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Making Information Available for Integrated Catchment Management

Science Report – SC060035/SR

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Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

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Science at the Environment Agency

Science underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us and helps us to develop monitoring tools and techniques to manage our environment as efficiently and effectively as possible.

The work of the Environment Agency's Science Group is a key ingredient in the partnership between research, policy and operations that enables the Environment Agency to protect and restore our environment.

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- **Delivering information, advice, tools and techniques**, by making appropriate products available to our policy and operations staff.

Steve Killeen

Steve Killeen

Head of Science

Executive summary

This report summarises a project run under the Environment Agency's Integrated Catchment Science (ICS) Programme. The majority of this report refers to work by Entec and the Environment Agency's Science Group between January and April 2007 and some later work in 2008. Other consultants and university departments also contributed.

The long-term aim of this work is to identify ways to support the development of programmes of measures (PoMs) using a 'whole catchment' approach within river basin management. However, to do this for all aspects of water management in a catchment was beyond the scope of this project. Instead we focused on diffuse pollution, which the Water Framework Directive (WFD) has identified as a major issue in the Frome-Piddle and in many rural catchments in the UK. The work is planned over several phases and this project covers Phase 1.

This project was planned in collaboration with local staff in the Environment Agency Blandford Forum office via several workshops. The agreed objectives were to:

1. Gather data and build a pilot Geographic Information System (GIS) and, working closely with Area staff, test its usefulness for the management of land use change and diffuse pollution in the Frome-Piddle.

2. Identify and summarise relevant previous work.

3. Investigate the usefulness of selected spatial and time variant models for estimating the effects of land use change on nutrient concentrations in the Frome-Piddle.

As an evidence-based regulator, good data is our lifeblood. The Environment Agency holds a large amount of data collected from its monitoring network, from third parties and derived by analysis. These data represent an enormous investment of time and money amounting to millions of pounds per year. This report concludes that it is our responsibility to extract the maximum benefit from this investment and makes the following recommendations.

Sharing data between local teams for river basin management

In 2007, when the bulk of the data on this project was collected, nearly two-thirds of the 150 GIS layers collected were not accessible to staff working in the Frome-Piddle. Area teams working on PoMs for river basin management planning need to know what data other teams hold and how to access them.

The cost of collecting data related to the management of diffuse rural pollutants for the two catchments on this project was about £25,000. If this is typical, the cost of making the data that we already hold available to the local teams across the country who are implementing the Water Framework Directive will be considerable.

We are starting to make national and regional datasets accessible, for example via the central data store, the planned regional data store, the Easimap, and the WFD objectives and measures database. But we still need to do this for local datasets and GIS layers.

We recommend that the relevant teams, probably the Area environment planning teams and the national data and information team, find a way of satisfying this need for a local repository of shared data. This could be done by expanding the Environment

Agency's existing data management procedures. Three options are described in Section 4.2.4 of this report as initial ideas for discussion.

Metadata increases the value of our data

Good metadata is essential to derive the maximum benefit from the data held. Few of the 150 datasets collected in 2007 had any metadata associated with them. This is likely to result in duplication of effort as several users collect the same metadata. But if metadata is recorded at the same time as the collection of the original data, the effort is minimal compared to creating it later.

We recommend that metadata be collected routinely using standard operating procedures and that the formal data management structure described in the Environment Agency's guidance (Section 4.2.3) be put in place at all levels for river basin planning.

IPR and licensing issues are obstacles to maximising our data investment

Some datasets are inaccessible because of licensing and intellectual property right (IPR) issues. Major changes in data protection legislation and the Environment Agency's data acquisition procedures are needed to resolve these issues but, to maximise the benefits from our data investment, we should be prepared to tackle them.

Use of GIS

The GIS developed on this project brought together useful national and local datasets from several sectors and functions (fisheries, conservation, agriculture, water management, flood risk and so on). The lead Area user reported that this improved local investigations and communication between staff.

Local Issues Tool

A GIS tool was developed in 2007 at the request of the Area staff in the Frome-Piddle as a trial method for mapping and making accessible local information that would otherwise not be recorded digitally, although the recently developed FARMS database will allow this type of local information to be recorded for agricultural issues.

We will provide feedback on the further trialling of the Local Issues Tool to the Environment Agency's data and information manager and GIS business change manager, and consider other options available for Area staff to record this kind of information.

Access to GIS and modelling results

The majority of local users of GIS said they did not want to spend time learning how to customise ArcGIS or use complicated tools. Users wanted easy access to GIS layers, for example via the Environment Agency's Easimap system, which could be expanded to include more local datasets. In addition, they wanted access to in-house expertise for GIS analysis and modelling results related to their local issues.

We recommend that Area managers consider whether their staff would benefit from access to this in-house expertise.

We also recommend that any future proposals for data and information management for river basin management planning and the WFD have the capability to be displayed on a geospatial basis.

Initial trialling of modelling tools

The data collection and organisation aspects of this project consumed the majority of the time available. Hence, most of the conclusions are related to data and GIS issues. However, we carried out some initial trialling of selected models and recommend that

the following models be investigated further in the next phase of the work: SCIMAP, NEAPN and PSYCHIC, TOPCAT-NP and AVGWLF.

Acknowledgements

Contents

1 Introduction

1.1 History and context of the project

This report summarises a project run under the Environment Agency's Integrated Catchment Science (ICS) Programme. The majority of this report refers to work undertaken by Entec and the Environment Agency's Science Group between January and April 2007 and some later work in 2008. Additional contributions to the overall project are included from other consultants and university departments.

The requirement for this work was established during a previous Environment Agency scoping study for integrated catchment modelling (Environment Agency, 2008). Part of this previous work involved a series of workshops at which many issues related to ICS were raised. This led to the development of a project specification and the lengthy process of agreeing intellectual property rights (IPR) issues related to the wide range of data sources that would be required.

The major driver for this project is the EU Water Framework Directive, which has set objectives for the UK to manage the most serious pressures on water quantity, quality and ecological status by 2015. Additional drivers include the Nitrates Directive, requiring an agricultural programme of measures within Nitrate Vulnerable Zones, and the Freshwater Fish Directive which considers action required by water companies and other bodies to reduce pollution impacts on fish.

Agricultural diffuse pollution is considered to be a major cause of deteriorating water quality, especially in the chalk streams of Southern England. Long-term trend analysis of nitrate in surface and groundwater has shown substantial increases since the 1940s. Studies show that phosphate levels have trebled since 1955 on the Hampshire Avon, with around 40 per cent coming from sewage treatment works, 43 per cent from agriculture (split equally between inorganic fertiliser and livestock sources) and the remainder from atmospheric and natural sources. (Defra, 2003). Agricultural soil erosion is leading to elevated loads of sediment entering rivers, which increases turbidity and siltation and can have adverse impacts on invertebrate and fish communities.

1.2 Purpose

The Water Framework Directive (WFD) requires an integrated approach to catchment management so that ecology, water quality and water quantity are considered in combination. Management actions that help us achieve the environmental objectives of the WFD are called measures and each River Basin Management Plan will include a programme of these measures.

The long-term aim of this work is to identify ways to support the development of programmes of measures (PoMs) using a 'whole catchment' approach. However, to do this for all aspects of water management in a catchment was beyond the scope of this project. Instead we focused on diffuse pollution, which the WFD has identified as a major issue in the Frome-Piddle and in many rural catchments across the country. Diffuse pollution is dependent upon a variety of processes: agricultural management, sediment transfer, groundwater flow, surface water flow and land use change, and so it is an appropriate example for trialling a 'whole catchment' approach and bringing together relevant information from several Environment Agency teams.

The work is planned over several phases. This project covers Phase 1.

1.3   Objectives

In February 2007, the Project Board agreed the following objectives:

1. Gather data and build a pilot Geographic Information System (GIS) and, working closely with Area staff, test its usefulness for the management of land use change and diffuse pollution in the Frome-Piddle.

2. Identify and summarise relevant previous work.

3. Investigate the usefulness of selected spatial and time variant models for estimating the effects of land use change on nutrient concentrations in the Frome-Piddle.

This followed a field visit with the Catchment Sensitive Farming (CSF) officer, a workshop with Area staff from several different Environment Agency functions who had local knowledge of the issues in the Frome-Piddle and a meeting of the Project Board.

The Project Board also agreed that:

- The project would consider the following diffuse pollutants: nitrate, phosphate and sediment.

- Catchment Sensitive Farming (CSF) officers in the Frome Piddle and Hampshire Avon would represent the end users for whom the data collected in the GIS would be developed.

Area staff on the Frome-Piddle used and appraised the data and GIS during the project and will continue to do so in subsequent phases. As a result, the main outputs from this project are the learning and experience gained by science and Area staff working together, to identify data and assessment tools useful in the management of diffuse pollution.

Subsequent phases will investigate approaches to identify local measures worthy of investment in the second round of the WFD. The recommendations from this project should shape some of this subsequent work.

1.4   Contents of this report

Section 2 describes the field visit and workshops held during the course of the project. These were used to help establish the scope of the work and the objectives, refine the outputs, develop the GIS with CSF officers and gain feedback from participants.

In Section 3 the methodology and structure of the GIS are described and a GIS tool for displaying notes and photographs about local issues (the Local Issues Tool).

Section 4 discusses the main data and GIS issues raised during the project.

Section 5 provides a brief review of the literature to identify other relevant work, and in particular modelling tools that may be useful in catchment-scale management of agricultural diffuse pollution. Details of the initial trialling of three such models are presented.

The conclusions and recommendations are presented in Section 6.

Appendices include A, which contains notes of the Hampshire Avon field visit, B which presents the user requirements analysis summary, C which contains a list of the GIS layers, D which details the contents and user instructions for the accompanying DVD, E which details the metadata file structure, F which presents the literature review, G which details the trialling of three models with potential application to integrated catchment management and H the feedback from the lead user in the Area.

A list of abbreviations and references can be found at the end of the report.

2 Field visit and workshops

2.1 Field visit to the Hampshire Avon

A field visit was made on 6 February 2007 to the Hampshire Avon catchment, with Melissa Robson (CSF officer), Paul Hulme (Environment Agency Project Manager) and Michelle Walker (Entec). The purpose of the visit was to see some representative sites relating to a range of nitrate, phosphate and sediment problems, both at source and impact sites. The visit gave a valuable indication of the nature and extent of catchment management problems relating to these three pollutants. Notes from the field visit are given in Appendix A.

2.2 Introduction to the workshops

A key feature of this project was the involvement of a range of Environment Agency staff and external stakeholders, both through the steering group and via a series of workshops held in the South West in February and March 2007.

The first workshop, which mainly involved Environment Agency and Entec staff, collected feedback on the requirements for the project. This was followed by a series of smaller meetings with CSF officers in Blandford. The aim of these meetings was to obtain specific feedback on the development of the GIS as it progressed, and to examine which GIS layers were of particular use. The final workshop, in March 2007, involved a wide range of interested parties to obtain feedback on the full GIS datasets and tools developed.

2.3 Workshop 1 - User requirements feedback

The first workshop was held in Exeter in February 2007 and provided the opportunity to carry out a structured user requirements analysis. Participants were asked to complete a questionnaire aimed at identifying key requirements for the current project and future work. This ensured that the likely end users of the data and the GIS could identify what they wanted and what obstacles they envisaged. The exercise generated valuable responses and helped to refine the project objectives. Appendix B contains a summary of the feedback obtained from the first workshop.

Participants were asked what they considered to be the benefits of the GIS, and the responses included:

- a tool for communication;
- a method of visualising sources, impacts and risks of diffuse pollution on the same map;
- helping prioritise the deployment of resources, such as locations of monitoring;
- a map showing related data, work and reports within the catchment of interest.

Participants were asked what they wanted to see from this work and their responses are summarised below under the headings of data, GIS and end-users.

2.3.1 Data

The data requirements identified by workshop participants included geology, land use and soils data as well as local model outputs, detailed water quality and topographic data. A full list of the data requirements is included in Appendix B. Organising these datasets so as not to overwhelm the user was a key challenge. Providing good metadata (Section 3.3) about the limits, assumptions, and ownership of datasets, and links to relevant reports and interpretation documents helps with this.

Other issues raised included the ability to update datasets, slow network and system speeds when using large datasets, and the need for training to understand and interpret the data which is currently available.

The need for improved accuracy and greater resolution of datasets was highlighted as a longer term issue.

2.3.2 GIS

Participants said they wanted to be able to capture local knowledge within the GIS, both for modelled data and to record events and experiences within the catchment. This was to help guard against knowledge being lost when staff moved on.

Feedback was mixed on whether the GIS should be standalone or available on the Environment Agency network. Many people requested monthly updates on CD or similar.

Users said they would like the data to be accessible in GIS form to both the casual user, for example via a system like the Easimap, and to the user who wants to use the analytical power of ArcGIS.

GIS training and access to GIS software was highlighted by many people as a requirement to derive benefit from the full range of data available. However, the Environment Agency is putting a hold on new ArcGIS licences and offering Easimap as a web GIS solution for the casual user. This will not provide the full GIS functionality and customisation options that ArcGIS offers.

2.3.3 End-users

The immediate aim of this project was to make the GIS datasets available to Environment Agency Area staff. In the longer term external parties involved in river basin management planning under the WFD such as Natural England, local liaison groups, water companies, local authorities, farmers and land owners may be interested (subject to confidentialities and licensing requirements). At its meeting in February 2007, the Project Board decided that the CSF officers would act as the representative end-users for this project. The CSF officer role is the closest to that of a "catchment officer" that currently exists in the Agency.

Participants also felt that the approach being developed in this project for diffuse pollution could be applied to other issues. For instance the Catchment Flood Management Plan (CFMP) officer, Felicity Liggins, said that this kind of GIS, where data from a variety of sources and at a variety of scales is gathered in one place, would be useful for her work in flood risk management.

2.4   CSF workshops

Three smaller workshops were held with various CSF officers for the Hampshire Avon, Frome and Piddle catchments, in Blandford and Exeter. The purpose of these smaller meetings was for our consultants (Entec) to demonstrate the data collected and tools developed to the users. These meetings also provided an opportunity for the CSF team to provide feedback on the Local Issues Tool (Section 3.4).

2.5   Workshop 2

Attendees of the second workshop included a range of Area, Regional and National Environment Agency staff as well as peer reviewers and other interested parties from outside the Environment Agency. The main aim of the workshop was to demonstrate progress and to obtain feedback.

Entec presented the draft conclusions and recommendations of the project, and gave a demonstration of the GIS including the Local Issues Tool. There were also presentations on how GIS is being used in Cornwall for strategic planning and the other modelling tools investigated on this project. The presentations generated much discussion, particularly on the use and customisation of the GIS, as well as raising issues relating to data ownership, quality control, confidentiality, uncertainty and data organisation and management. This feedback forms the basis of many of the final conclusions and recommendations presented in Chapter 6.

2.6   Peer review

Three peer reviewers (Paul Whitehead (University of Reading), David Lerner (Scott Wilson and University of Sheffield) and Steve Ormerod (Cardiff University)) were engaged to carry out the following tasks:

- Attend the final workshop at Blandford Forum in Dorset in March 2007.

- Review the final report.

- Review the GIS outputs produced by the project.

The reviewers were asked to address the following questions:

- What value has been added to the Environment Agency's capability to manage catchments under the Water Framework Directive (WFD)?

- Have we chosen the right tools and what others should we consider for review?

- Has anything been omitted that you would like to see included?

- Are you confident in the data and its analysis?

- Have the outcomes of the project met the stated objectives?

- Do you feel confident in the conclusions and recommendations?

- Are there any other comments you wish to make?

As well as their formal written reviews, the peer reviewers also made useful suggestions as the project progressed.

3   GIS data and tools

This chapter describes the GIS and metadata spreadsheet created during the project and are on the DVD that accompanies this report. They were produced after detailed discussions with and feedback from Area staff in their local offices.

Four main phases of work were carried out, detailed in Sections 3.1 to 3.4:

- gathering the data;

- developing the GIS and organising the layers;

- looking for metadata;

- developing the Local Issues Tool.

3.1   Data gathering

This part of the project proved to be the most time-consuming. The consultants spent about 50 days (i.e. almost 0.25 FTE) collecting and organising data that the Environment Agency already holds. This involved visiting potential data providers, discussing data sources, telephoning further leads, and reading background reports related to data modelling. A list of potential datasets and key contacts had been prepared at the start of the project. Each contact was very helpful, and often provided several other contact names or potential data sources, not all of which could be followed up in the time available.

Datasets were collected from National, Regional and local Environment Agency sources and from Entec staff who had worked on relevant GIS projects for the Environment Agency. A lot of data were provided in non-GIS form, such as spreadsheets and databases, which then had to be processed and geo-referenced to bring them into the GIS. Large volumes of data were provided from which key data were identified.

Environment Agency staff, particularly those trying to source data from other functions, must encounter similar problems. If there is no one person to co-ordinate this effort, staff time can be wasted as multiple functions collect and work with similar, or even the same, datasets in isolation from each other.

The ArcGIS project on the DVD accompanying this report focuses on the Frome and Piddle catchments and contains roughly four gigabytes (Gb) of data. Many tens of gigabytes of data for other areas or those which arrived too late for inclusion in the GIS are stored in the project archive. Nevertheless, less than 50 of the 150 data layers in the GIS on the DVD were available on the Environment Agency's regional I:\ drive.

The Environment Agency reviewed the complex intellectual property rights (IPR) related to the project and the consultants signed a background rights agreement, which set out the intellectual property statements for key datasets and specified any clauses regarding end use. Nearly all the data collated by the consultants are included on the project DVD. The major exception is the GeoSure data because the Environment Agency's license expired during the project

There is no intention to provide the data or the GIS to parties outside the Environment Agency at this stage. But if this is envisaged in the future, it will raise many IPR and licensing issues on Environment Agency and third party data.

The management and proper acknowledgement of IPR was undertaken using metadata management (Section 3.3).

3.2   GIS project and layer organisation

The data collected was assembled in the ArcGIS project *MIA Frome Piddle.mxd*, which can be found in the folder \ArcGIS on the DVD that accompanies this report. This GIS project contains a large amount of data for the Frome Piddle catchments, relating to diffuse pollution. To make it easy to locate particular datasets, the data is organised into various layer groupings as follows: local, nitrates, phosphates, sediments, sources, receptors, hydrology, water resources and reference. Further details of the data contained in each of these groupings and more information on installing and opening the ArcGIS map documents is contained in Appendix D.

Example displays of the nitrates and sediments datasets in the GIS are shown in Figures 3.1 and 3.2 respectively.

An Excel spreadsheet (*metadata.xls*) was used to record information about the data layers that were collected. Within this spreadsheet the layers have been organised into the same layer groupings as in the GIS (local, nitrates, phosphates and so on) so that individual datasets can be located and identified easily. In addition, each layer has been given a fully descriptive name to aid data understanding and sharing. Refer to column I (Layer name) in the spreadsheet (*metadata.xls*) for examples. The spreadsheet is on the DVD accompanying this report and selected parts of the spreadsheet are shown in Appendix C. More information on metadata is given below.

3.3   Metadata

Metadata is essential information about where data comes from and what it is for. A good metadata record will tell the user the source of the data, who collected it, when it was collected and for what purpose, its strengths and limitations, the structure and format of the data, licensing or IPR information and who the data custodian is.
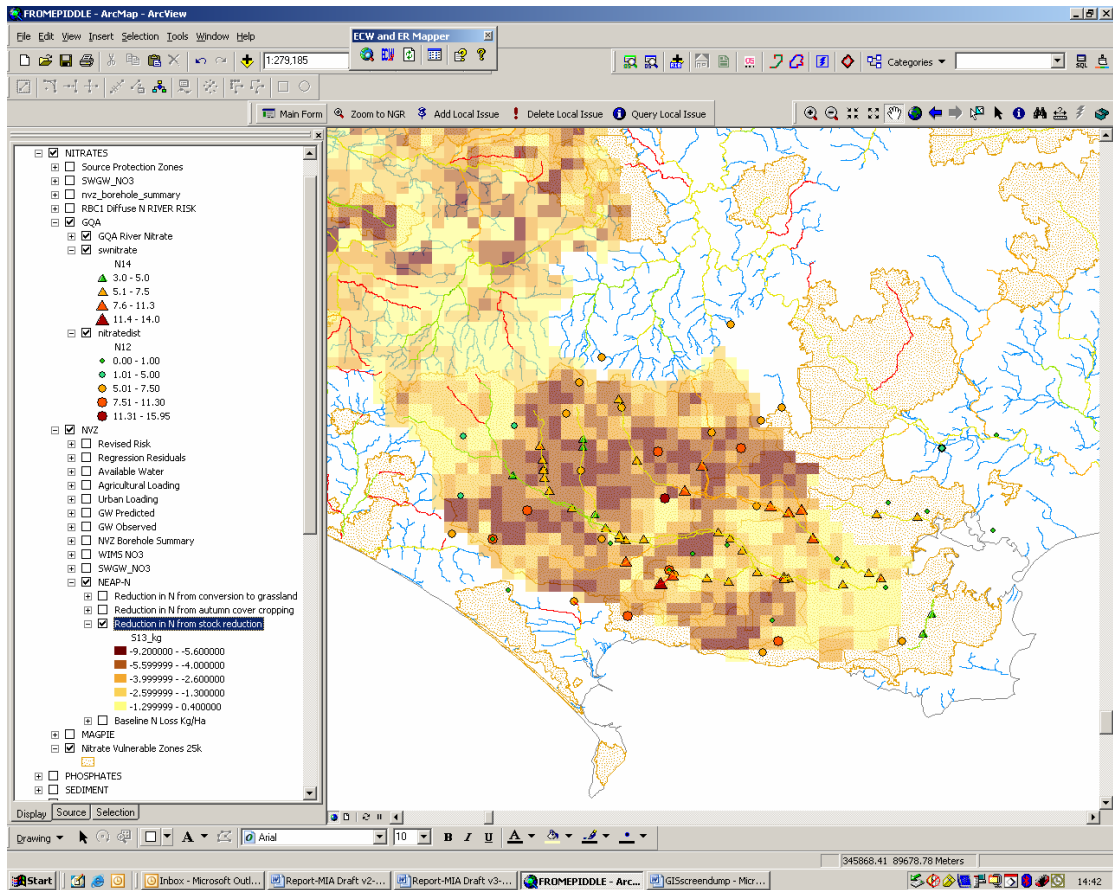
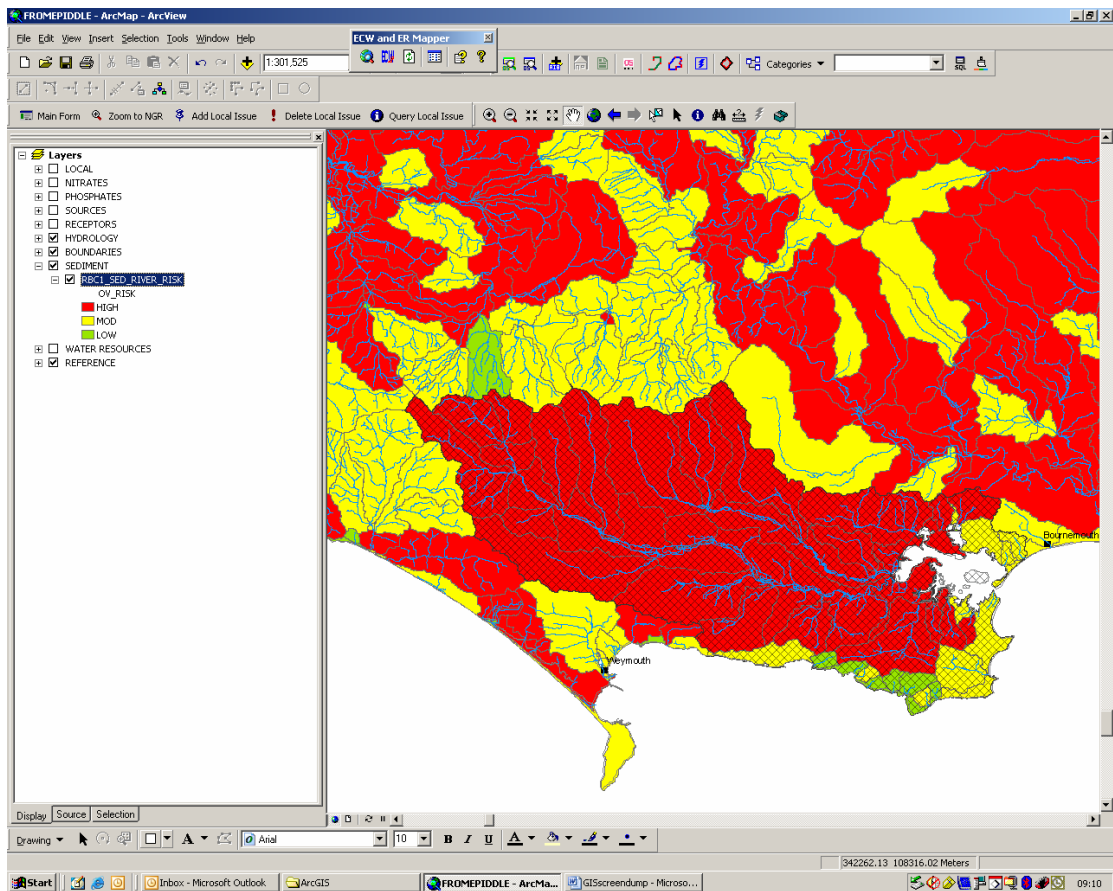**Figure 3.1 Example of selected nitrates datasets in the GIS**

Figure 3.2 Example of sediments dataset in GIS

The benefits of metadata are discussed in Section 4.2.3.

Virtually no metadata were supplied with any of the GIS layers gathered during early 2007, regardless of their source (Environment Agency, Entec or third parties).

We were able to find some of the information required by looking on the internal Easinet system. However, this was far from comprehensive, and little information was available to help the end user interpret or understand the various datasets. Additional information was gleaned from the Environment Agency's metadata Access database, which is on the I:\ drive. For the remaining information, it was necessary to track down the data custodians and modellers who understood the purpose and nature of the data.

In addition to the spreadsheet (*metadata.xls*), which summarises the basic metadata for each data layer in the GIS (see Section 3.2), we were able to collect full metadata records for a subset (15 out of 150) of the GIS layers in the time available. These contain detailed information, conforming to the Environment Agency's UK Gemini Plus standard. The full metadata (xml) files can be accessed in one of two ways:

- Via ArcCatalog from within the GIS project: the metadata are located with the shape files, or in the case of grids, within the grid folder.

- From within the metadata spreadsheet (*metadata.xls*): for the layers that have full metadata the 'Layer Name' is 'hot-linked' to the same ESRI style sheet that can be viewed via ArcCatalog. This provides the opportunity to browse the metadata with a user friendly browser format, without the need for ESRI software.

For the remaining layers, the metadata spreadsheet contains the key metadata descriptions, that is, the data custodian and source, layer and file names, display scale, coverage and an indication of whether the data are observed (measured) or derived (modelled).

Key reports and other supporting information have also been 'hot-linked' from within the metadata spreadsheet.

Full details of the two worksheets in the metadata spreadsheet (*metadata.xls*), including definitions of the column headings, can be found in Appendix D, and specific details of the full metadata xml files in the ArcGIS project (*MIA Frome Piddle.mxd)* are contained in Appendix E. The digital files are on the project DVD.

3.4   Local Issues Tool

Area staff at the first workshop said they would like a tool to capture knowledge about local issues following their field visits. This would enable easy and rapid recording of information about diffuse and point source pollution, which Catchment Sensitive Farming (CSF) officers collect on a daily basis. This information is usually not significant or serious enough for recording in the Environment Agency's National Incident Reporting System (NIRS), nor in any other Environment Agency database. And so the information remains in the notebooks or minds of the field staff where it is largely inaccessible to others who may find it useful. The CSF officer involved in this project reported that CSF staff often record this information informally, or not at all.

We wanted to ensure that this wealth of local knowledge on the sources and impacts of pollution could be recorded so that it could be used to investigate the spatial patterns of pollution, so that staff in other parts of the Environment Agency could access it, and so that it would not be lost when staff left.

By working closely with local CSF staff, Entec developed a pilot "Local Issues Tool". Being a pilot, it was designed to work on a standalone laptop, which meant it could be produced more simply and much more quickly than if it had been designed to work on the Environment Agency's network. It also meant that CSF staff had to take responsibility for the backup and management of the data.

Figure 3.3 shows an example of the type of information that can be recorded using the Local Issues Tool.
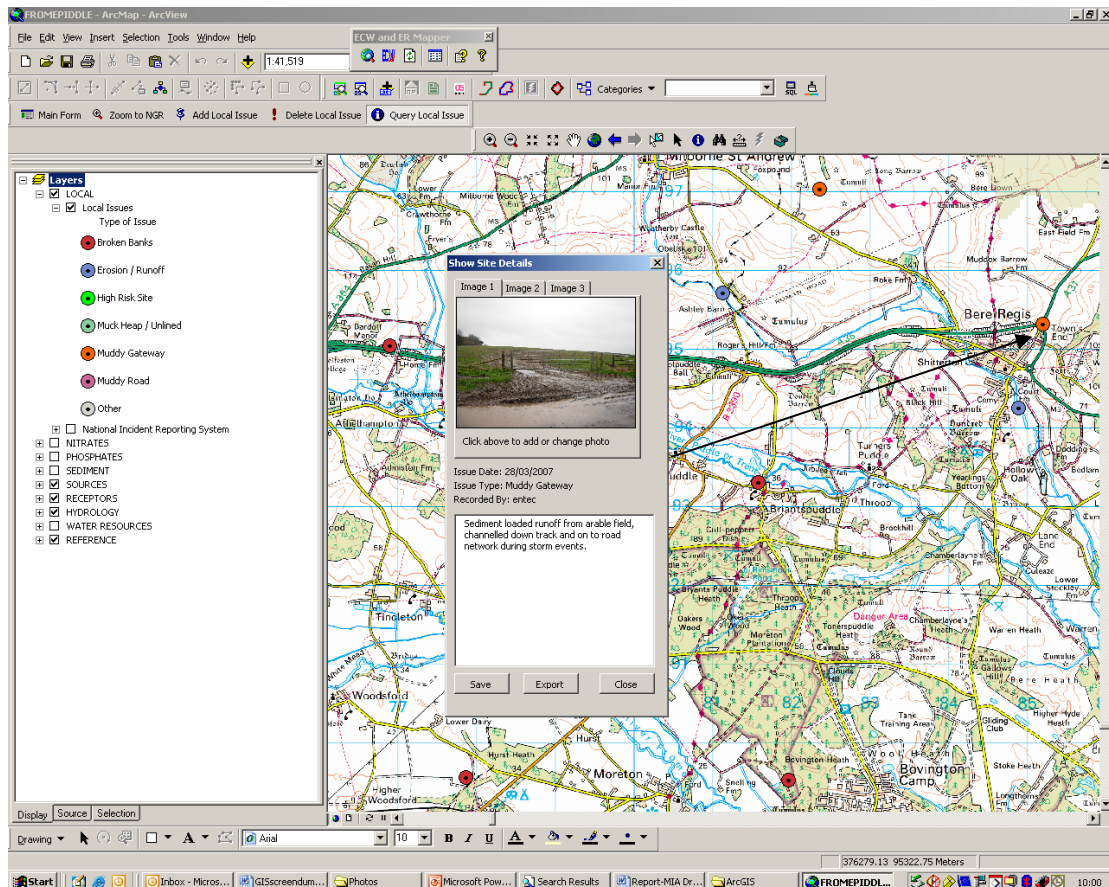
Figure 3.3 Local Issues Tool

Detailed information on how to use the Local Issues Tool can be found in Appendix D.

4 Discussion of data and GIS

Most of the work described in Chapter 3 was done in early 2007 and focused on the Frome and Piddle catchments. Since then, some of the lessons learned have been applied to the Blue Knot study on the River Parrett in Somerset (Entec, 2007) and to collaborative work with the Environment Agency's environment planning team in Penrith.

Two major areas of our work on this project are related to Objective 1 in Section 1.3:

- Collating data that the Environment Agency already holds from a variety of teams to support the selection of measures for the Frome-Piddle.

- Developing a GIS framework focusing on nitrate, phosphate and sediment issues in these two catchments.

This chapter discusses the implications of this work in early 2007 in the light of feedback from other parts of the Environment Agency, and from our Project Board member in the national data and information team in particular, on recent developments in data management.

The chapter begins with a summary of feedback from the lead user in the Area.

4.1 Feedback from the Area lead user

Melissa Robson, a CSF officer in the South West until February 2008, was the lead user on the project. She provided written feedback on her use of the project outputs in June 2007 and January 2008 (see Appendix H). The main points from Melissa's feedback are:

- The GIS has brought together in one place, a wide range of datasets from several Environment Agency sectors or functions, (surface water, groundwater, fisheries, conservation, flood risk and so on).

- This has made it easier for Melissa and her colleagues to investigate hypotheses and look for patterns in these data in ways that had not previously been possible.

- For example, they were able to:

    o Look at nitrate, phosphate and sediments pollution from all sources.

    o Review and amend catchment appraisals, which aim to identify what and where the main problems are within a catchment and where to target resources.

    o Evaluate data and model outputs from other sources.

- The GIS made data available to Melissa that she had not seen before, such as national datasets from WFD studies, soils maps and modelling data. In addition, data from the Environment Agency I:\ drive were given intuitive labels.

- Melissa used the Local Issues Tool to record experiences and local knowledge of problems and issues in a catchment which had not been recorded before and therefore would be susceptible to loss when staff left. Typical issues recorded were small scale run-off from a field, a muddy track, soil wash from a field, broken road banks or ill-sited intensive outdoor pigs. These are not 'incidents'

and hence are not recorded on the National Incident Recoding System (NIRS), but they are locally significant pollution issues or potential ones.

- The project demonstrated the importance and usefulness of metadata.

- Many measures to deal with pollution from nitrates, phosphates and sediments will be at the field scale and data will need to be collected and made available for analysis at this scale. It would be useful to conduct trials on moving from catchment-scale plans to field-scale measures.

- We will need to find methods for identifying the relative contribution from each source of a pollutant when we select local measures.

4.2   Data

At Project Board meetings and local workshops we were asked what we thought 'data' was. For instance, did it include results from models, or should the word 'data' only be used for raw observations? We agreed that many, if not the majority of, useful datasets were not simply raw observations. For example, land use maps show a snapshot in a particular year; soil maps bundle the soil types found at a sampling point into soil associations across a one km square; rainfall maps are interpolations of rainfall from individual gauges, and so on.

We agreed that in this study 'data' comprised raw measurements and any data derived from measurements, including:

- raw data interpolated or aggregated data in some way;

- data derived from the analysis of other data, such as water balances;

- results from models.

In addition, we suggested that metadata was an essential component of any dataset because it dramatically increased the value of the data (Section 4.2.3).

INSPIRE and Digital National Framework

Since the original work in 2007, we have learned of the Infrastructure for Spatial Information Repository in Europe (INSPIRE) Directive and the UK's Digital National Framework (DNF). National bodies including the Ordnance Survey, Department for Environment, Food and Rural Affairs (Defra), Natural England, the UK Hydrographic Office and the British Geological Survey are working on the DNF, which is a proposed industry standard for making data 'interoperable', enabling the integration and sharing of business and geographic information from multiple sources. It is likely that the UK will use many of the principles and rules of the DNF to implement components of INSPIRE. The recently developed Detailed River Network was created to DNF standards.

One member of the Project Board works in the national data and information team and he provided valuable insights and contributions to this section of the report. We recommend that this link is maintained for the next phase of this work

4.2.1   Data investment

As an evidence-based regulator, good data is our lifeblood (Appendix A of the Environment Agency's data and information strategy, Environment Agency, 2007c). One of the project's peer reviewers emphasised that the Environment Agency's operational work needs to be data-led and that staff should have full access to data and be fluent in the use of the relevant data-handling tools.

The Environment Agency holds a large amount of data collected from its monitoring network, bought or licensed from third parties such as the British Geological Survey and the Meteorological Office, and derived from further analysis of existing data. These data represent an enormous investment of time and money amounting to millions of pounds per year. It is our responsibility to extract the maximum benefit from this investment.

If we are to fully exploit the benefits of our data for river basin management, simply holding the data is not sufficient. We must make the data accessible to the Area teams who are implementing the WFD.

4.2.2   Data accessibility

In early 2007, most of the data collected on this project were not accessible to the Area staff responsible for the management of nitrates, phosphates and sediments in the Frome and Piddle catchments. Less than 50 of the 150 data layers in the GIS on the DVD (*MIA Frome Piddle.mxd)* were available on the regional I:\ drive.

This project gathered several tens of gigabytes of data that the Environment Agency already possessed and organised about four Gb of these data into the GIS on the project DVD (*MIA Frome Piddle.mxd*). This activity required more than 50 days of the consultants' time at a cost of about £25,000 (Section 3.1). It focussed on data relevant only to the management of nitrates, phosphates and sediments in the Frome and the Piddle catchments.

If this scenario is typical, there are likely to be considerable costs across the country in making available data already held to support the selection of local measures under river basin management planning. If the data is not made available, this is likely to lead to delays in decision-making. Reasons for the inaccessibility of the data are described below.

Since 2007, there have been developments in the storage and accessibility of national and regional data. Extensive internal guidance on data management is available on the Easinet system (for example, 43_05 Data Custodianship Guidance); there is a central data store (CDS) although the data on it cannot yet be used with ArcGIS so the I:\drives are still in use; regional data stores (RDS) are planned; summaries of the data collated for the risk assessment and classification stages of the WFD have been made available on the Easimap system; and the objectives and measures database, which houses the most recent WFD data, is available on request from the data and information team.

In future, it should be possible to request that national and regional data be made available on the CDS or the planned RDS to make them accessible via ArcGIS and the EasiMap.

We have agreed to provide feedback to the national Data and Information Manager, Alex Coley, as we use these new national and regional data sources in the next phase of this project and also trial any relevant new systems.

The accessibility of local data is discussed in Section 4.2.4.

IPR and licensing issues

Unresolved licence restrictions and IPR issues have prevented access to some existing data. For example, the Geosure dataset could not be used because the licence expired during the course of this project. IPR issues meant that the Centre for Ecology and Hydrology (CEH) river network data could not be included in the GIS, although the Environment Agency has since resolved this problem by developing its own Detailed River Network. But the general issues remain.

Major changes in data protection legislation and the Environment Agency's data acquisition procedures are needed to resolve these licensing and IPR issues.

Agricultural census data

Agricultural census data is a ten-yearly record of how land use is divided up at a farm address. It has been used to produce a one-km^2 grid of land use across the country.

Neither of these datasets provides the land use for each field. Probably the best way to obtain current information at the field scale is to visit and visually inspect the fields in question or use aerial photography.

Both datasets are subject to strict confidentiality agreements with Defra. We are allowed to publish derived data, such as a map of phosphate fertiliser applied to different parts of a catchment, but only if it is not possible to deduce the original land use data.

The one-km^2 grid has been used to produce catchment-scale risk maps and could be used as input for source apportionment modelling at the catchment scale.

4.2.3   Metadata

Good metadata is essential. It provides information about where data comes from and what it is for (Section 3.3). If the user knows who produced the data, he or she is likely to obtain this information directly from the originator. If not, this information needs to be obtained from the metadata.

Benefits

The fundamental importance and basic requirements of good metadata records are summarised in the Environment Agency management system document (*Guidance on metadata to be recorded*, 213_05).

The Environment Agency's flood risk management team has produced its own guidance document (*Flood risk management metadata standards*, 199_07) which lists the main benefits of metadata as:

- A searchable inventory of data holdings, allowing data reuse and providing additional information sources to staff.

- A record of the legal implications of the data, such as data protection implications, copyright and licensing arrangements, quality definitions, intellectual property rights ownership.

- A record of data custodians, which gives staff a point of contact for data.

- A tool to enable us to meet some of the Freedom of Information obligations.

ESRI (2002) lists the following additional benefits as:

- A means of recording the limitations and usefulness of the data.

- A means of determining when money will need to be spent on updating data.

Inadequate metadata records

Few of the 150 datasets collected in 2007 had any metadata associated with them (Section 3.3). The Environment Agency is striving to make sure there are metadata records for large national datasets, but this does not address the local datasets which are crucial for supporting local measures.

Without good metadata users may not have sufficient confidence to use the data, may use it inappropriately or may have to collect the information themselves. This may result in duplication as several users collect the same metadata.

Collecting metadata for an existing dataset typically involves tracking down the data originator, which can be laborious and expensive. If metadata is recorded at the same time as the collection of the data, the effort is minimal compared to creating it later.

The Environment Agency needs to ensure that all future datasets have an appropriate metadata record. This should be achieved by the development of a metadata culture, in line with national policy statement *Managing data and information* (26_02 V.3). This process, which is not equally developed across the organisation at present, could be based on the approach being used in flood risk management (FRM).

The FRM team has produced a number of instructions and guidance documents that build on those of the national data policy team, and has recognised the importance of good data management by creating a formal data management team at Area, Region and National level. These teams have a remit to ensure that any datasets collected within FRM are recorded in accordance with best practice.

We recommend that the collection of metadata, following Environment Agency guidance, be made part of standard operating procedures, and that time for metadata entry is included on the project plan for every GIS operation. In addition, we should consider developing a generic data management plan for all projects, as currently required within flood risk management (FRM).

Initiatives such as INSPIRE and the DNF have identified metadata as key to data sharing, without which effective geographical data services will not be able to operate.

4.2.4   Local data management

Several of the issues discussed above relate to data management and those responsible for it. The management of national or regional data were discussed in Section 4.2.2. This section discusses issues related to the management of local data.

The following internal Environment Agency documents provide guidance on the key roles and responsibilities for the management of local data:

- 143_05 *Data custodianship guidance*

- 144_05 *Data originator and line manager terms of reference*

- 145_05 *Local data custodians terms of reference*

- 213_05 *Guidance on metadata to be recorded*

and the strategy document:

- *A data and information strategy for the Environment Agency* (Amended DT Paper-strategy-080507).

Data originators create, maintain and review the quality of datasets and their associated metadata, and their line managers ensure the quality of their work.

Local data custodians act as a focal point for data originators; advise users; identify opportunities to improve the data; ensure that metadata is complete and up-to-date; and are aware of legal issues, such as licensing and IPR (see guidance document 145_05 above).

If this guidance is followed, then every local dataset (unless it is only temporary) including layers created for a GIS should have a local data custodian. The custodian should also act as the primary point of contact for other users.

Making data available across functions or sectors

The Area lead user on this project, Melissa Robson, stressed the benefit of GIS in bringing together a wide range of datasets from different sectors, or functions, (fisheries, conservation, agriculture, water management and so on). This allowed the data to be accessed in one place and shared more readily by people working in different sectors. The use of datasets across sectors is an essential component of integrated catchment management and lies at the heart of the Water Framework Directive.

Phosphates, for example, enter our watercourses from many sources and via several pathways. No single Environment Agency team controls all the relevant data.

The GIS developed on this project in early 2007, was the first repository which brought together cross-sector datasets relevant to the management of nitrates, phosphates and sediments for staff in that Area office. Several other staff in the local workshops said that a similar GIS would be useful for their own areas of work.

Since 2007, we have given the GIS to the environmental planning team in Penrith in North West region. They had already created a position in the team with responsibility for collecting similar cross-sector data, and wanted to see how we had used the GIS to organise the data.

Area teams working on programmes of measures for the WFD will evidently need to know what data other teams hold and how to access them via some sort of repository of local data. Such a store of local data could be real or virtual, as described in the three options below:

1. Option 1: A common local server where all Area teams could store their data. For example, some Regions already have an area of their I:\ drive where they can share data or they could they use shared G:\ drives.

2. Option 2: A space reserved on the regional data store (RDS) where all Area teams could store their data.

3. Option 3: A virtual store. This could be a list of all the local data in an Area, perhaps in a spreadsheet like the one described in Section 3.3 of this report, giving some basic details of each dataset and crucially the custodian and location of the dataset.

Each of these options would require different management:

1. Option 1: Someone in the Area would need to manage the local server.

2. Option 2: The manager of the RDS would manage the Area's data.

3. Option 3: Someone in the Area would be responsible for managing and updating the spreadsheet and making it accessible via a shared drive, for example the G:\ drive. The data themselves could be managed by each team in the same way as they are now. This is the simplest of the three options.

We recommend that these options are discussed by Area environment planning teams, given that they are responsible for the cross-sector planning required by the WFD, and by the national data and information team, because they will be able to write the appropriate guidance.

These options should also be considered when developing the strategic data management solution for WFD and river basin management planning nationally.

Co-ordinated management of local data from different sectors should also lead to more users of the data and less duplication of effort.

Encouraging communication across functions or sectors

Once data is made accessible across different sectors, it could be used to encourage communication between the staff in those sectors on overlapping issues, such as rural diffuse pollution.

We recommend that the local data custodian in each Area office is responsible for:

- Promoting awareness of datasets or maps that are likely to be of interest to other teams.

- Putting local datasets which are not suitable for storage on the RDS or CDS into the local store.

- Proposing datasets for inclusion on the RDS or CDS.

- Maintaining a repository or list of information such as reports or maps which support their data. This information is important for the proper understanding of certain datasets.

The following are some suggestions for promoting awareness of data between teams:

- Circulating the list of data layers available and informing people of new datasets that are added to the local store.

- Making sure that data from field visits is accessible via GIS to other teams.

- Arranging informal talks at lunchtime to illustrate datasets of common interest.

- Putting up hard copies of mapped data in a common space in the Area offices.

The FRM team already has staff in place with some of these responsibilities.

4.2.5   Scale

Risk assessments produced as part of river basin characterisation and related datasets are mapped to water body level, which is useful for giving a regional or national picture of risk but is not sufficiently detailed to support sub-catchment or field-scale measures.

In Section 4.1, the Area lead user pointed out that data needs to be collected and analysed at the field scale to underpin local measures.

Agricultural census data is only available to the Environment Agency once it has been aggregated to catchment level (Section 4.2.2). Local staff need this information at the farm or field scale to assess local risk and select appropriate local measures.

However, if very fine-scale information is incorporated into the GIS, it can cause problems with data storage and software performance, such as the aerial photography collected for the Frome-Piddle and Hampshire Avon. These large datasets can be handled differently by using a technique called 'image pyramids', which breaks down large image files into a mosaic of smaller tiles needed to display a specific portion of an image. This can help manage the performance of such large datasets and is expected to be available via the Enterprise systems on the Environment Agency's network.

4.2.6   Key datasets

Some potentially useful datasets which could not be located included data on:

- The location of septic tanks, which may be an important source of phosphate to water courses.

- Sediment resulting from the erosion of roads and their banks.

Given more time, it would have been possible to investigate ways of identifying the domestic properties likely to have septic tanks, for example by comparing the mains sewerage network, which the water company holds, with the Ordnance Survey address layer, which contains accurate locations of all UK properties.

Highways Agency datasets relating to roadside erosion and maintenance do exist, but not currently in a format which could be captured in the GIS within the time frame of this project.

The lead CSF officer believes that these data sources should be pursued in future phases of the project.

On the other hand, more data does not necessarily lead to better decision-making, or provide better evidence to support the selection of local measures to control diffuse pollution. In the next phase of work, we want to identify which datasets prove to be the most useful for providing such supporting evidence.

4.2.7   Sharing data externally

This project did not intend to provide data to third parties beyond the Environment Agency. In the future, if we want to share data with external organisations such as our partners on River Basin District Liaison Panels, we would need to ensure that we acquire the rights to do so. The Environment Agency is developing capabilities to deal with such issues under its INSPIRE implementation project.

4.3   GIS

As described in Section 4.2.4, we need cross-sector data to underpin our selection of measures for river basin management planning. We developed a GIS to house cross-sector data related to the management of nitrates, phosphates and sediments in the Frome and Piddle catchments. Section 3.2 describes how the GIS was used to organise and display these data prior to analysis.

The lead user from the Area described some of the benefits of having a GIS with data gathered from several sectors into one place (see Section 4.1). In addition, workshop participants recognised that GIS encouraged communication across sectors.

We recommend that any future proposals for data and information management for river basin management planning and the WFD have the capability to be displayed on a geospatial basis.

4.3.1   Local Issues Tool

The Local Issues Tool is a pilot GIS tool that was developed at the request of Area staff in the Frome-Piddle as a means of documenting, mapping and sharing local information that would otherwise not be recorded digitally (Section 3.4). There is also the potential to link the information stored in the Local issues Tool to other databases for wider analysis.

The Area lead user described the usefulness of this tool for recording such local issues (see Section 4.1) and since it was developed on the Frome-Piddle two other Area teams have asked to trial it. This illustrates that there is a wider need for this kind of facility.

In September 2008, the Environment Agency introduced the FARMS database, which allows this type of local information to be recorded for local issues related to specific farms. FARMS is not yet linked to a GIS, but since it holds grid references for every farm, it could be.

The environment planning team in Penrith is keen to test the Local Issues Tool for non-agricultural issues and we are currently advising the Environment Agency's data and information team on the tool's wider use.

We envisage using the pilot Local Issues Tool to help identify how Area staff wish to record and map this kind of local information.

We recommend providing feedback to the Data and Information Manager and the GIS Business Change Manager as we continue to trial this tool and consider the options available for satisfying the needs of Area staff in recording this type of information. Suggestions made so far include developing the tool as an ArcGIS toolbar custom-built for the Environment Agency, having a Local Issues Tool on the RDS, or using intranet mapping such as that used for Easimap on the Environment Agency's intranet.

4.3.2   GIS expertise

At the local workshops, Area and Regional staff emphasized that they did not need new tools and models but rather a better understanding of the data, model output and other information which already exists in the Environment Agency. Infrequent users of GIS identified their lack of familiarity with GIS tools and datasets as a significant barrier to using them (Section 2.3.1). This suggests a need for easy access to GIS-based data and access to expertise for analysing data with GIS tools.

Since 2007, the Environment Agency has developed the Easimap system for internal use. This provides easy access to key national and regional GIS layers but not local ones.

Suggestions for displaying and sharing local GIS layers might be dealt with in combination with ideas for a local data repository in Section 4.2.4, or via an Easimap for key local datasets. Alternatively, an Area based GIS expert could be responsible for producing GIS layers of key local datasets and storing them on the local repository.

The majority of local users of GIS said they did not want to spend time learning how to customise ArcGIS or use complicated tools.

One solution would be to provide staff with access to a dedicated GIS specialist in their Area office or in their team who could use GIS to analyse their data whilst helping them develop their own skills. The environment planning team in Penrith has assigned someone to just such a role. We recommend that Area managers consider whether their staff need this type of service and how it could be provided.

4.3.3 Further use of GIS tools GIS expertise

GIS for sub-catchment risk assessments

Deriving estimates of risk for sub-catchments was an idea raised in the user requirements assessment. This approach was trialled on the Blue Knot project in the River Parrett (Entec, 2007) and used much of the data collected during this project. The GIS was used to produce 'combined risk scores' for subdivisions of water bodies based on water quality, water resources and fisheries data. We recommend that this approach is investigated further in the next phase of the work.

GIS for external stakeholder engagement

GIS allows us to focus on a particular issue and display maps showing many different kinds of data. For example, for high nitrate levels in groundwater, we may be interested in maps showing nitrate loading due to fertiliser application, measured nitrate concentrations in groundwater and surface water, grids of soil type and land use and so on. This use of GIS forms the basis of several participatory techniques that have been used to work with local groups and decision-makers (Colvin, 2006).

Although it was beyond the scope of this project, it was suggested that controlled access to key data and maps could be worth pursuing for catchment stakeholder groups during implementation of the first River Basin Management Plans. For example, the Environment Agency and other stakeholders such as wildlife trusts or rivers trusts, could share some of their data via the internet. Filters and passwords could be used to make sure users could only access the data they were allowed to see. The Freshwater Biological Association, which is based in Windermere, has expertise in providing different levels of access and has obtained software for this purpose from the EU.

5 Literature review and trial of modelling tools for integrated catchment management

Two of the original objectives of this project were to:

- Identify and summarise previous projects relevant to integrated catchment management (Objective 2, Section 1.3).

- Investigate the usefulness of selected spatial and time variant models for estimating the effects of land use change on nutrient concentrations in the Frome-Piddle (Objective 3, Section 1.3).

However, since the data and GIS aspects of the project (Objective 1, Section 1.3) took up the majority of the time available, it was only possible to do a relatively brief search of the literature followed by an initial trial of three models.

5.1 Literature search

The results of the literature search are presented in Appendix F. Section 1 of Appendix F gives brief descriptions of several projects that may be of use to the catchment-scale management of agricultural diffuse pollution and Section 2 describes the features of some modelling tools. The review uncovered a wide range of potentially relevant projects and models and the examples in Appendix F are only a subset of the approaches available in this active and dynamic research area.

This literature review is rather broad and we recommend that the next phase of the work focuses on identifying approaches and tools for further testing in specific catchments to support the selection of local measures.

For example, SCIMAP (Section 2.12, Appendix F) seems to be a likely candidate because it aims to determine the relative risk of different parcels of land delivering diffuse pollution to a river. This information can then be used to prioritise and target measures for environmental improvement. However, in its current form it has some major limitations including being designed for use only on surface water-dominated catchments and having no time-variant capability because it uses annual averaged input data.

In identifying the candidate models or tools of use to the Environment Agency for supporting integrated catchment management, we need to consider questions such as:

- Which ones can best support a variety of Environment Agency staff, such as Area operational staff and technical specialists, regional river basin district managers and national policy makers?

- How easy they are to use and be trained in, and whether they are widely accessible?

- Which ones can best support issues at a variety of scales: field scale, catchment scale and regional scale?

- Which ones best represent which processes?

- Which ones are most compatible with existing Environment Agency software and in particular GIS?

5.2 Trial of models

GIS data and techniques are excellent for analysing and presenting spatial patterns, but they are less frequently used for handling time series or making predictions as part of 'what if' investigations. Other models are able to do these things and, when used in combination with GIS, can provide valuable information to support catchment managers in their decision making.

We chose the following three models for some initial trialling:

- The Environment Agency's Decision Support Tool (DST) for nutrient management and specifically the NEAPN and PSYCHIC components.

- Two components of Newcastle University's PROACTIVE toolkit: a set of decision support matrices and the nutrient mixing model TOPCAT-NP.

- The ArcView Generalised Watershed Loading Function (AVGWLF) model developed by Penn State University in the USA.

A brief summary of the results is given below. Further details are presented in Appendix G.

5.2.1 Environment Agency DST

The Decision Support Tool (DST) can be used to characterise agricultural diffuse pollution pressures from nutrients, sediments and pesticides and to investigate possible mitigation of these pressures by modelling the effects of land use change, such as changing arable land to grassland.

The trials carried out for this project focused on the NEAPN (nitrogen) and PSYCHIC (phosphorus and sediment) models, which calculate leaching from one-km^2 cells across a catchment. Example outputs were produced for the Frome and Piddle catchments. The baseline model outputs (for current land use) show catchment hotspots and the scenario outputs show where the best N, P and sediment improvements can be gained through mitigation.

The model outputs are predictions of catchment behaviour and need to be considered in conjunction with local observations on the ground and expert opinion.

The model is only reliably applicable to catchments over about 25 km^2 because of its one-km^2 grid.

NEAPN and PSYCHIC appear to be useful for gaining an initial insight into catchment issues and the potential effects of certain land use measures. These may help prompt discussions with catchment managers at an early stage. We recommend that their application is considered further in the next phase of the work.

5.2.2 Decision support matrices and TOPCAT-NP

Decision support matrices

The decision support matrices comprise a set of tools designed to advise farmers on the measures they can take to reduce diffuse pollution on their farms. These include

the Nutrient Export Risk Matrix (NERM) and the Phosphorus Export Risk Matrix (PERM). Although they are not models, at the request of the local CSF officer we trialled them and developed a prototype Nitrate Export Risk Matrix (NORM).

A pilot version of the PERM matrix is available to download from the website http://www.ncl.ac.uk/iq/DSM/DSM.html.

TOPCAT-NP

TOPCAT-NP is a simple hydrological model that provides time series modelling of flow, nitrates and phosphates. The model was calibrated for the Frome and Piddle catchments using readily available Environment Agency data, to assess how well the model performed as a quick assessment tool simulating catchment scale fluxes.

A good fit was obtained to the observed flow data for both catchments by dividing the active flow between a faster, shallow store in the soil layers and a slower, deeper groundwater store. Nitrate concentrations were relatively low compared to many intensively farmed areas, probably due to a combination of high nitrate inputs from farmland and low nitrate inputs from non-agricultural land. The phosphorus data was more difficult to interpret because the catchments are large (more than 10 km^2), the observed data are too infrequent to see the phosphorus losses resulting from storms and there are no observed data for total phosphorus to help with the interpretation.

The trial suggests that TOPCAT-NP could be useful for quickly investigating how nutrients may be travelling from sources to receptors, based on readily available Environment Agency time series data without the need to use GIS.

We recommend that TOPCAT-NP is considered in the next phase of work as a tool for testing whether our initial conceptual models are consistent with the observed river flow and nutrient concentrations.

5.2.3   ArcView Generalised Watershed Loading Function

The ArcView Generalised Loading Function (AVGWLF) model is a GIS-based model that predicts the loads of nitrate, phosphate and sediment in kilogrammes at specified points on streams within a catchment. The model also shows the contribution from each land use type and may therefore be a useful tool for source apportionment.

The Predict model uses the loads from the AVGWLF model and predicts the effect of introducing different mitigation measures.

These tools have several strengths, as they have a familiar GIS interface, are simple to use, and are already being used operationally. However, since they were developed for use in the US, further work is required to assess how readily they could be used in the UK.

5.2.4   Making available model results

Area staff reported that they would like to use model results but frequently do not want to run models themselves, nor do they have the time to properly train to use the many models they would like results from.

Thus, Area staff do not necessarily need new tools and models but rather a better understanding of the data, model output and other information which already exists.

We recommend that the Environment Agency finds ways of giving Area staff access to model results without having to run the models themselves. Area staff on this project said they would like to have access to Environment Agency's in-house modelling specialists and to work with them to make sense of model results in the context of their local issues. This would help make the most of the local expertise of Area staff, the Environment Agency's data and its modelling specialists.

6 Conclusions and recommendations

6.1 Conclusions

6.1.1 Data

1. The Environment Agency holds a large amount of data collected from its monitoring network, from third parties and derived by analysis. These data represent an enormous investment of time and money amounting to millions of pounds per year. It is our responsibility to extract the maximum benefit from this investment. (Section 4.2.1)

2. On this project, it cost an estimated £25,000 to organise and make accessible via a GIS, data already held on nitrates, phosphates and sediments in the Frome and the Piddle catchments (Section 4.2.1 and 4.2.2).

3. In 2007, nearly two-thirds of the 150 data layers collected in a GIS for this project were not accessible to Area staff working in the Frome-Piddle. Since then, accessibility of some national and regional data has improved (Section 4.2.2).

4. Some datasets are inaccessible because of licensing and IPR issues. Major changes in data protection legislation and the Environment Agency's data acquisition procedures are needed to resolve these (Section 4.2.2).

5. On this project, there was no intention to provide data to third parties beyond the Environment Agency. In the future, if we want to share data with external partners involved in river basin management planning, we need to ensure that we acquire the rights to do so (Section 4.2.7).

6. Good metadata is essential to derive the maximum benefit from the data held. Few of the 150 datasets collected in 2007 had any metadata associated with them. This is likely to result in duplication of effort as several users collect the same metadata (Section 4.2.3).

7. If metadata is recorded at the same time as the collection of the original data, the effort is minimal compared to creating it later (Section 4.2.3).

8. Area teams working on programmes of measures for river basin management planning need to know what local data other teams hold and how to access it (Section 4.2.4).

9. We need to collect and analyse data at the field scale to underpin local (sub-catchment or field scale) measures as part of River Basin Management Plans (Section 4.2.5).

6.1.2   GIS

10. The GIS brought together national and local datasets from several sectors and this gave rise to better investigations and better communication (Section 4.1).

11. The Local Issues Tool proved useful for documenting, mapping and sharing previously unrecorded information and there is the potential to link the information stored in it to other databases for wider analysis (Section 4.3.1).

12. Since developing the Local Issues Tool, other Areas have shown an interest in trialling it, which demonstrates that there is a wider need for this kind of facility (Section 4.3.1).

13. Area staff have easy access to key national GIS layers via the Easimap but not local ones (Section 4.3.2).

14. Area staff need access to expertise in analysing data with GIS tools in their local office (Section 4.3.2).

6.1.3   Literature search

15. A brief literature search revealed a wide range of potentially relevant projects and models in this dynamic research area (Section 5.1).

16. Based on the literature, SCIMAP seems a likely candidate for further investigation (Section 5.1).

6.1.4   Trial of models

17. GIS is excellent for analysing and presenting spatial patterns but it is less frequently used for handling time series or making predictions as part of 'what if' investigations. Other tools are required for these activities (Section 5.2).

18. The Environment Agency Decision Support Tool (DST) appears to be useful for estimating the potential effects of certain land use measures (Section 5.2.1).

19. TOPCAT-NP could be useful for quickly investigating how nutrients might be travelling from sources to receptors, based on readily available Environment Agency time series data without the need to use GIS (Section 5.2.2).

20. The ArcView Generalised Loading Function (AVGWLF) model looks useful for source apportionment and its partner, the Predict model, can be used to consider mitigation options. They have a familiar GIS interface, are simple to use and are already being used operationally but, since they were developed in the US, further work is required to assess how readily they could be used in the UK (Section 5.2.3).

21. Area staff would like access to model results but frequently do not want to run models themselves, and do not have time to train to use the many models they would like results from (Section 5.2.4).

6.2   Recommendations

6.2.1   Data

1. The Environment Agency should continue to invest in targeted data collection and management as the lifeblood of integrated river basin management planning, and strive to maximise the benefits from this investment at all scales (national, regional and local) (Section 4.2.1).

2. More data does not necessarily lead to better decision-making, or provide better evidence. We recommend that the next phase of work identifies which datasets prove to be the most useful in helping select specific local measures (Section 4.2.6).

3. The links we have established with the national Data and Information, and River Basin Management teams should be maintained for the next phase of work (Section 4.2). This should include trialling new national and regional data sources and providing feedback to the national Data and Information Manager (Section 4.2.2).

4. Metadata should be collected routinely using standard operating procedures and time for this should be factored into the project plan of every GIS operation. We should also consider creating data management teams at Area, Regional and National levels and developing a generic data management plan as currently required within flood risk management (Section 4.2.3).

5. Area environment planning teams, the national Data and Information team, the team working on the strategic data management solution for WFD and the national River Basin Management Planning team should consider the three options described in Section 4.2.4 and agree a way of satisfying the need for a local repository of shared data.

6. Local Data Custodians (Section 4.2.4) should also be responsible for:

    - Promoting awareness of datasets or maps of interest to other teams.
    - Putting local datasets which are not suitable for storage on the RDS or CDS into the local store.
    - Proposing datasets for inclusion on the RDS or CDS.
    - Maintaining a repository or list of information such as reports or maps which support their data.

6.2.2   GIS

7. We recommend that any future proposals for data and information management for river basin management planning and the WFD have the capability to be displayed on a geospatial basis.(Section 4.3)

8. We will provide feedback on the use of the Local Issues Tool to the Data and Information Manager and the GIS Business Change Manager, and we will consider the options available for satisfying the needs of Area staff for recording this kind of information (Section 4.3.1).

9. Area managers should consider whether their staff need access to a dedicated GIS specialist in their office or team who could use GIS to analyse their data whilst helping them develop their own skills (Section 4.3.2).

10. The 'Blue Knot' approach (Entec, 2007) to produce 'combined risk scores' for subdivisions of water bodies based on water quality, water resources and fisheries data should be investigated further (Section 4.3.3).

6.2.3   Literature search

11. The literature review in the next phase of work should focus on identifying approaches and tools for further testing in specific catchments to support the selection of local measures (Section 5.1).

6.2.4   Trial of models

12. The following models should investigated further (Section 5.2):

- SCIMAP catchment connectivity model.
- NEAPN and PSYCHIC.
- TOPCAT-NP, to test whether our initial conceptual models are consistent with observed river flow and nutrient concentrations.
- AVGWLF, to assess its applicability in the UK.
- Others identified by the literature review recommended above.

13. The Environment Agency should give Area staff access to model results without their having to run models themselves (Section 5.2.4).

Appendix A – Field Visit

Hampshire Avon Catchment Field Visit
6 February 2007
Melissa Robson, Catchment Sensitive Farming Officer (Environment Agency)
Paul Hulme (Environment Agency)
Michelle Walker (Entec)

Catchment Sensitive Farming scheme for around 40 catchments, focusing on P, N, sediment and pesticides.

PSYCHIC - Phosphorus and Sediment Yield Characterisation In Catchments. This model gives the PO_4 and sediment transferred from a one-km^2 grid cell

NEAPN - This model gives the NO_3 leached from the soil and the NO_3 concentrations in the soil water on a one-km^2 grid.

Morgan-Morgan-Finney model (sediments).

Neil Preedy has short summary document of these models written for Policy. Probably good to circulate to Steering Group. PH to ask Neil for copy.

Hydrological connectivity generally takes account of two km either side of a river.
On chalk generally we are talking about diffuse pollution at catchment level. However, at a local level, sediment transfer, e.g. on the greensand, consists of lots of small point sources.

Nitrate

Bourne catchment – NO_3 is high in bottom of catchment. General leaching over winter of nitrate from soil column. However this winter has been mild and wet, resulting in increased mineralisation of nitrogen from organic sources. The crops are very forward, which results in more disease and more leaching. Nitrate transfer in aquifers can take 30-40 years, so we may be seeing the consequence of historical activity.
11.3 mg/l (as N) = 50 mg/l (as NO_3) Drinking water standard.
Historical, post-war ploughing of large areas of land, then very cheap nitrogen in the 1980s led to vast release of N. Ongoing septic tank and slurry input. 1991 EU legislation led to NVZs, which have been re-done several times. They now cover 60% of the country, but only shallow sandy soils. EU requires this to be looked at again, and wants compulsory slurry storage standards and a closed season for application.
Winterbourne – dry in summer, so has unique ecology, and does not have usual banks and fencing of permanent stream. Past studies show that there is very little downstream accretion in this stream. N is 30/50 in stream = 7 index
Leckford Bridge water treatment works decommissioned due to exceedance of N levels.

Land Management

New Zealand system of grassland management becoming popular, which involves out wintering and strip grazing, resulting in heavy poaching of ground and increased nitrate release. This method of grazing is cheaper than winter housing cattle. Basic cross-compliance measures allow for 'sacrificial areas' on a farm, provided that these are reinstated. Size of areas is open to interpretation. Ploughing is expensive so preferred method is for drilling – a header drill is used to turn the soil and reseed.
Winter sown crops are dominant in arable areas, and August sees a large-scale poultry and pig muck spreading to avoid scorching plants which are already growing in spring. This N mineralises and there is no crop take-up at time of application so it goes straight into the soil. However, it is now technologically possible to apply low-level muck so it could be applied in the spring without crop scorch.

Maize has been growing in popularity for around 15 years. It is planted by dairy farmers as a fodder crop, but they are generally inexperienced in application of fertilisers. It is planted in late April/May and not harvested till November. Compaction results because of the harvest season, and the heavy crop requires heavy machinery. The dense canopy means that the soil is completely bare after harvest, and can be concrete-like. Chisel ploughing is used to break up the soil, especially at the top of a field, to allow water to penetrate the soil. Early harvest varieties are now available.

If recommend sub-soiling (deep ploughing) to solve compaction problem, need to know detailed archaeological records (only available in local authorities – often paper-based records).

Also need to know flood risk consequences if recommending change of agricultural practice.

P and Sediment

Phosphate is linked to sediment problems. Only a tiny proportion of the P in soil is readily available. An index above three is adequate for crops. P binds to soil colloids, and is readily transported with sediment. Excess P in water results in eutrophication and algal bloom/weed problems, which in turn rob water of oxygen when they break down. If there is not enough P in soil, this limits the take up of N. Sewage sludge is rich in P. Septic tanks are a significant source of P (Paul Stanfield has data on rural populations with septic tanks).

RB209 crop/soil/fertiliser recommendations. Under pressure from EU to make regulation.

Need to target risk-prone sites. E.g. ploughed field above a road and/or adjacent to a river = INHERENT RISK

E.g. Wylye chalk stream, with point input of sediment from road source (see case study below).

Would like to have database linked to points on map showing these types of incidents.

Also referred to interactive 3D model showing river flow and connectivity. Office-based system would be OK.

Defra ArcView 3.2 system

Data is ok if not familiar with area, but generally national-scale data is no good. E.g. P index national data is five-km resolution. Soils data is great though. Soil moisture deficit would be useful. From Met Office and also calculated for FP.

End users – e.g. Agricultural Environment Officers, Waste EOs, EM EOs all need to link – they all work in catchments.

PH: How do we prioritise our resources to implement WFD?

Need to rank risk and look wider than what we have power to control.

Wylye Catchment
Sediment Problem

Great Wishford

Major sediment problem in salmon stream. Sediment source appears to be from degrading road banks on two-mile stretch of laneway used as a commuter 'rat run'. Lane width is constricted, leading to road verge erosion and sediment runoff.

Eroding road banks upstream of Wylye river. Banks used to be four feet high – now degrading to two feet.

Sediment outflow directly below road – major problem, and needs frequent dredging to unblock road drain to prevent flooding of main A36.

Bourne Catchment
Nitrates Problem
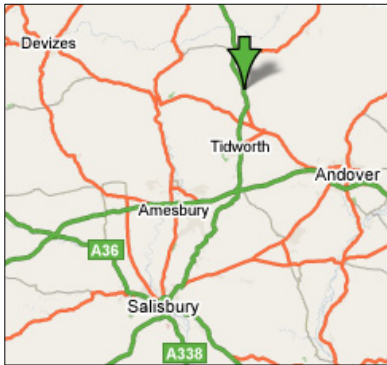
Leckford Bridge

Leckford Bridge water treatment works decommissioned due to nitrate problems.

Surrounding farmland change to New Zealand system of winter grazing. Leads to increased poaching and compaction. Basic cross-compliance measures allow for 'sacrificial areas' but there is a requirement to reinstate this land. However ploughing is expensive, so generally reseeding is done with a header drill, which turns and reseeds in one go.

Bare ground due to winter grazing crops – eg. stubble turnips.

Winter grazing field – heavily poached

Large areas of bare soil and poaching (stubble turnips, grown for grazing)

Bourne Catchment
Sediment Problem

Tanners Lane Ford

Ford heavily used by tractors and 4x4 vehicles. Sediment plumes in river result from mud washing off vehicles. 4x4s also drive up stream bed. Channel is sev times wider below ford, and much sediment deposited on stream bed. Highways Agency would charge £50,000 to improve crossing. Possible actions: Close ford and monitor sediment over several years. Monitor turbidity continuously over a week and compare to runoff events. Chain across stream to prevent vehicles driving along stream bed.

Widened river bed at ford

Clear river bed and natural channel width upstream of ford

Sediment on river bed downstream of ford – causes problems for salmon breeding

Access lanes used by tractors and recreational 4x4 vehicles

Appendix B – User requirements

The following is a summary of the feedback received from participants at the first workshop, held in Exeter on 7 February 2007. Participants were asked to complete a two-page questionnaire, and then broke into groups to discuss the findings. Key requirements for the current project and for future developments were formulated, and have been incorporated into the conclusions and recommendations of the final report.

1.1 What data sets/layers would you like the GIS to include if possible? Are there any datasets which you think we aren't yet aware of? Please include as many details as possible, especially any possible IPR/copyright issues.

1.1.1   Current

Field boundaries, Avon model output, Bourne and Nine Mile model output, groundwater quality network data, water company groundwater quality data, estimated unconsented discharges, some apportionment by river stretch, upstream accumulations, mean and Q95 flows, water quality statistics, loads – river, loads – discharges, loads – land or equivalent concentrations, sediment/rainfall events, detailed topography from LIDAR, land use, soil types, geology - bed rock, faulting, nitrate fertilizer usage, all locally derived Wessex Water/wAgrico data, Wessex Water AMP4 low flow data – hydrogeological, ecological.

1.1.2   Longer Term

Catchment boundaries to DTM accuracy, accurate river networks e.g. branded channels, plus routed channels, rainfall, Abs and DTs, for CFMPs and other FRM plans: record of local knowledge e.g. flooding history, sediment issues, erosion problems. CFMP policy units should be available linked to the actions identified in the CFMP for each unit (with appropriate caveats). Greater resolution soil data, High resolution topography, ground truthed land cover, land use datasets.

1.2 The immediate aim is to make the GIS datasets available to Environment Agency Area staff, but who else would you consider to be a potential end user?

1.2.1   Current

Water companies, English Nature – sharing data reduces longer term issues of resolving arguments over answers, Environment Officers, external water companies, water companies, public, they may relate to regional stakeholders interests, if the shared development of RBMPs goes as intended.

1.2.2   Longer Term

Water authorities, local authorities especially planning departments, Natural England, all Environment Agency functions, local liaison groups, agricultural and civic for co-ordinated action, local stakeholders (farmers, landowners, local authorities, water companies) layers offer common interface for discussion.

1.3 What would you consider to be the best method of 'delivery' for the GIS data? (for example, ArcView (version), What's In My Back Yard, EasiMap, MapView) Does the GIS need to be standalone or available over Environment Agency network?

1.3.1   Current

Definitely ArcView (9.1 if that's what we're getting). I think the metadata is vital to maintain integrity of data, maintain IPR issues, all necessary caveats. A standalone disc is great for field work but I would be very concerned about updating it and

currency. Networking the GIS would avoid this but it would have to be easy to update with local knowledge (GPS handset). Must be agency network – especially to ensure data is current. Or Entec website for frequent updates. If there is the availability of ArcView for users – then through that or a system like Planet which is on a CD with updates sent by e-mail, ArcView, EasiMap, Network. Basic GIS capability to view spatial data plus attributes. No need for full GIS capability at the outset – probably focus will be on GIS specialists for full functionality. Networked in a variety of ways. If typical use will be simplistic, then ArcView may not always be necessary.

1.3.2 Longer Term

If using 'basic' data sets use 'I drive'. Add on sets or derived sets may need to be placed elsewhere.

1.4 What type of questions or issues might the GIS help you to address? (for example, flagging priority areas for field work, communicating complex land management issues to stakeholders)

1.4.1 Current

Flag priority for groundwater monitoring providing information for new abstractions/ quality issues, data store (remembering system), communication, demonstrating connections, initial targeting of resources and time, having available information from other disciplines – considered or unconsidered, hazard/source identification, current harm e.g. current water quality, vulnerability – risk, give a 'feel' for spatial distribution of pressures in catchments.

1.4.2 Longer Term

Quicker calculations also Low Flows 2000 (LF2k) based on more LF2k data, accretion diagnosis, rainfall analysis e.g. Thiessen Polygons, visual regeneration, for CFMPs it would provide the starting point to investigate problems such as local erosion issues or provide a GIS platform to record local knowledge that is often lost when people leave. See what other plans/reports are available for your study area.

1.5 What do you think the main barriers to use of the GIS might be? (for instance software knowledge, number of data layers, variety of end users, software version)

1.5.1 Current

Lack of training and running time on Environment Agency systems, ability to easily update layers on I drive, training and knowledge of what can be viewed/produced, applicability of data (why it was collected), national versus local datasets, model outputs perceived as 'true', information overload, trying to convey too much, need to reduce – to derive to composite indexes, information sitting behind GIS layers. Analytical limitations of end users – GIS or otherwise. What layers are relevant to what user. Knowledge of software, software version.

1.5.2 Longer Term

Speed, updated sets, resolutions, accuracy e.g. catchment boundaries, river networks, training, knowing what it can do.

1.6 Can you recommend anyone else we should contact who is not on the steering group or involved in the workshops?

Environment management team leader – Julian Wardlaw; Consenting team leader – Craig Fisher; Monitoring team leader – Phil Lonenly; AEM – Ron Curtis; WFD – Ben Bunting; Need more pollution people; Suggest you look at the Cycleau Project CD as it addressed similar problems; Impacts people, Fisheries, Ecology team, Water quality monitoring; As diffuse pollution is the primary target, someone with an interest in that. Also, Ben Bunting should be involved since he will understand the region/area perspective of delivery. I still am unclear about how and who. The example of the field officer deciding on expenditure within a catchment seems far too simplistic. PoMs are set for a six-year project and will drive the expenditure. Wessex Water Catchment Advisors, wAgrico Catchment Advisors, CSF Co-ordinators, National Farmers Union.

Appendix C – GIS Layer List

GIS Datasets Master Spreadsheet   GIS Folder:

LEVEL1	LEVEL2	COVERAGE	OBSERVED / DERIVED	LAYER NAME	Filename
REFERENCE	OS10k	FP HA	OBS	OS10k Frome Piddle.lyr	
REFERENCE	OS10k	FP HA	OBS	OS10k Frome Piddle.lyr	
REFERENCE	OS50k	FP	OBS	OS50k Frome Piddle.lyr	ST40.tif
REFERENCE	OS50k	HA	OBS	OS50k Hants Avon.lyr	ST62.tif
REFERENCE	OS250k	SW	OBS	OS250k.lyr	
REFERENCE	TERRAIN	FP	OBS	Panorama 50m.lyr	pan_50m
REFERENCE	TERRAIN	FP	DER	Slope 50m.lyr	slope_50m
REFERENCE	TERRAIN	FP HA	OBS	Panorama 250m.lyr	pan_250m
REFERENCE	TERRAIN	FP HA	DER	Slope 250m.lyr	slope_250m
REFERENCE	GEOLOGY	SW	DER	Low K Drift.lyr	Uk_drift_sw.shp
REFERENCE	GEOLOGY	SW	OBS	1_250k BGS Solid Geol.lyr	250new_ew2_geology_sw.shp
REFERENCE	GEOLOGY	HA	OBS	50k Superficial Geol Hants Avon.lyr	EW329_bournemouth_v2_SUPERFICIAL_Geology_Polygons
REFERENCE	GEOLOGY	FP	OBS	50k Superficial Geol Frome Piddle.lyr	EW312_yeovil_V2_SUPERFICIAL_Geology_Polygons
REFERENCE	GEOLOGY	HA	OBS	50k Solid Geol Hants Avon.lyr	EW266_marlborough_v2_BEDROCK_Geology_Polygons
REFERENCE	GEOLOGY	FP	OBS	50k Solid Geol Frome Piddle.lyr	EW341_342w_west_fleet_and_weymouth_v2_BEDROCK_Geology_Polygons
REFERENCE	GEOLOGY	SW	DER	Groundwater Vulnerability.lyr	SWClip_gwv_100k.shp
REFERENCE	SOILS	SW	DER	Soil Leachability.lyr	soil_vuln_sw
REFERENCE	SOILS	SW	DER	Soil ByPass FLow.lyr	NATMAP1000.shp
REFERENCE	SOILS	SW	DER	Soil Structure.lyr	NATMAP1000.shp
REFERENCE	SOILS	SW	DER	Depth to Impermeable Layer.lyr	NATMAP1000.shp
REFERENCE	SOILS	SW	DER	Predisposition of Risk (Waste Disposal).lyr	NATMAP1000.shp
REFERENCE	SOILS	SW	DER	Soil Workability 1km.lyr	NATMAP1000.shp
REFERENCE	SOILS	SW	DER	Soil Workability 5km.lyr	FC_5k_EA.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	Main Towns.lyr	TOPTOWN_point.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	Small Towns.lyr	MIDTOWN_point.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	England Wales.lyr	england_wales.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	Counties.lyr	county_10k.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	EA Regions 250k.lyr	regionwm_250k.shp
REFERENCE	BOUNDARIES	FP	OBS	Frome Piddle.lyr	Frome_Piddle.shp
REFERENCE	BOUNDARIES	HA	OBS	Hampshire Avon.lyr	Hants_Avon.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	South West Region.lyr	sw_region.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	EA Areas 250k.lyr	areawm_250k.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	CAMS 250k.lyr	cams_250k.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	River Basin Districts.lyr	rbd_all.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	River Basin Sub-Districts.lyr	basins_eng_wales_3.shp
REFERENCE	BOUNDARIES	NATIONAL	OBS	Transitional Water Body Boundary.lyr	transitional_typology_1_9.shp

REFERENCE	BOUNDARIES	NATIONAL	OBS	**GW Boundaries.lyr**	**GWBodies_Dec06.shp**
REFERENCE	BOUNDARIES	NATIONAL	OBS	**SW Bodies.lyr**	**SWBodies.shp**
REFERENCE	BOUNDARIES	FP	OBS	**SW Bodies FP.lyr**	**SWBodiesFP.shp**
REFERENCE	AGREEMENTS	SW	OBS	**Organic Farming Scheme.lyr**	**ofs_agreements_010k_sw.shp**
REFERENCE	AGREEMENTS	SW	OBS	**ESA.lyr**	**esa_agreements_010k_sw.shp**
REFERENCE	DESIGNATIONS	SW	OBS	**Ancient Woodland.lyr**	**AnWood_sw.shp**
REFERENCE	DESIGNATIONS	SW	OBS	**AONB.lyr**	**aonb_sw.shp**
REFERENCE	DESIGNATIONS	SW	OBS	**Local Nature Reserve.lyr**	**lnr_sw.shp**
REFERENCE	DESIGNATIONS	SW	OBS	**National Nature Reserve.lyr**	**nnr_sw.shp**
REFERENCE	DESIGNATIONS	SW	OBS	**RAMSAR.lyr**	**ramsar_sw.shp**
REFERENCE	DESIGNATIONS	SW	OBS	**Special Areas of Conservation.lyr**	**sac_sw.shp**
REFERENCE	DESIGNATIONS	SW	OBS	**Special Protection Areas.lyr**	**spa_sw.shp**
REFERENCE	DESIGNATIONS	SW	OBS	**SSSI Site Units.lyr**	**sssi_SiteUnits_sw.shp**
REFERENCE	DESIGNATIONS	SW	OBS	**Site of Special Scientific Interest.lyr**	**sssi_sw.shp**
HYDROLOGY		SW	OBS	**Rivers 50k.lyr**	**rivers_50k_sw.shp**
HYDROLOGY	FLOOD	FP	DER	**NaFRA Frome Piddle.lyr**	**fc440075.shp**
HYDROLOGY	FLOOD	HA	DER	**NaFRA Hants Avon.lyr**	**fc450075.shp**
HYDROLOGY	FLOOD	FPHA	DER	**Flood Zone 2 FPHA.lyr**	**flood_zone_2_sw.shp**
HYDROLOGY	FLOOD	FPHA	DER	**Flood Zone 3 FPHA.lyr**	**flood_zone_3_sw.shp**
HYDROLOGY		FPHA	DER	**Depth to Water Table.lyr**	**unsat_depth**
HYDROLOGY		FPHA	DER	**Ground Water Level.lyr**	**minwl_mar06**
HYDROLOGY		SW	OBS	**Annual Rainfall 1941 to 1970 1km.lyr**	**rainfall_annual_1941to70_1km_sw.shp**
LOCAL		FP	OBS	**Local Issues.lyr**	**Incidents.shp**
LOCAL		SW	OBS	**National Incident Reporting System.lyr**	**Pollution_Incidents_NIRS_SW.shp**
NITRATES		SW	DER	**Regression Residuals.lyr**	**Regression Residuals.shp**
NITRATES	NVZ	SW	DER	**Available Water.lyr**	**AvailableWaterSW.shp**
NITRATES	NVZ	SW	DER	**Agricultural Loading.lyr**	**ag_fin_sw**
NITRATES	NVZ	SW	DER	**Urban Loading.lyr**	**urb_calc_sw**
NITRATES	NVZ	SW	OBS	**GW Observed.lyr**	**gw_obs_sw**
NITRATES	NVZ	SW	DER	**GW Predicted.lyr**	**gw_pred_sw**
NITRATES	NVZ	SW	OBS	**Nitrate Vulnerable Zones.lyr**	**nvz_25ksw.shp**
NITRATES	NVZ	SW	OBS	**WIMS NO3.lyr**	**SWClip_no3sum_01-06.shp**
NITRATES	NVZ	FP	OBS	**NVZ Borehole Summary.lyr**	**nvz_borehole_summary.shp**
NITRATES	NVZ	SW	DER	**Revised Risk.lyr**	**Rev_Risk_SWpw3.shp**
NITRATES	GQA	FP	OBS	**swnitrate.lyr**	**swnitrates.shp**
NITRATES	GQA	FP	OBS	**nitratedist.lyr**	**nitratedist.shp**
NITRATES	GQA	SW	OBS	**GQA River Nitrate.lyr**	**GQA_network_050k_sw.shp**
NITRATES		FP	DER	**MAGPIE N Concentration**	**magpieconcn**
NITRATES		FP	DER	**MAGPIE N Loading**	**magpieloadn**
NITRATES		SW	OBS	**Source Protection Zones.lyr**	**SPZ.shp**
NITRATES		SW	DER	**RBC1 Diffuse N RIVER RISK.lyr**	**RBC1_DIF_N_RIVER_RISK.shp**
PHOSPHATES	SIMCAT	FP	DER	**SIMCAT Loads**	**SIMCAT_Loads.shp**
PHOSPHATES	SIMCAT	FP	DER	**SIMCAT Top Loads**	**TopLoads.shp**
PHOSPHATES		SW	DER	**WFD phosphate SWTest background thresholds**	**phosphate_SWT_sw.shp**
PHOSPHATES		SW	OBS	**BGS Phosphate Background.lyr**	**basePhosphate_sw.shp**

PHOSPHATES	GQA	FP	OBS	orthophatedist.lyr	orthophatedist.shp
PHOSPHATES	GQA	FP	OBS	swortho_dist.lyr	swortho_dist.shp
PHOSPHATES	GQA	SW	OBS	GQA River Phosphate.lyr	GQA_network_050k_sw.shp
PHOSPHATES		SW	OBS	PO4 Monitoring Data.lyr	PO4111006211106_sw.shp
PHOSPHATES		SW	DER	RBC1 Diffuse P RIVER RISK.lyr	**RBC1_DIF_P_RIVER_RISK.shp**
SEDIMENTS		SW	DER	RBC1 Sediment RIVER RISK.lyr	**RBC1_SED_RIVER_RISK.shp**
RECEPTORS		SW	DER	PO4 Loading England.lyr	p_sw
RECEPTORS		SW	DER	RBC1 Coastal Waterbodies.lyr	RBC1_Coastal_Waterbodies.shp
RECEPTORS		SW	DER	RBC1 Transitional Waterbodies.lyr	RBC1_Transitional_Waterbodies.shp
RECEPTORS		SW	DER	Final PO4 Risk.lyr	PO4_risk_score_sw.shp
RECEPTORS		SW	DER	PO4 Risk.lyr	National_SSSI_PO4_sw.shp
RECEPTORS		SW	DER	PO4 Sensitivity.lyr	National_SSSI_PO4_sw.shp
RECEPTORS		SW	DER	Ground Water Connectivity Risk.lyr	National_SSSI_GWConn_sw.shp
RECEPTORS		FP	OBS		LOCAR
SOURCES		SW	OBS	Cereals Density AG Census 2000.lyr	agric_census_2000_catchment_sw.shp
SOURCES		SW	OBS	**Maize Value per Ha AG Census 2001.lyr**	agric_census_2000_catchment_sw.shp
SOURCES		SW	DER	Risk Category Crop.lyr	1km_cropsclass_sw.shp
SOURCES		SW	DER	Risk Category Livestock.lyr	1km_livestockclass_sw.shp
SOURCES		FP	OBS	Landfill Sites.lyr	landfill_010k.shp
SOURCES		FP	OBS	Railway Lines.lyr	railway_250k.shp
SOURCES		FP	OBS	Petrol Stations.lyr	petrol_stations_200k.shp
SOURCES		FP	DER	Land use 2000 FP 25m.lyr	landuse2000fp
SOURCES		SW	DER	**Land use 2000 50m.lyr**	lu2000_sw
SOURCES		FPHA	OBS	Consents To GroundWater.lyr	Consents_To_Ground.shp
SOURCES		FP	OBS	Discharges.lyr	Discharge.shp
SOURCES		FP	OBS	**Consented discharges.lyr**	consented_discharges.shp
WATER RESOURCES		FPHA	DER	**Total Recharge mm _a.lyr**	rechrun30
WATER RESOURCES		SW	DER	Natural River Flows Implied Effective Rainfall mm_a.lyr	IntegratedWBs_Nov06._sw.shp
WATER RESOURCES		NATIONAL	DER	RBC1 Abstraction pressure risk	RBC1 Abstraction pressure risk
WATER RESOURCES		NATIONAL	DER	RBC1 Coastal Water Risk	RBC1 Coastal Water Risk
WATER RESOURCES		NATIONAL	DER	RBC1 Transitional Waters Risk	RBC1 Transitional Waters Risk
WATER RESOURCES		SW	DER	Recharge from effective rainfall x BFI Host	recharge_sw
WATER RESOURCES	GQA	SW	OBS	GQA Chemistry Sample Points.lyr	gqa_chemistry_points_sw.shp
WATER RESOURCES	GQA	SW	OBS	GQA Biology Sample Points.lyr	gqa_biology_points_sw.shp
WATER RESOURCES		NATIONAL	DER	Natural River Flows QNmean Ml_d.lyr	IntegratedWBs_Nov06.shp
WATER RESOURCES		NATIONAL	DER	Natural River Flows QN95 Ml_d.lyr	IntegratedWBs_Nov06.shp
WATER RESOURCES		SW	DER	WFD River Waterbodies.lyr	river_typology_line_v1_5_sw.shp

Appendix D – GIS DVD

System Requirements

The GIS on the project DVD has been developed for ArcGIS version 9.1, and also requires Microsoft Office 2000 or later. The layer files are compatible with later versions of ArcGIS, and the shape files can be viewed with earlier versions of ESRI software. The system has been optimised to run on Windows XP (SP2), and some of the VBA code on the disk may cause problems on other operating systems.

Installation

Virus check and then copy the MIA Frome Piddle folder supplied on the project DVD to the C: drive. It can be placed anywhere on the C: drive, as long as the folder/file structure beneath the root MIA Frome Piddle folder is not changed.

Please note that this folder is about 3.5 Gb in size (for the Frome Piddle catchment) and it is a good idea to check that you have sufficient local space on your C: drive before attempting to copy the contents of the DVD.

The folders and files contained on the DVD and required to run the GIS tool are listed below:

C:\MIA Frome Piddle	This is the root folder that should be copied to your local drive.
C:\MIA Frome Piddle\ArcGIS	
.. MIA Frome Piddle.mxd	This is the GIS project file that has the Local Issues Tool embedded within it.
C:\MIA Frome Piddle\ArcGIS \NITRATES \PHOSPHATES \HYDROLOGY \RECEPTORS \REFERENCE \RESOURCE \SEDIMENTS \SOURCES	Sub-folders have been created that store the GIS data. For a full breakdown of what GIS data is available please refer to the *metadata.xls* spreadsheet.
C:\MIA Frome Piddle\ArcGIS\DOCS	Within this folder there are similar folders to the above – sub-categorised folders to place related documents/spreadsheets.
C:\MIA Frome Piddle\ArcGIS\LOCAL\Photos	All site photos should be copied across into this folder. They should not be renamed or moved once referenced from the GIS.

C:\MIA Frome Piddle\ArcGIS\VBA	
..Template.dot	This is a Microsoft Word template – this is used when exporting Local Incidents from ArcGIS. It should not be amended.
.. Editable_Headings.xls	This spreadsheet contains top level headings (which appear in the drop-down when adding new incidents with the tools) and sub-headings (which are the headings for tick boxes within the tool).
C:\MIA Frome Piddle\Metadata	
..metadata.xls	This spreadsheet contains metadata for all of the GIS datasets contained within the project.

Change the file properties

Open Windows Explorer and navigate to the MIA Frome Piddle folder that has just been copied from the project DVD. Select File, Properties.
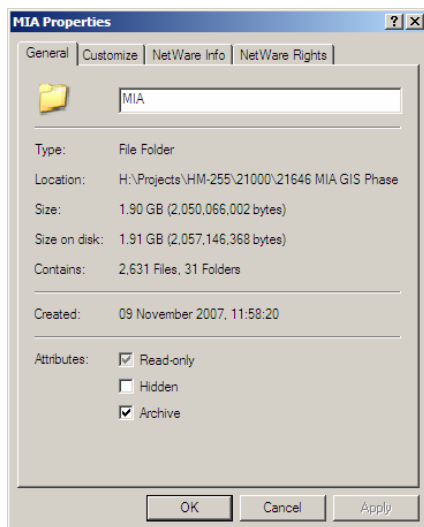

Unclick the Attributes Read-only box and click 'Apply'. This is necessary as the files on the DVD are by default read-only. On the Confirm Attribute Changes form – select 'Apply changes to this folder, subfolders and files' and click OK. This will ensure that all files are made read/write and enable correct operation of the tools supplied.

Opening the ArcGIS Map Documents

Open the MIA Frome Piddle \ArcGIS folder from your local drive and double click on the 'MIA Frome Piddle.mxd' file.

When opening the MIA Frome Piddle.mxd on the DVD, an Intellectual Property Rights statement appears, as illustrated below. The user must click acceptance of the statement before being allowed to proceed and browse the GIS layers.
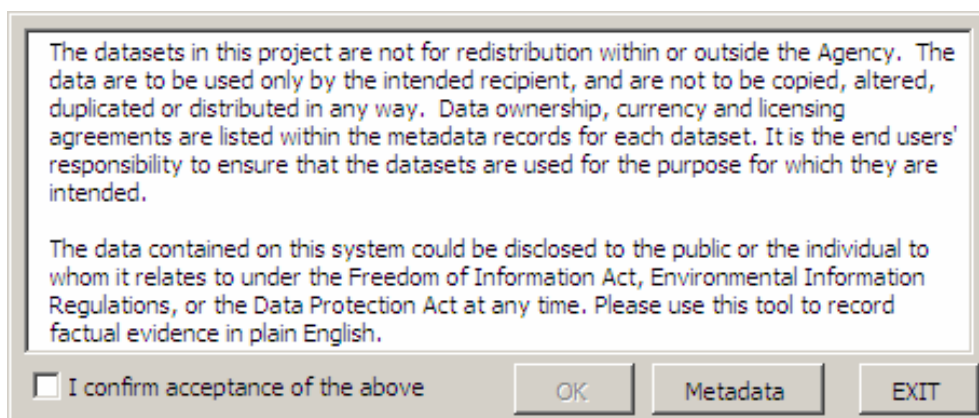
The metadata button allows the user to open the metadata.xls spreadsheet.   This form can be called up at any time by clicking on the Metadata button of the Local Issues toolbar, detailed further below.

GIS Layer Groupings

Once the GIS project is open, the display pane shows how the data has been organised into the following groupings for ease of navigation:

Local   Contains all the data related to NIRS and 'local issues' (refer to Section 3.4).

Nitrates   Data related to nitrates including NVZ data, GQA data, MAGPIE data and WFD nitrate data.

Phosphates   Data related to phosphates including SIMCAT data, WFD phosphate data, monitoring data and GQA data.

Sediments   WFD river risk sediment data.

Sources   Contains agricultural census data, land use data plus data on consented discharges, landfill sites and other potential sources of diffuse pollution.

Receptors   Contains data related to water bodies, groundwater connectivity, ecological sensitivity and so on.

Hydrology   Contains flood data, groundwater level data, depth to groundwater data and rainfall data.

Water Resources   Contains data related to recharge, river flows, WFD risk data and GQA sampling points data.

Reference   Contains all the base mapping data as well as data on boundaries, terrain, designations, agreements, soils and geology.

The Local Issues Tool

The Local Issues toolbar is where all of the required tools are accessible. If the toolbar is not displayed on the front screen, go to the View menu followed by the Toolbars menu in ArcGIS. Tick the Local Issues Tools – the toolbar should then appear. The functionality of the toolbar is described and shown below.

Metadata

Clicking will load up the metadata.xls spreadsheet. This spreadsheet lists all of the GIS datasets that have been collated for this project. It contains information such as filenames, resolutions, coverage, source and so on. It also contains hotlinks to the full metadata records and supporting documents for a sample of layers.
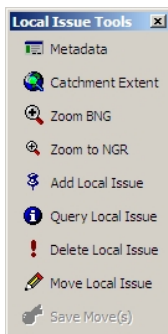
Catchment Extent

This button zooms out to the catchment extent defined within the code of the project.

Zoom British National Grid (BNG)

The user can type in a British National Grid reference, which will then pan the map view to the desired coordinates. The box has the functionality to handle a range of coordinate styles, for example four-figure or six-figure coordinates. If an invalid coordinate is entered, the user is informed.
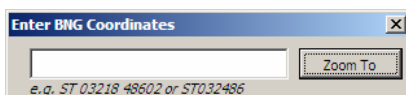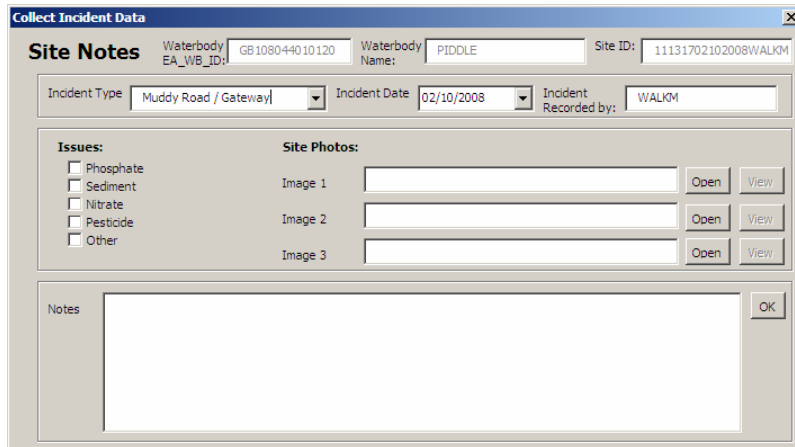
Zoom to NGR

Alternatively to zooming to a BNG reference, some users prefer to zoom to an absolute X and Y grid coordinate. This is useful if coordinates are taken from a GPS system.
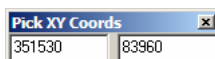
Add Local Issue

Once this button has been toggled on, the cursor will change to a cross-hair and you will be able to add "Local Issue" points to the map. When you click on a point on the map, a message box will confirm the location is correct and give an X and Y coordinate of the point clicked. If more precision is required, the user may need to zoom in.

Once the location of the issue is correct, a form is presented to capture information. By default, it sets the incident date to the current date, and gets the User-ID from Windows to populate the 'Recorded By' box. These can be manually overtyped if needed.

The code will also determine which WFD surface water-body underlies the point clicked – and record the *EA_WB_ID* and *NAME* attributes from this layer into the new record.

A unique identifier is created and assigned to the record. This is concatenated from the current date, time and user.

The Incident Type can be selected from a drop-down menu. If no suitable type is found in the drop-down, please read the section below on Changing Menu Headings.

If appropriate, tick the relevant tick-boxes to indicate the issues applying to the incident. These tick-box values can also be altered, refer to section Changing Menu Headings.

If there are site photos of the incident, copy the photos from the camera/local drives to the *MIA\ArcGIS\LOCAL\Photos*. Three photos can then be referenced via the "Open" buttons. Once the paths have been selected, the "View" buttons become active and the photos can be viewed in the default picture editor.

Any additional comments can then be recorded into the Notes box. Click 'OK' to save the data to the storage database, and the point then appears on the map.

Query Local Issue

Toggling this button will change the cursor to a cross-hair. Clicking on a Local Issue point will select the recorded data, and display a form with the site details. If the map is zoomed out too far to select a point, a message pops up to suggest zooming in further.
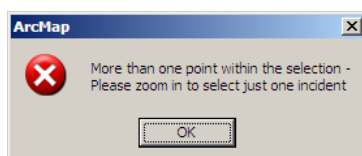
Thumbnails of any photos associated with the site can be viewed in the default picture editor via the View button.

The Comments can be edited from this form – If any changes are made, the Save button will need to be clicked to record these changes. The user is prompted if not clicked.

Clicking Export will take the site details, along with the photos and a snapshot of the map-view at 1:7,500 and put this into a Microsoft Word document. It will automatically create a folder under *MIA Frome Piddle\ArcGIS\LOCAL\Site Reports.* It will name the folder using the ID allocated when the site was created.

The View Folder will be greyed out until the record has been exported (which creates the folder). When active, clicking this button will open a folder in a new window.

Once a report has been exported for the site, a flag is set in the local issues table, and is shown in the map as a new symbol:
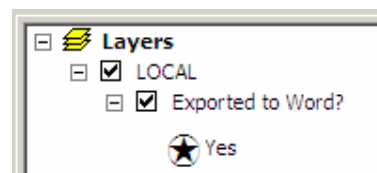
New Site Visits

If additional data needs to be recorded about an existing recorded site (such as visiting a site to monitor an incident), a new sub-record can be created for that site.

If a new sub-record needs to be created for a site, clicking New Site Visit will bring up a fresh data-entry form (same form you get when you add a new Local Issue to the map). This allows additional data about that site to be recorded; this data is saved as a sub-record to the original site, when OK is clicked.

Multiple sub-records can be recorded about an individual site.

If you have multiple sub-records for a site, when you query the site, you can scroll through these records using the next/previous buttons (< & >).

All sub-records exported will be saved into the same ID named folder.

Delete Local Issue

When this option is clicked, the cursor changes to a cross-hair to select a Local Issue point on the map. The user will be asked to confirm the deletion of the selected point; clicking "Yes" will delete the point. If this point has reports exported for it, a prompt will also ask if you wish to delete the folder and associated report as well. This action cannot be undone.
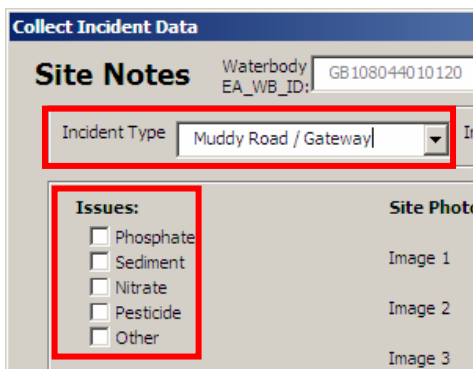
Move Local Issue

Clicking this will change the cursor to ArcMap's editing cursor. Points can then be selected and moved to a new location. Whilst in this mode, the user can make use of the following short-cut keys:

Z – Zoom In; X – Zoom Out; C – Pan

Once you have made some edits, the Save Move(s) button on the toolbar becomes enabled. To end the editing session, click the Save Move(s) button to save the edits.

Changing Menu Headings

When creating a new incident, the 'Incident type' window is visible. From this window there is the option to select the relevant incident type from the drop-down menu. Five sub-category headings are then selectable via the 'Issues' tick-boxes.

These headings can be altered to record different categories if the need arises.

You will first need to close the MIA Frome Piddle project (ArcMap), and then open the following file:

*MIA Frome Piddle\ArcGIS\VBA**Editable_Headings.xls***

The first column contains the four top-level headings (Incident Type). The subsequent five columns contain the five separate sub-category headings (Issues).

	A	B	C	D	E	F
1	Muddy Road / Gatewa	Phosphate	Sediment	Nitrate	Pesticide	Other
2	Erosion / Runoff	Phosphate	Sediment	Nitrate	Pesticide	Other
3	Muck Heap	Phosphate	Sediment	Nitrate	Pesticide	Other
4	High Risk Site	Phosphate	Sediment	Nitrate	Pesticide	Other

Additional rows/columns cannot be added to the spreadsheet – it is limited to four top-level headings/five sub-category headings.

Note that, every time the headings are changed, the Local Issues layer in the GIS project will have to be updated to accommodate the change in symbology.

Updating the symbology

Once the values in the Editable_Headings.xls have been changed, you will need to add these new values to the GIS symbology for the values to appear in the map window.

Right-click the Local Issues layer within the table of contents and click Properties.

Click the Symbology tab and click Categories.

ArcMap automatically selects the unique values option.

Ensure that **IncType** is selected in the Value Field drop-down.
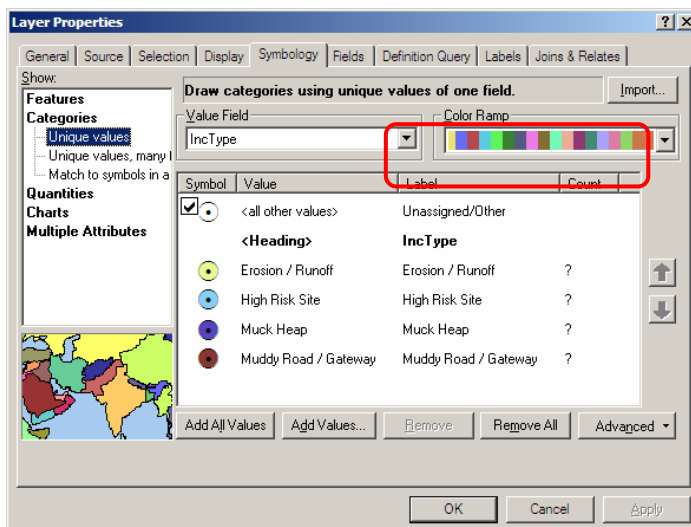
If you need to preserve the old headings but add some new headings, click Add Values. You can then manually type in the exact same value(s) that you added into the Editable_Headings.xls.

Alternatively, you can select the values you wish to remove and click Remove.

You can change the symbol/colour for your new values by double-clicking on the symbol and changing the properties.

Click a label in the Label column and type the label you want if you want to edit the default label so that the labels that appear in your legend and the table of contents are more descriptive.

Click OK.

metadata.xls

This Excel spreadsheet contains two worksheets: GIS Layers and Metadata Fields.

GIS Layers Worksheet

This worksheet contains the following columns:

LEVEL1	Level 1 layer grouping. Corresponds to ArcGIS layer file and top level directory underneath the ArcGIS folder on the DVD.
LEVEL2	Optional Level 2 layer grouping. Also corresponds to layer file and to second level directory on the DVD.
MINSCALE	Minimum display scale for data – saved to the individual ArcGIS layer file.
MAXSCALE	Maximum display scale also saved to the individual layer file.
SAMPLE	Y indicates that this layer has full metadata xml file.
COVERAGE	Whether national, regional (SW), local (FP or FPHA).
USER	Likely level of interest, whether all or just CSF officers.
OBSERVED/DERIVED	Observed (measured data) or derived (modelled) layer.
LAYER NAME	ArcGIS layer file name.
Filename	Shapefile, GeoDatabase feature class, grid or image file name.
HAVE	Y indicates that data have been collected and included in DVD.
DETAILS	Longer explanation of data or GIS layer.
SOURCE	Copyright or IPR holder.
I DRIVE	Y indicates that data are available on the Environment Agency's regional I Drive.
CONTACT	Custodian or main contact for further information.
FORMAT	Shapefile, grid or image.
RESOLUTION	Grid or image file pixel size.
PROJECT_PATH	Full relative path to GIS data file.

## Metadata Fields Worksheet

This worksheet contains the following columns:

Layer Metadata Form Item & Comments   Fields from the Environment Agency's metadata collection form. Comments are incorporated from the digital form to advise users on how to complete the metadata fields.

GEMINI PLUS (EA)	An indication of whether the field is Mandatory (M) or Optional (O) in the Environment Agency's adopted metadata standard.
GEMINI	An indication of the UK GEMINI mandatory and optional fields.
SPIRE (DEFRA)	Mapping of fields to the DEFRA SPIRE metadata standard (now superseded by UK GEMINI Plus).
MIA	An indication of the mandatory and optional fields identified by workshop participants in this project.
ArcCatalog Metadata Item	Identifying where to find the relevant item in the default FGDC metadata editor in ArcCatalog.
ArcCatalog XML Tag	Identifying the xml tag for the metadata item, using the default FGDC metadata standard.

Appendix E – Metadata Files

Metadata for a key sample of the GIS layers was collected, compiled and input to ArcCatalog, using the default FGDC template. A stylesheet based on the FGDC ESRI style was used to present the metadata to the user by adding the stylesheet to each directory containing the metadata xml files, and adding a header line to the xml file referencing the stylesheet **<?xml-stylesheet type="text/xsl" href="FGDC ESRI.xsl"?>**. This enables users to browse the metadata in a web browser (see below), and the files can be opened directly from the metadata.xls spreadsheet, without the need for ArcCatalog.
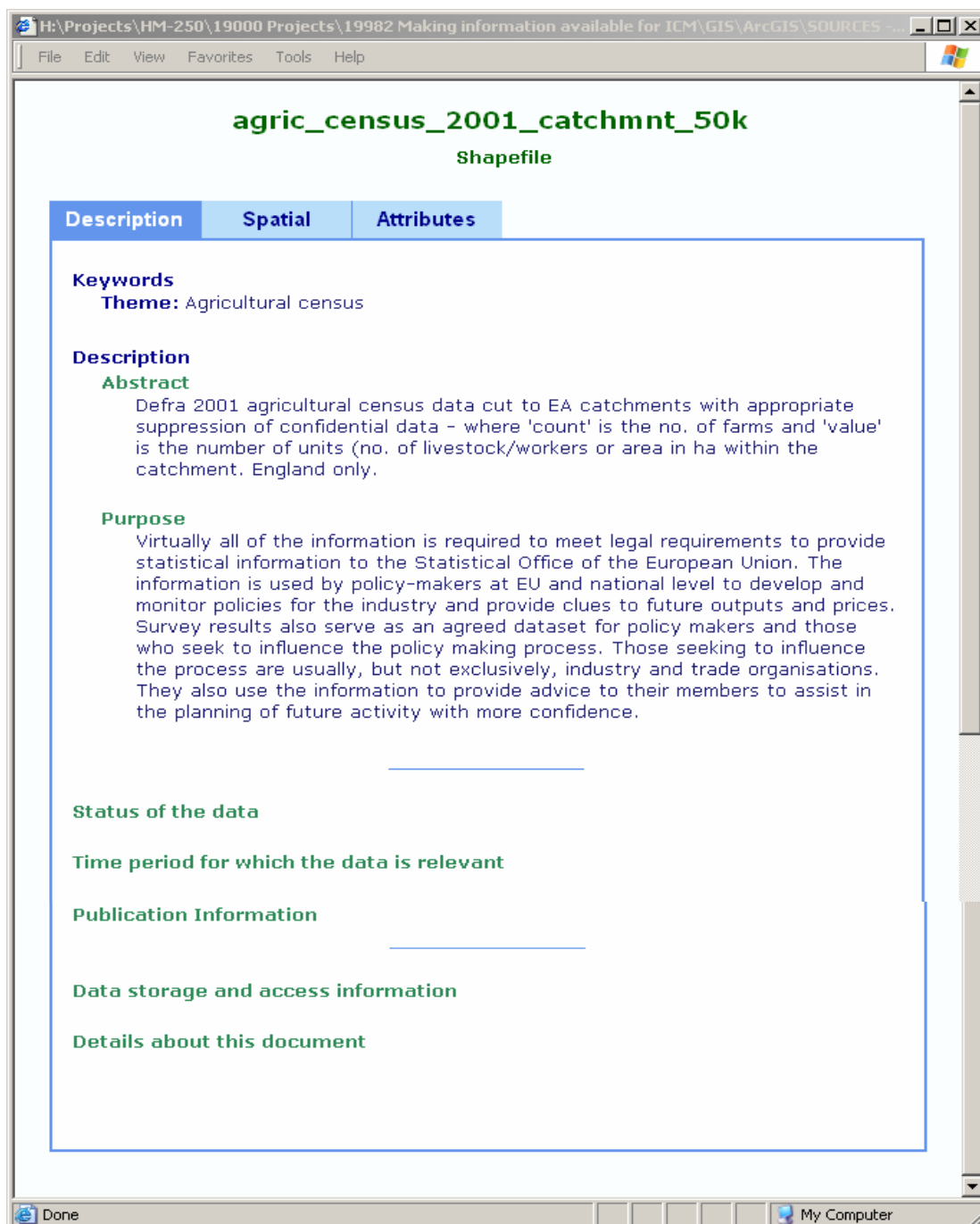
Sample Metadata XML file

```xml
<?xml version="1.0" ?>
- <!--
<!DOCTYPE metadata SYSTEM "http://www.esri.com/metadata/esriprof80.dtd">

  -->
- <metadata xml:lang="en">
   - <Esri>
        <MetaID>{9267A396-BA28-46A1-9349-B135576C50B9}</MetaID>
        <CreaDate>20070301</CreaDate>
        <CreaTime>21092000</CreaTime>
        <SyncOnce>FALSE</SyncOnce>
        <SyncDate>20070509</SyncDate>
        <SyncTime>07400800</SyncTime>
        <ModDate>20070509</ModDate>
        <ModTime>07400800</ModTime>
     </Esri>
   - <idinfo>
        <native Sync="TRUE">Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2;
           ESRI ArcCatalog 9.1.0.780</native>
      - <descript>
           <langdata Sync="TRUE">en</langdata>
           <abstract>Ordnance Survey 1:50,000 raster basemap</abstract>
           <purpose>National Mapping Agency base maps</purpose>
        </descript>
      - <citation>
        - <citeinfo>
             <origin>Ordnance Survey</origin>
             <pubdate>2006</pubdate>
             <title Sync="TRUE">St40.tif</title>
             <ftname Sync="TRUE">St40.tif</ftname>
             <geoform>raster digital data</geoform>

                <onlink>http://www.ordnancesurvey.co.uk/oswebsite/products/50k
                raster/</onlink>
          </citeinfo>
        </citation>
      - <timeperd>
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         - <timeinfo>
            - <sngdate>
                 <caldate>2006</caldate>
              </sngdate>
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              <southbc Sync="TRUE">50.795894</southbc>
           </bounding>
         - <lboundng>
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              <rightbc Sync="TRUE">360000.500000</rightbc>
              <bottombc Sync="TRUE">100000.500000</bottombc>
              <topbc Sync="TRUE">120000.500000</topbc>
           </lboundng>
        </spdom>
      - <keywords>
         - <theme>
              <themekt>REQUIRED: Reference to a formally registered thesaurus or a
                 similar authoritative source of theme keywords.</themekt>
              <themekey>Basemap</themekey>
           </theme>
        </keywords>
        <accconst>This map is reproduced from OS material with the permission of OS on
           behalf of the Controller of HMSO © Crown copyright. Unauthorised reproduction
           infringes Crown copyright and may lead to prosecution or civil proceedings. EA,
           100026380, 2007.</accconst>
```

```xml
        <useconst>This map is reproduced from OS material with the permission of OS on
            behalf of the Controller of HMSO © Crown copyright. Unauthorised reproduction
            infringes Crown copyright and may lead to prosecution or civil proceedings. EA,
            100026380, 2007.</useconst>
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    - <ptcontac>
        - <cntinfo>
            - <cntorgp>
                    <cntorg>National Data Unit, Twerton</cntorg>
                </cntorgp>
            </cntinfo>
        </ptcontac>
        <datacred>Ordnance Survey</datacred>
    </idinfo>
- <dataIdInfo>
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            2; ESRI ArcCatalog 9.1.0.780</envirDesc>
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            <resTitle Sync="TRUE">St40.tif</resTitle>
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        <metstdv Sync="TRUE">FGDC-STD-001-1998</metstdv>
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    - <metc>
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                    <cntorg>Entec UK</cntorg>
                </cntorgp>
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                        organization or individual.</addrtype>
                    <city>REQUIRED: The city of the address.</city>
                    <state>REQUIRED: The state or province of the address.</state>
                    <postal>REQUIRED: The ZIP or other postal code of the
                        address.</postal>
                </cntaddr>
                <cntvoice>01454 822032</cntvoice>
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    - <metextns>
            <onlink Sync="TRUE">http://www.esri.com/metadata/esriprof80.html</onlink>
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        </metextns>
    </metainfo>
- <mdLang>
```

```xml
            <languageCode Sync="TRUE" value="en" />
        </mdLang>
        <mdStanName Sync="TRUE">ISO 19115 Geographic Information - Metadata</mdStanName>
        <mdStanVer Sync="TRUE">DIS_ESRI1.0</mdStanVer>
    <mdChar>
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        </mdChar>
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```

```
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                        Meter(s)</conversionToISOstandardUnit>
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                </uom>
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    - <horizsys>
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```xml
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Appendix F – Integrated Catchment Management: projects and modelling tools

This review summarises the results of a brief search to identify projects and modelling tools relevant to integrated catchment management. This is an active area of research both nationally and internationally and consequently the list below is not exhaustive.

1. Research initiatives/projects identified

1.1 ASTHyDA (Analysis Synthesis and Transfer of Knowledge and Tools on Hydrological Drought Assessment) - www.geo.uio.no/drought/

The aims of this project are to:

- Review, analyse, and synthesise knowledge and tools on low stream flow and groundwater, including management practice and the impact of environmental changes on water quantity and in-stream ecology.

- Encourage harmonization of methods and provide recommendations for tools for drought estimation, monitoring, forecasting and mitigation.

- Foster cross flow of information between the consortium and representatives from national and local water management organisations across Europe.

- Disseminate the knowledge and tools to a wide audience through the publication of a textbook.

- Promote collaboration and capacity building between scientists and practicing water managers and hydrologists through the initiation of a European Drought Partnership.

1.2 CATCHMOD cluster

This EU-funded project is about making possible the construction of whole catchment models to support integrated catchment management.

The objective is to develop, implement and approve a European Open Modelling Interface and Environment (OpenMI) that will simplify the linking of models and hence allow catchment managers to explore the likely outcomes of different policies.

The simplification of the model-linking process will improve the ability to model process interactions, use appropriate model combinations and swap in and out different models of the same process and hence facilitate sensitivity analyses and benchmarking.

1.3 ChREAM - Catchment Hydrology, Resources, Economics and Management: Integrated Modelling of WFD Impacts upon Rural Land Use and Farm Incomes

http://www.uea.ac.uk/env/cserge/research/relu/index

ChREAM combines natural science with socio-economic research to assess the costs and benefits to the rural community of changing farming and community practices to produce a healthy and sustainable river environment of good amenity value. A key focus of the analysis is to examine how (within the context of reforms of the Common Agricultural Policy and complicating issues such as climate variability and non-agricultural sources of pollution) the EU Water Framework Directive is likely to affect farm activities involving fertilisers, pesticides and faecal matter and so impact upon incomes within already fragile farming communities. The work also assesses the value and transferability of potential water amenity and recreational benefits arising from such policies and compares this to their likely cost. It combines physical environment models with economic analyses and surveys of farmer attitudes and behaviour to provide a highly interdisciplinary study of this multifaceted issue.

Specific objectives of this research are to:

1. Develop a method for integrated hydrological-economic modelling of the relationship between rural land use (and consequent farm incomes) and water quality (including diffuse and point sources of nutrients, pesticides and faecal matter and consequent ecological status), with allowance for climate variability and instability.

2. Estimate the impact on rural land use and farm incomes of the consequences of implementing the Water Framework Directive (WFD) and Common Agricultural Policy (CAP) reforms.

3. Provide policy guidance on alternative strategies for meeting the objectives of the WFD and estimate the impacts of such strategies upon fragile rural economies.

4. Assess economic values for the social benefits that may be generated by implementation of the WFD.

6. Go beyond integrated modelling to combine this with attitude-behaviour surveys of farm decision-making.

For further details on ChREAM, please contact Professor Ian Bateman at the University of East Anglia on e-mail: i.bateman@uea.ac.uk.

Further details of similar research funded under the same research programme RELU (Rural Economy and Land Use) is available on the website:

http://www.relu.ac.uk/research

Further information on recent research relevant to diffuse pollution and integrated catchment management can be found on the adapt website:

http://www.uk-adapt.org.uk

There are other integrated catchment management initiatives funded outside academia. Recent examples in South West England include Cycleau (http://www.cycleau.com) and the Cornwall Rivers Project (described below).

1.4 Cornwall Rivers Project
Targeting 15 key river catchments across the county, this initiative was designed to bring significant benefits to both the environment and the economic viability of local

rural communities in Cornwall. The aim of the project was to improve the economic potential of Cornwall's freshwater fisheries resource, the development of which relies on a pristine riverine environment.

The primary aim of this four-year programme, funded by Defra and the EU, has been rehabilitation of key rivers and their catchments while bringing improvement in the economic viability of local rural communities. During the project, 870 landholdings across Cornwall were visited by West Country Rivers Trust officers, each one receiving a confidential, individually tailored, free Integrated River Basin Resource Management Plan, which identified opportunities to improve farming practice, protect the environment and make economic savings. These plans cover a total land area in excess of 560 km^2 and over 1,380 km of surveyed watercourses.

An independent economic survey of the project revealed that the majority of respondents have already made significant savings through taking up the advice – the average annual savings per farm are calculated to be in excess of £1,369. For more information, please see: http://www.cornwallriversproject.org.uk/

The Association of Rivers Trust is the umbrella of all the local rivers trusts across the UK. Further details of the activities of all the trusts can be found by following the link: http://www.associationofriverstrusts.org.uk/.

1.5 Environmental Effects of Agriculture and Land Use: Sub-project 1 – Review of Available Models and Recommendations for Inclusion in the Model Toolbox

This review presents the results and recommendations from a review of model tools suitable for inclusion in the toolbox of the Environment Agency's GIS-based Decision Support Tool (DST) for agriculture and land. The models are intended to support simulation for the following priority issues identified by the Environment Agency:

- surface water and groundwater hydrology, including river flow and recharge to groundwater;

- concentrations and loads of nutrients (nitrogen and phosphorus);

- concentrations and loads of pesticides from agriculture (including sheep dip);

- sediment load to surface waters.

The primary requirement for the model toolbox is a 'modular system' where specific models or model equations that address each priority pollutant issue can be selected and combined with one or more of a suite of hydrological models to predict impacts in terms of pollutant loadings and associated water volumes moving to surface or groundwaters.

Intended to operate at a national scale based on a one-km^2 grid resolution, the DST should be reliant on spatial datasets that are readily available. Free access to the intellectual property rights and the ability of developers to provide ongoing support was also a key component of the selection criteria. These criteria constrained the model selection to those considered both fit for purpose, in terms of their process representation, data requirements and scale of application, and freely available.

Main findings

The chosen models operate at different spatial and temporal scales and vary widely in complexity in terms of how they represent the underlying processes. Models considered most fit for purpose under the above categories were identified. Of

particular interest to this project are the following: at a national level, the procedures included in the MAGPIE project are recommended for estimating nitrogen transport, the Morgan-Morgan-Finney model is recommended for simulation of sediment transport and the PIT and PSYCHIC models are recommended for simulation of phosphate transport.

Limitations are also described and where appropriate, recommendations for further development and or linkage to other complementary approaches are suggested. One common limitation was associated with the aggregating of land units into the homogeneous grids used by the national-scale models. There is insufficient data to validate these spatial units and inadequate consideration is given to the interaction and connectivity between adjacent grids and therefore the link between the land surface and receiving waters. As a result, these approaches are considered to provide a 'Tier 1' screening type assessment of the risks of diffuse pollution from agriculture.

Field- or catchment-scale process-based models are required to integrate these 'Tier 1' source risks and link to receptors via pollutant transport pathways. These models can be calibrated against observed time-series and could be used to investigate the integrated response of a river and its catchment to agricultural practices and possible 'what if' scenarios. However, the data and resource requirements in setting up these models negate their application at the national scale and this review recommends their use for 'representative landscape scenario catchments' characterised by soil, substrate hydrology, land use and climate to represent a 'Tier 2' risk assessment within the DST. These catchments could then be the focus of more detailed monitoring and investigations as is currently underway in the 40 priority catchments identified by the catchment sensitive farming initiative.

1.6 EUROHARP – Towards European harmonised procedures for quantification of nutrient losses from diffuse sources http://euroharp.org/index.htm

One of the main aims of the EUROHARP project is to scientifically evaluate the performance and potential capability of quantification tools to estimate diffuse losses to receiving waters. This structured inter-comparison focused on nine contemporary catchment-scale models with the ability to simulate phosphorus and nitrogen loss from farmland. It was based on a literature review, a review of each model by the owner and outcomes from discussion at several workshops.

This structured assessment considered 15 different aspects of each model, including: purpose for original development; the pathways and processes represented and their complexity; the spatial and temporal resolution; data and resource requirements; sensitivity analysis and the ability to run 'what if' scenarios. Consideration was given to the suitability of each approach across 17 different European catchment typologies.

1.7 MOPEX (model parameter estimation experiment) -
http://nws.noaa.gov/oh/mopex/index.html

The MOPEX project investigates techniques for the *a priori* estimation of parameters used in land surface parameterization schemes of atmospheric models and in hydrological models. A first major step is the development of a comprehensive database containing many years of historical hydrometeorological time series data and land surface characteristics data for many basins in the United States and from other countries. The project has the following objectives:

1: Develop improved *a priori* model parameter estimation techniques for large-scale modelling applications and for ungauged basins.

2: Develop an international database of retrospective hydrometeorological data and basin characteristics data for a wide range of climate and geophysiological conditions.

3: Develop objective measures to evaluate the parameter estimate techniques and to understand parameter uncertainty.

4: Develop diagnostic tools to improve understanding of natural hydrologic processes at basin scales and related behaviour of hydrologic models.

5: Promote the exchange of ideas and experiences on approaches to model parameter estimation for different climatic regimes.

1.8 Optimizing Nutrient Management to Sustain Agricultural Ecosystems and Protect Water Quality (US Department of Agriculture)

This ongoing research by the US Department of Agriculture has the following aims:

- Quantify the impacts of fertilizer, manure, crop and grazing management on P, N and C cycling in soils.

- Define critical source areas and transport pathways of P and N by relating soil levels to losses in surface runoff and leachate, and delineate hydrologic processes controlling nutrient loss from watersheds.

- Determine stream channel hydrologic processes and fluvial sediment properties that control the transport of nutrients and pathogens from the edge-of-field to lakes, reservoirs, and estuaries.

- Develop and apply models and indices to assess and rank site vulnerability to nutrient loss and their impact on surface water quality.

- Define best management practices to minimize nutrient transfers from agricultural land to water.

This will be achieved through a multi-scale watershed-based study which will assess the fate of P, N, and C applied to land, describing chemical and physical interactions that control the transfer of P and N from soil to water and its subsequent transport in surface and subsurface flow in agricultural landscapes. This research will develop strategies and methods, including models and decision support systems, to provide solutions to reduce the impact of land-applied P and N on soil and water resources. In total, the research will enable best or alternative management practices to be targeted to critical source areas of the landscape for the most efficient and effective control of nutrient loss at a watershed scale. This will minimize the impacts of nutrient and pathogen losses from agricultural landscapes on receiving water resources.

For further information contact: andrew.sharpley@ars.usda.gov

1.9 SMURF (Sustainable Management of Urban Rivers and Floodplains)

http://smurf-project.info/

The aim of this project was to demonstrate how the principles of urban river basin management planning can be applied to highly modified and degraded catchments. As part of this work a report was produced, *Integrated catchment management and land use planning – Benchmark report on existing 'know-how' within the EU*. Although, primarily focused on the sustainable management of urban rivers the report provides a useful overview of available data relevant to integrated catchment management

including land use, hydrometry, water quality and ecology as well as infrastructure and operational assets. It identifies those responsible for collecting this information and the systems used to manage it. The roles and responsibilities of key organisations and wider stakeholders are also described. However, in part due to the implementation of the WFD and Defra's modernising regulation agenda, some of this information is now out of date.

The report examines 'enabling technology' which includes GIS, and how it can and is being used to support integrated catchment management. An overview of water management models is provided with descriptions of commonly used 'off the shelf' approaches such as the MIKE suite of models and SIMCAT. Recommendations are made for the integration of different systems to manage and interrogate all the data, to facilitate integrated catchment management.

2. Models and tools identified

Table F1: Overview of the models and tools identified

	Pressures	Processes	Pathways	Receptors	Model output	Recent use	Supplier/ developer/ availability
2.1 CASCADE	Diffuse pollution nutrients and sediments, point source water quality	Rainfall runoff and instream water quality processes	Surface runoff, throughflow, GW recharge + baseflow and river flows	Rivers			
2.2 ILC	All SW abs/dis pressures and point source water quality - basic GW and land use to generate diffuse loads	Rainfall runoff and water quality processes	Surface runoff, throughflow, GW recharge + baseflow and river flows	Rivers, lakes, reservoirs and water resource use (PWS abs)	Flow, nutrients (N & P) and other pollutant (DO, BOD, chlorophyll and metals) daily time series at up to 50 points across at catchment	In ongoing use since 1998 around 15 catchments across the UK (including the Wash)	Developer Imperial College, supplier Entec. Freely available for use but rights to source code retained by Entec.
2.3 INCA	Point and diffuse sources, GW and SW abstractions	Rainfall runoff, detailed in-stream water quality (including sediment) processes	Surface, near surface runoff, no direct GW component beyond baseflow storage	River network			Freely available
2.4 LowFlows 2000	Estimation of natural flows & artificial abstraction/discharge/impoundment influence	Rainfall runoff and river routing	Surface runoff and flow accretion	River flow			
2.5 Mike Basin	Abstraction, discharge, land use and water quality - basic GW	Hydrology, basic GW (sat. zone only), water quality	Surface runoff, throughflow, basic GW pathways + river routing	Rivers, lakes, reservoirs, GW (basic)			
2.6 DISTRIBUTED GROUNDWATER MODELS e.g. MODFLOW	GW abs + GW pollution (diffuse & point), SW abs/dis	Rainfall, runoff, recharge, saturated flow (& unsaturated flow), GW levels + SW interaction	Distributed groundwater flow	GW, rivers, wetlands, estuaries, lakes, GW PWS, winterbournes			
2.7 PEDAL / PIT	Diffuse pollution risk - phosphorus and sediment	Geographic, climatic and physical characteristics from	Surface runoff	Edge of field, no instream component	National scale risk map for phosphorus	Pedal	EA/ Lancaster University

		national datasets used to estimate time integrated export coefficients					
2.8 The PROACTIVE approach (TOPCAT, TOPMANAGE, DST)	Agricultural runoff, nutrients	Overland flow	Overland flow, subsurface flow	River network			
2.9 PSYCHIC	Phosphorus and sediment runoff	Erosion and runoff water chemistry for phosphorus	Surface runoff	Edge of field to drainage network, no instream component			ADAS
2.10 QUESTOR	Point sources	Instream processes, aeration, settling, decay and denitrification	Water quality routing and decay through river network	Rivers			
2.11 RAPHSA	SW abstraction	Relationship between physical habitat and flow	-	River flow			
2.12 SCIMAP	Relative risk of runoff from agricultural land	Temporal and spatial variability in hydrological linkage	Surface Runoff	Rivers	Risk of fine sediment delivery on river network	Around six catchments in UK to be trialled in 15 priority CSF catchments	Durham University, research ongoing
2.12 SIMCAT	Focus on point source water quality, only basic abstraction	Nutrient routing (no storage), no hydrology or GW	Water quality routing and decay through river network	River reaches (water quality)	Flow and water quality (mainly BOD, DO, Ammonia, P & N) summary statistics)	Ongoing use by Environment Agency includes most UK catchments	Environment Agency, freely available

2.1 CASCADE (CAtchment SCAle DElivery) - http://www.ceh.ac.uk/sections/wq/CASCADE.html

CASCADE is a research model developed to simulate the catchment-scale transfer of nutrients, sediment and other material from the land surface and the soil, through a river network to a catchment outlet. It provides day-by-day estimates of nutrient loads reaching rivers and extends to the simulation of transfers along the river network to the catchment outlet. The model comprises an in-stream and a delivery component, and operates on a catchment drainage network representation derived from a fine scale (50m) elevation grid. A network of river reaches with hydrological response units (HRUs) draining to them is generated from the complete drainage network. The HRUs are hydrologically independent, based on topography. Delivery of nutrients is based on a small number of landscape classes, each having its own drainage water quality characteristics. These are determined from existing knowledge or, preferably, from a survey of streams draining sub-catchments of a single landscape class. The HRU response is driven by precipitation, using a two-box soil model. This allows accumulation of material in solution in an unsaturated upper box, while drainage continues from the lower box. The in-stream component uses a one-dimensional kinematic wave approximation to route material through the stream network. In-stream processes associated with sediment and nutrient transport are included. Point source inputs are also accepted by the in-stream component of the model.

2.2 ILC (Integrated Lake and Catchment model)

The ILC model was initially developed by the Environmental Water Resources Research Group at Imperial College to support both the water industry and the regulators with water management decisions. ILC combines geographical information on catchment hydrology, artificial influences and inputs of diffuse and point source pollutants to simulate flow and solute concentrations at target locations in rivers or lakes. It is well suited to simulating the impact of 'what if' scenarios since key environmental controls (such as discharge consents, intermittent discharges, abstractions, river control structures, pumping rules and control curves) are modelled explicitly. Daily diffuse loads are generated as a function of effective rainfall and land use-based export coefficients for phosphorus and a simplified version of the INCA model for nitrates. In addition, the core in-stream model simulates ammonia, dissolved oxygen, BOD and chlorophyll-a. Conservative tracers or first order decay parameters can also be simulated. The model is dynamic, producing output time series (daily); it is semi-distributed and reliant on data that is readily available in UK catchments.

2.3 INCA (Integrated Nitrogen in Catchments) - http://www.rdg.ac.uk/INCA/

The INCA model is a process-based representation of plant/soil system and in-stream nitrogen dynamics. The INCA project aims to use the model to assess the nitrogen dynamics in key European ecosystems.

Based on mass balance and reaction kinetics, the INCA model accounts for the multiple sources of N and simulates the principle N mechanisms operating, including mineralisation, immobilisation, nitrification and denitrification. The model is dynamic and N concentrations and fluxes are produced as a daily time series. The model is semi-distributed, and as such, it does not model the catchment land surface in a detailed manner; rather, different land use classes within sub-catchments are modelled simultaneously and the information fed sequentially into a multi-reach river model.

The model provides an assessment of the river catchment N sources and sinks, and

estimates of the likely impacts of N deposition, land use and climate change scenarios on N fluxes, both in the plant/soil system and in-stream.

However, extensive databases that describe the hydrology and N dynamics of the study areas are required to run the model, thereby limiting its use as a generic tool.

Further research has led to the development of INCA- P and INCA-Sed that simulate phosphorus and sediments respectively.

For further information on the suite of INCA models, e-mail: aerc@reading.ac.uk

2.4 Low Flows 2000 - http://www.hydrosolutions.co.uk/lowflows1.html

Low Flows 2000 is a tool designed to estimate river flows at ungauged sites and to aid the development of catchment and regional water resources. It is the standard software system used by the Environment Agency and the Scottish Environment Protection Agency for providing estimates of river flows. Flow is represented by annual and monthly duration statistics, for any river reach in the UK.

2.5 MIKE BASIN

Mike-BASIN is lumped parameter catchment simulation model representing the hydrology of a basin in space and time. A full description of the software and its capability is given by http://www.dhigroup.com/Software/WaterResources/MIKEBASIN.aspx

Mike-BASIN was trialled as a tool for integrated catchment management in the Frome-Piddle catchment (Environment Agency, 2008).

2.6 Distributed Groundwater Models

MODFLOW is one such example. The Environment Agency has more than thirty distributed groundwater models covering the major UK aquifers. These focus on groundwater flow processes and their representation of surface water-groundwater interactions is limited.

2.7 The PROACTIVE Initiative – http://www.ncl.ac.uk/iq/index.html

This project by Newcastle University contains several tools described below.

a. TOPCAT is a simple hydrological model that provides time series modelling of flow and of nitrate, phosphates and phosphorus. It is a simplification of the rainfall-runoff model TOPMODEL and as such, uses identical soil moisture stores and subsurface flow equations. TOPCAT does not, however, use a topographic distribution function and thus does not allow the representation of topographically controlled variable source areas. TOPCAT also contains an extra baseflow/dry weather flow component and two overland flow components that are caused by intense agricultural management practices. TOPCAT-N and TOPCAT-P are based on simplified versions of the key equations used by EPIC, a physically based model. These describe transfer of nitrates and phosphates, respectively.

b. TopManage is a digital terrain analysis (DTA) tool which is designed to demonstrate to farmers and land managers the effect of different land uses on hydrology. Used in conjunction with a Geographical Information System (GIS) such as ArcView,

TopManage enables the user to assess what the effect would be of adding to, or removing from, the land topographic features. Starting from a digital terrain map of a particular field or area of farmed land, usually derived from Geographical Positioning System (GPS) measurement, maps can be input to the GIS, topographic features added, and augmented terrain maps analysed using TopManage. The model can identify sinks associated with a particular topography and estimates of the accumulation of flow at a point which is used as a basis for the prediction of source areas, saturation excess overland flow and subsurface flows.

c. Decision Support Tools (DST) These allow farmers and land use planners to assess the risk of nutrient loss from their land and to explore options to reduce nutrient loss whilst maintaining farmer income. This enable farmers and stakeholders to compare current land use practice within the wider context of alternative land management options. Examples include the NERM, PERM and the NORM.

2.8 Phosphorus Indicators Tool (PIT) - http://www.lec.lancs.ac.uk/cswm/pit/po.php

The development of the PIT model was funded by Defra. The aim of this project was to identify appropriate indicators of the sources of P and pathways of transfer that may lead to the delivery of P from agricultural land towards watercourses. The objective was to integrate these indicators within a single calculation system or model to predict the spatial variation in the risk of P loss. To achieve this, the model needed to:

- be able to respond to changes in both agricultural land use and management and to environmental factors;

- be structured in such a way that the individual parameters and stages of calculation have physical meaning based on field measurements;

- use readily available data at the catchment scale (for any catchment in England and Wales).

The model operates at the one-km^2 scale and has three layers: P sources (layer 1), P transfer (layer 2) and P delivery (layer 3). The capability for future modification of parameter/coefficient values as new empirical data becomes available and our understanding improves, through local knowledge, is built in. The PIT model is written in ArcGIS using the VBA programming language. Excel files containing the input data for the model are directly converted into an ArcGIS grid.

2.9 PSYCHIC – Phosphorus and Sediment Yield Characterization in Catchments

PSYCHIC has been jointly funded by Defra, the Environment Agency and English Nature to develop a risk assessment and decision support tool to control diffuse loads of phosphorus and particulates from agricultural land. It is a collaborative project with ADAS, the Centre for Ecology and Hydrology (CEH), the National Soils Resources Institute and the Universities of Exeter and Reading.

This research draws together the available knowledge and expertise on the sources, mobilization and delivery of sediment and P from agricultural land to water, to develop a prototype decision support tool. This will enable catchment stakeholders to target various control options within a catchment in a pragmatic and mutually acceptable way. The development of PSYCHIC has been undertaken in two study catchments suffering diffuse pollution, the Hampshire Avon and the Wye, and is designed to be compatible with current policy initiatives in England for bringing about the changes in farming practice that are identified by the tool.

2.10 QUESTOR (Quality Evaluation and Simulation Tool for River-systems)

http://www.ceh.ac.uk/products/software/CEHSoftware-QUESTOR.htm

QUESTOR is a software framework to support the development of in-stream water quality models. It provides the basic differential equations to simulate a set of parameters that include the following: flow, temperature, pH, dissolved oxygen, biological oxygen demand, nitrate, ammonia and ammonium. Aeration, settling and decay as well as nitrification and denitrification processes are simulated within well mixed reaches. There is no limit to the number of reaches that can be used to represent the river network. Diffuse inflows are not represented explicitly; instead, they are treated as inflows to the top of a specified reach.

For further information, email Dr David Boorman at CEH: dbb@ceh.ac.uk.

2.11 RAPHSA (Rapid Assessment of Physical Habitat Sensitivity to Abstraction)

RAPHSA was set up as a collaborative project between the Centre for Ecology and Hydrology (CEH) and the Environment Agency. It investigated the technical feasibility of developing a (suite of) catchment-wide tool(s) for rapidly determining the sensitivity of physical habitats to abstraction pressures. This makes use of the direct relationship between physical habitat and flow as a potential tool for assessing the ecological impact of changing the flow regime of a river. At the core of this study is the RAPHSA database that contains data from 66 detailed physical habitat studies across the UK.

The output from RAPHSA has been two new tools - the Direct Rapid Assessment of Physical Habitat Tool-kit (DRAPHT) and the Catchment Habitat Assessment Tool (CHAT). The DRAPHT tool-kit is a risk-based approach to rapid physical habitat assessment and contains three tools that differ in their input data requirements:

DRAPHT$_{CC}$ – a low confidence tool that requires physical catchment characteristics, such as drainage area and average annual rainfall. Values can be derived from computer-based tools such as Low Flows 2000, without the need for a field visit.

DRAPHT$_{TM}$ – a low-medium confidence tool that requires measurements of the river channel such as mean width and depth, with mapping of the river length of interest. The exceedance percentile of river flow at the time of measurement must be known.

DRAPHT$_{CM}$ – a medium confidence tool that requires measurements of the river channel (as with DRAPHT$_{TM}$) plus velocity measurements with a current meter. Again the exceedence percentile of the river flow at the time of measurement must be known.

CHAT is a high confidence tool developed for habitat assessment using hydraulic output data from a separate one-dimensional model output. Software has been written to allow the import of data from the ISIS one-dimensional hydraulic model often used in flood studies.

The tools produce estimated relationships between river flow and river width, depth, velocity or physical habitat. The slope of any relationship produced by RAPHSA indicates the sensitivity to abstraction at that flow.

For further information, contact Mike Acreman at CEH.

2.12 SCIMAP http://www.scimap.org.uk/

SCIMAP is a joint project between Durham and Lancaster Universities and is supported by the UK's Natural Environment Research Council, the Eden Rivers Trust, Defra and the Environment Agency.

It is an approach that aims to determine the relative risk that a particular parcel of land is contributing diffuse pollution to a river. This information can then be used to prioritise and target measures for environmental improvement.

SCIMAP works by combining a map of the relative risk of generating diffuse pollution for 5 m by 5 m locations in the landscape with the relative risk of each location being connected to a river. By combining the risk of pollution generation and the risk of connection, the model can determine the risk that pollution is released into the water environment. In the final stage, the connected risk is routed across the landscape, accumulating it along flow paths. SCIMAP can also dilute the accumulated risk by the upslope contributing runoff to produce a risk concentration.

The resulting maps allow all locations within the model area to be compared to identify the most likely problem locations, and hence where restoration should be prioritised, such as catchment sensitive farming.

The outputs from the model are impressive, both in terms of the detail and the validation of the output against more complex process-based models. However, as with all modelling approaches, the output needs to be interpreted with the assumptions on which the model is based in mind. The key potential limitations that should be considered are:

- SCIMAP does not consider the permeability of a catchment. This appears to be a significant restriction; however, data on land use and topography does contain a permeability 'signal'. Initial results in permeable catchments appear to be surprisingly good.

- The model does not maintain a water balance. This means that it cannot be used to assess concentrations against a threshold, only concentration risk.

- The inputs are based on annual averages and therefore the model's ability to capture time variant behaviour may be limited.

- The results are relative, not absolute, risk. This means that model results cannot be compared across catchments unless both catchments are treated as one larger catchment and run as one model.

Initial model development was based on the risk of delivery of fine sediment, the 'easiest' diffuse pollution task. Subsequent work will focus firstly on phosphate risk and then nitrate risk. It is anticipated that these will be considerably more challenging. There is a plan to incorporate permeability into the model directly along with 'measures' so that the model can be used to see how these impact the distribution of risk.

2.13 SIMCAT

SIMCAT is a one-dimensional, steady-state model that can represent river quality impacts resulting from inputs from point-source and diffuse effluent discharges. It uses the Monte Carlo Simulation approach to mix discharges and diffuse inputs with river waters and then routes flows in the river down through the catchment, applying water quality transformation processes en route. Hence, SIMCAT is able to predict flow and quality distributions at any selected point in the catchment and produce results as statistics for comparison with specific river quality standards.

Further information can be found at the following
http://www.wrcplc.co.uk/default.aspx?item=383

Appendix G – Initial trialling of three models with potential application to integrated catchment management

G1 – Environment Agency Decision Support Tool (DST)

In 2004, the Environment Agency reviewed a range of modelling tools suitable for inclusion in a GIS-based Decision Support Tool (DST) for agriculture and land (Environment Agency, 2004). This review made recommendations about models to simulate nitrate, phosphate, sediment and pesticide transport and included process-based models such as INCA and export coefficient models such as PSYCHIC and PIT. The DST has now been developed based on these recommendations.

The Decision Support Tool can be used to: (1) characterise baseline agricultural diffuse pollution pressures from nutrients, sediment and pesticide (Defra, 2005, 2006; Environment Agency, 2004, 2006; 1996; Lord and Antony, 2000; Morgan, 2001); and (2) investigate possible mitigation of diffuse pollution pressures by modelling land use and land management scenarios (Defra, 2005; Environment Agency, 2007a,b).

The DST uses a one-km^2 grid. Input data for each one-km^2 cell includes parameters for soil, land use, land management, climate, topography and hydrology and these are available for all of England. Note that the data held for each one-km^2 cell (e.g. soil and land use) are not ground-truthed and can mask local issues. Also note that the current land use dataset (Defra AgCensus 2000) will be updated to Defra AgCensus 2004 in July 2007. Further, the sensitivities of the AgCensus data mean that the DST AgCensus datasets have limited accuracy. For this reason, the models should not be used to produce model outputs for catchments smaller than 25 km^2.

This report focuses on model outputs from the NEAPN (nitrogen) and PSYCHIC (phosphorus and sediment) models. These enable us to investigate Defra's diffuse pollution mitigation options (Defra, 2005). A summary list of Defra's diffuse pollution mitigation options is shown in Table G1. Also shown are the mitigation options that can be represented within NEAPN and PSYCHIC (Environment Agency, 2007a,b).

Modelled outputs can be produced for all catchments in England. Example outputs are shown in Figures G1, G2 and G3 for the Frome and Piddle catchments in Hampshire. These figures show baseline outputs (existing land management AgCensus 2000) and a single scenario output (Option 1: change arable land to grassland, Table G1). This is not a wholly practicable measure for these catchments; however, it is used here as a simple demonstration of the kinds of model outputs that can be made available. The basic rationale for this measure is that reverting to grassland will promote reductions in nitrate leaching and the permanent grassland cover will minimise erosion of soil particles and loss of associated P in surface runoff. Modelled outputs shown are for NEAPN (baseline N leached and predicted reduction after mitigation), PSYCHIC Phosphorus (diffuse P reaching surface waters and predicted reduction after mitigation) and PSYCHIC sediment (total sediment reaching surface waters and predicted reduction after mitigation). The baseline model outputs show catchment hotspots and

the scenario outputs show where the best N, P and sediment improvements can be gained through mitigation.

The model outputs are predictions of catchment behaviour, which have not been validated using local observations on the ground. There are many assumptions that are used in modelling approaches that are not obvious without detailed knowledge of the models themselves. These modelling assumptions plus the limited accuracy associated with model input data (one-km^2 grid) mean that outputs may be wrong for individual catchments, that is, the nationally available datasets can easily mask important local issues. Thus, the model results should only be considered in conjunction with observations on the ground and expert opinion. Finally, neither the data nor the model outputs have been validated for individual catchments across England.

Table G1: Summary of Defra diffuse pollution mitigation measures to be included in NEAPN and PSYCHIC measures library.

Category	No.	NEA PN	PSYCHIC	Measure
Land use	1	X	X	Convert arable land to extensive grassland
Soil management	2	X	X	Establish cover crops in the autumn
	3			Cultivate land for crop establishment in spring rather than autumn
	4		X	Adopt minimal cultivation systems
	5			Cultivate compacted tillage soils
	6			Cultivate and drill across the slope
	7		X	Leave autumn seedbeds rough
	8		X	Avoid tramlines over winter
	9		X	Establish in-field grass buffer strips
	10		X	Loosen compacted soil layers in grassland fields
	11			Maintain and enhance soil organic matter levels
	12			Allow field drainage systems to deteriorate
Livestock management	13	X	X	Reduce overall stocking rates on livestock farms
	14			Reduce the length of the grazing day or grazing season
	15		X	Reduce field stocking rates when soils are wet
	16		X	Move feed and water troughs at regular intervals
	17	X	X	Reduce dietary N and P intakes
	18	X	X	Adopt phase feeding of livestock
Fertiliser management	19	X	X	Use a fertiliser recommendation system
	20	X	X	Integrate fertiliser and manure nutrient supply
	21	X	X	Reduce fertiliser application rates
	22		X	Do not apply P fertilisers to high P index soils
	23	X	X	Do not apply fertiliser to high-risk areas
	24	X	X	Avoid spreading fertiliser to fields at high-risk times
Manure management	25	X	X	Increase the capacity of farm manure stores
	26	X		Minimise the volume of dirty water produced
	27			Adopt batch storage of slurry
	28			Adopt batch storage of solid manure
	29			Compost solid manure
	30	X		Change from slurry to a solid manure handling system
	31			Site solid manure heaps away from watercourses and field drains
	32			Site solid manure heaps on concrete and collect the effluent
	33		X	Do not apply manure to high-risk areas
	34	X	X	Do not spread farmyard manure to fields at high-risk times
	35	X	X	Do not spread slurry or poultry manure to fields at high-risk times

	36		X	Incorporate manure into the soil
	37	X		Transport manure to neighbouring farms
	38			Incinerate poultry litter
Farm infrastructure	39		X	Fence off rivers and streams from livestock
	40		X	Construct bridges for livestock crossing rivers and streams
	41		X	Re-site gateways away from high-risk areas
	42		X	Establish new hedges
	43		X	Establish riparian buffer strips
	44			Establish and maintain artificial (constructed) wetlands

Figure G1.

Frome and Piddle River catchments
NEAPN model: N load leached (kg/ha)

Science Report – Making Information Available for Integrated Catchment Management
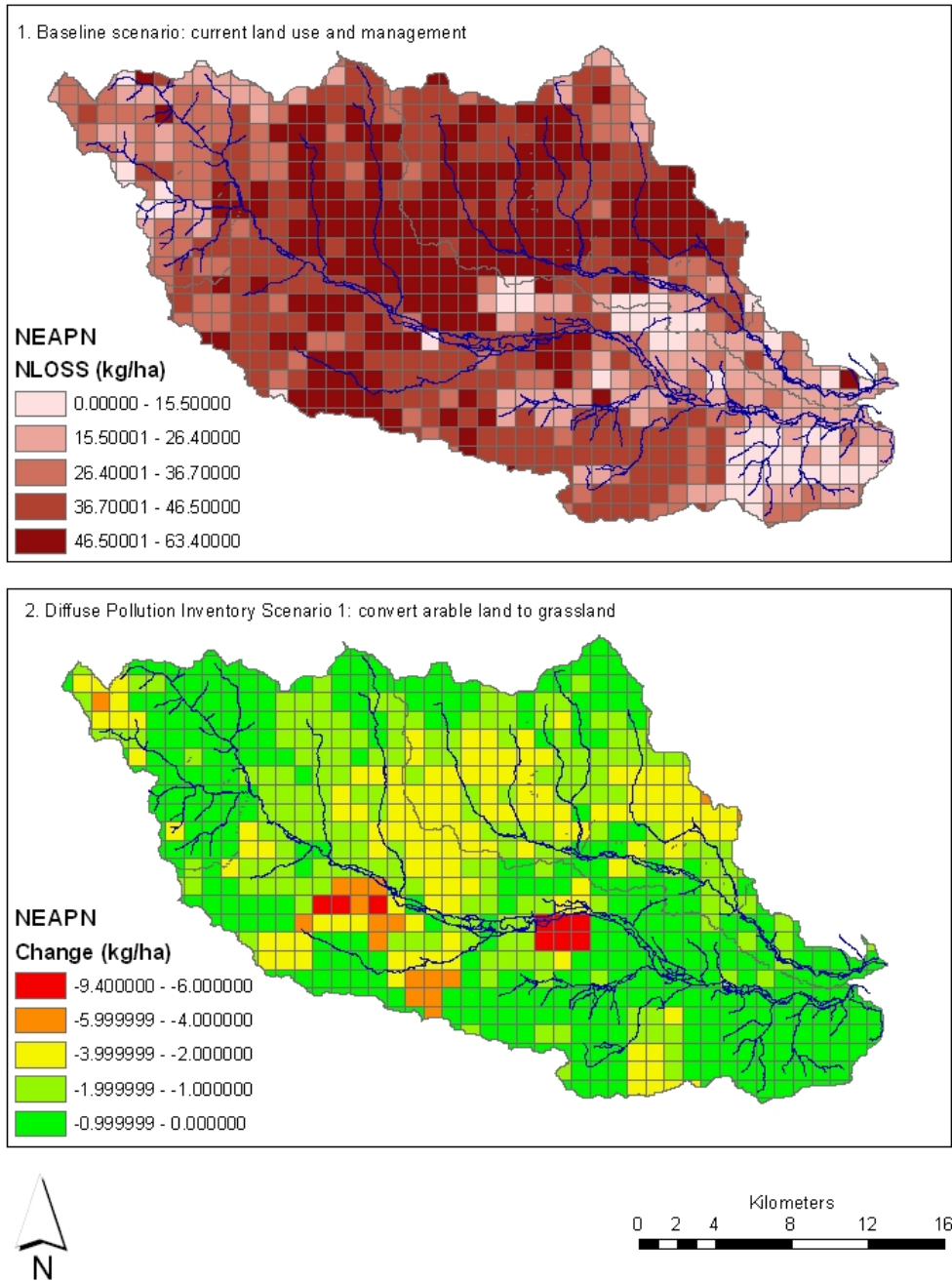
Figure G2.

Frome and Piddle River catchments
PSYCHIC model: diffuse transfer of P to surface
waters (kg/ha)
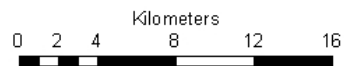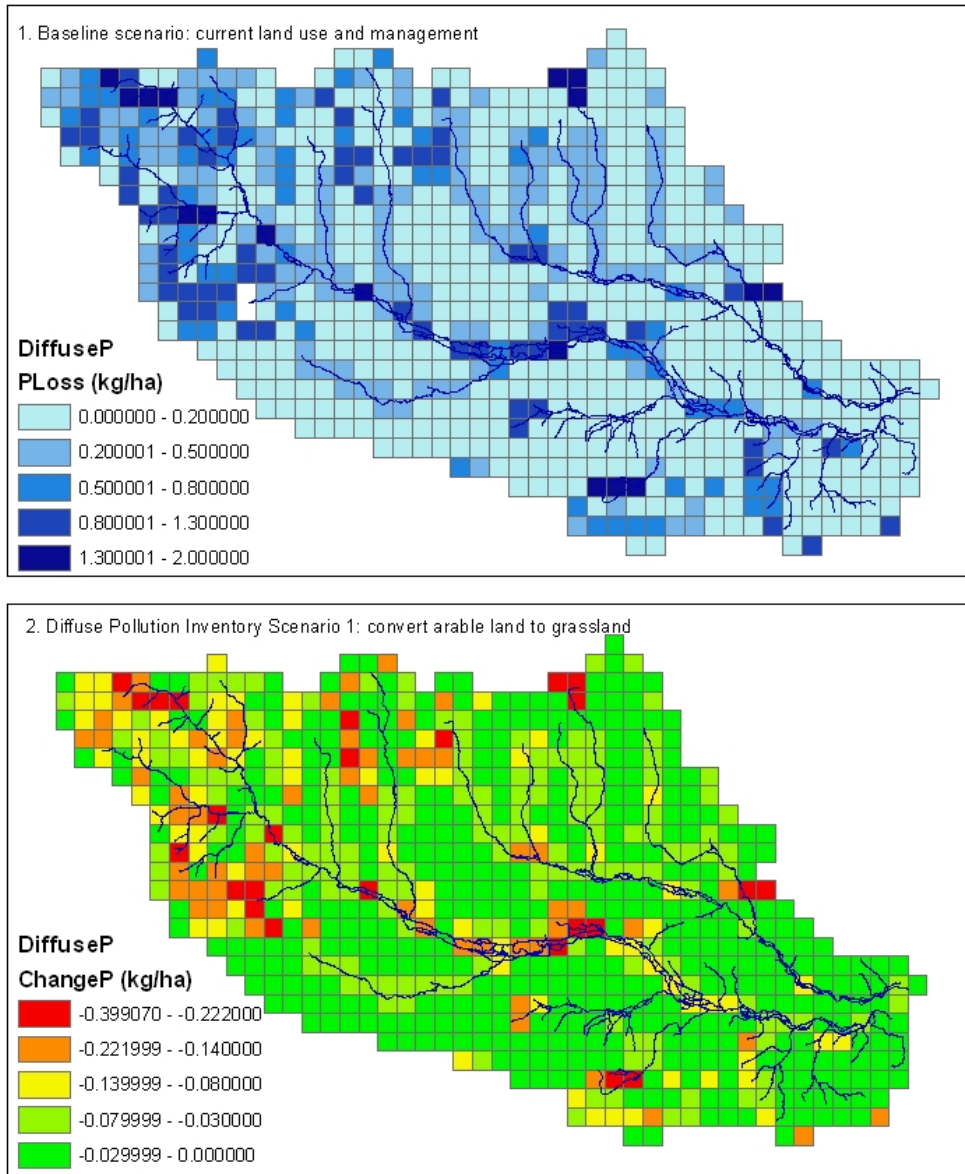
Figure G3.

Frome and Piddle River catchments
PSYCHIC model: diffuse sediment load to surface
waters (kg/ha)
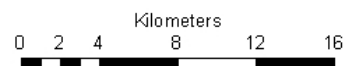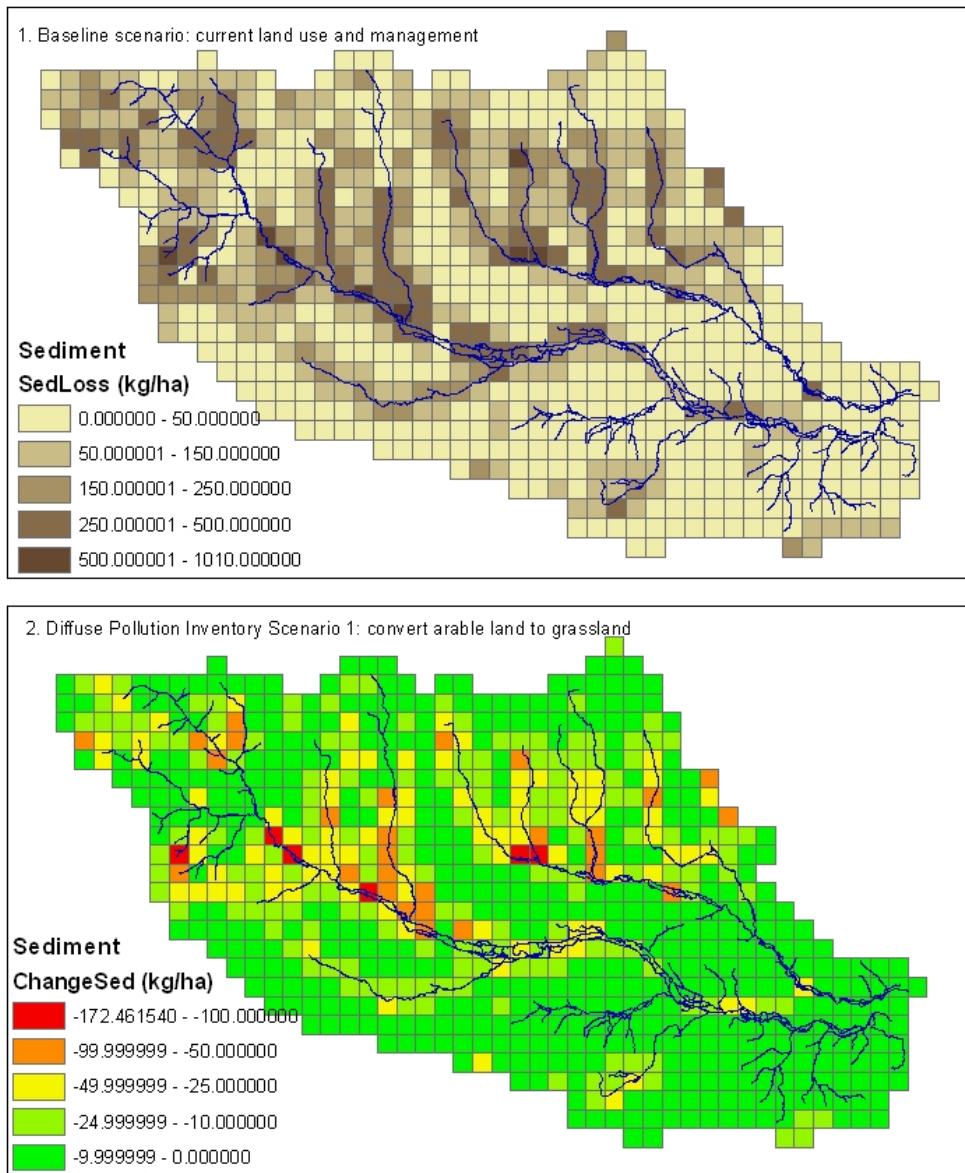
G2 - Newcastle University PROACTIVE approach for nutrient pollution management

The Environment Agency commissioned Newcastle University to apply two components of the PROACTIVE toolkit, Decision Support Matrices (DSMs) and TOPCAT-NP, to the Frome-Piddle so that we could assess their potential as tools for nutrient management.

The PROACTIVE approach is a dynamic philosophy geared towards intervening in the environment to improve water quality, reduce flood risk and diffuse pollution, recycle waste and introduce renewable energy generation into farming. The PROACTIVE approach includes introducing features such as temporary storage ponds, buffer strips and phosphorus stripping zones in the landscape. Demonstration sites are currently under development to prove the effectiveness of such features on working farms. Decision Support Matrices (DSMs) have been developed to communicate the results of research to farmers and land use managers, in particular the Nutrient Export Risk Matrix (NERM). In addition, PROACTIVE uses existing tools for catchment management such as TOPCAT-NP and visualisation tools such as TopManage. Full details of the PROACTIVE toolkit can be found at
http://www.ncl.ac.uk/iq/Proactive/Proact.html

G2.1 The Decision Support Matrix

The Decision Support Matrix (DSM) approach is built on a set of tools designed to support policy and decision making. Conceptual models, interactive tools and examples of good and bad land management practice are used to communicate the results of research to end users such as policy makers, farmers and agronomists. The DSM approach has proven effective for communicating concepts such as integrated runoff management and proactive interventions for improved land management.

Caspar Hewitt (Newcastle University) demonstrated two DSMs, the Nutrient Export Risk Matrix (NERM) and the Phosphorus Export Risk Matrix (PERM) and developed a prototype Nitrate Export Risk Matrix (NORM) with Melissa Robson, the CSF officer. A selection of screen prints from the NORM DSM is shown in Figures G4 to G6. Several of the questions in the NORM DSM were transferred directly from the PERM tool with minimal amendment, such as units and the definitions of high and low levels of input. But some extra questions were needed because the forms of nitrogen inputs differ from those for phosphorus. The feedback from the CSF officer was vital in determining the relative risks and in using language appropriate to current nitrogen management regimes on the farms in the Frome-Piddle.

All the DSM tools use a simple visual interface and a series of question and answer pages so that farmers and policy advisers can assess the relative risks of pollution from farm land and water management.
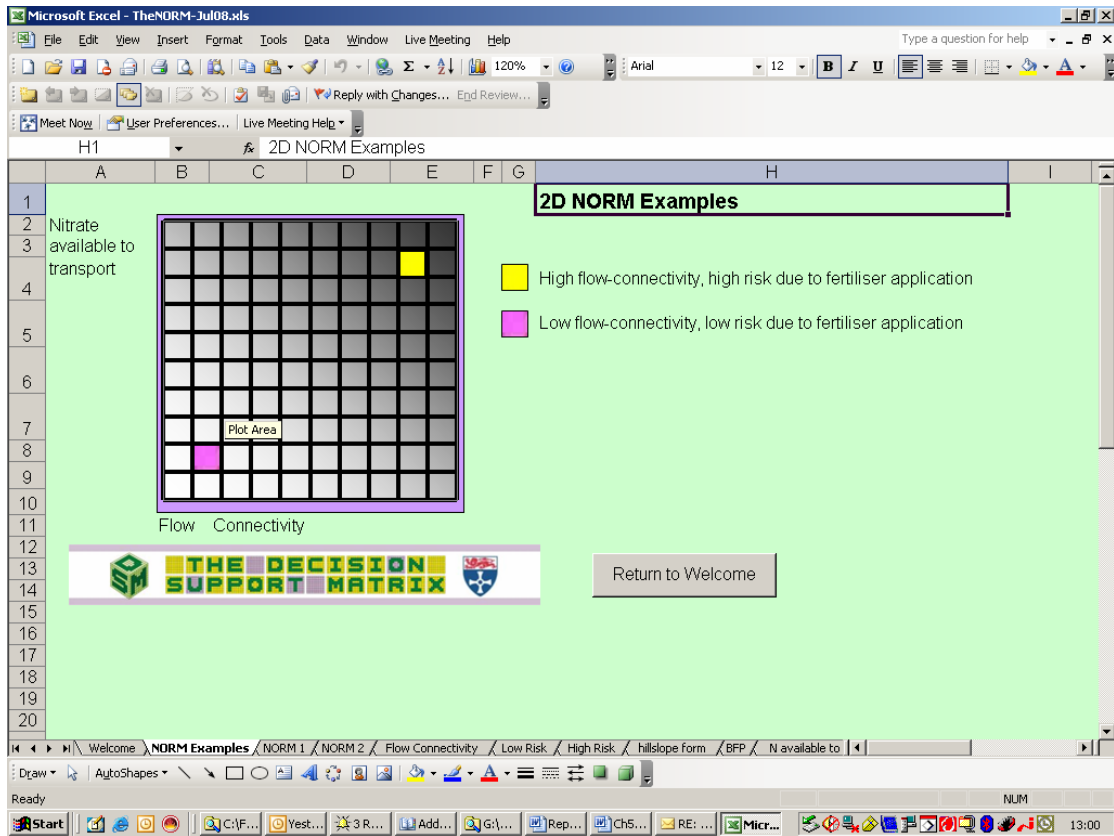
Figure G4 The NORM matrix, based on the Excel interface
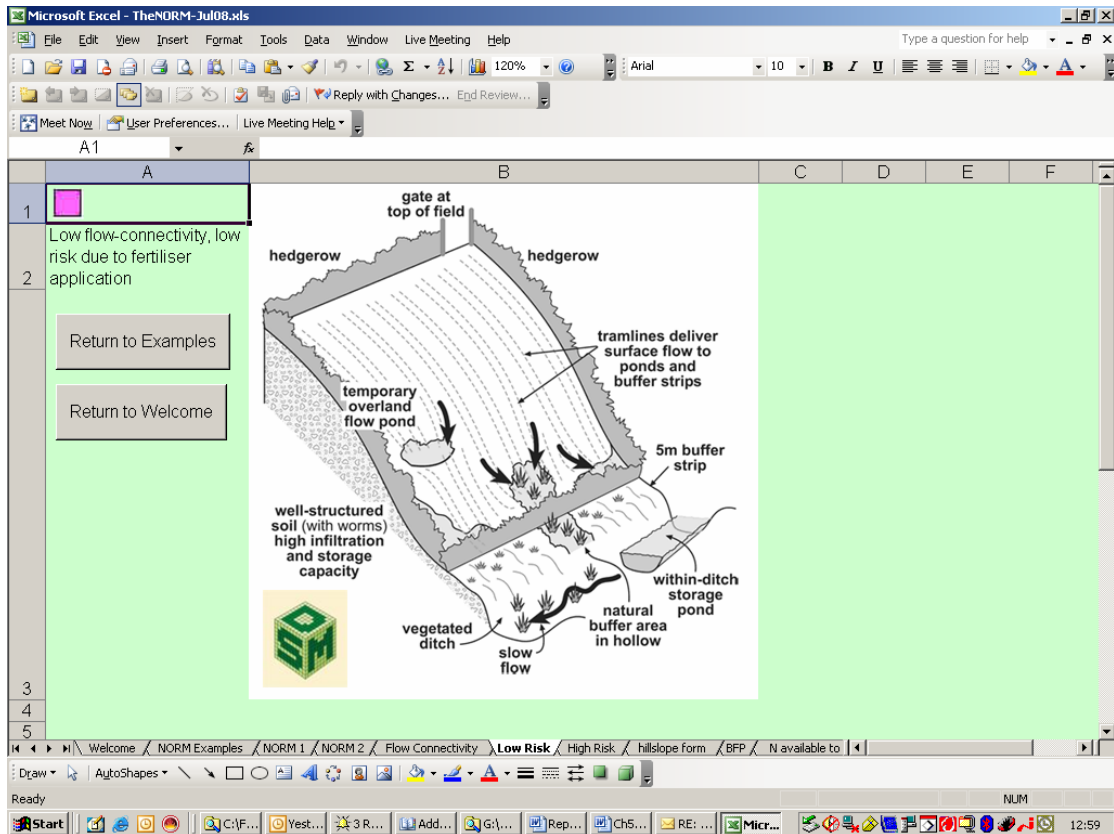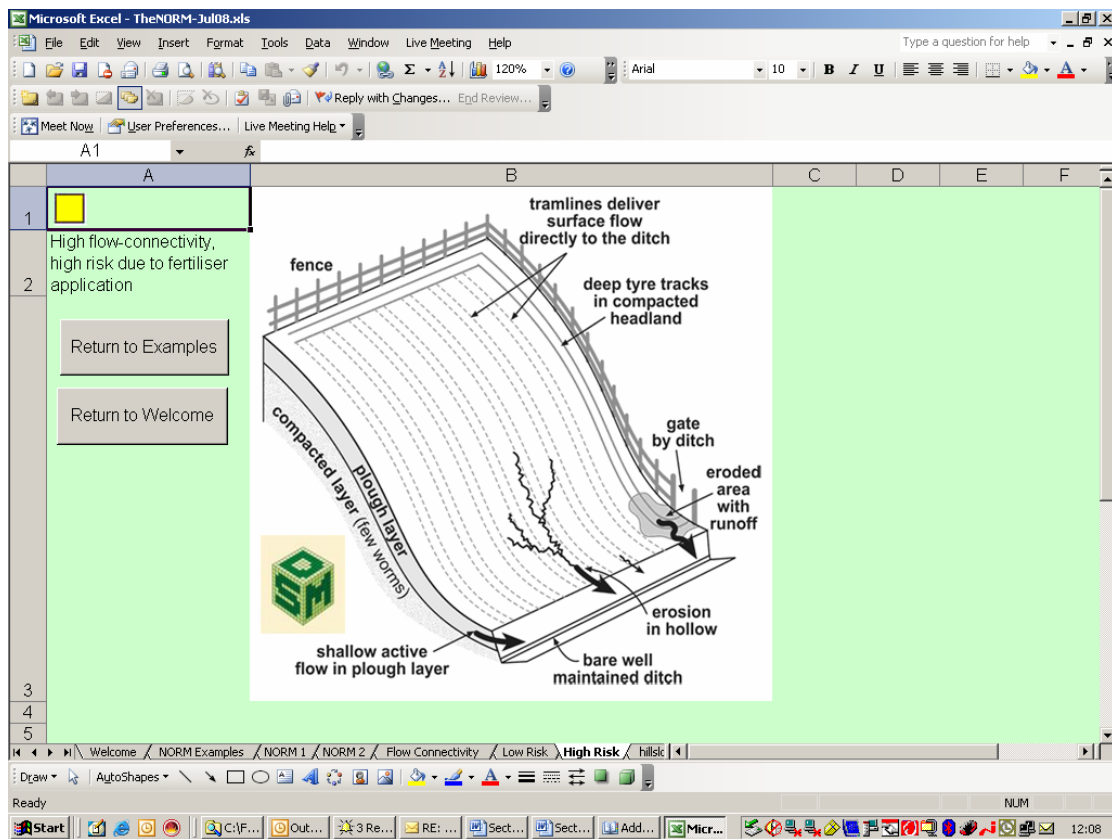

Figure G5 NORM - Sketch of field with LOW risk of nitrate pollution in the stream

Figure G6 NORM - Sketch of field with HIGH risk of nitrate pollution in the stream

G2.2 TOPCAT-NP

TOPCAT-NP (Quinn *et al.*, 2008) is a simple hydrological model that provides time series modelling of flow, nitrate, phosphates and phosphorus. We trialled it for use as an investigative tool to develop our understanding of how nutrients move through the surface water/groundwater system, based on observed data. The model was calibrated for the Frome and Piddle catchments, and the results of a number of the simulations were presented at the meeting in Blandford on 29 March 2007. Further details are presented below.

Data inputs and model set-up

The model requires the following inputs:
- Time series of rainfall - we used 10 years of daily local rainfall gauge data.
- Time series of potential evaporation - we used an estimate based on the annual average potential evaporation.
- Stream flow rates - we used the observed discharges from the Environment Agency gauges at Holme Bridge on the Frome and West Mills on the Piddle.
- Soil type - from the HOST dataset (to give a working knowledge of the storm runoff and baseflow dynamics).
- Total nitrogen and phosphorus applied to the land – estimated based on typical values (such as survey of fertilisers produced by Defra, or see Quinn 2004).
- Observed nitrate and phosphorus concentrations in the stream at the same locations as the observed flows - typically about two readings per month for the nutrient data: nitrogen as nitrate and soluble phosphorus.

- Aerial photographs and geological maps – very useful for building a conceptual understanding of the hydrogeological activity in the area and the range of land use types from intense agriculture to low intensity scrubland.

We know that the flows in the rivers Frome and Piddle are dominated by baseflow from the Chalk aquifer and that the soils are mainly sandy. Aerial photographs and maps for the area revealed a split between intensive agricultural zones and wooded non-agricultural zones. There are also some smaller urban areas, especially on the Frome.

The model was calibrated for the Frome (414 km^2) and the Piddle (183 km^2) using data supplied by the Environment Agency. We deliberately did not use any additional GIS data sources because we wanted to see how well TOPCAT-NP performed as a quick assessment tool for simulating catchment scale fluxes using only readily available data.

Figure G7 shows the model structure. The original TOPCAT-NP model uses a constant baseflow term but for the Frome-Piddle we added a dynamic, subsurface store (bottom left of Figure G7) to represent the flow to the rivers via the Chalk groundwater system. The model can run with any time step, however we chose daily time steps because we were representing a large catchment (above10 km^2) in a fairly coarse way. For smaller catchments (below 10 km^2), such as those on the demonstration farms, we would use hourly time steps. At a scale of one km^2 or less, the model is more suited to high resolution time series and more detail about the causes and effects of nutrient pollution can be addressed (see Quinn *et al*., 2008).

The TOPCAT-NP model can represent:

- seasonal flow patterns;
- flow patterns during storms;
- dominant flow paths;
- dominant nutrient regimes;
- potential sources of nutrient loss;
- the effects of nutrient mixing in a fast response store (representing surface and shallow subsurface flows), and in a slow response store (representing deeper flow through the unsaturated zone and the saturated groundwater system).

The equations used in TOPCAT-NP 'mimic' those in more complicated runoff and nutrient models, namely EPIC and TOPMODEL (Williams, 1995, Beven *et al*., 1995). This mimicking of physical processes attempts to give some physical basis to the terms used in the model. The model is deliberately designed for quick and easy calibration to observed data. If it cannot be calibrated quickly, this suggests that the processes represented in the model are incorrect, as opposed to the values of the input variables. This implies that there is either a flaw in our conceptual understanding of the observed data or a flaw in the representation in the TOPCAT-NP model.
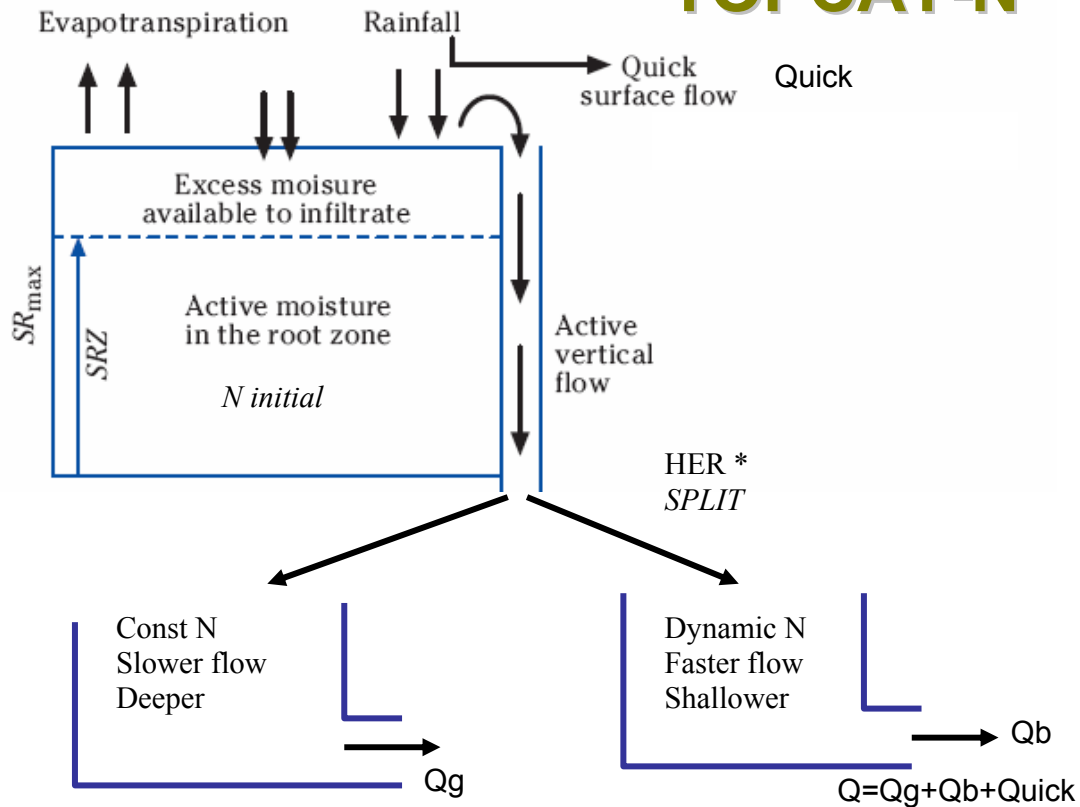
Figure G7 TOPCAT-NP model structure

(see Quinn *et al*., 2008 and http://www.ncl.ac.uk/iq/TOPCAT/TCTheory.html)

SR_{max}	=	maximum moisture content of soil root zone
Q	=	total flow
Quick	=	quick surface flow
Qg	=	flow from slow sub-surface store
Qb	=	flow from fast sub-surface store
HER	=	hydrologically effective rainfall
SPLIT	=	coefficient controlling split of *HER* to the two sub-surface stores
		(*SPLIT* is between 0 and 1)

Model results and interpretation

The initial simulations on the Frome-Piddle used the original version of TOPCAT-NP which did not contain the slow store representing flow via the groundwater system. This produced a poor match with the observed nutrient concentrations in the streams. However, once the slow store was added (bottom left of Figure G7) the model results were a much better match and could be fitted to the observed flow, nitrate and phosphorus data for both the Frome and Piddle (Figures G9 to G14).

However, even if the model results are a good match with the observed data, this is no guarantee that the model is 'right', because the determined parameter sets may not be non-unique. It may be only one of several combinations of input parameter values that would provide a match with the observed data. Nevertheless, this process gives us one plausible explanation of the observed data and helps rule out those **not** supported by the observed data. This helps guide us towards selecting appropriate measures for reducing nutrients, based on the available evidence and data.
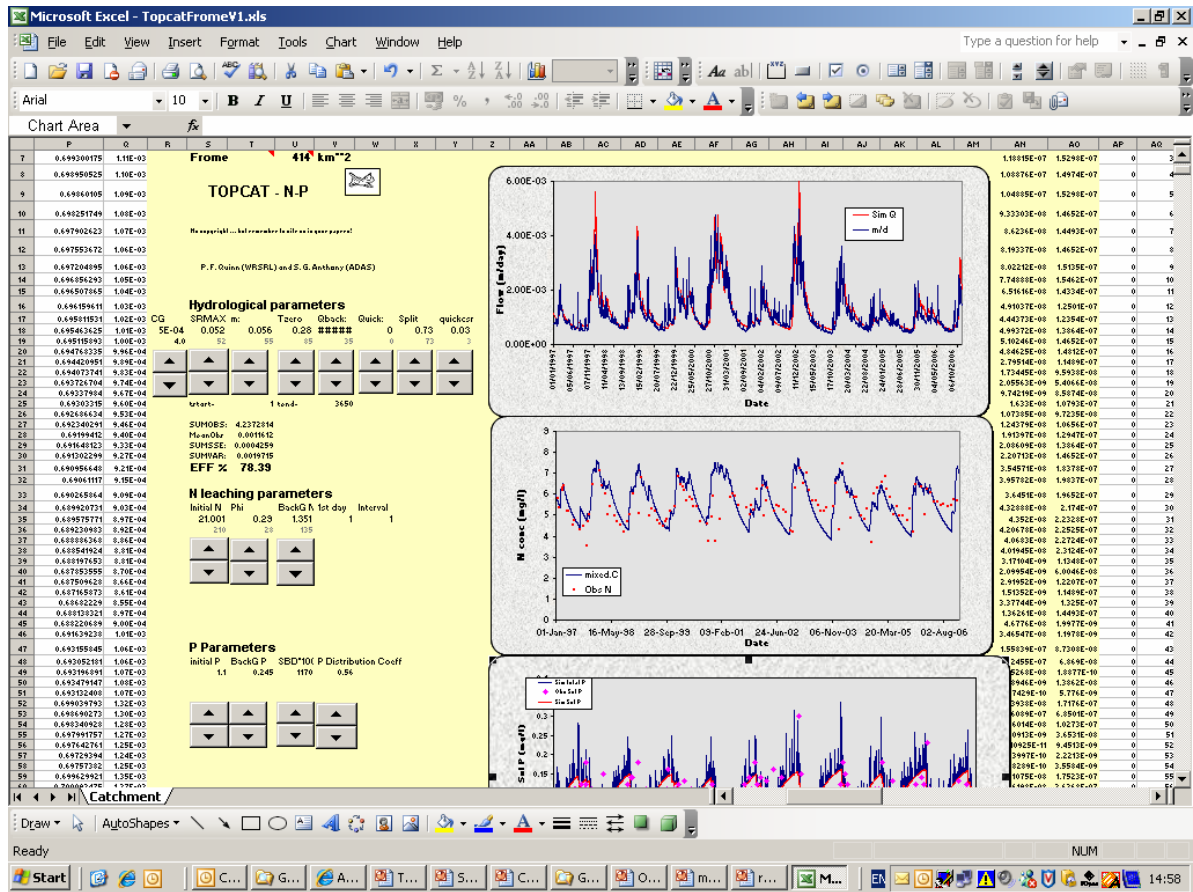
Figure G8 The TOPCAT NP Excel interface
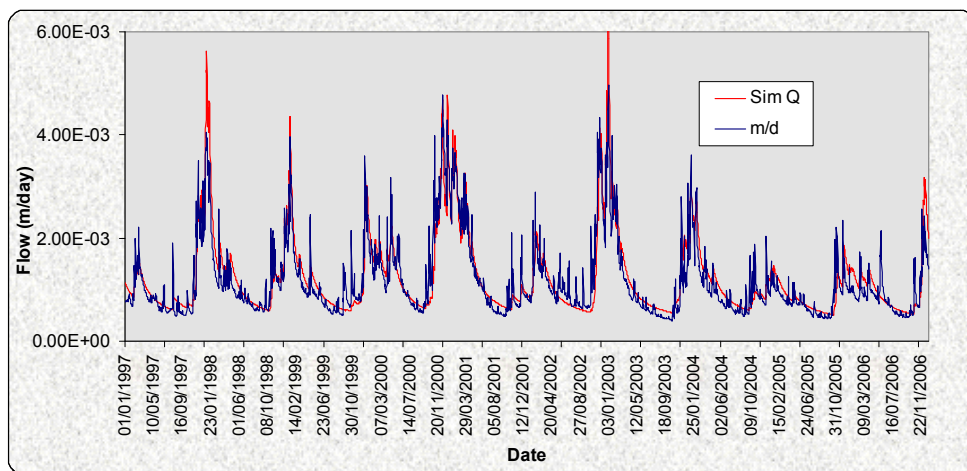
Figure G9 Flow in the River Frome (blue = observed; red = modelled)
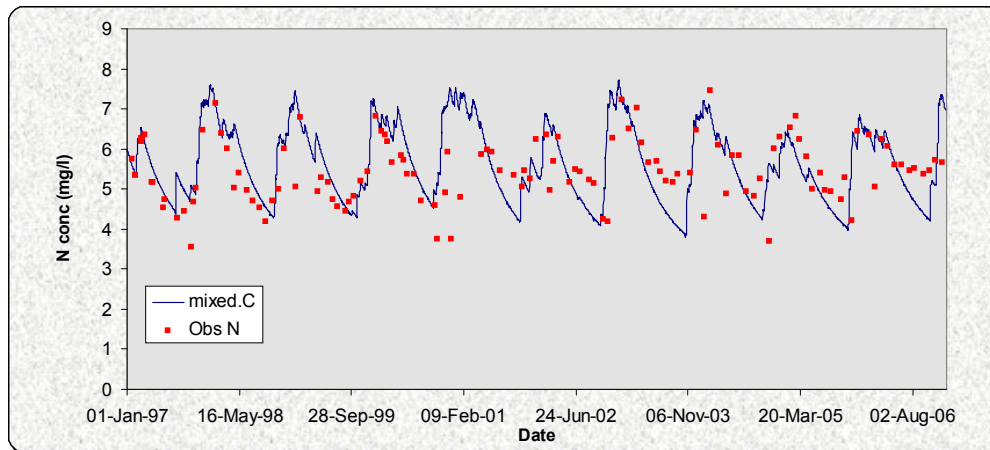
Figure G10 Nitrate concentration in the River Frome (red points = observed; solid blue line = modelled)

Model results for the River Frome

To obtain the final calibrated model, the flow and N simulations required a mixture of a faster shallow flow path with a rapid turnover of nitrate (Qb), and a slower groundwater store with a slower turnover of nitrate (Qg). The model is thus sensitive to the recession rates of both stores, that is, the speed at which they empty once recharged with flow from the soil.

Equally, the split of the vertical flow (the hydrologically effective rainfall) into the two stores is important. In this simulation, 70 per cent of the active runoff entered the fast subsurface store and 30 per cent entered the slower groundwater store. The observed base flow index is 0.9 and this is usually taken to imply that 90 per cent of the stream flow discharges from the groundwater system. In future work, we recommend investigating whether a good match with observed data can be produced with values of SPLIT which divert more flow to the slow store.

Finally, the total amount of active nitrate applied to the model and the soil type (Phi) scales the whole nutrient regime up and down.

The results show little variation in the range of nitrate concentrations when compared to other high nitrate catchments in the UK (which could be from two to 25 mg/l N), and the overall levels are not high (about six mg/l). We have interpreted this to be a result of the similar areas of agricultural and non-agricultural land in the catchment, with the low nitrate inputs from the non-agricultural land diluting the high nitrate inputs from the agricultural land.

The simulations for soluble phosphorus are more difficult to interpret. However, the levels seem to be high despite any dilution effects. The higher summer values are typical of phosphorus enriched baseflow often associated with human/urban input of phosphorus from treatment works and/or soakaways.
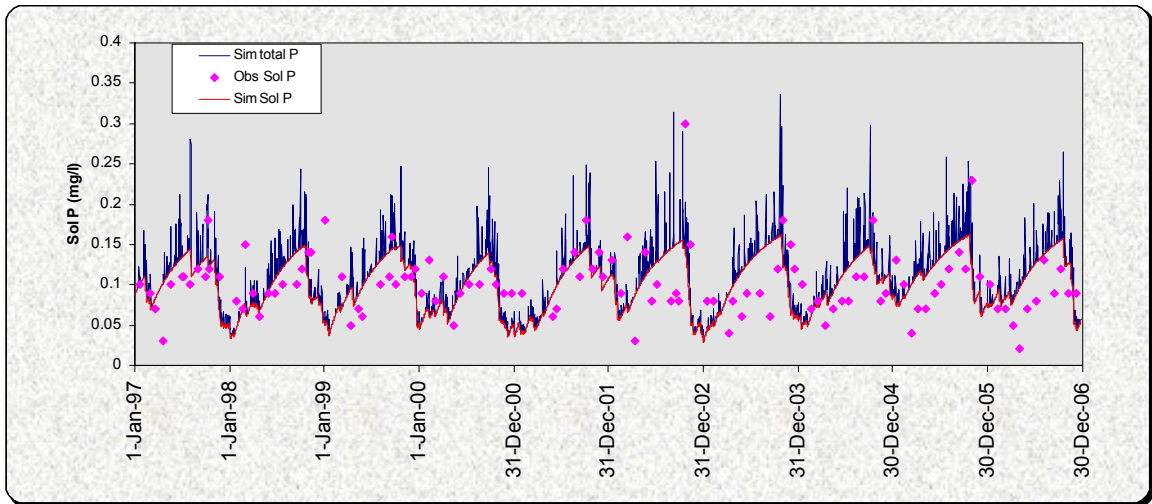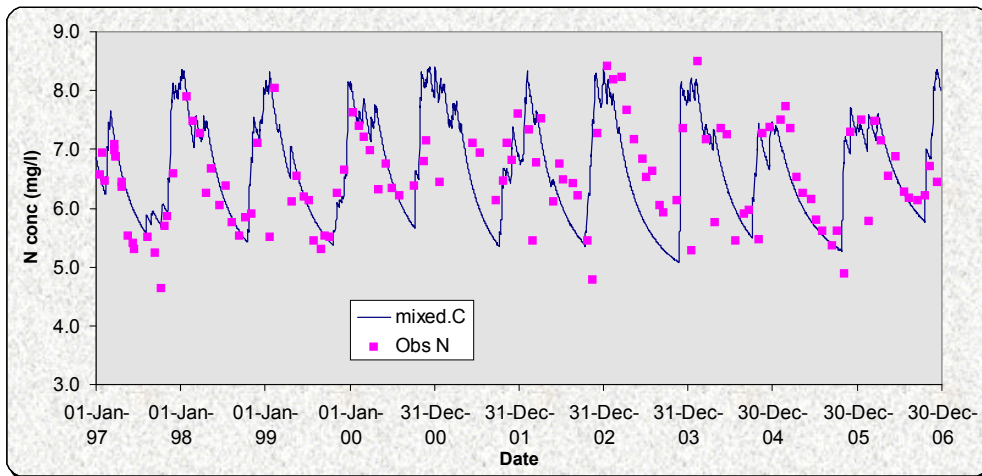
Figure G11 Phosphorus concentrations in the River Frome (magenta points = observed; solid blue line = modelled total phosphorus; solid red line = modelled soluble phosphorus)

Model results for the River Piddle

The situation for the Piddle was very similar and once again the model was fitted to the observed data with relative ease.
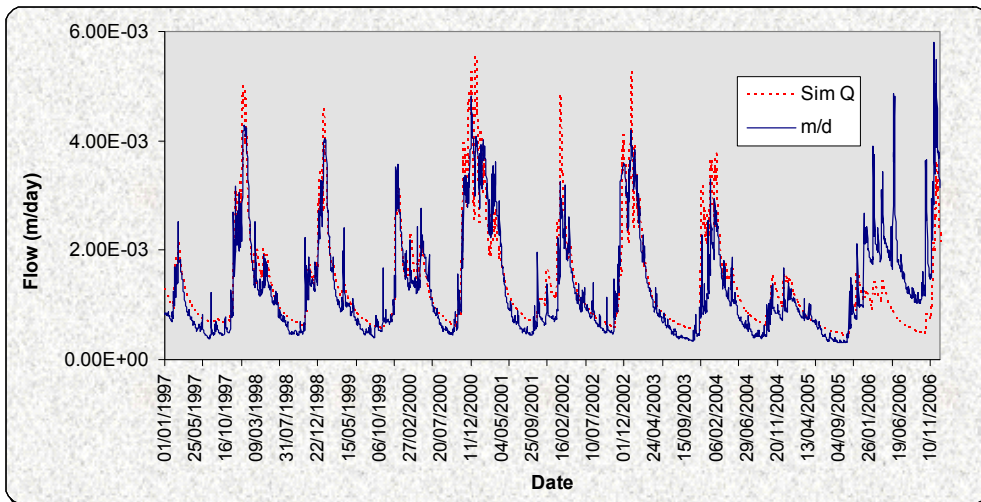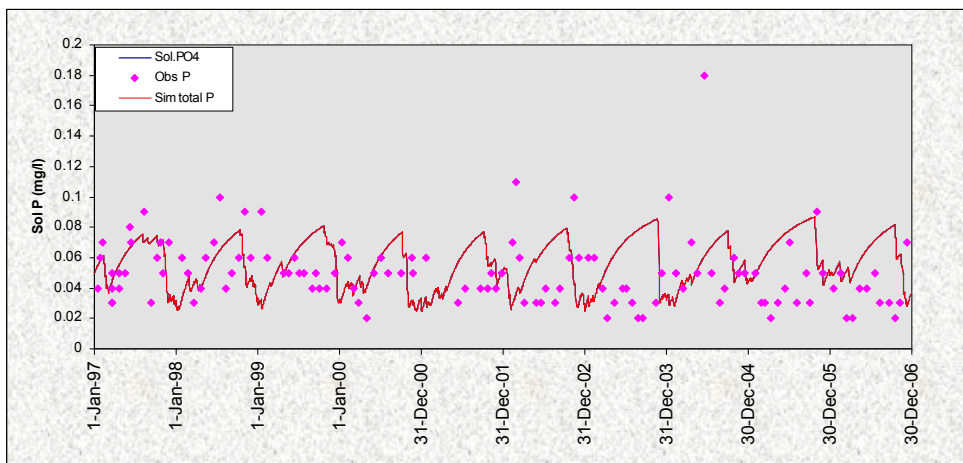

Figure G12 Flow in the River Piddle (blue solid line = observed; red dotted line = modelled)

Figure G13 Nitrate concentration in the River Piddle (magenta points = observed; solid blue line = modelled)

The N levels are higher than in the River Frome, which may reflect a greater proportion of agricultural land in the River Piddle catchment.

Figure G14 Phosphorus concentrations in the River Piddle (magenta points = observed; solid red line = modelled total phosphorus)

It is much more difficult to justify the simulated patterns seen in Figure G14. The simulation is essentially the same as the Frome, with higher summer peaks. However, there is considerably less soluble phosphorus in the catchment as a whole when compared to the Frome, which may reflect a lower human/urban input of phosphorus.

There may be problems with using phosphorus observations at the larger catchment scale. For example, phosphorus losses are sensitive to local events such as freshly ploughed fields and fresh additions of fertiliser to the soil surface, which can make the time series data very noisy. In addition, the sampling rate is too low to capture the dominance of phosphorus losses during storms. It is during storm events that phosphorus losses, and especially total phosphorus losses, are driven by erosion. However, occasional spikes may be due to storm events. Despite this, we can still see the mean phosphorus loss and deduce that there may be human inputs of phosphorus to the times series.

Interpretation of N loss
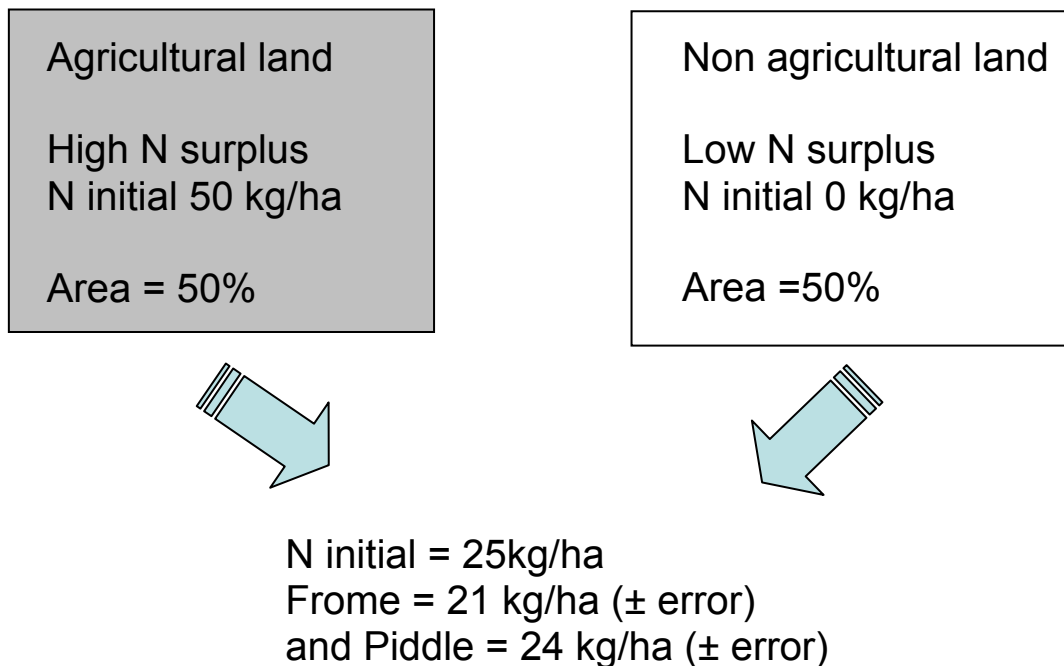
Figure G15 A simple conceptual model of the mixing effects that might explain the N dynamics in the Frome-Piddle

Figure G15 is an interpretation of the mixing of the high and low nutrient input zones. The initial nitrate input is typically half the value seen in simulations with 100 per cent intense agriculture (see Quinn, 2004), which we interpret as the agricultural land that has a high typical level of nutrient input. The slower groundwater may also have denitrified the flow, giving the lower overall nitrate losses.

Conclusions

Based on the calibration of TOPCAT-NP to the data available for Frome-Piddle we conclude that:

- The TOPCAT-NP modelling is helpful for quickly investigating how nutrients may be travelling from sources to receptors based on readily available Environment Agency time series data without having to use GIS.
- Both catchments when studied at this large scale exhibit a strong interaction of storm events with a dynamic response of the chalk aquifer. This was captured by allowing a faster storm event store (assumed to be the soil layers) and a slower groundwater store.
- There is a good fit to the observed flow, but some variation in the parameter values can allow a 'reasonable fit' to be achieved. The SPLIT parameter was probably the most significant parameter to the model, as this shared the active flow between the soil store and the groundwater store.

- The nitrate concentrations are relatively low compared to many intensively farmed areas (see Quinn *et al*., 2008). This is likely to be due to a combination of high nitrate inputs from agricultural land and low nitrate inputs from non-agricultural land.
- The phosphorus data is more difficult to interpret because the catchments are large (above 10 km^2), the observed data is too infrequent to see the phosphorus losses resulting from storms and there are no observed data for total phosphorus to help with the interpretation.

We recommend that TOPCAT-NP is considered in the next phase of work to test whether our initial conceptual models are consistent with the observed river flow and nutrient concentrations.

G3 - Penn State ArcView Generalised Watershed Loading Function (AVGWLF)

The ArcView Generalised Watershed Loading Function (AVGWLF) model is used routinely in Pennsylvania to assess the cost and benefits of land use change as a means of reducing nitrate (N), phosphate (P) and sediment loads in rivers and streams. It was developed at Penn State University (Evans, 2002).

Sections G3.1 and G3.2 describe the basis of the AVGWLF model and the related Predict model.

Barry Evans and Ken Corradini from Penn State University visited the UK for five days to set up models of the Frome-Piddle so that we could investigate the models' capabilities. Much of this time was spent collecting data in the formats required by the models. Initial models were produced and Evans and Corradini carried out calibration work on their return to the US. Their technical note describing this work is given in G3.3.

G3.1 AVGWLF

AVGWLF uses an ArcView interface to load and display spatial data which it then processes to produce ASCII files, which are used as input files for the main model – the Generalised Watershed Loading Function (GWLF) model.

GWLF uses this input data to predict the loads of N, P and sediment at specified points on streams in the catchment.   Thus, AVGWLF is a lumped mass balance model. The GIS provides a familiar and easy interface for displaying the inputs and outputs.

Inputs

The inputs required are listed below. Figure G16 shows a typical input screen.
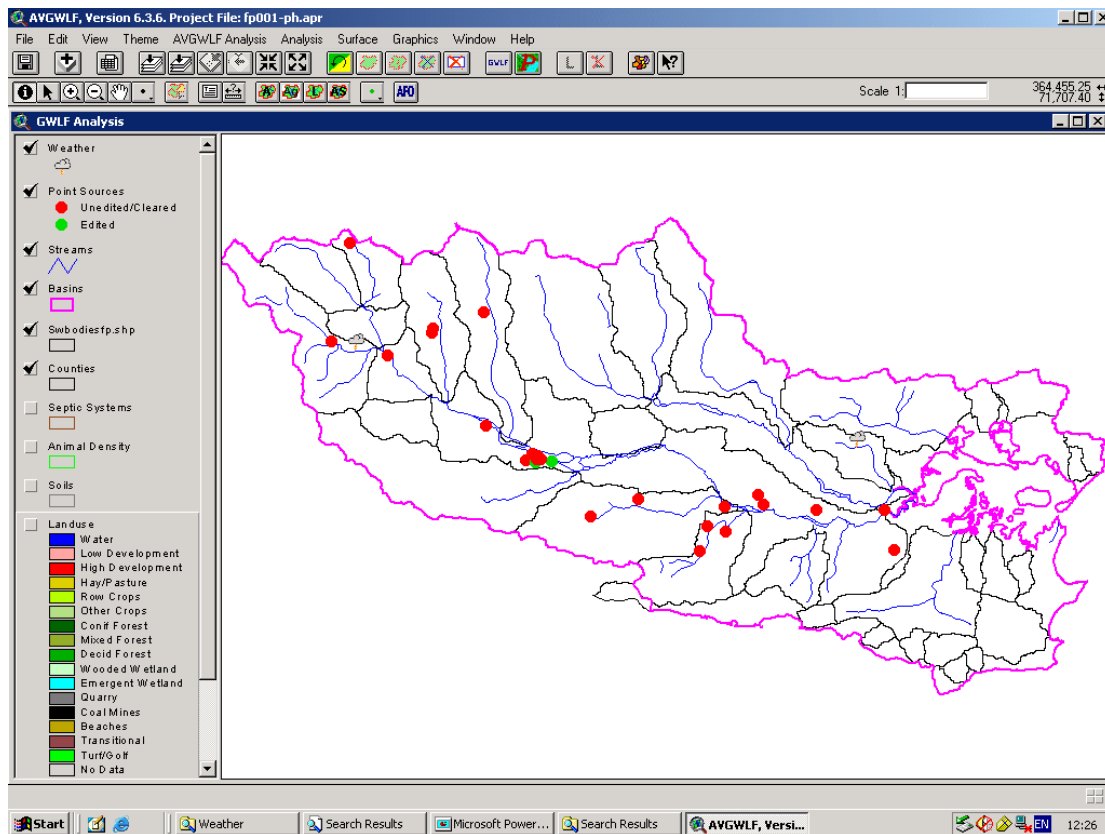
Figure G16 GIS input screen for AVGWLF

ESSENTIAL SHAPE FILES

Basins - Surface water body shape files
Streams - River network
DEM
Weather station data
- Uses two (and only two) closest weather stations to centroid of catchment and averages. This evens out high intensity rainfall that occurs in one location and not across the whole catchment.
- XLS spreadsheet of weather data (rainfall and temperature)

Soils data
- Available water holding capacity
- K factor
- Erodibility of soil
- Dominant hydrologic soil group. In the US they use A, B, C or D. We would use HOST (hydrology of soil types) classes which do not match
- Runoff = f(Curve No., rainfall intensity, land use). This is referred to as the SCS curve number approach

OPTIONAL SHAPE FILES

Point sources – sewage discharges
Water extraction   Mean monthly (actual) abstraction – not true GW abstraction
Tile drains
Unpaved roads - Unpaved roads generate PO_4

Data for estimating soil loss (erosion) – used in Universal Soil Loss Equation (USLE)

- C (cover) conservation factor – relates to vegetation cover (how much soil exposed) - less vegetation cover, more erosion (zero well covered, wooded = 0.002, one = maximum erosion)
- P (practice) - have measures been adopted to stop erosion - related to BMP (one means maximum erosion – no measures to avoid erosion)
- Erosion = sediment available
- Sediment = sediment delivered at outlet (where stream exits catchment)

Septic systems - Assume 3.5 people per household (gives 1,100 on septic systems) but this is probably only 10 per cent of total number on septic systems.

Animal stocking density

ESSENTIAL GRID FILES
Landuse
Digital elevation data (DEM)

OPTIONAL GRID FILES
Groundwater Nitrogen - This is concentration of N leaving bottom of soil layer
MAGPIE N concentration layer
Soil Phosphorus - Total P (not soil test P)
Rainfall
Temperature
Stream flow
Sewage discharge – e.g. from SIMCAT
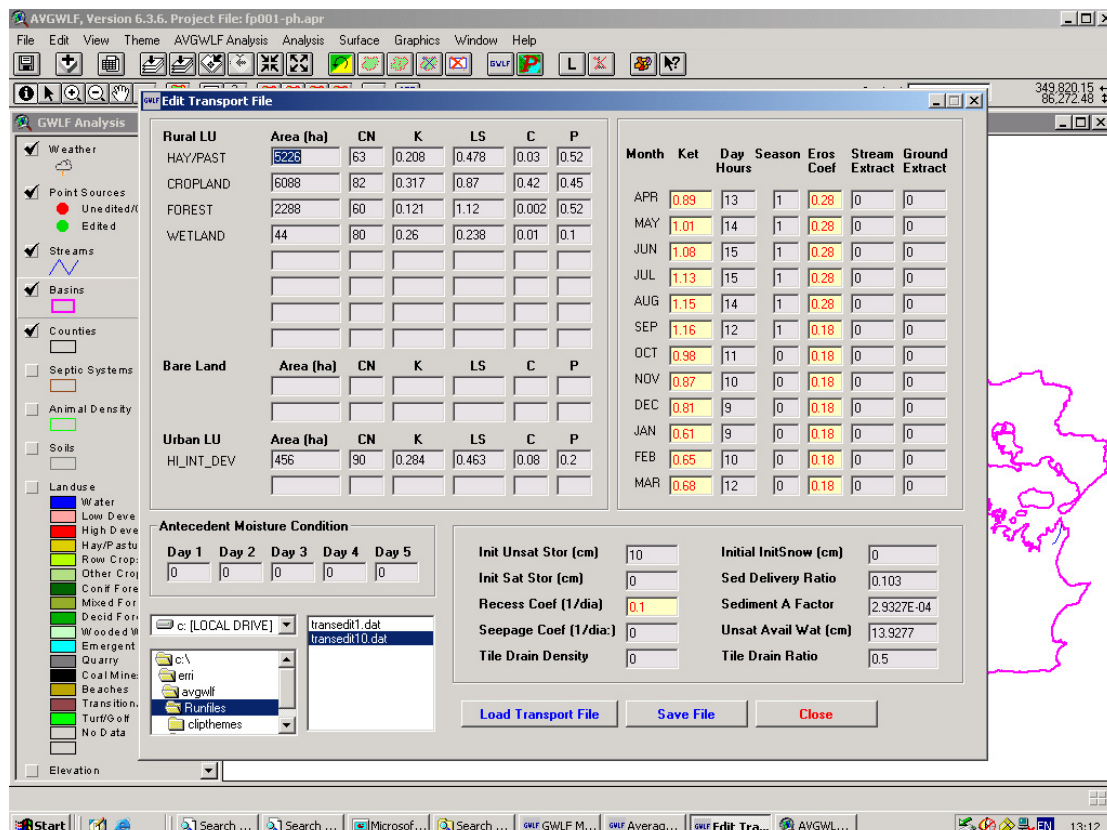
Figure G17 Input screen for the transport data for the GWLF model

Figure G17 shows the transport input data that has been produced from the GIS. These inputs can be edited via this screen or in the ASCII files. There is a similar dialogue box for nutrient input data.

Outputs

Figure G18 shows the output screen for the GWLF model. It gives the total loads of N, P and sediment in kg at a specified stream location and shows the contribution from each land use type.
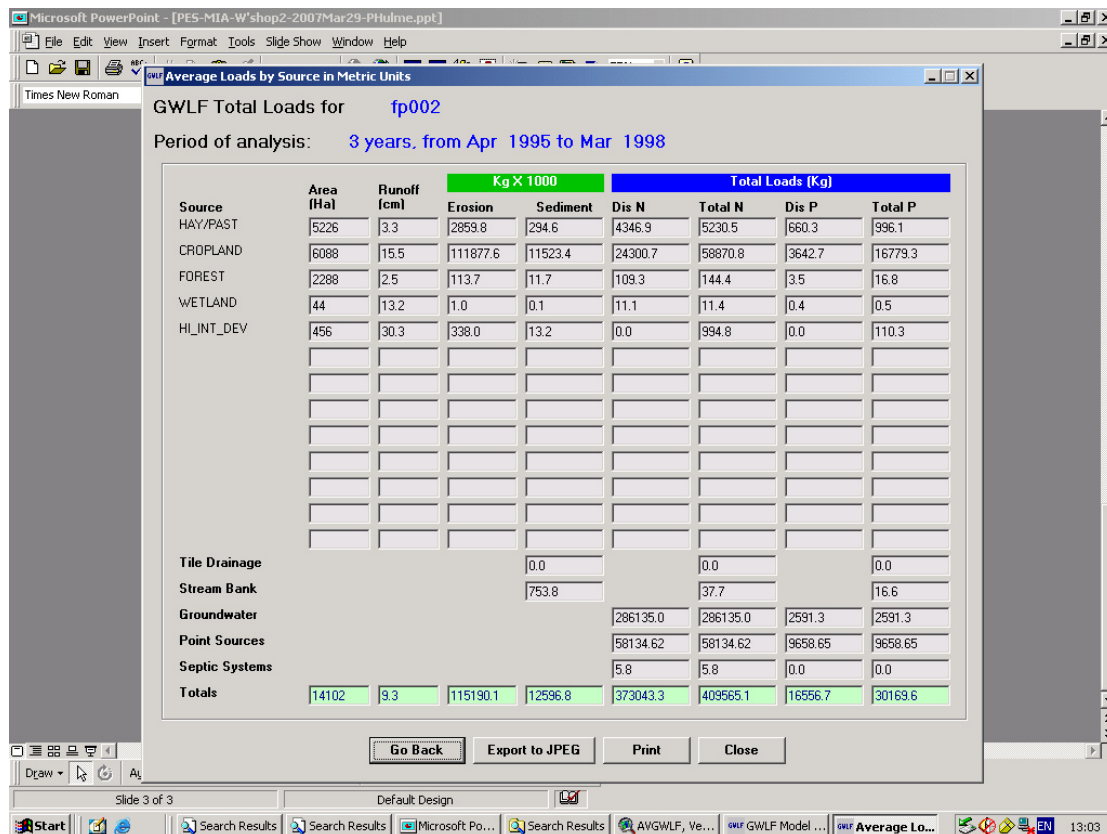

Figure G18 Output screen for the GWLF model

G3.2 The Predict model

The Predict model (Evans, 2003a) uses the GWLF loads as inputs and adjusts these by a factor based on the introduction of different mitigation measures. In the US these are called Best Management Practice (BMP) scenarios. The factors used to reduce the nutrient loads are empirically derived from over a decade of measurements in the US.

## G3.3 Simulation of nutrient loads for the Frome-Piddle

This section provides the technical note written by Barry Evans in October 2008, which summarises the results from the AVGWLF modelling for the Frome-Piddle.

Methodology

A GIS-based simulation model (AVGWLF) was used to quantify nutrient loads generated within the Frome and Piddle catchments. AVGWLF is a GIS-based modelling system developed by researchers at Penn State University (Evans *et al.*, 2002) that provides a link between ArcView GIS (geographic information system) software and the Generalized Watershed Loading Function (GWLF) model developed originally by Haith and Shoemaker (1987) at Cornell University. The GWLF model provides the ability to simulate runoff, sediment, and nutrient (N and P) loadings from a catchment given variable-size source areas (such as agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values. Since its initial incorporation into AVGWLF, the GWLF model has undergone numerous upgrades, including the addition of a streambank erosion routine (Evans *et al.*, 2003b), a BMP assessment module (Evans, 2005), and new routines for addressing farm animal populations (Evans *et al.*, 2007). AVGWLF has been used by the Pennsylvania Department of Environmental Protection for watershed assessments since 2000. It is presently being used for similar purposes in New York, and a "regionalized" version of it has recently been developed for use in New England through an EPA-funded project with the New England Interstate Water Pollution Control Commission (see http://www.neiwpcc2.org/AVGWLF/).

Essentially, AVGWLF is a customized interface that is used to parameterize input data for the GWLF model. In utilizing this interface, the user is prompted to identify required GIS (computer map) files describing critical catchment characteristics (such as soils, land use/cover, topography) and to provide other information related to "non-spatial" model parameters (such as the beginning and end of the growing season; the months during which manure is spread on agricultural land). This information is subsequently used to automatically derive values for required model input parameters which are then written to the various input files needed to execute the GWLF model. Also accessed through the interface are Excel files that contain temperature and precipitation information used to create the necessary weather input file for a given catchment simulation. For this project, the key GIS and climate datasets used were obtained from Environment Agency sources.

Figure G19 is a screen capture of the AVGWLF interface after the necessary datasets to derive model input have been loaded. In this figure, the Piddle catchment has been selected prior to data clipping and parameter estimation. In this image, the light green and brown colours depict pasture and cultivated lands located within this area, and the red colour depicts developed land. As can be seen from this image, crop cultivation is more or less evenly distributed throughout the area. In addition to basic landscape-related data, information on effluent discharges (flow volume and nutrient concentration) from wastewater treatment plants located in the area (primarily in the Frome catchment) was also collected. These plants are indicated by the black dots in Figure G19. Other map data depicting animal populations, septic system locations, and background levels of nitrogen concentration in groundwater were also compiled to support the modelling effort.
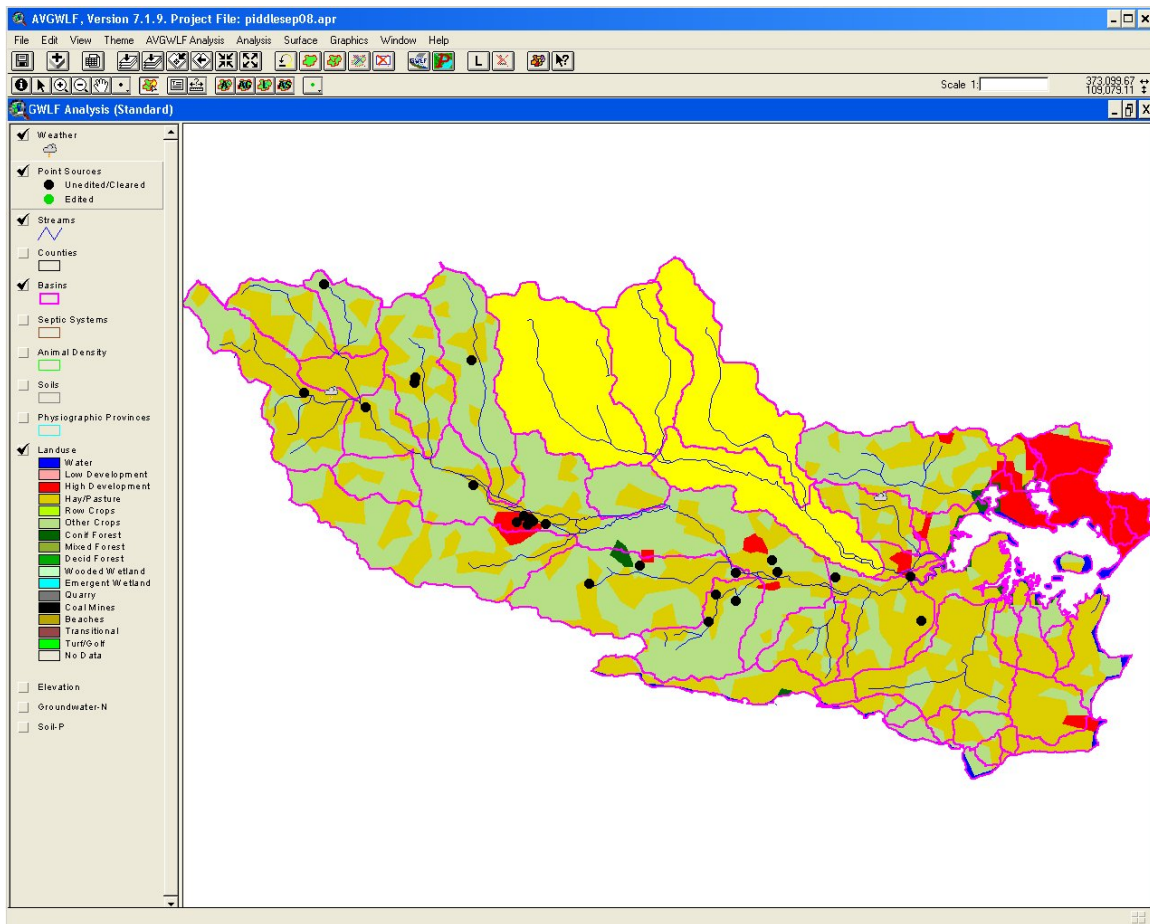
Figure G19 Initial AVGWLF with sub-catchments selected for analysis

Model Execution and Calibration

For the purposes of this study, GWLF model runs were conducted for those portions of
the Piddle and Frome catchments defined by the locations of existing in-stream
monitoring stations as depicted in Figure G20. This was done so that simulated stream
flows and loads for each catchment could be compared against observed datasets
developed using available monitoring data on flow and water quality.

The primary purpose of using AVGWLF is to automatically create GWLF input files
using available GIS and weather data. Since AVGWLF was developed in
Pennsylvania, some of the algorithms used to estimate various model parameters are
not necessarily tailored to deriving the best parameter values for geographic areas
exhibiting landscape and other conditions different than those typically found in
Pennsylvania. After AVGWLF was used to create model input files for both the Piddle
and Frome catchments, some additional parameter adjustment (calibration) was
required to achieve a better fit between the simulated and observed values for each. In
this case, calibration of the AVGWLF model was accomplished by comparing model
results with observed data compiled for both catchments for the period 1997-1999
when historical weather data and daily in-steam flow and water quality data were
available.
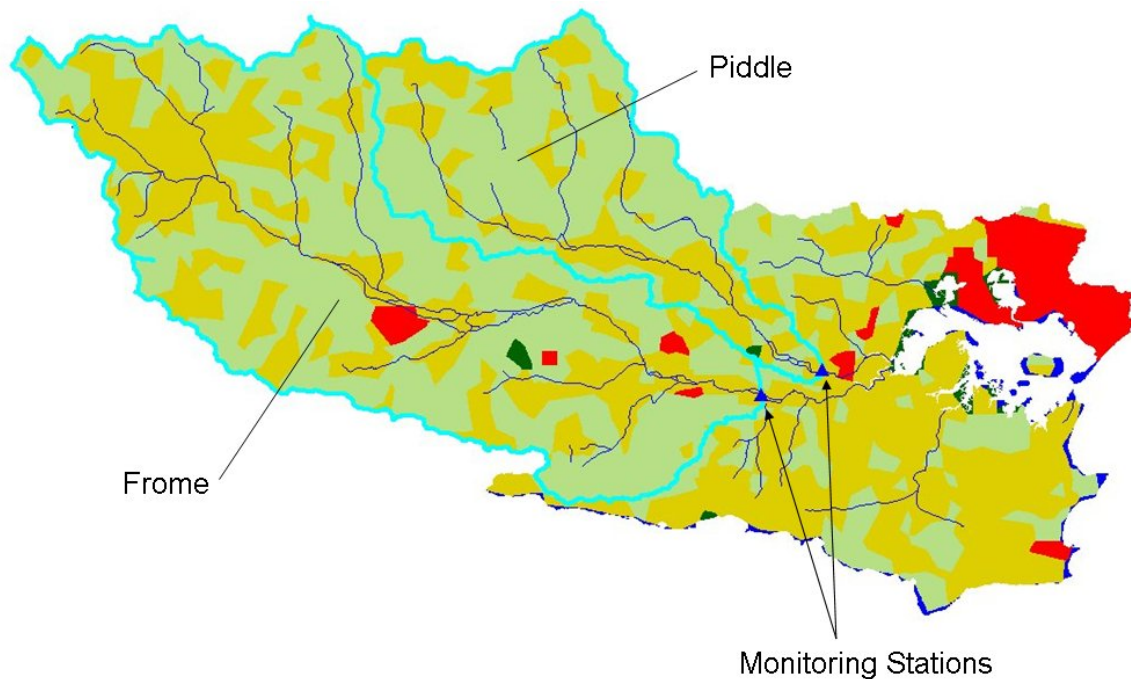
Figure G20 Delineation of Piddle and Frome catchments

To assess the correlation, or "goodness-of-fit", between observed and predicted values, two different statistical measures were used: 1) the Pearson product-moment correlation coefficient and 2) the Nash-Sutcliffe coefficient. The Pearson coefficient is calculated as:

$$R^2 = \left(\frac{\sum (y - y_m)(x - x_m)}{\sqrt{\sum (y - y_m)^2 \sum (x - x_m)^2}} \right)^2$$

where x_m is the mean of the observed (x) values, and y is the model-simulated value. The R^2 value is a measure of the degree of linear association between two variables, and represents the amount of variability that is explained by another variable (in this case, the model-simulated values). Depending on the strength of the linear relationship, the R^2 can vary from zero to one, with one indicating a perfect fit between observed and predicted values.

The Nash-Sutcliffe coefficient is calculated as:

$$1 - \frac{\sum (y - x)^2}{\sum (x - x_m)^2}$$

where x_m is the mean of the observed data, and y is the model-simulated value. Like the R^2 measure described above, it is another indicator of "goodness of fit", and is one that has been recommended by the American Society of Civil Engineers (ASCE, 1993) for use in hydrological studies. With this coefficient, values equal to one indicate a perfect fit between observed and predicted data, and values equal to zero indicate that the model is predicting no better than using the average of the observed data. Therefore, any positive value above zero suggests that the model has some utility, with higher values indicating better model performance. In practice, these coefficients tend to be lower than R^2 for the

same sets of data being evaluated, although in this study, the calculated Nash-Sutcliffe values tended to be similar to the R^2 values in most cases.

Figures G21 to G26 show the comparisons between simulated and observed flow and nutrient loads for both catchments (in these figures, water volume is depicted in units of water depth (cm) per month, and nutrient loads are reported in kilograms per month).
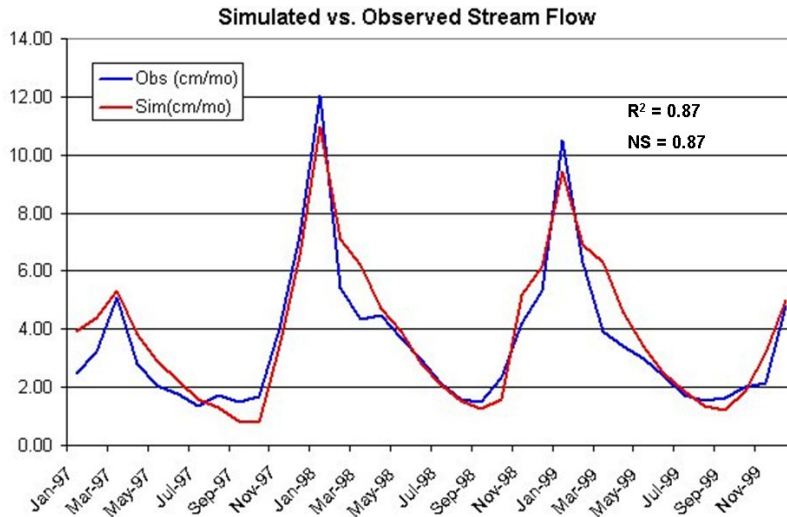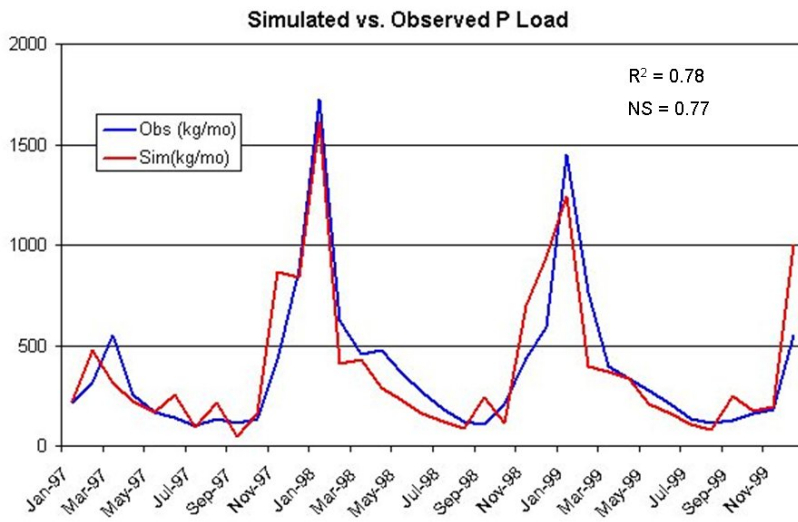

Figure G21 Comparison of stream flows for the Piddle
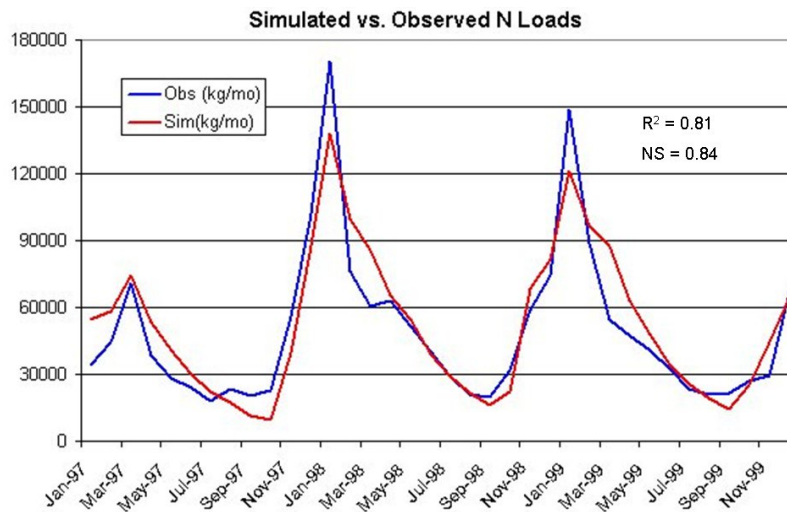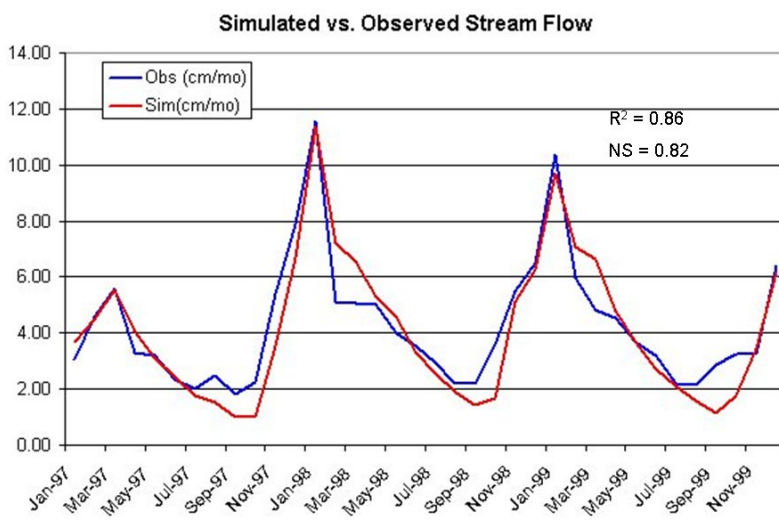

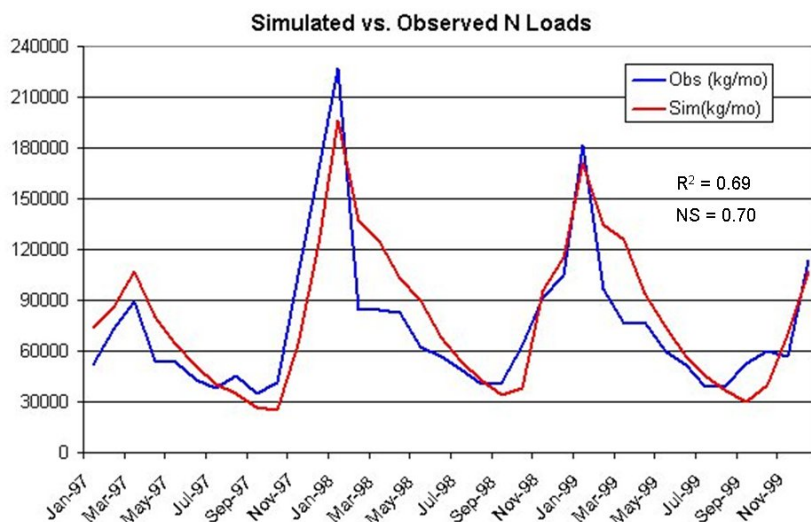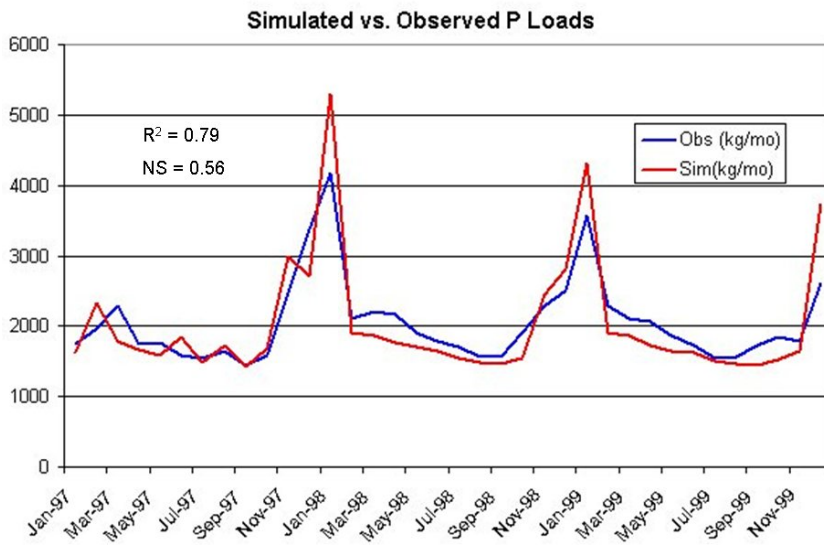**Figure G22 Comparison of nitrogen loads for the Piddle**

Figure G23 Comparison of phosphorus loads for the Piddle

Figure G24 Comparison of stream flows for the Frome

Figure G25 Comparison of nitrogen loads for the Frome

Figure G26 Comparison of phosphorus loads for the Frome

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Conclusions and Recommendations

Since its inception, AVGWLF has primarily been used to estimate nutrient and sediment loads in catchments where monitored data are not available. In Pennsylvania and other places in the United States, the parameter estimation algorithms have been fine-tuned so that "optimal" estimates are derived using GIS and weather data sets typically available to most users. If calibration data are available, model parameters can be further adjusted to provide even better results than when running the model in the absence of in-stream data. Based on past experience, the results reported in the previous section can be achieved with minimal effort. With funding from the USEPA, AVGWLF has been adapted for regional use in the northeast part of the US, including New York and New England (see www.neiwpcc.org). More recently, this modelling software has been adapted for use in EPA Region 6, which encompasses the states of Texas, New Mexico, Louisiana, Arkansas, and Oklahoma. It is also the basis for CANWET, a watershed modelling approach gaining widespread use in Ontario, Canada, and has been used for almost ten years by the Mexican Institute of Water Technology. Similarly, for future use by the Environment Agency of England and Wales, it would be possible to adjust various parameter estimation algorithms to better represent local landscape-related conditions as well.

The work described in this document was essentially accomplished using a version of AVGWLF that was available in 2007. This software has since been converted to a non-commercial GIS software package that is distributed free of charge. This software, called MapWindow, is available at www.mapwindow.org. One of the primary benefits of moving AVGWLF to a MapWindow environment is that it provides the ability to duplicate the functionality of AVGWLF without the need to have commercial GIS software (ArcView 3.x) installed on a computer. Additionally, MapWindow can directly use ESRI-formatted GIS data, which is the most commonly-used data format in the world. A "free" version of this GIS-based modelling tool would also allow a much wider audience (such as local watershed groups) to conduct the kind of analyses required to support future watershed restoration efforts. Penn State has just completed a beta version of this software (called MapShed) that will be released and made available via its current web site (www.avgwlf.psu.edu) within the next two months.

G3.4 Discussion

The strengths of the AVGWLF/Predict models are:

1. They are being used routinely and are not a research tool.

2. The models have a familiar GIS interface.

3. They are simple to use, easier to parameterise and much quicker to run than, for example, the Soil and Water Assessment Tool (SWAT), Gassman *et al*., 2007;

The limitations of the models include:

1. They are designed for use in the US. So, for example, the model uses four dominant hydrologic soil groups A, B, C or D. In the UK we use 29 HOST classes. It is not clear how these compare.

2. It is not clear if the algorithms are applicable to UK conditions.

3. There is no support in the UK.

The work done in 2007 used a version of AVGWLF that used ArcView 3.1 as its GIS interface. Since then the interface has been converted to a non-commercial GIS software package (MapWindow) that is distributed free of charge (see Section G3.3). This should mean that AVGWLF can use ESRI-formatted GIS data without the need to use commercial GIS software, such as ArcView or ArcGIS.

We would like to compare the AVGWLF/Predict models of the Frome-Piddle model with other similar tools which have been developed in the UK.

Appendix H – Feedback from Area Lead User

Melissa Robson was the lead user for the GIS and was a CSF Officer in the South West until February 2008. Melissa provided written feedback on her use of the GIS in June 2007 and January 2008 and this is reproduced below.

What was useful about the data collected on the project?
The first thing to say here is that the greatest use was being able to bring data together and look at it in a way that was not possible before. This made it much easier to start to investigate hypotheses, as you did not have to hold maps or data patterns in your head to compare them with others, or to see patterns.

The projects also accessed data that I had not used before such as national datasets, soils etc, and modelling data, and in labelling the Environment Agency I:\ drive layers with intuitive labels, this made this data available.

The sediments data were probably the least useful because they were not detailed enough in terms of scale. This is where the Local Issues Tool is so useful. A digital terrain model (DTM) would be useful. The modelling scripts for both PSYCHIC and NEAPN have been very useful.

Assessment of the Local Issues Tool
Although the aim of the project was to make existing information available, not to create a new tool, the development of the Local Issues Tool allows us to capture things that have not been recorded before and therefore lost with staff turnover. The Local Issues Tool allows us to record the experience and local knowledge of problems and issues in an Area. The Environment Agency has an incident recording system, but as the name suggests, it records incidents. When something happens and an incident is entered, it is categorised and some action taken. It is not an appropriate place to record issues.

The local issues layer allows people from different disciplines to enter information that would otherwise remain in their head, and then by doing so, share that information. The ongoing changes to the tool will hopefully also allow additional data, such as letters, reports, extra photographs etc. to be held and accessed through clicking on the location in question and then using a hotlink. This allows a much more intuitive way of organising and accessing information.

Recommendations for continuing the project
With WFD implementation on the horizon, one of the biggest challenges faced is how to get from national or river basin district level plans to achieving changes on the ground. Diffuse water pollution from agriculture, be it nutrients, sediments or pesticides will be managed on a field-by-field basis. It is at this scale that we need to be able to initiate change. In non-agricultural diffuse pollution (e.g. septic tanks), the problems will need to be dealt with on a similar scale.

Thus, the challenge is how to go from recognising that 'diffuse water pollution is an issue in the South West', to deciding how to implement measures on the ground. This is where I think that this project can come in.

I think that once it has been recognised that there is a particular issue in an Area and assess the severity, there needs to be a process in place to move forward.

This process should assess the catchment to gain understanding of the likely mechanisms of pollutant movement. Critically it needs to do a credible source apportionment exercise at an appropriate scale. Once we have a picture of the scale of the problem, the likely sources and transport mechanisms, we can start to consider measures.

In considering measures we need to look at their efficacy. The PSYCHIC and NEAPN modelling work could be used to simulate impacts of land use change on nitrate, phosphate and sediment loads. For non-agricultural sources, e.g. septic tanks or small sewage treatment works, either measured or standard discharges can be used. Here we can then match the sources of the problem to the measures, and estimate their efficacy compared to the amount that they produce as per the source apportionment.

I think that a trial run going from large scale plans to on the ground measures would be invaluable.

Melissa Robson, January 2008

Diffuse pollution is a major problem for many rivers and water bodies and is a significant barrier to meeting Water Framework Directive standards. Catchment Sensitive Farming is being trialled as a possible tool in the programme of measures to meet WFD targets. The remit of the officers' role is to try and reduce diffuse pollution from agriculture to improve water quality and ultimately ecological quality.

The data and Geographic Information System (GIS) framework produced by the *Making Information Available* project has been useful to me in the following ways:

1) Catchment appraisal The GIS brings together in one place datasets that have previously not been available (only about 50 out of 150 datasets currently on our I:\ drive). This has allowed me to investigate themes and hypotheses from a range of different fields. We write catchment appraisals to identify the main problems within a catchment and to target resources. I used this tool to review and amend my catchment appraisal and to challenge or support data and model outputs from other sources.

2) Local Issues Tool The Local Issues Tool provides a way of capturing data that has not been recorded previously. Within the Environment Agency we have a system for recording incidents (NIRS); however, there will be many problems that are not 'incidents' but are pollution issues or potential pollution issues, for example small-scale run-off from a field, a muddy track, soil wash from a field, broken road banks, or ill-sited intensive outdoor pigs.

At the moment such problems are often not recorded and only held in the minds of our local staff. As staff leave, this experience is lost; problems and issues are forgotten; the links between issues are not identified and persistent problems are not recognised. The Local Issues Tool is an easy method for recording all types of local information on a digital map with the opportunity to log a description and photographs. The data is held in a GIS layer which can be added to and searched by all operational departments.

3) Report function on Local Issues Tool The report function produces a report in a Word document with photographs and a map for any of the issues recorded in the

Local Issues Tool. This is useful and saves time as I can store the data and generate the report at the same time.

I am populating the local issues layer with information from my personal experience, and experience from Environment Officers, fisheries and ecological teams, highways, local fish clubs, farmers and other agencies, and it will become a central working tool in my role as a catchment officer.

4) Data availability The title of this project was aptly named *Making Information Available*. The majority of the information that has been collated was not previously available for use by local Area staff within the Environment Agency and that which was available was often inaccessible due to poor labelling on the I:\ drive and limited software licences to view these layers on.

5) Metadata This is extremely useful information to have on the data layers, including guidance on how and why the information was collected or the model outputs were generated, and how the data should be used and its limitations. I think there is generally a poor understanding of the importance and utility of metadata within the Environment Agency.

Finally, a valuable thing about this GIS is that it is cross-sector and not looking at pollution from only agriculture or only industry. So it allows a diffuse pollutant problem to be tackled across all the sectors that are possibly contributing. Although the post of catchment officer with a remit to look across sectors does not yet exist, it may be the most effective way of reducing diffuse pollution and the main user tool has already been developed and piloted on this project.

Melissa Robson, June 2007

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List of abbreviations

ADAS   Agricultural Development Advisory Service

CSF   Catchment Sensitive Farming

Defra   Department for Environment, Food and Rural Affairs

DSM   Decision Support Matrix

DST   Decision Support Tool

GEMINI   Geo-spatial Metadata Interoperability Initiative

GIS   Geographic Information Systems

INSPIRE   Infrastructure for Spatial Information Repository in Europe

ILC   Integrated Lake and Catchment Model

MAGPIE   Modelling Agricultural Pollution and Interactions with the Environment

NERM   Nutrient Export Risk Matrix

NORM   Nitrate Export Risk Matrix

PERM   Phosphate Export Risk Matrix

PEDAL   Phosphorus Export and Delivery in Agricultural Landscapes

PIT   Phosphorus Indicator Tool

PSYCHIC   Phosphorus and Sediment Yield CHaracterisation In Catchments

SCIMAP   Risk-based Management of Diffuse Agricultural Pollution

XML   Extensible Mark-up Language

VBA   Visual Basic for Applications

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