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Catchment hydrology, resources, economics and management (ChREAM): Integrated modelling of rural land use & farm income impacts of the WFD and its potential non-market benefits

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Management (ChREAM): Integrated Modelling of Rural Land
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by

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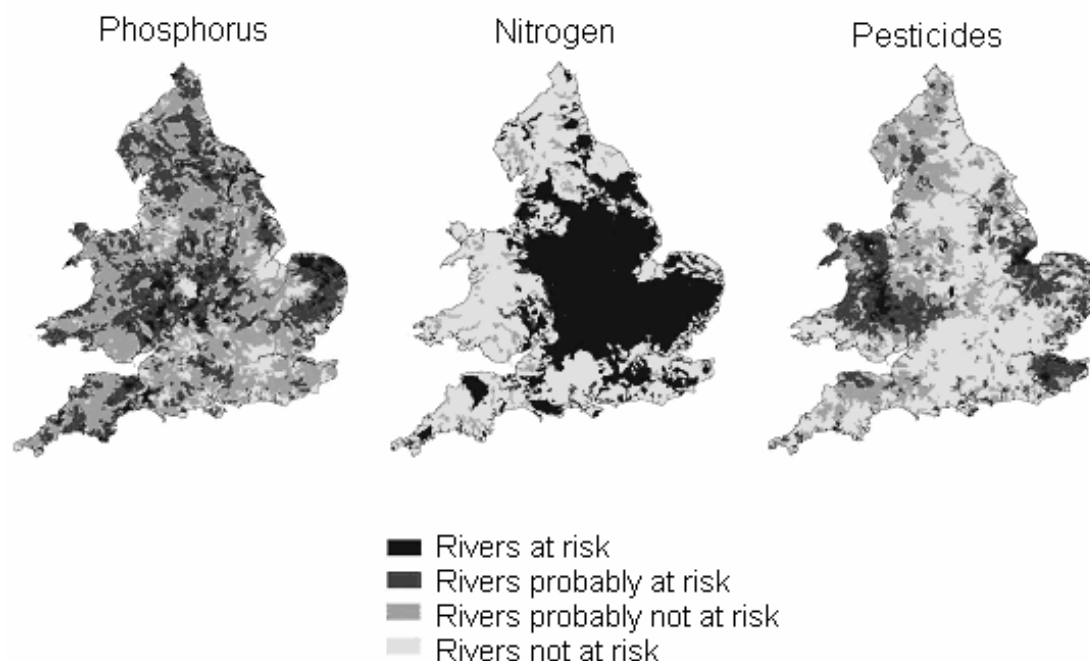
Abstract:

The paper outlines a programme of research funded under the Rural Economy and Land Use (RELU) programme. The proposed research will examine the likely effects of the Water Framework Directive (WFD) in terms of both its impacts upon the farming sector and the non-market benefits it may generate. From an agricultural perspective the WFD will impose a substantial extension of controls upon diffuse pollution from farms. A major objective of the research will be to assess the likely response and consequent economic costs to an already fragile farming sector. This objective will be addressed via a highly interdisciplinary methodology combining hydrological and other physical sciences with quantitative and qualitative socio-economic analyses to generate an integrated hydrological-economic model of farm activities and incomes. This will dynamically link farm local and regional activities to water standards, allowing feedback loops to indicate the impacts of altering farm activity and changing water quality targets. Model parameters and response scenarios will initially be established via quantitative estimation and then refined through a series of farm attitude and behaviour surveys. This cost-effectiveness analysis will be complemented by an assessment of the benefits arising from the WFD and an aggregation and equity analysis of the distribution of both costs and benefits. Planned deliverables include assessments of the impact of alternative WFD implementation strategies allowing policy makers to inspect effects upon farmer and the wider community at a variety of spatial scales.

1. Background

The Water Framework Directive (WFD) (European Parliament, 2000) represents a fundamental change in the management of water quality in Europe. The Directive imposes outcome based targets, requiring a shift away from standards framed in terms of the chemical composition of water in favour of an approach which assesses the ecological quality of waterbodies. These standards will be waterbody specific and hence require differentiated action. However, there is a general requirement to improve all European waters to “good ecological status” by 2015. Although the definition of such status depends upon reference conditions, it is generally agreed that implementation of the WFD will require substantial reductions in pollutant inputs to rivers both from point and diffuse sources (Environment Agency, 2004). The extent and the spatial variability of the changes required is illustrated in Figure 1, which shows the current assessment of the risks of rivers in England and Wales failing WFD objectives in terms of phosphate, nitrogen and pesticide levels. As can be seen, the changes required for WFD compliance are very substantial.

Figure 1: The risk of rivers in England and Wales failing WFD objectives



Source: Adapted from Environment Agency (2004)

In addressing sources of these pollutants the WFD specifically requires the control of diffuse emissions into water bodies, the primary source of such pollutants being agriculture. The effects of such control have been projected to be extreme, with a recent report to DEFRA indicating large changes in agricultural land use in order to achieve good ecological status (Haygarth et al., 2003; p.24). The scenarios considered in that report as necessary to achieve such goals included the reduction of fertiliser application rates to all crops and grass by 50% combined with a fall in sheep stocking rates by 50% and a reduction in cattle stocking numbers by 25%. Such major changes to the structure of UK agriculture are potentially disastrous for an already fragile rural economy (Countryside Agency, 2004) and appear to clash with official priorities for supporting the farming sector (DEFRA and HM Treasury, 2004). However, the actual extent of these economic impacts and their social consequences is highly uncertain although potentially extreme.

Another area of uncertainty concerns the benefits which implementation of the WFD might generate. According to official documentation the major driving force behind the WFD appears not to be in terms of the market benefits it will generate (say in terms of changes to drinking water quality or savings in private sector water treatment costs), but rather with respect to the non-market environmental benefits it will create (see Articles 4, 9 and 11 of the WFD and Environment Directorate-General, 2005). Similar official sources cite results from polls of environmental concerns in which (perhaps not surprisingly given the remit of such polls) water pollution has featured prominently (Eurobarometer, 2005). However, such arguably vague measures of general social attitudes give little indication of the scale of the benefits to be generated by a policy which is likely to incur uncertain but in all probability very high costs to an already economically fragile sector. Furthermore, it seems plausible that the incidence of benefits and costs may be very uneven, with rural groups bearing most of the costs and urban recreationalists capturing the majority of benefits. Therefore, the possibility that the WFD may constitute both a net economic loss and heighten rural-urban income inequalities cannot be ruled out¹.

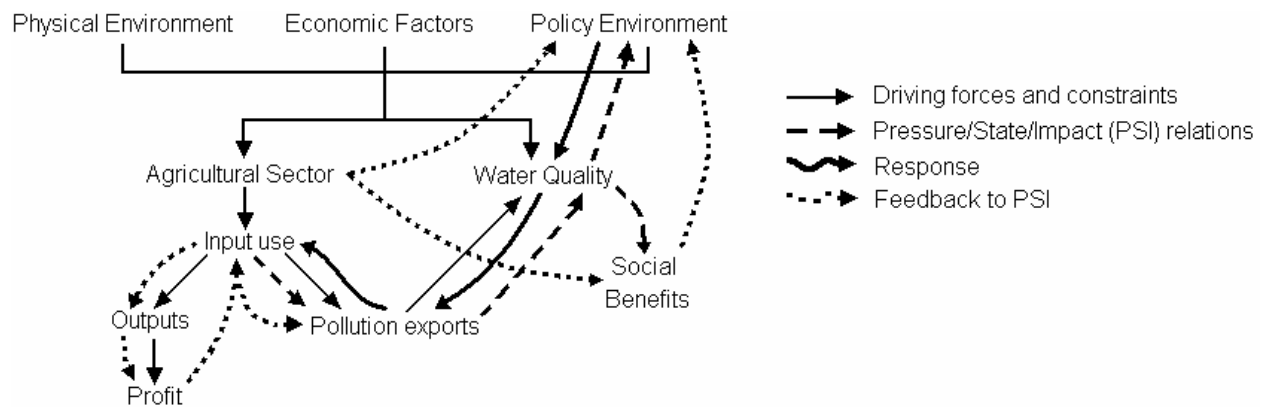
The ChREAM project, which has recently been funded under the RELU programme, sets out to assess the impact upon farm activities and economics which implementation of the WFD is likely to impose and to investigate strategies through which associated costs might be mitigated. The project also seeks to undertake an assessment of the non-market benefits claimed as the major *raison d'être* of the Directive. Section 2 provides a brief tour of the project, providing an overview of its four constituent workpackages which are discussed in turn in Sections 3 to 6. Given the interlocking nature of these workpackages, Section 7 discusses the timing of the research and the case study area which provides its empirical focus. Section 8 concludes with a discussion of deliverables and dissemination plans.

2. Overview of Approach

The central objective of the research is to develop an integrated, interdisciplinary model of land use at the catchment scale which allows the costs and benefits of alternative formulations of policy change, such as WFD transposition or CAP reform, to be understood. In modelling the physical and socio-economic consequences of implementing the WFD (and reforming the CAP), the proposed research will extend the DPSIR (Driving forces/Pressures/State of the Environment/Impacts on end points and policy/Responses) model as used by the European Commission, European Environment Agency and OECD (Pearce and Howarth, 1998) and illustrated in Figure 2.

¹ This passing of major directives without rigorous prior economic assessment is not unprecedented. Indeed the entire CAP appears to constitute a classic intervention failure and more recent policies such as the EU Bathing Water Directive can only avoid being considered a net economic loss if upper-bound estimates of derived benefits are adopted (Georgiou and Bateman, 2005).

Figure 2: DPSIR model showing feedback loops



The integrated approach of the research attempts to consider the full range of physical (land use, inputs, outputs, water quality, etc.) and economic (costs, revenues, profits, etc.) relationships and feedbacks arising in response to changes in the policy drivers. It is the interdisciplinary, integrated nature of the analytical modelling tool to be developed (combining separate modules for the water environment and socio-economic activities) which constitutes the scientific contribution of the proposed research. In undertaking such a study we acknowledge and build upon previous innovative and interdisciplinary work such as the Land Use Allocation Model (Jones et al., 1995) and the NELUP Land Use Modelling Programme (O'Callaghan, 1995, 1996; Moxey and White, 1998) as well as our own collaborative work under the EU EUROCAT and UK Land Ocean Interaction Study (LOIS) programmes (Robson and Neal, 1997; Neal and Davies, 2003 ; Cave et al. 2003a,b; Andrews et al. 2005).

As such analyses demonstrate, in order to simultaneously explore the costs and benefits of regulatory changes, such as the WFD, it is necessary to consider both land use and associated hydrology together. ChREAM sets out to deliver such integrated analysis through four workpackages (WP). The first of these (WP1) is hydrological model comprising two elements. The first of these is a within-catchment model of how focal pollutants, such as nitrogen, phosphorus, pesticide and faecal material, are attenuated and lost or released before entering the river channel. So, for example, this element models how the application of say fertiliser at a given location, will after accounting for the environmental characteristics of that location (soil type and depth, slope, underlying geology, etc.) result in an estimate of leeching into water ways. The second element assesses how such pollutant discharges are modified in-river, supplemented by the addition of point source discharges and how together these pollutants affect aquatic biology. So, extending our previous example, this module takes us from a given level of fertiliser application at a specified location, to the prediction of say the rate of algal bloom within a receiving waterway. This element of the research is extended to consider the role of climate change over the next two decades.

WP1 therefore provides essential information on the levels and spatial distribution of pollutants that enter catchments and river basins within the study area. For this study, the major types of pollutant risks that will be dealt with are those central to current UK concerns: nitrogen and phosphorus (which affect eutrophication), pesticides that affect aquatic ecosystem functioning, faecal material (linked to issues of health), and accidental spillage of farm wastes and pollutant runoff from agricultural land which can affect dissolved oxygen levels in rivers (causing effects such as fish kills). This will be dealt with in a distributed modelling approach using geographical information system (GIS) analyses to allow the crucial spatial dimension to be considered.

The use of a spatially sensitive approach also underpins WP2 which models farming activities, land use and incomes. Here we build upon our previous analyses of agricultural and other land uses (Bateman et al., 1999a, 2003) applying a GIS based methodology to combine complex physical variables such as topographic shelter, aspect, slope, soil moisture deficits, field capacity, etc., with financial data. These latter data will be made available through partnership with the Farm Business Survey (FBS). Use of the GIS allows farm records to be linked with detailed data concerning the physical characteristics of those farms. Econometric modelling of these combined data allows parameterisation of the relationship between policy (in the form of both direct payments and indirect subsidy), the physical environment, modifications to that environment (including, importantly for this research, inputs such as fertilisers) and the resultant activity/output levels and consequent profit measures. Estimated input use can then be fed back into WP1 to allow the prediction of consequent nutrient and pesticide loading upon waterways and resulting biological impacts. By specifying the farm activity model such that the level of diffuse pollution is an output (in the same manner that, say tonnage of wheat is an output), we can then constrain this output to some policy derived level (e.g. that necessary to attain WFD targets for 'good ecological quality'). Re-running the model to optimise say profit given this constraint provides us with an initial estimate of the economic impact of WFD compliance.

A potential problem of this approach concerns its ability to forecast reactions to the new business environment imposed upon farms through implementation of the WFD. It is perfectly likely that farms will react not simply by varying the input mix (e.g. switching from one fertiliser formulation to another) but also by adopting entirely different technologies (e.g. introducing runoff bunds around waterways or switching rotation systems to leave waterway corridors free of high intensity activities) or switching their output mix, potentially radically (e.g. increasing extensification, abandoning certain outputs altogether, etc.). While the modelling exercise of WP2 will be undertaken very much with this problem in mind and will seek to examine switch points in production, this remains an inherent weakness of a wholly model based, quantitative approach. The proposed research seeks to address such concerns by complimenting our modelling exercise with a two stage, on-farm survey of farmer attitudes and behaviour (WP3).

The first of the two farm surveys conducted by FBS for this research project gathers information useful for constructing the behavioural model which is the underpinning of the farm financial analysis of the WP2 hydrological-economic model. agricultural analysis. This, for example, allows the researchers to relax simple assumptions such as resource optimisation and pure profit maximisation as farm objectives and also permit the incorporation of realistic models of pollution mitigation and adaptation in modelling farmers response to the implementation of the WFD. This should considerably improve the realism and predictive accuracy of the model. It is these predictions which are the focus of the second WP3 farm survey. This seeks to ground-truth the estimates of the WP2 model by providing farmers with scenarios showing the likely economic impact of the WFD upon the economic viability of existing activities and the farm responses as predicted by the model. Farmer reaction to these scenarios will be used to upon the response parameters of the model so as to forecast response times. For example, there is a considerable literature cataloguing delayed agricultural response to changes in policy or market conditions. Responses to the second WP3 survey allow us to parameterise such response and assess the impact upon farm incomes over differing periods.

The fourth element of the research (WP4) seeks to assess certain of the more major non-market benefits of claimed to arise from WFD compliance. These may be substantial and range across a variety of value categories. In recognition of this, the research proposes a mixture of both revealed and stated preference valuation techniques both of which will utilise GIS techniques to capture the likely spatial variation in benefits (e.g. recreation values are likely to be higher in more accessible areas with greater nearby populations). This element

of the research will also consider the role of substitute and complimentary amenities in determining the value of improving a given amenity site. This element of the research raises a number of complex issues which arguably are under-researched in the literature. The project will attempt to address these as far as time and resource constraints permit. Particular issues of interest include: (i) the transferability of values across space and time; (ii) extending the issue of temporal change, we will also seek to examine the impact of agenda control (the effect of preceding changes to other sites) upon the marginal value of the provision or improvement of a given site and cumulative effects upon total programme values; (iii) similarly the issue of aggregation and the distance decay of benefit values is an area of interest; (iv) furthermore, the distribution of benefits across different social groups is of particular interest.

While the extent to which a single piece of research can address all of these issues is uncertain, one key objective is to compare these benefit assessments with estimates of the economic cost to farms at a spatially disaggregated level. The aim here is to identify efficient strategies for varying the application of WFD implementation strategies within the constraint of overall compliance with the requirements of the policy. So, for example, the goal of good ecological status could be attained through a number of measures such as those mentioned above. These will have differing cost implications in alternate locations and will generate different benefits. The research will investigate strategies for addressing this problem such as optimisation routines to search for best practice options defined according to policy relevant criteria (for example, satisfying WFD targets at least overall cost, or whilst protecting the most economically vulnerable sections of the farming sector, or while targeting measures to ensure the benefits of improved water quality accrue to poorer sections of the non-agricultural population).

Taking these various workpackages together, the research seeks to provide an integrated, holistic model of the implementation of the WFD and coincident reforms of the CAP showing how these impact upon the water environment, rural farming communities and wider society. In subsequent sections we consider each work package element in more detail and then briefly discuss project implementation plans. We then discuss our chosen case study area showing why, in our opinion, it provides an excellent test bed site for the development of a robust and more generally applicable methodology. Finally we conclude by discussing intended deliverables and a dissemination strategy.

3. Modelling the Water Environment (WP1): Assessing the direct impacts of the WFD

This work package sets out to model linkages from both the atmosphere and directly from the land, to the catchment and through into waterways, rivers and finally via estuaries to the sea. The basic element of this analysis is the hydrologically representative unit (HRU) which represents spatially distributed distinct hydrochemical and biological processes within a catchment.

The modelling of water and pollutant flows is achieved by applying the 'distributed catchment' approach developed by certain of the researchers under the LOIS programme. This comprises two components. The first, 'catchment supply' component applies the CASCADE model to integrate flows of water, nutrients, pesticides, etc., across HRU's via surface and near-surface runoff, within-soil processes and deeper water flows. The balance of these flows then passes through to tributary streams, on to rivers and downstream to the catchment outlet. A further module assesses those point source discharges from sewage treatment works which are not accounted for in the in-stream river model, to which we now turn.

The second 'in-stream' component applies QUESTOR, a pollutant transport and impact model. This examines the dispersion and advection of pollutants and their biological uptake and transformation. Although CASCADE and QUESTOR have already been integrated for the analysis of nitrogen transport, the present research will extend their integration across further pollutants within a new biological module, developed in tandem with a parallel initiative, REBECCA. This extension will assess the relative inputs of pollutants from atmospheric, agriculture and urban sources and predict biological responses such as eutrophication and aquatic weed growth allowing researchers to assess compliance with, or departure from, WFD requirements

In undertaking this extension, the list of assessed pollutants will be made more comprehensive to include nitrates, phosphates, pesticides, spillages, polluted sediment contamination effects and faecal material. With respect to the latter, the researchers will draw upon their prior work concerning faecal indicators, associated nutrient pollutant fluxes and the implementation of remediation strategies at the catchment level (Kay et al., 1999; 2004; Crowther et al., 2002, 2003). This element of the research will draw upon a newly developed generic faecal indicator flux modelling approach tested with recent support from the Environment Agency and EPSRC WITE in the Severn Estuary contributing catchments.

The temporal incidence and seasonal pattern of flows will be assessed so as to match this with data concerning critical periods (in terms of biological health) for pollution risk. The temporal dimension will also be considered via an iterative extension of the QUESTOR model to examine scenarios across a 20 year time frame of agricultural, urban and industrial change (building upon scenario work elsewhere in the RELU programme). Further planned developments include the assessment of analytical sensitivity so as to provide a measure of predictive uncertainty and the incorporation of climatic instability through integration with earlier research for modelling the Climate, Hydrochemistry and Economics of Surface-water Systems (CHESS) on a European scale (Boorman, 2003).

When considering the final stages of pollutant dispersal an expert judgments approach will be adopted to assess estuarine and marine impacts. This will provide an informed assessment of how changes in riverine fluxes derived from this project's land use change and river transport models will propagate through the estuarine systems and the effect of these changes within the estuaries themselves and beyond into the North Sea. Here researchers will draw upon their own collaborative work under the JONUS, LOIS and EUROCAT programmes which examined the biogeochemistry of, amongst others, the chosen study area (Jickells, 1998; Cave, et al., 2005; Kay, et al., 2004).

We now consider the proposed methodology for modelling agricultural land use and incomes, discussing the integration of models subsequently.

4. Modelling agricultural land use and income (WP2): Assessing WFD impacts upon farming

Agriculture's role in determining water quality, and hence in implementation of the WFD, is critical given that farming still accounts for over 76% of land area in England and Wales and diffuse agricultural sources are estimated as being responsible for 70% of nitrogen and 40-50% of phosphorous entering water in England (DEFRA and HM Treasury, 2004). WFD implementation will require a substantial reduction in these diffuse emissions, a reduction that will force farms to consider a range of response measures. These include reducing nutrient inputs into the system, addressing runoff enrichment, lowering rates of erosion and containing the contaminants contained in runoff. Within these general categories there are a range of specific options available. Hence nutrient inputs can be reduced by lowering

stocking rates, adjusting livestock diet, adopting alternative farming systems (e.g. at the extreme switching to organic production), changing pest management regimes, more closely matching inputs to crop requirements, etc. Similarly a number of options are available for the control of runoff contaminants, including investment in dirty waste management systems, the creation of buffer strips, etc. (RPA, 2003). However, while the individual farm is faced with a diverse range of response options, a common characteristic is that these have the potential for imposing costs on the agricultural economy, a sector which is well recognised as being in an already fragile and frequently parlous state (Cabinet Office, 2000, Countryside Agency, 2004; DEFRA, 2002).

Existing estimates of the measures and associated costs to agriculture arising from implementation of the WFD are accepted to be rough indicators of the scale of the problem. Nevertheless, as discussed in the opening section of this paper, the estimates provided by Haygarth et al (2003) suggests that dramatic reductions in stocking rates and fertiliser application would be required to satisfy WFD requirements. In estimating the economic consequences of the WFD Regulatory Impact Assessment (DEFRA, 2004) it has been suggested that these imply a reduction in gross margins of about 35% for wheat and 30% for dairy forage production (RPA, 2003). Given that many farms are already facing severe financial challenges in the form of the Fischler CAP reforms and the transition to the Single Farm Payment scheme, the combined body blow which these policy developments could deal to many economically vulnerable rural economies constitutes a pressing policy concern and focus for much needed assessment and research.

The farm level costs of WFD implementation will depend on the particular farming system, its scale and economics, and the hydrological, geological and topographic characteristics of its location. The research sets out to assess these costs via an integrated interdisciplinary framework that combines detailed, spatially sensitive, physical and economic data with agri-econometric models. In particular physical environment datasets (detailing information on soil characteristics, topographic shelter, aspect, slope, etc.), such as those compiled by CEH partners, will be combined with both standard and specifically commissioned financial and activity survey data collected by the FBS. Here the standard FBS data allows us to form a representative panel data set comprising large numbers of farms for which at least one and in most cases several annual records are held. This is supplemented by a specifically commissioned FBS survey examining the relationship between farm activity profile and input use (fertiliser formulation, quantity of input, input costs, etc.)². This multi-institution partnership will provide an extremely rich and detailed data resource for modelling agricultural activities and incomes. Throughout the exercise the use of spatial coordinates via a common GIS base provides a practical method of ensuring data and model integration as well as permitting direct linkage between farm modelling activities under WP2 and the water environment modelling conducted in WP1.

Our proposed agri-econometric modelling methodology is developed from studies harnessing the spatial analytic capacities of a GIS to integrate farm financial and physical environment characteristics (Bateman et al., 1999a; 2003) and, most pertinently, modelling exercises assessing the impact of prior water quality directives upon the economics of UK dairy farms (Rigby and Young, 1996; Rigby, 1997). Farm activities will be modelled within an econometric process analysis (Antle & Capalbo, 2001). This applies our panel data set to a multi-input / multi-output specified system, where production decisions are a function of farm characteristics, inputs and market conditions. Such a model can incorporate alterations to these parameters such as, for example, the output price changes associated with CAP reform or revisions to agri-environmental policy regimes. The empirical model provides estimates not only of farm income and welfare but also activity measures. These include pollution related measures such as the level of fertiliser use, stocking density, etc. These in

² We are very grateful to Kevin Andrews and others at DEFRA for funding this vital segment of the research.

turn provide the spatially resolved inputs to the pollutant assessment, transport and biological impact models of WP1.

The production modelling methodology set out above allows us to capture the productivity changes (both in terms of production and pollution outputs) associated with both alteration of input levels (such as changes in fertiliser application) and switches to alternative activities. In all cases the models estimate the income and welfare measures associated with each product mix. We therefore obtain estimates of farm welfare, diffuse pollution determinants and corresponding biological impact across a comprehensive mix of production possibilities and can seek to optimise the former under the constraints of the latter. Changing the biological impact constraint in line with the requirements of WFD implementation provides us with estimates of the welfare impact of the Directive.

Variations in physical environmental characteristics and farming systems mean that the risks posed by agriculture to water quality vary greatly both across and within catchments; an issue explicitly recognised in the use of River Basin Management Planning within the WFD and UK official initiatives to promote catchment-sensitive farming (DEFRA, 2004). As a result of this, there is likely to be great spatial variability in appropriate farm practice responses to the WFD and their associated costs. The same shifts in agricultural practice will generate very differing impacts on water quality in different areas. Similarly, very different changes in farming may be equally effective in reducing pollution in alternate locations. Spatial integration across farms in differing locations is therefore essential. The use of the GIS techniques which underpin all our analyses will be vital in this respect, allowing the analysis to operate at a diversity of spatial scales to ensure overall compliance with the WFD as well as to assess farm-level and aggregate agro-economic impacts of the Directive.

This methodology, capable of moving from basin level down through catchment to farm-level analysis, also allows inspection of the distributional effects of WFD implementation. For the reasons outlined above, it is extremely likely that the WFD will impact unevenly across farms, with some sectors and certain locations very strongly challenged by implementation while others may well be entirely untroubled by its requirements. The spatially sensitive agri-econometric approach developed in the research will set out to explicitly address this issue of impact distribution. In so doing it will attempt to identify those groups and areas most challenged by the Directive and provide scenarios for spatially sensitive application of alternative strategies for its implementation.

The modelling exercise also raises a number of interesting issue concerning the behavioural model which underpins our analysis. One aspect of this concerns farmers' objectives. Initial work will proceed from basic principles that, within the farm-specific constraints of technology, information and existing policy, producers combine farm inputs in order to produce that mix of outputs which maximises profits. However, these simplifying assumptions will be progressively relaxed using both the findings of a literature review and information obtained from the first phase of the direct farm survey. This survey will also be used to refine assumptions regarding the rate of adoption of alternative response strategies in the face of WFD constraints, including attitudes towards reducing inputs, switching activities and the adoption of pollution mitigation technologies. It is to this survey phase of the study to which we now turn.

5. Direct Surveys (WP3): Land conditions and farmer attitudes and behaviour in the face of WFD implementation

The research proposed under WP1 and WP2 is highly integrated and based on an exceptional combination of data sources. However, it will by its very nature involve the approximation of key

processes and parameters regarding both hydrology and human behaviour. WP3 seeks to directly address this potential weakness by providing additional information regarding existing land conditions and farmer attitudes and behaviour in the face of WFD implementation. This extends the original survey research concerning input use described under WP2.

The refinement of land condition data will be addressed via a literature review and direct contacts with experts in relevant agencies such as the Environment Agency and DEFRA, particularly those staff involved in on the ground preparation for WFD implementation in the study area. While academic literature is important to this process, it is considered that the 'grey literature' of local catchment reviews and pollution plans together with direct contact with local agency and related staff will be of particular value.

The second and major focus of WP3 will be to gather information directly from farmers concerning their attitudes and behaviour. As discussed previously, there are dual objectives here, the first being to assist in the construction of the initial agri-econometric modelling analysis of WP2 by enhancing the behavioural basis of the model, while the second seeks to ground-truth the subsequent predictions of that model. These objectives will be addressed through a two stage farm survey. In collaboration with colleagues at the FBS we will compile a set of survey farms selected to be representative of the range of farms found in the study area, most of which will also feature in our quantitative panel data set. FBS staff will advise on the mechanics of farm survey design and conduct interviews, using their expertise and relationships with farmers to ensure high quality data.

The first survey will be a primarily qualitative exercise aimed at providing attitudinal and behavioural information to enhance the basis of the modelling undertaken within WP2. This information will allow modellers to relax conventional economic simplifications and assumptions such as simple profit maximisation, replacing these with a richer and more realistic behavioural model. The survey will also ask farmers about their experience of and attitudes toward a range of diffuse pollutant mitigation measures, ranging from reductions in fertiliser and pesticide inputs, alternative choices of animal feeds, manure application timing, use of land races, buffer strips and alternative ploughing approaches and activity profiles. Investigation of such an attitude-behavioural model is in itself a recognised research need (Haygarth et al., 2003), but more importantly we believe that it will allow a substantial improvement to the realism of the land use model constructed in WP2 and through it a superior linkage with the water environment model of WP1. The initial survey will also examine farm production prior to the introduction of the new CAP single payment system and the impact this is having on farm activities. This information will assist the researchers in controlling for this factor within the modelling. In addition information will be sought regarding how aware, if at all, interviewees are of the WFD and what they expect it will mean to them and their neighbours. The interviews will allow initial exploration of what responses may be induced from some of the measures required to achieve good ecological status and consequent WFD compliance.

The second survey will follow after the completion of the first wave of integrated hydrological-economic modelling work and scenario analysis (WP1 and WP2). Here we will survey our full farm panel in a mixed methodology (Langford et al., 2000), qualitative-quantitative study designed to assess their reaction to the predictions of the integrated model regarding WFD impacts upon land use activities and consequent effects upon farm incomes. This ground-truthing exercise will collect information regarding (i) what farmers are expecting to do as the implications of WFD and cross compliance become clearer, (ii) their perceptions of and reactions to the agricultural responses predicted by the modelling exercise and how these can be improved in the next round of modelling and scenario analysis. This information will then be fed back into the WP2 analysis to permit a revision of the integrated modelling work and refinement of the final model predictions and policy recommendations.

6. Assessing the Benefits of the WFD (WP4): Valuation, Transfer and Distributional Analysis

The overarching focus of workpackages 1, 2 and 3 is the assessment of the potential economic costs to farms of the implementation of the WFD. Nevertheless, it is claimed that the WFD will deliver substantial (if as yet unquantified) benefits. These benefits are not, however, in terms of marketed goods but rather they are environmental benefits; non-market public goods such as reductions in eutrophication and improvements in the ecological status of waterways yielding open-access recreational benefits and, more contentiously, non-use values. Furthermore, where direct contact with water is likely, such as in bathing areas, then some health risk improvements may arise. The economic assessment of such benefits cannot rely upon market prices and therefore their value is not immediately obvious. WP4 seeks to assess the likely magnitude of these benefits through the application of techniques for the monetary valuation of preferences for non-market goods. In so doing we seek to address a number of contemporary methodological challenges to the application of such techniques.

The early phase of the benefit assessment work will consist of an expert analysis of the various categories of benefit likely to be generated by the WFD. The investigators will be assisted in this task by input from a 'Reference User Group' of stakeholders, policymakers and experts in local land use and water quality within the case study area. In initial research, rather than attempting to assess all categories of non-market value, the research will seek to develop robust methods through focus upon key benefit types, particularly those which are better understood by relevant individuals (e.g. open-access recreational benefits such as angling and walking) rather than more vaguely perceived non-use values such as those associated with improvements in biodiversity and habitat. Extensions to consider non-use values go somewhat beyond the intended remit of the research although, given ongoing policy concerns in this area (Environment Agency, 2003), they would be a target for further research should sufficient resources become available.

The objective of assessing the potentially substantial benefits which may accrue from the widespread improvement in the quality of amenity waterways under the WFD is a methodologically challenging one, not least because these changes will, if the targets of the Directive are met, affect all such waterways. In response to this challenge we propose a valuation strategy which consists of two highly integrated studies, both predicated upon the same underlying random utility model of behaviour and applied to the same majority user population of waterway visitors and potential visitors. These two studies will be integrated such that the questions left unanswered by the first analysis will be the target of the second. Taken together, the outputs should provide a richer, more robust and policy relevant picture of the benefits of the WFD and how these might be optimised through policy targeting.

The first of these two studies essentially examines the present day situation, however by careful application we aim to discover much if not all about responses to the WFD. Here we apply arguably the most common of the revealed preference valuation techniques, the travel cost random utility model. This examines the travel and visit frequency behaviour of recreationalists assuming that they choose visits with error from a selection of available recreational experiences. These experiences are characterised by the attributes of each site in terms of its nature, facilities and accessibility. These attributes vary across sites (e.g. offering different activities, facilities, qualities of water, etc.) as do their economic costs (in terms of varying direct travel expenditures, different travel time, etc.). Therefore, we can observe trade-offs between attributes and costs reflected in the behaviour of visitors and hence estimate economic welfare measures of benefit values. Furthermore, provided that we have sufficient variation in our sample of sites (including some with lower water quality and others with higher quality water, commensurate with the 'good ecological status'

objectives of the WFD), then the estimated models can be used to derive values for increases in water quality which should arise from implementation of the Directive.

The revealed preference approach has many strengths. Notably it relies exclusively upon observed rather than hypothetical behaviour. Also, embedded within this behaviour (and revealed through analysis of the data) will be visitors awareness of the existence of substitute and complimentary sites, a major factor in determining recreational visits (Jones, et al., 2002). This provides vital information regarding the effects of improving water quality, without which the benefits of such changes in provision are liable to be poorly assessed (for example, the value of improvements is likely to be over-estimated if the valuation model does not take due account of substitution effects). However, the overwhelming scale of the water quality changes envisioned under the WFD, where *all* rivers and waterways are supposed to be improved to 'good ecological status', introduces virtually unique problems to the field of non-market valuation. Furthermore, given that the present distribution of waterways with poor ecological status is decidedly non-random either spatially or with respect to the economic costs of accessibility (being clustered in and around urban areas) so the characteristics of improved sites will be similarly non-random (being greater in most accessible urban areas)³. This means that observed present visitation behaviour may be a somewhat incomplete guide to likely responses in the event of full WFD implementation.

In order to address this possible limitation to the revealed preference model a second study will be undertaken to investigate responses to widespread improvements to the quality of amenity waterways. Such an investigation beyond the remit of the present allocation of recreational goods requires use of stated preference techniques. Specifically we will apply the choice experiment method (Bateman et al., 2002) to present survey respondents with a series of choices between potential sites, each site described by a set of pertinent attributes (compatible with those of the previous exercise: water quality, facilities, accessibility, etc.) with the levels of those attributes set so as to range up to and including those envisaged under the WFD.

The preferences stated by survey respondents in the choice experiment provide useful indications of the *relative* responsiveness of visitors to the improvements in water quality provided under the WFD. However, the researchers are wary of certain of the drawbacks of stated preference techniques as applied to some non-market goods. For example, in the present context it seems plausible that the effect of substitute site availability detected in the revealed preference study of observed behaviour may differ from that found in the stated preference choice experiment (even when we restrict our comparison to the levels of water quality variation observed in the current stock of amenity waterways). This may arise for a number of reasons such as the focussing phenomena discussed by Daniel Kahneman where, during a survey, respondents over-value the objects presented and downgrade the value of alternative goods. This leads to over-estimation of the *absolute* value of water-quality improvements. However, the dual technique methodology proposed in this research seeks to address this problem in two ways. First, within the choice experiment we will investigate the potential for improving study design, particularly in the manner in which site improvements are conveyed to survey respondents. For example, our recent use of virtual reality linked to a GIS as a manner of conveying land use change within choice experiments (Bateman et al., 2006) might usefully be extended here. Second, and more fundamentally, the findings of the stated preference choice experiment will primarily be used not to generate

³ Note that this takes the claimed targets of the WFD at face value; that all waterways will be improved to 'good ecological status'. However, that status is the object of ongoing debate within the EU policy hierarchy and it may be that some non-absolute definition for targets (to put it bluntly; a 'fudge') is agreed which allows improvements to be relative to existing quality levels. As far as is reasonably possible, the research will be tailored to contemporary policy decisions as they develop.

welfare estimates in themselves⁴, but rather to recalibrate our revealed preference model and extend its predictive capabilities into the world of WFD implementation where there is generally much greater availability of high quality amenity waterways.

Primary data collection for both the revealed and stated preference exercises will be obtained from two large sample site surveys. The sampling strategy for these two studies is likely to differ somewhat. The revealed preference survey, while seeking to obtain an adequate mix of sites and visitor types may address a smaller number of locations in an effort to optimise the robustness of estimated models of visit behaviour. This set of locations may be extended within the stated preference study to boost the representativeness of the overall analysis.

As noted at the start of this section, the analysis conducted under WP4 also sets out to address a number of generic challenges to the application of non-market valuation techniques. Three key issues of particular interest are the aggregation of benefits estimates, their transfer across sites and analysis of the distribution of benefits. In order to analyse these issues the survey exercise will gather information not only regarding respondents' choices, preferences and values for the benefits under assessment, but also in respect of their socio-economic and demographic characteristics. Furthermore, in order to extrapolate findings and adjust for variation in the availability of substitutes and the characteristics of the populace, this data will be further augmented with measures obtained from a variety of secondary sources, including GIS based physical data sources and the UK Census.

This breadth and quality of spatial data is of crucial importance within the aggregation process. Theory and empirical regularities suggest that the value an individual holds for the improvement of a certain site will vary according to numerous spatially variable factors (for example, the accessibility of that site, the availability of substitute sites, interactions with facilities and attribute levels at all such sites, etc.) and the characteristics of the individual. Furthermore, when aggregating across individuals, these latter characteristics also vary spatially (for example, those with higher values and/or higher incomes may live closer to a given set of sites, etc.). A consideration of space is therefore vital to the accurate aggregation of benefit values for improvements to amenity waterways (and indeed most spatially confined environmental resources). The spatial analytic capabilities of a GIS provides an ideal medium for harmonising the diverse data necessary to undertaking such an aggregation exercise (Bateman et al, 1999b, 2005). In particular a GIS readily allows the researcher to specify a valuation function which varies across space according to say the distribution of rivers, lakes, estuaries, etc. and quality changes to those resources, the accessibility of complementary and substitute assets, and the distribution and socio-economic/demographic characteristics of the population. The inclusion of such variables allows the researcher to observe any 'distance decay' (Bateman et al., 2000) in values as we consider households which are more remote from a given improvement. Furthermore, once such a valuation function is estimated, by applying it within a GIS to data detailing all explanatory variables for all locations in a study area so we can generate 'value-maps' for differing improvement scenarios and calculate total benefit values for these scenarios (Bateman et al., 2005). This approach also allows decision makers to examine the consequences of different strategies for implementing a policy such as the WFD and if required allows the identification of priority areas for focusing such strategies so as to optimise the total benefits generated.

The estimation of spatially sensitive valuation functions also allows us to investigate the potential for 'benefit transfers'. Here value functions, estimated using data such as that described above, are applied to generate values for policy relevant sites which may not of

⁴ Although clearly comparisons between the benefits estimates provided by the stated and revealed preference approaches will be an interesting output of the research.

themselves have been part of the revealed or stated preference survey. Indeed once a robust valuation function has been estimated the researcher need only know the attribute levels and improvement scheme which characterises an unsurveyed site to estimate (via the valuation function) the benefit generated by improving that site. Such benefit transfers obviate the need for individual site surveys each time an environmental improvement is to be assessed and indeed this approach underpins contemporary Environment Agency assessments. However, at present these are conducted not via a value function but rather by transferring simple mean values from a relatively small pool of existing studies, few if any of which were conducted for such a purpose. Transferring functions rather than mean values allows the analyst to obtain a value which is adjusted for the characteristics and environs of the site in question. The key issue therefore is to determine the robustness or otherwise of the valuation function to be transferred. This is typically undertaken by taking a function estimated from one subset of observations and using it to estimate values for an alternative set of sites for which independent value estimates are already held. The proposed research will undertake such robustness analysis. In so doing we will be guided in part by our recent findings which suggest that the transfer of statistical 'best-fit' functions may inflate value estimation errors (Brouwer and Bateman, 2005). This is because such functions may include site specific contextual factors which are not relevant to those sites the function is transferred to. Conversely the specification of functions on the basis of those general factors identified in core economic theory (e.g. income levels, usage parameters, etc.) can produce functions with statistically insignificant errors when transferred.

The third key advantage offered by our spatially sensitive, GIS-based methodology is a ready ability to examine the distributional implications of the water quality improvements offered by the WFD. While valuations often note an association between say willingness to pay values and household income, the implications of this association are rarely explored. Furthermore, given that, as explained above, the spatial distribution of benefits is unlikely to be even-handed, the potential exists that some groups will fare better than others in capturing the non-market benefits of the Directive. The estimation of a value function which varies across space and socio-economic dimensions allows us to use the GIS to link between census measures of deprivation and corresponding WFD benefit values. It seems likely that many environmental benefits, such as those generated by National Parks, are evenly captured by the richer sections of society. This may be the case with regard to water quality benefits, however the case is less clear cut. Informal waterway recreation is open to all and, unlike National Parks, is, in spatial terms, much more widespread. Furthermore, again as outlined above, if the WFD is implemented as it stands then it seems likely that the benefits may indeed be relatively greater within urban and surrounding areas. However, while this Directive seems potentially redistributive in terms of its benefits, their urban bias conflicts markedly with the predominantly rural incidence of costs (as assessed in WP 1, 2 and 3). The contrast between costs and benefits is expected to form a concluding theme of the proposed research to which we turn after first briefly considering plans for administering the project and the case study area to be investigated.

7. Project Planning and the Case Study Area

The ChREAM project is a major undertaking and given the complex and interlocking nature of the workpackages, project planning and management is a particular priority. The project commences with focus upon WP1 & 2 with a data assembly phase being accompanied by literature review and model development. While preparation for the first WP3 survey starts early in the project, harmonisation with the patterns of the farming year means that this may not be completed until a year into the project. The WP2 modelling exercise is initially conducted separately from WP1 but development of the linkage between these WP's is a priority from the outset with full integration of the hydrological and economic models should be achieved prior to the midway point of the project. Further development of this model will

precede the second farm survey, planned for the end of the second year. Once these survey data are collected then final development of the hydrological-economic model will commence to be followed by policy relevant scenario analysis.

The revealed preference initiative of WP4 starts early in the project with a simulation exercise being undertaken with synthetic data to identify the informational requirements of the subsequent survey. The valuation survey work will commence once the simulation exercise is complete and the WP1 work is advanced sufficiently to provide information on the nature of the water quality improvements effects of WFD implementation. Ideally the revealed preference survey will commence prior to that for the choice experiment exercise, the latter being informed by the experience of the former. Analysis of both models will immediately follow the relevant survey and lead into the aggregation, transfer and distributional analyses. The final phase of the research will contrast cost and benefit estimates (albeit that this will not be a full cost-benefit analysis), focus upon enhancing the policy relevance of the work and disseminating its findings

In considering the choice of case study area we have sought to balance data availability with a desire to identify a large and diverse area. Such an area is provided by the Humber basin, (Figure 3) which comprises some 25,000 km² in which over 10 million people live and drains 28% of England, mainly via its two principal river catchments, the Ouse and the Trent.

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A comparison of Figures 1 and 3 indicates that the Humber is an ideal case study area as it captures a full range of emission levels of key pollutants such as phosphates, nitrogen and pesticides. Furthermore, the Humber is the major river system entering the North Sea, delivering 62% of the riverine flow input and being a major source of pollutants from the UK. In addition to its overall size and significance, the contrasting characteristics of sub-catchments across the Humber Basin provide useful variation for subsequent extrapolation. This allows the research to examine the effect of geographic targeting of WFD measures, for example in areas of high environmental risk.

The Humber Basin has also been the focus of considerable prior research including the EUROCAT and LOIS programmes, both of which were led by certain of the researchers with the LOIS work involving extensive modelling of nitrogen and phosphorus transport in the area (Neal and Davies, 2003; Neal et al., 1996; Robson and Neal, 1997). This combines with the usual high quality work by the FBS to provide an excellent base data resource for the proposed study.

8. Concluding Remarks

This project sets out to deliver a high research and policy return. On the research side our model of farm activities combines high quality FBS records with GIS based data detailing the spatial and physical environment characteristics of farms. Similarly the water environment model links nitrogen and phosphate transport with pesticide and faecal material modules and climate change extensions to permit improved prediction of ecological status impacts. Integrating these analyses to yield a genuinely integrated hydrological-economic model of the relationships between individual farm activity and catchment water quality provides arguably the key research deliverable of the project. This model will then be used to assess the consequences of the additional stressors WFD implementation may create within a rapidly transforming business environment being fundamentally restructured by ongoing CAP reform. The entire modelling enterprise is informed and ground-truthed by a cycle of new on-farm surveys investigating farmer attitudes and behaviour.

Analysis of the farm level costs likely to be imposed by the WFD is balanced by investigation of the potential benefits which the Directive might generate. Here we adopt an integrated mix of revealed and stated preference methods to assess the non-market values which are the *raison d'être* of the policy. As in our farm modelling the spatial dimension is key here and our GIS based methodology aims to extend previous research to address the transfer, aggregation and distribution of such benefits.

While it is hoped that, taken together, this research project will provide a significant contribution to the literature, it is also designed to address the key policy questions raised by implementation of the WFD; questions which will be focussed via the Reference User Group. Indeed the research aims to go beyond conventional issues of aggregate impact and response to raise and address new questions employing the spatial analytic basis which underpins the entire research enterprise to consider issues of optimal application, spatial and socio-economic distribution of costs and benefits, temporal trends, etc. Findings will be disseminated via the usual routes of publishing and conferences but also via targeted initiatives through the RUG and via workshops direct to farming, water sector, environmental and other relevant interest groups.

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