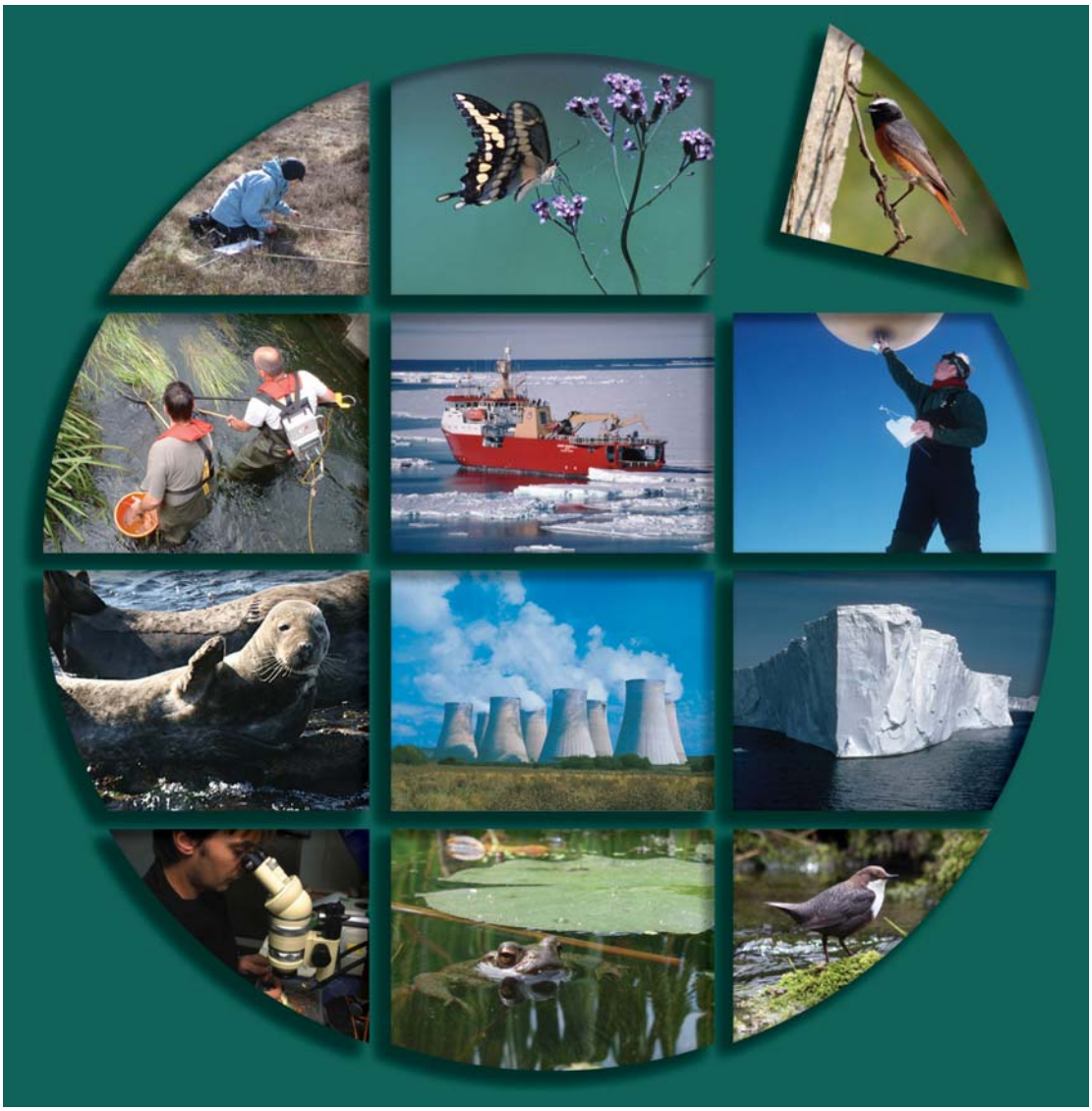
UK Environmental Observation Framework



Towards a Statement of Need

February 2010

Environment Research Funders' Forum

LWEC MERGED WITH THE ENVIRONMENT RESEARCH FUNDERS FORUM (ERFF) IN JUNE 2010, BEFORE THIS DATE THE UK-EOF WAS A PROGRAMME UNDER THE ERFF.

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ACKNOWLEDGEMENTS

The UK-EOF would like to thank all those who provided contributions to the content of this document.

We would like to hear your views on the general framework. Please email comments to office@ukeof.org.uk clearly labelled: Towards a Statement of Need (January 2010 version) - Comments from [insert your name or organisation]

Statement of Need – A Summary

In 2008 the ERFF Main Board, which comprises the major funders of publicly funded environmental observations agreed the following:

Observations provide the primary information to facilitate evidence-based decision making and increase our knowledge of environmental issues. Observations are made by a diverse community to achieve environmental, social or economic outcomes.

The UK needs a balanced suite of environmental observations to tackle the challenges associated with our changing natural environment. The balanced suite must span all environmental media, accommodate temporal and spatial variability, and allow changes to be assessed in the short, medium and long terms in local, national and international contexts.

This requires an appropriate infrastructure which will allow us to answer cost-effectively the questions and obligations that we have now and in the future. There is a need for the UK to optimise resources and put in place mechanisms for the community to work together to provide the required evidence. To achieve this we must develop:

- an observation framework based on a well-informed view of current and future needs
- adequate financial mechanisms to fund sustainable programmes
- an informed community that shares best practice and ensures efficiencies
- agreed or prescribed data sharing principles
- checks on data quality
- a process of regular review.

Towards a Statement of Need is the first step in this process and brings together the views of the community on the current and future needs. It does not represent the priorities.

EXECUTIVE SUMMARY

Towards a Statement of Need is the first attempt by the United Kingdom - Environmental Observation Framework (UK-EOF) to capture the observation requirements to fulfil national and international commitments, provide evidence to understand and manage major environmental issues and to answer crucial scientific questions. Observation requirements stated within the document have not been prioritised in any way, nor has current capability been identified. Prioritisation will be addressed via a decision support framework which is also being developed under the UK-EOF. Capability and current activities are searchable within the UK-EOF Environmental Observation Activity Catalogue (www.ukeof.org.uk).

The UK monitoring community is large, diverse and fragmented. Their observation needs arise from local to global environmental problems and require a diverse range of measurements and technologies to address them. Developing '*a holistic picture of the overall evidence needs and the role of observations in providing them*' is therefore a major goal of the UK-EOF.

Information on the UK's requirements for observations, now and in the future, have been gathered from experts, via open consultation and in a series of environmental domain based workshops over summer 2009.

Towards a Statement of Need has captured the observation requirements from three different perspectives. The first identifies the evidence needed to address a series of headline issues that relate to the environmental challenges both within the UK and globally. The second asks what a balanced suite would include under each environmental domain – such as land, biota, water (including marine) and air. The third reviews the motivations of various sectors of the community, recognising that many resources go to collect information required by legislation or by local, national or international obligations. In order to recognise the different rationale behind observing the environment, The Statement of Need must include the requirements of all communities be they private, public or volunteer.

From the information gathered it is clear that many of the issues which need observations relate to established topics such as pollution or to topics that are currently high on both the political and public agenda e.g. Climate Change.

Numerous issues require observation of the inputs to and impacts of change on the natural and built environment, assessment of the effects and prediction of both the extent and intensity of such change. There are many common themes that require a wide variety of observations to address, for example, pollution, diseases, non-native species and natural resources.

Several issues require information from more than one environmental domain. Cross sectoral working and an increased awareness of the activities and observations that are being carried out by or for the UK are therefore fundamental to the coordination of observation programmes.

Some of the issues are closely linked to research questions. Basic research is often needed prior to the generation of big questions, which themselves may require effective observation programmes. Conversely long term observations are often fundamental to providing the data to answer research questions, or to stimulate new ones. Dialogue is therefore required between the observation and research communities when considering observation programmes.

For some environmental domains the majority of requirements focus on the UK, whereas others such as Atmosphere, Marine and Cryosphere have many links to global issues, international agreements and joint observation programmes. Whilst this can cause additional complications for observation programmes (participation and funding), they are important if we are to understand large issues such as climate change.

Although this document and any subsequent Statements of Need will provide evidence of the UK's requirements for observations, individual organisations will remain responsible for prioritising the requirements. Towards a Statement of Need, together with other UK-EOF outputs, will underpin a decision support framework, currently under development. This framework will aid decision making in the specification, procurement and management of the resources that the UK invests in environmental observations.

In the future Towards a Statement of Need could be used to identify gaps and undertake an analysis of the UK's capability to address the requirements as stated in this document. This depends on the priorities of the UK-EOF sponsors and would be informed by the UK-EOF Environment Observation Activity Catalogue. Further consultation to fill information gaps regarding the spatial distribution, frequency of collection and use of the measurements would then be required to help users to identify the measurements that meet multiple needs.

The UK-EOF has attempted to obtain the views of all contributors to environmental observations however, some gaps remain - primarily the inclusion of social science and engagement with the industrial sector. These gaps will be addressed in future iterations of the Statement of Need.

The UK's observation requirements will change so the UK-EOF proposes to update this document over time. We hope that it will be used to stimulate discussion and inform decision makers, allowing the whole community to benefit from a wide perspective which unites policy and scientific questions and contemporary issues of society, economy and environment with the ongoing measurement requirements for the natural environment.

1 INTRODUCTION AND BACKGROUND

1.1 BACKGROUND

1.1.1 The UK Environmental Observation Framework (UK-EOF) is a programme of the Environment Research Funders' Forum (ERFF).

1.1.2 Following a review of the state of environmental monitoring in the UK [11, 12] the ERFF undertook to '*articulate a vision and a high-level plan to define and resolve UK environmental monitoring issues'.* The UK-EOF was the result.

1.1.3 In its 2008 framework document [14], the UK-EOF outlined the overall approach and main goals of the five year programme. The goals will be achieved through a series of interrelated workstreams which are illustrated in Figure 2. Towards a Statement of Need relates to the first of them: *'Collective Aspiration'*, which aims to develop and articulate the UK's overall needs for environmental observations.

1.1.4 For a full description of the UK-EOF and its complementary workstreams please see the website http://www.ukeof.org.uk/

1.2 WHAT IS THE STATEMENT OF NEED AND HOW IT WILL BE USED?

1.2.1 The Statement of Need, with its supporting material, will provide an overview of all the UK's requirements for observations. These requirements cover the need to understand both our surroundings and national or international obligations to which the UK subscribes. Thereby improving our ability to understand the natural environment and address current and future environmental policy priorities for economic benefit and quality of life.

1.2.2 The statement considers the public sector and the many other contributions of environmental evidence and observations, as shown in the PSVI Model in Figure 5. In this way it will help to develop a shared understanding of activities and responsibilities and will provide evidence to inform the future direction of not only the UK-EOF but each of its members and stakeholders.

1.2.3 The statement seeks to answer the key questions in Box 1, thereby articulating some fundamental principles and issues that determine UK environmental observations from all sectors.

Box 1: Key Questions for the Statement of Need

- What are the key (science and policy) questions that we need to answer, now and in the future?
- What are the national and international obligations and commitments that drive environmental observations?
- What assessments do we need to make?
- What are the types of organisations and institutes that undertake environmental observations and why do they do so?

(*from the UK – EOF Workshop July 2008*)

1.2.4 The statement will provide the framework in which to discuss current and future (for at least 20 years) requirements. It will present a sustainable and long term view of the factors believed to influence and change our needs for environmental observation.

1.2.5 In the future the Statement of Need could be used to set out the case for the UK to undertake and promote a balanced, progressive and efficient suite of observations that address key environmental issues

1.2.6 A description of future work for this Statement of Need workstream is included in Chapter 6: *'The Way Forward'*.

1.2.7 Towards a Statement of Need is the first step in collecting a holistic view of the UK's diverse and complex requirements for observations. No attempt has been made to prioritise the needs nor make the case for any player to take action. In essence it is a collective wish list, which, after a prioritisation process can be used to inform the procurement and management of resources in the light of existing observations and needs. Over time the statements will capture greater detail and be refined such that the needs may be matched by actual observation. It is therefore an iterative and continuing process.

1.3 THE STATEMENT OF NEED

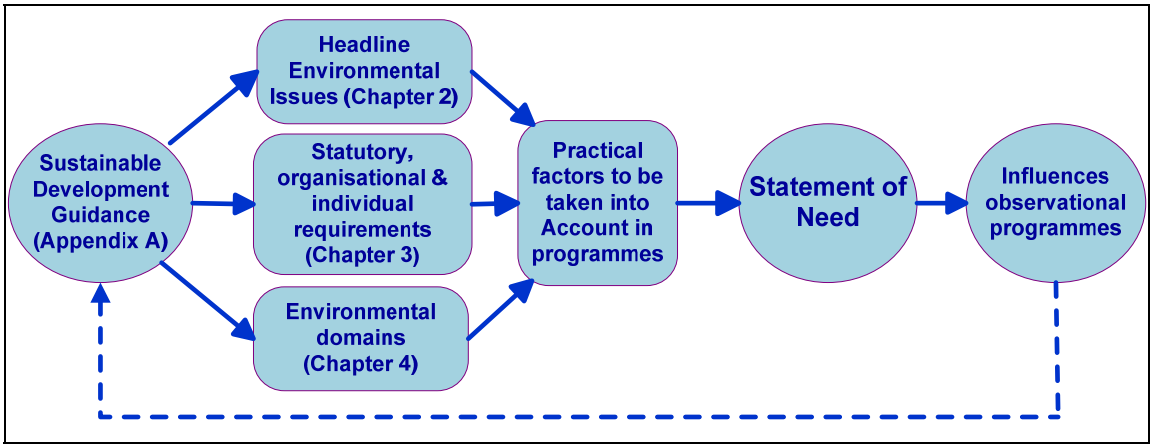
1.3.1 Towards a Statement of Need has been developed by examination of strategic factors that influence the development of observation programmes and via consultation with the observation community, combined with the collective aspirations and needs of those who use and or make national or international observations.

1.3.2 Figure 1 outlines the approach and structure of this document. In order to cover the breadth of requirements, information on the collective aspirations and needs have been captured from three important view points;

- To answer a the most important social (or headline) issues (Chapter 2)
- To meet statutory, organisational and individual requirements (Chapter 3)
- To cover each environmental domain perspective[1] (Chapter 4)

These viewpoints are of equal status and should be considered as complementary aspects of our observational needs. Each can be applied in national or international contexts.

Figure 1: Statement of Need approach and document structure

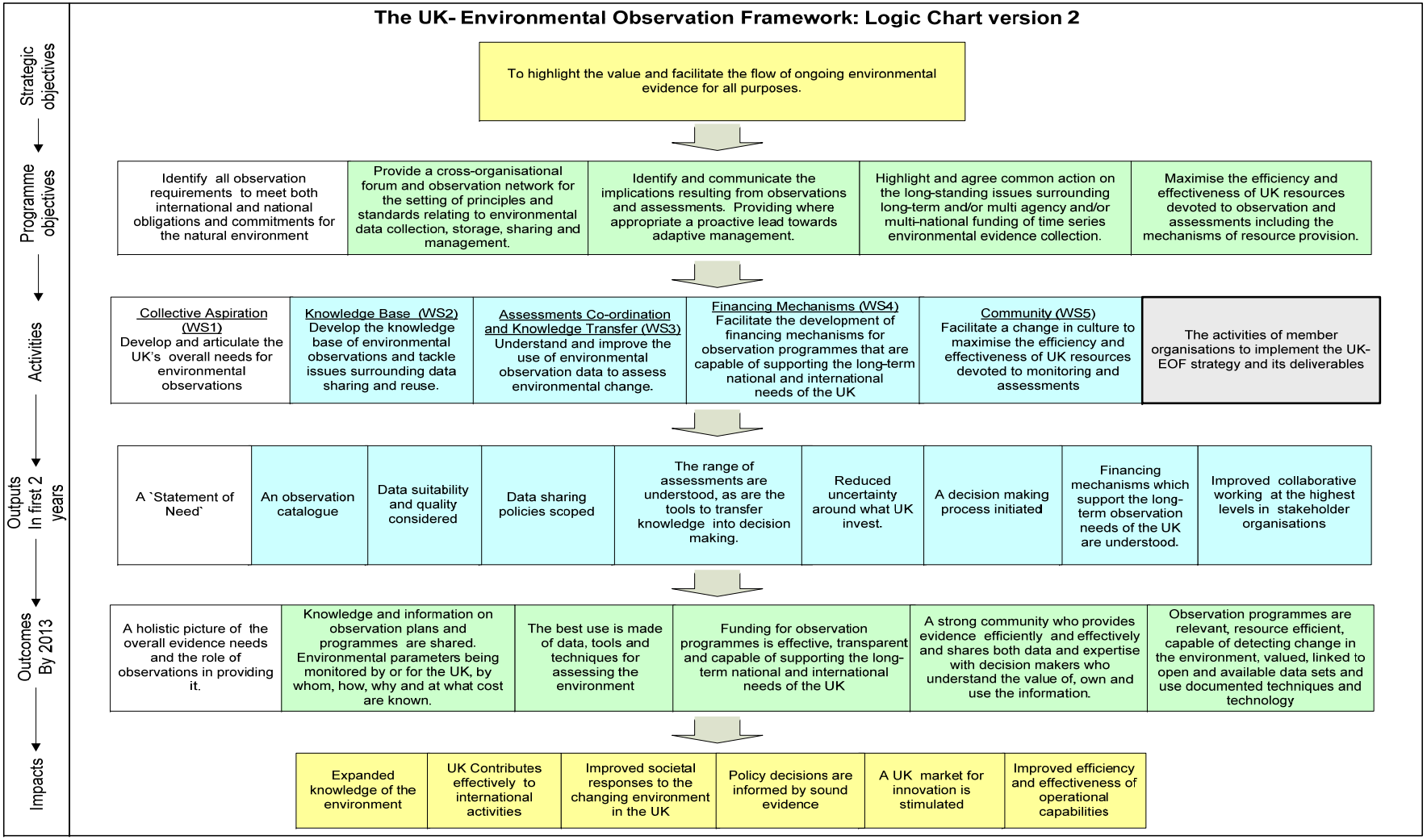


1.3.3 Sustainable development and the UK government's commitment to evidence based decision making are fundamental in the development of observation programmes, both have therefore been considered in the development of the Statement. Further information on the role of sustainable development and evidence-

[1] The Environmental Domain is the environmental 'fields' or 'spheres' often referred to when discussing the environment, for example air would fall under the atmosphere, ice and polar regions under the cryosphere. For a list of the 'environmental domains' being used by the UK-EOF please see Chapter 4.

based decision making can be found in Appendix A: The role of sustainable development and Appendix B: Evidence-based decision making respectively.

Figure 2: UK-EOF Logic chart: Illustrating how the Statement of Need contributes to the strategic objectives, outcomes and impacts of the UK-EOF.



2 HEADLINE ISSUES THAT REQUIRE OBSERVATIONS

2.1 OVERVIEW OF ISSUES AND SCOPE

2.1.1 The UK faces fundamental environmental issues and challenges. Environmental observation will lie at the heart of solving or understanding these matters. Expert environmental advice, which depends on our observations, is also essential for UK citizens to make the best possible use of the world around them.

2.1.2 The set of 9 headline issues, listed in Box 2, taken together with their associated sub issues, comprehensively cover all the reasons for making environmental observations. They cover the observations required in all environmental spheres, from marine to terrestrial and atmosphere etc – the full extent of their scope is illustrated in Appendix C: The scope of the 9 headline Issues.

2.1.3 The UK-EOF has derived the key phrases of the headline issues from many sources including the Natural Environment Research Council (NERC) Themes, Global Earth Observations System of Systems (GEOSS), ERFF horizon scanning and classification scheme, the UK-EOF inaugural workshop, the Millennium Ecosystem Assessment [22] and the Global Environmental Outlook (http://www.unep.org/geo/).

Box 2: Headline issues to address with observations

How may observations help to:

- Understand the pressures on all environments, particularly in the light of population growth and associated pollution.
- Supporting economic growth reconciled with sustainable use of natural resources such as aggregates, minerals, and energy – including nuclear, biofuel and renewable energy.
- Understand future states of the earth, particularly the carbon cycle (but not excluding other element cycles), in domains such as air, soil and seas.
- Understand the consequences of environmental change for fisheries and agriculture, food security and water supply.
- Understand the consequences of environmental change for human health, wealth and well-being.
- Understand, avoid and mitigate the effects of extreme events and disasters.
- Understand and reduce the impacts of environmental change on marine and terrestrial biological diversity, including ecosystems and the services they provide.
- Understand climate variability and climate change within earth system science.
- Stimulate scientific and technological advancement and innovation.

2.1.4 This list of issues (Box 2) is one way to understand and characterise the diversity of influences on our need for observational activity. The issues are cross-cutting and strategic; they should be understood in conjunction with chapters 3 and 4, which relate the fundamental needs to organisational perspectives and environmental domains (Figure 1). These are just some of the ways to collate and capture the need; other groupings exist with advantages and drawbacks.

2.1.5 The 9 headline issues are not permanent but we expect them to remain as core elements in roughly similar form for the next ten to twenty years. Although the framework may remain, the details should be reviewed regularly. Political, business and social perceptions change constantly while scientific enquiry and technological development open up new avenues of research and development of operational capabilities. The observational programmes to support these headline issues must therefore also be flexible and adaptable to deliver sound information for future decisions.

2.1.6 For the UK, many observations are driven by local or national legislation and needs, or by international agreements. Wider international programmes or aspects of global science are also intrinsically important for understanding natural processes and for shedding valuable light on many issues nearer home. Although, not often considered important to meet the immediate needs of the UK, it is important to find a balance between the information needed directly for local issues and that needed to understand global processes influencing local change.

2.1.7 Global initiatives to standardise the methodologies for environmental observations are moving towards gaining better consistency and quality of data and are therefore important for establishing interoperability for relevant observations across the globe (indeed, such standards do already exist in some areas, e.g. – World Meteorological Organisation (WMO) standards of quality for weather, climate and related environmental data).

Statements of Need with respect to the headline issues

2.1.8 The following sections attempt to capture the background and context of the questions and issues in Box 2. These were expanded further in the workshop process using the information gathering table illustrated in Appendix D: Example of an information gathering table. Completed tables are appended to the Statement of Need Workshops Report. The requirements are outlined for some of the sub issues below. Issues specific to an environmental domain are discussed in Chapter 4, Observations according to environmental domain.

2.1.9 Our future work will analyse if and where these observations are collected and where there are gaps in the programmes.

HEADLINE ISSUE:

2.2 PRESSURES ON ALL ENVIRONMENTS IN THE LIGHT OF POPULATION GROWTH AND ASSOCIATED POLLUTION

2.2.1 Human activity inevitably makes demands on the environment. To understand where these demands are excessive it is essential to relate activity to the environmental services it draws upon. Human actions change the natural environment; air quality and water supplies are increasingly vulnerable, many plants and animals are threatened with extinction, and climate - along with the earth's landscape - is changing.

2.2.2 Human population is growing rapidly towards or beyond the carrying capacity of the Earth. The Office of National Statistics (ONS) has predicted that if current trends continue the population of the UK will be 71.6 million by 2033.

2.2.3 Issues associated with population growth have been recognised by the *'Living with Environmental Change'* Programme (LWEC) [25], The National Ecosystem Assessment and the Government's Foresight Programme and Horizon Scanning Centre.

Natural Resources

2.2.4 As population grows, so does demand for natural resources (energy, food, freshwater, building materials) and living space. The issues are therefore intrinsically linked to those of sustainable development.

Urbanisation

2.2.5 Increased urbanisation linked to the spread of housing and associated services such as infrastructure for water supply, waste disposal, sewerage, energy demand and transport are all consequences of an increasing population. Development,

industry and expansion of our economic footprint all have an impact on the environment and observation of these pressures is essential to complement measurements of the environment itself.

Water resources

2.2.6 Many of the pressures have secondary issues associated with them, for example when addressing water resource allocation, demands from people, industry and agriculture need to be considered alongside adequate water volumes to sustain freshwater biodiversity. With a changing climate, it is predicted that there will be increased migration to coastal areas (despite increased risks of flooding), without careful management this could lead to increased run off and pollution to coastal areas.

Pollution & Diffuse Pollution

2.2.7 Pollution and inputs from diffuse pollution remain an issue in all environmental domains, for example, despite standards set by various statutes, air pollution still causes many premature deaths within the UK each year.

Policy Evaluation

2.2.8 In developing policies or planning interventions to improve or protect the environment it is essential to evaluate their effectiveness. For this, we must not only understand the current state of the environment but also be able to predict or make future forecasts of the impacts that will arise if there is no intervention. The effectiveness of interventions in relation to their aims and environmental improvement can then be assessed. However, when using observation to demonstrate this, the geographical (spatial) location or area of growth is an important factor that should be considered, as the pressures may be greater in some localities than others thus resulting in a need for targeted observations.

Observation requirements

2.2.9 Information required to address the issues and questions surrounding population growth and the associated pollution, as stated above, include:

- Pollution loads & emissions, including hazardous substances, run off from waste disposal and litter.
- Water resources and water quality
- Impacts on natural resources; minerals, building materials, energy
- Urbanisation and development: impacts of new infrastructure, soil sealing, coastal squeeze[2]
- Land use change

2.2.10 Many of the issues related to population growth and pollution are relevant across all environmental domains for example the release of pollutants into the environment can affect both air quality and water courses. Both would require observations but, due to the different media and pollutants involved, these would be different in each case.

2.2.11 To address some issues information is required across different domains and is pulled together to understand the overall impacts on the environment. For example, when considering urbanisation, sealing the soil with concrete will affect the soil and the biodiversity within that soil, but it could also have impacts on water resources.

[2] Due to the building in coastal areas, natural coastal habitats are being reduced and the area available for plants and organisms to live in is being 'squeezed' resulting in a decline in species abundance.

2.2.12 Depending on the issue, the scale of the observations will also vary. Some of the issues are localised e.g. the monitoring of discharge from an industrial factory, whereas others may start locally but have regional or even national consequences e.g. water resources. Some issues are global in nature such as long-range transboundary air pollution, upon which the UK reports to the United Nations Economic Commission for Europe every 2 years.

2.2.13 To fully understand the issues associated with population growth, information on the projections of growth and the areas which will be most affected is also required. This information is necessary for planning and sustainable development.

HEADLINE ISSUE:

2.3 SUPPORTING ECONOMIC GROWTH RECONCILED WITH SUSTAINABLE USE OF NATURAL RESOURCES (SUCH AS AGGREGATES, MINERALS AND ENERGY – INCLUDING NUCLEAR, BIOFUEL AND RENEWABLE ENERGY)

2.3.1 The principles of sustainable development are outlined in Appendix A: The role of sustainable development. A complementary and general UK view on the sustainable use of natural resources is described [24] succinctly by:

'The natural world provides resources that are vital for human life. It provides non-renewable resources such as fossil fuels and minerals and also resources such as crops and timber that can be renewed if they are not over exploited. Natural assets such as air, water and soil sustain life and support the biological resources on which we depend. The natural world also provides many potential forms of energy that cannot be depleted, such as wind, wave, tidal, solar and geothermal.

The global demand for natural resources continues to grow … between 1960 and 2000, the world population doubled and there was a two-and-a-half-fold increase in food production, a doubling of water use and a trebling of wood harvested for pulp and paper production. The UK government's 2007 energy white paper [*9*] *identifies the need to maintain reliable and affordable energy supplies while cutting carbon dioxide emissions.'*

Energy

2.3.2 Energy demands are likely to change in the future. Prediction of demand and the associated emissions will be required for planning purposes. It will also help to address whether the current energy supply is sufficient or whether alternatives are required.

2.3.3 When considering alternative power generation, observations that will allow the prediction of long term reliability of wind or solar energies will provide information to support these alternative energy options. Linked to this is the development and improvement of technologies to efficiently harness these energy sources.

2.3.4 The potential growth of the nuclear power industry, raises questions regarding the disposal of waste and impacts of building new plants and infrastructure. Observations are required to identify disposal sites, monitor contamination or leakage from the plants and/or disposal sites and also determine the impacts on the surrounding environment.

2.3.5 Within the UK, development of renewable energy will be significant to economic growth. This growth could impact both the marine and terrestrial (including sub surface - geological) environments. Understanding the full life cycle impacts and

footprints, particularly in areas where there may be multiple projects in the same region (e.g. installations in the marine environment could include wind, wave & tidal turbines), is important when providing advice for future planning, management and when determining whether effects should be mitigated. The use of shallow geothermal energy is also increasing, however to ensure that there is effective deployment and regulation, baseline observations of the subsurface properties and heat potential are required.

2.3.6 GEO has recognised the importance of observations related to energy. Under it's GEOSS strategic objective 11 it aspires to, 'close critical gaps in energy-related Earth observations and increase their use in all energy sectors in support of energy operations, as well as energy policy planning and implementation, to enable affordable energy with minimised environmental impact while moving towards a low-carbon footprint'.

Natural resources

2.3.7 The extraction of minerals and geological resources for use in construction activities has profound impacts on the environment both on land and to the seabed. Observations can be used to determine the effects of this disturbance to the surrounding ecosystem and also the success of regeneration after the completion of extraction.

2.3.8 Natural resources are finite. Mapping will allow the UK to understand the extent of the natural resource available and by comparing this to the demand, the UK can, if necessary find or develop alternative materials or arrange the appropriate international trade (imports or exports).

Land Use

2.3.9 Increasing economic growth can result in a need for suitable but safe land for development of industry or housing. Suitability can be assessed with surveys of ground stability and geohazards.

2.3.10 Competing uses for land, cause different levels of impact to surrounding ecosystems. Observations can be used to identify these impacts and provide evidence to determine the tradeoffs (see 2.3.16).

Tourism

2.3.11 Tourism provides a valuable income for the UK, however, it does have an impact on the natural environment. These impacts must be assessed and managed to ensure that problems are characterised and solutions or mitigating action put in place.

Non native species

2.3.12 Increasing international trade has led to a greater introduction of non-native species to both aquatic and terrestrial environments. Observations are being used to inform risk assessments and to determine the efficacy of control measures. However, there is further need to be able to share information trans-nationally.

Day-to-day decision making underpinning socioeconomic benefit

2.3.13 Citizens should be enabled to make every day decisions that promote social and economic well-being in a sustainable way, based upon on the best available environmental information. Routine observing systems are essential for providing the information that will not only underpin future policy decisions, but also provide essential "operational" data to users in their current day-to-day activities. Whilst sufficient warning and mitigation of severe events must necessarily assume priority when making decisions on the funding and organisation of an underpinning observational network, the

benefit to society and the economy of providing continuous datasets on a routine basis on the state of the environment cannot be underestimated.

Observation Requirements

2.3.14 In order to address the issues associated with Economic Growth and Sustainability, as stated above, information is needed on:

- Impacts of natural resource extraction and use on the environment and biodiversity
- Mapping of natural resources
- The viability for alternative energies: wind speeds, tidal streams, geothermal heat potential etc
- Results from impact assessments of using/installing alternative energies
- Ecosystem services and their value
- Species surveys
- Surveys of land stability and use, along with the identification of geohazards.
- Routine monitoring of parameters that underpin day-to-day socioeconomic value, e.g. – meteorological parameters required for the purposes of the Public Weather Service (PWS) offering and as the essential inputs to Numerical Weather Prediction (NWP).

2.3.15 The issues surrounding economic growth and sustainability are not limited to one environmental domain, for example the installation of renewable turbines can be on land, in freshwater or in the sea, each of which may affect the surrounding ecosystems and therefore need observation programmes specific for that medium.

2.3.16 When considering economic growth, the cost and benefits of the growth versus the environmental disturbance must be considered. In order to do this comprehensively, additional economic information on the monetary costs and the social benefits must also be gathered. The value of ecosystem services and the effect of decisions upon them is being taken forward under the Ecosystem Approach as described in Defra's Ecosystem Approach Action Plan [5] and the Millennium Ecosystem Assessment [22].

2.3.17 Economic growth is intrinsically linked to trade and industry. To date the views of the industrial sector have not been fully explored. Further engagement is required to capture the demands and needs of this sector.

HEADLINE ISSUE:

2.4 THE FUTURE STATES OF THE EARTH, PARTICULARLY THE CARBON CYCLE (BUT NOT EXCLUDING OTHER CYCLES), IN DOMAINS SUCH AS AIR, SOIL AND SEAS

2.4.1 The Earth System is regulated by a large and complex network of feedbacks. They act over wide ranges of space and time to stabilise the main biogeochemical cycles (carbon, nitrogen, phosphorus and sulphur) that regulate climate and biological productivity. These cycles are sensitive to changes in biological activity and physical processes. Regional or global human activity therefore perturbs the cycles and threatens the Earth System. The effect of rising greenhouse gas concentrations on climate change is an important example; there are numerous others, including acidification-induced loss of soil productivity, acidification of the oceans, and changes in the nitrogen cycle, each affecting productivity and climate.

2.4.2 The capacity of the Earth System to accommodate these changes is uncertain. Perturbation of any complex system may lead to disproportionate responses and sudden changes. A sound understanding of the whole system is needed before

impacts can be predicted. Observations are crucial to reduce uncertainty, verify models and give early warning of such rapid or abrupt changes.

2.4.3 Many organisations have already recognised the issues: in 2008, the UK government set up a Department of Energy and Climate Change (DECC), and GEOSS, under its climate theme, specifically highlights the climate-carbon cycle as a key area of uncertainty.

Carbon Cycle and Global Warming

2.4.4 Carbon is a major component of living things; it resides for various periods in reservoirs such as the soil, the atmosphere and the oceans. The movement or cycling of carbon between these areas is known as the carbon cycle.

2.4.5 Some carbon is locked away longer term in reservoirs or 'sinks' such as coal and oil. Burning of these fossil fuels releases the carbon to the atmosphere as carbon dioxide. Anthropogenic activities such as these disturb the natural carbon cycle (see sources and sinks below). As carbon dioxide is a greenhouse gas, an accumulation of atmospheric carbon dioxide allows solar radiation into the earth's atmosphere, but slows the exit of associated heat, thus raising global temperatures and resulting in 'global warming'.

2.4.6 The role of biota cannot be ignored when considering the carbon cycle. Different assemblages of biodiversity contribute to the sources and sinks of carbon as do habitats such as peats and soils. Although complex, a better understanding of feedbacks and cycling would enhance knowledge of the impacts of increasing atmospheric carbon dioxide and with observations of change, could potentially aid climate mitigation policies.

2.4.7 There is a pressing need to understand the climatic consequences of unbalancing the carbon cycle. In marine, terrestrial and atmospheric systems, long time series of various measurements will be needed to describe and model the cycle, although with thorough scientific understanding it may sometimes be possible to focus on key environmental compartments and use them as indicators of other changes. For example, it is possible to use high quality atmospheric carbon dioxide measurements to understand the global carbon cycle, even though most carbon resides in other reservoirs.

Sources and Sinks of Greenhouse Gases

2.4.8 To fully understand the human impact and unbalancing of the carbon cycle, there is a need to identify where or what the sources and sinks of carbon are. This issue is fundamental across all of the environmental domains and would involve measuring the quantity of inorganic and organic carbon some of which may be dissolved in aquatic environments.

2.4.9 Temperature changes can affect how carbon is stored, released and transferred globally. There is a risk that increasing global temperatures will trigger additional releases of carbon dioxide, thus accelerating further global warming. Observations of temperature change and the monitoring of sources and movement of carbon will inform and enhance knowledge of this risk.

2.4.10 The issue of understanding sources and sinks is not unique to carbon. Understanding the fluctuations and potential accumulation of other greenhouse gases such as methane and nitrous oxide are also important, as are the cycles of sulphur, nitrogen and phosphorous. Industrial burning of coal and petroleum generates sulphur

dioxide (SO_2), which reacts with atmospheric water and oxygen to produce sulphuric acid (H_2SO_4) – a component of acid rain.

2.4.11 Increases in nitrogen and phosphorous in the environment can damage ecosystems via eutrophication and changes in their cycles can influence greenhouse gas fluxes.

Ocean Acidification

2.4.12 Much of the carbon dioxide (CO_2) released since the beginning of the Industrial Revolution has been absorbed by the ocean thus moderating its effects on climate change. Because of the chemical reactions of carbon dissolved in seawater, the absorption of carbon dioxide is acidifying the ocean adversely. Due to the natural variability within the oceans, long term observations are needed to understand the rates of change and identify where the 'hotspots' are. This could be coupled with research into the potential impacts on marine life and future climate predictions.

Methane Hydrates (or Clathrates)

2.4.13 Vast deposits of methane are trapped within clathrate hydrates (a structure in which the water molecules trap the gas) in deep ocean sediments, deep lakes or within the sedimentary rocks of the polar regions.

2.4.14 Release of methane hydrates is of interest to the energy industry, who could potentially harness the methane as an energy source. Destabilisation and consequent gas release could however have large implications on global climate. The gravity of this risk is uncertain due to a lack of understanding on the extent and location of the methane hydrate reservoirs. Surveys to map the distribution of host sediments and presence of methane hydrates are necessary along with observations on rates of change (for example from permafrost melt, temperature or pressure) and consequent gas release. Other factors may also play a role in the release of methane hydrates including seismic events or landslides. Understanding these risks will help future predictions and can be fed into relevant climate change policy.

Emission Reduction and Carbon Sequestration (Capture and Storage)

2.4.15 As policy shifts towards a low carbon economy there are international, European and national commitments to reduce carbon dioxide emissions. For example, the UN Framework Convention on Climate Change Convention of the Parties (UNFCCC-COP) focuses on long-term cooperative international action. This and national efforts to understand the implications of carbon capture & storage should be underpinned with observations

2.4.16 Reducing emissions from transport and energy use, is not only dependent on improved technologies but also on social awareness, attitude and behaviour. This type of information is necessary to assess demand and therefore predict future emission scenarios.

2.4.17 In order for industry to meet demands for emission reduction, there is a need to accelerate the identification of potential carbon, capture and storage sites, most of which will be offshore. When selected, real time observation programmes will be required to assess whether there is any leakage or associated impacts.

Observation Requirements

2.4.18 The observations required to address the questions and sub-issues surrounding the future states of the earth include:

- Measurements of carbon dioxide, methane and other greenhouse gases in the atmosphere.

- Emissions from industry, transport, energy, etc
- Measurements of carbon content (all forms) in soils, freshwater and the oceans.
- Carbon dioxide fluxes between land-air, land-ocean and air-ocean.
- Habitat mapping and condition, including that of peat and permafrost.
- Measurements to determine the role of biodiversity in the cycling of carbon and other greenhouse gases
- Methane hydrate distribution and stability.
- Atmospheric and oceanic temperature and pressure changes
- Geophysical properties (for both permafrost stability and also carbon, capture and storage integrity)
- Ice cores
- Leakage monitoring from 'live' carbon, capture and storage sites

2.4.19 Many of the issues are related to understanding the anthropogenic disruption to natural cycles and the associated impacts. The disturbance is often related to other headline issues such as pollution and climate change for which the development of verified models is vital. Data collectors and modellers should decide together what data are needed to test and refine models or devise predictive models that can be adapted to new data. NERC involvement with the Integrated Ocean Drilling Program (IODP) is but one example of such an approach, where long term modelling can be validated against sediment records or ice cores.

HEADLINE ISSUE:

2.5 THE CONSEQUENCES OF ENVIRONMENTAL CHANGE ON FISHERIES, AGRICULTURE, FOOD SECURITY AND WATER SUPPLY

Food supply and Agriculture

2.5.1 The economic and environmental performances of farming are inextricably linked. We need to make progress with both if we are to meet the challenges ahead, feeding the world's population in a way that does not degrade the natural resources on which food production ultimately depends. This is one of the central principles of Defra's Code of Good Agricultural Practice (England).

2.5.2 Food supplies depend on natural environmental factors including weather, climate, fresh water, soil quality and moisture. Conversely, agriculture has a major impact on the environment. Unless sustainably managed, farmland may be eroded and may contribute to water and air pollution. Effective management must be based on sound environmental information.

2.5.3 Supply chains are affected by price increases and socio-economics. Over recent years prices have risen due to increased demand for meat and dairy produce (thus increasing grain demand) and rising oil costs (related to fuel, fertiliser, transport, packing and processing). Poor weather and increased demands for biofuel production (on land once used for food crops) have reduced harvests, which have resulted in higher domestic food prices, export restrictions and a smaller proportion of production being traded within the world market.

2.5.4 Guaranteed food security sits alongside other priorities such as climate change and a healthy natural environment. The UK produces a large volume of food but relies on some imports. Therefore when considering food security, global environmental issues and their impact or potential future impact on overseas food chains cannot be ignored. In the long term the UK needs to be able to judge whether the UK food supply chain is sufficiently resilient to withstand short term shocks and sufficiently strong to face long term challenges.

2.5.5 Information on air pollution, seasonal trends, climate variables and their effects on crop yield will be important when planting and planning in the future, and observations and forecasts are required to support day-to-day agricultural activities to maximise harvests. To address these issues and those listed above, greater resolution of data and linkages to information such as agricultural meteorology (guidance for which is given by the World Meteorological Organisation, or WMO) are required.

2.5.6 Identifying and understanding the impacts of agricultural change on the environment is complex. Observations and indicators of emerging agricultural and environmental change [7] are required to quantitatively assess the linkages between the environment and components such as 'set-aside', agricultural projections, agricultural census data and cross compliance measures. In future, information regarding the changes in the drivers of agricultural practice, such as CAP policy reforms or climate change, and their environmental impacts will be required along with an understanding of how farmers respond to changes in policy, institutional factors, the market and other behavioural drivers.

Pests, Diseases and Pollination

2.5.7 The changing environment can assert different pressures on the ecosystem. These changes can make the environment more favourable to non native (invasive) species to the detriment of indigenous ones. Pollinators, which play a vital role in the lifecycle of crops and plants, may also be affected. A decline in numbers could result in decreased harvest and food supplies.

2.5.8 As the environment changes new disease vectors or pathogens may emerge, each of which could have profound impacts on crops, livestock or human health. Existing examples of this have already been seen in the cases of Foot & Mouth and Blue Tongue, and dispersion models have been used to try and replicate the movement of such airborne diseases.

Biomass Burning

2.5.9 The burning of biomass to clear forests, savannahs or agricultural land releases greenhouse gases including carbon dioxide, methane and nitrous oxide into the atmosphere. The practice which has become increasingly common, especially in the tropics, contributes to the global emissions budget and results in the release of fine particulates hazardous to human health.

Fisheries and Mariculture

2.5.10 Fishing depends on a healthy water environment. Over-fishing can deplete stocks and damage coastal, deep water and freshwater ecosystems. Aquaculture exerts different pressures and needs to be managed on the basis of environmental observation, monitored husbandry and greater understanding of the interactions.

Water

2.5.11 Agricultural practices require vast quantities of water. Land owners are often licensed to abstract water from rivers, which itself can reduce flows and cause environmental problems. Water flows can be affected by droughts or storm conditions, both of which can be predicted using observations of agricultural meteorology.

2.5.12 Agricultural pollution (fertilizers, silage liquor etc), can seep into groundwater or enter water courses directly via run off. The increased nutrient loads can lead to an increase in the natural phytoplankton and associated eutrophication.

2.5.13 In order to protect the water environment, the UK balances demands to meet society's water needs with that necessary to maintain freshwater ecosystems. To

support this balance, evidence from both ecological observations and societal demands and behaviour are needed.

2.5.14 The Group on Earth Observations (GEO) supports the need for 'the production of comprehensive sets of data and information products to support decision making for efficient management of the world's water resources, based on coordinated, sustained observations of the water cycle on multiple scales', under the GEOSS strategic target 13.

Observation Requirements

2.5.15 The data used and needed to deal with the issues of food and water include:

- Water quality (nitrate, phosphate, eutrophication)
- Water availability (droughts, river flows, state of aquifers)
- Farmland biodiversity (species diversity and abundance)
- Pollutant emissions to air (carbon dioxide, methane, nitrous oxide, ammonia, particulates)
- Air quality (carbon dioxide, methane, nitrous oxide, ammonia, particulates)
- Climate change – impact on farming and the environment
- Weed monitoring
- Observations to support the production of climate change predictions and seasonal forecasts
- Forecasts of global food supply and demand
- Essential trace element availability
- Results from surveys of pesticide and fertiliser use
- Agricultural census data.

2.5.16 The available data reveal trends but are often collated in a way that does not show the effects of agriculture on, for example, water quality. Better spatial and temporal resolution and distribution of these data would enhance their value.

2.5.17 This is in agreement with the GEOSS strategic target 6 which aims to 'improve the utilisation of Earth observations and expanded application capabilities to advance sustainable agriculture, aquaculture, fisheries and forestry in areas including early warning, risk assessment, food security, market efficiency and as appropriate, combating desertification'.

HEADLINE ISSUE:

2.6 CONSEQUENCES OF ENVIRONMENTAL CHANGE FOR HUMAN HEALTH, WEALTH AND WELL-BEING

2.6.1 Defra's definition of well-being is:

'Wellbeing is a positive physical, social and mental state; it is not just the absence of pain, discomfort and incapacity. It requires that basic needs are met, that individuals have a sense of purpose, that they feel able to achieve important personal goals and participate in society.

It is enhanced by conditions that include supportive personal relationships, strong and inclusive communities, good health, financial and personal security, rewarding employment, and a healthy and attractive environment.'

2.6.2 Subtle environmental influences on human health and well-being are emerging. They include the human stress exerted by poor environments and the

opportunities that good environments offer for exercise and recovery. This work is in its early days; description and prediction of human-environment interactions will be informed by objective observations. However, to determine the causal links and beneficial interventions information on the location or spatial distribution of both the environmental and human health observations will be essential.

2.6.3 The impact of the environment on human health is an important area of work that is increasingly recognised as a vital cross-cutting issue. The UK Sustainable Development Strategy [17] highlights two overarching goals of *'living within environmental limits'* while *'supporting a strong, healthy and just society'*. These goals are explicit within various research councils and government departments.

2.6.4 GEO, under GEOSS strategic target 12 highlights the need to 'substantially expand the availability, use and application of environmental information for public health decision making in areas of health that include allergens, toxins, infectious diseases, food-borne diseases and chronic illnesses particularly with regard to the impact of climate and ecosystem changes'.

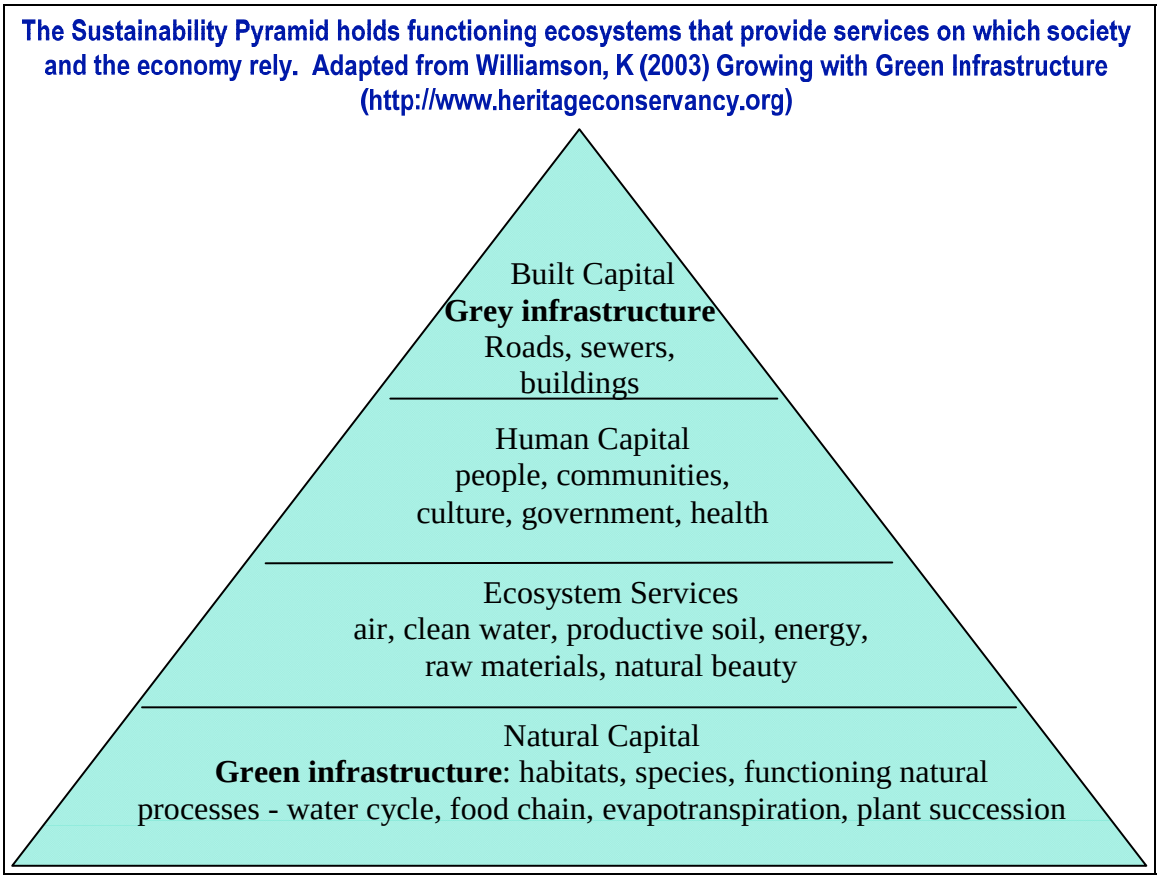
2.6.5 The UK-EOF aims to facilitate the collection of information to inform the understanding and prediction of how best to manage ecological systems for economic benefit and quality of life. As such, the framework includes environmental data that could be used to inform issues of 'well-being' [17] as well as human health.

Ecosystem Goods and Services

2.6.6 The UK presently needs a better way of capturing the inter-relationship between our environment (the *'Ecosystem Services'* and *'Natural Capital'* of Figure 3) and its effects on human health and well-being (the *'Human Capital'* of Figure 3).

2.6.7 Human wellbeing is influenced by the wide impacts of ecosystem goods and services; these range from global climate regulation by the oceans to food production on healthy, functioning soils. Environmental changes could alter the 'delivery' or availability of these goods and services, which in turn may affect some communities and their economic activities. To determine the relationships and the potential risks, environmental observations will need to be combined with socio-economic information.

Figure 3: Ecosystem goods and services in relation to human activity.



Green Space

2.6.8 Loss or degradation of recreational urban green space reduces the opportunity for people to take healthy exercise and could have implications for mental health. Quantification of the social value and impacts of green space need to be factored in when considering land use and development. If the physical and mental benefits of green space and the demographic preferences for its use are to be rigorously investigated, medically and statistically acceptable trials on accessibility to green space and local health will be needed. The UK Sustainable Development Strategy refers to a number of indicators of relevant information - such as the green spaces database - that will bring together information on features such as the location and extent of parks, allotments, city farms, playing fields and cemeteries.

Environmental Quality and Pollution

2.6.9 The quality of the environment can have direct effects on human health. For example, air pollution causes over 30,000 premature deaths in the UK each year. It also contributes to summer smogs, which reduce visibility and are hazardous to human health. A significant factor in determining environmental quality on a day-to-day basis is the natural variability in weather conditions (e.g. – wind direction), thus accurate modelling of such effects can help to mitigate impacts.

2.6.10 Water quality is important for both recreation and food supplies. Faecal bacteria or algal toxins can be harmful to both humans and animals and monitoring of their levels within designated bathing waters is required to meet EU directives. The

accumulation of toxins within shellfish can be fatal if eaten; again observations to meet statutory requirements are in place to protect consumers.

Diseases & Pathogens

2.6.11 Changing environmental conditions could result in the emergence of new diseases and pathogens or altered ranges and transmission of known diseases. Observations on the ranges of known vectors (e.g. mosquitos for malaria) coupled with spatially disaggregated, health data would provide an indication of the relationships between environment and disease and also identify changing disease patterns and inform assessments of the potential risks to the human population.

Pharmaceutical Discovery

2.6.12 The changing environment may provide opportunities for the discovery of new organisms, for example, the melting of ice in the Arctic, will make the region more accessible to map and survey organisms that could have biotechnological properties for the development of new pharmaceuticals or nutraceuticals[3].

Environmental Disasters & Weather Events

2.6.13 Environmental disasters, could lead to contamination and the spread of disease. They can also have a profound effect on the mental health of those involved. Observations on the risks of environmental disasters and their physical impacts could be used by those involved in the treatment of afflicted individuals.

2.6.14 High impact weather events such as: windstorms, flooding, drought and extremes of heat or cold pose risks to property, infrastructure and human life. Meteorological observations to predict and determine the intensity of such events will provide warnings and permit time for preparation and contingency planning.

2.6.15 Routine observations also underpin day-to-day activities, providing significant and ongoing socioeconomic value to the nation in enabling citizens to make best use of their environment.

Observation Requirements

2.6.16 These parameters, although not always collected directly to address human health issues, could be used to inform them. Such an undertaking may require monitoring of:

- Land use and quantity of urban green space
- The quality and quantity of urban tree cover
- Surface permeability (unsealed surfaces) and urban hydrology
- Air, soil or water pollutants (including from sewage and pathogenic micro-organisms).
- Disease vectors and emergence of new pathogens (in water, air and on land).
- Meteorological parameters required for the purposes of the Public Weather Service (PWS) offering and as the essential inputs to Numerical Weather Prediction (NWP).
- Weather and temperature in urban areas relative to historic data
- Ultra-violet light levels, in relation to vulnerable groups.
- Food security and nutrition
- The availability of essential trace elements e.g. iodine & selenium (for both human and animal health)
- Noise levels
- Environmental Disasters

[3] Nutraceutical definition: A naturally occurring food or food product isolated as a supplement, which is thought to have a beneficial effect on human health.

2.6.17 At present whilst there are some notable well developed national frameworks for collecting and disseminating data in some spheres (e.g. – meteorology), these often do not exist for other types of data. Consequently, the UK-EOF plays a vital role in assisting in such an aspiration. In turn, conservation organisations will be helped to measure health-related ecosystem goods & services as outlined in Figure 3.

2.6.18 Making environmental observations available in a format suitable for the health or other social sectors to use will not be easy. To do so successfully requires the linking of observations from known locations to those taken to meet the needs of social and health sciences. Recognition within the UK-EOF of the influence of the natural environment on health and well being and the need for improved partnership working will help us to improve understanding in this area.

HEADLINE ISSUE:

2.7 UNDERSTANDING, AVOIDING AND MITIGATING THE EFFECTS OF EXTREME EVENTS AND DISASTERS

2.7.1 The significance of extreme events for humankind has been summarised within the NERC Strategy [24]:

'Since 1990, over a million people around the world have died in natural disasters. Floods, droughts and earthquakes cause the most casualties. In addition to death and injury, economic losses from natural disasters have increased five-fold during the last decade, transforming natural hazards into a global issue. Total economic losses reported between 1991 and 2005 amount to more than $1 trillion. Climate change is likely to affect the frequency of some hazards, such as severe tropical storms, droughts and floods. Changing land use is increasing the impact of natural hazards. The increase in scope and frequency of natural disasters requires a step-change in efforts from the global community to address them.'

2.7.2 To achieve this, observations similar to those of climate will be necessary but must enable the recognition of extreme events - hot, cold, windy or wet. There will be extra emphasis on local events such as flooding, water shortage, pollution incidents and food shortages. All require specialist observational information, not only to manage immediate events but also to understand and mitigate those of the future. To reduce risk, it is essential that the susceptibility of human populations and their assets to hazardous events is monitored frequently.

Weather and Meteorological Extremes

2.7.3 Meteorological extremes have resulted in increased social and economic costs over recent years and remain a likely cause of loss of life or property in the UK over the coming decades. Furthermore, in a changing climate, the costs of extreme effects are likely to increase substantially.

2.7.4 Weather exerts a great influence on the built environment and on other natural hazards such as flooding, erosion, ground stability, landslides and wildfires. Measurements for extreme weather have a dependency on the standards set down by the WMO and parameters needed for Numerical Weather Prediction, and these underpin operational services such as the National Severe Weather Warning Service (NSWWS, provided by the Met Office as part of the Public Weather Service) for emergency responders. This information along with augmented targeted observations of meteorological variables will allow the optimisation of precipitation forecasts. Monitoring of wind speed and direction will verify and calibrate wind storm models and enrich storm forecasting.

2.7.5 Observations are needed to upgrade the quality of forecasting storm tracks and intensity, associated in the short term with numerical weather prediction and in the long term with improved climate prediction. These improvements will follow on from enhancements of ground-based observation such as radar, from expansion of spatial networks and from research-led technological improvements. To boost modelling capacity, airborne observations must be improved and remote sensing must be promoted; these developments will go hand-in-hand with better ways of assimilating data into models.

2.7.6 GEO's, GEOSS strategic target 14, agrees that enhanced observation capabilities are needed. It aims to 'close critical gaps in meteorological, ocean and related observations and enhance observational capabilities to improve weather information, especially for high impact events and in the developing world'.

Flooding

2.7.7 The susceptibility of catchments to trapping of waters will have to be surveyed and monitored. This will entail regular inspection of the quality and extent of flood defence measures, as well as assessment of the social and economic status of floodable areas. Periodic surveys of building structures and engineered surfaces will be needed.

2.7.8 Forecasting of fluvial flooding will benefit from targeted observation of water levels within catchments. To understand better the capacity of systems to transmit water and sediment, greater observation of altitude and bathymetry will be required.

2.7.9 In contrast to watercourses, pluvial flooding remains difficult to understand; model development is relatively immature because of the paucity of measurements of soil moisture and groundwater levels in built-up areas. Primary surveys of the permeability of engineered structures and surfaces are also lacking in many urban areas. Improved modelling will follow from monitoring of the flows of water and sediment through drainage systems during extreme events.

2.7.10 Groundwater monitoring should be increased in areas wherever groundwater affects water supplies or contributes to flood risk.

2.7.11 Populations close to the coast are commonly those most vulnerable to flooding. Present efforts in sea level recording should not be relaxed and improved forecasting of coastal floods from storm surges will depend on long term monitoring of sea level and coastal bathymetry.

2.7.12 The condition and extent of habitats such as wetlands, forests and salt marshes, which improve the resilience of the surrounding environment to flooding and can reduce the risk of erosion should be observed and mapped and their ability to retain water or reduce run off rates determined.

Tsunamis

2.7.13 Mechanisms for the monitoring and forecasting of storm surges already exist, but the forecasting of tsunamis may benefit from enhanced seismic and sub-sea pressure sensor networks that help predict impact in coastal areas. The effects of inundation in vulnerable areas may be forecast from detailed surveys of coastal bathymetry, topography and land use.

Coastal Erosion

2.7.14 Coastal erosion is a persistent issue. Improvements in its prediction depend heavily on undertaking baseline mapping and monitoring of processes, fluxes and ecosystems impacts occurring in the coastal zone, near shore and offshore. Such

measurements would include wave height & direction, coastal bathymetric survey, regular near shore monitoring of beach thickness & sediment flux, and geotechnical surveys of all materials in the coastal zone.

Geological processes and Natural Hazards

2.7.15 Our understanding of many geological processes that lead to disaster is significantly less mature than of the hydrometeorological phenomena. Observation and monitoring will always widen our understanding and contribute to the prediction of hazardous events such as earthquakes, volcanic eruptions and submarine landslides (often the cause of tsunamis).

2.7.16 Ground stability is a key concern in many parts of the world. Landslides are major killers during the earthquakes that commonly trigger them. However, the timing of landslides and the susceptibility of ground to subsidence are closely related to hydrometeorological extremes. This calls for measurements of geotechnical characteristics of susceptible formations, groundwater, pore pressures and other stability factors on potentially unstable slopes along with down-hole seismometers in networked boreholes which may provide crustal monitoring data useful for forecasting.

2.7.17 Although, measurements may not be directly relevant to the UK they will have relevance for some UK overseas territories; augmented seismic monitoring, particularly around fault systems where there are many other indicators of distortion or movement, is important when developing conceptual models for the future forecasting of earthquakes. Models of earth distortion, perhaps using GPS (Global Positioning System) or remote sensing such as interferometry, are needed.

Accidents/Disasters

2.7.18 Leakage from nuclear installations, both within the UK and abroad, is an issue of concern. However, there is no current UK statutory programme in place to cover any eventualities. Relevant observations are needed to ensure that sufficient contingency planning and if necessary emergency response are in place should there be an environmental disaster.

2.7.19 Prediction of toxic plume dispersal from industrial accidents, for example that seen during the Buncefield incident, is important when planning new installations and also for emergency services responding to events. Information on the boundary layer heights and parameters gathered for numerical weather prediction could be used to inform models which can predict dispersion routes.

2.7.20 In order to contribute to global disaster management and meet an international commitment as a WMO Regional Specialised Meteorological Centre (RSMC) for emergency response (for Europe and Africa), the UK (The Met Office) requires access to global meterological information (through the WMO).

2.7.21 Extra-terrestrial bodies such as meteorites and bolides may inflict extremely severe damage on the Earth. Though infrequent, such collisions - over geological time - have caused widespread and catastrophic environmental damage and change. There is a need to know the cost of any potential action against the benefits. The impact may be so severe that it must be ameliorated, or it may have such low probability that it could be ignored.

2.7.22 In summary observations related to extreme events fall into 3 generic categories:

- ***Prediction:*** Observations to increase our ability to predict the frequency, severity and areas at risk from extreme events or hazards - these are mainly

hydrometeorological, geological or even extra-terrestrial. This requires capability at different scales, from global to local and also the appropriate predictive capability using up-to-date 'background' information to identify signals, trends or triggers. Both the Met Office and the Environment Agency already provide many of these requirements, e.g. – operational weather and climate-related monitoring and prediction capability, including quality control and global standardisation of data requirements and formats through the WMO.

- ***Environmental Change*:** Observing environmental change (e.g. due to climate) and its impact on extreme event frequency, intensity and impact.
- ***Rapid Response***: there is a generic requirement for infrastructure and funding to permit rapid, investigative responses to observe and analyse the aftermath and impacts of extreme events. Such response may be rapid access to observations and data already taken for other purposes, for example satellite information, or it could involve the facility to mobilise resource to take additional measurements. Even though the information may be relevant to a local area, it could be incorporated into future risk monitoring, prediction and management systems, mitigation strategies and emergency planning.

2.7.23 This summary is echoed by GEO who under GEOSS strategic target 9, aim to 'enable the global coordination of observing and information systems to support all phases of the risk management cycle associated with hazards (mitigation and preparedness, early warning, response and recovery).

Observation Requirements

2.7.24 The observations required to meet the various needs associated with extreme events and disasters include:

- Meteorological parameters required for National Weather Prediction.
- Surveys of the state of flood defences, land topography and land use in areas at risk from flooding.
- Fluvial and ground water flows, levels and pore pressure (for the latter).
- Soil moisture content and drainage/permeability of ground surfaces.
- Habitat condition: wetlands, forests, saltmarshes, cliffs
- Coastal process information including wave height, direction, sediment movement, sealevel and bathymetry.
- Seismic activity
- Geotechnical characteristics of areas at risk from landslides and subsidence.
- Event monitoring and assessment

2.7.25 The prediction and monitoring of environmental disasters, when they strike, often affect several environmental domains and will require the rapid integration of information to provide an overall picture of the risk and impacts not only to human populations but also to the surrounding environments and ecosystems.

HEADLINE ISSUE:

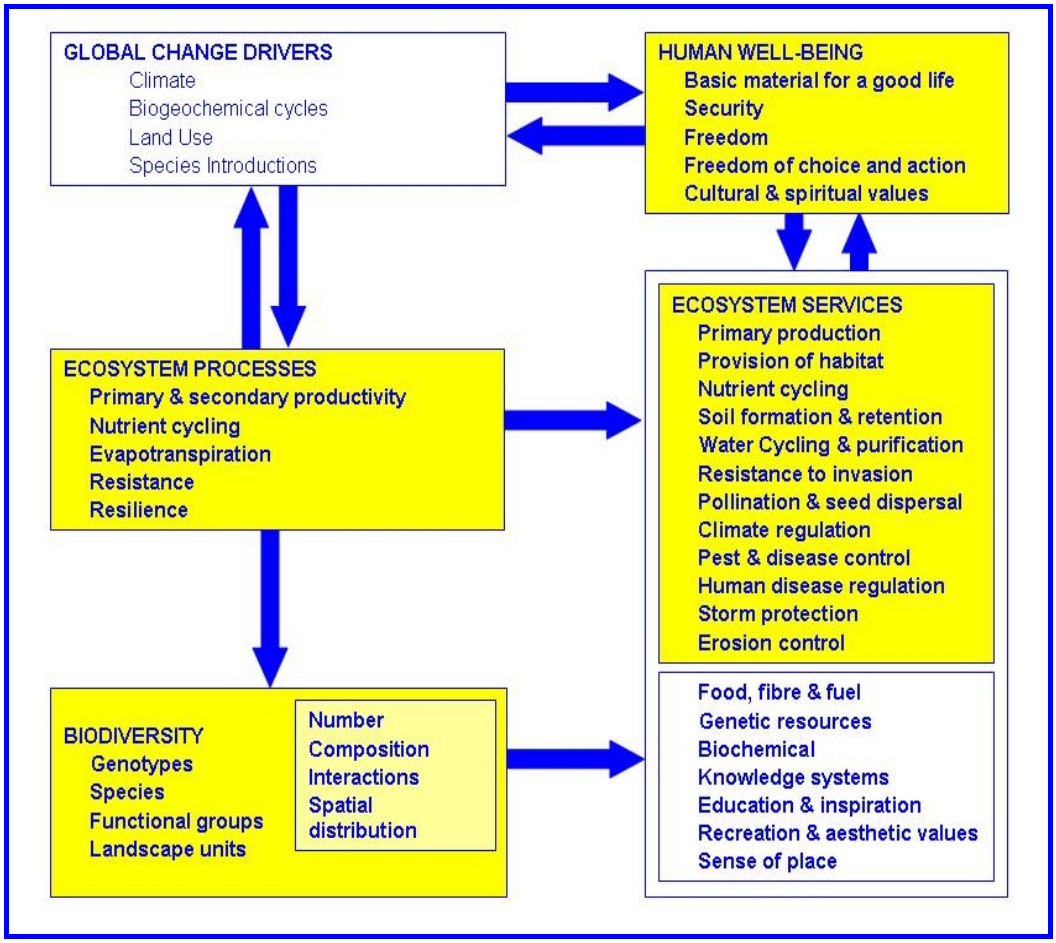
2.8 IMPACTS OF ENVIRONMENTAL CHANGE ON MARINE AND TERRESTRIAL BIOLOGICAL DIVERSITY, ECOSYSTEMS AND ECOSYSTEM SERVICES

2.8.1 Society has long sought to conserve biological diversity and has in many ways placed a high value on it. Policies have been framed and organisations have been created with the explicit goal of conserving biological diversity in the face of environmental change. It has been recognised that conservation of biological diversity is a vital component of sustainability and that it secures key services to humankind; as such it is fundamental to many questions in this Statement of Need.

Linkages Biodiversity, Ecosystems and Human Well Being (Services)

2.8.2 Figure 4, adapted from the GEO Biodiversity Observation Network [16] illustrates one view of the contribution of the biosphere to human well-being. The various interactions between the boxes in Figure 4 should remain dynamic and healthy; this is in part achieved by conservationists' safeguarding of biodiversity and ecosystem processes. These interactions are discussed and illustrated in further detail in the Millennium Assessment, Ecosystems and Well being [22].

Figure 4: A view to how biodiversity, ecosystem services and human well-being interact



(*Figure adapted from the GEO Biodiversity Observation Network [16]*)

2.8.3 The relationship between biodiversity and the ability of an ecosystem to deliver essential services is complex. None of the interactions is well enough understood to be able to predict future developments in the cycle with any certainty, but the availability and quality of biosphere information are often the most limiting factors in predictive modelling and scenario formulation. Observational data from the biosphere are needed to support conservation, to understand environmental processes and to predict future impacts on the wider environment.

2.8.4 A wider understanding of the processes that are occurring within an ecosystem will enhance our knowledge of the ecosystem functioning and the services

that it provides. Much contemporary debate focuses on defining and listing ecosystem services. From this three key generic questions emerge:

- How does nature contribute to the ecosystem service? This equates to setting priorities for conservation and monitoring
- How is the ecosystem service changing and what is the limit or resilience of the system to withstand change? This relates to the effects of a changing environment and the effectiveness of mitigating actions with regards to a socio-economic component.
- What could be done to maintain or enhance the ecosystem service? This identifies optional mitigating or management actions.

2.8.5 In order to answer these and related questions on a wide scale, GEO aims by 2015 to 'establish a worldwide biodiversity observation network to collect, manage, share and analyse observation of the status and trends of the world's biodiversity, and enable decision making in support of the conservation and improved management of natural resources'. In addition it also aims to 'establish a wide ranging monitoring capability for all ecosystems and the human impacts on them, to improve the assessment, protection and sustainable management of terrestrial, coastal and marine resources and the delivery of associated ecosystem services'.

Environmental Change

2.8.6 Observations relating environmental change to biological diversity therefore underpin some of the main questions. Observational data are needed to report on and evaluate the success of policies. Beyond these legal or quasi-legal obligations lies a need for broader observations to stimulate the formulation of conservational or more general environmental policies. All organisations and policy groups with a mandate for conservation of biological diversity have recognised these observational imperatives.

2.8.7 Analysis of observations is used to describe the status and trends of biological diversity and the services it provides. Observations must therefore be able to detect and aid the prediction of changing biodiversity. Effective nature conservation depends on stimulatory feedback from observation so as to re-focus work on threatened components of biodiversity. Trends in biological diversity need to be correlated or linked to environmental pressures and impacts in order to justify targeted intervention. The recognition that biological diversity provides fundamental services, vital to human well-being, underlines the importance of these observations.

Anthropogenic change

2.8.8 Long term surveillance may pick out unnatural change in biodiversity from the background of natural fluctuation. It sets the scene for understanding how changes in biodiversity correlate with other variables or how they depend on the ecological requirements of the component organisms. These long term time series play key roles in predictive modelling; they are rich resources for calibrating relationships built into predictive models of biodiversity and the environment.

Scale

2.8.9 To answer our questions we need to know the status and trends of broadly representative samples of species, soil fauna & flora, habitats and micro-organisms. We need observations at different scales according to their purpose, ranging from ten kilometre mapping when illustrating range changes to fine-scale or point data when dealing with rare or threatened species or habitats. The frequency of observations also depends upon need: operational actions, management and casework are the most demanding, often needing to be up-to-date or site-specific. Table 1 outlines Natural

England's need for species data and demonstrates very clearly the variety of observational requirements.

Table 1: Frequencies & scales of operational observation within Natural England

Purpose	Scale			Currency			Staff use		
	10 km	1 km	Site	Point	2 -10 yearly	Annually	Many	Specialist	Few
To inform targeting of agri-environment schemes		✓			✓		✓		
To support decision on scheme applications			✓	✓		✓	✓		
To support monitoring of agri-environment agreements			✓	✓		✓	✓		
To support condition assessment of designated sites			✓	✓	✓	✓	✓		
To support reporting of Natura 2000 favourable conservation status			✓	✓	✓		✓		
To support biodiversity indicators that form part of the UK indicator set		✓			✓	✓		✓	
To support European High Nature Value indicators		✓	✓		✓				✓
To support delivering and reporting on the England Biodiversity Strategy			✓	✓	✓		✓		
To inform policy development of adaptation to climate change	✓	✓			✓			✓	
To inform change assessment in the wider countryside	✓		✓		✓			✓	
To support site casework	✓	✓	✓	✓			✓		
To support decisions on licence applications		✓	✓	✓					✓

Biological Indicators

2.8.10 If the ecological requirements of components of the biosphere are sufficiently understood - including their interactions and responses to environmental pressures - it is sometimes possible to observe a sample of components as proxies for others or even to observe environmental pressures or physical parameters as proxies. This approach is most often seen in the development of 'indicators' that – taken collectively - are believed to measure progress towards overarching objectives such as the 2010 target set under the Convention on Biodiversity [2].

2.8.11 Things change; none of many previous horizon scanning initiatives identified ground level ozone as a concern, yet it has recently emerged as potentially damaging to the biosphere. Such unforeseen questions often stem from monitoring that is 'broad and shallow'. Other observations will probably reveal biosphere indicators sensitive to UK ground level ozone; changes in the pattern of these species and habitats will then feed into appraisal of the threat and into consequent mitigatory or preventive actions. The greater the sample of biosphere looked at in such programmes, the greater the chance of picking up sufficient predictive indicators for the whole biosphere.

Species

2.8.12 Changing climate brings with it new and important issues such as invasive alien species, which can be introduced intentionally (such as the American signal crayfish farmed as a food resource but escaped into the natural environment) or unintentionally via vectors such as ballast water or ship hulls. When established the invasive species can out compete native ones and alter the ecosystem dynamics.

2.8.13 The distribution and geographical range of native species are also changing and as a consequence new biological interactions are taking place. The outcome of these interactions and the consequences for ecosystem function is difficult to predict with confidence. However, this will be linked to the sensitivity of species at both the genetic and physical level and long term surveys of sensitivity could be related to genomic analysis set up for disappearing species.

Habitats

2.8.14 Coastal development and the building of coastal defences leads to a loss of natural coastal areas for habitation by both plant and animal species. This is exacerbated further by rising sea levels which submerge the remaining coastal areas thus leading to coastal squeeze.

2.8.15 Conservation management, either to meet legislative needs or otherwise, can lead to the protection of specified areas, such as Areas of Outstanding Natural Beauty (AONB) or Marine Protected Areas (MPA). Initial observations to assess the condition of the area and the species being protected should be undertaken along with periodic reviews to assess the effectiveness of the measures and record any changes.

Observation Requirements

2.8.16 General needs for information about the status and trends of biosphere components might be:

- A framework of surveillance schemes to measure status and trends within a set of habitats, species and ecosystem functions, and sufficient to help deliver the products or obligations required by national or international regulatory and conservational actions
- Assessment of the effectiveness of management or conservation measures, such as protected areas.
- Detection of pressures and their resulting impacts on the biosphere (invasive species, climate, urbanisation/development etc).
- Observation of components of the biosphere essential for short term ecosystem services and physical processes

2.8.17 Key components of the biosphere that provide essential life support and economic services must be monitored to detect trends, understand changes and predict their futures.

2.8.18 Many of the drivers of biodiversity are well understood and have fed numerous lines of surveillance, to the point of overlap and strong competition for funding across taxonomic groups. Henceforth, a more efficient and rational approach is needed towards sustainable surveillance projects: this is a short to medium term priority for any observational strategy.

HEADLINE ISSUE:

2.9 CLIMATE VARIABILITY AND CLIMATE CHANGE: CHALLENGES IN EARTH SYSTEM SCIENCE

2.9.1 It is widely understood that because of human actions the Earth faces further and perhaps unprecedented change. Multifaceted research and observational programmes continue to be necessary [32]. They show the historical context of current change, improve understanding of basic earth system processes, help to understand climate futures and deliver scientific evidence for policy.

2.9.2 Climate change is high on the political agenda, which is reflected in the establishment of the Department of Energy and Climate Change (DECC), the passing of the Climate Change Act in 2008 and the setting up of the Living With Environmental Change (LWEC) Programme to coordinate research into the effects of unprecedented change. Many other public and private organisations have climate change included within their strategic agendas.

2.9.3 GEOSS, under it's strategic target 9, aims to 'achieve effective and sustained operation of the global climate observing system and reliable delivery of climate information of a quality needed for predicting, mitigating and adapting to climate variability and change, including for better understanding of the global carbon cycle'.

Predicting and Detecting Climate Change

2.9.4 In order to understand the extent and implications of climate change it is necessary to characterise the state of the global climate system and its variability, which can arise from natural or anthropogenic forcing (or a combination of both).

2.9.5 Observations are crucial to this understanding and can be used to improve our knowledge of natural or anthropogenic changes and be fed into climate and earth system models. Indeed, it is impossible to model future climate reliably without supporting observations. Whether local, national or global, observations must be of better resolution in time and space and be complemented by clear information describing how they were calibrated and processed. GCOS-107 [29] documents these Climate Monitoring Principles, and observations conforming to them may be described as 'climate-quality'. In order to contribute and provide advice to the government (e.g. projections used as the basis for the Stern Review on the Economics of climate change) and international climate assessments or agreements (e.g. the proceedings of the UNFCCC and the Assessment reports of the International Panel for Climate Change (IPCC)), there is a need for the UK not only to observe the climate variables but also to maintain the predictive capacity to provide appropriate advice and direction.

2.9.6 Extensive national and international cooperation is a prerequisite for solving issues of impact and risk over a range of global and local scales. The observational ranges include, for example: Earth observation with satellites, polar stations & research vessels, river & stream flow recording, short term extreme events, local weather patterns, and routine meteorological and in-situ oceanic monitoring programmes ([29] and [32]). Without such observational data of diverse origins, the wide range of climate models may be neither calibrated nor validated. A more open and shared distribution of data will increase the efficiency of crucial model development, particularly where organisations can agree beforehand which data are optimal. GCOS have defined a set of principles when operating climate observing networks and identified specific parameters (Essential Climate Variables) which are required to support the work of both the UNFCCC and the IPCC.

2.9.7 Numerical weather prediction models and climatology can be used to assess what meteorological changes are occurring and what extremes or abrupt changes could be expected with varying climate. The World Meteorological Organisation (WMO) provides recommendations on measurements and their appropriate spatial coverage.

2.9.8 Climate change is not a linear process, changes could be dramatic and the effects catastrophic. There is therefore a need to understand the 'tipping points' or threshold effects.

2.9.9 The comparison of past climate records (paleo records) to modern day observations can provide insights into the potential trends and impacts.

Climate Feedback

2.9.10 To fully understand the impacts and effects of climate change, further knowledge of the feedback processes from all environmental domains are needed. Biological feedbacks on the climate system are not well quantified and their interactions along with measurements of carbon and nitrogen budgets, could be fed into models to allow effects to be predicted and change monitored.

2.9.11 Positive or negative feedbacks as a result of climate change need to be quantified, for example as the globe warms, sea ice and snow will melt revealing land and water, which are less reflective than ice (i.e. they have a lower albedo) and therefore absorb more solar radiation which contributes further to warming.

Impacts and Effects of Climate Change

2.9.12 There are both direct effects (e.g. changes to weather patterns) and indirect effects (e.g. changes to the way in which land is used or managed) of climate change. Both can impact the environment and human populations.

2.9.13 Changing climate will affect biodiversity, ecosystems and the associated ecosystem services. The degree of adaptation within the system is unknown as is the exact effect on the processes and therefore services. Observations to determine trends within a wide range of species could be combined with models to predict the ranges and population changes under various climate scenarios.

2.9.14 Changing weather patterns will lead to extreme heat or cold in certain regions. Increased flooding or drought affect the surrounding environment and could have impacts on water supply and quality. Assessment of these risks and impacts are necessary if we are to put procedures in place to enable us to adapt to climate change. Outcomes will need to be fed to the public as any adaptation strategies with regard to water consumption will rely heavily on their attitude to climate change, cooperation and behaviour.

2.9.15 Effects of global warming are already being seen with retreating ice fields and glaciers. The influx of fresh water into the polar regions could have profound effects on ocean circulation and has raised questions regarding whether the circulation, which is responsible for distributing heat around the globe, is slowing. Observations on the interactions of the oceans and sea ice are needed along with an assessment of the rate of change to both ice cover and ocean circulation.

Observation Requirements

2.9.16 Climate is controlled by many variables across several domains, however the atmosphere, oceans and polar regions play a major role. Observations are therefore needed across different domains and scales. Such observations include:

- Meteorological variables including air temperature, pressure, surface radiation, wind speed and direction, water vapour, air composition and upper air parameters.
- Marine meteorology (ocean currents, sea level, temperature, salinity)
- Geological records
- Sea ice and glacier extent, thickness and rates of change.
- Climate feedbacks including albedo, water vapour, biological feedback, soil moisture etc.
- Changing biodiversity and habitats – species, ranges and distributions.
- Water resources and quality

2.9.17 Many of the impacts of climate change relate to issues raised under other headline issues for example, increasing emissions and carbon are intrinsically linked to climate change and global warming. Ice shelf collapse due to warming could lead to rapid sea level rise as stated under extreme events and disasters.

2.9.18 Observations and the evidence they provide will be fundamental to the determination of any social response to climate change whether it be mitigation, adaptation or geoengineering to reverse the effects. Whatever, the response, its success will depend on public support, therefore relevant social data such as consumption trends will also need to be considered.

HEADLINE ISSUE:

2.10 STIMULATION OF SCIENTIFIC AND TECHNOLOGICAL ADVANCE AND INNOVATION

2.10.1 Scientists depend on technology to measure, observe, monitor and model the state of the Earth. Technology allows us to distribute and share the results of their work. Technological development is therefore an integral part of observational activity; science stimulates industry and industry helps science. The stimulation of the market for innovation is one key outcome of this symbiotic relationship.

2.10.2 The research community depends on several key areas of technology. Remote sensing plays a prominent part alongside informatics and telematics, with sensors based on satellites, aircraft, marine buoys or unmanned vehicles. Funders have a collaborative role to play in the development of both the instruments and the platforms that carry them. There are now opportunities to deploy intelligent field sensors or networks of sensors that work independently using wireless and other forms of data transmission. Reliability in the field is a key challenge for measurement in remote locations.

Drivers for Innovation

2.10.3 The main factors driving the stimulation of technological development in relation to environmental observations can be summarised as:

- ***Legislative***: UK departments, devolved administrations, agencies and businesses responsible for meeting legislative requirements play a key role; the implementation of various European directives has increased the range and diversity of the required environmental measurements
- ***Financial****:* development and implementation of new technologies can lower the costs of efficient collection, analysis and interpretation of measurements. Sensors with increased sensitivity to detect changes whilst using low power or smaller volumes of reagents and in-situ sensors that are capable of continuous monitoring would be advantageous for high frequency observations. These technologies could be coupled to finding parameters that link directly to management issues, therefore

reducing the need to monitor many different variables in the field. The technological improvements will enable the collection of more comprehensive datasets that can be used reliably in decision making.

- ***Socio-cultural*:** measurements need to be taken in a sustainable manner; the resulting information should be put into a form easily digested by the general public.

Government

2.10.4 The Government is committed to moving towards a low carbon economy. In doing so it has pledged approximately £10 billion to the development of technology and products to help the UK reduce their carbon emissions over the next 3 years [18]. The Department for Business, Innovation and Skills (BIS)[4] have recognised that to succeed in a rapidly changing world the UK must develop skills, do world class research and apply this knowledge for an innovative and competitive economy. In conjunction with the Department for Energy and Climate Change they have developed a strategy to ensure that UK businesses remain competitive and benefit from the change to a low carbon economy.

2.10.5 The Department of Transport (DfT) aim to provide an efficient transport system for all whilst finding a balance between the economy, environment and society. Their objective is to reduce emissions of carbon dioxide and other greenhouse gases from transport, thus helping to avoid dangerous climate change.

2.10.6 The success of any new technologies in meeting government requirements will need to be assessed and the collection of observation data will play a vital role in this process. The possibility of developing direct links between managers and real-time information (for example from remote sensing) via web platforms should be explored as this would reduce the time scales for decision making.

Collaboration Initiatives

2.10.7 Initiatives for collaboration of government and businesses have been set up. The UK Forum for Environmental Industries (UKFEI, http://www.ukfei.co.uk/) facilitates stronger links and cooperation across the English regions and the devolved administrations. Its focus is on increasing the industrial knowledge base, encouraging good environmental practice and skill development, and working in partnership to inform national and international policy.

2.10.8 Knowledge transfer networks are another mechanism. The Environmental Knowledge Transfer Network (E-KTN) recently produced a business case for the enhancement of UK technological capability within the area of Environmental Monitoring and Forensics [10].

2.10.9 The E-KTN identified three areas in which technological innovation could be involved in gathering of environmental data:

- Measurement and sampling devices, such as those required for specific environments e.g. within cold polar regions or those which can be used for a wider range of information such as remote sensing techniques and satellites.
- Network communication technologies
- Environmental modelling which can improve the capacity of scientists to represent, understand, predict or manage the environment. However, observations, to

[4] The Department of Business, Enterprise & Regulatory Reform was merged with the Department for Innovation, Universities and Skills on 5th June 2009 to form the Department for Business, Innovation and Skills.

validate and further develop the models are vital if we are to have the confidence to act upon the information generated.
- Data management software.

2.10.10 The E-KTN recognised some current barriers to the development and uptake of technologies: gaps in knowledge and information on what is needed; costs associated with new technologies; and a lack of appreciation of the value to be gained from environmental evidence. It is unlikely that these barriers will be overcome without increased investment, itself linked to a need for increased uptake of technologies and an associated better return for investors.

2.10.11 Other factors were identified which, if addressed, could lead to significant innovation:

- Improved knowledge of what measurements will be required and how to use them
- Improved knowledge and access to existing datasets
- Development of field calibration methods with a view to self-calibrating and self-validating in-situ tools
- Improved data interpretation software
- Standardisation of metadata and datasets.
- Changing industry's perception of gathering environmental data from a simple compliance activity to one capable of generating commercial benefits
- Accelerating the development and application of novel and effective measurement technologies within a variety of issues such as source determination, ecological health assessment and new pollutants
- Aiming for joint regulatory and industrial understanding of the demands of environmental observation. Thereafter, environmental measurements initiated by regulators and delivered by industry will feed back efficiently into better regulation.

3 FACTORS DRIVING ORGANISATIONS AND INDIVIDUALS TO MAKE ENVIRONMENTAL OBSERVATIONS

3.1.1 Observational programmes develop in response to numerous organisational or individual factors which may be international, national or local. Some are complex, their range extending from statutory duties of public agencies through the commercial or community interests of business to very personal collection of data by volunteers. It is essential that we understand these factors and harness the knowledge and enthusiasm that pervade them.

3.1.2 Box 3 gives a simple overview of some of the factors that drive observation - categorised according to Policy, Science, Voluntary and Industry factors (PSVI – see Figure 5). In truth, factors are more intricate and there can be significant overlap between sectors and categories.

Box 3: Overview of key elements driving observations, according to sector

Policy: development and delivery
- International obligations
- National obligations
- Evidence-based policy making
- Research and development
- Investigations and legal evidence
- Management of the environment
- Local issues
- Public outreach, communication and understanding

Science: funded research centres and universities
- Science investigations
- Research and development
- Technology development
- Teaching
- Near-to-research consultancy
- Knowledge Transfer

Industry
- Process control
- Regulation-driven monitoring
- Environmental impact
- Research and development
- Non-statutory monitoring

Voluntary sector
- Evidence for campaigns
- Targeted knowledge
- Research
- Coordinated observations
- Public outreach, communication and understanding

3.1.3 The public sector funds observations for many reasons: fulfilling national and international commitments to environmental protection and management; obtaining

evidence for policy decisions; research and development; and reporting the state of the environment.

3.1.4 As well as dealing with key environmental questions, public sector organisations fulfil a number of core national or international statutory obligations that determine the shape of their observation programmes. For example, the Environment Agency and its equivalents in the devolved administrations - the Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment Agency (NIEA) - have statutory duties to monitor the environment and provide advice to ministers. As the 'competent authority' for a number of European Union (EU) Directives, each is obliged to undertake large statutory monitoring programmes over a range of variables.

3.1.5 Each of the devolved administrations is responsible for the implementation of the various EU environmental directives. The directives do not stop at the borders and organisations such as SNIFFER (Scotland and Northern Ireland Forum for Environmental Research) play a major role in the implementation and design of suitable observation programmes. In Northern Ireland the NIEA must also consider international cross border environmental issues, for example, under the Water Framework Directive (WFD), there are commitments to develop common environmental indicators reported on a regular basis with the Environmental Protection Agency in the Republic of Ireland.

3.1.6 In respect of meteorological and climatic provision of core services and obligations, the Public Weather Service is the means by which the Met Office fulfils its Public Task as the UK's National Meteorological Service. The services outlined within this obligation conform to the WMO-defined Basic Service: to discharge its responsibility under Government to protect the life and property of UK citizens, to contribute to their general welfare and quality of their environment, and to meet the UK's international obligations under the Convention of the WMO and other relevant treaties and obligations.

3.1.7 The Met Office also use observational information to provide a variety of services to the government, for example emergency response such as dispersion modelling of hazardous plumes via their Emergency Monitoring and Response Centre (EMARC) or Climate Advice and predictions. The Hadley Centre is recognised as one of the world's leading climate change research centres; co-funded by stakeholders including Defra and DECC. The Hadley Centre provides in-depth information and advice to government on climate change issues (e.g. – projections used as the basis for the Stern Review on the Economics of Climate Change, UKCP09 and contributions to international proceedings of the UNFCCC and the Assessment Reports of the IPCC).

3.1.8 The Statutory Conservation Agencies, Countryside Council for Wales (CCW), Natural England (NE), Scottish Natural Heritage (SNH) and the NIEA also advise government. They protect and improve the natural marine and terrestrial environments (landscapes and wildlife) of their respective countries. The Joint Nature Conservation Committee (JNCC) shoulders the UK and international responsibilities for these agencies and advises government on national and international nature conservation. To meet their responsibilities, each agency carries out observation and surveillance programmes, often using large amounts of volunteer manpower.

3.1.9 Environmental laws and permit systems have been implemented to protect and improve the UK and global environments. Observations demonstrate compliance to specified environmental standards or can be used to enforce legislation e.g. To fulfil their obligation under the Environment Protection Act Part IIa, Local Authorities use observations of soil chemical element content to define contaminated land. The same

observations can be used to improve legislation by helping to determine more appropriate guidelines. Significant amounts of information are therefore collected on land and sea and most is ultimately placed in the public domain for additional purposes such as modelling, setting future standards, research and development.

3.1.10 The research councils (especially the Natural Environment Research Council (NERC) and their sponsored organisations embark on significant observational programmes to fulfil their duty to undertake and promote science. The NERC Strategy [24] has provided the framework for some of our key questions. Significant observations are also made outside the NERC themes, often in pursuit of innovative technologies or emergent research areas. Many of these areas cut across several research councils and involve the development of large infrastructure and facilities. Such programmes are listed within the Research Councils UK (RCUK) Large Facilities Roadmap [26].

3.1.11 Many research centres and similar organisations, in addition to their staple interests, work for the public and private sectors - monitoring, analysing and handling data, working on development and investigation. Some hold considerable amounts of environmental information and have great expertise in observational techniques and data manipulation.

3.1.12 Universities too act as commercial consultants and do observational work for the private and public sectors, filling a niche that may overlap with the research centres and agencies. The collection of environmental data for undergraduate and postgraduate projects can provide important environmental information and lead to new initiatives.

3.1.13 There are a number of research trusts and charitable organisations that focus on specific scientific areas. For example, the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), which observes oceanic plankton over long time periods, has charitable status and receives money from various public and private sponsors.

3.1.14 Private businesses do a lot of monitoring to control processes, to gauge their environmental impacts, or for research & development. The *'polluter pays'* principle applies increasingly and businesses are often expected to monitor to demonstrate their compliance with permits. Businesses are also encouraged to go beyond regulation, minimising their impact while also informing the public about it.

3.1.15 An extensive UK environmental business sector is developing and contains large multinational companies through to small niche consultancies. Environmental consultants may be paid for impact assessments, which often require analysis of previous data or specialised monitoring on behalf of public or private sector clients. All may therefore collect or hold substantial amounts of data. These form an important resource that might be used more efficiently.

3.1.16 Environmental trusts are increasingly important in certain observational areas. Examples are the landfill trusts, sponsored by the landfill tax and the waste industry, and the similarly constituted rivers trusts. These bodies receive money from a spectrum of stakeholders and employ professional scientists to focus on specific areas, including river ecology, contaminated land and soils.

3.1.17 Environmental charities such as the World Wildlife Fund (WWF), Royal Society for the Protection of Birds (RSPB), Friends of the Earth and Greenpeace collect important and large amounts of data in their particular areas of interest. These bodies often catalyse attitudinal change with campaigns backed by their own robust observations. The RSPB, for example, holds a wealth of information about birds,

habitats, land use and biodiversity trends in the UK and abroad. Government often uses charities' information as a key indicator of the health of our countryside.

3.1.18 Many individual experts make observations and draw together important datasets. Some contribute to local nature or wildlife trusts and organised surveillance such as dolphin or whale watches off the UK coast. There are specialist observations and datasets covering topics as diverse as ponds, bats, fungi, birds, butterflies, marine conservation and rainfall. Extensive datasets are held individually or uploaded into more centralised systems, such as the National Biodiversity Network (NBN).

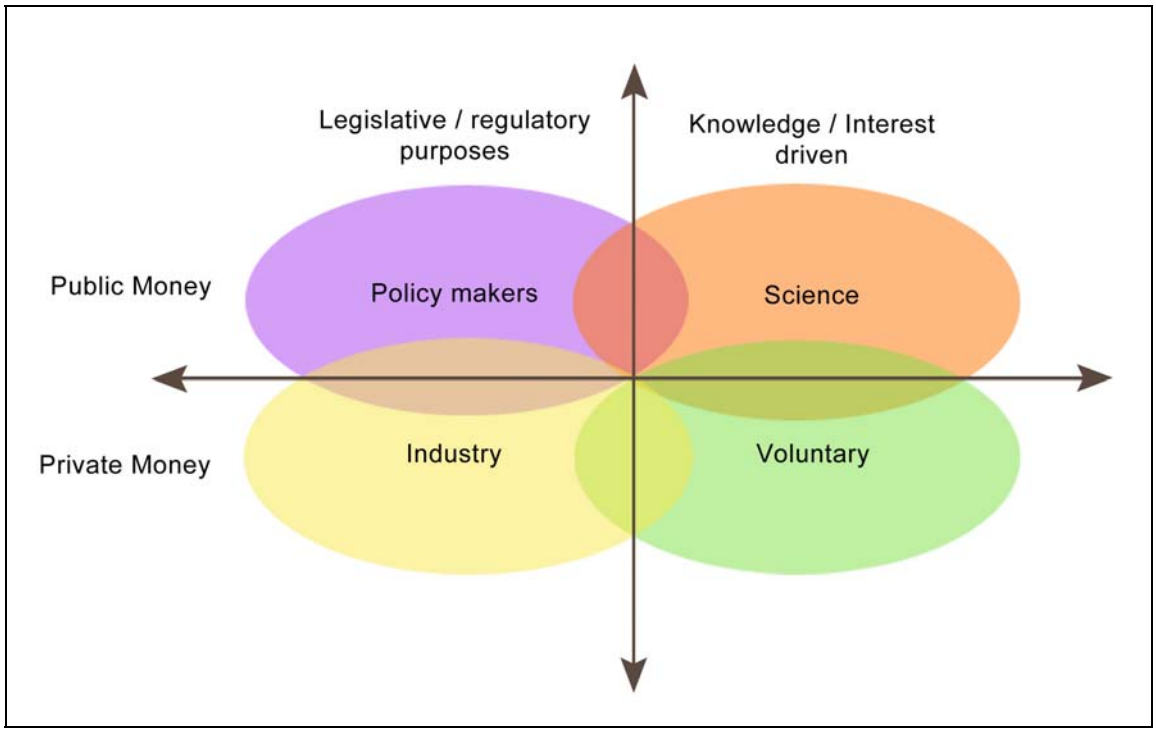
3.1.19 Non specialists often play a role in observing environmental change, for example each year the BBC encourage the public to contribute to 'Springwatch' and make observations to assess whether spring is coming earlier and whether species are suffering or benefiting. The Open Air Laboratory (OPAL), run by the Natural History Museum and Imperial College, organise activities and environmental surveys in which the public are asked to participate to help scientists assess the natural environment of the UK. In addition those that work closely with the environment, such as farmers or landowners often observe change over time and although this may be anecdotal evidence, if collected in a rigorous way then it can be evidence that the public readily relates to.

3.1.20 In summary, a very broad spectrum of UK observational activity contributes to our stock of environmental information. The observational community is diverse and, although sharing many aspirations and views and often working towards common goals, it contains little day-to-day interaction. There is only a limited mutual understanding of issues, constraints, restrictions, funding sources, or accountabilities.

The Policy, Science, Voluntary and Industry (PSVI) Model

3.1.21 The UK-EOF has explored a number of cluster models as ways of grouping the observational community, with a view to targeting communication and improving interactions. No single grouping is fully satisfactory but, for the purposes of this review, a focus on who monitors what domains for what reasons seems most appropriate. The PSVI model of Figure 5 represents one such view of this intricate community.

Figure 5: The Policy, Science, Voluntary and Industry (PSVI) Model: clustering the observational community and understanding its interaction



3.1.22 The PSVI model illustrates the combinations and interactions of the sectors of UK observational capacity. Other groups using the information but not themselves generating it are implicit within such an analysis. They include the modelling community, information providers and report writers. Nevertheless, these clusters and groupings may be secondary to the main need to develop the community as a whole, drawing together appropriate specialists on common issues.

3.1.23 From this viewpoint, it is important to include all contributors - public and private - in a Statement of Need and its future application, to recognise their different motivations for observing the environment.

4 OBSERVATIONS ACCORDING TO ENVIRONMENTAL DOMAIN

4.1 OVERVIEW

4.1.1 In addition to the key issues and statutory or organisational obligations, the need for observations may be seen from the perspective of environmental domains. This chapter looks at issues that depend on observations, from the standpoint of each environmental domain.

The list of domains has been derived from several sources, particularly the UK-EOF 2008 workshop & the ERFF Research Classification Schemes. Box 4 summarises the approach.

Box 4: Observations according to environmental domain

- Atmosphere (4.2)
- Hydrosphere
  - Marine (4.3)
  - Freshwater (4.4)
  - Groundwater (4.5)
- Cryosphere (Ice and frozen environments including the polar regions) (4.6)
- Lithosphere/Pedosphere (Soils and geology) (4.7)
- Biosphere (4.8)
- Societal Issues (4.9)

- Interfaces between Domains (4.10)

(further details are given in the relevant numbered sections)

4.1.2 Detailed information was gathered in a series of workshops held over Summer 2009 using the template illustrated in Appendix D: Example of an information gathering table which combines the perspectives of headline issue and environmental domain. The surrounding context of national and international obligations and commitments that involve observations are set out in Appendix E: international and national observational obligations.

4.2 ATMOSPHERE

Weather forecasting

4.2.1 Weather forecasting and its supporting observations are invaluable for guiding human activity - farming, military operations, air travel, insurance and many more. Observational data is required in order to provide a Public Weather Service (PWS), the outputs of which are essential to a wide range of customer services such as the National Severe Weather Warning Service, public media broadcasting and aviation/marine forecasting services.

4.2.2 Forecasting of severe weather events needs global information across international boundaries – there is therefore a need for the UK to contribute to the WMO Observing system. Water resources are also dependent upon precipitation and observations on the level of the water table are required for management and policy. The accumulated information is extremely important and improved records and understanding of extreme events will (and already do) help to protect against natural disasters.

Upper Atmosphere

4.2.3 The upper atmosphere is critically shaped by interactions of the troposphere, stratosphere, mesosphere and thermosphere. Fundamental understanding of ozone depletion, ultra-violet penetration and other upper atmosphere phenomena depends on significant support and infrastructure for the polar survey bases. The information generated will help our understanding of climate feedbacks and can also be used when assessing effects on human health.

Urban Heat Islands

4.2.4 Localised phenomenon, should not be forgotten. Urban areas are known to be warmer than the surrounding areas. It is unknown whether the localised weather is affected by these 'urban heat islands', this could be answered by the taking of localised meteorological observations.

Air Quality

4.2.5 Air quality is a major factor affecting human health, especially in urban areas. Fine particulate matter, as well as other pollutants such as oxides of nitrogen, sulphur dioxide and micropollutants are responsible for many premature deaths both in the UK and across Europe each year.

4.2.6 Air is polluted by individual industrial sources, diffuse sources (transport, agriculture, domestic activity, volcanoes) and large scale flows across national borders. These can all give rise to wide-scale events of poor air quality and need to be monitored and assessed. Air quality is monitored by local authorities to meet National Air Quality Objectives and also statutory EU requirements; however there is a need for integration across different networks which currently supply data to different places.

4.2.7 Understanding the relationship between air quality and transport requires observations for both monitoring and predictive purposes. All transport applications have a dependency on the parameters required to support global, regional and mesoscale numerical weather prediction (NWP). Many of the areas declared as 'Air Quality Management Areas' by Local Authorities are linked to major roads or transportation routes, therefore observations can determine the impact of any action to improve emissions/air pollution. Aviation emissions are not currently included within the Kyoto protocol but there is a view from climate scientists that they should be quantified.

4.2.8 Air quality can also be affected by other activities such as the burning of biomass which releases aerosols and photo-oxidants into the atmosphere. There is a need to monitor these events and assess the impacts that they may have on both the environment and human health.

4.2.9 Large scale air movements transfer and deposit pollutants across borders and require complementary monitoring programmes. Because of geographic scale, such monitoring is normally agreed internationally although it often has national implications. The International Convention on Long Range Transport of Air Pollution covers cooperation on monitoring and control of hazardous pollutants carried across borders by air flows. The measurements help to assess the magnitude of the problem and to calibrate chemical transport models.

4.2.10 International organisations have long deemed it important to measure fluxes to the atmosphere so as to set in place appropriate policy and regulatory regimes for control or mitigation. This fundamental approach has been reinforced by legislation such as the recent (2006) European Pollutant Release and Transfer Register (EPRTR) which reinforced and extended earlier EU commitments arising from the European Pollutant Emissions Register and the Large Combustion Plant Directive. Some carbon

dioxide emissions to atmosphere are now alternatively quantified through emissions trading. The EPRTR covers arisings from waste and emissions of many chemicals from industrial sources to air and water. These flows must be set in the context of those from natural and diffuse sources, which have to be quantified by extensive fieldwork and the study of specific processes.

4.2.11 When considering air pollution the scale of the observations needs to be taken into account. Satellites can be used for global scale issues, but are not good for local scale issues such as Particulate Matter (PM_{10}). Integrated measurements could be used to help determine the extent, areas and hence people most at risk from long range transport of air pollution.

Climate Change

4.2.12 The atmosphere and climate change are inextricably interlinked. Each affects the other. Sophisticated monitoring programmes are needed to understand weather systems in the short and long terms. Such information will inform the UK's contribution to WMO intergovernmental initiatives with its long-term monitoring of Essential Climate Variables. Observational programmes should cover physical and chemical factors, various temporal scales, global predictions and trends; all require substantial infrastructure and sensor networks.

4.2.13 In-situ measurements of greenhouse gases including carbon dioxide, methane, nitrous oxide and CFC's (ChloroFluroCarbons) are necessary to determine emissions and uptakes. This information, along with the fluxes, sources and sinks, are required from both the UK and overseas territories to contribute to the United Nations WMO Global Atmosphere Watch, validate UN Framework Convention on Climate Change (UNFCCC) emission declarations and also to better understand climate feedbacks such as the relationship between increasing temperature and carbon dioxide and methane. In addition to in-situ data, satellite information for carbon dioxide and methane is also important and there is a need to integrate satellite and ground measurements.

4.2.14 These atmospheric considerations also apply to the oceans and cryosphere. Further links between the domains include the use of atmospheric measurements of Argon/Nitrogen ratios to determine whether the oceans moderate atmospheric temperature and at what rate.

4.2.15 Our international obligations are set out by the UNFCCC and include maintenance and improvement of the national and Global Climate Observing System (GCOS) [30]. It is imperative even for our national needs that we contribute to UNFCCC assessments and GCOS, as well as IPCC assessments and observations of climate change, its impacts, and prospects for adaptation and mitigation.

Climate Impacts

4.2.16 Important and unresolved questions relate to the expression of climate change by extreme events such as floods, droughts, storms and heat waves, all of which are of economic and human significance and relevant to policy. Throughout the world, satellites, weather balloons and land stations are essential contributors to analyses of climate and climate scenario models.

4.2.17 Measurements to assess climate impacts are required on both regional and global scales, however both require different observation strategies. Observations more frequent and spatially-detailed than specified by GCOS-92 [30] and GCOS-94 [31] are needed within individual countries if extreme events are to be properly described, understood and modelled. For example, analysis of events like the Boscastle (2004) and

Ottery St Mary (2008) floods demands observations at a resolution of a kilometre or so. Correspondingly, future national assessments will be needed in the style of the UK Climate Impacts Programme UKCIP08 [28].

Observation requirements

4.2.18 The observations required to inform the issues associated with the atmosphere are diverse and cross cutting. They include:

- Air Quality – monitoring of hazardous pollutants – fine particulate matter, oxides of nitrogen and sulphur dioxide.
- Meteorological variables – temperature, pressure, wind, precipitation.
- Green house gas concentrations, their sources and sinks (via satellite and in-situ data).
- Argon/Nitrogen ratios
- Ozone and UV levels.

4.2.19 Many of the issues require the measurement of the same parameters. However, depending on the issue, the scale and spatial distribution of the measurements may vary.

4.2.20 Many of the issues associated with the atmosphere are intrinsically linked to society, with respect to both impacts upon (health and climate) and behavioural (attitudes to transport and pollution). Information generated by relevant observations will therefore also be of use to social and economic scientists.

4.3 HYDROSPHERE – MARINE

Sea-level rise

4.3.1 The majority of people live in coastal areas where many large cities and low-lying areas are vulnerable to marine flooding both in the UK and world-wide. Physical and chemical evidence of a changing climate is already apparent. Enhanced melting of land-based ice sheets, which due to uncertainties were excluded from the IPCC predicted rates, and thermal expansion of the ocean are raising global sea level. As a result sea level rise may be occurring more rapidly than the IPCC scenarios [23] suggest. Prediction and understanding of these effects depend on the maintenance of long-term sea-level recording systems of carefully controlled quality.

4.3.2 Areas of transition such as shores, beaches, salt marshes and mud flats are particularly significant for natural flood defences, bird feeding grounds and fish spawning areas. All require specific monitoring programmes.

Ocean circulation

4.3.3 Measurements of ocean salinity, temperature, ice cover and currents are needed to assess the reality and potential of perturbations to circulation patterns, with associated climatic instability. Due to the natural variability within ocean measurements, long term data to eliminate 'the noise' and identify trends are needed to gain a quantitative understanding of these factors.

Biogeochemical cycling

4.3.4 Understanding the role of the marine environment in maintaining biogeochemical cycling of nutrients, carbon and other important elements of climate requires long term data sets. Although changes are subtle, programmes which investigate the role of the marine environment as a source or sink of carbon dioxide and other greenhouse gases, are needed to construct and validate models of future changes. To achieve this rigorous measurement programmes with international

collaboration are required. Such programmes will need to be aligned to inform and pull information from other environmental domains.

With the onset of techniques and technology to mitigate the release of carbon dioxide, observations to inform and monitor the impacts of carbon capture and storage are required, along with those specific for other mitigating actions such as iron fertilization and other geoengineering activities.

Ocean Acidification

4.3.5 Acidification is a known effect of the uptake of atmospheric carbon dioxide by the oceans. Long term measurements will enable the natural and anthropogenic variability to be distinguished and increase knowledge on the ability of the system to cope with rapid change.

Biological Diversity

4.3.6 Long term data sets covering large geographic areas are important for illuminating the biological diversity, assessing whether it is changing and providing information on the ecological health of the seas. The UK's historical observations of plankton populations and the MarClim project are prime examples of how such records help to manage fish stocks, reveal the potential for harmful algal blooms, or relate climate to other parts of the marine ecosystem. However, this information is yet to be used to answer fundamental questions regarding the resilience of the marine ecosystem and its ability to absorb impacts such as those caused by population growth.

4.3.7 Specific observations on species can be used to determine whether distributions are changing and by coupling this with other information, such as climate variables or the appearance of non native species, the drivers of change can be identified.

Pollution

4.3.8 The sea is the sink for most industrial and agricultural chemicals, which can result in pollution by hazardous substances or nutrient enrichment and eutrophication. This can have adverse effects on both the environment and human health, for example harmful algal blooms have been implicated in coastal incidence of asthma and pharmaceutical substances with endocrine disrupting characteristics are of concern in estuaries and in coastal environments. Transition zones between fresh water and the sea may be particularly vulnerable to pollution because they support productive yet vulnerable ecosystems, sometimes of high conservation value.

4.3.9 International organisations have long sought to quantify fluxes so as to install policy and regulatory regimes for control or mitigation. This fundamental system was initially sculpted by international conventions such as the Joint Assessment and Monitoring Protocol of the Oslo and Paris Commissions (OSPAR) but is now reinforced by regulations stemming from legislation such as the Water Framework Directive (WFD) and the European Pollutant Release and Transfer Register (EPRTR).

4.3.10 Atmospheric deposition of some marine pollutants exceeds riverine inputs; monitoring of the magnitude and trends of this deposition is essential for a balanced account.

4.3.11 Litter can be problematic within the marine environment. Marine organisms can become entangled in or ingest the litter, both of which can result in death.

Fishing and Mariculture

4.3.12 Human consumption of fish and unsustainable harvesting has led to the depletion of some fish stocks. Climate change may also play a role in altering the profitability associated with some species. Therefore observation programmes are needed to assess the status of both the commercially viable and the potentially viable stocks. Mariculture is playing an increasing role in providing fish and seafood for human consumption, however there are concerns over potential impacts of disease and food supply.

Use of the Sea

4.3.13 Increased intensification of uses of the sea for tourism, leisure and recreation as well as infrastructure development or extractive activities to support economic growth (aggregates, shipping, fishing, oil and gas, renewable energy) put pressure on the marine environment. These activities, along with any associated impacts such as noise or heat generation, must be managed to ensure there is minimal environmental damage.

4.3.14 Increased understanding of the marine carrying capacity and the effects of cumulative pressures (at the regional seas level), will lead to better informed spatial planning and management decisions for marine and coastal waters.

Coordination, legislation and obligations

4.3.15 Many marine observations such as annual fish stock assessments or bathing water quality results are regularly incorporated into marine policy. There are periodic reviews of all data such as Charting Progress (2005) [4], Scotland's Seas (2008) [15] and Charting Progress 2 (due in 2010). These assessments rely primarily on data from programmes identified in the United Kingdom Directory of Marine Observing Systems catalogue (see http://www.ukdmos.org/welcome.asp).

4.3.16 The UK has obligations under the Habitats Directive and Natura 2000, to identify and designate Marine Protected Areas. In order to do this observations regarding the status of habitats and species are necessary, along with the appropriate programmes to assess the effectiveness of such areas.

4.3.17 The WFD requires substantial integrated monitoring and catchment management of estuaries and the coast, while the Marine Strategy Framework Directive (MSFD) will expand the area of routine surveillance to all UK seas, with a statutory requirement to achieve 'good environmental status' by 2020. As the seas have no boundaries, there is a need to work in collaboration to develop and observe common environmental indicators, with the Republic of Ireland.

4.3.18 The UK Marine Monitoring & Assessment Strategy (UKMMAS) has been conceived from a perspective of governmental policy, dealing with what should be measured in coastal waters, shelf seas and the open ocean.

The strategy takes a holistic view that, to measure progress towards the UK vision of *'clean, safe, healthy & productive and biologically diverse oceans and seas'*, a complex set of physical, chemical, biological and socio-economic information is needed. Although many such observations are already underway with integrated data management and assessment, significant gaps have been identified. Among them are: a programme to measure ocean acidity (pH) and carbon dioxide exchanges; survey of the abundance and impacts of marine litter - mainly plastic debris; and high-resolution mapping of seafloor topography and benthic communities.

Until now, UKMMAS has focussed on national waters or on associated international legislative obligations and commitments. In future, it may be desirable – in the wider context of the Marine Science Coordinating Committee (MSCC) – to embrace the national value of UK global monitoring activities such as Argos profiling floats, hydrographic time series in the Arctic & Southern Oceans, deep-ocean observatories, and biogeochemical measurements on long oceanic transects. This information and that collected via international collaborations are needed to understand the worlds oceans and polar regions and are required to validate and calibrate climate prediction models. At an international level, many of these activities are guided through the coordination of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM).

Technology and Sensors

4.3.19 Remote sensing and satellite imagery are already widely used to observe the sea (e.g. – satellite-borne applications such as the Jason series) but could be developed further. Airborne sensors need to be corroborated or verified with ground truth, and satellites do not see far below the sea surface. It follows that programmes of remote and in-sea sensing should be well integrated to make the most efficient use of the rich geographical data streams from these sources.

4.3.20 Many other techniques are at the research stage, pre-operational, or not yet fully exploited: subsea gliders, autonomous instruments on moorings, benthic landers, data buoys, ships of opportunity, molecular-based taxonomy, miniaturised sensors to track animals or to be carried by them, online ways of visualising data, new ways of retrieving data – these and others will lead to new databases and new insights into how the sea works.

Observation requirements

In summary the observation requirements to answer marine environmental issues and questions include:

- Salinity, temperature, currents, nutrients, carbon (partial pressure of carbon dioxide – pCO_2) at a local, regional and global scale.
- Ice cover and the interaction of the sea (polar regions).
- Hazardous substances at a local and regional scale.
- Marine litter surveys
- Sea level
- The extent and state of coastal habitats (wetlands, salt marshes, beaches, mud flats etc)
- Marine species and their distribution
- Plankton and fish surveys
- Impacts of fish farming/mariculture
- Impacts of individual pressures including dredging, shipping, aggregate extraction, installation of renewable energy turbines and assessment of the combined pressure (spatial planning).
- Measurements of the impacts or changes as a result of the introduction of climate mitigating techniques such as carbon capture and storage, iron fertilisation or geoengineering.

4.3.21 Many of the issues associated with the marine environment are linked to those of other domains, for example; the absorption of atmospheric carbon dioxide by the ocean or the melting of ice sheets, which falls under the cryosphere, but the resulting rise in sea level, is also an issue for the marine environment. There is therefore a need for cross discipline observations.

4.3.22 The marine environment has many links to global issues such as climate, for this reason observations are often required to meet international agreements and there is more scope for joint international monitoring programmes. UK participation within these programmes is vital if we are to tackle large global issues.

4.4 HYDROSPHERE - FRESHWATER

Water Quality & Resources

4.4.1 The health of UK freshwaters is crucial for drinking water, recreation and general amenity. Fresh water quality has improved significantly over the last twenty years. To progress further, we need to understand better the influence of many different activities. For example, as the quality of sewage effluents improves we increasingly need information on other contaminant sources such as agriculture and diffuse urban pollution.

4.4.2 Agriculture works at the interface of land and water. Diffuse pollution, irrigatory water supplies, soil loss, nutrient and pesticide flows to streams and rivers are all key issues for the quality and quantity of our waters. Many of these inputs are linked to flow, rainfall and temperature, all of which could be monitored by in-situ sensors. Observational programmes based on and leading to an understanding of these issues will help us to find solutions.

4.4.3 Changes in land use, not only for agriculture but for development and urbanisation can affect the water cycle and local water retention. Observations will be needed to understand the impacts and inform any planning decisions.

4.4.4 The increasing popularity of water for leisure pursuits and sports either in or on the water sets new challenges for management and collection of relevant social or environmental data. More stringent bathing water quality standards are required under the revised bathing water directive (76/1160/EEC) and, although some monitoring is already undertaken, monitoring programmes to meet the new standards and management systems will need to be in place by 2012, ready to report the status (classification) of UK Bathing Waters by 2015.

4.4.5 Sustaining a growing population increases the pressure on water resources. There is a need to understand the balance between water consumption and the amount of water required to protect freshwater habitats and ecosystems. Information on the health of the water courses and the volume of water is also important when considering issues that relate to flooding, droughts and hydroelectricity.

4.4.6 The environment agencies do a lot of monitoring for management purposes but other stakeholders also contribute. The water industry itself has a vested interest in the health of water resources and does significant monitoring of surface and ground waters. Because its abstractions and discharges are largely responsible for the quality and quantity of water in many of our rivers, the industry also monitors for regulatory purposes.

Climate Change

4.4.7 Climate change will alter water resources and the extent of artificial irrigation in relation to agricultural output. The interaction of climate, agricultural and demographic pressures will be a central research area; in particular, broad and catchment scale measurements will be at the heart of identifying the trade-offs between potable supplies and consumption, irrigation and the protection of freshwater habitats and ecosystem services within catchments.

4.4.8 With increasing atmospheric carbon dioxide and other greenhouse gases there is a need to better understand the role that freshwater bodies play as a source or sink of these gases. Alongside this is a need to understand the processes that are occurring and whether as a result, the level of dissolved carbon is changing in natural waters and what the consequence of such changes may be.

Extreme Events

4.4.9 Observations that contribute to the prediction of events such as flooding, droughts, storm surges or tsunamis are required to ensure that warnings and mitigating action can be taken in advance. Much of this information is already collected within the UK and increased collaboration will also be key to making optimal use of observations in protecting life and property, as evidenced by the recently formed joint Flood Forecasting Centre (FFC) between the Environment Agency and the Met Office in response to flooding from extreme rainfall events. Assessments will need to be undertaken to determine whether, with the potential increase of incidents due to a changing climate, the current infrastructure will cope. Questions such as, 'will increased flow change the form of natural and engineered rivers and if so what will be the consequences for the surrounding habitat, properties and infrastructure?' will need to be answered.

Habitats: Wetlands

4.4.10 Wetlands, including those that depend on groundwater, and wetland ecosystems are coming to the fore in the UK and globally. Wetlands are important for the maintenance of biodiversity and many have been designated as Sites of Special Scientific Interest or as Special Protected Areas. However, they act as important nutrient and carbon sinks and they reduce flood risk by retarding flows. The UK has signed up to the Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar Convention) and, although this is primarily aimed at the protection of habitat for biodiversity, it provides for management action plans, appropriate policy and legislation. To achieve this, observations regarding the water flows and quality may be needed along with information about plant and animal communities.

Renewable energy

4.4.11 The drive towards increasing the generation of energy from renewable sources could lead to the development of hydropower installations within freshwater systems. Before constructing any installation there will be a need to understand the flow rates, how these may be altered, and the consequence on the surrounding environment.

Management and Legislative Drivers

4.4.12 The WFD specifies a framework of integrated monitoring and management of the European aquatic environment; it will greatly influence observational programmes. The directive covers lakes, where previous monitoring has been sparse. It requires information on the current status, health and vulnerability of all freshwater ecosystems to be both accessible and reported. The WFD requires us to identify the pressures and activities affecting measured ecological status and to act accordingly. The monitoring framework will strike a balance between the revelation of trends and the identification of emerging issues; it will be complemented by observations to deal with particular problems and to decide what mitigation is needed.

The reporting requirements apply across all water categories and will shape many other observational programmes, such as the wide-scale Centre for Ecology and Hydrology (CEH) countryside survey.

4.4.13 The Habitats Directive and its associated biodiversity goals set significant standards for many important wildlife sites. Natural England (NE), Scottish Natural

Heritage (SNH), Countryside Council for Wales (CCW), Northern Ireland Environment Agency (NIEA) and JNCC are key players in ensuring that monitoring of these issues is adequate.

4.4.14 Long term datasets are critical and many are held and maintained by the above organisations. All monitoring is complemented by research in lakes and rivers, some of it involving long term observations, by organisations such as the Centre for Ecology and Hydrology. Such information could be used to help understand what the ecological thresholds are and what the response of the system will be to a changing environment. Responses could in the long term affect the UK's compliance with biodiversity related legislation and also ecosystem structure, function and the associated services.

4.4.15 It is clear that observation programmes should be designed for early warning of emerging issues such as new pollutants or shifts in species distributions. Long term observation alone is insufficient. Flexibility to detect and understand the impacts of new parameters is also required.

Observation requirements

4.4.16 To address the issues associated with the freshwater environment the following observations are needed:

- Water quality, including nutrients, chemistry and biology.
- Measurements of the diffuse pollution, nutrient, pesticide and hazardous substance flows into water courses.
- Water extraction and discharge flows.
- Flow, temperature, groundwater levels and meteorological parameters; rainfall, wind, storms etc
- Dissolved carbon and other greenhouse gases
- Habitat extent – river banks, wetlands.
- Species surveys, fish, wildfowl, migratory birds etc

4.4.17 Many of the observations required for freshwater issues are linked to those of other environmental domains, for example meteorological parameters are also required to address atmospheric issues, and habitats cross into the biosphere domain. There is therefore a need for interdisciplinary working and alignment of the relevant observations.

4.5 HYDROSPHERE - GROUNDWATER

Groundwater Quality

4.5.1 The interaction of surface water with groundwater is coming to the fore as a key interfacial issue. The timescales of groundwater movements are often long, making it essential to observe both water quality and quantity. Otherwise, it is difficult to manage effectively the resources that groundwater provides. Groundwater abstraction to provide potable water is on the increase; the costs of treatment rise substantially if source water is contaminated. Boreholes are necessary to monitor groundwater and are crucial to solving many key issues.

4.5.2 Within the UK the current resolution of groundwater observation regimes may not be adequate to provide a coherent understanding of the quality and status. Problems arise when monitoring for pollution, as decisions are required regarding which pollutants should be measured (and therefore any new pollution may be missed).

Water Resources

4.5.3 Aquifers are often used for multiple purposes e.g. energy, waste disposal, increased irrigation etc. There is therefore a need to ensure that the resource is properly managed and any impacts understood. In addition considerations regarding how environmental change may affect recharge should be undertaken and built into any management decisions.

4.5.4 As with freshwater, environmental change could potentially impact both groundwater quantity and quality. Changes to the seasonal distribution of freshwater may impact groundwater fed ecosystems, which in turn could affect the services that they provide.

4.5.5 Groundwater level is important when considering the risk, probability and impacts of flooding or droughts. Measurements can be fed into predictive models and used to inform both management and contingency planning.

4.5.6 Water resources in developing nations are often understood less, managed less and abused more than in the developed world. In marginal zones with rainfall less than 500 mm per year, resources are particularly susceptible to environmental and climate change; in these areas populations and environments depend for survival on sustainable water management. The effective deployment of national aid for such regions depends on good monitoring and observation.

4.5.7 Monitoring of water resources in developing nations is needed at national, catchment and local levels. However, monitoring networks may decline wherever finance & skills wane and conflict increases. Earth observation at national and catchment scales, at frequencies sufficient to descry seasonal and long term changes, therefore need to be developed and refined to ever smaller scales and higher frequencies in order to measure most efficiently and reliably the impacts of change.

Carbon Capture and Storage

4.5.8 There is a lack of understanding regarding the environmental impacts of carbon capture and storage on aquifers. Upon setting up of any schemes, observation programmes to monitor leakage into surrounding groundwater resources would be necessary.

Legislative Drivers

4.5.9 The main statutory drivers of groundwater monitoring are the WFD, its daughter directives and the Nitrates Directive. The proposed creation of water protection zones may present additional needs. Observations that justify statutory designation of particular areas are essential to protect water supplies.

Observation requirements

4.5.10 The components of the hydrosphere, marine, freshwater and groundwater are interlinked therefore many of the issues associated with groundwater are the same or similar to those that arise for surface freshwaters or the marine environment. Observations to address the issues that arise for groundwater include:

- Water quality; including nutrients, chemistry and biology.
- Groundwater level
- Assessments of changing seasonal water flows and therefore groundwater recharge.
- Abstraction rates and the associated impacts to the surrounding and/or water dependent ecosystems.
- Measurements to identify the sources and flows of diffuse pollution, nutrients etc.

- Measurements of dissolved carbon dioxide, especially near sites earmarked for carbon capture and storage.

4.5.11 Depending on the issue being addressed groundwater observations would need to be taken on a national, catchment or local scale, for example a pollution incident may require local monitoring, whereas monitoring for nitrates may be required at the catchment level.

4.6 CRYOSPHERE (ICE AND FROZEN ENVIRONMENTS INCLUDING THE POLAR REGIONS)

4.6.1 Polar regions play a central role in climate and the Earth's condition. Large heat transfers, long time scales, the polar stages of global atmospheric and marine circulations all mean that key global and national science and policy questions may only be answered by sustained polar observational programmes. Polar change itself and the global consequences must be quantified if we are to predict environmental polar futures and anthropogenic contributions to them. Both the scale of the effort and the returns from it are national and international.

Climate and Climate change

4.6.2 Much may be learned about fundamental climatic polar processes by using high latitude palaeoenvironmental records to tell us about past warmer global climates that had up to four times our pre-industrial carbon dioxide levels.

4.6.3 Atmospheric observations will also allow us to study how variations of the Earth's outer atmosphere and the Sun are coupled to the Earth's climate.

4.6.4 As well as a requirement to measure atmospheric carbon dioxide, methane and other greenhouse gases are of concern within polar regions. It is known that methane reserves are locked within the permafrost. As these warm, gas is released. Marine clathrates are also known to be present beneath the sea bed and recent studies have already shown that outgassing is occurring. Observations are therefore needed to improve our knowledge of the stability and distribution/cover of marine clathrates and permafrost respectively. However, any increase in observations should be made with links to the relevant policy forums, for example, the Arctic Council Working Groups and the United Nations Framework Convention for Climate Change (UNFCCC).

Ocean Circulation

4.6.5 We need to understand and quantify the polar controls and sources of the global ocean circulation. Changing ocean circulation has been linked with the freshening of the Arctic. Such changes could have large impacts on the climate of the UK. Increased measurements would enhance our understanding and with the help of models, allow the assessment of future implications and impacts.

Sea Ice, Ice sheets and Glaciers

4.6.6 Enhanced knowledge and measurement of the impact of changing sea ice cover on the oceans, atmosphere, climate and biology is required.

4.6.7 The melting of sea ice within the Arctic will lead to the opening of sea routes and the connection of the Pacific and Atlantic Oceans. This opening will permit transfer of water and organisms, which could impact fisheries as different species will be able to move between the two oceans. Change is not limited to the Arctic, long term impacts of melting ice on krill in the Southern Ocean could have large (but as yet unknown) consequences on the surrounding fisheries and ecosystems.

4.6.8 Melting ice sheets and deglaciation contribute to sea level rise and observations can be used to determine the rate and extent to which this is happening. As the globe warms there is increasing risk of catastrophic ice shelf collapse or rapid deglaciation. Measurements can be used to assess the potential impacts and probability of occurrence along with quantification of the risk.

4.6.9 Glacier and ice sheet melt is not limited to the polar regions. Many alpine regions around the globe are being impacted by a warming environment. The change in glacier, ice and snow volume in these regions could result in future problems for water resources and supply, power generation, flooding and also recreational activities such as skiing.

4.6.10 Icefields, icebergs and glaciers are all associated with natural hazards, therefore their nature, likelihood and scale should be investigated quantitatively if risk is to be managed well.

Ecosystems

4.6.11 Comprehension of the structure and function of polar ecosystems can be used to inform us about global biodiversity. The integration of physical, biological and biogeochemical models will aid the prediction of impacts from various pressures on both polar biodiversity and ecosystems. By quantifying polar ecosystem services, strategies for their sustainable management can be developed and put in place.

Pollution

4.6.12 Despite being remote, anthropogenic pollution is an issue within the Arctic. Pollution is transported to the Arctic from lower latitudes. There is concern over the presence of new and emerging organic pollutants which can accumulate in the food chain. Therefore international coordination to determine the impacts, sources and loads is required in order to implement mitigating action.

Management and Legislative Drivers

4.6.13 Much of the current UK activity takes place within an international legal and scientific framework. The UK has a legal responsibility to implement the Antarctic Treaty and three subsequent international agreements: the Convention for the Conservation of Antarctic Seals (1972), the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR, 1980), which includes the management of Southern Ocean Fisheries and the Protocol on Environmental Protection to the Antarctic Treaty (1991). The UK has an obligation under the Agreement on the Conservation of Albatrosses and Petrels and is a signatory to the Svalbard Treaty (1925). The Treaty system also imposes obligations regarding the provision of data.

Scientifically, the UK is committed to many monitoring activities such as the provision of underpinning scientific information to CCAMLR (by the British Antarctic Survey (BAS)) and routine and continuous meteorological and ozone recordings, which are submitted to an international network.

4.6.14 The information required to fulfil the Conservation Treaties is often narrowly focused on one aspect, however, programmes could be extended to widen the range of observations, for example the programme to meet the Agreement on the Conservation of Albatrosses and Petrels could include other species, especially those that are highly adapted to living within cold regions.

4.6.15 Instrumental and observational challenges are enormous but rewarding as we explore the frontiers of frozen environments. Sub-glacial lakes, deep polar oceans, the geology beneath major ice sheets or glaciers, and novel biodiversity all offer new

frontiers where only observation and measurement can reveal the full scientific, environmental or economic potential.

4.6.16 From the above scientific, legal and environmental standpoints, there is a well substantiated case for long term commitment to measurement of the physical and biological polar environment, and for sophisticated experiments to tease out key processes and relate them to lower latitudes. Advanced modelling capable of assimilating and adapting to the latest observations is vital for the synthesis of these activities and for predicting the future. The challenges are so huge in concept, technical demand and geographical extent that international collaboration and programmes are essential.

Observation requirements

4.6.17 The observations required to address the issues associated with the cryosphere include:

- (Polar) Ocean currents, temperature, depth and salinity
- Sea level
- Atmospheric measurements including carbon dioxide and other greenhouse gas concentrations.
- Measurements to determine Air-sea fluxes.
- Sea ice thickness, extent and properties.
- Measurements of the parameters which enable an understanding of the sea/ice interactions e.g. boundary currents, horizontal and vertical mixing.
- Glacier (both polar and alpine) volume, changing dynamics, lake drainage.
- Permafrost distribution, geophysical properties, temperature and rates of change (melt).
- Mapping of marine clathrates both within the permafrost and in the seabed. Observations to assess their stability
- Paleaoenvironmental climate records
- Measurements of marine biodiversity, including krill, fisheries and other iconic or highly adapted species to determine changing distributions and ecosystem interactions.
- Pollution; concentrations and sources.

4.6.18 The issues for the cryosphere are closely linked to those of the marine and atmosphere domains. Therefore there is a strong need for cross disciplinary working.

4.6.19 Many of the issues linked to the cryosphere have a global or international perspective. The measurements themselves generally need to be taken outside of the UK and require international coordination or the working within and alongside political boundaries.

4.6.20 Issues associated with the cryosphere are linked to our fundamental understanding of the earth's condition and are therefore vital to inform not only the science and policy communities, but also the public with regard to potential social impacts such as water resources and recreation due to glacier melt.

4.7 LITHOSPHERE AND PEDOSPHERE (SOILS & GEOLOGY)

4.7.1 Soils and soil systems are of great consequence to future productivity, nutrient fluxes and carbon storage, all affecting atmospheric and aquatic systems. There are weighty issues of mineral and fuel resources, and the use of land for waste disposal. Soils and geology are therefore intrinsically linked to a wide range of ecosystem

services and influence fluxes to the air, water and groundwater domains. To understand these issues presupposes many diverse but related observational programmes.

Agriculture/food production

4.7.2 Farmers and foresters hold centre stage as food and fibre producers, land managers, owners and stewards of much UK land. They supply valuable information about the status of land, management techniques, land values and emerging societal issues.

Natural Resources

4.7.3 Mineral resources and fuel production are important national economic issues. Coal, peat and oil are locally important and contribute to global budgets. Observations of mineral reserves, conservation, future development and the associated infrastructure all require monitoring programmes. Much of the information already collected is held by the private sector. This information along with baseline mapping of the resources could be coupled with statistics on usage and forecasts of future demands.

Population Growth and Pollution

4.7.4 With an increasing population additional pressures on soils and the underlying lithosphere arise, for example from pollution, increased demand for habitable land, access to recreational areas, industrial intensification and waste management. These pressures are often influenced by human behaviour e.g. the number of people living in the same household is decreasing and therefore the demand for more new housing is increasing.

4.7.5 Objective observations of water tables, geological properties and landscape are a prerequisite for responsible waste disposal on land. Large areas of urban land are appreciably affected by historic contamination from toxic chemicals. Soils and the deeper lithosphere can act as sinks or sources of these and other pollutants, and provide pathways, barriers or buffers for their transport. Mapping of such contaminants and determining which soils are the sources of pollutants is patchy and inadequate especially for the investigation of links with human disease. More observations will remedy this lack, providing a better evidence base for epidemiological studies and strategies.

Soil productivity/function

4.7.6 The relationship between productivity and function within both soils and geological environments and for example, water conservation, pollutant or climate buffering are not well understood, nor do we know how resilient the system is to cope with various threats and pressures. There is hence a need for accurate and observationally substantiated advice to policy makers, strategists and land use planners.

4.7.7 Changes to the quality of and functionality of soil can be identified using broadscale indicators, which upon triggering, induce further investigations. Defra are currently developing a series of biological soil quality indicators. The UK Soil Indicators Consortium has also prioritised a set of indicators for soil monitoring [8] and to monitor sustainability in farming and food, the Sustainable Farming and Food Strategy (SFFS) for England and Wales contains a list of indicators that includes topsoil. Soil organic matter is a headline indicator of better use of natural resources.

Land use

4.7.8 Land use is a critical determinant of fluxes between domains. The quality, nature and uses of soil and other land surfaces determine the composition and volume of all water run-off and percolation into groundwater. A firm understanding of this is

important when considering uses that could have an impact on groundwater quality, for example when identifying suitable locations for the burial of carcasses following a pandemic event.

Water

4.7.9 Geology and soils are intrinsically linked to water and water supply. As well as considerations of rock porosity and permeability, development and soil sealing can impact on both water and soil resources. The area of 'ground' lost to development needs to be monitored along with any impacts to the surrounding water supplies. Better understanding could lead to the development of effective mitigation against soil sealing.

4.7.10 Climate impacts such as temperature can affect both the water content and biodiversity within the lithosphere and pedosphere. Both are important for functioning and the ecosystem services that are provided.

Fluxes, sinks and sources

4.7.11 Across widespread upland areas, primary fluxes to the lithosphere come from the air; such ombrotrophic ecosystems are sensitive to nitrogen and other inputs from above. To protect and manage these zones, atmospheric fall-out must be quantified by direct environmental measurement or by modelling that has been calibrated by direct measurements.

4.7.12 Soils, especially in peaty upland areas, constitute an enormous reservoir of 'fixed' carbon compounds which may be leached and released as carbon dioxide. There is a need to determine, to what extent, other soils or rocks, including marine sediments and salt marshes are acting as sinks or sources of carbon and greenhouse gases. Along with their spatial distribution the erosion rates of these substrates and therefore their potential release of carbon dioxide should also be observed. Observations of the former are currently adequate for local areas however, due to a lack of coordination, there is no national picture.

Properties and characteristics

4.7.13 Spatial information on properties of soils, superficial deposits and bedrock provide essential baseline information on ground and subsurface conditions for spatial planning and safe development on and offshore. Information is required in the subsurface zone which has been impacted by human interaction (infrastructure development, extraction, waste disposal, historical contamination). Much of this information is held within the private sector and there is a need to not only engage with these stakeholders but also bring the information into the public domain.

4.7.14 Increasing our understanding of lithospheric properties will provide additional knowledge on areas at risk from erosion, landslides or subsidence. It could also help with flood prediction by identifying the soils/rocks that are capable of storing or infiltrating water. Observations on these areas can then be used to inform risk assessment, contingency and mitigation strategies, and provide information on future impacts due to environmental change.

Management and Legislative drivers

4.7.15 The significance of soils was reflected in a recent Scotland & Northern Ireland Forum for Environmental Research (SNIFFER) review [27] of twenty nine soil-related UK monitoring programmes. The two largest monitoring projects are the National Soil Inventory and the Countryside Survey.

4.7.16 Obligations for protection and management of UK soils are mainly covered by legislation relating to pollution and agriculture such as the contaminated land

legislation (Part 2A of the Environmental Protection Act 1990), Common Agriculture Policy, the Nitrate Pollution Prevention Regulations and others. To assess and report compliance with these obligations, appropriate observations and data must be collected. Non-legislative guidelines also exist: a Soil Strategy (2008) is due for release; the Scottish Soils Framework, the EA Soils Strategy and the Wales Soil Action Plan are soon to be published.

4.7.17 The European Commission is striving, so far without fruition, to introduce a framework directive to protect soil function. A current call (ENV.2009.2.1.3.1: soil processes and modelling) will enhance the base of evidence for such a directive. This legislative effort reflects major European initiatives on threats to soils, such as the ENVironmental ASsessment of Soil for mOnitoring (ENVASSO) project that aims to harmonise European soil data sets. In time it may require widespread and well recorded observations.

4.7.18 Some matters widely dealt with by UK Government agencies and departments also occur in the UK Standard Industrial Classification of Economic Activities, and are recognised under the EU Thematic Strategy for Soil Protection. This includes: food and fibre production; environmental interaction (between soils, air and water); support of ecological habitats and biodiversity; protection of cultural heritage; providing a platform for construction; providing raw materials.

Observation requirements

4.7.19 From the foregoing it is clear that the nature of the observations necessary to manage the lithosphere and pedosphere sustainably are very varied. There is a need for many and diverse observations relating to the economic and environmental significance of soils. Most generally, changes in soil status must be linked to causes of change if the implications for soil function and continued delivery of all ecosystem services are to be properly understood and managed. Required measurements include:

- Physical properties such as structure, compaction, bulk density, porosity, sealing and erosion
- Carbon stock and concentration to about one metre depth, including peat monitoring
- How organic matter and carbon content are stored and lost
- Contamination levels of contemporary and novel pollutants
- Nutrient status
- Mineral reserves in relation to current, conservational and future needs
- Changes in rural and urban soil quality and function on the national scale
- Processes influencing function and quality of soil
- The diversity, distribution and importance of soil organisms
- The role of soil and geology in provision of ecosystem services
- How to enhance the functioning of soils
- Threats to soil quality and function from changing climate and other pressures
- Effects of land and water management.
- Strategies for soil protection and integrated management of soil, water and air.
- Fluxes between soil and atmosphere; soil and water.

4.7.20 Many of the observations required for the lithosphere and pedosphere are also related to other environmental domains for example the percolation of water through soil and rock to groundwater reserves (hydrosphere). There is therefore a strong need for interdisiciplinary working.

4.7.21 Across the UK there is large spatial variability within the lithosphere and pedosphere. This makes up or down scaling and extrapolation of observations difficult.

4.8 BIOSPHERE

4.8.1 Although they may overlap, biosphere science and policy questions are often distinct. Science focuses mostly on processes, particularly on understanding linkages within ecosystems; the relationship between biological diversity and ecosystem services is one such key contemporary question. Policy deals more with understanding which activities may impair biological diversity, how they may be modified, and how successful policy-driven actions are for mitigation. An understanding of ecological processes provides a valuable context for policy and increases confidence in the efficacy of intervention but often may not be directly applicable to policy development.

Ecosystem Services

4.8.2 All living things provide a multitude of services some of which are essential to sustain mankind and other life. These services include food and fuel, pure water, climate regulation, flood retention, waste disposal and several less tangible but nevertheless inspiring benefits such as beauty, sound, colour and wonder. Consequently the need to safeguard ecosystem services and conserve nature shape our demands for information about the biosphere. To conserve or to exploit nature sympathetically, we need to understand the role of biodiversity in the key ecosystem processes which we exploit or to which we and other life are vulnerable.

4.8.3 The priorities for conserving ecosystem services may however differ from those that traditionally conserved biodiversity; the service priorities may focus on the diversity of whole ecosystems instead of on their rare or threatened components. Nevertheless, such a shift of emphasis alters neither the nature of the questions/pressures, e.g. increasing population, climate change, land use change etc nor their dependence on observational data.

4.8.4 It is acknowledged that ecosystems change naturally or are 'forced' due to anthropogenic changes. Regardless of the type of change, the consequence to the benefits both in terms of ecosystem service and the economic impact is of importance. It is these socio-economic impacts that the public relate to and there is therefore a need to communicate the results of observations and their consequence to the wider public.

Biodiversity and function

4.8.5 Biodiversity and its functioning sit at the heart of many environmental issues and questions. For example, in view of increasing food production within the UK, the condition of the soil biodiversity and chemistry will need to be considered (along with any potential impacts of increased agriculture on the surrounding ecosystem).

4.8.6 An important topical issue is how the functioning of the biosphere as a whole plays a role in acting as a sink or source of carbon dioxide, other greenhouse gases and pollutants. This needs to be understood if we are to gain overall knowledge of carbon budgets and the potential amelioration of emissions. To understand these links and the associated processes more sensitive technology, capable of taking the appropriate observations, is required.

4.8.7 Other climate feedbacks from the biosphere also need to be investigated. Feedbacks from the boundary layer could effect both weather and climate prediction. Any observations would need to be conducted in association with atmospheric scientists.

4.8.8 Impacts to biodiversity and functioning also need to be considered. There are multiple detrimental pressures including environmental disturbance, water extraction, development, mineral use, transport and competition with non native species. Individual species or habitats may benefit from some of these pressures however, disruption to the interactions could result in an overall reduction in biodiversity and the associated functioning.

Species and habitats

4.8.9 There is a need to measure both change in species and habitats and also the causes of this change e.g. from policy interventions; pollution; global warming; natural variability. Distinguishing the causes of change is very difficult and it may be that in doing so, some present interventions may prove to have been unnecessary, poorly targeted or inefficient uses of effort.

4.8.10 Ideally, comprehensive data from a wide range of biota would measure change. In practice, we are compelled increasingly to use surrogates for change and to express them as indicators. The underlying assumption is that observation of a few indicators is an economical way to represent the complexity of life. In reality, indicators are chosen expediently, according to already existing data and observation programmes. Such indicators are not necessarily the best to choose. As an example, in the UK we have relied in recent decades upon bird indicators, but birds and other vertebrates adapt to changes in their environment; only when conditions reach some critical point do they move; they are imperfect indicators. Thus, when assessing observations we need to be alert to the constraints and assumptions we have made when choosing them to indicate the biosphere.

4.8.11 As our environment changes, the risk of increasing extreme events and disasters, such as flooding, storm surges, forest fires etc may also increase. There is therefore a need to understand the condition and extent of our natural habitats that could be affected or could potentially buffer some of these effects e.g. wetlands, forests, saltmarsh and coastal habitats.

Management, conservation and legislative drivers

4.8.12 In the UK and many other countries, nature is conserved in its own right through statutory and voluntary conservation. Now and in the future observations will be needed to inform policy makers,and other stakeholders of:

- The priorities for conservation of nature.
- What actions need to be taken.
- How successful are the interventions/actions to sustain biodiversity.
- What contribution nature makes to ecosystem services.
- Where policy conflicts with other sectors.

4.8.13 Obligations and commitments for conservation of the biosphere arise from the remits of UK statutory conservation bodies, embracing various pieces of UK legislation such as the NERC act, Public Service Agreement targets, European Habitats & Birds Directives and commitments made under multilateral agreements such as Ramsar and the Convention on Biological Diversity (CBD). Interestingly, there are no commitments or obligations relating to the ecosystem services on which all life depends; such essentials rely on a healthy functioning biosphere but exactly how, and on which components, is very much unknown.

4.8.14 The EU has adopted a rigorous target to stem the decline of biodiversity, by 2010 if possible; it neatly overarches and captures all other commitments and obligations of EU countries with regard to the biosphere.

The 2010 target to significantly reduce the rate of biodiversity loss comes under the framework of the United Nations Millennium Development Goals. Collectively, these express an aspiration to improve human well-being, reduce poverty and develop in a sustainable manner. The 2010 target demonstrates society's recognition that all life forms may be critical to others' survival and that every effort should be made to safeguard them. In managing risk to essential services this is prudent and recognises the very important intrinsic aesthetic and cultural value of many life forms. It endorses a longstanding approach to conservation and its associated obligations and commitments.

4.8.15 The newly emerging duty to establish a UK programme of surveillance for species under the Habitats Directive is a good example of legislation leading to specific observations. Our measurements in this area need to be robust enough to support our reporting commitments, to sustain flexible response and to avoid legal straitjackets.

Observation requirements

4.8.16 Given a sound generic framework, specific questions may be answered by focussed surveillance, interpretative research or augmentation of baseline observations. This approach is highly desirable for the biosphere because of the extremely effective and efficient nature of observations made by the volunteer community. By maintaining a high resolution baseline of observations across a broad spectrum of biosphere components, most generic needs can be met. Such observations include:

- Measurements to determine the role of biodiversity in key ecosystem processes.
- Measurements that will increase understanding of ecosystem interactions and the services that they provide.
- Surveys of species and habitats: state, extent and their rates of change.
- Measurements to determine the causes and effects of change and whether it is due to natural pressures or anthropogenic forcing.
- Assessments to determine whether intervention has been successful (or whether more needs to be done).
- The role of the biosphere in carbon cycling and where there are key sources and sinks of both carbon dioxide and other greenhouse gases.
- The role of the biosphere in other climate feedbacks and the stability of these processes.

4.8.17 As found with other environmental domains, observations required for the biosphere are often cross cutting and feed into interdisciplinary issues such as climate or soil quality.

4.8.18 Each environmental domain has a biodiversity component and therefore many of the observations taken will be relevant to both the biosphere and the specific domain, for example species distributions within the polar regions could fall under both the cryosphere and biosphere.

4.9 SOCIETAL ISSUES

4.9.1 The domain approach is useful for organising the collection of information to understand our planet. However, many of the issues arise as a result of direct or indirect human activities therefore societal information is integral to any process for managing, improving or simply living within our environment.

Cooperation and Integration of Information

4.9.2 In order to address some of the questions that surround societal issues, there is a need to integrate natural and societal (and socio-economic) observations. Such integration will require cooperation of scientists and access to information or the

development of geospatial information technologies, which can be used by scientists working in all domains.

4.9.3 To date the UK-EOF has not collected environmental socio-economic information directly. It has however been acknowledged that it does need to work in the light of the interaction between society and the environment. The UK-EOF therefore aims to widen the scope of the framework to aid the collection and facilitate the reuse of socio-economic information relevant to the natural environment.

Public Engagement

4.9.4 Observations can constitute the core of evidence for decisions which have social impacts and influence societal perception of issues. It is therefore vital that there is engagement with the public to not only listen but also to share joint understanding on new initiatives and how their lifestyles may impact the environment. Improved communication will become increasingly important when answering a range of policy questions, for example adapting to climate change, where there is increased awareness and understanding of the issues amongst the public as well as a need for scientific data acquisition.

4.9.5 Formal economic and social impact assessments are expected at key stages of decision making. Observation programmes contribute to these evaluations of the true costs and benefits of environmental initiatives for both policy and society as a whole.

4.9.6 Initiatives such as the Water Framework Directive and the Floods Directive emphasise the importance of public engagement in the decision making processes that depend so much on the large structured observation programmes. These programmes are made public early in the process and tools (such as the NIEA's web mapping to illustrate the distribution of observations when consulting on the WFD) used to bring them to life; the public and stakeholders then have an opportunity to influence them in a significant way.

4.9.7 The role of sociologists and economists in working with progressive scientific teams will aid public support and understanding of all these key issues; it will help to make the most efficient societal use of the observation programmes, and ensure that the observations of the natural environment that sociologists need are being collected.

4.10 INTERFACES BETWEEN DOMAINS

4.10.1 It is important when designing observational programmes to remember the significant environmental flows of material between domains. Many of these have been covered above. To characterise these fluxes, a wide range of observations, on different scales, are needed within an experimental process. The flows between domains include:

- Rainfall composition and volume
- Uptake and release from plants, from and to the air
- Uptake and release from soil, from and to the air
- Soil, land and coastal surface leaching, run-off or erosion to water
- Atmosphere – ocean exchanges
- Runoff, rivers and groundwater to marine.
- Point and diffuse contaminant fluxes to atmosphere, water and land from industry, agriculture and urban sources

- Chemical, physical or biological transformations of non-conservative substances.

4.10.2 Fluxes between domains play a critical part in our understanding of environmental processes that determine environmental outcomes. When developing national policy and regulatory regimes, it is important to know with some accuracy the inter-domain fluxes of materials and contaminants. Flows between biota, air, land and sea are driven by the influence of natural (rainfall, photosynthesis) and anthropogenic (transport emissions, fertiliser application) inputs. The net fluxes may result from large unbalanced bi-directional flows; long term measurements are then particularly important to understand the fluxes' driving forces and quantitative trends if reliable models are to be developed and cost effective actions enabled.

4.10.3 The estimation of flux entails adequately accurate measurements of concentration, and volumetric or areal extent. Much field and experimental work is focussed on the first of these but the often difficult volume or extent determinations are equally important. In some cases, a large proportion of annual fluxes occurs over only a relatively few days. It follows that in this field - as in so many environmental observations - the frequency of measurement should be high enough to distinguish the sometimes short time scales of natural processes.

4.10.4 This approach raises a number of cross-cutting issues which span more than one domain e.g. The Gulf Stream and thermohaline circulation – any changes to this ocean circulation could have dramatic impacts on many other issues, including the climate of the UK. These and their associated processes are often unknown or not well understood and require innovative measurements and new types of observation. It is essential that action is taken to ensure that they do not fall between the gaps of different organisations or working groups.

4.10.5 Increasingly, cross-cutting analysis can solve key questions, but only where there is sound knowledge of each domain; otherwise, important interactions might not be uncovered. However, there is now a trend for organisations and sponsors to break down the traditional disciplines and to encourage multi-disciplinary teams to collaborate on the key questions and themes.

4.10.6 Much can be gained by linking information across disciplines and scales. For example, some satellite imagery - when linked to ecosystem analysis - helps recognise changes and trends. Money may be saved in some cases by consolidating traditional observations but in others by seeking novel remote methods.

5 DEVELOPING OBSERVATION ACTIVITIES

5.1 A UK OVERVIEW

5.1.1 To address the complex and multiple challenges associated with our changing natural environment, the UK needs a holistic overview of the needs arising from all sectors, domains and funders. There will never be enough resources and it is not desirable to collect everything on a continuous basis but, if taken strategically, the UK should aim to be collecting a balanced suite of environmental observations and to have the infrastructure, skills and funding to sustain these and make best use of them. The balanced suite must span all environmental media (domains), accommodate temporal and spatial variability, and allow changes to be assessed in the short, medium and long terms in local, national and international contexts. Furthermore, the resulting data and information must be fit-for-purpose and capable of reuse.

5.1.2 The UK already invests in environmental observations; it is therefore critical that any continuing or new investment should take into account the needs, as articulated here, as well as existing programmes or activities. There could be considerable benefits in working collaboratively to address multiple needs with the same observational activity or platform. Through a wide range of circumstances, careful planning of programmes will optimise the use of UK resources, be they public, private, NGO or voluntary.

5.1.3 In addition, when considering new programmes or revising existing programmes, account should be taken of how the data gathered will be used, synthesised, analysed and evaluated. Analysis products, which can be used to interpret and carryout reanalysis and/or post processing, are an integral part of the observation process and should therefore be considered. Constraints and limitations of measurements should also be built into programmes and the assumptions declared.

5.1.4 Models are playing an increasingly important role in our understanding of the natural environment. They have many applications including the prediction of future scenarios or determining ecological linkages. Modellers are generally the ‘user’ of the observations, not the collectors, therefore dialogue to ensure the correct, useful information will be collected in an observation programme is essential.

5.1.5 There will always be a need for programmes or environmental measurements that examine ‘blue sky’ issues or offer long term rather than immediate application. To realise these forward-looking aspects, observational activity must include a balanced suite of observations that are adaptable and able to take account of emerging knowledge and ‘known unknowns’. Exercises such as horizon scanning, NERC thematic research programmes and GEOSS Societal Benefits are useful indicators of such key issues. As we develop our knowledge of environmental issues, emerging challenges will be highlighted.

5.1.6 The planning, implementation and design of programmes in advance of operational deployment should stimulate innovation in the science and business sectors. Innovation and knowledge transfer may lead to development and calibration of new instruments better suited to the monitoring requirements of specific environments, or may increase efficiency by offering more for less, integrating results, having longer battery lives or performing ‘intelligent sampling’.

5.1.7 Observational data are most efficiently used when supplemented by other evidence, particularly by targeted research for example, once an impact on biological

diversity has been detected, extra information can quantify, localise or explain it, so that policy or management may be designed or differently implemented.

5.1.8 In summary, when considering observation activities, their priority and relevance to funders and users may be assessed by considering the following aspects:

- Be relevant to the UK's contemporary and future questions – as set out in this document
- Be effective, make efficient use of resources and ensure that existing activities are not collecting the same things, thus avoiding duplication
- Where appropriate obtain the information from rescoping, replacing or subsuming another activity.
- Provide science of the best quality
- Be flexible enough to adapt the outputs to alterations in political perception of environmental changes and risks
- Deal adequately with issues of scale, timing and frequency and ensure that the scale is matched to that of natural processes.
- Capture the most significant components of variability and trends above natural variations.
- Judge the degree of uncertainty in their conclusions
- Use documented techniques and the most appropriate technology
- Create open and available data sets that are archived and shared
- It may take time to establish the full potential of long term programmes but once established they should remain valuable for decades or more, enjoying appropriate security of funding.

5.1.9 UK-EOF is developing a decision making framework that will attempt to take into account these aspects and will provide a mechanism to prioritise the needs, as set out in this document (for further information see section 5.4).

5.2 DATA ISSUES

5.2.1 Reliable data sets are an asset to those who may use the data now, tomorrow or decades hence. It is crucial that measurements be made to a quality that is recorded along with the archived data set. Quality-assured sampling and analytic methods; accredited laboratories; reproducible and standard methods (e.g. – INSPIRE, OGC standards); confidence, accuracy and precision of measurements: all these aspects, properly archived, create a treasure house of information that may be shared and used in many ways throughout time to come. Persuasive contemporary examples of this could include the national climate record or the decades-long set of sea levels stored in the archives of the National Tidal and Sea Level Facility.

5.2.2 Adequate data systems to store observational information are critical, especially to provide for the needs of a wide range of future users and their (presently unforeseen) questions. In addition, mechanisms which permit the discovery of stored data sets and clear access policies are also needed.

5.2.3 If accompanying quality information (including the scale and frequency of sampling) is not attached to a data set, potential users may well be unable to use it. For example, what is fit for regulatory activities may be unsuitable for more detailed scientific analysis. If the quality of data is attached and shared, there is far greater opportunity to demonstrate why two different data sets may be needed, or to open dialogue between funders and users to enable information to be collected for two or more needs at the

same time. Such collection may require separate analyses of the data, at a cost to the relevant organisation.

5.2.4 There are many issues surrounding the access to data, these include commercial confidentiality and ownerships of IPR. Ideally data would be accessible to all, however it has been argued that fee based access should not necessarily be viewed as an impediment to accessibility – if the revenue generated is reinvested appropriately in effective management and delivery systems, fee based access could enhance data availability and security for the long-term.

5.2.5 Under Workstream 2, the UK-EOF will take forward a Data Initiative to review and make recommendations to deal with data related matters such as those above.

5.3 CONSIDERATIONS AT THE PROGRAMME LEVEL

5.3.1 Observations should be fit for their purpose. It is important to design monitoring programmes for the correct resolution, frequency and statistical significance. Correct design of programmes makes them efficient and cost-effective.

5.3.2 It is important to observe with the correct spatial detail. Global views may often be attained only through international effort and joint funding. National views provided by initiatives such as State of the Environment reports are useful to assess trends and prioritise interventions. Local views focus on specific risks and pressures and are often very important to local communities or the direct management of habitats and species.

5.3.3 When assessing ecosystem effects, observations must focus on the correct ecosystem level (habitat, population or species) or set of levels, often with the aim of protecting sites or optimising management. A pertinent example is the study of endocrine disruptors in river fish: effects are observed at the levels of tissue, individuals and populations. Each level provides different pieces of information that may be put together to understand the risks to human health and to decide the best methods of intervention and mitigation of the effects.

5.3.4 When dealing with particular or potential environmental changes, targeted measurement may be more effective than broad monitoring. Some statutory programmes, such as those supporting the implementation of the Water Framework Directive, encourage this by separating observations into surveillance, operational and investigative types of monitoring.

Surveillance monitoring validates the risk assessments (determined from Operational Monitoring), detects long term trends in natural conditions and widespread changes in anthropogenic activity. A full range of monitoring assesses the impacts and helps design a more targeted strategy.

Operational monitoring provides the evidence to classify those water bodies which are at risk of not achieving good ecological status. The ecological quality elements most sensitive to the pressures on water bodies are sampled regularly. Any changes resulting from the regulations (the programme of measures) put in place to reduce the risks are assessed and reported.

Investigative monitoring aims to ascertain the causes and effects of failure to achieve good ecological status, so that improvement action may be taken.

Each type of monitoring allows resources to be allocated according to the known catchment risks. There is a general movement from 'surveillance' to more focussed operational and investigative monitoring. Nevertheless, information gathered for each purpose needs to be evaluated carefully; to use surveillance data for investigative purposes may lead to unsound inference; to use investigative monitoring for surveillance purposes may lead to significant bias. For example, measurements of concentration during a pollution incident do not represent normal conditions. The context of observations and measurements is important to their future use if they are not to be misused.

5.3.5 Climatic and other researchers increasingly need to make different observations at the same sites so as to provide 'cleaner' links between causes and effects. This principle underpins approaches like the Environmental Change Network; in this, coincident observations help to understand ecological processes and predict future change. Multiple observational networks based on stratified (sampling of all sub-groups of a population) random sampling are more powerful if they share the same stratification. Wherever possible we should strive for coincident measurements so as to increase the power of observations and to increase the efficiency of programmes. With the use of models this information could be scaled up to address the impacts upon the whole country and also assess how well mitigation measures are working.

5.3.6 It may be cost-effective to make observations to improve operational capability of existing programmes. For example, understanding the seasonal nature of river flows allows for optimisation of abstraction and the mitigation of flood risk. When further combined with an understanding of pollutant loads, environmental protection, treatment and abstraction costs can also be optimised.

5.3.7 Regardless of the end use, it is critical that observations are impartial and objective if they are to be used to provide evidence for decisions on potentially contentious environmental issues.

5.4 CONCEPTUAL DECISION SUPPORT FRAMEWORK

5.4.1 When considering whether to conclude, modify or start up a new observational activity, decision makers and funders must prioritise resources. They must assess the effectiveness of existing activities, the need for new ones and the potential value of new measurements.

5.4.2 To make informed decisions it is necessary to understand:

- The required primary needs for observations
- Who the users of the observations are
- Whether programmes exist to meet these needs adequately or whether the observation is unique and must be taken in a certain way.
- Where the gaps are.
- What the cost and benefits will be.

5.4.3 Currently, there is no one method or guidance for developing observation programmes and different organisations approach the task in their own way. One such example is the JNCC UK Terrestrial Biodiversity Surveillance Strategy [21]. The comprehensive approach provides a process for integrating the many separate requirements for biodiversity observations and can be used to assess coverage of current activities and identify gaps and overlaps. The principles of this method could be adapted for wider application in some areas.

5.4.4 Funders and users need to prioritise any identified gaps. Existing programmes may be amended or realigned with extra observations to cover changing needs and fill the gaps. However, there are many reasons why adequate programmes or activities may not exist: issues may be newly emerging, priorities may have changed; funding may not permit such observations or there may be shortages in skills and technology.

5.4.5 Current observations are often funded ad hoc and there is a lack of information on what observations the UK is investing in and why. 'Towards a Statement of Need' is the first step in gathering the views from the whole community in order to move towards generating the holistic picture. At this stage the information has not been prioritised in any way. Prioritisation will be the responsibility of the individual organisation.

5.4.6 To aid prioritisation the UK-EOF is developing a Decision Support Framework, the details of which are currently under discussion. The criteria must be credible, reliable and accurate for scientists, funders and policy makers without being too detailed. It is proposed that it should encompass:

- A set of criteria
- Supporting evidence
- People and discussion/governance elements
- Implementation of the decisions

5.4.7 In addition to the Statement of Need, evidence will be provided from other areas within the UK-EOF including the investments made, knowledge of current activities (catalogue), funding mechanisms and data related issues. The criteria will be verified and tested in 2010 using one or two sectors to see whether the opportunities and potential cost savings can be realised.

5.4.8 The decision support framework will enable and empower the UK and each agency, department or initiative to contribute more clearly to existing and anticipated national and international programmes, to optimise its investments, to recognise dependencies and to work in partnership. In this way we will ensure that the UK has a balanced suite of observations, useful to address and adapt to the changing natural environment.

This Statement of Need will form part of such an evidence base.

6 THE PROPOSED WAY FORWARD

6.1.1 This document, Towards a Statement of Need, is the first attempt to provide an overview of the reasons why the UK observes the environment. It aims to stimulate thought and is a step towards ensuring that we have a balanced suite of observations which allow the UK to provide evidence to meet current and future challenges.

6.1.2 The statement has been developed with the help of experts in their field. Information has been captured by direct and open consultation, as well as via a series of workshops held in June and July 2009 that were designed to capture current observations and future needs. The workshops were also used as an opportunity to initiate discussions on the current capability to deliver the needs (now and to 2025).

6.1.3 Information from the workshops and consultations have been incorporated into this version of the document and the workshop report and annexes. Further work to include environmental socio-economic needs and engagement with industry, including an investigation of the industry codes of practice (that rely on the availability of public information) are recommended.

6.1.4 The statement is at present, a 'wish list' of the community's observational needs that have not been prioritised in any way. It provides evidence to support the holistic requirements of the UK. However in reality it is not possible to fund all the stated requirements. Prioritisation will be carried out by individual organisations who can use the Statement of Need as evidence alongside a decision support framework. These tools will aid the making of well informed and transparent decisions regarding the funding of environmental observation programmes. The details of the decision support framework are currently under discussion (see Chapter 5).

6.1.5 Current capacity or capability to meet the requirements has not been identified within the text. A capability analysis was initiated in the workshops, the information for which has been captured in the appropriate requirements tables. In the future such analyses could be undertaken for various sectors. Under the data initiative, data status tables will also be completed to identify whether the required information is available and easily accessible. However, the initiation of this work will depend on the priorities of the UK-EOF sponsors.

6.1.6 In the future further work on the Statement of Need may include the simplification of these volumes of information and the distilling of them into a key list of measurements required to meet the needs stated in the current document. Gaps in information regarding the spatial distribution, frequency of collection and use of the measurements would increase the ability to identify measurements which could meet multiple needs.

6.1.7 This information could feed into several of the other UK-EOF workstreams. The current and future needs may be mapped onto known observation programmes, thus helping to identify gaps and provide information on whether the suite of observations undertaken by the UK is balanced and fit for purpose. This work is linked to the capability analysis mentioned above (see 6.1.5).

6.1.8 In order to complete both the gap analysis and assess the capability to fulfil the immediate and future needs (twenty years or more), detailed information on current observation programmes will be necessary. This information will become more widely available upon upgrading of the environment observations activity catalogue in 2010. Further information on the resources, technology, skills and knowledge to meet

the observation needs set out in this document will also be required. To obtain such information close dialogue and consultation with the community will be required.

6.1.9 Towards a Statement of Need is a working document that will be updated approximately every 3 years. There are known gaps, such as industry requirements and links to social science that will be filled in further iterations of the document and transferred into any analysis.

7 SUMMARY

7.1.1 The UK faces significant environmental challenges. Alongside and complementary to research, observations of the natural environment play an essential role in providing evidence. They give us confidence in our assumptions, scenarios, models and consequent policy decisions. They also build up to long term time series from which trends and changes may be revealed, policy decisions are assessed and understanding is tested.

7.1.2 Reliable and non-disputable observations are at the heart of balancing the environmental, economic and social aspects of sustainable development which, in turn, plays a critical role in guiding the environmental agenda.

7.1.3 The requirements for observations have been considered from three perspectives:

- The headline issues we need to address (Box 2 and Table 2). These have been repeatedly raised in national and international fora and cover all aspects of 'environmental'.
- The factors, such as compliance or operational activities, which drive organisations and individuals to undertake environmental observations (Box 3, Table 3 and Table 4).
- The Environmental domain (atmosphere, biosphere, lithosphere, hydrosphere [freshwater, groundwater and marine], cryosphere); Box 4 and Table 2).

7.1.4 There are national and international statutory commitments to make observations and to report findings. The increasing emphasis on evidence-based policy making and risk-based assessments places new responsibilities on those who make the supporting environmental measurements. The public sector therefore undertakes and invests a vast amount in observation activities every year.

7.1.5 Businesses and the private sector also make a significant proportion of observations in the UK. They relate to industrial pollution loads and the environment, projections of resource consumption and availability, understanding of the fate and behaviour of chemicals and - increasingly - to knowledge of the nearby environment. As public understanding of environmental issues grows, society expects businesses to be more responsible in the conduct of their affairs. This encourages businesses to go 'beyond regulation' in their approach so that their contribution to the common good might increasingly be harnessed within the field of observation. Despite initial efforts it is acknowledged that further engagement with this sector is required.

7.1.6 Most of the issues raised by the community fell under one of the headline issues, those that did not generally related to data issues, including storage, handling and access. The importance of transforming environmental data into useable and reusable information should not be underestimated. The consequent integration and management of databases is a complementary workstream of the UK-EOF.

7.1.7 Many of the needs relate to issues that are currently high on the political and public agenda such as climate change and the associated effects and impacts. Although one of the headline issues, climate change impacts are relevant to all sectors and domains for example, floods and droughts could affect biodiversity, ecosystems, agriculture and human wellbeing. Climate is a global issue and as such international collaboration is required to address many of the issues raised.

7.1.8 Other more 'historical' issues such as pollution and environmental disturbance from development and extraction are also current. Increasing population results in increasing demands and pressure on resources, including food, energy and minerals. With a changing environment issues such as food security and alternative energies come to the forefront.

7.1.9 Observations on issues with profound socio-economic impacts, such as natural hazards – landslides, ground instability etc are required by many sectors to determine the risks, consequences, disaster prevention and if required emergency response mechanisms.

7.1.10 Although the UK-EOF does not cover human health data *per se*, many of the observational needs relate to fulfilling legislation or answering questions which themselves are directly linked to health, for example air or water pollution.

7.1.11 There is much emphasis on the importance of ecosystems and the services that they provide. Again associated issues are cross cutting for example, saltmarshes not only provide habitat for wild birds but are also natural flood defences. Observations to enhance our knowledge of the processes, biodiversity interactions and feedbacks, which lead to these ecosystem services are required to aid our understanding of their limitations and how we can better protect or sustainably exploit them.

7.1.12 There is significant overlap between the information needed for key questions, research, compliance assessments or environmental management. This provides fertile ground for common approaches to the design of observation programmes that optimise UK effort, achieve value for money and ensure that issues do not fall between the gaps.

7.1.13 Care, however should be taken when considering the reuse of information. Observations may be required in different media or because they are being collected for different reasons, they may have different spatial or temporal resolutions. Without fully understanding what the observations are being used for it is difficult to determine whether the same observations could be used for multiple purposes. By understanding the use of the observations such as legal obligations, research, decision making, management etc) basic suites of information that may be used to answer or provide supporting information for many questions or issues can be identified.

7.1.14 It is clear that, to take local, national and global issues forward most effectively for society and the environment, we need comprehensive, well targeted and accurate observations. Despite the diversity and complexity of the observational community, it has common interests and goals. There is a genuine desire to progress with science and the management of environmental issues. Observations are a vital area of synergy with strong potential for cooperation and sharing.

7.1.15 This process has allowed us to propose the following statement:

Statement of Need

Observations provide the primary information to facilitate evidence-based decision making and increase our knowledge of environmental issues. Observations are made by a diverse community to achieve environmental, social or economic outcomes.

The UK needs a balanced suite of environmental observations to tackle the challenges associated with our changing natural environment. The balanced suite must span all environmental media, accommodate temporal and spatial variability, and allow changes to be assessed in the short, medium and long terms in local, national and international contexts.

This requires an appropriate infrastructure which will allow us to answer cost-effectively the questions and obligations that we have now and in the future. There is a need for the UK to optimise resources and put in place mechanisms for the community to work together to provide the required evidence. To achieve this we must develop:

- an observation framework based on a well-informed view of current and future needs
- adequate financial mechanisms to fund sustainable programmes
- an informed community that shares best practice and ensures efficiencies
- agreed or prescribed data sharing principles
- checks on data quality
- a process of regular review.

7.1.16 It is clear that to obtain a holistic view of the UK's needs, considerations must include all contributors, be they private or public, in a Statement of Need to recognise their different motivations for observing the environment.

7.1.17 The details are beginning to emerge (see the workshop report and the requirements tables, but more work is needed to:

- Prioritise the needs and make decisions regarding which observations to fund.
- Understand the measurements needed to address each issue
- Assess current capability against needs
- Expand the scope of the UK-EOF to include environmental socio-economic issues.
- Engage with the industrial sector

7.1.18 The development of a decision support framework is currently under discussion. The other issues identified above will form part of the continuing work of both the Statement of Need and the wider UK-EOF work programme.

GLOSSARY OF TERMS

Biodiversity is defined in Article 2 of the Convention on Biodiversity (CBD, 2001) as *'the variability among living organisms from all sources including, among others, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'*. In short, this translates as the total range of the variety of life on earth.

Ecosystems: the CBD (CBD, 2001) defines an ecosystem as *'a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit'* (Article 2 of the Convention). In order to accommodate the Ecosystem Approach (EA) to biodiversity conservation, there is a need to recognise that *'humans, with their cultural diversity, are an integral component of ecosystems'*.

Ecosystems may operate at a wide range of spatial and temporal scales, from long term global systems, to very small, localised or ephemeral systems.

Environmental: UK-EOF Definition - broadest sense of observations from the natural environment concerning physical (including geological), chemical and biological properties of the environment. This includes observations collected from land, air, ice, freshwater, coastal and marine environments, for compliance or statutory information, earth observations from space and the effects of humans on the environment. Note the exceptions of social science and human health data.

Environment Research Funders Forum – The forum aims to maximise the coherence and effectiveness of environmental research by providing a joined-up strategic approach, identification of synergies and more effective coordination to help shape national and internal future science direction through identification of UK priorities. Environmental research, as defined by the forum includes research, associated monitoring, survey, policy, regulation and training.

The **Global Earth Observation System of Systems (GEOSS**) - is an initiative of GEO, an intergovernmental organisation now including 74 countries, the EU and the UN. GEOSS is simultaneously addressing nine areas of critical importance to society. It aims to empower the international community to protect itself against natural and human-induced disasters, understand the environmental sources of health hazards, manage energy resources, respond to climate change and its impacts, safeguard water resources, improve weather forecasts, manage ecosystems, promote sustainable agriculture and conserve biodiversity. GEOSS coordinates a multitude of complex and interrelated issues simultaneously. This cross-cutting approach avoids unnecessary duplication, encourages synergies between systems and ensures substantial economic, societal and environmental benefits.

Jason – Ocean altimeter satellites, which provided information to observe ocean circulation, sea level rise and wave height. Jason-1 and 2 are currently in orbit, 3 is scheduled to fly by 2013.

Observations: UK-EOF Definition - the taking, on a reasonably regular basis, of any form of observations relating to the status of the environment, regardless of the frequency and purpose for which the observations are made or how they are made (for example, satellites, ships or scientists). Such observations are designed to meet a wide range of societal needs by providing a variety of products and services.

LWEC - Living with Environmental Change is a large research programme which will help society respond better to environmental change. It facilitates greater collaboration

between research and policy. It aims to accelerate the production of tools, processes and knowledge which will help us make more informed choices about the future. Among other outputs, it will provide new ways of designing and adapting the built environment to climate change, produce a better analysis of the risks to human welfare from the degradation of ecosystems and widen social participation in decisions about how we manage the challenges ahead.

GLOSSARY OF ACRONYMS

AONB	Areas of Outstanding Natural Beauty
BAS	British Antarctic Survey
BBC	British Broadcasting Corporation
CBD	Convention on Biological Diversity
CCAMLR	Commission for Conservation of Antarctic Marine Living Resources
CCW	Countryside Council for Wales
CEH	Centre of Ecology and Hydrology
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
EA	Environment Agency
E-KTN	Environmental – Knowledge Transfer Network
EMARC	Emergency Monitoring and Response Centre (Met Office)
ENVASSO	ENVironmental ASsessment of Soil mOnitoring
EPICS	Environment, Pressures, Impacts, Consequences and Solutions (classification of environmental science activities by the Environment Research Funders Forum)
EPRTR	European Pollutant Release and Transfer Register
ERFF	Environment Research Funders Forum
EU	European Union
GCOS	Global Climate Observation System
GEO	Group on Earth Observations
GEO	Global Environment Outlook
GEOSS	Global Earth Observation System of Systems
GMES	Global Monitoring
IODP	Integrated Ocean Drilling Programme
IPCC	International Panel on Climate Change
JCOMM	Joint WMO-IOC technical Commission for Oceanography and Marine Meteorology
JNCC	Joint Nature Conservation Committee
LWEC	Living With Environmental Change programme
MPA	Marine Protected Area

MSCC	Marine Science Coordination Committee
MSFD	Marine Science Framework Directive
NBN	National Biodiversity Network
NE	Natural England
NERC	Natural Environment Research Council
NIEA	Northern Ireland Environment Agency
NSWWS	National Severe Weather Warning System
NWP	National Weather Prediction
ONS	Office of National Statistics
OPAL	Open Air Laboratories Network
OSPAR	Oslo-Paris Convention (1992 – to protect the marine environment of the North East Atlantic)
PSVI	Public, Science, Voluntary, Industry Model
PWS	Public Weather Service
Ramsar	Convention on wetlands (convened at Ramsar, Iran
RCUK	Research Councils United Kingdom
RSPB	Royal Society for the Protection of Birds
SAHFOS	Sir Alister Hardy Foundation for Ocean Science
SNH	Scottish Natural Heritage
SNIFFER	Scotland and Northern Ireland Forum for Environmental Research
UNFCCC	United Nations Framework Convention on Climate Change
UNFCCC-COP	United Nations Framework Convention on Climate Change – Conference of the Parties
UK-CIP	United Kingdom – Climate Impacts Programme
UK-EOF	United Kingdom – Environmental Observation Framework
UK-FEI	United Kingdom – Forum for Environmental Industries
WFD	Water Framework Directive
WMO	World Meteorological Organisation
WMO-IOC	World Meteorological Organisation – International Oceanographic Commission
WWF	World Wildlife Fund for nature

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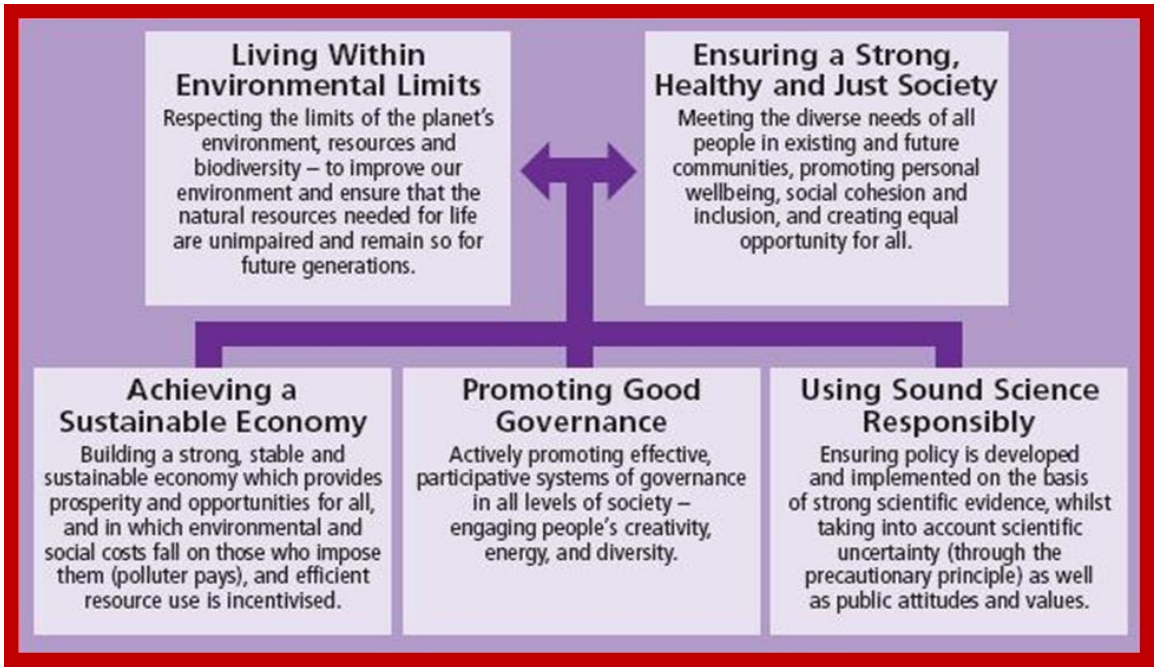
APPENDIX A: THE ROLE OF SUSTAINABLE DEVELOPMENT

The Sustainable Development Strategy [17] gives a clear imperative for a common approach to monitoring and is in itself an overarching guide for programme development. At the same time, monitoring and surveillance should inform and modify our approach to sustainable development.

Basic principles of sustainable development policy have been agreed by the UK Government, Scottish Executive, Welsh Assembly Government and the Northern Ireland Administration in a UK strategic framework [3]. Details of the principles are given in the UK Government's sustainable development strategy – Securing the Future [17].

Figure 6: Five principles of sustainable development



The sustainable development framework and its five key principles form the foundations of much contemporary UK policy[5]. For any policy (not just environmental policy) to be sustainable it must respect all these principles. For the UK to live within environmental limits and achieve a just society, we must develop a sustainable economy, good governance, and sound science.

To advance sustainable development, policies must be well informed, based on evidence and able to track progress. Indicators and key observations have been agreed for the demonstration of progress and therefore the pursuit of sustainable development is itself a fundamental reason for observing the environment.

Adhering to the principles not only influences the UK approach to observation, monitoring and research but provides criteria against which programmes and priorities should be tested. The Sustainable Development Strategy [17] gives a clear imperative for a common approach to monitoring and is in itself an overarching guide for programme development. At the same time, monitoring and surveillance should inform and modify our approach to sustainable development.

[5] For more information please see: www.defra.gov.uk/sustainable/government/what/principles.htm

APPENDIX B: EVIDENCE-BASED DECISION MAKING

The UK Government has made a commitment to use the best available evidence when making decisions, finding new policy solutions and identifying and tackling future issues. Evidence is any information that the UK can use to help formulate policy or to turn policy goals into something concrete, achievable and manageable. It may take many forms: research, analysis of stakeholder opinion, economic & statistical modelling, public perceptions & beliefs, anecdotal evidence and cost-benefit analyses. It may also include judgment of the quality of methods used to gather and synthesise the information.

Evidence is needed to answer big governmental strategic questions such as those originating from the Treasury or the Cabinet Office. ERFF studies (Holmes, 2005 [19]; Clark, 2007 [1], summarised by Holmes and Clark in 2008 [20]) highlighted the struggle policy makers can have to compose wide and forward-looking evidence-gathering questions to support or refute policy options. Their questions may tend to over-narrow perspectives or be short term. This can lead to duplication within commissioned projects or to inability to answer the questions with short time-series of data.

It was recommended that before starting new evidence gathering procedures government departments and agencies could devote more time to anticipating the issues that need evidence, or to finding out what is already known or already being collected.

Public appreciation of the need for evidence-based policy making has increased in recent years, particularly after the publication of high profile documents that used scientific evidence for political issues, such as the Stern and Intergovernmental Panel on Climate Change (IPCC) reports. The importance of stakeholder engagement in defining questions is widely accepted.

A significant proportion of UK-funded observations is intended to be relevant to policy; nevertheless, concern has been expressed that observations often fail to provide sufficiently coherent or effective outputs to inform policy-making.

The Statement of Need and the iterative process of its development will help address some of these issues for observations. It will be a tool to help policy makers and managers understand better the importance of observations in providing the evidence for their (and the UK's) needs. It will also allow scientists to understand the major policy drivers so they can be better informed about forthcoming knowledge requirements.

APPENDIX C: THE SCOPE OF THE 9 HEADLINE ISSUES

The 9 headline issues identified as the basis of this Statement of Need each have sub-issues and questions that can be informed by observations. Each issue is relevant to and includes all environments marine, terrestrial, atmospheric etc. Taken together the issues comprehensively cover the reasons for making environmental observations.

The key phrases have been derived from many sources, including the Natural Environment Research Council (NERC) Themes, GEOSS, ERFF horizon scanning and classification scheme [11], the UK–EOF workshop, the Millennium Ecosystem Assessment [22] and the Global Environmental Outlook (http://www.unep.org/geo/). They have been refined by discussion and the reflections and oversight of key senior policymakers. Each issue is discussed in further detail in this chapter and the subissues in the UK-EOF Workshops Report.

To illustrate the scope of each of the issues, they have been mapped onto the ERFF's EPICS Classification (See Figure 8). The EPICS scheme was developed to encapsulate four main categories into which environmental research topics can be usefully divided (13). However it is felt that this could also be used to consider the full range of environmental problems that in order to address, would require observations from each of the four categories:

E – for basic understanding of the **Environment** and its processes, including understanding natural hazards such as volcanoes or earthquakes.

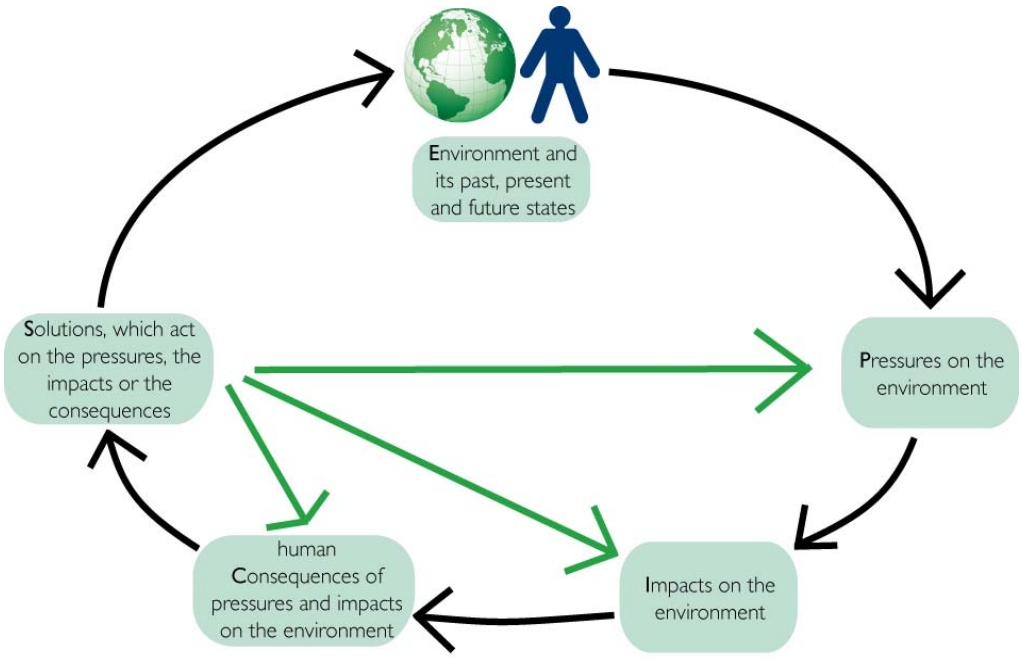
PI – for human **Pressures** and their **Impacts** on the environment, such as pollution, depletion of natural resources, or interference in land drainage characteristics by building development.

C – for the **Consequences** of these pressures and impacts, such as illness resulting from air pollution, or urban flooding resulting from building development in the flood plain.

S – for Solutions to environmental problems, including prevention or reduction of damage to the environment, mitigation or remediation and protection.

Figure 7 illustrates the interrelationships between the various parts of the EPICS Scheme. These interrelationships reflect in the many cross linkages between the various issues and sub issues, some of which are discussed in Chapters 3 and 5.

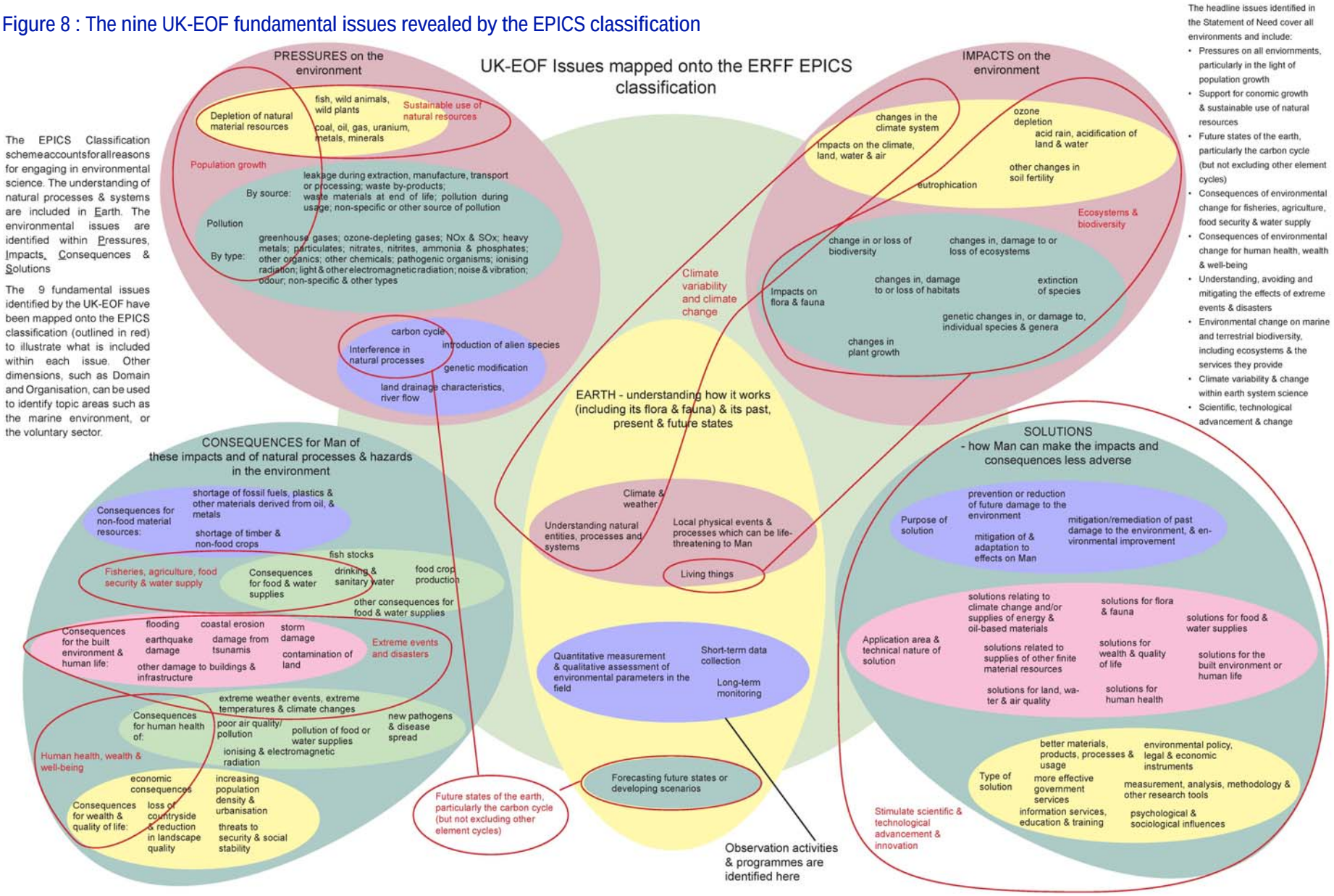
Figure 7: The EPICS Scheme - Environmental Pressures, Impacts, Consequences & Solutions



There is no one way to divide the issues neatly into discrete boxes. What is important is that all issues have a home. Duplicated issues can be removed (or observations combined), but they must be captured somewhere.

The workshop illustrated that all the sub issues raised could be grouped into these 9 areas. Other issues raised concerned data management and will be taken forward in other parts of the UK-EOF.

Figure 8 : The nine UK-EOF fundamental issues revealed by the EPICS classification



APPENDIX D: EXAMPLE OF AN INFORMATION GATHERING TABLE

These tables help to articulate the UK's requirements for observing the natural environment, the questions that we need to answer and how close we are to providing that evidence *via* a balanced suite of environmental observations. For ease, information gathering has been split into environmental domains. Consultation with the community via a series of workshops took place in summer 2009. Populated tables are appended to the Statement of Need Workshops Report.

Table 2: Fundamental issues arranged by environmental domain

One table required for each environmental domain						
Specific or sub-issue This refers to the questions that we need to answer.	**What are the key questions that require answering in order to address the specific/sub issue?**	**Measurement type** Variables that need to be measured to provide evidence to address the specific issues.	**Frequency of collection** e.g. Continuous measurement for 1 week in Spring, repeated every 2 years. Or Spot measurement, once a week, every week throughout the year. Or Irregular measurements as required e.g. extreme event monitoring.	**What geographic coverage do we need?** A) UK B) England C) N. Ireland D) Scotland E) Wales F) Localised UK (e.g. part of Wales) G) Europe (non UK) H) Global I) Other (please specify) Ocean/Sea (please specify).	**What is the primary use for the data?** A) Basic science B) Characterising environmental issues/solutions (influencing policy) C) Direct environmental management D) Modelling & prediction E) Complying with legislation. F) Development and Growth	**Are the current actions or measurements sufficient to provide the evidence needed to address the issue?** If known, please list the current programmes or sensors which are capable of providing the evidence (e.g. for Sea Surface Temperature AATSR, SLSTR. AVHRR, AMSR and Modis satellites are capable of measuring SST).
Population Growth (Pressures on all environments in the light of population growth and associated pollution)						
Economic Growth & Sustainability (Support economic growth whilst reconciling with sustainable use of natural resources)						
Carbon Cycle (Understand future states of the earth, particularly the Carbon cycle, but not excluding other element cycles						
Fisheries, Agriculture, Food Security & Water Supply (The consequences of environmental change)						
Human Health, Wealth and Wellbeing (The consequences of environmental change)						
Extreme Events & Disasters (Understanding, avoiding and mitigating the effects)						
Biological Diversity, Ecosystems & Services (Impacts of environmental change on marine and terrestrial biodiversity, ecosystems and services)						
Climate Change (variability & climate change within earth system science)						
Scientific & technological advancement/ innovation						
Others						

APPENDIX E: INTERNATIONAL AND NATIONAL OBSERVATIONAL OBLIGATIONS

Table 3 summarises international and national legislative and statutory obligations and commitments, together with their environmental aims and an outline of their contingent measurements.

Table 3: International and national obligations regarding environmental observations

Instrument or Commitment	Overall Aim	Parameters
Atmosphere		
Convention on long range transboundary air pollution 1979	Limit, reduce and prevent air pollution including long range transboundary air pollution. Develop policies and strategies to combat the discharge of air pollutants through exchanges of information, consultation, research and monitoring.	Emissions of the acidifying pollutants nitrogen oxides (NO_x), ammonia (NH_3), and sulphur dioxide (SO_2)
Council Directive 96/62/EC on ambient air quality assessment and management (Air Quality Framework Directive).	Protect the environment and human health. Concentrations of harmful air pollutants should be avoided, prevented or reduced. Limit values or alert thresholds to be set for ambient air pollution levels.	Assessment of ambient air quality based on measurements made in Member States to be comparable. The location and number of sampling points and reference methods should be specified when values are set for alert thresholds, limit values and target values.
Directive 2000/69/EC relating to limit values for benzene and carbon monoxide in ambient air (Second Daughter Directive).	Establish limit values and, as appropriate, alert thresholds for concentrations of benzene and carbon monoxide in ambient air to avoid, prevent or reduce harmful effects on human health and the environment. Assess concentrations on the basis of common methods and criteria. Obtain adequate information on ambient air concentrations and ensure that it is made available to the public	Values for benzene and carbon monoxide in ambient air.
Directive 2002/3/EC relating to ozone in ambient air (Third Daughter Directive)	Ensuring effective protection against harmful effects on human health from ozone. Reducing the adverse effect of ozone on vegetation, ecosystems and the environment (cannot be sufficiently achieved by the Member States because of the transboundary nature of ozone pollution and can therefore be better achieved at Community level).	Emissions of ozone-precursor pollutants: nitrogen oxides (NO_x), carbon monoxide (CO), methane (CH_4) and non methane volatile organic compounds (NMVOCs), each weighted by their respective tropospheric ozone-forming potential.
Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (Fourth Daughter Directive)	Coherent strategy containing measures to protect human health and the environment from the release of mercury, based on a life-cycle approach, and taking into account production, use, waste treatment and emissions. In this context, the Commission should consider all appropriate measures with a view to reducing the quantity of mercury in terrestrial and aquatic ecosystems, and thereby the ingestion of mercury *via* food, and avoiding mercury in	Target values are: 6 ng/m^3 for arsenic, 5 ng/m^3 for cadmium, 20 ng/m^3 for nickel and 1 ng/m^3 for PAH, represented by benzo(a)pyrene.

	certain products. Promoting research into the effects of arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons on human health and the environment, particularly *via* deposition.	
Council Decision 97/101/EC establishing a reciprocal exchange of information and data from networks and individual stations measuring ambient air pollution within the Member States (EoI Decision).	Establishing a common procedure for the exchange of information between the surveillance and monitoring networks, based on data relating to atmospheric pollution caused by certain compounds and suspended particulates. Exchange information by increasing the number of pollutants to be considered and by including networks and individual stations that measure ambient air pollution.	Establishing a common procedure.
Commission Decision 2004/461/EC laying down a questionnaire for annual reporting on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC and under Directives 2000/69/EC and 2002/3/EC of the European Parliament and of the Council.	While the plans and programmes would be drafted according to the specific administrative requirements in each Member State, the information submitted to the Commission should be harmonised and structured in accordance with the detailed arrangements laid down in the present Commission Decision	Limit values for SO_2, NO_2, NO_x, PM_{10} and Pb, benzene and CO
Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from Large Combustion Plants	The critical loads and levels of certain acidifying pollutants such as sulphur dioxide (SO_2) and nitrogen oxides (NO_x) should not be exceeded at any time. As regards air quality, all people should be effectively protected against recognised health risks from air pollution.	Limit values for SO_2, NO_2, NO_x, PM_{10} and Pb, and benzene and CO
Council Directive 1999/13/EC on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations	Control of emissions of volatile organic compounds (VOCs) in order to reduce their transboundary fluxes and the fluxes of the resulting secondary photochemical oxidant products so as to protect human health and the environment from adverse effects.	Quantity of used substances with VOCs .
Directive 1999/32/EC on reduction of sulphur content of certain liquid fuels	Reduce the emissions of sulphur dioxide resulting from the combustion of certain types of liquid fuels and thereby to reduce the harmful effects of such emissions on man and the environment.	Limit values and target values for sulphur in liquid fuels.
Directive 2001/81/EC on national emissions ceilings for certain atmospheric pollutants	Limit emissions of acidifying and eutrophying pollutants and ozone precursors in order to improve protection of the environment and human health against risks of adverse effects from acidification, soil eutrophication and ground-level ozone. Move towards the long term objectives of not exceeding critical levels and loads and of effective protection of all people against recognised health risks from air pollution by establishing national emission ceilings, taking the years 2010 and 2020 as benchmarks, and by means of successive reviews.	Limit values and target values.
Clean Air Act 1993	Control of all furnace installation, limits on rate of emission of grit and dust, arrestment plant for furnaces, measurement of grit, dust and fumes, outdoor furnaces, height of chimneys, smoke nuisances in Scotland	Creation of smoke control areas, prohibition on emission of smoke in smoke control areas, dealings with unauthorised fuel.
The Air Quality Standards Regulations 2007	Air quality standards, attainment of air quality standards, maintenance of air quality standards and action plans.	Other pollutants and background monitoring.

Climate change		
United Nations Framework Convention on Climate Change (UNFCCC)	To stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.	Level of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).
Kyoto Protocol	Sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions. Targets amount to an average of five per cent against 1990 levels over the five-year period 2008-2012.	Emissions of carbon dioxide, methane, nitrous oxide, HFCs, PFCs, and sulphur hexafluoride.
European Climate Change Programme (ECCP)	Review the implementation of EU-wide policies and measures related to climate change, assess their concrete implementation in the Member States and the resulting actual and projected reductions in emissions. Identify new opportunities for possible emission reductions	Rising sea levels, changing rainfall patterns, retreating glaciers, thinning of the arctic sea ice, incidence of extreme weather, species migrating out of historic ranges to colder climates and thereby changing ecosystems.
EU Emissions Trading System	Establishes a scheme for greenhouse gas emission allowance trading within the Community (referred to as the 'Community scheme') in order to promote reductions of greenhouse gas emissions in a cost-effective and economically efficient manner.	Quantified emission reduction.
Climate Change Act 2008	Set a target for the year 2050 for the reduction of targeted greenhouse gas emissions. Provide for a system of carbon budgeting. Establish a Committee on Climate Change. Confer powers to establish trading schemes for the purpose of limiting greenhouse gas emissions or encouraging activities that reduce such emissions or remove greenhouse gas from the atmosphere. Make provision for adaptation to climate change. Confer powers to make schemes for providing financial incentives to produce less domestic waste and to recycle more of what is produced. Make provision for the collection of household waste. Confer powers to make provision for charging for single use carrier bags. Amend the provisions of the Energy Act 2004 for renewable transport fuel obligations. Make provision for carbon emissions reduction targets. Make other provision for climate change	Emissions of carbon dioxide, methane, nitrous oxide, HFCs, PFCs, and sulphur hexafluoride
Climate Change and Sustainable Energy Act 2006	Reduction of emissions of greenhouse gases. Alleviation of fuel poverty. Promotion of microgeneration and the use of heat produced from renewable sources. Compliance with building regulations relating to emissions of greenhouse gases and the use of fuel and power. Renewables obligation relating to the generation and supply	Emissions of carbon dioxide, methane, nitrous oxide, HFCs, PFCs, and sulphur hexafluoride

	of electricity and the adjustment of transmission charges for electricity.	
Hydrosphere (Marine, Freshwater and Groundwater)		
Water Framework Directive (WFD) 2000/60/EC	Achieve good ecological status of water bodies by 2015, with no further deterioration, which includes meeting the pass criteria for good chemical status.	Ecological quality and supporting hydromorphological measures, chemical status, priority hazardous substances.
Marine		
Merchant Shipping (Prevention of Pollution)(Limits) Regulation 1996	Control operational pollution of discharge oil.	Oil discharge.
Merchant Shipping & Marine Security Act 1997	Extend powers to deal with emergencies at sea, pollution control and marine safety, funding of marine services, liability and compensation, protection of wrecks, marine security and to provide other amendments to the Merchant Shipping Act 1995.	Emergencies pollution control.
UK Marine Monitoring and Assessment Strategy	Make the most efficient use of UK resources, in terms of all existing obligations. Be prepared for emerging requirements such as the EU Marine Strategy Directive and Floods Directive.	MARG, CSSEG, Charting Progress
Convention for the International Council for the Exploration of the Seas (ICES)	Promote and encourage research and investigations for the study of the North Atlantic sea and to publish or otherwise disseminate the results of research and investigations.	Aquatic Habitats: oceans.
Convention for the Protection of the Marine Environment of the North - East Atlantic (OSPAR Convention)	Prevent and eliminate pollution from the north-east Atlantic.	Aquatic Habitats.
European Environment Agency Annual Management Plan - Marine Data (ME-1)	Improve the quality assurance of data flows with emphasis on the five thematic areas.	Marine environment.
EU Directive on port reception facilities for ship generated waste and cargo residues (EC 2000/59)	Reduce illegal discharges of ship-generated waste and cargo residues to the sea by managing the availability and use of port waste reception facilities.	Illegal waste discharges.
London Convention on the prevention of Marine Pollution by Dumping Wastes and Other Matter, 1972 (London Convention)	Prevent the deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures, as well as the deliberate disposal of these vessels or platform themselves.	Dumping, deliberate dumping at sea.
Marine Strategy Framework Directive	Achieve good environmental status in the Community's marine environment by 2021. Continue the protection and preservation of that environment, ensuring that subsequent deterioration is prevented.	Targets and objectives to be defined by 2012, consequent monitoring programmes by 2014.
International Convention on the Control of Harmful Anti-Fouling System on Ships	Prohibit or restrict the use of harmful anti-fouling systems on ships flying UK flag or operating under UK authority and all ships that enter a UK port, shipyard or offshore terminal.	Pollution
International Convention for the Prevention of Pollution from Ships 1973 (MARPOL 73/78)	Prevent pollution of the marine environment by ships from operational or accidental causes.	Litter, marine environment
UN Convention on the Law of the Sea (UNCLOS)	Provide a comprehensive new legal regime for the sea and oceans, establishing material rules concerning environmental standards as well as enforcement provisions dealing with pollution of the marine environment.	Environmental standards, pollution.

Freshwater		
The Drinking Water Directive (DWD), Council Directive 98/83/EC	Protect the health of the consumers in the European Union and to sure the water is wholesome and clean.	Sets standards for the most common substances (so-called parameters) found in drinking water. A total of 48 microbiological and chemical parameters must be monitored and tested regularly.
Directive 2006/44/EC on the quality of fresh waters needing protection or improvement in order to support fish life	Quality standards of fresh waters needing protection or improvement in order to support fish life.	Physical and chemical parameters applicable to salmonid and cyprinid waters.
Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water (new 2006/7/EEC)	Protect the environment and public health. Reduce pollution of bathing water and protect such water against further deterioration.	Microbiological parameters (total coliform and faecal coliform) and physicochemical parameters (mineral oils, surface-active substances and phenols)
Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment	Collection, treatment and discharge of urban waste water, and the treatment and discharge of waste water from certain industrial sectors. Protection of the environment from the adverse effects of waste water discharges.	5 different determinands (BOD, COD, TSS, total nitrogen and phosphorus).
Council Directive concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC)	Protect human health and living resources and aquatic ecosystems. Safeguard other legitimate uses of water. Reduce water pollution caused or induced by nitrates from agricultural sources and prevent further such pollution. Take measures concerning the storage and the application on land of all nitrogen compounds and concerning certain land management practices.	Limit values corresponding to certain parameters.
The European Directive on the Assessment and Management of Flood Risks (2007/60/EC of 23 October 2007) (the Floods Directive)	Prevent and limit floods and their damaging effects on human health, the environment, infrastructure and property.	Flood hazard maps, flood risk management plans and updates every 6 years.
Fish Hygiene Directive (91/493/EEC)	Specifies health conditions for the production and placing on the market of fishery products so as to ensure consumer protection.	Fishery products, chemicals, contaminants.
Shellfish Growing Waters Directive (79/923/EC)	Protect and improve waters including shellfish waters against pollution. Safeguard shellfish population from harmful consequences resulting from the discharge of pollutant substances into the sea.	Shellfish condition
Water Act 2003 Water Environment and Water Services (Scotland) Act 2003	Water resources management schemes, regulation of water industry, regulation of drinking water, land drainage and flood defence, border rivers, reservoirs, water conservation, fire hydrants, coal mine water pollution, contaminated land, sewers and drains.	Limit values corresponding to certain parameters.
Groundwater		
The new Groundwater Directive (2006/118/EC)	Control groundwater pollution, adopting criteria for assessing good groundwater chemical status and criteria for the identification of significant and sustained upward trends.	Limit values corresponding to certain parameters.

Cryosphere		
The Antarctic Treaty Act 1967	Protect mineral resources, fauna and flora, special areas, according to international rights, obligations and arrangements.	Protected areas proportion.
Protocol on Environmental Protection to the Antarctic Treaty, 1998	Comprehensive protection of the Antarctic environment and dependent and associated ecosystems, emphasising the Antarctic Treaty's designation of Antarctica as a natural reserve dedicated to peace and science. Protection of the Antarctic environment is to be fundamental consideration in the planning and conduct of all human activities in Antarctica. This includes protection of Antarctica's intrinsic value (including wilderness and aesthetic values) and its value as an area for the conduct of scientific research (especially research essential to understanding the global environment). The environmental principles in the Protocol also include requirements for prior assessment of the environmental impacts of all activities and regular and effective monitoring to assess predicted impacts and to detect unforeseen impacts.	Monitoring in arctic ice sheet stability and sea level rise, air composition, temperature.
Antarctic Act 1994	Protect mineral resources, fauna and flora, special areas, according to international rights, obligations and arrangements.	Protected areas proportion.
Endangered Species Act of 1973 (16 U.S.C. 1531-1544)	Authorizes the determination and listing of species as endangered and threatened. Prohibits unauthorized taking, possession, sale, and transport of endangered species. Provides authority to acquire land for the conservation of listed species, using land and water conservation funds. Authorizes establishment of cooperative agreements and grants-in-aid to states that establish and maintain active and adequate programs for endangered and threatened wildlife and plants. Authorizes the assessment of civil and criminal penalties for violating the Act or regulations and authorizes the payment of rewards to anyone furnishing information leading to arrest and conviction for any violation of the Act or any regulation issued there under.	Number of criminal penalties per year.
The Scientific Committee on Antarctic Research (SCAR), the International Arctic Science Committee (IASC), and the International Association of Cryospheric Sciences (IACS)	SCAR, IASC and IACS intend to combine their efforts in cryospheric activities (to be decided by mutual agreement) so as to raise the level of impact of all three organizations in terms of making scientific advances and of advising policy makers, as well as to avoid duplication.	Joint bipolar projects, workshops, conferences, and reports on topics of cryospheric science.
Lithosphere		
The Soil Framework Directive - proposal stage	Identifying risk areas with regard to soil erosion, loss of soil organic matter, compaction, salinisation and landslides. Drawing up a programme of measures to prevent soil contamination. Compiling an inventory of contaminated sites. Remediation of those sites.	Proportion of contaminated sites, erosion surface.
Geological Survey Act 1845	Ensuring adequate exploitation of geological resources.	
Minerals (Miscellaneous Provisions) Act (Northern Ireland) 1959	Make further provision with respect to mines, minerals and quarries and operations connected therewith.	
Environmental Protection Act (1990)	Identify areas of Contaminated Land (Local Authorities)	Land where significant harm

Part IIa	Reporting to the Relevant Authority (EA or SEPA) and potential remediation measures.	or potential significant harm is being caused. Pollution of controlled waters is being or likely to be caused.
EC Water Framework Directive (WFD) (2000/60/EC)	Improvement of surface water and groundwater quality. (Relevant water bodies within defined river basin districts must reach at least 'good' status by 2015)	Ecological quality and supporting hydromorphological measures, chemical status, priority hazardous substances.
Pollution Prevention Control Act (1999) (PPC)	Prevention or reduction of pollution by means of an integrated permitting process and use of the Best Available Technologies (BAT)	Measures and recording of emissions to air, water and land, energy consumption and waste production.
EC Sewage Sludge Directive (82/278/EEC)	The Sewage Sludge Directive 86/278/EEC seeks to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and man.	Sampling and analysis of sludges and soils (for heavy metals/pollutants). Records of sludge produced, quanitities used in agriculture, composition, properties, type of treatment & sites where used.
EC Mine Waste Directive (proposed)	Management of extractive waste to prevent or reduce the risk of damage to the environment and human health. To be regulated via permits and use of Best Available Technology.	Management plans include the prevention of environmental pollution. Permits will be administered by the EA/SEPA upon demonstration that measures have been taken to meet community standards and reduce/prevent the leaching or contamination to surfacewaters, groundwaters and soils.
EC Habitats Directive (92/43/EEC)	Conservation of natural habitats and of wild fauna and flora.	Network of protected areas (for which mapping is included)
EC Landfill Directive, more formally Council Directive 1999/31/EC of 26 April 1999	To prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including the greenhouse effect, as well as any resulting risk to human health, from the landfilling of waste, during the whole life-cycle of the landfill.	Waste. Waste must meet certain standards in order to be accepted at one of the 3 classes of landfill: - hazardous - non hazardous - inert
EC Carbon, Capture and Geological Storage Directive (2009/31/EC)	A legal framework for the environmentally safe geological storage of Carbon Dioxide in permanent containments which prevent or eliminate the negative impacts and risk to the environment and human health. Implementation will be via permits.	Carbon Dioxide Compulsory monitoring of the injection facilities, storage complex and the surrounding environment.
Managing Radioactive Waste Safety White Paper	The Government's framework for managing radioactive waste in the long-term through geological disposal, coupled with safe and secure interim storage and ongoing research and development to support	Assessment and evaluation of potential sites & the screening out of site that are unsuitable

	its optimised implementation.	
Planning and Policy guidance for Development on Unstable Land (14)	The guidance sets out the broad planning and technical issues that need to be considered when undertaking development of unstable land.	Landslides, unstable slopes, susidence
Minerals and Waste Planning Guidance	Guidance on land use planning issues related to minerals extraction, waste treatment and disposal	Mineral extraction (marine and terrestrial), waste management
Clean Neighbourhoods & Environment Act 2005	Prevent the defacement by litter of any place on land or water to which Section 87 applies. (England & Wales).	Litter.
Northern Ireland Litter Order	Control pollution caused by litter and dog fouling.	Litter, land based sources
Biosphere		
World Heritage Convention 1972	Define and conserve cultural and natural heritage.	Protected areas.
Convention on Biological Diversity, 1992	Conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources.	National Reports and Strategic Plans.
Convention on the Conservation of Migratory Species of Wild Animals	Conserve terrestrial, marine and avian migratory species throughout their ranges.	Number of species and number of individuals forming each population.
Cartagena protocol on biosafety to the Convention on biological diversity	Ensuring an adequate level of protection in the field of safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking into account risks to human health, and specifically focusing on transboundary movements.	Number of species and number of individuals forming each population.
Global Forest Resources Assessment	Provide an accurate and quality-rated picture of the status and trends of worldwide forest resources for facilitation of improved policies in relation to forests and forest management. Enable countries with the ability to view their forest sector within regional and global environmental and socio-economic contexts. Contribute some of the validated and harmonised data required for international monitoring and assessment functions. Provide data that can be used in scientific and technical studies and can contribute to investment decision support and private sector development. Present relevant information on forests to wider communities, including other sectors, NGOs and the general public.	Forestry data such as surface, volume & species.
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) 1975	All imports, exports, re-exports and introductions from the sea of species covered by the convention have to be authorised through a licensing system.	Number of CITES certificates. Information on convicted illegal traders and persistent offenders.
Convention on Wetlands of International Importance Especially as Waterfowl Habitat (RAMSAR Convention) 1975	To cover all aspects of wetland conservation and wise use, recognising the fundamental ecological functions of wetlands and their economic, cultural, scientific and recreational value.	Information on changes to ecological character caused by dams.
Council Directive 79/409/EEC on the conservation of wild birds, commonly referred to as the Birds Directive,	Protection for all wild bird species naturally occurring in the Union, as a response to increasing concern about the declines in Europe's wild bird populations resulting from pollution, loss of habitats and unsustainable use.	Wild bird populations.

Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora	Establishes Natura 2000 network of protected sites and the strict system of species protection. The directive protects over 1000 animals and plant species and over 200 so called 'habitat types' such as special types of forests, meadows and wetlands, which are of European importance.	Network of protected areas.
Countryside & Rights of Way Act (CROW) 2000	Protect, manage and provide access to areas of conservation importance.	Habitats, species, biodiversity, climate change.
Conservation of Seals Act 1970	Prohibit the killing, injuring or taking of seals.	Grey and common seals.
UK Biodiversity and Action Plan (BAP) 2002	Conserve the UK's biodiversity through action plans to halt biodiversity decline by 2010.	Aquatic habitats, pollution, megafauna, fisheries.
Wildlife and Countryside Act 1981	Control the killing, injuring, taking or trading of selected wild birds or animals. Prevent the establishment of non-native species which may be detrimental to native wildlife. Protection and creation of habitats.	Habitats, species, non-native species.
Nature Conservation (Scotland) Act 2004	Protect and enhance Scottish biodiversity.	Biodiversity, habitats, species.
Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) 1995	Conserve the birds that are ecologically dependent on wetlands throughout each species range.	Migratory birds.
Bern Convention for the Conservation of European Wildlife and Natural Habitats 1982	Conserve and protect all wild plant and animal species and their natural habitats.	Habitats, species.
Convention for the Conservation of Salmon in the North Atlantic Ocean (TIAS 10789) 1982	Promote the conservation, restoration, enhancement and rational management of salmon stocks in the North Atlantic Ocean through international cooperation.	Salmon.
International Convention for the Conservation of Atlantic Tunas 1966	Provide an effective programme of international cooperation in research and conservation to achieve the maximum sustainable catch of tuna.	Tuna.
Agreement on the Conservation of Albatrosses and Petrels (ACAP) 2004	Conserve albatross and the petrel populations and stop or reverse population declines by coordinating action to mitigate known threats.	Albatross and Petrels.
Biomass Action Plan COM(2005)628	Increase the development of biomass energy from wood, wastes and agricultural crops by creating market-based incentives to its use and removing barriers to the development of the market. In this way Europe can cut its dependence on fossil fuels, cut greenhouse gas emissions and stimulate economic activity in rural areas.	Assistance for afforestation costs.
Council Regulation (EEC) No 3528/86 of 17 November 1986 on the protection of the Community's forests against atmospheric pollution	Protect forests against atmospheric pollution, in order to provide increased protection for forests in the Community and thereby contribute in particular to safeguarding the productive potential of agriculture.	Periodic inventory of damage caused to forests.
The Conservation (Natural Habitats, &c.) Regulations 1994, UK	Conservation of natural habitats and of wild fauna and flora.	Network of protected areas.
Fluxes between environmental domains		
Strategic Environment Assessment (SEA) Directive 2001/42/EC	Protect the environment from adverse effects of construction and development; monitor adverse and beneficial environmental effects	Environmental assessment
Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment (EIA Directive)	Make environmental assessment of plans and projects.	Environmental assessment, biodiversity, baseline data.

Environmental Liability - Directive 2004/35/EC	Prevention and remedying of environmental damage - specifically, damage to habitats and species protected by EC law, and to species or habitat on a site of special scientific interest for which the site has been notified, damage to water resources, and land contamination which presents a threat to human health.	Surface of damaged surfaces.
Directive 2008/1/EC of 15 January 2008 concerning integrated pollution prevention and control (IPPC)	Preventing, reducing and as far as possible eliminating pollution by giving priority to intervention at source and ensuring prudent management of natural resources, in compliance with the 'polluter pays' principle and the principle of pollution prevention.	Number of IPPC permits.
Commission decision 2000/479/EC of 17 July 2000 on the implementation of a European Pollutant Emission Register (EPER) according to Article 15 of Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC)	Satisfy the public's right to know of emissions (releases) from industry to the environment.	Number of inspections and penalties.
Directive 2003/105/EC on the control of major-accident hazards involving dangerous substances	Prevention of major accidents which involve dangerous substances and the limitation of their consequences for man and the environment, with a view to ensuring high levels of protection.	Number of inspections and penalties.
Directive 2006/121/EC concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and establishing a European Chemicals Agency	Protection of human health and the environment from the risk that can be posed by chemicals, promotion of the alternative test methods and enhancing competitiveness and innovation	Number of inspections and penalties.
Council Directive 98/81/EC on the contained use of genetically modified micro-organisms	Common measures for the contained use of genetically modified micro-organisms for the purposes of protecting human health and the environment.	Monitoring and control of quantity and areas.
Council Directive 96/29/EURATOM	Ensure that the exposure of the population to ionising radiation is kept as low as reasonably achievable.	Ionising radiation.
Environmental Protection Act 1990	Control pollution arising from industrial and other processes.	Environment substances.
Environment Act 1995	Prevent, minimise, remedy or mitigate the effects of pollution of the environment.	Land, water and air sources, litter.
Societal Issues		
Information		
Freedom of Information Act 2000	Make provision for the disclosure of information held by public authorities or by persons providing services for them.	Information access.
Access to Environmental Information Directive 90/313/EC	Ensure that environmental information is systematically available and distributed to the public.	Information data.
Convention on Access to Information, Public Participation in Decision making and Access to Justice in Environmental Matters (Aarhus Convention)	Provide access to information, public participation in decision making and access to justice in environmental matters.	Information access.
Noise		
Directive 2002/49/EC relating to the assessment and management of environmental noise	Define a common approach to avoid, prevent or reduce (on a prioritised basis) the harmful effects, including annoyance, of exposure to environmental noise	Common noise indicators.
Commission Recommendation of 6 August 2003 (2003/613/EC) concerning the guidelines on the revised interim computation methods for industrial	Providing a basis for developing Community measures to reduce noise emitted by major sources as road, rail, air traffic and sites of industrial activity (IPPC).	Strategic noise mapping.

noise, aircraft noise, road traffic noise and railway noise, and related emission data		
Noise Act 1996, UK	Make provision for noise emitted from dwellings at night; about the forfeiture and confiscation of equipment used to make noise unlawfully; and for connected purposes.	Noise limit values and target values.
The Environmental Noise (England) Regulations 2006	Assessment, management and control of environmental noise.	Strategic noise mapping.
Waste Management		
Directive 2006/12/EC of the European Parliament and of the Council on waste	Ensure the disposal and recovery of waste. Take measures to restrict the production of waste particularly by promoting clean technologies and products which can be recycled and re-used, taking into consideration existing or potential market opportunities for recovered waste	Waste generation, expressed in kg per person, and the method of treatment (recycling, composting, landfill or incineration).
Directive 2000/76/CE on waste incineration.	Prevent, or limit as far as practicable, negative effects on the environment from incineration and co-incineration of waste.	Quantity of incinerated waste.
Council Directive 91/689/EEC on hazardous waste	Ensure that disposal and recovery of hazardous waste is monitored as fully as possible.	Quantity of hazardous waste produced by industry and the recycled proportion.
Regulation 1013/2006/EC of the European Parliament and of the Council on shipments of waste	Organise and regulate the supervision and control of shipments of waste in a way which takes account of the need to preserve, protect and improve the quality of the environment and human health and which promotes a more uniform application of the Regulation throughout the Community.	Common procedure.
Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators	Prohibits the placing on the market of certain batteries and accumulators with a proportional mercury or cadmium content above a fixed threshold. In addition, it promotes a high rate of collection and recycling of waste batteries and accumulators and improvement in the environmental performance of all involved in the life-cycle of batteries and accumulators, including their recycling and disposal.	kg per capita.
Directive 2002/96/EC on waste electrical and electronic equipment	Reduce the quantity of waste from electrical and electronic equipment and increase its re-use, recovery and recycling.	kg per capita.
Directive 94/62/EC on Packaging and Packaging Waste	Minimising the creation of packaging waste material and promoting energy recovery, re-use and recycling of packaging.	kg per capita.
End of Life Vehicles Directive	Reduce the amount of waste from vehicles when they are finally scrapped.	proportion of vehicles recycled.
Landfill Directive	Reduce the pollution potential from land-filled waste that can impact on surface water, groundwater, soil, air, and also contribute to climate change.	kg per capita.
Directive 75/439/EEC on the disposal of waste oils	Ensure the safe collection and disposal of waste oils and, as far as possible, give priority to the processing of waste oils by regeneration (refining). Where this process is not used, other methods may be considered: combustion, destruction, storage or disposal.	Records of the quantity, nature, origin and, where relevant, destination and treatment method of oil.
Dangerous Substances Directive (EU Directive 76/464/EEC, codified as 2006/11/EC)	Eliminate environmental pollution from discharge of various dangerous substances.	Pollution, List I and List II hazardous substances.
Titanium Dioxide Directive (78/176/EEC)	The prevention and progressive reduction, with a view to its elimination, of pollution caused by waste from the titanium dioxide industry.	Titanium Dioxide.

Radioactive Substances Act 1993	Prevent exposure to radiation resulting from inadequate control of radioactive materials and accumulation and disposal of radioactive waste.	Radioactive waste disposal.
The Waste Management (England and Wales) Regulations 2006	Prevention, reduction and elimination of pollution caused by waste and in relation to measures relating to the prevention, reduction and elimination of pollution of water.	Records of the quantity, nature, origin and, where relevant, destination and treatment method of all waste.
The Waste Management Licensing Amendment (Scotland) Regulations 2003	Prevention, reduction and elimination of pollution caused by waste and in relation to measures relating to the prevention, reduction and elimination of pollution of water.	Records of the quantity, nature, origin and, where relevant, destination and treatment method of all waste.
The Site Waste Management Plans Regulations 2008	Organise and regulate the supervision and control of shipments of waste in a way which takes account of the need to preserve, protect and improve the quality of the environment and human health.	Number of sites not applying the Regulations.
chlor - alkali Directive (EU Directive 82/176/EEC)	Limit mercury discharges by the chlor-alkali electrolysis industry.	Mercury.
The National Waste Strategy: Scotland 1999	Reduce, Reuse, Recycle!	Limit values and target values.

APPENDIX F: ORGANISATIONS' OBSERVATIONAL NEEDS

Some individual statements of needs are listed in Table 4

Table 4: Key documents that articulate observational needs

Owner Organisation	Document and Reference	Summary of Content
Environmental – Knowledge Transfer Network (E-KTN)	Priority Technology Area 8: Environmental Monitoring & Forensics. 32pp (2008)	Evidence-based and industrially-led business case for the enhancement of the UK's capability within the E-KTN's priority technology area of Environmental Monitoring and Forensics (EMF). The report provides a summary of the potential EMF market and the current gaps. The technological needs and R&D requirements are identified.
WMO-IOC/UNESCO- UNEP-ICSU Global Climate Observing System	Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC, GCOS-92, 2004	This summarises: the type, geographic and temporal distribution and quality of atmospheric, oceanic and terrestrial observations needed to meet the needs of the UNFCCC; the costs and agents; access to data; and future developments. In 2009, nations will be reporting to UNFCCC on progress.
WMO-IOC/UNESCO- UNEP-ICSU Global Climate Observing System	Systematic Observation Requirements for Satellite-Based Products for Climate (GCOS-107), 2006.	This gives specific requirements for spatial and temporal resolution, accuracy and stability for a wide range of atmospheric, oceanic and terrestrial observations - whether or not measured by satellite.
SAHFOS – Sir Alister Hardy Foundation for Ocean Science	Science Strategy 2008 - 2012	Emerging issues in the next five years: Interannual to decadal changes in the North Atlantic, including ecoregions and marine ecosystems that are particularly vulnerable to climate change. Ecosystems: large-scale change; stable or unstable states; prediction of abrupt shifts. Theory of marine ecosystem functioning, ecosystem resilience and the functional role of biodiversity. Effects of climate change on carrying capacity of all trophic levels of marine ecosystems. Understanding drivers of ecological environmental change such as climate warming, eutrophication and perhaps acidification). Identification of organisms, communities and ecoregions vulnerable environmental change Interannual to decadal scale indicators of ecosystem function and state, including those of use for ecosystem management and fisheries.