterprises; hence only 3% of the land area was under arable or fodder crops compared to a catchment average of 13%. The 25 survey farms accounted for 26% of the total cattle population and 14% of the total sheep population, prior to the FMD outbreak (*Table 3.5*). Of the 25 farms, 19 had all livestock culled during the FMD cull, one had only sheep culled, one had only cattle culled and the remainder were unaffected.

The average survey farm size was 140 ha (range 50 to 300 ha). The average area of yards, hard standing and roofs was 5650 m^2; the majority was accounted for by roof area (59%), but in total still represented less than 0.5% of the total farmed area. Only 26% of the total hardstanding area drained to a soakaway or slurry system, the remainder draining directly to a ditch or stream.

The survey farms areas are principally on medium (33%) and medium–heavy (58%) textured soils, with the majority (71%) having tile drainage systems connected to ditches and streams. The farms had between 11 and 56 fields, and a total of 851 fields were surveyed. Overall, 86% of the surveyed fields were under grass, which reflects the dominance of livestock farms. Of these fields, 54% received managed manure applications, 70% have artificial drainage installed, 49% are immediately adjacent to flowing waters and 25% have free access for livestock (*Table 3.6*). These data indicate a potentially high-risk environment for the transfer of faecal indicators in excreta and managed manure to the river system.

3.2 Immediate effects of foot and mouth disease

The catchment was heavily affected by FMD, with a total of 175 infected premises (IPs) and dangerous contacts (DCs) in which stock were culled. Approximately 80% of cattle and 90% of sheep in the catchment were culled, with almost complete destocking in some subcatchments. The majority of stock was culled during April and May 2001. As well as reducing animal numbers and manure production, FMD also disrupted the timing of manure spreading from March 2001 to autumn 2002. Spreading of manure from IPs and DCs was delayed for at least 90 days after the preliminary disinfection of a farm because of ‘Form A’ restrictions. On a number of farms, the manure was treated with lime by Defra contractors to allow earlier spreading.

Dirty water collected on IPs and DCs was typically treated with citric aid to allow spreading after preliminary disinfection and before ‘Form A’ restrictions were lifted. On some farms where storage capacity was plentiful, slurry may have been stored for a

[1]These figures include animals that belong to farms situated within the catchment, but which may be grazed on pasture outside the boundary of the catchment.

much longer period than normal until the lifting of 'Form A' restrictions. For many farms, this extended to the final months of 2001. Only a limited number of farms started restocking before the end of 2001. Significant restocking began during the early months of 2002 and increased through the spring.

3.2.1 Headwater fells

The upper part of the catchment consists of open fells at the north east corner of the Lake District National Park. These are normally grazed by sheep and a small number of horses and ponies. The fells are divided into three areas of common grazing each with a separate graziers association, as follows:

- Northern part of Mungrisdale Common (MC) – most is outside the catchment;
- Caldbeck Common (CC) – completely inside the catchment;
- Eastern part of Uldale Common (UC) – most is outside the catchment.

There is no fence between UC and CC so straying of sheep may take place. There is probably little straying between MC and CC.

MC has been in the ESAs scheme for a number of years with a maximum stocking rate set at 2 ewes/ha over most of it's area. MC has approximately 12 graziers, of which probably only two lost their sheep during FMD, so the overall stocking rate may not have been greatly affected by FMD.

The extra sampling point on MC located on the River Glenderamakin (site 14) is fed by a subcatchment that includes one heft[2] which, at 12th February 2003, had not been restocked, plus about another six hefts which were probably unaffected by FMD.

CC is by far the largest fell area in the catchment. It has approximately 30 graziers of which all but three lost their sheep during FMD, so the common suffered a dramatic fall in stocking rate. The extent of restocking on CC has not been established, but is believed to be very limited and patchy so far. The extra sampling point located on Carrock Beck (site 15) is fed by a subcatchment that probably contains very few sheep at present.

It appears that only a small proportion of UC graziers lost sheep during FMD, so the overall stocking rate on UC may not have been significantly affected by FMD.

There is usually considerable variation in fell stocking rates over the year because farmers typically keep some or all of their ewes off the fell during winter before turning single bearing ewes to the fell after lambing in April. Peak stocking is usually after weaning in August when most or all ewes are turned to the fell.

3.3 Livestock numbers

Farm holdings were geo-located by the unique County-Parish-Holding number to which Defra assigned a map reference marking the approximate location of the farm buildings. Holding locations were integrated with the map of drainage catchment boundaries to provide summary counts of livestock spanning the FMD outbreak (*Table 3.7a* to *3.7d*) from the Defra census statistics. These data are a snapshot of the numbers of animals on

[2]An area of fell land for grazing a controlled number sheep; a farmer may own or rent more than one heft.

farms on June 4th each year and do not reflect seasonality of animal numbers, especially of sheep. Although intended to be a complete census, it is a survey with approximately only 70% of the farm holdings completing census returns each year. Returns for no-return holdings are imputed by extrapolating statistics from farms of similar type (e.g. dairy or arable). During 2001 and 2002 census returns were expected to be especially low because of FMD and the consequent sensitivity of farmers to requests for data. It is known that in 2001 only a sample-based census was completed because of Defra commitments to FMD duties (Templeton, personal communication). It is not known what percentage of the returns were received for these two years. *Table 3.8* compares the census returns with the information provided by the 25 farms that ADAS surveyed as part of this project. The census returns do not agree with the farm records, and the magnitude of error varies from year to year. It is probable that this reflects a high proportion of imputed statistics in the Defra returns.

The census statistics show that cattle numbers were reduced by 80% and sheep numbers by 90% in the middle of the FMD outbreak. By mid-2002 numbers had increased rapidly to 75% of cattle and 52% of sheep those prior to FMD, but this rate of increase was not sustained and the most recent available census statistics for June 2003 show only 79% and 59% of pre FMD numbers (*Table 3.7a* to *3.7d*).

As part of the farm survey, farmers were asked, by keeping a log sheet, to record stock numbers by month during 2003 and to provide monthly stock numbers from the farm records for 2002. Animal numbers on the farms in 2003 were approximately stable, with a 10% rise in the number of cattle and a 15% decrease in the number of sheep between January and December 2003. These data for 2003 were therefore used to construct an index of the seasonality of cattle and sheep numbers (*Figure 3.4*). This describes the number of animals present as a proportion of the number on farm in June. Sheep numbers (including lambs) are shown to peak in May, and cattle in November and May, in association with newborn animals. The index re-enforces the point that the June census statistics are a snapshot of the farm year.

Monthly stock records from the survey farms through January to June 2003 and records of restocking during 2002 were used to construct a similar index of stock numbers from September 2001 to June 2003. It was assumed that no farm began restocking until September 2001 at the earliest, given that the last recorded outbreak of FMD in the catchment was in May 2001. The index expressed animal numbers as a proportion of those present on all the farms at the end of June 2003, and was calculated only for those survey farms that had been completely culled (*Figure 3.5*). The survey data indicate that cattle restocking was largely completed in a single phase that extended from September 2001 to August 2002, while sheep were imported in two phases over the winters of 2001/02 and 2002/03.

The records provided by the survey farms were validated against records of cattle births and live transfers between farms maintained by the Animal Movement Licensing System (AMLS). Each newborn calf is assigned a unique passport and all movements are registered with the AMLS. Cumulative numbers of animals born and moved onto the survey farms were compared with the farm records (*Figure 3.6*) and showed good agreement during the restocking period. There was a lag in the AMLS records that can be attributed to administrative delays, but the agreement indicated that the survey farm data could be trusted.

The Defra census statistics and survey index of restocking were integrated to provide a complete time-line for restocking in the catchment. For farms that had not been affected by FMD (i.e. sheep or cattle not culled), monthly estimates of animal numbers were made by linear interpolation between the June census returns for 2000, 2001, 2002 and 2003 for the individual holdings. These numbers were then scaled by the survey seasonality index to give a best estimate of the number of animals present on these farms in each month.

For farms that had been affected by FMD, monthly estimates of animal numbers were made by multiplication of the June census 2003 returns by the survey index of restocking, and further by the survey index of seasonality. This methodology assumed that the Defra census returns for 2000 and 2003, for all farms within the catchment, are definitive and have been spatially distributed to better reflect the likely distribution of stock across the catchment rather than based on the location of the farm unit itself. Thus, some stock have been assigned to land outside the Caldew Catchment boundary owned by farms located within the catchment, which results in slightly lower stock numbers than reported by the raw Defra census data. The final calculated monthly numbers of sheep and cattle in the whole of the catchment are shown in *Figure 3.7* and *Figure 3.8*, respectively.

To derive subcatchment livestock and manure application estimates, this pattern of livestock presence was used to scale estimates made for individual 1 km^2 cells in the catchment for the year 2000. Separate time series for each subcatchment are not presented, as the statistical base would be too small.

3.4 Grazing management

The timing of animal grazing is of special importance in assessing the risk of faecal indicator delivery to watercourses as fresh excreta voided directly onto fields is not subject to die-off in storage. The monthly records maintained by the survey farms during 2003 recorded the location and numbers of animals in housing and at grazing (*Table 3.9* and *Table 3.10*). Very strong seasonal cycles were recorded for cattle. Adult cattle are turned out to graze in April and May, and brought back in September and October. The overwinter grazing of beef cattle is rarely practiced. The younger calves and beef animals continue to spend at least 50% of their time indoors during the summer months. Fattening and wintering sheep grazed outdoors all year. An area of rough grazing was in use all year by the survey farms for the grazing of sheep (*Figure 3.9*).

The baseline questionnaire of 25 farms also recorded the turn-out[3] and turn-in dates[4] for the year 2002 and under pre-FMD conditions. Farms were classified as either dairy or beef, based on the relative numbers of adult beef and dairy cattle present. There were nine beef and 21 dairy farms in the baseline survey. For each class, the dates on which 50% of the farms turned cattle out for grazing and brought them into houses for winter were calculated.

[3]The date from which cattle are kept out in the fields during the day and night.
[4]The date when cattle are brought inside to be housed, all day and night, for the winter.

During 2002, the median grazing start date for dairy farms was 27th April (Julian 118) and the end of grazing was 14th October (Julian 288). Under pre-FMD conditions, the median grazing start date was 25th April (Julian 116) and the end of grazing was 6th October (Julian 280).

During 2002, the median grazing start date for beef farms was 6th May (Julian 127) and the end of grazing was 19th October (Julian 293). Under pre-FMD conditions, the median grazing start date was 9th May (Julian 130) and the end of grazing was 19th October (Julian 293).

There was some evidence that dairy cattle are turned out and let in earlier than beef cattle, by approximately 2 weeks, but the small sample numbers give a large uncertainty for this.

During 2002, the median grazing start date for all cattle was 3rd May (Julian 124) and end of grazing was 15th October (Julian 289). Under pre-FMD conditions, the median grazing start date was 1st May (Julian 122) and end of grazing was 11th October (Julian 285).

For 2003, the median dates of turn out and in were estimated from monthly records of adult animal numbers housed and grazing for each farm. For dairy cattle, the median grazing start date was 25th April (Julian 115) and the end of grazing was 15th October (Julian 288). For beef cattle, the median grazing start date was 11th May (Julian 131) and the end of grazing was 28th October (Julian 301).

Additionally, the SSLRC Agroclimatic Databank (Jones and Thomasson, 1985) provides algorithms for estimating the start and end of the grazing season for dairy cattle, based on an empirical analysis of practice related to site altitude, easting and northing. Application of these algorithms, taking a mean altitude of 250 m for the lowland dairy areas, gives a grazing start date of 1st May (Julian 122) and an end date of 30th August (Julian 241).

From this data, for the purposes of the water-quality data analysis and modelling work undertaken as part of this project, the study is therefore divided into 'summer' periods (May to September), when virtually all cattle are out in the fields, and the 'winter' periods (October to April), when the majority of the cattle are indoors. Flow-volume estimates, microbial water-quality data, budgets and export coefficients were generated for four periods, defined as follows:

- October 2001 to April 2002: restocking winter;
- May to September 2002: mostly stocked summer;
- October 2002 to April 2003: restocked post-FMD winter;
- May to September 2003: restocked post-FMD summer.

3.5 Land cover

Table 3.1 summarizes the areas of different land-cover types within the monitored subcatchments according to the ADAS National Land Use Map (2000; *Figure 3.1*). *Table 3.11* summarizes the numbers of livestock by detailed stock-age categories. According to this dataset, there were 30,300 cattle and 89,400 sheep within the Caldew Catchment in June 2000. The differences between these numbers and those mapped directly from the Defra census by farm holding locations reflects different assumptions about the distribution of livestock in the two data models. In the census, all animals are mapped to the location of the holding. In the ADAS dataset, livestock are mapped to the land on which they graze.

3.6 Manure management

The principal source of pathogens in agricultural catchments is excretion and the managed spreading of animal manures (both slurry and solid FYMs) to agricultural land. The rate at which manure is voided or spread on agricultural land varies seasonally with livestock type and numbers, weather conditions and land availability. For example, manures are largely spread on cereal land in late autumn and early spring. The type of manure produced (i.e. voided directly to land, or managed as slurry or solid manure) and, especially, the timing of application are known to influence the pathogen loads and the likelihood of pathogens reaching surface waters (Nicholson *et al.*, 2000). ADAS has developed a national modelling methodology and database that quantifies the spatial and temporal distribution of manure applications to agricultural land in England and Wales (Rose *et al.*, 2003). The database integrates national and regional manure practice survey data with local agricultural census data taken from the ADAS National Land Cover and Land Use Database.

A number of national and regional surveys of manure-management practices have been undertaken by ADAS within England and Wales. These surveys quantified livestock excreta production (Smith and Frost, 2000; Smith *et al.*, 2000), manure type, store type and length of storage (Nicholson and Brewer, 1994, 1997; Smith *et al.*, 2000), and timings of applications to arable and grassland (Smith *et al.*, 2000). These surveys have been supplemented with information on animal housing days taken from the National Ammonia Emissions Inventory (Pain *et al.*, 1998) and the areas of crops that receive different types of manures from the British Survey of Fertiliser Practice (BFSP, 2003). The modelling methodology uses the national and regional survey practice data as weights against the local data on crop areas and animal numbers, from which total excreta production and spreading practices are calculated.

The modelling methodology was applied to the Caldew Catchment, using the results of the farm survey to modify the weights, where appropriate, to better reflect local practices. Of particular relevance were the survey data on manure handling and storage periods, taken from the monthly records for 2003.

The majority of managed manures in the catchment are handled as slurry, with the exception of calves (put on straw for welfare reasons) and fattening beef stock (*Table 3.5*). On farms that manage manure as a slurry, the mean storage capacity was 2.8 months with a range of 0.5 to 5 months. The age of manures at spreading varied seasonally and with type of manure (*Table 3.12*). Solid manures (farm yard manure, FYM) are generally stored for longer as it is necessary to wait for opportune times in the crop year when it is possible to spread and incorporate solids on arable fields. Furthermore, manures are frequently cleared from housing and yards just after or before the housing period and stacked at a suitable site for months before spreading. The age of slurry at spreading shows a clear seasonality. Slurry age is greatest in late summer, as this is the time of minimum production because the livestock is outdoors, and farmers typically wait for the slurry store to be full before spreading at the next convenient moment in a busy season. Slurry spreading by the farm owner was found to be generally by splash plate tanker, and FYM spreading by flail spreaders. The farm owner spread 45% of the slurry, with the rest done by contractor using an umbilical system. The farm owner spread 90% of the FYM produced.

Manure spreading on the survey farms showed contrasting seasonal patterns by type (*Figure 3.10*). Slurry spreading was greatest during the winter months when numbers of housed animal numbers are highest and there is a greater need to spread. FYM spreading was greatest in the short period in later summer after the harvest of arable or fodder crops. In 2003, a total of 43,600 m^3 of slurry and 12,200 tonnes of FYM were spread on the 25 survey farms. Scaling up in proportion to the total number of cattle in the catchment, according to the June 2003 census, gives a managed manure application of 125,800 m^3 of slurry and 35,200 tonnes of FYM. These figures compare favourably with the independent ADAS Manure Management Database figures of 145,300 m^3 of slurry and 50,500 tonnes of FYM across the year. The ADAS Manure Management Database was used to calculate monthly baseline applications of manure (as excreta and managed) to agricultural land under pre-FMD good agricultural practice, according to the June 2000 census livestock numbers. The manure loadings were calculated separately for each cell of 1 km^2 and aggregated to the monitored subcatchments. *Table 3.13* summarizes the manure applications for the whole catchment. Adult dairy (46%) and beef (25%) cattle, and sheep (20%) were responsible for the majority of manure applications (*Figure 3.11*). Of particular significance for pathogen losses is that 50% of the manure application is as directly voided excreta, and that 36% of manure is applied as slurry predominantly during the winter months (*Figure 3.12*).

Manure loadings for each of the subcatchments were calculated by multiplication of the baseline figures by the index of stock numbers during the restocking period (*Table 3.13* to *Table 3.27*). This calculation included the effects of seasonality in animal numbers, especially of sheep and newborn lambs. *Figure 3.13* and *Figure 3.14* summarize the manure application time series for the whole of the Caldew Catchment, for cattle and sheep manure, respectively. The significant features of these graphs are the apparent rapid rate of restocking in the spring of 2002, and that there was relatively little spreading of manures over the winter of 2001/02. Applications of cattle manure increased only gradually during the 2002 monitoring period, while sheep manure applications increased significantly over the winter of 2002/03. The implication is that subcatchments with a large number of sheep farms are most likely to show an increase in faecal indicator concentrations during the monitoring period.

3.6.1 Faecal indicator organism content of excreta and spread manure

Values for the excretion of *Escherichia coli* (*E. coli*) are not available from the published literature for many livestock types. Some recent research on *E. coli* O157 VTEC reports the occurrence and prevalence of this particular strain of *E. coli* in livestock (e.g. Kudva *et al*., 1998), but the most frequently reported bacterial values are for faecal coliform bacteria (e.g. Moore *et al,* 1988; Metcalf and Eddie, 1991). For this reason, the risk modelling within this project was carried out using faecal coliform loading rather than *E. coli* loading from livestock. The coliform concentration values quoted within the published literature vary by up to two orders of magnitude for the same animal type, through factors such as diet, age of livestock and measurement technique. It was therefore decided that within the scope of this project it was not justifiable to assign different coliform concentrations to the different fresh manure types, and a generic value of 1 x 10^6 cfu g^{-1} wet weight (w.w.) was used as the best descriptor. Hence the variation in the coliform load between livestock types arises from the amounts of excreta produced and the length of storage before spreading only.

The die-off of faecal indicator organism during the storage of manure is influenced by a number of factors, including temperature, pH and oxygen availability. Experimental and field observations made by several authors, and collated by Moore *et al*. (1988), show a marked variability in decay rates in manure, from 0.026 to 1.3 day^{-1}. Work carried out by Walton and White (1982) showed that there were significant differences in die-off rates between aerated and non-aerated cattle and pig slurry, and that the addition of organic matter had a negative effect on die-off rates. In general, reported die-off rates in slurry tanks are higher than those in solid FYM heaps. This is likely to result from the higher predation rate experienced by faecal indicators in slurry, and the higher availability of organic matter in FYM. Temperatures in stored FYM and slurries are generally similar, and follow the ambient temperature, although they are much less variable. Since most of the stored wastes are kept over winter, a conservative constant estimate of die-off would be 0.1 day^{-1} for FYM and 0.3 day^{-1} for slurries (Bowie *et al*., 1985; Moore *et al*., 1988).

The duration of storage of manure on dairy, beef, pig and poultry farms in England and Wales has been reported by Dauven and Crabb (1998a,b) and Parham (1997a,b). There is considerable variability in the duration of storage between farm types and within farms of the same type. For example, more than 25% of beef slurry is stored for less than 1 month, compared to 16% of cattle slurry. Over 16% of pig slurry does not go through storage at all, while over 6% is stored for over 9 months. Using the figures on storage duration and frequency of cleaning out reported by the above authors, combined with the concentration and die-off constants, the average concentration of coliform bacteria for voided excreta, slurry and FYM produced for each of the livestock types can be estimated (*Table 3.28*).

4. WATER QUALITY

4.1 River discharge

Base-flow discharge, high-flow discharge and total flow volumes (m^3) and duration (hours) at the two Environment Agency flow-monitoring stations for the two winter and two summer periods are shown in *Table 4.1*. The corresponding data for the 15 sample sites are shown in *Table 4.2* (restocking winter), *Table 4.3* (mostly restocked summer), *Table 4.4* (restocked post-FMD winter) and *Table 4.5* (restocked post-FMD summer). Rainfall data at the six Environment Agency gauges for the four study periods are shown in *Table 4.6*.

Flows at the two Environment Agency flow-monitoring stations of Stockdalewath and Cummersdale were greater during the restocking winter and mostly stocked summer periods than during the corresponding restocked post-FMD periods (*Table 4.1*) as a consequence of the lower rainfall during winter 2002/03 and summer 2003 (*Table 4.6*). Base-flow volumes over the restocking winter period were within 2% of the corresponding flow during the restocked post-FMD period, although there was a greater discrepancy between the high-flow volumes. Consequently, the proportion of total flow represented by high flows was greater during the restocking winter period (*Table 4.1*). While high-flow volumes were greater than the base-flow volumes during the winter, the situation was reversed in summer, reflecting the lower rainfall and greater evapotranspiration during the warmer months. Most noticeable, however, is the different high-flow proportions between the two summer periods, with high flows during the restocked post-FMD summer period representing a much lower proportion of the total (*Table 4.1*). Base flows prevailed for the majority of each period, however, representing between 61% and 98% of the various periods (*Table 4.1*). The high-flow durations were longer at Cummersdale for each respective period, reflecting the greater number of sources and larger catchment area than at Stockdalewath.

The tables that describe the estimated flows at the water quality monitoring sites (*Table 4.2* to *Table 4.5*) reflect the pattern at the two Environment Agency gauges. Sites in the upper fell areas of the catchment (Sites 1-5 and 14) generally have the lowest proportions of high-flow volume during all but the restocked post-FMD summer period, which reflects the flashy nature of streams in this area. However, the regime seems quite different at the Carrock Beck site (site 15). During the restocked post-FMD summer period, sites in the middle and lower Roe Beck subcatchment (sites 8, 9 and 11) had very low high-flow volumes (*Table 4.5*), a result of the low rainfall and runoff as soil moisture stores are replenished, while the shallower soils in the fell areas allow a greater degree of runoff. Consequently, high flows prevailed for less than 60 hours (*Table 4.5*) compared to about 850 hours during the previous (mostly stocked) summer (*Table 4.3*).

4.1.1 Comparisons with longer term discharge records

A comparison of long-term average (LTA) daily mean, long-term median (LTM) daily mean, minimum and maximum daily mean values with those of the four study periods is included in *Table 4.7*. Long-term statistics were provided by the Environment Agency and were based on 5 years of data (1999-2002) for Cummersdale and 4 years of data (1999-2002) for Stockdalewath, being the only validated records available for these sites. Therefore, the flows during the restocking winter (October 2001 to April 2002) and mostly stocked summer (May to September 2002) were included in the long-term statistics calculations, although data from the restocked post-FMD winter and summer were excluded. The long-term statistics were calculated for the summer (i.e. bathing season, May to September) and winter (October to April) periods and therefore reflect expected differences in flows between the winter and summer periods, which would be masked if annual series were used.

Table 4.7 shows that the LTA daily mean-flow values and LTM daily-flow values at both Cummersdale and Stockdalewath during the winter and summer periods are comparable with the average daily mean and median daily mean values during the restocking winter and mostly stocked summer. Both the long-term minimum and maximum flows for the winter period occurred during the restocking winter at both gauges while the long-term maximum flow for the summer period at Stockdalewath occurred during the mostly stocked summer period. However, the summary flow statistics for the restocked post-FMD winter and summer periods are considerably lower than the long-term statistics (*Table 4.7*) with minimum values lower than those observed during the period covered by the long-term statistics at both gauges. Therefore, from the available data, flows during the restocked post-FMD winter and summer appear atypically low, although the long-term statistics were themselves calculated from a relatively limited dataset.

4.2 Faecal indicator organism concentrations

GM faecal indicator organism concentrations together with $\log_{10}$ SDs and sample numbers for base-flow and high-flow conditions over the four study periods are shown in *Table 4.8* to *Table 4.19*. These tables also include data for combined sites (sites 1 and 15, Sites 6 and 7, and sites 8 and 9) where land use and catchment area were similar. These data combinations were undertaken to increase sample numbers for the GM calculations. Sampling at sites 14 and 15 was not initiated until 11th February 2003, and therefore no data for these sites are available for the restocking winter and mostly stocked summer. Calculations for the restocked post-FMD winter (*Table 4.14* to *Table 4.16*) included high-flow samples collected in the subsequent winter (i.e. October 2003 to January 2004), again to increase high-flow sample numbers. On the whole, base-flow sample numbers were sufficient for a robust statistical analysis of the data, although only the winter periods had suitable sample numbers for high-flow periods. Even so, the different runoff response of the catchments resulted in a lower number of samples at sites within the Roe Beck and River Ive subcatchments (sites 7-9 and 11) during the restocked post-FMD winter, even with the inclusion of supplementary data from the subsequent winter. There were fewer high-flow samples during the summer periods, with a maximum of $n = 5$ for the mostly stocked summer and $n = 3$ for the restocked post-FMD summer. Thus, statistical tests between these data should be treated with some caution.

Concentrations were greater during high-flow conditions when saturated overland flow and stream stage rise over bank areas accessed by grazing livestock provides a pathway for faecal indicator delivery to the rivers, while increased velocities may re-entrain bacteria from settled sediments (McDonald and Kay, 1981; Wilkinson *et al.,* 1995). The majority of sites displayed statistically significant elevations in the GM faecal indicator organism concentrations at high flows. However, it is noticeable that high flows did not produce statistically significant elevations in the upper fell sites 1 and 2 for all three organisms during the restocking winter period (*Table 4.8* to *Table 4.10*). In fact, the upper fell sites with a high proportion of rough grazing (i.e. sites 1-3, 5, 14 and 15) generally show few statistically significant elevations during high flows. It is also noticeable that site 8 (River Ive at Low Braithwaite) does not show statistically significant high-flow elevations during the two winter periods, with the exception of enterococci during the restocking winter.

Generally, both base-flow and high-flow concentrations were lowest in the headwater fell and in areas of the upper Caldew Catchment (sites 1, 2 and 15) during all four study periods, while those at site 5, which contains a smaller proportion of fell area, were slightly greater. In contrast, the concentrations in the headwaters of the Roe Beck Catchment (sites 6 and 7), which are predominantly improved pasture, were greater. There was a general increase in microbial concentrations downstream under base-flow and high-flow conditions within the River Caldew subcatchment to site 10 and within the Roe Beck–River Ive subcatchment to site 11, again during all four study periods.

Concentrations within the Roe Beck–River Ive Catchment upstream of its confluence with the River Caldew itself (i.e. sites 6-9 and 11) were greater than those within the upper and middle Caldew Catchment (i.e. sites 1-5 and 10). Comparison of concentrations at sites 10 and 11 (i.e. the most downstream site in each subcatchment) show that site 11 concentrations were greater in all cases, although t-tests show significant differences between sites 10 and 11 for base flow during both winter periods, for total coliforms and faecal coliforms during the mostly stocked summer and for total coliforms only during the restocked post-FMD summer (*Table 4.20*). Only the restocking winter period showed significant differences during high flows (*Table 4.20*), although the low number of samples make statistical comparison of the remaining high flow datasets difficult (*Table 4.8* to *Table 4.19*). Nevertheless, these differences in water quality are reflected in the different proportions of land use within each catchment, with approximately two-thirds (66.3%) of the Roe Beck–River Ive Catchment being improved pasture compared to approximately only one-third (37.3%) for the Caldew Catchment. The River Caldew Catchment to site 10 comprises over half (52.9%) rough grazing in contrast to only 13.5% in the Roe Beck–River Ive Catchment (see *Table 5.2*).

Downstream of the confluence of these two main subcatchments there appears to be a degree of dilution of the higher concentrations derived from the Roe Beck–River Ive subcatchment as shown by lower concentrations at site 12 when compared to site 11. This is perhaps unsurprising given the greater discharge of the River Caldew (*Table 4.2* to *Table 4.5*). Generally, concentrations of faecal indicator organisms increase downstream at site 13.

To investigate the differences in faecal indicator organism concentrations during summer and winter, t-tests were carried out between the restocking winter and the mostly restocked summer (*Table 4.21*), and the restocked post-FMD winter and summer (*Table 4.22*), for both base-flow and high-flow conditions. The GM concentrations during the summer periods, with very few exceptions, were greater than those of the winter periods during both base-flow and high-flow conditions. The majority of these increases were statistically significant [n = 63 out of 90 tests for the restocking winter and mostly restocked summer (i.e. 15 sites times three organisms for base flow and high flow, *Table 4.21*) and *n* = 67 out of 108 tests for the restocked post-FMD winter and summer (i.e. 18 sites times three organisms for base flow and high flow, *Table 4.22*)]. The difference was not statistically significant where winter concentrations were greater (*n* = 4 for the restocking winter and mostly restocked summer, *Table 4.21*; and *n* = 4 for the restocked post-FMD winter and summer, *Table 4.22*).

t-tests were also carried out for the hypothesis that the restocked post-FMD winter and summer GM faecal indicator organism concentrations were greater than in the previous year – *Table 4.23* (winter) and *Table 4.24* (summer). Fewer significant differences in GM concentrations between the two winters and two summers are present [*n* = 47 out of 90 tests for the winter periods (i.e. 15 sites times three organisms for base flow and high flow, *Table 4.23*) and *n*=26 out of 90 for the summer periods, *Table 4.24*)] than between each winter and subsequent summer, and between base flow and high flow for each period. For the winter periods, the restocking winter displayed greater GM concentrations than the following winter in 16 cases (i.e. out of three organisms for base flow and high flow), although only four were statistically significant differences, and all of these were during base-flow conditions (*Table 4.23*). For the summer period, the majority of total coliform and faecal coliform GMs for base-flow conditions were greater during the restocking summer than during the following year, although only one was statistically significant (site 1 total coliforms, *Table 4.24*). Thus, changes in flow regime and winter–summer seasonal differences appear more pronounced than those between the two winter and two summer periods. This may have occurred because restocking was underway during the sampling period (see Section 3.3).

4.3 Faecal indicator organism budgets

Budgets for the combined sites (1 & 15, 6 & 7 and 8 & 9) were calculated as follows:

Sites 1 & 15: The combined GM concentrations were used in conjunction with flows from site 1;

Sites 6 & 7: The combined GM concentrations were used in conjunction with the summed flow from sites 6 and 7;

Sites 8 & 9: The combined GM concentrations were used in conjunction with the summed flow from sites 8 and 9.

Base-flow and high-flow faecal indicator organism loads[5] for each site and the combined sites during the four seasonal periods are shown in *Table 4.25* (total coliforms), *Table 4.26* (faecal coliforms) and *Table 4.27* (enterococci), but the winter and summer loads are not comparable because of the different lengths of the two periods (winter = 5088 hours, summer = 3672 hours). To allow for the different lengths of the winter and summer periods, the load data in *Table 4.25* to *Table 4.27* are presented as hourly delivery (i.e. flux[6]) in *Figure 4.1* and in *Table 4.28* (total coliforms), *Table 4.29* (faecal coliforms) and *Table 4.30* (enterococci).

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[5] The term ‘load’ is used here to refer to the actual number of organism colony forming units (cfu).
[6] The term ‘flux' is used here to refer to the hourly delivery rate of organisms (i.e. cfu hour^{-1}).

During each period, faecal indicator organism fluxes increase downstream in response to increased flows (Section 4.1) and the general trend of higher bacterial concentrations further downstream (Section 4.2), while high-flow fluxes exceed base-flow fluxes for each study period at each site. During base-flow conditions, there was a marked increase in load between sites 2 and 3 for all three organisms during each of the four periods (*Figure 4.1*), which is probably related to the transition of land cover from predominantly rough grazing to a greater proportion of improved pasture. There was a similar increase during high-flow conditions, although the increase was not as pronounced. There were also similar increases between sites 5 and 4 during both base-flow and high-flow conditions. While site 13 generally displayed the greatest fluxes during each period for all organisms, there was a noticeably high base-flow faecal coliform flux at site 3 during the mostly restocked summer.

Base-flow faecal indicator organism fluxes at the upper fell sites (sites 1, 2 and 15) were relatively low, and similar to the two small catchments in the upper Roe Beck Catchment (site 6 and 7). However, no clear pattern of changes between the different seasons emerges, with each organism displaying a different pattern.

During high flows, the flux of organisms was greater during the summer periods than during the winter periods for all sites in the case of total coliforms and faecal coliforms (*Table 4.28* and *Table 4.29*) and for 12 out of 15 sites for enterococci (*Table 4.30*). There was a marked increase in the high flow flux of total coliforms and faecal coliforms between the restocking winter and mostly stocked summer periods and between the restocked post-FMD winter and the restocked post-FMD summer periods at the majority of sites (*Figure 4.1*; *Table 4.28* and *Table 4.29*). The fluxes during the two winter periods were similar at the majority of sites for all three faecal indicator organisms, with the exception of sites 12 and 13 for enterococci. However, there were more marked differences between the two summer periods, with the greatest high-flow fluxes during the restocked post-FMD summer at the majority of sites. At sites 8, 11 and combined sites 8 & 9 for total coliforms and faecal coliforms and sites 9, 11 and combined sites 8 & 9 for enterococci, the delivery from the mostly restocked summer was greater (*Figure 4.1*).

4.3.1 Faecal indicator organism export coefficients

Export coefficients for faecal indicator organisms is a relatively new concept and no standard expression has evolved. Therefore, two export coefficients are presented here, one for the hourly delivery of organisms per unit area (cfu $hour^{-1}$ km^{-2}; *Table 4.31* to *Table 4.33*, *Figure 4.2*), and one for the hourly delivery of organisms per unit runoff (cfu $hour^{-1}$ cm $runoff^{-1}$; *Table 4.34* to *Table 4.36*, *Figure 4.3*). In these cases, the calculation of export coefficients enables a more direct comparison of catchments, which allows for differences in catchment area and rainfall and/or runoff.

The base-flow export coefficients based on area (*Table 4.31* to *Table 4.33*, *Figure 4.2*) are relatively low when compared to the high-flow coefficients. During base flows, mostly restocked summer coefficients are generally highest at most sites for total coliforms and faecal coliforms, although other periods dominate for some sites. However, the enterococci coefficients are generally greatest during the restocked post-FMD winter, although they were higher during the restocked post-FMD summer at sites 3 and 10, and during the restocking winter at site 4 (*Figure 4.2*). Coefficients for the upper catchment fell areas of sites 1, 2 and 15 were very low, although the coefficient for the restocked post-FMD summer at site 14 (River Glenderamakin at Mungrisdale), another fell site, was one of the highest observed. Coefficients were also relatively high in the upper Roe Beck Catchment areas (sites 6 and 7), despite the relatively low loads and delivery rates described in Section 4.3. High-flow coefficients were up to three orders of magnitude greater, with largest coefficients during the restocked post-FMD summer, followed by the mostly restocked summer for all three organisms. The exception to this was for enterococci at site 9 and all three organisms for the combined sites 8 & 9 data, where the mostly restocked summer exhibited the highest coefficients (*Figure 4.2*). The Roe Beck sites 6, 7 and 9 (and the combined data for sites 8 & 9), together with the Parkend Beck sites 4 and 5, display the highest export coefficients. The lower Roe Beck site (11) has a much lower coefficient, which suggests dilution further downstream. Interestingly, the mostly restocked summer coefficient decreases downstream from site 11 to site 13, although those for the restocked post-FMD summer increase for all three faecal indicator organisms (*Figure 4.2*). The summer coefficients were generally greater than the winter coefficients for both the first and second years after the FMD cull, while the high-flow coefficients were greater during the second winter and summer than during the first winter and summer, with the exception of enterococci during the winter.

The export coefficients based on runoff (*Table 4.34* to *Table 4.36*, *Figure 4.3*) show a different situation, although again the coefficients are low for the upper fell catchment sites (1, 2, 14 and 15) and, in contrast to the area-based coefficients, in the upper Roe Beck Catchment sites (6, 7 and 6 & 7). Base flow coefficients, and to a lesser extent, high-flow coefficients, display a marked increase between sites 2 and 3, between sites 5 and 4, and between sites 6 & 7 and site 9. This reflects the change in the proportions of rough grazing and improved pasture between the upper fell catchments and sites downstream, and the small catchment areas (rather than land-use change) in the case of sites 6 and 7. Both base-flow and high-flow coefficients generally increase downstream, particularly during the restocked post-FMD summer, although there appears to be a degree of dilution between sites 3 and 10 on the River Caldew, and between sites 8 & 9 and 11 on Roe Beck (*Figure 4.3*). The maximum high-flow coefficients were during the restocked post-FMD summer, which reflects the low high-flow volumes during this period. Again, the summer coefficients were generally greater than the winter coefficients for both the first and second years after the FMD cull, while the high-flow coefficients were greater during the second winter and summer than during the first winter and summer, with the exception of enterococci during the winter.

In summary, the high-flow periods dominate the delivery of faecal indicator organisms in the Caldew Catchment, particularly during the summer periods. There was also a marked increase in the high-flow flux of organisms and high-flow export coefficients during the restocked post-FMD summer period. The coefficients based on area indicate that the greatest delivery of organisms derived from the upper and middle Roe Beck–River Ive Catchment and, to a lesser extent, the Parkend–Cald Beck Catchment. The export coefficients based on runoff indicate that the greatest delivery of organisms derived from the middle and lower Roe Beck–River Ive Catchment and lower Caldew Catchments.

5. POTENTIAL FOR THE DESIGN AND APPLICATION OF A PREDICTIVE TOOL

5.1 Introduction to the modelling approach

The aim of this part of the study is to investigate, at 13 sampling points within the Caldew Catchment under base-flow and high-flow conditions, the relationships between GM concentrations of total coliforms, faecal coliforms and enterococci and land use, monthly stocking levels and monthly animal-waste inputs within the subcatchments.

The models developed in the present study to predict faecal indicator concentrations in rivers within the Caldew Catchment are similar to previous CREH empirical investigations of land use and of faecal indicator concentrations during the May to September bathing season in watercourses draining seven UK study areas:

- Staithes Beck, Yorkshire (Wyer *et al.*, 1996, 1998a; Crowther *et al.*, 2002);
- Afon ('River') Nyfer, south-west Wales (Wyer *et al.*, 1997, 1998c; Crowther *et al.*, 2002);
- Afon Ogwr, south Wales (Wyer *et al.*, 1998b);
- River Irvine, west Scotland (Wyer *et al.*, 1999b);
- Holland Brook, Essex (Wyer *et al.*, 1999a);
- Afon Rheidol–Afon Ystwyth, west Wales (Wyer *et al.*, 2000; Crowther *et al.*, 2003).
- River Ribble, including the Rivers Darwen, Douglas, Lostock and Yarrow (Wyer *et al.*, 2003).

For each study area, statistically significant regression models were developed to predict GM faecal indicator organism concentrations under base- and high-flow conditions at individual sampling points from the percentage of different land-use types within their subcatchments. It was further possible to develop generic models by combining the results from all six study areas. In undertaking the generic modelling it became apparent that faecal indicator concentrations were generally lower in those studies conducted under wetter conditions (i.e. when the amounts of runoff were greater). This is presumed to be attributable to a dilution effect and the depletion of 'ground surface' and 'stream bed' stores of faecal indicators during periods of prolonged wet weather. With appropriate corrections these generic models have been applied successfully to predicting faecal indicator organism concentrations (e.g. Wyer *et al.*, 2003; Stapleton *et al.*, 2004).

5.2 Development of a predictive tool for the Caldew Catchment

This project presented an opportunity to develop further the water-quality models based on land cover by including additional variables that describe potential sources of faecal contamination to the catchment, namely livestock numbers and animal-waste volumes. These variables represent factors that have a more direct linkage to faecal contamination of watercourses than do those of land cover, for which the actual sources of the contamination may only be implied. Again, the four periods identified in Section 3.4 were used.

A list of the 25 land-use classes identified in the CEH 2000 land-cover data, on which the ADAS National Land-use Map is based, is presented in *Table 5.1*, together with the land-use types used in the CREH models that correspond most closely with these (based on detailed notes that accompany the CEH 1990 Land Cover Map). Stocking densities and manure loadings were taken from the data collated for this project and described in Sections 3.3 and 3.6.

5.3 Statistical methods

Multiple regression, using the forward selection stepwise selection procedure (SPSS, 1999), was used to model the relationships between GM faecal indicator organism concentrations (dependent variables, *y*) and percentage land use, livestock numbers and animal-waste volumes within subcatchments (independent variables, *x*). Independent variables with ≥25% zero values were excluded and $\log_{10}$ transformations applied where skewness exceeded 1.00. In the regression analysis, relationships of the following form were generated:

$$y = a + b_1x_1 + b_2x_2 + ... + b_ix_i \pm u$$

where *a* is the intercept (*y* at *x* = 0), *b* is the slope (change in *y* per unit change in *x*) and *u* is the stochastic disturbance or random error term. Independent variables with a variance inflation factor >5 (i.e. tolerance, 0.200) were excluded to minimize multicollinearity (Rogerson, 2001); the probability of F-to-enter was set at 0.05; the strength of relationships was assessed using the coefficient of determination (r^2), adjusted for degrees of freedom and this expressed as a percentage; and the normal probability plot of standardized residuals was examined to confirm the normality of the residuals for each model. Pearson correlation (*r*) was also used to investigate simple bivariate relationships. All statistical tests were assessed at the 95% confidence level (α= 0.05), for which the significance value for a statistical test, *p*, must be $<\alpha$.

In view of the marked difference in microbial concentrations that occur between base-flow and high-flow conditions (see Section 4.2), the base-flow and high-flow data were analysed separately.

5.4 Results

5.4.1 Catchment characteristics

Details of the proportions of different land-use types within the 13 subcatchments are presented as percentages in *Table 5.2*. The Caldew Catchment as a whole, i.e. subcatchment 13 (25,300 ha), is largely rural and is dominated by livestock farming, mostly dairy and beef cattle, and sheep. This is reflected in relatively small proportion of built-up land (3.47%) and the presence of high proportions of improved pasture (51.28%) and rough grazing (33.05%). The subcatchments display marked variations in the proportions of different land-use types. Thus, three headwater subcatchments (1, 2 and 5) are dominated by rough grazing (maximum 94.84% in subcatchment 1), whereas those subcatchments that include significant areas of lowland terrain have relatively high proportions of improved pasture (maximum 67.45% in subcatchment 6). Some of the lowland subcatchments also include substantial areas of arable land (maximum 13.30% in subcatchment 8).

Representative data for use in the statistical analysis, based on the central month in each period, for the numbers of cattle, sheep and cattle-plus-sheep combined, as livestock units (LSUs), per ha are presented in *Table 5.3*, *Table 5.4* and *Table 5.5*, respectively. The total amounts of animal waste (FYM, slurry and faeces voided direct to land) inputs per ha are presented in *Table 5.6*, and the quantities of cattle-waste inputs are presented in *Table 5.7*.

Inevitably, there are significant correlations between the proportions of the main land-use types (*Table 5.8*). For example, 'improved pasture', which has been shown in previous CREH studies to be a key predictor of microbial water quality, is significantly correlated with 'rough grazing' (r = –0.984), 'arable' (r = 0.864) and 'built-up' (r = 0.760). Similarly, there are very strong correlations between the proportions of both improved pasture and rough grazing with livestock numbers and the quantities of animal-waste input to land (*Table 5.9*).

5.4.2 Statistical modelling

As a consequence of the very high levels of collinearity in the key independent (i.e. predictor) variables, in virtually all cases only a single variable was entered into the regression models. The remainder were excluded because of their strong correlation with the first variable entered. Therefore, bivariate correlations, using Pearson product-moment correlation coefficients (r), were performed between the GM faecal indicator concentrations during the individual study periods the land use, stocking densities and animal waste inputs per unit area. Statistical significance was assessed at $\alpha = 0.05$ (i.e. 95% confidence level).

The results of the correlation analyses for each of the four study periods are presented in *Table 5.10* to *Table 5.13*.

There are highly significant correlations in all four study periods between GM faecal indicator concentrations, at both base flow and high flow, and many of the land-use variables. As in previous CREH catchment modelling studies, the strongest correlations are with GM faecal indicator concentrations under high-flow conditions and land use (see base flow).

With very few exceptions, the strongest correlations are with the proportion of improved pasture, rather than with stocking densities and animal-waste inputs. Regression plots for the relationships between base-flow and high-flow concentrations of total coliforms, faecal coliforms and enterococci during the four study periods and percentage improved pasture are presented in *Figure 5.1* (restocking winter), *Figure 5.2* (mostly stocked summer), *Figure 5.3* (restocked post-FMD winter) and *Figure 5.4* (restocked post-FMD summer). The relationships were positive in all cases (i.e. the higher the proportion of improved pasture, the greater the bacterial concentration). This reflects the potential sources of faecal indicator organisms associated with this land-use type (i.e. grazing animals and spreading of animal wastes).

The strength of the correlations with improved pasture is generally greater in the summer periods than in the winter periods – which could reflect higher inputs of animal wastes to fields (voided faeces and spreading of FYM and slurry stored from the previous winter) during the summer months. However, there is no clear or consistent change in the strength of the correlations as restocking occurred within the catchment.

Interestingly, improved pasture did not display the strongest correlations for high flows during the period October 2002 to April 2003 (restocked post-FMD winter) for all three faecal indicator organisms, with the proportions of rough grazing and woodland ($\log_{10}$ transformed) both having stronger relationships (*Table 5.12*). The relationship with the proportion of rough grazing was negative (i.e. the higher the proportion of rough grazing, the lower the microbial concentration), which possibly reflects that these areas are a source of relatively clean waters. Furthermore, since most cattle grazing on improved pasture would be housed during the winter months, one source of faecal indicator organisms (i.e. directly voided animal waste) would be reduced, which possibly explains the slightly weaker winter relationships. The positive relationships observed with woodland, which (for upland conifer plantations) are normally associated with relatively clean water and hence negative relationships, are an artefact of the low proportions of this land-use type in the relatively clean upper catchment areas of sites 1, 2 and 5 and of the increase in proportion of this type of cover downstream, where more numerous sources of faecal indicators are likely to be present.

The best predictor of faecal indicator organism concentrations in the Caldew Catchment was the proportion of improved pasture in the majority of cases, and land-use variables produced the most significant relationships when compared to the stocking number and manure input variables. Land-use data are more readily available than the remaining variables considered here and the further development of the land –use–water quality models on this basis would be possible. The similarity of the most significant predictor variables to previous CREH modelling exercises suggests that this approach would be portable to other catchments.

5.5 A prototype predictive tool for the Caldew Catchment

The results of the statistical modelling described above demonstrate that statistically significant relationships exist between land use, livestock density and manure quantities. However, the strong collinearity present between the predictor variables prohibits the development of a predictive tool that can take into account variation in multiple factors. Therefore, two different approaches to predicting microbial water quality within the Caldew Catchment are described below. First, the existing generic land cover–water quality model developed by CREH and utilized in other recent studies of the Ribble Catchment (Wyer *et al.,* 2003) and Severn Estuary (Stapleton *et al.,* 2004) was used to predict water quality in the Caldew Catchment. These results were compared to the GM concentrations of the field survey data in a similar analysis to the 'residuals analysis' described in Wyer *et al.* (2003). Second, to derive a relationship between water quality and stocking density, the relationships that utilized LSUs were further developed using a more detailed classification system for LSUs and an enhanced statistical analysis.

5.5.1 Land-cover modelling residuals analysis

The generic land cover–water quality models described in Section 5.1 were used to predict microbial concentrations at the 13 monitoring points (*Figure 2.1*) within the Caldew Catchment. Data used to calibrate these models were collected before the FMD epidemic and are likely to represent a 'fully stocked' situation. Therefore, comparison of the observed concentrations within the Caldew Catchment with predicted concentrations could indicate whether microbial concentrations have reached the potential pre-FMD levels.

The CREH generic land cover – water quality models were developed using data collected during the UK bathing season (May to September, i.e. the summer season) and it would not be appropriate to extrapolate the results for the winter periods. Therefore, the results of this analysis are presented for the summer periods only (i.e. mostly restocked summer, May to September 2002, and restocked post-FMD summer, May to September 2003). Also, these models utilize land-cover data that have been corrected using specific procedures derived from the comparison of mapped land cover (i.e. CEH 1990 land-cover map) and field reconnaissance of the catchments from which the water quality data used to calibrate the models were obtained (e.g. Wyer *et al.,* 2003). For the present study, for the land-cover data, although ultimately derived from the same source (i.e. CEH 1990 land-cover map), the processes of verification were different. Therefore, a degree of error may be introduced and the data should be treated with some circumspection.

The generic models are calibrated to produce predictions for a runoff of 1 mm day^{-1}. To ensure the results from the field data are comparable it was necessary to apply a correction to the predicted results, based on the average runoff at each site as observed during each of the two summer periods (*Table 5.14*). Base-flow concentrations were corrected using the total runoff (i.e. base flow + high flow), while the high-flow concentrations were corrected using the high-flow runoff. The predicted base-flow and high-flow GM concentrations are shown in *Table 5.15*, while *Table 5.16* shows the $\log_{10}$ residual values (i.e. observed minus predicted).

It can be seen from *Table 5.15* and *Table 5.16* that, in the majority of cases, the observed GM concentrations were lower than the predicted values (i.e. the residual value was negative) for both summer periods. Where the residual value was positive, these were less than half an order of magnitude greater (i.e. $<0.5 \log_{10}$). Only one high-flow value (restocked post-FMD summer site 5 faecal coliforms) displayed a positive residual (*Table 5.16*). Therefore, it is possible that faecal indicator organism concentrations within the Caldew Catchment had not returned to pre-FMD levels by the end of summer 2003.

During high-flow conditions (i.e. those flows more likely to be impacted by runoff from agricultural areas) all sites in the upper and middle Caldew subcatchments displayed a smaller residual during summer 2003 (restocked post-FMD summer) than during summer 2002 (mostly restocked summer). This was also the case in the Roe Beck headwaters (sites 6 and 7) and in the Caldew downstream of the Roe Beck confluence (i.e. sites 12 and 13). This suggests that the increase in stocking levels between the summers of 2002 and 2003 may have resulted in an increase in microbial concentrations at these sites. However, this was not the case at the mid and lower Roe Beck–River Ive subcatchments (sites 8, 9 and 11), where the $\log_{10}$ residuals were greater during the restocked post-FMD summer (summer 2003) than during the mostly restocked summer (summer 2002). However, there was a considerable difference between the high-flow runoff values for these three sites for each summer period (restocked post-FMD summer high-flow runoff was one-twentieth of mostly restocked summer high-flow runoff) when compared to other sites (at most, restocked post-FMD summer runoff was one-quarter of mostly restocked summer runoff). Thus the algorithms used to correct the standardized predicted concentration are likely to have a greater impact on the final corrected GM concentrations.

5.5.2 Development of stock density–water quality relationships

To develop further the relationships between stock density (as LSUs) and microbial water quality described in Section 5.4.2 more detailed scaling factors were used for each animal category. Animal numbers were calculated for each monitored subcatchment by month using the scaling of the ADAS Land Use Database figures for June 2000 against the cumulative index of restocking (Section 3.3). For each livestock class, separated by type and weight (e.g. adult dairy cow in milk), grazing LSUs were taken from Nix (2003, *Table 5.17*) and multiplied by the numbers of animals to give a total LSU for each subcatchment. These LSUs are based on feed requirements and therefore may provide an index of the volume of excreta voided. The use of LSUs enables the numbers of cattle and sheep to be related to each other to provide a single stocking density for each subcatchment (LSU ha^{-1}), irrespective of the type of stock actually present. The stocking density calculation for each subcatchment utilized the actual catchment area (*Table 2.1*), rather than the rounded subcatchment area used in the initial statistical analysis, and stock numbers averaged over the winter and summer periods. The stock data were averaged over each period to reflect more accurately the changes in numbers over the season. Better to reflect the management of stock through the different seasons, estimates were also made of the number of LSUs likely to be outside grazing as opposed being kept indoors. This may be of particular relevance during the winter months, when a large proportion of cattle were kept inside. Using the average stock numbers over each period also allows for the variation in turn-in and turn-out dates for the different types of animal. Stock densities for both total number of LSU and number of LSU outside grazing are shown in *Table 5.18* and *Table 5.19*, respectively.

The relationships between GM faecal indicator organism concentrations and stocking density (both grazing outdoors and total cattle and sheep) were again investigated using the methods described in Section 5.3. To increase the number of data items included in the regressions, the combined catchment $\log_{10}$ GM concentrations for sites 6 & 7 and sites 8 & 9 were also included with their corresponding stock density. The results of the regressions for the two winter periods are shown in *Table 5.20*, while the results of the regressions for the two summer periods are shown in *Table 5.21*.

For the winter periods, statistically significant relationships were produced for all cases, with the exception of base-flow total coliforms during both the restocking winter (winter 2001/2) and restocked post-FMD winter (winter 2002/3) when using the stock density grazing outdoors as the predictor variable, and for base-flow total coliforms during the restocking winter when using all cattle and sheep stock density (*Table 5.20*). The different predictor variables produce quite different relationships with noticeably steeper slopes associated with the lower stocking densities of grazing stock. However, the r^2 values were generally lower than 50%, with the largest r^2 values being associated with high-flow relationships (*Table 5.20*). Inspection of the scattergraphs in *Figure 5.5* (all cattle plus sheep LSU ha^{-1}) and *Figure 5.6* (grazing LSU ha^{-1}) also shows that log-linear function does not adequately describe the distribution of the data. Thus, it appears that the stocking density is not simply related to faecal indicator organism concentrations during the winter months.

In contrast to the winter relationships, the regression models for the summer stock densities appear to be more robust. Base-flow models still displayed r^2 values of less than 50% (*Table 5.21*), although the scattergraphs in *Figure 5.7* (all cattle plus sheep LSU ha^{-1}) and *Figure 5.8* (grazing LSU ha^{-1}) indicate a better fit of the data. The r^2 values for high-flow conditions were all greater than 50%, reaching 87.4% in the case of enterococci during summer 2003 (*Table 5.21*). From a management perspective, this is encouraging given that the majority of the faecal indicator organism load was delivered during high-flow events during the summer period (Section 4.3). Inspection of *Table 5.21*, *Figure 5.7* and *Figure 5.8* shows that the relationships for each summer period, and for grazing stock density and all cattle and sheep stock density, are very similar. This is illustrated in *Figure 5.9*, in which all four models are plotted on the same graph.

To investigate whether the slopes and elevation (i.e. vertical position of the slope and the y-axis intercept) are statistically the same, the method for comparing simple linear regression equations outlined by Zar (1999) was followed. Mostly, restocked summer and restocked post-FMD summer regression slopes and elevations were not found to be statistically different (i.e. each line estimates the same population regression) in all cases (i.e. between summer 2002 and summer 2003 for both grazing LSU density and all cattle and sheep LSU density, and between the two density estimates for each year). In such a situation, it is possible to estimate a common regression equation for the combined dataset (Zar, 1999). From a management perspective, a relationship with all cattle and sheep LSU density would be preferable to a relationship with the grazing LSU density, since it would not require the scaling of the data to account for the proportion of stock kept indoors. Thus, common relationships between all cattle and sheep LSU density and $\log_{10}$ GM faecal indicator organism concentrations were derived using the method described by Zar (1999). The resultant high-flow relationships are summarized below, presented graphically together with the 95% confidence intervals in *Figure 5.10* and as a lookup table in *Table 5.22*.

$$\text{Log}_{10} \text{ total coliforms (cfu 100 ml}^{-1}) = 1.6437 \text{ stock density (LSU ha}^{-1}) + 2.9552 \quad \textbf{(5.1)}$$

$$\text{Log}_{10} \text{ faecal coliforms (cfu 100 ml}^{-1}) = 1.7878 \text{ stock density (LSU ha}^{-1}) + 2.5973 \quad \textbf{(5.2)}$$

$$\text{Log}_{10} \text{ enterococci (cfu 100 ml}^{-1}) = 1.9135 \text{ stock density (LSU ha}^{-1}) + 1.9292 \quad \textbf{(5.3)}$$

Despite the encouraging results of this analysis, it is important to recognize the fact that the high flow GM concentration data used to derive these relationships were based on only a few samples. Therefore, although these relationships indicate the potential for developing a relationship between stock density and faecal indicator organism concentrations, they should not be treated as definitive without further verification. Furthermore, the 95% confidence intervals for the functions are currently relatively wide, particularly for total coliforms and faecal coliforms, with a minimum of approximately an order of magnitude between the upper and lower limits[7] (*Table 5.22*). The enterococci 95% confidence interval is smaller, with a minimum of approximately half an order of magnitude. However, it should be remembered that the relationship is log-linear so that, in arithmetic terms, the confidence intervals progressive become much wider. Finally, total cattle and sheep stock density within the catchment ranged between 0.14 LSU ha^{-1} and 1.42 LSU ha^{-1}, so extrapolation of the functions beyond these limits should be treated with caution.

[7] The confidence limits are at their minimum at the pooled sample mean value: mean stock density = 0.745 LSU ha^{-1}.

6 DISCUSSION

Defra holding-level statistics, provided by the York Statistics Unit, showed that cattle numbers in the Caldew catchment were reduced by 80% and sheep numbers by 90% following the FMD outbreak. By mid-2002 stock numbers had increased rapidly (i.e. to 75% of cattle and 52% of sheep numbers prior to FMD), but this rate of increase was not sustained and the most recent available census statistics for June 2003 show only 79% and 59% of pre-FMD numbers, respectively. As a result, there may be under-grazing and biodiversity change on the upland vegetation.

Stocking rates may not have attained pre-FMD levels by the end of the project because of the planned changes in Common Agricultural Policy (CAP) support payments, from a system based on outputs to one based on environmental probity. Hence, farmers were unlikely to invest heavily in restocking until the details of the new scheme became known, especially upland sheep farmers who were the most likely to be affected. In addition, some farmers, having received FMD compensation payments, took the opportunity to retire. These were typically smaller, less profitable farms or were owned by older farmers for whom there were succession issues.

In 2005, the CAP support payments[8] farmers receive will change and the link between production and payments will be broken. Farmers will receive payments based upon the area of land they are farming, allowing farmers greater flexibility of cropping and livestock enterprises. The amount of monies a farmer receives will vary depending on the land classification. For the first 8 years, the farmer payment will represent a proportion of historical claims. This will decrease each year until 2012, when farmers will be paid on an area (or regional) basis.

These reforms have the potential significantly to change the farming system within the Caldew Catchment. For livestock farms this will depend upon land classification. If the farm is in a non-severely disadvantaged area (non-SDA) and the farm is looking to use the single farm payment (SFP) to support the farming activity, livestock numbers could increase as stock-density restrictions are removed. If a farmer was not willing to use the SFP to support his or her farming activities, livestock numbers might reduce as environmental options could provide a better return than livestock. With stocking restrictions removed, new legislation and conditions for receiving the SFP are designed to protect the environment, so farmers will have to demonstrate they are meeting the conditions set.

For farmers in SDA areas, the regional payment will be lower to reflect naturally lower stocking densities. For these farmers, the reduction in livestock numbers would allow alternative sources of income to be sought, with farmers also looking to generate income from new environmental schemes.

ADAS research carried out for Defra suggests that, because of the lower margin for each enterprise as a result of the withdrawal of headage support payments, the business would be financially better off in SDA areas if livestock numbers were reduced by 50-75% (ADAS, 2002). This would be most likely to occur on farms able to reduce their

[8] Details of proposed changes to the CAP can be found on the Defra website:at http://www.defra.gov.uk/farm/capreform/index.htm

fixed costs (e.g. labour). Medium-sized farms in Non-SDA areas would see a financial incentive by reducing livestock numbers by 75% and releasing grassland into arable production. For other farmers, the incentive to reduce livestock numbers is less clear, and their reactions will depend on their individual circumstances, their ability to reduce fixed costs and the flexibility of stocking and cropping options open to them.

For dairy farmers, milk price will have a greater impact on future stock numbers than will CAP reform, although a reduction in intervention price could see milk price reduce by 1.5-2.5 pence per litre. This would put financial pressure on many dairy enterprises. Combined with increased regulations, such as set aside for temporary grassland, this will also put pressure on stocking densities.

Approximately one-third of the Caldew Catchment is above the Moorland Line, and two-thirds within the Less Favoured Area designation. It is doubtful, therefore, whether stocking levels overall will ever attain the pre-FMD levels. This is particularly true in the beef and sheep sectors. The dairy industry is undergoing a restructuring (i.e. larger and fewer units) that will accelerate in areas recovering from FMD, for the reasons stated above. However, although the overall output from the dairy industry is likely to remain static as a result of quota controls, technical and genetic improvements, currently estimated at 2-3% per annum, will lead to an overall reduction of cattle numbers. There will, however be more intensive stocking on a local, farm basis.

The annual Defra survey data were necessary to establish the overall impact of FMD and the level of restocking, but it was the enrolment of farmers and direct access to farm logs that proved invaluable in establishing the rate of restocking within the Caldew Catchment. Farm records were used to establish a monthly index of restocking. Alternative, administrative sources of data, which included the AMLS database and the registration of cattle births, had a demonstrable administrative lag. These same farmers also provided local data on the handling of manures, the seasonality of animal numbers and the timing of grazing that guided the classification of the sample periods used to analyse the water quality data.

The survey farms also provided data on the connectivity of farm land and watercourses that clearly demonstrated the potential risk of faecal indicator organism from grazing animals and spread manures that enter the river system. The majority (71%) of grass fields had tile drainage systems connected to ditches and streams, 54% received manure applications, 49% were immediately adjacent to flowing waters and 25% had free access to livestock.

There is evidence from the most recent Defra agricultural census that some farms abandoned the rearing of sheep, with numbers standing at less than 60% of pre-FMD levels. There is a potential significant impact of under-grazing on the biodiversity of the upland vegetation. The rapid restocking of cattle (many of which were in –calf) in January to March 2002, occurred at a time when animals were normally housed. Hence, by the time animals were out grazing in June 2002 and presented the greatest risk of faecal indicator organism pollution of streams, the estimated excreta load was already at 70% of pre-FMD levels. The excreta load increased to 80% of pre-FMD levels in June 2003. Hence, there was not a large difference in excreta loadings between the water-quality monitoring periods.

Integration of the Defra census statistics with tables of excreta production and manure management showed that sheep accounted for only 20% and cattle for 75% of the excreta and managed manure applications to agricultural land. This was despite the three-fold greater number of sheep. Rose *et al*. (2003) found that the faecal indicator organism concentrations quoted within published literature for livestock excreta and manures varied by up to two orders of magnitude for the same animal type, through factors such as diet, age of livestock and measurement technique. It was concluded that a single representative concentration was valid for all livestock types and the variation in the risk between livestock types arose only from the different amounts of excreta produced and the length of storage before spreading. Therefore, scaling of the animal numbers to a common index, such as LSUs (Section 5.5.2), which is based on feed requirements, provides an indication of the amount of excreta provided and, hence, the input of faecal indicator organisms to the catchment from animal sources.

A search of the literature describing faecal indicator organism concentrations in animal excreta and spread manure (Section 3.6.1) indicated a 3-log difference in concentrations for voided excreta and managed manures. The difference in excreta volumes generated by cattle and sheep indicated that the primary risk factor for faecal indicator organism in the Caldew Catchment should be the area of grassland grazed by cattle in the summer months. This is confirmed by the analyses in Section 5.4, which demonstrates a significant statistical correlation between observed faecal indicator organism loads and both the area of grazed grassland and the cattle stock numbers.

Despite the relatively rapid initial restocking within the Caldew Catchment, water-quality monitoring appears to indicate a deterioration in water quality as stock numbers increased between the summer of 2002 (mostly restocked summer) and the summer of 2003 (restocked post-FMD summer). Statistical analysis of these summer data results in a prototype function that relates stock density to microbial concentration for each of the three faecal indicator organisms. This suggests that, with further investigation, it should be possible to develop relationships that could be used in a management capacity. Currently, the functions have relatively wide confidence intervals and were derived from a relatively narrow band of stock densities (i.e. 0.14-1.41 LSU ha^{-1}). Furthermore, the summer high-flow GM faecal indicator organism concentrations, on which these functions are based, were derived from only a few data items (maximum $n = 5$ for mostly restocked summer data and $n = 3$ for restocked post-FMD summer data). Therefore, to further develop these relationships as a management tool supplementary high-flow sampling is needed.

The relationships between stock density and base-flow summer faecal indicator organism concentrations were weaker. However, this may be because a number of factors are likely to impact upon base-flow water quality, both related to stock numbers (e.g. direct access to watercourses) and other variables (e.g. point source inputs of sewage, septic tank inputs). The estimates of faecal indicator organism flux presented in Section 4.3 demonstrate that the summer high-flow periods are associated with the highest fluxes within the Caldew Catchment. Similar budgets studies in other catchments (e.g. Fewtrell *et al.,* 1998; Wyer *et al.,* 1998a,b,c, 1999a,b, 2000, 2001, 2003; Stapleton *et al.,* 1999, 2000a,b, 2002; Wyer and Kay, 2000) produced similar results, while studies of antecedent environmental conditions demonstrated that high-flow events are associated with bathing water Directive 76/160/EEC compliance failures (Crowther *et al.,* 2001). Thus, management interventions to reduce faecal indicator organism flux during summer high-flow events present an opportunity to improve compliance with the bathing water Directive.

Faecal indicator organism concentrations observed during the summer high-flow events were generally lower than those observed during previous budget studies. This was also demonstrated by the predictions from the CREH generic land cover–water quality model, which were generally greater than the observed data in the Caldew Catchment. This may be explained by the low stock densities within the catchment after the FMD cull, and that the catchment had not reached pre-FMD densities by the end of the sampling programme, although, again, the low number of high-flow samples may also be a factor. Furthermore, the pre-defined regular monitoring programme undertaken by the Environment Agency during the project limited the response to high flows such that, in some cases, samples were collected during the receding limb of hydrograph events. The data collected during previous CREH budget studies, which underpin the generic land cover–water quality model, were generally sampled by dedicated field teams able to respond quickly to high-flow events, which ensured that rising limbs of hydrograph events were sampled. This method of sampling also enabled a more efficient targeting of events through a sampling period than could be achieved through a routine weekly and/or daily sampling programme, as it potentially increased the number of high-flow samples.

Faecal indicator organism concentrations and their response to rainfall-induced hydrograph events outside the bathing season (i.e. May to September) are understood less well and have been subject to less vigorous study. The results from this study showed concentrations to be much lower during the winter periods, even during high-flow conditions. Notwithstanding differences in stock levels within the Caldew Catchment during the current study, the results during the winter periods show similar patterns to samples collected during the winter at four sites in Scotland, as part of a study into the impact of measures to reduce agriculturally derived faecal indicator inputs currently being undertaken by CREH (Professor David Kay, CREH, University of Wales Aberystwyth, 2004, personal communication). The detailed statistical analysis of the winter data showed relatively weak or no relationships with stock density and the distribution of the data did not appear to approximate a log-linear function. The relationships between farm-management practices and water quality are likely to be complicated because the majority of cattle are housed during the winter months while sheep remain outdoors. Furthermore, the limited storage available for slurry means that spreading takes place throughout the winter, although dependent on the weather. The age of the slurry is likely to vary, which affects the concentration of faecal indicator organisms. Thus, further stochastic elements are introduced to potential faecal indicator organism sources during the winter months.

7. FURTHER RESEARCH

- *Riverine water quality.* The water-quality surveys carried out for this study resulted in only limited data for high-flow conditions, particularly during the summer periods when stock were grazing the catchment. To further enhance the reliability of the high-flow GM concentrations upon which the faecal indicator organism flux estimates, export coefficients and land use–stock density–/manure volume relationships are based, we recommend that further sampling should be carried out. This sampling should be based upon reactive sampling to target the rising limb of high-flow events and aim to produce at least 15 items of high-flow data in a similar manner to the methodology employed in previous catchment studies carried out by CREH (e.g. Wyer *et al.*, 2003).

- *Improvement of stock density–water quality relationships.* This project has resulted in a tentative relationship between stock density (expressed and LSUs) and $\log_{10}$ GM high-flow faecal indicator organism concentrations. To enhance further the precision and confidence intervals of these functions, more data is required. The functions described within this report are derived from the 13 subcatchments within the Caldew Catchment and the combined data from two pairs of subcatchments for which land use and catchment area were similar, to give a total of 15 data pairs. To reduce the confidence intervals of the relationships, the functions need to be based on a greater number of data pairs (i.e. subcatchments) and a wider range of stock densities. Repetition of this study in different catchments would enhance the applicability of such functions to other catchments, and the combination of data from several catchments would enable a generic model to be developed similar to the land cover–water quality models developed by CREH.

- *Analysis of nutrient data*. This project focussed on the delivery of faecal indicator organisms from agricultural sources. The water-quality samples collected as part of this project were also analysed for nutrient content and an analysis of nutrients, in particular those of sanitary significance (e.g. ammonia), may shed further light on the relationships between water quality and land cover, stock density and manure applications.

- *Relative impact of potential agricultural sources on faecal indicator organism concentrations*. The current study primarily investigated the relationships between faecal indicator organism concentrations and land cover, stock density and manure management practices. However, other sources, such as runoff from farm hardstandings and tracks used as routes for livestock to and from the dairy buildings, may potentially be important, especially if direct connectivity between the areas and watercourses exists. Data from the survey farms showed that only 26% of the total hardstandings area drained to a soakaway or slurry store, with the remainder draining directly to a ditch or stream. Therefore, investigations to further elucidate the importance of sources from farmstead areas would be beneficial to the understanding of agricultural sources as a whole, and could build on earlier studies in Scotland (Kay *et al.*, 2003).

- *Intensive small-scale experiments to assess faecal indicator organism delivery*. The current study only infers a linkage between the source of faecal indicator organisms (i.e. directly voided animal excreta to the fields, spreading of manure, etc.) and the concentrations observed in watercourses. Experiments designed to assess the export of faecal indicator organisms, perhaps through the use of tracer organisms, at field level may help to place inputs from other sources (e.g. farm hardstanding areas) into context.

- *Faecal indicator organism concentrations in animal excreta*. The coliform concentration values quoted within the published literature vary by up to two orders of magnitude for the same animal type, because of factors such as diet, age of livestock and measurement technique. Hence, the concentration of faecal indicator organisms in animal excreta were considered as being the same irrespective of the animal type, age, etc. Consequently, faecal indicator organism loads input to the catchment from directly voided excreta might not be calculated accurately. Further research to define more reliable faecal indicator organism concentrations within animal excreta would enable a more accurate reflection of the potential input directly to catchments during the summer months.

- *Impact of CAP reforms on stock densities and faecal indicator organism concentrations.* A large body of information on the Caldew Catchment that describes stock numbers and water quality throughout the process of restocking following the FMD cull now exists. Furthermore, the current study has established a pool of farmers willing to collaborate in research of this nature. Reforms to the CAP are likely to have a significant impact on the Caldew Catchment, in terms of changes to stock numbers, which are likely to result in further changes to water quality. An ideal opportunity therefore exists to characterize the impacts of CAP reform on both stock numbers and water quality, and the relationships between the two, through further study of this catchment. The catchment provides a particularly interesting exemplar in that current Defra classification defines the upper Caldew Catchment as a SDA. Thus, there is likely to be a variable pattern of changes to reflect the different designation of the upper Caldew Catchment to the Roe Beck–River Ive Catchments. Not only would such a study be able to assess the impact of CAP reforms on agricultural practices and water quality at a catchment level, it would also present an opportunity to collect further data of the type described above. This would improve the functions that describe the relationships between stock density and water quality.

8 CONCLUSIONS

Analysis of the Defra agricultural census data and farm-survey results indicates that after the FMD epidemic within the Caldew Catchment cattle numbers were reduced by 80% and sheep numbers by 90%. Stock numbers increased rapidly after the lifting of restrictions, so that by mid-2002 cattle numbers were 75% and sheep 52% of the pre-FMD levels. The restocking of cattle, many of which were in calf, occurred between January and March 2002 at a time when animals were normally housed. Therefore, by the time the animals were out grazing and presented the greatest risk of faecal indicator organism pollution of streams, the estimated excreta load was 70% of pre-FMD levels. Stock densities may never reach pre-FMD levels because of CAP reforms and the de-coupling of farm subsidies.

The farm survey also indicated a high degree of connectivity between farm land and watercourses, with the majority of grass fields having drainage systems connected to ditches and streams. Approximately half the grass fields within the catchment received manure applications, approximately half were immediately adjacent to flowing water and one-quarter had free access of livestock to watercourses.

The data from the field survey of microbial water quality during the period after the FMD cull (October 2001 to January 2004) were divided into winter (October to April) and summer (May to September) periods. This was based on information collected on livestock management from the farm interviews and monthly records that describe the turn-in and turn-out dates of cattle. These summer and winter periods correspond to the bathing season as defined under the bathing water Directive 76/160/EEC and 'close' non-bathing season. Consequently, this study has some synergy with catchment studies of faecal indicator organisms and budgets (fluxes) that were conducted to characterize inputs to bathing waters. Hence, it has been possible to use results from these studies to enhance the data analysis of this current study.

Faecal indicator organism concentrations within the Caldew Catchment exhibit strong seasonality, with summer concentrations that exceed winter concentrations at all sites. Rainfall-induced high-flow events during the two summer periods (2002 and 2003) exhibited the highest concentrations and such periods therefore dominated the delivery of faecal indicators. This characteristic was further exacerbated during summer 2003, corresponding with a greater number of livestock within the catchment than in the previous summer. The seasonality displayed within this catchment has also been observed elsewhere and in predominantly rural catchments this is likely to be related to stock-management practices, in particular the overwintering of cattle indoors. This seasonality has significance for the design of diffuse-pollution remediation strategies.

The concentrations of faecal indicator organisms in the Caldew Catchment closely reflect the pattern of agricultural practice across the catchment. Lowest concentrations were observed in the headwaters of the River Caldew and Parkend Beck, which include areas of the Lakeland Fells where common grazing of sheep is managed under the ESAs scheme. Concentrations decrease downstream along the River Caldew and Parkend–Cald Beck to the confluence of the River Caldew with Roe Beck, towards the lower catchment. The relatively lowland, predominantly improved pasture, headwaters of Roe Beck and the River Ive, contrast with the headwaters of the River Caldew in that faecal indicator organism concentrations were greater. Again, concentrations decrease downstream to the confluence with the River Caldew. Overall, concentrations in the Roe Beck–River Ive Catchment were greater than within the upper and middle Caldew Catchment.

Microbial concentrations across the Caldew Catchment were generally lower than in similar predominantly rural catchments, which may be because stock densities within the Caldew Catchment had not reached their pre-FMD levels by the end of December 2003. The generic land cover–water quality models developed by CREH, calibrated with water-quality data that preceded the FMD epidemic, also predicted higher faecal indicator organism concentrations than those observed during the field survey period. An analysis of the residuals (observed minus predicted) showed that smaller residuals were present during summer 2003 when compared to summer 2002, which suggests that concentrations within the catchment are approaching their predicted pre-FMD levels in response to the increase in stock numbers.

A detailed statistical analysis of the relationships between stock density, expressed as LSU, and faecal indicator organism concentration succeeded in deriving tentative functions for summer high-flow conditions. These functions currently have wide confidence intervals and are based on GM concentrations themselves derived from a maximum of five individual spot samples. Therefore, although these functions demonstrate the possibility of relating water quality to stock density, their current management value should be treated with some circumspection. However, further research into consolidating these relationships could produce a useful management tool to inform estimates of the impact of agricultural practices on diffuse-pollution generation.

It is recommended that the Environment Agency access holding-level statistics for this work from Defra Statistics, rather than relying on publicly available ward level statistics, to locate the animals as accurately as possible. However, there are limitations of mapping the census, even at holding level, with respect to catchment boundaries. The location of land and grazing animals reported by a holding may be many kilometres from the reporting office. This is especially true of upland sheep. Furthermore, for small areas, a significant percentage of the Defra holding data may be imputed and not based on actual survey returns. The ADAS Land Use Map, used in this work, integrates the holding-level data with information on land-cover distribution and potential grazing areas, at a range of spatial scales. This provides a best practical dataset on animal number and location, and is integrated with a suite of algorithms to calculate the production, storage and spreading of manure and excreta to agricultural land (Rose *et al*., 2003).

This work considers the potential diffuse sources of faecal indicators associated only with field grazing and manure spreading. Recent work in Scotland has identified that runoff from farmyards and animal tracks can be a significant source of faecal indicator organisms (Kay *et al*., 2003). The first flush losses of indicator bacteria from these areas may be more significant than the loss from fields, and it is possible that the disinfection of farmsteads and removal of waste during the FMD clean up resulted in a significant reduction in this source. The accumulation of waste in areas that are irregularly or imperfectly cleaned as the farms returned to normal operation may have resulted in an increase in these sources. Data from the survey farms showed that only 26% of the total hardstandings area drained to a soakaway or slurry store, the remainder draining directly to a ditch of stream.

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The Impact of Destocking on the Microbiological Quality of Rivers in the Caldew Catchment

Volume II: Tables, Figures and Appendices

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Table 2.1: Details of the water-quality monitoring sites and catchment areas to the monitoring point.

Site	River	Location	EA Code	Grid Ref.	Catchment Area (km^2)	Flow Estimate†
1	Caldew	d/s Grainsgill Beck	88006387	NY328326	28.99	Baro-diver/ Modelled
2	Caldew	Mosedale Bridge	88006388	NY357320	34.16	Baro-diver/ Modelled
3	Caldew	Hesket Newmarket	88020889	NY343886	83.89	Baro-diver/ Modelled
4	Cald Beck	Caldbeck Village	88006392	NY326399	35.89	Baro-diver/ Modelled
5	Parkend Beck	Parkend	88020890	NY300388	15.64	Baro-diver/Q-h/ Modelled
6	Peel Gill	Skelton Wood End	88020891	NY407386	1.58	Baro-diver/Q-h/ Modelled
7	Roe Beck	Crown Point	88020892	NY416374	3.53	Baro-diver/Q-h/ Modelled
8	River Ive	Low Braithwaite Br.	88006402	NY428422	21.17	Scaled (Stockdalewath)
9	Roe Beck	Roebank Bridge	88006395	NY393417	21.28	Scaled (Stockdalewath)
10	River Caldew	Sebergham	88006393	NY358419	130.78	Baro-diver/Q-h/ Modelled
11	Roe Beck	Gaitsgill	88006417	NY387465	67.44	Scaled (Stockdalewath)
12	River Caldew	Green Dalston	88006418	NY370497	222.96	Scaled (Cummersdale)
13	River Caldew	Holmehead	88006421	NY397544	254.58	Scaled (Cummersdale)
14	River Glenderamackin*	Mungrisdale	88021015	NY363303	8.73	Scaled (Carrock Beck)
15	Carrock Beck	Nr Calebreck	88021015	NY350350	3.87	Baro-diver/Q-h/ Modelled

* The River Glenderamackin is not within the Caldew Catchment.
† Flow Estimate Method (see Section 2.4 for further details):

Baro-diver/Modelled:	Stage record from baro-diver used in conjunction with flow modelling.
Baro-diver/Q-h/ Modelled:	Flow derived from stage supplemented with modelled flows.
Scaled:	Flow from named location scaled by catchment area.

Table 2.2: Details of the Environment Agency flow-monitoring stations in the Caldew Catchment.

Station Name	River	Station Number	Grid Ref	Gauge Zero	Catchment Area
Stockdalewath	RoeBeck	765850	NY387450	73.345 mAOD	62.99 km^2
Cummersdale	River Caldew	765013	NY394527	22.085 mAOD	245.9 km^2

Table 2.3: Details of the rainfall gauges located within the Caldew Catchment.

Station Name	Station Number	Grid Ref	Gauge Altitude	Record Type
Calebreck Hall Log	605543	NY345361	300 mAOD	Hourly
Mosedale Tel	605382	NY356321	230 mAOD	Hourly
Skelton Tel	605936	NY436361	205 mAOD	Hourly
Willow Holme Tel	606299	NY389565	15 mAOD	Hourly
Blackhall Wood	606217	NY392511	65 mAOD	Daily
Carrock Mine	605336	NY321332	400 mAOD	Daily

Table 3.1: Land cover of the Caldew Catchment (ha) by subcatchment, derived from the ADAS National Land Use Map (2000).

Site	Area (km^2)	Urban (ha)	Water (ha)	Woodland (ha)	Rough grazing (ha)	Arable (ha)	Grass (ha)
1	28	14	20	1	2655	0	110
2	6	2	3	14	549	0	32
3	51	133	27	674	1638	29	2599
4	21	69	16	18	764	17	1216
5	15	21	10	2	1168	1	298
6	2	8	2	7	26	21	135
7	4	23	1	67	53	42	214
8	21	83	14	47	288	279	1389
9	16	15	15	119	227	129	1095
10	9	23	8	108	99	65	596
11	22	55	18	136	284	232	1476
12	27	166	12	129	246	281	1866
13	31	266	21	150	365	351	1947
Total	253	877	167	1471	8363	1449	12973

Table 3.2: Livestock numbers on all farms and on those of a commercial size within the Caldew Catchment, reported by Defra June agricultural census for 2003.

	Count	Cattle	Pigs	Sheep	Fowls
All Farms	330	23480	14390	56350	25320
> 16 ECU	155	21870	14380	51300	11200

Table 3.3: Distribution of farm types of commercial size within the Caldew Catchment.

Farm Type	Percent
Cereals	0.6
Other horticulture	0.6
Specialist pigs	1.9
Dairy (LFA)	14.8
Dairy (lowland)	41.3
Specialist sheep (SDA)	7.7
Specialist beef (SDA)	1.3
Mixed cattle and sheep (SDA)	11.0
Cattle and sheep (DA)	4.5
Cattle and sheep (lowland)	13.5
Cropping and dairy	0.6
Cropping, cattle and sheep	1.9

LFA Less Favoured Area
DA Disadvantaged Area
SDA Severely Disadvantaged Area

Table 3.4: Total area of land (ha) managed by the 25 surveyed farms.

	2003	Pre FMD (2000)
Grassland (grazing & cutting)	2809.2	2979.1
Enclosed rough grazing	129.5	129.5
Fodder crops	8.0	8.0
Other crops	462.0	277.8
Total farmed area	3423.2	3365.9
Sheep fell-grazing rights	4811.5	4811.5

Table 3.5: Livestock numbers on the 25 surveyed farms and percentage management of manures by type.

	2003	Pre FMD (2000)	Percentage Waste Type	
	No.	No.	Slurry	FYM*
Dairy cows	2225	2387	96.0	4.0
Beef cows	531	923	77.1	22.9
Calves to 6 months	1309	1591	4.2	95.8
Followers to 6 months	1097	1428	66.0	34.0
Other beef over 6 months	1034	1423	16.4	83.6

* FYM: farm yard manure

Table 3.6: Attributes of surveyed fields on the 25 survey farms within the Caldew Catchment (*n* = 851). Fields were surveyed by type (arable or grass), presence of and whether there was free access to flowing water by livestock, installation of drainage and whether manures were spread in the fields.

Land Cover (%)	Stock Access (%)	Drainage	Spreading	Percent:
Grass 86.6	Access 21.7	Drained	Spread	10.8
			Not spread	6.9
		Undrained	Spread	1.1
			Not spread	2.9
	Water 21.0	Drained	Spread	11.9
			Not spread	2.2
		Undrained	Spread	2.7
			Not spread	4.2
	None 43.8	Drained	Spread	24.1
			Not spread	5.1
		Undrained	Spread	7.4
			Not spread	7.3
Arable 13.4	Access 1.6	Drained	Spread	1.3
			Not spread	0.0
		Undrained	Spread	0.4
			Not spread	0.0
	Water 2.4	Drained	Spread	1.9
			Not spread	0.0
		Undrained	Spread	0.5
			Not spread	0.0
	None 9.4	Drained	Spread	6.8
			Not spread	0.1
		Undrained	Spread	2.2
			Not spread	0.2

Table 3.7a: Total livestock numbers by subcatchment, reported by Defra June agricultural census for 2000.

	Subcatchment		Animal Numbers			
Site	River	Name	Cattle	Pigs	Sheep	Fowls
1	Caldew	Grainsgill Beck	2	0	127	0
3	Caldew	Hesket Newmarket	4325	1959	34356	3453
4	Cald Beck	Caldbeck Village	1205	0	14555	13
5	Parkend Beck	Partkend	476	0	9103	51
6	Peel Gill	Skelton Wood End	37	0	25	0
7	Roe Beck	Crown Point	483	0	882	16
8	River Ive	Low Braithwaite Bridge	3550	0	7791	59
9	Roe Beck	Roebank Bridge	1956	29	7421	10
10	Caldew	Sebergham	1814	0	5324	44
11	Roe Beck	Gaitsgill	5267	0	6755	155
12	Caldew	Green, Dalston	4456	0	4248	3160
13	Caldew	Holmehead	5994	12069	5894	161
		All subcatchments	29565	14057	96481	7122

Table 3.7b. Total livestock numbers by subcatchment, expressed as a percentage of 2000 numbers, reported by Defra June agricultural census for 2001.

	Subcatchment		Animal Numbers			
Site	River	Name	Cattle	Pigs	Sheep	Fowls
1	Caldew	Grainsgill Beck	101	-	95	-
3	Caldew	Hesket Newmarket	8	0	7	104
4	Cald Beck	Caldbeck Village	21	-	1	100
5	Parkend Beck	Partkend	25	-	20	136
6	Peel Gill	Skelton Wood End	100	-	96	-
7	Roe Beck	Crown Point	49	-	0	103
8	River Ive	Low Braithwaite Bridge	9	-	8	100
9	Roe Beck	Roebank Bridge	13	0	4	100
10	Caldew	Sebergham	1	-	1	100
11	Roe Beck	Gaitsgill	23	-	11	109
12	Caldew	Green, Dalston	24	-	0	104
13	Caldew	Holmehead	27	0	10	102
		All subcatchments	19	0	7	104

Table 3.7c. Total livestock numbers by subcatchment, expressed as a percentage of 2000 numbers, reported by Defra June agricultural census for 2002.

		Subcatchment		Animal Numbers		
Site	River	Name	Cattle	Pigs	Sheep	Fowls
1	Caldew	Grainsgill Beck	80.0	0.0	92.0	0.0
3	Caldew	Hesket Newmarket	80.8	87.2	48.5	97.4
4	Cald Beck	Caldbeck Village	64.3	0.0	52.7	92.3
5	Parkend Beck	Partkend	78.2	0.0	59.8	200.6
6	Peel Gill	Skelton Wood End	123.0	0.0	567.2	0.0
7	Roe Beck	Crown Point	181.3	0.0	90.3	93.8
8	River Ive	Low Braithwaite Bridge	80.4	0.0	63.1	109.8
9	Roe Beck	Roebank Bridge	60.9	87.2	63.4	165.0
10	Caldew	Sebergham	47.0	0.0	47.3	96.1
11	Roe Beck	Gaitsgill	67.4	0.0	49.8	112.2
12	Caldew	Green, Dalston	98.7	0.0	72.6	101.7
13	Caldew	Holmehead	65.2	14.3	18.7	6302.2
		All subcatchments	75.5	24.6	52.4	241.1

Table 3.7d. Total livestock numbers by subcatchment, expressed as a percentage of 2000 numbers, reported by Defra June agricultural census for 2003.

		Subcatchment		Animal Numbers		
Site	River	Name	Cattle	Pigs	Sheep	Fowls
1	Caldew	Grainsgill Beck	90.0	-	104.3	-
3	Caldew	Hesket Newmarket	86.5	180.9	54.0	97.7
4	Cald Beck	Caldbeck Village	68.5	-	56.3	92.3
5	Parkend Beck	Partkend	88.8	-	68.8	180.4
6	Peel Gill	Skelton Wood End	137.0	-	631.6	-
7	Roe Beck	Crown Point	194.6	-	103.5	131.3
8	River Ive	Low Braithwaite Bridge	68.1	-	60.3	591.7
9	Roe Beck	Roebank Bridge	63.9	73.1	63.0	141.0
10	Caldew	Sebergham	51.3	-	49.5	157.3
11	Roe Beck	Gaitsgill	76.9	-	50.4	4846.6
12	Caldew	Green, Dalston	95.7	-	120.8	102.8
13	Caldew	Holmehead	76.6	89.7	27.0	6587.1
		All subcatchments	79.4	102.4	58.4	355.5

Table 3.8: Livestock numbers reported by Defra June agricultural census and farm records for survey farms.

Livestock	Survey Feb '01	Census Jun '00	Survey Jun '02	Census Jun '02	Survey Jun '03	Census Jun '03
Cattle	7800	5600	5500	4800	6800	5300
Sheep	13300	17800	6600	8000	11600	10200

Table 3.9: Percent of cattle in housing by month for the 25 survey farms (2003).

Month	Dairy Cows	Beef Cows	Calves	Dairy Followers	Other Beef > 6 months
Jan	100.0	97.9	100.0	100.0	100.0
Feb	100.0	98.1	100.0	100.0	100.0
Mar	100.0	98.0	100.0	100.0	100.0
Apr	71.4	94.5	95.6	89.1	77.3
May	9.8	40.8	74.5	36.9	75.7
Jun	11.4	1.1	54.2	14.6	66.9
Jul	0.0	0.0	52.7	4.8	62.4
Aug	0.0	0.0	59.9	9.5	54.2
Sep	10.7	2.6	61.7	31.8	57.2
Oct	50.7	28.0	70.3	10.5	73.6
Nov	89.5	75.5	78.5	67.6	99.6
Dec	100.0	97.9	100.0	99.1	100.0

Table 3.10: Percent of sheep housed and grazing by month for the 25 survey farms (2003).

	Breeding Ewes			Fattening and Wintering Sheep		
Month	Housed	Grass Grazing	Other Grazing	Housed	Grass Grazing	Other Grazing
Jan	12.7	79.2	8.1	0.0	100.0	0.0
Feb	12.6	74.0	13.4	0.8	99.2	0.0
Mar	7.4	80.9	11.7	0.0	100.0	0.0
Apr	7.2	82.2	10.5	-	-	-
May	0.6	84.9	14.5	0.0	100.0	0.0
Jun	6.1	76.7	17.3	-	-	-
Jul	4.5	81.1	14.4	0.0	100.0	0.0
Aug	0.3	80.1	19.6	0.0	100.0	0.0
Sep	0.2	74.0	25.8	0.0	100.0	0.0
Oct	0.0	79.1	20.9	0.0	100.0	0.0
Nov	36.1	58.7	5.1	0.0	100.0	0.0
Dec	9.9	89.0	1.1	0.0	100.0	0.0

Table 3.11a: Summary livestock numbers by monitored subcatchment (1-13) according to the ADAS National Land Use Map for June 2000 (see *Table 3.11b* for key).

Subcatchment:	1	2	3	4	5	6	7	8	9	10	11	12	13
K1	16	8	1099	494	92	112	164	1258	910	341	1375	1530	1654
K2	4	1	134	79	16	10	15	120	82	38	133	168	181
K3	1	0	78	40	8	9	13	116	74	28	121	136	193
K4	1	0	38	20	3	2	4	28	20	9	32	39	41
K5	5	2	260	146	31	19	29	219	157	75	246	314	322
K6	33	11	776	419	105	22	39	207	180	158	223	388	240
K7	3	1	91	41	11	4	6	39	29	19	32	37	35
K8	1	0	25	12	3	2	3	18	16	7	21	26	22
K9	1	0	31	25	5	2	2	18	13	9	15	19	15
K10	2	1	123	71	17	9	13	85	71	37	81	86	87
K11	1	0	33	17	4	2	3	18	15	8	20	25	21
K12	0	0	16	9	2	2	2	14	12	6	12	11	6
K13	0	0	45	46	9	3	5	43	27	17	39	50	41
K14	5	2	252	133	28	20	30	200	164	73	216	243	258
K15	1	1	119	55	10	14	21	140	116	42	153	153	233
K16	7	3	345	211	40	25	38	257	203	98	301	383	380
K17	0	1	27	4	1	1	2	13	8	3	11	11	6
K18	21	6	656	345	77	45	69	505	367	179	551	686	690
K19	20	6	616	317	69	43	65	452	348	165	460	520	484
L1	0	1	26	0	0	0	1	2	2	0	1	0	137
L2	0	0	5	0	0	0	0	0	0	0	0	0	68
L3	0	0	8	0	0	0	0	0	0	0	0	0	52
L4	0	0	2	0	0	0	0	0	0	0	0	0	7
L5	0	0	5	0	0	0	0	0	0	0	0	0	6
L7	0	0	0	0	0	0	0	0	0	0	0	0	0
L10	0	0	6	0	0	0	0	0	0	0	0	0	0
L11	0	2	62	1	0	0	1	1	1	0	1	1	100
L12	0	4	145	1	0	0	4	3	3	1	3	1	746
L13	0	4	167	0	0	1	5	5	5	1	5	2	1070
L14	0	0	3	0	0	1	1	6	6	1	5	2	817
M1	6040	1349	9501	4600	3492	271	470	2694	2215	1424	2489	3040	1478
M4	311	74	500	233	171	15	26	155	124	74	143	166	91
M7	1363	288	2359	1404	1146	25	54	271	208	339	240	666	121
M9	155	29	251	126	95	11	18	106	92	47	103	106	65
M13	205	21	141	82	50	6	10	53	50	23	61	67	36
M14	39	8	89	60	48	2	3	19	15	16	22	42	19
M17	8230	1691	12451	6031	4526	431	722	4249	3533	2006	3818	4050	1986
N2	0	0	4	1	0	0	0	4	2	1	3	3	2
N3	4	34	1931	430	120	79	143	667	614	309	576	490	252
N5	0	0	15	1	0	1	2	10	9	3	10	8	7
N6	0	0	1406	1720	482	0	0	1479	0	629	390	1161	0
N7	1	0	159	187	52	0	1	139	2	69	40	130	8
N10	0	0	0	7	0	0	0	6313	0	0	1666	0	1
N13	1	0	18	10	2	1	2	11	9	5	13	17	14
N14	0	0	10	6	2	0	1	3	2	3	4	8	20
N15	1	135	5289	409	115	0	112	3	1	150	3	280	30
N16	1	0	31	35	10	0	0	1	1	13	1	25	15

Table 3.11b: Key to summary livestock numbers by monitored subcatchment (1-13) according to the ADAS National Land Use Map for June 2000 (see *Table 3.11a*).

Code	Description
K1	all dairy cows and heifers that have calved
K2	dairy heifers in first calf (2 years and over)
K3	dairy heifers in first calf (1-2 years)
K4	other females intended for dairy herd replacement (2 years and over)
K5	other females intended for dairy herd replacement (1-2 years)
K6	all beef cows and heifers that have calved
K7	beef heifers in first calf (2 years and over)
K8	beef heifers in first calf (1-2 years)
K9	other females intended for beef herd replacement (2 years and over)
K10	other females intended for beef herd replacement (1-2 years)
K11	bulls for service (2 years and over)
K12	bulls for service (1-2 years)
K13	other female cattle intended for slaughter (2 years and over)
K14	other female cattle intended for slaughter (1-2 years)
K15	other male cattle (2 years and over)
K16	other male cattle (1-2 years)
K17	other cattle and calves under 1 year intended for slaughter as calves
K18	other female calves under 1 year
K19	other male calves under 1 year
L1	sows in pig
L2	gilts in pig
L3	suckled or dry sows being kept for further breeding
L4	boars being used for service
L5	gilts – 50 kg and over not yet in pig, but expected to be used or sold for breeding
L7	barren sows for fattening
L10	other pigs 110 kg and over
L11	other pigs 80 to under 110 kg
L12	other pigs 50 to under 80 kg
L13	other pigs 20 to under 50 kg
L14	other pigs under 20 kg
M1	ewes and shearlings that have produced lambs in the last year, intended for further breeding
M4	ewes and shearlings that have produced lambs in the last year, intended for slaughter
M7	female sheep 1 year and over not yet used for breeding, to be used for breeding
M9	rams for service (1 year and over)
M13	other female sheep (1 year and over)
M14	other male sheep (1 year and over)
M17	lambs under 1 year
N2	layers – growing pullets up to point of lay
N3	layers – birds in the laying flock
N5	layer breeders
N6	broiler breeders
N7	cocks and cockerels
N10	broilers
N13	ducks
N14	geese
N15	turkeys
N16	all other birds

Table 3.12: Age of manures (months) at time of spreading for the 25 survey farms.

	Dec to Feb	Mar to May	Jun to Aug	Sep to Nov
		Slurry Applications		
Count	7.0	15.0	14.0	14.0
Min	0.3	0.3	1.5	0.3
Max	9.0	2.5	17.0	4.5
Average	1.9	1.4	3.5	1.5
GeoMean	0.9	1.1	2.8	1.1
		FYM Applications		
Count	10.0	12.0	5.0	10.0
Min	0.8	0.3	1.8	0.3
Max	12.0	16.5	7.0	19.0
Average	3.6	6.3	4.4	4.3
GeoMean	2.1	3.1	4.0	2.0

Table 3.13: Summary of manure applications made to agricultural land in the whole of the Caldew Catchment in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are tonnes by livestock and manure type.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	5092	26	1950	65	24424	4427	3745	70	1	371	3	76	1
Jun 01	981	5	376	12	4704	303	257	70	1	371	3	76	1
Sep 01	633	136	1628	90	5324	270	228	132	30	301	17	127	17
Oct 01	815	174	2096	115	4420	276	233	130	30	301	17	127	17
Nov 01	6280	41	1849	16	1548	319	270	41	3	301	4	122	2
Dec 01	6686	43	1968	17	65	689	583	41	3	301	4	122	2
Jan 02	8962	57	2613	22	86	1299	1099	41	3	301	4	124	2
Feb 02	17310	172	3135	46	78	1300	1100	168	5	400	8	183	1
Mar 02	18799	189	3404	50	102	1546	1308	168	5	400	8	183	1
Apr 02	19966	201	3616	53	3498	1515	1282	167	5	400	8	183	1
May 02	3477	18	1337	44	14770	1625	1375	70	1	375	3	76	1
Jun 02	3588	18	1374	45	17209	1561	1321	70	1	371	3	76	1
Jul 02	3634	18	1429	47	19557	1609	1362	70	1	371	3	76	1
Aug 02	2080	448	5349	294	19623	1640	1387	132	30	301	17	127	17
Sep 02	2149	462	5527	304	18076	1943	1644	132	30	301	17	127	17
Oct 02	2180	467	5605	309	11820	2385	2018	130	30	301	17	127	17
Nov 02	13804	89	4064	34	3402	2424	2051	41	3	301	4	122	2
Dec 02	13633	88	4013	34	132	2516	2129	41	3	301	4	122	2
Jan 03	13945	89	4066	34	133	2485	2103	41	3	301	4	124	2
Feb 03	24536	244	4443	65	111	2193	1856	168	5	400	8	183	1
Mar 03	24826	250	4496	66	135	2491	2108	168	5	400	8	183	1
Apr 03	25858	260	4683	68	4531	2644	2237	167	5	400	8	183	1
May 03	4392	22	1689	56	18656	2951	2497	70	1	375	3	76	1
Jun 03	4247	22	1626	54	20372	2739	2317	70	1	371	3	76	1
Jul 03	4072	21	1602	53	21916	2697	2282	70	1	371	3	76	1
Aug 03	2228	479	5729	315	21016	2537	2147	132	30	301	17	127	17
Sep 03	2334	502	6003	331	19636	2491	2107	132	30	301	17	127	17
Oct 03	2365	506	6082	335	12825	2541	2150	130	30	301	17	127	17
Nov 03	15024	97	4423	37	3703	2366	2002	41	3	301	4	122	2
Dec 03	14478	94	4262	36	140	2457	2079	41	3	301	4	122	2

Land Cover (ha)	
Arable	1448.97
Grass	12973.28
Rough	8362.61

Table 3.14: Summary of calculated manure applications made to agricultural land in the whole of the Caldew Catchment under baseline pre-FMD conditions for June 2000, not including the effects of the seasonality of animal numbers about the June census figures. Applications are expressed as tons by livestock, land use and manure type.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dairy - voided	0.0	0.0	0.0	4862.1	15830.1	15038.6	17526.2	17526.2	15151.7	8650.0	1752.6	0.0
Dairy - slurry to grass	12809.1	22539.1	22539.1	22539.1	3694.9	3694.9	3694.9	2093.8	2093.8	2093.8	12686.0	12686.0
Dairy - FYM to grass	764.5	592.5	592.5	592.5	178.4	172.0	172.0	592.5	592.5	592.5	764.5	764.5
Dairy - slurry to arable	72.9	233.2	235.7	235.7	17.0	17.0	17.0	485.9	485.9	483.5	72.9	72.9
Dairy - FYM to arable	10.8	26.9	26.9	26.7	3.0	3.0	3.0	35.9	36.1	36.1	10.8	10.8
Beef - voided	168.8	140.7	168.8	478.4	5177.5	8357.1	8722.9	8722.9	8216.4	6274.9	2054.1	168.8
Beef - slurry to grass	2200.6	3872.3	3872.3	3872.3	634.8	634.8	634.8	359.7	359.7	359.7	2179.5	2179.5
Beef - FYM to grass	4223.9	4910.3	4910.3	4910.3	1742.4	1742.4	1795.2	6705.5	6705.5	6705.5	4223.9	4223.9
Beef - slurry to arable	26.8	33.5	33.5	33.1	5.7	5.7	5.7	45.8	45.8	45.5	26.8	26.8
Beef - FYM to arable	30.5	50.3	50.3	50.3	61.0	61.0	62.5	366.0	366.0	366.0	30.5	30.5
Calves - voided	0.0	0.0	0.0	102.1	620.2	1028.5	1154.1	973.5	902.9	722.3	502.5	0.0
Calves - slurry to grass	2642.7	4650.2	4650.2	4650.2	762.3	762.3	762.3	432.0	432.0	432.0	2617.3	2617.3
Calves - FYM to grass	158.0	122.5	122.5	122.5	36.9	35.6	35.6	122.5	122.5	122.5	158.0	158.0
Calves - slurry to arable	13.4	42.8	43.3	43.3	3.1	3.1	3.1	89.2	89.2	88.8	13.4	13.4
Calves - FYM to arable	2.0	4.9	4.9	4.9	0.5	0.5	0.5	6.6	6.6	6.6	2.0	2.0
Pigs - slurry to grass	301.0	400.0	400.0	400.0	375.3	371.2	371.2	301.0	301.0	301.0	301.0	301.0
Pigs - FYM to grass	123.8	183.5	183.5	183.5	76.4	76.4	76.4	126.9	126.9	126.9	122.3	122.3
Pigs - slurry to arable	3.8	7.8	7.8	7.8	3.1	3.1	3.2	16.7	16.7	16.7	3.8	3.8
Pigs - FYM to arable	1.7	1.5	1.5	1.5	0.8	0.8	0.9	17.3	17.3	17.3	1.7	1.7
Poultry muck to grass	40.6	168.5	168.5	167.3	70.1	70.1	70.1	131.6	131.6	130.4	40.6	40.6
Poultry muck to arable	2.7	5.0	5.0	5.0	1.2	1.2	1.3	30.1	30.1	30.1	2.7	2.7
Sheep - voided (rg)	3869.9	3495.4	3869.9	3745.1	3869.9	3745.1	3869.9	3869.9	3745.1	3869.9	3745.1	3869.9
Sheep - voided (ig)	4574.3	4131.6	4574.3	4426.7	4574.3	4426.7	4574.3	4574.3	4426.7	4574.3	4426.7	4574.3

Table 3.15: Summary of manure applications made to agricultural land in subcatchment 1 (River Caldew d/s Grainsgill Beck) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	1262.7	6.5	101.2	32.1	772.4	460.6	424.0	0.2	0.0	0.6	0.0	0.1	0.0
Jun 01	243.2	1.2	19.5	6.2	148.7	31.6	29.0	0.2	0.0	0.6	0.0	0.1	0.0
Sep 01	255.1	27.7	85.0	43.1	166.9	28.1	25.8	0.4	0.8	0.5	0.2	0.2	0.2
Oct 01	321.4	35.4	109.4	55.5	149.5	28.7	26.4	0.4	0.8	0.5	0.2	0.2	0.2
Nov 01	545.3	10.4	91.8	6.5	59.7	33.2	30.5	0.1	0.1	0.5	0.0	0.2	0.0
Dec 01	615.9	11.1	97.7	6.9	3.5	71.7	66.0	0.1	0.1	0.5	0.0	0.2	0.0
Jan 02	392.3	14.7	129.7	9.2	4.6	135.2	124.4	0.1	0.1	0.5	0.0	0.2	0.0
Feb 02	708.0	37.0	160.7	17.7	4.2	135.3	124.5	0.5	0.1	0.7	0.1	0.3	0.0
Mar 02	905.2	40.5	174.5	19.2	5.5	160.8	148.0	0.5	0.1	0.7	0.1	0.3	0.0
Apr 02	1106.3	42.9	185.3	20.4	76.7	157.7	145.1	0.5	0.1	0.7	0.1	0.3	0.0
May 02	840.4	4.4	69.2	21.9	407.5	169.1	155.6	0.2	0.0	0.6	0.0	0.1	0.0
Jun 02	889.7	4.6	71.3	22.6	544.2	162.4	149.5	0.2	0.0	0.6	0.0	0.1	0.0
Jul 02	906.5	4.6	74.3	23.5	601.9	167.4	154.1	0.2	0.0	0.6	0.0	0.1	0.0
Aug 02	863.0	90.9	279.3	141.6	601.8	170.6	157.0	0.4	0.8	0.5	0.2	0.2	0.2
Sep 02	866.3	94.0	288.6	146.3	566.7	202.2	186.1	0.4	0.8	0.5	0.2	0.2	0.2
Oct 02	859.4	94.8	292.7	148.4	399.8	248.2	228.5	0.4	0.8	0.5	0.2	0.2	0.2
Nov 02	1198.6	22.9	201.7	14.3	131.3	252.2	232.2	0.1	0.1	0.5	0.0	0.2	0.0
Dec 02	1255.9	22.6	199.2	14.1	7.1	261.8	241.0	0.1	0.1	0.5	0.0	0.2	0.0
Jan 03	610.5	22.9	201.8	14.3	7.2	258.6	238.0	0.1	0.1	0.5	0.0	0.2	0.0
Feb 03	1003.5	52.4	227.8	25.1	6.0	228.2	210.1	0.5	0.1	0.7	0.1	0.3	0.0
Mar 03	1195.5	53.4	230.5	25.4	7.2	259.2	238.6	0.5	0.1	0.7	0.1	0.3	0.0
Apr 03	1432.8	55.5	240.0	26.4	99.4	275.1	253.2	0.5	0.1	0.7	0.1	0.3	0.0
May 03	1061.6	5.6	87.5	27.7	514.7	307.0	282.6	0.2	0.0	0.6	0.0	0.1	0.0
Jun 03	1053.2	5.4	84.4	26.8	644.2	284.9	262.3	0.2	0.0	0.6	0.0	0.1	0.0
Jul 03	1015.8	5.2	83.3	26.3	674.5	280.6	258.3	0.2	0.0	0.6	0.0	0.1	0.0
Aug 03	924.3	97.4	299.1	151.7	644.5	264.0	243.0	0.4	0.8	0.5	0.2	0.2	0.2
Sep 03	941.1	102.1	313.5	159.0	615.6	259.2	238.6	0.4	0.8	0.5	0.2	0.2	0.2
Oct 03	932.5	102.9	317.6	161.0	433.8	264.4	243.4	0.4	0.8	0.5	0.2	0.2	0.2
Nov 03	1304.5	24.9	219.5	15.5	142.8	246.2	226.7	0.1	0.1	0.5	0.0	0.2	0.0
Dec 03	1333.7	24.0	211.5	15.0	7.5	255.6	235.3	0.1	0.1	0.5	0.0	0.2	0.0

Land Cover (ha)	
Arable	0.17
Grass	109.92
Rough	2655.42

Table 3.16: Summary of manure applications made to agricultural land in subcatchment 2 (River Caldew at Mosedale Bridge) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	1419.4	8.7	124.9	39.4	1053.5	470.6	470.6	12.8	2.1	47.4	2.5	9.9	0.7
Jun 01	273.4	1.7	24.0	7.6	202.9	32.2	32.2	12.8	2.1	47.4	2.5	9.9	0.7
Sep 01	283.5	39.0	104.8	53.1	228.4	28.7	28.7	24.1	54.0	38.5	13.6	16.5	14.5
Oct 01	357.2	50.0	134.9	68.4	200.3	29.3	29.3	23.9	54.0	38.5	13.6	16.5	14.5
Nov 01	647.3	14.0	114.0	8.1	76.7	33.9	33.9	7.4	4.8	38.5	3.1	15.9	1.4
Dec 01	727.7	14.9	121.4	8.7	4.2	73.2	73.2	7.4	4.8	38.5	3.1	15.9	1.4
Jan 02	502.9	19.8	161.1	11.5	5.6	138.1	138.1	7.4	4.8	38.5	3.1	16.1	1.4
Feb 02	917.2	51.5	198.6	22.4	5.1	138.2	138.2	30.8	9.0	51.1	6.4	23.9	1.2
Mar 02	1144.8	56.4	215.7	24.3	6.7	164.3	164.3	30.8	9.0	51.1	6.4	23.9	1.2
Apr 02	1373.8	59.8	229.1	25.8	117.5	161.1	161.1	30.6	9.0	51.1	6.4	23.9	1.2
May 02	945.5	6.0	85.5	26.9	578.8	172.8	172.8	12.8	2.1	47.9	2.5	9.9	0.7
Jun 02	1000.1	6.2	88.0	27.8	742.3	166.0	166.0	12.8	2.1	47.4	2.5	9.9	0.7
Jul 02	1018.8	6.2	91.7	28.8	827.0	171.1	171.1	12.8	2.3	47.4	2.6	9.9	0.8
Aug 02	958.4	128.2	344.3	174.4	828.5	174.3	174.3	24.1	54.0	38.5	13.6	16.5	14.5
Sep 02	962.6	132.5	355.7	180.3	775.4	206.6	206.6	24.1	54.0	38.5	13.6	16.5	14.5
Oct 02	955.3	133.6	360.8	182.9	535.6	253.6	253.6	23.9	54.0	38.5	13.6	16.5	14.5
Nov 02	1422.7	30.7	250.6	17.9	168.6	257.7	257.7	7.4	4.8	38.5	3.1	15.9	1.4
Dec 02	1483.7	30.4	247.5	17.6	8.6	267.5	267.5	7.4	4.8	38.5	3.1	15.9	1.4
Jan 03	782.6	30.8	250.7	17.9	8.8	264.2	264.2	7.4	4.8	38.5	3.1	16.1	1.4
Feb 03	1300.0	73.0	281.5	31.8	7.3	233.2	233.2	30.8	9.0	51.1	6.4	23.9	1.2
Mar 03	1511.8	74.5	284.9	32.1	8.9	264.8	264.8	30.8	9.0	51.1	6.4	23.9	1.2
Apr 03	1779.2	77.4	296.7	33.4	152.2	281.1	281.1	30.6	9.0	51.1	6.4	23.9	1.2
May 03	1194.2	7.5	107.9	34.0	731.1	313.7	313.7	12.8	2.1	47.9	2.5	9.9	0.7
Jun 03	1183.9	7.3	104.1	32.9	878.7	291.1	291.1	12.8	2.1	47.4	2.5	9.9	0.7
Jul 03	1141.7	7.0	102.7	32.3	926.7	286.7	286.7	12.8	2.3	47.4	2.6	9.9	0.8
Aug 03	1026.4	137.3	368.7	186.8	887.4	269.8	269.8	24.1	54.0	38.5	13.6	16.5	14.5
Sep 03	1045.6	143.9	386.4	195.9	842.3	264.8	264.8	24.1	54.0	38.5	13.6	16.5	14.5
Oct 03	1036.6	145.0	391.4	198.4	581.2	270.1	270.1	23.9	54.0	38.5	13.6	16.5	14.5
Nov 03	1548.4	33.5	272.7	19.4	183.5	251.6	251.6	7.4	4.8	38.5	3.1	15.9	1.4
Dec 03	1575.7	32.2	262.8	18.7	9.2	261.2	261.2	7.4	4.8	38.5	3.1	15.9	1.4

Land Cover (ha)	
Arable	0.01
Grass	32.08
Rough	548.93

Table 3.17: Summary of manure applications made to agricultural land in subcatchment 3 (River Caldew at Hesket Newmarket) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	1774.1	15.7	144.7	47.7	1405.3	492.0	455.8	9.4	0.7	21.8	0.3	4.6	0.0
Jun 01	341.7	3.0	27.9	9.2	270.6	33.7	31.2	9.4	0.7	21.8	0.3	4.6	0.0
Sep 01	351.5	79.4	121.2	65.6	305.3	30.0	27.8	17.7	17.8	17.7	1.7	7.6	0.5
Oct 01	443.1	101.8	156.1	84.4	261.8	30.6	28.4	17.6	17.8	17.7	1.7	7.6	0.5
Nov 01	836.9	24.8	133.8	10.9	96.7	35.4	32.8	5.5	1.6	17.7	0.4	7.3	0.0
Dec 01	938.1	26.4	142.5	11.6	4.8	76.6	70.9	5.5	1.6	17.7	0.4	7.3	0.0
Jan 02	679.7	35.0	189.1	15.4	6.4	144.4	133.8	5.5	1.6	17.7	0.4	7.4	0.0
Feb 02	1246.0	101.6	231.0	31.3	5.9	144.5	133.9	22.7	3.0	23.5	0.8	11.0	0.0
Mar 02	1535.1	111.3	250.9	34.0	7.7	171.8	159.2	22.7	3.0	23.5	0.8	11.0	0.0
Apr 02	1823.7	118.1	266.5	36.0	175.5	168.4	156.0	22.5	3.0	23.5	0.8	11.0	0.0
May 02	1182.3	10.7	99.1	32.6	804.8	180.6	167.3	9.4	0.7	22.1	0.3	4.6	0.0
Jun 02	1250.0	11.1	102.0	33.6	990.1	173.5	160.7	9.4	0.7	21.8	0.3	4.6	0.0
Jul 02	1273.2	11.2	106.2	34.9	1112.4	178.9	165.7	9.4	0.8	21.8	0.3	4.6	0.0
Aug 02	1188.1	261.1	398.3	215.4	1115.2	182.2	168.8	17.7	17.8	17.7	1.7	7.6	0.5
Sep 02	1193.6	269.8	411.6	222.6	1036.8	215.9	200.1	17.7	17.8	17.7	1.7	7.6	0.5
Oct 02	1184.9	272.2	417.4	225.8	700.0	265.1	245.6	17.6	17.8	17.7	1.7	7.6	0.5
Nov 02	1839.5	54.5	294.1	23.9	212.5	269.4	249.6	5.5	1.6	17.7	0.4	7.3	0.0
Dec 02	1912.8	53.8	290.5	23.6	9.9	279.6	259.1	5.5	1.6	17.7	0.4	7.3	0.0
Jan 03	1057.7	54.5	294.3	23.9	10.0	276.2	255.9	5.5	1.6	17.7	0.4	7.4	0.0
Feb 03	1766.0	144.0	327.5	44.4	8.3	243.8	225.9	22.7	3.0	23.5	0.8	11.0	0.0
Mar 03	2027.3	147.0	331.3	44.9	10.1	276.9	256.5	22.7	3.0	23.5	0.8	11.0	0.0
Apr 03	2361.9	152.9	345.1	46.7	227.2	293.8	272.2	22.5	3.0	23.5	0.8	11.0	0.0
May 03	1493.5	13.5	125.2	41.2	1016.5	328.0	303.8	9.4	0.7	22.1	0.3	4.6	0.0
Jun 03	1479.8	13.1	120.7	39.8	1172.1	304.4	282.0	9.4	0.7	21.8	0.3	4.6	0.0
Jul 03	1426.7	12.5	119.0	39.1	1246.6	299.7	277.7	9.4	0.8	21.8	0.3	4.6	0.0
Aug 03	1272.4	279.6	426.6	230.6	1194.4	282.0	261.3	17.7	17.8	17.7	1.7	7.6	0.5
Sep 03	1296.6	293.0	447.1	241.8	1126.3	276.8	256.5	17.7	17.8	17.7	1.7	7.6	0.5
Oct 03	1285.7	295.3	452.9	245.0	759.5	282.4	261.6	17.6	17.8	17.7	1.7	7.6	0.5
Nov 03	2002.0	59.3	320.1	26.0	231.3	263.0	243.7	5.5	1.6	17.7	0.4	7.3	0.0
Dec 03	2031.4	57.1	308.5	25.1	10.5	273.1	253.0	5.5	1.6	17.7	0.4	7.3	0.0

Land Cover (ha)	
Arable	29.14
Grass	2599.39
Rough	1637.79

Table 3.18: Summary of manure applications made to agricultural land in subcatchment 4 (Cald Beck at Caldbeck Village) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	1932.0	13.7	171.0	54.9	1539.7	521.7	493.7	8.7	1.2	0.3	0.0	0.1	0.0
Jun 01	372.1	2.6	32.9	10.6	296.5	35.7	33.8	8.7	1.2	0.3	0.0	0.1	0.0
Sep 01	383.6	63.8	143.4	74.3	334.2	31.8	30.1	16.4	30.1	0.2	0.1	0.1	0.1
Oct 01	483.4	81.7	184.6	95.7	289.9	32.5	30.7	16.2	30.1	0.2	0.1	0.1	0.1
Nov 01	903.3	21.8	156.9	11.6	108.8	37.6	35.6	5.1	2.7	0.2	0.0	0.1	0.0
Dec 01	1013.3	23.2	167.1	12.4	5.8	81.2	76.8	5.1	2.7	0.2	0.0	0.1	0.0
Jan 02	725.7	30.8	221.8	16.4	7.7	153.1	144.9	5.1	2.7	0.2	0.0	0.1	0.0
Feb 02	1328.5	83.3	272.4	32.4	7.0	153.2	145.0	21.0	5.0	0.3	0.1	0.2	0.0
Mar 02	1641.9	91.2	295.8	35.2	9.2	182.1	172.4	21.0	5.0	0.3	0.1	0.2	0.0
Apr 02	1955.5	96.7	314.2	37.3	181.6	178.6	169.0	20.8	5.0	0.3	0.1	0.2	0.0
May 02	1287.4	9.4	117.0	37.5	863.4	191.5	181.2	8.7	1.2	0.3	0.0	0.1	0.0
Jun 02	1361.2	9.6	120.5	38.7	1084.8	184.0	174.1	8.7	1.2	0.3	0.0	0.1	0.0
Jul 02	1386.5	9.8	125.5	40.1	1213.5	189.7	179.5	8.7	1.3	0.3	0.0	0.1	0.0
Aug 02	1296.5	209.7	471.1	244.2	1216.5	193.2	182.9	16.4	30.1	0.2	0.1	0.1	0.1
Sep 02	1302.4	216.7	486.8	252.4	1134.9	229.0	216.7	16.4	30.1	0.2	0.1	0.1	0.1
Oct 02	1292.8	218.6	493.7	256.0	775.2	281.1	266.1	16.2	30.1	0.2	0.1	0.1	0.1
Nov 02	1985.5	48.0	344.9	25.5	239.1	285.7	270.4	5.1	2.7	0.2	0.0	0.1	0.0
Dec 02	2066.2	47.4	340.6	25.2	11.8	296.5	280.6	5.1	2.7	0.2	0.0	0.1	0.0
Jan 03	1129.4	48.0	345.1	25.6	11.9	292.9	277.2	5.1	2.7	0.2	0.0	0.1	0.0
Feb 03	1883.0	118.1	386.1	45.9	10.0	258.5	244.6	21.0	5.0	0.3	0.1	0.2	0.0
Mar 03	2168.4	120.5	390.7	46.5	12.1	293.6	277.8	21.0	5.0	0.3	0.1	0.2	0.0
Apr 03	2532.6	125.2	406.9	48.3	235.2	311.6	294.9	20.8	5.0	0.3	0.1	0.2	0.0
May 03	1626.1	11.8	147.8	47.3	1090.6	347.8	329.1	8.7	1.2	0.3	0.0	0.1	0.0
Jun 03	1611.5	11.4	142.6	45.8	1284.3	322.7	305.4	8.7	1.2	0.3	0.0	0.1	0.0
Jul 03	1553.7	11.0	140.6	45.0	1359.8	317.8	300.8	8.7	1.3	0.3	0.0	0.1	0.0
Aug 03	1388.6	224.6	504.6	261.5	1302.9	299.0	283.0	16.4	30.1	0.2	0.1	0.1	0.1
Sep 03	1414.8	235.3	528.8	274.2	1232.8	293.5	277.8	16.4	30.1	0.2	0.1	0.1	0.1
Oct 03	1402.8	237.2	535.7	277.7	841.1	299.5	283.4	16.2	30.1	0.2	0.1	0.1	0.1
Nov 03	2160.9	52.2	375.4	27.8	260.3	278.9	263.9	5.1	2.7	0.2	0.0	0.1	0.0
Dec 03	2194.2	50.3	361.7	26.8	12.5	289.6	274.0	5.1	2.7	0.2	0.0	0.1	0.0

Land Cover (ha)	
Arable	17.25
Grass	1216.35
Rough	764.1

Table 3.19: Summary of manure applications made to agricultural land in subcatchment 5 (Parkend Beck at Parkend) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	1724.0	9.8	157.1	45.3	1315.9	522.2	518.9	10.0	1.3	0.1	0.0	0.0	0.0
Jun 01	332.0	1.9	30.3	8.7	253.4	35.8	35.5	10.0	1.3	0.1	0.0	0.0	0.0
Sep 01	343.9	43.2	131.8	61.0	285.3	31.8	31.6	18.8	32.2	0.1	0.1	0.0	0.1
Oct 01	433.4	55.3	169.7	78.6	250.4	32.5	32.3	18.7	32.2	0.1	0.1	0.0	0.1
Nov 01	790.2	15.7	143.3	9.3	95.8	37.6	37.4	5.8	2.9	0.1	0.0	0.0	0.0
Dec 01	887.9	16.7	152.5	9.9	5.3	81.3	80.8	5.8	2.9	0.1	0.0	0.0	0.0
Jan 02	618.3	22.2	202.5	13.1	7.1	153.3	152.3	5.8	2.9	0.1	0.0	0.0	0.0
Feb 02	1128.5	57.2	249.8	25.5	6.5	153.4	152.4	24.1	5.4	0.1	0.0	0.0	0.0
Mar 02	1405.5	62.6	271.3	27.7	8.5	182.3	181.2	24.1	5.4	0.1	0.0	0.0	0.0
Apr 02	1684.0	66.4	288.2	29.4	145.9	178.8	177.6	24.0	5.4	0.1	0.0	0.0	0.0
May 02	1148.4	6.7	107.5	30.9	721.6	191.7	190.5	10.0	1.3	0.1	0.0	0.0	0.0
Jun 02	1214.6	6.9	110.7	31.9	927.2	184.2	183.0	10.0	1.3	0.1	0.0	0.0	0.0
Jul 02	1237.3	7.0	115.3	33.1	1032.5	189.8	188.6	10.0	1.4	0.1	0.0	0.0	0.0
Aug 02	1162.5	142.0	433.2	200.4	1034.6	193.4	192.2	18.8	32.2	0.1	0.1	0.0	0.1
Sep 02	1167.7	146.7	447.6	207.2	968.7	229.2	227.7	18.8	32.2	0.1	0.1	0.0	0.1
Oct 02	1158.9	148.0	453.9	210.1	669.7	281.4	279.6	18.7	32.2	0.1	0.1	0.0	0.1
Nov 02	1736.8	34.5	314.9	20.4	210.6	286.0	284.1	5.8	2.9	0.1	0.0	0.0	0.0
Dec 02	1810.5	34.1	311.0	20.2	10.9	296.8	294.9	5.8	2.9	0.1	0.0	0.0	0.0
Jan 03	962.1	34.5	315.1	20.4	11.0	293.2	291.3	5.8	2.9	0.1	0.0	0.0	0.0
Feb 03	1599.5	81.1	354.1	36.2	9.2	258.7	257.1	24.1	5.4	0.1	0.0	0.0	0.0
Mar 03	1856.1	82.7	358.3	36.6	11.2	293.9	292.0	24.1	5.4	0.1	0.0	0.0	0.0
Apr 03	2181.0	86.0	373.2	38.1	189.0	311.9	309.9	24.0	5.4	0.1	0.0	0.0	0.0
May 03	1450.6	8.4	135.8	39.1	911.5	348.1	345.9	10.0	1.3	0.1	0.0	0.0	0.0
Jun 03	1437.9	8.2	131.0	37.8	1097.6	323.1	321.0	10.0	1.3	0.1	0.0	0.0	0.0
Jul 03	1386.5	7.8	129.2	37.1	1157.0	318.1	316.1	10.0	1.4	0.1	0.0	0.0	0.0
Aug 03	1245.1	152.1	463.9	214.7	1108.1	299.3	297.4	18.8	32.2	0.1	0.1	0.0	0.1
Sep 03	1268.4	159.4	486.2	225.0	1052.2	293.8	292.0	18.8	32.2	0.1	0.1	0.0	0.1
Oct 03	1257.5	160.6	492.5	228.0	726.6	299.8	297.8	18.7	32.2	0.1	0.1	0.0	0.1
Nov 03	1890.3	37.5	342.8	22.2	229.3	279.2	277.4	5.8	2.9	0.1	0.0	0.0	0.0
Dec 03	1922.6	36.2	330.3	21.4	11.6	289.9	288.0	5.8	2.9	0.1	0.0	0.0	0.0

Land Cover (ha)	
Arable	1.15
Grass	297.83
Rough	1168.40

Table 3.20: Summary of manure applications made to agricultural land in subcatchment 6 (Peel Gill at Skelton Wood End) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare ($kg\ ha^{-1}$) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	2392.0	17.5	154.0	46.7	2088.8	339.8	339.8	1.3	0.2	1.8	0.1	0.4	0.0
Jun 01	460.7	3.4	29.7	9.0	402.3	23.3	23.3	1.3	0.2	1.8	0.1	0.4	0.0
Sep 01	466.8	91.2	128.3	64.7	455.6	20.7	20.7	2.4	5.5	1.4	0.5	0.6	0.5
Oct 01	588.2	116.8	165.3	83.3	375.2	21.2	21.2	2.4	5.5	1.4	0.5	0.6	0.5
Nov 01	1189.2	27.6	147.3	11.0	129.7	24.5	24.5	0.8	0.5	1.4	0.1	0.6	0.1
Dec 01	1326.6	29.4	156.8	11.8	5.1	52.9	52.9	0.8	0.5	1.4	0.1	0.6	0.1
Jan 02	1036.8	39.0	208.2	15.6	6.8	99.7	99.7	0.8	0.5	1.4	0.1	0.6	0.1
Feb 02	1908.5	115.9	248.2	32.3	6.2	99.8	99.8	3.1	0.9	1.9	0.2	0.9	0.0
Mar 02	2308.1	127.0	269.5	35.0	8.1	118.7	118.7	3.1	0.9	1.9	0.2	0.9	0.0
Apr 02	2701.6	134.7	286.2	37.1	308.8	116.3	116.3	3.1	0.9	1.9	0.2	0.9	0.0
May 02	1595.8	12.0	105.6	31.9	1279.8	124.8	124.8	1.3	0.2	1.8	0.1	0.4	0.0
Jun 02	1685.3	12.3	108.5	32.9	1471.7	119.9	119.9	1.3	0.2	1.8	0.1	0.4	0.0
Jul 02	1715.4	12.5	112.8	34.1	1677.4	123.6	123.6	1.3	0.2	1.8	0.1	0.4	0.0
Aug 02	1578.0	299.7	421.8	212.4	1683.2	125.9	125.9	2.4	5.5	1.4	0.5	0.6	0.5
Sep 02	1585.0	309.7	435.8	219.6	1547.1	149.2	149.2	2.4	5.5	1.4	0.5	0.6	0.5
Oct 02	1573.0	312.5	442.0	222.7	1003.4	183.1	183.1	2.4	5.5	1.4	0.5	0.6	0.5
Nov 02	2613.8	60.6	323.8	24.3	285.0	186.1	186.1	0.8	0.5	1.4	0.1	0.6	0.1
Dec 02	2704.9	59.9	319.7	24.0	10.4	193.2	193.2	0.8	0.5	1.4	0.1	0.6	0.1
Jan 03	1613.4	60.7	323.9	24.3	10.5	190.8	190.8	0.8	0.5	1.4	0.1	0.6	0.1
Feb 03	2705.1	164.2	351.7	45.7	8.8	168.4	168.4	3.1	0.9	1.9	0.2	0.9	0.0
Mar 03	3048.2	167.7	355.9	46.3	10.7	191.3	191.3	3.1	0.9	1.9	0.2	0.9	0.0
Apr 03	3499.0	174.5	370.7	48.0	399.9	203.0	203.0	3.1	0.9	1.9	0.2	0.9	0.0
May 03	2015.7	15.1	133.4	40.3	1616.6	226.5	226.5	1.3	0.2	1.8	0.1	0.4	0.0
Jun 03	1995.1	14.6	128.4	39.0	1742.3	210.2	210.2	1.3	0.2	1.8	0.1	0.4	0.0
Jul 03	1922.3	14.0	126.4	38.3	1879.7	207.0	207.0	1.3	0.2	1.8	0.1	0.4	0.0
Aug 03	1690.1	321.0	451.7	227.4	1802.8	194.8	194.8	2.4	5.5	1.4	0.5	0.6	0.5
Sep 03	1721.8	336.4	473.4	238.5	1680.6	191.2	191.2	2.4	5.5	1.4	0.5	0.6	0.5
Oct 03	1706.8	339.0	479.6	241.6	1088.8	195.1	195.1	2.4	5.5	1.4	0.5	0.6	0.5
Nov 03	2844.8	66.0	352.4	26.4	310.2	181.7	181.7	0.8	0.5	1.4	0.1	0.6	0.1
Dec 03	2872.5	63.6	339.6	25.5	11.0	188.6	188.6	0.8	0.5	1.4	0.1	0.6	0.1

Land Cover (ha)	
Arable	21.45
Grass	135.08
Rough	26.34

Table 3.21: Summary of manure applications made to agricultural land in subcatchment 7 (Roe Beck at Crown Point) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	2268.6	16.9	148.6	45.6	1972.1	368.0	354.6	2.6	0.3	7.4	0.2	1.5	0.1
Jun 01	436.9	3.3	28.6	8.8	379.8	25.2	24.3	2.6	0.3	7.4	0.2	1.5	0.1
Sep 01	443.2	87.6	123.9	63.1	430.0	22.4	21.6	4.9	8.1	6.0	1.3	2.5	1.4
Oct 01	558.3	112.3	159.6	81.2	355.5	22.9	22.1	4.9	8.1	6.0	1.3	2.5	1.4
Nov 01	1119.9	26.6	141.6	10.7	123.7	26.5	25.5	1.5	0.7	6.0	0.3	2.4	0.1
Dec 01	1249.6	28.3	150.7	11.4	5.0	57.3	55.2	1.5	0.7	6.0	0.3	2.4	0.1
Jan 02	971.7	37.6	200.0	15.1	6.6	108.0	104.1	1.5	0.7	6.0	0.3	2.5	0.1
Feb 02	1785.3	111.4	239.2	31.3	6.1	108.1	104.2	6.3	1.4	8.0	0.6	3.7	0.1
Mar 02	2162.8	122.1	259.8	33.9	7.9	128.5	123.8	6.3	1.4	8.0	0.6	3.7	0.1
Apr 02	2535.1	129.5	275.9	35.9	287.2	126.0	121.4	6.2	1.4	8.0	0.6	3.7	0.1
May 02	1513.4	11.5	101.9	31.2	1200.8	135.1	130.2	2.6	0.3	7.5	0.2	1.5	0.1
Jun 02	1598.4	11.9	104.7	32.2	1389.5	129.8	125.1	2.6	0.3	7.4	0.2	1.5	0.1
Jul 02	1626.8	12.1	108.9	33.3	1581.5	133.8	128.9	2.6	0.3	7.4	0.2	1.5	0.1
Aug 02	1498.6	288.0	407.3	207.1	1586.8	136.3	131.3	4.9	8.1	6.0	1.3	2.5	1.4
Sep 02	1504.8	297.6	420.8	214.1	1460.0	161.5	155.6	4.9	8.1	6.0	1.3	2.5	1.4
Oct 02	1492.9	300.2	426.8	217.2	950.7	198.3	191.1	4.9	8.1	6.0	1.3	2.5	1.4
Nov 02	2461.4	58.5	311.1	23.6	271.9	201.5	194.2	1.5	0.7	6.0	0.3	2.4	0.1
Dec 02	2548.1	57.8	307.3	23.3	10.2	209.2	201.5	1.5	0.7	6.0	0.3	2.4	0.1
Jan 03	1512.1	58.5	311.3	23.6	10.3	206.6	199.1	1.5	0.7	6.0	0.3	2.5	0.1
Feb 03	2530.5	157.9	339.0	44.3	8.6	182.4	175.7	6.3	1.4	8.0	0.6	3.7	0.1
Mar 03	2856.3	161.3	343.1	44.8	10.5	207.1	199.6	6.3	1.4	8.0	0.6	3.7	0.1
Apr 03	3283.3	167.8	357.3	46.5	372.0	219.8	211.8	6.2	1.4	8.0	0.6	3.7	0.1
May 03	1911.7	14.6	128.7	39.4	1516.7	245.3	236.4	2.6	0.3	7.5	0.2	1.5	0.1
Jun 03	1892.3	14.1	123.9	38.1	1644.9	227.7	219.4	2.6	0.3	7.4	0.2	1.5	0.1
Jul 03	1823.0	13.5	122.0	37.4	1772.2	224.2	216.0	2.6	0.3	7.4	0.2	1.5	0.1
Aug 03	1605.0	308.4	436.2	221.8	1699.5	211.0	203.3	4.9	8.1	6.0	1.3	2.5	1.4
Sep 03	1634.6	323.2	457.1	232.6	1586.0	207.1	199.5	4.9	8.1	6.0	1.3	2.5	1.4
Oct 03	1619.9	325.8	463.1	235.7	1031.5	211.3	203.5	4.9	8.1	6.0	1.3	2.5	1.4
Nov 03	2678.9	63.7	338.6	25.6	295.9	196.7	189.6	1.5	0.7	6.0	0.3	2.4	0.1
Dec 03	2706.0	61.4	326.3	24.7	10.8	204.3	196.8	1.5	0.7	6.0	0.3	2.4	0.1

Land Cover (ha)	
Arable	42.01
Grass	214.06
Rough	52.87

Table 3.22: Summary of manure applications made to agricultural land in subcatchment 8 (River Ive at Low Braithwaite) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	2523.8	19.0	149.7	44.0	2204.9	329.8	324.8	9.5	2.3	1.4	0.1	0.3	0.0
Jun 01	486.1	3.7	28.8	8.5	424.6	22.6	22.3	9.5	2.3	1.4	0.1	0.3	0.0
Sep 01	491.6	101.8	124.6	61.4	481.2	20.1	19.8	17.8	60.2	1.2	0.4	0.5	0.4
Oct 01	619.3	130.4	160.4	79.1	393.2	20.5	20.2	17.6	60.2	1.2	0.4	0.5	0.4
Nov 01	1260.0	29.9	144.6	10.9	134.2	23.8	23.4	5.5	5.4	1.2	0.1	0.5	0.0
Dec 01	1404.8	31.8	153.9	11.6	4.9	51.3	50.6	5.5	5.4	1.2	0.1	0.5	0.0
Jan 02	1106.6	42.2	204.3	15.4	6.5	96.8	95.3	5.5	5.4	1.2	0.1	0.5	0.0
Feb 02	2036.7	128.5	241.9	32.3	6.0	96.9	95.4	22.8	10.1	1.5	0.2	0.7	0.0
Mar 02	2459.1	140.8	262.7	35.1	7.8	115.2	113.4	22.8	10.1	1.5	0.2	0.7	0.0
Apr 02	2874.4	149.4	279.0	37.1	335.9	112.9	111.2	22.6	10.1	1.5	0.2	0.7	0.0
May 02	1684.0	13.0	102.7	30.0	1368.2	121.1	119.2	9.5	2.3	1.4	0.1	0.3	0.0
Jun 02	1778.2	13.4	105.4	31.0	1553.5	116.3	114.5	9.5	2.3	1.4	0.1	0.3	0.0
Jul 02	1809.6	13.6	109.6	32.1	1775.7	119.9	118.1	9.5	2.6	1.4	0.1	0.3	0.0
Aug 02	1662.2	334.5	409.4	201.6	1781.9	122.1	120.3	17.8	60.2	1.2	0.4	0.5	0.4
Sep 02	1669.2	345.6	423.0	208.5	1634.1	144.8	142.6	17.8	60.2	1.2	0.4	0.5	0.4
Oct 02	1656.2	348.7	429.1	211.5	1051.4	177.7	175.0	17.6	60.2	1.2	0.4	0.5	0.4
Nov 02	2769.4	65.6	317.8	23.9	294.9	180.6	177.9	5.5	5.4	1.2	0.1	0.5	0.0
Dec 02	2864.4	64.8	313.9	23.6	10.1	187.5	184.6	5.5	5.4	1.2	0.1	0.5	0.0
Jan 03	1722.0	65.7	318.0	23.9	10.2	185.2	182.4	5.5	5.4	1.2	0.1	0.5	0.0
Feb 03	2886.8	182.1	342.9	45.8	8.5	163.4	160.9	22.8	10.1	1.5	0.2	0.7	0.0
Mar 03	3247.5	186.0	346.9	46.3	10.3	185.6	182.8	22.8	10.1	1.5	0.2	0.7	0.0
Apr 03	3722.7	193.5	361.3	48.1	435.1	197.0	194.0	22.6	10.1	1.5	0.2	0.7	0.0
May 03	2127.1	16.4	129.7	37.9	1728.2	219.8	216.5	9.5	2.3	1.4	0.1	0.3	0.0
Jun 03	2105.1	15.9	124.8	36.7	1839.1	204.0	200.9	9.5	2.3	1.4	0.1	0.3	0.0
Jul 03	2027.9	15.2	122.8	36.0	1989.8	200.9	197.9	9.5	2.6	1.4	0.1	0.3	0.0
Aug 03	1780.2	358.3	438.5	216.0	1908.4	189.0	186.2	17.8	60.2	1.2	0.4	0.5	0.4
Sep 03	1813.2	375.4	459.5	226.5	1775.1	185.6	182.8	17.8	60.2	1.2	0.4	0.5	0.4
Oct 03	1797.1	378.4	465.5	229.5	1140.9	189.3	186.4	17.6	60.2	1.2	0.4	0.5	0.4
Nov 03	3014.1	71.4	345.9	26.0	320.9	176.3	173.6	5.5	5.4	1.2	0.1	0.5	0.0
Dec 03	3041.9	68.8	333.3	25.0	10.7	183.1	180.3	5.5	5.4	1.2	0.1	0.5	0.0

Land Cover (ha)	
Arable	279.32
Grass	1389.34
Rough	287.54

Table 3.23: Summary of manure applications made to agricultural land in subcatchment 9 (Roe Beck at Roebank Bridge) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	2403.4	17.5	155.7	46.5	2088.8	339.8	339.8	1.3	0.2	1.7	0.1	0.4	0.0
Jun 01	462.9	3.4	30.0	9.0	402.3	23.3	23.3	1.3	0.2	1.7	0.1	0.4	0.0
Sep 01	469.3	91.0	129.8	64.4	455.6	20.7	20.7	2.4	5.5	1.4	0.5	0.6	0.5
Oct 01	591.5	116.5	167.1	82.9	375.2	21.2	21.2	2.4	5.5	1.4	0.5	0.6	0.5
Nov 01	1196.2	27.5	148.9	11.0	129.7	24.5	24.5	0.8	0.5	1.4	0.1	0.6	0.1
Dec 01	1334.5	29.3	158.6	11.7	5.1	52.9	52.9	0.8	0.5	1.4	0.1	0.6	0.1
Jan 02	1041.0	38.9	210.5	15.5	6.8	99.7	99.7	0.8	0.5	1.4	0.1	0.6	0.1
Feb 02	1918.3	115.5	250.9	32.1	6.2	99.8	99.8	3.1	0.9	1.8	0.2	0.8	0.0
Mar 02	2320.2	126.6	272.5	34.9	8.1	118.7	118.7	3.1	0.9	1.8	0.2	0.8	0.0
Apr 02	2716.0	134.3	289.4	36.9	308.8	116.3	116.3	3.1	0.9	1.8	0.2	0.8	0.0
May 02	1603.4	11.9	106.8	31.8	1279.8	124.8	124.8	1.3	0.2	1.7	0.1	0.4	0.0
Jun 02	1693.4	12.3	109.7	32.8	1471.7	119.9	119.9	1.3	0.2	1.7	0.1	0.4	0.0
Jul 02	1723.9	12.5	114.1	34.0	1677.4	123.6	123.6	1.3	0.2	1.7	0.1	0.4	0.0
Aug 02	1586.0	298.9	426.5	211.4	1683.2	125.9	125.9	2.4	5.5	1.4	0.5	0.6	0.5
Sep 02	1593.4	308.8	440.7	218.5	1547.1	149.2	149.2	2.4	5.5	1.4	0.5	0.6	0.5
Oct 02	1581.7	311.6	446.9	221.7	1003.4	183.1	183.1	2.4	5.5	1.4	0.5	0.6	0.5
Nov 02	2629.1	60.5	327.4	24.2	285.0	186.1	186.1	0.8	0.5	1.4	0.1	0.6	0.1
Dec 02	2721.1	59.7	323.3	23.9	10.4	193.2	193.2	0.8	0.5	1.4	0.1	0.6	0.1
Jan 03	1620.0	60.5	327.6	24.2	10.5	190.8	190.8	0.8	0.5	1.4	0.1	0.6	0.1
Feb 03	2719.0	163.8	355.7	45.5	8.8	168.4	168.4	3.1	0.9	1.8	0.2	0.8	0.0
Mar 03	3064.1	167.2	359.9	46.1	10.7	191.3	191.3	3.1	0.9	1.8	0.2	0.8	0.0
Apr 03	3517.6	174.0	374.8	47.8	399.9	203.0	203.0	3.1	0.9	1.8	0.2	0.8	0.0
May 03	2025.2	15.1	134.9	40.1	1616.6	226.5	226.5	1.3	0.2	1.7	0.1	0.4	0.0
Jun 03	2004.7	14.6	129.9	38.8	1742.3	210.2	210.2	1.3	0.2	1.7	0.1	0.4	0.0
Jul 03	1931.7	14.0	127.8	38.1	1879.7	207.0	207.0	1.3	0.2	1.7	0.1	0.4	0.0
Aug 03	1698.6	320.1	456.8	226.4	1802.8	194.8	194.8	2.4	5.5	1.4	0.5	0.6	0.5
Sep 03	1730.9	335.5	478.7	237.4	1680.6	191.2	191.2	2.4	5.5	1.4	0.5	0.6	0.5
Oct 03	1716.2	338.1	485.0	240.5	1088.8	195.1	195.1	2.4	5.5	1.4	0.5	0.6	0.5
Nov 03	2861.4	65.8	356.3	26.3	310.2	181.7	181.7	0.8	0.5	1.4	0.1	0.6	0.1
Dec 03	2889.6	63.4	343.4	25.3	11.0	188.6	188.6	0.8	0.5	1.4	0.1	0.6	0.1

Land Cover (ha)	
Arable	128.98
Grass	1094.59
Rough	227.06

Table 3.24: Summary of manure applications made to agricultural land in subcatchment 10 (River Caldew at Sebergham) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	2071.9	12.7	157.2	48.3	1721.4	427.8	436.5	6.3	1.4	0.8	0.0	0.2	0.0
Jun 01	399.0	2.4	30.3	9.3	331.5	29.3	29.9	6.3	1.4	0.8	0.0	0.2	0.0
Sep 01	407.9	60.1	131.5	65.5	374.6	26.1	26.6	11.9	36.2	0.7	0.1	0.3	0.1
Oct 01	514.0	77.0	169.3	84.3	316.6	26.6	27.2	11.8	36.2	0.7	0.1	0.3	0.1
Nov 01	997.0	20.2	146.9	10.3	114.2	30.8	31.4	3.7	3.2	0.7	0.0	0.3	0.0
Dec 01	1115.3	21.5	156.3	11.0	5.3	66.6	67.9	3.7	3.2	0.7	0.0	0.3	0.0
Jan 02	835.2	28.6	207.5	14.6	7.1	125.5	128.1	3.7	3.2	0.7	0.0	0.3	0.0
Feb 02	1531.8	78.2	251.7	28.9	6.5	125.7	128.2	15.2	6.1	0.9	0.1	0.4	0.0
Mar 02	1872.5	85.6	273.3	31.4	8.4	149.4	152.4	15.2	6.1	0.9	0.1	0.4	0.0
Apr 02	2210.8	90.8	290.3	33.3	229.0	146.4	149.4	15.1	6.1	0.9	0.1	0.4	0.0
May 02	1381.4	8.7	107.7	33.0	1010.4	157.0	160.2	6.3	1.4	0.8	0.0	0.2	0.0
Jun 02	1459.8	9.0	110.8	34.0	1212.8	150.9	153.9	6.3	1.4	0.8	0.0	0.2	0.0
Jul 02	1486.3	9.1	115.3	35.3	1369.6	155.5	158.7	6.3	1.5	0.8	0.0	0.2	0.0
Aug 02	1379.1	197.4	432.1	215.1	1373.7	158.4	161.7	11.9	36.2	0.7	0.1	0.3	0.1
Sep 02	1385.2	204.0	446.5	222.4	1271.8	187.8	191.6	11.9	36.2	0.7	0.1	0.3	0.1
Oct 02	1374.6	205.8	452.8	225.5	846.6	230.5	235.2	11.8	36.2	0.7	0.1	0.3	0.1
Nov 02	2191.4	44.5	322.8	22.7	251.1	234.2	239.0	3.7	3.2	0.7	0.0	0.3	0.0
Dec 02	2274.2	43.9	318.8	22.4	10.8	243.1	248.1	3.7	3.2	0.7	0.0	0.3	0.0
Jan 03	1299.7	44.5	323.0	22.7	11.0	240.2	245.0	3.7	3.2	0.7	0.0	0.3	0.0
Feb 03	2171.2	110.8	356.7	41.0	9.2	212.0	216.3	15.2	6.1	0.9	0.1	0.4	0.0
Mar 03	2472.9	113.1	361.0	41.5	11.1	240.7	245.6	15.2	6.1	0.9	0.1	0.4	0.0
Apr 03	2863.3	117.5	376.0	43.1	296.6	255.5	260.7	15.1	6.1	0.9	0.1	0.4	0.0
May 03	1744.9	11.0	136.0	41.6	1276.2	285.2	291.0	6.3	1.4	0.8	0.0	0.2	0.0
Jun 03	1728.1	10.6	131.1	40.3	1435.8	264.6	270.0	6.3	1.4	0.8	0.0	0.2	0.0
Jul 03	1665.5	10.2	129.2	39.5	1534.8	260.6	265.9	6.3	1.5	0.8	0.0	0.2	0.0
Aug 03	1477.0	211.5	462.8	230.4	1471.2	245.2	250.2	11.9	36.2	0.7	0.1	0.3	0.1
Sep 03	1504.7	221.6	485.0	241.6	1381.6	240.7	245.6	11.9	36.2	0.7	0.1	0.3	0.1
Oct 03	1491.6	223.3	491.3	244.7	918.6	245.5	250.5	11.8	36.2	0.7	0.1	0.3	0.1
Nov 03	2385.1	48.4	351.3	24.7	273.2	228.7	233.3	3.7	3.2	0.7	0.0	0.3	0.0
Dec 03	2415.1	46.7	338.6	23.8	11.5	237.4	242.3	3.7	3.2	0.7	0.0	0.3	0.0

Land Cover (ha)	
Arable	65.28
Grass	596.03
Rough	99.25

Table 3.25: Summary of manure applications made to agricultural land in subcatchment 11 (Roe Beck at Gaitsgill) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	2530.4	19.0	152.1	45.4	2249.3	304.3	281.6	3.2	0.7	1.2	0.1	0.2	0.0
Jun 01	487.3	3.7	29.3	8.7	433.2	20.8	19.3	3.2	0.7	1.2	0.1	0.2	0.0
Sep 01	492.2	101.5	126.6	63.3	491.1	18.5	17.2	5.9	17.2	1.0	0.3	0.4	0.4
Oct 01	620.2	130.0	163.0	81.5	400.4	19.0	17.5	5.9	17.2	1.0	0.3	0.4	0.4
Nov 01	1275.4	29.9	147.2	11.1	136.0	21.9	20.3	1.8	1.5	1.0	0.1	0.4	0.0
Dec 01	1421.2	31.9	156.7	11.8	4.9	47.4	43.8	1.8	1.5	1.0	0.1	0.4	0.0
Jan 02	1127.8	42.3	208.1	15.7	6.6	89.3	82.6	1.8	1.5	1.0	0.1	0.4	0.0
Feb 02	2080.1	128.2	246.0	33.0	6.0	89.4	82.7	7.6	2.9	1.3	0.2	0.6	0.0
Mar 02	2505.9	140.5	267.1	35.8	7.8	106.2	98.3	7.6	2.9	1.3	0.2	0.6	0.0
Apr 02	2923.7	149.1	283.7	37.9	344.9	104.2	96.4	7.5	2.9	1.3	0.2	0.6	0.0
May 02	1688.5	13.0	104.4	31.0	1399.8	111.7	103.4	3.2	0.7	1.2	0.1	0.2	0.0
Jun 02	1782.9	13.4	107.2	32.0	1584.8	107.3	99.3	3.2	0.7	1.2	0.1	0.2	0.0
Jul 02	1814.6	13.6	111.4	33.2	1812.5	110.6	102.4	3.2	0.7	1.2	0.1	0.2	0.0
Aug 02	1663.4	333.5	416.0	207.8	1819.1	112.7	104.3	5.9	17.2	1.0	0.3	0.4	0.4
Sep 02	1671.1	344.5	429.8	214.9	1667.4	133.6	123.6	5.9	17.2	1.0	0.3	0.4	0.4
Oct 02	1658.7	347.6	435.9	217.9	1070.9	164.0	151.8	5.9	17.2	1.0	0.3	0.4	0.4
Nov 02	2803.2	65.8	323.6	24.5	298.9	166.6	154.2	1.8	1.5	1.0	0.1	0.4	0.0
Dec 02	2897.9	65.0	319.6	24.2	10.1	173.0	160.1	1.8	1.5	1.0	0.1	0.4	0.0
Jan 03	1755.0	65.8	323.8	24.5	10.2	170.8	158.1	1.8	1.5	1.0	0.1	0.4	0.0
Feb 03	2948.4	181.7	348.6	46.7	8.5	150.8	139.5	7.6	2.9	1.3	0.2	0.6	0.0
Mar 03	3309.3	185.6	352.8	47.3	10.3	171.2	158.5	7.6	2.9	1.3	0.2	0.6	0.0
Apr 03	3786.6	193.1	367.4	49.1	446.7	181.7	168.2	7.5	2.9	1.3	0.2	0.6	0.0
May 03	2132.8	16.4	131.8	39.2	1768.1	202.8	187.7	3.2	0.7	1.2	0.1	0.2	0.0
Jun 03	2110.6	15.9	126.9	37.9	1876.1	188.2	174.2	3.2	0.7	1.2	0.1	0.2	0.0
Jul 03	2033.5	15.2	124.8	37.2	2031.1	185.4	171.6	3.2	0.7	1.2	0.1	0.2	0.0
Aug 03	1781.6	357.1	445.5	222.6	1948.3	174.4	161.4	5.9	17.2	1.0	0.3	0.4	0.4
Sep 03	1815.3	374.3	466.9	233.4	1811.3	171.2	158.5	5.9	17.2	1.0	0.3	0.4	0.4
Oct 03	1799.8	377.2	473.0	236.5	1162.0	174.7	161.6	5.9	17.2	1.0	0.3	0.4	0.4
Nov 03	3050.9	71.6	352.2	26.6	325.3	162.7	150.5	1.8	1.5	1.0	0.1	0.4	0.0
Dec 03	3077.5	69.0	339.4	25.7	10.7	168.9	156.3	1.8	1.5	1.0	0.1	0.4	0.0

Land Cover (ha)	
Arable	231.81
Grass	1475.98
Rough	283.79

Table 3.26: Summary of manure applications made to agricultural land in subcatchment 12 (River Caldew at the Green, Dalston) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	2371.4	18.0	152.9	45.7	2100.7	306.8	300.6	3.7	0.6	0.4	0.0	0.1	0.0
Jun 01	456.7	3.5	29.4	8.8	404.6	21.0	20.6	3.7	0.6	0.4	0.0	0.1	0.0
Sep 01	462.2	94.9	127.4	63.5	458.3	18.7	18.3	7.0	14.6	0.3	0.1	0.1	0.1
Oct 01	582.4	121.6	164.1	81.8	376.7	19.1	18.7	6.9	14.6	0.3	0.1	0.1	0.1
Nov 01	1186.1	28.4	146.5	11.0	129.6	22.1	21.7	2.2	1.3	0.3	0.0	0.1	0.0
Dec 01	1322.5	30.2	156.0	11.7	5.0	47.8	46.8	2.2	1.3	0.3	0.0	0.1	0.0
Jan 02	1040.2	40.1	207.0	15.5	6.7	90.0	88.2	2.2	1.3	0.3	0.0	0.1	0.0
Feb 02	1916.7	120.2	246.5	32.3	6.1	90.1	88.3	8.9	2.4	0.4	0.0	0.2	0.0
Mar 02	2314.1	131.8	267.7	35.0	8.0	107.1	105.0	8.9	2.4	0.4	0.0	0.2	0.0
Apr 02	2704.9	139.8	284.3	37.1	312.8	105.0	102.9	8.9	2.4	0.4	0.0	0.2	0.0
May 02	1582.2	12.3	104.9	31.2	1291.1	112.6	110.3	3.7	0.6	0.4	0.0	0.1	0.0
Jun 02	1670.8	12.7	107.7	32.2	1480.1	108.2	106.0	3.7	0.6	0.4	0.0	0.1	0.0
Jul 02	1700.7	12.9	112.0	33.4	1688.0	111.5	109.3	3.7	0.6	0.4	0.0	0.1	0.0
Aug 02	1562.2	311.8	418.7	208.5	1694.1	113.6	111.3	7.0	14.6	0.3	0.1	0.1	0.1
Sep 02	1569.3	322.2	432.6	215.6	1556.2	134.7	131.9	7.0	14.6	0.3	0.1	0.1	0.1
Oct 02	1557.5	325.1	438.7	218.6	1007.4	165.3	162.0	6.9	14.6	0.3	0.1	0.1	0.1
Nov 02	2607.0	62.4	322.0	24.1	284.9	168.0	164.6	2.2	1.3	0.3	0.0	0.1	0.0
Dec 02	2696.7	61.6	318.0	23.8	10.3	174.4	170.8	2.2	1.3	0.3	0.0	0.1	0.0
Jan 03	1618.7	62.4	322.2	24.1	10.4	172.3	168.8	2.2	1.3	0.3	0.0	0.1	0.0
Feb 03	2716.7	170.4	349.4	45.7	8.7	152.0	148.9	8.9	2.4	0.4	0.0	0.2	0.0
Mar 03	3056.1	174.0	353.5	46.3	10.5	172.7	169.2	8.9	2.4	0.4	0.0	0.2	0.0
Apr 03	3503.2	181.1	368.2	48.0	405.1	183.2	179.5	8.9	2.4	0.4	0.0	0.2	0.0
May 03	1998.6	15.6	132.4	39.5	1630.8	204.5	200.4	3.7	0.6	0.4	0.0	0.1	0.0
Jun 03	1978.0	15.0	127.5	38.2	1752.2	189.8	186.0	3.7	0.6	0.4	0.0	0.1	0.0
Jul 03	1905.8	14.4	125.5	37.4	1891.6	186.9	183.1	3.7	0.6	0.4	0.0	0.1	0.0
Aug 03	1673.1	333.9	448.4	223.3	1814.4	175.9	172.3	7.0	14.6	0.3	0.1	0.1	0.1
Sep 03	1704.7	350.0	469.9	234.2	1690.5	172.6	169.1	7.0	14.6	0.3	0.1	0.1	0.1
Oct 03	1690.0	352.7	476.0	237.2	1093.1	176.1	172.5	6.9	14.6	0.3	0.1	0.1	0.1
Nov 03	2837.4	67.9	350.4	26.3	310.1	164.0	160.7	2.2	1.3	0.3	0.0	0.1	0.0
Dec 03	2863.8	65.4	337.7	25.3	10.9	170.3	166.8	2.2	1.3	0.3	0.0	0.1	0.0

Land Cover (ha)	
Arable	281.38
Grass	1866.05
Rough	245.65

Table 3.27: Summary of manure applications made to agricultural land in subcatchment 13 (River Caldew at Holmehead) in the period June 2000 to December 2003, including the effects of culling, restocking and the seasonality of animal numbers about the June census figures. Applications are expressed as kilograms per hectare (kg ha^{-1}) of the relevant land use within the subcatchment.

Stock:	Cattle					Sheep		Poultry		Pig			
Type:	Slurry		FYM		Voided	Voided		Litter		Slurry		FYM	
Land:	Grass	Arable	Grass	Arable	Grass	Grass	Rough	Grass	Arable	Grass	Arable	Grass	Arable
Jun 00	2235.4	17.5	138.5	41.0	2089.8	122.4	125.0	0.4	0.1	156.1	8.7	32.0	2.3
Jun 01	430.5	3.4	26.7	7.9	402.5	8.4	8.6	0.4	0.1	156.1	8.7	32.0	2.3
Sep 01	432.9	93.4	115.2	57.3	456.5	7.5	7.6	0.8	1.7	126.6	46.6	53.2	48.0
Oct 01	545.6	119.7	148.4	73.7	371.4	7.6	7.8	0.8	1.7	126.6	46.6	53.2	48.0
Nov 01	1144.5	27.5	134.2	10.1	125.2	8.8	9.0	0.2	0.1	126.6	10.5	51.3	4.8
Dec 01	1273.7	29.3	142.9	10.7	4.5	19.1	19.5	0.2	0.1	126.6	10.5	51.3	4.8
Jan 02	1029.9	38.8	189.7	14.3	6.0	35.9	36.7	0.2	0.1	126.6	10.5	51.9	4.8
Feb 02	1902.3	118.0	224.0	30.0	5.5	36.0	36.7	1.0	0.3	168.2	21.8	76.9	4.1
Mar 02	2281.4	129.3	243.3	32.5	7.1	42.7	43.7	1.0	0.3	168.2	21.8	76.9	4.1
Apr 02	2651.9	137.2	258.4	34.4	322.9	41.9	42.8	1.0	0.3	168.2	21.8	76.9	4.1
May 02	1492.1	12.0	95.0	28.0	1305.0	44.9	45.9	0.4	0.1	157.8	8.7	32.0	2.3
Jun 02	1575.0	12.3	97.6	28.9	1472.4	43.2	44.1	0.4	0.1	156.1	8.7	32.0	2.3
Jul 02	1602.8	12.5	101.4	30.0	1685.0	44.5	45.5	0.4	0.1	156.1	8.9	32.0	2.5
Aug 02	1463.0	307.0	378.6	188.0	1691.8	45.3	46.3	0.8	1.7	126.6	46.6	53.2	48.0
Sep 02	1469.9	317.2	391.2	194.4	1549.9	53.7	54.9	0.8	1.7	126.6	46.6	53.2	48.0
Oct 02	1459.0	320.0	396.8	197.2	993.2	66.0	67.4	0.8	1.7	126.6	46.6	53.2	48.0
Nov 02	2515.5	60.4	295.1	22.2	275.3	67.0	68.5	0.2	0.1	126.6	10.5	51.3	4.8
Dec 02	2597.2	59.7	291.4	21.9	9.2	69.6	71.1	0.2	0.1	126.6	10.5	51.3	4.8
Jan 03	1602.6	60.4	295.2	22.2	9.3	68.7	70.2	0.2	0.1	126.6	10.5	51.9	4.8
Feb 03	2696.3	167.2	317.6	42.5	7.8	60.7	62.0	1.0	0.3	168.2	21.8	76.9	4.1
Mar 03	3012.8	170.8	321.3	43.0	9.4	68.9	70.4	1.0	0.3	168.2	21.8	76.9	4.1
Apr 03	3434.6	177.7	334.7	44.6	418.2	73.1	74.7	1.0	0.3	168.2	21.8	76.9	4.1
May 03	1884.7	15.1	120.0	35.4	1648.4	81.6	83.3	0.4	0.1	157.8	8.7	32.0	2.3
Jun 03	1864.5	14.6	115.5	34.2	1743.1	75.7	77.3	0.4	0.1	156.1	8.7	32.0	2.3
Jul 03	1796.1	14.0	113.6	33.6	1888.2	74.6	76.2	0.4	0.1	156.1	8.9	32.0	2.5
Aug 03	1566.9	328.8	405.5	201.4	1811.9	70.2	71.7	0.8	1.7	126.6	46.6	53.2	48.0
Sep 03	1596.7	344.5	425.0	211.2	1683.6	68.9	70.4	0.8	1.7	126.6	46.6	53.2	48.0
Oct 03	1583.1	347.2	430.5	213.9	1077.7	70.3	71.8	0.8	1.7	126.6	46.6	53.2	48.0
Nov 03	2737.8	65.8	321.1	24.2	299.6	65.4	66.8	0.2	0.1	126.6	10.5	51.3	4.8
Dec 03	2758.1	63.4	309.5	23.3	9.8	68.0	69.4	0.2	0.1	126.6	10.5	51.3	4.8

Land Cover (ha)	
Arable	351.02
Grass	1946.58
Rough	365.47

Table 3.28: Estimates of faecal coliform concentration in excreta and spread manure (Moore *et al*., 1988).

	Faecal coliform concentration (cfu g^{-1} w.w.)
Cattle	
Beef slurry	2.82×10^{3}
Beef FYM	5.53×10^{2}
Dairy slurry	1.78×10^{3}
Dairy FYM	5.53×10^{2}
Voided	1.00×10^{6}
Pigs	
Slurry	4.34×10^{4}
FYM	4.07×10^{2}
Sheep	
Voided	1.00×10^{6}
Poultry	
Layers	1.96×10^{5}
Broilers	5.03×10^{4}

Table 4.1: Summary of discharge (m^3) and duration (hours) of base-flow, high-flow and total flow periods measured at Environment Agency gauging stations in the Caldew Catchment for the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

Gauge	Period	Discharge (m^3)			Discharge (% of total)		Duration (hours)			Duration (% of total)	
		Base Flow	High Flow	Total Flow	Base Flow	High Flow	Base Flow	High Flow	Total Flow	Base Flow	High Flow
Stockdalewath	Restocking winter	10142818	18433245	28576062	35.5	64.5	3925	1163	5088	77.1	22.9
	Mostly restocked summer	3541218	3223758	6764976	52.3	47.7	3353	322	3672	91.3	8.8
	Restocked post-FMD winter	10002146	11053716	21055862	47.5	52.5	4243	845	5088	83.4	16.6
	Restocked post-FMD summer	1112026	144995	1257021	88.5	11.5	3614	58	3672	98.4	1.6
Cummersdale	Restocking winter	51855643	133888642	185744285	27.9	72.1	3096	1992	5088	60.8	39.2
	Mostly restocked summer	29741305	22386519	52127824	57.1	42.9	3090	582	3672	84.2	15.8
	Restocked post-FMD winter	50936167	76372421	127308588	40.0	60.0	3667	1421	5088	72.1	27.9
	Restocked post-FMD summer	19037751	5654825	24692576	77.1	22.9	3478	194	3672	94.7	5.3

Table 4.2: Estimated discharge (m^3) at the water-quality monitoring sites in the Caldew Catchment for the restocking winter period (October 2001 to April 2002; 5088 hours).

Site	Discharge (m^3)			Discharge (% of total)		Duration (hours)		Duration (% of total)	
	Base Flow	High Flow	Total Flow	Base Flow	High Flow	Base Flow	High Flow	Base Flow	High Flow
1	11517717	14323859	25841576	44.6	55.4	3581	1507	70.4	29.6
2	13951981	16681976	30633957	45.5	54.5	3703	1385	72.8	27.2
3	29707606	30879952	60587558	49.0	51.0	3625	1463	71.2	28.8
4	14195088	15137928	29333016	48.4	51.6	3757	1331	73.8	26.2
5	7994462	9135144	17129606	46.7	53.3	3685	1403	72.4	27.6
6	314410	1127479	1441889	21.8	78.2	3181	1907	62.5	37.5
7	225286	1186310	1411597	16.0	84.0	3310	1778	65.1	34.9
8	3435266	6102232	9537498	36.0	64.0	3952	1136	77.1	22.9
9	3415370	6172889	9588259	35.6	64.4	3930	1158	77.1	22.9
10	22725783	74723340	97449123	23.3	76.7	3071	2017	60.4	39.6
11	10903546	19495372	30398919	35.9	64.1	3936	1152	77.1	22.9
12	47252281	120783010	168035292	28.1	71.9	3109	1979	61.1	38.9
13	53947752	137968421	191916173	28.1	71.9	3107	1981	61.1	38.9
14	3468426	4313463	7781889	44.6	55.4	3581	1507	70.4	29.6
15	365114	1945494	2310608	15.8	84.2	3628	1460	71.3	28.7

Table 4.3: Estimated discharge (m^3) at the water-quality monitoring sites in the Caldew Catchment for the mostly restocked summer period (May to September 2002; 3672 hours).

Site	Discharge (m^3)			Discharge (% of total)		Duration (hours)		Duration (% of total)	
	Base Flow	High Flow	Total Flow	Base Flow	High Flow	Base Flow	High Flow	Base Flow	High Flow
1	5042386	1852069	6894455	73.1	26.9	3056	616	83.2	16.8
2	5941629	2182360	8123990	73.1	26.9	3056	616	83.2	16.8
3	12667457	3194090	15861547	79.9	20.1	3231	441	88.0	12.0
4	5089392	1570788	6660180	76.4	23.6	3222	450	87.7	12.3
5	2850138	955159	3805297	74.9	25.1	3230	442	88.0	12.0
6	150674	196090	346764	43.5	56.5	2727	945	74.3	25.7
7	108493	169676	278169	39.0	61.0	3051	621	83.1	16.9
8	1177566	1080424	2257991	52.2	47.8	3351	322	91.3	8.8
9	1180935	1089048	2269984	52.0	48.0	3347	328	91.3	8.8
10	16439346	11576726	28016072	58.7	41.3	2896	776	78.9	21.1
11	3772745	3424148	7196892	52.4	47.6	3353	323	91.3	8.8
12	26925801	20233601	47159402	57.1	42.9	3092	580	84.2	15.8
13	30814268	23048083	53862351	57.2	42.8	3094	578	84.3	15.7
14	1518456	557729	2076185	73.1	26.9	3056	616	83.2	16.8
15	195524	213767	409290	47.8	52.2	3226	446	87.9	12.1

Table 4.4: Estimated discharge (m^3) at the water-quality monitoring sites in the Caldew Catchment for the restocked post-FMD winter period (October 2002 to April 2003; 5088 hours).

Site	Discharge (m^3)			Discharge (% of total)		Duration (hours)		Duration (% of total)	
	Base Flow	High Flow	Total Flow	Base Flow	High Flow	Base Flow	High Flow	Base Flow	High Flow
1	7640926	4691607	12332533	62.0	38.0	4003	1085	78.7	21.3
2	9260307	5238667	14498973	63.9	36.1	4010	1078	78.8	21.2
3	23222641	13825137	37047778	62.7	37.3	4031	1057	79.2	20.8
4	11648016	9190440	20838456	55.9	44.1	3734	1354	73.4	26.6
5	6517681	6281590	12799271	50.9	49.1	3777	1311	74.2	25.8
6	278117	559423	837541	33.2	66.8	3586	1502	70.5	29.5
7	263239	660614	923853	28.5	71.5	4020	1068	79.0	21.0
8	3331312	3702069	7033381	47.4	52.6	4238	850	83.4	16.6
9	3337183	3732671	7069854	47.2	52.8	4236	852	83.4	16.6
10	28566529	33312221	61878750	46.2	53.8	3595	1493	70.7	29.3
11	10591738	11813106	22404845	47.3	52.7	4235	853	83.4	16.6
12	45676727	69524801	115201528	39.6	60.4	3653	1435	71.8	28.2
13	52206700	79326935	131533635	39.7	60.3	3656	1432	71.9	28.1
14	2300976	1412823	3713798	62.0	38.0	4003	1085	78.7	21.3
15	311513	667548	979060	31.8	68.2	3870	1218	76.1	23.9

Table 4.5: Estimated discharge (m^3) at the water-quality monitoring sites in the Caldew Catchment for the restocked post-FMD summer period (May to September 2003; 3672 hours).

Site	Discharge (m^3)			Discharge (% of total)		Duration (hours)		Duration (% of total)	
	Base Flow	High Flow	Total Flow	Base Flow	High Flow	Base Flow	High Flow	Base Flow	High Flow
1	3423283	1230638	4653922	73.6	26.4	3298	374	89.8	10.2
2	3863910	1294301	5158211	74.9	25.1	3299	373	89.8	10.2
3	9414481	3529402	12943883	72.7	27.3	3302	370	89.9	10.1
4	3495996	1543860	5039856	69.4	30.6	3298	374	89.8	10.2
5	1730164	1201878	2932042	59.0	41.0	3300	372	89.9	10.1
6	93451	35444	128895	72.5	27.5	3516	156	95.8	4.2
7	35956	24767	60723	59.2	40.8	3600	72	98.0	2.0
8	370719	48712	419431	88.4	11.6	3614	58	98.4	1.6
9	372608	49098	421706	88.4	11.6	3614	58	98.4	1.6
10	14963547	6161767	21125314	70.8	29.2	3237	435	88.2	11.8
11	1184499	152953	1337452	88.6	11.4	3615	57	98.4	1.6
12	17273559	5065771	22339329	77.3	22.7	3483	189	94.9	5.1
13	19728831	5785020	25513851	77.3	22.7	3483	189	94.9	5.1
14	1030882	370592	1401474	73.6	26.4	3298	374	89.8	10.2
15	120088	91070	211158	56.9	43.1	3424	248	93.2	6.8

Table 4.6: Summary of rainfall (mm) measured at Environment Agency rainfall gauges in the Caldew Catchment for the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

Rain Gauge	Gauge Altitude	Restocking Winter (Oct '01 to Apr'02)	Mostly Restocked Summer (May to Sept '02)	Restocked post FMD Winter (Oct '02 to Apr'03)	Restocked post FMD Summer (May to Sept '03)
Carrock Mine	400 mAOD	1026.5*	759.0	1070.5	518.5
Calebreck Hall Log	300 mAOD	979.6	412.0	780.0	376.8
Mosedale Tel	230 mAOD	897.0*	544.4	849.2	444.0
Skelton Tel	205 mAOD	511.0*	408.0	516.8	259.2
Blackhall Wood	65 mAOD	549.9	334.3	483.0	260.8
Willow Holme Tel	15 mAOD	539.30[†]	315.8	483.6	251.8

*Missing data.
[†]Restocking winter data from daily record, other periods from hourly records.

Table 4.7: Comparison of flow statistics from the study period with long-term statistics.

	Long-term Winter Statistics•	Restocking Winter (2001/2)	Restocked Post-FMD Winter (2002/3)	Long-term Summer Statistics*	Mostly Stocked Summer (2002)	Restocked Post-FMD Summer (2003)
	Cummersdale Winter (Oct to April)			Cummersdale Summer (May to Sept)		
Average daily mean	9.932	10.138	6.951	3.130	3.943	1.880
Median daily mean value	6.381	6.665	4.672	1.948	5.585	1.164
Maximum daily mean value	89.864	89.864	47.594	30.524	25.270	15.716
Minimum daily mean value	1.335	1.335	1.021	0.794	1.265	0.649
	Stockdalewath Winter (Oct to April)			Stockdalewath Summer (May to Sept)		
Average daily mean	1.694	1.560	1.150	0.315	0.512	0.095
Median daily mean value	0.846	0.728	0.647	0.112	0.206	0.052
Maximum daily mean value	20.611	20.611	11.062	9.262	9.262	0.948
Minimum daily mean value	0.086	0.086	0.064	0.035	0.082	0.024

* Long-term statistics based on: Cummersdale 1998-2002; Stockdalewath 1999-2002

Table 4.8: Geometric mean and standard deviation of $\log_{10}$ transformed total coliform concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the restocking winter period (1st October 2001 to 30th April 2002).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	$3.82x10^{1}$	0.137	29	$5.39x10^{1}$	0.732	9
2	$4.72x10^{1}$	0.224	29	$7.85x10^{1}$	0.732	10
3	$9.08x10^{2}$	0.432	28	$7.79x10^{2}$	0.445	11
4	$4.82x10^{2}$	0.466	27	$1.34x10^{3†}$	0.439	12
5	$2.52x10^{2}$	0.472	27	$4.92x10^{2}$	0.540	11
6	$2.65x10^{2}$	0.606	26	$6.45x10^{2†}$	0.708	13
7	$1.09x10^{2}$	0.581	28	$5.62x10^{2†}$	0.671	11
8	$4.42x10^{3}$	0.471	30	$3.90x10^{3}$	0.170	9
9	$2.90x10^{2}$	0.616	30	$1.51x10^{3†}$	0.497	9
10	$3.13x10^{2}$	0.393	22	$1.03x10^{3†}$	0.346	17
11	$3.66x10^{3}$	0.637	31	$3.43x10^{3}$	0.160	8
12	$6.20x10^{2}$	0.867	30	$2.62x10^{3†}$	0.176	9
13	$1.55x10^{3}$	0.720	25	$3.68x10^{3†}$	0.337	13
6 & 7*	$1.67x10^{2}$	0.612	54	$6.05x10^{2†}$	0.677	24
8 & 9*	$1.13x10^{3}$	0.611	60	$2.43x10^{3†}$	0.418	18

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at α = 0.05 (95% confidence).

Table 4.9: Geometric mean and standard deviation of log_{10} transformed faecal coliform concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the restocking winter period (1st October 2001 to 30th April 2002).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	$5.79x10^{0}$	0.137	29	$6.66x10^{0}$	0.293	9
2	$6.50x10^{0}$	0.224	29	$1.30x10^{1}$	0.557	10
3	$2.04x10^{2}$	0.432	28	$3.99x10^{2}$	0.399	11
4	$2.38x10^{2}$	0.466	27	$6.67x10^{2\dagger}$	0.558	12
5	$3.49x10^{1}$	0.472	27	$2.10x10^{2\dagger}$	0.635	11
6	$7.49x10^{1}$	0.606	26	$2.89x10^{2\dagger}$	0.763	13
7	$3.40x10^{1}$	0.581	28	$4.62x10^{2\dagger}$	0.735	11
8	$4.31x10^{2}$	0.471	30	$6.73x10^{2}$	0.413	9
9	$1.20x10^{2}$	0.616	30	$8.95x10^{2\dagger}$	0.527	9
10	$8.72x10^{1}$	0.393	22	$4.80x10^{2\dagger}$	0.393	17
11	$4.70x10^{2}$	0.637	31	$1.51x10^{3\dagger}$	0.246	8
12	$1.07x10^{2}$	0.867	30	$6.44x10^{2\dagger}$	0.383	9
13	$2.90x10^{2}$	0.720	25	$9.02x10^{2\dagger}$	0.391	13
6 & 7*	$4.97x10^{1}$	0.612	54	$3.58x10^{2\dagger}$	0.741	24
8 & 9*	$2.28x10^{2}$	0.611	60	$7.76x10^{2\dagger}$	0.464	18

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at $\alpha = 0.05$ (95% confidence).

Table 4.10: Geometric mean and standard deviation of $\log_{10}$ transformed enterococci concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the restocking winter period (1st October 2001 to 30th April 2002).

	Base flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	$5.00x10^{0}$	0.000	29	$5.85x10^{0}$	0.149	9
2	$5.46x10^{0}$	0.144	29	$7.12x10^{0}$	0.293	10
3	$5.85x10^{1}$	0.441	28	$2.03x10^{2\dagger}$	0.474	11
4	$1.28x10^{2}$	0.628	27	$3.24x10^{2}$	0.773	12
5	$1.41x10^{1}$	0.403	27	$1.04x10^{2\dagger}$	0.704	11
6	$3.21x10^{1}$	0.685	26	$1.86x10^{2\dagger}$	0.822	13
7	$1.56x10^{1}$	0.652	28	$1.82x10^{2\dagger}$	0.683	11
8	$1.02x10^{2}$	0.558	30	$2.88x10^{2\dagger}$	0.434	9
9	$5.24x10^{1}$	0.778	30	$4.50x10^{2\dagger}$	0.692	9
10	$3.78x10^{1}$	0.555	22	$2.12x10^{2\dagger}$	0.535	17
11	$1.13x10^{2}$	0.729	31	$4.50x10^{2\dagger}$	0.260	8
12	$5.64x10^{1}$	0.737	30	$2.88x10^{2\dagger}$	0.501	9
13	$1.46x10^{2}$	0.910	25	$1.09x10^{3\dagger}$	0.713	13
6 & 7*	$2.21x10^{1}$	0.680	54	$1.84x10^{2\dagger}$	0.745	24
8 & 9*	$7.33x10^{1}$	0.687	60	$3.60x10^{2\dagger}$	0.569	18

*Combined data from sites with similar land cover and catchment area.

^{V}Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at α = 0.05 (95% confidence).

Table 4.11: Geometric mean and standard deviation of log_{10} transformed total coliform concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the mostly restocked summer period (1st May 2002 to 30th September 2002).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	9.47×10^{1}	0.524	12	2.54×10^{2}	0.732	4
2	6.64×10^{1}	0.470	12	$3.46 \times 10^{2\dagger}$	0.732	4
3	3.90×10^{3}	0.533	11	4.38×10^{3}	0.445	5
4	1.78×10^{3}	0.411	11	4.29×10^{3}	0.439	5
5	1.24×10^{3}	0.496	11	3.40×10^{3}	0.540	5
6	1.88×10^{3}	0.454	12	7.01×10^{3}	0.708	4
7	1.59×10^{3}	0.657	12	$8.08 \times 10^{3\dagger}$	0.671	4
8	7.88×10^{3}	0.508	14	3.35×10^{4}	0.170	2
9	1.83×10^{3}	0.618	15	$6.61 \times 10^{4\dagger}$	0.497	1
10	9.04×10^{2}	0.300	11	2.58×10^{3}	0.346	5
11	3.60×10^{3}	0.696	13	$3.33 \times 10^{4\dagger}$	0.160	1
12	1.05×10^{3}	0.644	14	$1.61 \times 10^{4\dagger}$	0.176	1
13	4.29×10^{3}	0.627	13	7.85×10^{3}	0.337	2
6 & 7*	1.73×10^{3}	0.596	24	$7.52 \times 10^{3\dagger}$	0.677	8
8 & 9*	3.70×10^{3}	0.819	29	$4.20 \times 10^{4\dagger}$	0.418	3

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at $\alpha = 0.05$ (95% confidence).

Table 4.12: Geometric mean and standard deviation of log_{10} transformed faecal coliform concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the mostly restocked summer period (1st May 2002 to 30th September 2002).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	1.30×10^{1}	0.137	12	$8.19 \times 10^{1\dagger}$	0.293	4
2	1.72×10^{1}	0.224	12	$1.07 \times 10^{2\dagger}$	0.557	4
3	1.34×10^{3}	0.432	11	1.81×10^{3}	0.399	5
4	5.83×10^{2}	0.466	11	2.29×10^{3}	0.558	5
5	5.14×10^{2}	0.472	11	$2.42 \times 10^{3\dagger}$	0.635	5
6	6.19×10^{2}	0.606	12	4.16×10^{3}	0.763	4
7	5.56×10^{2}	0.581	12	$4.38 \times 10^{3\dagger}$	0.735	4
8	1.65×10^{3}	0.471	14	$1.28 \times 10^{4\dagger}$	0.413	2
9	1.08×10^{3}	0.616	15	$3.99 \times 10^{4\dagger}$	0.527	1
10	4.72×10^{2}	0.393	11	1.17×10^{3}	0.393	5
11	1.43×10^{3}	0.637	13	9.29×10^{3}	0.246	1
12	3.39×10^{2}	0.867	14	$4.12 \times 10^{3\dagger}$	0.383	1
13	5.96×10^{2}	0.720	13	2.79×10^{3}	0.391	2
6 & 7*	5.87×10^{2}	0.612	24	$4.27 \times 10^{3\dagger}$	0.741	8
8 & 9*	1.33×10^{3}	0.611	29	$1.87 \times 10^{4\dagger}$	0.464	3

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at $\alpha = 0.05$ (95% confidence).

Table 4.13: Geometric mean and standard deviation of $\log_{10}$ transformed enterococci concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the mostly restocked summer period (1st May 2002 to 30th September 2002).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	1.20×10^{1}	0.000	12	3.19×10^{1}	0.149	4
2	7.98×10^{0}	0.144	12	$2.83 \times 10^{1\dagger}$	0.293	4
3	1.92×10^{2}	0.441	11	6.15×10^{2}	0.474	5
4	1.58×10^{2}	0.628	11	$6.41 \times 10^{2\dagger}$	0.773	5
5	8.01×10^{1}	0.403	11	3.38×10^{2}	0.704	5
6	9.77×10^{1}	0.685	12	$7.84 \times 10^{2\dagger}$	0.822	4
7	5.41×10^{1}	0.652	12	$7.69 \times 10^{2\dagger}$	0.683	4
8	3.30×10^{2}	0.558	14	$4.14 \times 10^{3\dagger}$	0.434	2
9	1.75×10^{2}	0.778	15	$1.94 \times 10^{4\dagger}$	0.692	1
10	1.66×10^{2}	0.555	11	2.71×10^{2}	0.535	5
11	1.73×10^{2}	0.729	13	$4.40 \times 10^{3\dagger}$	0.260	1
12	7.40×10^{1}	0.737	14	$1.73 \times 10^{3\dagger}$	0.501	1
13	5.43×10^{1}	0.910	13	$5.49 \times 10^{2\dagger}$	0.713	2
6 & 7*	7.27×10^{1}	0.680	24	$7.76 \times 10^{2\dagger}$	0.745	8
8 & 9*	2.37×10^{2}	0.687	29	$6.93 \times 10^{3\dagger}$	0.569	3

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at $\alpha = 0.05$ (95% confidence).

Table 4.14: Geometric mean and standard deviation of $\log_{10}$ transformed total coliforms concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the restocked post-FMD winter period (1st October 2002 to 30th April 2003). These data include high-flow samples collected during the subsequent winter period (1st October 2003 to 1st February 2004).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	$2.35x10^{1}$	0.415	32	$8.76x10^{1\dagger}$	0.529	13
2	$4.19x10^{1}$	0.486	32	$1.19x10^{2\dagger}$	0.429	13
3	$2.01x10^{3}$	0.587	33	$4.84x10^{3\dagger}$	0.553	12
4	$6.11x10^{2}$	0.424	31	$2.62x10^{3\dagger}$	0.480	14
5	$1.92x10^{2}$	0.487	30	$1.02x10^{3\dagger}$	0.636	14
6	$5.46x10^{2}$	0.676	32	$4.17x10^{3\dagger}$	0.483	13
7	$3.68x10^{2}$	0.812	38	$8.37x10^{3\dagger}$	0.894	7
8	$2.83x10^{3}$	0.563	40	$3.80x10^{3}$	0.476	5
9	$4.75x10^{2}$	0.670	40	$4.50x10^{3\dagger}$	0.471	5
10	$9.62x10^{2}$	0.574	31	$3.24x10^{3\dagger}$	0.506	14
11	$2.32x10^{3}$	0.505	39	$6.17x10^{3\dagger}$	0.239	5
12	$5.20x10^{2}$	0.589	30	$3.99x10^{3\dagger}$	0.343	14
13	$3.27x10^{3}$	0.533	28	$4.32x10^{3\dagger}$	0.521	15
14	$1.66x10^{2}$	1.146	18	$6.50x10^{2}$	0.829	10
15	$2.58x10^{1}$	0.569	19	$1.18x10^{2\dagger}$	0.434	10
1 & 15*	$2.43x10^{1}$	0.473	51	$9.97x10^{1\dagger}$	0.483	23
6 & 7*	$4.41x10^{2}$	0.753	70	$5.33x10^{3\dagger}$	0.650	20
8 & 9*	$1.16x10^{3}$	0.728	80	$4.14x10^{3\dagger}$	0.448	10

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at α = 0.05 (95% confidence).

Table 4.15: Geometric mean and standard deviation of log_{10} transformed faecal coliforms concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the restocked post-FMD winter period (1st October 2002 to 30the April 2003). These data include high-flow samples collected during the subsequent winter period (1st October 2003 to 1st February 2004).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	$1.14x10^{1}$	0.244	32	$3.72x10^{1†}$	0.496	13
2	$1.46x10^{1}$	0.297	32	$5.66x10^{1†}$	0.566	13
3	$2.66x10^{2}$	0.351	33	$2.72x10^{3†}$	0.547	12
4	$2.59x10^{2}$	0.490	31	$1.70x10^{3†}$	0.473	14
5	$3.04x10^{1}$	0.423	30	$5.97x10^{2†}$	0.670	14
6	$1.16x10^{2}$	0.786	32	$1.73x10^{3†}$	0.583	13
7	$7.80x10^{1}$	0.781	38	$5.68x10^{3†}$	0.643	7
8	$7.59x10^{2}$	0.579	40	$1.73x10^{3}$	0.137	5
9	$1.08x10^{2}$	0.837	40	$1.48x10^{3†}$	0.665	5
10	$1.55x10^{2}$	0.502	31	$1.84x10^{3†}$	0.514	14
11	$5.78x10^{2}$	0.481	39	$2.50x10^{3†}$	0.427	5
12	$8.99x10^{1}$	0.617	30	$1.48x10^{3†}$	0.376	14
13	$1.99x10^{2}$	0.675	28	$9.02x10^{2†}$	0.407	15
14	$1.16x10^{2}$	1.273	19	$2.32x10^{2}$	0.969	10
15	$1.21x10^{1}$	0.292	19	$4.17x10^{1†}$	0.524	10
1 & 15*	$1.17x10^{1}$	0.260	51	$3.91x10^{1†}$	0.497	23
6 & 7*	$9.37x10^{1}$	0.783	70	$2.62x10^{3†}$	0.640	20
8 & 9*	$2.86x10^{2}$	0.833	80	$1.60x10^{3†}$	0.454	10

*Combined data from sites with similar land cover and catchment area.
†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at α = 0.05 (95% confidence).

Table 4.16: Geometric mean and standard deviation of log_{10} transformed enterococci concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the restocked post-FMD winter period (1st October 2002 to 30th April 2003). These data include high flow samples collected during the subsequent winter period (1st October 2003 to 1st February 2004).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	$1.10x10^{1}$	0.182	32	$1.66x10^{1\dagger}$	0.301	13
2	$1.17x10^{1}$	0.212	32	$1.60x10^{1\dagger}$	0.226	13
3	$1.92x10^{2}$	0.468	33	$1.53x10^{3\dagger}$	0.485	12
4	$6.54x10^{1}$	0.394	31	$6.58x10^{2\dagger}$	0.567	14
5	$1.58x10^{1}$	0.348	30	$1.74x10^{2\dagger}$	0.728	14
6	$1.22x10^{2}$	0.684	32	$7.52x10^{2\dagger}$	0.581	13
7	$4.50x10^{1}$	0.608	38	$3.25x10^{3\dagger}$	0.830	7
8	$3.74x10^{2}$	0.559	40	$5.10x10^{2}$	0.352	5
9	$1.24x10^{2}$	0.782	40	$1.11x10^{3\dagger}$	0.532	5
10	$6.54x10^{1}$	0.539	31	$7.50x10^{2\dagger}$	0.560	14
11	$2.43x10^{2}$	0.647	39	$1.14x10^{3\dagger}$	0.447	5
12	$6.37x10^{1}$	0.500	30	$7.69x10^{2\dagger}$	0.401	14
13	$1.95x10^{2}$	1.000	28	$4.81x10^{2\dagger}$	0.528	15
14	$5.80x10^{1}$	0.730	19	$8.15x10^{1}$	0.672	10
15	$1.10x10^{1}$	0.129	19	$1.74x10^{1}$	0.368	10
1 & 15*	$1.10x10^{1}$	0.163	51	$1.69x10^{1\dagger}$	0.324	23
6 & 7*	$7.10x10^{1}$	0.675	70	$1.26x10^{3\dagger}$	0.726	20
8 & 9*	$2.15x10^{2}$	0.717	80	$7.53x10^{2\dagger}$	0.461	10

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at α = 0.05 (95% confidence).

Table 4.17: Geometric mean and standard deviation of log_{10} transformed total coliforms concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the restocked post-FMD summer period (1st May 2003 to 30th September 2003).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	$2.41 x 10^{1}$	0.415	7	$9.83 x 10^{2}$	0.529	3
2	$1.11 x 10^{2}$	0.486	7	$1.65 x 10^{3\dagger}$	0.429	3
3	$3.44 x 10^{3}$	0.587	6	$1.58 x 10^{4}$	0.553	3
4	$1.73 x 10^{3}$	0.424	8	$3.98 x 10^{4\dagger}$	0.480	2
5	$6.44 x 10^{2}$	0.487	8	$2.71 x 10^{4\dagger}$	0.636	2
6	$1.34 x 10^{3}$	0.676	8	$9.16 x 10^{4\dagger}$	0.483	2
7	$9.17 x 10^{2}$	0.812	8	$7.56 x 10^{4\dagger}$	0.894	2
8	$3.29 x 10^{3}$	0.563	8	$1.15 x 10^{5\dagger}$	0.476	2
9	$1.37 x 10^{3}$	0.670	8	$2.78 x 10^{5\dagger}$	0.471	2
10	$1.81 x 10^{3}$	0.574	7	$1.67 x 10^{4\dagger}$	0.506	3
11	$4.09 x 10^{3}$	0.505	8	$3.96 x 10^{4\dagger}$	0.239	2
12	$8.78 x 10^{2}$	0.589	8	$3.37 x 10^{4\dagger}$	0.343	2
13	$2.29 x 10^{3}$	0.533	8	$4.43 x 10^{4\dagger}$	0.521	2
14	$2.41 x 10^{3}$	0.557	7	$8.89 x 10^{3}$	0.371	3
15	$4.21 x 10^{1}$	0.552	7	$5.70 x 10^{2}$	1.521	3
1 & 15*	$3.19 x 10^{1}$	0.529	14	$7.48 x 10^{2\dagger}$	1.250	6
6 & 7*	$1.11 x 10^{3}$	0.753	16	$8.32 x 10^{4\dagger}$	0.650	4
8 & 9*	$2.13 x 10^{3}$	0.728	16	$1.79 x 10^{5\dagger}$	0.448	4

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at α = 0.05 (95% confidence).

Table 4.18: Geometric mean and standard deviation of $\log_{10}$ transformed faecal coliforms concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the restocked post-FMD summer period (1st May 2003 to 30th September 2003).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	$1.75x10^1$	0.244	7	$6.31x10^2$	0.496	3
2	$3.63x10^1$	0.297	7	$1.03x10^3$	0.566	3
3	$6.38x10^2$	0.351	7	$6.59x10^3$	0.547	3
4	$1.16x10^3$	0.490	8	$3.81x10^{4\dagger}$	0.473	2
5	$2.87x10^2$	0.423	8	$2.30x10^{4\dagger}$	0.670	2
6	$4.43x10^2$	0.786	8	$1.10x10^{5\dagger}$	0.583	2
7	$5.19x10^2$	0.781	8	$7.08x10^{4\dagger}$	0.643	2
8	$1.09x10^3$	0.579	8	$5.50x10^{4\dagger}$	0.137	2
9	$5.82x10^2$	0.837	8	$2.54x10^{5\dagger}$	0.665	2
10	$4.00x10^2$	0.502	7	$6.47x10^3$	0.514	3
11	$8.59x10^2$	0.481	8	$3.00x10^{4\dagger}$	0.427	2
12	$3.49x10^2$	0.617	8	$3.15x10^{4\dagger}$	0.376	2
13	$3.62x10^2$	0.675	8	$3.28x10^{4\dagger}$	0.407	2
14	$1.68x10^3$	0.542	7	$4.58x10^3$	0.159	3
15	$2.45x10^1$	0.443	7	$4.51x10^2$	1.438	3
1 & 15*	$2.07x10^1$	0.369	14	$5.34x10^{2\dagger}$	1.269	6
6 & 7*	$4.79x10^2$	0.783	16	$8.84x10^{4\dagger}$	0.640	4
8 & 9*	$7.97x10^2$	0.833	16	$1.18x10^{5\dagger}$	0.454	4

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at α = 0.05 (95% confidence).

Table 4.19: Geometric mean and standard deviation of log_{10} transformed faecal streptococci concentrations (cfu 100 ml^{-1}) at river sampling points in the Caldew Catchment for the restocked post-FMD summer period (1st May 2003 to 30th September 2003).

	Base Flow			High Flow		
Site	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*	Geometric Mean Concentration (cfu 100 ml^{-1})	Log_{10} Standard Deviation	Number of Samples *n*
1	1.24×10^{1}	0.182	7	2.02×10^{2}	0.301	3
2	1.27×10^{1}	0.212	7	2.68×10^{2}	0.226	3
3	3.90×10^{2}	0.468	7	2.04×10^{3}	0.485	3
4	3.09×10^{2}	0.394	8	$4.72 \times 10^{3\dagger}$	0.567	2
5	6.22×10^{1}	0.348	8	$2.79 \times 10^{3\dagger}$	0.728	2
6	1.03×10^{2}	0.684	8	$2.74 \times 10^{4\dagger}$	0.581	2
7	9.18×10^{1}	0.608	8	$2.51 \times 10^{4\dagger}$	0.830	2
8	3.52×10^{2}	0.559	8	$4.17 \times 10^{4\dagger}$	0.352	2
9	1.84×10^{2}	0.782	8	$4.02 \times 10^{4\dagger}$	0.532	2
10	2.53×10^{2}	0.539	7	1.35×10^{3}	0.560	3
11	4.30×10^{2}	0.647	8	$1.55 \times 10^{4\dagger}$	0.447	2
12	1.95×10^{2}	0.500	8	$5.60 \times 10^{3\dagger}$	0.401	2
13	1.24×10^{2}	1.000	8	$6.36 \times 10^{3\dagger}$	0.528	2
14	5.12×10^{1}	0.568	7	5.96×10^{2}	0.216	3
15	2.57×10^{1}	0.331	7	1.06×10^{2}	0.728	3
1 & 15*	1.78×10^{1}	0.300	14	$1.47 \times 10^{2\dagger}$	0.865	6
6 & 7*	9.73×10^{1}	0.675	16	$2.62 \times 10^{4\dagger}$	0.726	4
8 & 9*	2.54×10^{2}	0.717	16	$4.09 \times 10^{4\dagger}$	0.461	4

*Combined data from sites with similar land cover and catchment area.

†Results of Student's t-test show a significant elevation in GM at high flow compared to base flow at $\alpha = 0.05$ (95% confidence).

Table 4.20: Probabilities associated with Student's t-tests between faecal indicator organism concentrations at sites 10 (River Caldew, Sebergham) and 11 (Roe Beck, Gaitsgill). Probability is only shown where geometric mean concentrations are significantly greater at site 11 (α = 0.05, 95% confidence).

Period	Base Flow			High Flow		
	Total Coliforms	Faecal Coliforms	Enterococci	Total Coliforms	Faecal Coliforms	Enterococci
Restocking winter	<0.001	<0.001	0.007	<0.001	0.002	0.026
Mostly restocked summer	<0.001	0.010	n.s.	n.s.	n.s.	n.s.
Restocked post-FMD winter	0.002	<0.001	<0.001	n.s.	n.s.	n.s.
Restocked post-FMD summer	0.019	n.s.	n.s.	n.s.	n.s.	n.s.

n.s., not significant.

Table 4.21: Probabilities associated with Student's t-tests between faecal indicator organism concentrations during the restocking winter and the mostly restocked summer. Probability is only shown where geometric mean concentrations are significantly greater at site 11 (α = 0.05, 95% confidence).

Site	Base Flow			High Flow		
	Total Coliforms	Faecal Coliforms	Enterococci	Total Coliforms	Faecal Coliforms	Enterococci
1	0.017	n.s.	0.044	n.s.	0.041	n.s.
2	n.s.	0.002	n.s.	n.s.	0.020	0.015
3	0.001	<0.001	0.005	0.008	0.013	n.s.
4	0.001	0.014	n.s.	n.s.	n.s.	n.s.
5	<0.001	<0.001	<0.001	0.025	0.012	n.s.
6	0.009	0.001	0.033	0.009	0.009	n.s.
7	<0.001	<0.001	0.012	0.004	0.001	n.s.
8	n.s.	0.001	0.003	<0.001	0.003	0.012
9	<0.001	<0.001	0.019	0.007	0.009	0.028
10	0.003	<0.001	0.005	n.s.	n.s.	n.s. †
11	n.s. †	0.009	n.s.	0.001	0.010	0.005
12	n.s.	0.011	n.s.	0.002	0.041	n.s. †
13	0.035	n.s.	n.s. †	n.s.	n.s.	0.080
6 & 7*	<0.001	<0.001	0.002	<0.001	<0.001	0.005
8 & 9*	0.002	<0.001	<0.001	<0.001	<0.001	0.002

*Combined data from sites with similar land cover and catchment area.
†Summer GM concentration lower than winter GM concentration.
n.s, not significant.

Table 4.22: Probabilities associated with Student's t-tests between faecal indicator organism concentrations during the restocked post-FMD winter and summer. Probability is only shown where geometric mean concentrations are significantly greater at site 11 (α = 0.05, 95% confidence).

	Base Flow			High Flow		
Site	Total Coliforms	Faecal Coliforms	Enterococci	Total Coliforms	Faecal Coliforms	Enterococci
1	n.s.	0.044	n.s.	n.s.	n.s.	n.s.
2	0.024	0.002	n.s.	0.002	n.s.	n.s.
3	n.s.	0.007	0.049	n.s.	n.s.	n.s. †
4	0.006	0.001	<0.001	0.002	0.001	<0.001
5	0.003	<0.001	<0.001	<0.001	0.003	0.020
6	n.s.	0.034	n.s. †	0.001	<0.001	<0.001
7	n.s.	0.003	n.s.	n.s.	0.002	n.s.
8	n.s.	n.s.	n.s.	0.006	<0.001	0.001
9	0.035	0.011	n.s.	0.001	0.001	0.002
10	n.s.	0.023	<0.001	0.029	n.s.	n.s.
11	0.012	n.s.	n.s.	0.003	0.010	0.012
12	n.s.	0.007	0.008	0.001	<0.001	0.006
13	n.s.†	n.s.	n.s. †	0.009	<0.001	0.006
14	0.009	0.002	n.s.	0.023	0.024	0.028
15	n.s.	n.s.	0.013	n.s.	n.s.	0.012
1 & 15*	n.s.	0.015	n.s.	n.s.	0.040	0.022
6 & 7*	0.025	<0.001	n.s.	0.001	<0.001	<0.001
8 & 9*	0.046	0.022	n.s.	<0.001	<0.001	<0.001

*Combined data from sites with similar land cover and catchment area.
† Summer GM concentration lower than winter GM concentration.
n.s., not significant.

Table 4.23: Probabilities associated with Student's t-tests between faecal indicator organism concentrations during the restocking winter and the restocked post-FMD winter. Probability is only shown where geometric mean concentrations are significantly greater at site 11 (α = 0.05, 95% confidence).

	Base Flow			High Flow		
Site	Total Coliforms	Faecal Coliforms	Enterococci	Total Coliforms	Faecal Coliforms	Enterococci
1	0.043[†]	<0.001	<0.001	n.s. [†]	<0.001	<0.001
2	n.s. [†]	<0.001	<0.001	n.s. [†]	0.007	0.002
3	0.010	n.s.	<0.001	0.001	0.001	0.001
4	n.s.	n.s.	0.013[†]	n.s. [†]	0.027	n.s.
5	n.s. [†]	n.s. [†]	n.s.	n.s.	n.s.	n.s. [†]
6	0.020	n.s.	0.001	0.001	0.004	0.020
7	0.003	0.022	0.003	0.003	0.003	0.002
8	0.009[†]	n.s.	0.001	n.s.	0.028	n.s.
9	n.s.	n.s. [†]	n.s.	n.s.	n.s.	n.s.
10	0.001	n.s.	n.s.	0.017	0.017	0.044
11	0.021[†]	n.s.	n.s.	0.020	n.s.	n.s.
12	n.s. [†]	n.s. [†]	n.s.	n.s.	0.018	0.017
13	0.023	n.s. [†]	n.s.	n.s.	n.s.	n.s. [†]
6 & 7*	<0.001	0.018	<0.001	<0.001	<0.001	<0.001
8 & 9*	n.s.	n.s.	<0.001	n.s.	0.049	n.s.

*Combined data from sites with similar land cover and catchment area.
[†]Restocked post-FMD winter GM concentration lower than restocking winter GM concentration.
n.s., not significant.

Table 4.24: Probabilities associated with Student's t-tests between faecal indicator organism concentrations during the mostly restocked summer and the restocked post-FMD summer. Probability is only shown where geometric mean concentrations are significantly greater at site 11 (α = 0.05, 95% confidence).

	Base Flow			High Flow		
Site	Total Coliforms	Faecal Coliforms	Enterococci	Total Coliforms	Faecal Coliforms	Enterococci
1	0.013†	n.s.	n.s.	n.s.	n.s.	n.s.
2	n.s. †	0.039	n.s.	n.s.	n.s.	n.s.
3	n.s. †	n.s. †	n.s.	n.s.	n.s.	n.s.
4	n.s. †	n.s.	n.s.	0.033	0.025	0.018
5	n.s. †	n.s. †	n.s. †	n.s.	0.035	0.032
6	n.s. †	n.s. †	n.s.	0.033	0.028	0.009
7	n.s. †	n.s. †	n.s.	0.006	0.001	0.005
8	n.s. †	n.s. †	n.s.	n.s.	n.s.	n.s.
9	n.s. †	n.s. †	n.s.	n.s.	0.043	n.s.
10	n.s.	n.s. †	n.s.	n.s.	n.s.	n.s.
11	n.s.	n.s. †	n.s.	n.s.	n.s.	n.s.
12	n.s. †	n.s.	0.043	n.s.	n.s.	0.014
13	n.s. †	n.s. †	n.s.	0.050	0.038	0.002
6 & 7*	n.s. †	n.s. †	n.s.	<0.001	<0.001	<0.001
8 & 9*	n.s. †	n.s. †	n.s.	0.018	0.04	n.s.

*Combined data from sites with similar land cover and catchment area.
†Restocked post-FMD summer GM concentration lower than mostly stocked summer GM concentration.
n.s, not significant

Table 4.25: Estimated total coliform base-flow and high-flow loads (number of organisms) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct ’01 to Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to Apr’03)	Restocked Post-FMD Summer (May to Sept ’03)	Restocking Winter (Oct ’01 to Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to –Apr ’03)	Restocked Post-FMD Summer (May to Sept ’03)
1	$4.38x10^{12}$	$4.79x10^{12}$	$1.76x10^{12}$	$8.22x10^{11}$	$7.73x10^{12}$	$4.63x10^{12}$	$4.13x10^{12}$	$1.21x10^{13}$
2	$6.56x10^{12}$	$3.92x10^{12}$	$3.89x10^{12}$	$4.25x10^{12}$	$1.30x10^{13}$	$7.64x10^{12}$	$6.29x10^{12}$	$2.20x10^{13}$
3	$2.70x10^{14}$	$4.94x10^{14}$	$4.64x10^{14}$	$3.20x10^{14}$	$2.41x10^{14}$	$1.41x10^{14}$	$6.64x10^{14}$	$5.65x10^{14}$
4	$6.81x10^{13}$	$9.16x10^{13}$	$7.11x10^{13}$	$5.94x10^{13}$	$1.97x10^{14}$	$6.75x10^{13}$	$2.39x10^{14}$	$6.18x10^{14}$
5	$2.00x10^{13}$	$3.42x10^{13}$	$1.24x10^{13}$	$1.11x10^{13}$	$4.48x10^{13}$	$3.25x10^{13}$	$6.28x10^{13}$	$3.25x10^{14}$
6	$8.17x10^{11}$	$2.86x10^{12}$	$1.53x10^{12}$	$1.21x10^{12}$	$7.22x10^{12}$	$1.37x10^{13}$	$2.35x10^{13}$	$3.26x10^{13}$
7	$2.48x10^{11}$	$1.74x10^{12}$	$9.74x10^{11}$	$3.31x10^{11}$	$6.64x10^{12}$	$1.37x10^{13}$	$5.55x10^{13}$	$1.88x10^{13}$
8	$1.51x10^{14}$	$9.30x10^{13}$	$9.33x10^{13}$	$1.22x10^{13}$	$2.38x10^{14}$	$3.57x10^{14}$	$1.41x10^{14}$	$5.85x10^{13}$
9	$9.90x10^{12}$	$2.13x10^{13}$	$1.60x10^{13}$	$5.22x10^{12}$	$9.26x10^{13}$	$7.19x10^{14}$	$1.68x10^{14}$	$1.37x10^{14}$
10	$7.04x10^{13}$	$1.48x10^{14}$	$2.74x10^{14}$	$2.69x10^{14}$	$7.47x10^{14}$	$3.01x10^{14}$	$1.07x10^{15}$	$1.05x10^{15}$
11	$4.03x10^{14}$	$1.36x10^{14}$	$2.44x10^{14}$	$4.86x10^{13}$	$6.63x10^{14}$	$1.13x10^{15}$	$7.32x10^{14}$	$6.12x10^{13}$
12	$2.93x10^{14}$	$2.69x10^{14}$	$2.38x10^{14}$	$1.52x10^{14}$	$3.14x10^{15}$	$3.24x10^{15}$	$2.78x10^{15}$	$1.72x10^{15}$
13	$8.09x10^{14}$	$1.33x10^{15}$	$1.72x10^{15}$	$4.54x10^{14}$	$5.10x10^{15}$	$1.82x10^{15}$	$3.41x10^{15}$	$2.55x10^{15}$
14	No water quality data		$3.91x10^{12}$	$2.47x10^{13}$	No water quality data		$9.18x10^{12}$	$3.30x10^{13}$
15	No water quality data		$8.10x10^{10}$	$5.04x10^{10}$	No water quality data		$8.01x10^{11}$	$5.19x10^{11}$
1&15*	No water quality data		$1.91x10^{12}$	$1.13x10^{12}$	No water quality data		$5.36x10^{12}$	$9.91x10^{12}$
6&7*	$9.17x10^{11}$	$4.41x10^{12}$	$2.38x10^{12}$	$1.42x10^{12}$	$1.41x10^{13}$	$2.74x10^{13}$	$6.47x10^{13}$	$5.00x10^{13}$
8&9*	$7.54x10^{13}$	$8.73x10^{13}$	$8.00x10^{13}$	$1.56x10^{13}$	$2.95x10^{14}$	$9.11x10^{14}$	$3.05x10^{14}$	$1.76x10^{14}$

*Combined data from sites with similar land cover and catchment area.

Table 4.26: Estimated faecal coliform base-flow and high-flow loads (number of organisms) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct '01 to –Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)	Restocking Winter (Oct '01 to –Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)
1	$6.68x10^{11}$	$6.56x10^{11}$	$8.41x10^{11}$	$5.82x10^{11}$	$9.60x10^{11}$	$1.52x10^{12}$	$1.74x10^{12}$	$7.75x10^{12}$
2	$9.07x10^{11}$	$1.01x10^{12}$	$1.39x10^{12}$	$1.39x10^{12}$	$2.17x10^{12}$	$2.40x10^{12}$	$2.99x10^{12}$	$1.29x10^{13}$
3	$5.94x10^{13}$	$1.65x10^{14}$	$6.27x10^{13}$	$6.03x10^{13}$	$1.24x10^{14}$	$5.75x10^{13}$	$3.73x10^{14}$	$2.33x10^{14}$
4	$3.41x10^{13}$	$2.95x10^{13}$	$3.03x10^{13}$	$4.20x10^{13}$	$1.01x10^{14}$	$3.61x10^{13}$	$1.56x10^{14}$	$5.87x10^{14}$
5	$2.80x10^{12}$	$1.45x10^{13}$	$1.96x10^{12}$	$5.02x10^{12}$	$1.92x10^{13}$	$2.29x10^{13}$	$3.77x10^{13}$	$2.76x10^{14}$
6	$2.36x10^{11}$	$9.34x10^{11}$	$3.34x10^{11}$	$4.11x10^{11}$	$3.27x10^{12}$	$8.24x10^{12}$	$9.51x10^{12}$	$3.90x10^{13}$
7	$7.66x10^{10}$	$6.08x10^{11}$	$2.05x10^{11}$	$1.87x10^{11}$	$5.46x10^{12}$	$7.47x10^{12}$	$3.77x10^{13}$	$1.76x10^{13}$
8	$1.48x10^{13}$	$1.88x10^{13}$	$2.53x10^{13}$	$4.08x10^{12}$	$4.09x10^{13}$	$1.40x10^{14}$	$6.29x10^{13}$	$2.68x10^{13}$
9	$4.10x10^{12}$	$1.30x10^{13}$	$3.67x10^{12}$	$2.16x10^{12}$	$5.56x10^{13}$	$4.36x10^{14}$	$5.60x10^{13}$	$1.23x10^{14}$
10	$1.98x10^{13}$	$7.73x10^{13}$	$4.28x10^{13}$	$5.99x10^{13}$	$3.59x10^{14}$	$1.39x10^{14}$	$6.00x10^{14}$	$4.01x10^{14}$
11	$5.12x10^{13}$	$5.28x10^{13}$	$6.14x10^{13}$	$1.02x10^{13}$	$2.92x10^{14}$	$3.18x10^{14}$	$2.95x10^{14}$	$4.59x10^{13}$
12	$5.20x10^{13}$	$9.15x10^{13}$	$4.11x10^{13}$	$6.05x10^{13}$	$7.73x10^{14}$	$8.30x10^{14}$	$1.04x10^{15}$	$1.57x10^{15}$
13	$1.56x10^{14}$	$1.85x10^{14}$	$1.04x10^{14}$	$7.10x10^{13}$	$1.24x10^{15}$	$6.45x10^{14}$	$7.14x10^{14}$	$1.91x10^{15}$
14	No water quality data		$2.76x10^{12}$	$1.75x10^{13}$	No water quality data		$3.25x10^{12}$	$1.70x10^{13}$
15	No water quality data		$3.74x10^{10}$	$3.00x10^{10}$	No water quality data		$2.80x10^{11}$	$4.10x10^{11}$
1&15*	No water quality data		$9.54x10^{11}$	$7.44x10^{11}$	No water quality data		$2.09x10^{12}$	$7.01x10^{12}$
6&7*	$2.70x10^{11}$	$1.53x10^{12}$	$5.09x10^{11}$	$6.21x10^{11}$	$8.33x10^{12}$	$1.57x10^{13}$	$3.17x10^{13}$	$5.30x10^{13}$
8&9*	$1.58x10^{13}$	$3.07x10^{13}$	$1.93x10^{13}$	$5.95x10^{12}$	$9.57x10^{13}$	$4.12x10^{14}$	$1.19x10^{14}$	$1.17x10^{14}$

*Combined data from sites with similar land cover and catchment area.

Table 4.27: Estimated enterococci base-flow and high-flow loads (number of organisms) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct '01 to –Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)	Restocking Winter (Oct '01 to –Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)
1	$5.76x10^{11}$	$6.05x10^{11}$	$8.41x10^{11}$	$4.11x10^{11}$	$8.45x10^{11}$	$5.93x10^{11}$	$6.10x10^{11}$	$2.46x10^{12}$
2	$7.67x10^{11}$	$4.75x10^{11}$	$1.11x10^{12}$	$5.02x10^{11}$	$1.18x10^{12}$	$6.11x10^{11}$	$6.81x10^{11}$	$3.49x10^{12}$
3	$1.72x10^{13}$	$2.41x10^{13}$	$4.41x10^{13}$	$3.67x10^{13}$	$6.18x10^{13}$	$1.98x10^{13}$	$1.66x10^{12}$	$7.06x10^{13}$
4	$1.85x10^{13}$	$8.14x10^{12}$	$7.57x10^{12}$	$1.08x10^{13}$	$4.84x10^{13}$	$1.01x10^{13}$	$1.29x10^{12}$	$7.26x10^{13}$
5	$1.12x10^{12}$	$2.28x10^{12}$	$1.04x10^{12}$	$1.07x10^{12}$	$9.14x10^{12}$	$3.25x10^{12}$	$8.79x10^{11}$	$3.37x10^{13}$
6	$1.01x10^{11}$	$1.48x10^{11}$	$3.34x10^{11}$	$9.35x10^{10}$	$2.14x10^{12}$	$1.53x10^{12}$	$7.27x10^{10}$	$9.57x10^{12}$
7	$3.60x10^{10}$	$5.86x10^{10}$	$1.18x10^{11}$	$3.31x10^{10}$	$2.14x10^{12}$	$1.31x10^{12}$	$4.62x10^{10}$	$6.19x10^{12}$
8	$3.44x10^{12}$	$3.89x10^{12}$	$1.23x10^{13}$	$1.30x10^{12}$	$1.77x10^{13}$	$4.43x10^{13}$	$1.85x10^{11}$	$2.05x10^{13}$
9	$1.78x10^{12}$	$2.01x10^{12}$	$4.00x10^{12}$	$6.71x10^{11}$	$2.78x10^{13}$	$2.07x10^{14}$	$1.87x10^{11}$	$1.96x10^{13}$
10	$8.64x10^{12}$	$2.79x10^{13}$	$1.86x10^{13}$	$3.74x10^{13}$	$1.57x10^{14}$	$3.13x10^{13}$	$4.66x10^{12}$	$8.01x10^{13}$
11	$1.20x10^{13}$	$6.41x10^{12}$	$2.54x10^{13}$	$5.09x10^{12}$	$8.77x10^{13}$	$1.51x10^{14}$	$5.91x10^{11}$	$2.45x10^{13}$
12	$2.65x10^{13}$	$1.99x10^{13}$	$2.92x10^{13}$	$3.28x10^{13}$	$3.50x10^{14}$	$3.44x10^{14}$	$9.73x10^{12}$	$2.84x10^{14}$
13	$8.09x10^{13}$	$1.66x10^{13}$	$9.92x10^{13}$	$2.37x10^{13}$	$1.52x10^{15}$	$1.27x10^{14}$	$1.19x10^{13}$	$3.70x10^{14}$
14	No water quality data		$1.33x10^{12}$	$5.26x10^{11}$	No water quality data		$1.41x10^{11}$	$2.22x10^{12}$
15	No water quality data		$3.43x10^{10}$	$3.12x10^{10}$	No water quality data		$6.68x10^{10}$	$1.00x10^{11}$
1&15*	No water quality data		$8.75x10^{11}$	$6.38x10^{11}$	No water quality data		$1.23x10^{12}$	$1.98x10^{12}$
6&7*	$1.19x10^{11}$	$1.89x10^{11}$	$3.84x10^{11}$	$1.26x10^{11}$	$4.16x10^{12}$	$2.85x10^{12}$	$2.44x10^{11}$	$1.57x10^{13}$
8&9*	$5.00x10^{12}$	$5.66x10^{12}$	$1.47x10^{13}$	$1.86x10^{12}$	$4.42x10^{13}$	$1.50x10^{14}$	$7.43x10^{11}$	$4.01x10^{13}$

*Combined data from sites with similar land cover and catchment area.

Table 4.28: Estimated hourly total coliform base-flow and high-flow loads (number of organisms per hour) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct ’01 to –Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to –Apr ’03)	Restocked Post-FMD Summer (May to Sept ’03)	Restocking Winter (Oct ’01 to –Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to –Apr ’03)	Restocked Post-FMD Summer (May to Sept ’03)
1	1.22×10^{9}	1.57×10^{9}	4.39×10^{8}	2.49×10^{8}	5.13×10^{9}	7.52×10^{9}	3.81×10^{9}	3.22×10^{10}
2	1.77×10^{9}	1.28×10^{9}	9.70×10^{8}	1.29×10^{9}	9.39×10^{9}	1.24×10^{10}	5.83×10^{9}	5.90×10^{10}
3	7.46×10^{10}	1.53×10^{11}	1.15×10^{11}	9.69×10^{10}	1.65×10^{11}	3.19×10^{11}	6.28×10^{11}	1.53×10^{12}
4	1.81×10^{10}	2.84×10^{10}	1.90×10^{10}	1.80×10^{10}	1.48×10^{11}	1.50×10^{11}	1.76×10^{11}	1.65×10^{12}
5	5.42×10^{9}	1.06×10^{10}	3.28×10^{9}	3.36×10^{9}	3.19×10^{10}	7.35×10^{10}	4.79×10^{10}	8.72×10^{11}
6	2.57×10^{8}	1.05×10^{9}	4.27×10^{8}	3.46×10^{8}	3.78×10^{9}	1.45×10^{10}	1.56×10^{10}	2.09×10^{11}
7	7.49×10^{7}	5.69×10^{8}	2.42×10^{8}	9.19×10^{7}	3.74×10^{9}	2.21×10^{10}	5.20×10^{10}	2.61×10^{11}
8	3.82×10^{10}	2.78×10^{10}	2.20×10^{10}	3.39×10^{9}	2.09×10^{11}	1.11×10^{12}	1.66×10^{11}	1.01×10^{12}
9	2.52×10^{9}	6.35×10^{9}	3.78×10^{9}	1.44×10^{9}	8.00×10^{10}	2.19×10^{12}	1.97×10^{11}	2.37×10^{12}
10	2.29×10^{10}	5.11×10^{10}	7.63×10^{10}	8.32×10^{10}	3.70×10^{11}	3.88×10^{11}	7.14×10^{11}	2.41×10^{12}
11	1.02×10^{11}	4.05×10^{10}	5.75×10^{10}	1.34×10^{10}	5.75×10^{11}	3.50×10^{12}	8.59×10^{11}	1.07×10^{12}
12	9.42×10^{10}	8.71×10^{10}	6.50×10^{10}	4.36×10^{10}	1.59×10^{12}	5.58×10^{12}	1.94×10^{12}	9.11×10^{12}
13	2.60×10^{11}	4.28×10^{11}	4.71×10^{11}	1.30×10^{11}	2.58×10^{12}	3.15×10^{12}	2.38×10^{12}	1.35×10^{13}
14	No water quality data		9.77×10^{8}	7.50×10^{9}	No water quality data		8.46×10^{9}	8.82×10^{10}
15	No water quality data		2.09×10^{7}	1.47×10^{7}	No water quality data		6.58×10^{8}	2.09×10^{9}
1&15*	No water quality data		4.77×10^{8}	3.44×10^{8}	No water quality data		4.94×10^{9}	2.65×10^{10}
6&7*	2.52×10^{8}	1.44×10^{9}	5.95×10^{8}	4.32×10^{8}	9.76×10^{9}	4.45×10^{10}	5.98×10^{10}	1.34×10^{11}
8&9*	2.07×10^{10}	2.78×10^{10}	1.99×10^{10}	4.73×10^{9}	2.03×10^{11}	1.72×10^{12}	2.85×10^{11}	4.74×10^{11}

*Combined data from sites with similar land cover and catchment area.

Table 4.29: Estimated hourly faecal coliform base-flow and high-flow loads (number of organisms per hour) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct ’01 to –Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to –Apr ’03)	Restocked Post-FMD Summer (May to Sept ’03)	Restocking Winter (Oct ’01 to –Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to –Apr ’03)	Restocked Post-FMD Summer (May to Sept ’03)
1	$1.87x10^{8}$	$2.14x10^{8}$	$2.10x10^{8}$	$1.76x10^{8}$	$6.37x10^{8}$	$2.47x10^{9}$	$1.60x10^{9}$	$2.07x10^{10}$
2	$2.45x10^{8}$	$3.31x10^{8}$	$3.46x10^{8}$	$4.22x10^{8}$	$1.57x10^{9}$	$3.90x10^{9}$	$2.77x10^{9}$	$3.47x10^{10}$
3	$1.64x10^{10}$	$5.10x10^{10}$	$1.56x10^{10}$	$1.82x10^{10}$	$8.44x10^{10}$	$1.30x10^{11}$	$3.53x10^{11}$	$6.30x10^{11}$
4	$9.07x10^{9}$	$9.16x10^{9}$	$8.11x10^{9}$	$1.27x10^{10}$	$7.62x10^{10}$	$8.03x10^{10}$	$1.15x10^{11}$	$1.57x10^{12}$
5	$7.59x10^{8}$	$4.50x10^{9}$	$5.18x10^{8}$	$1.52x10^{9}$	$1.37x10^{10}$	$5.19x10^{10}$	$2.87x10^{10}$	$7.43x10^{11}$
6	$7.41x10^{7}$	$3.43x10^{8}$	$9.31x10^{7}$	$1.17x10^{8}$	$1.71x10^{9}$	$8.72x10^{9}$	$6.33x10^{9}$	$2.50x10^{11}$
7	$2.31x10^{7}$	$1.99x10^{8}$	$5.11x10^{7}$	$5.19x10^{7}$	$3.07x10^{9}$	$1.20x10^{10}$	$3.53x10^{10}$	$2.44x10^{11}$
8	$3.74x10^{9}$	$5.62x10^{9}$	$5.97x10^{9}$	$1.13x10^{9}$	$3.60x10^{10}$	$4.36x10^{11}$	$7.40x10^{10}$	$4.62x10^{11}$
9	$1.04x10^{9}$	$3.88x10^{9}$	$8.67x10^{8}$	$5.98x10^{8}$	$4.80x10^{10}$	$1.33x10^{12}$	$6.57x10^{10}$	$2.12x10^{12}$
10	$6.44x10^{9}$	$2.67x10^{10}$	$1.19x10^{10}$	$1.85x10^{10}$	$1.78x10^{11}$	$1.79x10^{11}$	$4.02x10^{11}$	$9.21x10^{11}$
11	$1.30x10^{10}$	$1.58x10^{10}$	$1.45x10^{10}$	$2.82x10^{9}$	$2.54x10^{11}$	$9.86x10^{11}$	$3.46x10^{11}$	$8.05x10^{11}$
12	$1.67x10^{10}$	$2.96x10^{10}$	$1.13x10^{10}$	$1.74x10^{10}$	$3.91x10^{11}$	$1.43x10^{12}$	$7.27x10^{11}$	$8.31x10^{12}$
13	$5.04x10^{10}$	$5.98x10^{10}$	$2.86x10^{10}$	$2.04x10^{10}$	$6.27x10^{11}$	$1.12x10^{12}$	$4.99x10^{11}$	$1.01x10^{13}$
14	No water quality data		$6.90x10^{8}$	$5.31x10^{9}$	No water quality data		$2.99x10^{9}$	$4.56x10^{10}$
15	No water quality data		$9.66x10^{6}$	$8.77x10^{6}$	No water quality data		$2.30x10^{8}$	$1.65x10^{9}$
1&15*	No water quality data		$2.38x10^{8}$	$2.26x10^{8}$	No water quality data		$1.93x10^{9}$	$1.87x10^{10}$
6&7*	$7.41x10^{7}$	$5.00x10^{8}$	$1.27x10^{8}$	$1.88x10^{8}$	$5.76x10^{9}$	$2.55x10^{10}$	$2.93x10^{10}$	$1.42x10^{11}$
8&9*	$4.34x10^{9}$	$9.75x10^{9}$	$4.81x10^{9}$	$1.80x10^{9}$	$6.58x10^{10}$	$7.80x10^{11}$	$1.11x10^{11}$	$3.16x10^{11}$

*Combined data from sites with similar land cover and catchment area.

Table 4.30: Estimated hourly enterococci base-flow and high-flow loads (number of organisms per hour) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct ’01 to –Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to –Apr ’03)	Restocked Post-FMD Summer (May to Sept ’03)	Restocking Winter (Oct ’01 to –Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to –Apr ’03)	Restocked Post-FMD Summer (May to Sept ’03)
1	$1.61x10^{8}$	$1.98x10^{8}$	$2.10x10^{8}$	$1.25x10^{8}$	$5.61x10^{8}$	$9.62x10^{8}$	$5.62x10^{8}$	$6.58x10^{9}$
2	$2.07x10^{8}$	$1.56x10^{8}$	$2.77x10^{8}$	$1.52x10^{8}$	$8.55x10^{8}$	$9.92x10^{8}$	$6.32x10^{8}$	$9.37x10^{9}$
3	$4.75x10^{9}$	$7.45x10^{9}$	$1.09x10^{10}$	$1.11x10^{10}$	$4.22x10^{10}$	$4.49x10^{10}$	$1.57x10^{9}$	$1.91x10^{11}$
4	$4.91x10^{9}$	$2.53x10^{9}$	$2.03x10^{9}$	$3.29x10^{9}$	$3.64x10^{10}$	$2.23x10^{10}$	$9.50x10^{8}$	$1.94x10^{11}$
5	$3.04x10^{8}$	$7.06x10^{8}$	$2.76x10^{8}$	$3.25x10^{8}$	$6.51x10^{9}$	$7.35x10^{9}$	$6.71x10^{8}$	$9.05x10^{10}$
6	$3.16x10^{7}$	$5.41x10^{7}$	$9.31x10^{7}$	$2.66x10^{7}$	$1.12x10^{9}$	$1.62x10^{9}$	$4.84x10^{7}$	$6.13x10^{10}$
7	$1.09x10^{7}$	$1.92x10^{7}$	$2.95x10^{7}$	$9.19x10^{6}$	$1.20x10^{9}$	$2.10x10^{9}$	$4.33x10^{7}$	$8.60x10^{10}$
8	$8.69x10^{8}$	$1.16x10^{9}$	$2.91x10^{9}$	$3.59x10^{8}$	$1.56x10^{10}$	$1.38x10^{11}$	$2.18x10^{8}$	$3.53x10^{11}$
9	$4.52x10^{8}$	$6.00x10^{8}$	$9.45x10^{8}$	$1.86x10^{8}$	$2.40x10^{10}$	$6.31x10^{11}$	$2.19x10^{8}$	$3.39x10^{11}$
10	$2.81x10^{9}$	$9.65x10^{9}$	$5.17x10^{9}$	$1.16x10^{10}$	$7.78x10^{10}$	$4.03x10^{10}$	$3.12x10^{9}$	$1.84x10^{11}$
11	$3.05x10^{9}$	$1.91x10^{9}$	$6.00x10^{9}$	$1.41x10^{9}$	$7.62x10^{10}$	$4.66x10^{11}$	$6.92x10^{8}$	$4.29x10^{11}$
12	$8.51x10^{9}$	$6.44x10^{9}$	$8.00x10^{9}$	$9.42x10^{9}$	$1.77x10^{11}$	$5.93x10^{11}$	$6.78x10^{9}$	$1.50x10^{12}$
13	$2.60x10^{10}$	$5.38x10^{9}$	$2.71x10^{10}$	$6.80x10^{9}$	$7.66x10^{11}$	$2.19x10^{11}$	$8.31x10^{9}$	$1.96x10^{12}$
14	No water quality data		$3.33x10^{8}$	$1.59x10^{8}$	No water quality data		$1.30x10^{8}$	$5.95x10^{9}$
15	No water quality data		$8.85x10^{6}$	$9.12x10^{6}$	No water quality data		$5.48x10^{7}$	$4.04x10^{8}$
1&15*	No water quality data		$2.19x10^{8}$	$1.93x10^{8}$	No water quality data		$1.14x10^{9}$	$5.30x10^{9}$
6&7*	$3.26x10^{7}$	$6.19x10^{7}$	$9.59x10^{7}$	$3.81x10^{7}$	$2.88x10^{9}$	$4.63x10^{9}$	$2.26x10^{8}$	$4.19x10^{10}$
8&9*	$1.38x10^{9}$	$1.80x10^{9}$	$3.65x10^{9}$	$5.63x10^{8}$	$3.04x10^{10}$	$2.83x10^{11}$	$6.95x10^{8}$	$1.08x10^{11}$

*Combined data from sites with similar land cover and catchment area.

Table 4.31: Total coliform base-flow and high-flow export coefficients (cfu hr^{-1} km^{-2}) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct '01 to –Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)	Restocking Winter (Oct '01 to –Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)
1	$4.22x10^{7}$	$5.41x10^{7}$	$1.51x10^{7}$	$8.59x10^{6}$	$1.77x10^{8}$	$2.59x10^{8}$	$1.31x10^{8}$	$1.11x10^{9}$
2	$5.18x10^{7}$	$3.76x10^{7}$	$2.84x10^{7}$	$3.77x10^{7}$	$2.75x10^{8}$	$3.63x10^{8}$	$1.71x10^{8}$	$1.73x10^{9}$
3	$8.89x10^{8}$	$1.82x10^{9}$	$1.37x10^{9}$	$1.16x10^{9}$	$1.96x10^{9}$	$3.80x10^{9}$	$7.48x10^{9}$	$1.82x10^{10}$
4	$5.05x10^{8}$	$7.92x10^{8}$	$5.30x10^{8}$	$5.02x10^{8}$	$4.12x10^{9}$	$4.18x10^{9}$	$4.92x10^{9}$	$4.60x10^{10}$
5	$3.47x10^{8}$	$6.77x10^{8}$	$2.10x10^{8}$	$2.15x10^{8}$	$2.04x10^{9}$	$4.70x10^{9}$	$3.06x10^{9}$	$5.58x10^{10}$
6	$1.63x10^{8}$	$6.64x10^{8}$	$2.70x10^{8}$	$2.19x10^{8}$	$2.39x10^{9}$	$9.19x10^{9}$	$9.90x10^{9}$	$1.32x10^{11}$
7	$2.12x10^{7}$	$1.61x10^{8}$	$6.86x10^{7}$	$2.60x10^{7}$	$1.06x10^{9}$	$6.27x10^{9}$	$1.47x10^{10}$	$7.41x10^{10}$
8	$1.81x10^{9}$	$1.31x10^{9}$	$1.04x10^{9}$	$1.60x10^{8}$	$9.90x10^{9}$	$5.23x10^{10}$	$7.82x10^{9}$	$4.76x10^{10}$
9	$1.18x10^{8}$	$2.98x10^{8}$	$1.78x10^{8}$	$6.78x10^{7}$	$3.76x10^{9}$	$1.03x10^{11}$	$9.26x10^{9}$	$1.11x10^{11}$
10	$1.75x10^{8}$	$3.91x10^{8}$	$5.83x10^{8}$	$6.36x10^{8}$	$2.83x10^{9}$	$2.97x10^{9}$	$5.46x10^{9}$	$1.84x10^{10}$
11	$1.52x10^{9}$	$6.01x10^{8}$	$8.53x10^{8}$	$1.99x10^{8}$	$8.53x10^{9}$	$5.19x10^{10}$	$1.27x10^{10}$	$1.59x10^{10}$
12	$4.23x10^{8}$	$3.91x10^{8}$	$2.92x10^{8}$	$1.96x10^{8}$	$7.12x10^{9}$	$2.50x10^{10}$	$8.69x10^{9}$	$4.09x10^{10}$
13	$1.02x10^{9}$	$1.68x10^{9}$	$1.85x10^{9}$	$5.12x10^{8}$	$1.01x10^{10}$	$1.24x10^{10}$	$9.36x10^{9}$	$5.29x10^{10}$
14	No water quality data		$1.12x10^{8}$	$8.59x10^{8}$	No water quality data		$9.70x10^{8}$	$1.01x10^{10}$
15	No water quality data		$5.41x10^{6}$	$3.81x10^{6}$	No water quality data		$1.70x10^{8}$	$5.41x10^{8}$
1&15*	No water quality data		$1.40x10^{7}$	$1.01x10^{7}$	No water quality data		$1.45x10^{8}$	$7.76x10^{8}$
6&7*	$1.61x10^{7}$	$9.22x10^{7}$	$3.80x10^{7}$	$2.76x10^{7}$	$6.24x10^{8}$	$2.85x10^{9}$	$3.82x10^{9}$	$8.56x10^{9}$
8&9*	$9.80x10^{8}$	$1.31x10^{9}$	$9.41x10^{8}$	$2.23x10^{8}$	$9.57x10^{9}$	$8.14x10^{10}$	$1.35x10^{10}$	$2.24x10^{10}$

*Combined data from sites with similar land cover and catchment area.

Table 4.32: Faecal coliform base-flow and high-flow export coefficients (cfu hr^{-1} km^{-2}) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct '01 to –Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)	Restocking Winter (Oct '01 to –Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)
1	6.43×10^{6}	7.40×10^{6}	7.24×10^{6}	6.09×10^{6}	2.20×10^{7}	8.50×10^{7}	5.52×10^{7}	7.15×10^{8}
2	7.17×10^{6}	9.68×10^{6}	1.01×10^{7}	1.23×10^{7}	4.58×10^{7}	1.14×10^{8}	8.11×10^{7}	1.02×10^{9}
3	1.95×10^{8}	6.08×10^{8}	1.85×10^{8}	2.18×10^{8}	1.01×10^{9}	1.55×10^{9}	4.21×10^{9}	7.50×10^{9}
4	2.53×10^{8}	2.55×10^{8}	2.26×10^{8}	3.54×10^{8}	2.12×10^{9}	2.24×10^{9}	3.22×10^{9}	4.37×10^{10}
5	4.85×10^{7}	2.88×10^{8}	3.31×10^{7}	9.72×10^{7}	8.74×10^{8}	3.32×10^{9}	1.84×10^{9}	4.75×10^{10}
6	4.69×10^{7}	2.17×10^{8}	5.89×10^{7}	7.40×10^{7}	1.09×10^{9}	5.52×10^{9}	4.01×10^{9}	1.58×10^{11}
7	6.56×10^{6}	5.64×10^{7}	1.45×10^{7}	1.47×10^{7}	8.69×10^{8}	3.41×10^{9}	9.99×10^{9}	6.92×10^{10}
8	1.77×10^{8}	2.66×10^{8}	2.82×10^{8}	5.33×10^{7}	1.70×10^{9}	2.06×10^{10}	3.50×10^{9}	2.18×10^{10}
9	4.90×10^{7}	1.82×10^{8}	4.07×10^{7}	2.81×10^{7}	2.25×10^{9}	6.24×10^{10}	3.09×10^{9}	9.94×10^{10}
10	4.92×10^{7}	2.04×10^{8}	9.11×10^{7}	1.41×10^{8}	1.36×10^{9}	1.37×10^{9}	3.07×10^{9}	7.04×10^{9}
11	1.93×10^{8}	2.34×10^{8}	2.15×10^{8}	4.18×10^{7}	3.76×10^{9}	1.46×10^{10}	5.13×10^{9}	1.19×10^{10}
12	7.50×10^{7}	1.33×10^{8}	5.05×10^{7}	7.79×10^{7}	1.75×10^{9}	6.42×10^{9}	3.26×10^{9}	3.73×10^{10}
13	1.98×10^{8}	2.35×10^{8}	1.12×10^{8}	8.01×10^{7}	2.46×10^{9}	4.39×10^{9}	1.96×10^{9}	3.97×10^{10}
14	No water quality data		7.90×10^{7}	6.09×10^{8}	No water quality data		3.43×10^{8}	5.22×10^{9}
15	No water quality data		2.50×10^{6}	2.27×10^{6}	No water quality data		5.95×10^{7}	4.27×10^{8}
1&15*	No water quality data		6.98×10^{6}	6.60×10^{6}	No water quality data		5.64×10^{7}	5.48×10^{8}
6&7*	4.74×10^{6}	3.20×10^{7}	8.12×10^{6}	1.20×10^{7}	3.68×10^{8}	1.63×10^{9}	1.88×10^{9}	9.07×10^{9}
8&9*	2.05×10^{8}	4.61×10^{8}	2.27×10^{8}	8.51×10^{7}	3.11×10^{9}	3.68×10^{10}	5.26×10^{9}	1.49×10^{10}

*Combined data from sites with similar land cover and catchment area.

Table 4.33: Enterococci base-flow and high-flow export coefficients (cfu hr^{-1} km^{-2}) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct ’01 to –Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to Apr ’03)	Restocked Post-FMD Summer (May to Sept ’03)	Restocking Winter (Oct ’01 to –Apr ’02)	Mostly Restocked Summer (May to Sept ’02)	Restocked Post-FMD Winter (Oct ’02 to Apr ’03)	Restocked Post-FMD Summer (May to Sept ’03)
1	$5.55x10^{6}$	$6.83x10^{6}$	$7.24x10^{6}$	$4.30x10^{6}$	$1.93x10^{7}$	$3.32x10^{7}$	$1.94x10^{7}$	$2.27x10^{8}$
2	$6.07x10^{6}$	$4.55x10^{6}$	$8.11x10^{6}$	$4.46x10^{6}$	$2.50x10^{7}$	$2.90x10^{7}$	$1.85x10^{7}$	$2.74x10^{8}$
3	$5.67x10^{7}$	$8.88x10^{7}$	$1.30x10^{8}$	$1.33x10^{8}$	$5.03x10^{8}$	$5.35x10^{8}$	$1.87x10^{7}$	$2.27x10^{9}$
4	$1.37x10^{8}$	$7.04x10^{7}$	$5.65x10^{7}$	$9.16x10^{7}$	$1.01x10^{9}$	$6.22x10^{8}$	$2.65x10^{7}$	$5.41x10^{9}$
5	$1.94x10^{7}$	$4.51x10^{7}$	$1.77x10^{7}$	$2.08x10^{7}$	$4.16x10^{8}$	$4.70x10^{8}$	$4.29x10^{7}$	$5.78x10^{9}$
6	$2.00x10^{7}$	$3.43x10^{7}$	$5.89x10^{7}$	$1.68x10^{7}$	$7.11x10^{8}$	$1.02x10^{9}$	$3.06x10^{7}$	$3.88x10^{10}$
7	$3.08x10^{6}$	$5.44x10^{6}$	$8.35x10^{6}$	$2.60x10^{6}$	$3.40x10^{8}$	$5.96x10^{8}$	$1.23x10^{7}$	$2.44x10^{10}$
8	$4.11x10^{7}$	$5.48x10^{7}$	$1.37x10^{8}$	$1.70x10^{7}$	$7.36x10^{8}$	$6.50x10^{9}$	$1.03x10^{7}$	$1.67x10^{10}$
9	$2.12x10^{7}$	$2.82x10^{7}$	$4.44x10^{7}$	$8.72x10^{6}$	$1.13x10^{9}$	$2.96x10^{10}$	$1.03x10^{7}$	$1.59x10^{10}$
10	$2.15x10^{7}$	$7.38x10^{7}$	$3.95x10^{7}$	$8.84x10^{7}$	$5.95x10^{8}$	$3.08x10^{8}$	$2.39x10^{7}$	$1.41x10^{9}$
11	$4.52x10^{7}$	$2.84x10^{7}$	$8.90x10^{7}$	$2.09x10^{7}$	$1.13x10^{9}$	$6.92x10^{9}$	$1.03x10^{7}$	$6.37x10^{9}$
12	$3.82x10^{7}$	$2.89x10^{7}$	$3.59x10^{7}$	$4.23x10^{7}$	$7.94x10^{8}$	$2.66x10^{9}$	$3.04x10^{7}$	$6.73x10^{9}$
13	$1.02x10^{8}$	$2.11x10^{7}$	$1.07x10^{8}$	$2.67x10^{7}$	$3.01x10^{9}$	$8.61x10^{8}$	$3.26x10^{7}$	$7.69x10^{9}$
14	No water quality data		$3.82x10^{7}$	$1.83x10^{7}$	No water quality data		$1.49x10^{7}$	$6.81x10^{8}$
15	No water quality data		$2.29x10^{6}$	$2.36x10^{6}$	No water quality data		$1.42x10^{7}$	$1.04x10^{8}$
1&15*	No water quality data		$6.40x10^{6}$	$5.66x10^{6}$	No water quality data		$3.33x10^{7}$	$1.55x10^{8}$
6&7*	$2.08x10^{6}$	$3.96x10^{6}$	$6.13x10^{6}$	$2.43x10^{6}$	$1.84x10^{8}$	$2.96x10^{8}$	$1.44x10^{7}$	$2.68x10^{9}$
8&9*	$6.50x10^{7}$	$8.51x10^{7}$	$1.72x10^{8}$	$2.66x10^{7}$	$1.44x10^{9}$	$1.34x10^{10}$	$3.28x10^{7}$	$5.10x10^{9}$

*Combined data from sites with similar land cover and catchment area.

Table 4.34: Total coliform base-flow and high-flow export coefficients (cfu hr^{-1} cm $runoff^{-1}$) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct '01 to Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to Apr '03)	Restocked Post-FMD Summer (May to Sept '03)	Restocking Winter (Oct '01 to Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to Apr '03)	Restocked Post-FMD Summer (May to Sept '03)
1	$1.10x10^{11}$	$2.75x10^{11}$	$6.67x10^{10}$	$6.96x10^{10}$	$1.57x10^{11}$	$7.25x10^{11}$	$2.55x10^{11}$	$2.84x10^{12}$
2	$1.61x10^{11}$	$2.25x10^{11}$	$1.43x10^{11}$	$3.76x10^{11}$	$2.66x10^{11}$	$1.20x10^{12}$	$4.10x10^{11}$	$5.81x10^{12}$
3	$7.63x10^{12}$	$3.27x10^{13}$	$1.68x10^{13}$	$2.85x10^{13}$	$6.54x10^{12}$	$3.69x10^{13}$	$4.03x10^{13}$	$1.34x10^{14}$
4	$1.72x10^{12}$	$6.46x10^{12}$	$2.19x10^{12}$	$6.10x10^{12}$	$4.67x10^{12}$	$1.54x10^{13}$	$9.33x10^{12}$	$1.44x10^{14}$
5	$3.91x10^{11}$	$1.88x10^{12}$	$2.97x10^{11}$	$1.00x10^{12}$	$7.66x10^{11}$	$5.32x10^{12}$	$1.56x10^{12}$	$4.22x10^{13}$
6	$4.11x10^{10}$	$3.00x10^{11}$	$8.69x10^{10}$	$2.05x10^{11}$	$1.01x10^{11}$	$1.11x10^{12}$	$6.64x10^{11}$	$1.45x10^{13}$
7	$3.88x10^{10}$	$5.65x10^{11}$	$1.31x10^{11}$	$3.25x10^{11}$	$1.98x10^{11}$	$2.86x10^{12}$	$2.97x10^{12}$	$2.68x10^{13}$
8	$9.31x10^{12}$	$1.67x10^{13}$	$5.93x10^{12}$	$6.99x10^{12}$	$8.26x10^{12}$	$6.99x10^{13}$	$8.04x10^{12}$	$2.54x10^{14}$
9	$6.17x10^{11}$	$3.83x10^{12}$	$1.02x10^{12}$	$2.98x10^{12}$	$3.19x10^{12}$	$1.40x10^{14}$	$9.58x10^{12}$	$5.96x10^{14}$
10	$4.05x10^{12}$	$1.18x10^{13}$	$1.26x10^{13}$	$2.35x10^{13}$	$1.31x10^{13}$	$3.40x10^{13}$	$4.18x10^{13}$	$2.22x10^{14}$
11	$2.50x10^{13}$	$2.43x10^{13}$	$1.55x10^{13}$	$2.77x10^{13}$	$2.29x10^{13}$	$2.23x10^{14}$	$4.18x10^{13}$	$2.70x10^{14}$
12	$1.38x10^{13}$	$2.23x10^{13}$	$1.16x10^{13}$	$1.96x10^{13}$	$5.80x10^{13}$	$3.57x10^{14}$	$8.92x10^{13}$	$7.58x10^{14}$
13	$3.82x10^{13}$	$1.09x10^{14}$	$8.40x10^{13}$	$5.86x10^{13}$	$9.42x10^{13}$	$2.01x10^{14}$	$1.09x10^{14}$	$1.12x10^{15}$
14	No water quality data		$1.48x10^{11}$	$2.10x10^{12}$	No water quality data		$5.67x10^{11}$	$7.77x10^{12}$
15	No water quality data		$1.01x10^{10}$	$1.63x10^{10}$	No water quality data		$4.64x10^{10}$	$2.21x10^{11}$
1&15*	No water quality data		$8.20x10^{10}$	$1.09x10^{11}$	No water quality data		$3.42x10^{11}$	$2.56x10^{12}$
6&7*	$8.69x10^{10}$	$2.69x10^{11}$	$6.95x10^{10}$	$1.74x10^{11}$	$9.64x10^{10}$	$1.19x10^{12}$	$8.37x10^{11}$	$1.31x10^{13}$
8&9*	$4.67x10^{12}$	$1.57x10^{13}$	$5.09x10^{12}$	$8.91x10^{12}$	$1.02x10^{13}$	$1.78x10^{14}$	$1.74x10^{13}$	$7.64x10^{14}$

*Combined data from sites with similar land cover and catchment area.

Table 4.35: Faecal coliform base-flow and high-flow export coefficients (cfu hr^{-1} cm $runoff^{-1}$) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct '01 to Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to Apr '03)	Restocked Post-FMD Summer (May to Sept '03)	Restocking Winter (Oct '01 to Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to Apr '03)	Restocked Post-FMD Summer (May to Sept '03)
1	$1.68x10^{10}$	$3.77x10^{10}$	$3.19x10^{10}$	$4.93x10^{10}$	$1.94x10^{10}$	$2.38x10^{11}$	$1.07x10^{11}$	$1.83x10^{12}$
2	$2.22x10^{10}$	$5.81x10^{10}$	$5.12x10^{10}$	$1.23x10^{11}$	$4.44x10^{10}$	$3.76x10^{11}$	$1.95x10^{11}$	$3.42x10^{12}$
3	$1.68x10^{12}$	$1.09x10^{13}$	$2.27x10^{12}$	$5.37x10^{12}$	$3.36x10^{12}$	$1.51x10^{13}$	$2.27x10^{13}$	$5.54x10^{13}$
4	$8.61x10^{11}$	$2.08x10^{12}$	$9.33x10^{11}$	$4.31x10^{12}$	$2.40x10^{12}$	$8.25x10^{12}$	$6.10x10^{12}$	$1.36x10^{14}$
5	$5.47x10^{10}$	$7.98x10^{11}$	$4.69x10^{10}$	$4.54x10^{11}$	$3.28x10^{11}$	$3.75x10^{12}$	$9.38x10^{11}$	$3.60x10^{13}$
6	$1.19x10^{10}$	$9.80x10^{10}$	$1.90x10^{10}$	$6.95x10^{10}$	$4.58x10^{10}$	$6.64x10^{11}$	$2.69x10^{11}$	$1.74x10^{13}$
7	$1.20x10^{10}$	$1.98x10^{11}$	$2.75x10^{10}$	$1.84x10^{11}$	$1.62x10^{11}$	$1.55x10^{12}$	$2.01x10^{12}$	$2.51x10^{13}$
8	$9.10x10^{11}$	$3.39x10^{12}$	$1.61x10^{12}$	$2.33x10^{12}$	$1.42x10^{12}$	$2.75x10^{13}$	$3.60x10^{12}$	$1.16x10^{14}$
9	$2.55x10^{11}$	$2.34x10^{12}$	$2.34x10^{11}$	$1.23x10^{12}$	$1.92x10^{12}$	$8.51x10^{13}$	$3.19x10^{12}$	$5.32x10^{14}$
10	$1.14x10^{12}$	$6.15x10^{12}$	$1.96x10^{12}$	$5.23x10^{12}$	$6.28x10^{12}$	$1.57x10^{13}$	$2.35x10^{13}$	$8.50x10^{13}$
11	$3.17x10^{12}$	$9.44x10^{12}$	$3.91x10^{12}$	$5.80x10^{12}$	$1.01x10^{13}$	$6.27x10^{13}$	$1.69x10^{13}$	$2.02x10^{14}$
12	$2.45x10^{12}$	$7.58x10^{12}$	$2.01x10^{12}$	$7.80x10^{12}$	$1.43x10^{13}$	$9.14x10^{13}$	$3.34x10^{13}$	$6.91x10^{14}$
13	$7.38x10^{12}$	$1.53x10^{13}$	$5.09x10^{12}$	$9.16x10^{12}$	$2.29x10^{13}$	$7.13x10^{13}$	$2.29x10^{13}$	$8.40x10^{14}$
14	No water quality data		$1.05x10^{11}$	$1.48x10^{12}$	No water quality data		$2.01x10^{11}$	$4.02x10^{12}$
15	No water quality data		$4.64x10^{9}$	$9.68x10^{9}$	No water quality data		$1.63x10^{10}$	$1.74x10^{11}$
1&15*	No water quality data		$4.10x10^{10}$	$7.17x10^{10}$	No water quality data		$1.33x10^{11}$	$1.81x10^{12}$
6&7*	$2.56x10^{10}$	$9.32x10^{10}$	$1.49x10^{10}$	$7.58x10^{10}$	$5.69x10^{10}$	$6.79x10^{11}$	$4.11x10^{11}$	$1.39x10^{13}$
8&9*	$9.76x10^{11}$	$5.52x10^{12}$	$1.23x10^{12}$	$3.40x10^{12}$	$3.31x10^{12}$	$8.07x10^{13}$	$6.79x10^{12}$	$5.09x10^{14}$

*Combined data from sites with similar land cover and catchment area.

Table 4.36: Enterococci base-flow and high-flow export coefficients (cfu hr^{-1} cm $runoff^{-1}$) at each site during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

	Base Flow				High Flow			
Site	Restocking Winter (Oct '01 to Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to Apr '03)	Restocked Post-FMD Summer (May to Sept '03)	Restocking Winter (Oct '01 to Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to Apr '03)	Restocked Post-FMD Summer (May to Sept '03)
1	$1.45x10^{10}$	$3.48x10^{10}$	$3.19x10^{10}$	$3.48x10^{10}$	$1.71x10^{10}$	$9.28x10^{10}$	$3.77x10^{10}$	$5.80x10^{11}$
2	$1.88x10^{10}$	$2.73x10^{10}$	$4.10x10^{10}$	$4.44x10^{10}$	$2.43x10^{10}$	$9.56x10^{10}$	$4.44x10^{10}$	$9.22x10^{11}$
3	$4.87x10^{11}$	$1.59x10^{12}$	$1.59x10^{12}$	$3.27x10^{12}$	$1.68x10^{12}$	$5.20x10^{12}$	$1.01x10^{11}$	$1.68x10^{13}$
4	$4.67x10^{11}$	$5.74x10^{11}$	$2.33x10^{11}$	$1.11x10^{12}$	$1.15x10^{12}$	$2.30x10^{12}$	$5.02x10^{10}$	$1.69x10^{13}$
5	$2.19x10^{10}$	$1.25x10^{11}$	$2.50x10^{10}$	$9.70x10^{10}$	$1.56x10^{11}$	$5.32x10^{11}$	$2.19x10^{10}$	$4.38x10^{12}$
6	$5.06x10^{9}$	$1.55x10^{10}$	$1.90x10^{10}$	$1.58x10^{10}$	$3.00x10^{10}$	$1.23x10^{11}$	$2.05x10^{9}$	$4.27x10^{12}$
7	$5.65x10^{9}$	$1.91x10^{10}$	$1.59x10^{10}$	$3.25x10^{10}$	$6.35x10^{10}$	$2.72x10^{11}$	$2.47x10^{9}$	$8.83x10^{12}$
8	$2.12x10^{11}$	$6.99x10^{11}$	$7.83x10^{11}$	$7.41x10^{11}$	$6.14x10^{11}$	$8.68x10^{12}$	$1.06x10^{10}$	$8.89x10^{13}$
9	$1.11x10^{11}$	$3.62x10^{11}$	$2.55x10^{11}$	$3.83x10^{11}$	$9.58x10^{11}$	$4.04x10^{13}$	$1.06x10^{10}$	$8.51x10^{13}$
10	$4.97x10^{11}$	$2.22x10^{12}$	$8.50x10^{11}$	$3.27x10^{12}$	$2.75x10^{12}$	$3.53x10^{12}$	$1.83x10^{11}$	$1.70x10^{13}$
11	$7.42x10^{11}$	$1.15x10^{12}$	$1.62x10^{12}$	$2.90x10^{12}$	$3.03x10^{12}$	$2.97x10^{13}$	$3.37x10^{10}$	$1.08x10^{14}$
12	$1.25x10^{12}$	$1.65x10^{12}$	$1.43x10^{12}$	$4.24x10^{12}$	$6.47x10^{12}$	$3.79x10^{13}$	$3.12x10^{11}$	$1.25x10^{14}$
13	$3.82x10^{12}$	$1.37x10^{12}$	$4.84x10^{12}$	$3.05x10^{12}$	$2.80x10^{13}$	$1.40x10^{13}$	$3.82x10^{11}$	$1.63x10^{14}$
14	No water quality data		$5.06x10^{10}$	$4.45x10^{10}$	No water quality data		$8.73x10^{9}$	$5.24x10^{11}$
15	No water quality data		$4.26x10^{9}$	$1.01x10^{10}$	No water quality data		$3.87x10^{9}$	$4.26x10^{10}$
1&15*	No water quality data		$3.76x10^{10}$	$6.15x10^{10}$	No water quality data		$7.86x10^{10}$	$5.12x10^{11}$
6&7*	$1.12x10^{10}$	$1.15x10^{10}$	$1.12x10^{10}$	$1.53x10^{10}$	$2.84x10^{10}$	$1.23x10^{11}$	$3.16x10^{9}$	$4.11x10^{12}$
8&9*	$3.10x10^{11}$	$1.02x10^{12}$	$9.34x10^{11}$	$1.06x10^{12}$	$1.53x10^{12}$	$2.93x10^{13}$	$4.25x10^{10}$	$1.74x10^{14}$

*Combined data from sites with similar land cover and catchment area.

Table 5.1: Details of the Centre for Ecology and Hydrology (CEH) 1990 land-cover classification and the corresponding CREH land-use type to which they have been attributed*.

CEH Clas s	Description	CREH Land-use Type
0	Unclassified	Unclassified
1	Sea, coastal waters and estuaries, inland to first bridging point or barrier	Other
2	Inland fresh waters and estuarine waters above the first bridging point or barrier	Other
3	Bare coastal mud, silt, sand shingle and rock, including coastal accretion and erosion features above high water	Other
4	Intertidal seaweed beds and salt marshes up to normal levels of high-water spring tides	Other
5	Semi-natural, mostly acid, grasslands of dunes, heaths and lowland–upland margins	Rough grazing
6	Pastures and amenity swards, mown or grazed, to form a turf throughout the growing season	Improved pasture
7	Meadows, verges, low intensity amenity grasslands and semi-natural cropped swards, not maintained as short turf	Improved pasture
8	Lowland marsh–rough grasslands, mostly uncropped and unmanaged, forming grass and herbaceous communities of mostly perennial species, with high winter litter content	Rough grazing
9	Montane–hill grasslands, mostly unenclosed *nardus–molinia* moorland	Rough grazing
10	Upland, dwarf shrub–grass moorland	Rough grazing
11	Upland evergreen dwarf shrub-dominated moorland	Rough grazing
12	Bracken-dominated herbaceous communities	Rough grazing
13	Lowland evergreen shrub-dominated heathland	Rough grazing
14	Deciduous scrub and orchards	Other
15	Deciduous broadleaved woodland and mixed woodlands	Woodland
16	Conifer and broadleaved evergreen trees	Woodland
17	Lowland herbaceous wetlands with permanent or temporary standing water	Rough grazing
18	Arable and other seasonally or temporarily bare ground	Arable
19	Ruderal weeds colonizing natural and man-made bare ground	Other
20	Suburban and rural developed land comprising buildings and/or roads, but with some cover of permanent vegetation	Built-up
21	Industrial, urban and any other developments lacking permanent vegetation	Built-up
22	Ground bare of vegetation, surfaced with ‘natural’ materials	Other
23	Felled forest, with ruderal weeds and rough grass	Other
24	Lowland herbaceous wetlands with permanent or temporary standing water	Rough grazing
25	Lowland dwarf shrub–grass heathland	Rough grazing

* Based on notes that accompany the classification scheme.

Table 5.2: Area of subcatchments and percentage area of different land-use types.

Subcatchment	Area (ha)	Improved Pasture (%)	Rough Grazing (%)	Arable (%)	Woodland (%)	Built-up (%)	Water (%)
1	2800	3.93	94.84	0.01	0.03	0.49	0.72
2	3400	4.18	94.25	0.01	0.43	0.45	0.69
3	8500	32.25	56.97	0.34	8.10	1.74	0.59
4	3600	42.06	53.68	0.51	0.55	2.49	0.71
5	1500	19.86	77.89	0.08	0.10	1.39	0.68
6	200	67.54	13.17	10.73	3.54	4.03	1.00
7	400	53.52	13.22	10.50	16.80	5.84	0.13
8	2100	66.16	13.69	13.30	2.25	3.93	0.67
9	2200	65.62	13.92	8.75	8.80	2.12	0.79
10	13000	37.32	52.88	0.87	6.28	2.01	0.65
11	6500	66.29	13.50	10.82	5.79	2.83	0.76
12	22200	49.67	36.02	4.95	5.95	2.75	0.66
13	25300	51.28	33.05	5.73	5.81	3.47	0.66

Table 5.3: Number of cattle per hectare within each subcatchment.

Subcatchment	January 2002	July 2002	January 2003	July 2003	December 2003
1	0.022	0.031	0.035	0.035	0.036
2	0.025	0.035	0.039	0.040	0.041
3	0.295	0.414	0.458	0.464	0.481
4	0.425	0.598	0.661	0.670	0.693
5	0.180	0.252	0.279	0.283	0.293
6	0.882	1.240	1.372	1.389	1.438
7	0.663	0.933	1.032	1.045	1.082
8	0.907	1.275	1.412	1.429	1.480
9	0.850	1.195	1.323	1.339	1.387
10	0.362	0.508	0.563	0.570	0.590
11	0.896	1.260	1.395	1.412	1.462
12	0.585	0.822	0.910	0.921	0.954
13	0.611	0.860	0.951	0.963	0.997

Table 5.4: **Number of sheep per hectare within each subcatchment.**

Subcatchmen t	January 2002	July 2002	January 2003	July 2003	December 2003
1	1.658	2.054	3.171	3.441	3.135
2	1.654	2.049	3.165	3.434	3.129
3	1.507	1.867	2.883	3.128	2.850
4	1.741	2.156	3.330	3.613	3.292
5	1.804	2.235	3.451	3.745	3.412
6	1.082	1.340	2.069	2.246	2.046
7	0.926	1.147	1.771	1.921	1.751
8	1.021	1.265	1.953	2.119	1.931
9	1.072	1.328	2.050	2.225	2.027
10	1.553	1.924	2.971	3.224	2.937
11	0.993	1.230	1.900	2.061	1.878
12	1.304	1.616	2.495	2.708	2.467
13	1.187	1.471	2.271	2.464	2.245

Table 5.5: **Number of livestock units (cattle + 0.15 x sheep) per hectare within each subcatchment.**

Subcatchmen t	January 2002	July 2002	January 2003	July 2003	December 2003
1	0.271	0.339	0.510	0.551	0.507
2	0.273	0.343	0.514	0.555	0.510
3	0.521	0.694	0.891	0.933	0.908
4	0.686	0.921	1.161	1.212	1.187
5	0.450	0.588	0.797	0.845	0.805
6	1.044	1.441	1.682	1.726	1.745
7	0.802	1.104	1.298	1.333	1.345
8	1.060	1.465	1.705	1.747	1.769
9	1.011	1.394	1.631	1.673	1.691
10	0.595	0.797	1.008	1.053	1.030
11	1.045	1.445	1.680	1.721	1.744
12	0.780	1.064	1.284	1.327	1.324
13	0.789	1.080	1.292	1.333	1.334

Table 5.6: Total amount of animal waste (manure, slurry and voided faeces from cattle, sheep, pigs, etc.) input ($t\ ha^{-1}$) within each subcatchment.

Subcatchment	Oct '01 to Apr '02	May '02 to Sep '02	Oct '02 to Apr '03	May '03 to Sep '03	Oct '03 to Dec '03
1	0.889	1.104	2.013	1.625	0.891
2	0.932	1.156	2.088	1.689	0.925
3	3.727	4.727	6.635	5.731	3.064
4	5.030	6.493	8.953	7.818	4.183
5	2.595	3.324	4.946	4.225	2.281
6	9.579	12.146	16.082	14.075	7.305
7	7.264	9.236	12.231	10.729	5.572
8	9.945	12.545	16.607	14.514	7.501
9	9.270	11.735	15.570	13.607	7.073
10	4.389	5.606	7.768	6.749	3.602
11	9.775	12.335	16.350	14.276	7.390
12	6.618	8.394	11.318	9.866	5.171
13	6.952	8.737	11.747	10.218	5.342

Table 5.7: Total amount of cattle waste (manure, slurry and voided faeces) input ($t\ ha^{-1}$) within each subcatchment.

Subcatchment	Oct '01 to Apr '02	May '02 to Sep '02	Oct '02 to Apr '03	May '03 to Sep '03	Oct '03 to Dec '03
1	0.230	0.309	0.385	0.352	0.193
2	0.258	0.345	0.431	0.393	0.214
3	2.990	3.892	4.956	4.431	2.352
4	4.215	5.535	7.003	6.299	3.351
5	1.776	2.349	2.958	2.673	1.430
6	9.126	11.612	14.998	13.230	6.841
7	6.828	8.739	11.233	9.955	5.147
8	9.442	11.983	15.498	13.653	7.033
9	8.813	11.200	14.484	12.760	6.609
10	3.641	4.749	6.038	5.406	2.866
11	9.319	11.810	15.298	13.457	6.943
12	5.997	7.681	9.880	8.748	4.559
13	6.274	8.015	10.327	9.130	4.744

Table 5.8: Pearson correlation coefficients (r) for relationships between the percentage areas of the principal land-use types in the 13 subcatchments.

	Rough grazing	Arable	Woodland†	Built-up
Improved pasture	–0.984**	0.864**	0.740*	0.760*
Rough grazing		–0.902**	–0.786**	–0.830**
Arable			0.560*	0.777*
Woodland†				0.650*

Statistical significance: *$p \leq 0.05$ (95% confidence level); **$p \leq 0.001$ (99.9% confidence level).
†Log_{10} transformed to improve parametricity.

Table 5.9: Pearson correlation coefficients (r) for relationships between the percentage areas of improved pasture and rough grazing with livestock numbers and animal-waste inputs in the 13 subcatchments.

	Cattle (Number ha^{-1})	Sheep (Number ha^{-1})	Livestock units (Number ha^{-1})	Total manure input (t ha^{-1})	Cattle manure input (t ha^{-1})
Improved pasture	0.987**	–0.843**	0.989**	0.990**	0.987**
Rough grazing	–0.977**	0.908**	–0.962**	–0.975**	–0.977**

Statistical significance: *$p \leq 0.05$ (95% confidence level); ** $p \leq 0.001$ (99.9% confidence level).

Table 5.10: Pearson correlation coefficients (r) for relationships between geometric mean faecal indicator concentrations and the percentage areas of the principal land-use types in the 13 subcatchments for the restocking winter period (October 2001 to April 2002).

	Base Flow:			High Flow:		
Independent Variables	Total Coliforms	Faecal Coliforms	Enterococci	Total Coliforms	Faecal Coliforms	Enterococci
Improved pasture (%)	0.675*	0.771*	0.737*	0.820**	0.840**	0.823**
Rough grazing (%)	–0.606*	–0.697*	–0.653*	–0.763*	–0.803**	–0.780*
Arable (%)	0.491	0.475	0.404	0.553*	0.528	0.496
Woodland (%)	0.485	0.606*	0.579*	0.665*	0.754*	0.727*
Built-up (%)	0.374	0.456	0.423	0.545	0.612*	0.606*
Cattle (number ha^{-1})	0.650*	0.711*	0.668*	0.766*	0.764*	0.744*
Sheep (number ha^{-1})	–0.449	–0.459	–0.403	–0.546	–0.544	–0.529
LSU (number ha^{-1})	0.669*	0.738*	0.698*	0.786**	0.784*	0.763*
All manure (t ha^{-1})	0.662*	0.721*	0.678*	0.775*	0.770*	0.750*
Cattle manure (t ha^{-1})	0.647*	0.704*	0.660*	0.760*	0.755*	0.735*

Statistical significance: *$p \leq 0.05$ (95% confidence level); **$p \leq 0.001$ (99.9% confidence level).
†Log_{10} transformed to improve parametricity.

Table 5.11: Pearson correlation coefficients (*r*) for relationships between geometric mean faecal indicator concentrations and the percentage areas of the principal land-use types in the 13 subcatchments for the mostly stocked summer period (May 2002 to September 2002).

	Base Flow:			High Flow:		
Independent Variables	Total Coliforms	Faecal Coliforms	Enterococci	Total Coliforms	Faecal Coliforms	Enterococci
Improved pasture (%)	0.800**	0.808**	0.728*	0.913**	0.900**	0.883**
Rough grazing (%)	–0.767*	–0.774*	–0.662*	–0.890**	–0.877**	–0.853**
Arable (%)	0.579*	0.542	0.430	0.750*	0.721*	0.707*
Woodland† (%)	0.625*	0.684*	0.546	0.693*	0.661*	0.645*
Built-up (%)	0.635*	0.586*	0.412	0.590*	0.604*	0.506
Cattle (number ha^{-1})	0.745*	0.741*	0.658*	0.897**	0.875**	0.866**
Sheep (number ha^{-1})	–0.554*	–0.519	–0.365	–0.731*	–0.685*	–0.685*
LSU (number ha^{-1})	0.759*	0.760*	0.688*	0.904**	0.886**	0.877**
All manure (t ha^{-1})	0.754*	0.751*	0.670*	0.901**	0.880**	0.871**
Cattle manure (t ha^{-1})	0.744*	0.740*	0.657*	0.896**	0.874**	0.866**

Statistical significance: *$p \leq 0.05$ (95% confidence level); **$p \leq 0.001$ (99.9% confidence level).
†Log_{10} transformed to improve parametricity

Table 5.12: Pearson correlation coefficients (*r*) for relationships between geometric mean faecal indicator concentrations and the percentage areas of the principal land-use types in the 13 subcatchments for the restocked post-FMD winter period (October 2002 to April 2003).

	Base Flow:			High Flow:		
Independent Variables	Total Coliforms	Faecal Coliforms	Enterococci	Total Coliforms	Faecal Coliforms	Enterococci
Improved pasture (%)	0.747*	0.777*	0.838**	0.861**	0.789**	0.795**
Rough grazing (%)	–0.707*	–0.725*	–0.798**	–0.865**	–0.800**	–0.815**
Arable (%)	0.488	0.548	0.650*	0.598*	0.531	0.528
Woodland† (%)	0.720*	0.637*	0.715*	0.854**	0.806**	0.841**
Built-up (%)	0.542	0.525	0.539	0.753*	0.743*	0.730*
Cattle (number ha^{-1})	0.683*	0.729*	0.808**	0.785**	0.704*	0.710*
Sheep (number ha^{-1})	–0.519	–0.522	–0.669*	–0.650*	–0.562*	–0.598*
LSU (number ha^{-1})	0.698*	0.752*	0.814**	0.791**	0.714*	0.713*
All manure (t ha^{-1})	0.694*	0.741*	0.815**	0.789**	0.709*	0.712*
Cattle manure (t ha^{-1})	0.679*	0.726*	0.807**	0.779*	0.698*	0.704*

Statistical significance: *$p \leq 0.05$ (95% confidence level); **$p \leq 0.001$ (99.9% confidence level).
†Log_{10} transformed to improve parametricity.

Table 5.13: Pearson correlation coefficients (r) for relationships between geometric mean faecal indicator concentrations and the percentage areas of the principal land-use types in the 13 subcatchments for the restocked post-FMD summer period (May 2003 to September 2003).

	Base Flow:			High Flow:		
Independent Variables	Total Coliforms	Faecal Coliforms	Enterococci	Total Coliforms	Faecal Coliforms	Enterococci
Improved pasture (%)	0.770*	0.802**	0.732*	0.904**	0.885**	0.947**
Rough grazing (%)	–0.726*	–0.759*	–0.674*	–0.885**	–0.867**	–0.949**
Arable (%)	0.473	0.508	0.394	0.714*	0.710*	0.870**
Woodland† (%)	0.749*	0.669*	0.673*	0.666*	0.604*	0.651*
Built-up (%)	0.544	0.618*	0.443	0.708*	0.713*	0.796**
Cattle (number ha^{-1})	0.694*	0.725*	0.648*	0.866**	0.853**	0.943**
Sheep (number ha^{-1})	–0.477	–0.462	–0.395	–0.668*	–0.655*	–0.810**
LSU (number ha^{-1})	0.722*	0.763*	0.686*	0.884**	0.872**	0.944**
All manure (t ha^{-1})	0.708*	0.740*	0.663*	0.873**	0.860**	0.945**
Cattle manure (t ha^{-1})	0.692*	0.723*	0.646*	0.864**	0.852**	0.943**

Statistical significance: *$p \leq 0.05$ (95% confidence level); **$p \leq 0.001$ (99.9% confidence level).
†Log_{10} transformed to improve parametricity.

Table 5.14: Runoff (mm day^{-1}) for each subcatchment during the mostly restocked summer (May to September 2002) and restocked post-FMD summer (May to September 2003).

	Summer 2002		Summer 2002	
Subcatchment	Total Runoff (mm day^{-1})	High Flow Runoff (mm day^{-1})	Total Runoff (mm day^{-1})	High Flow Runoff (mm day^{-1})
1	1.61	0.43	1.09	0.29
2	1.56	0.42	0.99	0.25
3	1.22	0.25	1.00	0.27
4	1.21	0.29	0.92	0.28
5	1.66	0.42	1.28	0.52
6	1.13	0.64	0.42	0.12
7	0.45	0.28	0.10	0.04
8	0.70	0.34	0.13	0.02
9	0.67	0.32	0.13	0.01
10	1.41	0.58	1.06	0.31
11	0.72	0.34	0.13	0.02
12	1.39	0.60	0.66	0.15
13	1.39	0.60	0.66	0.15

Table 5.15: Predicted geometric mean faecal indicator organism concentrations (cfu 100 ml^{-1}) for each subcatchment during the mostly restocked summer (May to September 2002) and the restocked post-FMD summer (May to September 2003), corrected for runoff as estimated for each sampling point (see *Table 5.14*).

	Mostly Restocked Summer (May to September 2002)						Restocked Post-FMD Summer (May to September 2003)					
	Base Flow			High Flow			Base Flow			High Flow		
	Total Coliforms (cfu 100 ml^{-1})	Faecal Coliforms (cfu 100 ml^{-1})	Enterococci (cfu 100 ml^{-1})	Total Coliforms (cfu 100 ml^{-1})	Faecal Coliforms (cfu 100 ml^{-1})	Enterococci (cfu 100 ml^{-1})	Total Coliforms (cfu 100 ml^{-1})	Faecal Coliforms (cfu 100 ml^{-1})	Enterococci (cfu 100 ml^{-1})	Total Coliforms (cfu 100 ml^{-1})	Faecal Coliforms (cfu 100 ml^{-1})	Enterococci (cfu 100 ml^{-1})
1	1.42×10^{3}	1.47×10^{2}	3.23×10^{1}	2.60×10^{4}	1.08×10^{4}	1.35×10^{3}	1.75×10^{3}	1.93×10^{2}	4.21×10^{1}	3.15×10^{4}	1.42×10^{4}	1.91×10^{3}
2	1.41×10^{3}	1.48×10^{2}	3.24×10^{1}	2.60×10^{4}	1.08×10^{4}	1.36×10^{3}	1.80×10^{3}	2.01×10^{2}	4.39×10^{1}	3.31×10^{4}	1.54×10^{4}	2.13×10^{3}
3	2.90×10^{3}	7.16×10^{2}	1.30×10^{2}	1.09×10^{5}	5.04×10^{4}	9.78×10^{3}	3.23×10^{3}	8.22×10^{2}	1.49×10^{2}	1.04×10^{5}	4.71×10^{4}	8.98×10^{3}
4	3.63×10^{3}	1.20×10^{3}	2.04×10^{2}	1.87×10^{5}	9.08×10^{4}	1.76×10^{4}	4.22×10^{3}	1.45×10^{3}	2.46×10^{2}	1.89×10^{5}	9.19×10^{4}	1.79×10^{4}
5	2.16×10^{3}	3.61×10^{2}	7.11×10^{1}	6.10×10^{4}	2.64×10^{4}	3.86×10^{3}	2.49×10^{3}	4.31×10^{2}	8.46×10^{1}	5.48×10^{4}	2.26×10^{4}	3.17×10^{3}
6	5.26×10^{3}	3.63×10^{3}	5.24×10^{2}	2.85×10^{5}	1.10×10^{5}	2.65×10^{4}	8.99×10^{3}	7.13×10^{3}	1.02×10^{3}	6.30×10^{5}	3.46×10^{5}	1.13×10^{5}
7	1.14×10^{4}	6.33×10^{3}	9.72×10^{2}	2.54×10^{5}	1.02×10^{5}	2.90×10^{4}	2.61×10^{4}	1.79×10^{4}	2.70×10^{3}	6.20×10^{5}	3.69×10^{5}	1.49×10^{5}
8	6.70×10^{3}	4.75×10^{3}	6.88×10^{2}	3.57×10^{5}	1.56×10^{5}	4.19×10^{4}	1.67×10^{4}	1.50×10^{4}	2.13×10^{3}	1.50×10^{6}	1.24×10^{6}	5.86×10^{5}
9	4.49×10^{3}	3.02×10^{3}	4.44×10^{2}	2.56×10^{5}	1.12×10^{5}	2.99×10^{4}	1.12×10^{4}	9.53×10^{3}	1.37×10^{3}	1.08×10^{6}	8.88×10^{5}	4.18×10^{5}
10	2.92×10^{3}	8.17×10^{2}	1.44×10^{2}	9.34×10^{4}	3.70×10^{4}	6.36×10^{3}	3.40×10^{3}	9.91×10^{2}	1.74×10^{2}	1.25×10^{5}	5.64×10^{4}	1.09×10^{4}
11	5.22×10^{3}	3.61×10^{3}	5.27×10^{2}	2.96×10^{5}	1.28×10^{5}	3.42×10^{4}	1.30×10^{4}	1.14×10^{4}	1.63×10^{3}	1.25×10^{6}	1.02×10^{6}	4.81×10^{5}
12	3.60×10^{3}	1.44×10^{3}	2.35×10^{2}	1.48×10^{5}	5.79×10^{4}	1.15×10^{4}	5.40×10^{3}	2.41×10^{3}	3.87×10^{2}	2.81×10^{5}	1.46×10^{5}	3.74×10^{4}
13	4.22×10^{3}	1.80×10^{3}	2.88×10^{2}	1.72×10^{5}	6.69×10^{4}	1.37×10^{4}	6.33×10^{3}	3.00×10^{3}	4.75×10^{2}	3.26×10^{5}	1.69×10^{5}	4.45×10^{4}

Table 5.16: Residual values (observed minus predicted) for mean $\log_{10}$ transformed base-flow and high-flow faecal indicator organism concentrations (cfu 100 ml^{-1}), corrected for runoff as estimated for each sampling point (see *Table 5.14*), for each subcatchment during the mostly restocked summer (May to September 2002) and the restocked post-FMD summer (May to September 2003). A negative value indicates the observed geometric mean was *lower* than the predicted geometric mean.

	Mostly Restocked Summer (May to September 2002)						Restocked Post-FMD Summer (May to September 2003)					
	Base Flow			High Flow			Base Flow			High Flow		
	Total Coliforms (cfu 100 ml^{-1})	Faecal Coliforms cfu 100 ml^{-1})	Enterococci (cfu 100 ml^{-1})	Total Coliforms (cfu 100 ml^{-1})	Faecal Coliforms (cfu 100 ml^{-1})	Enterococci (cfu 100 ml^{-1})	Total Coliforms (cfu 100 ml^{-1})	Faecal Coliforms (cfu 100 ml^{-1})	Enterococci (cfu 100 ml^{-1})	Total Coliforms (cfu 100 ml^{-1})	Faecal Coliforms (cfu 100 ml^{-1})	Enterococci (cfu 100 ml^{-1})
1	–1.18	–1.05	–0.43	–2.01	–2.12	–1.63	–1.86	–1.04	–0.53	–1.51	–1.35	–0.97
2	–1.33	–0.93	–0.61	–1.88	–2.00	–1.68	–1.21	–0.74	–0.54	–1.30	–1.17	–0.90
3	0.13	0.27	0.17	–1.39	–1.45	–1.20	0.03	–0.11	0.42	–0.82	–0.85	–0.64
4	–0.31	–0.31	–0.11	–1.64	–1.60	–1.44	–0.39	–0.10	0.10	–0.68	–0.38	–0.58
5	–0.24	0.15	0.05	–1.25	–1.04	–1.06	–0.59	–0.18	–0.13	–0.31	0.01	–0.06
6	–0.45	–0.77	–0.73	–1.61	–1.42	–1.53	–0.83	–1.21	–0.99	–0.84	–0.50	–0.62
7	–0.86	–1.06	–1.25	–1.50	–1.37	–1.58	–1.45	–1.54	–1.47	–0.91	–0.72	–0.77
8	0.07	–0.46	–0.32	–1.03	–1.08	–1.01	–0.70	–1.14	–0.78	–1.12	–1.35	–1.15
9	–0.39	–0.45	–0.41	–0.59	–0.45	–0.19	–0.91	–1.21	–0.87	–0.59	–0.54	–1.02
10	–0.51	–0.24	0.06	–1.56	–1.50	–1.37	–0.27	–0.39	0.16	–0.87	–0.94	–0.91
11	–0.16	–0.40	–0.48	–0.95	–1.14	–0.89	–0.50	–1.12	–0.58	–1.50	–1.53	–1.49
12	–0.54	–0.63	–0.50	–0.96	–1.15	–0.82	–0.79	–0.84	–0.30	–0.92	–0.67	–0.82
13	0.01	–0.48	–0.72	–1.34	–1.38	–1.40	–0.44	–0.92	–0.58	–0.87	–0.71	–0.84

Table 5.17: Scaling factors used to define livestock units (LSUs; Nix, 2003).

Animal Category	LSU Equivalent	Description
K1	1.00	All dairy cows and heifers that have calved
K2	0.80	Dairy heifers in first calf (2 years and over)
K3	0.80	Dairy heifers in first calf (1-2 years)
K4	0.80	Other females intended for dairy herd replacement (2 years and over)
K5	0.65	Other females intended for dairy herd replacement (1-2 years)
K6	0.75	All beef cows and heifers that have calved
K7	0.80	Beef heifers in first calf (2 years and over)
K8	0.80	Beef heifers in first calf (1-2 years)
K9	0.60	Other females intended for beef herd replacement (2 years and over)
K10	0.50	Other females intended for beef herd replacement (1-2 years)
K11	0.65	Bulls for service (2 years and over)
K12	0.65	Bulls for service (1-2 years)
K13	0.80	Other female cattle intended for slaughter (2 years and over)
K14	0.65	Other female cattle intended for slaughter (1-2 years)
K15	0.80	Other male cattle (2 years and over)
K16	0.65	Other male cattle (1-2 years)
K17	0.34	Other cattle and calves under 1 year intended for slaughter as calves
K18	0.34	Other female calves under 1 year
K19	0.34	Other male calves under 1 year
M1	0.08	Ewes and shearlings that have produced lambs in the previous year, intended for further breeding
M4	0.08	Ewes and shearlings that have produced lambs in the previous year, intended for slaughter
M7	0.08	Female sheep 1 year and over not yet used for breeding, but to be used for breeding
M9	0.08	Rams for service (1 year and over)
M13	0.08	Other female sheep (1 year and over)
M14	0.08	Other male sheep (1 year and over)
M17	0.04	Lambs under 1 year

Table 5.18: Stock density of all cattle and sheep (LSU ha^{-1}) within each subcatchment during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

Subcatchment	Restocking Winter (Oct '01 to Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)
1	0.088	0.144	0.206	0.222
2	0.092	0.151	0.215	0.232
3	0.254	0.392	0.465	0.501
4	0.349	0.536	0.646	0.677
5	0.188	0.296	0.379	0.402
6	0.791	1.203	1.367	1.418
7	0.538	0.819	0.938	0.972
8	0.644	0.973	1.106	1.146
9	0.630	0.953	1.086	1.126
10	0.295	0.454	0.539	0.574
11	0.617	0.932	1.060	1.098
12	0.438	0.665	0.770	0.806
13	0.451	0.685	0.789	0.824
6 & 7*	0.616	0.937	1.070	1.110
8 & 9*	0.637	0.963	1.096	1.136

*Combined data from sites with similar land cover and catchment area.

Table 5.19: Stock density of cattle and sheep grazing outdoors (LSU ha^{-1}) within each subcatchment during the restocking winter (October 2001 to April 2002), mostly restocked summer (May to September 2002), restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

Subcatchment	Restocking Winter (Oct '01 to –Apr '02)	Mostly Restocked Summer (May to Sept '02)	Restocked Post-FMD Winter (Oct '02 to –Apr '03)	Restocked Post-FMD Summer (May to Sept '03)
1	0.077	0.143	0.188	0.221
2	0.079	0.150	0.194	0.230
3	0.097	0.369	0.219	0.475
4	0.122	0.504	0.274	0.641
5	0.098	0.284	0.231	0.388
6	0.165	1.095	0.335	1.291
7	0.119	0.748	0.244	0.887
8	0.136	0.881	0.269	1.042
9	0.136	0.866	0.273	1.027
10	0.105	0.426	0.234	0.542
11	0.129	0.845	0.256	0.998
12	0.116	0.612	0.246	0.745
13	0.114	0.627	0.237	0.759
6 & 7*	0.133	0.855	0.272	1.012
8 & 9*	0.136	0.873	0.271	1.034

*Combined data from sites with similar land cover and catchment area.

Table 5.20: Summary of regression models between $\log_{10}$ geometric mean faecal indicator organism concentration and stock density (LSU ha^{-1}) within each subcatchment during the restocking winter (October 2001 to April 2002) and the restocked post-FMD winter (October 2002 to April 2003).

	Base Flow						High Flow					
	Total Coliforms		Faecal Coliforms		Enterococci		Total Coliforms		Faecal Coliforms		Enterococci	
	2001/2	2002/3	2001/2	2002/3	2001/2	2002/3	2001/2	2002/3	2001/2	2002/3	2001/2	2002/3
Models using stock density grazing outdoors as the predictor variable												
b (slope)	12.104	8.054	14.954	7.839	7.839	7.584	14.818	10.653	19.234	10.287	17.840	10.899
a (constant)	1.189	0.730	0.184	0.116	0.116	–0.007	1.215	0.727	0.253	0.471	0.130	–0.034
r^2 (adj) (%)	15.7	16.4	30.4	24.1	25.7	28.2	33.9	38.4	42.1	34.3	41.1	31.7
p	n.s.	n.s.	0.019	0.036	0.031	0.024	0.013	0.008	0.005	0.013	0.006	0.017
Models using stock density of all cattle and sheep as the predictor variable												
b (slope)	1.374	0.997	1.577	0.921	1.138	0.964	1.634	1.237	2.056	1.135	1.898	1.252
a (constant)	2.003	1.959	1.243	1.351	1.073	1.130	2.233	2.417	1.602	2.150	1.386	1.705
r^2 (adj) (%)	19.2	28.4	30.1	35.2	23.5	49.2	37.3	53.1	43.0	42.3	41.5	43.2
p	n.s.	0.024	0.020	0.012	0.038	0.002	0.009	0.001	0.005	0.005	0.006	0.005

n.s., not significant.

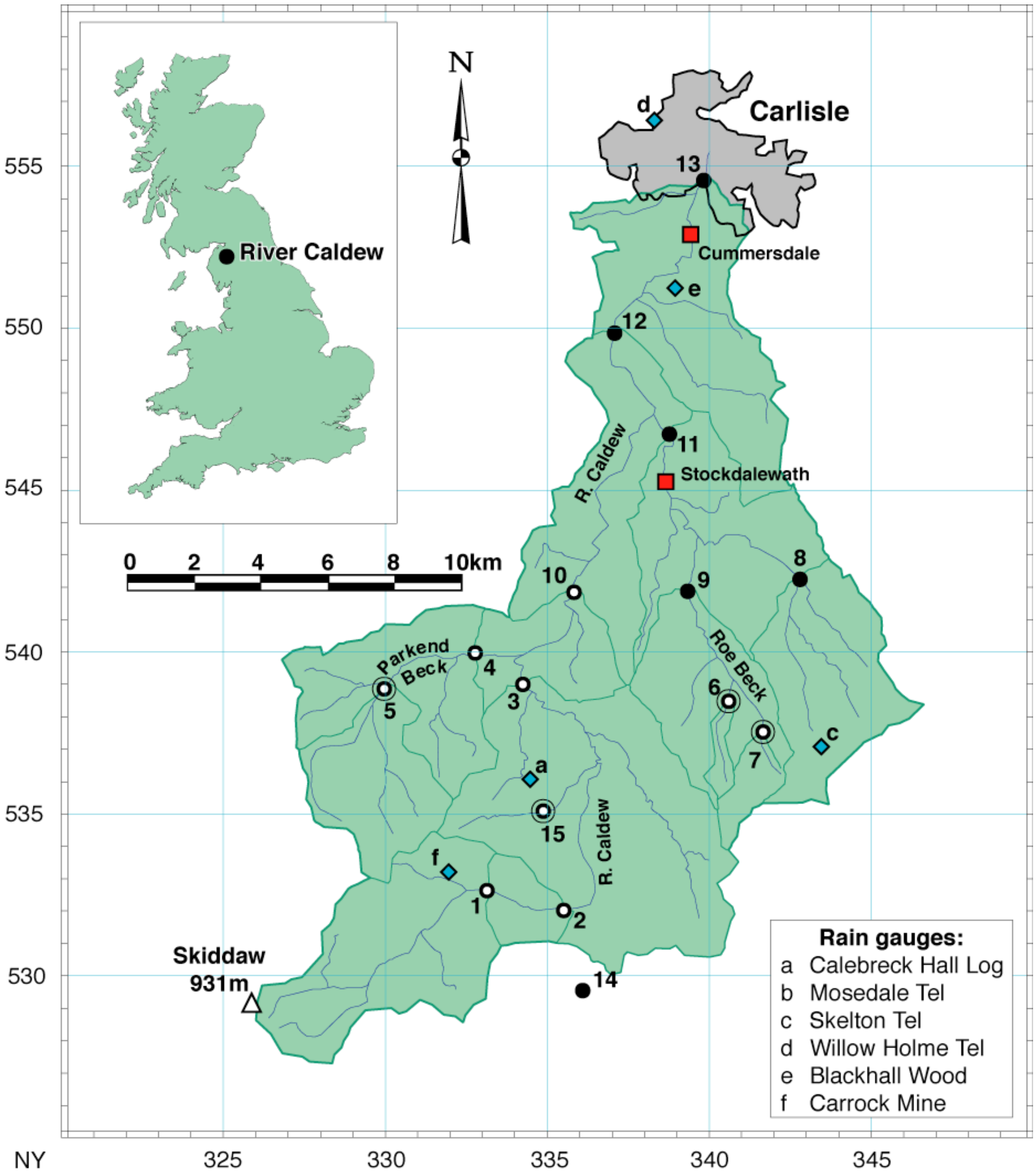
Table 5.21: Summary of regression models between $\log_{10}$ geometric mean faecal indicator organism concentration and stock density (LSU ha^{-1}) within each subcatchment during the mostly restocked summer (May to September 2002) and restocked post-FMD summer (May to September 2003).

	Base Flow						High Flow					
	Total Coliforms		Faecal Coliforms		Enterococci		Total Coliforms		Faecal Coliforms		Enterococci	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Models using stock density grazing outdoors as the predictor variable												
b (slope)	1.344	1.141	1.503	1.078	0.918	0.809	1.926	1.8	2.041	1.999	2.072	2.208
a (constant)	2.322	2.159	1.719	1.757	1.375	1.498	2.634	3.179	2.202	2.890	1.620	2.145
r^2 (adj) (%)	43.9	35.1	45.1	43.0	30.6	24.6	64.3	73.7	66.2	75.4	59.1	87.4
p	0.004	0.012	0.004	0.005	0.019	0.034	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Models using stock density of all cattle and sheep as the predictor variable												
b (slope)	1.195	1.005	1.335	0.948	0.815	0.711	1.719	1.591	1.819	1.766	1.850	1.958
a (constant)	2.349	2.198	1.750	1.794	1.394	1.527	2.667	3.235	2.239	2.953	1.656	2.209
r^2 (adj) (%)	43.7	34.6	44.7	42.2	30.3	24.1	64.5	73.2	66.2	74.8	59.4	87.4
p	0.004	0.012	0.004	0.005	0.02	0.036	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 5.22: Estimated high-flow geometric mean faecal indicator organism concentrations (cfu $100ml^{-1}$) and 95% confidence intervals (CIs) predicted using the functions given in Equations (5.1) to (5.3).

	Total Coliforms (cfu 100 ml^{-1})			Faecal coliforms (cfu 100 ml^{-1})			Enterococci (cfu 100 ml^{-1})		
Stock Density (LSU ha^{-1})	Geometric Mean	Lower 95% CI	Upper 95% CI	Geometric Mean	Lower 95% CI	Upper 95% CI	Geometric Mean	Lower 95% CI	Upper 95% CI
0.0	$9.02x10^{2}$	$1.87x10^{2}$	$4.36x10^{3}$	$3.96x10^{2}$	$9.61x10^{1}$	$1.63x10^{3}$	$8.50x10^{1}$	$2.80x10^{1}$	$2.58x10^{2}$
0.1	$1.32x10^{3}$	$2.99x10^{2}$	$5.80x10^{3}$	$5.97x10^{2}$	$1.57x10^{2}$	$2.26x10^{3}$	$1.32x10^{2}$	$4.64x10^{1}$	$3.75x10^{2}$
0.2	$1.92x10^{3}$	$4.74x10^{2}$	$7.80x10^{3}$	$9.01x10^{2}$	$2.56x10^{2}$	$3.17x10^{3}$	$2.05x10^{2}$	$7.65x10^{1}$	$5.50x10^{2}$
0.3	$2.81x10^{3}$	$7.45x10^{2}$	$1.06x10^{4}$	$1.36x10^{3}$	$4.13x10^{2}$	$4.48x10^{3}$	$3.19x10^{2}$	$1.25x10^{2}$	$8.11x10^{2}$
0.4	$4.10x10^{3}$	$1.16x10^{3}$	$1.45x10^{4}$	$2.05x10^{3}$	$6.59x10^{2}$	$6.40x10^{3}$	$4.95x10^{2}$	$2.03x10^{2}$	$1.21x10^{3}$
0.5	$5.99x10^{3}$	$1.77x10^{3}$	$2.02x10^{4}$	$3.10x10^{3}$	$1.04x10^{3}$	$9.25x10^{3}$	$7.69x10^{2}$	$3.26x10^{2}$	$1.81x10^{3}$
0.6	$8.74x10^{3}$	$2.67x10^{3}$	$2.86x10^{4}$	$4.68x10^{3}$	$1.61x10^{3}$	$1.36x10^{4}$	$1.19x10^{3}$	$5.19x10^{2}$	$2.75x10^{3}$
0.7	$1.28x10^{4}$	$3.97x10^{3}$	$4.10x10^{4}$	$7.06x10^{3}$	$2.47x10^{3}$	$2.02x10^{4}$	$1.86x10^{3}$	$8.15x10^{2}$	$4.23x10^{3}$
0.8	$1.86x10^{4}$	$5.79x10^{3}$	$6.00x10^{4}$	$1.07x10^{4}$	$3.73x10^{3}$	$3.05x10^{4}$	$2.88x10^{3}$	$1.27x10^{3}$	$6.57x10^{3}$
0.9	$2.72x10^{4}$	$8.30x10^{3}$	$8.91x10^{4}$	$1.61x10^{4}$	$5.53x10^{3}$	$4.67x10^{4}$	$4.48x10^{3}$	$1.94x10^{3}$	$1.03x10^{4}$
1.0	$3.97x10^{4}$	$1.17x10^{4}$	$1.35x10^{5}$	$2.43x10^{4}$	$8.10x10^{3}$	$7.28x10^{4}$	$6.96x10^{3}$	$2.95x10^{3}$	$1.65x10^{4}$
1.1	$5.80x10^{4}$	$1.63x10^{4}$	$2.07x10^{5}$	$3.66x10^{4}$	$1.17x10^{4}$	$1.15x10^{5}$	$1.08x10^{4}$	$4.42x10^{3}$	$2.65x10^{4}$
1.2	$8.47x10^{4}$	$2.23x10^{4}$	$3.21x10^{5}$	$5.53x10^{4}$	$1.67x10^{4}$	$1.83x10^{5}$	$1.68x10^{4}$	$6.57x10^{3}$	$4.30x10^{4}$
1.3	$1.24x10^{5}$	$3.02x10^{4}$	$5.05x10^{5}$	$8.35x10^{4}$	$2.35x10^{4}$	$2.96x10^{5}$	$2.61x10^{4}$	$9.68x10^{3}$	$7.04x10^{4}$
1.4	$1.80x10^{5}$	$4.06x10^{4}$	$8.02x10^{5}$	$1.26x10^{5}$	$3.30x10^{4}$	$4.82x10^{5}$	$4.06x10^{4}$	$1.42x10^{4}$	$1.16x10^{5}$
1.5	$2.64x10^{5}$	$5.40x10^{4}$	$1.29x10^{6}$	$1.90x10^{5}$	$4.58x10^{4}$	$7.90x10^{5}$	$6.30x10^{4}$	$2.06x10^{4}$	$1.92x10^{5}$
1.6	$3.85x10^{5}$	$7.14x10^{4}$	$2.07x10^{6}$	$2.87x10^{5}$	$6.32x10^{4}$	$1.30x10^{6}$	$9.79x10^{4}$	$2.99x10^{4}$	$3.21x10^{5}$
1.7	$5.62x10^{5}$	$9.39x10^{4}$	$3.36x10^{6}$	$4.33x10^{5}$	$8.68x10^{4}$	$2.16x10^{6}$	$1.52x10^{5}$	$4.31x10^{4}$	$5.36x10^{5}$
1.8	$8.20x10^{5}$	$1.23x10^{5}$	$5.48x10^{6}$	$6.54x10^{5}$	$1.19x10^{5}$	$3.60x10^{6}$	$2.36x10^{5}$	$6.20x10^{4}$	$9.01x10^{5}$
1.9	$1.20x10^{6}$	$1.60x10^{5}$	$8.96x10^{6}$	$9.87x10^{5}$	$1.62x10^{5}$	$6.02x10^{6}$	$3.67x10^{5}$	$8.89x10^{4}$	$1.52x10^{6}$
2.0	$1.75x10^{6}$	$2.08x10^{5}$	$1.47x10^{7}$	$1.49x10^{6}$	$2.19x10^{5}$	$1.01x10^{7}$	$5.70x10^{5}$	$1.27x10^{5}$	$2.56x10^{6}$

Figures



1. Caldew, d/s Grainsgill Beck
2. Caldew, Mosedale Bridge
3. Caldew, Hesket Newmarket
4. Cald Beck, Caldbeck Village
5. Parkend Beck, Parkend
6. Peel Gill, Skelton Wood End
7. Roe Beck, Crown Point
8. River Ive, Low Braithwaite Bridge
9. Roe Beck, Roebank Bridge
10. Caldew, Sebergham
11. Roe Beck, Gaitsgill
12. Caldew, Green, Dalston
13. Caldew, Holmehead
14. R. Glenderamakin, Mungrisdale
15. Carrock Beck, Nr Calebreck

Sample site	Flow gauge station
Sample site with baro-diver	Rain gauge
Sample site used for flow gauging (includes baro-diver)	Subcatchment Boundary

Figure 2.1: Location of water-quality monitoring points, baro-diver locations, Environment Agency flow gauge stations and rainfall gauges in the River Caldew catchment.

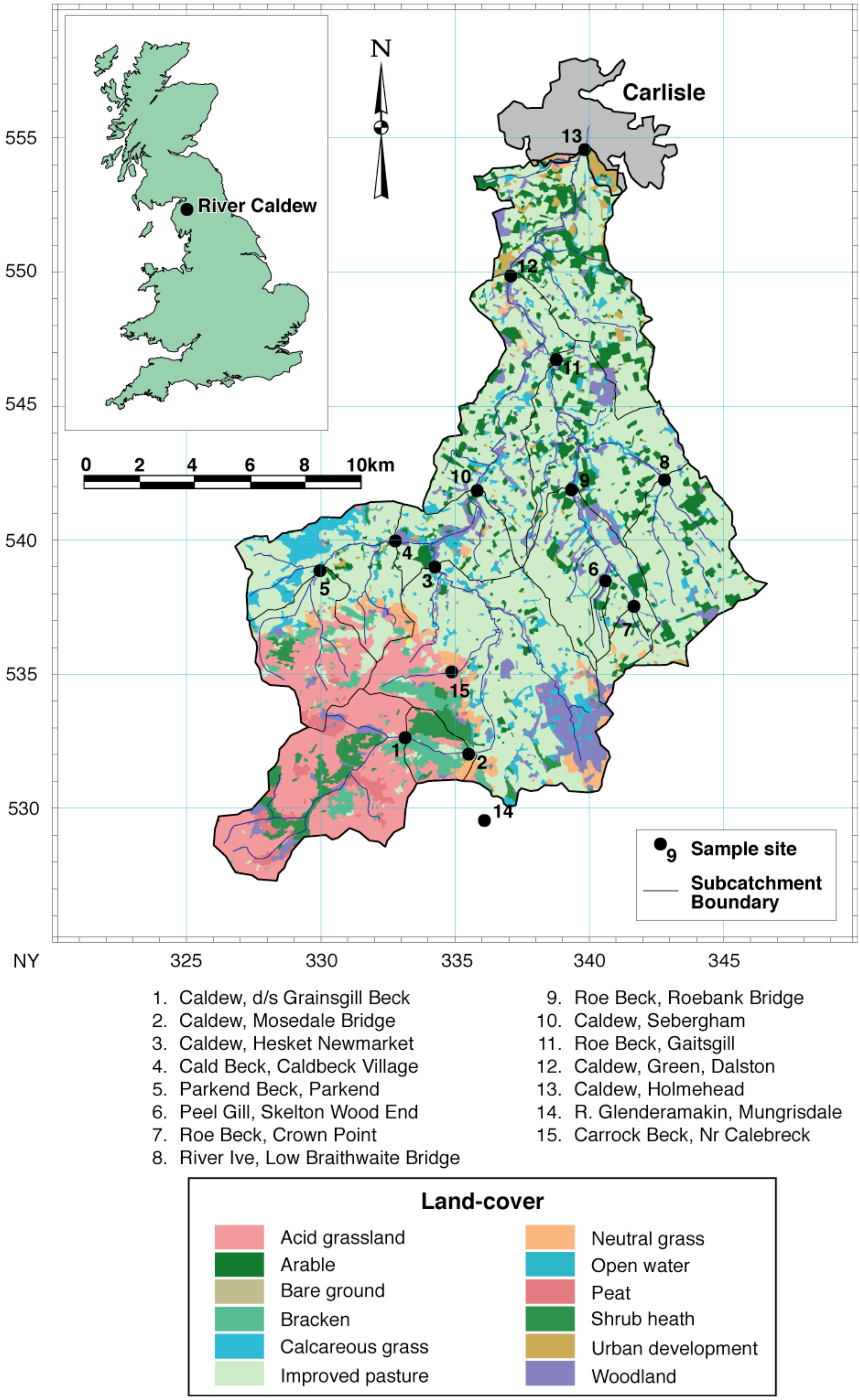


Figure 3.1: Land-cover distribution of the River Caldew catchment, derived from the CEH Land Cover Map (2000).

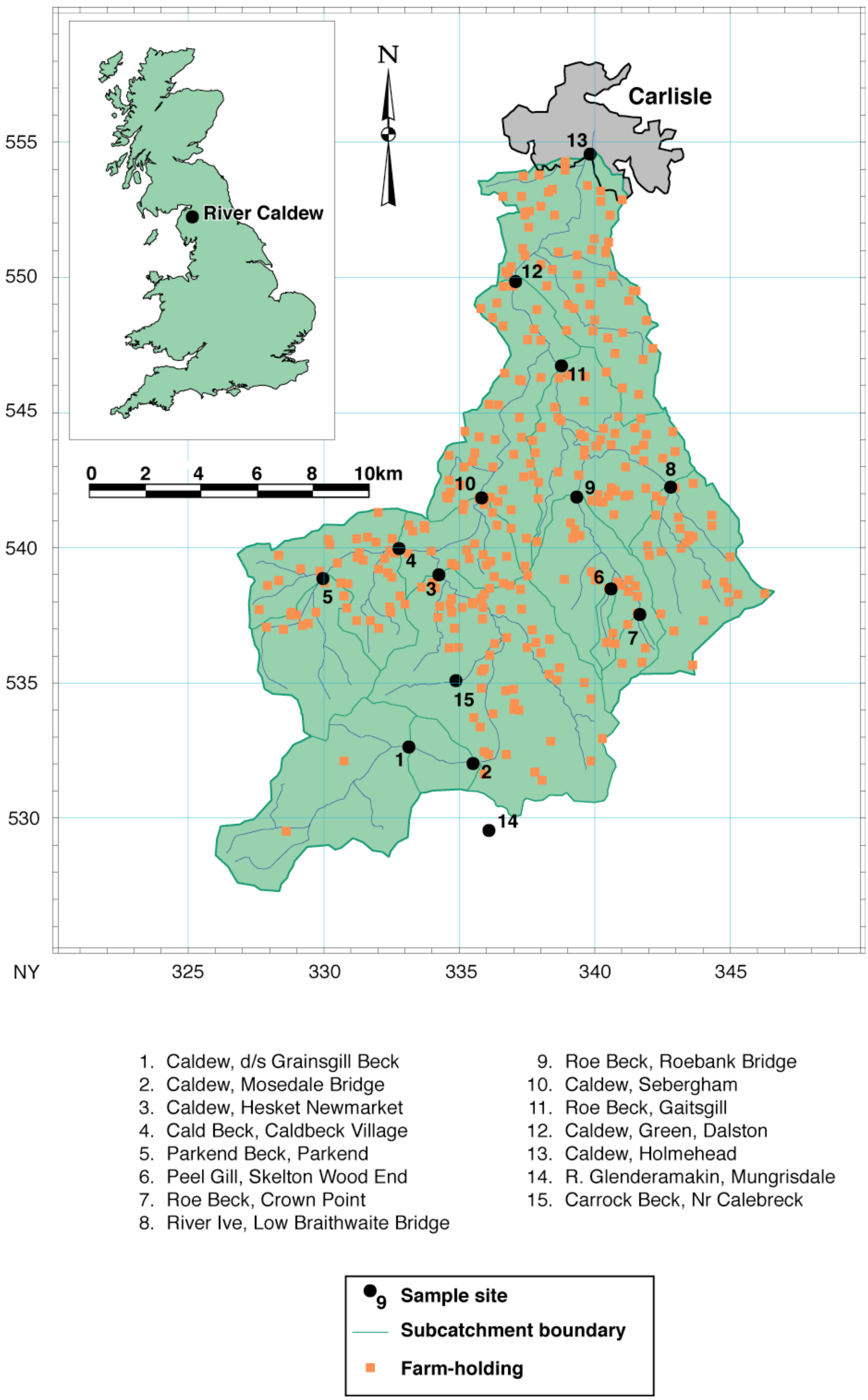
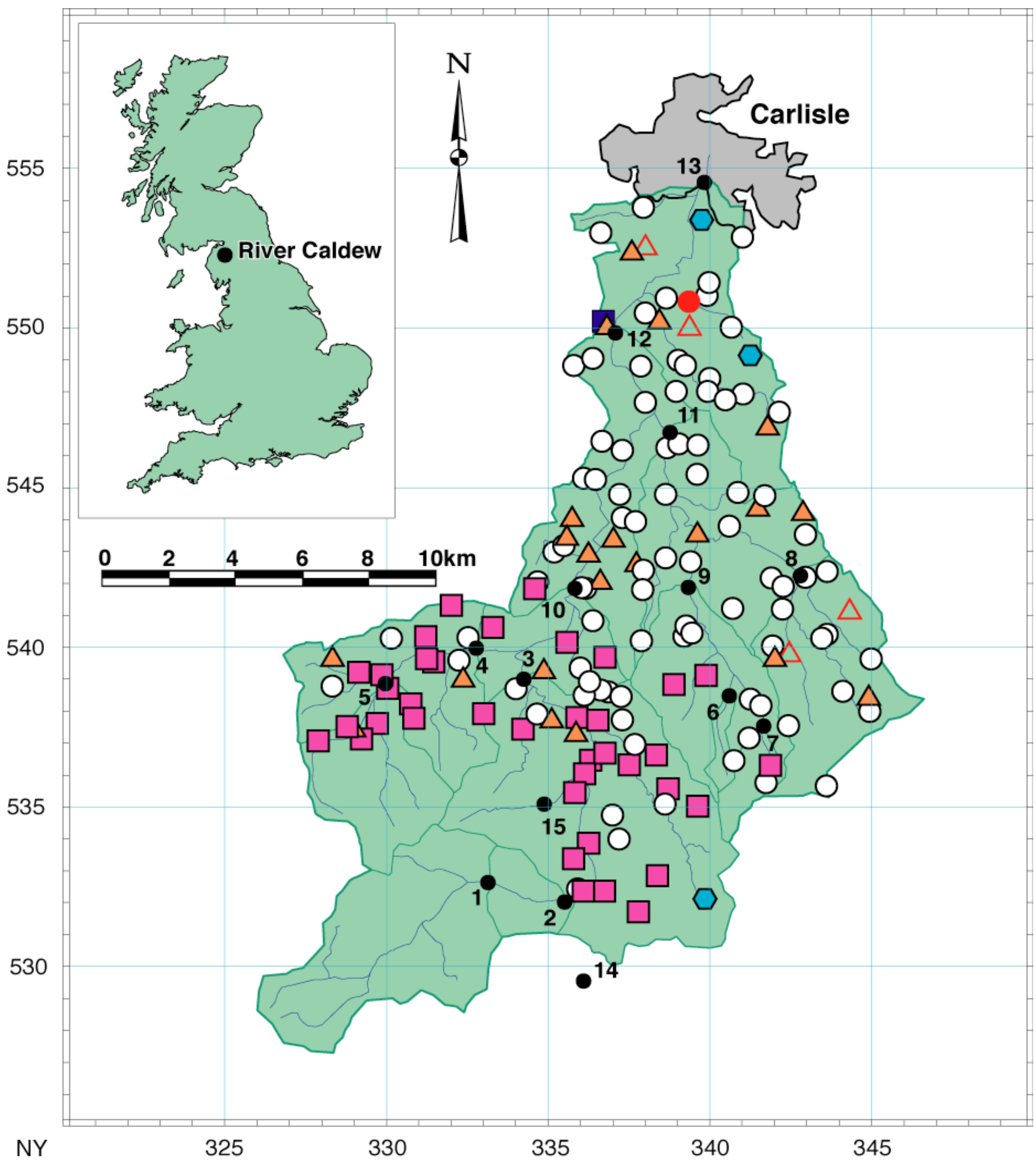


Figure 3.2: Farm-holding locations in the Caldew catchment.



1. Caldew, d/s Grainsgill Beck
2. Caldew, Mosedale Bridge
3. Caldew, Hesket Newmarket
4. Cald Beck, Caldbeck Village
5. Parkend Beck, Parkend
6. Peel Gill, Skelton Wood End
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9. Roe Beck, Roebank Bridge
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11. Roe Beck, Gaitsgill
12. Caldew, Green, Dalston
13. Caldew, Holmehead
14. R. Glenderamakin, Mungrisdale
15. Carrock Beck, Nr Calebreck

Figure 3.3: Farm types of commercially sized enterprises in the Caldew catchment.

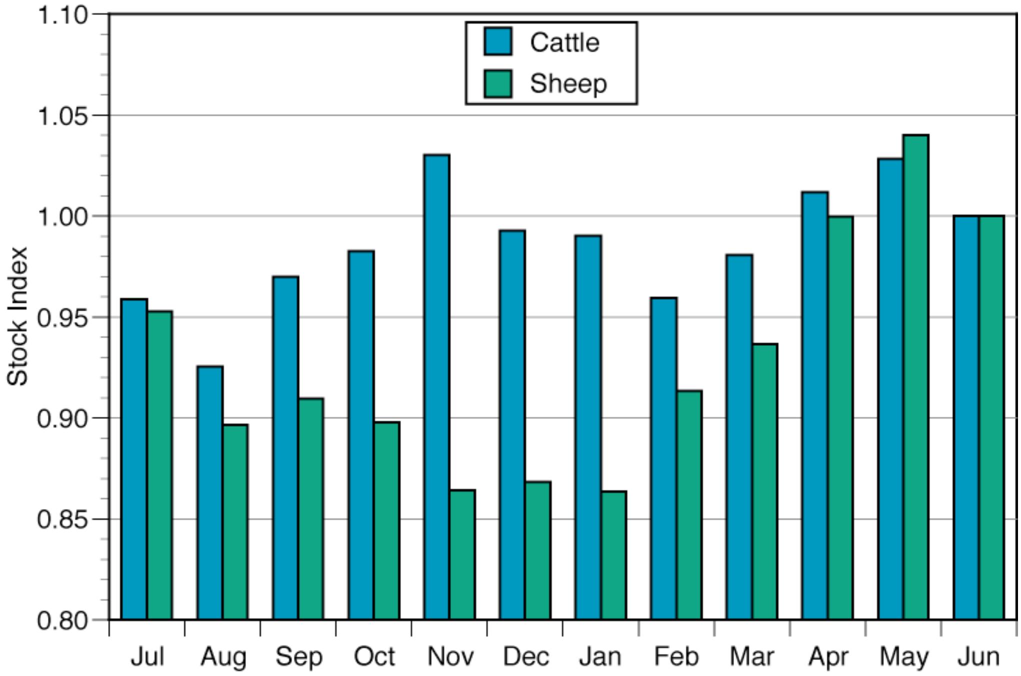

Figure 3.4: Calculated seasonality index of animal numbers on the 25 survey farms during 2003, relative to the number present in June.

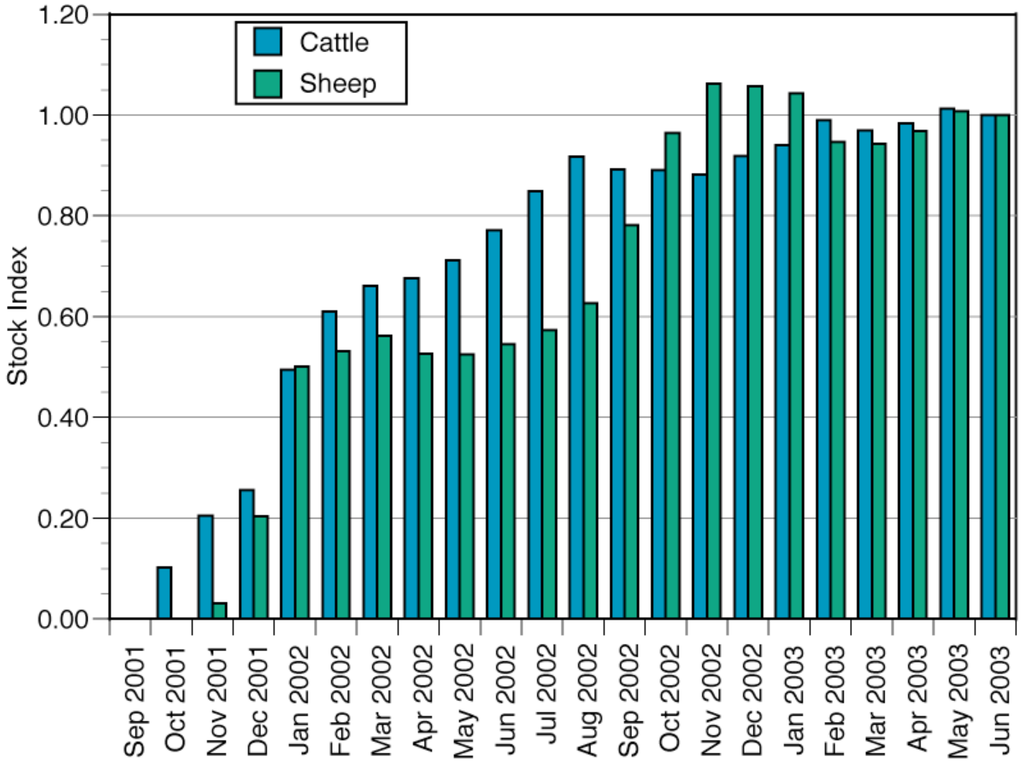

Figure 3.5: Calculated restocking index of animal numbers on the 25 survey farms between September 2001 and June 2003, relative to the number present in June 2003.

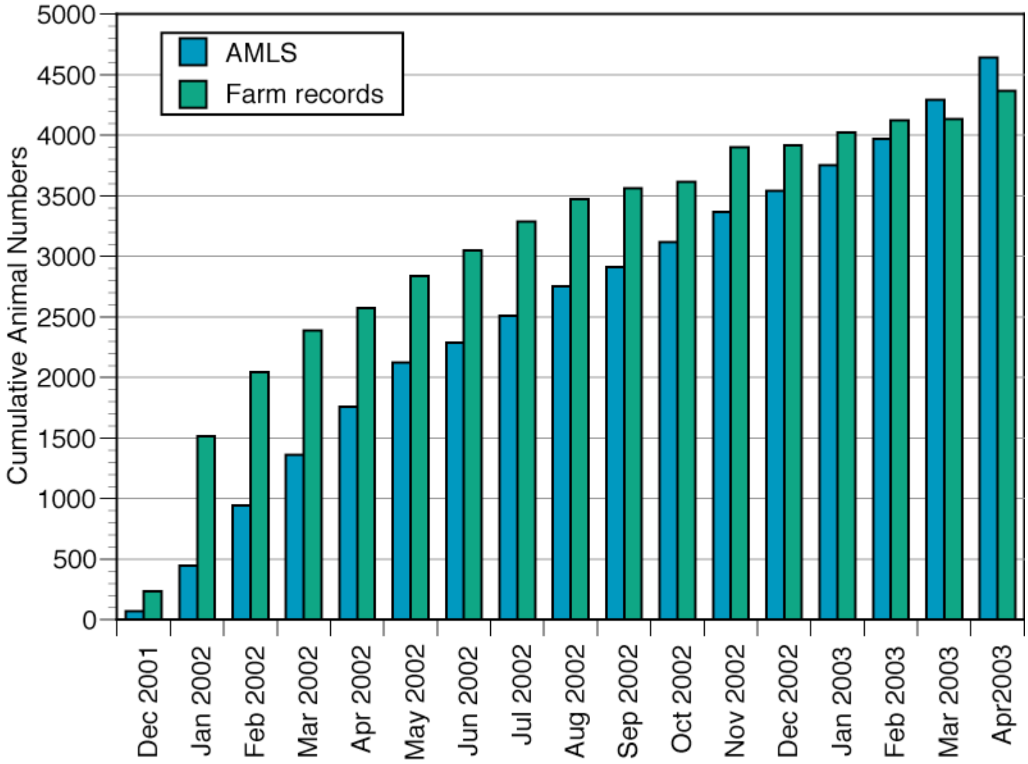

Figure 3.6: Cumulative net numbers of animals moved onto survey farms, as determined from Animal Movement Licensing Service (AMLS) records of animal movements and registered births and from farm records. Data are for the period December 2001 to April 2003.

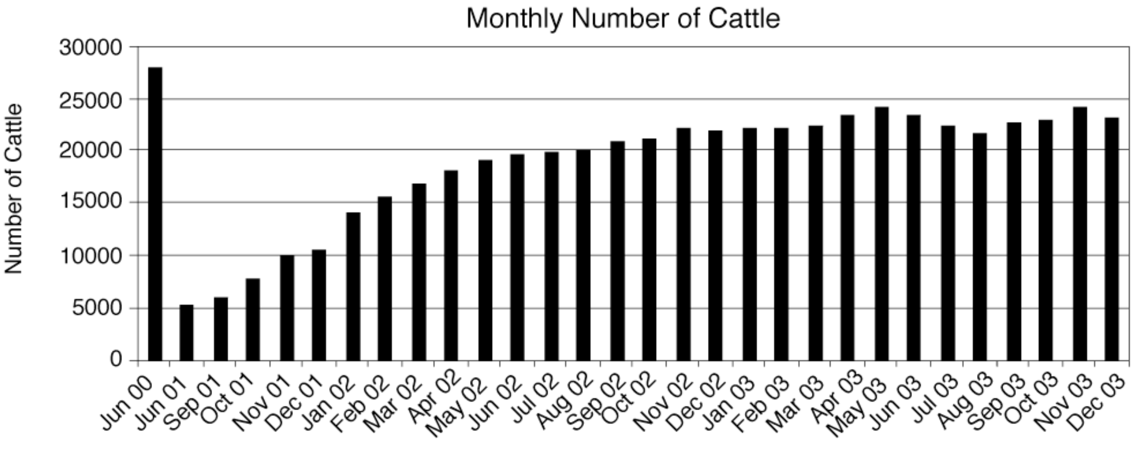

Figure 3.7: Calculated total numbers of cattle in the Caldew catchment, between June 2000 and December 2003. Note that the raw Defra Census data (June) have been spatially assigned better to reflect the distribution of cattle across the catchment. Thus, June data do not correspond directly to the actual Census data shown in Table 3.7.

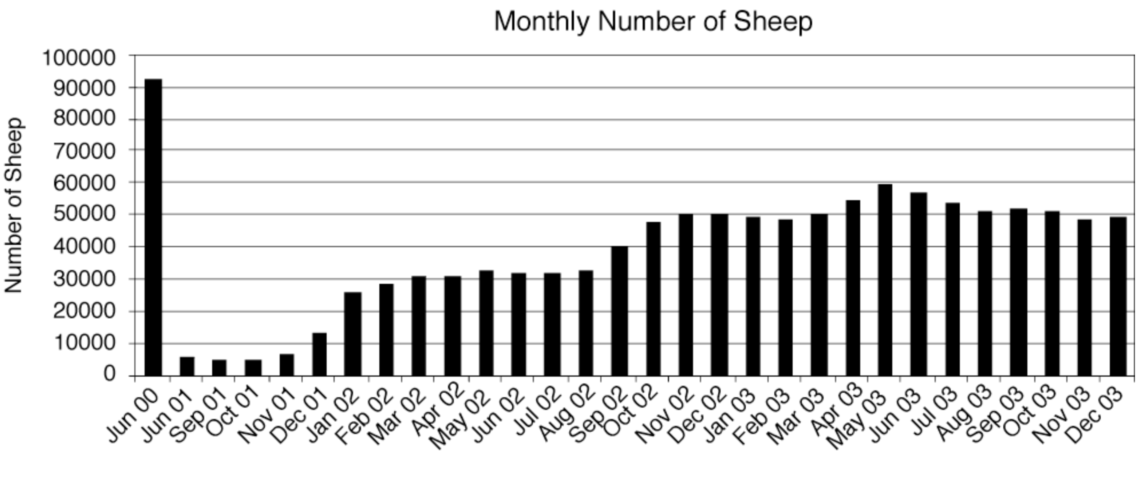

Figure 3.8: Calculated total numbers of sheep in the Caldew catchment, between June 2000 and December 2003. Note that the raw Defra Census data (June) have been spatially assigned better to reflect the distribution of sheep across the catchment. Thus, June data do not correspond directly to the actual Census data shown in Table 3.7.

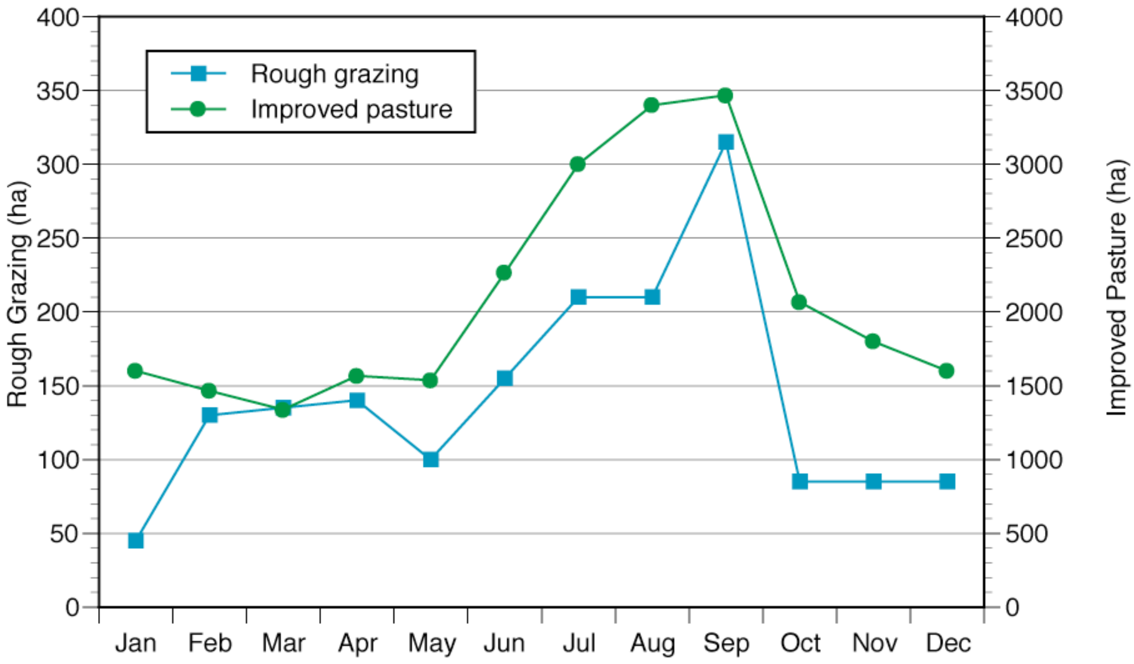

Figure 3.9: Area of land grazed by cattle and sheep on the 25 survey farms by month (2003).

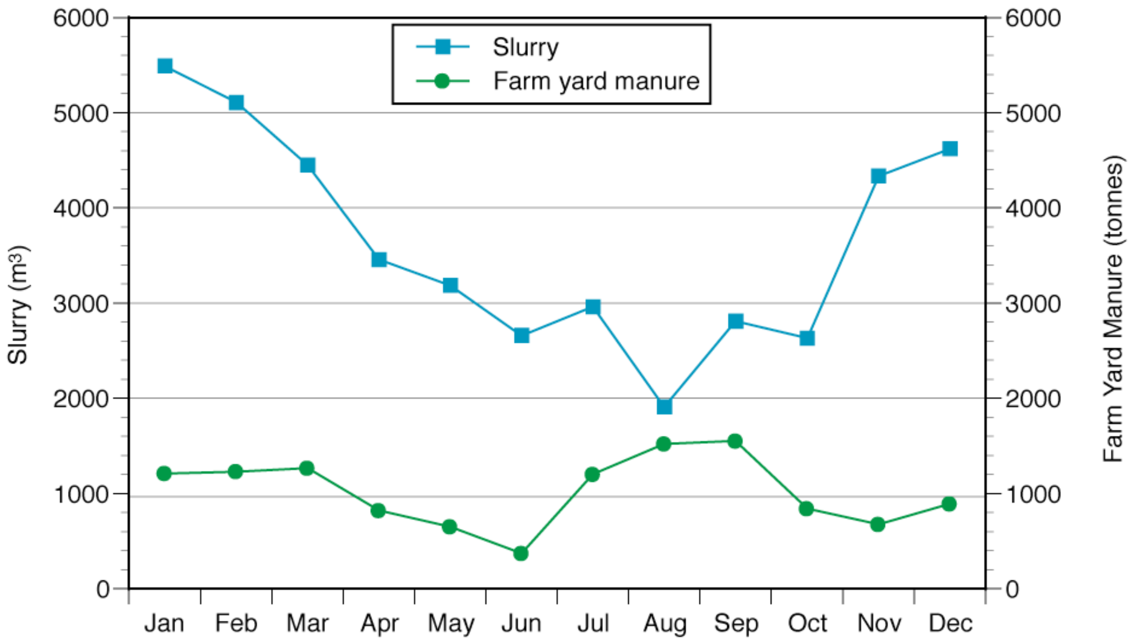

Figure 3.10: Volumes of manure spread by the 25 survey farms by month (2003).

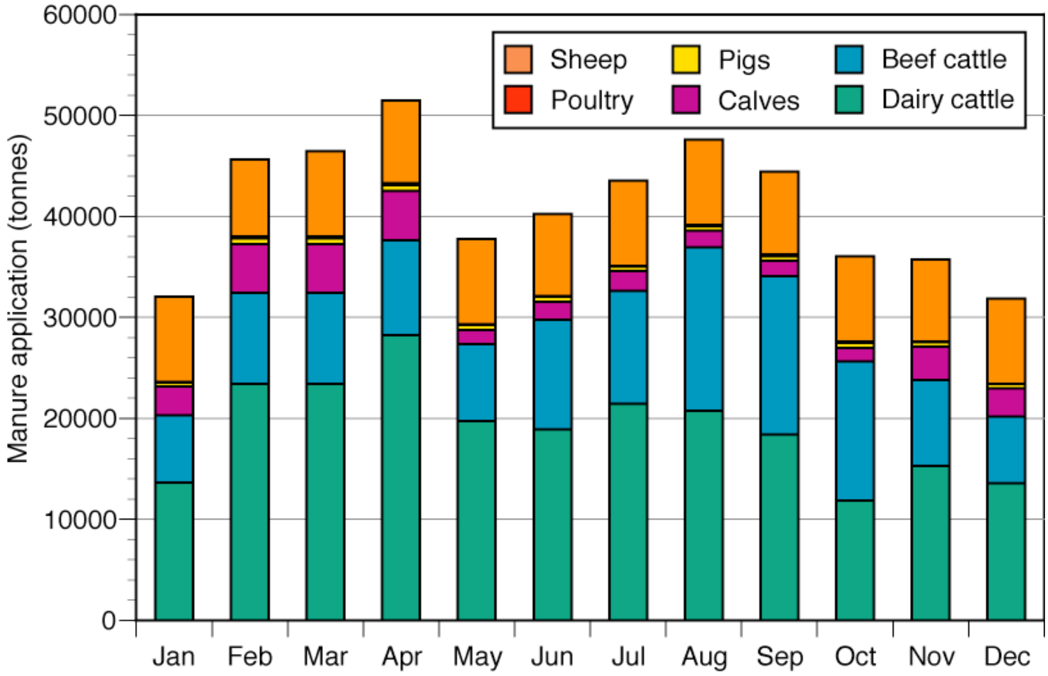

Figure 3.11: Summary of the calculated manure applications made to agricultural land in the whole of the Caldew catchment under baseline pre-FMD conditions for June 2000, not including the effects of seasonality of animal numbers about the June census figures. Applications are expressed as tonnes by livestock type.

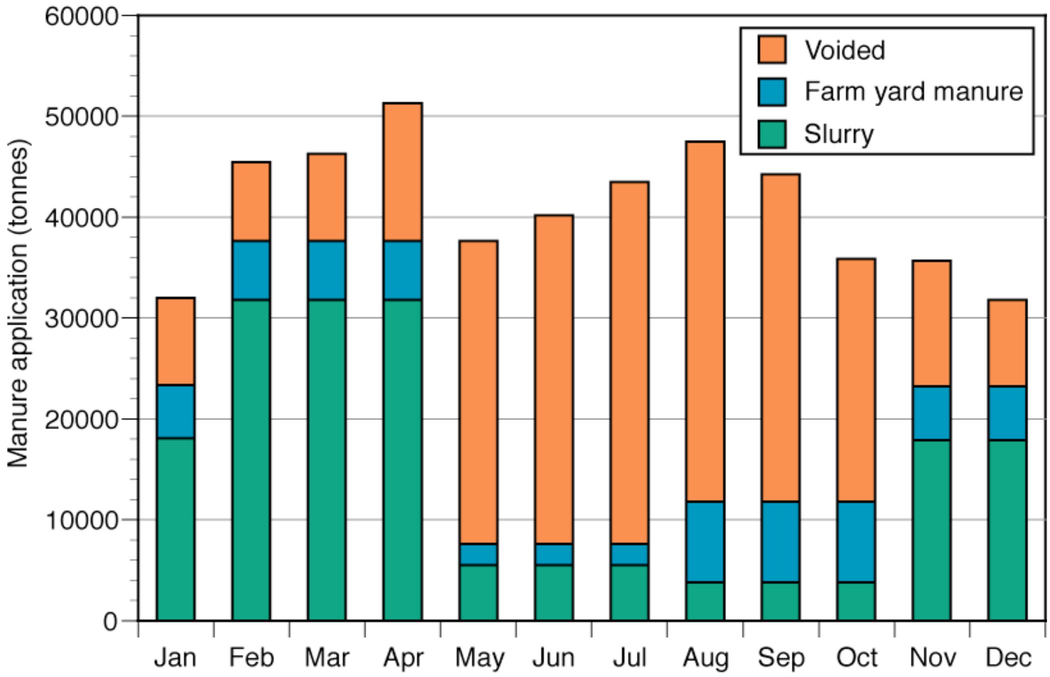

Figure 3.12: Summary of the calculated manure applications made to agricultural land in the whole of the Caldew catchment under baseline pre-FMD conditions for June 2000, not including the effects of seasonality of animal numbers about the June census figures. Applications are expressed as tonnes by manure type.

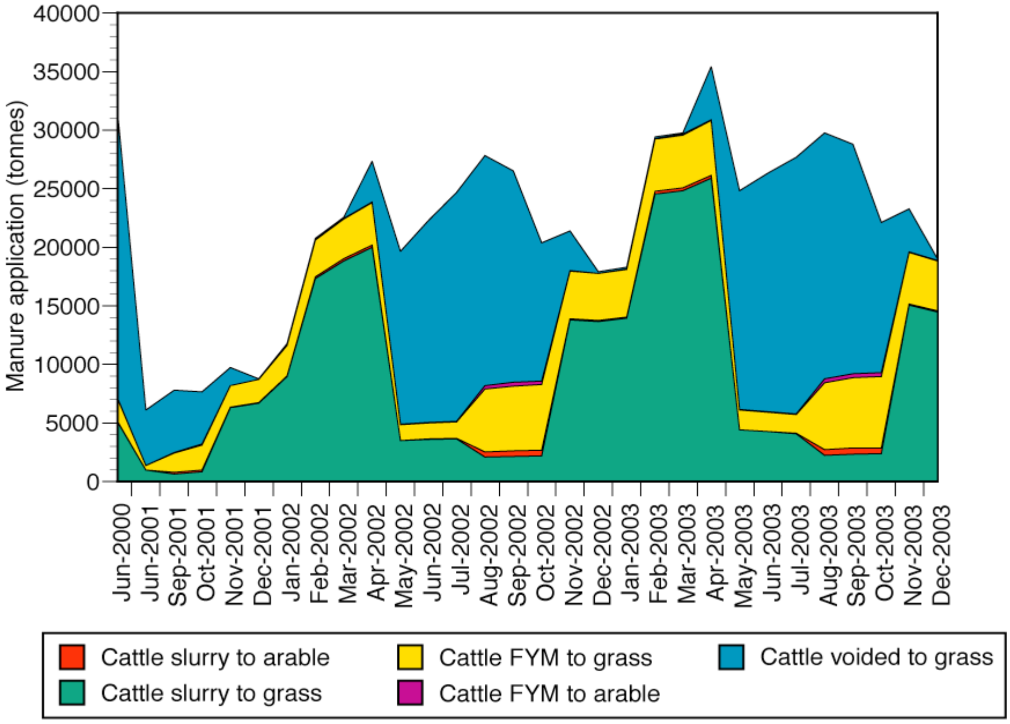

Figure 3.13: Summary of calculated cattle manure applications made to agricultural land in the whole of the Caldew catchment in the period June 2000 to December 2003, including the effects of culling, re-stocking and the seasonality of animal numbers about the June census figures. Applications are expressed as tonnes, by land use and manure type.

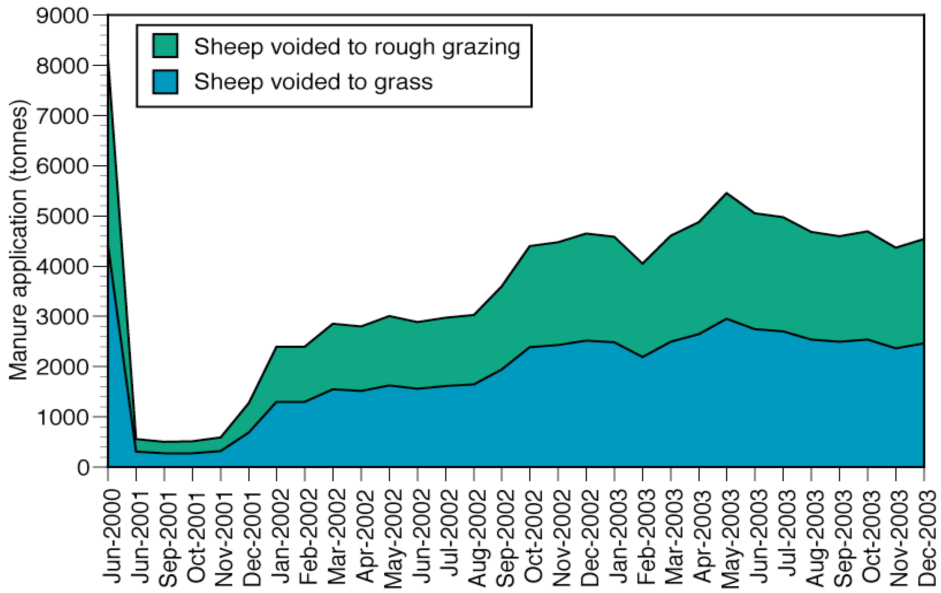

Figure 3.14: Summary of calculated sheep manure applications made to agricultural land in the whole of the Caldew catchment in the period June 2000 to December 2003, including the effects of culling, re-stocking and the seasonality of animal numbers about the June census figures. Applications are expressed as tonnes, by land use and manure type.

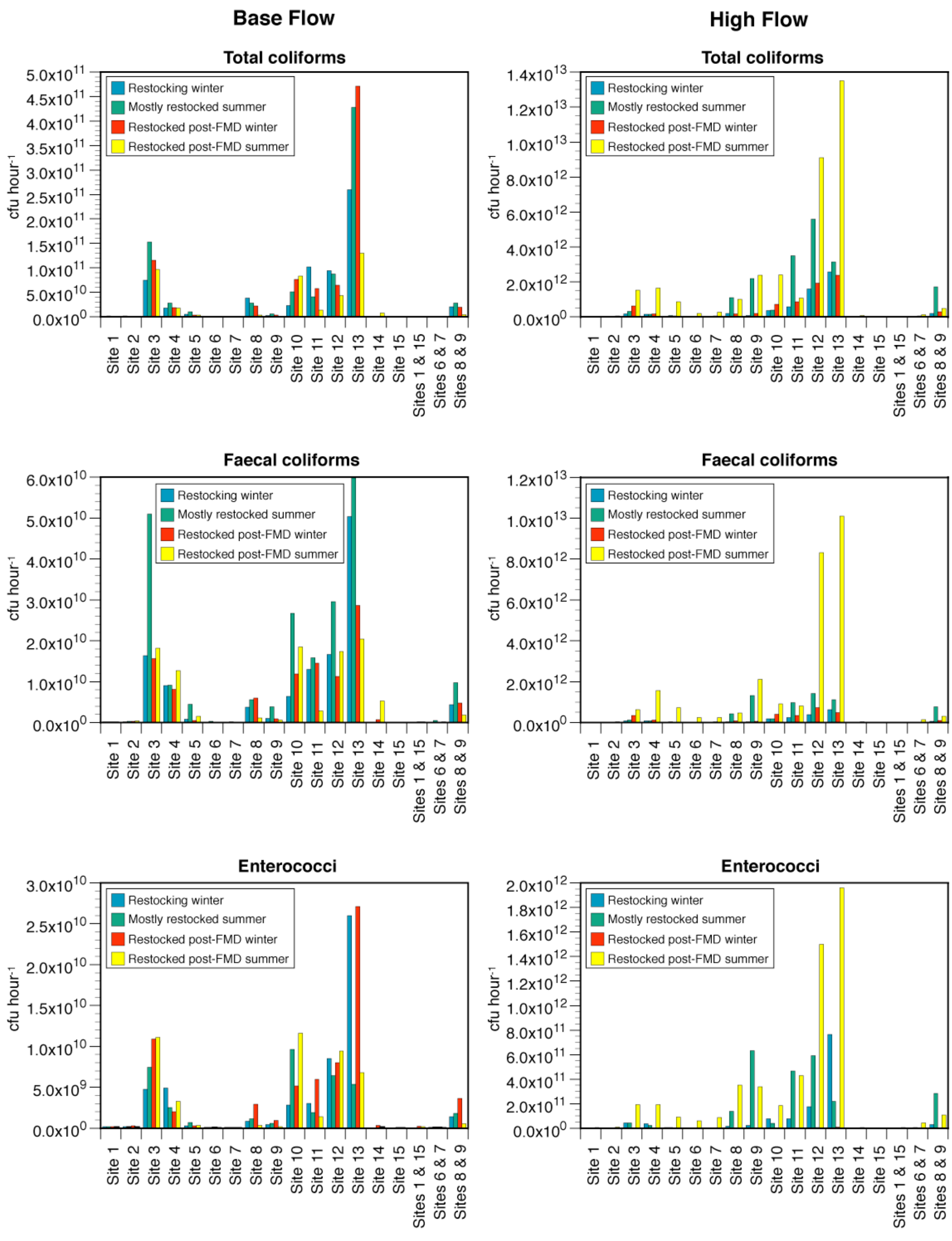

Figure 4.1: **Base flow and high flow faecal indicator organism hourly delivery (no. cfu per hour) during the restocking winter (October 2001 to April 2002), mostly stocked summer (May to September 2002) restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).**

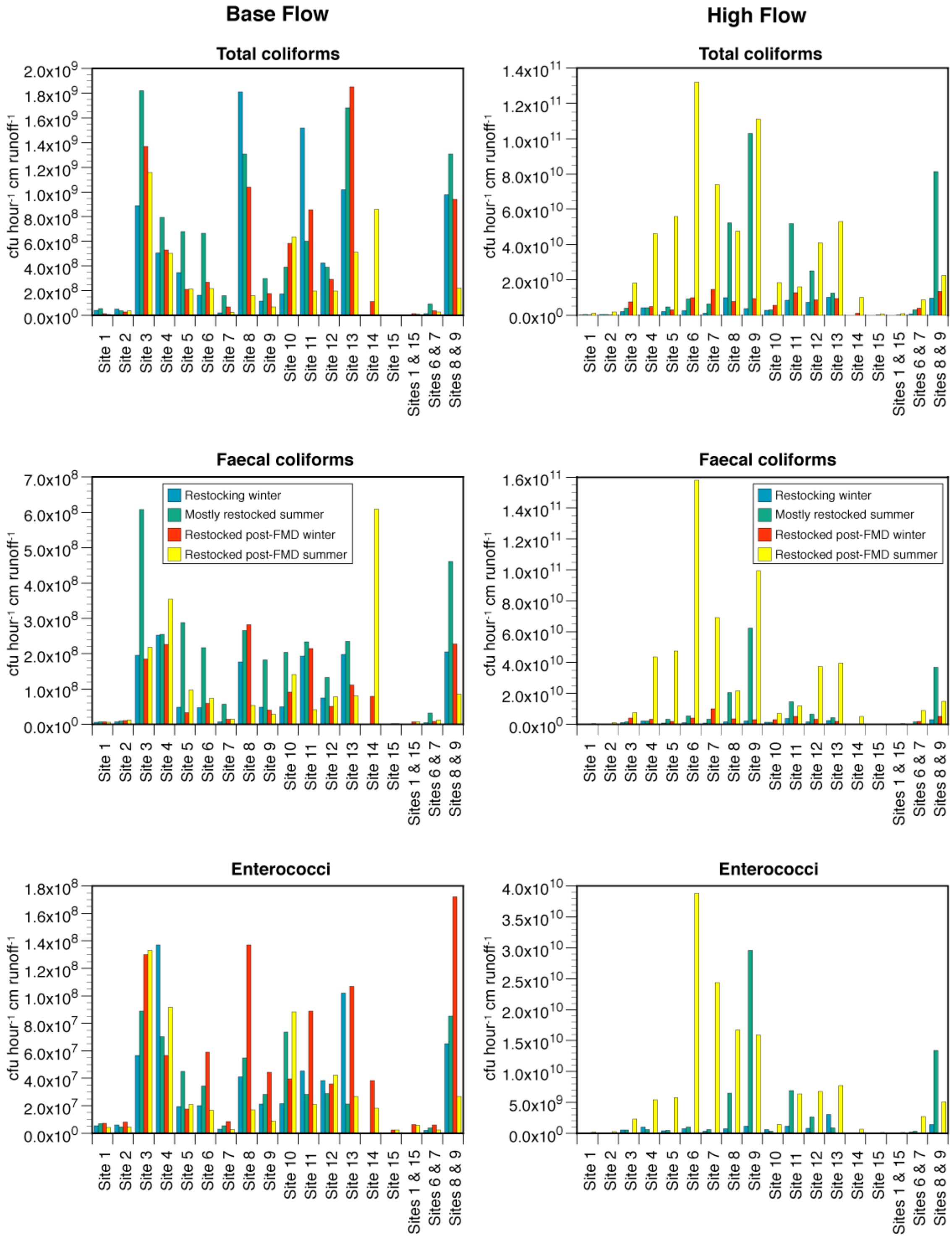

Figure 4.2: Base flow and high flow faecal indicator organism export coefficient (cfu hr^{-1} km^{-2}) during the restocking winter (October 2001 to April 2002), mostly stocked summer (May to September 2002) restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).

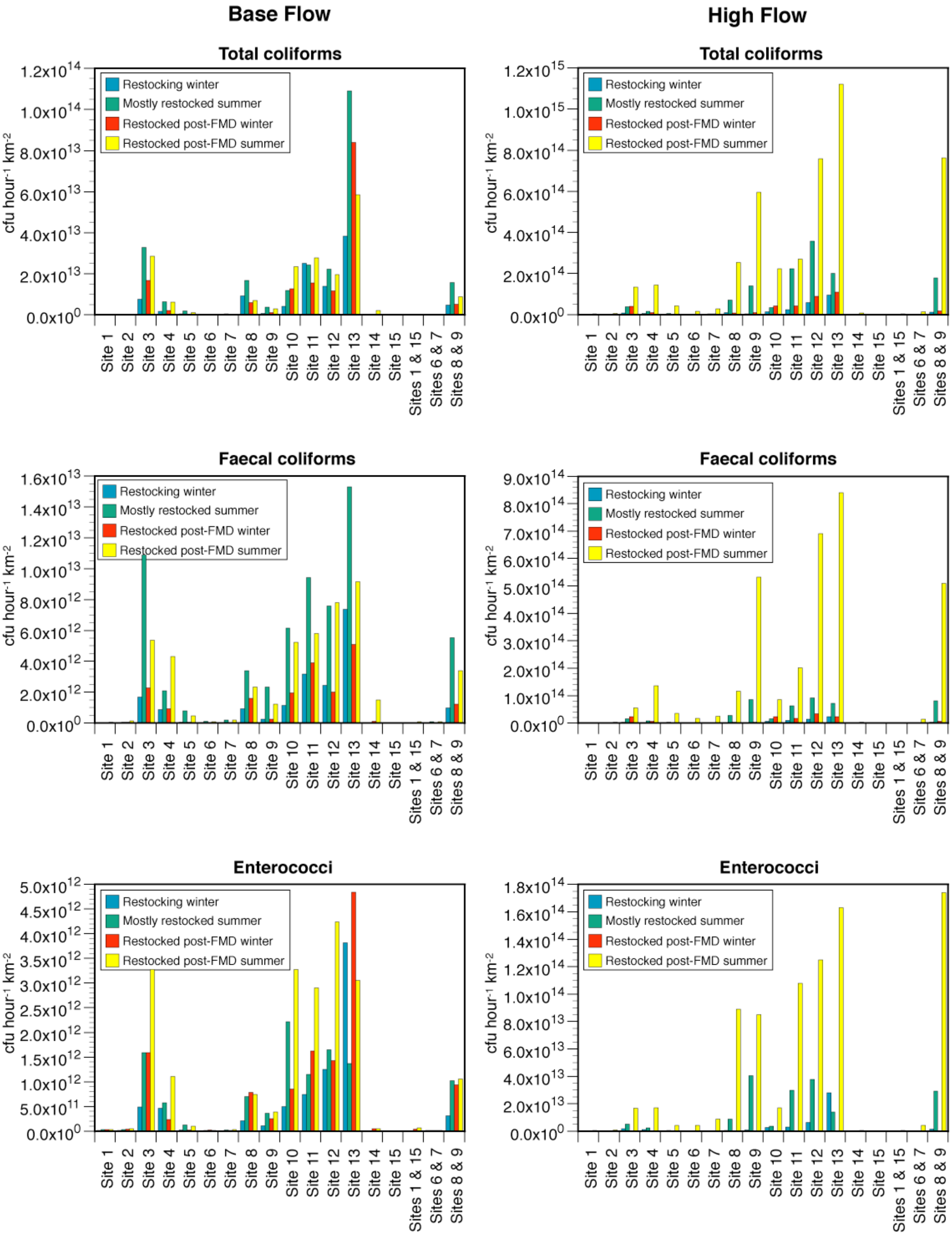

Figure 4.3: **Base flow and high flow faecal indicator organism export coefficients (cfu hr^{-1} cm runoff^{-1}) during the restocking winter (October 2001 to April 2002), mostly stocked summer (May to September 2002) restocked post-FMD winter (October 2002 to April 2003) and restocked post-FMD summer (May to September 2003).**

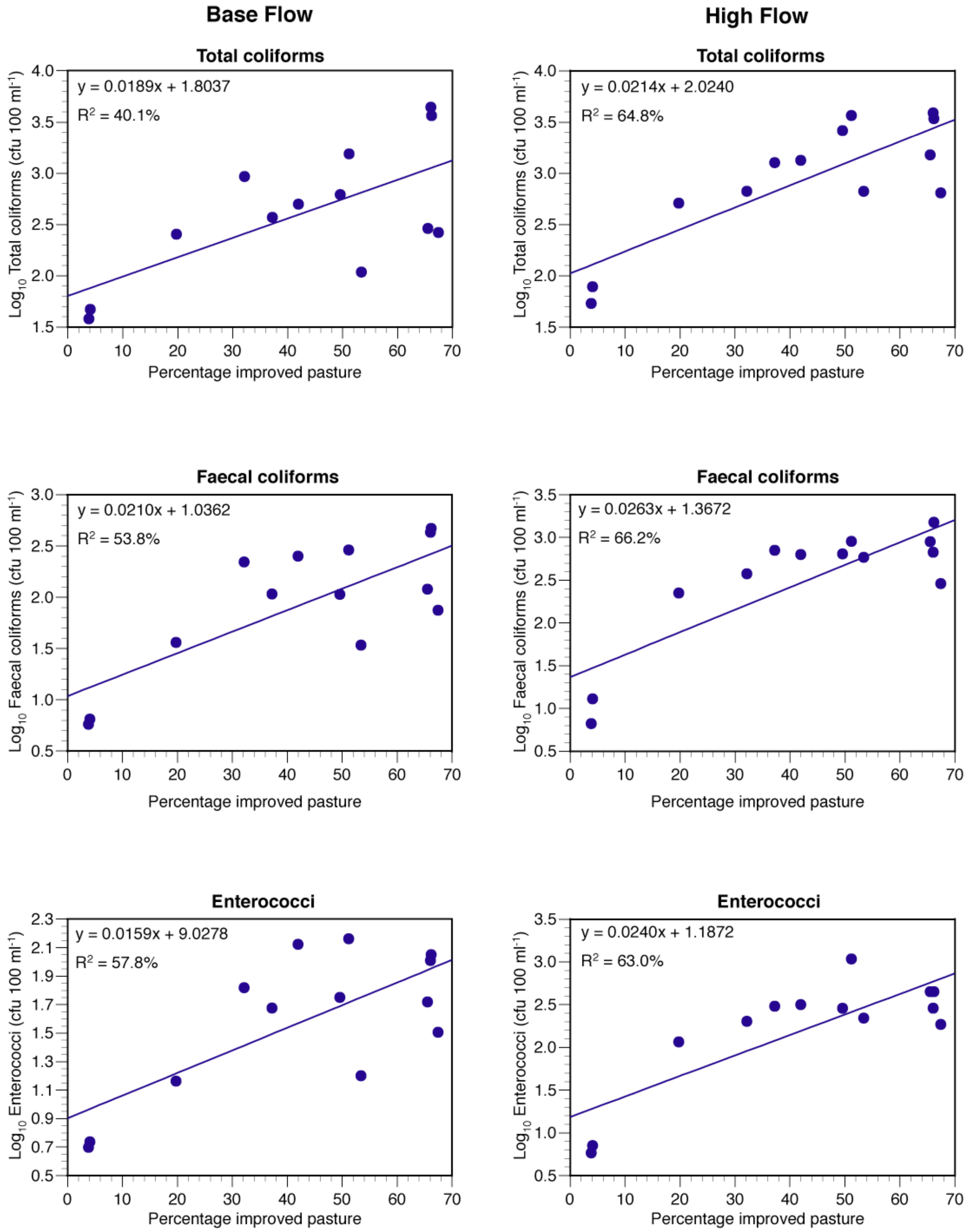

Figure 5.1: Plots of the relationship between GM base flow and high flow faecal indicator organism concentration ($\log_{10}$ cfu $100ml^{-1}$) during the restocking winter (October 2001 - April 2002) and percentage improved pasture within the subcatchment ($n = 13, p \leq 0.05$).

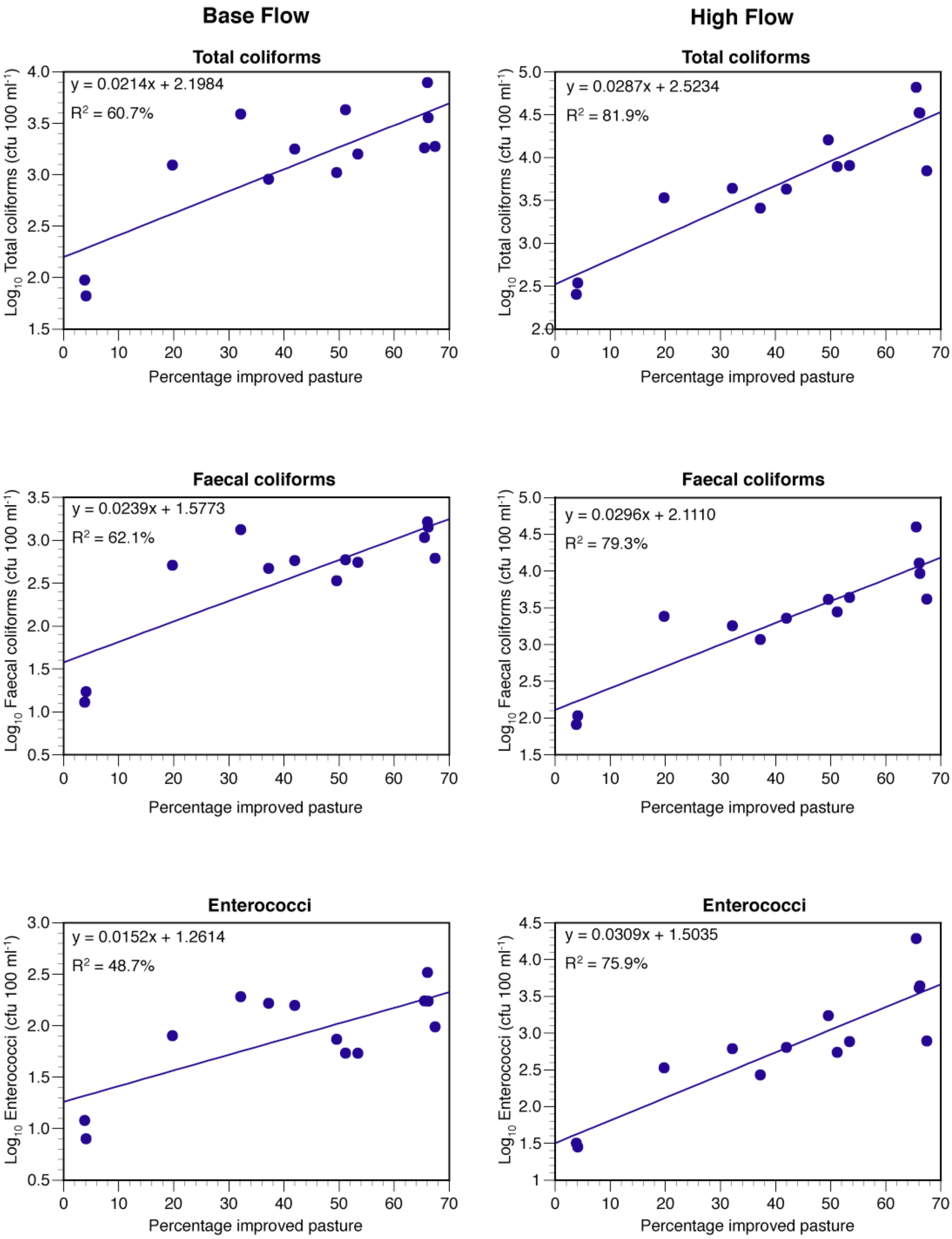

Figure 5.2: Plots of the relationship between GM base flow and high flow faecal indicator organism concentration (log_{10} cfu $100ml^{-1}$) during the mostly restocked summer (May - September 2002) and percentage improved pasture within the subcatchment (n = 13, $p \leq 0.05$).

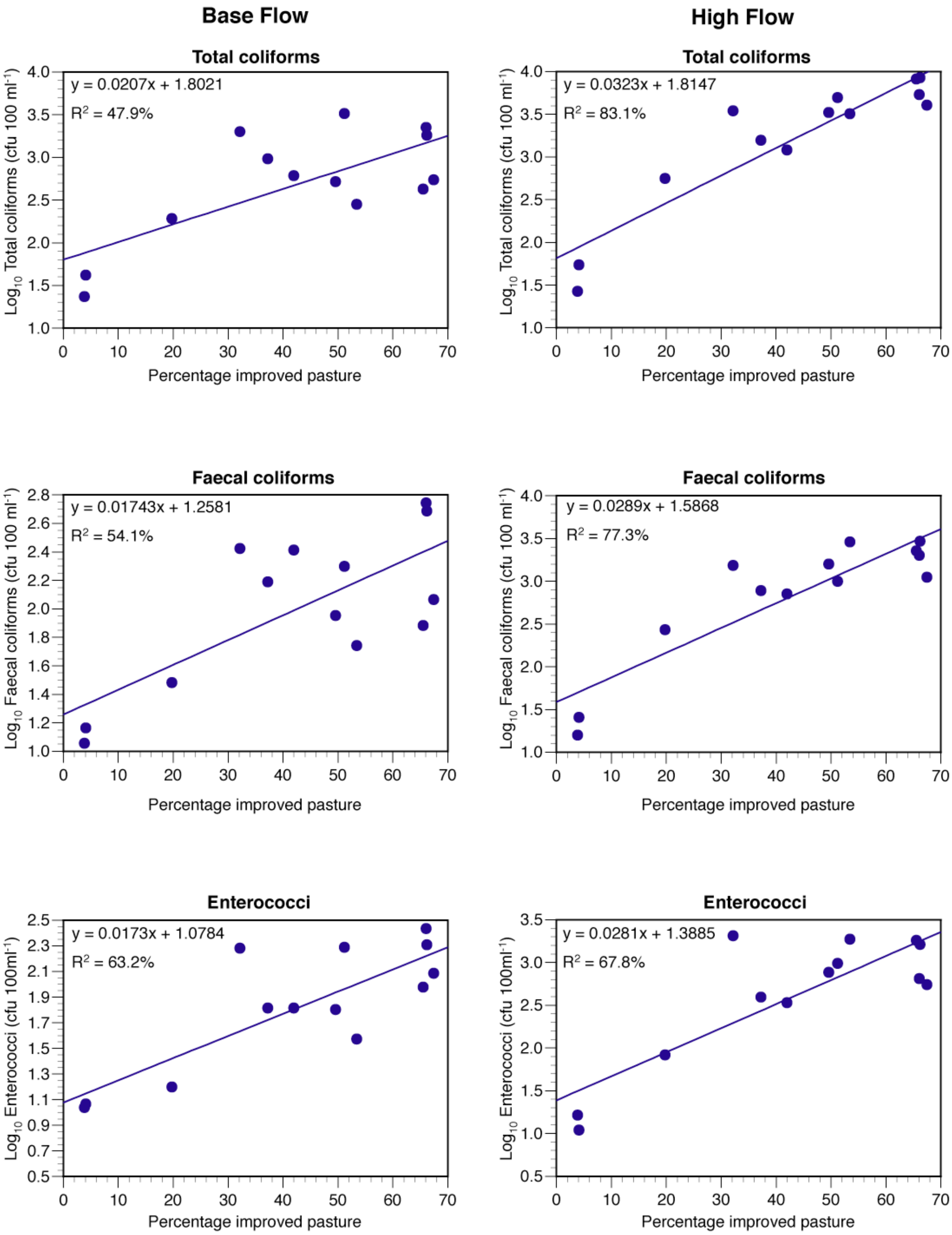

Figure 5.3: Plots of the relationship between GM base flow and high flow faecal indicator organism concentration (log_{10} cfu $100ml^{-1}$) during the restocked post-FMD winter (October 2002 - April 2003) and percentage improved pasture within the subcatchment (n = 13, $p \leq 0.05$).

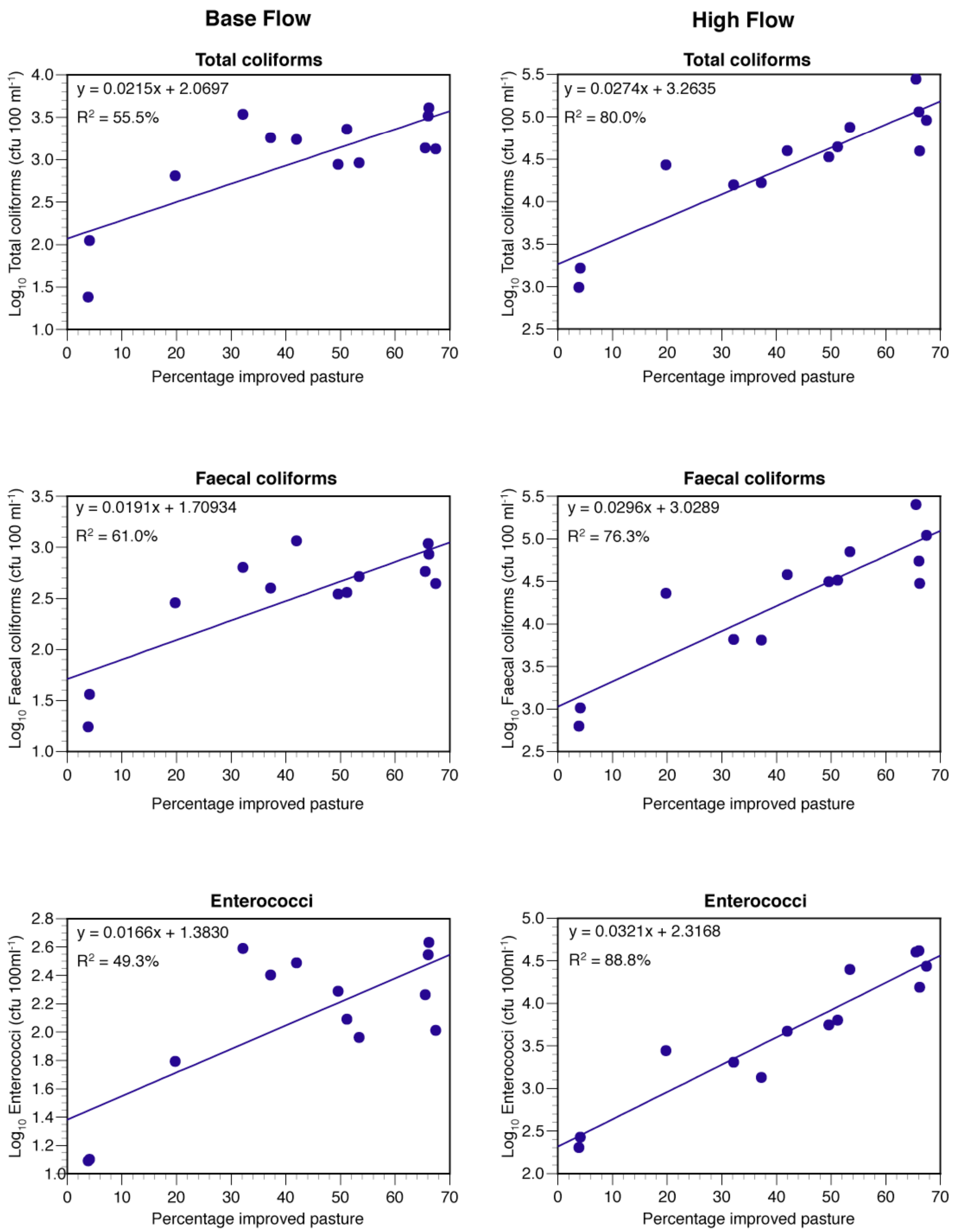

Figure 5.4: Plots of the relationship between GM base flow and high flow faecal indicator organism concentration (log_{10} cfu $100ml^{-1}$) during the restocked post-FMD summer (May - September 2003) and percentage improved pasture within the subcatchment (n = 13, $p \leq 0.05$).

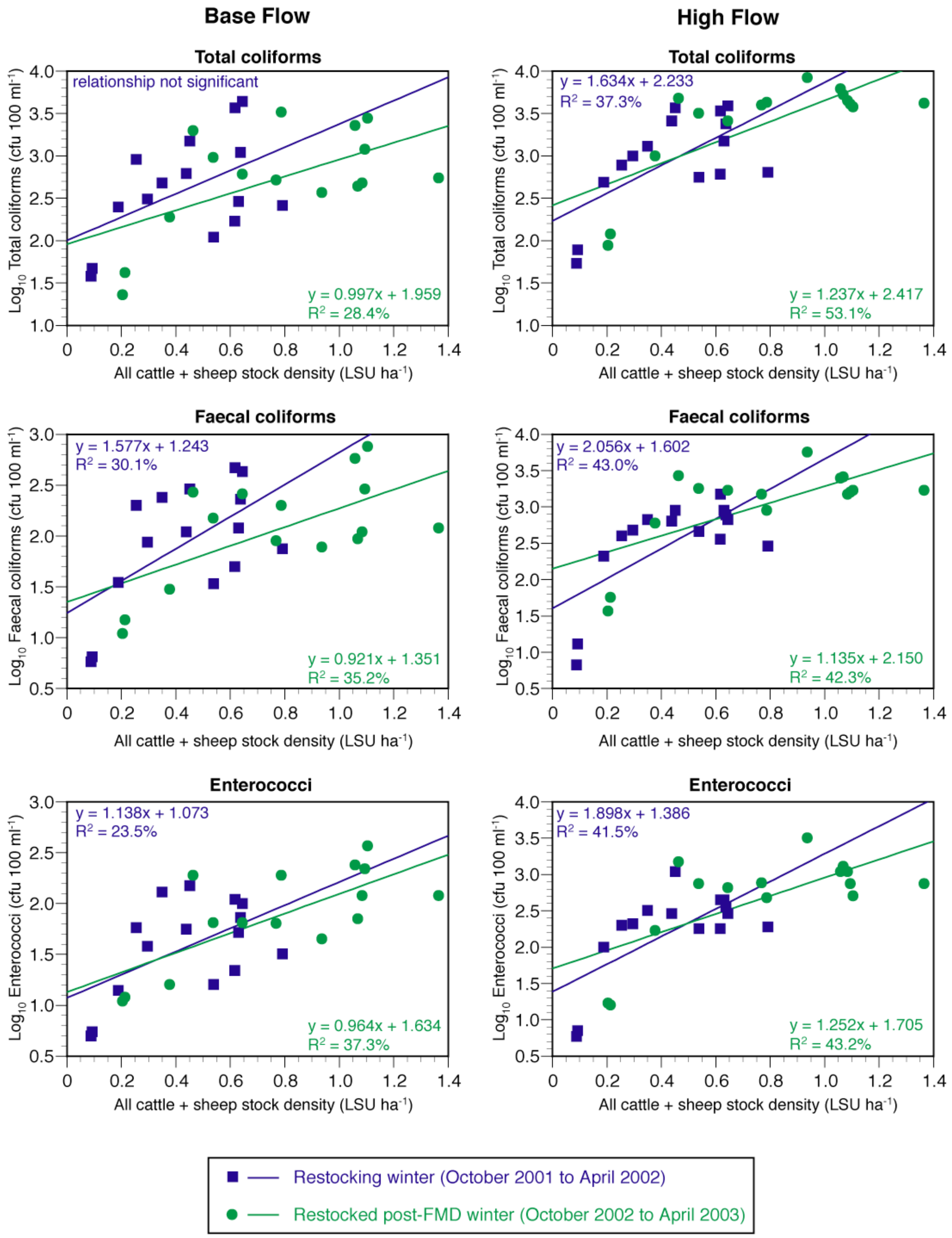

Figure 5.5: Plots of the relationships between GM base flow and high flow faecal indicator organism concentration ($\log_{10}$ cfu 100ml^{-1}) during the restocking winter (October 2001 to April 2002) and restocked post-FMD winter (October 2002 to April 2003) and all cattle + sheep stock density (LSU ha^{-1}; n = 15, $p \leq 0.05$ for each line unless otherwise indicated).

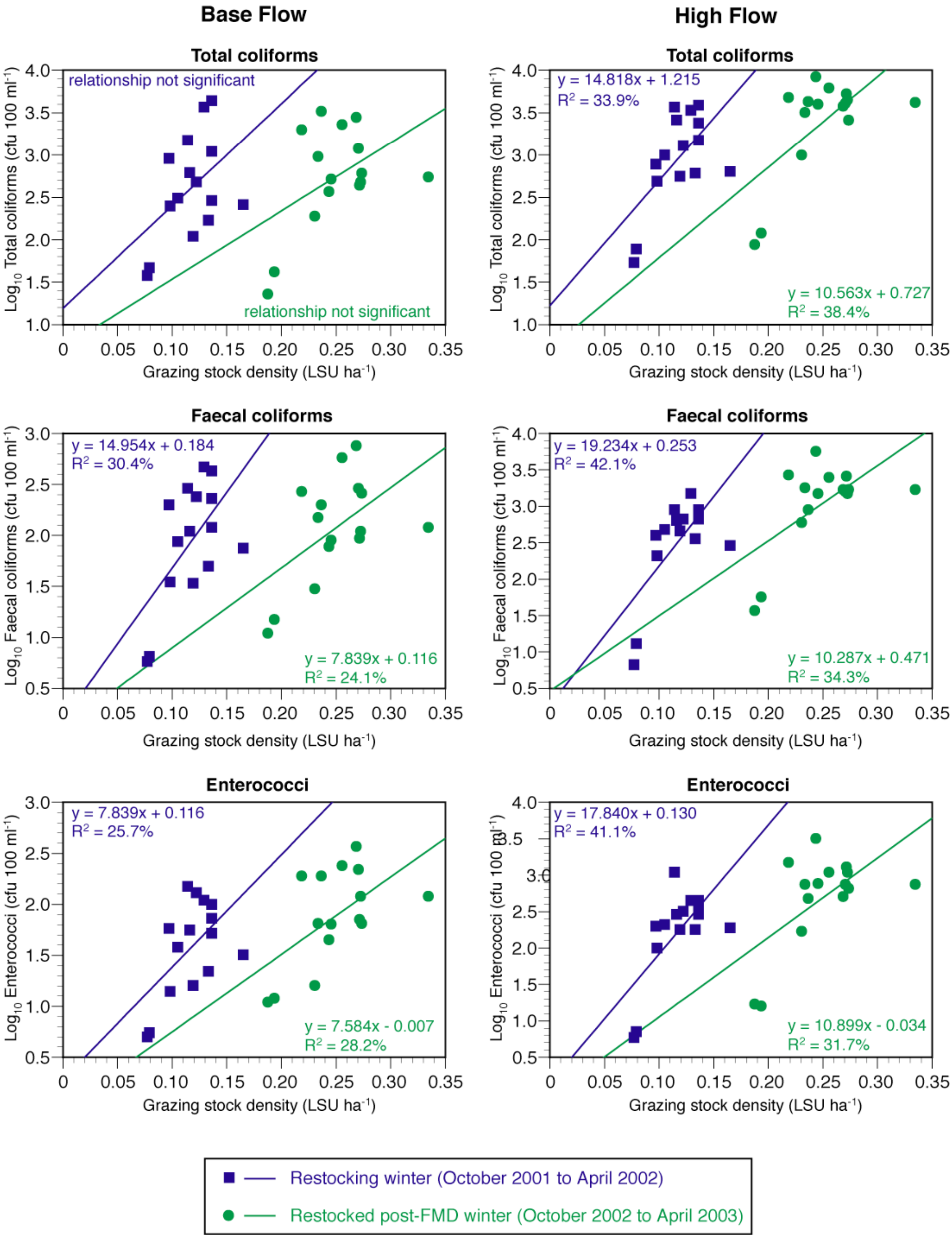

Figure 5.6: Plots of the relationships between GM base flow and high flow faecal indicator organism concentration ($\log_{10}$ cfu 100ml^{-1}) during the restocking winter (October 2001 to April 2002) and restocked post-FMD winter (October 2002 to April 2003) and grazing stock density (LSU ha^{-1}; $n = 15$, $p \leq 0.05$ for each line unless otherwise indicated).

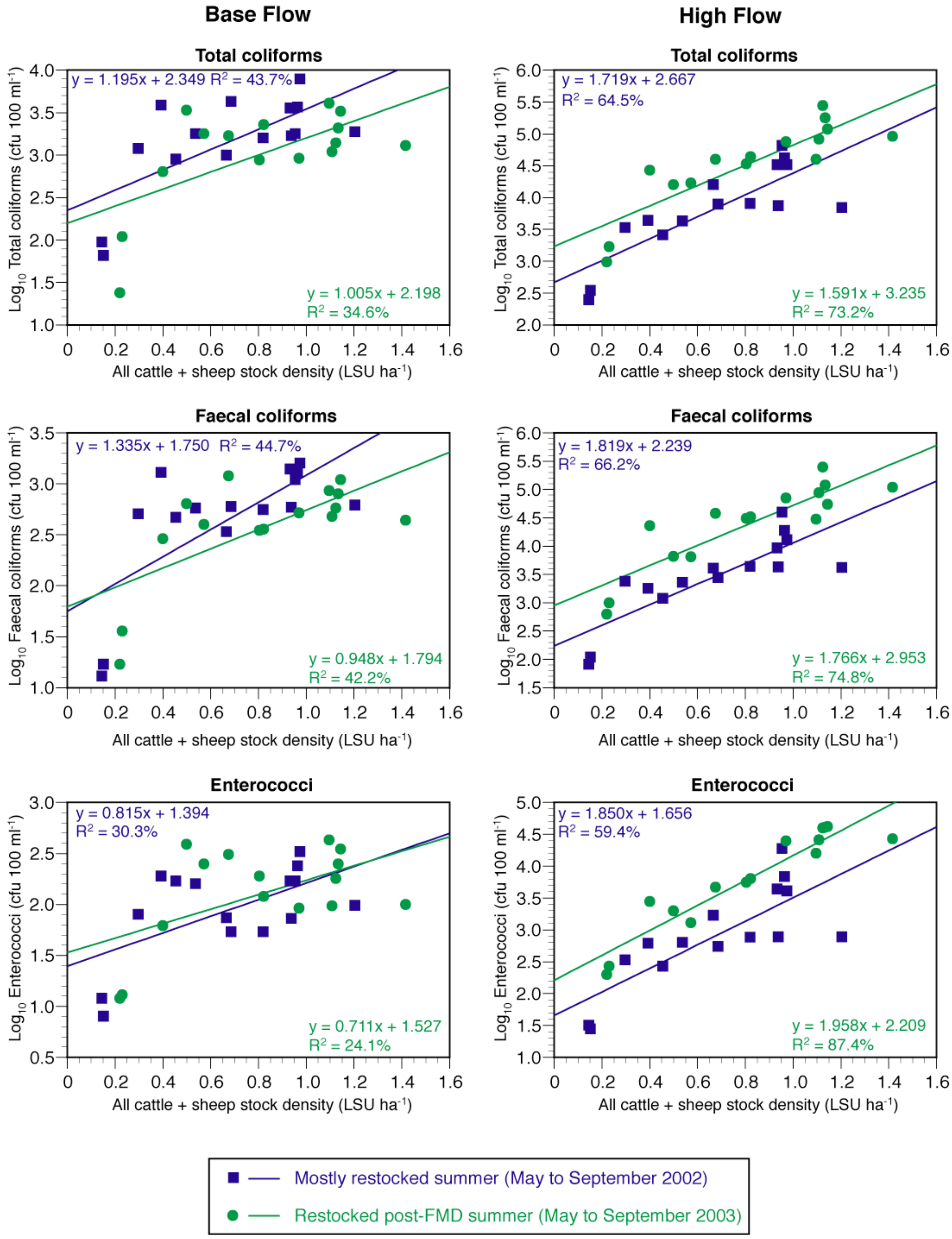

Figure 5.7: Plots of the relationships between GM base flow and high flow faecal indicator organism concentration ($\log_{10}$ cfu 100ml^{-1}) during the mostly restocked summer (May to September 2002) and restocked post-FMD summer (May to September 2003) and all cattle + sheep stock density (LSU ha^{-1}; $n = 15$, $p \leq 0.05$ for each line).

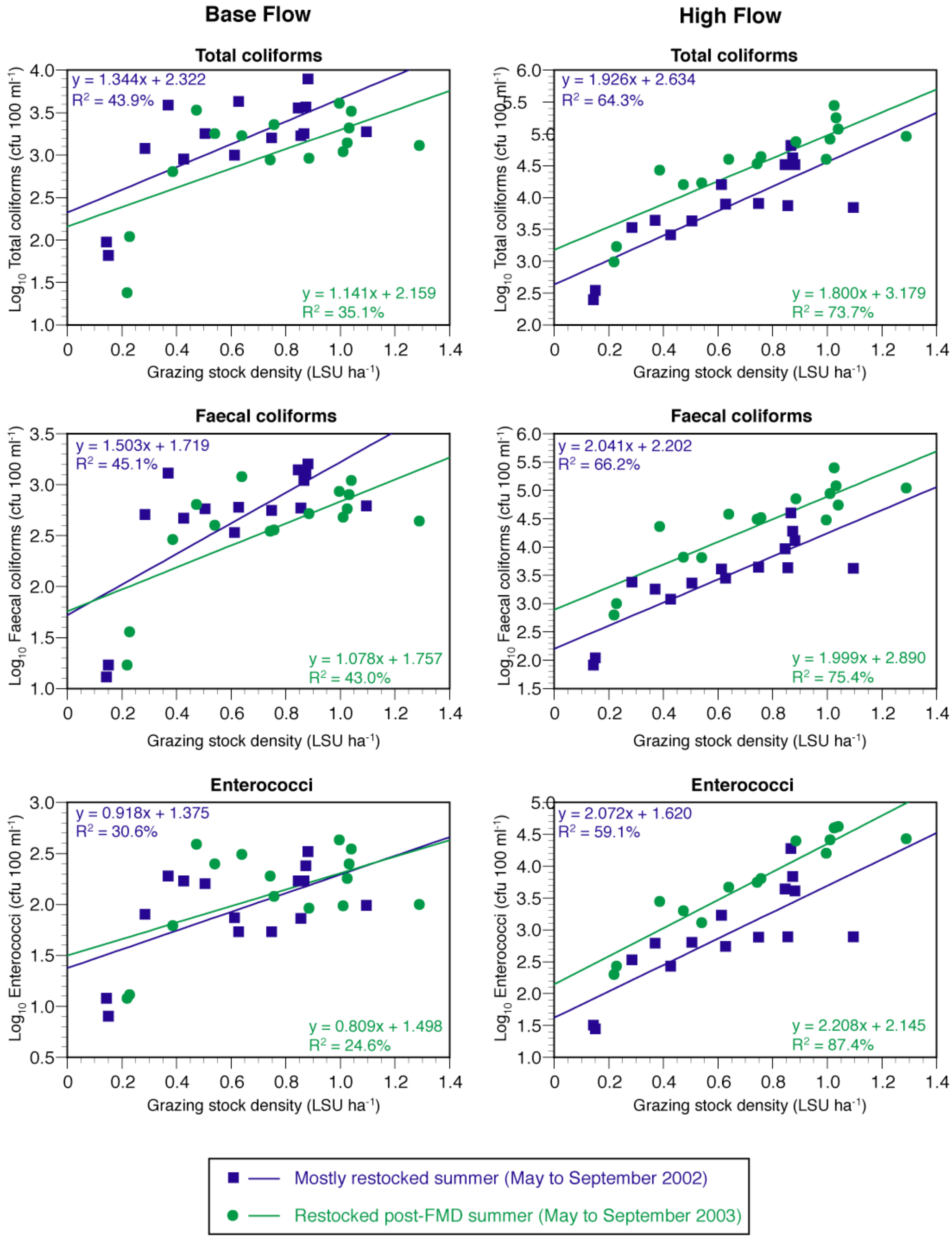

Figure 5.8: Plots of the relationships between GM base flow and high flow faecal indicator organism concentration ($\log_{10}$ cfu $100ml^{-1}$) during the mostly restocked summer (May to September 2002) and restocked post-FMD summer (May to September 2003) and grazing stock density (LSU ha^{-1}; $n = 15$, $p \leq 0.05$ for each line).

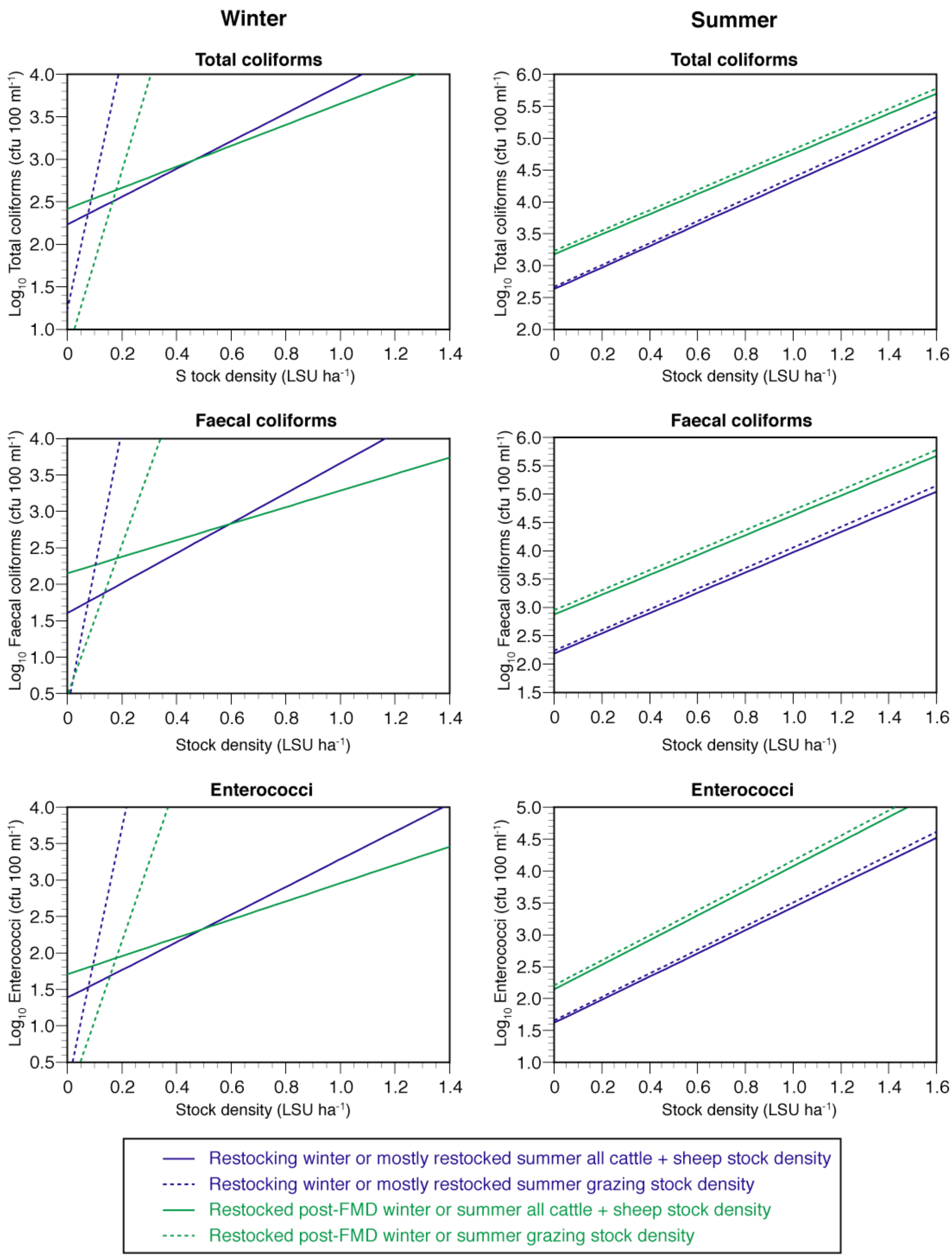

Figure 5.9: Plots of the relationships between GM high flow faecal indicator organism concentration ($\log_{10}$ cfu $100ml^{-1}$) and all cattle + sheep stock density and grazing stock density (LSU ha^{-1}; $n = 15$, $p \leq 0.05$ for each line). The graphs on the left show winter high flow relationships, those on the right summer high flow relationships.

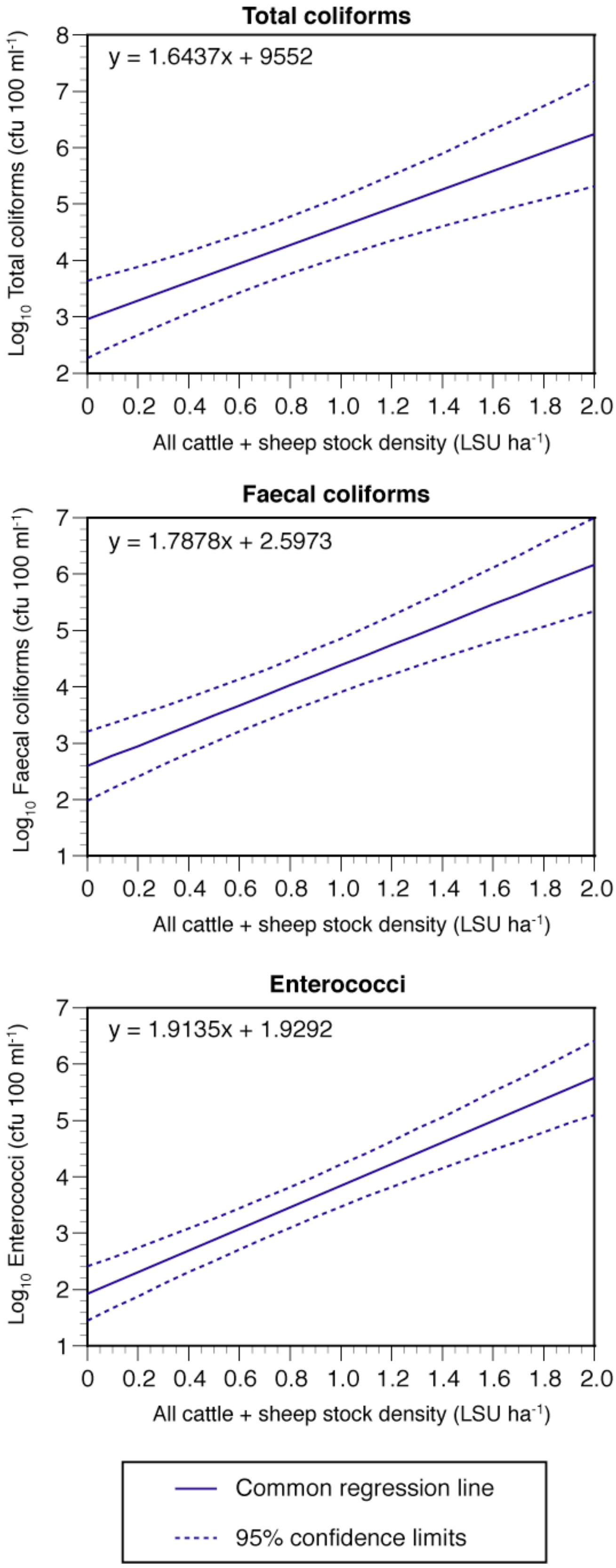

Figure 5.10: Plots of the common relationships between GM high flow faecal indicator organism concentration (log_{10} cfu $100ml^{-1}$) and all cattle + sheep stock density (LSU ha^{-1}; n = 30, $p \leq 0.05$), showing the 95% confidence limits.

Appendix I:
Farm survey letter of invitation, questionnaire and monthly log sheets

20 November 2002

«Title» «Initial» «Surname»
«Farm»
«Add1»
«Add2»
«Add3»
«PostCode»

Dear «Title» «Surname»

RIVER CALDEW CATCHMENT
STUDY OF RIVER WATER QUALITY AND FARM STOCKING DENSITY

I hope you will kindly consider taking part in a research study being conducted in the Caldew Catchment. ADAS is working closely with the Environment Agency on this and wish to involve a sample of farmers as part of the study.

The objective of the study is to identify possible relationships between changes in stocking density and water quality. Following last year's foot and mouth epidemic stock numbers in the Caldew Catchment were very low. This provided an opportunity to study these relationships as stock numbers recover over a period of time and this is why the catchment was chosen.

Bacteria levels in rivers are used as an indicator of water quality. Since December last year, the Environment Agency has been taking weekly measurements of river water bacteria levels from 13 sampling points in the catchment and this will continue until summer next year. The study period will therefore cover 1.5 years.

We will use aggregated census and stock movement data to give total stocking numbers/density for the catchment as a whole for each month of the study period. The sample of farms taking part will provide additional actual farm information. This will help identify other factors that may be involved and aid interpretation of results.

The sample of farms being approached has been chosen to give a range of farm types spread over the whole catchment. Your co-operation in the study would involve:

A visit from an ADAS consultant to complete a questionnaire of your farm system and a field map of the farm.

Completing a simple monthly log sheet for the next 7 months recording relevant farm activities. The ADAS consultant will help complete the first log sheet.

I realise I am asking you to do a bit more paperwork at a time when this may be unwelcome. To balance this we would make a payment of £200 for your help.

The reason I encourage you to take part is for the interest of the farming industry. Environmental information from studies such as this can influence government policies. It is therefore in farming's interest that such information is soundly based on valid scientific studies. **This is more likely to happen with the involvement of farmers.**

An early opportunity to review the results will be given to all who take part. A study report will be published on the Environment Agency website. **No individual farm will be referred to in the report and individual farm information will remain confidential.**

I hope you will take part in the study and I will phone you to arrange an appointment to discuss this further.

Yours sincerely

JOE WILSON
ADAS Consultant

FARM QUESTIONNAIRE

1) Farmer & farm name: ………………………………………………………………...

2) Holding no: …………………………………….

3) Date: …………………………….. Tel no: ………………………………

4) Enter areas that you farm. (Ideally use areas from IACS records)

	Current year 2002	Pre-FMD 2000
Grassland (grazing & cutting)	ha	ha
Enclosed rough grazing	ha	ha
Fodder crops	ha	ha
Other crops	ha	ha
Total farmed area (exclude non productive land)	ha	ha
Sheep fell grazing rights (ewe & lambs at foot equivalent units)	number	number

5) Enter stock numbers and % of waste produced for each class of stock.

	Current stock numbers	Pre-FMD numbers	Type of waste (approx %)	
			Slurry	FYM
Dairy cows				
Beef cows				
Calves to 6 months				
Followers over 6 months				
Other beef cattle over 6 months				
Breeding ewes				
Purchased fattening & wintering sheep				
Breeding sows				
Weaners				
Fattening pigs				
Broilers				
Other (specify) ……………………..				

6) Were a significant number of your animals slaughtered during the foot and mouth epidemic? Yes / No

If yes, tick the appropriate box and go to question 7. If no, go to question 8.

	Tick (✓)
All livestock slaughtered	
Sheep only slaughtered in the cull	
Other (please specify) ………………………………………………	

7) If you have restocked either fully or partly, complete the following table to show in which months restocking took place.

	Enter number of animals moved onto the farm		
	Cattle	Sheep	Pigs
Before Dec 2001			
Dec 2001			
Jan 2002			
Feb			
Mar			
Apr			
May			
Jun			
Jul			
Aug			
Sep			
Oct			
Nov 2002			

8) How are wastes normally spread on your farm? (Present spreading practice, or pre-FMD practice if this has not yet been resumed following disruption by FMD)

	Tick (✓)	
Spreading Method	By self	By contractor
Slurry tanker		
Umbilical		
Farm yard manure spreader		
Dirty water low-rate irrigation		
Soil injection		
Other method (please specify) ……………………………….		
	Approx % of waste	
Waste Type	By self	By contractor
Slurry	%	%
Farm yard manure	%	%

9) Estimated total slurry storage capacity on the farm during a typical winter to nearest 0.5 month? ………… months

10) Estimated average age of wastes spread during the last 12 months.

	Enter average age of waste when spread (e.g. if collected and stored for 2.5 months before being spread = 1.25 months average age)	
Month spread	Slurry	Farm yard manure
Dec 01 - Feb 2002		
Mar - May 2002		
Jun - Aug 2002		
Sep - Nov 2002		

Day Month

11) Date most of your cattle were turned out in spring 2002: …… …………..

12) Normal spring turn-out date for most of your cattle: …… …………..

Date most of your cattle were housed in autumn 2002: …… …………..

Normal autumn housing date for most of your cattle: …… …………..

13) Did you import any organic wastes for spreading on your farm during the last 12 months, e.g. sewage sludge or waste from other people's farms? Yes / No

If yes, state type, approximate quantity and month spread.

………………………………………………………………………………………

14) Did you export any farm wastes off your farm for spreading on other people's farms during the last 12 months? Yes / No

If yes, state type and approximate quantity.

………………………………………………………………………………………

15) What soil types are on the farm?

	Light	Medium	Medium/heavy	Heavy
Approx %	%	%	%	%

16) What area of yards, hardstandings and building roofs are there on your farm?
(Estimate area in m^2 by pacing out, if dimensions are not known)

	Approx. Area	Where does surface water drain to? Tick (✓)		
Dirty yards and clean areas draining to slurry system	m^3	Ditch or stream	Soakaway	Other (specify) ……………
Clean yard & hardstandings	m^3			
Building roof area	m^3			

17) Were any cattle outwintered in fields last winter 2001/02? Yes / No

If yes, detail cattle numbers and type: ……………………………………………

and write OW on fields used for outwintering on the farm map.

18) Do you intend to outwinter any cattle in fields this winter? Yes / No

FARM MAP

Make a copy of a map which shows field boundaries (scale 1:7500 is usually best as a whole farm can usually be copied on one A3 sheet).

Mark the following on the map:

- Boundary of the farm (blue highlighter)
- Colour whole field or part field areas where wastes are normally spread (hatch with yellow highlighter)
  Not necessary to mark 10 metre non-spreading margins beside watercourses as the map is not a farm waste management plan. However, confirm this good practice when speaking to the farmer.
- Colour whole field or part field areas where effective land drains are present (hatch with orange highlighter)
- Colour streams, ditches and freshwater ponds that cattle can walk into or through (red highlighter)
- Current use of fields, i.e. write F (fodder crops), C (other crops), RG (enclosed rough grazing and G (grassland).
- Write OW on fields used for outwintering cattle

MONTHLY LOG SHEET

Complete a log sheet for each month from December 2002 to June 2003.
Post completed log sheet at the end of each month to Angela Dewhurst, ADAS,
15 Eastway Business Village, Olivers Place, Preston PR2 9WT. (Tel: 01772 703070)

Farmer & farm name: ………………………………………………………………………

Holding no: ……………………………………..

Month and Year: ……………………………………………

Average stock numbers over the calendar month in housing or grazing outdoors

	Numbers added across each row = total on the farm this month. For example, if 100 cows are housed for 2 weeks and grazed on grass for 2 weeks, enter 50 in column A and 50 in column B				
	Housed (A)	**Grassland grazing (B)**	**Enclosed rough grazing (C)**	**Fell grazing (D)**	**Fodder crop grazing (E)**
Dairy cows					
Beef cows					
Calves to 6 months					
Followers over 6 months					
Other beef cattle over 6 months					
Breeding ewes					
Purchased fattening & wintering sheep					
Breeding sows					
Weaners					
Fattening pigs					
Broilers					
Other (specify) ……………………..					

Area of grassland grazed this month (complete if any stock in column B on page 1)	ha / acres
Area of rough grazing grazed this month (complete if any stock in column C on page 1)	ha / acres
Area of fodder crops grazed this month (complete if any stock in column E on page 1) also state type of crop (e.g. swedes, kale etc)	ha / acres type: ……………………………….…
If additional area has been acquired this month above the 2002 total farmed area, state area and type (e.g. summer grazing not taken in 2002)	ha / acres type: ……………………………….…

Waste spreading record for the calendar month

	Slurry	**Farm yard manure**
Total amount spread during this month (enter 0 if none spread)	gallons OR m^3	tonnes
Application rate	gallons/acre OR m^3/ha	tonnes/acre OR tonnes/ha
Estimate average age of waste when spread to nearest 0.5 month *	months	months

* E.g. if collected and stored over 2.5 months before spreading = 1.25 months average age.

Farmer Comments

Was the above typical spreading practice for this time of the year? Yes / No

If spreading practice was non-typical or weather conditions were unusual for this time of the year, please detail: (e.g. prolonged frozen period or prolonged drought)

220 gallons = 1 m^3	1000 gallons/acre = 11 m^3/ha	10 tonnes/acre = 25 tonnes/ha