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Climate proofing rural resource protection policies and strategies in Wales

Science Report: SC030298/SR

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

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Steve Killeen
Head of Science

Executive summary

Public policy plays an important role in adapting to climate change. This project assessed the capacity and resilience of six natural resource policies, strategies and plans to function in changed climates in 2020 and 2050.

The schemes chosen for analysis were:

- Sites of Special Scientific Interest (SSSI)
- Welsh agri-environment schemes (Tir Gofal)
- Woodlands Strategy
- Biomass Action Plan
- Catchment Abstraction Management Strategies (CAMS)
- Catchment Flood Management Plans (CFMP),

These collectively cover nature conservation, water resource management, flood protection and economic and recreational use of the countryside. Each of these initiatives was analysed using a common framework, which assessed the vulnerability of key components of each policy to climate change. Overall policy vulnerability was then considered as the sum of its key components, so that if one or more component had a high probability of failure, then the overall policy was considered to be vulnerable.

The project used the UK Climate Impacts Programme (UKCIP) risk assessment methodology, developing risk assessment matrices which demonstrate how generic policy analysis can be used to assess vulnerability to climate change and guide adaptation at a scale useful to resource managers and policy makers. The study created the first database of climate change impacts on socio-economic indicators for Wales. Future climate and socio-economic scenarios were considered for 2020 and 2050 (developed from UKCIP02 and UKCIP socio-economic scenarios) and applied to a case study in the River Usk Catchment, South Wales. Results are presented for each policy area.

SSSI policy is not robust in conditions of climate change. Major risks relate to the inability of the policy to guarantee the survival of Britain’s wildlife. This aspect may fail as species disperse in response to climate and communities currently protected by SSSI change in nature. Policy adaptation is limited as the policy is firmly site-based, while the future distribution of species across the UK is uncertain. However, SSSI sites could play an important role in landscape scale approaches to conservation, including developing sufficient levels of connectivity. Enabling species to move and colonise new habitats, is key to a more appropriate policy which would interact positively with others.

Welsh agri-environment policies have a potentially resilient structure. Regular review of management practices and payments renders them potentially well suited to adapt to changing climatic and socio-economic conditions. However, the policy assumes farmers will adopt it voluntarily. Continuation of these policies depends on positive attitudes towards environmental protection and farming and proven success in enhancing biodiversity. Agri-environment schemes in general have the potential to enhance the performance of other policies through components which seek or need to act at landscape scales. After some modification, targeted agri-environment schemes could help develop landscape level planning and in this way, would contribute to maintaining the resilience of other policies discussed here.

The success of the Woodland Strategy for Wales depends on the future demand for timber products, the world price for timber and future levels of environmental awareness. Policy components seeking to develop new woodland could enhance biodiversity by reinforcing strategies that enhance habitat connectivity. However, conflicts may arise between new woodlands managed for timber and biodiversity conservation. There is great potential for landscape level planning of new woodlands to support other conservation and water resource policies, but more research is needed. The resilience of the policy will also relate to the provenance of trees, planting urban and shade trees, maximising carbon sequestration and ensuring that new plantings consider fire management.

The Biomass Action Plan depends on viable markets for biomass products, to encourage investment by farmers to help meet climate policy targets. There are potential environmental problems associated with wide scale planting of commercial biomass crops and some of these may be exacerbated under climate change, such as water use and soil management. However, strategic landscape planting of biomass could potentially support the woodland strategy, conservation policy and water resource planning. The vulnerability of this policy depends on political attitudes and market trends.

CAMS is only one part of the overall UK water resource planning framework, and in itself is a flexible policy with regular review periods which should reduce its vulnerability to climate change. However, the policy faces a serious challenge in seeking to balance social and environmental demands on water resources under a changed climate of decreased rainfall. There is an urgent need to encourage water efficiency and enhance water storage in many catchments. There may also be a need to restrict further urban developments in some catchments. Only if water demand is managed can the ecological aspirations of CAMS and wider water resource planning be met.

CFMP policy is resilient, with regular reviews of activities, and has the potential to become a very inclusive and participatory process, as is being attempted in Wales. However, it has a high risk of failure due to uncertainty in predicting the likely frequency, magnitude and social and economic impact of future floods. CFMPs could potentially interact with other land use policies, such as developing woodlands in key places to increase infiltration of water and reduce flood risks. However, further research is needed to understand the contribution of different land uses to water infiltration and flood risk. Both CAMS and the CFMP would benefit from climate scenario-driven hydrological modelling to improve climate prediction at local scales.

This report makes specific recommendations for each policy area. For example, in the future SSSI may need to be managed as units to support changing assemblages of species, rather than as habitats for specific species. To increase policy effectiveness, it is recommended that the vulnerability of existing policies should be explored, for example during mid-term reviews, and that all new policies should explicitly consider climate change. Also, if policies incorporate greater flexibility in delivery, more holistic outcomes can be achieved. More planned integration at the landscape scale is recommended, to transcend the local level and also cover the national scale. Improving the accuracy of local level predictions would help achieve this. A key recommendation of this report is that all resource protection policies should be managed as a coherent whole, to offer a 'joined-up' approach to managing the countryside.

Crynodeb gweithredol

Mae polisi cyhoeddus yn chwarae rôl bwysig yn y gwaith o ymaddasu i newid yn yr hinsawdd. Asesodd y prosiect hwn allu a gwytnwch chwech o bolisïau, strategaethau a chynlluniau adnodd naturiol o safbwynt gweithredu mewn hinsoddau sydd wedi newid yn 2020 a 2050.

Y cynlluniau a ddetholwyd i'w dadansoddi oedd:

- Safleoedd o Ddiddordeb Gwyddonol Arbennig (SDdGA)
- Cynlluniau amaethyddol-amgylcheddol Cymreig (Tir Gofal)
- Strategaeth Coetiroedd
- Cynllun Gweithredu Biomas
- Strategaethau Rheoli Tynnu Dŵr o Ddalgylchoedd (SRhTDD)
- Cynlluniau Rheoli Llifogydd mewn Dalgylchoedd (CRHLLD),

Gyda'i gilydd, mae'r rhain yn rhychwantu cadwraeth natur, rheoli adnoddau dŵr, amddiffyn rhag llifogydd a sut y defnyddir cefn gwlad yn economaidd ac ar gyfer hamdden. Cafodd pob un o'r mentrau hyn eu dadansoddi gan ddefnyddio fframwaith cyffredin, a fu'n asesu pa mor fregus o safbwynt newid yn yr hinsawdd oedd elfennau allweddol pob polisi. Yna ystyriwyd natur fregus gyffredinol y polisi fel swm ei elfennau allweddol, yn y fath fodd fel os oedd gan un elfen debygolrwydd uchel o fethu, yna ystyriwyd bod y polisi yn gyffredinol yn fregus.

Defnyddiodd y prosiect fethodoleg asesu risg Rhaglen Effeithiau Hinsawdd y DU (UKCIP), gan ddatblygu matricsau asesu risg sy'n arddangos sut gellir defnyddio dadansoddiad polisi generig er mwyn asesu gwendidau yn wyneb newid yn yr hinsawdd a thywys gwaith addasu ar raddfa sy'n ddefnyddiol i reolwyr adnodd a llunwyr polisi. Creodd yr astudiaeth y gronfa ddata gyntaf o effeithiau newid yn yr hinsawdd ar ddangosyddion cymdeithasol-economaidd ar gyfer Cymru. Ystyriwyd senarios hinsawdd a chymdeithasol-economaidd y dyfodol ar gyfer 2020 a 2050 (wedi'u datblygu o senarios cymdeithasol-economaidd UKCIP02 a UKCIP) a'u cymhwyso i astudiaeth achos yn Nalgylch Wysg, De Cymru. Cyflwynir canlyniadau ar gyfer pob maes polisi.

Nid yw polisi SDdGA yn gadarn mewn amgylchiadau lle ceir newid yn yr hinsawdd. Ceir peryglon pwysig yng nghyswllt anallu'r polisi i sicrhau fod bywyd gwyllt Prydain yn goroesi. Gall yr agwedd hon fethu fel bod rhywogaethau yn gwasgaru fel ymateb i'r hinsawdd ac fel bod cymunedau a warchodir ar hyn o bryd gan SDdGA yn newid o ran eu natur. Cyfyngedig yw'r posibilrwydd o addasu'r polisi oherwydd caiff ei seilio'n bendant ar safleoedd, tra bod sut dosbarthir rhywogaethau ar draws y DU yn y dyfodol yn ansicr. Fodd bynnag, medrai safleoedd SDdGA chwarae rhan bwysig mewn agweddau tuag at gadwraeth ar raddfa tirwedd, gan gynnwys datblygu lefelau digonol o gysylltedd. Mae galluogi rhywogaethau i symud a gwladychu cynefinoedd newydd yn allweddol i bolisi mwy addas a fyddai'n rhyngweithio'n gadarnhaol gydag eraill.

Mae gan bolisïau amaethyddol-amgylcheddol Cymreig strwythur gwydn potensial. Mae cynnal adolygiadau rheolaidd o arferion rheoli a thaliadau, yn golygu eu bod, o bosib, yn gweddu'n dda o safbwynt addasu i gyflyrau hinsoddol a chymdeithasol-economaidd. Fodd bynnag, mae'r polisi'n rhagdybio bydd ffermwyr yn ei fabwysiadu'n wirfoddol. Mae parhad y polisïau hyn yn dibynnu ar agweddau cefnogol tuag at warchod yr amgylchedd a ffermio, a llwyddiant y gellir ei brofi o ran gwella bioamrywiaeth. Yn gyffredinol mae gan gynlluniau amaethyddol-amgylcheddol y potensial i wella perfformiad polisïau eraill drwy gyfrwng elfennau sy'n ceisio neu sydd angen iddynt weithredu ar raddfeydd tirwedd. Ar ôl rhywfaint o addasu, medrai cynlluniau amaethyddol-amgylcheddol wedi'u targedu helpu i ddatblygu cynllunio ar lefel tirwedd ac yn y modd hwn, byddent yn cyfrannu at gynnal gwytnwch y polisïau eraill a drafodir yma.

Mae llwyddiant Strategaeth Coetiroedd i Gymru yn dibynnu ar y galw yn y dyfodol am gynhyrchion pren, y pris byd-eang am bren a lefelau o ymwybyddiaeth amgylcheddol yn y dyfodol. Medrai elfennau polisi sy'n ceisio datblygu coetiroedd newydd wella bioamrywiaeth drwy atgyfnerthu strategaethau sy'n gwella cysylltedd cynefinoedd. Fodd bynnag, medrai gwrthdrawiadau godi rhwng coetiroedd newydd a reolir ar gyfer pren a chadwraeth bioamrywiaeth. Mae llawer o botensial yn bodoli ar gyfer cynllunio ar lefel tirwedd er mwyn cefnogi polisïau cadwraeth ac adnodd dŵr eraill, ond mae angen mwy o ymchwil. Bydd gwytnwch y polisi yn gysylltiedig yn ogystal â tharddleoedd coed, plannu coed trefol a choed cysgod, cynyddu atafaeliad carbon i'r eithaf a sicrhau fod planhigfeydd newydd yn ystyried rheoli tân.

Mae'r Cynllun Gweithredu Biomas yn dibynnu ar farchnadoedd ymarferol ar gyfer cynhyrchion biomas, er mwyn annog ffermwyr i fuddsoddi er mwyn helpu i gwrdd â thargedau polisi hinsawdd. Gall problemau amgylcheddol potensial sy'n gysylltiedig â phlannu cnydau biomas masnachol ar raddfa eang gael eu gwaethygu fel bod yr hinsawdd yn newid, megis defnyddio dŵr a rheoli pridd. Fodd bynnag, medrai plannu biomas yn strategol o fewn y dirwedd, o bosib, gefnogi'r strategaeth coetiroedd, polisi cadwraeth a chynllunio adnoddau. Mae natur fregus y polisi hwn yn dibynnu ar agweddau gwleidyddol a thueddiadau'r farchnad.

Un rhan yn unig o fframwaith cynllunio adnodd dŵr cyffredinol y DU yw SRHTDD, ac ynddo'i hun mae'n bolisi hyblyg gyda chyfnodau arolwg rheolaidd a ddylai leihau pa mor fregus ydyw yn wyneb newid yn yr hinsawdd. Fodd bynnag, mae'r polisi'n wynebu her ddifrifol o ran ceisio cydbwyso galwadau cymdeithasol ac amgylcheddol ar adnoddau dŵr mewn hinsawdd sydd wedi newid o lawiad is. Mae angen dybryd i annog effeithlonrwydd dŵr a gwella sut caiff dŵr ei storio mewn llawer o ddalgylchoedd. Gall fod yn rhaid cyfyngu ar ddatblygiadau trefol pellach mewn rhai dalgylchoedd yn ogystal. Gellir cyflawni uchelgeisiau ecolegol SRHTDD a chynllunio adnodd dŵr ar raddfa ehangach yn unig os gellir rheoli'r galw am ddŵr.

Mae'r polisi CRhLlD yn wydn, gydag adolygiadau rheolaidd o weithgareddau, ac mae ganddo'r potensial i ddyfod yn broses gynhwysol a chyfranogol dros ben, fel yr ymdrechir i'w gyflawni yng Nghymru. Fodd bynnag, mae ganddo risg uchel o fethu oherwydd yr ansicrwydd sydd ynghlwm wrth ddarogan tebygolrwydd amlder, maint ac effaith gymdeithasol ac economaidd llifogydd yn y dyfodol. Medrai CRhLlD o bosib ryngweithio gyda pholisïau defnyddio tir eraill, megis datblygu coetiroedd mewn mannau allweddol er mwyn cynyddu faint o ddŵr sy'n hydreiddio a lleihau peryglon llifogydd. Fodd bynnag, mae angen rhagor o ymchwil er mwyn deall cyfraniad dulliau gwahanol o ddefnyddio tir i faint o ddŵr sy'n hydreiddio a'r perygl o lifogydd. Byddai SRHTDD a CRhLlD yn elwa o fodelu hydrolegol ar sail senario hinsawdd er mwyn gwella rhagolygon hinsoddol ar raddfeydd lleol.

Mae'r adroddiad hwn yn cynnig argymelliadau penodol ar gyfer pob maes polisi. Er enghraifft, yn y dyfodol gall fod yn rhaid rheoli SDdGA fel unedau er mwyn cefnogi ymgynulliadau o rywogaethau sy'n newid, yn hytrach na chynefinoedd ar gyfer rhywogaeth benodol. Er mwy cynyddu effeithiolrwydd polisïau, argymhellir fod natur fregus polisïau cyfredol yn cael ei archwilio, ac y dylai pob polisi newydd ystyried newid yn yr hinsawdd yn benodol. Hefyd, os bydd polisïau yn cynnwys mwy o hyblygrwydd o ran eu gweithrediad, gellir cyflawni canlyniadau mwy cyfannol. Argymhellir mwy o integreiddio wedi'i gynllunio ar raddfa tirwedd, er mwyn codi uwchlaw y lefel leol a chwmpasu'r raddfa genedlaethol yn ogystal. Bydd gwella manwl gywirdeb daroganau ar lefel leol o gymorth i gyflawni hyn. Un o argymelliadau allweddol yr adroddiad yw y dylid rheoli pob polisi gwarchod adnodd fel cyfanwaith cydlynol, er mwyn cynnig agwedd 'gyfannol' tuag at reoli cefn gwlad.

Contents

1 Introduction

1.1 Background

Climate change is happening now and further change is inevitable. Global mean temperatures are projected to continue rising over the coming decades (IPCC, 2000, 2001, 2002). This trend will be unavoidable due to continually rising emissions and inertia within the climate system (Wigley, 2005). As a result, we are committed to 50 years of climate change and the need to develop adaptation strategies. A number of studies have looked at climate change impacts on various elements of our natural and built environment (Smith and Almaraz, 2004; Scherm, 2004; Darwin, 2004; Solomon and Sambrook, 2004; Thomas *et al*., 2004), however, few have looked at adaptation strategies.

The United Kingdom Climate Impacts Programme (UKCIP) has played an important role in leading the UK response to climate change, and has helped with the commissioning of work on methods for government and business to understand and manage climate change, alongside a series of regional impact studies (Farrar and Vase, 2000; Lu *et al.,* 2001; North West Regional Assembly, 1999; Wade *et al*., 2000). Early work has raised awareness of likely impacts and it is now possible to explore other climate change related issues, many of which relate to political and institutional responses to climate change.

One such issue relates to the resilience of current policies to climate change. There is much potential to reduce the harmful impacts of climate change by adapting human activities (Hulme, 2005). Clearly the policy environment is vital in any adaptation process, and appropriate policies should enable acceptable levels of adaptation (such as through planning laws and the location of new homes), while seeking to prevent less acceptable adaptive behaviours (such as the use of non-renewable resources for powering air conditioners). New policies may be needed to enable this adaptation and an important first step is to identify the vulnerability of current policies to climate change, and identify which policies may fail to meet objectives under future climate change. For example, policies advocating a site-based conservation strategy may begin to look ineffective if the majority of species in the protected sites migrate northwards as the climate changes (Parmesan and Yohe, 2003; Thomas *et al.,* 2004), while controls for abstraction from ground and surface waters may be put under strain by human migration and large scale changes in demand by agriculture and industry.

The ability of policies to deal with future challenges is further complicated by the possibility of interaction. Policies may provide mutually reinforcing signals to citizens (where the interaction between policies brings about outcomes which support the aims of individual policies). Alternatively, interactions may provide perverse incentives, such that citizens respond in a manner not intended by the policies, resulting in maladaptation. Examples of these sorts of interactions have been well documented in the rural sector. For example, for much of the period 1975-1995 the agricultural support policy in the UK, as detailed under the Common Agricultural Policy, seemed to be at odds with the nature conservation policies of the time (Winter and Gaskell, 1998). Similarly, planning policy can still be at odds with the objective of reducing the flooding of homes.

Clearly, at its most fundamental policy making is a political process, and for this reason it is hard to predict the nature of policies very far into the future. However, a basic level of scientific and policy analysis can inform future debate, and it would seem prudent to begin to consider some of the policy-related issues well in advance of significant climate change. While such analysis is undoubtedly ongoing within government, to date relatively little scientific analysis has sought to consider how policies deal with the challenges of climate change, and its associated ramifications. This report sought to make some progress in considering the resilience to climate change of policies relating to the countryside.

1.1.1 Climate change and Wales

The current review of the European Climate Change Programme is placing greater emphasis on the need to adapt and develop adaptation strategies. The Environment Strategy for Wales and the accompanying Action Plan (Welsh Assembly Government, 2006) led by Welsh Assembly Government (WAG) includes a commitment for WAG to develop a Climate Change Adaptation Action Plan working with key partners, such as Environment Agency Wales and Countryside Council for Wales (CCW).

Wales has some level of devolved government, through WAG and a series of government agencies which operate under varying levels of independence from their English and Scottish counterparts. These regional differences are particularly noticeable in the area of land use, because WAG has responsibility for agriculture, planning, forestry and environmental protection within Wales. While policies relating to Wales may differ slightly from those acting elsewhere in the UK, in reality there are many similarities given that they all derive from overarching policy at the EU or UK level. Thus, many of the conclusions arising from this work will be relevant to other regions in the UK.

The impact of climate change in Wales has been considered previously, when the National Assembly for Wales (NAW) commissioned a scoping study in collaboration with the UK Climate Impacts Programme (Farrar and Vase, 2000). This study combined climatological modelling of Wales with expert review of 11 key sectors and stakeholder analysis (interviews with nearly 70 stakeholders drawn from a wide range of institutions and interest groups within Wales). At the heart of this work was some novel regional scale climate modelling (discussed in Chapter 2) and the identification of issues which may be at risk from climate change. A selection of issues related to environment and land use are summarised in Table 1.1.

Farrar and Vase (2000) found that stakeholders generally had a good understanding of climate change, particularly in sectors relating to ecology, water resources and flooding. Businesses were in general less well informed, and the wider public needed to know much more about climate change, particularly since a widely-held view of stakeholders was that adaptation needed to proceed with the consent and cooperation of an informed public. The study also revealed that those interviewed often cited institutional inertia as a reason for there being little adaptation, and suggested that there was a wide perception that both mitigation and adaptation needed a firm lead from government.

In order to follow up these issues, the 2000 report stated that the National Assembly for Wales must ensure that climate change is considered as a component of sustainability – a key cross-cutting theme of the Assembly – in determining policies, and further that regulators must ensure that water and power utilities place sufficient emphasis on measures to assist adaptation to climate change. Thus, the current project may be viewed as a logical progression of the work undertaken in the Welsh scoping study.

1.2 Aims and objectives

1.2.1 Purpose

The purpose of this work was to consider whether current formal and informal natural resource protection policies which operate in the Welsh countryside would be appropriate in the changed climate of 2020 and 2050. The overall objectives were to:

- identify and appraise resource protection agreements important to the management of the Welsh countryside in a changing climate, including both formal and informal arrangements between a variety of 'players' in the rural environment;
- examine the countryside's vulnerability to climate change resulting from the way the agreements are formulated and how they interact up to 2050;
- explore how the agreements may be 'climate-proofed', both individually and as a coherent set, to increase the countryside's resilience and enhance rural sustainability;
- produce guidance for decision makers to help them create a more resilient countryside and rural environment.

Table 1.1: Summary of the impacts of climate change in Wales as identified by Farrar and Vase (2000). Only sectors relating to this project are reported here.

- The increasingly Mediterranean climate will be accompanied by a migration northwards of sensitive species. Migration will be hampered unless there are 'corridors' connecting similar habitats, and species which can neither adapt nor migrate may be lost.
- Biodiversity Action Plans cover many parts of Wales and whilst some mention climate change, they do not fully allow for its impacts; nor do site designations for Sites of Special Scientific Interest (SSSI) and Special Areas of Conservation (SAC).
- Coastal and lowland zones, estuaries (Dee, Severn), saltmarshes and sand dunes (Morfa Harlech) will be impacted by storms and sea level rise, and in many cases managed retreat may be too expensive.
- The internationally important raised bogs at Cors Erdrreiniog and Cors Tregaron may dry out unless their water tables are artificially maintained.
- Important effects will be on the upland semi-natural communities of the north and west (48 per cent of the land area). Arctic-alpines such as the Snowdon lily may be lost. There may be unknown ecological outcomes of interactions with other environmental pressures such as acid rain, nitrogen deposition and intensity of grazing.
- There may be altered distribution of freshwater birds, while summer warmth and drought might reduce salmonid growth. Blue-green algal blooms may become more frequent.
- Archaeological sites in low-lying regions will be subject to flooding, and other built heritage will suffer damage from both severe winter storms and, in dry summers, subsidence as the ground dries out.
- The population of Wales will probably increase slowly, although it will depend critically on migration.
- The fertilising effect of extra CO_2 in the atmosphere will increase plant growth and interact with temperature rise and altered patterns of precipitation and evapotranspiration. Cereal yields may be depressed but grass yields should increase. It is diffcult to predict how the occurrence of pests and diseases of crops and livestock will change.
- Forests will be damaged by an increased frequency of storms and high winds and forest fires may be more frequent in dry summers.
- Adaptation by farmers to the new climate may increase demand for irrigation in hot, dry summers.
- Getting machinery onto the land will be harder if the land is waterlogged in autumn and winter.
- Patterns of land use will also be driven by market forces internationally: the current prediction is that the uplands will be little affected but arable farming will increase in eastern Wales.
- Whilst warming should benefit tourism, the prediction of increased precipitation in autumn may mitigate against increased trips during this period.
- The sea level will rise around the Welsh coasts, by about 40 cm by 2080. One estimate is that flooding events will be between 10 and 50 times as frequent by 2090.
- It is estimated that up to 18 of the 43 water supply zones could go into water deficit over the next 25 years in dry summers. Assuring summer supplies may depend on increased storage of rain from winter.
- Winter storms and increased intensity of daily precipitation will lead to the capacity of drains and sewers being exceeded.

Against this background, the specific objectives of this study were to:

- review current resource protection policies, their objectives and the extent to which they are able to integrate the implications of climate change;
- identify as full a range as possible of current and potential future agreements (defined in the broadest sense) relevant to countryside land use, management and the rural economy;
- identify key resource protection agreements that will have a significant impact on the ability of the countryside to adapt to climate change in a sustainable manner;
- consider how these may evolve in different socio-economic scenarios and under a range of climate scenarios;
- consider ways in which climate change could be integrated into land use management decision making and provide sustainable management of socio-economic and natural resources;
- explore the interactions and overall impacts of the proposed changes through a catchment-based case study;
- report and disseminate the generic results derived from the project to raise awareness and engage decision makers across Wales and all English regions .

1.2.2 Structure of the report

The work reported here centred around the analysis of six policies and strategies which were selected for analysis through consultation with a stakeholder group. These were:

- Sites of Special Scientific Interest (SSSI) which relate explicitly to nature conservation, and in institutional terms are most relevant to the statutory nature conservation agency, the Countryside Council of Wales (CCW).
- Agri-environment schemes which relate to agriculture, access to the countryside, and wildlife and landscape protection. Institutions with the closest relationship to these policies are the CCW, representatives of the farming sector and the Welsh Assembly Government which administers the scheme.
- The Woodland Strategy for Wales, which is concerned with the development of woodlands in Wales for economic, conservation, landscape and recreational purposes. The Forestry Commission and WAG have the closest involvement with this strategy, but other organisations such as CCW and representatives of landowners are also involved in delivering the strategy.
- The Biomass Action Plan, which seeks to develop a strategy for developing biomass in Wales. Again, the Forestry Commission and WAG have the closest involvement with this strategy, but many other organisations also have interests including landowners and industry.
- Catchment Abstraction Management Strategy (CAMS), which are concerned with managing the levels of abstraction from catchments. Delivering this strategy is largely the responsibility of the Environment Agency.
- Catchment Flood Management Plans (CFMP), which are concerned with reducing the risk from flooding in catchments. Again, delivering this strategy is largely the responsibility of the Environment Agency.

Each of these policies was analysed using the same framework, described in Chapter 2. This method sought to consider the vulnerability of key components of each policy to climate change. Through necessity, this was a reductionist process which analysed each component and considered how well it would perform under climate change. The overall policy was then considered to be the sum of its key components, and if one or more component had a high probability of failing under climate change, then the overall policy was felt to be vulnerable and to have a high probability of failure. This process is analogous to engineering processes of risk assessment, whereby each individual component of a larger system, such as a chemical plant, is tested to destruction, the assumption being that the larger system is only as robust as its weakest link.

This reductionist approach introduces some philosophical discord into the work, because one of the main assumptions underlying the work was that a greater level of interaction between policies would bring about a positive synergistic effect, and serve to reduce the vulnerability of individual policies. Further, the policies selected for analysis are not the only means by which certain policy aims are met. For example, the SSSI is not the only nature conservation policy in operation in Wales, and similarly CAMS and CFMP are only two parts of a much larger water resource planning framework which exists within the Environment Agency and beyond.

For this reason, it could be argued that a better approach to assessment could be to consider the vulnerability of all policies and strategies which contribute to an overall policy goal, such as nature conservation or water resource planning. In this way, it would be possible to identify any checks and balances within the overall system. For example, the failure of one component of a single policy under climate change might not matter if there were sufficient checks and balances elsewhere to identify that failure and undertake appropriate mitigating action.

Such an approach may bring benefits to the institutions responsible for delivering on broad policy areas, such as CCW for nature conservation and the Environment Agency for water resource planning, but the work here deliberately chose policies from different institutions which covered a wide range of issues relevant to the countryside; in this way it was hoped that the results would inform any future analyses of policies undertaken by single institutions. In other words, the study sought to explore whether the integration of a wide range of policies relevant to different institutions could bring benefits beyond those possible by any one institution alone. If such integration were potentially beneficial, then undoubtedly achieving such cross-institutional synergy would take time, and this work is only one small step on that road.

Given the assumption that integration between policies and institutions would deliver greater benefits than a more atomised approach, it may be desirable for users to read all chapters of this report. However, if this is not possible then three key chapters are recommended for reading: Chapter 2 on the risk assessment method, the policy chapter of most interest to them, and Chapter 8 which offers an overview and conclusions. In addition, users may wish to consult the accompanying CD which provides details of the analysis and the catchment case study.

The report is divided as follows:

- Chapter 1 introduces the project and the report
- Chapter 2 details the methodology and steps involved in policy analysis used in all subsequent chapters
- Chapter 3 analyses SSSI policy and its application to the River Usk catchment
- Chapter 4 analyses the Tir Cymru agri-environment scheme and its application to the Usk
- Chapter 5 analyses woodlands and biomass policies and application to the Usk
- Chapter 6 analyses CAMS and its application to the Usk
- Chapter 7 analyses CFMP and its application to the Usk

- Chapter 8 summarises policy and strategy interactions, discusses overall vulnerabilities and limitations of the study and makes climate proofing recommendations.

On the attached CD:

- Appendix 1 provides the report from a stakeholder workshop to identify and select resource agreements
- Appendix 2 gives the multiplication factors for conversion from the UKCIP02 2080s medium-high scenario to other emission scenarios and time slices
- Appendix 3 gives SSSI additional information and risk assessment matrices
- Appendix 4 gives Tir Cymru additional information and risk assessment matrices
- Appendix 5 provides woodlands and biomass additional information and risk assessment matrices
- Appendix 6 lists CAMS additional information and risk assessment matrices
- Appendix 7 lists CFMP additional information and risk assessment matrices

2 Methodology

The work presented here is quite novel in approach and relatively complex. This section presents a simplified overview of the process, with more detailed workings given in Appendices 3-7 on the accompanying CD to this report.

2.1 General approach

An outline of the general approach adopted for the risk assessment process is shown in Figure 2.1. The process was split into two major phases: a pre-analysis and the individual policy assessment. The pre-analysis was common to all policies analysed for a given region, in this case Wales, and only needed to be undertaken once. The policy assessment procedure was undertaken for every policy analysed. The approach taken in each of these stages is discussed below.

2.1.1 Risk categorisation and identification

Formally, risk is defined as the probability of a given hazard causing a given consequence, multiplied by the magnitude (severity) of that consequence. This may be represented mathematically as:

$$R = P*M$$

Where:

R = risk
P = probability of a given hazard producing a given consequence
M = magnitude of harm that the given consequence would cause

In the work reported here, the standard risk assessment terms were defined as follows:

- the hazard was climate change;
- the consequences were the failure of a given policy to achieve its objectives;
- the magnitude was the harm done by a policy failing to meet its objectives;
- the probability was the likelihood that a given degree of climate change would cause a failure in a policy.

A complete quantification of risk requires relevant, comprehensive datasets. In this case, calculating the probability was made difficult by the uncertainty surrounding the extent and nature of climate change. The situation was further complicated by the fact that a changed climate may affect other aspects of the natural, economic or social environment, which in turn will affect the ability of a given policy to achieve its task. The temporal scale to climate change also complicated the assessment, as climate will progressively change both before 2020 and through to 2050. These temporal issues needed to be considered in the risk assessment.

2.1.2 Risk assessment method

This study made use of the risk assessment method developed by UKCIP specifically for climate change issues (Willow *et al*., 2002). This method offers a number of tools for analysing the risks associated with projects which might be more or less susceptible to climate change.

The UKCIP risk assessment method includes guidance in how to develop a risk analysis in the form of structural questions, and is based on the following definitions of inputs:

- risk exposure unit - where the system considered to be at risk, such as a defined land area or type;
- receptor - important or potentially vulnerable aspect of the exposure unit, such as a species;
- threshold - the critical level of effect arising from some impact, such as a population decline;
- risk assessment endpoint - the probability of some criterion not being met, such as a policy objective.

While the overall structure of the UKCIP method was extremely useful, several modifications had to be made to render it suitable for the purposes of this project:

- The guidance questions in the original method related to projects, and these had to be amended to be more relevant to policy assessment (Table 2.1).
- The original method assumed a considerable input of time to the risk assessment process (for example, 3-4 person weeks per project). But for this project, only 3-4 person days where available to analyse each policy, hence the UKCIP methodology could not be implemented in full. This reduced timescale required some steps to be amended slightly in order to meet our purposes.

Finally, in order for the method to be relevant to policy analysis, we defined a further category of variable for the risk assessment process. This we termed 'policy component', relating to important or potentially vulnerable aspects of the policy.

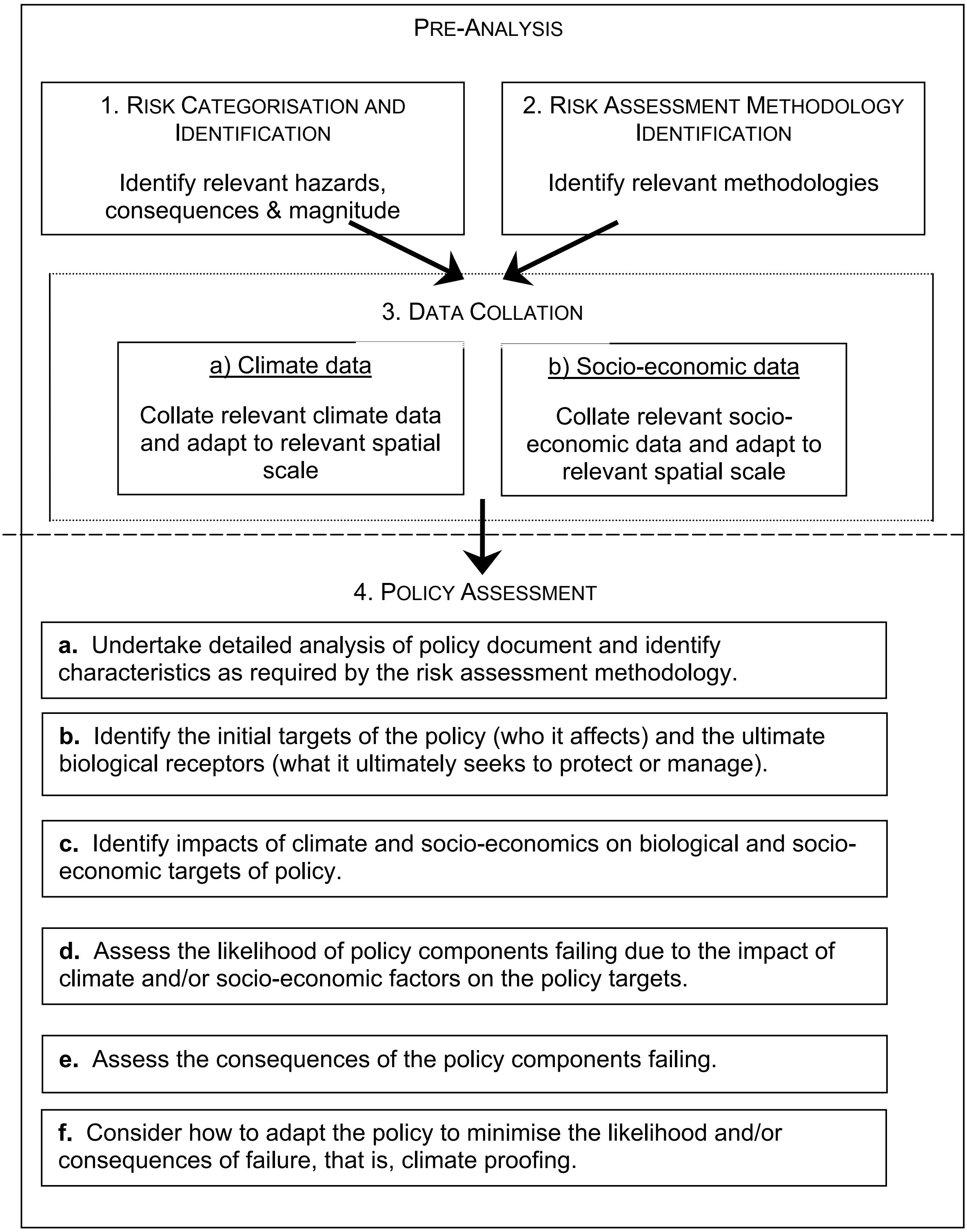

Figure 2.1: General method for assessing the risk of policy failure under climate change

Table 2.1a: Adaptation of UKCIP climate change risk analysis method for decision making (Willow *et al*., 2002) into a method appropriate for policy evaluation. Task number refers to numbers in the original methodology. The method is split into three stages. Stage 1 is presented here and Parts 1 and 2 of Stage 2 are presented in Tables 2.1b and 2.1c respectively.

Task No.	Task in the UKCIP climate change risk analysis method	Task adapted for use in policy-oriented risk analyses
Stage 1	*Identify problem and objectives*	*Identify policy needs and objectives*
1.1	Main drivers for decision making	Main drivers for original policy/policy adaptation
1.1	Where does need to make decision arise?	Who and what require the policy/adaptation
1.2	Is the problem explicitly one of climate change (managing present or future)?	Unchanged
1.3	If not, is climate change believed to be a factor in the problem?	Unchanged
1.3	How important is climate change perceived to be, that is, climate-influenced problem?	Unchanged
1.4	Is it a policy, programme or project level decision?	Is the agreement in question at policy, programme or project level?
1.5	Who or what benefits from the problem being addressed?	Who or what is the policy/policy adaptation designed to help?
1.5	Who are the key stakeholders representing their interests?	Unchanged
1.6	Have timescales been established for making and implementing decisions?	What timescales are implicit in the policy; what timescales are established for policy adaptation?
1.6	Do these timescales constrain the time available for decision appraisal or vice versa?	Do these timescales constrain the time available for analysing policy adaptation options?
1.7	Is the decision expected to provide benefits in the long term or have long-term consequences?	Does the policy address current or long-term concerns (less or more than 10 years) or have long-term consequences?
1.7	Describe time period, consequences and to whom they are important	Unchanged

Table 2.1b: Adaptation of UKCIP climate change risk analysis method for decision making (Willow *et al*., 2002) into a method appropriate for policy evaluation. Task number refers to numbers in the original methodology. The method is split into three stages. Part 1 of Stage 2 is presented here, and Stage 1 and Stage 2, Part 2 are presented in Tables 2.1a and 2.1c respectively.

Task No.	Task in the UKCIP climate change risk analysis method	Task adapted for use in this policy-oriented risk analysis
Stage 2 Part 1	*Establish decision-making criteria*	*Establish criteria for adapting policy*
2.1.1	What is the correct decision, that is, what are the criteria against which options are appraised in stage 5 (such as risk of failure, ease of implementation, cost, equity, public approval)?	What criteria does the policy/policy adaptation have to meet, for example in same terms (costs, equity and so on)?
2.1.2	What are the legislative requirements or constraints? Any appraisal necessary, such as costs and benefits consideration?	What legislation affects the policy under consideration and what types of appraisal are required for adapting the policy?
2.1.3	What are the rules for making the decision, given the uncertainty of climate change? For example, is the organization risk averse or focused on maximizing benefit or minimizing cost?	Characterise policy and policy makers in terms of objectives and preferences for meeting them, such as income generation or nature conservation as prime target, risk averse or cost averse. Are they open to radical adaptation (minimum regret) or cost-constrained?
2.1.4	What is the decision-making culture of the organization: open and explicit, requiring different stakeholders, how are they to be involved and is the goal consensus or demonstrably rational choice?	Characterise the culture of the policy-making and implementing bodies in terms of their approach to adapting policy and making decisions for its adaptation, in similar terms to above.
2.1.5	Could the decisions being considered possibly constrain other decision makers' ability to adapt to climate change (and contribute to climate maladaptation)? These may only be apparent in stage 5. Consider their involvement in the process if necessary.	Could adapting the policy being considered possibly constrain other decision makers' ability to adapt to climate change?
2.1.6	Who is the ultimate decision maker?	Who is ultimately responsible for the policy and any policy adaptation measure?
2.1.7	Has climate change already been accounted for at a strategic level? If so, is it adequate and does it take account of all possible climate change outcomes?	Unchanged
2.1.8	What resources are available to help you make the decision?	What resources are available for risk analysis and policy adaptation?

Table 2.1c: Adaptation of UKCIP climate change risk analysis method for decision making (Willow *et al*., 2002) into a method appropriate for policy evaluation. Task number refers to numbers in the original methodology. The method is split into three stages. Part 2 of Stage 2 is presented here, and Stage 1 and Stage 2, Part 1 are presented in Tables 2.1a and 2.1b respectively.

Task No.	Task in the UKCIP climate change risk analysis method	Task adapted for use in this policy-oriented risk analysis
Stage 2 Part 2	*Establish decision-making criteria*	*Establish criteria for adapting policy*
2.2.1	Have receptors at risk and the exposure unit been defined?	Unchanged
2.2.2	Have assessment endpoints or thresholds been identified as a basis for assessing risk to the exposure unit and receptors? Assessment endpoints should be directly relevant to the problem, useful to the decision maker, and amenable to risk analysis. One or more assessment endpoints may be required, depending on the complexity of the problem. Can assessment endpoints be analysed in terms of: a) past records and future scenarios of climate variability? b) other non-climate factors? Can assessment endpoints be developed to provide a basis of quantitative (tier 3) risk assessments (stage 3) if required?	Unchanged
2.2.3	Have assessment endpoints and timescales over which they will be assessed been agreed between decision makers (policy lead, programme officer or project manager), stakeholders, and risk assessors? If there are consequences beyond this time frame, such as to future stakeholders (sustainability), it may be beneficial to consider longer timeframes.	Unchanged
2.2.4	Have all project management issues been agreed? For example: are the resources and time allocated to undertake the risk assessment reasonable and proportionate to the importance and urgency (see stage 1) of the decision problem? Are the objectives clearly defined and achievable? Are the necessary expertise and data accessible?	Unchanged

2.1.3 Data collation

Two sets of scenarios developed by UKCIP were identified as being relevant to the risk assessment. These were the UKCIP98 and UKCIP02 climate change scenarios for the UK and the UKCIP02 socio-economic scenarios for UK (Hulme *et al*,1998, 2002). The climate scenarios project the range of climate possibilities for the UK up until 2080 under a series of scenarios. Each scenario assumes a different level of greenhouse gas emissions over the intervening period, so the results are presented as low, low-medium, medium-high and high for each of 2020, 2050 and 2080.

In addition, UKCIP has developed four socio-economic scenarios, based on a review of the large global futures literature which identified five main dimensions of change in:

- demography and settlement patterns;
- the composition and rate of economic growth;
- the rate and direction of technological change;
- the nature of governance;
- social and political values.

Using these five dimensions, the scenario framework segments the future 'possibility space' into four quadrants which are defined by a 'values' and a 'governance' axis (UKCIP, 2001). Thus, four possible independent states are envisaged, though in reality the boundaries between these are likely to be fuzzy. The four possible states are:

- Global Sustainability: high community values and interdependent governance;
- World Markets: high consumerism and interdependent governance;
- National Enterprise: high consumerism and governmental autonomy at national level;
- Local Stewardship: high community values and autonomy at the community level.

While considerable amount of work has been invested in developing the UKCIP climate and socio-economic data, this was developed at a UK level. This scale of analysis does not facilitate regional level analysis, so prior to using these tools at a regional scale it is necessary to scale the data down to an appropriate geographic area. The process of downscaling the climate and socio-economic scenarios to a Wales level is summarised in Table 2.2, and the methods used for each task are discussed in detail below.

Table 2.2: Tasks undertaken in the data collation phase of the pre-analysis work (as described in Figure 2.1) which relate to downscaling UK level scenarios to a Wales level. Task numbers are used in the text to aid further discussion of the methods used at each stage.

Task	Descriptor
i	Identify policy-relevant climate indicators from UKCIP climate scenarios for 2020 and 2050
ii	Downscale these to the area covered by the land of Wales (UKCIP98, 02 and Hulme, 2002)
iii	Identify policy-relevant socio-economic indicators per UKCIP02 scenario for 2020 defined for whole of the UK
iv	Find or interpolate Welsh indicators that parallel UKCIP02 socio-economic scenario indicators
v	Extrapolate 2020 indicators for Wales to 2050.

Deriving relevant climate data for Wales (Steps i-ii in Table 2.2)

The UKCIP98 and the updated UKCIP02 climate scenarios were available for all of the UK for the years 2020, 2050, 2080. The most expert characterisation of future Welsh climate scenarios was given by Hulme (2000), downscaled from the UKCIP98 scenarios (Table 2.3). Unfortunately, this characterisation was not a complete quantitative description of the climate database analogous to the full UKCIP models, but rather an expert view of how the UKCIP98 model for the UK could be interpreted in a Welsh context. Few numerical indicators were given, the predictions were not time-lined and the work only considered the medium-high emissions scenario. Also, the work reported by Hulme (2000) has to some extent been superseded by more recent climate scenarios for the UK. The UKCIP02 scenarios differ in some respects from the UKCIP98 ones and may offer a more up-to-date set of scenarios.

In order to try and work within the constraints of the available data, the Welsh climate indicators were abstracted from Hulme's work (based on UKCIP98) and, where possible or necessary, updated from the UKCIP02 findings. This involved gaining indicators of Welsh projections from 2080s climate change maps and using the UKCIP multiplication factors for scaling between different time slices and emission scenarios (see Appendix 2 on CD). The final outcome of this process was not a complete quantitative description of the Welsh climate at any specific date; rather, it was a characterisation of the climate from 2020 to 2050. While this situation was not ideal, it was the only practicable option available, given the constraints of the available data.

The results of the analysis are presented in Table 2.4. This table presents the most comprehensive available data and predictions for Wales (gained from Hulme, 2000, plus interpolation of UKCIP98 data) but where necessary, includes Wales-relevant updates under the results of the UKCIP02 models.

Table 2.3: Characterisation of the Welsh climate for 2080 derived from the UKCIP98 climate model (Farrar and Vase, 2000)

Climate variable	Predicted variation from current climate
greater warmth all year round	by 1.1-2.9 °C
warming rate (degrees C per 100 yrs)	low emission – 1 °C, high emission – 2.9 °C
more precipitation in winter	by 7-24 %
less precipitation in summer	by 7-14 %
greater annual precipitation	by 2-9 %
a rise of sea level	of 18-79 cm
a higher mean wind speed	by 1-4 %
more evapotranspiration	by 13-27 %
more variability from year to year	the number of extreme years will increase; more frequent and more violent storms
more drought years	by 10 %
more very severe gales	by 10 %

Table 2.4: Changes in the characterisation of the Welsh climate from the UKCIP02 climate predictions, instead of the UKCIP98 predictions used by Farrar and Vase (2000). Predictions relating to temperature, sea level and precipitation have been amended according to the new predictions using the UKCIP02 models. Variables related to evaporation and soil moisture were not included in the UKCIP98 models and are additions to the characterisation of the Welsh climate.

Climate variable	2020 medium high	2050 medium high
Temperature		
Warming rate (degrees C per 100 yrs)	1 °C	5 °C
Precipitation		
Average annual precipitation	0 to -4 %	0 to -10 %
Winter rainfall (%)	0 to +5.4 %	0 to +11 %
Summer rainfall (%)	0 to +8 %	0 to -17 %
Sea level		
Sea level rises (cm)	8	25
Evaporation		
Annual potential evapotranspiration (%)		up to +10 %
Potential evapotranspiration in autumn (%)		up to +15 %
Potential evapotranspiration in summer (%)		up to +10 %
Soil		
Annual soil moisture (%)	up to -8 %	up to -17 %
Winter soil moisture (%)	up to +2 %	up to +4.5 %
Summer soil moisture (%)	up to -10	up to -23 %

In summary, the results suggest that while warming projections for the whole of the UK have increased between the 1998 and 2002 models, projections for Wales only show small differences in temperatures. The largest difference between the two models relates to the precipitation projections, notably that:

- the 2002 model predicts stable or decreased average annual precipitation, compared to the increase predicted by the 1998 model;
- both models predict increased winter rainfall, but the 2002 model suggests less of an increase than the 1998 model;
- both models predict decreased summer rainfall, but the 2002 model predicts a greater decrease than the 1998 model.

In other words, the most recent predictions suggest that summer drought, both climatic and edaphic, will be more pronounced than suggested by the 1998 model; and the 2002 predictions of annual moisture availability are lower than predicted by the 1998 model.

The best that can be gained from these data is a mostly qualitative description of the Welsh climate between 2020 and 2050, assuming the medium-high emissions scenario only. The absence of quantified, time-lined climate predictions for Wales in Table 2.4 is a consequence of the lack of extant regional data. The data in Table 2.4 are as comprehensive as possible under current data constraints and do not make any untenable assumptions. Further characterisation of the future Welsh climate would require an extensive modelling exercise.

Deriving socio-economic indicators for Wales (Steps iii-iv in Table 2.2)

UKCIP02 socio-economic scenarios provide a list of quantitative indicators for the UK in 2020 under each of the four scenarios (National Enterprise, Local Stewardship, World Markets and Global Sustainability), while a fifth scenario is offered by a linear extrapolation of current socio-economic trends to some designated future time. No study has yet been conducted for similar indicators at the Welsh level. Thus, in order to carry out the risk assessment, we established a database of relevant socio-economic indicators for Wales for the year 2000. The changes in indicators under each scenario were then scaled to those in the UKCIP02 scenarios. These data were extrapolated to 2050. Where reasonable, the extrapolation was undertaken by multiplying the change from 2000 to 2020 by three. Where such an extrapolation was irrational (such as where negative kilometres of hedgerow would result), the values were defaulted to the nearest rational figure (for example, zero). This slightly non-linear change (linear to 2060) can be considered to account for small positive feedback effects or may be considered as arbitrary. Any more realistic assumptions would require considerable in-depth study of the indicators in question and would likely differ for each. Such an in-depth analysis of the socio-economic indicators was beyond the scope of this project.

The socio-economic indicators for Wales in 2020 and 2050 plus their sources, and the assumptions made in downscaling to Wales and extrapolating to 2050 are given in Table 2.5.

Table 2.5a: Estimates of the socio-economic variables used in the UKCIP socio-economic scenarios and estimates of how they will change by 2020 under five socio-economic scenarios

	Socio-economic characteristic	Data	Wales 2000	Linear 2020	National Enterprise 2020	Local Steward-ship 2020	World Markets 2020	Global Sustain-ability 2020
1	Land use							
	i) % agricultural	a	77	74.4	75	78	73	73
	ii) % forest/ woodland/other	a	13	14.3	13	11.7	14.3	16.9
	iii) % urban	a	10	11	11.3	10	12	10.7
2	Passenger transport							
	i) % road private	c	92	97.3	94.1	78.8	93.6	82
	ii) % road public	c	3	1.9	2.3	6.9	2.8	5.5
	iii) % rail	c	2	1.1	1.8	3.6	1.3	2.9
3	Total agricultural area (million ha)	b	1.63	1.55	1.59	1.68	1.46	1.55
4	Agri area under production (million ha)	b	1.57	1.49	1.53	1.64	1.40	1.49
5	Agri area not under production (ha)	b	58,120	57,342	57,732	36,630	56,567	57,342
6	Value of agri goods (Index: yr 2000 = 100%)	f	100	68	104	132	125	125
6	Value of agri goods per area (£/ha)	f	700	500	700	800	950	850
7	Pesticide use (kg/ha)	f	3.8	*no stable trend*	4	1.5	3	2
8	Nitrogen use (Mt N/yr)	f	0.15	0.13	0.16	0.11	0.14	0.12
9	Agricultural subsidies (million £)	b	167.5	*no stable trend*	228.9	396.4	134.0	435.5

Data sources: a) Land Cover Map 2000, b) NAWa 2004, c) DETR 1997, d)NAW 2004b, e) CCW 2003, f) Cannot find specifically for Wales, hence figures for UK used or calculated according to relative area, g) Farrar, J. and Vase, P. (eds) (2000) Wales: Changing Climate, Challenging Choices, NAW. * agri-environment schemes % of subsidies already approx 2.5 times higher in Wales, organic farming area approx 3 times higher in Wales, hence extrapolation from UK non-computable (> 100 %) --> comparable estimates made instead.

*agri-environment schemes: percentage of subsidies already approx 2.5 times higher in Wales, organic farming area approx three times higher in Wales, hence extrapolation from UK non-computable (> 100 %) --> comparable estimates made instead.

Table 2.5a – continued

	Socio-economic characteristic	Data	Wales 2000	Linear 2020	National enterprise 2020	Local steward ship 2020	World markets 2020	Global sustain-ability 2020
10	Agri subsidies to agri-env schemes							
	i) %	*	10		3.6	55	30	70
	ii) million £	b*	17.8	*no stable trend*	8.2	218.0	40.2	304.8
11	Area of organic farming (ha)							
	i) ha	d*	52,000		0	1,103,030	156,000	693,333
	ii) %	d*	3	*no stable trend*	0	70	9	40
12	Milk yield (litres/hd/yr)	f	5,500	7,000	7,300	6,200	8,700	7,000
13	Wheat yield (tonnes/ha)	f	7.7	9.4	9.6	7	9.8	8
14	Water demand							
	i) % change pa	f	-	0.5	0.5	-0.5	1	0
	ii) cumulative change 2000 – 2020 %			10.5	10.5	-10.5	22	0
15	Water supply (% change)		-	15	15	-15	35	0
16	River quality (% classified as good)							
	i) biologically (%)	d	78.5	*improving*	71.8	80.2	76	80.2
	ii) chemically (%)	d	92.2	*improving*	73.2	95	87.8	99
17	Area of SSSI (ha)	d	262,000	497,800	196,500	589,500	327,500	720,500
18	Area of lowland heath (ha)	e	7,000	*decreasing*	6,276	7,483	7,000	7,724
19	Length of hedgerows (km)	e	49,000	0	48,090	51,990	19,496	25,995
20	Coast protected by flood defences							
	i) %	g	17.7	-	17.3	16.2	17.7	16.6
	ii) km		223	-	218	204	223	209

Data sources: a) Land Cover Map 2000, b) NAWa 2004, c) DETR 1997, d)NAW 2004b, e) CCW 2003, f) Cannot find specifically for Wales, hence figures for UK used or calculated according to relative area, g) Farrar, J. and Vase, P. (eds) (2000) Wales: Changing Climate, Challenging Choices, NAW. * agri-environment schemes % of subsidies already approx 2.5 times higher in Wales, organic farming area approx 3 times higher in Wales, hence extrapolation from UK non-computable (> 100 %) --> comparable estimates made instead.
*agri-environment schemes: percentage of subsidies already approx 2.5 times higher in Wales, organic farming area approx three times higher in Wales, hence extrapolation from UK non-computable (> 100 %) --> comparable estimates made instead.

Table 2.5b: Estimates of the socio-economic variables used in the UKCIP socio-economic scenarios and estimates of how they will change by 2050 under five socio-economic scenarios

	Socio-economic characteristic	**Data**	**Wales 2000**	**Linear 2050**	**National enterprise 2050**	**Local steward ship 2050**	**World markets 2050**	**Global sustain-ability 2050**
1	Land use							
	i) % agricultural	a	77	71.9	71.9	77	61.6	71.9
	ii) % forest/ woodland/other	a	13	23.4	14.3	14.3	23.4	19.5
	iii) % urban	a	10	8	12.7	9.3	14.7	10
2	Passenger transport							
	i) % road private	c	92	99	90	74	90	68
	ii) % road public	c	3	0.7	3.2	6.7	0.9	9
	iii) % rail	c	2	0.2	2.6	5.5	3.6	5.5
3	Total agricultural area (million ha)	b	1.63	1.41	1.52	1.74	1.19	1.41
4	Agri area under production (million ha)	b	1.57	1.36	1.49	1.74	1.14	1.36
5	Agri area not under production (ha)	b	58,120	56,175	35,272	4,395	54,237	56,175
6	Value of agri goods (Index: yr 2000 = 100%)	f	100	20	110	180	163	163
6	Value of agri goods per area (£/ha)	f	700	200	700	950	1,325	1,075
7	Pesticide use (kg/ha)	f	3.8	*no stable trend*	4.3	0	1.8	0
8	Nitrogen use (Mt N/yr)	f	0.15	0	0.4	0	0	0
9	Agricultural subsidies (million £)	b	167.5	*no stable trend*	396.4	739.8	83.8	837.5

Data sources: a) Land Cover Map 2000: Wales; b) Farming Facts and Figures: Wales 2004, Wales Statistics, National Assembly for Wales; c) National Travel Survey, DETR; d) Key Environment Statistics for Wales 2004, National Assembly for Wales; e) Habitat Action Plans; f) Cannot find specifically for Wales, hence figures for UK used or calculated according to relative area; g) Farrar, J. & Vase, P. (eds) (2000) Wales: Changing Climate, Challenging Choices, NAW.

*agri-environment schemes: percentage of subsidies already approx 2.5 times higher in Wales, organic farming area approx three times higher in Wales, hence extrapolation from UK non-computable (> 100 %) --> comparable estimates made instead.

**some linear extrapolations < 0 % or > 100 % - these are taken to be 0 % or 100 %.

Table 2.5b – continued

	Socio-economic characteristic	Data	Wales 2000	Linear 2050	National enterprise 2050	Local steward ship 2050	World markets 2050	Global sustain-ability 2050
10	Agri subsidies to agri-env schemes							
	i) %	*	10	*no stable trend*	0	70	88	88
	ii) million £	b*	17.8	*no stable trend*	0	518.4	73.8	735.4
11	Area of organic farming (ha)							
	i) ha	d*	52,000	*no stable trend*	0	1,743,645	312,000	1,412,570
	ii) %	d*	3	*no stable trend*	0	100	26	100
12	Milk yield (litres/hd/yr)	f	5,500					
13	Wheat yield (tonnes/ha)	f	7.7	9,250	1,000	7,250	1,350	9,250
14	Water demand							
	i) % change pa	f	-	0.5	0.5	-0.5	1	0
	ii) cumulative change 2000 – 2020 %			28.3	28.3	-28.3	50	0
15	Water supply (% change)		-	37.5	37.5	-37.5	87.5	0
16	River quality (% classified as good)							
	i) biologically (%)	d	78.5	*improving*	61.75	82.75	72.25	82.75
	ii) chemically (%)	d	92.2	*improving*	44.7	99.2	81.2	99.9
17	Area of SSSI (ha)	d	262,000	851,500	98,250	1,080,750	425,750	1,408,250
18	Area of lowland heath (ha)	e	7,000	*decreasing*	5,190	8,207	7,000	8,810
19	Length of hedgerows (km)	e	49,000	0	46,725	56,475	0	0
20	Coast protected by flood defences							
	i) %	g	17.7	-	16.7	13.95	17.7	14.95
	ii) km		223	-	210.5	175.5	223	188

2.2 Revisiting the risk assessment process in detail

Combining elements of classic risk assessment and perspectives from the UKCIP risk method, it is possible to state that:

1. The aim of the risk analysis undertaken here was to determine the comparative vulnerability of various policies to future climate and socio-economic change.
2. The risk analysis for each policy was centred around detailed analysis of the vulnerability f receptors and policy components to climate and socio-economic change.
3. The time horizon of interest was the next 20 to 50 years (with two specific points of interest at 2020 and 2050).
4. Ideally, it would be desirable to consider the risk that a policy would not be performing well in 2020 by considering its performance separately under each of the four climate scenarios and the four socio-economic scenarios. The same process could also be undertaken for other future years, such as 2050. Thus, in theory it would be possible to consider all socio-economic scenarios under all climate scenarios, thereby giving a total of 16 possible futures for each of 2020 and 2050. In addition, it would also be interesting to know how the policy would perform if current trends in socio-economics continued on a linear path at recent rates, giving another four possible futures for 2020 and 2050. This would then form a type of baseline assessment. In essence, this is how the risk assessment proceeded here, with some modifications. Firstly, data limitations on future Welsh climates restricted analysis of climate scenarios to a consideration of only the medium-high emissions scenario. This reduced the possible number of scenarios from 20 to five for each of 2020 and 2050. Given recent indications of the current trends in global emission rates, the medium-high climate scenario is arguably the most realistic choice.
5. While the overall analysis was concerned with current policies, the approach adopted here considered particular components or objectives of the policies in question. This approach ensured that regardless of the future survival of a given policy, its major objectives (such as the conservation of species of particular note), which would be likely to be key in any relevant future policy, were duly assessed.
6. Rather than considering only the policy components per se, we also analysed, according to latest current knowledge, the likely effects of climate and socio-economic change on policy-relevant receptors. These included such classes as species and habitats under protection, resources such as woodland and water, as well as groups such as farmers or water abstractors, tourists or local communities. Thus, while the focus of the risk analysis was on assessing the vulnerability of policies related to rural environment, the *process* also afforded an issue-based analysis that will remain relevant even under evolution or radical change of the policies in question.

Notwithstanding the severe data limitations on the quantification of risk, this semi-quantitative method, combined with a structured approach to the qualitative assessment of vulnerability, offers a sound and suitable method for risk assessment and yields reliable results and insights. A conceptual outline of how this approach relates to the way policy functions is shown in Figure 2.2a, and an outline of how the risk assessment process was applied to this process is shown in Figure 2.2b.

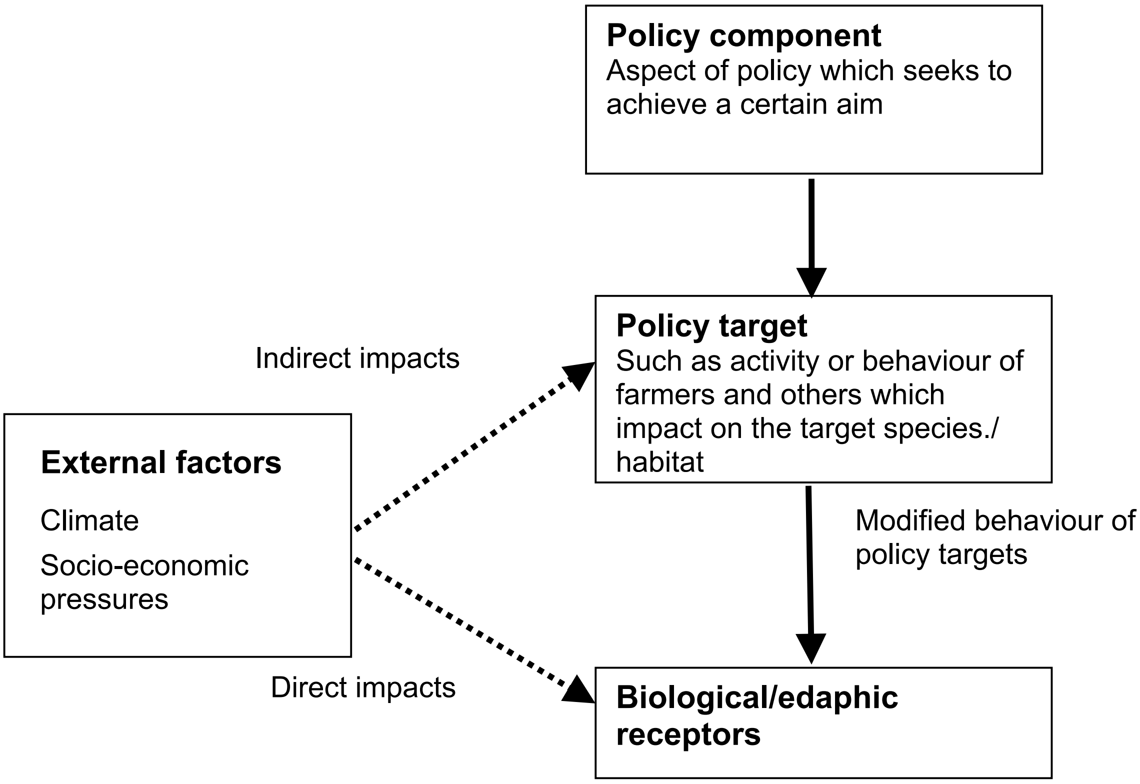

Figure 2.2a: Summary of how a policy serves to protect a biological receptor (a species or habitat) through modifying the behaviour of certain people such as farmers. The modified behaviour of these groups of individuals then affects the ultimate policy receptor, that is, the species or habitat. Various external factors, including climate and other socio-economic variables, also affect the biological receptor directly and indirectly through their impact on key groups of people like farmers.

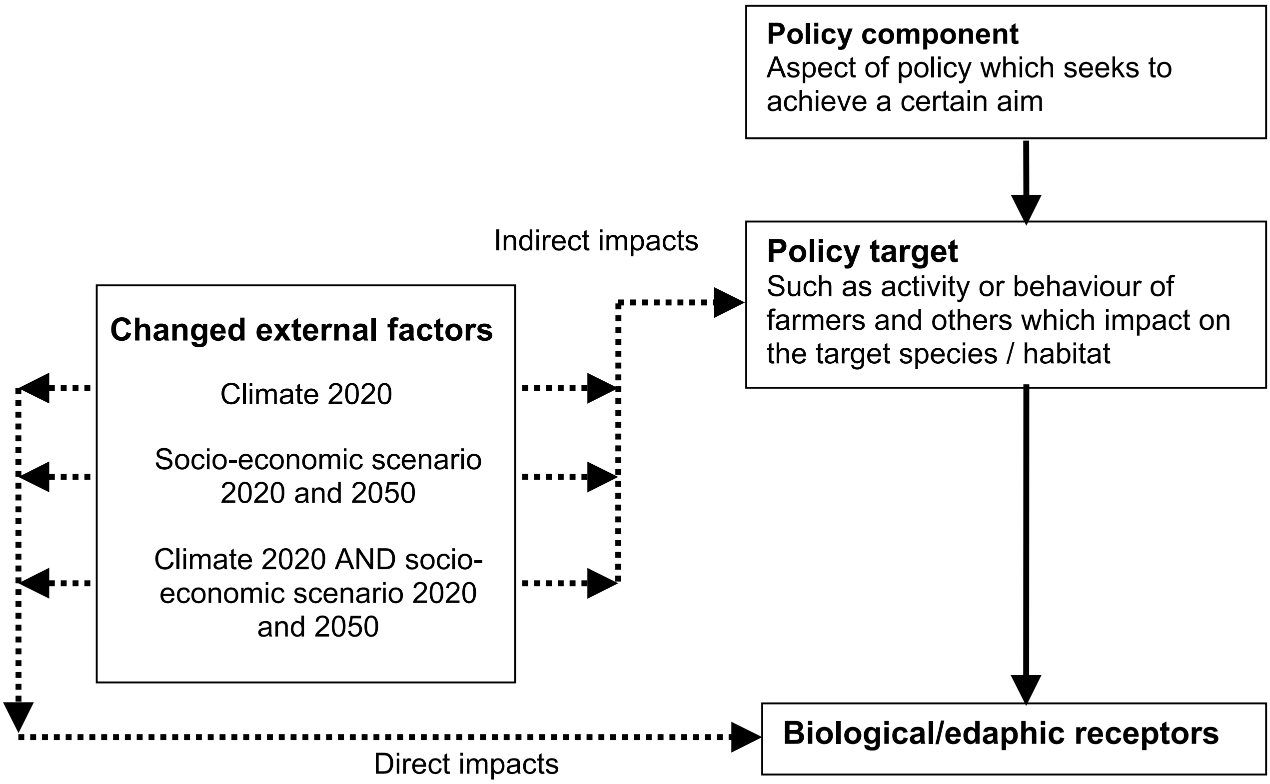

Figure 2.2b: A conceptual diagram of the risk assessment method which considers the direct and indirect impacts of altered climate and socio-economic scenarios on existing policy components, and on their ability to achieve their stated aims on biological receptors.

2.3 Policy analysis

The methodology described so far relates to the pre-analysis phases of the work outlined in Figure 2.1. The outputs of these tasks are generic, and apply equally to all policies. However, while the next sets of tasks (Table 2.6) are similar for each policy, the outputs are policy specific. Within a general risk assessment method these tasks could be approached in a number of different ways; however, in an attempt to provide some structure and comparability a similar analytical framework was applied to all policies analysed here, as shown in Table 2.6.

Table 2.6: The detailed tasks required as part of the risk assessment of specific policies. Task numbers carry on from those in Table 2.2.

Task	Descriptor
vi	Identify policies to be analysed
vii	Identify key components of policies to be analysed
viii	Answer adapted UKCIP risk analysis guidance questions for the policy in question
ix	Identify risk exposure units, receptors, thresholds, endpoints and policy components
x	Research potential effects of climate change on receptors via survey of scientific literature, experiments, modelling and analysis
xi	Undertake receptor risk analysis
xii	Undertake policy component risk analysis
xiii	Test the results of the process and use the results to 'climate proof' the policies.

Task vi – Identify policies to be analysed

A list of policies (resource protection agreements) relevant to Wales was compiled with input from the team members aided by colleagues at the Environment Agency, CCW and WAG (Table 2.7). These were then subjected to some component analysis prior to being presented to participants at a workshop which took place in Cardiff in April 2005.

Participants at the workshop had been invited from a range of organisations concerned with natural resource policy development and management in Wales. All participants were familiar with some aspects of resource policy in some detail (such as water resources, agriculture, National Parks, conservation) and also had a broad overview of other areas. The list of agreements was presented to participants who were asked to:

a) select and prioritise those agreements that would have a significant impact upon the ability of the countryside and rural economy to adapt to climate change;

b) discuss how those agreements might change over time and might evolve under different socio-economic scenarios, including identifying interactions between agreements.

The outputs from these tasks were recorded, as was the discussion which led to all decisions. These are recorded in a full report on the workshop which accompanies this report (Appendix 1). The stakeholder workshop identified around 15 key resource agreements that were then prioritised, before five were selected for analysis, ensuring that they represented a range of natural resource protection issues in the countryside. These were: site-based conservation, agri-environment schemes, forestry and biomass, managing droughts and managing flooding.

In the context of the workshop and the selection process, a resource protection agreement included both formal and informal arrangements, between a variety of 'players' in the countryside, and included formal legislative policies and less formal agreements mediated by the market or informal institutions. Information on all these agreements was obtained from official documentation where possible, supplemented through discussion with relevant experts. This information was then subjected to a document analysis with information noted under a list of agreed headings.

Table 2.7: **Resource protection agreements presented to the workshop for prioritisation and selection for further analysis. The agreements were presented under the topic headings shown.**

Topic: Waste management	Topic: Conservation agreements
Agreements: Sludge to land regulations Groundwater regulations Waste management licences Duty of Care - Transport of Waste Landfill regulations Integrated Pollution Permit and Control Waste management – alternative systems	***Agreements:*** Sites of Specific Scientific Interest (SSSI) Special Areas of Conservation (SAC) Special Protection Areas (SPA) Local Nature Reserves National Nature Reserves Marine Nature Reserves Ramsar (Wetland) sites Biosphere reserves Biogenetic reserves RSPB reserves Country Parks Areas of Outstanding Natural Beauty (AONB) National Parks Biodiversity Action Plans (BAP)
Topic*: *Water quality	**Topic*: *CAP reform agreements**
Agreements: Local Environment Agency Plans (LEAP) Discharge consents Herbicide use near watercourses (LERAP) Nitrate Vulnerable Zones (NVZ)	***Agreements:*** Tir Mynydd Set-aside (new rules) Dairy Produce Quotas Regulations 2005 & Dairy Premium Single Farm Payment/Cross Compliance
Topic: Water quantity	**Topic: Agri-environment and rural industry agreements**
Agreements: Land drainage consents Catchment Flood Management Plans (CFMP) CAMS - Abstraction licences Drought orders/permits	***Agreements:*** Environmentally Sensitive Areas Scheme (ESA) Tir Gofal Tir Cynnal LEADER+ Organic Farming Scheme Tir Cymen
Topic: General water	**Topic: Other**
Agreements: Water Framework Directive	***Agreements:*** Market-based agreements in food and farming Non-market agreements in food and farming CROW Act Tourism and recreation Energy policies and plans Forestry – general Local Biodiversity Action Plans (BAP)

Task vii – Identify key components of policies to be analysed

Resource protection agreements relating to the priority areas were subjected to a detailed document analysis in order to identify their key components (Table 2.8).

Task viii – Answer adapted UKCIP risk analysis guidance questions for the policy in question

The list of questions adapted from the UKCIP risk analysis methodology was answered for each policy. The results of this analysis are presented in the detailed package for each policy presented in the appendices on the accompanying CD.

Task ix – Identify risk exposure units, receptors, thresholds, endpoints and policy components

Subsequent to answering the UKCIP risk analysis guidance questions, it was necessary to identify the relevant risk exposure units, receptors, thresholds, endpoints and policy components as defined above and by Willow *et al*. (2002). This is an important phase as the receptors and policy components are vital elements in the risk assessment. Despite the available guidance, this is fundamentally a qualitative process and future analyses may wish to modify the analysis undertaken here. The results of this process are evident in the Risk Assessment Matrices which were constructed for each policy and are available in the appendices on the accompanying CD.

Table 2.8: Proforma for document analysis, showing category headings under which specific information was documented.

1. Name of agreement/plan
2. Longevity of plan/agreement (for example, reviewed five-yearly; funding for two years, or longer term?)
3. Summary of agreement/plan objectives
4. Spatial level of operation
5. Summary of process by which agreement or plan was developed (such as consensus building; consultation; partnership; locally-led or more top-down approach)
6. Use of scientific data in generating the agreement/plan (such as ecological survey data; water/soil quality data and so on)
7. Stakeholders/actors involved in developing agreement and their roles
8. Funding/resource arrangements (such as staffing; shared premises; shared advisors) Mechanisms for delivery on the ground (such as shared machinery; advice provision; physical works)
9. Delivery agents and relationships between them
10. Activities on the ground (include examples, such as best practice)
11. Monitoring arrangements
12. Nodal links to other relevant plans/policies/funding arrangements (how does agreement fit into broader policy framework?). Which *elements* of the plan/agreement are potentially vulnerable under climate change scenarios and why (for example, the plan has been developed to work under a specific soil-water regime where certain economic activities can take place – what would be the implications of change for this agreement?)?

Task x – Research potential effects of climate change on receptors via survey of scientific literature, experiments, modelling and analysis

Available literature was used to identify the impacts of climate and socio-economic change on the receptors. Only a limited amount of literature was available on the key policy/receptor interactions, and while every effort was made to base assessments on published data, good scientific data were absent for a range of important interactions. This aspect can be strengthened as more research is undertaken.

Task xi – Undertake receptor risk analysis

This process considered the impact on each receptor for three sets of scenarios: climate alone, socio-economic change alone and finally climate and socio-economic change. Details of this process are shown in Table 2.9. The results for each policy are available in the Risk Assessment Matrices in the appendices on the accompanying CD.

Task xii – Undertake policy component risk analysis

This process was similar in nature to the risk receptor analysis but required the impact of climate and socio-economic change to be considered against the policy components, in the light of the receptor analysis. The mechanics of this process are also summarised in Table 2.9 and the detailed results are available in the RAM in the accompanying CD.

Task xiii – Test the results of the process and use the results to 'climate proof' the policies

Up to this point, the risk assessment process had been relatively abstract in nature. In order to test the process against real issues, the outcomes of the risk assessment were applied to a case study area in order to explore the risk of the resource protection agreements failing to perform in real situations. As a result of this process, it was hoped to identify practical failures of the agreements, which when considered alongside the analysis presented in the Risk Assessment Matrices could be used to climate proof the resource protection agreements.

The Usk catchment in South Wales was selected as the case study area because it was felt to have a varied land use, a variety of conservation designations and is affected by both drought and flooding. In order to undertake assessment of policies with water components, or interactions with local hydrology, the catchment was divided into sub-catchments. These were topographically defined using the ArcView extension Hydrologic Modelling v1.1. for an area extending just beyond the River Usk Catchment Abstraction Management Strategy boundary (Environment Agency Wales, 2005). The study area boundary excluded the urban areas of Newport and Cwmbran since this study was focussed on rural areas. The analyses resulted in eleven component sub-catchments. Subsequently, on obtaining gauging station locations and flow data for the River Usk it was found that the stations at Trallong (GR 22 SN 947 295) and Llandetty (GR 32 SO 127 203) did not allow an analysis of the upland component sub-catchments to be undertaken. It was therefore decided to modify the boundaries between sub-catchments 10 and 11, and sub-catchments 6 and 7. Sub-catchments are referred to in subsequent chapters by number, as shown in Figure 2.3.

The rest of this document reports the results of this case study-based analysis for each of the five priority resource protection agreements: site-based conservation policy as represented by the current regulations for SSSI, the forestry and biomass strategy, agri-environment schemes as represented by Tir Gofal, drought management and flood management. After presenting the results of each of these agreements separately, they are considered as a coherent whole and some recommendations for climate proofing are made.

Table 2.9: **Steps involved in the receptor and policy component risk analysis. These are tasks xi and xii in Table 2.6.**

---

1) Consider impacts on receptors from climate change 2020 and complete the following:

- likelihood of impact (high, medium, low, uncertain backed up by qualitative comments)
- ability to adapt naturally (high, medium, low, unknown backed up by qualitative comment)
- option form managed adaptation (high, medium, low backed up by qualitative comment)
- vulnerability (very low, low, medium low, medium, medium high, high, very high)
- source – data used during analysis.

2) Consider impacts on receptors from socio-economic change 2020 for each of five scenarios:

- a linear change in receptor from present day, assuming recent trends continue
- the UKCIP National Enterprise scenario
- the UKCIP Local Stewardship scenario
- the UKCIP World Markets scenario
- the UKCIP Global Sustainability scenario.

3) Identify impacts on receptors from the combination of climate change and socio-economic scenarios identified previously, based on five separate analyses:

- climate change 2020 and socio-economic changes under a linear change scenario
- climate change 2020 and the UKCIP National Enterprise scenario
- climate change 2020 and the UKCIP Local Stewardship scenario,
- climate change 2020 and the UKCIP World Markets scenario
- climate change 2020 and the UKCIP Global Sustainability scenario.

4) Provide a qualitative summary of the vulnerability of key receptors under climate and socio-economic scenarios.

5) Repeat steps 1-4 using the 2050 climate change and socio-economic scenarios.

6) Identify the policy components of the resource agreement and consider their vulnerability to:

- climate change 2020
- a linear change in receptor from present day, assuming recent trends continue
- the UKCIP National Enterprise scenario
- the UKCIP Local Stewardship scenario
- the UKCIP World Markets scenario
- the UKCIP Global Sustainability scenario.

7) Summarise results for all policy components.

8) Repeat steps 6 and 7 for 2050 climate change and socio-economic scenarios.

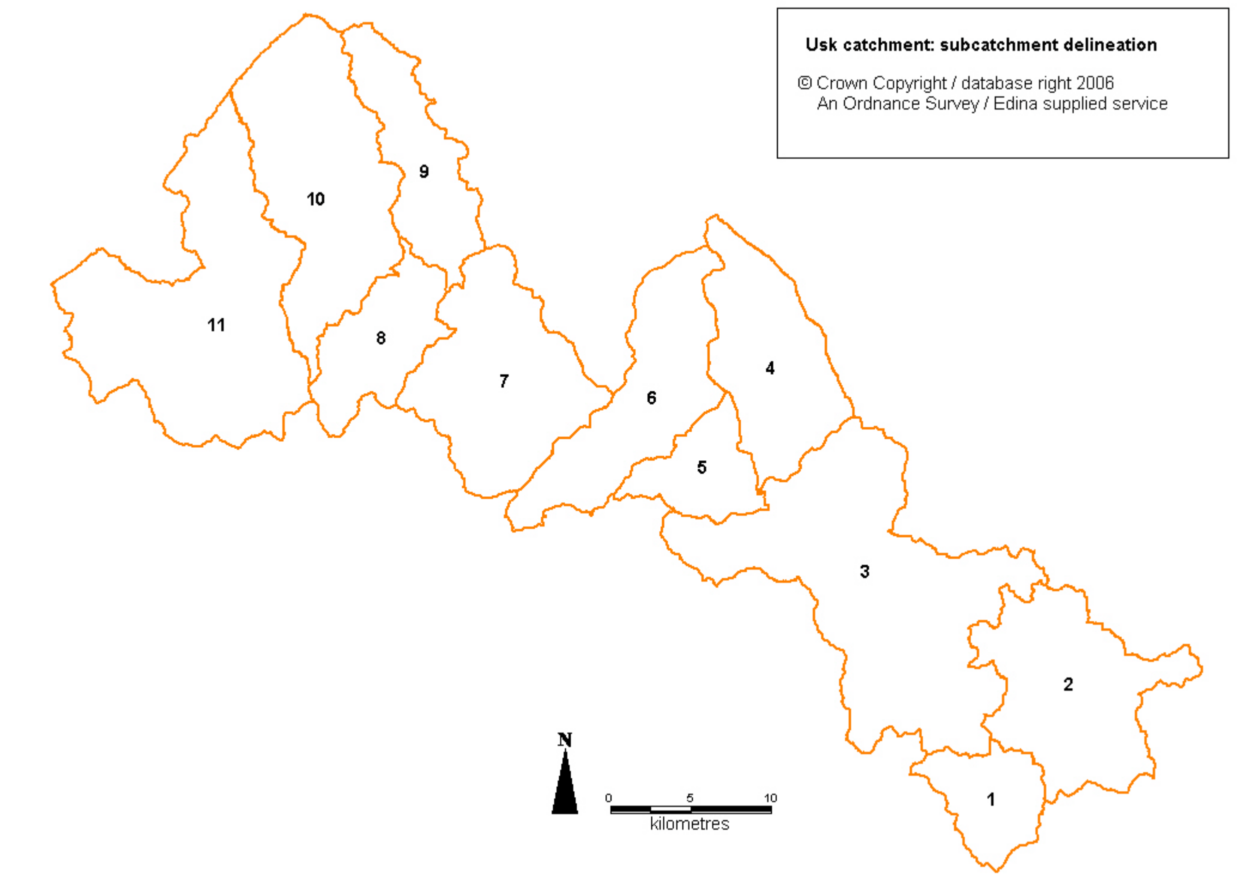

Figure 2.3: Usk catchment sub-boundaries

3 Sites of Special Scientific Interest

3.1 Background on policy

The notification of Sites of Special Scientific Interest (SSSI) is the primary statutory mechanism for the protection of important areas for flora, fauna, geological and physiographical features in the UK. SSSI were originally enabled by the National Parks and Access to the Countryside Act 1949, and under the Wildlife and Countryside Act 1981 (amended in 1985) the government has a duty to notify as a SSSI any land which it considers to be of special interest because of its flora, fauna, geological or geographical features. SSSI can be applied to land, freshwater bodies, rivers and intertidal land, but not to areas below low water mark. Currently, the Joint Nature Conservation Committee (JNCC) works with nature conservation agencies to develop guidelines and methods for the selection and monitoring of SSSI.

As a result of the above, SSSI tend to represent the best sites for wildlife and geology either regionally within Areas of Search or nationally within the UK. They support many characteristic, rare and endangered species, habitats and natural features. SSSI also contribute to the overall maintenance of biodiversity of species and habitats and their special interest is protected in accordance with specific guidelines. SSSI status does not change the use of the land, but local authorities, owners and occupiers must consult the relevant conservation organisation (the Countryside Council for Wales (CCW) in Wales and Natural England in England) on any potentially damaging operations (PDO) or activities which may affect the site features.

3.1.1 SSSI in Wales

CCW are responsible for overseeing all matters relating to SSSI selection and condition monitoring in Wales. They liaise with the JNCC and the Welsh Assembly Government (WAG) on site selection, notification and monitoring of their conservation status.

In 2002, there were 1003 SSSI in Wales covering over 10 per cent of the land area. These range in nature from small fens, bogs and riverside meadows to sand dunes, woodlands and vast tracts of uplands. Most are in private hands, although some are owned and managed by local wildlife trusts and other voluntary conservation bodies. SSSI policy was chosen for analysis on the basis that it is the key underpinning nature conservation policy for statutory designations.

3.1.2 Stakeholders involved in developing agreement and their roles

The management of SSSI hinges on a strong working partnership between CCW and the landowners and occupiers. CCW prepares Site Management Statements (SMS) that set out in broad terms the management objectives for all SSSI in Wales, while on many sites detailed conservation management plans are prepared too. In some instances, a landowner can enter into a management agreement with CCW to protect the site's special qualities. Under such an agreement, the owner may be offered payment to protect and enhance the site's important features. These agreements are designed to ensure consistent, favourable long-term management. Currently, there are 645 management agreements with farmers in Wales to help conserve wildlife on SSSI.

Local planning authorities are required to consult CCW before allowing any development to proceed that may affect a SSSI. Water, gas and electricity companies must also do the same. The Countryside and Rights of Way Act, which came into force in England and Wales in 2000, gives the statutory agencies a new power to refuse consent for damaging activities. It increased the penalties for deliberate damage to SSSI to up to £20,000 in the magistrates' court and unlimited fines in the crown court. In addition, there is a new court power to order restoration of the damaged special interest feature where this is practicable, and the ability to prosecute third parties (not landowners or tenants) for damage to SSSI.

3.2 Methodological summary

For the purposes of comparability across chapters, 'policy' is used to describe all of the resource protection agreements analysed in the report, regardless of whether they are technically classified as 'strategies', 'action plans', 'processes' or 'policies'. We recognise that this is not always technically correct, but it does enable a generic methodological framework to be used across a range of different resource agreements.

The risk assessment of the SSSI policy followed the approach outlined in Chapter 2. The pre-analysis work generic to all policies was completed prior to undertaking the assessment of the SSSI policy and followed the structure outlined in Figure 2.1. The policy assessment work followed the pattern outlined in Table 2.6, and relevant details of the outcomes for each step are reported below.

1. Identify key components of policies to be analysed
The key components of the policy were identified and are shown in Table 3.1.

2. Answer adapted UKCIP risk analysis guidance questions for the policy in question
This was undertaken and the results are shown in Appendix 3 on the accompanying CD.

3. Identify risk exposure units, receptors, thresholds and endpoints
The receptors identified are shown in Appendix 3 on the accompanying CD.

4. Research potential effects of climate change on receptors via survey of scientific literature, experiments, modelling and analysis
This was completed as required when undertaking the receptor risk analysis and is reported on below.

5. Undertake receptor risk analysis
This required an assessment of the vulnerability of each receptor to change under each of the socio-economic scenarios, and in combination with the UKCIP medium-high climate scenarios for 2020 and 2050 as reported in Table 2.9. The full results of this process are available in the Risk Assessment Matrices (RAM) shown on the accompanying CD.

6. Undertake policy component risk analysis
This analysis also followed the process outlined in Table 2.9 and the full results of this process are available in the RAM shown in Appendix 3 on the accompanying CD.

7. Test the results of the process and use the results to 'climate proof' the policies
This aspect of the risk assessment is specific to each policy analysed and was not discussed in detail in Chapter 2. The remainder of Chapter 3 is dedicated to discussing the methods and results of this process. It begins with a discussion of how the generic risk assessment method was applied to the case of SSSI policy in the Usk catchment, and is followed by an analysis of the risks to the policy components.

Table 3.1: Key components of Sites of Special Scientific Interest policy

Policy component
1. The national total protected areas should be large and varied enough to guarantee the survival of the necessary minimum of Britain's wildlife and physical features.
2. Criteria for site evaluation include primarily: size, diversity, rarity, naturalness and typicalness; and secondarily: recorded history, position in an ecological/geographical unit, potential value and intrinsic appeal.
3. Criteria for site evaluation for geological and physiographic features include: representativeness, exceptional features and international importance.
4. When notifying a SSSI, produce a Site Management Statement (SMS) describing desired management of the land for conservation and enhancement of its flora or fauna or features.
5. Evaluate the condition of the site in terms of favourable conservation status (FCS).
6. Set operational limits for factors considered to have positive or negative effects on FCS.
7. Define attributes and specify thresholds to use as performance indicators in monitoring.
8. The use of habitat translocations for habitat restoration should not damage important sites or ancient habitats, and habitats translocations should only take place where it can be shown that there is a net gain for biodiversity conservation.
9. Integration with, and effects on, other policies and agreements.

3.2.1 Applying the risk assessment method to SSSI policy in the Usk catchment

Risk assessment methods

The risk assessment for SSSI policy in the Usk catchment followed a seven-step process, illustrated in Table 3.2. Fundamental to this were the risk assessment matrices (RAM) developed as part of the receptor and policy component risk analyses. These are presented in full in Appendix 3 on the accompanying CD.

Data availability (Step 1)

Good data on the nature, location and size of SSSI in the Usk catchment were available in a digital form which was amenable to query and manipulation. Hence, it was possible to undertake an assessment of each SSSI and consider their individual vulnerability.

Manipulating SSSI data (Step 2)

The SSSI site boundary data and the individual habitat or species features for which each SSSI was notified within the Usk catchment were obtained from CCW (see Figure 3.1). The Usk SSSI dataset was modified to include features data on the basis of individual, mixture and species assemblages and the SSSI boundary polygons were split into their respective sub-catchments, so an analysis of protected areas within each of the eleven case study sub-catchments could be undertaken.

Table 3.2: The risk assessment procedure for SSSI

Step	Action
1	Get SSSI details from CCW.
2	Map SSSI on catchment boundary.
3	Consider the qualifying feature for each SSSI.
4	Use RAM to assign a level of vulnerability to the habitat type for which each SSSI was designated.
5	Consider each SSSI individually, taking particular note of the primary and secondary qualifying feature, its size, its location in the catchment and the surrounding land use and comment on the level of vulnerability of the site to climate and/or socio-economic changes in general, such as the likelihood of land use change, species change, and so on.
6	Summarise the vulnerability of each site under the five future scenarios according to the vulnerability of its major features and that of the site in general. This process needs cross checking with RAM for details on the scenarios.
7	Use the results of this process to inform the assessment of the SSSI policy in general.

Categorising SSSI data (Step 3)

The risk assessment method only considered habitats as key receptors because very limited or no data were available on the future climate envelopes of species notified within the sites. Thus, it was not possible to consider the impact of climate and socio-economic change on individual species within sites. While individual species were not discussed explicitly, some broad trends in their vulnerability may be expected. For example, we can assume that species with wide distributions have a lower vulnerability than those with narrow distributions (Schwartz *et al*., 2006), and that mobile species will have a greater chance of migrating to new habitats than less mobile ones (for example, Hickling *et al*., 2005). Also, not all species will have an equal chance of migrating to new habitats with a similar climate envelope, as even if such habitats exist they may be too far to be colonised naturally (such as Mediterranean trees, Ohlemuller *et al.,* 2006). As further data on climate envelopes of species become available, it should be possible to refine the risk assessment so that it can become more species-focused. A further limitation of the method used here is that geological sites were not considered.
Because of these constraints, the total list of SSSI in the Usk was divided according to the manner in which the sites were treated within the risk assessment, as shown below:

1. SSSI designated for habitats, which were entered into the risk assessment.

2. SSSI designated for species, where the species have an intimate and obvious relationship with running water. These SSSI were not entered into the full risk assessment process, but some comments are made about potential risks.

3. SSSI designated for species, where the species have no intimate or obvious relationship with running water. These SSSI were not entered into the risk assessment.

4. SSSI designated for geological reasons were not entered into the risk assessment here, but those which may be affected by regular flooding will be highlighted.

5. SSSI designated for geological and biological reasons were entered into the risk assessment, and considered on the basis of their biological features only.

Vulnerability analysis (Step 4)

The vulnerability analysis was entirely qualitative and followed the procedures outlined in Willow *et al*. (2001). Generally, six levels of vulnerability were identified: low, low medium, medium, medium high, high, very high. These should be interpreted such that an item with a low vulnerability means there is little chance that the item will change its basic nature in the future; that is, it is resistant to change and has a small chance of changing. Conversely, a high vulnerability suggests an item is very likely to change its basic nature in the future. The vulnerability assessment itself does not necessarily state how the nature of an item may change, it simply states whether change is more or less likely. Details of likely changes are given in the RAM.

When considering the SSSI, two types of vulnerability analysis were undertaken. One was an assessment of the vulnerability of the main habitat feature in the SSSI (details are in the RAM), the second considered the vulnerability of the site itself to being affected by other changes in the landscape. For example, if a wetland site were situated close to a river channel, then it may be vulnerable to changes in the patterns of flow, flooding and drought (as is likely under some predictions of climate change). Similarly, if a grassland site were situated on good agricultural land and close to good modes of communication then it may be susceptible to land use changes in the surrounding landscape, but also it may come under pressure to be converted from its current use to other more profitable uses.

Factors taken into consideration during the vulnerability analysis were:

- size of the site (small is more vulnerable than large);
- slope of land (steeply sloping land is less likely to be converted to other uses than flat land);
- quality of the land for agriculture (good land is more likely to be converted to other uses);
- dependence on grazing (sites which are heavily dependent on grazing in order to maintain their characteristic nature are more vulnerable than those which do not);
- dependence on hydrological regime (sites which are heavily dependent on some element of the hydrological regime, such as running water, in order to maintain their characteristic nature are more vulnerable than those which are not);
- location in the catchment (sites near the top of the catchment are less likely to be influenced by catchment-level changes to the hydrological regime than those lower down the catchment).

While these factors helped structure the risk assessment, it must be stressed that the site vulnerability assessments were purely qualitative, even though they were informed by quantitative data such as the size and location of the SSSI, the agricultural land classification, Phase 1 Habitat maps for the catchment, the topography and slope of the catchment and the underlying soils (all shown as supporting maps in Appendix 3).

A more detailed consideration of vulnerability might have taken note of the condition score of individual reserves. We did not do so for two reasons. One was due to insufficient resources within the project to consider the individual conditions of each reserve. A second is the absence of a theoretical link between vulnerability to change and condition score. The condition score is a human-derived classification which indicates how close a reserve is to a desired state. That desired state may not necessarily be ecologically resilient as it may be vulnerable to a range of natural changes, such as successional change.

Example of the vulnerability analysis

In order to illustrate the vulnerability analysis, some example results are shown here for one habitat receptor – that of broadleaved woodland. Final results of all receptors are shown in the RAM in Appendix 3 on the accompanying CD.

The vulnerability of broadleaved woodland habitat to climate-induced change was assessed as part of the receptor analysis. At this stage of the assessment process, these changes relate solely to the changed biophysical environment, and are not influenced by socio-economic changes at all. The results suggest that overall the habitat type has a medium vulnerability, but certain types of woodland, such as those associated with wetter areas, and certain constituent species within a woodland may be more vulnerable to climate-induced change (Table 3.3).

The amount of broadleaved woodland that will occur in Wales under each of five socio-economic scenarios was also estimated as part of the receptor analysis (Table 3.4). The results suggest that in a future world similar to that of the Local Stewardship scenario, the amount of broadleaved woodland is expected to fall by 2020 and again by 2050 (note that these calculations are based on UK estimates of the UKCIP (2001) downscaled to the Welsh scale in Table 2.5 of Chapter 2). Conversely, under the scenario of Global Sustainability broadleaved woodland is expected to increase in area. In essence, these calculations say how much of the habitat there will be in each future scenario. They do not say anything about the biological composition of the habitat; they simply estimate the amount of broadleaved woodland that will exist in Wales in the future.

Table 3.3: Vulnerability of broadleaved woodland to climate predicted for 2020 – 2050 (taken from the risk assessment matrices)

Likelihood of impact	Ability to adapt naturally	Option for managed adaptation	Vulnerability
Medium but the evidence may be slow and episodic; summer drought may stress some species, particularly bryophytes and invertebrates associated with damp woods	Medium: some species/community types may have potential to move to wetter/more northerly areas	Medium: Planting of new forests as part of woodland initiatives and farm woodland schemes could encourage the extension of this habitat in appropriate areas	Medium

Table 3.4: Extent (hectares) of broadleaved woodland in Wales 2000 and the estimated area under five possible future scenarios in 2020 and 2050. Data from Forestry Commission and assumptions about changes under the different scenarios are from the UKCIP woodland trend (UKCIP, 2001).

Year	Current/2000	Scenario				
		Linear	National Enterprise	Local Stewardship	World Markets	Global Sustainability
2020	123,000	135,300	123,000	110,700	135,300	159,900
2050	123,000	159,900	123,000	86,100	159,900	233,700

These two analyses are then combined to consider how broadleaved woodland may be susceptible to the simultaneous effects of climate change and socio-economic change as shown in Table 3.5. So in theory, a habitat may be susceptible to biophysical change because of climate change, and it may also be likely to decrease in extent because of socio-economic changes. In this case it would be classified as being highly vulnerable. Conversely, a habitat may be robust to climate-induced biophysical changes and may increase in extent due to socio-economic changes, and in this case it would have low vulnerability. For broadleaved woodland, the analysis suggests that the habitat is most vulnerable under the scenarios National Enterprise and Local Stewardship and least vulnerable under the scenario of World Markets.

The example described in Tables 3.3 to 3.5 was for the year 2020; however, a second timescale was also considered, 2050, and the analytical procedure for 2050 followed the exact same process as for 2020. The full results from 2020 and 2050 are available in Appendix 3 on the accompanying CD.

Table 3.5: Example of the types of results obtained when considering the vulnerability of broadleaved woodland under climate change and socio-economic scenarios. Summary results are shown for the scenario National Enterprise and climate change. Full results are available in Appendix 3 on the accompanying CD.

Scenario	Area (ha)	Likelihood of climate impact	Ability to adapt naturally	Option for managed adaptation	Vulnerability under climate and socio-economic change
National Enterprise and climate change	123,000	Medium but the evidence may be slow and episodic; summer drought may stress some species, particularly bryophytes and invertebrates associated with damp woods	Medium: some types may have potential to move to wetter/more northerly areas	Medium: planting of new forests as part of woodland initiatives and farm woodland schemes could encourage the extension of this habitat in appropriate areas	Medium-high: likely some overall decline given zero expansion under socio-economic scenario and drought stress under climate change

Vulnerability in the Usk catchment (Step 5)

The process described so far has only used information in the RAM. When applying this to the case study area, the RAM were combined with basic information on the important features within each SSSI in order to classify the sites and to aid further analysis.

For example, ten SSSI in the Usk catchment are designated with semi-natural broadleaved woodland as their primary feature and the vulnerability analysis summary for two of these ten woodlands, Coed Dyrysiog and Coed Ynys-Faen, is shown in Table 3.6. The habitat vulnerability assessment is similar for both sites but the site vulnerability differs. Both are quite small and therefore potentially vulnerable to changes in the surrounding landscape. However, as long as they are not felled, they should maintain their essential woodland character. Coed Dyrysiog is surrounded by good agricultural land, which has high potential for change of use or management in the future. Activities on the surrounding land may affect the woodland species; also, if these land uses are extremely profitable then there may be mounting pressure to convert the woodland to more profitable uses. Coed Ynys-Faen is under similar threat, but in addition is close to the river channel, so any future changes in the hydrological and fluvial regime may increase the vulnerability of this particular site. However, the actual importance of river flooding or drought on the essential nature of this site can only be estimated through a site visit and detailed analysis of its ecology and component species.

This example highlights the nature of the vulnerability assessment used here, which simply considers broad habitat types, and not the species composition or relative abundance of species that are often used to assess the condition status of the woodland. This is a potential weakness of the method used here, and the inclusion of species oriented work would help improve the outputs considerably.

Table 3.6: Example of a vulnerability analysis of broadleaved woodland Sites of Special Scientific Interest in the Usk catchment

Name	Code	Qualifying feature	Vulnerability of habitats	Vulnerability of site
Coed Dyrysiog	**32 WQD**	Semi natural broad-leaved **woodland**	**Generally resilient as a habitat type, although exact species composition may change. The amount of woodland in Wales may vary with socio-economic scenario.**	**This 7.7 ha site is situated between an area of upland and the river channel in a landscape of improved agricultural land on grade 4 land. Assuming it maintains its essential woodland integrity, it should not be vulnerable.**
Coed Ynys-Faen	**33 WFJ**	Semi natural broad-leaved **woodland**	**See above**	Set close to the river channel in a sloping and narrow valley, this 9.4 ha site should be free of major threats, assuming that the river flood/drought regime does not change and affect its integrity.

Summarise vulnerability under the different scenarios (Step 6)

Having considered the vulnerability of each SSSI, the findings were summarised and major differences which might arise under the different socio-economic scenarios were highlighted. This was achieved by assigning two scores for vulnerability to each site under each scenario. The first of these was related to the vulnerability of the habitat type to change, and the second to the vulnerability of the site itself. These were recorded for each site, a process which required the reconciliation of the RAM with the sort of site specific information presented in Table 3.6.

3.3 Results

3.3.1 Number and type of SSSI in the Usk catchment

A total of 50 SSSI lie within the Usk catchment. Together they cover 11,158 ha, with the mid-catchment region having the greatest extent of area designated as SSSI (Figure 3.1). Thirty-nine sites were designated for their biological interest, eight for geological interest and three for a combination of both. The geological sites are distributed across the mid-catchment region, and there are two large areas designated for biology and geology (Figure 3.2). The majority (29) of the 39 biological SSSI were designated for the habitats they support, five were supported for aquatic species and five for non-aquatic species (four of which were designated for lesser horseshoe bats). The network of SSSI in the catchment underpins other nature reserve designations such as National Nature Reserves (Figure 3.3), Proposed Special Areas of Conservation (Figure 3.4) and local nature reserves (Figure 3.5). In addition to these designations, there is also some overlap between the boundaries of the Usk catchment and the Wye Valley Area of Outstanding Natural Beauty (AONB) (Figure 3.5).

Vulnerability analysis

On the basis that only SSSI designated for their habitats could sensibly be entered into the risk assessment framework, these sites were classified according to their key habitat (Table 3.7). These habitat types then formed the basis of the risk assessment (Tables 3.8 and 3.9).

Table 3.7: Primary habitat for which Sites of Special Scientific Interest (SSSI) in the Usk catchment had been designated on the basis of their biological interest.

Habitat for which SSSI was primarily designated	Number in Usk catchment
Blanket bog	1
Calcareous grassland	4
Lowland raised bog	1
Marsh fen	1
Marshy grassland	3
Neutral grassland	9
Semi-natural broadleaved woodland	10

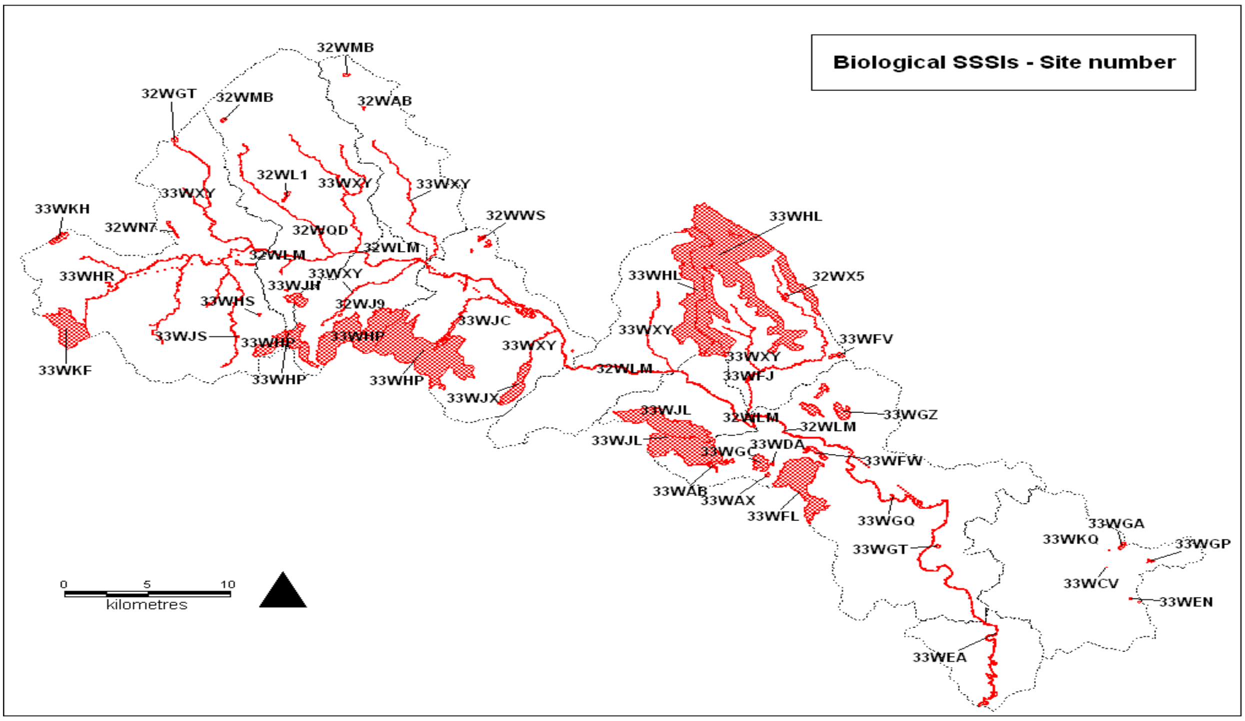

Figure 3.1: Location of SSSI in the Usk catchment (with site number)

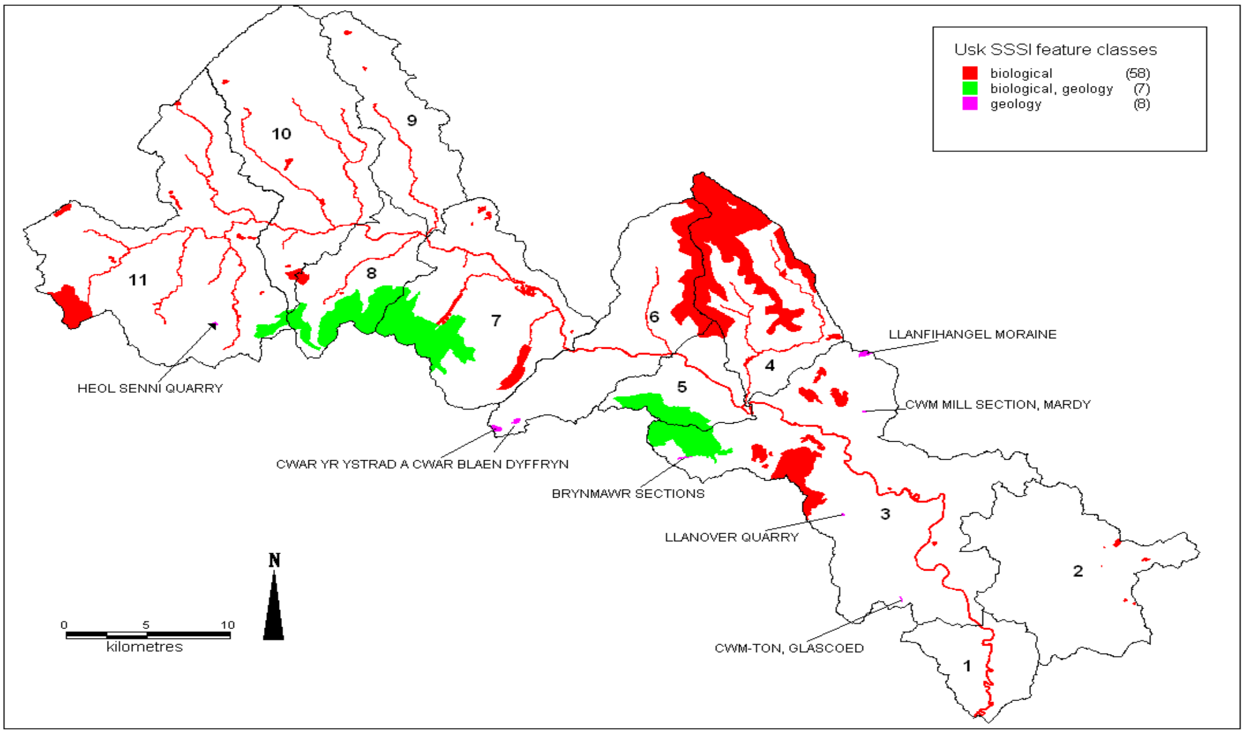

Figure 3.2: Classification of SSSI by feature type

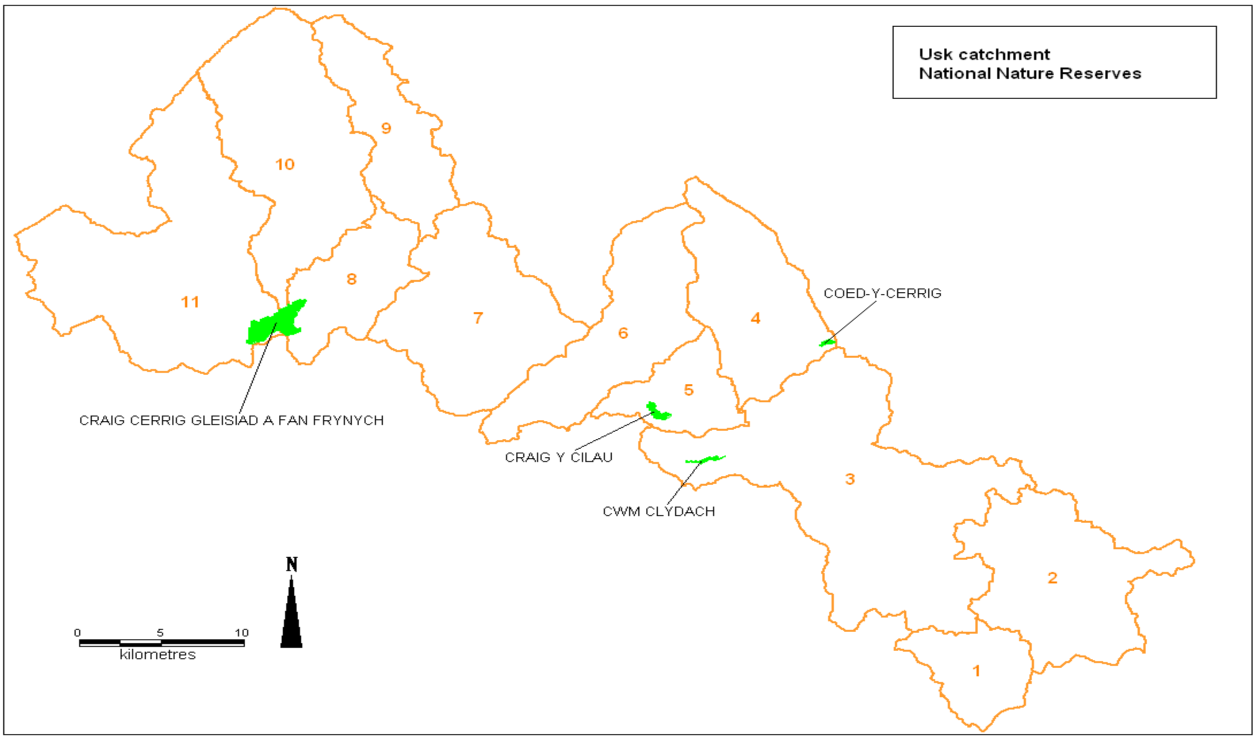

Figure 3.3: National Nature Reserves in the Usk catchment

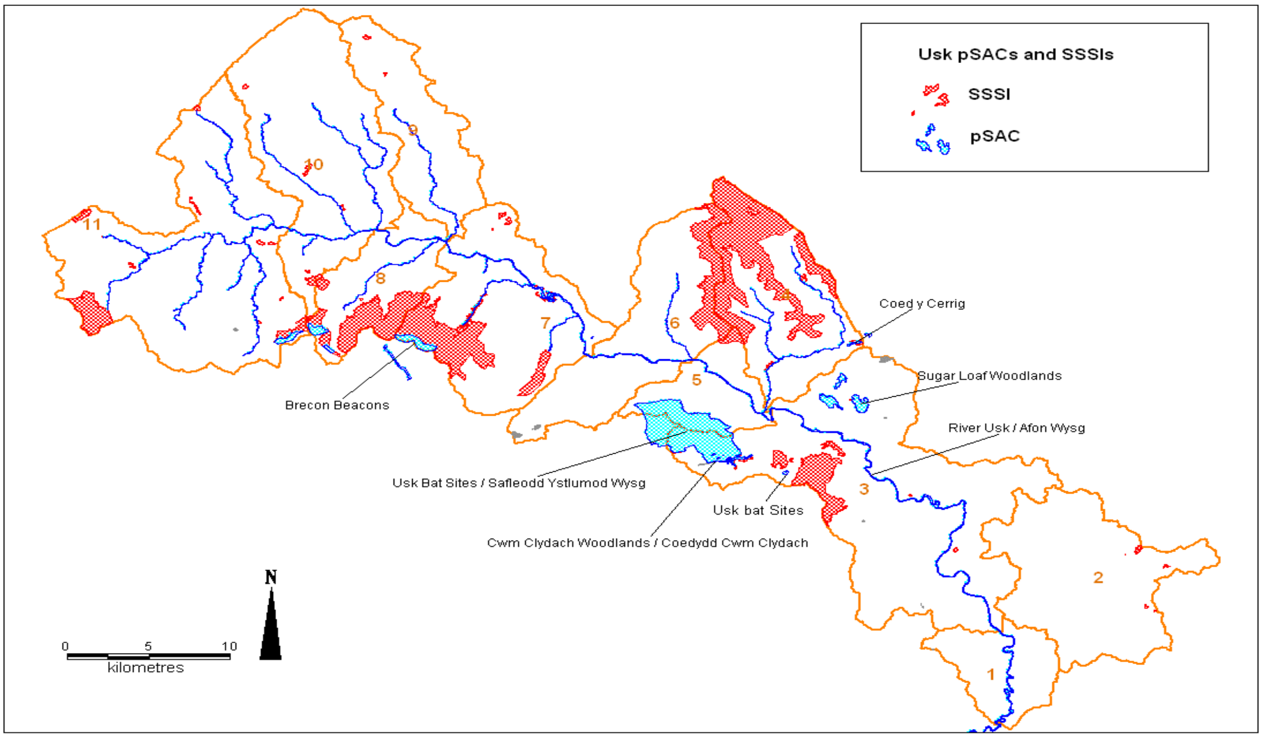

Figure 3.4: Proposed Special Areas of Conservation (pSAC) in the Usk catchment

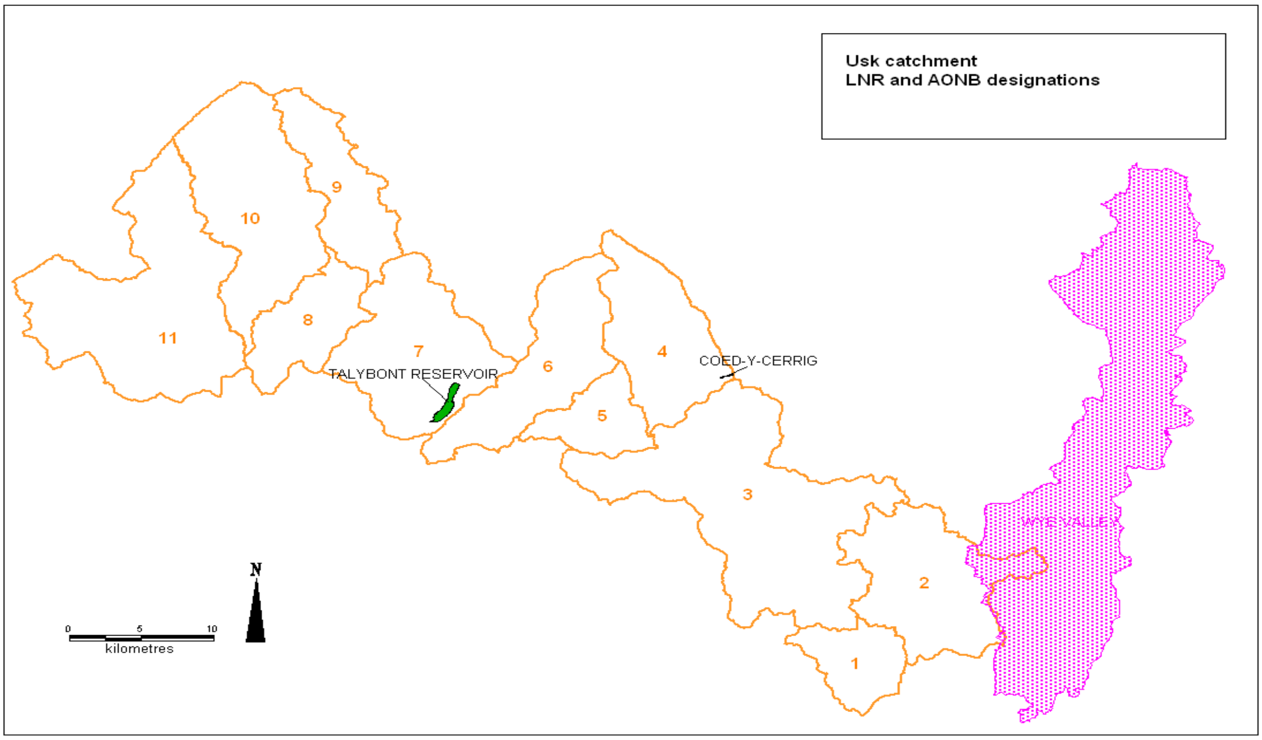

Figure 3.5: Local Nature Reserves (LNR) and Areas of Outstanding Natural Beauty (AONB) in the Usk catchment

As may be expected, the innate vulnerability of the sites varied considerably. Sites such as Blorenge were felt to have low innate vulnerability due to their large size (981 ha) and local topography, which means it is unlikely that changes in adjacent land uses will affect the site in a major way. However, even large, steeply sloping grassland sites can be subject to impact from changing on-site land use, such as grazing regimes (Table 3.8). Conversely, sites like Gyfartha have high innate vulnerability due to the combination of their small size (two hectare), their isolation from other larger areas of rough grassland and the nature of the surrounding land uses. In addition, Gyfartha lies in a zone of potential land use change, being on the border of grade 4 and 5 land, which is an area where major land use change may occur in the future (Table 3.8). While Tables 3.8 and 3.9 provide a summary of the innate vulnerability of sites, a more detailed explanation of the reason for the vulnerability designation for all sites is presented in Appendix 3.

The vulnerability of different habitat types to the direct impacts of climate change also varies. For example, habitats like broadleaved woodland were felt to be generally resilient as a habitat type, although the exact species composition of the woodland may change with a changing climate. Similarly, neutral grassland was classified as having a medium vulnerability as it is fairly resilient to climate change as a habitat type, assuming the management is appropriate. Again, however, the exact species composition may change under a changed climate. Marshy grassland was felt to have a medium to high vulnerability due to the potential impacts of summer drought on its basic wet nature. Further analysis of the vulnerability of all habitats is presented in the RAM in Appendix 3.

The penultimate element of the vulnerability assessment related to the combined impact of climate change and socio-economic scenario on the habitats. For example, under the scenario of National Enterprise lowland raised bogs have a high vulnerability as they are likely to decrease in abundance across Wales, and at the same time they are highly vulnerable to summer drought and changes in nutrient dynamics. Generally, both grasslands and broadleaved woodlands tend to have a medium vulnerability, even though there are some differences in their abundance under each socio-economic scenario (Tables 3.8 and 3.9). The summary data presented in Tables 3.8 and 3.9 are supplemented by a detailed explanation of the vulnerabilities of each habitat which is available in the RAM in Appendix 3.

The final assessment of the vulnerability of each SSSI required a qualitative assessment of the combined innate site vulnerability and the vulnerability under climate change and socio-economic scenarios. As may be expected, a range of vulnerabilities emerge across the sites. Some sites like Blorenge have a low innate site vulnerability but a medium-high vulnerability under all socio-economic scenarios, while others like Gyfartha with a high innate site vulnerability and a medium-high vulnerability under all socio-economic scenarios in 2020 (Table 3.8). It is also apparent that the overall vulnerability of the SSSI may alter between 2020 and 2050 due to a combination of socio-economic and climate variables, and this is clearly seen in Figures 3.7 to 3.18 with more SSSI being in the 'high' or 'very high' vulnerability class in 2050 than in 2020.

If a changed climate does alter the nature of the habitat which currently occurs within SSSI, then this raises concerns about their purpose. If the species and habitats present in a SSSI alter markedly from that which occurred at the time it was designated, then it could be argued that the original designation should be removed. Alternatively, the land designated as a SSSI could be viewed as a structure in which a new set of species and communities could develop. For example, those sites which are currently designated for their woodland interest are likely to always stay as woodland of some type (assuming this is the climax community); however, the exact species of tree within the woodland may change. There will always be species of plants and animals which will inhabit woodland habitats, and so the physical structure we call 'woodland' may exist on the sites for some time, and will probably support species of invertebrate and vertebrate herbivores, carnivores and decomposers typical of woodlands. Given the relative rarity of woodland in the landscape, it is likely that the species which inhabit any future woodland will also have a social value of some type.

Table 3.8: Summary of vulnerability of each SSSI in the Usk catchment to six future scenarios for the year 2020

Name of SSSI	Habitat type	Site vuln	Scenario					
			CC	Lin	NE	LS	WM	GS
Waun-ddu	bbog	ml	M	m	m	m	ml	m
Coed Mawr Blaen-Car	blw	ml	M	m	mh	mh	m	ml
Coed Dyrysiog	blw	m	M	m	mh	mh	m	ml
Coed Ynys-Faen	blw	ml	M	m	mh	mh	m	ml
Coed y Cerrig	blw	ml	M	m	mh	mh	m	ml
Coed-y-Person	blw	m	M	m	mh	mh	m	ml
Gaer Wood, Llangoven	blw	m	M	m	mh	mh	m	ml
Penarth Brook Woodlands	blw	ml	M	m	mh	mh	m	ml
Priory Wood	blw	m	M	m	mh	mh	m	ml
Sugar Loaf woodlands	blw	l	M	m	mh	mh	m	ml
Coed Nant Menascin	blw	ml	M	m	mh	mh	m	ml
Gilwern Hill	blw	l	M	m	mh	mh	m	ml
Cwm Clydach	blw	l	M	m	mh	mh	m	ml
Brecon Beacons	blw/hth	ml	Mh	mh	mh	mh	mh	mh
Blorenge	cg	l	Mh	mh	mh	mh	mh	mh
Mynydd Du (Black Mountain)	cg	ml	Mh	mh	mh	mh	mh	mh
Black Mountains	cg	ml	Mh	mh	mh	mh	mh	mh
Mynydd Llangatwg	cg	ml	Mh	mh	mh	mh	mh	mh
Illtyd pools	lrb	ml	H	h	h	h	h	mh
Cae Gwernllertai	mg	mh	Mh	mh	mh	m	m	mh
Blaen Cilieni	mg	ml	Mh	mh	mh	m	m	mh
Gyfartha	mg	h	mh	mh	mh	m	m	mh
Cae Bryn Tywarch	mg	m	mh	mh	mh	m	m	mh
Upper Chapel Pastures	ng	ml	m	m	m	m	m	m
Pentregwyn	ng	mh	m	m	m	m	m	m
Caeau Fferm	ng	mh	m	m	m	m	m	m
Cobble’s Plain Meadows, Devauden	ng	mh	m	m	m	m	m	m
Penllwyn-yr-hendy	ng	m	m	m	m	m	m	m
Cwm Llanwenarth Meadows	ng	ml	m	m	m	m	m	m
Nant Clydach Pastures	ng	l	m	m	m	m	m	m
Alexanderstone Meadows	ng	m	m	m	m	m	m	m
Penpergwm Pond	pond	h	mh	mh	mh	mh	mh	mh

‘Habitat type’ refers to that habitat type across Wales. Habitat types: cg – calcareous grassland; mg – marshy grassland; ng – neutral grassland; hth – heath; blw – broadleaved woodland; bbog – blanket bog; lrb – lowland raised bog.

‘Site vuln’ (site vulnerability) refers to the vulnerability of a specific SSSI to changes in the surrounding landscape. Vulnerability categories: l = low; ml = medium low; m = medium; mh = medium high; h = high.

Scenarios: CC – climate change only; Lin – linear change; NE – National Enterprise; LS – Local Stewardship; WM – World Markets; GS – Global Sustainability.

Table 3.9: Summary of vulnerability of each SSSI in the Usk catchment to six future scenarios for the year 2050

Name of SSSI	Habitat type	Site vuln	Scenario					
			CC	Lin	NE	LS	WM	GS
Waun-ddu	bbog	ml	m	mh	h	mh	mh	mh
Coed Mawr Blaen-Car	blw	ml	m	m	mh	h	m	l
Coed Dyrysiog	blw	m	m	m	mh	h	m	l
Coed Ynys-Faen	blw	ml	m	m	mh	h	m	l
Coed y Cerrig	blw	ml	m	m	mh	h	m	l
Coed-y-Person	blw	m	m	m	mh	h	m	l
Gaer Wood, Llangoven	blw	m	m	m	mh	h	m	l
Penarth Brook Woodlands	blw	ml	m	m	mh	h	m	l
Priory Wood	blw	m	m	m	mh	h	m	l
Sugar Loaf woodlands	blw	l	m	m	mh	h	m	l
Coed Nant Menascin	blw	ml	m	m	mh	h	m	l
Gilwern Hill	blw	l	m	m	mh	h	m	l
Cwm Clydach	blw	l	m	m	mh	h	m	l
Blorenge	cg	l	mh	mh	mh	mh	mh	mh
Mynydd Du (Black Mountain)	cg	ml	mh	mh	mh	mh	mh	mh
Black Mountains	cg	ml	mh	mh	mh	mh	mh	mh
Illtyd pools	lrb	ml	h	vh	vh	h	vh	mh
Cae Gwernllertai	mg	mh	mh	mh	mh	mh	mh	mh
Blaen Cilieni	mg	ml	mh	mh	mh	mh	mh	mh
Gyfartha	mg	h	mh	mh	mh	mh	mh	mh
Cae Bryn Tywarch	mg	m	mh	mh	mh	mh	mh	mh
Upper Chapel Pastures	ng	ml	m	m	m	m	m	m
Pentregwyn	ng	mh	m	m	m	m	m	m
Caeau Fferm	ng	mh	m	m	m	m	m	m
Cobble's Plain Meadows, Devauden	ng	mh	m	m	m	m	m	m
Penllwyn-yr-hendy	ng	m	m	m	m	m	m	m
Cwm Llanwenarth Meadows	ng	ml	m	m	m	m	m	m
Nant Clydach Pastures	ng	l	m	m	m	m	m	m
Alexanderstone Meadows	ng	m	m	m	m	m	m	m
Penpergwm Pond	pond	h	h	h	h	h	h	h
Mynydd Llangatwg	cg	ml	mh	mh	mh	mh	mh	mh
Brecon Beacons	blw/hth	ml	mh	m	mh	h	m	m

'Habitat type' refers to that habitat type across Wales. Habitat types: cg – calcareous grassland; mg – marshy grassland; ng – neutral grassland; hth – heath; blw – broadleaved woodland; bbog – blanket bog; lrb – lowland raised bog.

'Site vuln' (site vulnerability) refers to the vulnerability of a specific SSSI to changes in the surrounding landscape. Vulnerability categories: l = low; ml = medium low; m = medium; mh = medium high; h = high.

Scenarios: CC – climate change only; Lin – linear change; NE – National Enterprise; LS – Local Stewardship; WM – World Markets; GS – Global Sustainability.

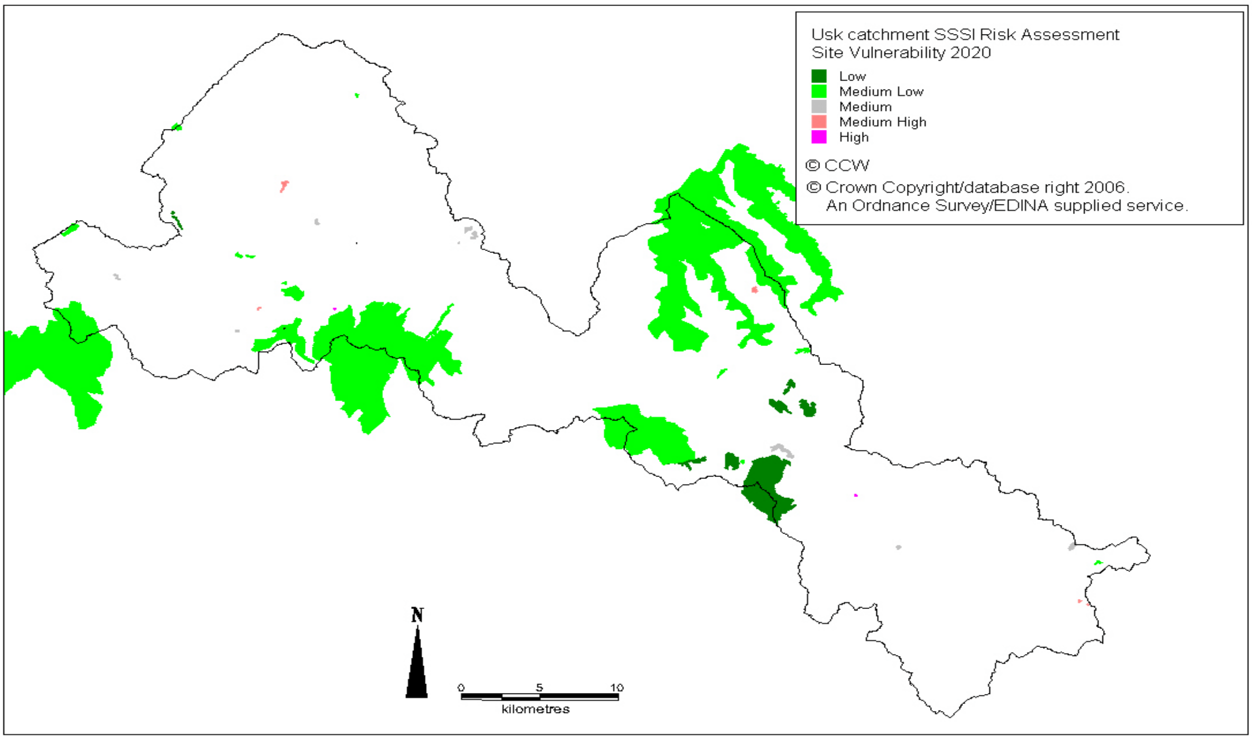

Figure 3.6: Innate vulnerability of the location of SSSI within the Usk catchment in 2020

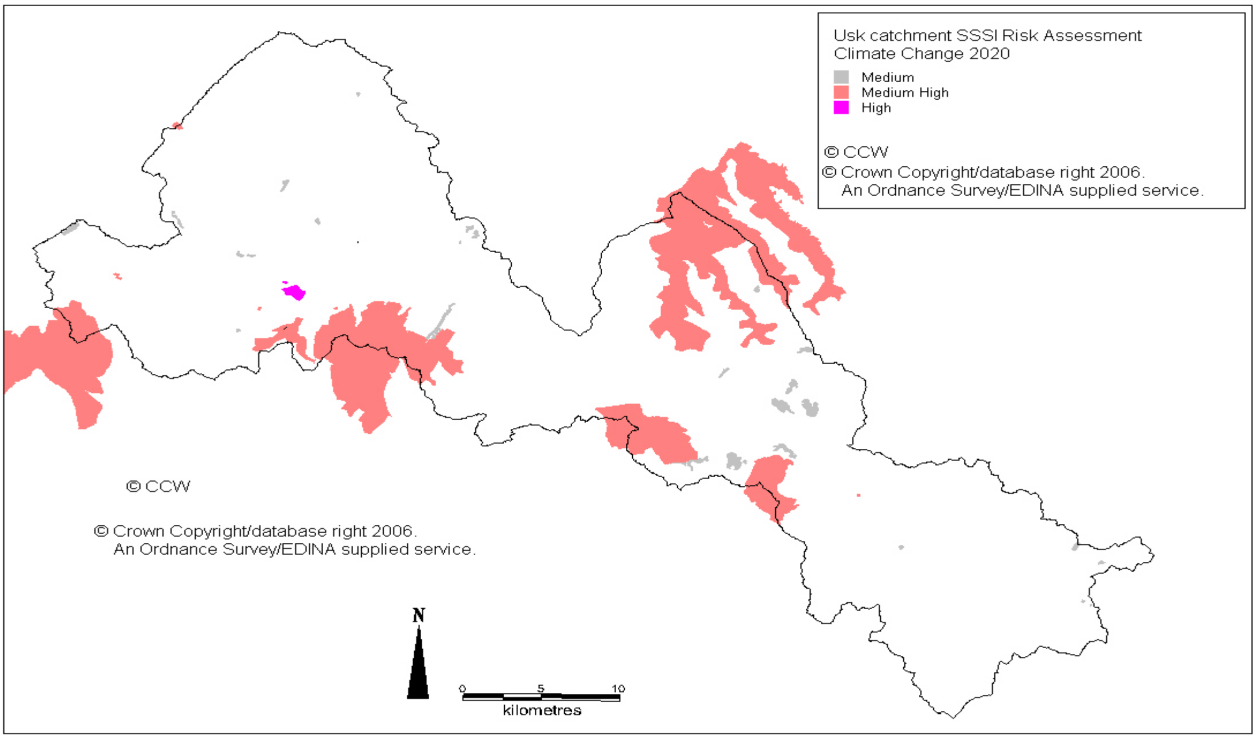

Figure 3.7: Vulnerability of SSSI within the Usk catchment in 2020 to climate change only

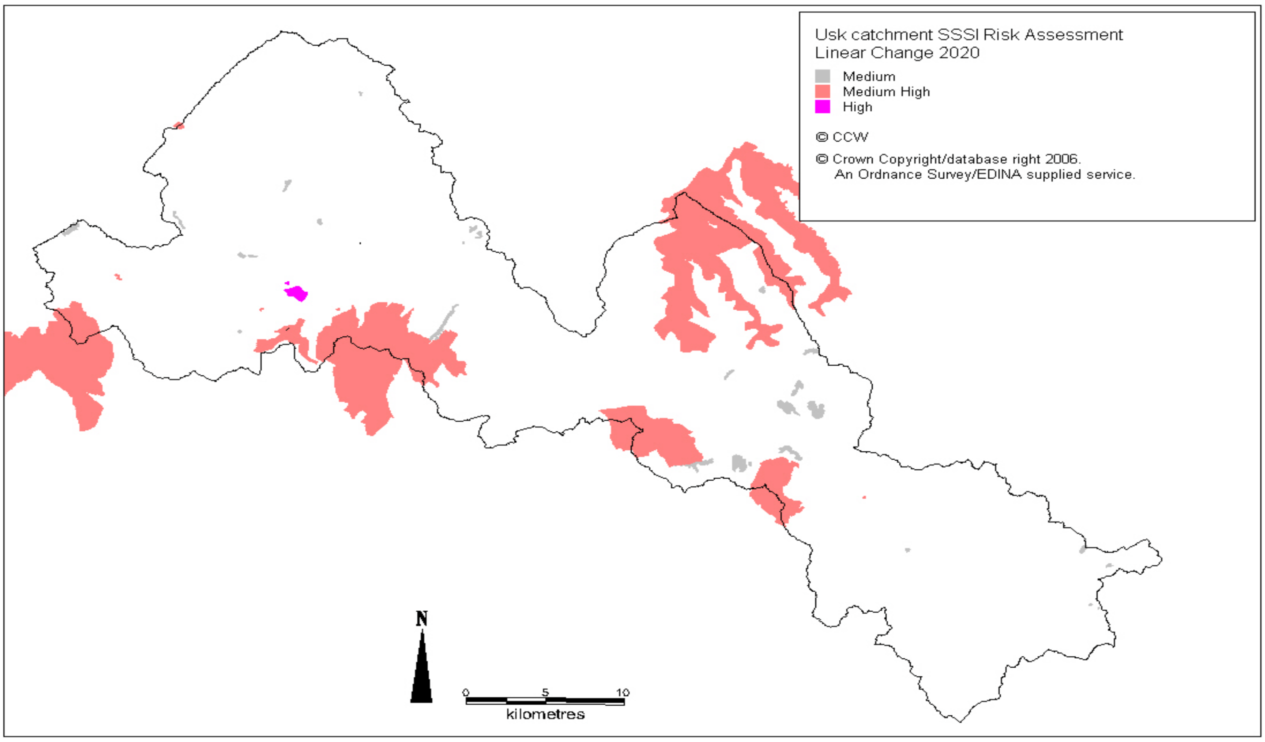

Figure 3.8: Vulnerability of SSSI within the Usk catchment in 2020 to climate change and a socio-economic scenario of linear change

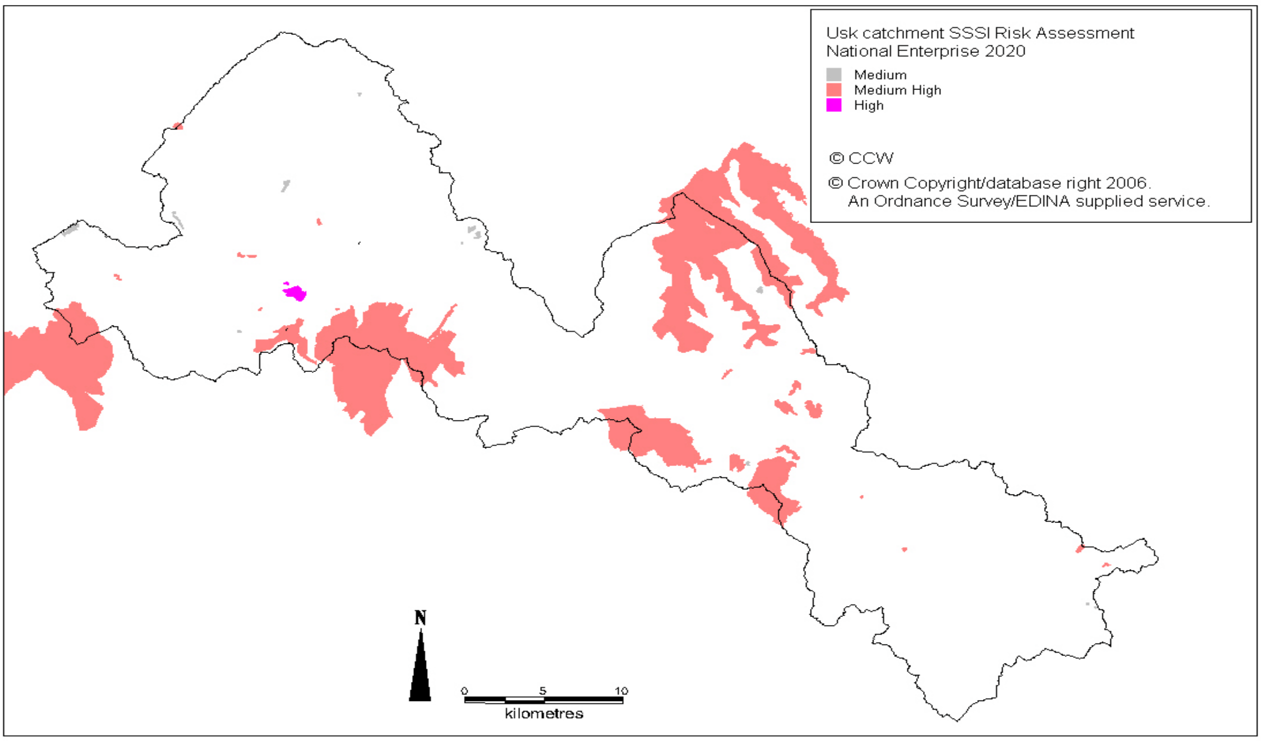

Figure 3.9: Vulnerability of SSSI within the Usk catchment in 2020 to climate change and a socio-economic scenario of National Enterprise

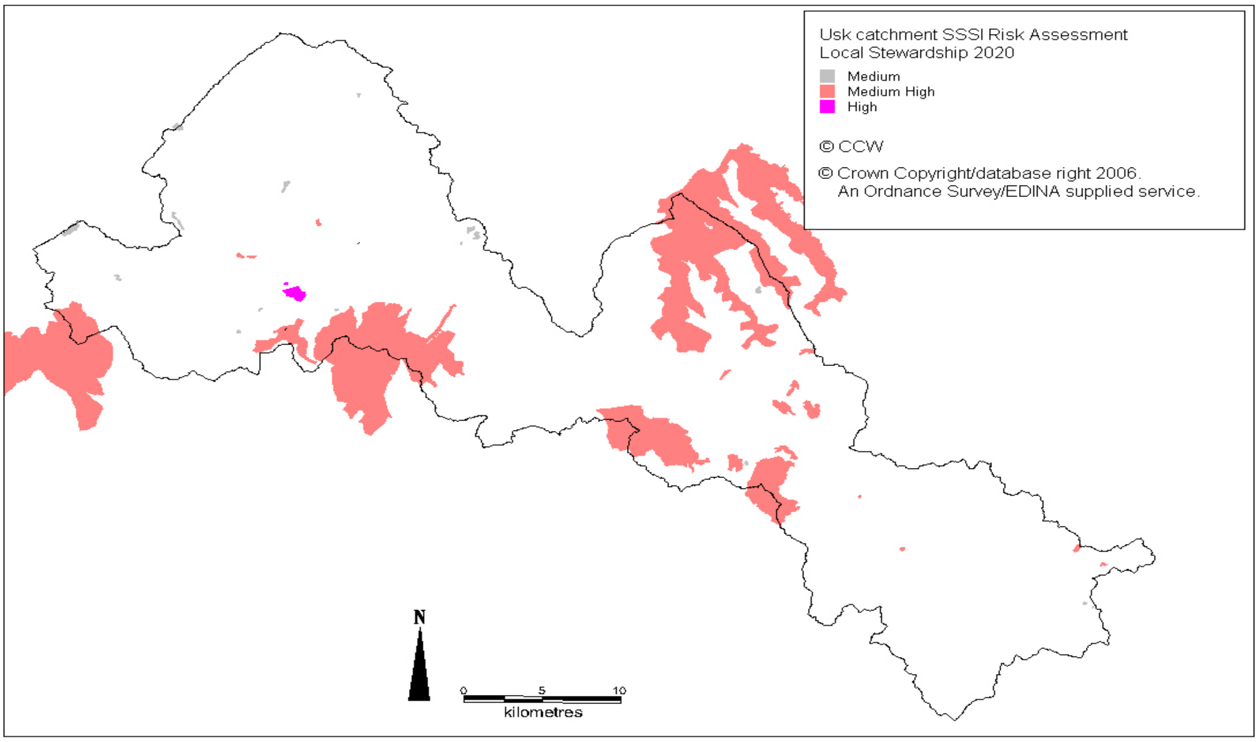

Figure 3.10: Vulnerability of SSSI within the Usk catchment in 2020 to climate change and a socio-economic scenario of Local Stewardship

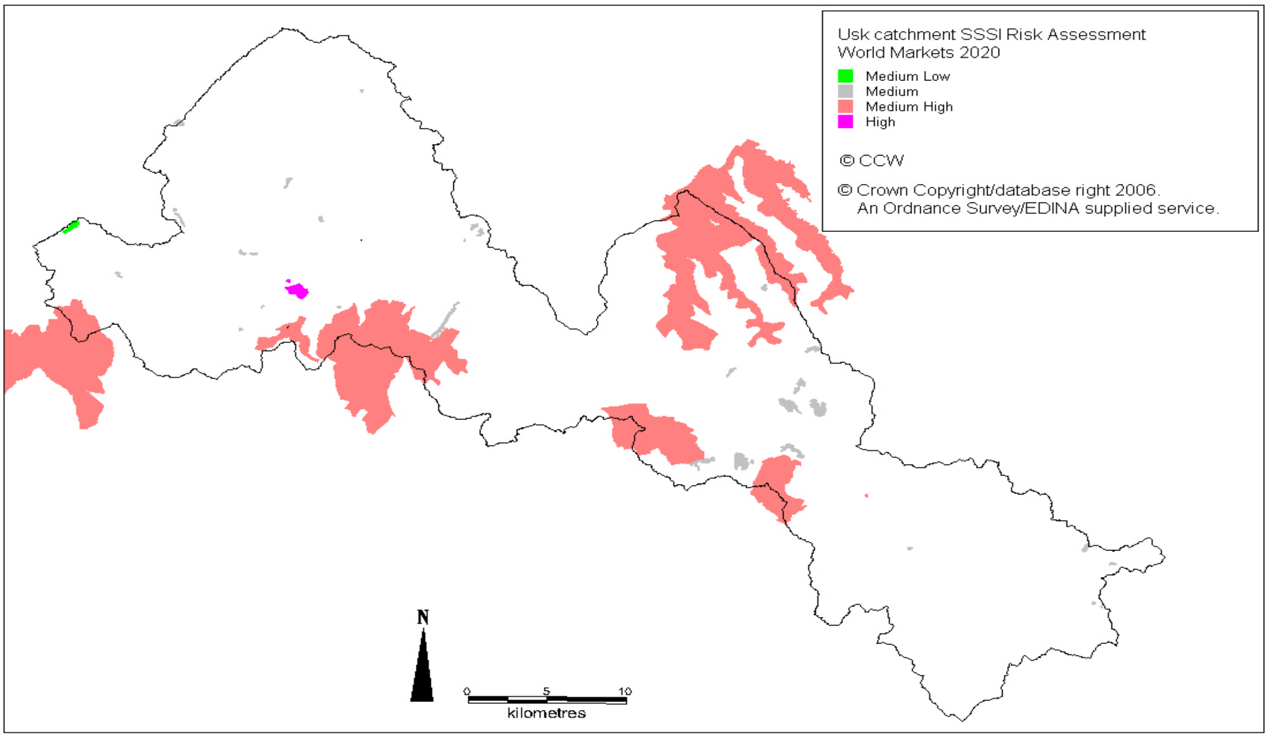

Figure 3.11: Vulnerability of SSSI within the Usk catchment in 2020 to climate change and a socio-economic scenario of World Markets

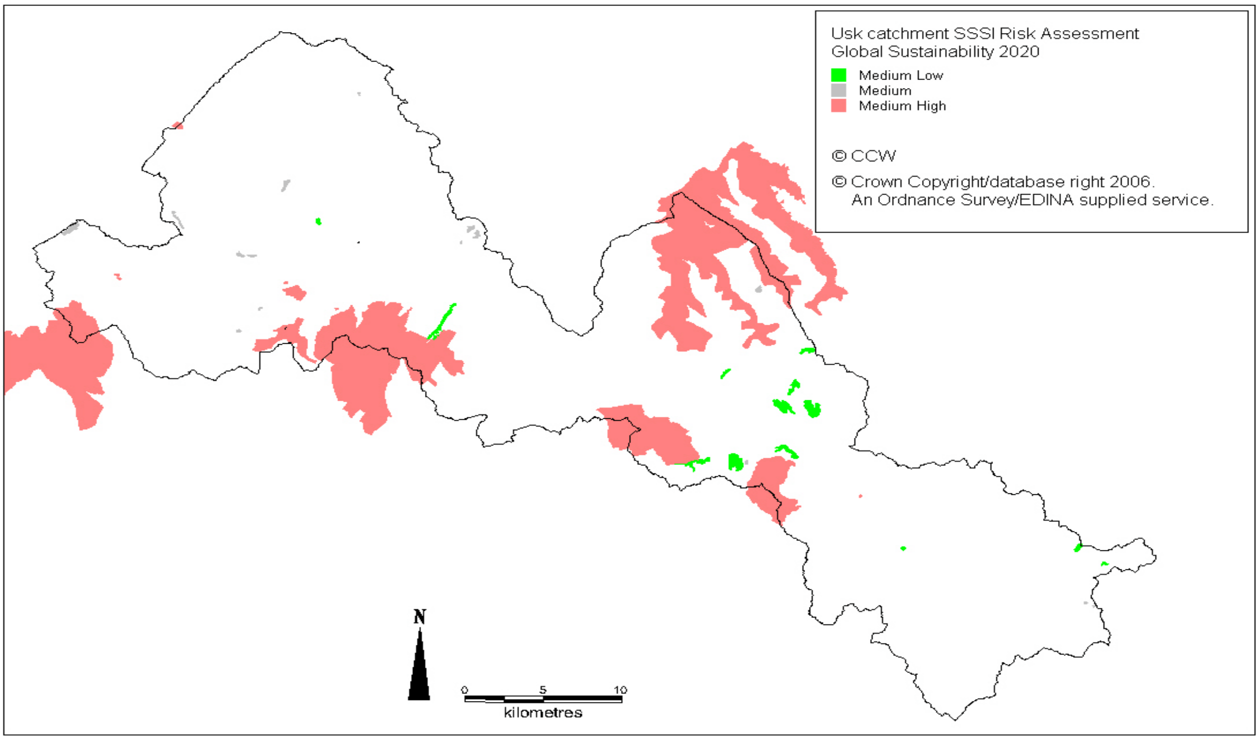

Figure 3.12 Vulnerability of SSSI within the Usk catchment in 2020 to climate change and a socio-economic scenario of Global Sustainability

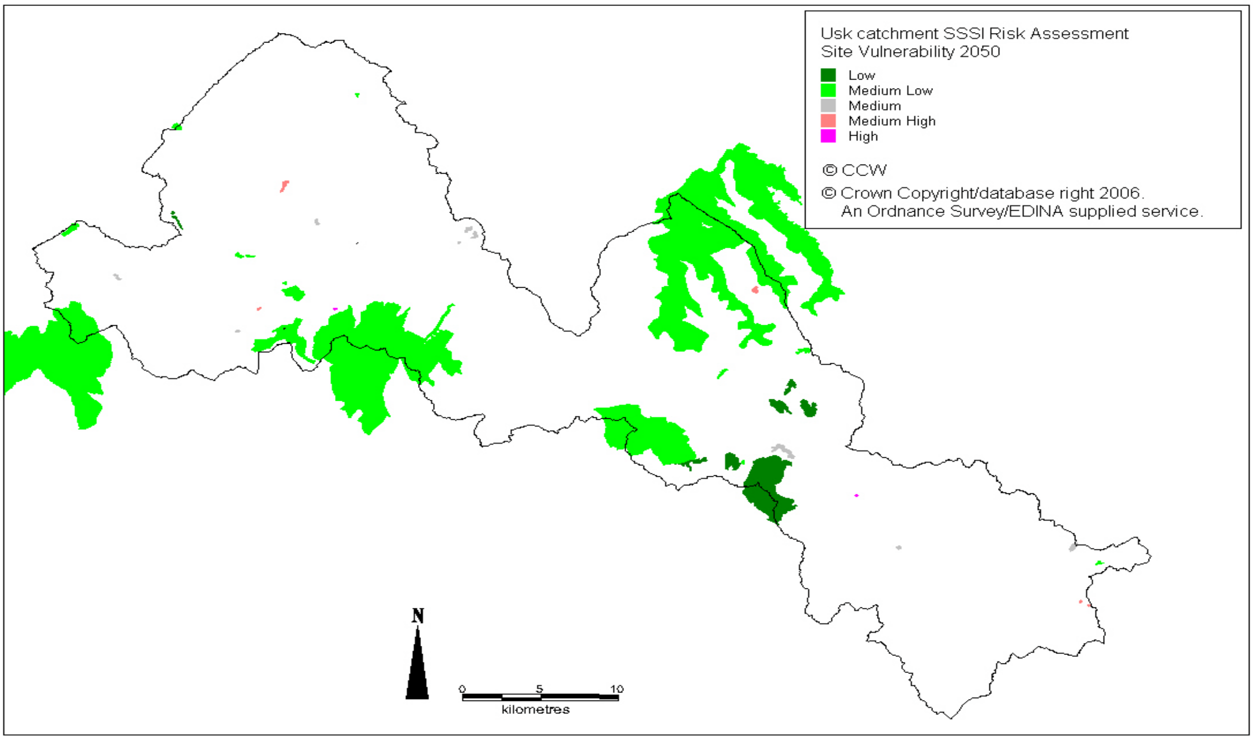

Figure 3.13: Innate vulnerability of sites within the Usk catchment where SSSI are located in 2050

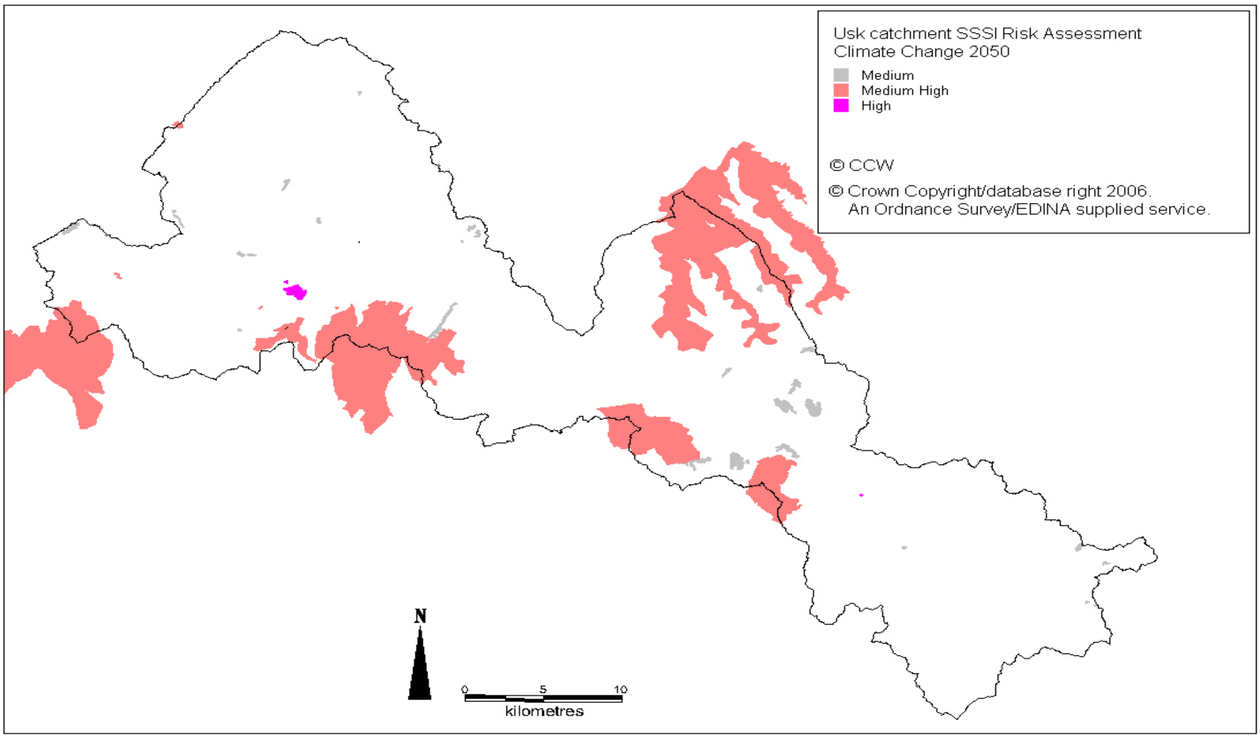

Figure 3.14: Vulnerability of SSSI within the Usk catchment in 2050 to climate change only

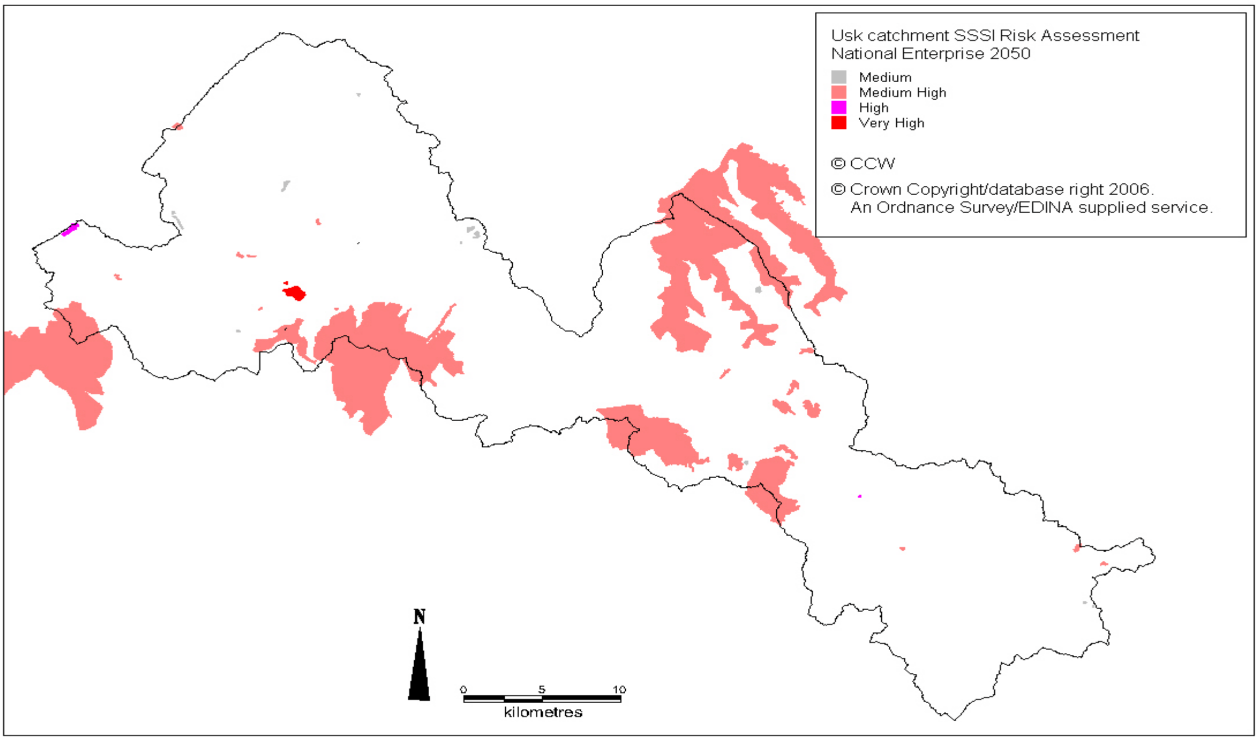

Figure 3.15: Vulnerability of SSSI within the Usk catchment in 2050 to climate change and a socio-economic scenario of National Enterprise

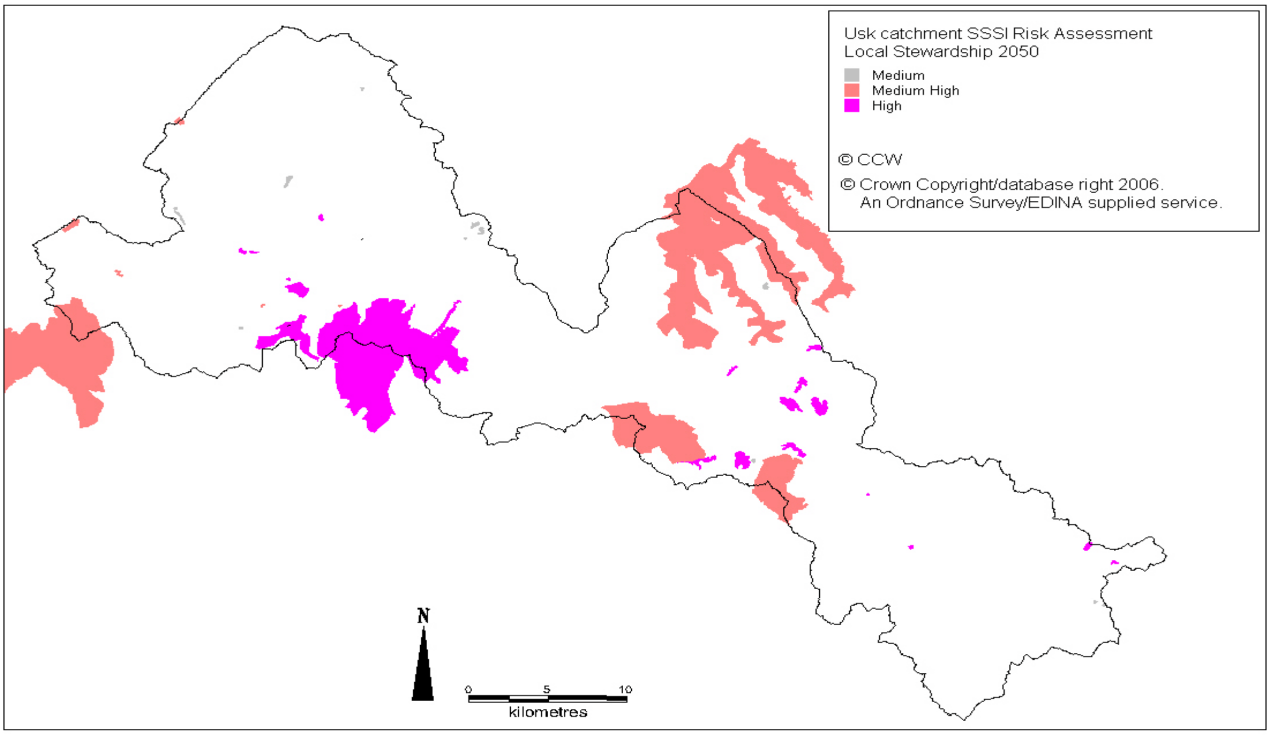

Figure 3.16: Vulnerability of SSSI within the Usk catchment in 2050 to climate change and a socio-economic scenario of Local Stewardship

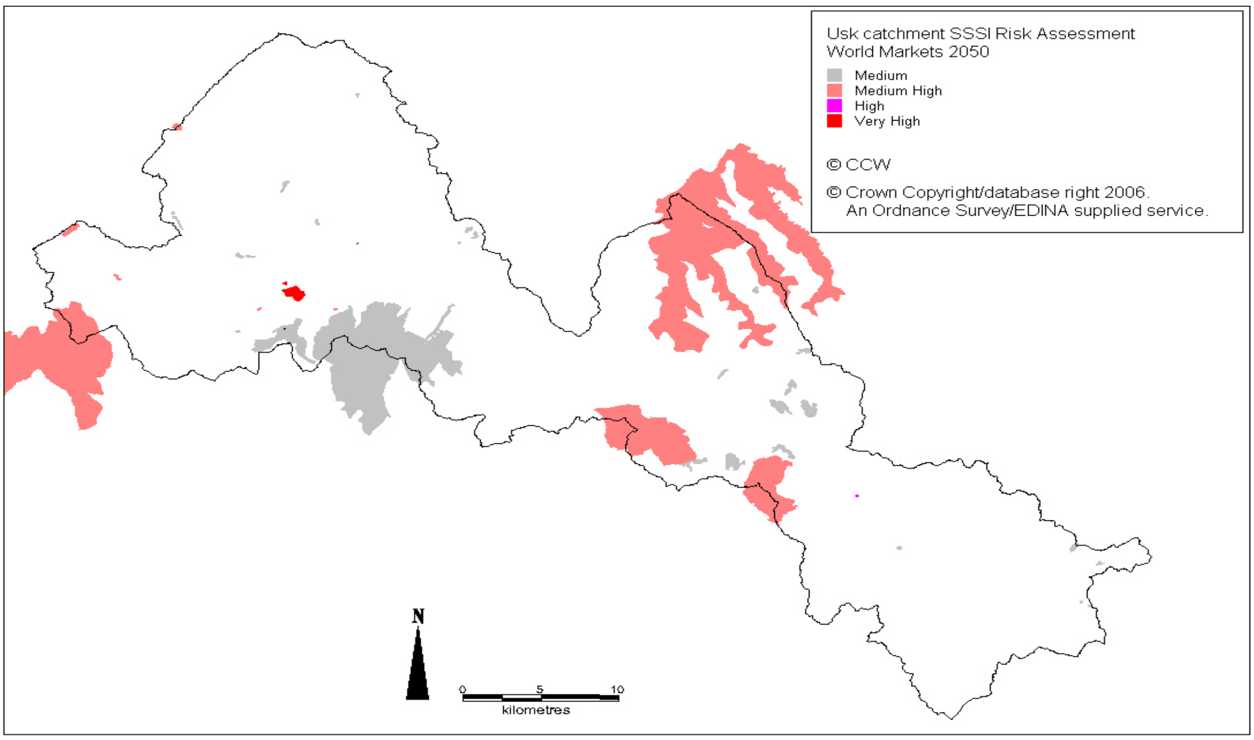

Figure 3.17: Vulnerability of SSSI within the Usk catchment in 2050 to climate change and a socio-economic scenario of World Markets

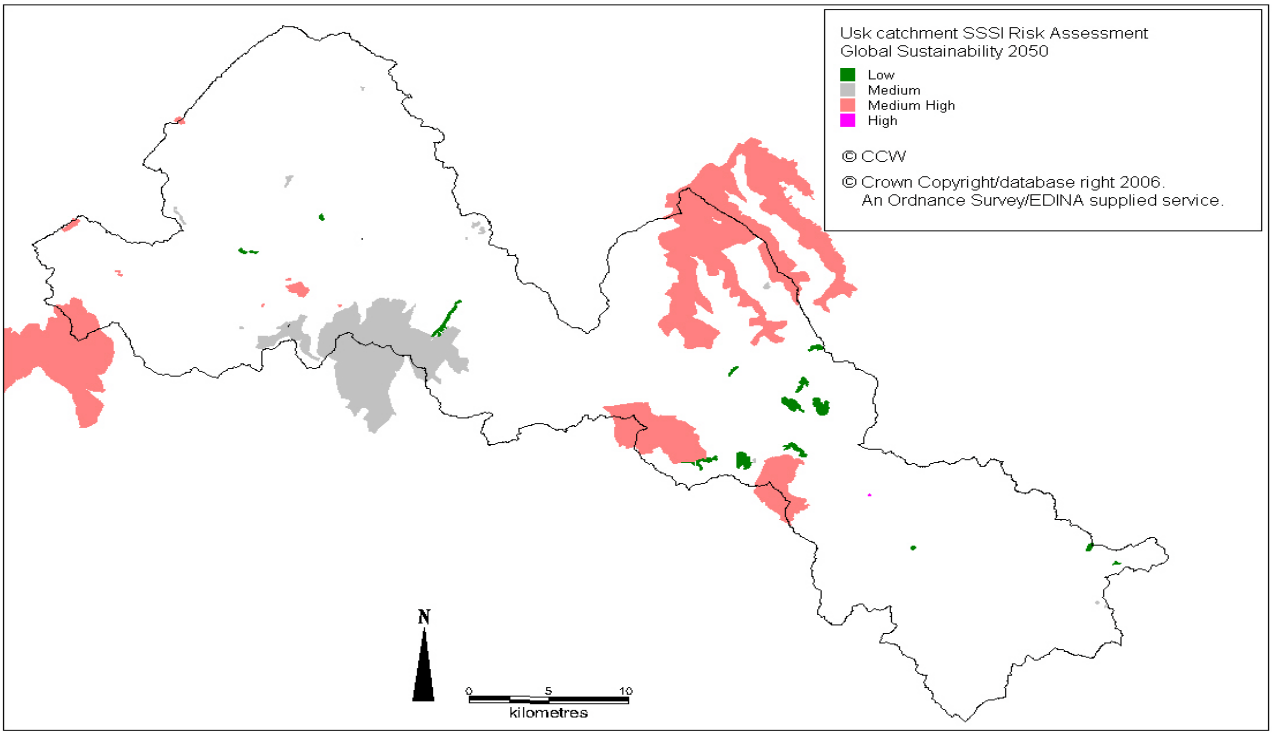

Figure 3.18: Vulnerability of SSSI within the Usk catchment in 2050 to climate change and a socio-economic scenario of Global Sustainability

Similarly, areas of rich lowland meadow, rocky outcrops and mountain plateaus will all support characteristic communities of plants and animals in the future; they will just be different communities of plants and animals to those which exist today. So rather than removing the designation of SSSI, we may view them as representative pieces of the landscape in which characteristic new communities will develop under a changed climate.

Before such an idea can be accepted it will be necessary for the EU, governments, society, experts and the public to move away from valuing certain characteristic species above all else, and start to learn to value collections of species characteristic of certain habitats. Such a shift in policy and public attitude is unlikely to occur quickly or easily.

3.4 Policy analysis

3.4.1 General comments

The problems of site-based approaches

The analysis of the Usk SSSI highlighted several issues relating to the future of SSSI and site-based conservation approaches in general. The first of these relates to the nature of site-based conservation in the UK under a changed climate. There is good evidence that many species are shifting their range in response to climate (Hickling *et al*., 2005; Hughes, 2000; Parmesan *et al*., 1999). So if a site was designated in order to protect a species, then it is possible that the species may either emigrate away from the site or be competitively excluded by some other species which disperses into or increases in abundance on the site due to climate-related factors. This will undermine the basis on which the site was designated.

Ten of the 50 SSSI in the Usk catchment were designated primarily on the basis of species present within them, although several others had species as secondary features (see Table 3.10). Each of these species may respond differently to climate-induced change, and each may be more or less susceptible to competitive exclusion from new or increasing species. A detailed analysis of their vulnerability would be appropriate before any species-specific comments can be made. However, it is noteworthy that many of the species cited in the Usk SSSI designations either occur in aquatic habitats (such as otter, brook lamprey) or are associated with aquatic and/or wet habitats (such as goosander, orange foxtail). As climate change is predicted to alter patterns of precipitation and evapotranspiration, there is a likelihood that the nature of the habitat for these species will change, with potential knock-on effects on the species themselves and the validity of the designations (see Chapter 6 on CAMS).

Table 3.10: Species cited in the designation of SSSI in the Usk catchment

SSSI name	Species cited in the designation
Gilwern Hill	autumn gentian
Nant Clydach Pastures	broadleaved cottongrass
Talybont Reservoir	goosander
Cae Bryn Tywarch	lesser butterfly orchid
Buckland Coach House & Ice House	lesser horseshoe bats
Llangovan Church	lesser horseshoe bats
Saimbre Ddu	lesser horseshoe bats
Wye valley	lesser horseshoe bats
Mynydd Llangatwg	*opegrapha paraxanthodes* (a lichen), lesser horseshoe bats
Penpergwm Pond	Orange foxtail
Afone Wysg (Isafonydd)/ River Usk (tributaries)	otter, bullhead, atlantic salmon, river lamprey, brook lamprey
River Usk (Lower Usk)/ Afon Wysg (Wysg Isaf)	otter, bullhead, twaite shad, river lamprey, brook lamprey, Allis shad
Upper Usk/Afon Wysg (Wysg Uchaf)	otter, twaite shad, allis shad
Alexanderstone Meadows	Pepper saxifrage
Black Mountains	Red grouse, marsh fern, cowberry
Mynydd Du	*Scapania gymnostomophalia* (a liverwort)

This is only one small part of the challenge to site-based conservation under a changed climate. Even if species find a site unfavourable and start to disperse, it is uncertain whether or not they will find habitats suitable for colonisation within the range of their maximum dispersal distance. The standard answer to this sort of problem is to create habitat corridors or stepping stones through which individuals may disperse while they seek a more permanent habitat. This concept envisages plants and animals moving between patches or 'islands' of favourable habitat which are separated by a 'sea' of unsuitable habitat.

Experiments have shown that corridors can enhance movement between patches within a landscape (for example, Tewksbury *et al*., 2002). However, their development is simplified if they are designed for only one species of animal (such as for silver studded blue butterflies), or they are composed of one habitat type (such as broadleaved woodland) which can be used by all the species which share that habitat. Creating corridors becomes complex when there is a need to have many different types of habitat corridors connecting different habitat patches in a similar region (such as making separate corridors of broadleaved woodlands, grasslands and blanket bogs).

A complementary concept is that of landscape permeability. Landscape permeability can be defined as “the quality of a heterogeneous land area [a landscape] to provide for passage of animals” (Singleton *et al*., 2002). Highly permeable landscapes are those which present the fewest obstacles or hazards to individuals as they move around, and low permeability landscapes pose many hazards, such as roads, urban areas, large expanses of unsuitable habitat, and so on. The relative permeability of any one landscape will vary between species, so a landscape that is more permeable to wood mice may not be permeable to water voles and vice versa.

While both corridors and permeability are useful concepts, their practical application to land use planning in the UK is largely untested. In the context of managing climate change in the Usk, it may be possible to develop ‘corridors of high permeability’ where, rather than seeking a corridor composed of one solid habitat type, certain areas of land are managed to maintain high permeability for certain species types. So we may imagine some areas which run approximately north-south within Wales that would maintain a high percentage of woodland cover and would seek to minimise hazards to the movement of woodland species. Other corridors of permeability could be developed for lowland species and also aquatic species. This concept becomes difficult to apply to species characteristic of uplands as, when viewed at a landscape scale, mountain tops are very similar to islands in a sea of lowland. In this situation, there is very little that increasing landscape connectivity can do to enhance the movement of species characteristic of mountain plateaus.

While the creation of corridors and stepping stones is relatively easy to discuss and model, it poses a real practical problem in a landscape which is largely in private ownership and is reasonably intensively managed. One option for creating such habitat connectivity would be through some sort of agri-environment scheme which would engage landowners in relevant types of habitat creation which may vary with the location of the farm (see Chapter 4 on agri-environment schemes).

Surrounding land use

Many of the SSSI in the area were highly dependent in some way on the hydrological regime, such as marshy grasslands and blanket bogs which both need a suitable level of precipitation to maintain their essential character. In addition, the river channel of the Usk is itself a SSSI and clearly many of the species living in the river may be affected by changes in water temperature and flows. Given the uncertainty in rainfall predictions for future climate, it is difficult to know exactly what impact this will have on the sites and their constituent species.

The natural hydrological regime is likely to be impacted further by changes in land use. Given that much of the land in the lower part of the Usk catchment is of good agricultural quality, and that it is close to markets, we may expect this land to have high potential for changing uses. Extra challenges to the hydrological regime may be associated with these changed uses, not only in alterations to drainage patterns, but also in terms of abstraction for irrigation, which may become necessary under a changed climate (see chapter on CAMS).

This issue is exemplified by the SSSI at Cae Gwernllertai (33 WHAS) which is classified as ‘acid grassland, marshy grassland, semi-natural woodland, wet heath’. While both acid grassland and woodland are expected to be reasonably resilient to climate change (presuming management is appropriate), marshy grassland will be more vulnerable to climate change, due to the increasing frequency of summer droughts. This vulnerability will be exacerbated as this particular site is a very small site surrounded by improved grassland on grade 4 land. Adjacent land uses should not pose major threats to the woodland element of the site, but if land use changed higher up in the catchment then the hydrological regime which supports the wet heaths and marshy grasslands may alter, with potential impacts on habitats within the SSSI. It is interesting to compare this situation to Waun-ddu (33 WKH) which is a 35 ha blanket bog situated right at the top of the catchment. While this habitat type is dependent on high levels of precipitation, its size and location in the catchment should render it far less vulnerable to the impacts brought about by land use change.

SSSI may be vulnerable to other land use changes and the development of new agricultural enterprises which are unknown at this time. Generally, small SSSI surrounded by good agricultural land will be more vulnerable than large ones surrounded by poor land. This issue raises the need for the most important and vulnerable SSSI to be surrounded by appropriate land use, which would act as some form of buffer zone.

A further purpose of buffer zones may be to provide space for habitat migration. For example, habitats like woodland may in response to climate migrate up an altitudinal gradient. In order for this to happen, suitable land would need to be available for colonisation, where a buffer zone could provide this land in some circumstances.

Interestingly, while much work has considered the impacts of general agriculture on birds (see Vickery *et al.,* 2002; Henderson *et al.,* 2000) and other taxa (see Meek e*t al.,* 2002), the relationship between land use and SSSI remains relatively under-worked (but see related work on buffer zones and amphibians (Trenham and Shaffer, 2005), land use and water quality (Mancini *et al*., 2005) and lakes (Wilson, 1999)). Given this knowledge gap, more research in a Welsh context may be needed to consider the impacts of land use on reserves.

Grazing regimes

Grazing (either under-grazing or over-grazing) has been recognised as the most important activity causing SSSI to be in unfavourable condition (JNCC, 2006). Some of the large SSSI in the Usk catchment are very dependent on the grazing regime. Consider for example Blorenge (33 WFL), which is 981 ha in size and is important for its calcareous grassland and dry heath. The maintenance of both of these habitats depends on the grazing regime. However, there will undoubtedly be changes in agricultural policies and markets over the next 50 years, and these drivers will determine how many grazing animals farmers will want to keep. Further, these drivers may not be constantly acting in the same way, and we may well see major fluctuations in the international demand for livestock between now and 2050, just as we have over the last 50 years. If Welsh farmers respond to these market signals we may well see grazing patterns changing over time, and this will undoubtedly have impacts on the quality of certain SSSI. In addition, climate change itself may bring about changes in the financially optimal levels and patterns of grazing, if the availability and quality of forage in the pasture changes in the future compared to current conditions. Altered seasonal patterns of rainfall may also enable temporal patterns of grazing to change, with perhaps more grazing in the uplands in the autumn and spring than occurs currently.

While there are some good data on the impacts of grazing on certain species (see for example, Evans *et al*., 2006; Woodcock *et al*., 2006), there remains much uncertainty about the impacts of an altered grazing regime under a changed climate on species and ecosystems. Recent work by Wallisdevries et al. (2006) suggests that earlier spring growth in environments rich in nitrogen may actually serve to cool microclimates relative to current baselines, and this in turn may affect species, in this case certain butterfly species. This work highlights the complex interactions which can occur between environment, management and a changed climate and it underlines the need to develop a greater understanding of environment and land use change on species and habitats.

Social attitudes to conservation

The final issue relates to the social desire to have sites of conservation interest in the UK landscape over the next 50 to 100 years. Some of the socio-economic scenarios suggest changing attitudes to conservation. For example, under a scenario of National Enterprise we may expect a lack of deep concern for environmental policy and a strong emphasis on economic returns being made from the environment, resulting in low social support for conservation. However, under a scenario of Global Sustainability we may expect very high investment in environmental sustainability and positive attitudes towards conservation of all types.

These social issues may not be a direct threat to site-based conservation *per se*, but consider a future situation where society decides that it would rather have more land in production than in conservation. In such a situation habitats like broadleaved woodland and lowland meadows, which in themselves may not be under great threat from climate change, would become vulnerable to conversion to other land uses, particularly in the areas of land which offer more potential for economically productive activities (typically in the lowlands of catchments). While this situation may seem a little unlikely at the moment, it is only necessary to consider government and society's attitudes towards native and plantation woodland in the UK from 1906 to the present day to appreciate how society's attitude to aspects of the environment can change markedly over periods of only a few decades.

3.4.2 Specific comments on policy components

Nature Conservancy of Great Britain objectives and SSSI criteria

A. The national total protected areas should be large and varied enough to guarantee the survival of the necessary minimum of Britain's wildlife and physical features.

This component is extremely complex to assess, even without climate change. The problems of its assessment are exacerbated by the fact that climate change is likely to imply the non-viability of some species which are currently native to the UK, while simultaneously enabling colonisation by species which are not currently native. Thus, it will not be a trivial question to decide what Britain's wildlife will be, let alone decide if the SSSI are representative and sufficient. Given the change in species composition of the UK, and the likely climate-induced changes in their distributions, it would seem that this major objective is likely to eventually fail under all possible future scenarios. However, the speed of failure may be somewhat ameliorated by the ambient socio-economic conditions of the time, depending on the type of world which evolves (such as National Enterprise and Local Stewardship).

B. Criteria for site evaluation include primarily: size, diversity, rarity, naturalness and typicalness; and secondarily: recorded history, position in an ecological/geographical unit, potential value and intrinsic appeal.

These criteria were suggested on the basis of good ecological insight in the UK in the 1970s, and have been adapted for use in many other countries. Several of them, such as size, are based on scientific relationships which seem unlikely to change. However, other scientific criteria, such as rarity, may become more difficult to interpret in a changed climate. Species may continue adapting to the changed climate for many decades, and so getting a baseline against which to assess diversity may become difficult, if not impossible. Consider, for example, the national lists of plants and animals considered to be native to the UK, and therefore likely to be protected within SSSI. As climate envelopes shift, particularly for southern species and those from continental Europe, so the list of native species will also change. This will require a whole new evaluation of how conservation engages with species which are rare, native and/or alien. Similar debates will need to be had over several other of Ratcliffe's criteria, such as typicalness and naturalness, which as for rarity, will be challenged by changing species distributions and community composition and structure.

Even very subjective criteria like intrinsic appeal may need re-evaluation. Consider, for example, the intrinsic appeal of some of the large and colourful Lepidoptera and birds which may migrate into the UK from continental Europe. It is possible that a reasonably large proportion of the public would value such species over the less attractive traditionally native fauna. Given all of the above, it seems highly unlikely that site evaluation criteria as applied in 1977 and 2006 will still be viable under a changed climate.

C. Criteria for site evaluation for geological and physiographic features include: representativeness, exceptional features and international importance.

Geological and physiographic features are not usually directly susceptible to climate-induced change, so these criteria should remain relevant, assuming society does not change its basis for valuing these features.

Legal requirement (Section 28(4) of the Wildlife and Countryside Act 1981)

A. When notifying a SSSI, produce a Site Management Statement (SMS) describing desired management of the land for conservation and enhancement of its flora or fauna or features.

As long as site-based conservation seeks to maintain existing (or even historical) habitats or species, there will be a need to manage these sites. So it seems unlikely that the basic concept of a Site Management Statement (SMS) will disappear under a changed climate. However, clearly the management that is prescribed today may not be valid under a changed climate, so the nature of current SMS will need to change, as indeed may the basic nature conservation philosophy informing their production.

For example, as mentioned above the continuance of appropriate grazing regimes will be particularly important on several of the larger SSSI in the Usk catchment. Unfortunately, we cannot predict the level of stock that farmers will keep over the next 50 years. Further, we cannot predict what level of grazing would be appropriate for any new plant communities which may form in the future.

In the face of both of these uncertainties, one option would be for government (or other suitable institutions) to take direct control of the sites and manage them solely for their conservation value. In this way, the management of habitats would not be susceptible to changes in market demand for livestock products. Further, it would be possible to change the grazing regime quickly and precisely as demanded by the condition of the site. However, such an approach goes against the current philosophy of entrusting the management of the countryside to its farmer stakeholders. It would also probably be quite expensive to enact in the short term.

An alternative is to have very long-term management agreements with landowners, of 20 to 30 years in length, where the landowner is paid to produce the habitat demanded by government, regardless of the cost to him of achieving this. This would require a reasonably large annual payment to landowners in order to 'buffer' them from market-led changes in income; for example, if conservation management required stocking to decrease, then the farmer might lose out on lamb sales. Alternatively, in conditions where sheep farming was unprofitable, the conservation management regime might require more stock be kept than the market would support.

A further change in approach relates to the need to manage the land surrounding a SSSI as a buffer to the specific biological interest in the SSSI. So for example, where a particular site required a certain hydrological regime be maintained, it might be necessary to extend the management to include all land which influenced the hydrological regime affecting the SSSI. In effect, this option would significantly increase the amount of land subject to conservation management agreements and would entail significant extra costs to government and possibly further restrictions on landowners. While such an approach might not be welcomed by either party, this sort of thinking is broadly in line with that encompassed in the Water Framework Directive, although the enactment of this in the UK remains unclear at this point.

Non-legally obligatory CCW undertakings for preparing management plans for SSSI

A. Evaluate the condition of the site in terms of favourable conservation status (FCS).

The definition of FCS includes various features (for example, population of key species must be stable or increasing, long-term sustainability of habitat) which are based on current understanding of the species and communities they are meant to protect. However, the exact composition of these communities will change with the climate, and so the science which currently underpins the definition of FCS will no longer be valid. For example, within the Usk catchment the hydrological regime of rivers may change, as may the abundance of aquatic invertebrates, so our understanding of the ecology of fish species like the bullhead, Atlantic salmon and the Allis shad may no longer be valid. This will require a re-evaluation of the exact meaning of a viable population of these species in this catchment, and their conservation management may change accordingly. In this situation, we would expect our understanding and definition of favourable conservation status to alter also. However, it seems likely that some form of indicator will be needed in the future to monitor conservation status. So the basic concept of FCS will probably survive, but the form and application will almost certainly have to change.

B. Set operational limits for factors considered to have positive or negative effects on FCS.

As stated above, some form of management and monitoring will be needed in the future, so it is likely that operational limits will also be needed. However, current operational limits on factors such as grazing, fire management, water table levels and so on are unlikely to be valid under climate change.

Not only will we need new research to inform our understanding of the impact of these factors on species, but we will also need to consider for how long and how rapidly we expect the climate to change. Consider, for example, management-related research on a hypothetical grassland community (community X). The research identifies grazing level J as being appropriate for maintaining the community. However, after 30 years of climate change, community X no longer exists and is replaced by grassland community Y. Is it worthwhile investing in new research to establish optimal grazing regimes for community Y? Or is there a chance that, as the climate is still changing, community Y will cease to exist in a further 30 years, to be replaced by grassland community Z? This level of uncertainty in the impact and duration of climate change will raise serious challenges for conservation philosophy and practice.

C. Define attributes and specify thresholds to use as performance indicators in monitoring.

For the reasons stated above, performance indicators suitable for monitoring under current conditions may not be suitable under changing climatic ones. New indicators will need to be developed once the favourable status of sites has been decided.

JNCC habitat translocation policy for Britain

A. The use of habitat translocation for habitat restoration should not damage important sites or ancient habitats, and habitat translocation should only take place where it can be shown that there is a net gain for biodiversity conservation.

Currently, the JNCC and other countryside agencies are strongly against habitat translocation, but this viewpoint may become increasingly difficult to sustain if extinction of species and radical changes in composition occur under climate and land use change. An inability to use important but deteriorating sites for supporting colonisation by other species/habitats may undermine overall conservation, yet demonstrating net gains under a changing climate could be highly problematic.

Other

A. Integration with, and effects on, other policies and agreements.

The impacts of climate change and the need to create a more resilient countryside are likely to strengthen the case for integrating nature conservation, spatial planning, forestry and agricultural policy together as an integrated land use and landscape policy. However, the practicalities of achieving sensible integration suggest that real integration is more likely to occur under a situation of stable policies than under evolving policy. Unfortunately, some element of evolution to conservation policy is likely as adaptation to climate change is integrated into nature conservation policy.

3.5 Discussion and climate proofing

The vulnerability assessment of SSSI in the Usk catchment shows that nearly all SSSI are vulnerable to the direct and indirect impacts of climate change under all socio-economic scenarios. Unfortunately, from a policy perspective, the exact nature of the vulnerability varies with the location of the site and the nature of the habitats within it. For this reason, it is unlikely that easy generic solutions will be available to reduce the vulnerability of the sites. The general lessons learnt from this analysis are that SSSI dependent on the current hydrological regime are perhaps most vulnerable to the direct impacts of climate change. In addition, those dependent on current land management practices are also vulnerable, as these practices are likely to change dramatically under some socio-economic scenarios, and not necessarily in a monotonic linear fashion. The size and location of the sites then influence the overall vulnerability assessment, with small sites being more vulnerable than large ones, and those in landscapes which are likely to change being more vulnerable than those in landscapes where radical land use change is unlikely, such as on steep slopes. The analysis conducted here was based only on habitat characteristics of the SSSI and not on individual species. The change in species' ranges under a changed climate will tend to exacerbate the vulnerability of many SSSI.

While the case study in the Usk clearly shows the particular problems faced by designated SSSI over the next 50 years, the generic policy assessment also suggests that many aspects of the policy are likely fail (see Table 3.11 for a summary). Given this conclusion, it is apposite to consider what type of policy could be formed in order to meet nature conservation needs over the next 100 years.

As part of developing a relevant and resilient conservation policy, some key questions need to be debated:

- Do SSSI have a future role as areas that are available to be colonised by a changing array of species over time?
- Do we give up the notion of differentiating between native and alien species in conservation policy?
- Do we give up concepts like 'typicalness', as communities are likely to be in a state of change for many years to come?
- Are geological sites resilient to climate change?
- If sites are to be maintained for biological reasons, then do they need to be 'buffered' from changes in the wider landscape? If so, how can this be achieved?
- How should we define favourable conservation status when natural communities and species distributions will be in state of flux?
- Should we designate those areas which will form transitory habitats for species moving across the landscape?
- Are we content to accept the loss of some species due to climate change?
- How do we decide appropriate management for sites when the communities are novel and in a state of change?
- What do we do about species that are likely to be lost within Welsh sites but persist elsewhere in the UK or Europe when prioritising conservation?
- What role should translocation play in nature conservation under a changing climate?

Table 3.11: Summary of the vulnerability of different components of SSSI policy

Policy	Component	Proba-bility of failure	Notes
Nature Conservancy of Great Britain objectives and SSSI criteria	The national total protected areas should be large and varied enough to guarantee the survival of the necessary minimum of Britain's wildlife and physical features.	high	Britain's wildlife will change in composition and distribution over next 20-50 years.
	Criteria for site evaluation include primarily: size, diversity, rarity, naturalness and typicalness; and secondarily: recorded history, position in an ecological/geographical unit, potential value and intrinsic appeal.	medium	Criteria will need restating in light of changed ecological and socio-economic situation.
	Criteria for site evaluation for geological and physiographic features include: representativeness, exceptional features and international importance.	low	Geological features should be more stable than biological ones.
Legal requirement (Section 28(4) of the Wildlife and Countryside Act 1981)	When notifying a SSSI, produce a Site Management Statement (SMS) describing desired management of the land for conservation and enhancement of its flora or fauna or features.	medium	A great deal of uncertainty surrounds management needs on sites and in surrounding areas.
Non-legally obligatory CCW undertakings for preparing management plans for SSSI	Evaluate the condition of the site in terms of favourable conservation status (FCS).	medium	The basis of favourable conservation status will need to be reviewed.
	Set operational limits for factors considered to have positive or negative effects on FCS.	high	Too much uncertainty to set operational limits.
	Define attributes and specify thresholds to use as performance indicators in monitoring.	high	Too much uncertainty to set performance indicators.
JNCC habitat translocation policy for Britain	The use of habitat translocation for habitat restoration should not damage important sites or ancient habitats, and habitat translocation should only take place where it can be shown that there is a net gain for biodiversity conservation.	medium	
Other	Integration with, and effects on, other policies and agreements.	low	No problems in theory.
OVERALL POLICY		**HIGH**	**Future ecological and socio-economic situation is too dynamic and uncertain to enable a static, site-based policy to work.**

While many of these questions may seem intractable when approached from a conceptual level, at a practical level it seems essential that site-based conservation should be viewed as one part of a wider landscape scale approach to nature conservation. Species are already responding to climate by shifting their distributions, but due to the uncertainty of the extent of biophysical and socio-economic changes that will occur under a changed climate, we are unable to determine the location and range of species at any given future time.

For this reason, it is essential that a landscape level approach to conservation is adopted. This will require the integration of strict conservation policy, agricultural and forest policy, agri-environment schemes and urban planning. The need for truly integrative planning for land use and natural resource management will not only be essential to nature conservation, but will also be necessary for other sectors like woodlands (Chapter 5) and water resources (Chapters 6 and 7) and more generally (Chapter 8). Given this need for integration of sectoral policies, it will be important for the stakeholders and institutions from within the UK and across the EU to conduct discussions in as open-minded manner as possible. This may be the most important action that can be taken in the short term.

Along with the integration of planning and policy, several other actions could be undertaken in order to develop a more resilient nature conservation policy:

1. Identify all SSSI designated for species, and consider the likelihood of these species being lost from the site for climate-related reasons. Also consider the likelihood of new species colonising these sites and causing a decline in the species of interest.

2. Identify possibilities in improving connectivity and permeability in the landscape to enable migration of species from their current sites to new locations.

3. Investigate the possibility of using targeted agri-environment schemes to provide the necessary long-term habitat permeability and connectivity.

4. Identify SSSI designated for features dependent on a particular hydrological regime and identify mechanisms of managing the hydrological regime over the long term for the benefit of the SSSI feature. This would require consideration of the surrounding land use and options that may include land purchase, off-site long-term management agreements or the extension of SSSI boundaries.

5. Identify SSSI designated for features dependent on a particular management practice, such as a grazing regime, and consider the implications of a changing climate for the development of an optimal management regime over the long term for the benefit of the SSSI feature.

6. Begin a dialogue with stakeholders and the public on the advantages and disadvantages of developing a landscape level conservation policy.

4 Agri-environment schemes

4.1 Background on policy

During the 1980s, UK and EU agricultural policy shifted from purely providing financial support for the production of agricultural goods, as had previously occurred under the Common Agricultural Policy (CAP), to allowing financial payments to farmers for protecting and enhancing the natural environment. Environmentally Sensitive Areas (ESA) were the first manifestation of this policy, and these offered farmers in certain geographical locations the opportunity of joining the scheme and receiving fixed annual payments for undertaking specific activities on their farms.

During the next ten years more farmers became eligible to apply for ESA support, and the basic concept of agri-environment schemes evolved to include a wide range of other programmes such as Habitat, Moorland and Countryside Access Schemes as well as Tir Cymen. By the end of the 1990s, it had been widely accepted that in order to obtain maximum benefit from agri-environment schemes they should be made available to all farmers, regardless of location. Further, within Wales, farms were often so rich in environmental features it was felt that farmers should be obliged to enter the whole of their farm into the scheme and not just a part of it, as had been possible in the Habitat and Moorland Schemes and early ESA agreements. As a result of this policy evolution, and the simultaneous development of devolved government across the UK, slightly different schemes were developed in England, Wales and Scotland. Within Wales, Tir Gofal (literally translated as 'land care') became available in April 1999. Tir Gofal is a whole farm agri-environment scheme which is menu-based and requires all agreements to reach a minimum environmental standard. Tir Gofal offers farmers annual payments for every hectare of land entered into the scheme and additional capital grants for agreed investment items.

The scheme aims to encourage farmers to maintain and enhance landscape, cultural features and biodiversity as well as provide new opportunities for people to visit the countryside. It simplified this task for farmers by replacing all previous schemes such as Environmentally Sensitive Areas, Tir Cymen and the Habitat, Moorland and Countryside Access Schemes (although existing agreements under these schemes will continue to operate until 2010 in some cases). Tir Gofal operates under the Common Agricultural Policy Rural Development Regulation (EC Reg 1257/99) and is jointly funded by the European Union and the Welsh Assembly. In addition, the scheme was designed to ensure it meets the requirements of UK Biodiversity Action Plans as well as contribute to the enhanced management of the Natura 2000 network of Special Protection Areas (SPA) and Special Areas of Conservation (SAC).

While Tir Gofal has been widely heralded as a successful scheme, budgetary constraints mean that far more applications have been received than can be dealt with in any one year. In addition, farms with a high proportion of improved land have found it difficult to develop applications that met the minimum environmental standards required for entry. So, in order to ensure that a level of environmental enhancement could be obtained across Wales, a second scheme, Tir Cynnal (translated as 'land maintenance'), was introduced in 2005. Tir Cynnal is an entry-level whole farm agri-environment scheme which allows farmers to receive payment for protecting the areas and features of environmental importance on their land. The scheme requires levels of environmental protection that are greater than legal requirements or cross-compliance standards required for receipt of payments under the Single Payment Scheme (SPS), but which are not as comprehensive or demanding as those in Tir Gofal.

A further development of Welsh agri-environment schemes is proposed that will enable those farmers who enter into cooperative arrangements with neighbouring holdings to tackle a range of issues where the action of the group can deliver more benefits than an equivalent number of individuals. Such issues might include control of diffuse pollution, wetland restoration, flood management and dealing with common land. In addition, targeted measures designed to tackle diffuse pollution are being piloted experimentally in the Deepford Brook (Pembrokeshire) and Llyn Tegid (Gwynedd) catchments. It is anticipated that a cooperative land management scheme will follow on from these two-year pilots. However, it is likely that funding will be limited, so the number of localities in which it will occur may be very restricted.

These three types of scheme come together to form what has become know as "the agri-environment pyramid" (Figure 4.1). At the base of this model lie the baseline requirements for entry for which no payments can be made. Above this is the entry level scheme - Tir Cynnal. This seeks to enable a large number of farmers to engage with some level of environmental enhancement at a basic level. The step up from the entry level scheme is the Tir Gofal scheme which enables a limited proportion of farmers to engage in habitat restoration and re-creation, provide new public access and carry out a wide range of one-off capital projects. Finally, at the highest tier lies the cooperative scheme designed to tackle particularly intractable land management problems that can only be dealt with through a landscape scale approach.

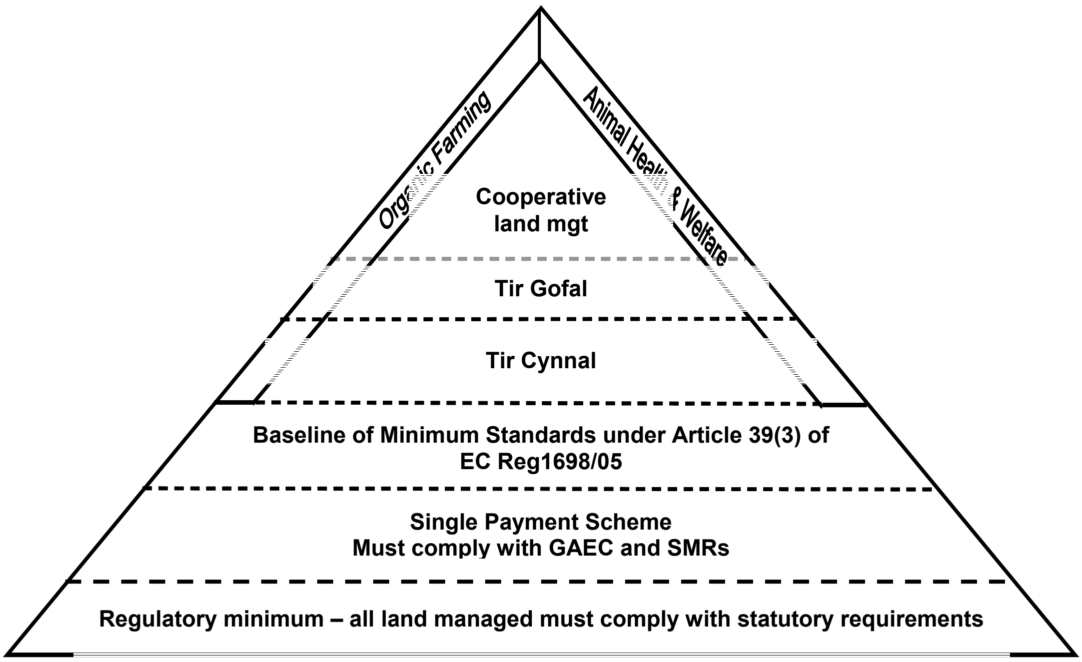

Figure 4.1: The agri-environment pyramid

4.2 Stakeholders involved in developing agreements and their roles

The success of agri-environment schemes hinges on the relationship between the project officers responsible for negotiating agreements and monitoring compliance, and the farmers responsible for carrying out the necessary management. Tir Gofal was developed in 1998 by a working group drawn from a wide range of statutory organisations, NGOs and farming organisations. From 1999, the scheme was managed on a day-to-day basis by the Countryside Council for Wales, although overall control of the scheme remained with the Welsh Assembly Government. This arrangement changed in autumn 2006 when day-to-day management of the scheme transferred to WAG. Project officers also transferred to WAG, but in most cases remained based in CCW offices to ensure a close link with both environmental expertise and datasets. In overall terms, as long as the relationship between project officers and farmers is maintained, there should not be any major issues in terms of delivering the scheme. However, as with all agri-environment programmes, the time-limited nature of the agreements and the long-term funding of the underpinning schemes remains unclear.

Historically, there have been more farmers interested in joining Tir Gofal than there were funds available under the scheme. For example, Tir Gofal attracted just under 5,500 applications during the first four application rounds, and by August 2006 there were just over 3,000 agreements covering 18 per cent of Welsh agricultural land. While this is a substantial proportion of the agricultural land in Wales, it should be noted that there are around 26,000 farms in Wales, of which about 18,000 are felt to be full time enterprises largely dedicated to commercially oriented food production. So even with the current levels of success, it is a minority of farmers in Wales who have sought to engage with Tir Gofal, and fewer still have fully adopted the policy.

Although the influence of Tir Gofal has taken time to develop, beneficiaries are now widespread across the country, with substantial concentrations of holdings and land under agreement occurring in parts of Snowdonia. It is hoped that the Tir Cynnal entry level scheme will be adopted by the majority of farmers and will act as a stepping stone to Tir Gofal.

As part of the draft Rural Development Plan (2007-2013), the Welsh Assembly Government is proposing to make a number of minor amendments to Tir Gofal, in particular where these will assist with delivery of the biodiversity targets set out in the Wales Environment Strategy. Further amendments may take place in 2009 following a fundamental review of all existing Welsh land management schemes, including LFA as well as agri-environment. This review is scheduled to commence in early 2007.

4.3 Methodological summary

For the purposes of comparability across chapters, 'policy' is used to describe all of the resource protection agreements analysed in the report, regardless of whether they are technically classified as 'strategies', 'action plans', 'processes' or 'policies'. We recognise that this is not always technically correct, but it does enable a generic methodological framework to be used across a range of different resource agreements.

The risk assessment of the Welsh agri-environment suite of policies followed the approach outlined in Chapter 2. The pre-analysis work, generic to all policies, was completed prior to undertaking the assessment of the agri-environment policies and followed the structure outlined in Figure 2.1. Unfortunately, the Tir Cynnal entry-level scheme had not been established for long enough to enable analysis within the Usk catchment, while the targeted higher tier scheme had not been established at all in the catchment. So for the purposes of the case study analysis, it was necessary to focus on the Tir Gofal scheme. However, the examination of the policy components was undertaken for all three schemes within the agri-environment programme. The policy assessment work followed the pattern outlined in Table 2.6, and relevant details of the outcomes for each step are reported below.

1. Identify key components of policies to be analysed
The key components of the policy were identified and are shown in Table 4.1.

2. Answer adapted UKCIP risk analysis guidance questions
This was undertaken and the results are shown in Appendix 2 on the accompanying CD.

3. Identify risk exposure units, receptors, thresholds and endpoints
The receptors identified are shown in Table 4.2.

4. Research potential effects of climate change on receptors via survey of scientific literature, experiments, modelling and analysis
This was completed as required when undertaking the receptor risk analysis and is reported on below.

5. Undertake receptor risk analysis
This required an assessment of the vulnerability of each receptor to change under each of the socio-economic scenarios, and in combination with the UKCIP medium-high climate scenarios for 2020 and 2050 as reported in Table 2.9. The full results of this process are available in the Risk Assessment Matrices shown on the accompanying CD.

6. Undertake policy component risk analysis
This analysis also followed the process outlined in Table 2.9 and the full results of this process are available in the Risk Assessment Matrices shown on the accompanying CD.

7. Test the results of the process and use the results to 'climate proof' the policies
This aspect of the risk assessment is specific to each policy analysed, so the remainder of this chapter is dedicated to discussing the methods and results of this process. This begins with a discussion of how the generic risk assessment method was applied to Tir Gofal policy in the Usk catchment, and is followed by an analysis of the risks to the policy components for all three schemes.

Table 4.1: Key components of the Welsh agri-environment schemes as defined in the Risk Assessment Matrices. (Level 3, the cooperative action, was still under development at the time of writing).

Policy	Component
Level 1 Tir Cynnal	Preparation of whole farm resource management plans; Inventory, mapping and protection of environmental features; Compliance with the General Environmental Conditions (based on Tir Gofal whole farm section); Safeguard existing wildlife habitats; Minimum requirement is that at least five per cent of the farm comprises wildlife habitats; Payments and controls.
Level 2 Tir Gofal	Scoring system for assessing minimum environmental standard required for entry to Tir Gofal; Compliance with the whole farm section of Tir Gofal (General Environmental Conditions applicable to all of the farm); Preparation of whole farm resource management plans (likely to be mandatory on new entrants post-2007, but voluntary for existing agreement holders); Mandatory requirement that all existing habitats are managed according to Tir Gofal prescriptions; Optional prescriptions for habitat creation and provision of new public access (but may be essential to do some of these in order to get to minimum threshold score needed for entry); Optional capital works projects such as restoration of traditional field boundaries or fencing for environmental.
Level 3	Cooperative action to address wide range of intractable land management issues (such as diffuse pollution, wetland restoration, flood management, common land or species management); Need for specially trained project officers or facilitators; Interaction with other policies.

Table 4.2: Receptors identified for Welsh agri-environment schemes

Receptors
Broadleaved woodland
Scrub
Orchards/farmed parklands
Upland heath including high mountain heath
Lowland heath
Unimproved acid grassland (enclosed, unenclosed and common land)
Unimproved neutral grassland
Unimproved limestone grassland
Semi-improved grassland (grazing and hay meadow)
Marshy grassland
Blanket bogs
Raised bogs
Reed beds, swamps and species-rich fens
Coastal grazing marsh and floodplain grassland
Salt-marshes: short turf, managed for breeding birds or ungrazed
Maritime cliffs: grazed and ungrazed
Sand dunes
Traditional field boundaries including hedgerows
Peat soils (in relation to peaty habitats such as blanket bog)
Other soils (in relation to Farm Resource Management Plans and specific prescriptions)
Water bodies and rivers
Landscape features
Farm structures
Historical monuments
Crops (in relation to prescriptions relating to prescriptions for less intensive management)
Pests
Land under grazing
Land subject to nitrogen enrichment
Land subject to grazing and nitrogen enrichment
Habitats under prescribed burning
Invasive species – Rhododendron
Invasive species – Bracken
Invasive species – Japanese knotweed
New public access

4.3.1 Applying the risk assessment method to the case of Tir Cymru suite of agri-environment schemes in the Usk catchment

Risk assessment method

The risk assessment for Welsh agri-environment schemes in the Usk catchment followed an eight-step process, illustrated in Table 4.3. Fundamental to this risk assessment were the RAM developed as part of the receptor and policy component risk analyses. These are presented in full on the accompanying CD.

Data availability (Step 1)

The boundaries of farms entered into Tir Gofal were available and were used in analyses. It was not possible to obtain details of the individual Tir Gofal agreements within the timescale of the project, and it was therefore impossible to establish the precise nature of the habitats entered into the scheme. However, by combining farm boundary data with Phase 1 habitat survey data in the catchment, it was possible to estimate the habitats included in the Tir Gofal agreements, and thereby inform the risk assessment of the overall policy.

Table 4.3: Risk assessment procedure for Tir Gofal

Step	Action
1	Get details of Tir Gofal entrants from CCW.
2	Map location of Tir Gofal farms on catchment boundary.
3	Use geographical information system to estimate type and extent of Phase 1 habitat entered into Tir Gofal.
4	Compare proportions of habitat entered into Tir Gofal with the proportions of habitat which occur across the Usk catchment.
5	Use RAM [to assign a level of vulnerability to the habitat type entered into Tir Gofal].
6	Consider the location of Tir Gofal farms in terms of size, location in the catchment and the surrounding land use and comment on the level of vulnerability of the site to change arising from climate and/or socio-economic changes in general, that is, likelihood of land use change, species change, and so on.
7	Summarise the vulnerability of the land entered into Tir Gofal and comment on its value at the catchment scale.
8	Use the results of this process to inform the assessment of the Tir Gofal policy in general.

Manipulating Tir Gofal data (Step 2)

An all-Wales dataset of Tir Gofal agreement holders in 2005 was obtained from CCW. Each agreement was represented by a single database entry of one or more polygons representing the boundaries of the land parcels held within the agreement. The dataset queries were used to identify all Tir Gofal land within the catchment boundary, without disaggregating the original source data.

The results of this analysis show that just over 13 per cent of the catchment land is entered into Tir Gofal agreements (Table 4.4). The distribution of these farms is not uniform across the catchment, with those sub-catchments at the top of catchment tending to have proportionally more land entered into Tir Gofal than those at the bottom of the catchment (Table 4.4, Figure 4.2). This type of distribution, where more land of poor quality is entered into conservation agreements than good quality land, is commonly observed across the world (Hazen and Anthamatten, 2004; Oldfield *et al.,* 2004). This tends to occur because conservation is seen by many landowners, be they farmers or governments, as a 'second best' land use. In other words, if the land has very few productive alternatives then it can be used for conservation without accruing too many opportunity costs. For this reason, in many countries national parks are situated in unproductive land, like mountains and deserts, and similarly very few farmers plant trees in their best field. Only when conservation offers a better financial return than the most profitable use of land will the landowner make conservation the 'first best' use. Over the last five years, Tir Gofal payments have been rather more attractive to sheep and beef farmers, who tend to farm the worst land, typically in the uplands, but not so attractive to dairy and arable farmers who tend to occupy the better land lower down catchments.

Table 4.4: Area and distribution of land entered into Tir Gofal in each sub-catchment

Sub-catchment	Area of sub-catchment (ha)	Area in Tir Gofal (ha)	Proportion (%) of sub-catchment in Tir Gofal
1	3,922	599	15.2
2	10,667	606	5.7
3	21,258	1,741	8.2
4	8,645	45	0.5
5	3,793	365	9.6
6	9,141	1,126	12.3
7	11,147	1,779	15.9
8	5,355	244	4.5
9	6,344	1,332	21.0
10	13,236	1,895	14.3
11	18,202	5,129	28.2

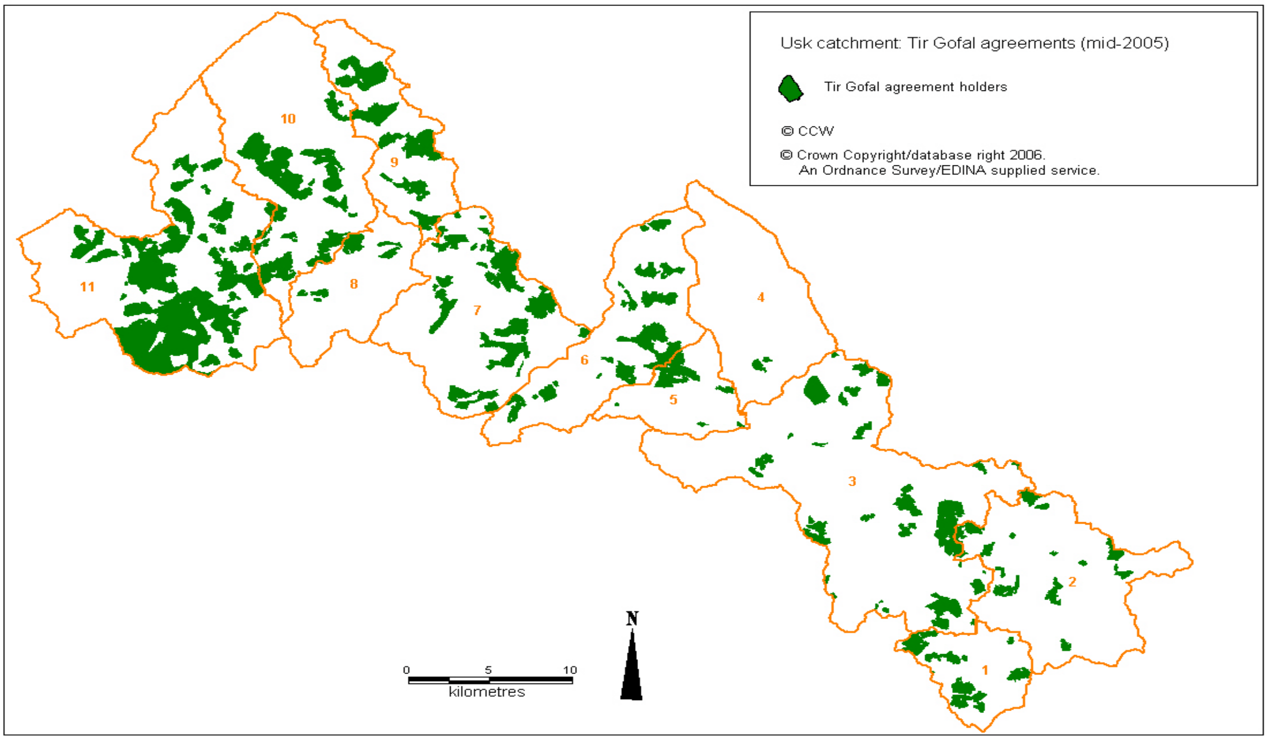

Figure 4.2: Tir Gofal agreements in the Usk catchment

Use geographical information system to estimate type and extent of Phase 1 habitat entered into Tir Gofal (Step 3)

The resultant Usk Tir Gofal boundary data were used to create a subset of the Usk Phase 1 habitat data using a 'cookie cutter' approach. The Phase 1 data were split using the boundaries, then refined by subsequently erasing any geographic entities outside the Tir Gofal boundary polygons. Tables were then updated to reflect the Cartesian areas of the constituent Phase 1 habitat polygons. A SQL query was used to sum the areas of the different Phase 1 types and report the areas by order of the classes found.

Compare proportions of habitat entered into Tir Gofal with the proportions of habitat which occur across the Usk catchment (Step 4)

There are several limitations with this approach which may lead to some inconsistent results. Firstly, while Phase 1 habitat data forms the basis of many landscape analyses, it is unclear how accurate these data actually are. Uncertainties arise as Phase 1 data have been collected consistently since the late 1980s, so it is possible that land use could have changed since some of the older data were collected. In addition, there may be errors in the classification of habitats, as not all land was accessed directly by surveyors and was thereby assessed from a distance. Unfortunately, no measures of confidence are attached to each parcel of land in the Phase 1 habitat maps, and so it is not possible to identify which parcels are more or less likely to be accurately classified. Given the existence of these potential sampling errors, it is possible that the Phase 1 maps do not offer an accurate representation of all on-farm habitats. These issues need to be borne in mind when considering any analysis based on Phase 1 habitat data.

The type and proportion of Phase 1 habitats within the Tir Gofal farms were compared with the type and amount of Phase 1 habitat within the entire catchment (Table 4.5). Not only are there fewer habitats on Tir Gofal farms than occur in the entire catchment (39 compared with 59), but also they are not in direct proportion to their occurrence. For example, planted coniferous forest covers 6.4 per cent of the catchment but only 1.9 per cent of Tir Gofal farms. This result is not surprising given that most planted coniferous forest occurs in specialised forests outside farm holdings. However, it is interesting to note that bracken, scrub, dry acid heath, dry modified bog, unimproved acid grassland and wet heath/acid grassland mosaic are proportionately under-represented in Tir Gofal. Conversely, improved grassland, semi-improved acid grassland and marshy grassland are all more common on Tir Gofal land than in the catchment as a whole.

There are good reasons why on-farm conservation is unlikely to be a perfect representation of the surrounding landscape. In the case of Tir Gofal, some of these relate to the complexities of entering common land into the scheme, and this may explain the under-representation of habitats such as heathland in the Tir Gofal farms. Also, not all land is farmed and therefore is not eligible for entry into Tir Gofal. Further, it is not surprising that habitats on farms are unrepresentative, as Tir Gofal applications are based on farmer interest in the scheme and for this reason alone, they are very unlikely to form a representative sample.

Vulnerability analysis (Step 5)

Within the case study area, only 9.9 per cent of the habitat currently entered into Tir Gofal is classified as having a medium-high vulnerability to climate change (Table 4.6). Just over 12.5 per cent has medium vulnerability and 64 per cent has low vulnerability. This reflects the fact that improved grassland is the most frequently occurring habitat in Tir Gofal in this part of Wales, and it has a low vulnerability under all socio-economic scenarios (Table 4.7). While Tir Gofal does support a wide range of other grasslands, most have medium vulnerability. The exception is marshy grassland, which has a medium-high vulnerability under most socio-economic scenarios (Table 4.7). Approximately 36 per cent of the catchment's marshy grassland is entered into Tir Gofal. However, only 10 per cent of wet heath, which has high vulnerability, is entered into Tir Gofal. Taken together, these results do not suggest that Tir Gofal will provide protection for many of the most vulnerable habitats in the Usk catchment. This underlines the need for agri-environment schemes to be developed in an integrated manner with other conservation instruments, to ensure adequate protection of all valuable habitats.

Table 4.5: The type and amount of Phase 1 habitat which occurs a) within the whole of the Usk catchment and b) within the Tir Gofal farms which lie within the catchment. Habitats comprising less than 30 hectare within the catchment have been put together in the 'other' category.

Habitat type	**Whole catchment**		**Tir Gofal**	
	Area (ha)	**%**	**Area (ha)**	**%**
Acid/neutral flush	292	0.28	8.09	0.08
Amenity grassland	344	0.33	4.61	0.05
Arable	4,555	4.43	544.90	5.38
Blanket bog	197	0.19	0	0
Bracken	5,710	5.55	154.62	1.53
Buildings	2,047	1.99	66.08	0.65
Dense scrub	256	0.25	19.87	0.20
Dry acid heath	5,074	4.93	7.58	0.07
Dry heath/acid grassland mosaic	1,723	1.68	22.45	0.22
Dry modified bog	1,255	1.22	4.63	0.05
Felled broadleaved woodland	42	0.04	3.52	0.03
Felled coniferous woodland	100	0.10	1.56	0.02
Gardens	100	0.10	1.71	0.02
Improved grassland	46,901	45.60	6,286.65	62.08
Marshy grassland	814	0.79	296.96	2.93
Marshy grassland (Molinia dominated)	1,909	1.86	661.24	6.53
Not accessed	798	0.77	42	0.42
Other habitats	248	0.24	6.84	0.07
Other rock exposure	121	0.12	2.83	0.03
Planted broadleaved woodland	335	0.33	23.52	0.23
Planted coniferous woodland	6,601	6.42	193.06	1.91
Planted mixed woodland	265	0.26	45.08	0.45
Quarry	36	0.03	0	0
Running water	675	0.66	40	0.40
Semi-improved acid grassland	1,165	1.13	261.	2.58
Semi-improved neutral grassland	1,753	1.70	227.	2.24
Semi-natural broadleaved woodland	5,298	5.15	697.	6.89
Spoil	207	0.20		0
Standing water	209	0.20		0.03
Tracks	99	0.10	17	0.17
Unimproved acid grassland	12,852	12.50	441.	4.36
Unimproved calcareous grassland	197	0.19		0.02
Wet heath	222	0.22	22	0.22
Wet heath/acid grassland mosaic	331	0.32		0.04
Wet modified bog	128	0.12	11	0.11
TOTAL	**102,860**		**10,127.40**	

Table 4.6: Area of each habitat in Tir Gofal grouped by habitat vulnerability. 'Other habitats' are comprised of: tracks (not comprehensively digitised), buildings, planted coniferous woodland, not accessed land, felled coniferous woodland, bare ground, acid/neutral rock, gardens, amenity grassland, caravan site, other rock exposure and arable.

Vulnerability	Habitat type	Area (ha)	%
High	Wet heath	22.50	0.22
Low	Bracken	154.62	1.53
Low	Dense shrub	19.87	0.20
Low	Ephemeral/short perennial	0.09	0.00
Low	Tall ruderal herb	0.75	0.01
Low	Improved grassland	6,286.65	62.08
Low to medium	Semi-improved acid grassland	261.12	2.58
Low to medium	Semi-improved neutral grassland	227.33	2.24
Medium	Semi-natural broadleaved woodland	697.85	6.89
Medium	Felled broadleaved woodland	3.52	0.03
Medium	Semi-natural mixed woodland	0.24	0.00
Medium	Planted broadleaved woodland	23.52	0.23
Medium	Acid/neutral flush	8.09	0.08
Medium	Planted mixed woodland	45.08	0.45
Medium	Basin mire	2.07	0.02
Medium	Wet heath/acid grassland mosaic	4.41	0.04
Medium	Dry acid heath	7.58	0.07
Medium	Dry heath/acid grassland mosaic	22.45	0.22
Medium	Swamp	1.62	0.02
Medium	Dry modified bog	4.63	0.05
Medium	Wet modified bog	11.40	0.11
Medium	Fen	0.57	0.01
Medium	Unimproved acid grassland	441.38	4.36
Medium to high	Marshy grassland	296.96	2.93
Medium to high	Running water	40.84	0.40
Medium to high	Marshy grassland (Molinia dominated)	661.24	6.53
Medium to high	Unimproved calcareous grassland	2.11	0.02
Medium to high	Standing water	2.89	0.03
n/a	Other habitats	876.05	8.66

Table 4.7: Vulnerability of semi-improved grassland and marshy grassland under four scenarios in 2020 and 2050

Receptor	Scenario			
	National Enterprise & climate change	**Local Stewardship & climate change**	**World Markets & climate change**	**Global Sustainability & climate change**
2020				
Semi-improved grassland (grazing and hay meadow) (%)	Low-medium: low vulnerability to climate changes of 2020.	Low vulnerability to climate changes of 2020.	Low-medium: decrease under socio-economic scenarios but low vulnerability to climate changes of 2020.	Low-medium: decrease under socio-economic scenario but low vulnerability to climate changes of 2020.
Marshy grassland (%)	Medium-high: decrease due to socio-economic changes and vulnerable to summer drought.	Medium: slight increase due to socio-economics but vulnerable to summer drought.	Medium-high: decrease due to socio-economics and vulnerable to summer drought.	Medium-high: decrease due to socio-economics and vulnerable to summer drought.
2050				
Semi-improved grassland (grazing and hay meadow) (%)	Medium: decrease due to socio-economics; more vulnerable to climate changes of 2050.	Medium: slight increase due to socio-economics but increased vulnerability to climate changes of 2050.	Medium: decrease due to socio-economics; more vulnerable to climate changes of 2050.	Medium: decrease due to socio-economics; more vulnerable to climate changes of 2050.
Marshy grassland (%)	Medium-high: decrease due to socio-economics and vulnerable to summer drought.	Medium-high: slight increase due to socio-economics but vulnerable to summer drought.	Medium-high: decrease due to socio-economics and vulnerable to summer drought.	Medium-high: decrease due to socio-economics and vulnerable to summer drought.

4.4 Policy analysis

4.4.1 General comments

The Welsh agri-environment schemes have many features which should make them resilient to climate change. Chief among these is the ability to manipulate the management prescriptions according to both the ambient environmental situation and society's objectives. While the ability to change these prescriptions is a major strength of the policy, it does assume that policy makers know enough about the current and future environmental situation to be able to make rational judgements. Given that climate change will bring about environmental situations which are beyond our previous experience, maintaining a good evidence base on which to base environmental prescriptions will be a major challenge for this type of policy.

A second factor which will affect on the ability of this type of policy to perform in the future is related to society's desire to fund conservation objectives. Under the scenario of National Enterprise particularly, society will be less motivated to fund conservation activities than now. If funding is removed from agri-environment schemes, it may not be possible to get landowners to engage with the policy voluntarily, particularly in the higher tier schemes. Not only is sufficient funding required to pay farmers for environmental enhancement, but also funding is necessary to maintain the staff and institutions which support the schemes. Well-motivated, knowledgeable staff would seem essential for the effective delivery of this type of policy.

The issue of identifying adequate reward to farmers is linked to the market price they receive for their goods. This also is uncertain and varies between scenarios. So if this type of policy is to adapt to future challenges, then both management prescriptions and funding will need to be reviewed and updated regularly. This will require the conservationists to regularly consider what the actual conservation aims of the policy are over a given time period. As noted in Chapter 3 dealing with SSSI, the impacts of climate change may bring about a radical change in the underlying philosophy of nature conservation. This in turn may need to be reflected in the practical work undertaken on farms. In addition, the business of farming will also change with a changed climate. Not only will agricultural practices change and be adapted, but also the returns the farmer receives from different enterprises will also alter over time. History suggests that agricultural practices can change quite fast when the need/opportunity arises. It often takes time for environmental scientists to then fully understand the impacts of the changed system on the environment, and even longer to devise a means of mitigating any unwanted effects. For example, it could be argued that the agri-environment schemes we now have in place across the UK are well suited to mitigate the land intensification problems of the 1980s, but are not so well suited to mitigate the changes that may arise in the short term from CAP reform and in the long term from climate change.

A final general point relates to location of participating farms in the wider landscape. Because of the manner in which farmers apply for and are accepted onto the schemes, to date there has been no ability to target their location in the landscape. The higher level scheme of the Welsh agri-environment schemes should encourage cooperative action among farmers and enable targeting of environmentally sensitive areas with specific diffuse pollution or conservation management problems, and thereby partially rectify this situation. However, given the movements of species in response to climate change, it may be prudent to pay more attention to the location of Tir Cymru farmers in the landscape, and to actively target farmers and other landowners in certain areas to undertake specific management activities, to achieve a network of well-managed habitats that improve the permeability of the landscape for wildlife. The proposed cooperative land management scheme could have an important role in this respect. The interaction of this concept with other policies is discussed further in Chapter 8.

4.4.2 Specific comments on the policy components

Tir Cynnal – the entry level scheme

Preparation of whole farm resource management plans

This activity is fundamental to the development of a plan to protect and enhance the environmental resources on farms. However, the action itself is unlikely to be affected directly or indirectly by climate or socio-economic change. For this reason, it is felt to have a low vulnerability under all future scenarios.

Inventory, mapping and protection of environmental features

The inventory and mapping activities within this component are generic and should not be directly or indirectly affected by climate or socio-economic change. However, the protection of environmental features will be substantially affected by climate change. Species distributions will change and the composition, relative abundance and structure of many ecological communities will also change. So any assessment of the vulnerability of the 'protection of environmental features' policy component depends on the definition of the word 'protection'. If, as is largely the case for Tir Cynnal, farmers are simply required not to cause damage, then as long as damaging activities can be identified this component should not be vulnerable under climate change. However, the Tir Gofal and higher level schemes which require farmers to follow specific prescriptions designed to maintain habitat in favourable condition or bring about environmental enhancements, will suffer from the same problems inherent in trying to preserve the habitat or species status within SSSI according to their original condition.

These problems relate to the changing nature of natural communities under climate change. There is good evidence that many species are shifting their range in response to climate (Hickling *et al*., 2005; Hughes, 2000; Parmesan *et al*., 1999). So if a site was managed in order to protect a particular species, then it is possible that the species may either emigrate away from the site, or be competitively excluded by some other species which disperses into or increases in abundance on the site due to climate related factors, undermining the basis on which the site was managed. For this reason, it is important that the rationale for conservation management is well thought out and is not aimed at the protection of a species which will naturally emigrate from the area over time.

In view of this, one of the possible purposes of future agri-environment schemes would be to enable connectivity to be developed within the landscape. One way to achieve this would be to use agri-environment schemes to create habitat corridors or stepping stones through which individuals may disperse while they seek a more permanent habitat. A complementary approach would be to engage in landscape level planning so that agri-environment schemes helped to increase the 'permeability' of a landscape, where permeability is defined as "the quality of a heterogeneous land area [a landscape] to provide for passage of animals" (Singleton *et al*., 2002).

In the context of managing climate change, these approaches may be combined in order to develop 'corridors of high permeability'. Here, rather than seeking a corridor composed of one solid habitat type, certain areas of land are managed to maintain high permeability for certain species types. Within this concept, the targeted use of agri-environment schemes could be integrated with the suite of sites already designated for conservation (SSSI, SAC and so on) in order to provide a landscape level solution.

A separate issue relates to social perception of the environment, the willingness of society to continue to fund such activities and the interaction of these concerns with the natural environment. For example, under the National Enterprise scenario, society will have low environmental concern and is unlikely to require maintenance of environmental features. So, perhaps counter-intuitively, the vulnerability of this particular component is low. This is because it is unlikely to fail the societal expectation placed upon it. However, under a scenario of Local Stewardship the vulnerability is low-medium as society will require maintenance of environmental features, but the impacts of climate change are such that the policy component may fail to meet societal expectations; that is, its environmental features will change and will not be protected in their original state.

When viewed across all scenarios, the vulnerability for this particular policy component ranges from low to medium in 2020 and low to high in 2050 (for further details see Appendix 3 on accompanying CD). However, the redefinition or greater flexibility in terms of the objective for 'protection of environmental features' could reduce these vulnerabilities considerably, by accepting that climate change will lead to a different matrix of habitats and species. But the failure of the policy to maintain marshy grassland or other vulnerable habitats leads to the conclusion that this policy component is likely to be vulnerable, even if the policy objective adapts to a changing climate.

Compliance with entry level general environmental conditions of the Tir Gofal whole farm section

The vulnerability of this policy component to climate change is low for most scenarios. This is because it is largely concerned with ensuring farmers are compliant with rules to prevent damage to the environment. As long as these activities are known and communicated with farmers, it should be possible to ensure compliance.

However, the list of permitted activities should be reviewed, as there is the potential for some actions currently listed to interact with other environmental changes. For example, under the World Markets scenario, upland heather and moorland decrease in area in Wales, while the amount of lowland heathland is stable. If the requirement to enable access to walkers in areas of upland moorland remains in place in 2020 and 2050, then there is the possibility of walkers causing damage to a diminishing habitat type. The possibility of fires also increases in this scenario. Generally, however, a constant review of the prescriptions should ensure a low vulnerability for this policy component.

Core scheme objective: safeguarding wildlife habitats defined in the Environmental Impact Assessment Regulations by not damaging the habitats through agricultural activities

This policy component requires farmers not to damage wildlife habitats, rather than to manage them to ensure their persistence. For this reason, as long as wildlife habitats are defined and the damaging activities for each can be identified, the vulnerability of this policy component is low under all scenarios.

Ensure at least five per cent of the farm comprises wildlife habitats

Assuming this flexibility in the definition of wildlife habitats is maintained, the vulnerability of this policy component under all future scenarios is low.

Payments and controls

There are two key issues concerning the payment rate for farmers and the cost of monitoring and assessing the delivery of the scheme.

Currently, farmers get a payment for every hectare entered into Tir Cynnal (although the payment per hectare is tapered in order to avoid over-compensation on larger farms). The possibility of continuing to be able to offer this payment depends on society's desire to offer support for this type of activity and the level of payment farmers would need to be induced to adopt the scheme. These two factors vary with scenario. For example, under a scenario of Global Sustainability, society is willing to make large investments into agri-environment schemes, but under National Enterprise the opposite is true. However, the value of agricultural goods will tend to be greatest under Local Stewardship and least under National Enterprise (see Table 2.5 in Chapter 2). So under a scenario of National Enterprise the level of payments will probably be small, but this may be acceptable as the value of the agricultural outputs will be lowest in this scenario. However, given the fluidity in market prices and general agricultural policy, it is impossible to predict the relative sizes of the actual and required payment with any precision at this time. Because of these complex interactions the vulnerability of this policy component varies with scenario, and ranges from medium-high under National Enterprise to very low under Global Sustainability.

There is also a general desire to keep running costs of entry level schemes low, and not to offer any support to farmers who participate at this level. There should be no direct impact of climate on this policy component, hence its vulnerability may be thought of as low. However, one generic problem with this policy component relates to the need to monitor change and maintain flexibility in responses. The Tir Cynnal agri-environment scheme is available across Wales, so some level of monitoring will be needed over the medium term to ensure delivery of outcomes and facilitate adaptation to many factors, including changes in farmer behaviour and climate change. Unless this occurs, policy makers will be ignorant of the effects of changing climate and will be unable to develop adequate policy responses. This situation is most acute under the National Enterprise scenario, where there is very little investment in agri-environment schemes in general. This then increases the potential of change going unnoticed, which in turn puts the viability of the whole policy in doubt.

Tir Gofal – the whole farm scheme

Scoring system for assessing minimum environmental standard for entry into Tir Gofal

In theory, the means by which farmers qualify for entry into Tir Gofal can be modified regularly. This would simply require that any system for assessing potential entries was updated and reflected changing priorities in relation to climate change (for example, the provision of certain habitats might decrease in some area and increase in others). However, whether or not any such review would be adequately conducted depends on the overall level of investment in agri-environment schemes. As investment is likely to be lowest in a situation of National Enterprise, it is under this scenario that the policy component is most vulnerable and it is least vulnerable under Local Stewardship and Global Sustainability. This holds true for 2020 and 2050.

Compliance with the general environmental conditions applicable to the whole farm

As mentioned above, the vulnerability to climate change for this sort of activity is low across all scenarios.

Implementation of the Farm Resource Management Plan

This policy component is currently voluntary for participating farms, but is likely to be mandatory for those entering from 2007 onwards. The development of a plan should not be affected by climate change. However, implementation of the plan may be affected in several ways. Firstly, the level of support for, and investment in, agri-environment schemes will vary between socio-economic scenarios. So under a scenario of Global Sustainability there is likely to be high investment in agri-environment schemes, which in turn should lead to well-informed stakeholders and a significant investment in farmers' adaptive capacity. In this scenario, the vulnerability of implementing the plans would be lower than under the National Enterprise scenario, where we would expect to see very low investment in agri-environment schemes.

In addition to adequate investment, it is also important to have sufficient knowledge about the actual and future impacts of climate change on the environment in order to inform plan development and implementation. This level of knowledge is particularly relevant to the development and implementation of Farm Waste Plans, as they will need to take note of altered patterns of rainfall and the risk of flooding, drought effects on pollution and access to land. Similar issues are relevant to the Soil and Nutrient Management Plan, and particular note will need to be taken of the impact of climate on nutrient dynamics, soil erosion and poaching. While the two plans are similar in these respects, the issues covered by the Farm Waste Plan are more likely to be solved if adequate investment is available, than those pertaining to the soil and nutrient plan. This difference simply reflects the more 'point source' nature of farm wastes compared with the more diffuse soil and nutrient issues.

The Pesticides Management Plan is subject to the same issues of investment as the other two plans. High levels of investment should lead to better implementation, and there will also be a requirement to have knowledge of both emerging pest problems and the impacts of changed climate on potential pollution incidences.

Mandatory requirement that all existing habitats are managed according to Tir Gofal prescriptions

Many of the issues related to this policy component have been discussed under the Tir Cynnal policy components above. Basically, if management prescriptions are rigid then they are unlikely to be suited to a changed environment. Persistence with inappropriate prescriptions in a changing world effectively transforms an agri-environment scheme into a site-based scheme, which then becomes subject to the problems discussed in the chapter on SSSI. Unfortunately, within current agreements there is little flexibility for short-term change, as prescriptions are agreed over a five or ten-year period. At the moment, it is unclear whether there will be the potential to continue in a similar agri-environment scheme after the ten-year period is complete. It is therefore crucial that those involved in planning and running the scheme are very clear about the types of environmental management they want to promote. Given our current lack of understanding about the impacts of climate change, it is hard to state management prescriptions that farmers may need to follow in the future. It is also highly likely that different prescriptions will be needed in different locations.

While in theory a system such as Tir Gofal with five-yearly reviews has the flexibility to respond to the changing needs of climate change, in reality it will be hard to identify these needs ahead of time. For these reasons, the actual flexibility of the policy structure with built-in reviews has a low vulnerability, but the overall effectiveness of the policy will depend on the details of the management prescriptions provided.

Optional prescriptions for habitat creation and provision of new public access

In addition to the mandatory management required in Tir Gofal, there is a range of optional activities farmers can choose to engage with. The same sets of issues relate to these as to the mandatory options and revolve around adequate investment and appropriateness of the management prescriptions. The interaction of these factors serves to alter the vulnerability from high under National Enterprise to low in Local Stewardship and Global Sustainability.

Optional capital works projects such as restoration of traditional field boundaries or fencing for environmental reasons

The vulnerability of this policy component is subject to the same influences as the optional management activities.

Training programme for agreement holders

This component is vulnerable to the political attitude to training. If the resources are available, then this component should continue with little difficulty. However, it will be more vulnerable under National Enterprise and World Markets than Local Stewardship and Global Sustainability.

Proposed higher tier scheme

Cooperative action

There is likely to be a greater need for landowners to cooperate in order to develop the flexible range of responses necessary to protect the environment under a changed climate. In a strict sense, the policy component itself should not be vulnerable to climate change; that is, it will still probably be valid to ask farmers to cooperate in 2050. However, it is unclear whether or not they will be more or less willing to cooperate than they are now. It could be that if climate effects and socio-economic conditions make farming more difficult than now, then this may influence cooperative actions one way or the other. Also, it could be argued that under the scenarios of Local Stewardship and Global Sustainability there will be a prominent social 'ethos' of cooperation, which may be reflected in farmers' willingness to cooperate formally and informally.

Training of local project officers

The training of local project officers, particularly arming them with knowledge of climate change effects and adaptive strategies, appears to be a key mitigation factor for the negative effects of climate change and potential policy failure. The vulnerability of this component relates almost entirely to the social and financial support available for agri-environment schemes, so it is more vulnerable under National Enterprise and World Markets than Local Stewardship and Global Sustainability.

Interaction with other policies

There is no fundamental reason why the agri-environment schemes should not interact in an integrated and constructive manner with other relevant policies. Indeed, as discussed in Chapter 8, such an interaction may be essential if significant levels of environmental protection and enhancement are to be achieved.

4.5 Discussion and climate proofing

A summary of the above discussion and a qualitative assessment of the probability of failure of each component of the Welsh agri-environment schemes is shown in Table 4.8.

The basic nature of the Welsh suite of agri-environment schemes renders it potentially adaptable to climate change. The key features which offer this adaptive capacity are:

- flexibility in deciding on criteria for entry to the schemes;
- flexibility to alter the management prescriptions required by farmers;

- regular review of the management prescriptions overall;
- regular review of the performance of each individual farmer.

The features which will tend to increase vulnerability are:

1. The inherent voluntary nature of the schemes and turnover of participants. At the end of their agreement some farmers may choose not to re-enter an agri-environment scheme. Indeed, under some future scenarios there may be none available. For this reason it is hard to plan a landscape level environment strategy, when there is a chance that some of the participants will move in and out of the scheme over time. While the voluntary and fixed-term nature of agri-environment schemes seem to be essential at a practical level, this also works against using agri-environment schemes when planning any long-term landscape level strategy.

2. The possibility of improved agricultural incomes. The voluntary nature of agri-environment schemes means that their financial attraction to many farmers depends on their profitability relative to other land uses. Over recent years the traditional farm subsidies have declined in value, and this has occurred at the same time as the world market price for many food commodities has also declined. For this reason, over the last five years the financial incentives for engaging in agri-environment schemes have seemed quite attractive relative to other land uses. But this may not always be the case. For example, over the last 18 months there has been serious discussion about the development of various land uses related to energy production such as biomass and biofuels. If these biofuels are to provide substitutes for fossil fuels, then significant areas of land will need to be diverted from food production to fuel production. This will inevitably reduce the supply of food or suck in imports. Under the former scenario, the impact on farm gate prices may reduce the relative financial attraction of agri-environment schemes relative to production-related activities, and farmers may show less interest in volunteering for agri-environment schemes. Alternatively, since under WTO rules all agri-environment payments are based on income forgone, an increase in farm profitability could lead to an increase in agri-environment payment rates. With fixed budgets, this would inevitably lead to less land being maintained under agri-environment prescriptions.

3. Lack of monitoring on farms. As the composition and structure of ecological communities may change with climate change, standard management prescriptions may not have the expected impacts. If regular wide scale monitoring does not occur, these changes may go unnoticed. This would mean that certain management practices may continue even when their outcomes are suboptimal.

4. Lack of understanding of the impacts of climate on ecology and environment. If scientists are unable to predict the impact of a particular management prescription on a given habitat, then the logic of setting management prescriptions becomes meaningless. For this reason, there will be a need to undertake continued research on the impacts of given management prescriptions on key habitats. The failure to develop such an understanding will jeopardise the policy.

5. Lack of understanding of changing farming practices and profitability. Welsh agri-environment schemes offer payments to farmers in return for the adoption of environmentally beneficial practices. If the policy is to remain voluntary, but be adopted by enough farmers to have an impact at the national level, then payments need to be set at an appropriate level. In addition, farming practices may change in direct response to climate, such as altered timing of silage cutting and stock movements, and also in response to market conditions, such as increased demand for local vegetables. The

continued success of agri-environment schemes will require regular reviews of payment levels and also of farming practice and its interaction with the environment.

6. Lack of investment and political support. Agri-environment schemes are dependent on social and political support. This support is important in defining the structure of agri-environmental policy relative to other CAP policies such as the Single Payment Scheme (SPS), and in particular the balance to be struck between regulation (such as cross compliance, which defines the activities required as a condition of receiving another form of subsidy such as SPS) and incentives. Political support is also important in defining the level of financial support available to run and support the scheme. Finance is needed to pay farmers for their participation in the scheme, provide training, fund the provision of staff and IT systems, monitor both compliance with prescriptions and the eventual environmental outcomes as well as carry out relevant research designed to ensure that prescriptions are fit for purpose. The level of investment available will depend on the level of social and political support.

7. Lack of coverage of key environmental features. It is important to note that no single agri-environment scheme is likely to be able conserve all key species and habitats. As shown in Table 4.5, in the early years of Tir Gofal the application of the scheme within the Usk catchment conserved particular subsets of habitats. Other means need to be found to conserve the kind of habitats which tend to be under-represented in schemes such as Tir Gofal, either by designing complementary agri-environment schemes or by combining voluntary schemes with a mix of regulatory measures and market-based approaches designed to ensure that farmers receive a premium price for products which are produced in an environmentally beneficial way.

In order to ensure the continued success of the policy, attention needs to focus on the above points. The most important of these relates to maintaining investment in the operation of, and support for, the scheme.

Table 4.8: Summary of the vulnerability of different policy components of the Tir Cymru agri-environment schemes

Policy	Component	Proba-bility of failure	Notes
Level 1 Tir Cynnal	Preparation of whole farm resource management plans	Low	This activity is not affected by climate
	Inventory, mapping and protection of environmental features	Medium	Less likely to fail if the ‘protection’ aspect is treated flexibly
	Compliance with Entry-Level General Environmental Conditions of the Tir Gofal whole farm section	Low	No problems
	Core scheme objective: safeguarding wildlife habitats defined in the Environmental Impact Assessment Regulations by not damaging the habitats through agricultural activities	Low	The only issue relates to understanding the nature of ‘damage’ in a changed environment
	Ensure at least five per cent of the farm comprises wildlife habitats	Low	So long as definitions of habitats are kept flexible, the risk of failure is low
	Payments and controls	Low to medium-high	The ability to maintain payments depends on society’s view of conservation
Level 2 Tir Gofal	Point system for assessing eligibility to Tir Gofal	Medium to high	Ability to modify the scheme will depend on knowledge and level of investment
	Compliance with the general environmental conditions not covered in Level 1 (Tir Cynnal)	Low	No problems
	Implementation of the Farm Resource Management Plan	Low to high	Success will depend on knowledge and level of investment
	Mandatory management following prescriptions set out in Tir Gofal scheme of land and habitats	Low to high	Success will depend on knowledge and level of investment
	Optional capital activities as detailed in annexes	Low to high	Success will depend on knowledge and level of investment
Level 3	Cooperative action	Low to high	The likelihood of farmers cooperating may vary with socio-economic situation
	Training of local project officers	Low to high	Investment depends on social values at the time
	Interaction with other policies – CAP, Organics and SSSI	Low	Should not be a problem, and may be essential

5 Woodlands and biomass

This chapter deals with two related policies, those concerned with woodlands and biomass. While there are clearly very close links between these issues at practical and land use levels, they come from very different policy backgrounds. For this reason, policy analyses and risk assessments for both these sectors are reported here in parallel, and then brought together at the end of this chapter and again in Chapter 8.

5.1 Background on forest and woodland policy

Traditionally, forest policy has used a combination of regulatory controls and financial incentives. Felling licences and tree preservation orders control the felling of trees, whilst forestry and woodland grant schemes, forest plans (for the private sector) and forest design plans (for the national estate) serve as the principal mechanisms for granting forestry approvals and supporting economic, community and recreational activities. While these incentives continue to evolve, a recent strategy document published in 2001, *Woodlands for Wales*, lays out the vision for the national forest estate and also for how private forestry should develop. This document reflects a changed vision for forests and woodlands and it places greater emphasis on multi-purpose woodlands managed for recreation, landscape and wildlife, as well as for timber production. As such, the current strategy is the latest manifestation of a gradual movement in the attitudes and emphasis of the forest industry. For example, the Forestry Commission has not been actively acquiring land for afforestation for some time, and there is very little new planting on Forestry Commission land (Munday and Roberts, 2001).

However, while the rate of new national investment in growing conifers may have decreased, there has been increasing interest in developing the woodlands which exist on private land, including farms. This is evidenced by increased financial support for broadleaved woodlands in Wales, and investment in the marketing and development of their products (Coed Cymru, 1997). This segment of the market seems likely to grow over the next few years, along with other forms of production from private forests, where new planting of trees has continued in recent years (Munday and Roberts, 2001).

5.1.1 Forestry in Wales

Currently, about 14 per cent of Wales's land area is covered in trees. Of this, about 48 per cent are planted with coniferous species and 37 per cent with broadleaf, with the remainder being mixed (National Inventory of Woods and Trees, NIWT, 2003) About 56 per cent of this land area is in private ownership, with the rest being owned by the National Assembly for Wales (NIWT, 2003). These woodlands are still partly managed for timber, and 800,000 cubic metres of wood were harvested from the Forestry Commission estate in 2004. At present, there are around 1,750 businesses directly involved in forestry in Wales and around 500 secondary processing industries. The industry has a revenue turnover of over £2 billion per year.

5.1.2 Biomass energy

Biomass energy is a general term which describes fuel based on organic matter. Generally, the energy resources covered by the term 'biomass energy' are wood and co-products (broadleaf and coniferous), energy crops such as short rotation coppice and energy grasses like elephant grass (*Miscanthus*), switch grass and reed canary grass.

In response to UK commitments under the Kyoto Agreement, the UK government has set a target of generating 10 per cent of the electricity supply from renewable sources by 2010. The Welsh Assembly Government (WAG) has an obligation under devolution legislation to implement the UK's international greenhouse gas abatement commitments. Wales, therefore, must contribute towards the UK government's target. This commitment is in line with general political support for clean technologies in Wales.

The formal process of developing a biomass strategy began in 2001, when the Woodland Development and Biomass Strategy Group was formed by the Welsh Assembly to explore the potential of farm woodland and biomass to contribute to farm income and a sustainable rural economy. This group produced the Farm Woodland Development and Biomass Action Plan in 2002, which was approved by the National Assembly (July 2002). This plan formed the basis of this research. However, during 2006 the Woodland Development and Biomass Steering Group was established to provide a more coordinated and strategic approach to the implementation of the plan. The group's remit included assessing delivery of the action plan, coordinating ongoing delivery, identifying priorities and acting as a forum to assess the biomass market in Wales. The Environment Strategy for Wales (WAG, 2006) aims to publish a biomass energy strategy by the end of 2007.

There has been limited development of the biomass industry in Wales, especially when compared with that of many European countries. In Finland, for example, 19 per cent of energy consumption came from wood fuel in 1998. Relatively few examples of existing small scale heating plants exist in Wales to date. A small number of Welsh companies currently invest in research and development in the biomass industry, ranging from wood chip/pellet boilers and burners, pyrolysis (conversion of wood to oil) systems, gasification systems (conversion of wood to gas) and charcoal production equipment. Also, the Wood Energy Business Scheme aims to act as a driver to stimulate the market for biomass.

The largest biomass project to date is the development of a 35 MW biomass co-firing plant at Aberthaw, South Wales. Recent estimates (IGER, 2006) suggest that, to satisfy the needs of the Aberthaw Power station for 25 per cent of biomass to be met by energy crops in 2009, significant areas of short rotation coppice (SRC) will need to be planted during 2006, 2007 and 2008. Other initiatives include the development of a combined heat and power plant at Shotton Paper Company in North Wales, due for completion in late 2006. This plant will use 250,000 tonnes of woody biomass and sludge from its recycled fibre plant and will produce 20 MW of electricity and 85 MW of thermal energy. A little further into the future is Western Bio-Energy's planned 12.5 MW wood-based electricity plant at Port Talbot.

Under current legislation, the SRC biomass system is regarded as afforestation and removal of the crop as deforestation, and as such environmental impact assessment (EIA) regulations apply. EIA regulations place a statutory obligation on the Forestry Commission to examine proposals for new areas of SRC and decide if a full EIA is necessary. Current UK policy states that woodland should not be cleared for agricultural use: this means that where SRC has been established, the land cannot be returned to pasture unless an acceptable case is made to the Forestry Commission. In reality this may not be a major problem, however it may be a perceived problem amongst farmers considering planting SRC biomass crops. In addition, there may be ecological reasons why biomass crops may be encouraged on currently cultivated arable land, but not on semi-improved or unimproved land. This restricts the amount of land on which they can be developed, as does the practical issue of slope, altitude and soil type, which can restrict planting and harvesting regimes.

5.2 Methodological summary

For the purposes of comparability across chapters, 'policy' is used to describe all resource protection agreements analysed in the report, regardless of whether they are technically classified as 'strategies', 'action plans', 'processes' or 'policies'. We recognise that this is not always technically correct, but it does enable a generic methodological framework to be used across a range of different resource agreements.

Risk assessments of the Biomass Action Plan and Woodland Strategy for Wales followed the basic pattern outlined in Chapter 2. The pre-analysis work generic to all policies was completed prior to undertaking the assessment of the woodland and biomass policies and followed the structure outlined in Figure 2.1. The policy assessment work followed the pattern outlined in Table 2.6, and details of the outcomes for each step are reported below.

1. Identify key components of policies to be analysed

The key policy components of both *Woodlands for Wales* and *Farm woodland development and biomass: an action plan* were analysed separately and the complete lists of components are shown in Tables 5.1 and 5.2. Initial analysis of the components of the *Woodlands for Wales* policy revealed that a large proportion of components and their associated activities are concerned with business and social issues. For example, one aim of the *Woodlands for Wales* strategy is “to provide opportunities for communities to have their say in the management of woods close to where they live”. To achieve this aim, three activities are suggested:

- establish a Woodland Forum for Wales;
- involve local people and communities in decision making;
- promote understanding of woodlands through partnership working and action.

The achievement of this sort of policy component centres on the relationship between government and people. While the exact nature of this relationship may be influenced by climate and associated socio-economic change, adaptive management of this relationship could probably resolve any emerging issues.

Given the diversity of policy components in the *Woodlands for Wales* strategy, they were classified into one of three groups (as shown in Table 5.1):

- policy components that are vulnerable only to socio-economic change and that depend only on the level of environmental concern under each scenario (marked ‘I’);
- policy components that are vulnerable only to socio-economic change and that depend on both the level of environmental concern and on economic conditions under each scenario (marked ‘II’);
- policy components potentially vulnerable to environmental concern, economic conditions and climate conditions (marked ‘III’).

All policy components were included in the risk assessment, but the focus of the formal analysis was on the third group of policy components, that is, those influenced by environmental concern, economics and climate.

2. Answer adapted UKCIP risk analysis guidance questions

This was undertaken and the results are shown in Appendix 4 on the accompanying CD.

3. Identify risk exposure units, receptors, thresholds and endpoints

The key receptors of both the strategy and action plan were identified. The receptors from both were found to be very similar and are presented together in Table 5.3.

4. Research potential effects of climate change on receptors via survey of scientific literature, experiments, modelling and analysis

This was completed as required when undertaking the receptor risk analysis and is reported on below as appropriate.

5. Undertake receptor risk analysis

This required an assessment of the vulnerability of each receptor to change under each of the socio-economic scenarios, and in combination with the UKCIP medium-high climate scenarios for 2020 and 2050 as reported in Table 2.9. The full results of this process are available in the Risk Assessment Matrices (RAM) shown on the accompanying CD.

6. Undertake policy component risk analysis

This analysis also followed the process outlined in Table 2.9 and the full results of this process are available in the RAM shown in Appendix 4 on the accompanying CD.

7. Test the results of the process and use the results to 'climate proof' the policies

This aspect of the risk assessment is specific to each policy and was not discussed in detail in Chapter 2. The remainder of this chapter is dedicated to discussing the methods and results of this process. It begins with a discussion of how the generic risk assessment method was applied to the woodlands and biomass policies in the Usk catchment, and is followed by an analysis of the risks to the policy components.

Table 5.1: Policy components of *Woodlands for Wales* strategy document

Policy component	Activity
1. To use woodlands as a social and cultural asset for some of our most disadvantaged communities	1. Use woodlands as catalysts for regenerating local communities (I). 2. Develop a series of community woodlands throughout Wales (II). 3. Promote woodland planning as a way of encouraging people to get involved in local sustainability (I). 4. Undertake research to help identify the barriers to community involvement (II). 5. Encourage the planting of woodland as an interim use of vacant industrial sites before redevelopment (II).
2. To maximise the use of woodlands for learning	1. Develop forest education initiative to promote the use of woodlands as an educational resource (I). 2. Develop links with schools in Wales (I). 3. Promote the use of woodlands as an opportunity for further education and lifelong learning (II). 4. Encourage the University of Wales to develop a centre of excellence in forest science (II).
3. To provide opportunities for communities to have their say in the management of woods close to where they live	1. Establish a Woodland Forum for Wales (I). 2. Involve local people and communities (I). 3. Promote understanding of woodlands through partnership working and action (I).
4. To promote best practice in woodland management	1. Develop ways of encouraging the use of best practice in managing woodland and of extending long-term planning (II). 2. Encourage the thinning of woodland to increase the future flexibility of management, to create greater diversity within woodlands and to produce more valuable timber products (III). 3. Ensure fair and equitable mechanisms are established for recognizing the social and environmental benefits of woodlands (I). 4. Continue to monitor condition of woodlands, providing managers with information about management operations (II).
5. To move to a greater use of continuous cover systems	1. Aim to convert at least half of the National Assembly woodlands to continuous cover over the next 20 years, where practical, and to encourage conversion in similar private sector woodlands (III). 2. Gather information about continuous cover systems and how best to manage them for the range of benefits that society demands (II).
6. To find appropriate sites for new trees and woodlands	1. Encourage landowners to take opportunities for appropriate woodland expansion, seeking to maximise the value to society of new woodlands (III). 2. Work with community groups and landowners to encourage the use of trees and woodlands to improve air quality and urban landscapes (III).
7. To provide Welsh forest industries with effective business support	1. Increase competitiveness of forest industries (III). 2. Develop and promote the availability of systems for business support and training (II).

Table 5.1 – continued

8. To develop the wood supply chain, create new products and support marketing	1. Continue to bring forecasted timber volumes to the market from National Assembly woodlands (II). 2. Use marketing techniques that give long-term assurance to customers and suppliers (II). 3. Work with industry to develop business in the wood supply chain (II). 4. Promote the use of wood and encourage business to develop local added value to their products (II).
9. To provide support for farm woodlands and the wider rural economy	1. Work with farming sector to develop farm woodland subject group (II). 2. Encourage farmers to diversify their businesses (II). 3. Help farmers make best use of farm woodland resources for livestock shelter and for timber products for farm use (II). 4. Help Coed Cymru to continue delivering support for farmers (II).
10. To foster the development of renewable energy based on wood	1. Integrate energy from wood fuel into the Assembly's renewable energy strategy (II). 2. Work with partners to develop advice on wood-based renewable energy (II).
11. To conserve and enhance the biodiversity of our woodlands	1. Increase the quality of native woodlands for wildlife and implement the Biodiversity Action Plan targets for their restoration and extension, creating links between fragmented woodlands (III). 2. Increase the area of woodland achieving independent environmental certification to internationally recognised standards (III). 3. Increase the area of native woodlands, targeting extension and connection of existing woods and incorporating the concept of increasing the core area of native woodland habitats (III). 4. Encourage the owners to incorporate different habitats, such as heath and bog, within woodlands, to maximise the connections between similar habitat types (III). 5. Increase the biodiversity of coniferous woodlands through the use of continuous cover systems (III).
12. To conserve and enhance the landscapes of Wales	1. Use woodlands to restore the landscapes of areas affected by past mineral extraction and other industrial activities (III). 2. Develop action plans to prioritise work in historic parks and landscapes (I). 3. Continue the restructuring of existing plantations (II).
13. To better integrate woodlands with other countryside management	1. Use catchment management planning to develop the role that woodlands can play in the management of water and the reduction of flood risks (III). 2. Work to prevent the further loss of ancient and semi-natural woodland (II). 3. Work to develop appropriate links between woodlands and wider countryside management through Tir Gofal and other environmental schemes (I). 4. Continue to support scientific research on the interactions between woodlands and the wider countryside (II).

Table 5.1 – continued

14. To use woodlands to help create a high-quality visitor experience	1. Use existing partnerships to promote the use of woodlands to develop a high-quality visitor experience (II). 2. Support the development of wood-using crafts (II). 3. Encourage the use of woodlands as part of the setting for tourist developments (II). 4. Promote the development of specialist recreation in woodlands (III). 5. Work to develop forest-based holiday accommodation (II).
15. To promote health through access to woodlands for all communities	1. Extend access to woodland, particularly for disadvantaged communities, using good design and community involvement to overcome perceptions of risk associated with woodland (II). 2. Support research to seek better understanding of the health benefits of trees and woodlands (II). 3. Seek opportunities to use trees in urban settings to maximise emotional and physical wellbeing (II). 4. Encourage visitors to all the National Assembly woodlands (III).

Table 5.2: Policy components of biomass part of Woodland Development and Biomass Action Plan

Policy component
1. Integrate biomass strategy with the general aims and biomass objectives of the Welsh woodlands strategy.
2. Provide support for farm woodlands and the wider rural community given recent decline in farm incomes.
3. Encourage farmers to bring woodlands back into production via schemes including Coed Cymru, Farming Connect, LEADER and TIMBER II.
4. Develop renewable energy production based on wood biomass.
5. Support WAG commitment to meet UK renewable energy targets defined at Kyoto (5% of electricity from renewable sources by 2003, 10% by 2010) and advised extension by Cabinet Office (2002) to 20% of electricity from renewable sources by 2020.
6. Develop and support biomass products, markets and end users.
7. Market and promote Welsh timber products including biomass.
8. Develop a grant scheme for biomass crops to support speculative farming in suitable areas based on sustainability criteria.
9. Promote and train heating engineers.
10. Ensure compliance with EIA regulations so that planting on sensitive areas such as unimproved grasslands or other habitats is avoided.
11. Set up a series of farm woodlands at various altitudes and site conditions in order to investigate and demonstrate best practice.
12. Encourage the use of biomass heating in WAG and other public sector buildings in order to stimulate the local supply chain.
13. Integrate with other policies and agreements.

Table 5.3: Receptors identified for woodland and biomass

Receptors
Invasive species – Rhododendron
Invasive species – Bracken
Habitats – Broadleaved woodland
Habitats – Scrub
Habitats – Upland heath in woodland clearings
Habitats – Lowland heath in woodland clearings
Habitats – Blanket bogs in woodland clearings
Habitats – Raised bogs in woodland clearings
Soils
Foresters
Related industries
Recreational users

5.2.1 Applying the risk assessment method to the woodland and biomass policies in the Usk catchment

Risk assessment method

The risk assessment for woodland and biomass policies in the Usk catchment followed an eight-step process, illustrated in Table 5.4. Fundamental to this risk assessment were the Risk Assessment Matrices (RAM) developed as part of the receptor and policy component risk analyses. These are presented in full in Appendix 4 on the accompanying CD.

Table 5.4: Risk assessment procedure for woodland and biomass

Step	Action
1	Identify the components of the two policies which relate to land use and could be analysed at a catchment scale.
2	Collate and manipulate data to predict the potential for woodland expansion in the catchment.
3	Map location of current woodlands.
4	Map location of potential new woodlands.
5	Collate and manipulate data to predict the potential for biomass in the catchment.
6	Map location of potential biomass sites.
7	Use RAM to understand the impact of land use change associated with expanded woodland and biomass plantings.
8	Summarise the vulnerability of the land use components of the policy and comment on their value at the catchment scale.
9	Use the results of this process to inform the assessment of the woodland and biomass policies in general.

Identify the components of the two policies which relate to land use and could be analysed at a catchment scale (Step 1)

Woodland

Given the nature of many policy components in the *Woodlands for Wales* strategy, it was necessary to identify a subset of components which could be analysed within a spatially defined region. The policy component of most relevance aimed "to conserve and enhance the biodiversity of our woodlands". Some activities linked to this component were based on woodland expansion, and these were particularly amenable to further study in the Usk catchment. They would also serve to "encourage landowners to take opportunities for appropriate woodland expansion". Another policy component, "to better integrate woodlands with other countryside management", was relevant to flood management and agri-environment schemes.

Biomass

As for woodlands, many of the policy components relating to biomass were difficult to analyse in a spatially explicit manner. In order to explore the 'spirit' of the policy, which aims to increase the use of biomass in Wales, the analysis of the Usk catchment sought to identify the extent and location of land in the catchment which could potentially be used to grow short rotation coppice for biomass. The potential location of biomass plantations is subject to a range of restrictions and these were integral to the analysis, as discussed below.

Collate and manipulate data to predict the potential for woodland expansion in the catchment (Step 2)

In theory, it would be possible to expand woodland by planting new trees anywhere on non-wooded lands. However, conservation theory suggests that linking fragments and expanding small woodlands could bring more benefit than a set of random plantings. A recent attempt to refine the theoretical basis for establishing woodland networks is presented by Watts *et al.* (2005). Watts' approach concentrates on the functional connectivity of existing woodland habitats rather than on predictions of future cover itself, but it can nevertheless be used to guide future woodland expansion (Jim Latham, *personal communication*). The focal networks identified by the application of Watts' approach are intended to target certain management and conservation activities. These range from protecting and managing high-quality sites, through the restoration and improvement of poor quality sites to the creation and expansion of new woodlands (Kevin Watts, *personal communication*).

As part of the risk assessment, the focal network for the Usk catchment was obtained. We assumed that the development of a broadleaved network would be desirable, but trees would not be planted on other priority habitats. Priority habitats were identified from the CCW Phase 1 dataset using a habitat class conversion table (Jane Stevens, *personal communication*). The resultant lowland and upland habitat classes were then manually modified according to elevation. The resultant priority habitat polygons were clipped from the focal network coverage to determine suitable areas for potential woodland expansion.

Map location of current woodlands (Step 3)

There is a total of 13,476 ha of woodland in the Usk catchment. This is comprised of 6,004 ha of broadleaved woodlands in the catchment and 6,921 ha of conifer, with a further 286 ha of mixed woodlands and 265 ha of scrub. Most of these woodlands occur in sub-catchments 3, 7 and 11 (Figure 5.1).

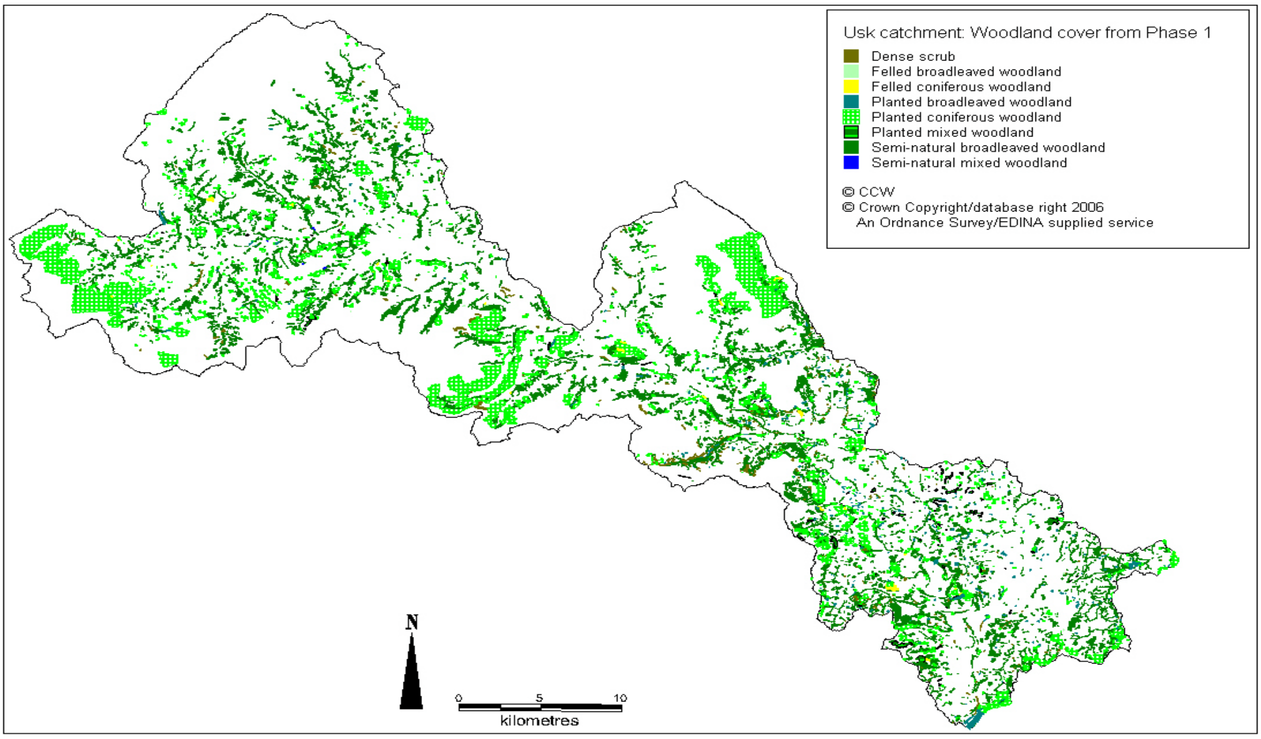

Figure 5.1: Woodland cover in the Usk catchment

Map location of potential new woodlands (Step 4)

After considering the biophysical habitat as discussed above, the distribution of potential new woodland in the catchment is shown in Figure 5.2. This analysis suggests that 25,416 ha is potentially available for new woodland. This land is largely comprised of improved and semi-improved grasslands. If this potential were realized it would almost triple the woodland cover within the catchment.

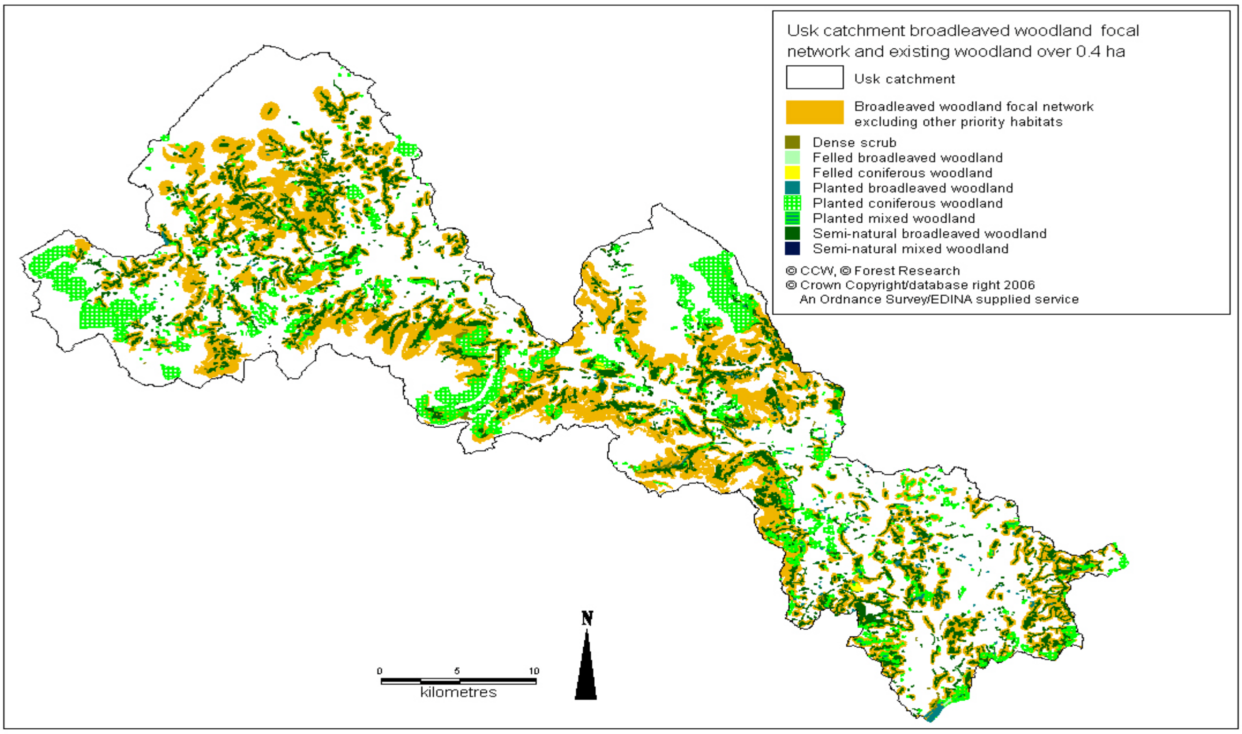

Figure 5.2: Focal network for woodland in the Usk catchment

Collate and manipulate data to predict the potential for biomass in the catchment (Step 5)

Background

Biomass plantings are normally either short rotation coppice (SRC) of a tree like willow or energy grasses like elephant grass (*Miscanthus*). Most of the research to date has focused on SRC, and very little data are available on the environmental impact of growing energy grasses on agricultural land in Wales. For this reason, the analysis undertaken here focused on SRC.

Decisions about where to plant biomass crops will depend upon a series of biological, economic and legal restrictions. For example, the economics of biomass usage are such that it is currently not financially viable to transport biomass long distances, and so most biomass production will be close to its point of use. Also, farmers may be reticent to convert land to a long-term crop unless there is real potential for a financial gain. In addition, there are biological restrictions on where biomass may be grown; these have been detailed in the scientific literature and are summarized in Table 5.5.

In order to estimate the potential for biomass in the Usk catchment, a GIS model was developed which took cognisance of the restrictions listed in Table 5.5. This model followed an original approach suggested by Veitch and McMellin (2001) and used the parameters outlined by the Department for Environment, Food and Rural Affairs (Defra 2002a; b), Tubby and Armstrong (2002) and Heaton *et al*. (2000).

Table 5.5: Summary of the biophysical and regulatory restrictions on the establishment of short rotation coppice biomass crops and the rules and datasets used in the development of the GIS model

Guidance	Rule	Dataset
Low rainfall areas are unsuitable for SRC. Annual precipitation 600-1,000 mm is required.	Avoid areas where rainfall is less than 900 mm.	Annual rainfall data 5 km x 5 km UKCIP averages 1961-2000. © Met Office
Potential growth restricted at higher elevations.	Avoid land with elevations greater than 356 m in Wales.	Digital elevation model. © Ordnance Survey 10 m Profile dataset
Harvesting constraints suggest relatively flat land is required.	Slope of land should not exceed 15 per cent.	Slope characteristics derived from DEM. © Ordnance Survey 10 m Profile dataset
Can be established on a wide range of soils.	Light sandy or gravelly soils best avoided. Avoid planting on soils waterlogged for much of the year.	Vector 1:250,000 National Soil Map; Properties and functional values for soil series. © NSRI
Harvesting occurs in winter. Land which is very wet or susceptible to flooding is unsuitable.	Avoid seasonally wet soils and areas where flooding is likely to occur.	Vector 1:250,000 National Soil Map; Properties and functional values for soil series. © NSRI
Ecological value of selected sites/surrounding area should be taken into account.	Land in or adjacent to ecologically designated areas is unsuitable.	SSSI, SAC boundary datasets. © CCW
EIA is a requirement for uncultivated land or semi-natural areas or land in the process of reversion to such a habitat.	Avoid agriculturally unimproved or semi-improved land. Restrict to improved grassland or arable land.	Vector Phase 1 habitat classification. © CCW Phase 1
SRC should not be planted close to, nor surround, archaeological sites including areas with potential for waterlogged deposits.	Avoid planting on or around archaeological sites.	Vector point Scheduled Ancient Monument records. © CADW, © Ordnance Survey 1:25,000 raster tile backdrops
Visual impact of SRC plantations in areas of high landscape value.	Planning constraints within Brecon Beacons National Park and Wye Valley AONB.	Vector Brecon Beacons National Park boundary. © OS Strategi 1:250,000; Wye Valley AONB. © CCW Protected Areas
Difficulty of establishing SRC local to urban areas.	Land within outer limit of large or small urban settlements deemed unsuitable.	Vector Brecon Beacons National Park boundary. © OS Strategi 1:250,000
Large plantations may affect groundwater recharge.	Avoid areas where more than one borehole abstraction licence per km^2.	Abstraction licence records. © Environment Agency

Water relations

Both willow and poplar SRC use large quantities of water, and during the summer months the water use from mature SRC exceeds that from all other vegetation, while on an annual basis it is second only to coniferous forest. This is because of high transpiration rates and large interception losses arising from large leaf areas. The scale of water use is demonstrated by an example which shows that for a clay soil site with an annual rainfall of 700 mm, poplar SRC will use about 600 mm of water compared to about 400 mm for barley or wheat, 475 mm for broadleaved trees and 650 mm for pine forest (Hall, 2003).

In order to yield 12 oven dry tonnes per hectare, agronomic models suggest that willow SRC needs an estimated annual average rainfall of 1,200 mm and a seasonal one of greater than 550 mm. Willow will grow well at lower rainfalls, but the yield may decline accordingly.

For these reasons, care must be taken in planning the location of large SRC plantations. Much of Eastern England appears to have rainfall too low to support maximum growth, a situation which will only worsen with climate change. Similarly, SRC planting must be sensitive to the hydrological regimes within a catchment. Consider, for example, that a SRC strip 50 m wide and one km long could seriously affect the summer flows of headwater streams.

Data collation and manipulation

Given the need to plant SRC in areas with greater than 900 mm rainfall per year (Hall, 2003), annual rainfall averages were obtained from the Meteorological Office. The lowest rainfall 5 km x 5 km grid square within the study catchment was reported as 940 mm. On this basis, the entire study area was deemed suitable on the basis of the rainfall criterion.

Because of the potential of SRC to deplete soil water, it is advisable to treat an SRC plantation in a similar way to an abstraction, and good practice suggests avoiding more than one abstraction per km^2. For this reason, ground water abstraction data were assessed for a clustering of licences and where more than one borehole licence existed per km^2, the area of the immediate micro-catchment was excluded. Groundwater recharge is clearly a more complex issue than reported here, but this simple analysis was felt to make at least some allowance for hydrological issues.

Physical land restrictions

Heaton *et al.* (2000) state that SRC has not been grown in Wales at elevations above 356 metres. A 10 m Ordnance Survey Profile Digital Elevation Model (DEM) for the study catchment was reclassified into two classes: below 356 m and over 356 m. The land above 356 m was then excluded in all subsequent analyses. Slope was calculated for the study catchment using the 10 m DEM and the resultant slope grid contoured using Vertical Mapper into two classes: below 15 per cent slope and over 15 per cent slope. The resultant contour dataset was used to exclude all areas above 15 per cent slope from subsequent analysis.

Soils series vector polygons were extracted for soil types prone to seasonal flooding and wetness from the NSRI NATMAP 1:250,000 database descriptors for subsequent analysis.

Protected areas and EIA

For the purposes of the analysis, it was assumed that SRC is most likely to be restricted to improved grassland and arable land, and least likely to occur on protected areas. Further, and solely for the purposes of the analysis, it was assumed that SRC would not be allowed anywhere within the AONB area. These assumptions are conservative, as technically there is no legal reason why SRC could not be planted on unimproved land or protected areas, as SRC is classed as forestry and therefore does not fall within the EIA regulations for uncultivated land, which relate to changing land use for intensive farming only.

The relevant land cover types (improved grassland and arable) were identified from the Phase 1 habitat survey and amalgamated into a single ‘potential land’ dataset. The location of protected sites was extracted from the SSSI database described in Chapter 3 and stored as a separate database. Archaeological site point data (SAMS) were identified so an appropriate exclusion area surrounding each monument (depending upon type and location) could be digitised from the field boundaries and saved as an archaeological exclusion dataset, overlayed onto the potential land dataset and removed.

It was also deemed problematic to establish plantations of SRC within an urban setting, although there are no formal regulations on this matter. Thus, the component classes large urban area (outer limit) and small urban (outer limit) were extracted from the OS 1:250,000 Strategi dataset and digitised as polygons, for exclusion from the potential land dataset.

The data components listed above were used to define the potential area for SRC by subsequent exclusion using a ‘cookie cutter’ or spatial sieving approach. Once the overlay and exclusion calculations had been completed, the resultant polygons were disaggregated into individual entities. Areas of the individual polygons were calculated and those polygons under one hectare in size were removed on the basis that those with very small areas were sliver polygons resulting from repeated overlay operations, and that areas under one hectare would be uneconomic and unsuitable for the establishment of a SRC crop.

Map location of potential biomass sites (Step 6)

After manipulating the data, it was possible to map the areas in the catchment which were suitable for SRC biomass crops (Figure 5.3). The map suggests that 34,054 ha would be suitable for SRC biomass plantations. This would be on land currently used for agriculture.

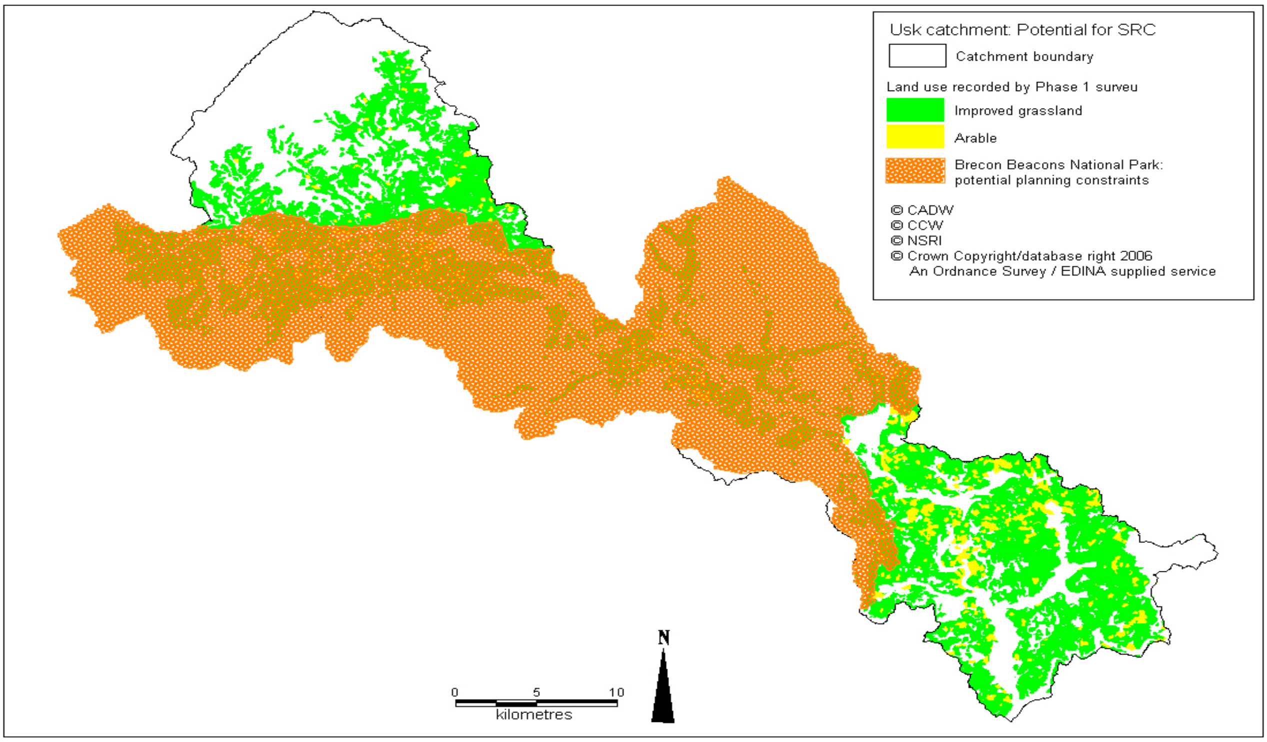

Figure 5.3: Potential area for growing short rotation coppice in the Usk catchment

5.3 Policy analysis

5.3.1 General comments on woodland policy

Disaggregation of the UKCIP scenario data to Wales level, as discussed in Chapter 2, suggests that by 2050 the extent of broadleaved woodland in Wales will increase from the 123,000 ha recorded in the year 2000 to 159,900 ha under a scenario of World Markets and 233,700 ha under Global Sustainability. Conversely, this type of woodland is projected to decrease to 86,100 ha under Local Stewardship, and to stay constant under National Enterprise. If forest-related industries were to follow a similar trend, then they would remain constant under National Enterprise, decrease to 70 per cent of current activity under Local Stewardship and increase to 130 per cent and 190 per cent of current activity under the scenarios of World Markets and Global Sustainability respectively.

As well as affecting the extent of woodland habitats through socio-economic change, climate change will have a direct effect on trees and woodlands. Climate-induced change will probably progress slowly, with major changes happening in periodic steps. This is because the major agents of change will be related to summer droughts (Peterken and Mountford, 1996), increased fire risk and high intensity storms, and each of these will occur irregularly over the next 50 years. They will also vary in severity with location. Superimposed upon these stepwise changes will be the more gradual and continual biological changes in woodland communities. Changes relating to altered precipitation and potential evapotranspiration will probably bring about change in woodland fauna, such as invertebrates, and flora, such as bryophytes. In addition, as climate envelopes of species shift northwards, the presence of 'alien' species in woodlands will increase and this may include changes in the tree species which are dominant in particular locations. However, in general the dominant tree species within woodlands are expected to remain unchanged over the next 50 years, because of their long life-span and persistence (Berry *et al*., 2005).

The growth of trees will also be affected, including enhanced photosynthesis arising from increased CO_2 in the atmosphere. This may increase growth by 30 to 50 per cent for young trees (Broadmeadow and Randle, 2002). The growth of older trees will also be enhanced, but at lower rates than in the young trees. This enhanced growth will have knock-on effects on tree structure, the nutritional status of leaves (Watt *et al*., 1996) and timber quality (Donaldson *et al*., 1987). In addition, climate change will provide a lengthened growing season and increased temperatures, which together effect accumulated temperatures, which are a major determinant of tree growth. However, greater storminess under a changed climate may cause more damage to trees than now, and may serve to curtail crop rotations before ages of either maximum profitability or maximum biomass productivity are reached.

The exact impact of these changes on tree productivity is uncertain. Cannell *et al*. (1998) estimate that the combined impacts of nitrogen deposition, increased CO_2 concentrations and higher temperatures have accounted for 0.5 m^3 ha^{-1} yr^{-1} increase per decade in the General Yield Class (GYC, a measure of timber production) of conifers in Northern Britain since the 1930s. They go on to suggest that increasing CO_2 and N could increase GYC by over 0.5 m^3 ha^{-1} yr^{-1} per decade up to 2050, which when combined with an increased temperature, genetic and silvicultural improvements may mean a substantial acceleration in growth rates.

These increases will not only occur in the UK, but will also occur around the globe to greater or lesser amounts. This may well effect the financial return available to foresters, and Solberg *et al*. (2003) suggest that should supply increase by 20 per cent across Europe, then by 2020 log prices may be seven to nine per cent lower than in 2000, and sawnwood may decrease by up to 4.5 per cent. Solberg *et al.* (2003) go on to suggest that despite these price drops, the market for timber products will be buoyant in 2020 and the actual amounts of timber harvested will increase across Western Europe. As a result, the income from forests should increase relative to that in the year 2000.

The growth rates of broadleaved trees will also alter under a changed climate. Broadmeadow and Randle (2002) consider the impacts of climate (temperature, exposure, moisture deficit and continentality) on the growth rates of six species of broadleaved tree in the UK (beech, ash, oak, silver birch, sycamore and sweet chestnut). The results of this work suggest large decreases in growth rates of most of the six species in South East England. The outcomes for Wales are largely neutral, although the growth rate of oak does increase slightly. Broadmeadow and Randle (2002) note that both birch and sycamore are susceptible to drought-related mortality, and further that sweet chestnut should thrive under the warmer, drier climate across most of southern England and Wales.

Future growth rates and market value may also be affected by an altered complex of pests and diseases under a changed climate. Climate change will make it both more likely that new pests and diseases will occur, and also that the dynamics of existing pests and diseases may change (for example, increased winter survival in milder winters enabling pest populations to build up to damaging levels). Synergistic effects may also occur; for example, pest or disease attack could be exacerbated by physiological stress caused by summer drought. There are already examples of new diseases such as Phytopthera which have become widespread in the last few years. Highly damaging outbreaks (similar to Dutch Elm Disease or Sudden Oak Death in California) are a strong possibility. The impact of pests and disease is unpredictable, but the probability of significant damage is probably high in the medium to long term (the next 50 years). Monocultures, especially those with a limited genetic base, are potentially more vulnerable.

5.3.2 Specific comments on the policy components

The discussion of policy components is grouped according to the classification made in Table 5.1, where policy components were identified as being:

- vulnerable only to socio-economic change and dependent only on the level of environmental concern under each scenario (marked 'I');
- vulnerable only to socio-economic change and depend on both the level of environmental concern and on economic conditions under each scenario (marked 'II');
- components potentially vulnerable to environmental concern, economic conditions and climate conditions (marked 'III').

Policy components that are vulnerable only to socio-economic change and that depend only on the level of environmental concern under each scenario

The four scenarios developed by UKCIP and used here are partially predicated upon the level of environmental awareness which is evident in society and government. Generally, we may expect high levels of environmental awareness in the scenarios Local Stewardship and Global Sustainability. Also under these scenarios will be a commitment to research, education and sustainable development. As a consequence, policy components which depend solely on social and political support should have a low vulnerability to failure under these scenarios.

Conversely, under scenarios of National Enterprise and World Markets there is likely to be less support for research, education and environmental sustainability in general. Rather, economic outcomes will be prioritised over social and environmental activities. As a result, policy components dependent on high levels of support for environmental sustainability are likely to fail.

For example, within the policy component “to provide opportunities for communities to have their say in the management of woods close to where they live”, there is an activity which seeks to “establish a Woodland Forum for Wales with membership drawn from a wide range of organisations to guide implementation, monitor progress and oversee the development of targets and indicators”. The establishment of such a forum is dependent on social and political conditions, though the development of pertinent targets and indicators may be highly susceptible to climate change. Under Local Stewardship it is very likely that a forum would be established, with a strong emphasis on developing targets and indicators. These may be 'climate-proofed' to some extent by sound research, but will be somewhat vulnerable to uncertain climate effects. By contrast, under National Enterprise it is unlikely that a forum would be established. This type of thinking can be applied to all policy components in this class (marked as I).

In actuality, the Woodland Forum was formed soon after the strategy was published, and has now been replaced by a new body, the Woodland Strategy Advisory Panel which combines the forum with previously existing advisory panels, but the same arguments apply to all such initiatives.

Policy components that are vulnerable only to socio-economic change and that depend on both the level of environmental concern and on economic conditions under each scenario

These policy components, such as “to plant trees on industrial sites” or “to develop and support woodland-based business initiatives”, are not likely to be particularly susceptible to the direct impacts of climate change. However, their implementation is reliant on both levels of environmental concern and, depending on the scenario, the degree to which they offer positive financial returns.

Under National Enterprise, these policies will only be supported if they provide strong economic returns. Thus, if prices for woodland products are high, support for related infrastructure is likely to be forthcoming. Encouragement is likely to be targeted at such income generation (such as public-private ventures rather than public-volunteer initiatives). For these reasons, these policy components will generally have a medium vulnerability.

Similarly, under World Markets the low level of environmental concern suggests that support for these policy components depends upon their positive effects on income generation rather than on environmental protection. An increase in forest under this scenario indicates some potential for economic returns, but these may be reaped with unsustainable management unless sustainable methods also offer good financial returns. Thus, in this situation these policy components are classified as having a medium vulnerability.

Forest cover will be lower under Local Stewardship, but those woodlands that exist may be of high quality. High levels of environmental concern suggest that policy components that have positive environmental gains will be supported in preference to those biased more towards income generation, particularly if there are conflicts between these (see Henwood and Pidgeon, 1998; West, 2003). While such an emphasis can promote sustainability, the quality of woodland management may suffer if economic returns are low. Despite the relatively positive attitudes to the environment, the decline in woodland cover suggests policies will have a medium vulnerability.

Generally, vulnerability is lowest under the scenario of Global Sustainability as the high levels of forest cover, coupled with strong environmental concern, suggests that those policy components with environmental payoffs will be supported. Income-generating initiatives will also be supported, provided they do not conflict with environmental objectives.

As an example of this type of policy component, consider that which seeks to "increase the area of woodland achieving independent environmental certification to internationally recognised standards". There are three main reasons for achieving environmental certification. One is because of a genuine and altruistic concern for the environment, a second is to do with gaining a satisfying feeling of 'acting rightly' and a third relates to gaining a market advantage (or avoiding political disadvantage) among environmentally aware consumers. Under both Local Stewardship and Global Sustainability, there will be greater political and consumer support for environmentally friendly products than in the other scenarios. However, under the other more market-orientated scenarios there will be less consumer demand for environmentally friendly products, and the attitudes of neither industry nor governments are likely to override this low level of concern.

Policy components potentially vulnerable to environmental concern, economic conditions and climate conditions

These policy components are potentially vulnerable to society's levels of environmental concern, economic conditions and climate conditions. Each of the components in this category (marked as III in Table 5.1) is discussed in detail below.

Increase the quality of native woodlands for wildlife and implement the Biodiversity Action Plan targets for their restoration and extension, creating links between fragmented woodlands

As discussed in Chapter 3, many species are shifting their ranges, new species are entering the UK and new ecological communities are forming. These biological changes will present a challenge to current conservation thinking, and even though species range shifts have been recorded already, it is likely that the largest shifts will be observed after 2020. Over the next 14 years, the greatest challenge to this policy component may arise from some of the more market-orientated components which are expounded in the strategy. For example, under National Enterprise greater emphasis will be placed on production and less on conservation. Even under Local Stewardship where attitudes to conservation will be more positive, there may be a necessity to extract more timber resources from UK woodlands than currently occurs as imports. The vulnerability of this policy component is probably least under Global Sustainability where there will be a positive attitude to conservation and imports from sustainable production systems should occur, thereby reducing demand for home reduced timber. The issue of creating links between fragments is discussed below.

Increase the area of native woodlands, targeting extension and connection of existing woods and incorporating the concept of increasing the core area of native woodland habitats

Some of the points relating to the balance of market and environmental concern have been discussed above, and these also apply here. This would suggest greatest vulnerability under National Enterprise and World Markets and least under Local Stewardship and Global Sustainability. However, this analysis is complicated by variation in the demand for land between the scenarios. Under the more autonomous scenarios of Local Stewardship and National Enterprise, there will be a greater demand for local production of timber, food and biomass, thereby creating a demand for land. Conversely, under the less autonomous World Markets and Global Sustainability there is likely to be greater acceptance of trade, and less demand for local production. This may provide opportunities for forest expansion in some areas.

A further complication relates to the species and provenance of the trees to be planted. While there has been much recent concern about the use of local provenances, it is unclear if these provenances will continue to be the best to plant. Clearly, local provenances are adapted to local biophysical conditions and as these will change with a changed climate, the rationale for using local provenances may be challenged. It may be prudent to undertake a review of the species and provenances of trees to be planted as part of any future wide-scale expansion of woodland (see Broadmeadow *et al*., 2005, for a discussion of these issues).

Encourage landowners to take opportunities for appropriate woodland expansion, seeking to maximise the value to society of new woodlands

This policy component is subject to the same type of constraints and vulnerabilities as discussed above for other forms of woodland expansion.

Encourage the owners to incorporate different habitats, such as heath and bog, within woodlands, to maximise the connections between similar habitat types

The achievement of this component will depend almost entirely on the attitudes of landowners. Any land which is taken out of production and managed as wildlife habitat will not offer a financial return. Unless future market-based certification schemes required forest owners to do this, or there was some woodland scheme analagous to agri-environment schemes, then we might only expect this component to be upheld under the scenarios of greatest environmental awareness, that is, Local Stewardship and Global Sustainability.

Encourage the thinning of woodland to increase the future flexibility of management, to create greater diversity within woodlands and to produce more valuable timber products

This policy component may be vulnerable to internal disputes regarding the merits of production-dominated versus environmentally based woodland management. For example, it is possible that thinning may increase product quality, but may also have negative impacts for some woodland species. Hence, under scenarios where economic considerations will dominate thinning may be encouraged. Conversely, under Local Stewardship and Global Sustainability thinning will be encouraged if it is positive for conservation, but may be challenged if it is perceived as only being beneficial to timber values.

Increase the biodiversity of coniferous woodlands through the use of continuous cover systems

Continuous cover is a silvicultural system which seeks to fell trees on smaller spatial scales than traditional clear felling. This leads to a patchwork of different-sized stands within a forest. Advocates suggest it offers superior and constant financial returns and is also better for the environment than clear felling, although good UK evidence supporting this view is lacking at the moment. If the political desire was strong enough, then this form of management could be introduced regardless of the climate. However, some climate effects may impinge on continuous cover systems. One relates to wind, where it is possible that the rougher canopy in continuous cover systems will cause more turbulence than an even-aged canopy. A second relates to hydrology, where continuous cover generally leads to greater evaporative losses over the long term that clear cutting. A third relates to access to the land. Continuous cover may require more access to the land by machinery around the year than the current systems, and so care must be taken to ensure harvesting practices do not damage the soil unduly and reduce future productivity on the site. Both increased rainfall in the winter and less in the summer will create challenges for harvesting activities.

If the motivation of the policy component is to enhance biodiversity within the forest, then its vulnerability will depend upon the balance of social attitudes and financial returns from forestry. Under National Enterprise, forest production will be given a greater emphasis than biodiversity enhancement. Hence continuous cover will only become widespread if it offers financial benefit over other silvicultural systems. A similar logic will apply under World Markets, but here there may be a need for UK forests to compete more strongly with international timber, which may mean a greater emphasis on cost cutting, and this will serve to minimize the uptake of silvicultural systems which are not financially competitive. The vulnerability of the policy component is lower under the scenarios of Local Stewardship and Global Sustainability, but in the latter case international markets may still challenge the policy component if it is not financially viable.

Aim to convert at least half of the National Assembly woodlands to continuous cover over the next 20 years, where practical, and to encourage conversion in similar private sector woodlands

Due to a reduction in harvest and an increase in management inputs, it is likely that a move from the existing system to one of continuous cover will be more expensive in the short term than staying with the existing system. Full conversion of Welsh forests will take up to 20 years. If political and industry support is to be maintained over this period, the benefits of continuous cover must be very clear, be they economic or environmental.

Under the economically orientated scenarios of National Enterprise and World Markets, support for continuous cover woodlands may not be forthcoming if it is shown to be less profitable than traditional clear felling systems. As stated above, changing climate conditions may pose some challenges to achieving continuous cover both in terms of establishing suitable tree species and varieties, and in terms of access of machinery to woodlands at some times of year. World markets for timber will also influence the economics and desirability of this system. If the availability of timber on the world market grows, then the economic underpinning of this policy component may decrease. For these reasons, the vulnerability varies from low under a scenario of Local Stewardship to high under National Enterprise.

Use catchment management planning to develop the role that woodlands can play in the management of water and the reduction of flood risks

There is some evidence that woodlands can help alleviate floods in some circumstances. For example, Caroll *et al.* (2004) suggest that in mid-Wales, the infiltration of water into soil from over ground flow was up to 60 times higher in areas planted with young trees than in adjacent grazed pastures. Similar results have been observed elsewhere (for example, Ellis *et al*., 2006) where the level of infiltration was related to better soil surface conditions in the absence of stock and a 50 mm layer of tree litter. In addition, the presence of trees tends to reduce the amount of water reaching a river in the long term, for two reasons. Firstly, they intercept rainfall directly, and this evaporates from the foliage and never reaches the soil surface. Secondly, trees and forests have a greater evapotranspiration potential than grassland and crops and so tend to enhance water transfer from the soil to the atmosphere.

The impacts of trees on water flows over the short and long term may offer some potential to alleviate some types of floods, in the long term by reducing the total amount of water flowing into the river channel from the surrounding land, and in the short term, via increased infiltration reducing the speed by which water reaches water courses during a storm event. For these reasons, the strategic planting of woodlands in the uplands and in river valleys may help alleviate flooding. However, there are some constraints on this in practice. Firstly, Carroll *et al*. (2004) reported differences in infiltration between woodland and heavily compacted sheep pasture, although it is probable that the differences in infiltration rates will vary with the land uses being compared. Secondly, enhancing infiltration only helps alleviate flooding when the soil is not saturated with water. Once the soil is at saturation there is no possibility for more water to enter the soil, and so it will move over ground. Thirdly, there is great uncertainty as to where any given woodlands should be planted in order to maximise their impact on flood events. Identifying relevant locations requires a good understanding of the hydrological regime of the catchment.

Given all of the above, if new woodlands were to be planted to help alleviate floods then this planting would probably be on improved agricultural land. In this situation, the woodland may be perceived as providing biodiversity and landscape benefits in addition to flood alleviation. Conversely, if they were planted on land of some conservation value, say in the uplands, then their overall benefit may be less apparent.

If the benefit of woodlands in alleviating floods could be demonstrated, then this component should offer both economic and environmental benefit and should have low vulnerability under all socio-economic scenarios. However, given the length of time woodlands take to establish and mature, a detailed analysis of the probability of a given woodland alleviating a given flood event is necessary prior to undertaking wide-scale planting.

Seek to increase the competitiveness of our forest industries, working in partnership with industry to develop and implement action plans across the sector

It is likely that competitiveness will be a policy aim at some level under all scenarios. However, this aim may be frustrated by the desire to ensure environmental sustainability in some scenarios. Also, competitiveness will vary with the state of the global markets. Under World Markets we may expect competitiveness to be emphasized, assuming that Welsh timber products can compete with production elsewhere in the world. It is important to remember that climate change may affect the relative competitiveness through a differential effect on timber growing conditions in different regions. Predictions of warming but adequate rainfall in Wales should not decrease production, which may occur elsewhere if the climate changes are not favourable for tree growth. For these reasons, vulnerability varies between scenarios from low in National Enterprise to medium-high in Global Sustainability.

Promote the development of specialist recreation in woodlands, including wildlife observation and artistic pursuits, and more noisy and physical sports in appropriately zoned areas

Forest recreation may increase under all climate change scenarios as hotter summers will put a greater premium on shade, but to some extent access and recreational activities are vulnerable to both socio-economic conditions and climate effects. For example, under a changed climate which offers drier springs and summers, woodlands may become more susceptible to both soil erosion and fire. Reducing the impacts of these may require some level of visitor management.

Under scenarios of low environmental concern, forest-based recreation will be driven by profitability and little regard may be given to minimize the impacts on wildlife and the environment. Further, given the potentially large impact of fire, forest owners may be reluctant to permit public access to areas managed for production. Under National Enterprise, access will be limited to non-productive areas of woodland, and in these areas there will be little concern for environmental management. However, under a scenario of Global Sustainability only sustainable recreational pursuits (such as local recreation trips, preferably on foot or bike or public transport) will be encouraged and public access will be promoted.

Continue to encourage visitors to all National Assembly woodlands, actively promoting the opportunities available

Much of the previous discussion applies to this policy component too. However, the attitude of government to timber production will be paramount in determining its success. If government seeks to make forests economically viable then it will respond in a similar way to private owners, and impose restrictions on access. On the other hand, should government value health promotion and active living above timber production then it is likely to promote these activities, and thereby help achieve this policy component.

5.3.3 Biomass policy component analysis

Integrate biomass strategy with the general aims and biomass objectives of the Welsh woodlands strategy

Regardless of climate effects, there are potential conflicts between the aims of the biomass strategy and woodland strategy. Some of these are evident in Figure 5.4, which shows the land in the Usk catchment which is suitable for both biomass production and woodland expansion. These potential conflicts will vary according to the levels and type of environmental concern society has, and also the relative economic returns to biomass. Should economic returns be dominant, as under the National Enterprise and World Market scenarios, then we may expect society to emphasise profitable biomass production over the creation of broadleaved woodland for environmental purposes. Conversely, should environmental concerns be strong, as in Global Sustainability, then the development of new broadleaved woodland for environmental gains may be valued to some extent. However, there is clearly a debate needed on the relative environmental benefit of producing and burning biomass and developing new woodlands, whether for their own sake or as wildlife corridors and/or water management mechanisms. Because of these interactions, this policy component has a vulnerability varying from medium to medium-high in 2020 and medium to very high in 2050 (see Appendix 4 on the accompanying CD for further details).

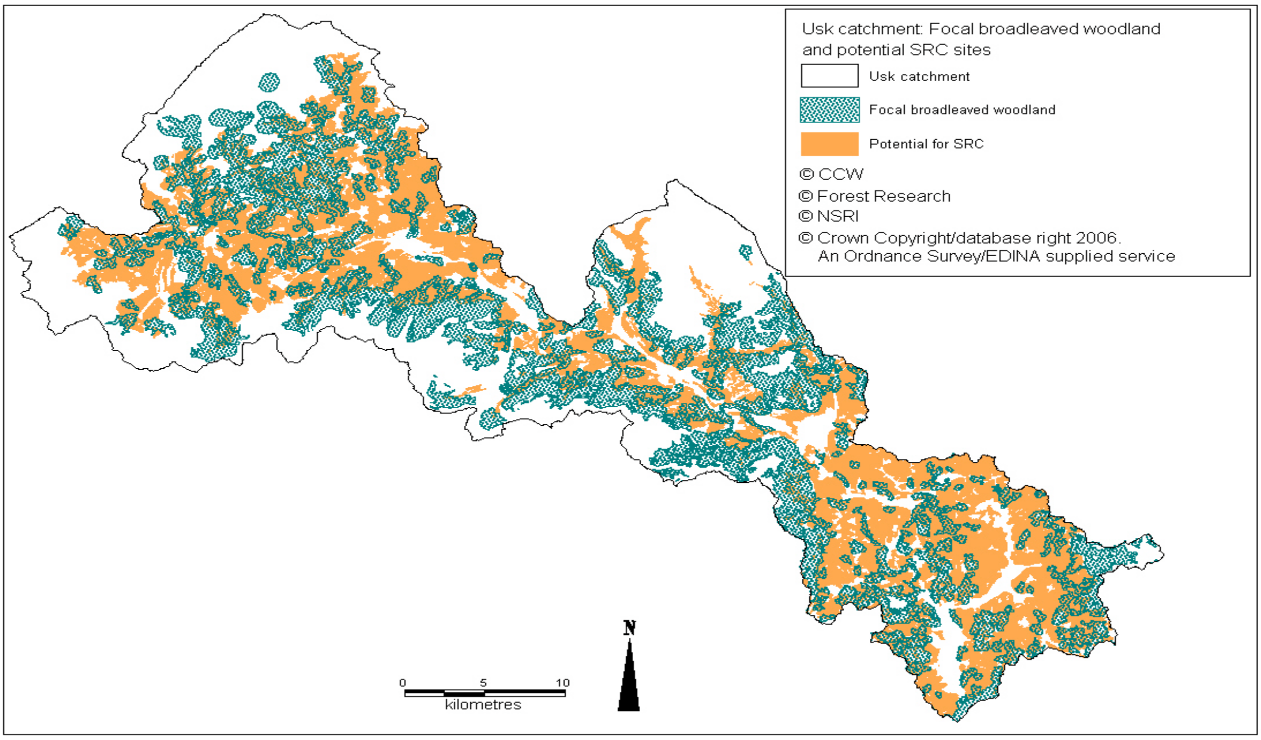

Figure 5.4: Overlap between the focal woodland network and the potential biomass growing areas

Provide support for farm woodlands and the wider rural community given the recent decline in farm incomes

The amount of support society wishes to offer farmers and others to develop biomass resources will depend on the balance of attitudes to farmers and to the environment on one hand, and the prevailing economic situation on the other. Under National Enterprise low amounts of support are likely to be available, providing a medium-high vulnerability in 2020 and high in 2050. Conversely, under Global Sustainability high levels of support may be felt to be desirable and would probably be forthcoming, giving a vulnerability of medium-low in both 2020 and 2050.

Encourage farmers to bring woodlands back into production via schemes including Coed Cymru, Farming Connect, LEADER and TIMBER II

These schemes tend to be reliant on agency support rather than real markets, and hence are vulnerable to social attitudes and economic conditions. However, as levels of woodland production may increase in Wales under climate change, farmers may be more likely to invest in woodlands as long as market conditions are positive. Under Global Sustainability, the vulnerability of this policy component is low as we may expect woodland development to be supported by both the market and agencies. Conversely, under a scenario of World Markets, even though there may be good economic returns for biomass products agency support is likely to be low, suggesting a high vulnerability in 2020. By 2050 extraction costs may increase under climate conditions, thereby discouraging production and increasing the vulnerability to high.

Development of renewable energy production based on wood biomass

Analysis of the Usk catchment suggests that there are considerable amounts of land available for SRC biomass production. However, much of this land could also be used for food production. Currently, the economics of biomass suggest that it is not financially rational to move biomass long distances. However, it can be economically viable to import food products. Under a scenario of World Markets it may be possible to produce biomass locally and import food, although there will also be a market in food goods and Welsh farmers may choose to engage in food production for export markets rather than produce biomass. The financial return on both of these sets of goods will be a major factor in determining land use decisions.

In the medium term, public funds may need to be invested in biomass production technology, and this is unlikely to occur in the scenario of National Enterprise. In addition, competition between biomass and other less renewable forms of fuels is likely to be intense over the next decade, thereby reducing investment incentives to farmers, entrepreneurs and government. Positive environmental attitudes amongst society may serve to overcome some of these economic concerns, and thereby encourage investment in relevant technology.

A final factor relates to regulations on the establishment of biomass crops. Where strong environmental concern occurs, there may be a call to restrict the development of biomass to land of lower environmental quality, such as arable and improved grassland. Indeed, there may be a desire to further regulate biomass production with respect to variables like water and soil erosion. However, these desires will also potentially conflict with society's desire to encourage the use of biomass over fossil fuels. Conversely, under National Enterprise and World Markets there may be less environmental regulation which could then serve to allow, if not encourage, greater production of biomass.

The combination of these interacting factors is quite complex. Overall, however, the risk assessment suggests the policy has medium-low vulnerability under Local Stewardship and Global Sustainability in both 2020 and 2050, and high vulnerability in the other two scenarios.

Support WAG commitment to meet UK renewable energy targets defined at Kyoto (5 per cent of electricity from renewable sources by 2003, 10 per cent by 2010) and advised extension by Cabinet Office (2002) to 20 per cent of electricity from renewable sources by 2020

Current trends suggest that Kyoto targets are somewhat vulnerable to political priorities. Under National Enterprise and World Markets the Kyoto agreements are likely to be highly vulnerable, as there is an emphasis on markets and growth in countries all around the world. In this situation the input from Welsh woodlands and land use becomes almost irrelevant, suggesting the policy component is highly vulnerable. Under Local Stewardship, the Kyoto agreements are likely to be supported, if not enhanced, and renewable energy production is likely to receive strong support if economic conditions allow, suggesting a medium vulnerability. However, vulnerability is low under Global Sustainability as Kyoto agreements are likely to be strongly supported internationally and at UK level, while sustainable biomass production is likely to be strongly supported in Wales.

Develop and support biomass products, markets and end users

As with other policy components, the vulnerability of this particular component varies with the social and political support available to fund any development. Under National Enterprise the vulnerability is high; while there may be reduced regulation in terms of planning, there is unlikely to be support for investment in developing markets. However, under Global Sustainability the vulnerability is medium-low, as under this scenario the production of renewable energy is likely to be emphasised across the globe.

Market and promote Welsh timber products including biomass

This policy component is unlikely to be vulnerable to direct changes in climate: rather it will be a combination of social attitudes and economic conditions which will determine the degree of marketing and promotion that occur. The component is most vulnerable under Local Stewardship, where social attitudes will not be supportive of governmental promotion unless economic returns are very high (in which case promotion may be unnecessary). However, under Global Sustainability vulnerability will be low as there is likely to be considerable social and political support for market development.

Develop a grant scheme for biomass crops to support speculative farming in suitable areas based on sustainable criteria

As with the previous component, it is the social and economic conditions which will have the greatest effect on the vulnerability of this policy component. However, the definition of sustainable criteria will depend on climate conditions, in particular water availability. Overall vulnerability will be greatest in scenarios of National Enterprise and World Markets where social support will be scarce, and least vulnerable under Global Sustainability where social attitudes will be supportive of developing a grant scheme.

Promote and train heating engineers

Again, this component has low vulnerability to climate change as social and economic conditions will determine the degree of investment in training. Under Global Sustainability vulnerability is low, and it is medium-high under National Enterprise.

Ensure compliance with EIA regulations so that planting on sensitive areas such as unimproved grasslands or other habitats is avoided

The success of this component depends on the social and economic situation rather than the state of the climate. However, there is some variation between scenarios in the amount of pressure exerted on sensitive land. For example, woodlands do not expand under National Enterprise and so there will be less pressure on sensitive habitats from potential plantings. Conversely, there will be growth in woodland under World Markets and this, coupled with lack of concern regarding conservation, suggests that sensitive areas could be more vulnerable to tree planting. This results in a vulnerability of high-medium, which is the same under Global Sustainability. However, the reasons for arriving at this classification of vulnerability under Global Sustainability relate to high levels of afforestation and high concern for conservation, which together may increase pressure for planting on sensitive areas.

Set up a series of farm woodlands at various altitudes and site conditions in order to investigate and demonstrate best practice

This policy component is vulnerable only to social and economic conditions. However, should experimental woodlands be established, then their response to climate change effects would provide very useful information. Under both Local Stewardship and Global Sustainability there will be a strong social commitment to renewable fuels and research, so it seems likely that demonstration farm woodlands would be established. Conversely, it seems unlikely that demonstration woodlands would be established under the other two scenarios.

Encourage the use of biomass heating in WAG and other public sector buildings in order to stimulate the local supply chain

Again, this component depends largely on social and economic conditions, and is not affected by direct climate effects. This suggests lower vulnerability under Local Stewardship and Global Sustainability than National Enterprise and World Markets.

Integration with, and effects on, other policies and agreements

There is no fundamental reason why integration between this and other policy should not occur, as it depends solely on the attitudes of the politicians. However, these attitudes may vary with scenario. For example, under National Enterprise it is unlikely that environmental sustainability will have much political support, hence integration with other conservation initiatives is unlikely to occur, rendering the policy component highly vulnerable. Under Global Sustainability, it seems very likely that there would be good integration between land use and conservation policies, suggesting low vulnerability for this policy component.

5.4 Discussion and climate proofing

A summary of the policy components and their probability of failure is shown in Tables 5.6 and 5.7 for woodland and biomass strategies respectively. Issues of climate proofing are discussed below.

Table 5.6: Summary of the vulnerability of the different policy components of the woodland strategy

Component	Probability of failure	Notes
Increase the quality of native woodlands for wildlife and implement the Biodiversity Action Plan targets for their restoration and extension, creating links between fragmented woodlands.	Low to high	Changing distributions of species and difficulties of linking fragments challenge this component.
Increase the area of woodland achieving independent environmental certification to internationally recognised standards.	Low to high	Success linked to levels of environmental concern.
Increase the area of native woodlands, targeting extension and connection of existing woods and incorporating the concept of increasing the core area of native woodland habitats.	Low to high	Achieving this will need political support and significant investment.
Encourage the owners to incorporate different habitats, such as heath and bog, within woodlands, to maximise the connections between similar habitat types.	Low to high	Success depends on the financial returns to forestry and the level of social and political support for the environment.
Encourage the thinning of woodland to increase the future flexibility of management, to create greater diversity within woodlands and to produce more valuable timber products.	Low to high	Success depends on balance of financial returns from forestry and conservation.
Increase the biodiversity of coniferous woodlands through the use of continuous cover systems.	High	Uncertain benefits of continuous cover and long lead in time put this component under pressure from changing economics.
Aim to convert at least half of the National Assembly woodlands to continuous cover over the next 20 years, where practical, and to encourage conversion in similar private sector woodlands.	Medium	As above – so political support and investment is crucial to the success of this component.
Use catchment management planning to develop the role that woodlands can play in the management of water and the reduction of flood risks.	Low	As long as the science is clear this should offer economic and environmental benefits.
Seek to increase the competitiveness of our forest industries, working in partnership with industry to develop and implement action plans across the sector.	Medium	Competitiveness depends on the response of other countries to a changing climate.
Promote the development of specialist recreation in woodlands, including wildlife observation and artistic pursuits, and more noisy and physical sports in appropriately zoned areas.	Medium to high	Success depends on balance of economic returns from timber production and touristic activities.
Continue to encourage visitors to all the National Assembly woodlands, actively promoting the opportunities available.	Medium	As above – promotion can continue, but the desirability of more access will vary between scenarios.

Table 5.7: Summary of the vulnerability of the different policy components of the biomass strategy

Component	Probability of failure	Notes
Integrate biomass strategy with the general aims and biomass objectives of the Welsh woodlands strategy.	Medium to high	Conflicts between the two strategies may be exacerbated by climate.
Provide support for farm woodlands and the wider rural community given recent decline in farm incomes.	Low to high	Vulnerability varies with social and political situation.
Encourage farmers to bring woodlands back into production via schemes including Coed Cymru, Farming Connect, LEADER and TIMBER II.	Low to high	Vulnerability varies with social and political situation.
Development of renewable energy production based on wood biomass.	Medium to high	Lack of markets, poor competitiveness, lack of knowledge and regulations reduce chance of success.
Support WAG commitment to meet UK renewable energy targets defined at Kyoto (5% of electricity from renewable sources by 2003, 10% by 2010) and advised extension by Cabinet Office (2002) to 20% of electricity from renewable sources by 2020.	Low to high	Influenced by actual chance of achieving Kyoto and only then by extent of planting in Wales.
Develop and support biomass products, markets and end users.	Medium to high	Varies with social and political situation and is influenced by market conditions.
Market and promote Welsh timber products including biomass.	Low to medium	Vulnerability varies with social and political situation.
Develop a grant scheme for biomass crops to support speculative farming in suitable areas based on sustainable criteria.	Low to high	Vulnerability varies with social and political situation.
Promote and train heating engineers.	Low to medium	Vulnerability varies with social and political situation.
Ensure EIA regulations that planting on sensitive areas such as unimproved grasslands or other habitats is avoided.	Low to high	Social and economic situation affects vulnerability, but pressure on sensitive land from different amount of planting.
Set up a series of farm woodlands at various altitudes and site conditions in order to investigate and demonstrate best practice.	Low to high	Vulnerability varies with social and political situation.
Encourage the use of biomass heating in WAG and other public sector buildings in order to stimulate the local supply chain.	Low to high	Vulnerability varies with social and political situation.
Integration with, and effects on, other policies and agreements.	Low to high	Commitment to integration varies with social and political attitudes.

5.4.1 Biodiversity

As discussed in Chapter 3 on SSSI, the nature of our natural communities will change in the future as species distributions change. This will require a radical rethink of current conservation policy. Any changed philosophy will obviously impact on woodland biodiversity. However, given the long timescales involved in woodland planning and management, it would be prudent for those interested in woodlands to be aware of these debates, and to formulate possible responses sooner rather than later.

Current thinking (for example, Watts *et al.,* 2005) suggests that responses will embrace the importance of developing increased levels of connectivity within a landscape. This connectivity can be a real physical entity, as illustrated by the development of habitat corridors. Alternatively, it can be aimed at improving the ease with which plants and animals move through the landscape, so called 'permeability'. Increasing permeability may not simply require the physical juxtaposition of similar habitats, but it may also include a reduction in obstacles to movement. These obstacles may be physical man-made structures, like roads, and also land uses such as intensive farming.

One problem with increasing the physical level of connectivity of woodland habitats is that at some point, these new habitats become impediments to the movement of species characteristic of other habitats. For this reason, it remains a challenge to develop levels of connectivity which are simultaneously suitable for woodland and non-woodland species. Theory suggests that within a landscape comprised of 10 to 20 per cent woodland cover, there are potentially a large number of small isolated woods and relatively little or no core woodland habitat (Franklin and Forman, 1987; Peterken, 2000, 2002, 2003). However, as woodland cover reaches 30 per cent small woods tend to clump together to form larger woods. This provides a greater area of core woodland habitat which benefits species typical of woodlands. When woodland cover exceeds 60 per cent, then woodland comes to dominate the landscape and it forms the matrix within which other habitats are located. While this may be an ideal situation for woodland species, it may not be ideal for species from other habitats.

Within the Usk catchment woodland currently comprises about 12 per cent of the catchment area, with just over half being comprised of conifer plantation. If the focal woodlands were developed as shown in Figure 5.2, then they would cover 35 per cent of the catchment area. Given an aim to enhance woodland biodiversity, this would seem to be a desirable level of woodland within the catchment.

Achieving this level of woodland cover could have beneficial impacts on other ecosystem services such as water run off and potential flooding, carbon sequestration, landscape aesthetics and access. But could also lead to water loss from the catchment and land used for woodland could not be used for other purposes, such as biomass (Figure 3) or food production. The social and economic impacts of this land use change are unknown, and careful consideration is needed before deciding whether achieving 30% woodland cover is actually a socially desirable aim. Suffice to say at this point, that achieving this level of woodland cover in order to enhance woodland biodiversity could be in conflict with several other policies.

5.4.2 Provenance of trees

Most trees planted now will probably still be alive in 2040. For this reason, it is necessary to consider the species and provenances to be planted. Local provenances may not be well suited to the predicted changed climate.

When considering provenances of suitable broadleaved trees, *et al* (2005) suggest that suitable genetic material be sourced from areas with climates similar to that expected in the UK in 2050. For mid-Wales the suggested matched climate is Britanny. Genetic material of suitable tree species should be sourced from there and at least planted alongside trees of local provenance in new plantings.

The provenances of commercial conifers should also be considered and again, suitable varieties need to be planted to be harvested in 2050. The movement towards continuous cover management systems could help this, as new varieties of tree could be planted in the felled areas from now onwards. This issue is not so important for SRC, as the trees can be replaced on shorter timescales than larger broadleaved trees and conifers.

5.4.3 Land use

Extending the woodland network should bring biodiversity benefits for woodland species. The planting and use of biomass should reduce the amount of CO_2 released from fossil fuels. But both cannot happen on the same pieces of land. In addition, there may be a greater call for land for other conservation activities not related to woodlands (see Chapter 3 on SSSI), for flood management (see Chapter 7 on flood management) and also for food production. As evidenced from Figure 5.4, the same pieces of land are best suited for some of these activities (such as the bottom of the Usk catchment). For this reason, there is a need for some radical land use planning which at least would identify indicative planning areas, where certain areas would be deemed suitable for SRC. This is a difficult job, as these decisions will require a holistic view of the interactions between land uses, such as the impact of SRC on hydrology, and the decisions made may well impact on people's livelihoods in the future.

There may be possibilities for synergies between land uses. For example, could certain types of SRC offer any benefit in the focal woodland network or are they totally incompatible land uses? Could SRC and woodland planting bring any benefit to flood alleviation and reducing soil erosion? These are possibilities that need to be explored, but it must be recognised from the start that it is unlikely that any one land use system can meet all the needs of future generations, and so compromises will need to be made.

5.4.4 Shade trees and urban planning

Although not mentioned in the policies, shade is an important commodity in hot climates. Given the length of time trees take to mature, it may be prudent to start designing shade trees into urban areas, new housing and industrial developments. While trees are frequently designed in new developments at the moment, their purpose tends to be for landscaping, while their use as providers of shade may alter designs and species selection.

5.4.5 Research alternatives to SRC

The risk analysis undertaken here concentrated on SRC. However, there are other options for biomass generation including energy grasses and traditional cereals. These crops may offer advantages in terms of lower water requirements than SRC and greater flexibility for land use. Further research on these biomass systems may be warranted.

5.4.6 Fire

Forest fire will become more probable under the hotter summers of the future predicted climate. For this reason, all forest and woodland planting should take this increased risk into consideration at the design stage. There will be a greater requirement for fire breaks and restrictions on access during high risk conditions.

5.4.7 Carbon sequestration

As trees grow they tend to lock up, or sequester, carbon. Carbon sequestration tends to reduce the concentration of CO_2 in the atmosphere and thereby mitigate climate change. For example, a 40-year old crop of thinned Sitka spruce of yield class 16 can store between 30 and 40 tonnes of carbon per hectare, whereas an unthinned crop at yield class 24 can store up to 150 t C ha^{-1} (Bateman and Lovett, 2000).

However, carbon is also sequestered in the soil, and in Wales soil carbon is typically in the range 40 to 140 t ha^{-1} (D L Jones, *personal comm*unication). The greatest amount of carbon is stored in the peaty soils typical of many Welsh uplands. Unfortunately, planting trees in these peaty soils can serve to release the carbon stored in the soil. This occurs because, in addition to any physical damage incurred during tree planting, the action of the growing tree roots tends to enable soil micro-organisms to increase respiration and thereby release soil carbon. Because of this, there is an interaction between the carbon that can be sequestered directly by trees as they grow, and the carbon that can be released from soil stocks over the same period. Table 5.8 taken from Bateman and Lovett (2000) clearly shows that in upland peaty soils the planting of trees will increase overall carbon emissions, and even in many lowland situations the actual level of carbon sequestration is very uncertain. Against this general background, it is clear that detailed site-specific studies are necessary to ascertain the exact impact of any increase in woodland cover on carbon sequestration.

A similar set of arguments may also apply to the planting of biomass, but no UK data are available on this topic. However, in Belgium Deckmyn *et al*. (2004) undertook a modelling study and compared the carbon sequestration in an oak-beech forest with a poplar-based short rotation coppice. Their results suggest that overall net primary production of the oak-beech forest was low at 2.5 t C ha^{-1} yr^{-1} after 150 years, while that of the SRC plantation was 6.2 t C ha^{-1} yr^{-1}. However, the yield from the SRC poplar was used as fuel and thus the carbon was returned quickly to the atmosphere, while the timber from the oak-beech forest was used in long-lasting wood products. Overall, the total carbon pool in the mixed forest (living biomass, wood products and soil) after 150 years amounted to 324 t C ha^{-1} compared to 162 in the poplar coppice. On a straight biological comparison, the oak-beech system sequestered more carbon than the biomass system. However, the biomass would be used as a substitute for fossil fuels, and when account was taken of the energy substitution, the SRC reduced overall emissions by 24.3 to 29.3 t CO_2 ha^{-1} yr^{-1}, while the mixed forest reduced them by only 6.2 to 7.1 t CO_2 ha^{-1} yr^{-1}. This picture is further complicated by a more recent experimental study which suggests that, under future CO_2 concentrations which will be higher than at present, SRC poplar may exhibit higher potential for carbon sequestration than currently assumed (Liberloo *et al.,* 2006). Much more work is needed in this area before any definite policy recommendations can be given.

Table 5.8: Post-afforestation changes in equilibrium soil carbon storage levels for various soils previously under grass (t C ha^{-1}) for upland and lowland sites. Figures in parentheses are negative, representing losses of carbon (from Bateman and Lovett, 2000).

Soil type	Upland sites			Lowland sites		
	Under grass	Under trees	Change	Under grass	Under trees	Change
Peat	1,200	450	(750)	n/a	n/a	n/a
Humic gley	180-400	250-450	50-70	180-350	180-450	0-100
Podzol	200-400	250-450	50	100-200	100-450	0-250
Brown earths	n/a	n/a	n/a	100-120	100-250	0-130
Humic stagno podzol	180-400	250-450	50-70	120-350	120-250	0-100
Stagnogley	170-400	170-450	0-50	100-120	100-450	0-330

5.4.8 Short rotation coppice and the rural economy

Biomass will only be planted if it provides a long-term and sustainable income to the landowner. While in England there is government support for the establishment of energy currently worth £1,000 per hectare, this is not the case in Wales. Given that the supply and planting of SRC willow whips is currently estimated at £970 per hectare, it is clear that the costs may be a disincentive for some farmers (Horne, 2006).

It is also unclear what the market price will be for biomass once a fully functioning market is established. Currently, Greenergy (2006) offer £45 per oven-dried tonne (odt) for SRC woodchips, although growers are responsible for meeting costs of drying and transport, estimated at around £20 per tonne with 25 miles haulage.

Results from ongoing trials of SRC willow in South Wales suggest yields of 2.7 to 6 odt ha^{-1} yr^{-1} in the first rotation and 7.7 to 11 odt ha^{-1} yr^{-1} in the second rotation. Assuming the worst case scenario of a yield of 8 odt ha^{-1} yr^{-1} and the current market price offered by Greenenergy, a farmer may expect a revenue of £200 per hectare. This revenue would need to cover the capital costs of establishment and the ongoing costs of maintenance and pest management (Powlson *et al.,* 2005). However, as biomass technology improves we may expect to see significant yield increases and management efficiencies, which will radically alter the financial return on production.

With current technology it takes about 15 kW of thermal energy to heat a single house. This would require five oven dry tonnes of biomass fuel per year. Similarly, a medium-sized school might require 350 kW of thermal energy, which could be provided by 100 oven dry tonnes of fuel per year. If yields of 10 odt ha^{-1} yr^{-1} could be achieved across the Usk valley then, given our estimates that the Usk catchment could support 34,054 ha of SRC willow, there would be a total production of 340,540 odt yr^{-1} from the catchment. This could provide the heating for 68,000 houses or 3,405 medium sized schools. However, achieving this would mean that land currently in food production would need to be converted to biomass production, and that the aspirations of the woodland strategy may also be compromised.

6 Catchment Abstraction Management Strategies

6.1 Background on policy

Water is abstracted from surface and groundwaters for a variety of reasons, including use in public water supply, domestic and industrial sectors, for power generation in hydroelectric schemes and for irrigation. Regulation of the abstraction process is based on the findings of Catchment Abstraction Management Strategies (CAMS) (Environment Agency, 2002, 2005) CAMs are reviewed every 6 years within a broader national framework of water resource strategy planning which looks 25 years into the future. CAMS are designed for water resource management and do not aim to address issues of flood management; they provide the baseline conditions for abstraction within a catchment. Currently there are 129 CAMS areas across England and Wales, and 64 had been completed by April 2006.

The main aims of CAMS are to:

- make information on water resources and licensing available to the public;
- provide a consistent approach to local water resources management, recognising the reasonable needs of water users and the environment;
- provide the opportunity for greater public involvement in managing the water resources of a catchment;
- provide a framework for managing time-limited licences;
- facilitate licence trading.

Once developed, a CAMS should outline the abstracting practice for a catchment and identify how abstraction is to be managed in accordance with four elements of sustainable development: society, economy, environment and natural resources. Although individual CAMS are formally reviewed every six years, the catchment level ledgers which are used to assess water availability are updated on an ongoing basis as licences and discharges change, for example through expiry or revocation.

Abstraction licences are issued according to regulations outlined in local CAMS; however, in general if less than 20 m^3 per day is to be abstracted then no licence is required. If the abstraction is greater than 20 m^3 per day then it requires a formal licence, although some purposes are still currently licence exempt (such as trickle irrigation and canal supply for navigation and some groundwater and surface water abstractrations not deemed to be important water resources for which exemptions were granted in 1965). This system was implemented in April 2005; prior to this date a more complex system existing with regulation of some abstractions from 5 to 20 m^3. Deregulation post 2005 followed a risk based assessment..

The purpose of an abstraction licence is to regulate the amount of water that can be abstracted from surface and groundwaters, to ensure that sufficient water is available for other users, including the environment. Originally, only some abstraction licences were time limited, most were offered indefinitely, however since April 2004 it has been a statutory duty to introduce time-limited abstraction licences. Currently, though, less than 20 per cent of abstractions are time-limited (John Waddingham, *personal communication*). The CAMS framework also enables licences to be traded between abstractors within a catchment, although this may be restricted by abstraction location and water availability.

Abstractors need to apply for a licence to the Environment Agency, which then undertakes statutory consultations with Internal Drainage Boards, navigation, harbour and conservancy authorities. In addition, relevant countryside agencies (CCW in Wales and Natural England in England) are consulted where a site designated for its conservation interest might be affected. When considering the licence application, the Environment Agency has a duty to ensure that interests downstream of the abstraction will not be compromised by the proposed abstraction. This includes ensuring that downstream flows meet ecological requirements. When granting a licence, the Environment Agency can set conditions which ensure that the abstraction does not compromise other interests. For example, the licence may define a minimum flow in a river below which abstractions can not be made. These decisions are made by referring to location-specific data which include rainfall data, borehole measurements, river flow measurements and consideration of existing abstractions and discharges. These data are used to estimate natural flows from which sustainable levels of abstraction can be assessed.

Local impacts can be managed through varying the abstraction regime; this is needed in some areas where abstraction during low summer flows can cause ecological damage. In general, the Environment Agency prefers applicants to use a 'hands-off' approach to controlling abstraction. This can mean structures such as weirs and sluices put in place to automatically ensure water is not abstracted when flows fall below a prescribed level. This is felt to be a more reliable method for controlling abstraction than human intervention, particularly for impoundments. Abstraction decisions are supported by ongoing research, which assesses the range of flows necessary to maintain rivers and streams in a healthy state. To date these assessments have not taken account of climate change, and licences have been granted for fixed abstraction amounts relative to hands-off flows at the time of granting the licence; this could prove to be a significant problem in future. Where changes are required to a licence, for example if identified by CAMs or Habitats Directive, these are undertaken within the Environment Agency Restoring Sustainable Abstraction Programme.The longer term Water Resourse Strategies will take account of future climate change but it is unclear to what extent we will need to model catchment scale climate change impacts to do this. Good ecological status requirements of the Water Framework Directive may result in changes to flows required to maintain good status; it is not yet clear what the effects of climate change will be on freshwater ecology (Wilby *et al.*, 2006).

While CAMS are extremely important management tools at the catchment level, they are not the only method by which the Environment Agency and other organisations manage water supply. For example, both water company water resources plans and the Environment Agency water resources strategy cover actions and plans which ensure that water supply balances demand. Further, a wide range of Environment Agency plans and programmes work together to help protect the aquatic environment, and while CAMS is an important part of this process, it is not the only element. In order to maintain comparability with the other policies analysed here, it is assumed that CAMS is a stand alone policy; however, we fully acknowledge that a more complete risk assessment may need to consider all relevant water management strategies and activities as a coherent whole, rather than on an individual basis.

6.1.1 Abstractions in Wales

The end uses of abstracted water in Wales differ enormously. Considerable amounts of water are used for hydroelectric power, while water used for irrigation in agriculture accounts for less than one per cent, although it may be locally very significant in terms of the rural economy. While agricultural demand is relatively small in volume, spray irrigation can place a significant pressure on river flows in dry years in both South West and South East Wales.

The vast majority (98 per cent) of the 20,000 million litres of water abstracted each day in Wales comes from surface waters. The remainder is derived from groundwater. Although the latter accounts for only a small proportion of the water, it can be locally significant as the only source of water for agriculture in particular, but also for domestic use in some rural areas. Some areas were exempt from all abstraction through the Water Resources Act of 1963 as they were deemed to have no major water resource. As a consequence most of Western Wales is, to this day, a licence exempt area for all groundwater abstractions.

Within Wales, leakage rates vary considerably. In the North East, leakage is among the lowest in England and Wales, while in the South East it is among the highest. This issue is being addressed by water companies, partly because the Office of Water Services has set mandatory targets for improvements before more abstractions can be considered.

There are 9 ‘reservoir operating agreements’ across Wales which use mainly reservoirs (the Clwyd is groundwater support) to increase river flows when they are low to ensure abstractions can take place downstream. There are two other regulated rivers where no agreements exist (Cleddau and Usk); these are controlled through agreements stipulated in the abstraction licences. Most of the other 140 reservoirs in Wales have some agreed discharge to maintain flows directly below the dam. There are 18 CAMS in the Environment Agency Wales region, and another five which are part of the Severn catchment, which also cover Wales. A CAMS for the Usk is currently under development and will be finalised in 2007.

6.2 Methodological summary

For the purposes of comparability across chapters, ‘policy' is used to describe all resource protection agreements analysed in the report, regardless of whether they are technically classified as 'strategies', 'action plans', 'processes' or 'policies'. We recognise that this is not always technically correct, but it does enable a generic methodological framework to be used across a range of different resource agreements.

Risk assessment of the CAMS policy followed the approach outlined in Chapter 2. The pre-analysis work generic to all policies was completed prior to undertaking the assessment of the CAMS policy and followed the structure outlined in Figure 2.1. The policy assessment work followed the pattern outlined in Table 2.6. However, as the CAMS for the Usk was not available for analysis, it was necessary to undertake a more generic approach to risk assessment than for some of the more fully developed policies. Details of the outcomes for each step in the risk assessment step are reported below.

1. Identify key components of policies to be analysed
The key policy components of CAMS were analysed and the relevant policy components are shown in Table 6.1.

2. Answer adapted UKCIP risk analysis guidance questions
This was undertaken and the results are shown in Appendix 6 on the accompanying CD.

3. Identify risk exposure units, receptors, thresholds and endpoints
The key receptors were identified and are presented in Table 6.2.

Table 6.1: Policy components of catchment abstraction management strategy (CAMS)

Policy component
1. Balance social and environmental demands on water resources.
2. Protect aquatic environment, species and habitats.
3. Ensure that abstraction does not cause river flows, groundwater levels or wetland water levels to fall artificially below the minimum level required for conservation of the aquatic environment.
4. Provide an indication of water availability/deficit within the catchment.
5. Divide catchment into Water Resource Management Units (WRMU) and carry out sustainability appraisal for each.
6. Provide a framework for managing time-limited abstractions.
7. Provide a framework for licence trading.
8. Ensure open public discussion and consultation.
9. Set appropriate 'hands-off' flows and apply on a tiered basis (particularly to surface water abstractors and sometimes to ground water abstractors).
10. Ensure workable links to other initiatives.

Table 6.2: Receptors identified for abstraction and low flow management

Receptors
Fish, especially salmon and trout
Marshy grassland
Blanket bogs
Raised bogs
Reed beds, swamps and species-rich fens
Coastal grazing marsh and floodplain grassland
River features
Abstractors
River livelihood dependents
Other river users

4. Research potential effects of climate change on receptors via survey of scientific literature, experiments, modelling and analysis
This was completed as required when undertaking the receptor risk analysis and the results are discussed where appropriate throughout this chapter.

5. Undertake receptor risk analysis
This required an assessment of the vulnerability of each receptor to change under each of the socio-economic scenarios, and in combination with the UKCIP medium-high climate scenarios for 2020 and 2050 as reported in Table 2.9. The full results of this process are available in the Risk Assessment Matrices (RAM) shown on the accompanying CD.

6. Undertake policy component risk analysis
This analysis also followed the process outlined in Table 2.9. The results of this process are fundamental to the entire risk assessment, as discussed below. The complete results of this process are available in the RAM shown in Appendix 6 on the accompanying CD.

7. Test the results of the process and use the results to 'climate proof' the policies

This aspect of the risk assessment is specific to each policy analysed and was not discussed in detail in Chapter 2. The remainder of Chapter 6 is dedicated to discussing the methods and results of this process. It begins with a discussion of how the risk assessment method was applied to the Usk catchment, and is followed by an analysis of the risks to the policy components.

6.2.1 Applying the risk assessment method to CAMS policy in the Usk catchment

Risk assessment method

The risk assessment for CAMS policy in the Usk catchment followed a seven-step process, illustrated in Table 6.3. Fundamental to this risk assessment were the risk assessment matrices (RAM) developed as part of the receptor and policy component risk analyses. These are presented in full in Appendix 6 on the accompanying CD.

Abstractions in the Usk Catchment (Steps 1, 2 and 3)

Number and type of abstractions

Abstraction licences and river flow gauging stations were mapped for the Usk in a GIS environment and superimposed on hydrological sub-catchments (Figures 6.1 and 6.2). There are currently 127 licences for abstraction of more than 20 m^3 day^{-1} granted for the Usk, and 319 abstractions for 5-20 m^3 day^{-1}. The number of abstractions tends to be greater in the lower part of the catchment than the upper reaches, and sub-catchment 3 has the greatest number of abstractions both above and below 20 m^3 day^{-1}.

For the purposes of the risk assessment, it was desirable to classify the types of abstractions at a basic level in order to permit further analysis. Unfortunately, the descriptions of abstractions in the licence database are general in nature and include phrases like:

- 'drinking, cooking, sanitary, washing, (small garden) - household and commercial', 'general farming and domestic';
- 'drinking, cooking, sanitary, washing, (small garden) - household and commercial/industrial/public services, potable water supply - direct, spray irrigation - storage, make-up or top-up water and filling/maintaining swimming pool/pond and commercial supply';
- 'transfer between sources'.

This imprecision arises because a number of less than 20 m^3 per day abstractions are entered as one entry in the ledger, while generally those of greater than 20 m^3 are given a more precise description.

Because of the imprecision of the descriptors, the classification scheme was based on six major categories of abstraction purpose, where abstractions were allocated to a class on the apparent primary purpose of the abstraction (for example, see Table 6.4). In addition, estimates were made of the overall level of abstraction for each purpose, but given that an abstraction licence could be for many purposes, as shown above, it was not possible to calculate exactly how much water went to each use. Given the imprecision of this classification, these data must be viewed with some care. A summary of the nature and location of the abstraction licences is given in Tables 6.4 and 6.5 and further details are presented in Appendix 6 in the accompanying CD.

Table 6.3: Risk assessment procedure for CAMS

Step	Action
1	Get data on abstractions from Environment Agency and flow data from UK National River Flow Archive.
2	Map abstractions on catchment boundary.
3	Consider the nature of abstractions in the catchment.
4	Use Risk Assessment Matrices to assess vulnerability of habitat receptors to climate change.
5	Use Risk Assessment Matrices to assess vulnerability of in-stream receptors to climate change.
6	Consider the impact of potential future irrigation on water demand in the catchment.
7	Use the results of this process to inform the assessment of the CAMS policy in general.

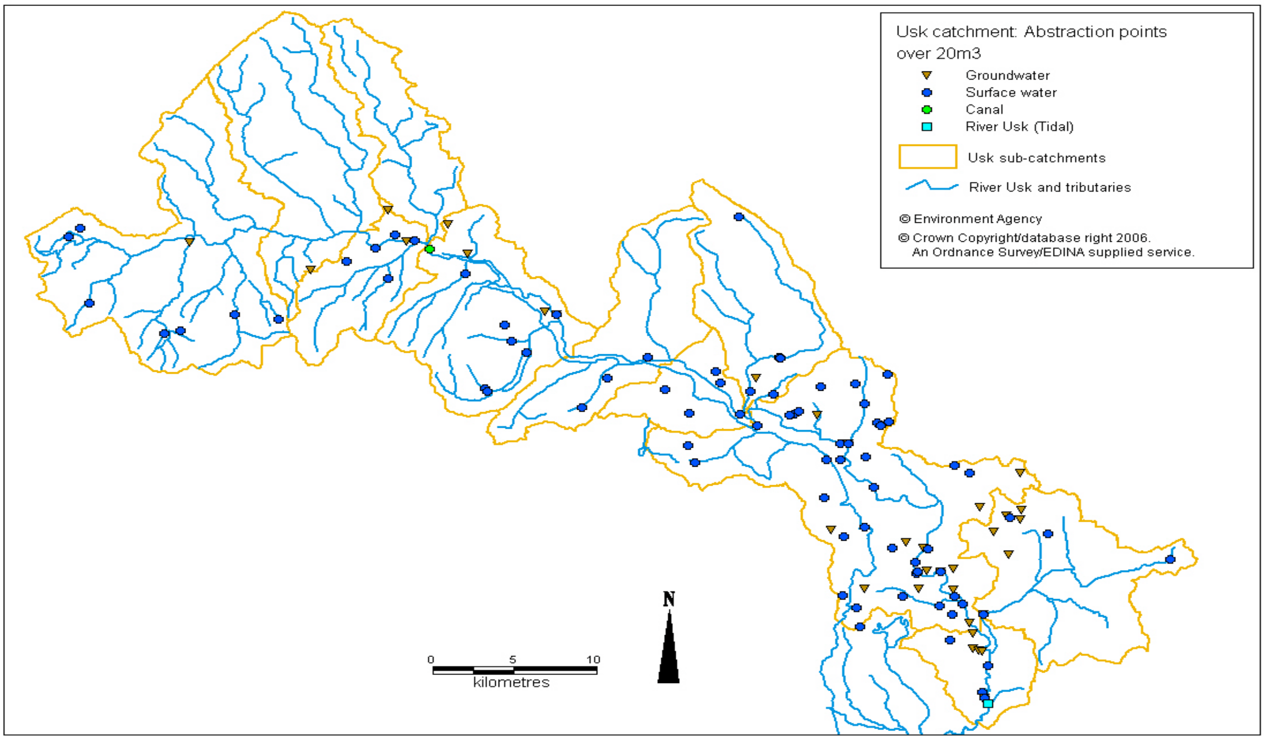

Figure 6.1: Location of points in the Usk catchment licensed to abstract more than 20 m^3 per day

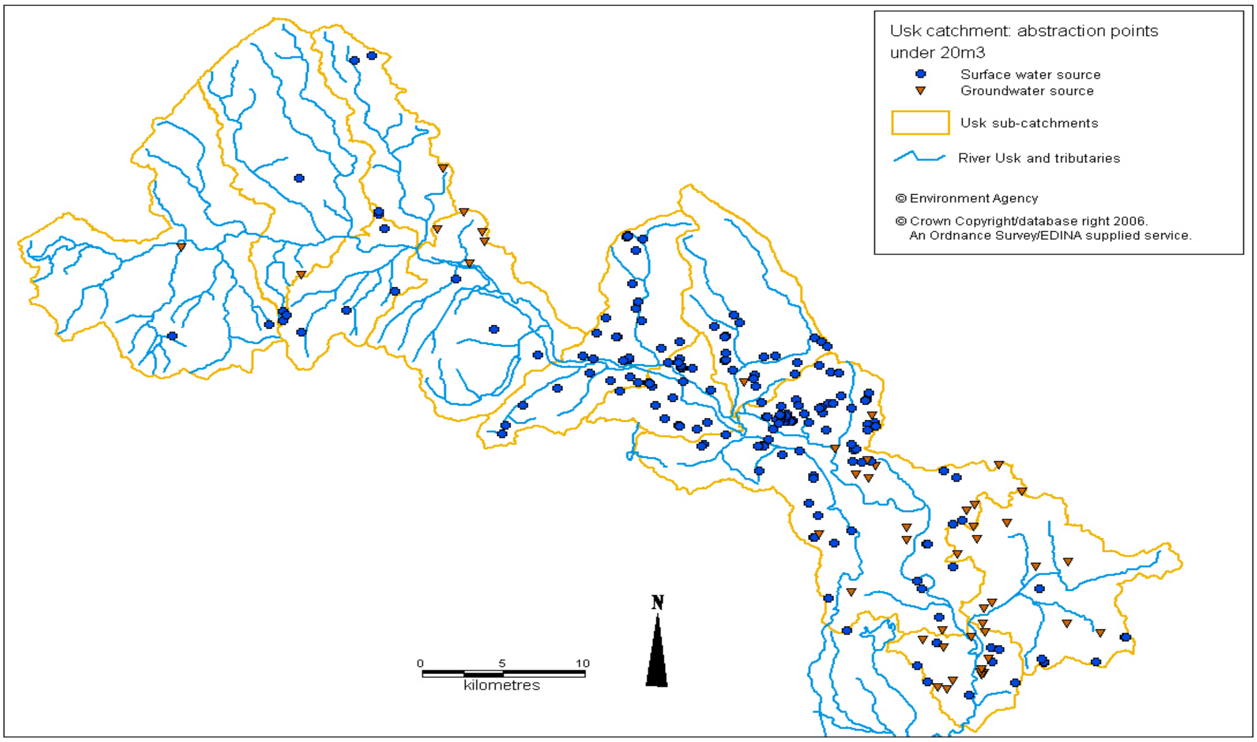

Figure 6.2: Location of points in the Usk catchment licensed to abstract less than 20 m^3 per day

Table 6.4: Summed daily rates (m^3) permitted for abstraction of 5-20 m^3 listed by category of use of the abstracted water

Item	Sub-catchment											Total
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
No of licences	22	23	149	26	28	39	8	9	3	8	4	**319**
Use												
Potable	0	0	4	11	0	1	2	0	0	0	0	18
Drinking	23	3	123	11	21	37	5	14	1	3	1	242
Irrigation	0	0	40	0	0	0	0	6	0	0	0	46
Transfer	0	0	10	0	0	0	0	0	0	0	0	10
General	94	86	202	27	49	39	15	15	8	6	21	562
Other	0	0	0	0	0	0	0	0	0	0	0	0
Total	117	89	379	49	70	77	22	35	9	9	22	878

Table 6.5: Summed daily rates (m^3) permitted under licences for abstraction of over 20 m^3 listed by category of use of the abstracted water

Item	Sub-catchment											Total
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
No of licences	12	11	57	7	6	0	17	8	0	0	9	**127**
Use												

Potable	77,282	186	12,369	10,060	883	0	72,801	7,816	0	0	86,692	268,089
Drinking	28	3	256	23	61	0	131	4	0	0	1	507
Irrigation	535	181	3,381	0	0	0	0	350	0	0	0	4,447
Transfer	0	140	318,680	346	0	0	97,819	0	0	0	50,006	466,991
General	112	237	526	26	89	0	98	23	0	0	23.7	1,135
Other	0	0	3,308	0	0	0	34,526	0	0	0	1,455	39,289
Total	77,957	747	338,520	10,455	1,033	0	205,375	8,193	0	0	138,178	780,458

Volume of abstractions

The Environment Agency licence database also gave the maximum quantities permitted to be abstracted per hour, per day and per year in m^3 for each licence, and some licences had restrictions which only permitted abstraction during certain months of the year, or if a particular river flow level was exceeded (so-called 'constrained licences'). These data were not commonly available for all licences as the level of restriction varies with the licence, where some licences have restrictions per day or per month, while others just have permitted annual rates of extraction.

This type of data is difficult to summarise. However, given that it is the maintenance of low flows that is most crucial to the ecology of the river, and that the frequency of these low flows is expected to increase under climate change, a summary of total abstraction levels based on maximum daily abstraction rates is presented in Tables 6.6 and 6.7. While the resulting summary figures must be interpreted with care, they do have the advantage of explicitly taking the worst case situation, which is when all abstractors remove water to the limit permitted under their licence.

In rough percentage terms, the data for licences for less than 20 m^3 day^{-1} suggests that about five per cent of abstractions go to irrigation, two per cent for potable water and 64 per cent for general uses (Table 6.6). Data for licences greater than 20 m^3 show a slightly different pattern, where 60 per cent of all water abstracted is for transfer, 34 per cent for human consumption and less than one per cent for irrigation (Table 6.7). Much of the water abstracted as 'transfers' is also destined for human consumption, and water from the Usk catchment assists in supplying much of South East Wales including Newport, Cardiff, Cwmbran and Pontypridd, as well as Swansea and Ebbw valleys (EAW, 2000). These figures are annual statistics, and aggregated data of this nature may mask seasonal variations in levels of peak abstractions and consumption.

Table 6.6: Percentage of the summed daily rates (m^3) permitted for abstraction of 5-20 m^3 for each category in each sub-catchment

Item	Sub-catchment											Overall %
	1	2	3	4	5	6	7	8	9	10	11	
Potable	0	0	0.5	1.3	0	0.1	0.2	0	0	0	0	2.1
Drinking	2.6	0.3	14.0	1.3	2.4	4.2	0.6	1.6	0.1	0.3	0.1	27.6
Irrigation	0	0	4.6	0	0	0	0	0.7	0	0	0	5.2
Transfer	0	0	1.1	0	0	0	0	0	0	0	0	1.1
General	10.7	9.8	23.0	3.1	5.6	4.4	1.7	1.7	0.9	0.7	2.4	64.0
Other	0	0	0	0	0	0	0	0	0	0	0	0.0

Table 6.7: Percentage of the summed daily rates (m^3) permitted under licences for abstraction of over 20 m^3 for each category in each sub-catchment

Item	Sub-catchment											Overall %
	1	2	3	4	5	6	7	8	9	10	11	
Potable	99.1	24.9	3.7	96.2	85.5	0	85.5	95.4	0	0	62.7	34.4
Drinking	0.0	0.4	0.1	0.2	5.9	0	5.9	0.1	0	0	0.0	0.1
Irrigation	0.7	24.2	1.0	0.0	0.0	0	0.0	4.3	0	0	0.0	0.6
Transfer	0.00	18.7	94.1	3.1	0.0	0	0.0	0.0	0	0	36.2	59.8
General	0.1	31.7	0.2	0.3	8.6	0	8.6	0.3	0	0	0.0	0.2
Other	[illegible]	[illegible]	1.0			0	0.0	0.0	0	0	1.1	5.0

Consumptiveness of abstractions

Some abstractions result in nearly all the water being returned to the river system close to the point of abstraction, such as in the case of the abstraction for hydroelectric purposes in sub-catchment 7. In other cases, abstracted water may not be returned to the catchment, as sometimes occurs when water is used for consumption. In this situation, the use may be consumptive if the water is transported out of the catchment prior to use, and also when less water is returned to the catchment through waste streams than was abstracted. The Environment Agency licence database provides estimates of the amount of abstracted water that will be returned to the catchment system for each licence. These estimates are made on a 100-point scale, where 100 represents the situation when none of the water returns to the river system (so-called highly consumptive use), and zero represents non-consumptive use, implying that all the water abstracted is returned. As seen in Table 6.8, in the Usk catchment the majority of abstractions are consumptive, implying that little of the abstracted water returns to the system.

Table 6.8: Categorisation of the consumptiveness of abstraction licences in the Usk catchment. Figures under 'licence type' are the number of abstractions with a given level of consumptiveness.

Consumptiveness (0 is no consumption 100 is complete consumption)	**Licence type**	
	> 20 m^3 a day	**< 20 m^3 a day**
0	7	0
10	1	0
40	35	162
50	1	0
70	2	1
80	3	1
90	1	0
100	77	155

Source of abstraction

Within the Usk catchment, just under a third of the > 20 m^3 day^{-1} abstractions are made from groundwater sources, along with 15 per cent of the < 20 m^3 day^{-1} abstractions, with most of the rest coming from surface waters (Appendix 6). This mix of abstraction sources introduces a further level of complexity into analyses and when viewed from the simplest position, the abstraction of surface water for a highly consumptive use directly reduces the downstream flow. However, it is more difficult to predict the impact of groundwater abstraction on river flows. The exact nature of the relationship depends on the levels of connectivity that exist between ground and surface waters, which will vary with location. For example, within the Usk catchment groundwater is particularly important in sub-catchment 3 because of the underlying carboniferous limestone. Springs are numerous in this area and because of this, rivers in this sub-catchment return relatively high flows in the summer. However, this situation is not common elsewhere in the catchment. Understanding the impact of abstractions on in-stream flows is made even more difficult because deliberate and managed discharges into the river system also affect surface flows. During development of the Usk CAMS, we assumed that all groundwater abstractions had a 100 per cent impact on surface water, which is the worst case scenario.

Applying a hydrological model of the catchment which could represent this level of complexity under a changed climate was beyond the scope of this work. For this reason, the case study aspect of the risk assessment focused on the impacts of land use change on water resources in the catchment, and considered the overall vulnerability of the catchment to continue to meet the needs of the abstractors under a changed climate.

Assess vulnerability of receptors to climate change (Step 4)

The receptors identified as being relevant to CAMS comprised individual species, habitats and users of the rivers (Table 6.2). As stated in Chapters 2 and 3 on methodology and SSSI respectively, the risk assessment process undertaken here is not concerned with risks to individual species, but focuses on habitats. For this reason, there is no specific discussion of fish or other aquatic species. However, several studies have been carried out on the impacts of climate change on riverine fish and these suggest that low flows affect movement within the river system (Booker and Dunbar, 2004; Solomon and Sambrook, 2004), and may also contribute to increased water temperatures. These in turn have been shown to directly affect the speed of movement of salmon (Salinger and Anderson, 2006) and to increase disease levels in brown trout (Hari *et al*., 2006). When viewed at a global scale, Xenopoulous *et al*. (2005) suggest that the combined effects of low flows and increased temperatures may reduce local fish biodiversity by up to 75 per cent.

When considering human receptors, the importance of abstractors has been described above, and will be considered again later in the policy analysis section. We are unaware of any other stakeholders who derive a livelihood from the river. For these reasons, the remainder of this section concentrates on the relationship between river flows and habitats.

Habitats

Several habitats were identified as receptors in the risk analysis process and as such, are potentially influenced by any changes in the hydrological regime such as flow levels and stream power (Table 6.1). Not only do these hydrological variables affect the amount of water available to species, but they can also alter sediment transport and deposition and river morphology, both of which can have impacts on aquatic habitats and species. In order to estimate their vulnerability, the area of the most appropriate Phase 1 habitats was estimated for each sub-catchment (Table 6.9) and their vulnerability to changes in in-stream flow is discussed below.

Table 6.9: Area (ha) and percentage of land area of receptor habitats in each sub-catchment. All habitats are Phase 1 habitat types. 'Marshy grassland' is an aggregate of marshy grassland, marshy grassland (*Juncus* dominated) and marshy grassland (*Molinia* dominated).

Habitat	Sub-catchment																					
	1		2		3		4		5		6		7		8		9		10		11	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Marshy grassland	4	<1	6	<1	241	1	21	<1	161	<1	232	4	190	3	134	2	106	3	304	2	1454	8
Blanket bog	0	0	0	0	4	<1	71	<1	74	2	15	<1	5	<1	0	0	0	0	4	<1	24	<1
Raised bog	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	<1	0	0	0	0	0	0
Wet modified bog	0	0	0	0	99	<1	17	<1	0	0	0	0	0	0	0	0	0	0	11	<1	0	0
Dry modified bog	0	0	0	0	0	0	922	11	0	0	123	1	201	2	0	0	1	<1	4	<1	5	<1
Flush and spring	0	0	0	0	0	0	0	0	0	0	0	0	2	<1	4	<1	0	0	0	0	0	0
Acid/neutral flush	0	0	0	0	79	<1	3	<1	2	<1	12	<1	36	<1	5	<1	8	<1	32	<1	122	1
Basic flush	0	0	0	0	0	0	5	<1	0	0	5	<1	0	0	3	<1	0	0	0	0	5	<1
Fen	0	0	0	0	1	0	0	0	2	<1	0	0	0	0	2	<1	0	0	0	0	1	<1
Valley mire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	<1
Basin Mire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	<1	0	0	16	<1	0	0
Bare peat	0	0	0	0	0	0	0	0	0	0	18	<1	0	0	0	0	0	0	0	0	0	0
Swamp	0	0	1	<1	3	<1	0	0	0	0	0	0	2	<1	0	0	0	0	0	0	4	<1
TOTAL	4		7	0	426	1	1041	11	240	2	405	6	437	4	158	2	115	3	371		1622	

The greatest areas of receptor habitats are in sub-catchments 11 and 4. Sub-catchment 11 is situated at the top of the catchment and would only be susceptible to abstraction from within the sub-catchment. Currently, about 60 per cent of licensed abstraction from sub-catchment 11 is related to the supply of potable water, while a further 36 per cent is classified as a 'transfer between sources'. All of these uses are highly consumptive, with no return of the water to the sub-catchment. The habitat receptors in this sub-catchment would seem to be vulnerable to increased abstraction. However, it is difficult to calculate their exact vulnerability without undertaking a specific study of the sensitivity of individual habitats to changes in flow.

The receptor habitats in sub-catchments 9 and 10 are largely independent of the flows leaving sub-catchment 11, and are most susceptible to abstraction from within their own boundaries. Abstractions in these sub-catchments are very low, suggesting a very low risk to the receptor habitats.

Sub-catchment 8 is dependent on the flows in the upstream sub-catchments (9, 10 and 11), and is also the location of substantial marshy grasslands and the only raised bog in the Usk catchment. This is a potential concern, as raised bogs are highly vulnerable to a changed climate and Wales has some of the best examples of raised bogs in Europe. Abstraction in the sub-catchment is dominated by two licences for potable supplies, with the rest being for irrigation of farmland and a golf club. Further abstraction may increase the risk of damage to receptor habitats, particularly if the raised bog is dependent upon spring flow rather than restricted drainage.

Sub-catchment 4 also has a relatively large area of receptor habitat, but is not dependent on the flow from other sub-catchments. Sub-catchment 3, on the other hand, receives the flow from all sub-catchments upstream, and is the sub-catchment with the greatest level of abstraction. There are some receptor habitats in the sub-catchment, totalling about two per cent of the land area, but these tend to be on the uplands and away from major areas of urbanisation and agricultural development. Sub-catchments 1 and 2 have very low amounts of receptor habitat, and their management is heavily dependent on the flow received from further up the catchment. A more detailed analysis of the location of the receptor habitats in relation to the hydrological regime in these lower sub-catchments is necessary to prepare a more detailed vulnerability analysis.

Assess vulnerability of in-stream receptors to climate change (Step 5)

Some policy receptors are related to the level of flow in the river. These include fish and in-stream users, such as recreational users. Current unpublished estimates of the state of flow in the river undertaken by the Environment Agency, as part of the development of the CAMS, suggest that much of the river has a 'very high sensitivity' to abstraction, and the rest has a 'high sensitivity' (Table 6.10). Because the Usk CAMS is still under development, these analyses are currently incomplete, but they do suggest that there is little spare capacity for further abstraction from the upper, middle and lower reaches of the catchment. Indeed, so great is the concern in some reaches that two licences are being investigated under the auspices of the Habitats Directive. Despite this level of concern, current assessments do not consider the impacts of climate change on future flows, and this is an area that should be included in future CAMS processes.

As reported in Chapter 2, current predictions of the climate in 2020 suggest the average annual level of precipitation in Wales will increase by between three and five per cent of current levels. Rainfall in winter will increase by up to 5.4 per cent, while in the summer it will decrease by up to eight per cent. Similar levels of precipitation are expected by 2050, but the seasonal variation will be greater, with winter rainfall increasing by up to 11 per cent, and summer rainfall decreasing by up to 17 per cent.

The relationship between precipitation and in-stream flows varies between catchments. However, the UK Water Industry Research Ltd recently commissioned a report which makes some general observations on the effects of climate change on river flows and groundwater recharge (UKWIR, 2002). This report presents a series of 'flow factors' which may be used to determine the effects of climate change on mean monthly run-off in 2020. The analysis is based on UKCIP climate scenarios, and for this reason these factors do not provide forecasts of in-stream flow and recharge in 2020, but rather provide a range of possible conditions. In essence, these 'flow factors' represent the percentage change in the mean monthly run-off that will be observed in 2020 relative to the 1961-1990 average. UKWIR (2002) present these factors as a series of monthly figures for five climate scenarios in each of 13 UK regions.

Table 6.10: Summary of the Environment Agency's assessment of the sensitivity of different reaches of rivers in the Usk catchment to abstraction. (Environment Agency, *pers. comm.,* 2005). Assessment points are marked on Figure 6.3.

River reach upstream of assessment point	Description	Phase 1
1	Sor Brook	High abstraction sensitivity
2	Usk at Newbridge, close to tidal limit	High abstraction sensitivity
3	Dowlais Brook	High abstraction sensitivity
4	Olway Brook (at gauging station)	High abstraction sensitivity
5	Usk upstream of confluence with Dowlais Brook	High abstraction sensitivity
6	Berthin Brook	High abstraction sensitivity
7	Usk, Trostrey Weir upstream to Gavenny	High abstraction sensitivity
8	Gavenny	Very high abstraction sensitivity
9	Usk and Cibi Brook to Gwynne	Very high abstraction sensitivity
10	Clydach Brook	Very high abstraction sensitivity
11	Gwynne (from reservoir to Usk)	Very high abstraction sensitivity
12	Usk from Clydach confluence to Caerfannell confluence	Very high abstraction sensitivity
13	Caerfannell	Very high abstraction sensitivity
14	Usk from Caerfannell confluence to Honddu confluence	Very high abstraction sensitivity
15	Usk upstream of Brecon	Very high abstraction sensitivity
16	Crai Brook	Very high abstraction sensitivity
17	Usk downstream of reservoir	Very high abstraction sensitivity
18	Bettws/Malpas Brook	High abstraction sensitivity

To get some indication of likely future flows in the Usk catchment, we took the UKWIR (2002) flow factors for the medium climate change scenario for Wales and applied them to mean monthly stream flow 1975-1991 (data from National River Flow Archive) for four gauging stations in the Usk catchment. These were Olway Brook gauging station (no. 56015), Gwyne at Millbrook (no. 56012), Yscir at Pontaryscir (no. 56013) and Honddu at The Forge, Brecon (No. 56003). These gauging stations were chosen for analysis as good long-term naturalised flow data were available for them (details are in Figure 6.3 and Appendix 6).

The results of this process suggest slightly increased flows in December, January and February and lower flows in all other months (see Figure 6.4 for results for Olway Brook and Appendix 6 for information on other gauging stations). Of particular note is that flows in July, August and September may only be 75 per cent of the long-term average flow. Strictly speaking, the exact results of this analysis can only apply to the four gauging stations analysed; however, as the flow factors are constants these results can be taken to be indicative of future flows across the Usk catchment. Given that many areas of the river are already classified as being very high sensitive to abstraction, any reduction in flows, particularly in the summer months, may lead to conflict between the needs of the natural environment and human abstractors. This highlights the need for future management of river flows to take cognisance of future climate, land use, demographic and economic change within the catchment.

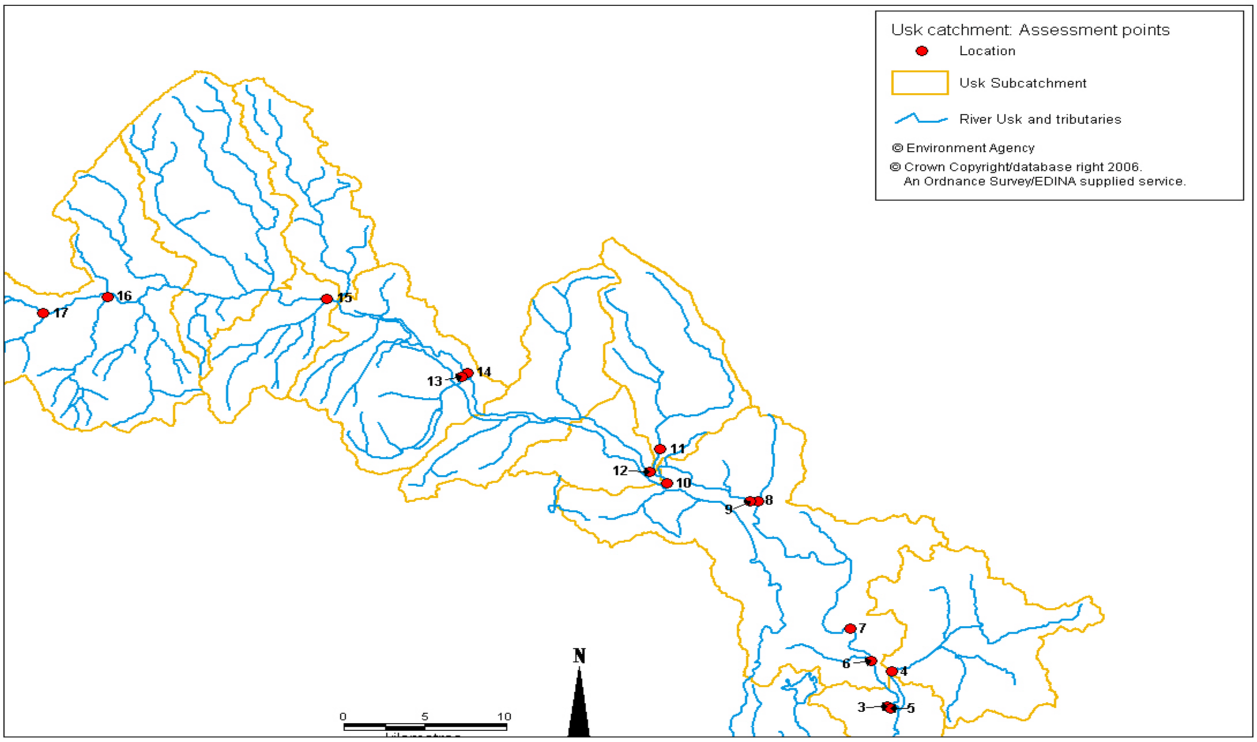

Figure 6.3: Location of data assessment points in the Usk catchment used to generate naturalised stream flows presented in Figure 6.4.

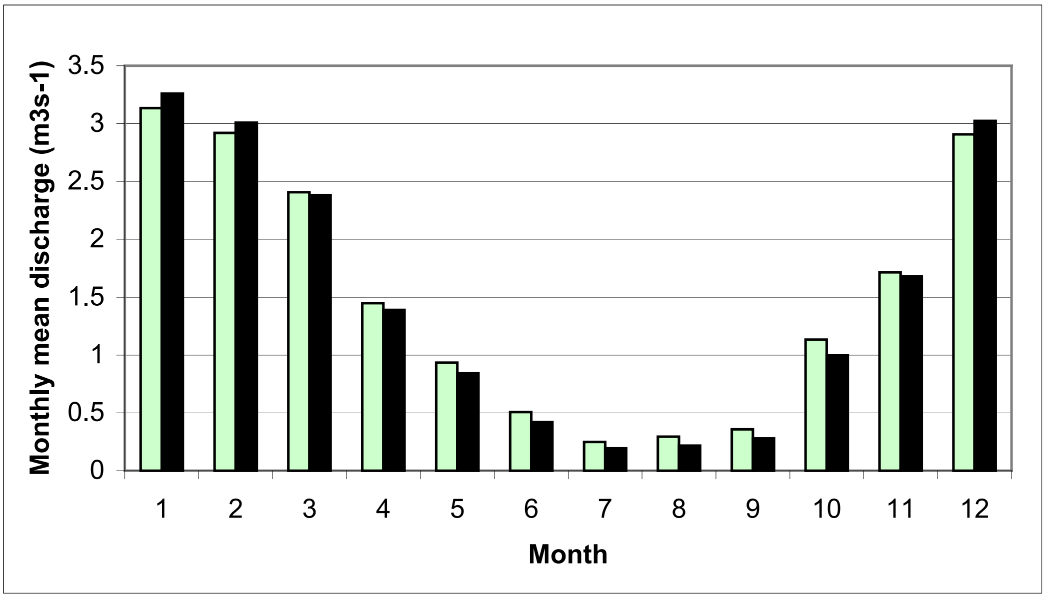

Figure 6.4: Mean monthly naturalised stream flow ($m^3 s^{-1}$) 1975-1991 for Olway Brook and estimated flows under climate change in 2020. Light shading: 1975-1991 average, dark shading: likely flows in 2020 (conversion based on data from UKWIR, 2002).

The impact of potential future irrigation on water demand in the catchment (Step 6)

The volume of water abstracted for irrigation has increased across the UK from around 16 million $m^3 yr^{-1}$ in 1974 to around 62 million $m^3 yr^{-1}$ in 1997. This is far less than the amount enabled by abstraction licences, which was around 148 million $m^3 yr^{-1}$ in 1997 (Weatherhead and Knox, 2000). This increase in the use of irrigation water in the UK has been driven by market demands and changing land uses. These changes are likely to continue, and even without climate change the total amount of land under irrigation and the total amount of water used for irrigation are likely to increase for the foreseeable future. Currently, the crops most likely to receive irrigation in the UK are potatoes, sugar beet, orchard fruit, small fruit and vegetables (Weatherhead and Knox, 2000).

These sorts of high value crops are normally grown on the most fertile land. Typically this land is classified as grade 1 and 2 in the Agricultural Land Classification System. It is possible to grow some crops such as potatoes and some fruits on land graded as 3, and under a changed climate this may become worthwhile in some situations. The exact amount of water needed by a crop via irrigation depends on the type and growth stage of the crop, the soil, the level of precipitation and evapotranspiration. None of these are known with any precision for any given time in the future. In order to make some estimate of the potential demand for water in the Usk catchment, the work of Weatherhead and Knox (2000) was used. This work predicted the change in irrigation demand across England and Wales from 1996 to 2021 across all crops, but did not include climate change as a driver in the demand for irrigation.

According to Weatherhead and Knox (2000), the total net theoretical volumetric irrigation demand in a 'design' dry year in 2021 for South East Wales varies with location and ranges from 5,000-10,000 m^3 per km^2 to 10,000-15,000 m^3 per km^2 (a design dry year is a year with an irrigation need with a 20 per cent probability of exceedance). These figures compare with the very high demand in some areas of eastern England of 20,000-25,000 m^3 per km^2. However, these levels of irrigation only occur in relatively small areas, and most of East Anglia has a predicted irrigation of 15,000-20,000 m^3 per km^2.

In order to estimate the range of impacts of future irrigation (without climate change) on the Usk catchment, it was assumed that all land classified as 1, 2 and 3 would be planted to crops and irrigated at a low and a high rate for South East Wales, as identified by Weatherhead and Knox (2000) (Table 6.11). The agricultural land classification of the Usk catchment is shown in Appendix 4.

Applying the range of demand for irrigation water in 2021, suggested by Weatherhead and Knox (2000), to grade 3 land suggests irrigation demand will vary from 902,383 to 2,707,150 m^3 per year (Table 6.11). The current maximum level of abstraction licensed for use as irrigation in the Usk catchment is 4,452 m^3 per day (Appendix 6). If we assume that this daily rate is applied for all of June, July and August, which are the three months when irrigation is typically applied in the UK, this would give an estimate of current use of 400,702 m^3 per year. This is substantially less than the lowest estimate of the range predicted for 2021 using the figures from Weatherhead and Knox (2000).

These calculations are very imprecise. The estimates from Weatherhead and Knox (2000) for irrigation demand in 2021 do not include any allowance for climate change or major changes in cropping patterns. So at one level they may be underestimates of actual demand under a changed climate. However, the assumption that all land of grade 3 or above in the Usk would receive a level of irrigation equivalent to 15,000 m^3 per km^2 is probably a major overestimate.

From the perspective of a risk assessment, current abstraction licences for irrigation constitute 0.01 per cent of the annual maximum licensed abstraction. By 2021, the range of likely irrigation demand ranges from 0.32 per cent to 0.92 per cent of current annual maximum licensed abstraction.

If we assume as a worst case that by 2020, climate change will increase demand to the same as East Anglia in 2021, then total demand for the Usk catchment will vary between 2,707,150 and 3,609,533 m^3 per year. Even at this upper figure, the total demand for irrigation water will only be a little over 1.2 per cent of current total licensed abstractions. All other things being equal, the vulnerability of the catchment to increases in irrigation appears to be quite low when compared with other sources of demand, such as human consumption.

Some evidence for this assertion comes from the Local Environment Action Plan (Environment Agency Wales, 2000) which states that all of the zones supplied with water from the Usk catchment require action to ensure the adequacy of supplies by 2025. The current proposal is to meet this demand through infrastructure improvement, such as reduced leakage. It is unclear from LEAP if these predictions take cognisance of any climate change induced effects; if they do not, then meeting the increased demand will be even harder than envisaged within the LEAP.

Table 6.11: Estimates of the amount of irrigation water which will be used in the Usk catchment in 2021 on land of grades 1, 2 and 3. Data on irrigation rates are from Weatherhead and Knox (2000). It is assumed that all land will be irrigated at the specified rate.

Sub-catchment	Area of sub-catchment (ha)	Area of irrigable land (ha)	Area of irrigable land (km^2)	Irrigation rate (m^3 per km^2)	
				5,000	15,000
1	3,910	1,109	11.1	55,438	166,314
2	10,6367	6,035	60.3	301,731	905,192
3	21,195	7,245	72.4	362,234	1,086,701
4	8,619	2	0.0	101	303
5	3,782	214	2.1	10,712	32,137
6	9,114	360	3.6	18,022	54,065
7	11,113	1,374	13.7	68,696	206,085
8	5,339	766	7.7	38,281	114,842
9	6,324	282	2.8	14,099	42,298
10	13,195	661	6.6	33,071	99,215
11	18,144	0	0	0	0
TOTAL				902,383	2,707,150

6.3 Policy analysis

6.3.1 General comments

The UKCIP socio-economic scenario analysis considers the balance of future water supply and demand in the UK (UKCIP, 2001). The key driver governing demand relates to the level of economic growth, while the levels of supply are also affected by levels of economic investment in the water-related infrastructure and social attitudes towards water conservation. UKCIP (2001) go on to estimate the levels of supply and demand for the UK in a quantitative way for each scenario and to make some comment on the state of water quality (for a summary of the analysis, see Table 6.12). A more detailed analysis of the balance of supply and demand is presented in Appendix 6.

While there are advantages in presenting quantitative data alongside the qualitative descriptors of the scenarios, as done by UKCIP (2001), care must be taken when interpreting these data, particularly those relating to water supply. UKCIP (2001) data are not estimated according to any predictions of future climate and/or rainfall levels, rather they are assumed to follow demand. In other words, they do not take cognisance of any altered rainfall patterns due to climate change.

Table 6.12: Data relating to water supply and demand supplied as part of the UKCIP socio-economic scenarios for 2020, with a qualitative descriptor of changes in water quality (UKCIP, 2001).

Variable			**Scenario**		
	2020 Linear	**National Enterprise**	**Local Stewardship**	**World Markets**	**Global Sustainability**
Water demand (% change p.a.)	+0.5 % p.a.	+0.5 % p.a.	-0.5 % p.a.	+1 % p.a.	+/-0 % p.a.
Public water supply (volume)	23,000 Ml day^{-1}	23,000 Ml day^{-1}	17,000 Ml day^{-1}	27,000 Ml day^{-1}	20,000 Ml day^{-1}
Water quality		Deteriorates	Improves markedly	Mixed response across sectors	Improves

A summary figure for supply and demand in each socio-economic scenario can be obtained by calculating a demand ratio (supply/demand). If the demand ratio is greater than one, then that supply will be greater than demand (there will be water surplus), while a demand ratio of less than one suggests a water deficit. Using the data presented in Table 2.5 (Chapter 2), the demand ratios within Wales for the future socio-economic scenarios were estimated and compared with the demand ratio in the year 2000, when demand was assumed to be in perfect balance with supply (a demand ratio of one). Supply and demand are unlikely to have been balanced in 2000 but the analysis indicates a relative change in demand.

Analysis of these demand ratios suggests that supply and demand for abstracted water will be unchanged under a scenario of Global Sustainability in 2020, while under Local Stewardship there will be less water available and potential water deficit, with a demand ratio of 0.955. However, under both the scenarios of National Enterprise and World Markets, there is more water available and a potential surplus of 1.43 and 1.59 respectively (see Table 2.5). This kind of analysis may be better suited to larger scale assessments for example within the Water Resource Strategy.

As stated above, UKCIP estimates of future supply and demand do not include any estimates of actual future rainfall; rather, the differences in demand ratios between the scenarios arise due to the relative valuations society places on economic growth, domestic supply and the needs of the environment. Where a demand ratio is above one, this implies society gives available water to domestic and economic uses before considering environmental needs. Under Local Stewardship there is a high level of environmental awareness, which would then be translated into ensuring that river flows meet ecological demands rather than abstractor demands. The converse occurs under National Enterprise and World Markets, where the environment is vulnerable to shortage in these scenarios.The same pattern is evident in 2050, where the water demand ratios are one for Global Sustainability, 0.91 for Local Stewardship, 1.36 for National Enterprise and 2.05 for World Markets. Currently, water abstraction licencing is undertaken on a 'first come first served basis'. Long-term planning at the Water Resource Strategy level, may require this kind of water allocation to change under future climates.

In addition to the above analysis, it is important to superimpose future precipitation and evapotranspiration rates onto these socio-economic scenarios, as these may suggest different levels of physical supply of water to the catchment. While predicting local levels of rainfall is extremely difficult with current models of climate change, the type of analysis on in-stream flows, described above for parts of the Usk, do indicate that for most months of the year the physical supply of water will be lower than in the year 2000.

It is also evident that within the Usk catchment there are a number of reaches which are already felt to be ecologically sensitive (Table 6.10), so even in the absence of climate change the ecological integrity of the river would probably be compromised by further abstraction from within the catchment. The indication from the Olway Brook analysis, that future low flows may be 75 per cent of historical ones, suggests that if the ecological integrity of the system is to be maintained, then there is little or no capacity for increased abstractions in the future.

This constraint on future abstraction is unfortunate, as there will probably be further pressures on water resources in the catchment. These may come from increased irrigation demand for agriculture and from the increased evapotranspiration associated with new crops, like short rotation coppice for biomass (Hall, 2003). However, given that the vast majority of abstracted water is currently for human use, either as a potable source or for general domestic and industrial use, the catchment is most vulnerable to future changes in these sectors. Given that there is relatively little industry in the Usk CAMS area, it is the level of domestic demand that is particularly important within the catchment. Therefore, this policy component will be particularly vulnerable in the Usk if there is an expansion in the human population living within the catchment and/or others supplied by water derived from the catchment. Climate change adaptation is likely to involve greater control on demand and increases in efficiency. The recent deregulation of abstraction licences may mean that ongoing impacts of this type are difficult to monitor on an ongoing basis. Some mitigation of these impacts would be possible by increasing the capacity for water storage from winter rainfall. Indeed, given the importance of domestic supply such winter storage may be necessary for supplying irrigation, and also perhaps to manipulate the hydrological regime of ecologically important habitats, both within and beyond the river channel.

6.3.2 Specific comments

Balance social and environmental demands on water resources

The vulnerability of this component will depend upon the amount of river water available for abstraction, the levels required to maintain the ecological integrity of dependent species and habitats and the demand from society for water. There will undoubtedly be changes in the amount of river flow under a changed climate, and the most important factors in determining whether or not these flows will be managed for the benefit of the environment are the social and political attitudes to the economy and the environment.

Given the above, the vulnerability of this policy component is high under the scenarios of National Enterprise and World Markets, medium under Global Sustainability and low under Local Stewardship. However, the nature of future developments within the catchment will determine the amount of pressure that will be placed on this component.

Protect aquatic environment, species and habitats

Much of the discussion on the previous component is also relevant to this policy component. Its success is highly dependent on the levels of river flow and the commitment to any mitigating actions.

A second potentially complicating issue relates to the importance of river flows in diluting pollutants which enter the river. These pollutants include any point source discharges from industry and sewage works, and non-point source pollution derived from agriculture. Currently, the regulation of this issue tends to be covered under existing flexible discharge consents and does not need to be taken into account in abstraction licensing.

In an arable situation, nitrogen fertilisers and pesticides are the major potential pollutants, and both of these are expected to have greatest use under National Enterprise and lowest use under Local Stewardship (Table 2.5, Chapter 2). Although currently the dilution of diffuse pollution is not considered to be a major issue (J. Waddingham, *personal communication*), given that social attitudes to the environment are expected to be low under National Enterprise we may expect the overall environmental 'health' of the river to be poorest under this scenario, and the vulnerability of this policy component to increase relative to current levels.

Conversely, under Local Stewardship the vulnerability is medium-low in 2020, as river health increases markedly under this scenario. Although the direct effects of climate on the river system may begin to undermine protection measures, the general ethos under this scenario suggests that efforts will be made to protect the environment. A similar set of arguments applies to World Markets (vulnerability high in 2020 and very high in 2050) and Global Sustainability (medium in 2020 and medium-high in 2050).

Ensure that abstraction does not cause river flows, groundwater levels or wetland water levels to fall artificially below the minimum level required for conservation of the aquatic environment

This policy component is subject to the same problems of balancing social and environmental needs as the above two policy components. However, it is further complicated by a need to understand the interaction between surface water, groundwater and the needs of the aquatic environment. The vulnerability of this policy component under Global Sustainability and Local Stewardship is very low in 2020, as abstraction will be in balance with the ecological needs of the river. This will be coupled with high levels of investment in conservation schemes (such as reserve networks and agri-environment schemes) and also in environmental research, thereby providing a good level of understanding in natural systems. Conversely, vulnerability is very high under National Enterprise as general levels of river health decrease and abstraction levels are high, while investment in conservation schemes and research is low.

Provide an indication of water availability/deficit within the catchment

The success of this policy component depends on investment in research, firstly for understanding the requirements of the aquatic environment and secondly for providing good projections of the impacts of climate on water availability. Vulnerability under National Enterprise is high as there are low levels of research on environmental issues. However, it is very low under Global Sustainability as understanding the habitat needs and the effects of climate are strongly pursued. On the other hand, to some extent this general situation may be moderated by the actions of industry, which will need to understand the impacts of water supply on businesses. While such industrial research may occur under all scenarios, it is unclear if it will be shared with all stakeholders, particularly under the economically oriented scenarios of National Enterprise and World Markets.

Divide catchment into Water Resource Management Units (WRMU) and carry out sustainability appraisal for each

Once again, this policy component relies on investment in research and information and this suggests a vulnerability falling in the order National Enterprise > World Markets > Local Stewardship > Global Sustainability.

Provide a framework for managing time-limited abstractions

The basic objective to provide a framework for managing time-limited abstractions is unlikely to be undermined by the direct impacts of climate change. Indeed, the occurrence of climate change will make this policy component even more important in the future than it is now. This is one policy component which will need substantial climate proofing to consider the interactions between land use, conservation and abstraction on the one hand and abstraction and social and economic development on the other.

To some extent this component is affected by the wider framework of water resource planning undertaken by the Environment Agency and Water companies. It is at this level that prevailing social and political attitudes will be most important. If they are positive towards sustainable management of the resource, then there will be investment in necessary research and forecasting. However, if the political situation is not so positive, then less investment will occur and the policy will be more vulnerable to failure. For these reasons, vulnerability is lowest under Global Sustainability and Local Stewardship and greatest under National Enterprise and World Markets.

Provide a framework for licence trading

The vulnerability of this component is low in most scenarios, because it is unlikely to be affected by climate change or socio-economic conditions. However, the socio-economic situation may become more difficult if demand for abstractions is greater than supply. This is only probable under the scenario of Local Stewardship, and vulnerability under this scenario is greater than in the other three scenarios.

Ensure open public discussion and consultation

As for many other policy components. this one is unlikely to be subject to climate change but will be vulnerable to socio-economic conditions. For example, under National Enterprise and World Markets public consultation is not likely to be a priority, resulting in a high vulnerability of this policy component. By contrast, public consultation will thrive under the socially-conscious scenario of Local Stewardship, but despite this consultation there are likely to be strong conflicts as some abstraction needs will go unmet in this scenario. Overall. its vulnerability is lower than in the other three scenarios.

Set appropriate 'hands-off' flows and apply on a tiered basis

When specified in the licence, hands-off flows serve as the minimum flows which are needed for ecological reasons. When flows are at this level, no abstraction is permitted until the flow rates increase. However, some licences are granted with no associated hands-off flow, and these abstractors can continue regardless of the river flow/levels.

The setting of hands-off flows requires good information on the environmental needs of biological receptors in different reaches of the river system. Climate change is likely to affect the response of biological receptors, for example higher temperatures may lead to damage at the same levels of flow. Adaptation measures may include increased flow deoth. Achievement of this policy component depends on achievement of policy components 3, 4 and 5 discussed above. In addition, the process of negotiating appropriate tiering may require significant efforts be put into consultation and conflict resolution.

For these reasons, vulnerability is high under National Enterprise as the vulnerability of policy components 3, 4 and 5 is high; further, there will be a low level of commitment for consultation and conflict resolution under this scenario. Conversely, vulnerability is low under Global Sustainability as the vulnerability associated with policy components 3, 4 and 5 is very low and in addition, there will be a high level of commitment to deal with conflicts under this scenario.

Under Local Stewardship, hands-off flows are likely to be adequate and well-planned to meet environmental needs, but they will not fully meet the demands of abstractors. However, there will be a commitment to consultation and conflict resolution. This results in a medium vulnerability.

Ensure workable links to other initiatives

Generally, links to components of other initiatives designed to safeguard the environment will be more robust under scenarios where there are positive social and political attitudes towards the environment. Under the National Enterprise and World Markets, links to environmental policies are unlikely to be supported and most likely to fail. However, links to policies and components that promote enterprise and economic growth are likely to be quite robust. Conversely, under Global Sustainability links to environmental policies will have equal, if not greater, support than links to economic policies. The Water Framework Directive (WFD) will seek to integrate many of the policies relating to water quality, and achieving levels of abstractions which are resilient to climate change would seem to be essential to meeting the aims of the WFD.

6.4 Discussion and climate proofing

A summary of the above discussion and a qualitative assessment of the probability of failure of each component of the CAMS policy is shown in Table 6.13.

The future success of the CAMS policy depends on six main factors:

- a good understanding of the needs of the different users of water, and how these will change over the medium and long term;
- adequate understanding of the hydrological regime, to be able to predict the impact of abstractions and other actions on water quantity across the catchment;

- good medium-term forecasts of water supply in terms of precipitation, and loss from the environment in terms of evapotranspiration;
- a framework for resolving conflicts should supply not meet demand;
- an institutional framework that enables medium and long-term planning across the catchment and integrates economic, social and environmental needs;
- uptake of water conservation measures.

By addressing these needs, it should be possible to 'climate proof' the policy. Suggested actions for climate proofing are listed below. Some of these issues will already be part of water resource planning at a national level, but due to their importance they outlined here:

1. Predict the likely demand from domestic users in the CAMS area (and also those outside the area who will be dependent on water transferred from the area). This will require estimates of numbers of households, and also how their patterns of demand will change under a changed climate (such as garden use, car cleaning, bathing, consumption, metering).

2. Predict the likely demand from industrial users in the CAMS area. This will entail understanding the economic and industrial trends and plans for development. What sorts of industries will move into, and out of, the area, and how will this impact water demand?

3. Predict the likely demand from agriculture for irrigation. Take particular cognisance of the predicted pattern of UK land use in accordance with climate change, where the cropping and horticultural belts typical of eastern England may move westward due to temperature and water restrictions in the east and that climate related pressures in southern Europe may lead to greater economic returns for agriculture in the UK.

Each of these first three issues may currently be dealt with by the ongoing cycle of strategy planning undertaken by the Environment Agency and water companies. Given that there is a devolved government in Wales, and also that there may be very large changes in supply and demand in the future, it may be useful in the future to explicitly consider other catchment level planning activities in relation to CAMS.

4. Estimate the likely changes in land use over time within each CAMS area, and consider the knock-on effects of land use change on water supply. Take particular note of the impacts of converting grassland and crop land to woodland and biomass, as these land uses have particularly high evapotranspiration rates.

5. Continue to encourage water efficiency in homes and industry, through public information and technological change in domestic and industrial appliances.

6. Transfer technology related to water efficient irrigation technologies. Much work has been carried out on irrigation systems in arid areas of the world, but to date very little effort has been invested in presenting the results to farmers and growers. Farmers are increasingly likely to be investing in irrigation equipment over the next ten years. Having made a capital investment in equipment, they will be loath to reinvest in newer equipment until they really need to. For this reason, there is a need to offer advice to farmers on efficient irrigation systems from now onwards.

7. Consider the use of storage ponds on farms. These may act as a means of holding water back in the winter, and thereby mitigating flood events, and then act as a source of irrigation water in the summer.

8. Understand species-specific responses to altered in-stream flows. Species will migrate as a result of climate change; however, water requirements for specific habitats need to be maintained for migrating species and must continue to be part of water allocation within CAMS. Consider the philosophy underlying the conservation of aquatic species under a changed climate (see Chapter 3).

9. Make use of the climate change-driven hydrological models which will enable predictions to be made of the impacts of abstractions and discharges at one location on flows at other locations.

10. Given the increased likelihood that future supply may not meet demand, it will be necessary to develop a means of prioritising which users to supply. Currently this is on a 'first come first served basis'. A conflict resolution framework should be responsive to medium-term forecasts in supply shortfalls, but also be able to cope with seasonal shortages in supply. Such a framework will need to take cognisance of local demands and priorities and could be undertaken through the River Basin Management Planning phase of the Water Framework Directive. An enhanced water pricing scheme may be part of such a framework. While it may be appropriate to consider such a framework at a national level, there may also be a role for varying the prioritisation of users according to local conditions. If this occurs, CAMS may need to interact with national level planning frameworks.

11. The Environment Agency provides an institutional framework that enables medium and long-term planning across the catchment, integrates economic, social and environmental needs but does not fully integrate land use and water resources. The Water Framework Directive (WFD) requires all water bodies to reach good ecological status, which represents a move away from a water quality focused approach. This will require managing land, people and water in an integrated way but the competent authority for the WFD (the Environment Agency) has no jurisdiction over land management. Currently, different institutions are responsible for making planning decisions, developing inward investment strategies, generating energy, sustaining and conserving the natural heritage and regulating the environment. In addition, individual farmers and landowners are responsible for making decisions about the exact use of their land. It is a challenge to achieve integrated decision-making in any situation where responsibilities are fragmented. This challenge is magnified in periods of change, such as those that will occur over next 20 years as historically adequate water resources start to decline, and social, economic and environmental systems start to respond to a changed climate. Achieving sustainable development in this situation will either require unprecedented levels of cooperation between existing agencies and statutory bodies, or a totally new institutional structure. These issues need to be developed as the consultation and planning for the WFD progresses.

Table 6.13: Summary of the risk assessment of the CAMS policy

Component	Probability of failure	Notes
Balance social and environmental demands on water resources	Medium to high	Hard to do as supplies diminish, but ultimately depends on definition of environmental needs and the weighting given to potable supplies
Protect aquatic environment, species and habitats	Medium to high	As above
Ensure that abstraction does not cause river flows, groundwater levels or wetland water levels to fall artificially below the minimum level required for conservation of the aquatic environment	Medium to high	As above – but for this component to be successful good models are needed of the hydrological regime in each catchment
Provide an indication of water availability/deficit within the catchment	Medium	Dependent on levels of investment into research on the catchment and also on the level of uncertainty over future climates and developments.
Divide catchment into Water Resource Management Units (WRMU) and carry out sustainability appraisal for each	Low to medium	Will succeed if investment is sufficient
Provide a framework for managing time-limited abstractions	Medium	It can be achieved if investment is adequate
Provide a framework for licence trading	Low	
Ensure open public discussion and consultation	Low to medium	
Set appropriate ‘hands-off’ flows and apply on a tiered basis	Medium to high	Subject to same pressures are first three components
Ensure workable links to other initiatives	Medium	Entirely possible, but success depends on socio-political attitudes

7 Catchment Flood Management Plans

7.1 Background on policy

Around five million people, in two million properties, live in flood risk areas in England and Wales. An extensive system of river and coastal flood defence embankments and flood defence schemes is in place to protect these properties, including: flood walls, embankments, diversion channels, pumped drainage systems in low-lying areas where gravity drainage is not possible, tidal flood barriers and associated defences. Catchment Flood Management Plans (CFMP) have been introduced to provide a strategic approach on a catchment basis (Environment Agency, 2004). They are an important element of the Department for Environment, Food and Rural Affairs (Defra) and Welsh Assembly Government (WAG) strategy for fluvial flood risk management, which aims to reduce flood risks by:

- encouraging the provision of adequate and cost-effective flood warning systems;
- encouraging the provision of adequate, technically, environmentally and economically sound and sustainable flood defence measures;
- discouraging inappropriate development in areas at risk from flooding.

Catchment Flood Management Plans (CFMP) “will identify broad policies for sustainable flood risk management that make sense in the context of the whole catchment and for the long term (50 to 100 years). They will not determine specific flood risk reduction measures or management approach for flooding issues in a catchment.” (Environment Agency, 2004). Through an assessment of land use across catchments they inform decisions relating to flood defence. Decisions to increase flood defence need to balance the potential for increasing flooding elsewhere against the need to protect property. Climate change is likely to lead to more difficult decisions in this area.

CFMP are based on an understanding of catchment processes and an ability to predict the long-term effects of climate change, land use/land management change and development on such processes throughout the catchment. In this context, the catchment approach to flood management provides:

- an overall understanding of flood risk in the catchment;
- an integrated and optimised approach to the provision of flood mitigation measures in the catchment;
- an assessment of the impact of flood mitigation measures elsewhere in the catchment.

The plans integrate scientific and socio-economic data and are developed in consultation with, and provide information to, all flood defence/land drainage operating authorities and catchment decision makers including the Environment Agency, local authorities and drainage boards (who are responsible for drainage of low-lying agricultural areas). There is an iterative relationship with planning and development in the catchment. The CFMP should advise on development in the floodplain, but it will also be affected by development. Changes in land use will affect the pathways of water through catchments and either contribute to more frequent flooding or help reduce the risk of flood damage.

The specific objectives of a CFMP are to:

- define, in general terms, the current flood risks to people, property and the developed, historic and natural environment within the catchment;
- identify scenarios likely to affect flood risk over the next 50 years;
- identify the preferred catchment policies for managing the flood risks over the next 50 years;
- identify the consequences of implementing the preferred catchment policies;
- guide future land use (such as agriculture, forestry, land management) and development planning of the catchment, taking due account of the flood risks;
- protect and where appropriate enhance the human and natural environment;
- establish procedures for monitoring the effectiveness of catchment policies;
- identify and establish the requirements and scope of work for strategy plans;
- identify priority actions for flood risk management that can be taken in the short-term without compromising the overall CFMP.

The Environment Agency is responsible for the production of CFMP, although consultants undertake much of the technical work. The approach taken to developing the CFMP in England and Wales is slightly different, and in Wales the Environment Agency is seeking a more integrated approach to delivery than in England. Although the plans will have long-term perspectives, they will have periodic reviews built in, typically on a five-year cycle. The CFMP include the assessment of flood risk under both present conditions and with future scenarios of climate and land use change. The Environment Agency Wales (EAW) aims to deliver nine CFMP by the end of March 2009, and at the time of writing all nine are currently at the inception stage.

The Foresight Future Flooding Report estimates that the risk of flooding from rivers and the sea will at least double by the 2080s, and could increase by up to 20 times. The number of people at high risk of flooding could also rise from 1.5 million to between 2.3 and 3.5 million over the same period, with the cost of flooding rising from the current £1 billion a year to between £1.5 billion and £2.1 billion. In addition, other potential risks arising from floods could include pluvial flooding, rapid run-off which could affect land stability through increased frequency of mass movements such as landslides, debris flows and activation of relict landslides, storm sewer overflows and contamination (Ashley *et al*., 2005; Fowler and Kilsby, 2003; Mitchell, 2003).

7.2 Methodological summary

For the purposes of comparability across chapters, 'policy' is used to describe all resource protection agreements analysed in the report, regardless of whether they are technically classified as 'strategies', 'action plans', 'processes' or 'policies'. We recognise that this is not always technically correct, but it does enable a generic methodological framework to be used across a range of different resource agreements.

The risk assessment of the CFMP process followed the approach outlined in Chapter 2. The pre-analysis work generic to all policies was completed prior to undertaking the assessment of the CFMP policy and followed the structure outlined in Figure 2.1. The policy assessment work followed the pattern outlined in Table 2.6. The CFMP for the Usk catchment was still under development and was not available for analysis; this limited the resources available for study in this project. For this reason, it was necessary to adopt a more generic approach to the risk assessment than for some of the other policies. Details of the outcomes for each step in the assessment are reported below.

1. Identify key components of policies to be analysed
The key policy components of CFMP were analysed and the relevant policy components are shown in Table 7.1.

2. Answer adapted UKCIP risk analysis guidance questions
This was undertaken and the results are shown in Appendix 7 on the accompanying CD.

3. Identify risk exposure units, receptors, thresholds and endpoints
The key receptors were identified and are presented in Table 7.2.

4. Research potential effects of climate change on receptors via survey of scientific literature, experiments, modelling and analysis
This was completed as required when undertaking the receptor risk analysis and the results are discussed throughout this chapter.

5. Undertake receptor risk analysis
This required an assessment of the vulnerability of each receptor to change under each of the socio-economic scenarios, and in combination with the UKCIP medium-high climate scenarios for 2020 and 2050 as reported in Table 2.9. The full results of this process are available in the Risk Assessment Matrices (RAM) shown on the accompanying CD.

6. Undertake policy component risk analysis
This analysis also followed the process outlined in Table 2.9. The results of this process are fundamental to the entire risk assessment, as discussed below. The complete results of this process are available in the Risk Assessment Matrices (RAM) shown in Appendix 7 on the accompanying CD.

7. Test the results of the process and use the results to 'climate proof' the policies
This aspect of the risk assessment is specific to each policy analysed and was not discussed in detail in Chapter 2. The remainder of this chapter is dedicated to discussing the methods and results of this process as applied to CFMP. It begins with a discussion of how the risk assessment method was applied to the Usk catchment, and is followed by an analysis of the risks to the policy components.

Table 7.1: Key components of CFMP

Policy component
1. Reduce the risk of flooding and harm to people, the natural, historic and built environment caused by floods. 2. Maximise opportunities to work with natural processes and deliver multiple benefits from flood risk management, and make an effective contribution to sustainable development. 3. Inform and support planning policies, statutory land use plans and implementation of the Water Framework Directive. 4. Understand current and future flood risk from all sources and quantify in economic, social and environmental terms. 5. Identify opportunities and constraints for reducing flood risk, such as through changes in land use, land management practices and/or the flood defence infrastructure. 6. Identify opportunities during flood risk management to maintain, restore or enhance the total stock of natural and historic assets (including biodiversity). 7. Use Strategic Environmental Assessment (SEA) to provide detailed environmental assessment and Modelling and Decision Support Framework (MDSF) to support analysis and decision making in formulation of the CFMP. 8. Integration with, and effects on, other policies and agreements.

Table 7.2: Receptors identified for CFMP

Receptors
River and water body boundaries
River and wetland species
Non-wetland species
River and wetland habitats
Non-wetland habitats
Soils
River and water body features
River and water body structures
Land-based structures
Proximate people and communities
River livelihood dependents
Other river users

7.2.1 Applying the risk assessment method to the ongoing CFMP process in the Usk catchment

Risk assessment method

The risk assessment for CFMP policy in the Usk catchment followed a five-step process, illustrated in Table 7.3. Fundamental to this risk assessment were the RAM developed as part of the receptor and policy component risk analyses. These are presented in full on the accompanying CD.

Table 7.3: **Risk assessment procedure for CFMP**

Step	Action
1	Overlay flood risk maps (Environment Agency 1 in 100 year and 1 in 1000 year return period 1) with Phase 1 Habitat Survey and Developed Land Use Areas (DLUA, Ordnance Survey Meridian 2).
2	Interpret the flood risk maps to consider the impact of floods on receptors.
3	Consider the impacts of changes in flood risk within the catchment due to climate change.
4	Use the results of this process to inform the assessment of the resilience of the CFMP process in general.

Impact of floods on receptors (Step 3)

Habitats

Flood inundation (normally within the 1 in 100 year floodplain) is likely to be more frequent, with greater risk of extreme events covering more of the 1 in 100 year floodplain and potentially the 1 in 1,000 year floodplain. The areas inundated by 1 in 100 and 1 in 1,000 year floods are relatively similar in extent over most of the catchment (Figure 7.1). This reflects the topography of the catchment, which is characterised by relatively narrow valley bottoms and steep slopes.

The habitats most affected by flooding are semi-natural broadleaved woodland, improved grassland and arable habitats (Table 7.4). From a conservation perspective it is the broadleaved woodland which is of most concern, as 5.8 per cent of the woodland in the catchment is inundated during a 1 in 100 year event.

Fifteen SSSI lie within the 1 in 100 and 1 in 1,000 year flood zones (Figure 7.2). However, only a very small proportion of the area of these SSSI is likely to be affected by floods of these magnitudes (Table 7.5); none are completely inundated. Penpergwm Pond (Table 7.5) is the most impacted site, with 98 per cent of its area being inundated by a 1 in 1,000 year flood. But given the nature of this site, such a level of inundation is not likely to be detrimental to its status.

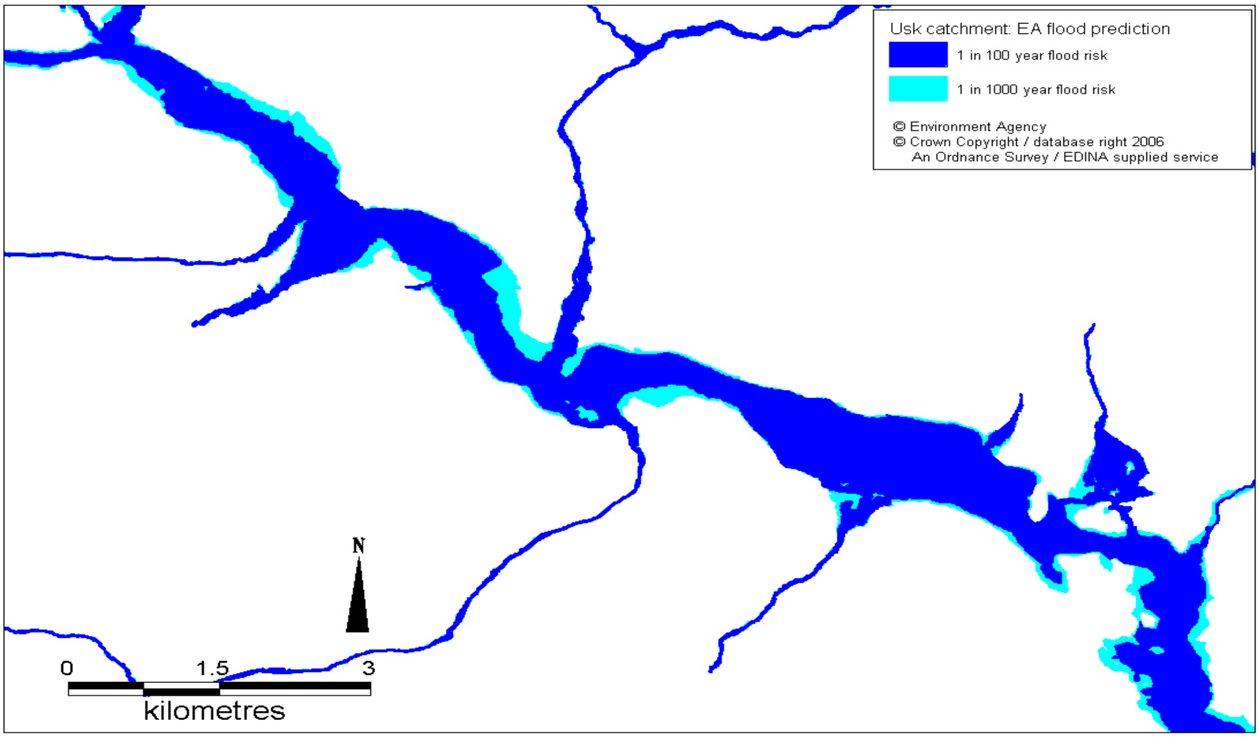

Figure 7.1: Area inundated in 1 in 100 year flood (dark blue) and 1 in 1,000 year flood (light blue) for the Usk catchment

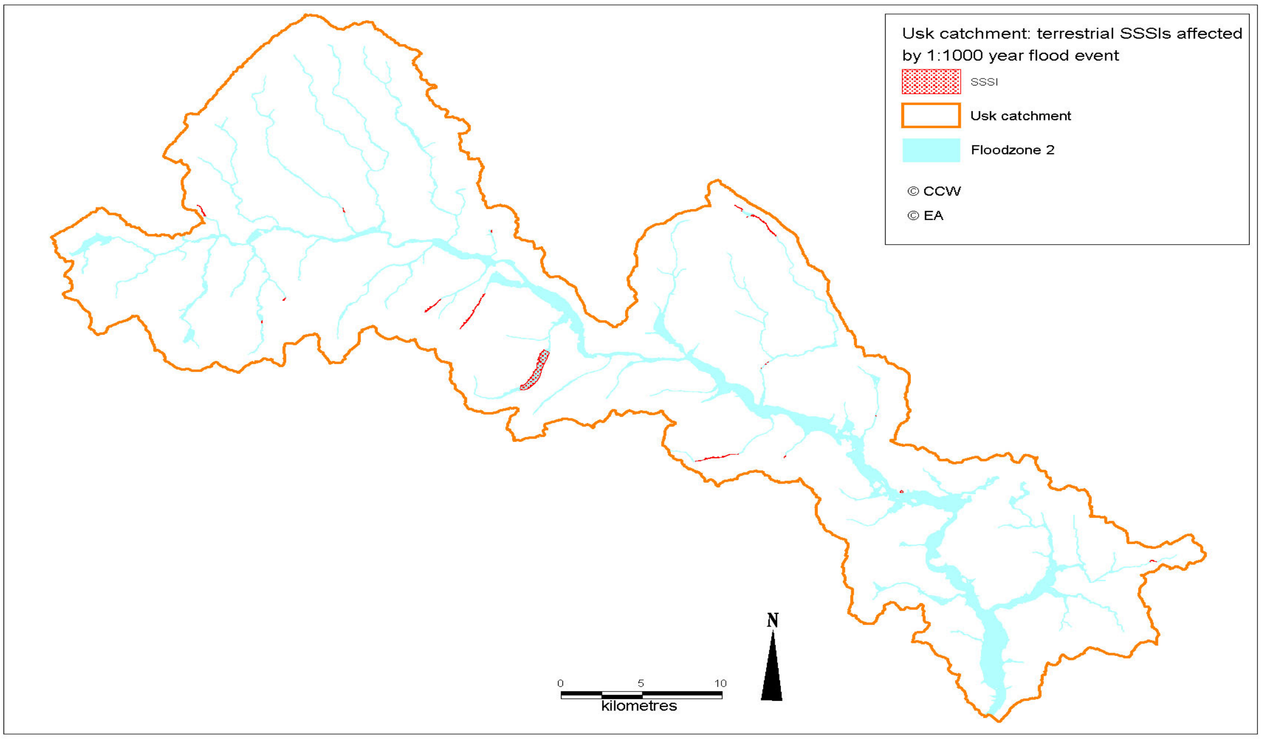

Figure 7.2: Terrestrial SSSI potentially at risk from a 1 in 1,000 year flood in the Usk catchment

Table 7.4: **Area of habitats inundated by 1 in 100 and 1 in 1,000 year floods. The absolute area inundated at each flood frequency is expressed in hectares, and also as a percentage of the total inundated area. 'Diff.' is short for 'difference' and is the difference between the 1 in 1,000 and 1 in 100 year floods.**

Phase 1 habitat type	Area (ha)			%		
	1 in 1000	1 in 100	Diff.	1 in 1000	1 in 100	Diff.
Semi-natural broadleaved woodland	365.7	296.6	69.2	5.9	5.78	6.5
Planted broadleaved woodland	15.1	10.5	4.6	0.2	0.2	0.4
Planted coniferous woodland	57.1	40.4	16.8	0.9	0.8	1.6
Semi-natural mixed woodland	0.4	0.4	0.0	0	0	0
Planted mixed woodland	18.4	12.0	6.4	0.3	0.2	0.6
Dense scrub	16.6	14	2.7	0.3	0.3	0.3
Felled broadleaved woodland	4.7	4.6	0.0	0.1	0.1	0
Felled coniferous woodland	1.4	0.1	1.2	0	0	0.1
Unimproved acid grassland	94.9	86.2	8.8	1.5	1.7	0.8
Semi-improved acid grassland	15.8	13.9	1.9	0.3	0.3	0.2
Semi-improved neutral grassland	102.9	87.6	15.3	1.7	1.7	1.5
Unimproved calcareous grassland	0.2	0.2	0	0	0	0
Semi-improved calcareous grassland	1.0	1.0	0.1	0	0	0
Improved grassland	4,264.7	3,579.7	685.0	69.1	69.9	64.8
Marshy grassland	52.9	44.4	8.5	0.9	0.9	0.8
Marshy grassland Molinia dominated	2.3	2.1	0.2	0	0	0
Bracken	22.8	18.5	4.3	0.4	0.4	0.4
Tall ruderal herb	2.7	2.3	0.4	0	0.1	0
Dry acid heath	1.4	0.9	0.5	0	0	0.1
Dry modified bog	7.0	6.7	0.3	0.1	0.1	0
Acid/neutral flush	0.6	0.6	0.1	0	0	0
Swamp	4.0	3.8	0.2	0.1	0.1	0
Inundation vegetation	0.2	0	0.1	0	0	0
Standing water	155.2	151.9	3.4	2.5	3.0	0.3
Acid/neutral inland cliff	0.5	0.5	0	0	0	0
Acid/neutral rock	9.3	9.0	0.2	0.2	0.2	0
Spoil	0.8	0.8	0	0	0	0
Refuse-tip	1.3	0.2	1.1	0	0	0.1
Arable	460.8	367.4	93.4	7.5	7.2	8.8
Amenity grassland	116.8	81.3	35.4	1.9	1.6	3.4
Introduced scrub	0.3	0.1	0.2	0	0	0
Gardens	9.3	7.1	2.1	0.2	0.1	0.2
Caravan site	2.8	2.6	0.3	0.1	0.1	0
Buildings	264.7	186.0	78.7	4.3	3.6	7.5
Track	6.0	3.0	3.1	0.1	0.1	0.3
Bare ground	0.8	0.2	0.6	0	0	0.1
Not accessed land	94.5	82.7	11.8	1.5	1.6	1.1
Total	6,176.4	5,119.4	1,056.9			

Table 7.5: Area of SSSI which are inundated in 1 in 100 and 1 in 1,000 year flood events

SSSI name	Area of SSSI affected by 1 in 1000 yr flood (ha)	Area of SSSI affected by 1 in 1000 yr flood (ha)	Total area of the affected SSSI (ha)	Summary of qualifying feature
Cwm Clydach	0.59	0.66	45.15	Broadleaved woodland
Brynmawr Sections	0.54	0.55	4.36	Geology
Cwm Mill Section, Mardy	0.03	0.10	0.62	Geology
Penarth Brook Woodlands	0.85	0.90	4.48	Broadleaved woodland
Penpergwm Pond	1.52	1.64	1.66	Orange foxtail
Cwm Llanwenarth Meadows	0.43	0.48	3.03	Grasslands
Alexanderstone Meadows	0.44	0.46	22.43	Neutral grassland
Black Mountains	6.96	7.49	7,974.34	Grassland, heaths and mires
Brecon Beacons	2.27	2.43	5,009.95	Grassland, heaths and woodland
Coed Dyrysiog	0.31	0.35	7.17	Broadleaved woodland
Coed Ynys-Faen	0.18	0.21	9.38	Broadleaved woodland
Nant Clydach Pastures	2.32	2.67	11.61	Grassland and bogs
Penllwyn-yr-Hendy	0.25	0.41	2.70	Neutral grassland
Talybont Reservoir	135.38	136.99	196.40	Goosander
Mynydd Llangatwg	4.11	4.27	1,681.30	Grassland, bogs, geology and woodland
Cae Gwernllertai	0.27	0.29	1.70	
Caeau fferm	0.01	0.01	10.78	Neutral grassland
Coed Nant Menascin	5.62	6.02	49.15	Broadleaved woodland
TOTAL	162.08	165.93	15,036.21	

Farmland

There has been considerable research investigating the relationship between agricultural land and flood risk (for example, Holman *et al.,* 2003; Schnug and Haneklaus, 2002), but very little on the impacts of flooding on agricultural productivity in the UK. While floods may occasionally benefit farming by depositing soil and nutrients on fields, it is well known that waterlogged soils undergo chemical changes and generally become anoxic (Ponnamperuma, 1972) and these conditions can reduce crop yields (Belford, 1981; Belford *et al*., 1980). The exact impact of waterlogging on growth differs between crops and varieties within a crop (Davies and Hillman, 1988; Glaz and Gilbert, 2006; Sah *et al.,* 2006).

Waterlogging in soils does not only occur when fields are submerged during floods; it can also occur due to prolonged rainfall. This factor tends to complicate any analysis seeking to consider the impact of actual flooding on agricultural productivity, separate to the impact of heavy rainfall. Analyses are further complicated because the exact impact of waterlogging on final crop yields is partly determined by the time of the flood event in relation to the stage of crop growth. For example, the waterlogging of autumn-sown wheat may have relatively small effects on final yields, due to compensatory growth during the rest of the season (Cannell *et al.,* 1980). In addition to waterlogging, prolonged floods will reduce photosynthesis and growth in plants. Further, should a flood occur at a time when arable land has either bare soil or a newly established crop, then this may lead to soil erosion.

A further impact of flooding on agricultural land relates to the deposition of pollutants on the land. For example, Lake *et al.* (2005) discovered that there were higher concentrations of polychlorintated biphenols (PCB) in the milk of cows that grazed regularly flooded pastures, than in those that grazed unflooded pastures. In addition, severe floods may bring about direct loss of stock. Finally, flooding may also restrict access of machinery to land, and should this delay agricultural activities like sowing, then there may well be a knock-on effect on crop yields and profitability.

Within the Usk catchment, 367 ha of arable land will be inundated by a 1 in 100 year flood and 461 in a 1 in 1,000 year flood. If we assume that all of this land were under winter wheat and that the entire crop was lost, then the farmer would lose a revenue from the sale of the crop of between £548 ha^{-1} (for a yield of 6 t ha^{-1}) and £913 ha^{-1} (10 t ha^{-1}) (SAC, 2004). However, the total loss to the farm business would be greater than this, as the farmer would already have purchased seed (£58 ha^{-1}), some fertiliser (£58 ha^{-1}) and some sprays (£15 ha^{-1}). The total of lost direct costs would thus be £131 ha^{-1} (excluding labour and cultivation costs). The total loss to the farmer would be the lost revenue for sales and costs of the inputs. This would vary between £679 ha^{-1} and £1,044 ha^{-1}, depending on the expected yield. However, this is very much the worst case scenario and it would be unlikely that the whole crop would be lost; even if it were, then assuming that most floods occur in the winter time, the farmer would have an opportunity to replant the field with another crop, in which case he would suffer the direct losses of £131 ha^{-1} plus the difference in overall profitability between wheat and the newly planted crop.

Based on these calculations, direct losses from flooding to arable farmers from a 1 in 100 year flood would be a minimum of £48,077 and a maximum of £383,148. A 1 in 1,000 year flood would cause damage in the range £60,391 to £481,284.

The area at risk from a 1 in 100 year flood also includes 3,580 ha of improved grassland, and that at risk from a 1 in 1,000 year flood, 4,265 ha of improved pasture. It is far more difficult to estimate the costs of flooding on this land use, as the possible impacts relate to a direct loss of forage to livestock for the duration of the flood, any introduced pollutants which may be deposited on the pasture land and contaminate the food chain and any longer term impact of the flood on grass productivity during the following season. Given that most floods occur in winter, and that most stock is housed for some or all of the winter, the direct costs are likely to be small. Direct loss of uninsured livestock and damage to fences from receding flood waters are probably the greatest costs. These will vary with the location and extent of inundation and the duration of any one flood.

These data are estimates of the direct financial costs to the farm business. It is impossible to comment in general terms on the impacts on the local economy of losses of this type, without using sophisticated economic methods like input-output models to estimate multiplier effects. However, it should not be assumed that the impact of flooding on the local economy will necessarily be negative; for example, if a farmer has to recultivate and resow a field lost to floods, then the purchase of inputs and labour for a second time may be a benefit to the wider local economy. Appropriate adaptation could be to explore the income and risks for alternative land uses on regularly inundated floodplains.

Historic and archaeological sites

Twenty-two registered historic and archaeological sites are at risk from a pne in 100 year event, and 29 from a 1 in 1,000 year event (Figures 7.3 and 7.4). The nature of these sites varies considerably, from castles to hillforts and earthworks. The risk to each site from flooding needs to be assessed individually, as it will vary with type, condition and location.

Urban environment and roads

The impact of floods on the urban environment may be more of a concern than on natural or agricultural areas, particularly in the lower catchment (Figures 7.5 and 7.6). For example, 56 per cent of the area within the town of Usk would be inundated during a 1 in 100 year flood, rising to nearly 60 per cent during a 1 in 1,000 year event. Other areas suffering a high impact during 1 in 100 year events are Llanellan (49.8 per cent of area flooded), the Bryn (46.3 per cent of area flooded), Torfaen (26.6 per cent of area flooded), Crickhowell and neighbouring area (25.6 per cent of area flooded), Llandenny (21.2 per cent of area flooded) and Brecon (16.4 per cent of area flooded). The extent of urban areas flooded under 1 in 1,000 year floods does rise, but not substantially (Figure 7.3). For example, the urban area of Llanellan that is flooded rises to 58.5 per cent, and that in Usk to 59.9 per cent. However, no assessment is made here of the impact of existing flood defence schemes and their ability to withstand larger flood events.

There is little difference in the length of A roads inundated by a 1 in 100 year flood (20.95 km) and a 1 in 1,000 year flood (29.14 km) (Figures 7.7 and 7.8). However, there is a slightly greater difference for minor roads (65.82 km for 1 in 100 year events and 81.57 km for 1 in 1,000 year events). While the length of the road inundated is 1 measure of the impact of flooding on transport, the true impact on the economy will depend on the importance of the inundated roads in the overall transport network. Unfortunately, we could not estimate this as the data on road usage were not available for use in this project.

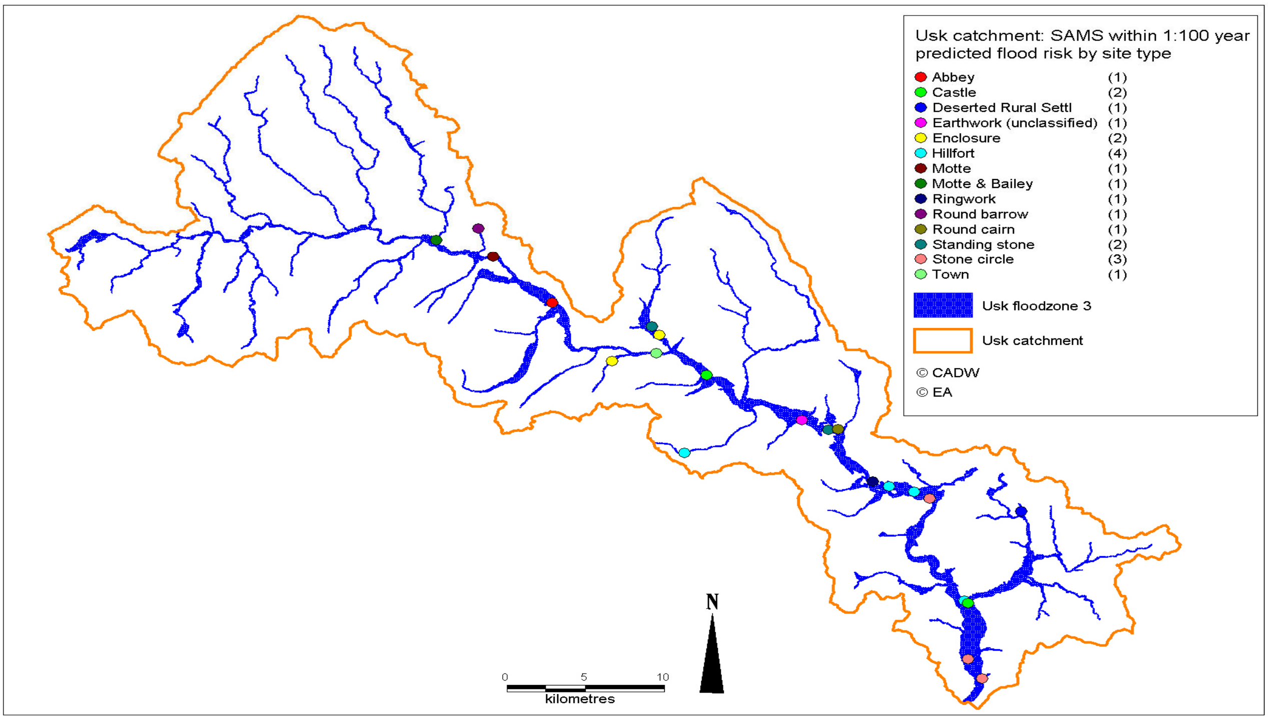

Figure 7.3: Historical and archaeological sites potentially at risk from a 1 in 100 year flood in the Usk catchment

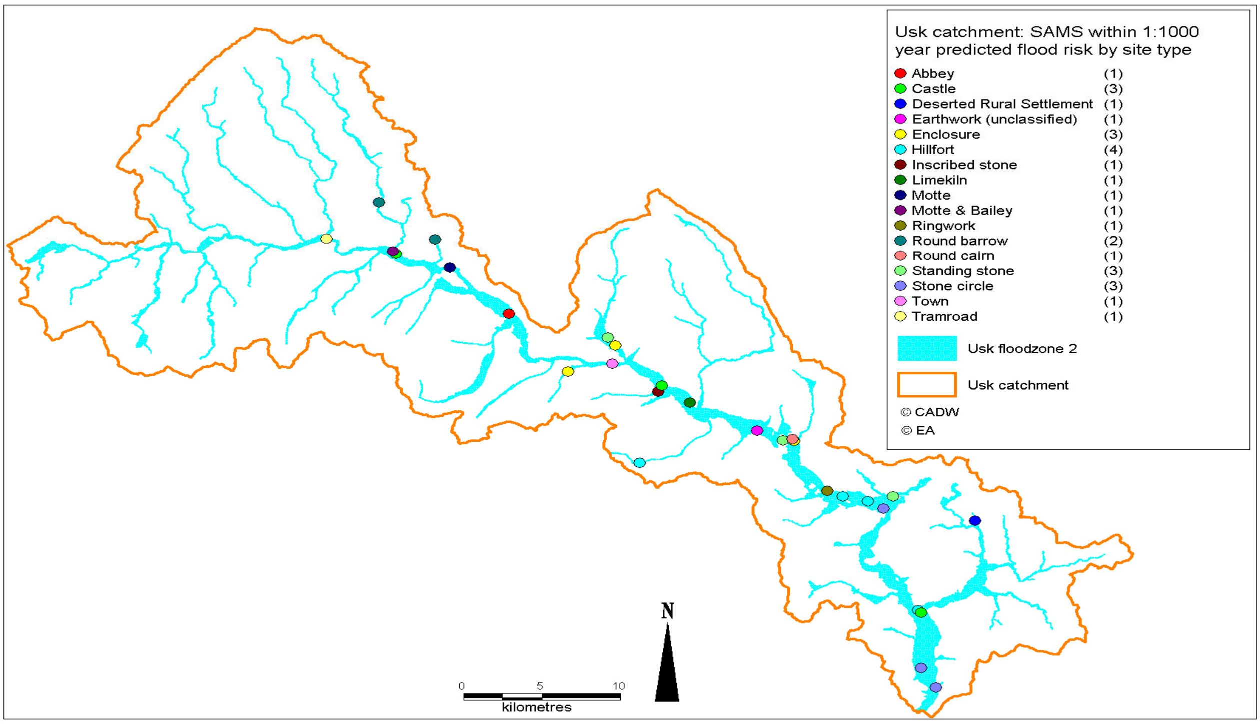

Figure 7.4: Historical and archaeological sites potentially at risk from a 1 in 1,000 year flood in the Usk catchment

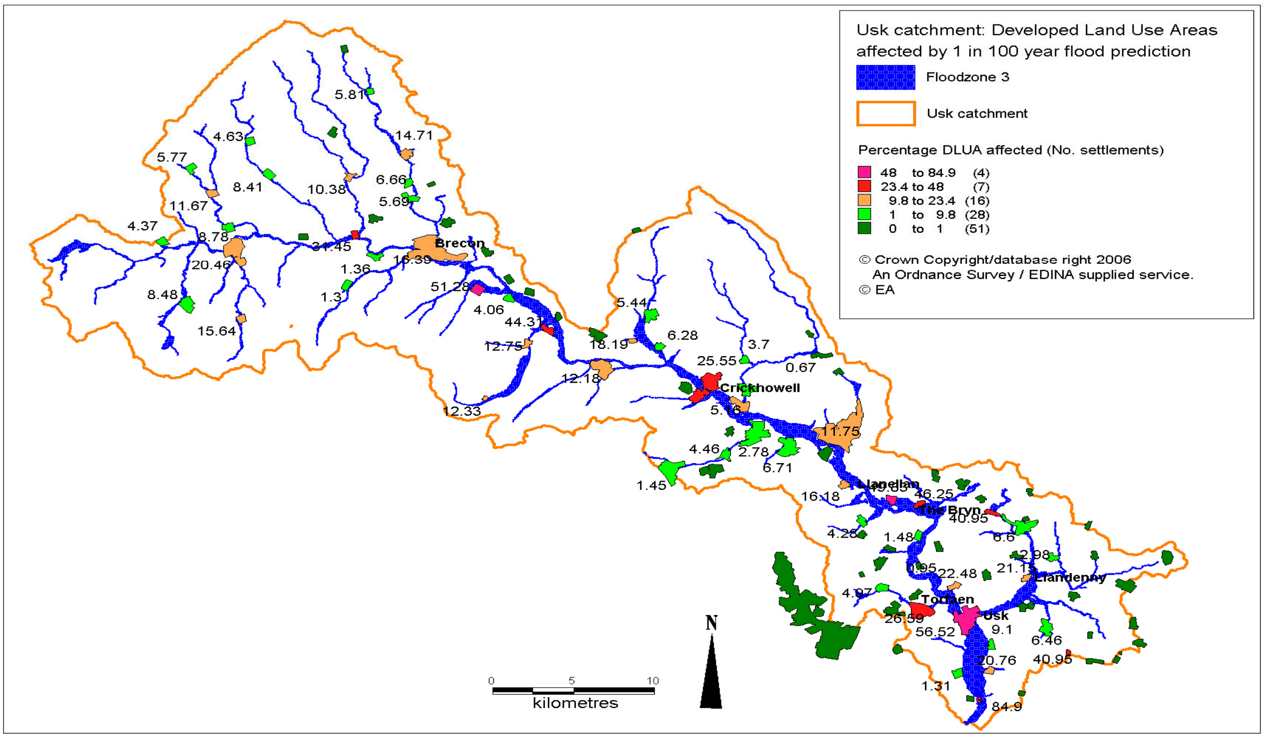

Figure 7.5: Percentage of urban areas inundated by 1 in 100 year flood for the Usk catchment

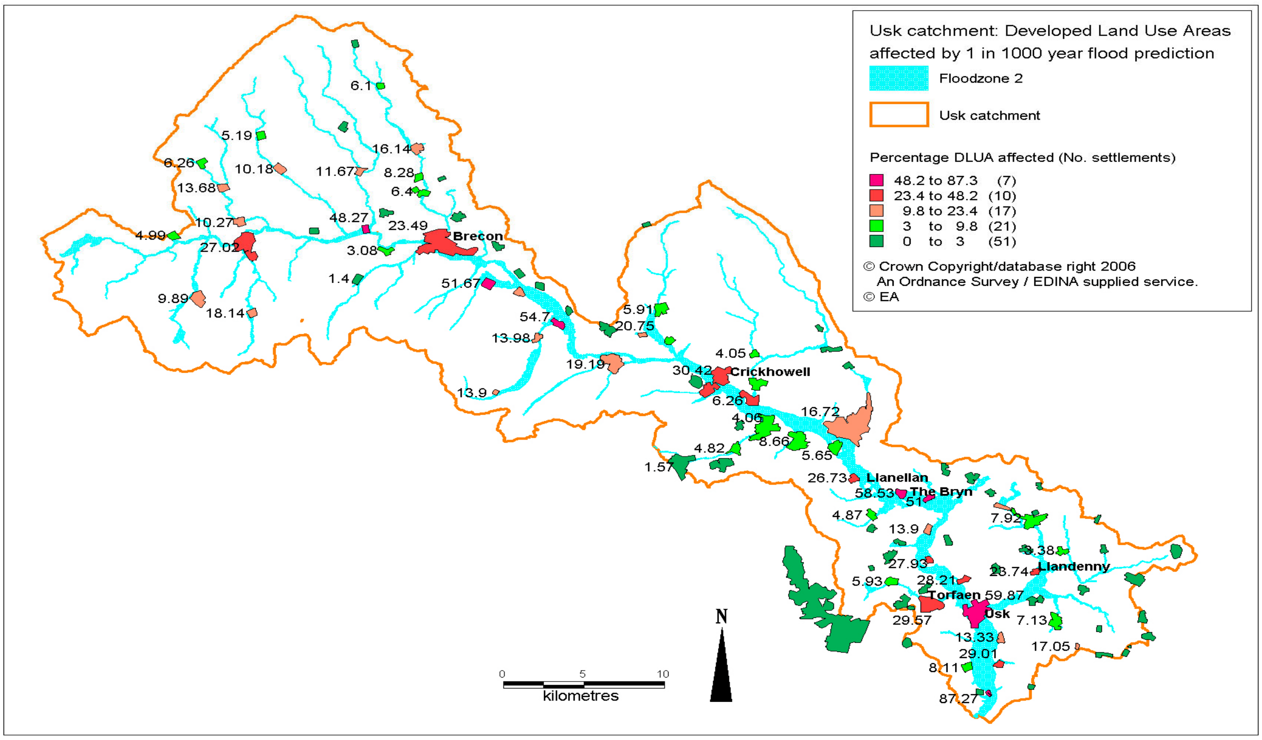

Figure 7.6: Percentage of urban areas inundated by 1 in 1,000 year flood for the Usk catchment

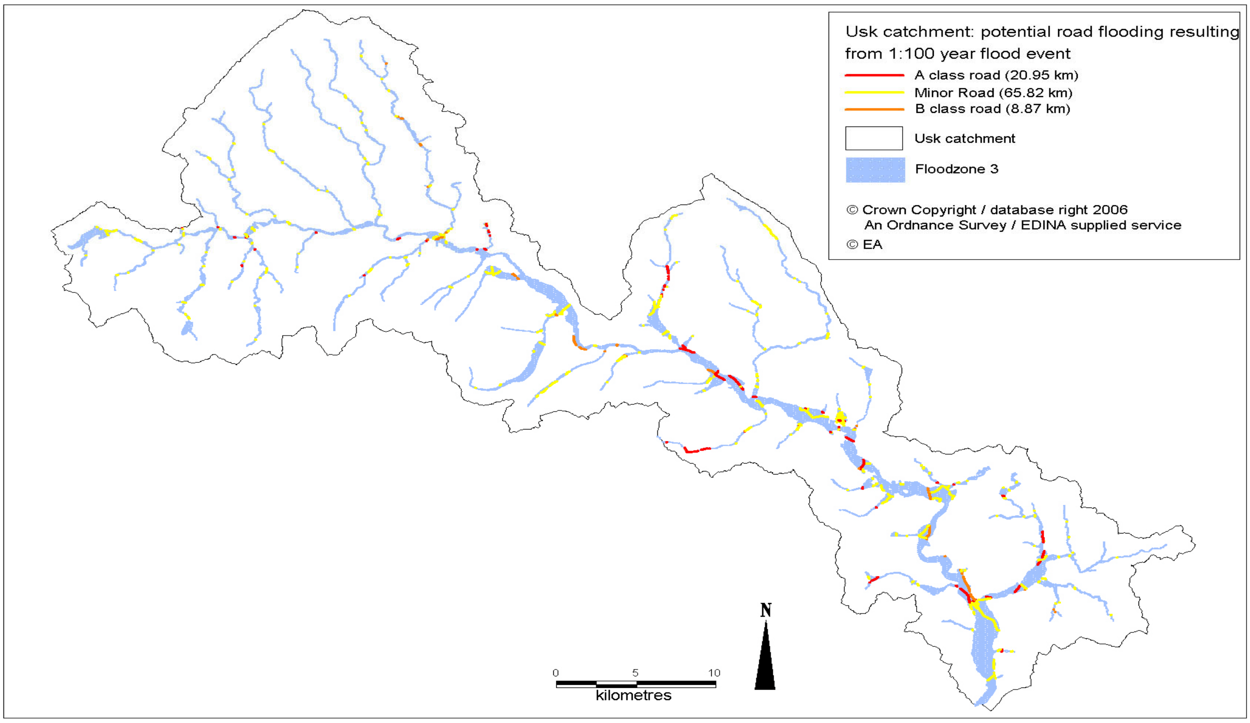

Figure 7.7: Potential road flooding resulting from a 1 in 100 year flood in the Usk catchment

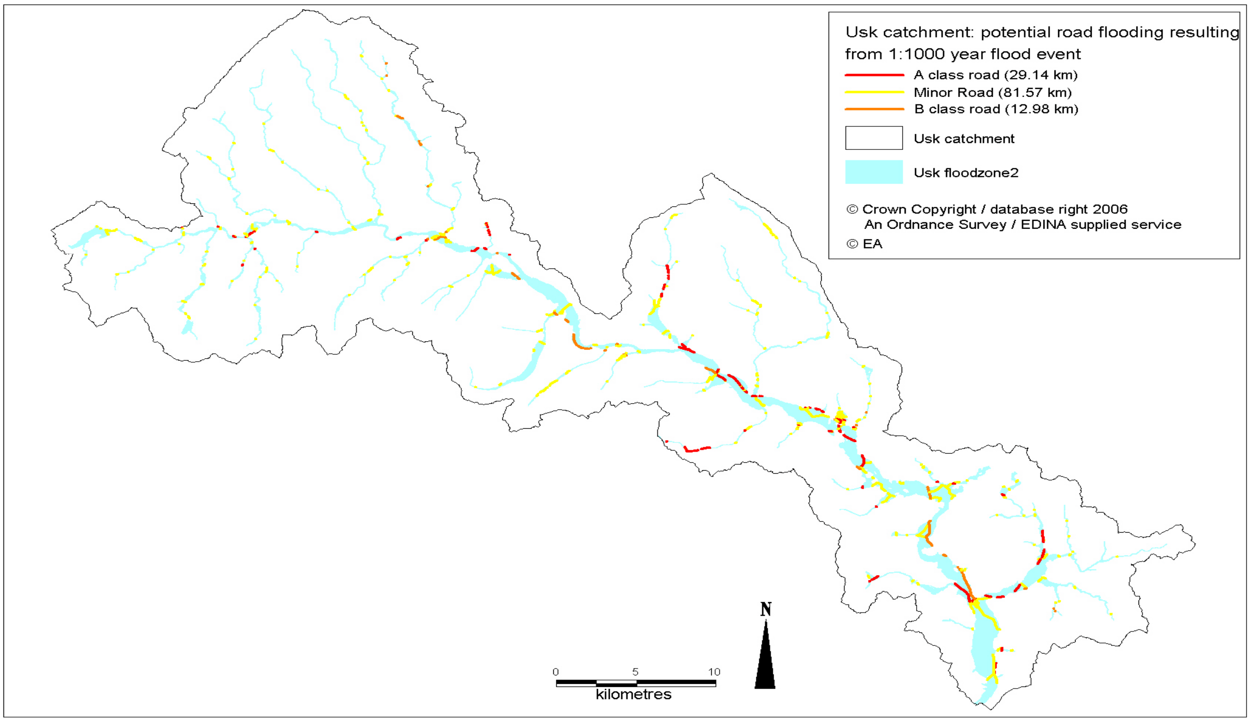

Figure 7.8: Potential road flooding resulting from a 1 in 1,000 year flood in the Usk catchment

The impact of flooding on people dependent on the river for livelihoods or for recreation

Natural resources such as fisheries should be adaptable to flooding and whilst densities of individual species may decrease immediately after a flood, they should recover with time. Spawning grounds may experience more frequent washout of eggs, where appropriate adaptation may be to ensure that spawning areas are in good condition and free from other pressures throughout the catchment. Similarly, while recreational users may suffer temporary restrictions during and immediately after floods, these restrictions should disappear relatively soon after any flood event.

The only situation where this might not occur would be when the flood caused severe damage to infrastructure, such as roads and bridges, and thereby restricted access for a long time after the flood had subsided. Detailed consideration of these factors was beyond the scope of this work.

Consider the impacts of changes in flood risk within the catchment due to climate change (Step 4)

Understanding the dynamics of floods and climate change

Climate change has the potential to increase flood risks for three main reasons. Firstly, Global Circulation Models predict that the UK will receive more intense rains, particularly in the winter, and that this will increase peak river flows. Secondly, the impact of these peak flows on flooding will be exacerbated by the fact that soils will tend to be wetter on average in winter, thereby reducing their ability to absorb water. Thirdly, sea level rise will provide a greater risk of tidal surges during storms.

While the generality of these broad statements is well accepted, it is an extremely difficult task to predict future river flows and floods based upon current climate change scenarios (Arnell, 1996; Werrity *et al*., 2001). However, Arnell (Arnell, 1996; Arnell *et al*., 1997; UKWIR, 2002) offers an approach to a rapid strategic level assessment of the effects of climate change on monthly river flows and annual groundwater recharge. Using outputs from UKCIP02, Arnell applied generated annual water balances and flow duration curves for a series of representative catchments across Britain under the anticipated climate of the 2050s (Arnell *et al*., 1997) and 2020s (UKWIR, 2002).

The percentage change in the mean monthly run-off by 2020 compared with the 1961-1990 long-term average data suggests that under the medium UKCIP02 climate scenario, flows in Welsh rivers will increase by four per cent in December and January and three per cent in February. Flows are reduced in all other months. An example of how this affects flows in the Usk catchment is shown in Figure 7.9 (see Appendix 7 for further details).

However, while monthly rainfall may increase only a small amount, this does not give any indication about either the daily rainfall or the flood frequency. At a basic level, all we can conclude with certainty from this analysis is that increased winter rainfall will lead to increased floods, but the frequency of these floods remains uncertain.

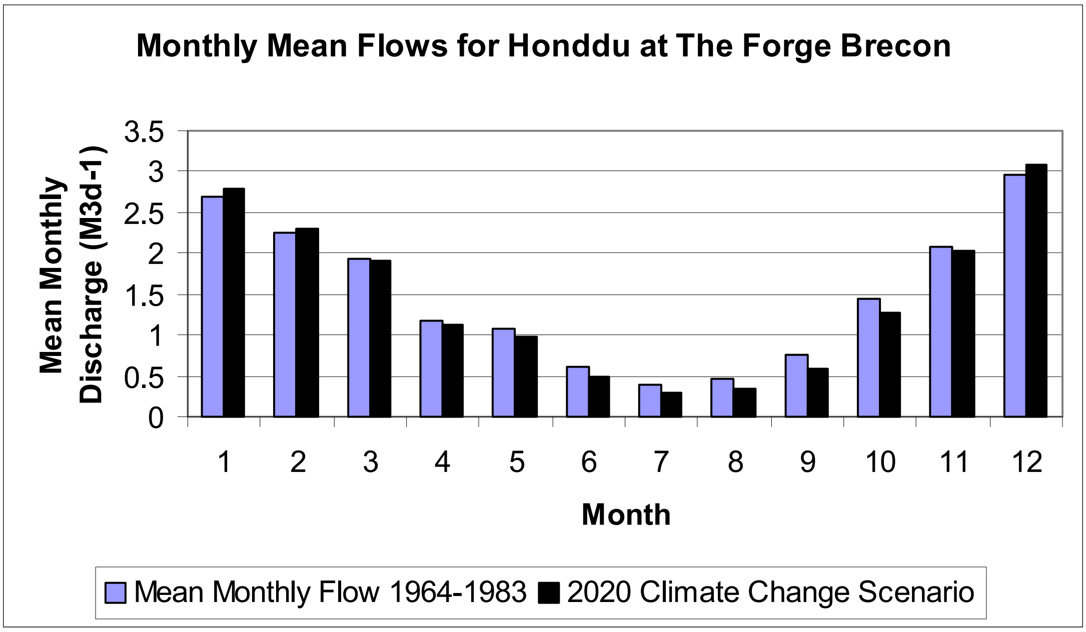

Figure 7.9: Mean monthly naturalised stream flow (m^3 d^{-1})1964-1983 for Honddu at the Forge, Brecon, and the estimate of flows under climate change in 2020. Light shading: 1964-1983 average; dark shading: likely flows in 2020 (conversion based on data from UKWIR, 2002).

7.2.2 Flood risks in Wales

Prudhomme *et al*. (2003) suggested that "flood events of any given magnitude are expected to become more frequent than currently observed on average", and their work suggested that for the Wye at Cefn Brwyn in mid-Wales the return period for flood events would be halved, where 1 in 10 year events would become 1 in five year events by 2050. However, it may not be possible to generalise from this specific site to the whole of Wales. For example, a more recent study by Kay *et al*. (2006) used the UKCIP02 climate predictions as inputs to flood models in 15 catchments around the UK and found that, despite decreases in annual average rainfall in all but one catchment, eight showed an increase in flood frequency at most return periods, whereas two showed substantial decreases by 2080. The variation in flood frequency between catchments is evidenced by considering the four catchments in Wales, modelled by Kay *et al*. (2006) (Table 7.5).

Kay *et al.* (2006) suggest that the relationship between frequency of flooding and climate change will vary with region and with the nature of the catchment. The reason why some catchments show a decreased return period of floods relates to changes in the seasonal pattern of rainfall and to the warmer summers and autumns, which will tend to increase soil moisture deficits, thereby increasing the amount of water they can absorb.

The uncertainty in predictions about flood frequency under climate change makes a specific analysis of the impact of future flooding in the Usk valley difficult. Ideally, a catchment specific model would be available to make predictions, as suggested by Werrity *et al.* (2001). Unfortunately, none were available for the Usk, and the development of such a model is beyond the scope of this work. However, quantitative indications about flood frequency under a changed climate are available for the Taff at Pontypridd, which is in a catchment immediately adjacent to the Usk (Table 7.5) (Kay *et al*., 2006). These results suggest very little change in flood frequency under climate change. However, as the geography of each catchment is unique, it is not certain that these results will apply to the Usk. Further, while the predictions of Kay *et al*. (2006) are based on good science, they are too recent to have become widely accepted, and for this reason it may be prudent to consider the damage that may arise in the catchment from increased flooding.

Table 7.5: **Percentage change in flood frequency for two return periods in four Welsh catchments (adapted from Kay *et al.,* 2006)**

National Water Archive gauging station number	Location of gauging station	% change in flood frequency at the 10 year return period	% change in flood frequency at the 50 year return period
57005	Taff at Pontypridd	+3	-6
60002	Cothi at Felin Mynachdy	+4	0
60003	Taf at Clog-y-Fran	+12	+20
55008	Wye at Cefn Brwyn	+32	+56

In order to understand the impact of increased flooding, there is a need to combine the damage done by the flood with the frequency with which it occurs. Large floods may be expected to cause greater levels of damage than small ones; however, frequently occurring small floods may also cause significant damage in some instances, although data from Hoes *et al.* (2005) suggest that this is not the case in the Netherlands. While there is scientific work exploring the frequency of flood damage in the USA (Zhang and Singh, 2005), no frequency damage curves were available for the Usk.

If relatively small scale floods (1 in 10 years) do become more frequent in South Wales under a changed climate, then existing flood defences should be sufficient to limit damage to urban areas. Within an agricultural situation, frequent small scale flooding may have a large impact on the areas affected, and may ruin crops while making grazing land unusable. In fact, the frequent inundation of agricultural land may be more damaging to affected farmers than a more widespread, but infrequent flood. This highlights the need for economic appraisal of a range of land uses on floodplains using climate change scenarios.

From a conservation perspective, more frequent small scale floods will bring about a change in the composition of species that occur in communities, and as discussed in Chapter 3, species change will occur in many habitats under a changed climate for a variety of reasons. More frequent small-scale floods may also affect recreational activities, restrict access and generally present a nuisance to the local community.

While traditional flood defences may prevent damage from small-scale floods, Tollan (2002) suggests that alteration in land use can also serve to mitigate the impact of small floods, and there is some evidence that woodlands can help alleviate floods in some circumstances. For example, Carroll *et al.* (2004) suggest that in mid-Wales, the infiltration of water into soil from over ground flow was up to 60 times higher in areas planted with young trees than in adjacent grazed pastures. Similar results have been observed elsewhere (Ellis *et al*., 2006), where the level of infiltration was related to better soil surface conditions in the absence of stock and a 50 mm layer of tree litter. In addition, the presence of trees tends to reduce the amount of water reaching a river in the long term, for two reasons. Firstly, they intercept rainfall directly, and this evaporates from the foliage and never reaches the soil surface. Secondly, trees and forests have a greater evapotranspiration potential than grassland and crops, and so they tend to enhance water transfer from the soil to the atmosphere.

The impacts of trees on water flows over the short and long term may offer some potential to alleviate some types of floods, in the long term by reducing the total amount of water flowing into the river channel from the surrounding land, and in the short term via increased infiltration which reduces the speed by which water reaches water courses during a storm event. For these reasons, the strategic planting of woodlands in the uplands and in river valleys may help alleviate floods. However, there are some constraints on this in practice. Firstly, Carroll *et al*. (2004) reported differences in infiltration between woodland and heavily compacted sheep pasture. However, it is probable that the differences in infiltration rates will vary with the land uses being compared. Secondly, enhancing infiltration only helps alleviate floods when the soil is not saturated with water. Once the soil is at saturation there is no possibility for more water to enter the soil, and so it will move over ground. Thirdly, there is great uncertainty as to where any given woodlands should be planted in order to maximise their impact on flood events. Identifying suitable locations to site woodlands and other flood mitigating habitats requires a good understanding of the hydrological regime of the catchment, but could lead to multiple gains for a range of policies.

7.3 Policy analysis

For the purposes of comparability across chapters, this section is termed 'policy analysis'; however, this phrase may not be correct for CFMP, which is perhaps more appropriately viewed as a process with specific aims and objectives.

7.3.1 Specific comments

Reduce the risk of flooding and harm to people, the natural, historic and built environment caused by floods

This overarching policy component is at risk from both climate change and social factors, including:

- climate uncertainty;
- modelling uncertainty;
- lack of enforcement of CFMP and Environment Agency recommendations;
- conflict between development targets and flood management;

- lack of capacity to adapt to future insights;
- lack of research or information, particularly suitable catchment level hydrological models;
- lack of linkage to land use planning;
- poor cost/benefit analysis;
- lack of stakeholder involvement.

The degree of vulnerability of this policy component for all scenarios is greater in 2050 than 2020. The vulnerability of this component is medium-high to very high under the scenarios in which the environment is of low concern and pressure to develop the flood plain is high, such as Linear, National Enterprise and World Markets in 2020 and 2050. The level of vulnerability can be reduced to some degree by increasing the level of investment in flood mitigation strategies, undertaking enhanced modelling to reduce uncertainty and through active engagement with stakeholders.

For scenarios in which the environment is of high concern and the pressure to develop the floodplain is less, then the policy component shows reduced levels of vulnerability in both 2020 and 2050. The degree of vulnerability is further affected by land use, in particular the amount of increase in urban cover and the level of deforestation. For example, under Local Stewardship flooding could be increased due to increasing deforestation across the catchment.

However, given the results of Kay *et al.* (2006) which suggest that flooding may decrease under climate change in certain catchments, there is a possibility that in some areas this policy component will be met regardless of any direct action undertaken by the Environment Agency or others.

Maximise opportunities to work with natural processes and deliver multiple benefits from flood risk management, and make an effective contribution to sustainable development

There is no difference in vulnerability of this component between 2020 and 2050. The relative cost-effectiveness of washland strategies and managed realignment relative to engineered responses to flooding will depend on the demand for development land, the specific costs of engineering and whether or not total economic costs are incorporated into the cost/benefit analyses. Therefore this policy component is highly vulnerable under scenarios where demand for development land is high, such as National Enterprise and World Markets. Where demand for development land is low, washland strategies and managed realignment are likely to be more cost effective and in demand for flood management.

Inform and support planning policies, statutory land use plans and implementation of the Water Framework Directive (WFD)

This policy component is at risk only from socio-economic conditions. The current CFMP process is able to fulfil this component, but may flounder or thrive under future socio-economic conditions. The Local Stewardship and Global Sustainability scenarios, which have strong support for informed planning policies, show low levels of vulnerability for this component. Under National Enterprise and World Markets scenarios, it is likely that the elements of CFMP which do not bring direct economic gain will either be dropped or rendered ineffective, therefore denying support to planning decisions, land use planning and the WFD. Hence this component is highly vulnerable. Under the Linear scenario, current CFMP strongly support informed planning policies and the implementation of the WFD, but will require further integration with statutory land use plans.

Linear extrapolation of present conditions therefore maintains this status quo and the vulnerability of this component is medium in 2020 and medium-high in 2050.

Understand current and future flood risk from all sources and quantify in economic, social and environmental terms

This policy component is subject to intrinsic uncertainty in modelling complex systems, and its vulnerability depends on the level of investment in research under each scenario. Uncertainty should decrease towards the 2050s as actual effects become better known.

Under scenarios where there is low investment in environmental and social research, such as National Enterprise and World Markets, this component is highly vulnerable in both 2020 and 2050. Under the Linear and Local Stewardship scenarios where there is moderate investment in research, there will be a greater understanding of flood risk and the development of tools for quantifying effects; however, intrinsic uncertainty adds to vulnerability. Therefore, these scenarios show medium-high and high levels of vulnerability in 2020 falling to medium levels in 2050. Under Global Sustainability, good investment in research should promote better understanding of risks and quantification and more complex modelling of effects may be supported.

Identify opportunities and constraints for reducing flood risk, such as through changes in land use, land management practices and/or the flood defence infrastructure

This policy component is subject to socio-economic conditions which may or may not provide effective and balanced approaches to flood management. There is no change in vulnerability for any scenario between 2020 and 2050.

Under the Linear scenario, moderate investment in research will help identify some opportunities and constraints; these are likely to include some balance of washland and engineered approaches and therefore the vulnerability of this component will be medium. Under the National Enterprise and World Markets scenarios, the vulnerability of this component is medium-high as moderate investment in flood mitigation is likely, but with a focus on engineering solutions due to lack of environmental concern and preference to develop buildings on floodplains.

A moderate/high level of investment in research under the Local Stewardship and Global Sustainability scenarios will help identify opportunities and constraints for reducing flood risk. Under these scenarios, these are likely to emphasise washland and land use changes rather than engineered approaches and therefore this component shows medium levels of vulnerability under these scenarios.

Identify opportunities during flood risk management to maintain, restore or enhance the total stock of natural and historic assets (including biodiversity)

This policy component is vulnerable to climate effects that may mitigate attempts to conserve nature, and socio-economic conditions that may or may not target nature conservation. Climate effects are likely to radically alter patterns of biodiversity by 2050, therefore, with the exception of Local Stewardship, vulnerability increases for all scenarios by 2050.

Under Local Stewardship, this component shows medium vulnerability. Here there is likely to be considerable concern over enhancing natural and historical assets, and wetland development under flood risk is likely to be strongly supported. The decrease in woodland may interact negatively with climate effects to increase flood risks. Concerns are similar under the Global Sustainability scenario and when combined with high rates of afforestation, this component shows medium-low vulnerability in 2020. However, climate factors will decrease populations of some species and so vulnerability increases to medium in 2050.

Under the Linear scenario it is likely that attempts will be made to conserve natural and historic assets, but climate effects may mitigate some of these (for example, via drought) while enhancing opportunities for others (such as wetland development). Vulnerability of this component is medium in 2020 and medium-high in 2050.

It is unlikely that nature conservation will be a priority under the National Enterprise and World Markets scenarios; thus, the negative effects of climate change will go unchecked and potentially positive effects will not be exploited. Under these scenarios, vulnerability of this component is high increasing to very high in 2050.

Use Strategic Environmental Assessment (SEA) to provide detailed environmental assessment and Modelling and Decision Support Framework (MDSF) to support analysis and decision making in formulation of the CFMP

This policy component may not be implemented under certain socio-economic scenarios. It is also possible that criteria chosen for SEA and analysis under MDSF are not well-adapted to future conditions under climate change, or that newer tools are better adapted. Development or replacement of these tools may be required. There is no difference in vulnerabilities in 2020 and 2050.

Under the Linear scenario these tools are likely to be implemented, but their findings may not put enough pressure on planning committees to make appropriate decisions and so the vulnerability of this component is medium-high.

Under the National Enterprise and World Markets scenarios these tools are likely to be abandoned or their findings ignored, along with a general failure in implementing CFMP and the Water Framework Directive, leading to very-high vulnerability.

Under Local Stewardship and Global Sustainability scenarios these tools are likely to be implemented, and policy is likely to support an environment in which their findings and recommendations strongly influence planning. Ability to develop or replace these tools may, however, be restricted or delayed unless current policy acknowledges potential future requirements. The vulnerability of this component under these scenarios is medium-low.

Integration with, and effects on, other policies and agreements.

CFMP must interact closely with Catchment Abstraction Management Strategies or any other abstraction scheme and with the Water Framework Directive. Conflicts between aims or implementation of these policies could severely hinder positive outcomes, both for society and for the environment. This component is significantly more vulnerable in 2050 compared to 2020. However, over the near future the setting up of River Basin Management Plans for WFD should enhance policy integration.

Linear extrapolation suggests integration at current levels and moderate spending on social and environmental benefits. Under 2020 climate conditions these may be adequate for ensuring reasonable integration of policies, but may be increasingly stressed and inadequate by 2050 given multiple demands and the need for high investment in water saving and storage. Vulnerability is medium-low in 2020 but increases to medium-high in 2050.

Under the National Enterprise scenario, strong emphasis on economic growth suggests that the environmental sustainability components of all policies will be neglected. It is likely that abstraction will be promoted while flood management is neglected, except where economic costs are high. Such lack of attention to sustainability suggests high vulnerability of policies and their adaptation to climate change, therefore this component has high vulnerability in 2020 increasing to very high in 2050.

Under Local Stewardship emphasis on sustainable catchment management should be strong, with stakeholders well-integrated into the decision-making processes related to all water policy initiatives, while vulnerability is low. Direct effects of climate change may begin to stress the integrated approach by 2020, and by 2050 they may be exerting significant stress on efforts for integration, increasing vulnerability to medium-high.

General disregard for strongly environmental policy initiatives under the World Markets scenario suggests components of policies that support markets will gain precedence. This suggests the eventual failure of CFMP along with strong emphasis on abstraction. Therefore, vulnerability of this policy component is medium-high in 2020 increasing to high in 2050.

The Global Sustainability scenario is likely to strongly support policy integration, with particular emphasis on streamlining policies towards integration with the Water Framework Directive. Integration should be somewhat robust to 2020 climate effects and so vulnerability is low, though it may increase to medium levels by 2050.

7.4 Discussion and climate proofing

The CFMP is a flexible process with built in five-yearly reviews, which suggests resilience to changing situations. In addition, the incisive approach adopted by Environment Agency Wales to operationalise CFMP is a positive step in reducing vulnerability (see Table 7.6 for a summary of CFMP resilience). However, at the core of CFMP is a need to inform decisions over the long term. The ability to make some predictions about the size, frequency and duration of floods is central to the effectiveness of the policy.

Table 7.6: **Summary of the risk assessment of CFMP policy.**

Component	Probability of failure	Notes
\reduce the risk of flooding and harm to people, the natural, historic and built environment caused by floods.	Medium to high	Our inability to predict future floods will mean that inappropriate development may go ahead. Simultaneously, our inability to bring about change in land use and land management will not help mitigate floods.
Maximise opportunities to work with natural processes and deliver multiple benefits from flood risk management, and make an effective contribution to sustainable development.	Varies	Vulnerability varies with the social attitudes to economic growth, investment in research and environmental protection.
Inform and support planning policies, statutory land use plans and implementation of the Water Framework Directive.	Low (in the first instance)	Under some scenarios the stress on economic growth serves to de-emphasise both WFD and CFMP.
Understand current and future flood risk from all sources and quantify in economic, social and environmental terms.	Medium to high	Vulnerable to intrinsic uncertainty in modelling complex systems, and investment in research under each scenario.
Identify opportunities and constraints for reducing flood risk, such as through changes in land use, land management practices and/or the flood defence infrastructure.	Medium to high	Vulnerability varies with socio-economic conditions which may or may not provide effective and balanced approaches to flood management.
Identify opportunities during flood risk management to maintain, restore or enhance the total stock of natural and historic assets (including biodiversity).	Medium to high	Changing patterns of land use and biodiversity will complicate this issue in the future. The social attitude towards conservation will vary between scenarios.
Use Strategic Environmental Assessment (SEA) to provide detailed environmental assessment and Modelling and Decision Support Framework (MDSF) to support analysis and decision making in formulation of the CFMP.	Medium to very high	Current models are unlikely to be able to achieve this task under a changing climate.
Integration with, and effects on, other policies and agreements.	Varies	Depends entirely on the social attitudes towards integrated environmental management

Uncertainty about future climates and the individual responses of catchments to changing rainfall suggest that, in order to get a meaningful understanding of future flood events, it will be necessary to develop detailed models for every catchment. By its nature this will be an expensive and time-consuming task. But if CFMP are to be effective in the long term, it is one which should be attempted as soon as possible.

In addition to getting a good prediction about the physical extent, duration and frequency of floods, decisions within a CFMP will depend on an understanding of the costs caused by any given flood. This is illustrated by an example taken from the CFMP policy document (Environment Agency, 2004), which suggests that as part of a CFMP there may be a need to undertake decisions such as the following:

> "The expected annual damages in town A are £xx m yr^{-1} and amount to xx per cent of the total damages within the catchment. The expected annual damages could increase by xx per cent by 2020 as a result of the impacts of climate change and further development planned within the catchment. The other consequences of flooding in terms of the environmental and social impacts are ….."

As evident in the example, current analysis of the cost of floods is largely restricted to the damage caused to properties. However, this is only one part of the suite of costs which floods may cause. If CFMP is to truly assess the impact of floods on the whole of society, then it needs to consider the full range of costs associated with flooding. Some research questions pertinent to this issue are presented below.

1. Understanding the costs of flooding to agriculture

Very little work has been done on this topic in the UK in over 20 years. However, if CFMP are to fully cover the impacts of alternative flood management systems, then they need to capture all the financial and social impacts associated with flooding. Some relevant research questions may be:

- How does the impact of complete inundation of a crop for a specified period at different stages of crop development affect the profitability of that crop? (see Castel *et al*. (2006) for an American example)
- How does frequent flooding of a crop/pasture field impact on the long-term profitability of the enterprise, both in terms of direct impact on the crop and in terms of the workability of the land with machinery?
- Do floods contaminate leafy vegetables with coliform or other bacteria?
- Do floods play a role in spreading wildlife/livestock disease such as bovine TB?
- What economic gains could be realised by crop or land use change on floodplains?

2. Understanding the costs of flooding to human health

The are many studies documenting the impact of floods on physical and mental health from countries around the world (such as Haines *et al*., 2006; Liu *et al,*. 2006; Patz, 2001) and the UK (Floyd *et al*., 2004; Tapsell *et al,*. 2002, 2003). This work shows that victims of flooding suffer "short-term physical effects and short- and long-term psychological effects" (Floyd *et al*., 2004). Many people are willing to pay to avoid the health impacts associated with flooding, and Floyd *et al.* (2004) estimated this willingness to pay to be about £200 per household per year. This economic estimate of the impacts of flooding on health can be incorporated in flood defence expenditure decisions, by assuming that the benefits of any proposed flood defence structure will include £200 for every household protected by that defence for every design year of the defence structure. While this approach is exemplary, further work may be warranted to more fully understand the costs of flooding on health and community cohesion (see Fordham and Ketteridge, 1995). Any such analyses should consider the impact of more frequent flooding on health, as discussed below.

3. Understanding the economic impacts of more frequent flooding

Existing studies have considered the level of assets at risk in a floodplain and also the amount of damage historical floods have caused. But few studies present a framework for considering the costs arising from increased flooding frequency (see Beard, 1997, for a discussion of an American example). This sort of analysis is important, as it may not be correct to conclude that the economic costs of a 1 in 100 year flood would be the same if the frequency of occurrence increased to once in every 10 years. The economic and natural systems may take time to recover in some way after a flood, and if they are perturbed by another flood before reaching a new equilibrium then the costs may be very different to that of two independent flood events.

In addition, there is a need to research the capacity of landscapes to absorb and retain water. While there is a general interest in the role trees can play in enhancing infiltration, there has been very little work on the role of other land use systems in achieving the same goal. As it will not be practicable to plant trees everywhere, it may be worthwhile considering the impact of other more traditional crops in enhancing infiltration, such as a strip of biomass crops like short rotation coppice willow or Miscanthus, a strip of arable crops, a strip of regularly ploughed grassland, horticultural crops and so on. There may also be a role for farmers to develop reservoirs, ponds and wetlands which will serve to store water in the winter, and thereby help mitigate flooding.

In the shorter term, the vulnerability of the CFMP could be reduced if stakeholders engaged in some well known and practical actions:

- prevent inappropriate development in areas at risk from flooding;
- avoid development which could increase the flood risk elsewhere;
- seek to minimise surface run-off from developed and agricultural land;
- maintain and upgrade the discharge capacity of piped systems.

8 Policy interactions and recommendations

8.1 Introduction

This chapter explores the interaction between the separate policies, where they work against each other and their potential synergies. Opportunities for policy adaptation to future climate change are discussed in three sections: (1) interaction between the policies; (2) lessons and limitations; and (3) recommendations.

Policy interactions are complex; given that six policies were analysed, there are 15 potential pairs of interactions. There are also potential three-way interactions, four-way interactions and so on. A formal analysis of all 15 two-way interactions is provided in Tables 8.1 to 8.21, where Tables 8.1 to 8.6 present summary data on the policy components to be analysed, and Tables 8.7 to 8.21 cover the interactions. A formal analysis of three-way interactions is too complex to be presented here. However, the section on policy interactions discusses these multiple interactions. No specific references are made to the Tables 8.1 to 8.21 in the text, but it is assumed that readers will consult the tables alongside the text.

The second section in the chapter discusses the limitations of the work, and outlines some of the lessons learnt which may aid future analyses of this type.

The third section offers some recommendations for climate proofing the set of policies analysed. Policy specific recommendations are given at the end of each policy chapter, and specific recommendations for improving two-way interactions are presented in Tables 8.6 to 8.21. The purpose of this section is not to repeat these recommendations, but rather to highlight a few key issues which could help climate proof resource protection agreements and policies in a more integrated manner.

8.2 Policy interactions

8.2.1 Sites of Special Scientific Interest (SSSI)

The risk assessment suggests that the SSSI policy has a high probability of failing under climate change. Major risks relate to the inability of the policy to supply a national set of protected areas which guarantee the survival of Britain's wildlife under a changed climate. This aspect of the policy will fail as species migrate in response to climate; some existing British species will migrate out of current ranges and new species will invade from continental Europe. Because of this, many of the natural communities which are currently protected by SSSI will change in nature. The ability of the current SSSI policy to respond to these changes is limited, as the policy is firmly site-based, and it is very difficult to designate new sites to protect any given species or community, as the future distribution of species across the UK is uncertain.

One adaptation to this risk is to develop sufficient levels of connectivity in the landscape so that species can move across Britain in response to climate, with SSSI serving as key centres of biodiversity resource and forming part of the connected landscape. A network of potential new habitats needs to be maintained which migrating species can colonise where appropriate. It is in developing this strategy that SSSI policy could potentially interact most closely with other policies.

For example, the woodland strategy emphasises the need for new woodland to be developed, and this could contribute positively to increased connectivity, thereby supporting the movement of species through the landscape. Similarly, within a Catchment Flood Management Plan (CFMP), natural floodplains could be deliberately left undefended. This would serve to limit any productive agricultural potential, and these areas could then be managed for multiple benefits such as flood management downstream, recreation and extensive agriculture. In addition, they may contribute to the connectivity in the landscape, and act as refuges and/or stepping stones for certain species. It is even possible that developments of short rotation coppice (SRC) biomass, which in essence are managed woodlands, could improve the connectivity and permeability of landscapes if managed appropriately (although very little research work has been undertaken on this topic to date).

While these interactions may be positive there are also potential problems, particularly with the location and management of new habitats. For example, new woodland may be planted for economic gain, and its management will be geared towards that aim. So while the amount of woodland habitat may increase in the landscape, the exact quality of that habitat will undoubtedly vary with location. This may not matter for all species, but it may limit the utility of woodland as a connecting habitat for some others. Further, not all new woodland would be equally valuable at the landscape scale. Some landowners may wish to plant areas that do not connect existing habitat fragments, and thereby offer few improvements in overall landscape connectivity. Similarly, when designating floodplains, the practical necessity of protecting residential properties will determine their location and not their contribution to landscape connectivity.

In theory, Catchment Abstraction Management Strategy (CAMS) can also contribute to increasing connectivity in the landscape. Rivers and river corridors function well as dispersal corridors for aquatic and non-aquatic species. The maintenance of appropriate in-stream flow levels at particular times of year can enhance their utility as dispersal corridors. However, river corridors are not infinite, and on their own they cannot provide the connectivity required to enable all species to move long distances. Further, even if an aquatic species migrated up river in response to a changing climate, at some point the natural form and physico-chemistry of the upper reaches would restrict further movement, and at this point the utility of rivers as movement corridors would fail. For this reason, the long-term value of managing the river as a migration corridor will vary for different species between rivers.

In summary, not all new habitat contributes equally to landscape connectivity. Because of this, measures to enhance the movement of species through the landscape require the development of specific habitats in specific locations. Further, these habitats may need to be managed in particular ways to meet the requirements of different species. Consequently, we need strategic landscape planning of land use, spatial planning and land management. Agri-environment schemes could be used to encourage development of desired habitats, where specifically targeted schemes would offer one tool for filling in the gaps between other parts of the green infrastructure in the landscape.

However, before they could fill this role, the Welsh suite of agri-environment schemes would need to significantly evolve from their current form. Specific targeting would be needed to encourage landowners in region X to develop a certain habitat type, and those in region Y to develop another habitat type. If it were politically acceptable to do this, then the current point scheme which is a fundamental part of the process by which farms are selected for entry into Tir Gofal could be adapted to enable targeting. Further targeting could focus around the potential for cooperative action, where certain groups of farmers would be encouraged to engage in complementary activities. A further change might be needed in the degree of flexibility offered by these schemes for location specific management, with payment rates varying accordingly. River Basin Management Plans could potentially help deliver this targeted approach.

If these changes were made to Welsh agri-environment schemes, then they could help enhance landscape connectivity. Ultimately, however, their contribution to connectivity will depend on the level of resources available for contracting farmers into the scheme.

A second element of SSSI policy which also has a high probability of failing under a changed climate relates to the setting of operational limits for factors considered to have a positive or negative effect on conservation status. It is difficult to know which species/communities will need protecting in the future and in which location, and it is also currently impossible to say how we could manage future habitats under a changed climate and land use system to protect any given species. Given this situation, it would seem essential for any complementary environmental schemes to have an in-built element of flexibility in their management prescriptions, so that they can be modified with location and over time.

Table 8.1: Summary of policy components of SSSI policy and the identification numbers used in the analyses presented in Tables 8.7 to 8.21.

No.	SSSI component
1	The national total protected areas should be large and varied enough to guarantee the survival of the necessary minimum of Britain's wildlife and physical features.
2	Criteria for site evaluation include primarily: size, diversity, rarity, naturalness and typicalness; and secondarily: recorded history, position in an ecological/geographical unit, potential value and intrinsic appeal.
3	Criteria for site evaluation for geological and physiographic features include: representativeness, exceptional features and international importance.
4	When notifying a SSSI, produce a Site Management Statement (SMS) describing desired management of the land for conservation and enhancement of its flora or fauna or features.
5	Evaluate the condition of the site in terms of favourable conservation status (FCS).
6	Set operational limits for factors considered to have positive or negative effects on FCS.
7	Define attributes and specify thresholds to use as performance indicators in monitoring.
8	The use of habitats translocation for habitat restoration should not damage important sites or ancient habitats, and habitat translocation should only take place where it can be shown that there is a net gain for biodiversity conservation.
9	Integration with, and effects on, other policies and agreements.

8.2.2 Woodlands and biomass

The vulnerability of components of the woodland strategy to climate change will vary quite considerably between socio-economic scenarios (as discussed in Chapter 5). Fundamentally, the success of the policy components will depend on the demand for timber products in the future, the world price for timber, and future levels of environmental awareness in society and government.

As noted for SSSI policy, components seeking to develop new areas of woodland would potentially enhance biodiversity policy, and in particular would reinforce future strategies for enhancing connectivity in the landscape. However, there might be a conflict between the role of new woodlands managed for timber and their role in biodiversity conservation. The conflict might be particularly apparent in scenarios which prioritise economic return over environmental conservation. One possible way to ensure that some woodland was managed for biodiversity would be to require a certain proportion of grant-aided plantings to be allocated as wildlife habitat, as occurs in agricultural policy. However, if the economic returns on woodland did increase substantially in the future, then landowners might not require grants to fund the establishment of new woodlands. An alternative would be for government to only grant aid for woodlands which would contribute to environmental conservation in an agreed manner.

This approach may be one way of developing opportunities to use woodlands to mitigate flooding. However, it would be necessary to fully understand the hydrology of the catchment, so that the location and design of any new woodland could contribute fully to flood mitigation. The lack of fully distributed catchment hydrological models and poor understanding of the impact of new woodland on run-off are current impediments to this process. Development could be helped by more experimental systems to measure and model the impact of different woodland designs on infiltration and flood mitigation.

When designing any new woodland, it is important to remember that due to high levels of evapotranspiration, woodlands can serve to remove water from landscapes throughout the year, and not just in the winter flood season. In areas of adequate water supply this is not a problem, however if levels of precipitation decrease significantly under a changed climate then the impact of woodlands on the local availability of water may become an issue. In this situation, the impact of woodlands on water availability may need to be taken into account when planning and designing new woodlands.

This is a particular concern in the planning of new short rotation coppice (SRC) biomass developments, as they are known to have large evapotranspiration rates, and for this reason it is recommended that an SRC plantation should be treated as an abstraction. This may become an increasing concern in some areas, as SRC crops may serve to further reduce in-stream flows during the summer months. Until further field data are available, it may be wise to restrict the development of SRC plantations close to ecologically sensitive reaches of rivers.

The greatest risk to the biomass strategy relates to the lack of markets. Unless there are viable markets for biomass products, then farmers will not invest in growing biomass crops. If government is serious about using biomass to help meet Kyoto targets, then some aid may be required to establish all parts of the biomass chain. Given that England seems to be offering greater support to farmers to develop biomass crops than Wales, there is a risk that Welsh businesses will not benefit from the early stages of commercialisation of the sector unless the Welsh Assembly offers greater support for biomass initiatives.

A further uncertainty for the biomass sector relates to the most appropriate form of biomass to be developed in Wales. While current efforts are focused on short rotation coppice willow and poplar, there may be a demand for other types of biomass crops such as grasses (*Miscanthus* and *Phalaris*) and cereals. If these markets do develop then some of the components of the biomass strategy may be met, but the level of synergy between the woodland and biomass strategies will be diminished.

Table 8.2: **Summary of policy components of the *Woodlands for Wales* strategy and identification numbers used in the analyses presented in Tables 8.7 to 8.21.**

No.	Woodland component
1	Increase the quality of native woodlands for wildlife and implement the Biodiversity Action Plan targets for their restoration and extension, creating links between fragmented woodlands.
2	Increase the area of woodland achieving independent environmental certification to internationally recognised standards.
3	Increase the area of native woodlands, targeting extension and connection of existing woods and incorporating the concept of increasing the core area of native woodland habitats.
4	Encourage the owners to incorporate different habitats, such as heath and bog, within woodlands, to maximise the connections between similar habitat types.
5	Encourage the thinning of woodland to increase the future flexibility of management, to create greater diversity within woodlands and to produce more valuable timber products.
6	Increase the biodiversity of coniferous woodlands through the use of continuous cover systems.
7	Aim to convert at least half of the National Assembly woodlands to continuous cover over the next 20 years, where practical, and to encourage conversion in similar private sector woodlands.
8	Use catchment management planning to develop the role that woodlands can play in the management of water and the reduction of flood risks.
9	Seek to increase the competitiveness of our forest industries, working in partnership with industry to develop and implement action plans across the sector.
10	Promote the development of specialist recreation in woodlands, including wildlife observation and artistic pursuits, and more noisy and physical sports in appropriately zoned areas.
11	Continue to encourage visitors to all the National Assembly woodlands, actively promoting the opportunities available.

Table 8.3: Summary of policy components of the biomass strategy and the identification numbers used in the analyses presented in Tables 8.7 to 8.21.

No.	Biomass component
1	Integrate biomass strategy with the general aims and biomass objectives of the Welsh woodlands strategy.
2	Provide support for farm woodlands and the wider rural community given recent decline in farm incomes.
3	Encourage farmers to bring woodlands back into production via schemes including Coed Cymru, Farming Connect, LEADER and TIMBER II.
4	Develop renewable energy production based on wood biomass.
5	Support WAG commitment to meet UK renewable energy targets defined at Kyoto (5% of electricity from renewable sources by 2003, 10% by 2010) and advised extension by Cabinet Office (2002) to 20% of electricity from renewable sources by 2020.
6	Develop and support biomass products, markets and end users.
7	Market and promote Welsh timber products including biomass.
8	Develop a grant scheme for biomass crops to support speculative farming in suitable areas based on sustainable criteria.
9	Promote and train heating engineers.
10	Ensure EIA regulations that planting on sensitive areas such as unimproved grasslands or other habitats is avoided.
11	Set up a series of farm woodlands at various altitudes and site conditions in order to investigate and demonstrate best practice.
12	Encourage the use of biomass heating in WAG and other public sector buildings in order to stimulate the local supply chain.
13	Integration with, and effects on, other policies and agreements.

8.2.3 Catchment Abstraction Management Strategy (CAMS)

CAMS is only one part of the overall UK water resource planning framework, and in itself is a reasonably flexible policy with regular review periods, which should serve to reduce its vulnerability to climate change. Unfortunately, while the overall structure enables adaptation with time, the policy faces a serious challenge in seeking to balance social and environmental demands on water resources under a changed climate of decreased rainfall.

Given that many rivers, streams and associated habitats are designated as SSSI and protected areas, there is a clear need for the flow levels set under CAMS to reinforce those required under the Site Management Statements of SSSI. Unfortunately, the setting of operational limits for factors considered to have positive or negative effects on conservation status has a high probability of failure under a changed climate. This is because firstly, it is difficult to know which species/communities will need protecting in which locations in the future. Secondly, it is also difficult to say how we could manage new assemblages of aquatic species under a changed hydrological regime.

Regardless of the ecological requirements of any habitat, the scenario analysis suggests that should the social demand for water be greater than the social demand for environmental goods, then increased abstraction will occur to the detriment of aquatic biodiversity. For this reason, there is an urgent need to encourage water efficiency and enhance water storage in many catchments. Further, there may be a need to restrict further urban developments in some catchments. Only if water demand is managed can the ecological aspirations of CAMS and wider water resources planning be met.

Although current use of water by agriculture in Wales is relatively low compared with that of other sectors, there is no direct requirement under the Welsh agri-environment schemes for farmers to either save water or ensure adequate flows into rivers and streams throughout the year. This is an area which could be developed significantly in the future. As part of farm resource plans, farmers in certain areas could be required to undertake winter storage of water, and to use this water to enhance summer flows as required. The potential for farmers to engage in water storage for economic gain should also be explored. If feasible, this idea could either be developed within agri-environment policy, or the legislative framework could be altered to enable farmers to benefit directly form the sale of water. Future manifestations of Welsh agri-environment schemes may need to consider the general topic of irrigation, and how good irrigation practice can be brought into the scheme. This will be particularly important in those areas where there is likely to be future expansion of high value horticultural crops.

A current limitation of both CAMS and the CFMP is the lack of catchment-specific hydrological models. It is very difficult to develop a sustainable level of abstraction unless there are models to calculate the impact of abstracting a given amount of water from a certain location on the availability of water downstream. In addition, hydrological model application has been hindered by a lack of regional predictions of rainfall under a changed climate. Tools to do this are becoming increasingly available, along with new climate change scenarios. However, until these are fully developed it is extremely difficult to provide indications of future water availability/deficit within a catchment. This issue is a serious impediment to long-term planning, and ongoing research in this area needs to be actively supported.

Table 8.4: Summary of policy components of CAMS and the identification numbers used in the analyses presented in Tables 8.7 to 8.21.

No.	CAMS component
1	Balance social and environmental demands on water resources.
2	Protect aquatic environment, species and habitats.
3	Ensure that abstraction does not cause river flows, groundwater levels or wetland water levels to fall artificially below the minimum level required for conservation of the aquatic environment.
4	Provide an indication of water availability/deficit within the catchment.
5	Divide catchment into Water Resource Management Units (WRMU) and carry out sustainability appraisal for each.
6	Provide a framework for managing time-limited abstractions.
7	Provide a framework for licence trading.
8	Ensure open public discussion and consultation.
9	Set appropriate ‘hands-off’ flows and apply on a tiered basis.
10	Ensure drought management is carried out and restrictions imposed where necessary.
11	Ensure workable links to other initiatives.

8.2.4 Catchment Flooding Management Plans (CFMP)

CFMP have several features which serve to reduce their vulnerability to climate change. These relate to the regular review of activities and the potential for it to become a very inclusive and participatory process, as is being attempted in Wales (a different approach to that in England). Despite these features being in place, under the analysis used in this study CFMP has a high risk of failure under a changed climate, largely due to the increased risks suggested by future climate scenarios. The risk of failure relates primarily to the uncertainty in predicting the likely frequency and magnitude of future flood events and what the impacts of these will be. In addition, the probability that we can understand current and future flood risk from all sources and quantify these in social and economic terms is at a medium to high risk of failure. This stems from a lack of knowledge of the full economic impacts of flooding. Future research may need to assess the economic impact of flooding on land use, including agricultural land, historical heritage and nature conservation, and also to build on the recent work of Tapsell *et al.* (2003) and Floyd *et al.* (2004) in estimating the health and social costs of flooding.

Given the above, we are in a situation where the flood management process seeks to arrive at rational flood defence options, but the information available on the size and frequency of future floods is very broad and does not generally include economic costs of any size of flood. It is thus hard to make decisions about the allocation of resources for flood defence. Hopefully, the CFMP will benefit from the wider use of appropriate predictive modelling tools when they become available.

As discussed above, there is a direct interaction between CFMP and SSSI policy, relating to the situation where a SSSI (or other designated area) is dependent upon a given level of flooding. In most situations, flooding may serve to maintain high soil water levels in order to support certain plant communities. However, it is possible, though less likely, that in some areas the protected habitat may require low soil moisture, and in this situation it could be harmed if flooding increased. In both these situations, changes in the frequency or duration of flooding may bring about a change in the species composition of these communities. For this reason, any changes in flood management should take account of the requirements of any designated sites which may be affected.

In practice, it is unclear if the needs of a SSSI would be given prominence in any flood defence measures. Traditional flood defence seeks to reduce the amount of flooding to residential properties and urban areas and historically agricultural land over the long term. It would be very difficult not to argue for such defences, even if they did reduce the flooding of designated nature reserves. Given that under a changed climate rainfall will decrease and potential evapotranspiration will increase, it seems almost inevitable that soils will be drier during summer months. So even if historical levels of flooding were maintained in nature reserves, the structure of plant communities may change anyway.

The CFMP also seeks to identify opportunities and constraints for reducing flood risk through changes in land use and/or land practice. Achieving this may enhance nature conservation, as future flood defences may involve increasing water storage capacity in the landscape and leaving natural floodplains undefended. As a consequence of more regular flooding, habitats typical of these areas may change. If these areas were taken out of intensive agricultural management then they might contribute to the connectivity in the landscape, and act as refuges and/or stepping stones for certain species. However, the practical necessity of protecting residential properties means that the location of such sites may be determined more by the hydrology and risk to property than their contribution to landscape connectivity.

Another way of increasing water storage capacity in the landscape is to increase infiltration into soils. Currently, attention is focusing on the use of trees for this purpose, but other land management options might also increase infiltration (such as biomass, arable strips, reduced grazing). Again, the exact location of these strips may be determined by the hydrological regime; however, if managed correctly their exact composition and management may contribute to connectivity in the landscape.

Seeking to increase infiltration in the landscape highlights the potential for positive interaction between CFMP, agri-environment schemes and the woodland strategy. This could arise if agri-environment schemes encouraged the development of new habitats such as woodlands in specific locations which may enhance water infiltration. In addition, agri-environment schemes could encourage the sympathetic management of existing habitats. However, this would require an understanding of the influence of land use in any given area of a catchment on flood risks, and how this risk could be managed through habitat/land use management.

Further research is required, particularly in relation to the role of land management on infiltration. While current work focuses on woodlands, there may also be a role for other land uses to enhance infiltration in some situations, such as biomass, arable, root crops, set aside and rotational grassland. Many of these options may be more financially attractive to farmers than planting woodland, and for this reason their role in enhancing infiltration may warrant further investigation.

Table 8.5: **Summary of policy components of CFMP and the identification numbers used in the analyses presented in Tables 8.7 to 8.21.**

No.	CFMP component
1	Reduce the risk of flooding and harm to people, the natural, historic and built environment caused by floods.
2	Maximise opportunities to work with natural processes and deliver multiple benefits from flood risk management, and make an effective contribution to sustainable development.
3	Inform and support planning policies, statutory land use plans and implementation of the Water Framework Directive.
4	Understand current and future flood risk from all sources and quantify in economic, social and environmental terms.
5	Identify opportunities and constraints for reducing flood risk, such as through changes in land use, land management practices and/or the flood defence infrastructure.
6	Identify opportunities during flood risk management to maintain, restore or enhance the total stock of natural and historic assets (including biodiversity).
7	Use Strategic Environmental Assessment (SEA) to provide detailed environmental assessment and Modelling and Decision Support Framework (MDSF) to support analysis and decision making in formulation of the CFMP.
8	Integration with, and effects on, other policies and agreements.

8.2.5 Agri-environment schemes

The Welsh suite of agri-environment policies has a resilient structure. The periodic review of management prescriptions and related payments render them potentially well suited to adapt to the changing climatic and socio-economic conditions. However, there are three aspects of the policy which tend to increase its vulnerability. First, the policy assumes farmers will adopt it voluntarily, but if farm incomes increase in the future due to enhanced food and fibre prices, then the adoption of any agri-environment scheme will become less attractive than economic drivers, unless payments are enhanced to attract entrants on the basis of financial return alone. The second issue is concerned with the attitudes of the public and government towards environmental protection and farming. These attitudes vary with socio-economic scenarios, and agri-environment schemes will only be acceptable when attitudes towards both aspects are positive. The third vulnerability relates to the success or otherwise of the scheme. Welsh agri-environment schemes aim to enhance biodiversity; if for some reason expected enhancements do not occur, then the relevance of the scheme may come into question. Indeed, establishing the effectiveness of the policy will become more difficult as the abundance and distribution of species and habitats alter under a changed climate, unless expectation can be managed and a greater emphasis placed on maintaining habitats for connectivity.

Despite these vulnerabilities, agri-environment schemes have the potential to enhance the performance of many other policies. This potential is related to aspects of other policies which either seek to, or will need to, act at a landscape level.

The most direct current interaction between SSSI and agri-environment policy occurs when farms in an agri-environment scheme also have a SSSI (or other designated site) on their land. In this situation, there is a clear need for the management prescriptions agreed under the agri-environment scheme to reinforce those required under the Site Management Statement. Informal feedback from farmers in this situation suggests that such interaction has not always been straightforward and that the agri-environment prescriptions can be a little inflexible. While every scheme needs some rules, it is unfortunate when such schemes do not complement each other.

Whilst it would seem sensible for agri-environment and SSSI policy to be more integrated, there is a high probability that the setting of operational limits for factors considered to have positive or negative effects on favourable conservation status will fail under a changed climate. This is because it is difficult to know which species and communities will need protecting where in the future, and it is also currently impossible to say how we could manage future habitats under a changed climate and land use system in order to protect any individual species. Given this situation, it would seem essential for any complementary environmental scheme such as agri-environment to have an in-built element of flexibility in its management prescriptions, so that they can be modified with location and over time.

Given the vulnerability of protected area nature conservation policies to achieve their aims under a changing climate, it seems probable that establishing a connected and permeable landscape is the best way of enabling wildlife to respond to climate change. However, there are serious practical challenges to achieving this aim, most of which relate to developing suitable habitat in the most appropriate locations to enhance connectivity, that is, landscape scale planning. Targeted agri-environment schemes offer one tool for developing target habitats in the required location. This not only benefits nature conservation policy, but it can also enhance the aims of the woodland strategy and water management.

Before this can be achieved, agri-environment schemes will need to undergo significant change from their current form. Cooperative action would be one positive step in the evolution; others may include the need for very specific targeting and the flexibility to undertake location specific management.

A modified agri-environment scheme could also address issues related to water shortage. These may include incentives for farmers to save water for on-farm use and also ensure adequate flows into rivers and streams. This is an area which could be developed significantly in the future. Future manifestations of agri-environment schemes may need to consider the general topic of irrigation, and how good irrigation practice can be brought into the scheme. This will be particularly important in those areas where there is likely to be future expansion of high value horticultural crops (see maps of crop distributions in Appendix 7).

Table 8.6: **Summary of policy components of the Tir Cymru suite of agri-environment schemes and the identification numbers used in the analyses presented in Tables 8.7 to 8.21.**

No.	Tir Cymru component
1	Preparation of whole farm resource management plans.
2	Inventory, mapping and protection of environmental features.
3	Compliance with Entry Level General Environmental Conditions of the Tir Gofal whole farm section.
4	Core scheme objective: safeguarding wildlife habitats defined in the Environmental Impact Assessment regulations by not damaging the habitats through agricultural activities.
5	Ensure at least five per cent of the farm comprises wildlife habitats.
6	Payments and controls.
7	Point system for assessing eligibility to Tir Gofal.
8	Compliance with the general environmental conditions not covered in Level 1 (Tir Cynnal).
9	Implementation of the Farm Resource Management Plan.
10	Mandatory management following prescriptions set out in Tir Gofal scheme of land and habitats.
11	Optional capital activities as detailed in annexes.
12	Cooperative action.
13	Training of local project officers.
14	Interaction with other policies.

8.3 Lessons and limitations

This project developed climate change scenarios for Wales based upon the UKCIP02 climate models, along with Wales-based socio-economic scenarios which were disaggregated from UK-based UKCIP socio-economic scenarios. This is the first time that these sets of scenarios have been developed for Wales, and they clearly suggest that future climate will be different to that predicted by the earlier qualitative assessment undertaken by Farrar and Vase (2000). Both the climate and socio-economic scenarios are now available to inform future research and could be used in other impact and adaptation studies (see Tables 2.4 and 2.5).

The major contribution of this work lies in the development of the risk assessment methodology and the Risk Assessment Matrices (RAM) (see Appendices 3 to 7). This framework is now available for analysis of a wider range of policies and agreements. In addition, the RAM for the policies analysed here can be updated as new knowledge about the impacts of climate change is acquired, such as localised rainfall patterns and effects on species. This would enable further assessment of the vulnerability of these policies.

This study has several important limitations, relating to the nature of the agreements and the methodology used. A standard method was necessarily prescribed by project budget and time constraints and this worked best for land-based agreements and those that were more established. For example, the SSSI policy has been in existence for many years, and as a result a lot is known about its strengths and weaknesses. In addition, there is some good biological evidence on the impact of climate change on wildlife, which aids any analysis of wildlife-related policies, such as SSSI. Similarly, agri-environment policies have also been in existence for some time, and this basic policy structure is well known and well researched. However, other policies are much younger. The *Woodland for Wales* strategy has only been in existence for five years and the Biomass Action Plan for four years. Both CAMS and CFMP are only in the first round of being implemented at a UK level and neither was available for the case study area. As relatively

little is known about the impact of these young and evolving policies, their analysis is inevitably less robust than that of SSSI and the agri-environment schemes.
The application of RAM to the case study area proved to be far more complicated and resource intensive than initially anticipated. Whilst a risk assessment framework has been established for future use, its application to the case study would have benefited from more detailed analysis than was possible in this project. As a result, some elements have been considered in a relatively superficial way, and results should therefore be considered indicative.

A second limitation arising from this work relates to stakeholder involvement. Stakeholders had a major influence on the direction of the work and in particular on the selection of agreements and the case study site. More progress might have been made had the stakeholders been guided towards selecting a case site which had already been well studied.

This type of problem raises a major issue inherent in all research projects which involve stakeholders: namely, that it is impossible to predict stakeholders' responses ahead of time. For this reason, the standard way of structuring research projects is often sub-optimal as it does not include the flexibility to respond to stakeholders' needs. If research projects are to involve stakeholders in deciding the research agenda, then perhaps they need to be structured in two distinct phases. Phase 1 could comprise the stakeholder engagement and identification of needs. Phase 2 would then reflect the stakeholders' needs and would enable an appropriate research team to be developed. In practice this could either occur through two separate but consecutive projects, or by letting a single contractor alter their team composition after stakeholder engagement had occurred.

8.4 Recommendations

As noted in the introduction to this chapter, recommendations are given at the end of each policy chapter and not repeated here. Additional recommendations on achieving synergy between pairs of policies are given in Tables 8.7 to 8.21. This work should also be useful for improving the implementation of policies specifically within the Usk catchment. However, this section focuses on key overarching issues.

8.4.1 Explicit recognition of climate change in all new policies

Every policy and strategy document developed in Wales (and the UK) should include an explicit recognition that climate change is occurring. Further, the policy should discuss the possible impacts of climate change on policy receptors, and go on to consider the potential of climate change to affect the probability of the policy delivering on its targets. In addition, there should be some discussion of potential adaptive responses to any impact of a changed climate on the policy deliverables. This study offers a potential approach to the use of UKCIP risk assessments for this purpose.

8.4.2 Incorporate recognition of climate change into existing policies

An explicit recognition of climate change should be incorporated into all existing policies and strategies at the next available opportunity, such as in mid-term reviews. As part of recognising the importance of climate, policy documents should include a discussion of the possible impacts of climate change on policy receptors, and they should also consider the potential of climate change to affect the ability of the policy to deliver on its targets. There should also be some discussion of potential adaptive responses to any impact of a changed climate on the policy deliverables. Again, this could be developed through the approach applied in this study.

8.4.3 Development of a more flexible and holistic policy outlook

All policies and resource agreements should develop sufficient flexibility in their delivery to enable adaptive response to climate change. While there is often a requirement for policies to have a clear audit trail of activities and achievements, strict adherence to actions which only deliver on policy targets in the short term will tend to mitigate any potential to deliver on longer term actions, and also on any beneficial potential interactions with other policies. Those involved in policy development, delivery and audit should move away from a narrow target-focused policy regime to a more holistic consideration of environmental and land use policy. This approach would embrace interactions with other policy mechanisms when this would lead to a benefit, regardless of the institutional origin of the policies. Achieving this may require action at UK and EU level, and while this is a potentially daunting task, the benefits of any change would be substantial. Developments may be possible through integration with the planning process and implementation of both the Water Framework and Habitats Directives.

8.4.4 Development of an integrated land use plan

While the UK has adopted a neo-liberal approach to policy development over recent decades, achieving sustainable development under climate change may require a move to a more centralised planning regime. For example, to enable wildlife to respond to a changing climate there is a need to enhance connectivity in the countryside. If such initiatives are to bring real benefit, then they need to be coordinated across large scales. This will inevitably mean that these planned landscapes will cross administrative boundaries at the local and national level. In Wales, WAG, CCW and EAW are well positioned to develop an integrated approach, but it will be more difficult to integrate across Britain or Ireland.

The development of essential landscape structures will entail identifying areas where certain habitats such as woodland would be welcomed or encouraged, and others where they would be discouraged (CCW have begun exploring this process in Wales; see also Gaston *et al.,* 2006). Similar arguments can be made about the role of land use in water management, such as flood alleviation, and these have already been highlighted in the government's strategy, *Making space for water* (Defra, 2005).

A plan is needed to highlight the types of land use that would be welcomed in each area, and state those land uses which would not be encouraged. Such a land use plan would need to be developed at the national scale for processes like species migration, and at a catchment level for more local processes like water management. This would require cooperation between devolved governments and statutory agencies.

Along with such a plan, it would be necessary to develop a means of bringing about the desired land use change. The use of highly targeted agri-environment schemes would perhaps be the easiest and least controversial mechanism for bringing about change, at least in the short term.

8.4.5 Consider institutional change

Responses to climate change and sustainable development require a greater integration of policies and more joined-up government. However, it may be difficult to bring about real change in policy development and implementation if existing institutions do not have the power or the will to bring about change.

An institutional structure is needed to consider the impact of policy across environment, land use, community and economy and recommend the best solution to achieve sustainable development under a changing climate. This structure would have the ability to make hard decisions about the implementation of issues like a land use plan and other outputs. For this reason, it would be beneficial if it were free from political influence.

The government recently announced that it will establish an Office of Climate Change as a non-departmental public body (Defra news release, 22/9/06). This office will aim to provide a shared resource for analysis and development of climate change policy and strategy. Such a development is to be welcomed and should help bring about institutional change.

8.4.6 Improve climate prediction at smaller scales

Current Global Circulation Models (GCM) make predictions about future climate at a relatively large scale. However, responses to climate change need to occur at a much smaller scale, for example in planning flood defences. Research is ongoing to develop methods for downscaling global level predictions (for example, Mehrotra and Sharma, 2006; Haylock *et al.,* 2006; Charlton *et al*., 2006). This work needs to continue and should aim to produce small-scale spatially explicit predictions to enable local decision makers to adapt to climate change in an informed manner while managing for uncertainty.

8.4.7 Undertake a vulnerability assessment of policies and strategies which interact to achieve an overall broad policy aim

Institutions may wish to undertake a vulnerability assessment of all the policies and strategies which contribute to a broad policy goal, such as nature conservation or water resource planning. This could be used to identify any checks and balances within the overall system which could serve to enhance or reduce the vulnerability of individual constituent policies. This would address the major weakness of this work, where such a small selective group of policies was analysed, even though every effort was taken to cover the range of natural resource policies or strategies within the practical constraints of selecting only five agreements. The application of this method to a wider suite of agreements is a crucial next step in the development of this work.

8.4.8 Seek to fill data gaps while recognising the need to manage for uncertainty

This research identified many data gaps at the catchment scale. These need to be addressed to help effective adaptation planning, but it will always be necessary to develop policies that build in the need to manage for uncertainty due to data limitations. Given the many unknowns and unquantifiable interactions between policies, it is essential that policies are monitored effectively so that outcomes can feed into policy development under a changing climate.

Table 8.7: **Interactions between policy components relating to Sites of Special Scientific Interest (SSSI) and the woodland strategy (W), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
SSSI		**W**			
1	hi	1	lo-hi	There is a need to maintain a suitable range of woodlands as habitats for the UK's wildlife.	Redefine purpose of site-based conservation and include woodlands in landscape level planning for connectivity.
4	md	1	lo-hi	These relate to the development of a Site Management Plan, which in woodland habitats may interact with other environmental aspects of woodland management.	Understand the impact of new woodland management on the woodland ecology. Recognise that new woodlands may be managed more as a business than at present.
		3	lo-hi		
		4	lo-hi		
		5	lo-hi		
		6			
6	hi	1	lo-hi	Woodland management may interact with the operational limits required to maintain specified features in SSSI. These may include issues such as felling regimes, thinning, continuous cover, and levels of recreation and access.	Need to redefine operational limits in light of changing woodland species assemblages and altered woodland management practices.
		4	lo-hi		
		5	lo-hi		
		6	hi		
		10	md-hi		
		11			
1	hi	3	lo-hi	The development of new woodlands can play an important role in increasing connectivity in the landscape, and they may also have positive and negative impacts on permeability of the landscape for different species.	Identify and prioritise areas where new woodland would enhance connectivity. Consider the role of SRC biomass as a constituent of the landscape.
		4	lo-hi		
		5	lo-hi		
		6	hi		
		8	lo		
6	hi	7	md	Unclear how continuous cover over a large scale will impact operational limits.	Research impacts of continuous cover over time. Do not undertake continuous cover on most sensitive sites.

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
SSSI		**W**			
1		3		The development of new woodlands can play an important role in increasing connectivity in the landscape, and they may also have positive and negative impacts on permeability of the landscape for different species.	Develop a land use plan that identifies locations where new woodland could make a positive contribution to landscape connectivity/permeability.
		4			
		5			
		6			
		8			
6		7		Converting woodlands to continuous cover could potentially impact the favourable conservation status of some woodland sites.	Consider the potential impact on designated sites prior to converting woodlands to continuous cover.

Table 8.8: **Interactions between policy components relating to Sites of Special Scientific Interest (SSSI) and Tir Cymru agri-environment schemes (TC), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
SSSI		**TC**			
4	md	1	lo	There is a need for all Tir Cymru planning and prescriptions to recognise SSSI requirements.	Ensure policy officers understand the statutory and management needs of relevant designated sites.
		2	md		
		3	lo		
		4	lo		
		8	lo		
		9	lo-hi		
		10	lo-hi		
6	hi	1	lo	There is a need for all Tir Cymru planning and prescriptions to recognise the operational limits which apply to relevant SSSI.	Enable sufficient flexibility in the TC management schemes such that the designated sites can be enhanced by TC activities.
		2	md		
		3	lo		
		4	lo		
		8	lo		
		9	lo-hi		
		10	lo-hi		
9		13	lo-hi	Need to explicitly recognise other policies.	Ensure policy officers at all levels are familiar with the needs and requirements of all policies.

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
SSSI		TC			
1	hi	1	lo	Tir Cymru could help SSSI policy meet the requirement to guarantee the survival of the necessary minimum of Britain's wildlife.	Target TC to enable it to fill a 'buffering' role for particularly sensitive SSSI and also to contribute to a more connected and permeable landscape.
		2	md		
		7	md-hi		
		9	lo-hi		
		10	lo-hi		
		12	lo-hi		
4		11	lo-hi	A need for cooperative actions to recognise SSSI management, when they are formed.	Cooperative actions under TC could offer significantly greater benefits in terms of buffering and enhancing connectivity/permeability than single farms.
		12	lo-hi		
6		11	lo-hi	Operational limits on SSSI could be helped by appropriate capital investment on farms.	Ensure flexibility under TC such that capital investment can be made on farms to enhance management and condition of designated sites.

Table 8.9: Interactions between policy components relating to Sites of Special Scientific Interest (SSSI) and the biomass strategy (BM), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
SSSI		BM			
1	hi	10	lo-hi	EIA regulations which apply to biomass development must take note of the need to conserve wildlife.	Consider direct and indirect impacts on designated sites prior to planning large areas of biomass crops.
4	md	3	lo-hi	When farmers bring woodlands back into production they need to take note of relevant SSSI requirements.	Discuss the potential impacts of woodland management on designated sites with landowners before they begin a new enterprise. Update guidelines on woodland management and communicate these effectively.
		10	lo-hi		
6	hi	10	lo-hi	EIA for biomass need to take note of operational limits on relevant SSSI.	Use EIA of biomass sites to encourage wildlife enhancing developments.
9		13	lo-hi	Recognition of other policies.	Ensure policy officers at all levels are familiar with the needs and requirements of all policies.

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
SSSI		BM			
1		3	lo-hi	The management of woodlands may enhance their value for some wildlife species. The growth of biomass crops may do the same through enhancing landscape connectivity.	Research the potential role of woody biomass plantations to enhance connectivity and permeability in the landscape.
		8	lo-hi		
4		8	lo-hi	Any grant scheme for biomass should note the needs of relevant SSSI so it may complement its needs.	Develop suitable environmental payments in any future biomass grant scheme.

Table 8.10: **Interactions between policy components relating to Sites of Special Scientific Interest (SSSI) and Catchment Abstraction Management Strategies (CAMS), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
SSSI		CAMS			
4	md	1	md-hi	Flow rates set under CAMS need to take account of the site management plans of SSSI.	Ensure that minimum flow rates are explicitly stated in management plans for designated sites.
		2	md-hi		
		3	md-hi		
6	hi	1	md-hi	Potential for flow regimes set under CAMS to conflict with the requirements of aquatic and adjacent SSSI. This may become more likely in the future.	Ensure that ecologically robust data on flow rates are submitted to CAMS planning activities. When setting abstraction rates be aware that low rates will decrease in the longer term, and maybe even in the relatively short term in some areas.
		2	md-hi		
		3	md-hi		
		9	md-hi		
9		11	md	Mutual recognition of other policies.	Ensure policy officers at all levels are familiar with the needs and requirements of all policies.

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	**Prob. failure**	**Policy components**	**Prob. failure**	**Reason for interaction**	**Recommendation**
SSSI		**TC**			
1		1	md-hi	Maintaining appropriate water flows will be important to the conservation of Britain's wildlife, especially in the future as rainfall decreases.	a) Maintain flexibility in setting abstraction levels/licences. b) Inform all abstractors that there is a real possibility that their licence may be revoked in the future if flows fall below ecological requirements, thereby mitigating any large investments which may depend on long-term abstractions. c) Encourage increased water storage in the catchment for use in times of low flow. d) Research likely future flow rates for each catchment.
		2	md-hi		
		3	md-hi		
		9	md-hi		
6		10	var.	Drought management may conflict with SSSI needs in the future.	a) Encourage increased water storage in the catchment for use in times of low flow. b) Develop a robust framework for prioritising abstractions which may need to be restricted during times of drought.

Table 8.11: Interactions between policy components relating to Sites of Special Scientific Interest (SSSI) and Catchment Flood Management Plans (CFMP), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.

a) actual interactions (lo = low; md = medium; hi = high)

Policy compo nents	Prob. failure	Policy compo nents	Prob. failure	Reason for interaction	Recommendation
SSSI		CFMP			
4	md	1	md- hi	Flood management needs to take account of SSSI site management plans.	Ensure all SSSI management plans have explicit statements about the impact of inundations at various times of the year.
		2	var		
		3	lo		
6	hi	1	md- hi	Flood management needs to take note of the operational limits set for SSSI which may be affected by an altered hydrological scheme.	Consider the needs of SSSI when developing flood management schemes.
		2	var		
		3	lo		
9		8	var	Mutual recognition of other policies.	Ensure policy officers at all levels are familiar with the needs and requirements of all policies.

b) potential interactions (lo = low; md = medium; hi = high)

Policy compo nents	Prob. failure	Policy compo nents	Prob. failure	Reason for interaction	Recommendation
SSSI		CFMP			
1		1	md- hi	Flood management plans could enhance the conservation of Britain's wildlife in a positive manner through designating areas for flooding, which could contribute to connectivity.	Integrate catchment level land use planning with larger scale land use planning with the aim of enhancing large scale landscape connectivity and permeability.
		2	var		
		3	lo		
		6	md-hi		

Table 8.12: **Interactions between policy components relating to Tir Cymru (TC) and the woodland strategy (W), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
TC		W			
1	lo	1	lo-hi	Development of the farm resource plans will include consideration of existing woodlands.	Officers responsible for preparation of whole farm resource plans should be aware of the aims of the woodland strategy, particularly the issues relating to economic development of woodlands and the issues of landscape connectivity.
		3	lo-hi		
		4	lo-hi		
		5	lo-hi		
2	md	1	lo-hi	Mapping of on-farm woodlands and their subsequent management will include farm woodlands.	Mapping to be undertaken with an awareness of the larger landscape conservation requirements.
		3	lo-hi		
4	lo	1	lo-hi	On-farm plans will safeguard wildlife and habitats.	Officers to be aware of appropriate management of woodland habitats.
		3	lo-hi		
10	lo-hi	1	lo-hi	Tir Cymru mandatory management options may impact woodlands.	Prescriptions need to have sufficient flexibility to enable sensitive woodland management. This may include consideration of any economic activity in the woodlands.
		2	lo-hi		
		3	lo-hi		
		4	lo-hi		
		5	lo-hi		
		6	hi		
11	lo-hi	2	lo-hi	Capital expenditure under Tir Cymru may impact woodland habitats, such as fencing.	Maintain flexibility in terms of capital expenditure such that appropriate expenditure may benefit woodland habitats if appropriate.
		3	lo-hi		
		4	lo-hi		
		6	hi		

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
TC		W			
1	lo	8	lo	Whole farm plans could include actions which would enhance water management at the catchment scale.	Ensure officers are aware of the management aims for the catchment, and encourage environmental activities which will enhance catchment management.
2	md	8	lo	Mapping and protection of on-farm features could take cognisance of the needs of catchment management.	Ensure farm maps include features relevant to catchment management and also that their location in the catchment is considered during the identification of management options.
3	lo	2	lo-hi	Entry level schemes could encourage appropriate woodland management.	Enable entry scheme regulations to include woodland management for environmental purposes while permitting appropriate economic activity.
		5	lo-hi		
		6	hi		
7	md-hi	1	lo-hi	Point system could be amended to recognise the importance of particular woodlands in enhancing landscape level management of biodiversity and water.	Alter the point system so that farms in key locations in the landscape can be identified and prioritised.
		3	lo-hi		
		8	lo		
8	lo	2	lo-hi	On-farm management could encourage enhanced woodland management.	Permitted management activities need to recognise the importance of economic activity within woodlands.
		5	lo-hi		
		6	hi		
10	lo-hi	8	lo	Mandatory management could include actions important at the catchment scale.	Alter the point system so that farms in key locations in the catchment can be identified and prioritised. Introduce management prescriptions that are relevant to catchment management.
12	lo-hi	1	lo-hi	Cooperative action could enhance landscape level aims for biodiversity and water management.	As discussed above, cooperative actions in key areas could be encouraged in order to enhance landscape connectivity and/or catchment management.
		3	lo-hi		
		4	lo-hi		
		6	hi		
14	lo	all	see above	Tir Cymru has great potential to enhance many other countryside policies.	Ensure policy officers at all levels are familiar with the needs and requirements of all policies.

Table 8.13: **Interactions between policy components relating to Tir Cymru (TC) and the biomass strategy (BM), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
TC		**BM**			
1	lo	2	lo-hi	Whole farm plans could identify existing woodlands being managed for biomass and also areas for potential new biomass developments.	Potential for biomass production from appropriate existing woodlands should be noted when developing whole farm plans.
		3	lo-hi		
		10	lo-hi		
2	md	2	lo-hi	Mapping and protection of features may need to take cognisance of the potential impacts of planned biomass activities.	Maps should note potential for biomass production from appropriate existing woodlands.
		3	lo-hi		
		10	lo-hi		
3	lo	2	lo-hi	Requirement of entry level schemes can interact with management of existing woodlands for biomass and potential new biomass developments.	Regulations of entry level schemes should be sensitive to biomass production and include appropriate management actions.
		3	lo-hi		
		10	lo-hi		
4	lo	2	lo-hi	Protection of habitats can interact with management of existing woodlands for biomass and potential new biomass developments.	Management plans should consider the impacts of biomass production on wildlife and consider both negative and positive interactions.
		3	lo-hi		
		10	lo-hi		
8	lo	2	lo-hi	Compliance with Tir Gofal requirements can interact with management of existing woodlands for biomass and potential new biomass developments.	Regulations of Tir Gofal should be sensitive to biomass production and include appropriate management actions.
		3	lo-hi		
		10	lo-hi		
9	lo-hi	2	lo-hi	Implementation of the farm resource management plan can interact with management of existing woodlands for biomass and potential new biomass developments.	Farm resource management plan should be sensitive to biomass production and permit appropriate management actions.
		3	lo-hi		
		10	lo-hi		
10	lo-hi	2	lo-hi	Mandatory management can interact with management of existing woodlands for biomass and potential new biomass developments.	Mandatory management should be sensitive to biomass production and permit appropriate management actions.
		3	lo-hi		
		10	lo-hi		
14	lo	13	lo-hi	There is great potential for interaction between these two policies.	Training of Tir Cymru officers needs to cover the actual and potential advantages and disadvantages of encouraging biomass production on farms.

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Ptob. failure	Reason for interaction	Recommendation
TC		**BM**			
12	lo-hi	2	lo-hi	Cooperative action could encourage farmers to engage in joint activities related to woodland management and biomass production.	Enable farmers engaging in cooperative actions to develop biomass schemes where appropriate.
		3	lo-hi		

Table 8.14: **Interactions between policy components relating to Tir Cymru (TC) and Catchment Abstraction Management Strategies (CAMS), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
TC		**CAMS**			
1	lo	2	md-hi	Whole farm plans can note the potential for protecting the aquatic environment.	Whole farm plans to note the location of the farm in the catchment and consider its impact on aquatic life on the farm and elsewhere in the catchment.
2	md	2	md-hi	Inventory and mapping can include aquatic habitats and the land use systems which interact with them.	Maps to note the relevant aquatic wildlife on the farm and in other appropriate places in the attachment.
3	lo	2	md-hi	Entry level schemes can include requirements for land management to be sensitive to the aquatic environment.	Entry level scheme to include relevant management requirements which are sensitive to the needs of aquatic wildlife and in-stream flows.
4	lo	2	md-hi	Aquatic habitats on farm can be protected.	Develop management activities relevant to protecting aquatic species on the farm and beyond, and which can contribute to the maintenance of in-stream flows.
8	lo	2	md-hi	General environmental conditions can include measures to protect aquatic habitats.	General environmental conditions to include the needs of aquatic wildlife and in-stream flows.
9	lo-hi	2	md-hi	Farm resource management plan can include protection and enhancement of aquatic habitats.	Include management activities relevant to protecting aquatic species on the farm and beyond, and which can contribute to the maintenance of in-stream flows.
10	lo-hi	2	md-hi	Tir Gofal management conditions can include measures to protect aquatic habitats.	Develop management activities relevant to protecting aquatic species on the farm and beyond, and which can contribute to the maintenance of in-stream flows.
14	lo	11	md	Both policies are aware of the need to interact with other policies.	Ensure policy officers at all levels are familiar with the needs and requirements of all policies.

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
TC		CAMS			
1	lo	1	md-hi	Whole farm plans may need to consider the impact of abstraction on aquatic habitats on the farm and beyond.	Need to view the activities on the farm in the context of the whole catchment.
		3	md-hi		
2	md	1	md-hi	The inventory and mapping could take more note of habitats which could potentially be affected by increased abstraction on the farm and elsewhere.	Need to map the farm on a catchment map and consider its importance to catchment level processes, and then to act accordingly.
		3	md-hi		
3	lo	1	md-hi	Entry level schemes could encourage good practice in terms of abstraction, irrigation and water storage.	Need to consider issues of water management within entry level schemes in the future.
		3	md-hi		
4	lo	1	md-hi	Need to consider how water management on farms could impact habitats on the farm and beyond.	Need to view the activities on the farm in the context of the whole catchment.
		3	md-hi		
12	lo-hi	1	md-hi	Cooperative action could seek to enhance on-farm water storage for on-farm use, or to supplement low flows in times of general water shortage.	Need to enable farmers to act together to enhance catchment level processes, such as on-farm water storage for economic and ecological purposes.
		2	md-hi		
		3	md-hi		
13	lo-hi	all	-	Tir Cymru officers could be made more aware of how agri-environment schemes could interact with water management policies.	Enhance the training of officers in WAG and the Environment Agency.

Table 8.15: **Interactions between policy components relating to Tir Cymru (TC) and Catchment Flood Management Plans (CFMP), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	**Prob. failure**	**Policy components**	**Prob. failure**	**Reason for interaction**	**Recommendation**
TC		**CFMP**			
14	lo	3	lo	Both policies are aware of the need to interact with other countryside policies.	Ensure policy officers at all levels are familiar with the needs and requirements of all policies.

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
TC		CFMP			
1	lo	1	md-hi	Farm resource management plans could make note of the potential for on-farm management which could alleviate flooding.	Note the potential to alleviate flooding in farm resource management plans.
		2	var		
		5	md-hi		
		6	md-hi		
2	md	2	var	Inventory and mapping could highlight the potential to alleviate flooding.	Map the areas on farms which could be used to alleviate flooding and/or enhance infiltration. This may require the location and potential of the farm to be considered at the catchment level.
		5	md-hi		
		6	md-hi		
4	lo	6	md-hi	Could further explore biodiversity benefits of on-farm water storage as part of a flood alleviation plan.	Undertake research on the impacts of on-farm water storage on biodiversity.
8	lo	6	md-hi	Compliance with general environmental conditions could require flood alleviation activities.	Consider if the current regulations are appropriate to enable flood alleviation and amend as appropriate.
9	lo-hi	2	var	Implementation of the farm resource management plan could help alleviate floods.	Develop permitted activities which could help alleviate flooding and/or enhance infiltration where appropriate.
		5	md-hi		
		6	md-hi		
10	lo-hi	2	var	Mandatory management under Tir Gofal could help alleviate floods.	Develop permitted activities under Tir Gofal which could help alleviate flooding and/or enhance infiltration where appropriate.
		5	md-hi		
		6	md-hi		
12	lo-hi	1	md-hi	Cooperative action could help alleviate floods.	Enable groups of farmers to cooperate in order to help alleviate flooding and/or enhance infiltration where appropriate.
		2	var		
		5	md-hi		
13	lo-hi	all	-	Tir Cymru officers could be made more aware of how agri-environment schemes could interact with water management policies.	Ensure policy officers at all levels are familiar with the needs and requirements of all policies.

Table 8.16: **Interactions between policy components relating to the woodland strategy (W) and the biomass strategy (BM), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
W		**BM**			
2	lo-hi	1	md-hi	There is a need to enhance the commercial returns from woodlands and biomass which may require different management actions.	Investigate any potential conflicts and then either seek to change the relevant regulations or identify the single best management option for any given woodland.
		2	lo-hi		
		4	md-hi		
		6	md-hi		
5	lo-hi	1	md-hi	Thinning of woodlands can produce useful woody biomass.	Ensure landowners are aware of opportunities to sell thinnings. Enable cooperative action for initial processing and transport.
		2	lo-hi		
		3	lo-hi		
		4	md-hi		
		6	md-hi		
6	hi	1	md-hi	Conversion to continuous cover may enhance biodiversity and simultaneously supply useful biomass.	As above
		3	lo-hi		
7	md	1	md-hi	Conversion to continuous cover may enhance biodiversity and simultaneously supply useful biomass.	As above

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
W		BM			
1	lo-hi	1	md-hi	Woodland management for biodiversity enhancement may interact with biomass production. New woody biomass developments could also reduce fragmentation of woodland habitats.	Research potential for biomass to offer some of the same connectivity services as woodland and then conduct landscape planning with biomass substituting for woodland as appropriate.
		3	lo-hi		
		4	md-hi		
		10	lo-hi		
3	lo-hi	1	md-hi	New woody biomass developments may help reduce fragmentation of woodlands at a landscape scale, but development of biomass on inappropriate land may have detrimental environmental impacts.	As above, but ensure that consideration is given to any negative impacts of biomass on the entire environment, and not just the forest environment.
		10	lo-hi		
4	lo-hi	1	lo-hi	New woody biomass may help enhance connectivity at the farm scale but development of biomass on inappropriate land may have detrimental environmental impacts.	As above.
		10	lo-hi		
8	lo	1	md-hi	New biomass developments may increase infiltration of water and thereby help reduce flood risks.	Research potential for biomass to offer some of the same infiltration services as woodland and then conduct landscape planning with biomass substituting for woodland as appropriate.
9	md	1	md-hi	Increasing competitiveness of forest industries may interact with the development of the biomass sector.	Consider the impact of a competitive and prosperous forest industry on any new biomass enterprise, such as availability of thinnings and brash.
		2	lo-hi		
		3	lo-hi		
		6	md-hi		
10	md-hi	1	md-hi	New and existing biomass developments may offer recreational opportunities.	Research opportunity for recreation activities in biomass plantations, such as walking, cycling, riding, game shooting, and then encourage access accordingly.
11	md	1	md-hi	New and existing biomass developments may offer access opportunities.	As above.

Table 8.17: **Interactions between policy components relating to the woodland strategy (W) and Catchment Abstraction Management Strategies (CAMS), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
W		CAMS			
1	lo-hi	2	md-hi	The development of new woodlands can increase evaporation from a catchment and thereby reduce in-stream flows.	Consider the impact of new woodland developments on hydrological regimes, especially in-stream flows in the summer. In areas of hydrological sensitivity consider choosing different tree species to reduce evapotranspiration.
3	lo-hi	2	md-hi	The development of new woodlands can increase evaporation from a catchment and thereby reduce in-stream flows.	Consider the impact of new woodland developments on hydrological regimes, especially in-stream flows in the summer.
6	hi	2	md-hi	Continuous cover forestry may have greater evapotranspiration than standard forestry.	Research the evapotranspiration rates of continuous cover forests and then plan their conversion to continuous cover with sensitivity to any impacts on hydrological regimes.
7	md	2	md-hi	Continuous cover forestry may have greater evapotranspiration than standard forestry.	As above.
8	lo	1	md-hi	The size and location of new woodlands can increase evapotranspiration in a catchment.	Consider the impact of new woodland developments on hydrological regimes, especially in-stream flows in the summer. In areas of hydrological sensitivity consider choosing different tree species to reduce evapotranspiration.
		3	md-hi		

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	**Prob. failure**	**Policy components**	**Prob. failure**	**Reason for interaction**	**Recommendation**
W		**CAMS**			
1	lo-hi	3	md-hi	The planning of new woodlands should be sensitive to potential impacts on in-stream flows.	Consider the impact of new woodland developments on hydrological regimes, especially in-stream flows in the summer. In areas of hydrological sensitivity consider choosing different tree species to reduce evapotranspiration.
3	lo-hi	3	md-hi	The planning of new woodlands should be sensitive to potential impacts on in-stream flows.	As above.

Table 8.18: **Interactions between policy components relating to the woodland strategy (W) and Catchment Flood Management Plans (CFMP), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
W		**CFMP**			
1	lo-hi	1	md-hi	The location of new woodlands may increase infiltration of water into soil and thereby help alleviate floods. Also new flood defences may reduce the water flow into woodlands, and thereby affect their biodiversity.	Consider the impact of woodlands of all sizes on infiltration into soils and seek to locate new plantings so as to maximise infiltration. Consider the impact of flood defences on protected areas of woodland.
		2	var		
		3	lo		
		4	md-hi		
		5	md-hi		
		6	md-hi		
		7	md-v.hi		
		8	var		
3	lo-hi	1	md-hi	As above.	As above.
		2	var		
		3	lo		
		4	md-hi		
		5	md-hi		
		6	md-hi		
		7	md-v.hi		
		8	var		
8	lo	1	md-hi	Woodlands can impact both low flows and high flows within a catchment.	As above and also see Table 8.17.
		2	var		
		3	lo		
		4	md-hi		
		5	md-hi		
		6	md-hi		
		7	md-v.hi		
		8	var		

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
W		CFMP			
7	md	3	lo	Conversion of forestry to continuous cover may affect the water relations in the catchment.	Research the evapotranspiration rates of continuous cover forests and then plan their conversion to continuous cover with sensitivity to any impacts on hydrological regimes.

Table 8.19: Interactions between policy components relating to the biomass strategy (BM) and Catchment Abstraction Management Strategies (CAMS), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
BM		**CAMS**			
4	md-hi	1	md-hi	SRC willow and poplar are known to have large evapotranspiration rates and for this reason it may be necessary to treat SRC plantations as an abstraction.	Plan the location of new biomass plantations with care so as to avoid impacts on in-stream flows.
		2	md-hi		
		3	md-hi		
10	lo-hi	1	md-hi	The potential impact of biomass plantations on hydrological systems needs to be considered in any environmental assessment.	Ensure that environmental assessments of biomass explicitly include a requirement to consider the impact on hydrological regimes, especially in-stream flows.
		2	md-hi		
		3	md-hi		

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
BM		**CAMS**			
6	md-hi	1	md-hi	Increased plantation of biomass may impact hydrological regimes.	Be aware that planting biomass so as not to impact hydrological regimes may limit the areas in which it can be developed commercially, and thereby its impact on Kyoto targets.
		2	md-hi		
		3	md-hi		
8	lo-hi	1	md-hi	Any grant scheme aimed at supporting biomass needs to ensure all developments are sensitive to hydrological issues.	Ensure that any grant scheme for supporting biomass production has suitable safeguards relating to the terrestrial and aquatic environments.
		2	md-hi		
		3	md-hi		

Table 8.20: **Interactions between policy components relating to the biomass strategy (BM) and Catchment Flood Management Plans (CFMP), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
BM		CFMP			
6	md-hi	2	var	SRC and poplar biomass plantations may act like woodlands and increase the infiltration of water into soil, and thereby help mitigate flooding.	Research the potential for biomass plantations to enhance infiltration and then seek to encourage the development of new biomass plantations in areas which would benefit from enhanced infiltration.
		3	lo		
		5	md-hi		
		7	md-v hi		

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
BM		CFMP			
7	lo-md	2	var.	New biomass developments may help alleviate floods.	As above – but also consider a means of encouraging the development of biomass plantations in the locations which will bring greatest benefit in terms of flood alleviation.
		3	lo		
		5	md-hi		
8	lo-md	2	var	Any grant scheme aimed at supporting biomass needs to ensure all developments are sensitive to hydrological issues.	Ensure that any grant scheme for supporting biomass production has suitable safeguards relating to the terrestrial and aquatic environments.
		3	lo		
		5	md-hi		

Table 8.21: **Interactions between policy components relating to Catchment Abstraction Management Strategies(CAMS) and Catchment Flood Management Plans (CFMP), where a) actual interactions, b) potential interactions. A list of the components and their numbers for these policies are provided in Tables 8.1 to 8.6 for reference. 'Prob. failure' is the probability of that policy component failing under climate change.**

a) actual interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
CAMS		CFMP			
1	md-hi	2	var	Flood management systems could affect aquatic biodiversity and/or reduce in-stream flows outside periods of high flood risk.	Ensure that all designated sites have explicit statements about the desirability of specific hydrological regimes and then require new flood management plans to consider the impact of their plans on designated sites.
		3	lo		
		5	md-hi		
		7	md-vhi		
		8	var		
2	md-hi	1	md-hi	The need to protect biodiversity in terrestrial and aquatic habitats may be compromised through inappropriate actions under these policies.	As above, but also consider the impacts of any proposed management agreement on aquatic and terrestrial biodiversity in the broad sense.
		4	md-hi		
		6	md-hi		
		8	var		
11	md	8	var	Both policies recognise the need to integrate with other policies.	Ensure policy officers at all levels are familiar with the needs and requirements of all policies.

b) potential interactions (lo = low; md = medium; hi = high)

Policy components	Prob. failure	Policy components	Prob. failure	Reason for interaction	Recommendation
CAMS		CFMP			
1	md-hi	1	md-hi	Water storage capacity could be developed in the catchment which would reduce winter flows and thereby mitigate floods, while in the summer the water could be used to reduce the level of abstraction from rivers and/or released into streams to enhance natural flows.	Research the possibility of enhancing water storage in the winter, which could then be used to enhance summer flows.

References

Arnell, N.W., 1996 *Global Warming, River Flows and Water Resources*, Chichester: Wiley.

Arnell, N.W., Reynard, N., King, R., Proudhomme, C. and Branson, J., 1997 *Effects of climate change on river flows and groundwater recharge: Guidelines for resource assessment*. Environment Agency Technical Report W82, London.

Ashley, R.M., Balmforth, D.J., Saul, A.J., Blanskby, J.D., 2005 Flooding in the future – predicting climate change, risks and responses in urban areas. *Water Science and Technology* **52** (5), 265-273.

Bateman I. J. and Lovett A. A. (2000) Estimating and valuing the carbon sequestered in softwood and hardwood trees, timber products and forest soils in Wales. *Journal of Environmental Management* **60** (4) 301-323

Beard, L. R. 1997 Estimating flood frequency and average annual damage *Journal of Water Resources Planning and Management* –ASCE, **123** (2): 84-88

Belford, R.K., 1981 Response of winter wheat to prolonged waterlogging under outdoor conditions. *Journal of Agricultural Science*, Cambridge, **97**, 557-568.

Belford, R.K., Cannell, R.Q., Thompson, R.J. and Dennis, C.W., 1980 Effects of waterlogging at different stages of development on the growth and yields of peas (*Pisum sativum* L.). *Journal of the Science of Food and Agriculture* **31**, 857-869.

Berry, P.M., Harrison, P.A., Dawson, T.P. and Walmsley, C.A., 2005 *Modelling Natural Resource Responses to Climate Change (MONARCH): A local approach*. UKCIP Technical Report, Oxford.

Booker, D.J. and Dunbar, M.J., 2004 Application of physical habitat simulation (phabsim) modelling to modified urban river channels. *River Research and Applications* **20**,167-183.

Broadmeadow M. S. J. and Randle T. 2002 The impacts of increased CO_2 concentrations on tree growth and function. In: *Climate change and UK forests,* ed. M.S.J. Broadmeadow. Bulletin 125. Forestry Commission, Edinburgh,119–140.

Broadmeadow, M.S.J., Ray, D. and Samuel, C.J.A. 2005 Climate change and the future for broadleaved tree species in Britain. *Forestry* **78** (2), 145-161.

Cabinet Office (2002) *The Energy Review*. UK Government, London.

Cannelll, R.Q., Belford, R.K., Gales, K, Dennis S, C.W. and Prew, R.D. 1980 Effects of waterlogging at different stages of development on the growth and yield of winter wheat. *Journal of the Science of Food and* Agriculture **31** (2): 117-132.

Cannell, M.G.R., Thornley, J.H.M., Mobbs, D.C. and Friend, A.D., 1998 UK conifer forests may be growing faster in response to increased N deposition, atmospheric CO_2 and temperature. *Forestry* **71** (4), 278-296.

Carroll, Z.L., Bird, S.B., Emmett, B.A., Reynolds, B. and Sinclair, F.L., 2004 Can tree shelterbelts on agricultural land reduce flood risk? *Soil Use and Management* **20** (3), 357-359.

Castel, M.J., Sobsey, M.D. and Mueller, J.P., 2006 Faecal contamination of agricultural soils before and after hurricane-associated flooding in North Carolina. *Journal of Environmental Science and Health Part A – Toxic/hazardous substances and Environmental Engineering* **41**: 173-184.

CCW (2003). *Priority habitats of Wales a technical guide*. PS Jones, D P Stevens, T H Blackstock, C R Burrows and E A Howe. Countryside Council for Wales, Bangor

Charlton, R., Fealy, R., Moore, S., Sweeney, J., Murphy, C., 2006 Assessing the impact of climate change on water supply and flood hazard in Ireland using statistical downscaling and hydrological modelling techniques. *Climatic Change* **74** (4), 475-491.

Coed Cymru, 1997 *Biennial Report 1994 -1996*. Coed Cymru, Newtown.

Darwin, R., 2004 Effects of greenhouse gas emissions on world agriculture, food consumption, and economic welfare. *Climatic Change* **66** (1-2), 191-238.

Davies, M.S. and Hillman, G.C., 1988 Effects of soil flooding on growth and grain yield of populations of tetraploid and hexaploid spoecies of wheat. *Annals of Botany* **62**, 597-604.

Deckmyn, G., Muys, B., Garcia Quijano and Ceulemans, R., 2004 Carbon sequestration following afforestation of agricultural soils: Comparing oak/beech forest to short-rotation poplar coppice combining a process and a carbon accounting model. *Global Change Biology* **10**, 1482-1491.

Defra, 2002a *Growing Short Rotation Coppice: Best Practice Guidelines*. PB 7135.

Defra, 2002b *Guidelines for Environmental Impact Assessment for use of uncultivated land or semi-natural areas for intensive agricultural purposes*. PB6475.

Defra, 2005 *Making Space for Water: Taking forward a new Government strategy for flood and coastal erosion risk management*. DEFRA, UK.

DETR (1997), Department of Environment, Transport and the Regions (1997) *National Travel Survey 1994/96: transport statistics report*, London: The Stationery Office.

Donaldson, L.A., Hollinger, D., Middleton, T.M. and Souter, E.D., 1987 Effects of CO_2 enrichment on wood structure in *Pinus radiata* (D. Don). *IAWA Bulletins* **8**, 285-289.

Ellis, T.W., Leguedois, S., Hairsine, T.B. and Tongway, D.J., 2006 Capture of overland flow by a tree belt on a pastured hillslope in south eastern Australia. *Australian Journal of Soil Research* **44** (2), 117-125.

Environment Agency, 2002 *Managing water abstraction. The catchment abstraction management strategy process*. Environment Agency, Bristol, July 2002.

Environment Agency, 2004 *Catchment Flood Management Plans Volume I – Policy Guidance.* Environment Agency, Bristol.

Environment Agency, 2005 *Managing water abstraction – Interim update. The catchment abstraction management strategy process*. Environment Agency, Bristol, March 2005.

Environment Agency Wales, 2000 *Local Environment Agency Plan 2000-2005. Rural Usk Action plan. April 2000*. Environment Agency Wales. Cardiff.

Evans, D.M., Redpath, S.M., Elston, D.A., Evans, S.A., Mitchell, R.J. and Dennis, P., 2006 To graze or not to graze? Sheep, voles, forestry and nature conservation in the British uplands. *Journal of Applied Ecology* **43**, 499-505.

Farrar, J. and Vase, P., 2000 Editors *Wales: Changing Climate, Challenging Choices – A scoping study of climate change impacts in Wales*. Institute of Environmental Science, University of Wales, Bangor.

Floyd, P. *et al*, 2004 *The Appraisal of Human-Related Intangible Impacts of Flooding RandD.* Technical Report FD 2005/TR. Environment Agency, Bristol.

Fordham, M. and Ketteridge, A.-M., 1995 *Flood Disasters – Dividing the Community.* Paper presented at the Emergency Planning '95 Conference, Lancaster UK. http://www.apu.ac.uk/geography/dsp/dividing-the-community.doc [Accessed 07 December 2004]

Fowler, H.J. and Kilsby, C.G., 2003 A regional frequency analysis of United Kingdom extreme rainfall from 1961 to 2000. *International Journal of Climatology* **23**, 1313-1334.

Franklin, J.F. and Forman, R.T.T., 1987 Creating landscape patterns by forest cutting: Ecological consequences and principles. *Landscape Ecology* **1** (1), 5-18.

Gaston, K.J., Charman, K., Jackson, S.F., Armsworth, P.R., Bonn, A., Briers, R.A., Callaghan, C.S.Q., Catchpole, R., Hopkins, J., Kunin, W.E., Latham, J., Opdam, P., Stoneman, R., Stroud, D.A., Tratt, R., 2006 The ecological effectiveness of protected areas: The United Kingdom. *Biological Conservation* **132** (1), 76-87.

Glaz, B. and Gilbert, R.A., 2006 Sugarcane response to water table, periodic flood and foliar nitrogen on organic soil. *Agronomy Journal* **98**, 616-621.

Greenergy, 2006 *Short Rotation Coppice – FAQs.* http://www.greenergy.com/SRC /faqs.html [Accessed 22 May 2006]. Greenergy, London.

Haines, A., Kovats, R.S., Campbell-Lendrum, D. and Corvalan, C., 2006 Climate change and human health: impacts, vulnerability, and mitigation. *Lancet* **367** (9528), 2101-2109.

Hall, R.L., 2003 *Short rotation coppice for energy production hydrological guidelines*. Report for the Dti B/CR.00783/Guidelines/src/URN 03/883.

Hari, R. E., Livingstone, D.M., Siber, R., Burkhardt-Holm, P. and Guttinger, H 2006 Consequences of climatic change for water temperature and brown trout populations in Alpine rivers and streams. *Global Change Biology* **12** (1): 10-26

Haylock, M.R., Cawley, G.C., Harpham, C., Wilby, R.L., Goodess, C.M., 2006 Downscaling heavy precipitation over the United Kingdom: A comparison of dynamical and statistical methods and their future scenarios. *International Journal of Climatology* **26** (10): 1397-1415.

Hazen, H.D. and Anthamatten, P.I., 2004 Representation of ecological regions by protected areas at the global scale. *Physical Geography* **25** (6), 499-512.

Heaton, R., Randerson, P. and Slater, F., 2000 *The silviculture, nutrition and economics of short rotation coppice in the uplands of mid-Wales.* ETSU B/M4/00532/13/REP. http://www.dti.gov.uk/renewables/publications/pdfs/b05320.pdf [Accessed 29 March 2006]

Henderson, I.G., Cooper, J., Fuller, R.J. and Vickery, J., 2000 The relative abundance of birds on set-aside and neighbouring fields in summer. *Journal of Applied Ecology* **37**, 335-347.

Henwood, K. and Pidgeon, N., 1998 *The place of forestry in modern Welsh culture and life*. Report to the Forestry Commission, Aberystwyth, 76 pp.

Hickling, R., Roy, D.B., Hill, J.K. and Thomas, C.D., 2005 A northward shift of range margins in British Odonata. *Global Change Biology* **11** (3), 502-506.

Hoes, O. A.C.; Schuurmans, W. and Strijker, J. 2005 Water systems and risk analysis *Water Science and Technology* **51** (5): 105-112

Holman, I.P., Hollis, J.M., Bramley, M.E. and Thompson, T.R.E., 2003 The contribution of soil structural degradation to catchment flooding: a preliminary investigation of the 2000 floods in England and Wales. *Hydrology and Earth System Sciences* **7**, 754-765.

Horne, S., 2006 Willow helps keep cash flowing. *Crops*, 20 May 2006: 16-17.

Hughes, L., 2000 Biological consequences of global warming: Is the signal already apparent? *Trends in Ecology and Evolution* **15**, 56-61.

Hulme, M, Jenkins, G.J., 1998. *Climate change scenarios for the United Kingdom: Scientific Report.* UK Climate Impacts Programme. Technical Report No. 1, Climate Research Unit, Norwich, UK.

Hulme M 2000. Characterisation of the Welsh climate based on UKCIP98 scenarios. In: Farrar, J. and Vase, P., 2000 (Eds.) *Wales: Changing Climate, Challenging Choices – A scoping study of climate change impacts in Wales*. Institute of Environmental Science, University of Wales, Bangor.

Hulme, M., Jenkins, G.J., Lu, X., Turnpenny, J.R., Mitchell, T.D., Jones, R.G., Lowe, J., Murphy, J.M., Hassell, D., Boorman, P., McDonald, R., Hill, S., 2002. *Climate change scenarios for the United Kingdom: the UKCIP02 Report*, UK Climate Impacts Programme.

Hulme, P.E., 2005 Adapting to climate change: Is there scope for ecological management in the face of a global threat? *Journal of Applied Ecology* **42**, 784-794.

IGER, 2006 *Biomass, the sleeping giant of renewables.* Paper to the Environment and Planning Committee of the Welsh Assembly. EPC(2) 05-06 (p5).

IPCC, 2000 *IPCC Special Report on Emission Scenarios.* Cambridge University Press, Cambridge.

IPCC, 2001 *Climate Change 2001: Synthesis Report,* edited by Watson, R.T. and the Core Writing Team. Cambridge University Press, UK. pp 398.

IPCC, 2002 *Climate Change and Biodiversity*, edited by H Gitay, A Suárez, RT.Watson, DJ Dokken. IPCC, Geneva, Switzerland. pp 85.

JNCC, 2006 *Common Standards Monitoring for Designated Sites: First Six Year Report*, edited by Willliams, J.M. JNCC, Peterborough. http://www.jncc.gov.uk/page-3520

Kay, A.L., Jones, R.G. and Reynard, N.S., 2006 RCM rainfall for UK flood frequency estimation. II Climate change results. *Journal of Hydrology* **318**, 163-172.

Land Cover Map 2000: See: http://www.ceh.ac.uk/sections/seo/lcm2000.html

Lake, I.R., Foxall, C.D., Lovett, A.A., Fernandes, A., Dowding, A., White, S. and Rose, M., 2005 Effects of river flooding on PCDD/F and PCB levels in cows' milk, soil and grass. *Environmental Science and Technology* **39**, 9033-9038.

Liberloo, M., Calfapietra, C., Iukac, M., Godbold, D., Luos, Z.B., Polle, A., Hoosebeek, M.R., Kull, O., Marek, M., Raines, C., Rubino, M., Taylor, G., Scarascia-Mugnozza, G. and Ceulmans, R., 2006 Woody biomass production during the second rotation of a bio-energy Populus plantation increases in a future high CO_2 world. *Global Change Biology* **12**, 1094-106.

Liu, A.Z., Tan, H.Z., Zhou, J., Li, S.Q., Yang, T.B., Wang, J.R., Liu, J., Tang, X.M., Sun, Z.Q. and Wen, S.W., 2006 An epidemiologic study of posttraumatic stress disorder in flood victims in Hunan China. *Canadian Journal of Psychiatry – Revue Canadienne de Psychiatrie* **51**, 350-354.

Lu, X.F., Crossley, J. and Hulme, M., 2001 An exploration of regional climate change scenarios for Scotland. *Scottish Geographical Journal* **117** (4), 251-270 2001.

Mancini, L., Formichetti, P., Anselmo, A., Tancioni, L., Marchini, S. and Sorace, A., 2005 Biological quality of running water in protected areas: the influence of size and land use. *Biodiversity and Conservation* **14**, 351-364.

Meek, B., Loxton, D., Sparks, T., Pywell, R., Pickett, H. and Nowakowski, M., 2002 The effect of arable field margin composition on invertebrate biodiversity. *Biological Conservation* **106**, 259-271.

Mehrotra, R. and Sharma, A., 2006 A nonparametric stochastic downscaling framework for daily rainfall at multiple locations. *New Journal of Physics* **8**, Art. No. D15101.

Mitchell, J.K., 2003 European river floods in a changing world. *Risk Analysis* **23** (3), 567-574.

Munday, M. and Roberts, A., 2001 The role of forestry industry transactions in the rural economy. *Journal of Rural Studies* **17**, 333-346.

National Travel Survey, DETR (1997), Department of Environment, Transport and the Regions (1997) National Travel Survey 1994/96: transport statistics report, London: The Stationery Office.

NAW 2004a. *Farming Facts and Figures: Wales 2004*. Wales Statistics, National Assembly for Wales, Cardiff.

NAW 2004b. *Key Environment Statistics for Wales 2004*. Wales Statistics, National Assembly for Wales, Cardiff.

NIWT (2003) *National Inventory of woodland & Trees – Great Britain*. Forestry Commission, Edinburgh

North West Regional Assembly, 1999 *Spatial Options for the North West*. North West Assembly, Wigan.

Ohlemuller, R., Gritti, E.S., Sykes, M.T. and Thomas, C.D. 2006 Quantifying components of risk for European woody species under climate change *Global Change Biology* **12** (9): 1788-1799

Oldfield, T.E.E., Smith, R.J., Harrop, S.R. and Leader-Williams, N., 2004 A gap analysis of terrestrial protected areas in England and its implications for conservation policy. *Biological Conservation* **120**(3), 303-309.

Parmesan, C., Ryrholm, N., Stefanescu, C. *et al*., 1999 Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature* **399**, 579–583.

Parmesan, C. and Yohe, G., 2003 A globally coherent fingerprint of climate change impacts across natural systems. *Nature* **421** (6918), 37-42.

Patz, J.A., 2001 Public health risk assessment linked to climatic and ecological change. *Human and Ecological Risk Assessment* **7**, 1317-1321.

Peterken, G.F. and Mountford, E.P., 1996 Effects of drought on beech in Lady Park Wood, an unmanaged mixed deciduous woodland. *Forestry* **69**, 125-136.

Peterken, G.F., 2000 Rebuilding networks of forest habitats in lowland England. *Landscape Research* **25**, 291-303.

Peterken, G.F., 2002 *Reversing the Habitat Fragmentation of British Woodlands.* WWF-UK, Godalming, Surrey.

Peterken, G.F., 2003 Developing forest habitat networks in Scotland, in *The Restoration of Wooded Landscapes.* In *Proceedings of a conference held at Heriot Watt University, Edinburgh, 14-15 September 2000, edited by* Humphrey, J., Newton, A., Latham, J., Gray, H., Kirby, K. H., Poulsom, E. and Quine, C., Forestry Commission, Edinburgh, pp. 85-91.

Ponnamperuma, F.N., 1972 The chemistry of submerged soils. *Advances in Agronomy* **24**, 29-96.

Powlson, D 2005 Climatology - Will soil amplify climate change? *Nature* **433** (7023): 204-205

Prudhomme, C., Jakob, D. and Svensson, C., 2003 Uncertainty and climate change impact on the flood regime of small UK catchments. *Journal of Hydrology* **277**, 1-23.

SAC, 2004 *Farm Management Handbook.* SAC, Edinburgh.

Sah, S., Reed, S., Jayachandran, K., Dunn, C. and Fisher, J.B., 2006 The effects of repeated short-term flooding on mycorrhizal survival in snap bean roots. *Hortscience* **41**, 598-602.

Salinger, D.H. and Anderson, J.J., 2006 Effects of water temperature and flow on adult salmon migration swim speed and delay. *Transactions of the American Fisheries Society* **135**, 188-199.

Scherm, H., 2004 Climate change: can we predict the impacts on plant pathology and pest management? *Canadian Journal of Plant Pathology* **26** (3), 267-273.

Schnug, E. and Haneklaus, S., 2002 Agricultural production technique and infiltration significance of organic farming. *Landbauforschung Volkenrode* **52**, 197-203.

Schwartz, M. W., Iverson, L.R., Prasad, A.M., Matthews, S.N. and O'Connor, R.J. 2006. Predicting extinctions as a result of climate change. *Ecology* **87** (7): 1611-1615

Singleton, P.H., Gaines, W.L. and Lehmkuhl, J.F., 2002 *Landscape Permeability for Large Carnivores in Washington: A Geographic Information System. Weighted-Distance and Least-Cost Corridor Assessment United States.* Department of Agriculture Forest Service Pacific Northwest Research Station Research Paper PNW-RP-549 December 2002.

Smith, D.L., Almaraz, J.J., 2004 Climate change and crop production: Contributions, impacts, and adaptations. *Canadian Journal of Plant Pathology* **26** (3), 253-266.

Solanski, S.K., Usoskin, I.G., Kromer, B., Schussler, M., Beer, J., 2004 Unusual activity of the Sun during recent decades compared to the previous 11,000 years. *Nature* **431** (7012), 1084-1087.

Solberg, B., Moiseyev, A. and Kalio, A.M.I., 2003 Economic impacts of accelerating forest growth in Europe. *Forest Policy and Economics* **5** (2), 157-171.

Solomon, D.J. and Sambrook, H.T., 2004 Effects of hot dry summers on the loss of Atlantic salmon, *Salmo salar*, from estuaries in South West England. *Fisheries Management and Ecology* **11** (5), 353-363.

Stott, P.A., Stone, D.A., Allen, M.R., 2004 Human contribution to the European heatwave of 2003. *Nature* **432** (7017), 610-614.

Tapsell, S.M., Penning-Rowsell, E.C., Tunstall, S.M. and Wilson, T.L., 2002 Vulnerability to flooding: health and social dimensions. *Philosophical Transactions of the Royal Society* **360**, 1511-1525.

Tapsell, S.M., Tunstall, S.M. and Wilson, T., 2003 *Banbury and Kidlington four years after the flood: An Examination of the long-term health effects of flooding. Report to the Environment Agency.* Enfield: Flood Hazard Research Centre.

Tewksbury, J.J. *et al*., 2002 Corridors affect plants, animal and their interactions in fragmented landscapes. *Proceedings of the National Academy of Science* **99** (20), 12923-12926.

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., de Siqueira, M.F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A.S., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Peterson, A.T., Phillips, O.L. and Williams, S.E., 2004 Extinction risk from climate change. *Nature* **427** (6970), 145-148.

Tollan, A., 2002 Land-use change and floods: What do we need most, research or management? *Water Science and Technology* **45**, 183-190.

Trenham, P.C. and Shaffer, H.B., 2005 Amphibian upland habitat use and its consequences for population viability. *Ecological Applications* **15**, 1158-1168.

Tubby, I. and Armstrong, A., 2002 *Establishment and Management of Short Rotation Coppice*. Forestry Commission FCPN7.

UKCIP, 2001 *Socio-economic scenarios for climate change impact assessment: A guide to their use in the UK Climate Impacts Programme.* UKCIP, Oxford.

UKWIR, 2002 *Effects of climate change on river flows and groundwater recharge. UKCIP02 Scenarios.* UK Water Industry Research Ltd, London.

Veitch, N. and McMellin, G., 2001 *Environment Agency constraints mapping project*. Paper presented at the DEFRA/FC National Energy Crops Conference, 27 September 2001. http://www.defra.gov.uk/FARM/acu/energy/nat_conf/map.pdf [Accessed 29 March 2006]

Vickery, J., Carter, N. and Fuller, R.J., 2002 The potential value of managed cereal field margins as foraging habitats for farmland birds in the UK. *Agriculture, Ecosystems and Environment* **89**, 41-52.

Wade, S.D., Sutherland, D., and Barber, J., 2000 *Socio-economic scenarios for climate impacts assessment: Application of scenarios in South East scoping study.* Paper commissioned for UKCIP.

WAG 2006. *Environment strategy for Wales*. Welsh Assembly Government, Cardiff.

Wallisdevries, M.F., Van Swaay, C.A.M. and Chris A. M. (2006) Global warming and excess nitrogen may induce butterfly decline by microclimatic cooling. *Global Change Biology* **12** (9) 1620-1626

Watt, A.D., Lindsay, E., Leith, I.D., Fraser, S.M., Docherty, M., Hurst, D.K. *et al.*, 1996 The effects of climate change on the winter moth, *Operophtera brumata*, and its status as a pest of broadleaved trees, Sitka spruce ad heather. *Aspects of Applied Biology* **45**, 307-316.

Watts, K., Griffiths, M., Quine, C., Ray, D. and Humphrey, J., 2005 *Towards a Woodland Habitat Network for Wales.* Forestry Commission Wales Report CT-W.H.N.S.W – 0303. Research Project No. 686.

Weatherhead, E.K. and Knox, J.W., 2000 Predicting and mapping the future demand for irrigation water in England and Wales. *Agricultural Water Management* 43, 203-218.

Werrity, A., Black, A., Duck, R., Finlinson, B., Thurston, Shackley, S. and Crichton, D., 2001 *Climate change: Flooding occurrences review.* Scottish Executive Central Research Unit.

West, V. (2003) *UK Public Opinion of Forestry 2003*. Forestry Commission, Edinburgh, 32 pp.

Willows, R and Connell, R (eds), 2003*. Climate Adaptation: Risk, Uncertainty and Decision-Making,* UKCIP Technical Report.

Wilson, H., 1999 Legislative challenges for lake eutrophication control in Europe. *Hydrobiologia* **395**, 389-401.

Winter, M. and Gaskell, P., 1998 The Agenda 2000 debate and CAP reform in Great Britain. Is the environment being sidelined? *Land Use Policy* **15** (3), 217-231.

Woodcock, B.A., Lawson, C.S., Mann, D.J. and McDonald, A.W., 2006 Effects of grazing management on beetle and plant assemblages during the re-creation of a flood-plain meadow. *Agriculture, Ecosystems and Environment* **116**, 225-234.

Xenopoulos, M.A., Lodge, D.M., Alcamo, J., Marker, M., Schulze, K. and Van Vuuren, D.P., 2005 Scenarios of freshwater fish extinctions from climate change and water withdrawal. *Global Change Biology* **11**, 1557-1564.

Zhang, L and Singh, V.P. 2005. Frequency analysis of flood damage. *Journal of Hydrologic Engineering* **10** (2): 100-109

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