State of Scotland's Environment 2006

change
tomorrow
today

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Foreword

The Scottish Environment Protection Agency State of Scotland's Environment 2006

We present this report at a time when questions about climate change, the environment and sustainable development are high on the political and public agendas. This report represents a SEPA contribution to those agendas.

The report itself is simultaneously modest and ambitious. It is modest in the sense that it is largely a collation of existing data and information from SEPA and other sources, and it sticks closely to the integrity of its simple, primary purpose – to report on the state of the environment. It is ambitious in that we wish to see this unique record of Scotland's environment in 2006 being used as a catalyst for stimulating interest in the issues, and informed thinking and debate about the priorities and the actions needed to deal with them.

In drawing the report together a number of things became clear. Firstly there are no simple answers, secondly there are data and knowledge gaps that need to be filled and thirdly, the data and trends on most issues point, perhaps unsurprisingly, to a mixed picture – some good aspects, some poor, some things that have improved over the last decade, some that are getting worse and some that have stayed much the same. The Summary chapter includes a 'barometer' showing SEPA's judgements about the 'state' and 'trends' relating to each aspect of the environment.

We also realised early on that there were three overarching issues to which all the chapters related – biodiversity, human health and climate change – and the final three chapters of the report deal with these important topics. These are of course on global as well as local agendas at the moment, reflecting their paramount importance.

When SEPA published its first State of the Environment report in 1996, climate change was only recognised as a 'possible' effect associated with greenhouse gas emissions. SEPA itself was a brand new organisation with a specific duty to address sustainable development, based on SEPA-specific guidance provided to us by the then Secretary of State for Scotland.

Since then, the political framework within which SEPA works has changed radically. We are now responsible to the Scottish Parliament via Scottish Ministers, and the Scottish Executive has recently published two landmark documents: *Changing Our Ways: Scotland's Climate Change Programme*, and *Choosing Our Future: Scotland's Sustainable Development Strategy*, the latter of which embeds the concept of environmental justice in the policy agenda. In these pages there is information about many of the issues central to those documents, and absolutely fundamental to Scotland's economic, environmental and social success.

Can a country as small as Scotland, with 5 million or so people, make any real difference to the global threats of climate change and unsustainable development? To those who say no, we offer this report as evidence that progress can be made, that problems do remain but, most importantly, that many of the solutions to global problems are to be found locally. To those who are saying yes, it provides a benchmark and encouragement.

We in Scotland can set an example to the world in our pursuit of sustainability. In doing so we can benefit not only environmentally and economically, but also in our overall well-being. An ambitious agenda? Yes, but an achievable one if we recognise that many of the solutions lie in our own hands.

Sir Ken Collins, Chairman **Dr Campbell Gemmell, Chief Executive**

Scottish Environment Protection Agency
October 2006

Summary and introduction

Summary

This report provides information on the different aspects of Scotland's natural environment, using the most recent data available from a variety of sources to provide a picture of its overall condition or state.

While some aspects would benefit from more data and better information, it is clear that the most important message is that climate change is happening and that there is evidence of fundamental alterations to the key elements of our climate system as a result of mankind's activities. Left unchecked these changes will accelerate, causing further damage to the physical, biological and chemical processes that sustain not only Scotland's environment but our economic and social well-being as well.

Positives and negatives

On the positive side, the Scottish environment is generally of good quality. Historically, there have been many improvements, particularly as a result of the reduction in emissions from industrial sources. In most areas, air quality standards are met for most of the time and the state of our freshwater environments is largely good, thanks to concerted and continuing action to reduce pollution and control discharges. Similarly, for much of the year, Scotland has abundant water in most, but not all areas and our landscapes of mountains and coasts provide the backdrop for a generally high quality of life and the basis of a successful tourism industry and vibrant economy.

However, there are problems, including:

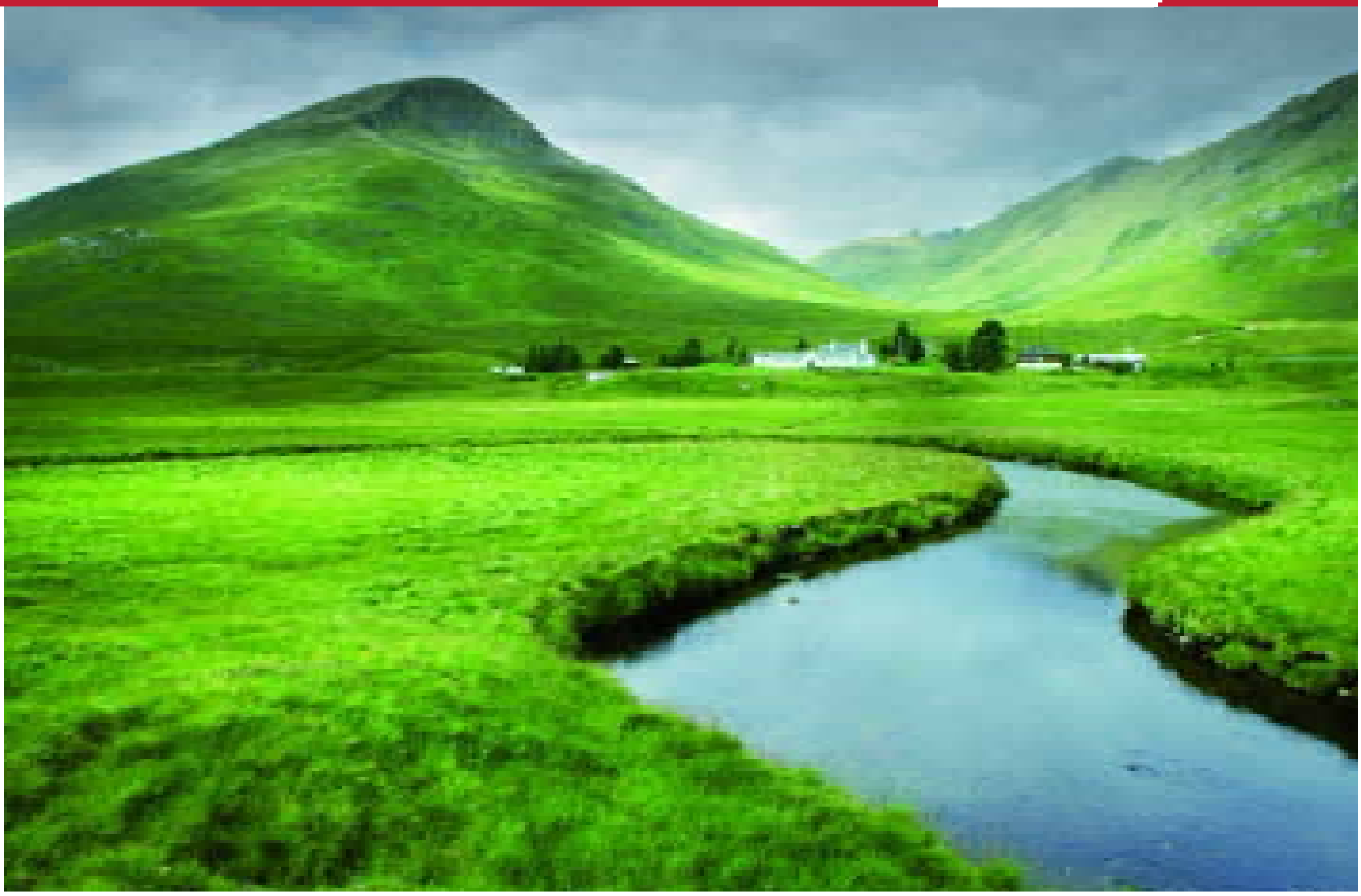
- localised air pollution;
- reductions in stratospheric ozone;
- risks to water quality from diffuse pollution;
- increases in the amount of waste being produced;
- potential ecological damage from nutrient enrichment and acidification;
- loss of biodiversity.

There are also gaps in knowledge about a number of aspects of the environment including, for instance land (especially soil) quality, the environmental implications of hazardous chemicals and the relationships between the environment and human health.

Most significantly, climate change is leading to changes in temperature, rainfall patterns, snow cover, wind and storm events, flooding and coastal erosion: all of these could have significant impacts on Scotland's environment, economy and people.

Long term implications

Although Scotland's population has stabilised in recent years, the number of households and our consumption of materials is increasing. Many of the environmental challenges that we face have long-term implications. These problems are linked to everyday consumption generally, and to our use of food, water, energy, goods, services, land, property and transport specifically. Globally, Scotland's ecological footprint is three times greater than is sustainable and we are living beyond our current means.



The State of Scotland's Environment: summary of key findings

The following table presents SEPA's views on the overall situation, looking in particular at the **state** of the environment (is it good, poor or in between) and the **trend** (whether it is getting better, worse or is mixed - with different individual aspects better, worse or largely unchanged). We offer this as a starting point for what we hope will be a robust and informed debate about Scotland's progress towards sustainability.

The overall picture of the state of Scotland's environment is complex and has to be seen relative to Scotland's position as a small nation within the European Union and relative to the aspiration set out in Scotland's Sustainable Development Strategy to be an 'exemplar of sustainability'. There is a growing recognition of the need to develop comparative environmental indicators across the enlarged EU, but these are not fully developed. Because of this difficulty of comparing like with like, we have not attempted to benchmark Scotland against other countries.

The assessments of the state of the environment represent SEPA's judgement of the condition of Scotland's environment. The judgements are based on SEPA's accumulated data, information, knowledge and expertise, and are inevitably challenging due to uncertainties and the complexity of environmental processes. The table is intended as an informal guide to the relative overall degree of concern about different aspects of the environment, by highlighting how far away from the aspirational state we are.

The trend indicates whether we are moving towards or away from the aspirational state. Judgements about the trend have been made by referring to the major contributing factors over the last ten years. Many of the subject areas are complex and there may be some aspects that are improving within an area while others may be deteriorating. The commentary in the table aims to provide more context as to how the view was reached.

Further information on each aspect can be obtained by referring to the relevant chapter in the report.

Aspect	Summary of state (POOR ⟷ GOOD)	Trend	Explanation
Air			Overall air quality is improving but further improvements are needed to reduce adverse health effects and deaths brought forward by air pollution. Poor air quality also has the potential to damage ecosystems and water quality. Transport is an increasingly significant source of air pollution and increasing energy demand may lead to increased emissions. Emissions of nitrogen oxides and sulphur dioxide have fallen, and emissions of particulates and volatile organic compounds are showing a downward trend. However, there is a general increase in ground-level ozone concentrations, and a decline in stratospheric ozone levels over Scotland.
Land			Land quality in Scotland is reasonable, although there are significant knowledge gaps, especially about soils. Agriculture and forestry can lead to soil erosion and losses of nutrients but new policies are encouraging good practice in conserving soil organic matter and promoting biodiversity. Measures are being taken to enhance habitats and to counteract loss of species, and progress has been made with the regeneration of derelict and contaminated land. Soil erosion is a continuing problem and there are concerns about loss of soil organic matter and soil sealing by impermeable surfaces.
Water			Water quality in Scotland is generally good and is improving due to a reduction in end-of-pipe discharges. There have been major improvements in the quality of bathing, shellfish and freshwater fish waters. Diffuse pollution, for example from farmland and roads, is now the largest problem. Water is generally abundant but increased demand is likely to put pressure on levels in groundwater, lochs and rivers. Changes in river flow patterns may increase the risk of flooding and rivers in the east may experience lower flows in summer. Impacts on the physical structure of rivers, estuaries and coastal waters are widespread.
Waste and resources			Around 20 million tonnes of waste is produced each year, mostly from commerce and industry. Household waste continues to increase and fly tipping and litter remain problems. Waste disposal to landfill is falling and there is more recovery and recycling of waste. Emissions to the environment from landfills and thermal treatment plants are reducing and more landfill gas is being used to produce energy. Stricter controls on landfill operations mean that the environmental impact of sites is decreasing. Emissions of dioxins and nitrogen oxides from municipal waste incinerators have fallen.
Radioactivity			Levels of man-made radioactivity in the environment show a general downward trend. Concentrations in drinking water remain well below the limit set to protect human health. Some localised areas of contamination from man-made radioactivity remains Averaged exposure to ionising radiation from man-made sources is less than one fifth of that from natural background radiation and medical uses represent the predominant source of man-made exposures. Exposure from radioactive emissions to the environment is less than 0.1% of all sources of ionising radiation. Overall, radioactive emissions from nuclear installations have fallen since 1996.
Hazardous chemicals			The use of hazardous chemicals has reduced but many are still used and the long-term effects are unclear. A number of 'hotspots' of chemical contamination persist but historic problems caused by heavy metals and persistent organic chemicals have reduced. Problems caused by hazardous substances in run-off from urban areas continue to have ecological impacts. There is increasing concern over the rising concentrations of some newly identified chemicals and over more subtle impacts like food chain contamination and accumulation of persistent chemicals. Further problems may become more apparent as knowledge and understanding of them grows.

Aspect	Summary of state	Trend	Explanation
	POOR ⟷ GOOD	↓ ↔ ↑	
Nutrient enrichment		↑	Nutrient enrichment of rivers, lochs and groundwater can damage ecosystems and is a significant problem in some areas. Effects on estuarine and coastal waters are limited. The area of semi-natural terrestrial habitats at risk from nitrogen deposition has declined slightly, but the potential for damage to specific habitats remains high. Emissions of nitrogen oxides to air show a downward trend. Ammonia emissions are the dominant source of nitrogen deposition and remain a major problem. Better targeting and supply of nutrients in fertilisers can prevent nutrient enrichment. Discharges of nutrients to water from sewage treatment works are being reduced.
Acidification		↑	Acidification can damage ecosystems and is a potential problem across upland Scotland. There is evidence of ecological damage in Galloway, the Cairngorms and the western and central Highlands. Between 1986 and 1997 deposition of sulphur dioxide declined by 52%, and nitrogen oxides by 16%. Impacts on vegetation, soil and freshwater habitats show a slight decrease and there is some evidence that soils are becoming slightly less acidic. Some areas are showing signs of recovery but some watercourses remain devoid of acid-sensitive plants, invertebrates and fish. Recovery may take decades and climate change may slow or halt this.
Human health		↑	The environment plays a significant part in the health and quality of life of individuals and communities in Scotland, but the relationship between environmental pollutants and health is complex and uncertain. Other factors also affect health and further work is required to investigate environmental impacts. There is growing evidence that environmental factors affect both our health and well-being and contribute to environmental injustice. Air pollutants such as nitrogen dioxide, sulphur dioxide and small particles make respiratory and cardiovascular illnesses worse and, in some circumstances, hasten death in vulnerable people.
Biodiversity		↔	Intensive land use in the last 250 years led to significant declines in Scotland's biodiversity. In 2005 nearly 32% of habitats and 18% of species identified under the UK Biodiversity Action Plan were declining, although around 32% of habitats and 39% of species were either stable or showing signs of recovery. However, the impact of climate change is already evident with some species ranges being reduced, others extended and food chains being disrupted. This makes the attainment of the EU target to halt loss of biodiversity by 2010 challenging. Active management will be necessary to maintain many habitats and species in Scotland. The Scottish Biodiversity Strategy provides a framework for this.
Climate change		↓	Climate change is already causing a number of impacts on Scotland, including changes in the growing, breeding and migration seasons, shifts in species abundance and diversity and changing weather patterns with the potential for more floods and droughts. Left unchecked, climate change will accelerate with significant consequences for Scotland's environment, economy and society. The use of fossil fuels and growing demand for energy will escalate emissions of carbon dioxide to potentially irreversible levels. Scotland needs to take action to tackle the problem and to prepare itself for the inevitable impacts.

Introduction

Why the state of the environment is important

The state (or condition) of our local, regional and global environment is important to everyone who works in, lives in or visits Scotland. A healthy environment is not only fundamental to our own health, it is our life support system. It provides us with the basic essentials for life:

- air to breathe, water to drink and productive land for food, fuel and fibre;
- a favourable climate for growth and development;
- space for recreation
- shelter and protection from the elements.

The natural environment also provides us with services which are essential for all life on earth. These 'ecosystem services' include pollination, photosynthesis, water supply, the maintenance of soil fertility, water retention and storage, flood alleviation, waste breakdown and disposal, carbon storage and sources of energy. However, we rarely recognise the ecological or human health benefits of these services, or their true financial value.

A good environment can encourage a healthy lifestyle and contribute to the well-being of the population. Green spaces in urban areas and easily accessible, attractive paths are vital resources and being close to and watching wildlife is an increasingly popular pastime.

Scotland has a rich and diverse environment. It is home to a wide range of habitats and species, many of which are of international conservation importance (e.g. peatlands, seabird populations and Atlantic salmon).

The environment is fundamental to our economy and is one of Scotland's biggest assets. It generates income both directly (for example through farming, forestry and as a source of raw materials) and indirectly. For example, much of the tourism in Scotland, which is estimated as contributing over £5 billion to the Scottish economy in 2006[I1], is dependent on the wild and beautiful landscape of our coasts, lochs, rivers and mountains. At the same time, the countryside plays a role in attracting and retaining good quality enterprises and a highly skilled workforce.

This report considers Scotland's natural environment in terms of its three main components: air, land and water. This division is somewhat artificial as each element is strongly linked to the others, with processes taking place in one having impacts on another (see Figure I1).

The Scottish Environment Protection Agency (SEPA)

As Scotland's environment protection agency, SEPA has a duty to monitor and report on the state of Scotland's environment. Since it was established in 1996 SEPA has published reports on the overall state of the environment (1996) and on individual aspects of the environment – Air (1999), Land (2001), Water (1999) and Waste (annually since 1999), as well as recent characterisation and impacts analyses for the Scottish River Basins required as part of the EU Water Framework Directive. In addition, SEPA has published a very wide range of data, information and advice on specific topics. All of this information can be accessed on the website www.sepa.org.uk

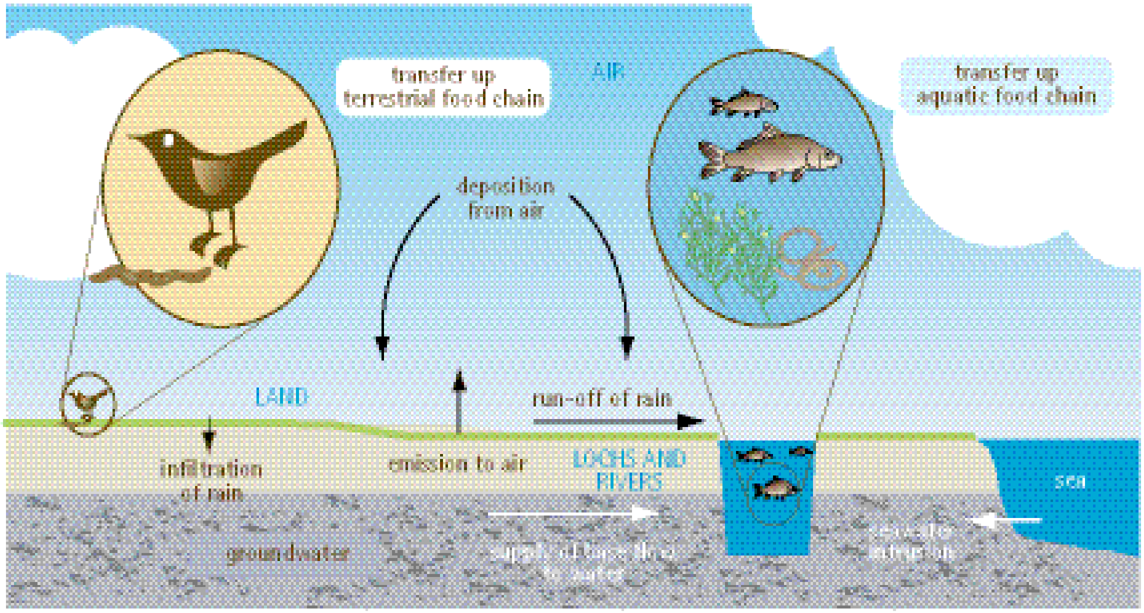
SEPA is a non departmental public body, responsible to Scottish Ministers who are ultimately accountable to the Scottish Parliament for SEPA's activities and performance. As Scotland's environmental regulator and advisor SEPA is responsible for:

- controlling pollution;
- promoting the sustainable management of natural resources;
- encouraging public understanding and participation;
- protecting the environment and human health.

Although SEPA works closely with the relevant organisations, SEPA's remit does not cover all aspects of the environment. For instance, Scotland's 32 Local Authorities are responsible for local air quality monitoring and the declaration of Air Quality Management Areas, and for much of the contaminated land regime. Energy policy is not devolved to the Scottish Parliament and remains the responsibility of the UK government.

A list of environmental legislation, along with guidance on its application, can be found on the NetRegs website www.netregs.gov.uk

Figure I1: Environmental links between air, water and land

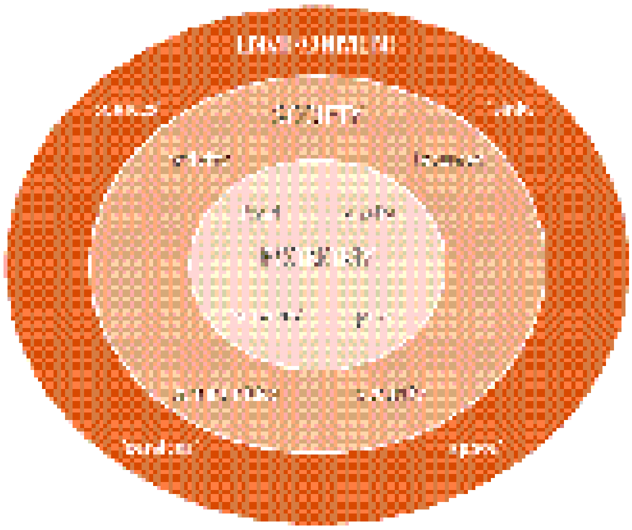


This central importance of the state or condition of the natural environment is ultimately captured in the concept of sustainable development, which has at its core the interlinking dependency between the three elements:

- environment;
- economy;
- society.

Scotland's Sustainable Development Strategy *Choosing our Future*[I2] recognises that achieving a sustainable economy and ensuring a strong, healthy and just society can be achieved only by living within environmental limits. The state of the environment is therefore very important, as highlighted in Figure I2.

Figure I2: Relationship between environment, society and economy



Source: *Environment in the European Union at the Turn of the Century*, European Environment Agency, 1999.

In the 19th century, rapid economic growth led to very rapid social change in Scotland and the rest of the developed world – a pattern now being repeated globally. It is becoming apparent that continued economic growth can not be sustained unless there is increased focus on protection and care for the environment, including sustainable use of resources. However, Scotland is not isolated from a world in which demand for oil, gas and water, for example, is huge and growing rapidly (particularly in China and India), but where half the population is still living on less than £1.50 a day and 2.2 billion people have no access to effective sanitation.

Just how important the environment is to the global economy has been the subject of various studies that have attempted to capture in monetary terms the value of the environment and its associated services. At a global level, this has been estimated at $38 trillion per annum[13]. Work by SEPA using the same methodology has suggested that the ecosystem services provided by the natural environment are annually worth some £17 billion in Scotland – equivalent to 27% of gross domestic product (GDP) in 1998[14].

Our ecological footprint

The Ecological Footprint is one way of measuring how our lifestyles impact not only on the planet, but also on other people. It calculates how much productive land and sea is needed to feed us and provide all the energy, water and materials we use in our everyday lives. It also calculates the emissions generated from the oil, coal and gas we burn at ever-increasing rates, and it determines how much land is required to absorb our waste.

It has been estimated that the lifestyles of Scotland's 5 million population use up the equivalent of three planets – which is not sustainable. The estimate is based on the fact that Scotland, in common with the rest of the UK, has one of the biggest footprints in the world, requiring 5.4 global hectares per person compared with an available global capacity of just 1.8 global hectares per person[15]. Although its contribution from food, housing, services and holiday activities are the same as the rest of the UK, Scotland's carbon dioxide emissions are higher for household energy.

At a global level, mankind's current footprint exceeded the Earth's biological capacity by about 21% in 2001, or put another way, globally we needed 1.2 planets to support us at that time[16]. Although by their very nature these measurements are not precise, they show in a dramatic and simple manner just how unsustainable our current lifestyle is. Geographical areas of higher incomes where inhabitants have greater access to resources and travel opportunities, have the least sustainable lifestyles and the greatest adverse impact on the environment.

For more information on ecological footprints, see: www.wwf.org.uk/researcher/issues/footprint/index.asp

Factors influencing the state of the Scottish environment

Historically (and pre-historically) the dominant factors influencing the Scottish environment were:

- natural variations at a global scale, such as volcanic activity;
- the coming and going of ice ages;
- colonisation by plants and animals.

In more recent historic times, the impact of settled forms of agriculture and movements of human populations across Europe, along with sustained population growth has been a dominant factor on the Scottish environment. In the last three centuries, Scotland has seen major changes at a national level as a result of the industrial revolution and the associated population growth and movement away from the countryside to urban areas.

Scotland's environment is subject to continuous change. Some is as a result of the natural forces acting upon it, but most now is strongly influenced by human activities. Some of these changes have been very obvious, for example, emissions of pollutants from industrial processes and sewage disposal, and these have been increasingly controlled by environmental laws. Others are less obvious, such as run-off from agricultural land leading to nutrient enrichment of surface waters, or small-scale discharges of exotic chemicals at extremely low concentrations leading to changes in fish reproductive biology. There may be as yet unknown changes such as the potential impacts of the development of nanotechnology. It is these changes generated by human activity that are of concern, particularly when they occur at such a rapid rate that the environment may not be able to adjust. Our concern must be that some changes, such as climate change, may prove to be irreversible and a point will be reached where the consequences are dramatic (see Box I1).

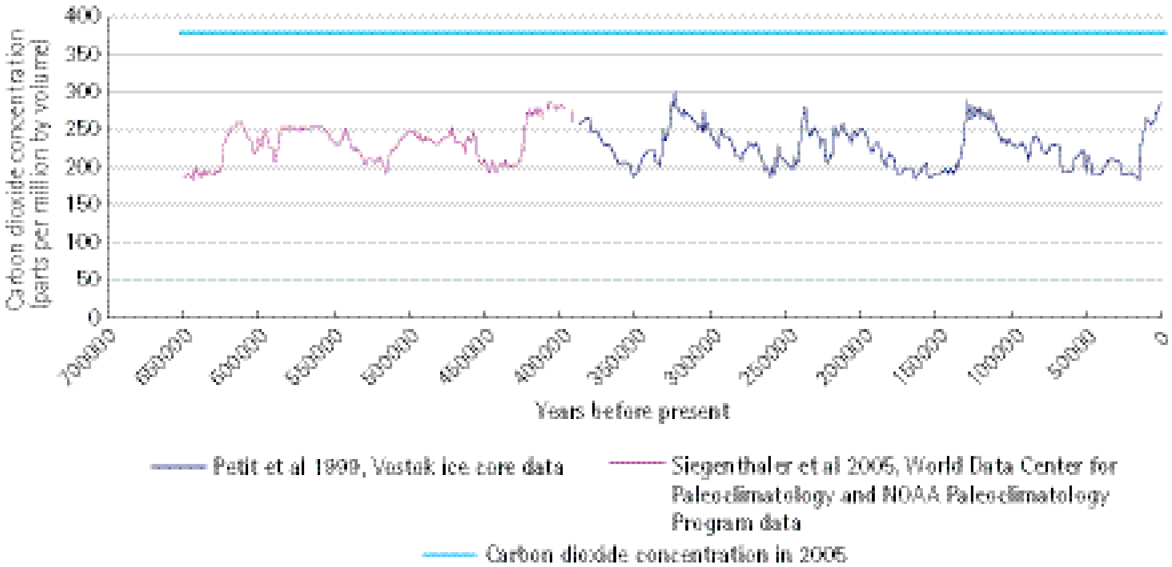
The state of Scotland's environment is influenced primarily by flows of materials through the environment and, in particular, by production to meet our increasing requirements for:

- food, fuel and fibre – derived from livestock, fish, crops, timber, oil, gas, coal and the forces of nature;
- fresh water – its collection, treatment and distribution;
- housing – using aggregates, timber, other materials and agricultural land;
- transport – relying on the combustion of fossil fuels;
- goods and services – energy-intensive and often sourced from abroad.

These factors, and the impacts of our use of materials, extend way beyond what might be seen as traditional views, as exemplified by one modern day Scottish 'essential' – the car (see Figure I3).

Box I1: Carbon dioxide and climate change

The concentration of carbon dioxide in the Earth's atmosphere reached 380 parts per million (ppm) in April 2006. Deep ice cores from the Antarctic, which contain tiny bubbles of ancient atmospheres, reveal that carbon dioxide has never been higher than 300 ppm over the last 650,000 years – across numerous ice ages and interglacial warming periods (see figure below). In the last year alone, the concentration has risen by 2.1 ppm – an acceleration of the rate of increase. Since our climate is directly linked to carbon dioxide in the atmosphere, there is good reason to be worried.

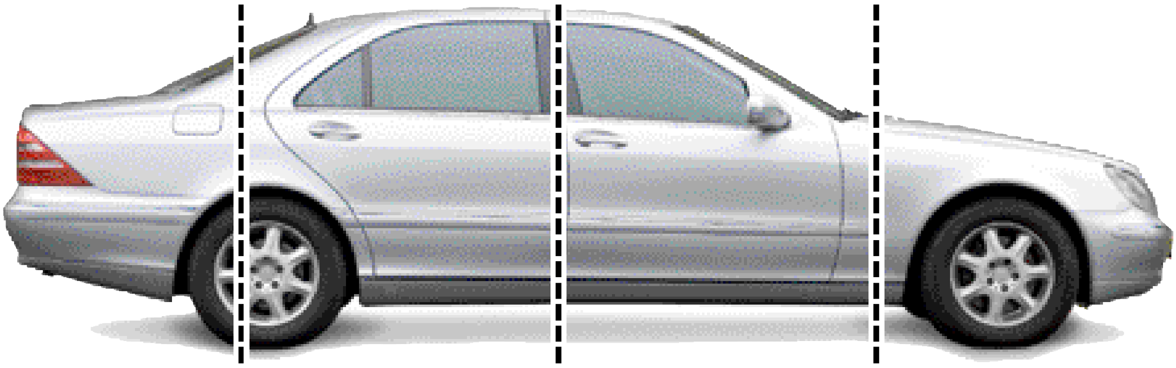


In the past 100 years, the average temperature in the northern hemisphere has risen by 0.7°C. Powerful computer models predict increasing temperature rise in the next century, increased storms, rising sea level, and the fearsome prospect of floods and droughts. It is expected that many millions of people will be displaced by flooding in south-east Asia; millions will face drought and failing crops in Africa. It seems likely there will be mass migrations and disputes over water resources and food supplies. There will be mass extinctions of species as they are unable to move or adapt to changed conditions.

Urgent action is therefore needed to reduce our emissions of carbon dioxide.

Figure I3: An illustration of how an everyday commodity (the car) can change the state of Scotland's environment

Climate change	Air	Water	Land
The 73% increase in road traffic between 1980 and 2002 has resulted in a 39% increase in greenhouse gas emissions from transport, which now accounts for 26% of UK emissions. *Source: DfT Transport Trends 2002*	Traffic is the main cause of exceeding EU air quality objectives for nitrogen oxides (NOx) and particulates (PM_{10}) and air quality is still deteriorating in relation to NOx. *Source: ENDS 2005*	In Scotland, it is estimated that 20% of downgraded rivers are caused by urban drainage. A major input of hazardous metals and organic pollutants into urban drainage is run-off from road traffic. *Source: SEPA report*	In Scotland, there are 54,543km of public road, representing 0.6% of land coverage. This a distance equivalent to travelling around the world one and half times. *Source: DfT, 2005*



A tonne of carbon is emitted by: • Driving round trip Edinburgh to London 10 times • Taking the train round trip Edinburgh to London 70 times. *Source: www.transform scotland.org.uk/info/ publications.html#Cars*	In traffic jams the air quality can be poorer inside the car than out. Car users suffer up to three times as much pollution as pedestrians. *Source: Fédération Internationale de l'Automobile (FIA) Foundation*	Contaminants are deposited on roads from vehicle exhaust emissions, atmospheric deposition and tyre erosion. Rainfall events then wash these contaminants into receiving water bodies, often leading to degradation in water quality. *Source: SEPA*	In Scotland, it is estimated that a high proportion (maybe up to 75%) of otters that die before they reach their expected lifespan are killed in road accidents. The otter is a protected species, its habitat extending up to 50 km along a river bank. *Source: download. edinburgh.gov.uk/ biodiversity/027_Otter.pdf*

Fact or Fiction – old cars are more environmentally friendly than new cars?

An older car will probably use more fuel per mile during its remaining time on the road. However, manufacturing a car takes a lot of energy and materials – some estimates say this embodied energy equals 15% of the total fuel used during the life cycle of the vehicle. The average age of a car in the UK is 6.8 years.

Source: green choices – transport section

About this report

This report presents information about Scotland's environment ten years after SEPA first reported on the state of the environment[I7]. It aims to raise awareness, to inform people of the key environmental issues and to encourage greater debate on how to progress towards a sustainable Scotland.

There is a need for robust environmental evidence to be available so that, individually and collectively, we can make better decisions when faced with choices and the need to balance social and economic considerations with environmental ones[I2]. There are many challenges ahead in promoting and adopting sustainable lifestyles and activities. These challenges cannot be met unless people have the necessary knowledge and understanding.

What does the report contain?

The report provides details of the state of the air, land and water of Scotland for 2005 or the most recent year for which data are available. Information has been gathered not only from SEPA's own sources of data, but also from other organisations across Scotland and the UK where relevant. These data and the analyses and commentary provided have been reviewed both internally by SEPA staff and externally by invited reviewers.

The report highlights recent changes, as well as historic trends, and identifies any broad implications that these may have – for example on human health or biodiversity. The changes are linked to contributing factors such as land use and emissions associated with production and consumption. The reported state may change as our understanding of the environment improves.

The report is divided into a number of parts:

Part A – contains this Introduction and a Summary, which considers the main environmental issues by 'state' and 'trend'

Part B – details the state of air, land and water in Scotland, the main focus of the report

Part C – highlights key environmental issues that cut across these media

Part D – outlines the key environmental challenges

Part E – presents our conclusions.

Examples are given to illustrate key points. References to particular sources of information are numbered, with details provided in a table at the end of each chapter. Sources of further information are provided via web addresses (current as of June 2006) within the text or in a separate table at the end of each chapter.

Some chapters have supplementary material accessible through the online version of the report. A glossary of terms (highlighted in blue when they first appear in a chapter) and a list of acronyms are provided.

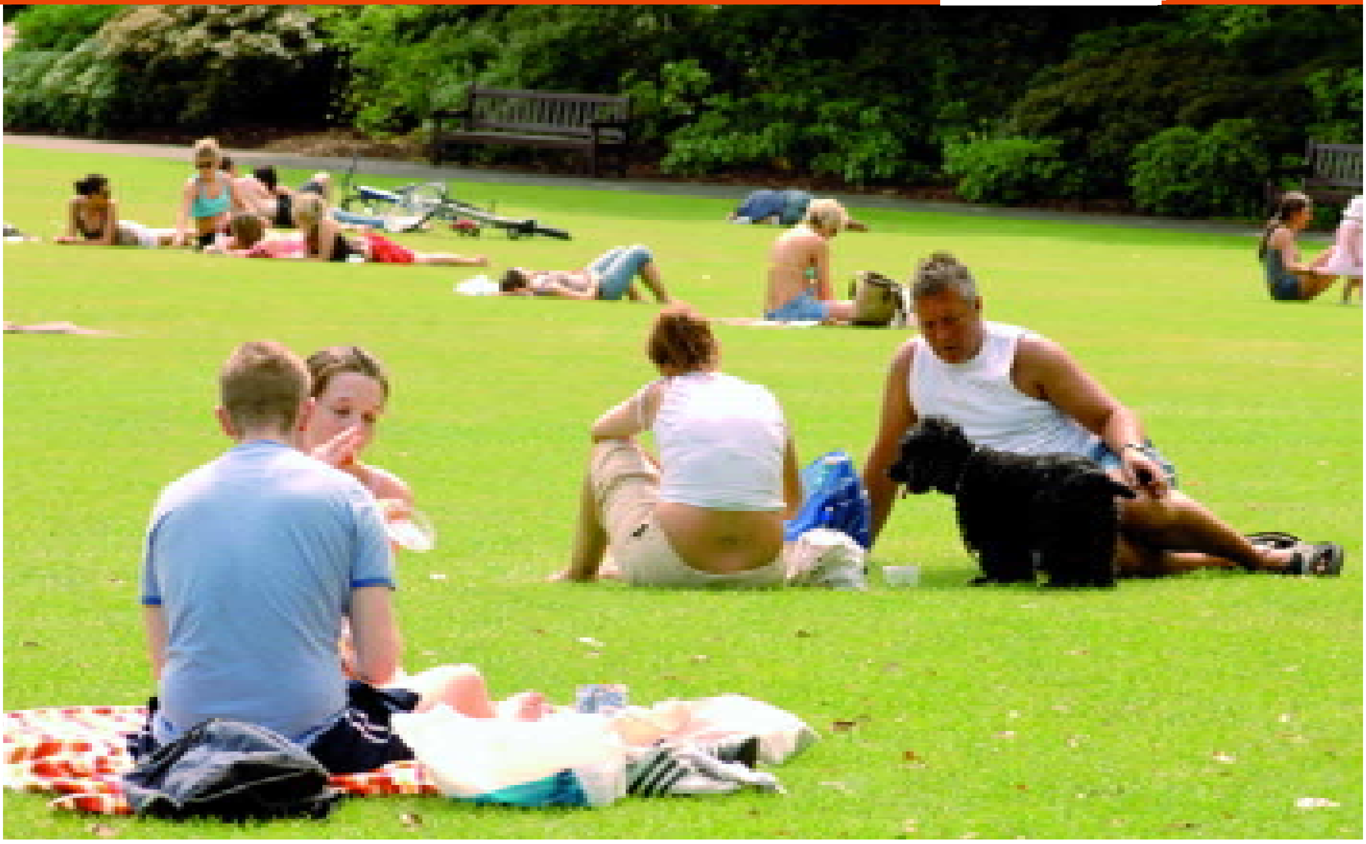
Box I2: What's not included?

The term 'environment' is widely used and can mean different things to different people. This report deals with aspects of the natural environment, including the quality of Scotland's air, land and water. It does not cover the built or cultural environment, drinking water quality, noise or indoor air quality. Nor does it provide a comprehensive account of our natural heritage or resources.

The report does not attempt to compare the state of Scotland's environment with other countries. This is because those assessments that have been done have used different indicators, measurements or timescales, making direct like-for-like comparisons difficult.

The report does not aim to set out in detail the legal framework of environmental controls in Scotland, the work that SEPA and other organisations do to protect and enhance the environment, or any specific actions or policy changes required to meet these challenges.

Further information can be found on SEPA's website (www.sepa.org.uk), in our corporate plan and annual report, as well as from the other sources highlighted in the text. Information about the state of the environment in EU countries can be found in the European Environment Agency report *The European Environment: State and Outlook 2005* http://reports.eea.europa.eu/



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No.	Details	Available from:
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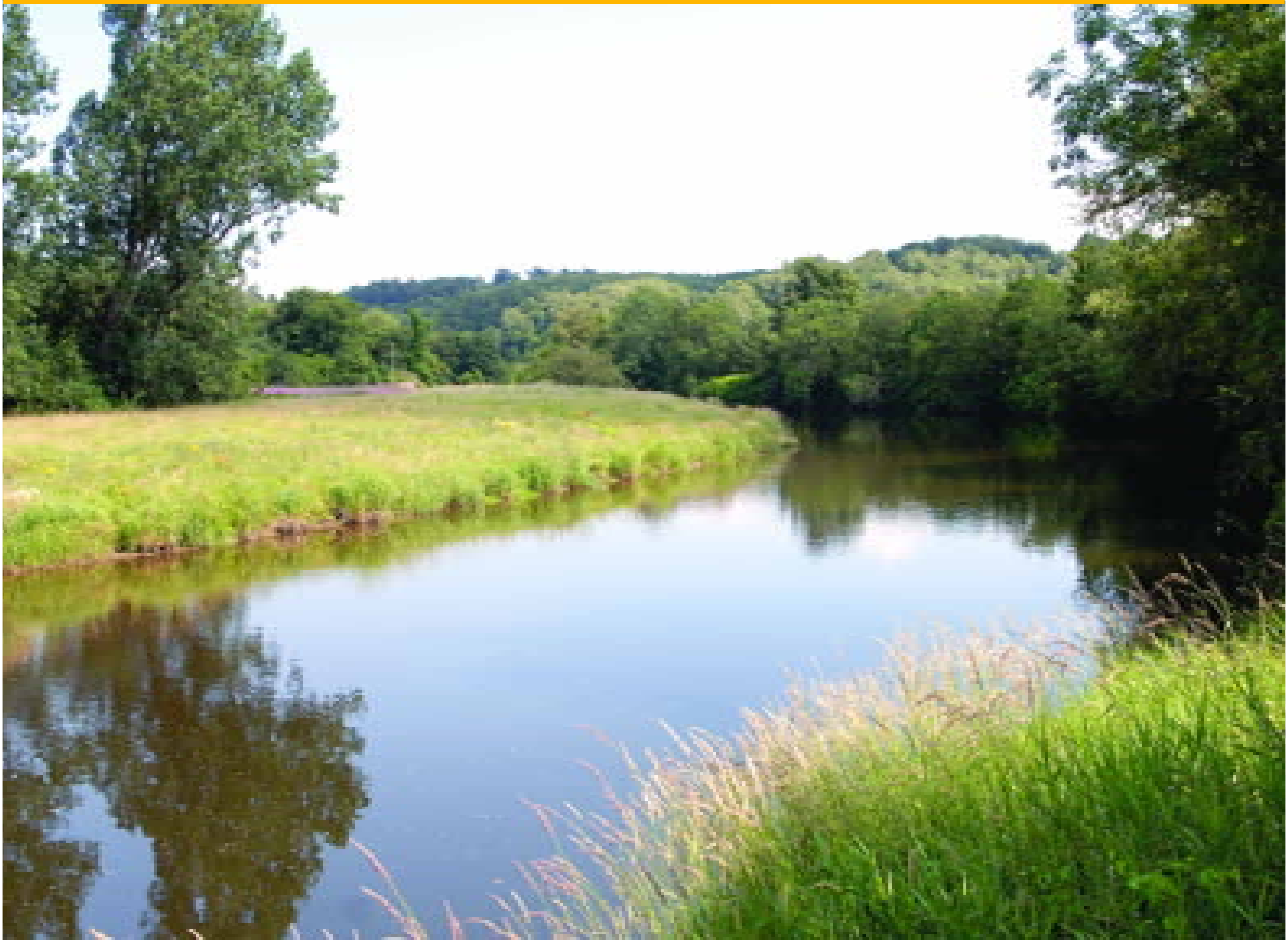
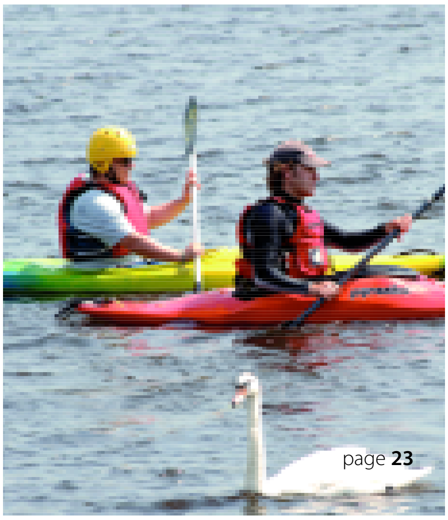
I2	*Choosing Our Future: Scotland's Sustainable Development Strategy*, Scottish Executive, 2005.	www.scotland.gov.uk/Publications/2005/12/1493902/39032
I3	*The Value of the World's Ecosystem Services and Natural Capital*, Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill R V, Paruelo J, Raskin R G, Sutton P and van den Belt M, 1997.	Nature, Vol. 387, 253–260.
I4	*The Value of Scotland's Ecosystem Services and Natural Capital*, Williams E, Firn JR, Kind V, Roberts M and McGlashan J, 2003.	European Environment, Vol. 13 No 2, 67–78.
I5	*Counting Consumption*, WWF-UK, 2006.	www.wwf.org.uk/filelibrary/pdf/countingconsumption.pdf
I6	*Practising What We Preach. Environmental Report 2003–2004*, WWF-UK, 2004.	www.wwf.org.uk/filelibrary/pdf/envreport0304.pdf
I7	*State of the Environment Report 1996*, SEPA, 1996.	www.sepa.org.uk/publications/state_of/index.htm
SI1	Supplementary material on indicators used the *State of Scotland's Environment* report	Online version of the report

The state of Scotland's air, land and water environments





Air

Summary

Overall air quality in Scotland is improving with statistics showing it is generally good. However, further improvements are needed to reduce the adverse health effects and the number of deaths brought forward by air pollution in urban areas. In rural areas, poor air quality still has the potential to damage ecosystems and to contribute to acidification and nutrient enrichment.

The main sources of air pollution include transport, energy generation, industry, waste and agriculture. With reductions in large-scale industrial emissions, transport is rapidly becoming an increasingly significant source. The continual increase in demand for energy may also give rise to increased emissions.

In relation to specific pollutants, emissions of nitrogen oxides and sulphur dioxide from large industrial sources have fallen. The decrease in domestic coal use has also led to significant reductions in emissions of sulphur dioxide. Emissions of particulates and volatile organic compounds are showing a general downward trend. These improvements contrast with a general increase in ground-level ozone concentrations, with potential to harm humans, crops and ecosystems. In addition, a decline in stratospheric ozone levels over Scotland has the potential to increase levels of exposure to harmful ultraviolet radiation.

Good air quality is essential for human health, the climate, habitats and the built environment. This chapter provides information about the state of Scotland's air quality, how air quality is monitored, and the trends in individual pollutants. Associated air quality issues are discussed individually in more detail in the chapters on climate change, acidification, nutrient enrichment and hazardous chemicals.

Information about the health effects of the pollutants described in this chapter can be found in the chapter on human health.

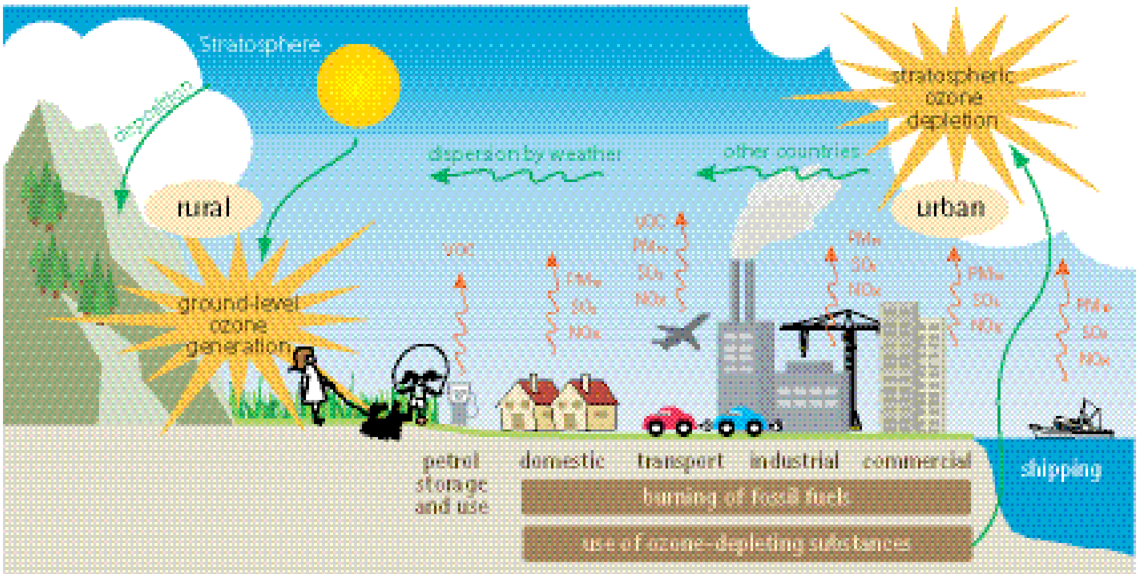
Why air quality is important

Good air quality is essential for a good quality of life and for achieving the goal of sustainable development. The quality of the air we breathe is altered by substances released mainly through human activity. These include nitrogen oxides (NO_X), sulphur dioxide (SO_2), particulates ($PM_{2.5}$ and PM_{10}), ozone (O_3), volatile organic compounds (VOCs) and ozone-depleting substances. When released to the air in sufficient quantities, these substances can cause:

- **Deterioration in human health:** air pollutants can trigger, or exacerbate, breathing difficulties such as those caused by asthma and bronchitis in sensitive individuals. A recent consultation on air quality states that air pollution is currently estimated to reduce the life expectancy of every person in the UK by an average of eight months[A1]. An earlier study indicated that an estimated 24,000 deaths per year are brought forward by the effects of air pollution in the UK[A2].
- **Changes in climate:** emissions of greenhouse gases such as carbon dioxide, methane and nitrous oxide alter our climate (see climate change chapter).
- **Acidification and eutrophication of habitats:** pollutants like nitrogen oxides and sulphur dioxide as well as ammonia undergo changes in the atmosphere. When deposited, they can result in acidification and nutrient enrichment of land and water, harming ecosystems (see nutrient enrichment and acidification chapters).
- **Oxidative damage:** pollutants like ozone can cause damage to plants, animals and building materials, impacting on their growth and integrity.
- **Nuisance:** odour, light, noise and particulates (including haze and smoke) can affect the overall amenity value of Scotland's environment.
- **Depletion of the ozone layer:** when certain man-made chemicals enter the atmosphere they can destroy stratospheric ozone and can lead to increased exposure to harmful ultraviolet (UV) radiation.

Air quality is affected by the emission of pollutants to air and the dispersion, reaction and deposition of the substances emitted (see Figure A1). These substances have different impacts on our health and the environment. These can be direct impacts or can be the result of pollutants reacting together.

Figure A1: Emissions to air and key processes determining air quality



In general, human health effects are more common in urban areas with their higher population density and higher proportion of transport, commercial and industrial activities, while ecosystem effects are more likely in the fragile habitats common in rural areas.

Air quality in Scotland

Air quality can vary considerably across Scotland, and is dependent on many factors including local and national weather conditions and the emissions of substances to air both within and outside Scotland. A critical factor in air pollution is the movement of pollutants over a long distance, known as transboundary movement. In particular, this plays a role in:

- the formation of secondary pollutants such as ground-level ozone;
- the deposition of pollutants associated with the acidification or eutrophication of habitats;
- the creation of pollutants that lead to climate change and stratospheric ozone depletion.

The UK[A3] air-banding scheme, developed by the Department for Environment, Food and Rural Affairs (Defra), and the Department of Health, assigns a human health risk band according to how pollutant concentrations compare with objectives and standards. This scheme is also used within the UK National Air Quality Information Archive (www.airquality.co.uk), which provided some of the data used in this report.

Box A1: Air pollution controls

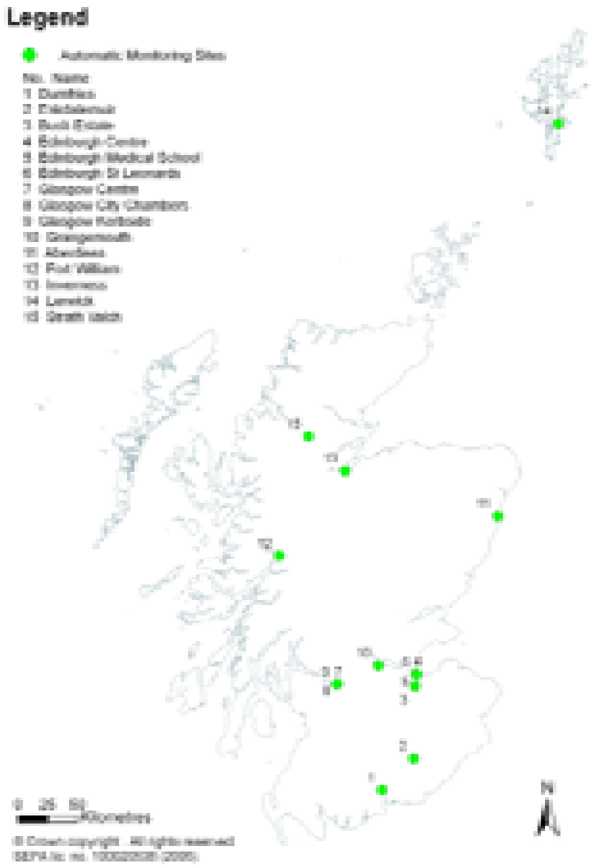
Air pollution was identified as a significant problem during the 19th century. The Alkali Act 1863 was the first legislation which sought to control emissions to air. Historically, control measures focused on smoke (particulates) and sulphur dioxide emissions from industrial activities – an important factor in the creation of smog which was common in the early to mid 20th century.

More recently, cleaner fuels have replaced coal burning in industry and homes and our understanding of the causes and effects of air pollution has increased. Other pollutants like ground-level ozone, volatile organic compounds, odour and noise are now also controlled under a variety of environmental laws and regulations.

The major sources of air pollution are now shifting from large-scale industrial activities to energy production and transport. Proposed measures such as the Clean Air For Europe (CAFE) Programme (www.europa.eu.int/comm/environment/air/cafe/) are intended to expand the control on the sources and effects of air pollution.

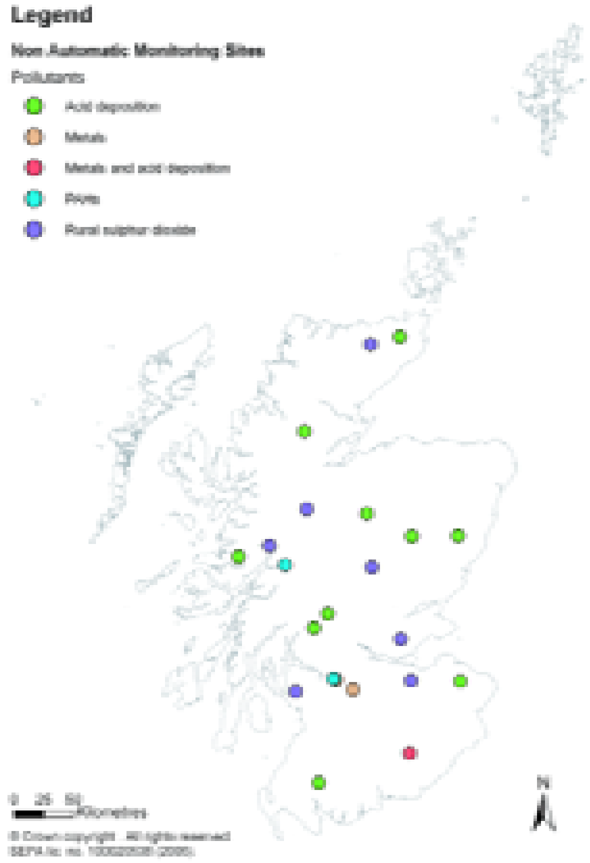
In Scotland there is a programme of continuous monitoring and periodic assessment of air quality. Figures A2 and A3 show the location of monitoring sites for different pollutants. This report uses longer-term annual average concentrations and shorter term pollution event quality controlled data from the automatic monitoring sites.

Figure A2: Automatic monitoring sites in Scotland



Source: *Air Pollution in the UK: 2004*, Defra, 2005.

Figure A3: Current Scottish sampler-based measurement programmes



Source: *Air Pollution in the UK: 2004*, Defra, 2005.

Box A2: Air Quality Strategy and Air Quality Management Areas

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland is designed to protect human health and the environment from air pollution. It sets policy objectives and measures to tackle air quality issues from a variety of sources, including transport (not aviation), industry and domestic. UK health and habitat based standards and objectives are set under the strategy for the main air pollutants: 1,3-butadiene, benzene, carbon monoxide, lead, nitrogen dioxide, ozone, particles measuring 10 micrometres or less (PM_{10}), ozone and sulphur dioxide.

Performance against objectives is monitored in places where people and sensitive habitats might be exposed to air pollution. This is done by the Government through its automatic monitoring network and by local authorities under the Local Air Quality Management regime.

Where monitoring indicates that objectives may not be met or are being breached in an area, the local authority designates an Air Quality Management Area. The local authority must then develop an Air Quality Action Plan. Air quality is generally better in Scotland than elsewhere in the UK and, as a result, the Scottish air quality strategy has some more challenging objectives. Eleven Air Quality Management Areas have been declared to date (see table), mainly for traffic related pollutants.

The strategy is being reviewed, with new measures and objectives being developed as knowledge and understanding of air quality improves. Air quality management is an ongoing process, with many challenges that require proactive, integrated action.

Air Quality Management Areas in Scotland, July 2006

Local authority	Area declared an AQMA	Substance(s) declared
Aberdeen City Council	An area covering Market Street, Union Street, King Street (between Castle Street and Roslin Terrace), Virginia Street, Commerce Street, Guild Street (between Market Street and Stirling Street) and Holburn Street (between Great Southern Road and Union Street).	Nitrogen dioxide and PM_{10}
City of Edinburgh Council	An area covering the city centre, including the main link roads into the city centre.	Nitrogen dioxide
City of Glasgow Council	An area of Glasgow city centre bounded broadly by the M8 motorway to the north and west, the River Clyde to the south, and the High Street and Saltmarket to the east.	Nitrogen dioxide
Dundee City Council	An area covering the city centre.	Nitrogen dioxide
East Dunbartonshire Council	An area encompassing a 60 m wide corridor along the A803 Kirkintilloch Road, Bishopbriggs, between the Council's border with Glasgow City and a point 30 m north of Cadder roundabout.	Nitrogen dioxide
Falkirk Council	An area encompassing Grangemouth petrochemical complex and adjacent areas.	Sulphur dioxide
North Lanarkshire Council	An area of Coatbridge, extending along Whifflet Street and North Road and encompassing buildings fronting the road.	PM_{10}
North Lanarkshire Council	An area of Chapelhall extending along Main Street, Bellside Road and Lauchope Street, and extending to cover a number of properties close to the junctions of these roads.	PM_{10}
North Lanarkshire Council	An area encompassing part of the centre of Motherwell to the north of the civic centre in the vicinity of Merry Street, Menteith Road and Airbles Road.	PM_{10}
Perth and Kinross Council	An area covering the city centre within the by-pass and including the Kinnoull area and the Inveralmond industrial estate.	Nitrogen dioxide and PM_{10}
Renfrewshire Council	An area covering part of Central Road, Paisley between Smithhills Street and County Square and the service road for the Piazza Shopping Centre adjacent to Central Road.	Nitrogen dioxide

Source: www.airquality.co.uk/archive/laqm/laqm.php

Emissions from certain regulated industrial processes are monitored to assess the levels of emissions and compliance with legislative requirements. The results can be accessed via the Scottish Pollutants Release Inventory (SPRI) (www.sepa.org.uk/spri/index.htm). SPRI builds on information gathered under two EU requirements; the Large Combustion Plant Directive and the European Pollutants Emissions Register (see supplementary material[SA1]).

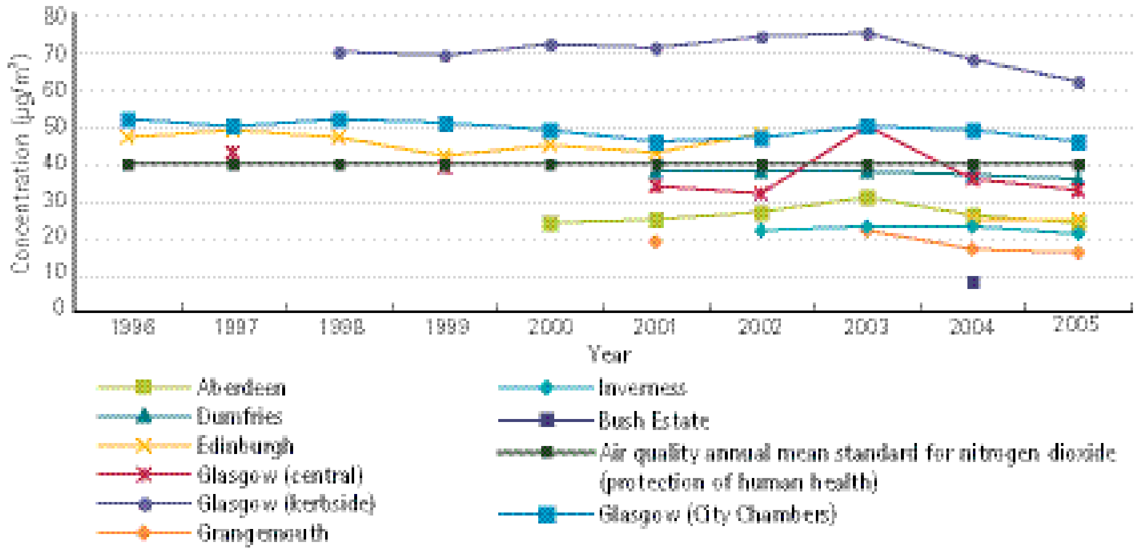
The National Atmospheric Emissions Inventory (NAEI) has collated estimates of emissions from all sources on a UK basis since 1970. This report uses NAEI data (www.naei.org.uk) to highlight UK trends in emissions.

Nitrogen oxides

Emissions of nitrogen oxides from large industrial sources show a general downward trend, but emissions from transport and fossil fuel based energy production are increasingly significant.

Annual mean nitrogen dioxide concentrations have been collected at urban locations for up to ten years; data for seven urban automatic monitoring sites in Scotland are available for 2005 (see Figure A4). Of these sites, two exceeded the standard set to protect human health (40 micrograms per cubic metre). The levels at the Glasgow kerbside and city chambers locations consistently fail to meet the standards and are considerably higher than those at the other monitoring locations, due to the high volume of traffic and the dense urban area.

Figure A4: Annual mean nitrogen dioxide concentrations



Source: www.airquality.co.uk/archive/autoinfo.php

For more information on annual mean concentrations and pollution events for nitrogen oxides see supplementary material[SA2].

Nitrogen oxides are formed during high temperature combustion processes, for example from the engines of vehicles. Road traffic emissions are responsible for 95% of the Air Quality Management Areas declared in the UK[A4]. UK emissions rose markedly from 1984 as a result of the growth in road traffic, reaching a peak in 1989. Since then, total UK emissions from traffic have declined due to the fitting of catalytic converters to vehicles, despite continued growth in traffic numbers[A5].

Box A3: Aberdeen City Council: Air Quality Management Area

Generally air quality in Aberdeen is good and levels of benzene, 1,3-butadiene, carbon monoxide, lead and sulphur dioxide are well below current air quality standards and objectives. Levels of nitrogen dioxide and particulates are also low in most areas, but levels in the city centre are predicted to exceed air quality objectives. Emissions from road traffic are the main source of the raised pollution levels.

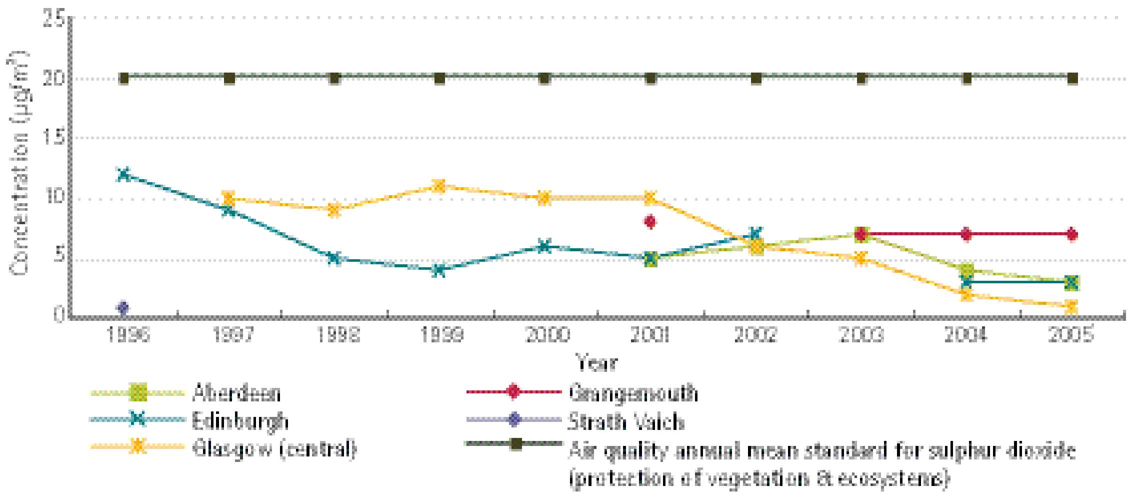
The affected area, centred on Union Street and Market Street, has been declared an Air Quality Management Area. Short and medium term actions to address air quality issues include raising public awareness of air quality issues, green transport plans and improvements to the public transport network and vehicle fleets. Longer term actions include the pedestrianisation of Union Street and associated changes to the road network.

Sulphur dioxide

Emissions of sulphur dioxide from large industrial sources have fallen considerably in the UK since 1970. Emissions from combustion of solid fuels (including domestic coal) have declined by 80% and those from petroleum sources by 94%. UK emissions of sulphur dioxide continue to show a downward trend[A5], due in part to the legal requirement for lower sulphur content of fuels[A5].

Annual mean sulphur dioxide concentrations were available for four urban automatic monitoring sites in Scotland in 2005 (see Figure A5). All are below the comparable standard for ecosystems of 20 micrograms per cubic metre (health based standards are only set for shorter time periods).

Figure A5: Annual mean sulphur dioxide concentrations



Source: www.airquality.co.uk/archive/autoinfo.php

For more information on annual mean concentrations and pollution events see supplementary material[SA3].

Box A4: Air quality in Grangemouth

Assessments by Falkirk Council found that concentrations of nitrogen dioxide, benzene, 1,3-butadiene, carbon monoxide, particulates and lead in the Grangemouth area were below EU air quality standards and objectives, but there was a possibility that the UK 15-minute objective for sulphur dioxide would not be met by the deadline of 31 December 2005. This particularly stringent UK objective (now a standard) is designed to protect people with breathing and respiratory difficulties, who are likely to be more sensitive to the effects of this pollutant.

Falkirk Council consequently designated the area as an Air Quality Management Area. Further work is underway to prepare and implement an Air Quality Action Plan. For information about SEPA monitoring of air quality in Grangemouth see supplementary material[SA4].

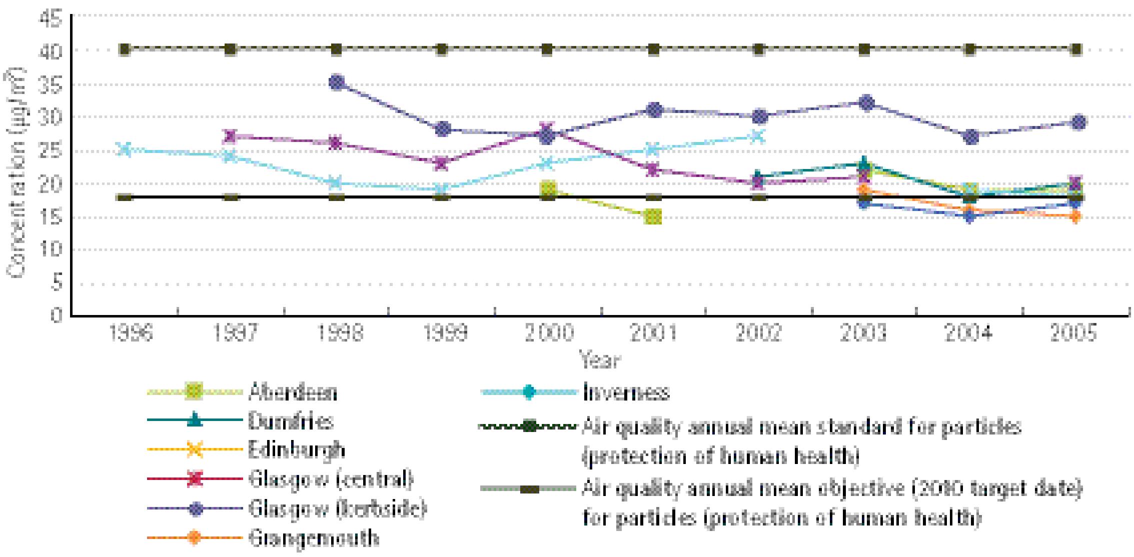
Particulates

Emissions of particulates in Scotland show an overall slight downward trend with a general decline in pollution episodes.

Annual mean concentrations of particles measuring 10 micrometres or less (PM_{10}) were available for seven Scottish urban automatic monitoring sites in 2005 (see Figure A6); all are below the standard of 40 micrograms per cubic metre set to protect human health. Air Quality Management Areas for PM_{10} have been declared because they may not meet the air quality objective of 18 micrograms per cubic metre to be achieved by 2010 in Scotland.

Particulates can be generated locally from both natural and man-made sources, but can also travel long distances in certain weather conditions and this can have a significant impact on the measured concentrations in the atmosphere[A7]. Particulates occur naturally, for example from sea salt, soil erosion and forest fires, as well as from human activities such as road transport, fossil fuel combustion and industrial processes. UK emissions of particulates have declined since 1970, mainly due to the reduction in coal use[A5].

Figure A6: Annual mean concentration of particulates (PM_{10})



Source: www.airquality.co.uk/archive/autoinfo.php

For more information on annual mean concentrations and pollution events for particulates see supplementary material[SA5].

Box A5: Smog events of the past

Smogs are the result of weather conditions (cold, stable, stagnant air) combining with pollutants like particulates and sulphur dioxide to form particle-laden and poisonous low-level atmospheric conditions. These events have severe consequences – including death – for vulnerable people and can cause widespread disruption to routine life. Smog episodes in the UK increased with the advent of large-scale fossil fuel combustion from the industrial revolution onwards. The peak event occurred in 1952 when an estimated 4,000 people died from the effects in the south-east of England[A7].

The Clean Air Acts of 1956 and 1968 sought to stop such severe pollution events with measures such as restrictions on emissions of smoke and the use of 'smokeless fuels' in densely populated urban areas. The result has been the widespread elimination of such events and it is unlikely that conditions such as those that led to the 'great smog of 1952' will occur again.

Volatile organic compounds

Emissions of volatile organic compounds show a general downward trend. They are generally emitted to air through combustion products, as vapours arising from the use and storage of petrol and organic solvents and from natural sources[A8]. Volatile organic compounds have a key part to play in the formation of ground-level ozone, which affects human health and ecosystems (see below). Benzene and 1,3-butadiene are of particular concern because, as highlighted in the human health chapter, human exposure to these substances may increase susceptibility to cancer.

Data about the atmospheric concentrations of volatile organic compounds in Scotland are limited. The urban automatic monitoring site at Glasgow (kerbside) recorded an annual average benzene concentration of 1.38 micrograms per cubic metre in 2005, less than the annual mean standard of 16.25 set to protect human health and the 2010 objective of 3.25. An annual average 1,3-butadiene concentration of 0.21 micrograms per cubic metre was also reported for 2005 at Glasgow (kerbside); this is less than the 2.25 micrograms per cubic metre standard.

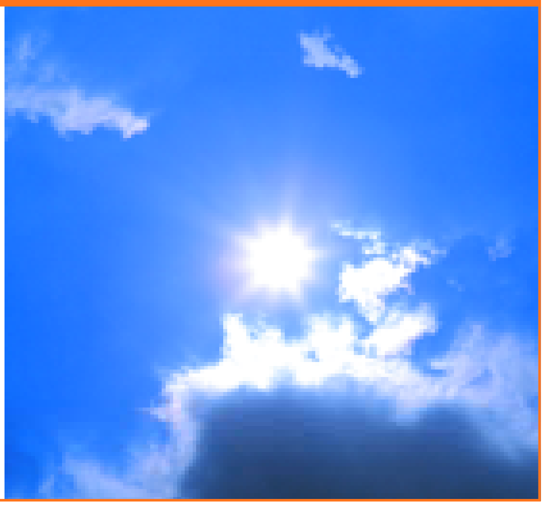
Benzene and 1,3-butadiene are mainly emitted as a result of the treatment and combustion of petroleum products. Important sources include the manufacture and use of petroleum products and associated evaporation (also known as fugitive emissions). UK emissions have fallen steadily since 1990, mainly due to the fitting of catalytic converters to vehicles. Emissions from the domestic and industrial sectors are also falling[A5].

Box A6: Ozone – negative and positive effects

Ozone can have both negative and positive effects as a substance in the environment.

A high concentration of ozone at ground-level has a negative effect. It can act as a greenhouse gas and be harmful to humans by aggravating breathing difficulties. It can also cause damage to ecosystems, including a reduction in crop yields.

A high concentration of ozone at high altitude in the atmosphere (in the stratosphere) has a positive effect as it filters out harmful ultraviolet radiation, thought to be a contributing factor to skin cancer, and reduces the levels reaching the Earth's surface. Stratospheric ozone is created naturally but it can be destroyed by specific man-made pollutants.



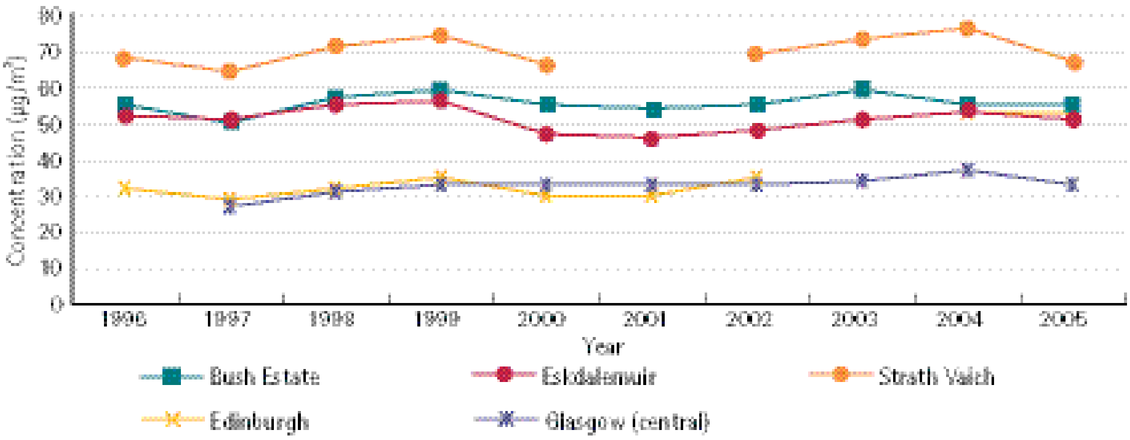
Ground-level ozone

Concentrations of ground-level ozone are slowly increasing in urban locations and background levels are increasing at a constant rate of 1–2% per year. Although the number of episodes of pollution in rural and urban locations remains high, the total number has reduced over the last 15 years[A9].

The formation of ground-level ozone requires the presence of primary pollutants (nitrogen oxides and volatile organic compounds), high levels of sunlight, high air temperatures and stagnant air. These substances can be transported over large distances and due to reaction processes in the atmosphere, peaks can occur in rural areas hundreds of kilometres from the sources of the pollutants. The increase in ground-level ozone concentrations at urban locations has been linked to a fall in nitrogen dioxide levels[A10].

Ground-level ozone concentrations are monitored at three urban and three rural automatic monitoring sites in Scotland. During the last ten year recording period, the data from these sites show that the rural locations (Bush Estate, Eskdalemuir and Strath Vaich) experienced higher annual average concentrations than the urban ones (see Figure A7). The annual averages recorded at Strath Vaich are considerably higher than those recorded at the other monitoring stations. This could be due to prevailing wind conditions, and the long-range transport of the primary pollutants.

Figure A7: Annual average ozone concentrations



Source: www.airquality.co.uk/archive/autoinfo.php

For more information on annual mean concentrations and pollution events for ground-level ozone see supplementary material[SA6].

Monitoring at just a few sites does not reveal the true extent of ground-level ozone change in Scotland. However, ground-level ozone concentrations across Scotland are estimated by the Centre for Ecology and Hydrology; Figures A8 and A9 indicate the cumulative concentrations of ozone above the critical level of 40 parts per billion (equivalent to 80 micrograms per cubic metre) set for the protection of vegetation and ecosystems.

The critical level for ground-level ozone was exceeded across 55% of Scotland during the 1990–1994 reporting period, falling to only 0.5% of the country during 2000–2004[A10]. In terms of vegetation effects, 65% of agricultural land and 54% of semi-natural habitats exceeded the safe limits for ozone exposure, potentially damaging those crops and natural habitats exposed to the pollutant. However, by 2000–2004, the corresponding figures had fallen dramatically to 0.65% and close to 0 respectively.

Figure A8: Ozone concentrations, 1990–1994

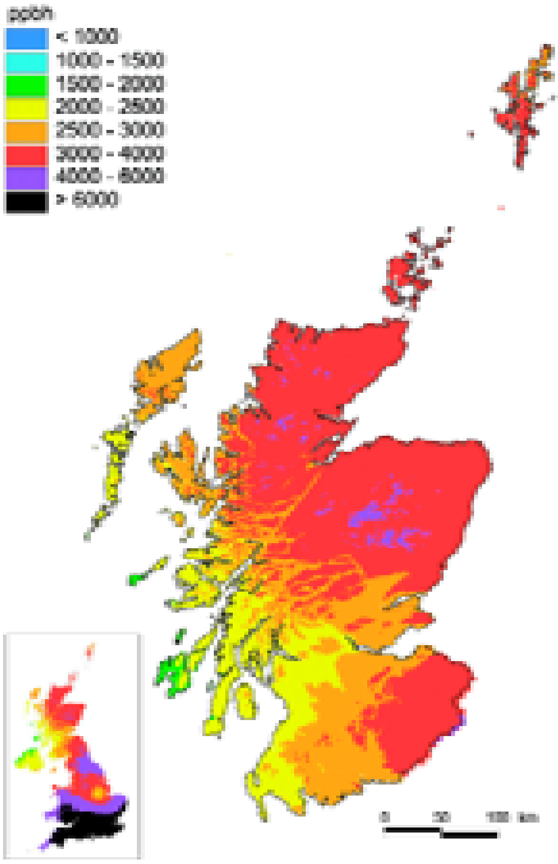
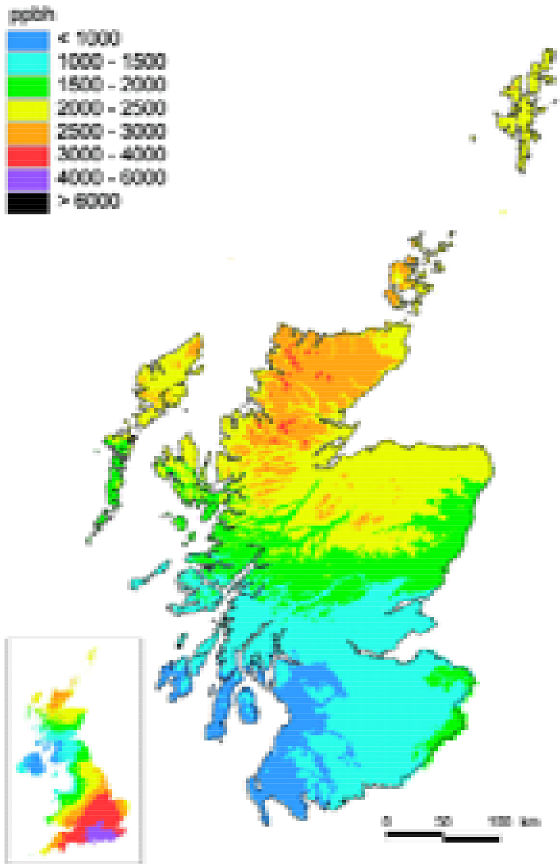


Figure A9: Ozone concentrations, 2000–2004



Source: Centre for Ecology and Hydrology[A11]

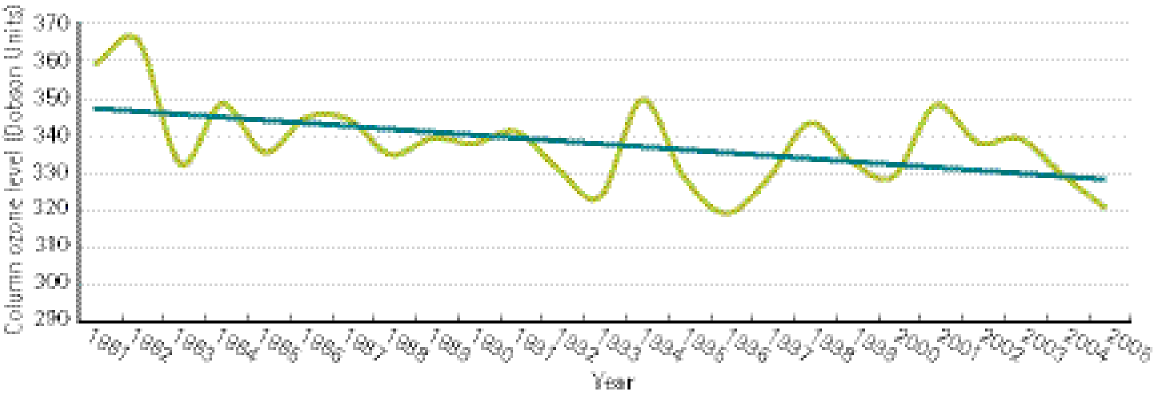
This dramatic fall in episodes of ground-level ozone exposure over the last 15 years is partially in line with the lower emissions of the pollutants that lead to its formation. Although peak concentrations have fallen, background concentrations are rising across Europe and the UK[A12], due to the long-range transport of pollutants from other parts of the world. This increase could potentially result in the critical level being exceeded more frequently and some rural sites such as Strath Vaich experiencing concentrations close to or above critical levels for longer periods of time. Reductions in the primary pollutants, not only in Scotland but across Europe, are essential to maintain and reduce background levels below the critical level for vegetation.

Stratospheric ozone

Stratospheric ozone levels over Scotland have continued to decline. Since the 1980s, thinning of the ozone layer has been observed, with Antarctica experiencing the greatest level of depletion. The hole in the Antarctic ozone layer shows no sign of reducing in size, with some of the lowest ozone layer concentrations recorded in the last 2–3 years[A13].

Lerwick in the Shetland Islands is one of two stratospheric ozone monitoring sites in the UK, the other is in Cornwall. Over the last 20 years, total ozone layer coverage over Scotland has declined by almost 5%; with particularly low levels observed in 1996 and 2005 (see Figure A10).

Figure A10: Changes in column ozone concentrations over Scotland, 1981–2005, based on data from the Lerwick monitoring site (the dark green line indicates the trend over the last two decades)[A14]



For more information on stratospheric ozone concentrations see supplementary material[SA7].

During the 1970s, certain man-made chemicals that release chlorine and other halogens were identified as a key factor in the depletion of stratospheric ozone. These include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and hydrobromofluorocarbons (HBFCs) commonly found in refrigeration equipment, foam, solvents, aerosols and fire extinguishers. The level of destruction is due to the fact that a single atom of chlorine can destroy 100,000 ozone molecules during the lifetime of the substance in the stratosphere[A15].

The Montreal Protocol, agreed in 1987, limited the use of the most common ozone-depleting substances[A16], and their production and consumption have since fallen substantially e.g. world production of CFCs fell by 91% between 1986 and 2002[A17].

Ozone-depleting substances have largely been phased out in the UK, but they have a long atmospheric life and many products containing them are still in use, so monitoring and controls are still necessary. Even if the current bans and restrictions are adhered to, the recovery rate of the ozone layer will be slow, and full recovery is not expected to happen until the middle of this century.

Forward look

Understanding the state of air quality in Scotland will improve as information on emissions from SEPA regulated processes is recorded in the Scottish Pollutant Release Inventory. It is anticipated that there will be a reduction in emissions from regulated processes but that any reduction in emissions from vehicles will be off-set by an increase in vehicle use.

However, more or better data does not necessarily mean a better environment. As monitoring and knowledge improves it is likely that more data will highlight certain issues which will need to be addressed and areas for attention, as has been experienced under the Air Quality Strategy. We now have 11 Scottish Air Quality Management Areas, more than ever expected, and this number may increase.

The major challenge is likely to be meeting new European air quality objectives, as well as reduced limits on certain other pollutants.

Transport is likely to be an increasingly important issue. New 'cleaner' diesel engines appear to be resulting in elevated emissions of nitrogen dioxide causing new air quality problems. Other unforeseen issues such as this may occur, as well as trade-offs between air quality and climate change in the transport and industrial sectors.

Ground-level ozone is now a problem across the northern hemisphere, with recent monitoring identifying pollution that has been emitted in the Far East and that has crossed the United States to the UK and Ireland. This will require hemispheric action and will increasingly impact on Scottish air quality.

References

No.	Details	Available from:
A1	*The Air Quality Strategy for England, Scotland, Wales and Northern Ireland*, Department for Environment, Food and Rural Affairs (Defra), 2006.	www.defra.gov.uk/corporate/consult/airqualstrat-review/index.htm
A2	*The Quantification of the Effects of Air Pollution on Health in the United Kingdom*, Committee on the Medical Effects of Air Pollutants (COMEAP), 1998.	www.dh.gov.uk/PublicationsAndStatistics/Publications/PublicationsLibrary/fs/en
A3	*Air Pollution: What it means for your Health*, Department for Environment, Food and Rural Affairs (Defra), 2002.	www.defra.gov.uk/environment/airquality/airpoll/pdf/airpollution_leaflet.pdf
A4	*Air Pollution in the UK: 2004*, Department for Environment, Food and Rural Affairs (Defra), 2005.	www.airquality.co.uk/archive/reports/reports.php?report_id=380
A5	*National Atmospheric Emissions Inventory*	www.naei.org.uk
A6	*Air Quality Expert Group Report on Particulate Matter in the UK*, Air Quality Expert Group (AQEG), 2005.	www.defra.gov.uk/environment/airquality/aqeg/particulate-matter/index.htm
A7	*Pollution Handbook 2006*, National Society for Clean Air (NSCA), 2006.	www.nsca.org.uk
A8	*Emission of isoprene, monoterpenes, ethene and propene by vegetation*, Hadley Centre technical note 40, Met Office, 2002	www.metoffice.com/research/hadleycentre/pubs
A9	*Annual Levels of Particles and Ozone in the Air: 1987 – 2005*, Department for Environment, Food and Rural Affairs (Defra), 2006.	www.defra.gov.uk/environment/statistics/airqual/kf/aqkf02a.htm
A10	*Ozone in the UK 1997: 4th Report of the Photochemical Oxidants Review Group*, Centre for Ecology and Hydrology (CEH) on behalf of Department of Environment, Transport and Regions, 1997.	www.aeat.co.uk/netcen/airqual/reports/porg/fourth1.html
A11	*Ozone and Ammonia – Maps and Statistics for Scotland*, Centre for Ecology and Hydrology (CEH), 2005.	www.sepa.org.uk/publications/
A12	*Transboundary Air Pollution: Acidification, Eutrophication and Ground-Level Ozone in the UK*, National Expert Group on Transboundary Air Pollution (NEGTAP), 2001.	www.edinburgh.ceh.ac.uk/negtap/finalreport.htm
A13	*Report of the Sixth Meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer 2005*, World Meteorological Organization, September 2005.	www.wmo.ch/web/arep/gaw/publications2.html
A14	*Column Ozone Measurements above Lerwick*, Scottish Environment Statistics online	www.scotland.gov.uk/Topics/Statistics
A15	*The Ozone Layer*, Department for Environment, Food and Rural Affairs (Defra), 2003.	www.scotland.gov.uk/Topics/Environment/Climate-Change/16918/8120
A16	Montreal Protocol United Nations Environment Programme (UNEP)	www.unep.ch/ozone/montreal.htm
A17	*e-Digest of environmental statistics*, Department for Environment, Food and Rural Affairs (Defra)	www.defra.gov.uk/environment/statistics

SA1	Supplementary material on future developments – pollutant data	Online version of the report
SA2	Supplementary material on nitrogen dioxide: annual averages and pollution events	Online version of the report
SA3	Supplementary material on sulphur dioxide: annual averages and pollution events	Online version of the report
SA4	Supplementary material on SEPA monitoring of air quality in Grangemouth	Online version of the report
SA5	Supplementary material on particulates: annual averages and pollution events	Online version of the report
SA6	Supplementary material on ground-level ozone: annual averages and pollution events	Online version of the report
SA7	Supplementary material on stratospheric ozone: summary of column ozone measurements over lerwick	Online version of the report

Sources of further information

Topic	Source
Air quality and the Air Quality Strategy	www.defra.gov.uk/environment/airquality/laqm.htm
Pollutants and their impacts	www.apis.ac.uk
Ground-level ozone in the UK	*Ozone in the United Kingdom: Fourth Report of the Photochemical Oxidants Review Group, 1997* www.aeat.co.uk/netcen/airqual/reports/porg/fourth1.html Netcen Air Pollution Forecasting reports www.airquality.co.uk/archive/reports/reports.php?action=category&section_id=12

Land

Summary

Land quality in Scotland is generally considered to be reasonable, although there are significant gaps in our knowledge, especially relating to soils.

The way in which land is used and managed is a major factor in determining its quality. Agriculture and forestry can lead to soil erosion and losses of nutrients to the water environment but new policies are encouraging good practice in conserving soil organic matter and promoting biodiversity.

Measures are being taken to enhance habitats and to counteract loss of species and improvements have also been made in the regeneration of derelict and contaminated land in previously industrialised areas.

Soil is a significant component of land but remains poorly understood. Soil erosion is a continuing problem in Scotland and there are concerns about loss of soil organic matter and soil sealing by impermeable surfaces associated with buildings and roads.

Scotland has a land area of around 78,000 km^2, a coastline estimated at 10,000 km and around 100 inhabited islands[L1]. Key features of land in Scotland include the large indented coastline, the mountains, glens, moorland, forests and a patchwork of farmland. A large proportion is of high environmental quality, valued for its natural heritage as well recreation and tourism. Over 20% of the land area is protected by various natural heritage designations (for more information see www.snh.org.uk).

This chapter covers a number of land related issues, focusing on those aspects which are of greatest interest to SEPA, before considering soils, a significant component of land.

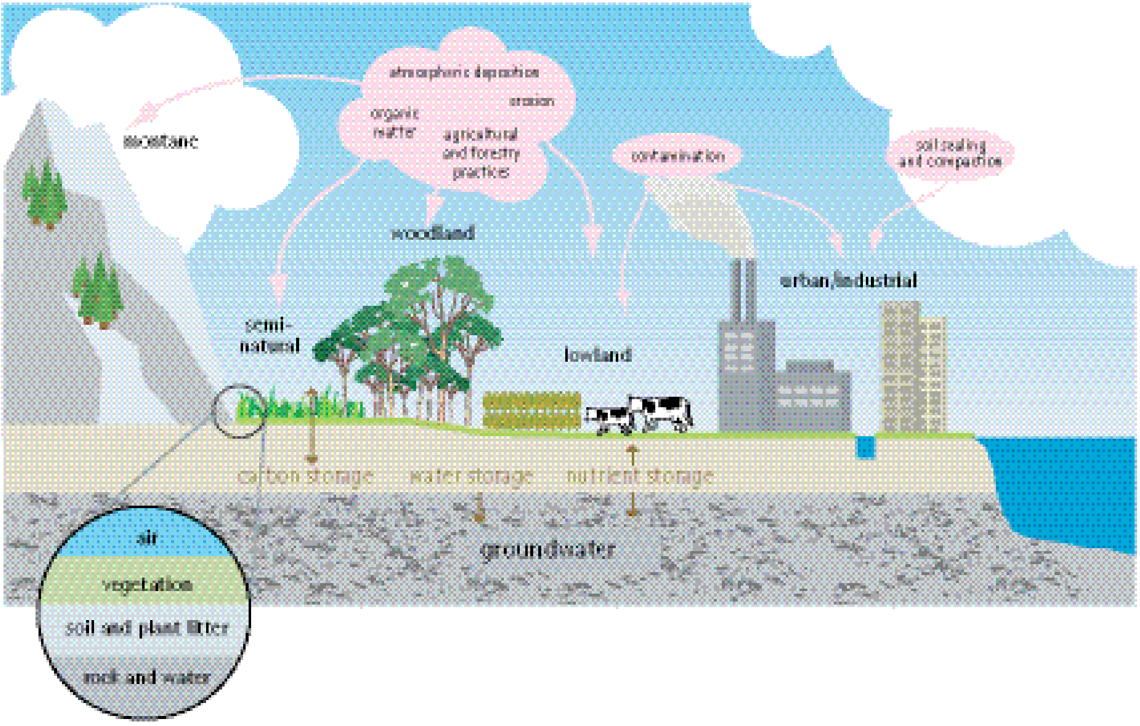
Factors influencing the land environment

Land is subject to complex natural processes. Temperature, moisture, geology, altitude and slope determine the physical, chemical and biological make up of the land and what it can support. Human activities can also cause radical change to landscapes, biodiversity, soil, air, water and climate.

The main threats to land are:

- deposition of substances, altering soil chemistry (for more information see the acidification and nutrient enrichment chapters);
- inappropriate use or disposal of chemicals, oil or waste, causing land contamination;
- inappropriate agricultural and forestry practices, resulting in an increased risk of soil erosion, loss of soil organic matter and nutrients, removal of protective vegetation, species shift and habitat change;
- 'sealing' or replacement of soil with impermeable hard surfaces such as roads, car parks and buildings, increasing run-off and flood risk;
- land use changes, resulting in decreasing biodiversity;
- compaction of soil from vehicle tracking and trampling by livestock, which affects soil structure and therefore its ability to hold the moisture, nutrients and air necessary for plant growth.

Figure L1: Pressures on land and soil function



Land use and management

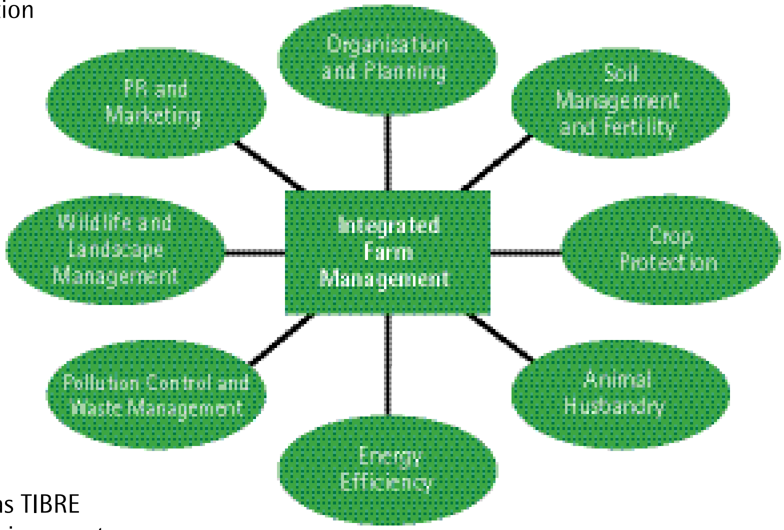
The way land is used and managed influences land, water and air environments as well as biodiversity. Agricultural land cover in Scotland has changed little since 1990[L2], remaining the dominant land use activity covering approximately 75% of land area. Soil type, geology, topography and climate limit agricultural potential and only 6% is classed as prime agricultural land[L1].

Agricultural land use has considerable potential to affect soil erosion, soil organic matter, habitats and biodiversity depending on the type of farming as well as the nature of the soil and weather conditions, vegetative cover and land management practices.

Recent changes in agricultural policies are leading to a shift from subsidising food production to supporting rural development, environmental benefit, animal health and welfare and food safety. 344,416 hectares of agricultural land were covered by the Organic Aid Scheme in 2005 – an increase since 1996[L3] – with a total of £3.1 million spent on supporting the conversion to organic agriculture. Provisional figures also indicate that there were 501,000 hectares of agricultural land subject to good land management practices under the Land Management Contract Menu Scheme in 2005[L4]. A number of the practices encouraged under the Scheme have positive implications for air, land and water. These include testing soil, nutrient planning, creating wetlands, converting arable land to grassland and leaving uncultivated buffer strips alongside watercourses to minimise diffuse pollution of water and to retain eroded soil in the field (see Box L1).

Box L1: Integrated Farm Management

Linking Environment And Farming (LEAF) has eight demonstration farms and two innovation centres in Scotland following the principles of Integrated Farm Management (IFM). The farmers run their businesses with the protection of the environment in mind. For further information see www.leafuk.org



Good practice guidance is available in the *Prevention of Environmental Pollution from Agricultural Activity (PEPFAA) Code* (see www.scotland.gov.uk/Topics/Agriculture/Environment). Scottish Natural Heritage has also developed a handbook for arable farmers, known as TIBRE (Targeted Inputs for a Better Rural Environment (see www.snh.org.uk/tibre).

Forestry is an important land use in Scotland using both native and non-native tree species. There are 1.33 million hectares (13,300 km^2) of woodland in Scotland, having risen from 4.5% of land area in 1905 to 11.8% in 1980 and 17.1% in 2006[L5].

The climate in Scotland provides good conditions for growing trees and the last century saw a large expansion of conifer plantations in the uplands. Poor forestry management was recognised as contributing to soil erosion, loss of organic matter and damage to habitats and led to the introduction of Forestry Commission guidelines covering water, nature conservation and soil[L6]. Ongoing redesign of conifer plantations is helping to improve biodiversity and soils by creating a greater mix of tree species and ages (see supplementary material[SL1]). There are also increasing opportunities to integrate forestry with agriculture.

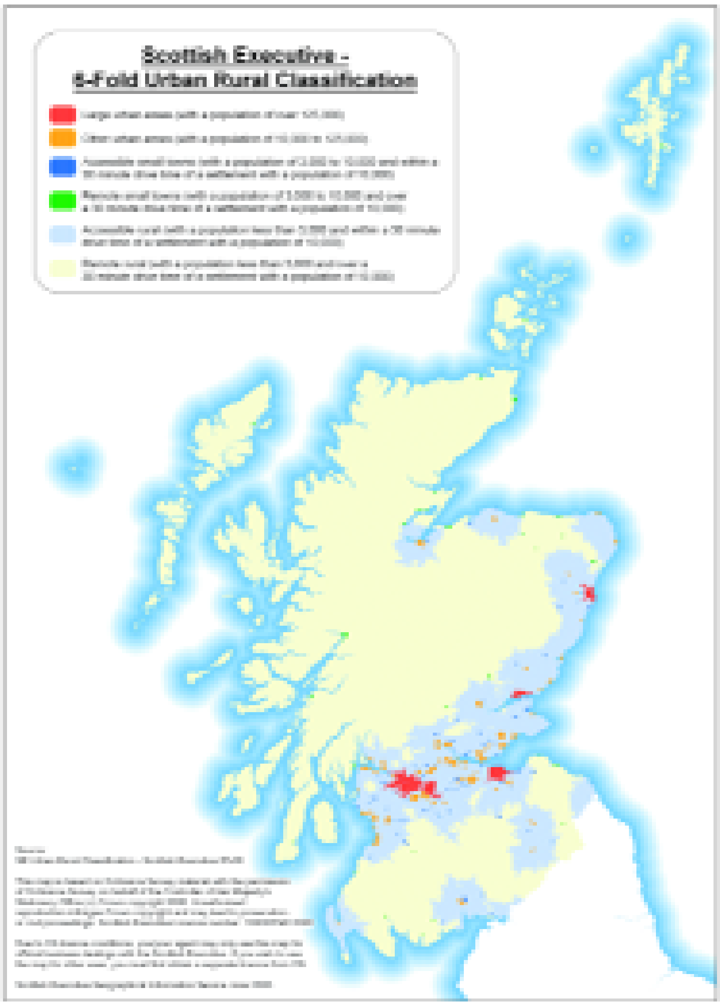
Mining and opencast coal sites are still important activities in Scotland and have considerable local significance. In 2003 there were 364 mineral workings producing 40.2 million tonnes of minerals[L7]. Their nature, scale, duration and location mean that mineral workings can have significant environmental impacts. Many old sites have been restored for recreation, forestry and nature conservation.

Box L2: Reclamation of derelict mining land to greenspace

The former Scottish Coal site at Dalquhandy and the Holmhills Wood Community Park in Cambuslang is a good example of an area where derelict land damaged through mining has been brought back into beneficial use. Derelict land was reclaimed, landscaped and planted as woodland. Wetlands and amenity areas were created, and cycleways and green routes installed. For further information on Holmhills see supplementary material[SL2].

A relatively small proportion (2%) of Scotland is classed as urban[L1]. Towns and cities are concentrated in the central belt and along parts of the east coast (see Figure L2). Some urban areas are rich in green space[L2] and have excellent natural heritage potential.

Figure L2: Scottish Executive's six-fold urban rural classification[L8]



Source: Scottish Executive

The overall trend is one of increasing urbanisation with 1,403 hectares of agricultural land given over to roads, housing or industry in 2002–2003 (140% increase since 1989–1990)[L9].

Major land reclamation in former mining areas, together with projects such as the Central Scotland Forest and the Millennium Link restoration of the Forth and Clyde and Union canals, has already improved the environment and opened up new opportunities for economic development and recreation. Three new priority areas (Clyde corridor, Inverclyde and across Ayrshire) were recently identified for regeneration.

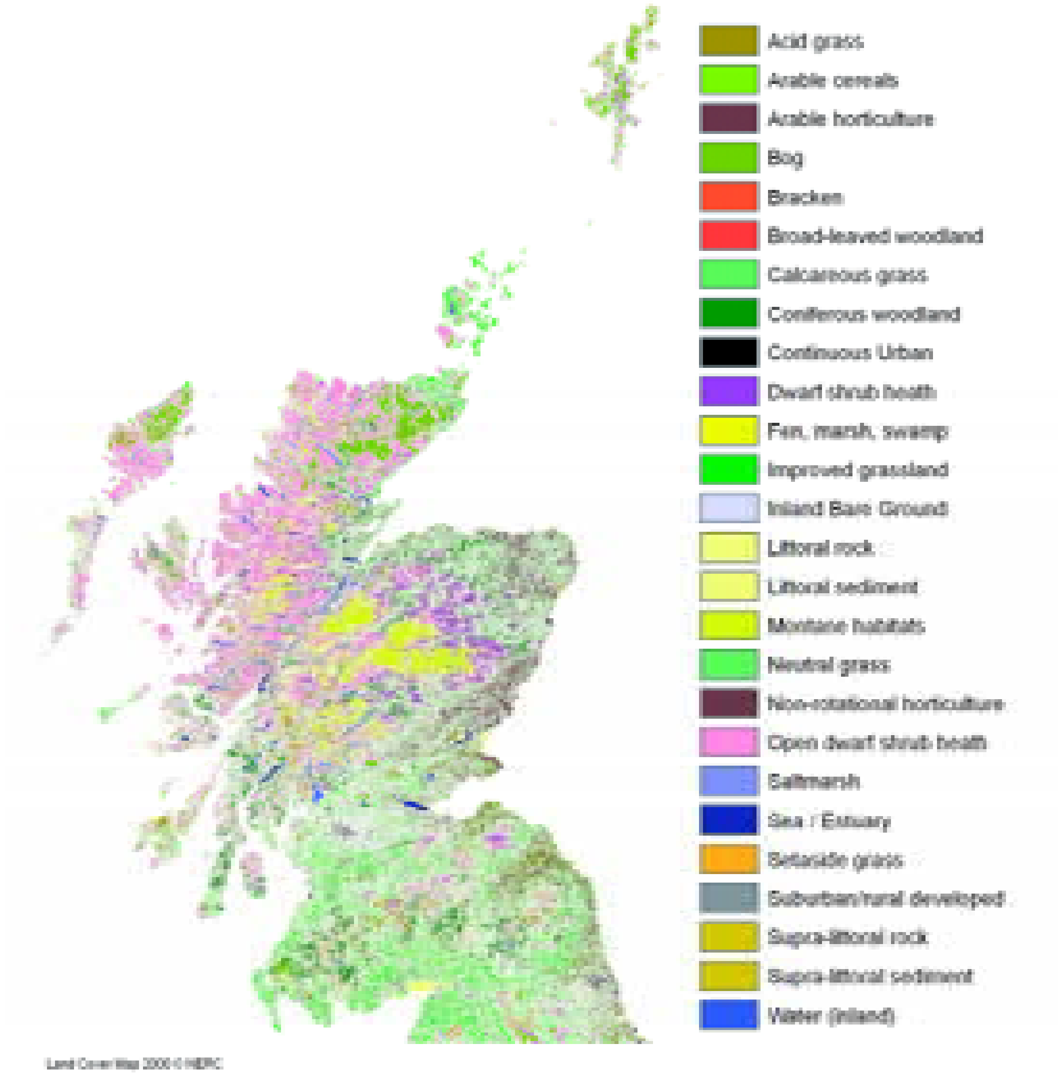
Many major brownfield (i.e. previously developed) sites stem from the closure of manufacturing industries which often left poor environments and significant areas of vacant and derelict land, some of which is contaminated. North Lanarkshire and Glasgow City together contain 24% of recorded derelict and urban vacant land in Scotland. In 2005, there were 7,610 hectares of derelict and 2,960 hectares of urban vacant land[L10].

The amount of derelict and urban vacant land fell from 13,571 hectares in 1995 to 10,570 hectares in 2005[L10]. This fall is partly due to land being brought back into productive use. Residential development was the most common new use (43%) for urban vacant and derelict land since the 2004 survey.

Land cover and habitats

The Countryside Survey, carried out in 1998[L11], showed that Scotland has a high proportion of semi-natural habitats compared with the rest of the UK. Semi-natural grassland, mountain, heath, bog and native woodland habitats cover just over half of the land area of Scotland (see Figure L3).

Figure L3: Land cover in Scotland, 1998



Source: Land Cover Map 2000 (www.ceh.ac.uk/sections/seo/lcm2000_home.html)

Between 1990 and 1998 there was an increase in managed land (built-up and arable areas) and a decrease in semi-natural habitats (grasslands)[L11, L12]. There was also an increase in broadleaved and mixed woodland.

Land supports many plant and animal species and is essential to maintaining biodiversity. In Scotland, there are over 20 priority terrestrial habitats including bogs, heaths, woodland and coastal mud flats (www.ukbap.org.uk). There are over 100 priority terrestrial species, including great yellow bumblebee, corncrake, slender Scottish burnet moth, and many plants ranging from the yellow marsh saxifrage to the Scottish beard-moss and the ear-lobed dog lichen.

These species are monitored at selected sites and the results are summarised in the biodiversity chapter. Habitats and species are also monitored at some designated conservation sites. Scottish Natural Heritage completed the first round of site condition monitoring between 1999 and 2005 and the results will be published on its website (www.snh.org.uk).

Semi-natural woodland, wetland and grassland habitats are particularly important for wildlife. Responsibly managed agricultural land can also be rich in biodiversity, with arable fields particularly important for birds such as skylark, grey partridge and corn bunting. Between 1968–1972 and 1988–1991, Scottish populations of 12 out of 20 farmland bird species declined[L12], partly due to intensive farming practices such as the use of larger fields, resulting in a loss of hedges and field margins. A more recent survey from 1993–2004[L13] revealed an improvement in the numbers of 8 out of 13 farmland bird species and 12 out of 23 woodland bird species. Research commissioned by SNH[L14] will provide further insight into these trends.

Land contamination

Contaminated land poses risks to people, plants, animals and property and may also leach out to surface waters and groundwaters. Land contamination in Scotland is mainly a result of historical practices at industrial sites, gasworks and mines and can sometimes involve radioactivity (see radioactivity chapter).

The area of contaminated land in Scotland is relatively small but of significant local importance. In 2005 the Scottish Vacant and Derelict Land Survey (SVDLS)[L10] recorded 171 derelict sites (total area 1,186 hectares) with known contamination and 18 derelict sites (total area 144 hectares) brought back into use.

As of June 2006, Scottish local authorities had identified six sites (total area 42 hectares) as chemically contaminated land. Contamination at other sites is being addressed either through the planning regime and/or voluntary remediation. A more complete picture will be obtained when the contaminated land performance indicators developed by the Scottish Executive are fully implemented in 2006/2007.

Chemical contamination is now less of an issue than indicated by previous SEPA reports in 1996[L15] and 2001[L16]. Regulations now require improved containment of potential pollutants and as a result land historically affected by chemical contamination is gradually being cleaned up. However, the deposition of atmospheric pollutants remains an important source of chemical contamination and is of particular concern for acidification, nutrient enrichment and persistent organic pollutants.

Box L3: Land contamination and coastal erosion at Monifieth

Coastal erosion at Monifieth, Angus, exposed a variety of waste materials, some containing asbestos, which are believed to have been used in early land reclamation works; see photograph above taken in June 2003.

Remediation works were undertaken to contain the waste material so that there was no dispersal of contaminants into the environment and to prevent future coastal erosion; see photograph below in November 2003.

For further information see supplementary material[SL3].

Soils

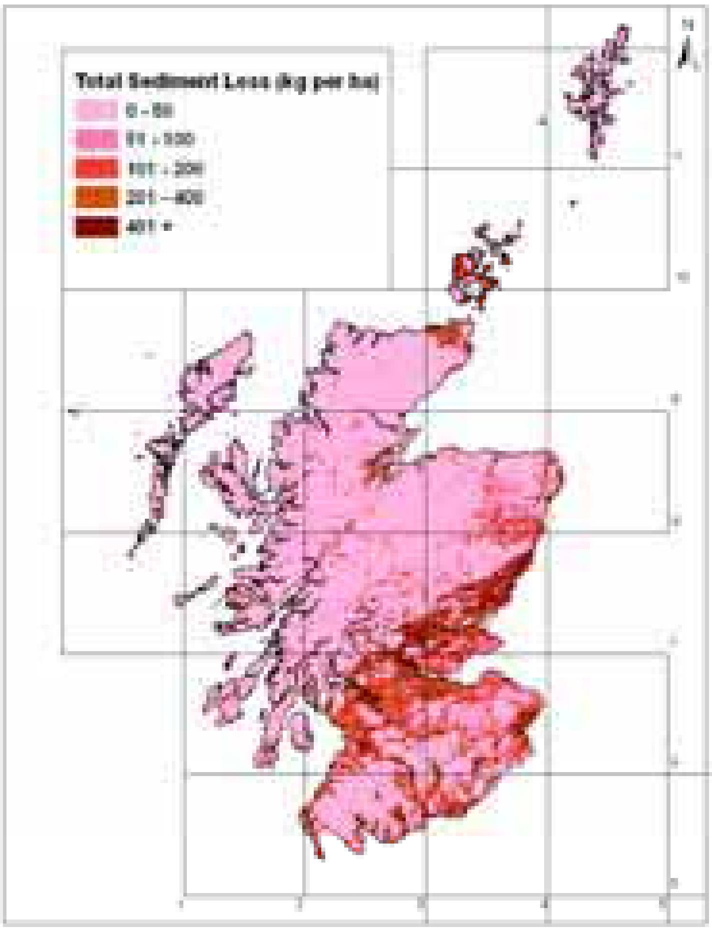
Soil is a significant component of land but remains the least understood of all environmental media. The nature, extent and diversity of soil types present a considerable challenge in terms of reporting on the overall state of Scotland's soil, so conclusions are based on historical, modelled or 'proxy' data.

Soil (formed from minerals, organic matter, air and water) is particularly important as it:

- is naturally slow to form but can be destroyed rapidly;
- enables vegetation growth, supporting ecosystems, agriculture and forestry;
- mediates water flow by capturing and filtering rainfall and delivering it to rivers, lochs and underlying rock formations (forming part of the water cycle);
- serves as a filter and buffer, transforming harmful substances and minimising their entry to water and food chains[L17];
- forms an essential part of the carbon cycle (the organic matter it contains acts as a sink for carbon dioxide and as a carbon store).

Soil is also a habitat in its own right and supports a very varied biodiversity. A handful of soil contains millions of bacteria and other micro-organisms, fungi and invertebrates (e.g. mites, springtails and worms). The Natural Environment Research Council (NERC) research programme at Sourhope in the Scottish Borders (http://soilbio.nerc.ac.uk/Sour hope.htm) has helped to highlight the links between biodiversity below and above ground.

Figure L4: Estimated sediment loss across Scotland, 2004[L18]



Soil erosion and landslides

Erosion occurs principally by the action of water and wind, and can become a problem when effects are enhanced through poor management, particularly on exposed, damaged and unstable soils. Examples include coastal erosion and mass erosion by landslides and debris flow. Once soil particles are eroded, they can be carried overland and may enter streams and rivers causing the silting up of watercourses, harm to fish, damage to structures such as bridges and the pollution of watercourses with excess nutrients or harmful chemicals, such as pesticides and metals. Erosion of peat soil also exposes the peat to drying and oxidation which reduces soil carbon stocks and releases gases that contribute to climate change.

An estimated 900,000 tonnes of soil were lost by erosion to freshwater during 2004, of which 88% was from agricultural land[L18]. Figure L4 shows the estimated sediment loss across Scotland in 2004. Earlier work by The Macaulay Institute and Scottish Natural Heritage identified soil most at risk of erosion by overland flow in Scotland[L19].

Erosion is often triggered by heavy rain falling onto exposed and unstable soil, though the action of wind is important in areas with lighter soils such as Moray and Fife. Other contributing factors include slope steepness and instability, soil texture and structure as well as damage caused by grazing livestock and human trampling. An extreme case of soil erosion is highlighted in the supplementary material[SL4].

Land management practices can increase the rate of soil loss. Farmers are now required to keep land in 'good agricultural and environmental condition' by adopting practical measures that avoid damage to soil, habitats and vegetation. Forests are already covered by best practice guidelines designed to protect both soil and water[L6].

The Scottish Executive[L20] and the British Geological Survey[L21] have made initial risk assessments of landslide and debris flows across Scotland, but it is unclear whether they are becoming more frequent. A SNH study[L22] suggests that there is evidence of more extensive debris flow activity in the past few centuries, but no dominant cause was identified. However, steep valley sides (>30^0) are most likely to experience debris flows.

Climate change, with a predicted increase in the storminess and intensity of rain events, may itself change the pattern of soil erosion in the future. Severe weather, such as localised storms, can act as a trigger for landslides and debris flows that can damage road, rail and other essential infrastructure, as illustrated by the two landslides in 2004 between the river Tay and the A9, north-west of Dunkeld, and in Glen Ogle, near Lochearnhead.

Loss of soil organic matter

Soil organic matter is vitally important in terms of soil quality as it:

- increases the ability of soil to hold and supply both nutrients and water;
- promotes and enhances soil structure;
- physically binds pollutants to soil particles, so that they are 'immobilised';
- supports biodiversity in soil.

Soil organic matter is also a significant carbon store and its loss increases carbon dioxide emissions and levels of organic carbon in water. Scotland's soils contain an estimated 2,196 million tonnes of soil carbon (to a depth of 100 cm) compared with a total of 4,566 million tonnes for the whole of the UK[L23]. Small changes in terrestrial carbon stocks will result in large emissions: one estimate suggests that only 0.1% needs be released to the atmosphere for Scotland's current man-made carbon dioxide emissions to double[L24].

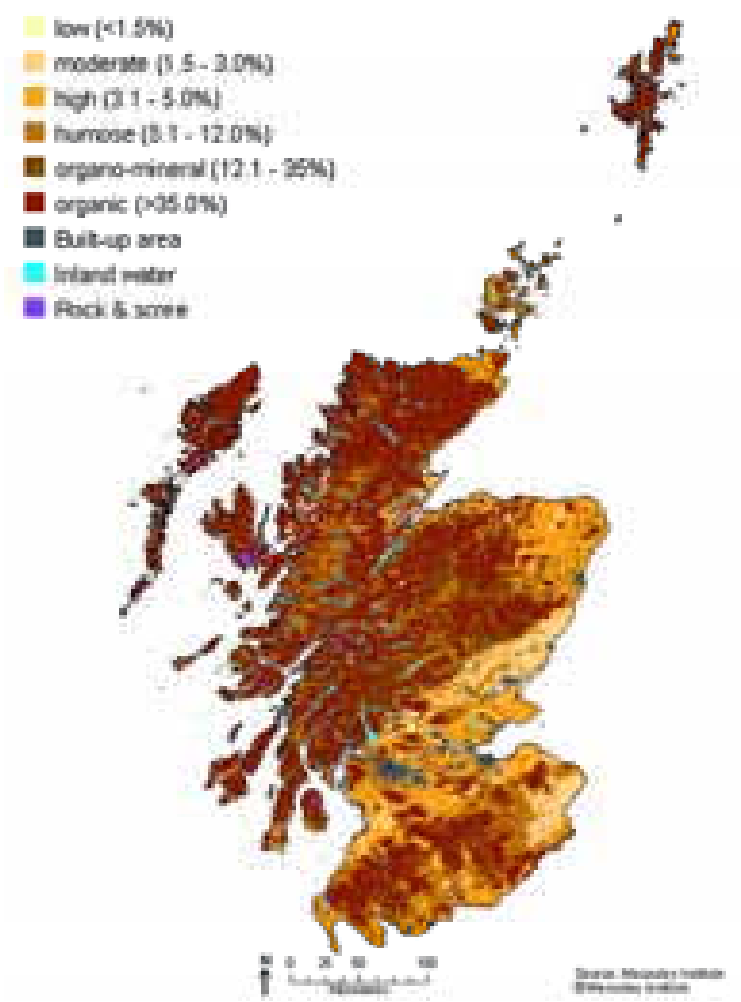
The organic matter content of soils varies considerably across Scotland; wet and acidic soils are generally rich in organic matter and dominate the north and west of Scotland (see Figure L5).

Scottish soils contain high levels of organic matter due to the cold, wet climate associated, in particular, with the Scottish Highlands. Low temperatures and wet soils slow the decomposition of organic matter in plant material deposited on the soil surface. In areas of poor soil drainage, the accumulation of organic matter is often more rapid than decomposition and a peat soil forms. The organic matter content of peat soil can be up to 100%. Peats are often several metres deep and can hold water up to 20 times their dry weight.

Studies in England and Wales have estimated that peat soils are losing soil organic matter at a mean rate of 0.6% per year relative to the existing soil carbon content[L25]. A similar loss of soil organic matter from peat soil in Scotland would be very serious for soil as well as climate (see climate chapter) as it has been estimated that Scotland may possess 48% of UK soil carbon stocks[L23]. Indirect evidence from long-term monitoring at certain locations suggests a significant increase in dissolved organic carbon levels in rivers[L26].

In upland areas, direct losses of soil organic matter and carbon can occur if peat is extracted for burning or for use in horticulture. Drainage of peat accelerates the loss of organic matter through oxidation. Peat drying out due to climatic influences also promotes oxidation and erosion. Keeping upland bogs and other peaty soils in a stable, waterlogged condition is therefore vital.

Figure L5: Topsoil organic carbon content



Land use and management have a major influence on soil organic matter content. The growing of arable crops reduces soil organic matter unless it is returned to the soil through applications of manure or other organic materials. Timber removal can lead to a reduction in soil organic matter in peat soils. Leaf/needle litter, brash, dead wood and tree rooting can enhance soil organic matter in other soil types. Sewage sludge has been applied to agricultural and forestry land for many years and composted organic wastes can also result in soil improvement (see Box L4).

Organic materials applied to land can bring benefits but may also carry both chemical and microbiological contamination and, if poorly or inappropriately applied, can pose a risk to soil, air, water, plants, animals and humans. Data on the volume of waste handled under exemption from waste management licensing indicate that some 273,000 tonnes of waste were used to treat land for agricultural benefit or ecological improvement in 2004. The types of waste most commonly applied are mineral waste (including soil, stones and gravel) followed by vegetable waste from food preparation and processing, and treated sludge from sewage or other waste treatment works. A further 774,000 tonnes of waste was used to treat land for reclamation.

Box L4: Composted garden waste improves sports pitches and flower beds

North Lanarkshire Council Community Services Department has composted the garden waste it generates for the past four years. At its Auchenkilns composting site, 800–1,000 m^3 of parks and garden waste are processed each quarter. The compost produced is used as a partial replacement of topsoil to level the playing surface of sports pitches when preparing the area for reseeding. The compost provides nutrients to the grass as well as organic matter to the soil.

The Community Services Department is pleased with the results of using the garden waste compost and has noticed that the grass has established more quickly and more uniformly. The compost has also been used to improve the workability of garden beds, improving the size and appearance of the plants.

For further information see 'Case Study: Turf Top Dressing of Sports Pitches' at www.remade.org.uk/documents.aspx?id=1

Soil sealing

Soil can act as a natural sponge by capturing rainfall and surface run-off, and then releasing water more gradually to groundwater and surface waters. This ability is lost where soil is replaced or sealed by impermeable surfaces such as concrete and asphalt.

Soil 'sealing' means that the soil is often removed or cut off from inputs of organic matter and natural interactions with air and water, which can result in greater flood risk. Groundwater recharge is also reduced, with implications for the quantity of water and supply to surface waters. The significance of this for soil functions is now recognised in planning guidance[L27].

There is currently no single mechanism at a national level to gather and report data on the extent of soil sealing in Scotland. It is primarily related to the degree of urbanisation and will occur on all sites where development takes place. Identifying soil types with suitable infiltration rates where sustainable urban drainage systems (SUDS) can be used is helping to minimise the impact of sealing and development (see www.sepa.org.uk/dpi/suds/index.htm). Drainage to SUDS or equivalent systems is now a requirement for all new developments in Scotland.

Forward look

Progress is being made at UK and European levels towards establishing a more consistent set of indicators with which to assess and monitor soil and land condition. New requirements under the Common Agricultural Policy and developments in Land Management Contracts should lead to improvements in soil management and condition within farming. Further improvements are expected in the future as a result of the European Union Soil Thematic Strategy as well as through the planning system and new approaches to waste management.

References

No.	Details	Available from:
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L2	*Accounting for Nature: Assessing Habitats in the UK Countryside*, Department for Environment, Food and Rural Affairs, and Natural Environment Research Council, 2000.	www.cs2000.org.uk
L3	*Organic Annual Report*, Scottish Executive, 2005.	www.scotland.gov.uk/Publications/2005/10/10103806/38070
L4	*Land Management Contract Menu Scheme*, Scottish Executive press release, 25 August 2005.	www.scotland.gov.uk/News/Releases/2005/08/25151946
L5	*Forestry Statistics*, Forestry Commission, 2005.	www.forestry.gov.uk/website/foreststats.nsf/byunique/index_main.html
L6	*Forests and Water Guidelines*, 4th edition, Forestry Commission, 2003.	www.forestresearch.gov.uk/PDF/fcgl002.pdf/$FILE/fcgl002.pdf
L7	*UK Minerals Year Book 2004*, British Geological Survey, 2005.	www.bgs.ac.uk/mineralsuk/home.html
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L11	*Trends in Broad Habitats: Scotland 1990–1998*, Scottish Natural Heritage Commissioned Report FOONB03, 2002.	www.snh.org.uk/strategy/landcover/home.asp
L12	*Natural Heritage Trends*, Scottish Natural Heritage.	www.snh.org.uk/trends/
L13	*Breeding Birds in the Wider Countryside: their Conservation Status 2004*, British Trust for Ornithology, 2005.	www.bto.org/birdtrends2004/
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L15	*State of the Environment Report 1996*, SEPA, 1996.	www.sepa.org.uk/publications/state_of
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L17	*Indicators of Soil Resilience for Scotland and Northern Ireland*, Project code LQ06, Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), 2005.	www.sniffer.org.uk
L18	*Provision of a Screening Tool to Identify and Characterise Diffuse Pollution Pressures: Phase II*, Project code WFD19, Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), 2006.	www.sniffer.org.uk
L19	*The Inherent Geomorphological Risk of Soil Erosion by Overland Flow in Scotland*, Scottish Natural Heritage Research, Survey and Monitoring Report No. 183, Scottish Natural Heritage, 2002.	Scottish Natural Heritage

L20	*Scottish Road Network Landslides Study Summary Report*, Scottish Executive, 2005.	www.scotland.gov.uk/Publications/2005/06/13103229/32495
L21	*Britain Beneath Our Feet*, British Geological Survey and Natural Environment Research Council, 2005.	www.bgs.ac.uk/britainbeneath/
L22	*Geomorphological Changes and Trends in Scotland: Debris Flows*, Scottish Natural Heritage (SNH) Commissioned Report, 2004	www.snh.org.uk/pubs/cr.asp
L23	*A Soil Carbon and Land Use Database for the United Kingdom*, Bradley RI, Milne R, Bell J, Lilly A, Jordan C and Higgins A, 2005.	Soil Use and Management, Vol. 21, No. 4, 363–369.
L24	*Climate Change, Land Use and Agriculture: A Scottish Perspective*, Soil Association, 2005.	www.soilassociation.org/web/sa/saweb.nsf/librarytitles/64DA.HTMl
L25	*Carbon Losses from all Soils across England and Wales 1978–2003*, Bellamy PH, Loveland PJ, Bradley RI, Lark RM and Kirk GJD, 2005.	Nature, Vol. 437, 245–248.
L26	*Export of Organic Carbon from Peat Soils*, C Freeman C, Evans CD, Monteith DT, Reynolds B and Fenner N, 2001.	Nature, Vol. 412, 785.
L27	*The Role of the UK Planning System in Protecting and Enhancing Soils*, Project code UKLQ01,Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), 2004.	www.sniffer.org.uk
SL1	Supplementary material on sustainable forestry	Online version of the report
SL2	Supplementary material on Holmhills Wood Community Park in Cambuslang	Online version of the report
SL3	Supplementary material on land contamination and coastal erosion at Monifieth	Online version of the report
SL4	Supplementary material on soil erosion on the Trotternish ridge, Isle of Skye	Online version of the report

Sources of further information

Topic	Source
Contaminated land	www.sepa.org.uk/contaminated-land/
European Union Soil Thematic Strategy	http://ec.europa.eu/environment/soil/index.htm
Common Agricultural Policy reforms	www.scotland.gov.uk/Topics/Agriculture/Agricultural-Policy/CAPRef
Soil and geology	www.bgs.ac.uk/britainbeneath/land_introduction.html www.soils.org.uk www.macaulay.ac.uk
Protected areas	www.snh.org.uk/about/ab-pa00.asp
Scottish Executive's Organic Aid Scheme	www.scotland.gov.uk/Topics/Agriculture/Agricultural-Policy/15869/3753
National Parks	www.lochlomond-trossachs.org www.cairngorms.co.uk
The state of Scotland 's farmed environment in 2005	www.macaulay.ac.uk/LINK/link_sitemap.html
NERC soil biodiversity project	www.soilbio.nerc.ac.uk
Scotland's Soil Resource – Current State and Trends	www.scotland.gov.uk Study by the Macaulay Institute and the University of Stirling on behalf of SEERAD. The report is due to be published in 2006.
Sustainable urban drainage schemes	www.sepa.org.uk/publications/leaflets/suds/index.htm

Water

Summary

Water quality in Scotland is generally good and continues to improve due to a reduction in end-of-pipe discharges. There have been major improvements in the quality of bathing, shellfish and freshwater fish waters. Diffuse pollution originating from farmland and urban areas is a significant issue and is now the largest source of pollution.

Water is generally abundant but demand requires better management to maintain levels in groundwater, lochs and rivers. Changes in river flow patterns may increase the risk of flooding in some areas and there are indications that rivers in the east may be experiencing lower flows in summer.

Impacts upon the physical structure of rivers, estuaries and coastal waters are widespread.

Scotland has a generally high quality water environment. The condition in which we maintain this vital resource has major implications for biodiversity, our health, our enjoyment of and pride in our country and the performance of the Scottish economy.

Scotland's reputation for a high quality water environment provides many social and economic benefits including good quality drinking water, high 'brand value' for Scottish products like whisky, beer, spring water, shellfish and salmon, and opportunities for tourism and recreation.

Other important benefits include energy generation. Scotland generates approximately 3,000 gigawatt hours (GWh) of renewable electricity from hydropower each year. This accounts for almost 10% of the country's needs and over 20% of the UK's renewable electricity generation[W1].

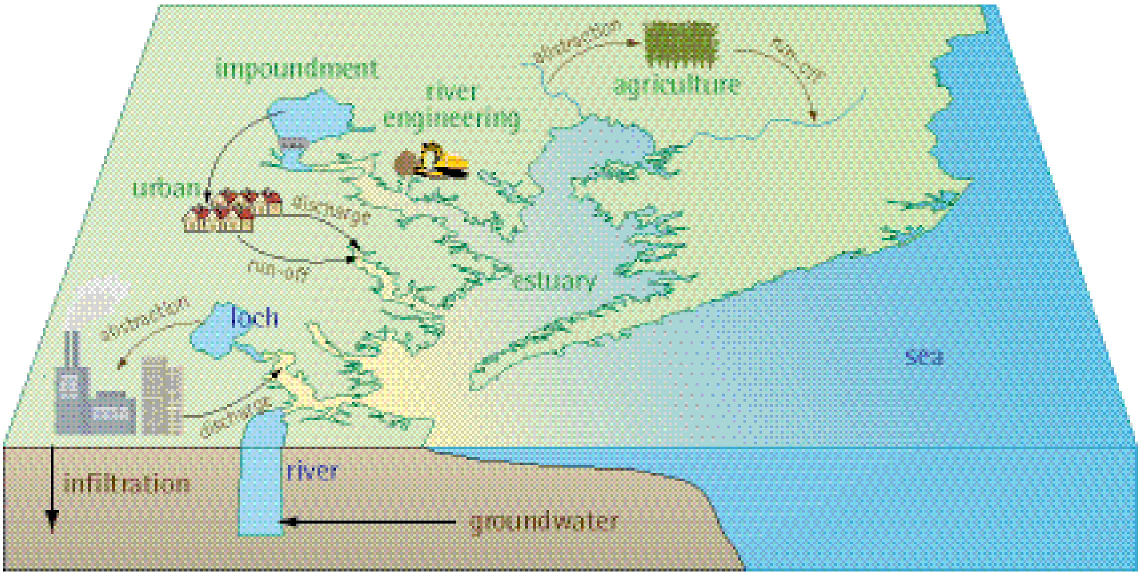
Human activity can damage the water environment, compromising the benefits upon which we all rely. The integrated management of whole river basins and stretches of coastline, a key component of the Water Framework Directive, will be fundamental to controlling the risks to our water environment in the future.

Factors influencing the water environment

The state of water is influenced by changes taking place in water itself and in the climate, as well as inputs from land and air. Human activities which result in changes and inputs can harm the water environment affecting water resources, the benefits upon which we all rely and damaging ecosystems (see Figure W1). These activities include:

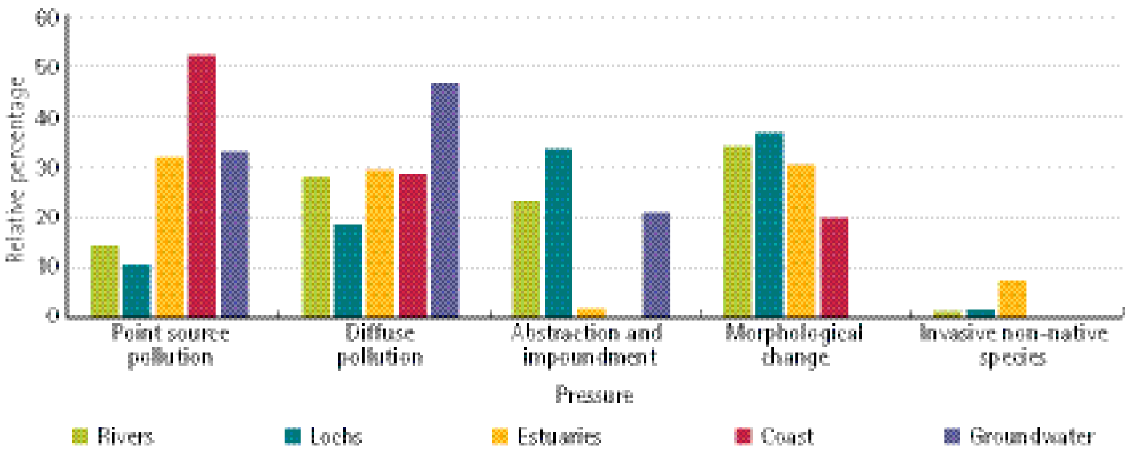
- point source pollution - includes discharges from factories and sewage treatment works; overflows from sewers during heavy rain; inputs from fish farms;
- diffuse pollution - includes contaminated run-off from streets and yards; the deposition of acid pollutants from air; leaks or overspills from the sewerage system; and run-off of pesticides, soils and nutrients caused by agriculture and forestry;
- abstractions and impoundments (flow regulation) – includes major hydropower and water supply schemes which take water from one catchment and divert it to another; the building of dams and weirs; and the drilling of boreholes to extract groundwater;
- changes to the physical structure of water bodies (morphological change) – includes engineering works that straighten rivers; building work on flood plains or estuary mudflats; and land use practices such as intensive livestock farming, which can degrade vegetation and lead to riverbank erosion;
- invasive non-native species – the disruption to water habitats and species caused by the introduction of invasive non-native species of plants and animals.

Figure W1: The effects of human activity on the water environment



In 2005 information on the pressures and impacts upon the water environment was compiled to make an assessment of those water bodies potentially at risk failing the environmental objectives of the Water Framework Directive[W2]. Summary information of the pressures on rivers, lochs, estuaries, coastal waters and groundwaters is provided in Figure W2. Supplementary material[SM1] provides information on the industry sectors associated with the major pressures.

Figure W2: Relative significance of pressures on river, loch, estuary, coastal and groundwater bodies



The quantity of water

Water is generally in abundant supply in Scotland, but there are many instances where human activities have created localised imbalances between supply and demand. The quantity of water in the natural environment is important because:

- insufficient water can result in poor water quality (e.g. there is less capacity to dilute pollutants);
- too little water could lead to shortages, severely damaging or destroying important habitats;
- too much water can result in flooding causing both economic and environmental damage.

Scotland has become wetter since 1961, with an average increase in winter rainfall of almost 60% in the north and west, and an increase of 20% in the average annual rainfall for the whole country[W3].

The rates of flow in many Scottish rivers have been measured since the middle of the 20th century (see climate change chapter). Annual flows show a corresponding relationship to rainfall with:

- no significant change for the rivers Dee, Avon and Tweed which rise in the east;
- a 20–35% increase for the rivers Kelvin, Nith, Tay and Teith which rise in the west;
- a significant increase in the number of high flow events for the rivers Dee, Ewe, Kelvin, Teith and Tay[W4].

There are indications that:

- the overall quantity of water in Scottish rivers is increasing;
- spells of very wet weather are occurring more frequently and with it the risk of flooding;
- some rivers in the east may be experiencing lower flows, particularly during the summer.

Flooding is a natural phenomenon, with both positive and negative consequences. For example, flood waters deposit large quantities of silt, rich in organic matter and nutrients, on farmland. Floods also sustain many important wetland habitats and can benefit natural ecological processes.

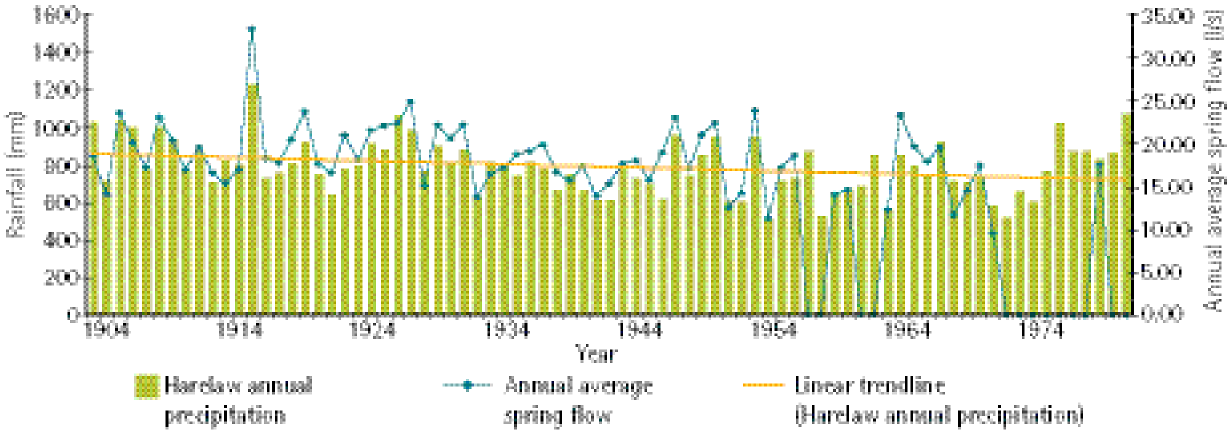
Floods can have adverse impacts upon agriculture and property. It is impractical, and unsustainable, to prevent flooding along the entire length of a river or coastline, so flood defences have been concentrated to date in the most vulnerable and heavily populated areas. Unfortunately, this approach may simply have the effect of increasing the flood risk elsewhere. Consequently, there is now a statutory requirement to consider flood defences in the context of the whole river catchment in order to evaluate all options before deciding on the best approach. This is known as sustainable flood management.

Planning policy now states that new development should be directed away from areas subject to flood risk rather than placing it where expensive and environmentally damaging flood defences will be required.

There is limited information on groundwater resources in Scotland. The quantity of groundwater available is assessed through estimates of recharge inputs and long term measurements of groundwater levels or spring flow volumes. There are few locations in Scotland where such measurements have been made for sufficiently long periods of time to identify meaningful trends.

Many Scottish shallow bodies of underground water (aquifers) are expected to react relatively quickly to rainfall. The data presented in Figure W3 are thought to represent a typical example; they are derived from records of spring flow in the Pentland Hills at Black Springs south of Edinburgh[W5] and local rainfall as measured at nearby Harelaw. The gradual decrease in spring flows over the 80 years from 1904 appears to be the result of decreases in local annual rainfall totals. Unfortunately, the records do not cover the last 20 years, so the effect of more recent changes in rainfall cannot be assessed (long-time series of data are not available for another location).

Figure W3: Flow in the Black Springs near Edinburgh, 1904–1984

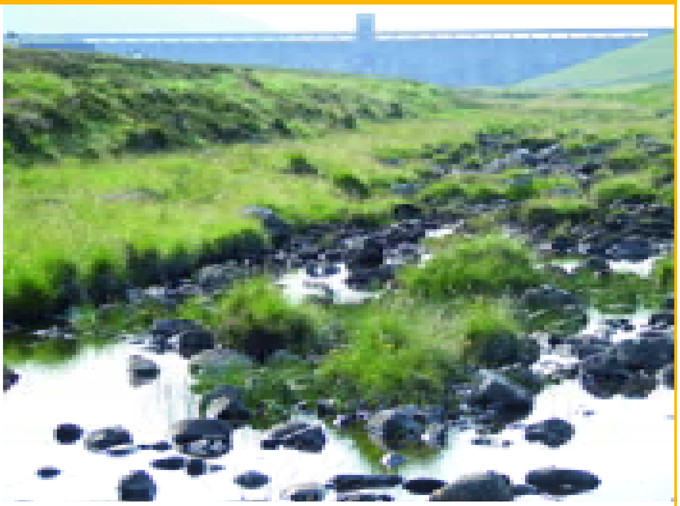


Direct local impacts upon the water environment can result from the design and operation of abstractions and impoundments such as weirs and dams. For example:

- Over-abstraction means there is less water available to dilute pollutants and can cause ecological damage, impacting on biodiversity interest (see supplementary material[SW2] for the challenges this presents for a major river).
- As the amount of water abstracted from groundwater, rivers and lochs increases, associated wetlands dry out and the size of associated rivers will decrease reducing their capacity to support fish and other species. In severe cases, rivers may actually dry up altogether.
- The vast majority of Scotland's public water supply comes from lochs, artificial reservoirs and rivers. Although Scotland's population has declined slightly in recent decades, changes in lifestyle (e.g. larger numbers of smaller households) are leading to increased rates of water consumption[W6].
- Irrigation of arable crops during periods of low rainfall also reduces the flow in rivers, impacting on the species that inhabit them (see supplementary material[SW3] for the challenges this presents to a specific burn).
- Dams affect the flow of water and this can have a number of impacts, for instance by stopping fish migration unless fish ladders are provided. Regulating the flow of water from dams can reduce flood risk in urban areas but, when associated with abstractions, reservoirs may not release any water from the dam during dry weather. Where 'compensation' flows are provided, it is impossible to use this to recreate the natural variations in river flow that occur in response to rainfall (see Box W1). The loss of high flows leads to the accumulation of silt within the gravels and the growth of algae and moss. These conditions are not suitable for the spawning of salmon and trout.

Box W1: Hydropower schemes

Hydropower schemes provide a significant source of renewable energy, however, they can have local environmental impacts upon the water environment. To maximise the amount of water flowing through the power stations, they employ techniques such as the damming of lochs, the creation of new reservoirs and the diversion of water from one river to another. The potential environmental impacts of these schemes include greater fluctuations in loch water levels and very low flows in stretches of river subject to diversion.



Glascarnoch River below the hydropower dam, showing changes to the river channel due to lack of compensation flows from the reservoir

The Conon Hydropower Scheme was constructed in three phases between 1946 and 1961. In the north, the artificial reservoirs of Lochs Vaich and Glascarnoch were created to supply water via a series of tunnels to the 24 megawatt power station at Mossford by Loch Luichart. Loch Vaich supplies some compensation flow to the Black Water via the River Vaich, but the 3 km stretch of river between the Glascarnoch dam and the confluence with the River Vaich can often have very low water levels.

The aquatic habitat in the upper reaches of the catchment has been altered radically.

Glascarnoch dam

Analysis in 2005 of the pressures on water resources in Scotland[W2] concluded that abstractions and flow regulations posed a risk to:

- 14,406 km^2 of groundwater (equivalent to 18% of Scotland's land area);
- 6,534 km of rivers (26% of total river length);
- 465 km^2 of lochs (47% of total loch area);
- 49 km^2 of estuaries (5% of total estuary area).

Until recently there has been no licensing of water abstractions in Scotland and as a result it has not been possible to fully determine if groundwater resources are being depleted, or if changes in groundwater flows are affecting river flows or causing saline intrusion. The map in Figure W4 shows estimates of recharge to groundwater from rainfall across Scotland. There is some evidence of localised impacts arising from abstractions. For example, monitoring of a borehole at Redbank (near Dumfries) since 1981 has revealed a 1-metre drop in groundwater level due to a local abstraction[W7].

Figure W4: Rates of recharge to groundwater in Scotland

The quality of water

The quality of water is important because:

- it dictates its suitability for use in drinking water supply, fisheries, recreation, etc.;
- it affects the populations of the many species which it supports.

There is extensive monitoring of rivers, lochs, estuaries and coastal waters and, to a more limited extent, groundwater. Monitoring covers a wide range of chemical parameters but it also includes biological parameters and aesthetic appearance. The monitoring results are combined such that a body of water is placed into one of four or five classification bands, which describe the current condition ranging from excellent or good quality, through fair and poor quality to seriously polluted.

Classification schemes exist for all types of water except groundwater (see supplementary material[SW4]). Classifications are produced every year (or every five years for lochs); trends in the quantity of poor or seriously polluted waters between 1999 and 2005 are presented in Figures W5–W7. Summary information is also provided in Table W1.

- For information on trends in water quality between 1996 and 2000, see www.sepa.org.uk/data/classification/index.htm
- For information on the classification parameters see supplementary material[SW5].

Figure W5: Total amount of class C (poor) and class D (seriously polluted) rivers, 1999–2005

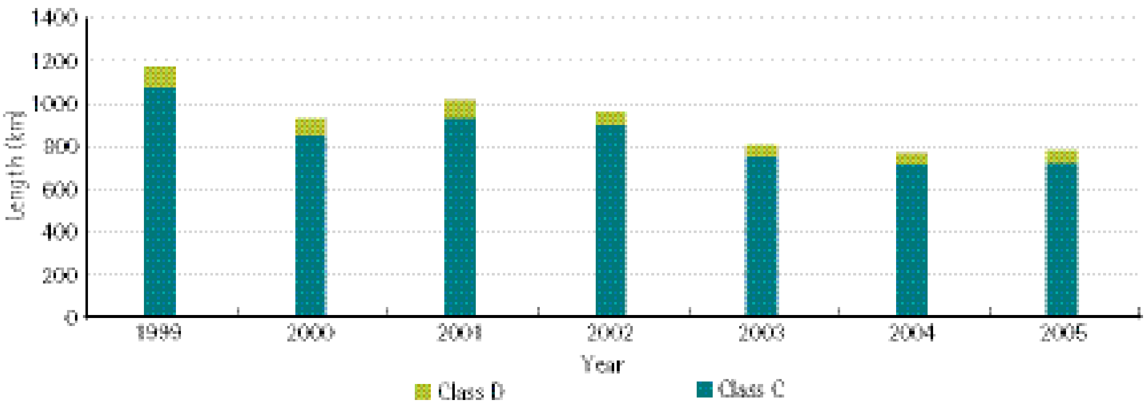


Figure W6: Total amount of class C and D estuaries, 1999–2005

Figure W7: Total amount of class C and D coastal waters, 1999–2005

The condition of waters formally protected under European Directives on water quality is also monitored. These waters include:

- designated bathing waters;
- shellfish growing waters;
- rivers of particular importance as salmon and trout fisheries.

Summary information on the status of these designated waters is also presented in Table W1. For further information on waters protected under these Directives, see www.sepa.org.uk/data/index.htm

Table W1: Water quality classification, 2005[W8, W9, W10, W11]

Type	Excellent quality	Good quality	Trend (excellent and good quality combined) since 2000
Rivers	8,004 km (31%)	12,053 km (47%)	Not possible to make direct comparisons due to sampling site changes
Estuaries	692 km^2 (86%)	95 km^2 (12%)	2% increase
Coastal waters	11,103 km (94%)	579 km (5%)	1% increase
Lochs (157)*	735 km^2 (78% or 123 in number)		8% decrease (since 1995)
Designated bathing waters (60)	32 (53%)	24 (40%)	10% increase
Designated shellfish growing waters (104)	35 (34%)	67 (64%)	24% increase
Designated salmonid waters (205)	72 (35%)	127 (62%)	2% increase

*Greater than 1 km^2 in area. Data from 2000 classification.

Some 78% of rivers, 98% of estuaries and 99% of coastal waters in Scotland are currently classified as either excellent or good quality. The situation has continued to improve from that reported by SEPA in 1996[W12] and 1999[W13]. The amount of poor quality or seriously polluted (class C and D) rivers, estuaries and coastal waters has declined by 16%, 44% and 57% respectively since 2000. The situation will change when the classification scheme is amended and the monitoring changed (see www.sepa.org.uk/wfd/monitoring/index.htm) to meet the more wide-ranging requirements of the Water Framework Directive.

Further improvements to water quality will depend largely on the successful management of diffuse pollution from large areas of rural and urban land. The build-up of excess nutrients – especially in lochs, rivers and groundwaters – is discussed in more detail in the chapter on nutrient enrichment.

Good examples of the combined impact of point and diffuse pollution are provided by the Rivers Clyde (see Box W2) and Almond (see supplementary material[SW6]).

Over the last decade, coastal water quality has improved dramatically as a result of the application of full treatment to sewage discharges, improved treatment of industrial effluents, and work to reduce diffuse pollution. Marine fish farming has expanded in extent and economic value, but has been managed and controlled to minimise its impact.

The dramatic improvements to coastal water quality are illustrated by the quality of designated bathing waters. A key indicator of bathing water quality is the number of faecal coliforms. These bacteria are present in human sewage and in traces of animal faeces washed from farmland during periods of wet weather. If swallowed in sufficient quantities by people swimming or bathing in affected waters, faecal coliforms can cause serious stomach upsets. Figure W8 shows the steady decline in the average counts of faecal coliforms at all 60 designated bathing waters in Scotland. Box W3 highlights how changes to agricultural practices in Scotland have improved bathing waters.

Box W2: Water quality in the River Clyde and Clyde estuary

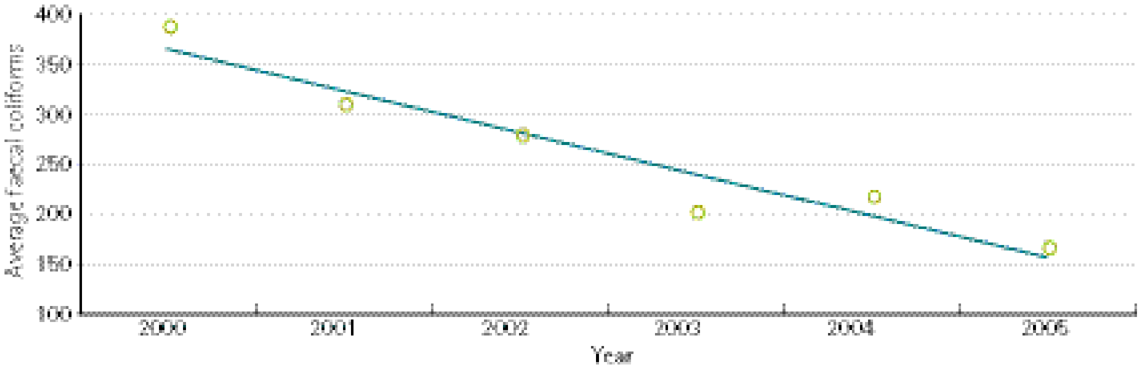
The River Clyde and its tributaries, both within and outwith Glasgow City boundary, are affected by pollution from the largest populated area in Scotland. A significant sign of success in improving water quality was the return of salmon in the early 1980s. Ecological conditions in both the freshwater and tidal estuary sections of the river have since improved further, partly due to the substantial upgrading of sewage treatment works at Daldowie, Shieldhall and Dalmuir.

Remaining water quality problems are caused by urban diffuse pollution and by overflows from the sewerage system following periods of rain. This causes poor water quality in the Clyde, its tributaries and the estuary. It can also lead to the flooding of streets and buildings with polluted water. The economic consequence of this pollution and flooding is that, in some areas, new developments cannot connect to the sewerage network.

Work has started to address these problems. The Glasgow Strategic Drainage Plan will provide a detailed understanding of the issues and proposes a strategic solution to drainage within the greater Glasgow area. This will require major investment in new sewers but will provide improve the quality of life for people in Glasgow and support the regeneration of the city.

For more information, see supplementary material[SW7] and www.hyderconsulting.com/proj_datasheets/proj_1701_data1_4E79CA74-EAEA-4F8B-AB1B-B.pdf

Figure W8: Average faecal coliform counts at designated bathing waters



Box W3: Adoption of good agricultural practices improves bathing water quality

Over three years until 2005, audits of 2,173 farms (mostly in south-west Scotland) showed that 80% of the farms audited were found to be fully compliant with environmental standards.

During the same period, investment in farm and field pollution improvement and mitigation measures were commissioned at two agricultural catchments, Ettrick Bay on Bute and Brighouse Bay on the Solway coast.

Early evidence of improvements and lower average levels of microbiological indicators have been observed at Ettrick Bay. Encouragingly, for the first time, all bathing waters on the west coast of Scotland met mandatory EU bathing water quality standards in 2005. Longer-term studies are required to confirm trends for Brighouse Bay as the field-based measures mature and take effect.

For more information see supplementary material[SW8].

Analysis of the pressures on water quality in Scotland in 2005[W2] (see also supplementary material[SW3]) concluded that point and diffuse pollution posed a risk of failing to meet the objectives of the Water Framework Directive to:

- 36,264 km^2 of groundwater (equivalent to 46% of Scotland's land area);
- 7,947 km of rivers (31% of total river length);
- 350 km^2 of lochs (35% of total loch area);
- 759 km^2 of estuaries (76% of total estuary area);
- 3,441 km^2 of coastal waters (7% of total area of coastal waters).

In rivers, the largest impacts are caused by diffuse pollution from farmland and urban areas, and the disposal of sewage.

In freshwater lochs, the most significant point sources are fish farms, followed by sewage disposal. The main sources of diffuse pollution are farmland and forestry, reflecting the rural setting of most lochs.

For groundwaters, the main sources of diffuse pollution are drainage from farmland and urban areas. Groundwaters are particularly vulnerable to a build-up of nitrate from fertiliser and pesticides which are washed down when excessive amounts are applied to farmland. For more information see the chapter on nutrient enrichment. The main causes of point source pollution to groundwaters are disposal of sewage and refuse (to landfill sites – see waste chapter), followed by mining and quarrying, and then manufacturing.

Point source pollution from sewage and industry is still an important threat to the quality of estuary and coastal water bodies. Despite the considerable investment in sewerage infrastructure over the past ten years, there are still many unsatisfactory discharges from sewer overflows during periods of wet weather in towns and cities along the coast.

The effect of change to the physical structures of the water environment

The physical structure (morphology) of the water environment has been progressively changed by human activity. Once changed it may take decades or centuries for the system to return to a natural condition.

Changes to the morphology of the water environment are important because:

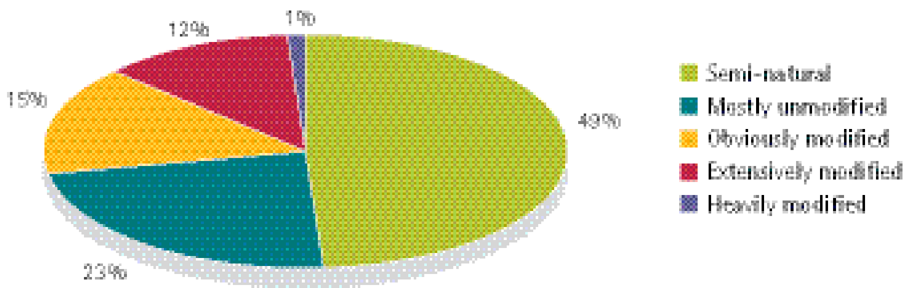
- engineering activities that straighten or deepen rivers reduce the range of habitats and reduce biodiversity. By increasing the speed of flood water these activities also increase flood risks downstream and reduce the capacity of rivers to assimilate pollution;
- introduction of structures such as bank reinforcement and croys can directly remove habitats and change the direction of flow. This leads to erosion pressure downstream which in turn can undermine bank stability, threatening productive farmland and property. Flood defence structures, if not planned at a catchment level, can destroy floodplain wetlands and can increase the risk of upstream or downstream flooding;
- land management can have an indirect impact upon the morphology of rivers. Ploughing up to the edge of the water or allowing uncontrolled access by livestock can remove vegetation cover and undermine the stability of river banks or loch shores. The result is increased bank erosion and sediment transport downstream. Drainage of shallow lochs and wetlands and straightening of burns and ditches can also impact on morphological condition.

There are two complementary methods for describing the scale of impacts upon the morphology of the water environment. Habitat surveys describe the condition of a habitat at a site. Risk assessments describe the scale of impacts caused by pressures upon morphology.

Aquatic habitats can support a wealth of diverse flora and fauna, and Scotland's waters provide a haven for a variety of important species, including a number of European protected species such as otters, natterjack toads and great crested newts.

Habitat surveys were undertaken at 779 river sites across Scotland between 1995 and 1997[W14]. Of the sites visited, 72% were described as 'unmodified' or 'mostly unmodified', while 28% were described as exhibiting significant modifications (see Figure W9). Some habitats have been surveyed more recently, but the survey has yet to be repeated across Scotland.

Figure W9: Results of a study (1995–1997) into impacts on river habitats in Scotland



Results of risk assessments concluded that pressures on morphology posed a risk to:

- 8,827 km of rivers (35% of total river length);
- 509 km^2 of lochs (51% of total loch area);
- 558 km^2 of estuaries (56% of total estuary area);
- 1,272 km^2 of coastal waters (3% of total area of coastal waters).

The river habitat surveys and the risk assessment show the majority of sites are in a good condition, but between 28% and 35% of rivers are affected to a level where ecological and economic impacts are likely. In rivers, the majority of pressures are caused by agricultural and forestry related activities, particularly the straightening, widening and extension of channels to improve drainage.

The largest scale of morphological impacts is to be found in estuaries and lochs, with over half of these water bodies subject to serious impacts.

Hydropower electricity production and water supply operations cause the most pressures on lochs, though agriculture and forestry are still significant sources of pressure.

In estuaries and along the coastline, most pressures are caused by land claim activities and the construction of flood defences (see Box W4 and supplementary material[SW9] for an assessment of the effects of land claim on the Forth estuary). The risk assessment indicates that Scotland's coasts are in a very good condition with only 3% of the coast morphology modified to a scale where economic and ecological impacts are likely.

Improving the quality of aquatic habitats will require continued and co-ordinated efforts between all groups and parties interested in the protection of Scotland's natural resources (for example, see supplementary material[SW10]).

Box W4: The effects of land reclamation in the Forth Estuary

Since the 17th century, land reclamation has approximately halved the intertidal area (the extent of land between high and low water marks) in the Forth estuary from 46.1 km^2 to the present area of 22.8 km^2. Much of the upper estuary between Kincardine and Stirling is now flanked by embankments built to convert the former mudflats and saltmarsh to land suitable for agricultural use and for flood defence for low-lying settlements. In the middle and lower estuary, the embankments give way to areas of industrial and port development, including Longannet power station, the former Kincardine power station, the ash lagoons in Torry Bay and the ports of Grangemouth, Bo'ness and Rosyth (see map). This has modified the natural shape of the Forth estuary, reducing its width and altering the flow of the tides. It has also resulted in the large-scale loss of mudflat and saltmarsh habitat. For more information see supplementary material[SW9].

Intertidal areas of the Forth estuary claimed for agriculture (■), industry (■) and port and harbour development (■) – inter-tidal mud flat is highlighted as (■).

Forward look

SEPA is beginning a new system for managing the water environment: River Basin Management Planning involves promoting the sustainable use of water whilst ensuing that the resource is protected for use by others. SEPA expects that this planning process, together with new monitoring responsibilities and new powers to control abstractions and impoundments, will deliver major improvements in the water environment. For the first time, comprehensive controls will be available to manage the impacts of abstractions, impoundments and engineering activities. The major challenges are likely to be tackling the impacts of intensive land management to avoid diffuse pollution and habitat damage and promoting sustainable flood management by influencing the planning process to avoid developments within areas liable to flooding.

References

No.	Details	Available from:
W1	Electricity generation statistics from the Department for Trade and Industry (DTI) and the Scottish Executive	www.dti.gov.uk/files/file17378.xls www.scotland.gov.uk/Publications/2006/04/24110728/8
W2	*Characterisation and Impacts Analyses Required by Article 5 of the Water Framework Directive – Scotland River Basin District*, SEPA, 2005.	www.sepa.org.uk/publications/wfd/index.htm
W3	*Patterns of Climate Change Across Scotland: Handbook*. Project code CC03. Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) 2006.	www.sniffer.org.uk
W4	Analysis of unpublished SEPA hydrology data	Scottish Environment Protection Agency
W5	*Assessing the Value of Historic Spring Flow Records in Scotland: A Study Focusing on the North Pentland Springs*. Research report produced for SEPA, 2006.	www.sepa.org.uk/publications/index.htm
W6	*Public Water Supplies in Scotland: Water Resources Survey 2003–2004*, Scottish Water, 2005.	www.scottishwater.co.uk
W7	Unpublished SEPA hydrology data	Scottish Environment Protection Agency
W8	SEPA water quality classification reports	www.sepa.org.uk/data/classification/index.htm
W9	Unpublished SEPA loch classification data	
W10	SEPA bathing waters reports	www.sepa.org.uk/publications/bathingwaters/index.htm

W11	SEPA shellfish waters and freshwater fisheries reports	www.sepa.org.uk/data/index.htm
W12	*State of the Environment Report 1996*, SEPA, 1996.	www.sepa.org.uk/publications/state_of/index.htm
W13	*Improving Scotland's Waters*, SEPA, 1999.	www.sepa.org.uk/publications/state_of/index.htm
W14	*River Habitat Quality: The Physical Character of Rivers and Streams in the UK and Isle of Man*. River Habitat Survey Report No. 2, Environment Agency, 1998.	www.environment-agency.gov.uk/publications
SW1	Supplementary material on pressures affecting Scottish water bodies	Online version of the report
SW2	Supplementary material on pressures on the Upper Spey Catchment	Online version of the report
SW3	Supplementary material on water quality in the West Peffer Burn	Online version of the report
SW4	Supplementary material on future developments in groundwater monitoring network	Online version of the report
SW5	Supplementary material on causes of polluted water	Online version of the report
SW6	Supplementary material on water quality in the River Almond	Online version of the report
SW7	Supplementary material on water quality in the Clyde river and Clyde estuary	Online version of the report
SW8	Supplementary material on improvement of bathing waters through agricultural practices	Online version of the report
SW9	Supplementary material on land reclamation in the Forth estuary	Online version of the report
SW10	Supplementary material on the Nigg Bay coastal realignment project	Online version of the report

Sources of further information

Topic	Source
SEPA water data	www.sepa.org.uk/data/index.htm
Water Framework Directive (WFD)	www.sepa.org.uk/wfd/index.htm
Controlled Activities Regulations (CAR)	www.sepa.org.uk/wfd/regimes/index.htm
SEPA water quality classification scheme	www.sepa.org.uk/data/classification/index.htm
Sustainable urban drainage systems (SUDS)	www.sepa.org.uk/publications/leaflets/suds/index.htm
Monitoring of marine waters around the UK	www.cefas.co.uk/monitoring/page-b3.htm
Groundwater	www.groundwateruk.org/default.htm www.sepa.org.uk/groundwater

Environmental Issues

Community
Compost

White Spirit

Waste and resources

Summary

Around 20 million tonnes of waste is produced in Scotland each year, mostly from commerce and industry. The amount of household waste produced in Scotland continues to increase. Fly tipping and litter remain a problem. The amount of waste disposed of to landfill is continuing to fall with substantial progress having been made in the recovery and recycling of waste.

There have been reductions in emissions to the environment associated with landfilling and thermal treatment. More landfill gas is being used to produce energy and stricter controls on landfill operations mean that the environmental impact of sites is decreasing. Emissions of dioxins and nitrogen oxides from municipal waste incinerators have fallen to low levels compared with those from other UK sources.

As defined by the EU Waste Framework Directive, waste 'shall mean any substance or object.... which the holder discards or intends or is required to discard'. This very wide definition means that every resource that households, commerce and industry exploit eventually ends up as a waste. Many wastes continue to have significant resource value in material or energy terms.

Around 20 million tonnes of waste is produced in Scotland each year[WS1]. It consists of 3.7 million tonnes of waste collected by local authorities, 8.9 million tonnes of commercial and industrial waste, and 7.2 million tonnes of construction and demolition waste[WS1].

Most of the waste collected by local authorities in Scotland is from households, but they also collect some commercial waste and small amounts of industrial waste. Household waste arisings are increasing at approximately 1.5–2% per year in Scotland[WS1].

It is therefore vital to ensure that:

- the consumption of raw materials is reduced and resources are used efficiently;
- as little waste as possible is produced (waste minimisation and prevention);
- the maximum value is recovered from waste that is produced by promoting the use of waste as a resource through reuse, recycling and recovery (including energy recovery from waste);
- the minimum amount is disposed of in landfill sites or burnt without recovering energy.

It is also important to make sure the processes used to recover and dispose of wastes do not themselves harm human health or pollute the environment.

SEPA's annual Waste Data Digest (www.sepa.org.uk/nws/data/data_digest.htm) contains:

- details of the types and quantities of controlled waste produced in Scotland;
- a list of currently licensed waste sites.

Impact of waste on people and the environment

Waste can affect the state of the environment in a number of ways, including:

- emissions to air including greenhouse gases such as methane, carbon dioxide, trace gases from decomposing waste and dioxins, sulphur dioxide, particulates, nitrogen dioxide and metals from thermal treatment;
- discharges of landfill leachate to groundwater and surface water;
- the impact on land use from landfilling waste (this can be positive where industrial sites such as quarries are brought back into use and adverse where virgin land is used);
- unsightly litter;
- positive impacts where waste can be used in place of virgin resources or used for ecological improvement, to benefit agriculture or to produce energy.

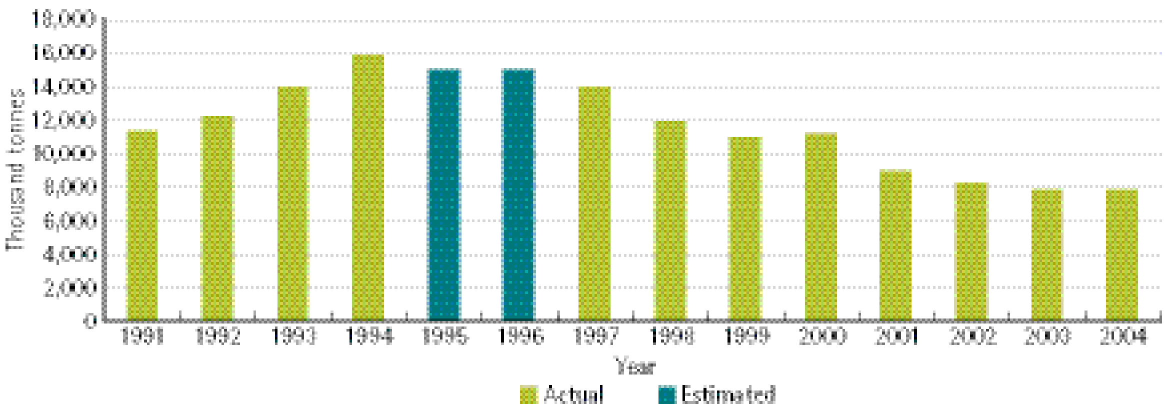
In general, the impacts of waste on people and the environment are reduced by:

- minimising the quantity of waste generated;
- reducing the use of hazardous constituents in products that will one day become waste;
- reusing waste;
- applying controls to waste recovery and disposal activities to ensure that human health and the environment are protected.

Impacts from landfill

In 1991, 11.3 million tonnes of waste was landfilled in Scotland. This amount rose to a peak of just under 16 million tonnes in 1994 and then declined to 7.8 million tonnes in 2004 (see Figure WS1). Data for the last three years suggest that the landfill rate has settled at about 8 million tonnes per year. That equates to about 1.6 tonnes of household, industrial and commercial waste per person per year.

Figure WS1: Total controlled waste going to landfill in Scotland, 1991–2004[WS1]



Historically, landfills were not lined, so polluted liquid (leachate) generated from the degrading waste was allowed to 'dilute and disperse' into the water environment. Leachate can contain degradable and non-degradable organic and inorganic materials, and can have an offensive smell. Landfills must now be lined and leachate treated before it can be discharged to surface waters.

Landfill gas is a by-product of the decomposition of organic waste. It is mainly made up of methane and carbon dioxide. These greenhouse gases were historically allowed to vent to the atmosphere, but they must now be collected, where practicable, and used as a fuel or flared at high temperature to destroy toxic and odorous components. As the amount of organic waste being landfilled falls, the quantities of landfill gas produced will decline. In 2004, ten sites in Scotland were converting landfill gas to electricity and 19 used flares[WS1].

There has been a fall in the number of landfill sites in Scotland. There were 555 operational sites in 1991 and 232 in 2003–2004. This number is expected to further decline to around 100, about 60 of which will probably accept non-hazardous waste and possibly 40, inert waste.

With the exception of a few sites that can take asbestos and one that can take some stable non-reactive hazardous wastes, since 2004 no landfill in Scotland has been licensed to accept hazardous waste. Hazardous waste producers have responded by:

- replacing hazardous substances with non-hazardous substances so that the waste they produce is also non-hazardous;
- treating their hazardous waste to make it non-hazardous;
- minimising the amount of hazardous waste they generate;
- sending their hazardous waste to landfills in England or Wales that are licensed to accept it.

This last option means that some Scottish waste is transported hundreds of miles.

Impacts from thermal treatment

There are two municipal waste incinerators in Scotland; one generates power and the other provides heat for a district heating scheme. In addition, 18 operational incinerators and thermal treatment plants dealt with commercial and industrial wastes in Scotland during 2004. Many handled only waste arising on-site and were designed to handle specific waste streams such as clinical waste, animal carcasses and industrial wastes. Table WS1 shows the quantity of commercial and industrial waste handled by incinerators and thermal treatment plants in 2004.

Table WS1: Commercial and industrial waste handled by incinerators and thermal treatment plants, 2004

Waste type	Amount (tonnes)
Animal remains/litter	118,448
Chemical wastes excluding used oils	30,098
Other commercial and industrial waste	15,341
Shredded tyres	8,000
Wood waste	2,104
Clinical waste	516
Total	**174,507**

Source: Information from operators provided to SEPA

Thermal treatment plants are now operated to European Waste Incineration Directive standards[WS2]. New treatment technologies and improved emission controls have resulted in a fall in emissions from these plants in the UK of dioxins and nitrogen oxides.

- Emissions of dioxins from incinerators and co-incinerators dropped from 602 g in 1990 (representing 55% of total UK dioxin releases) to 11 g in 1997 (representing only 3% of total UK dioxin release). Total emissions from all sources fell 81% between 1990 and 2003 in the UK[WS3].
- Emissions of nitrogen oxides from incinerators and co-incinerators now form less than 1% of UK emissions compared with 42% from road traffic[WS3].

Impacts from the recovery and disposal of 'controlled' substances in refrigerators and freezers

Certain man-made compounds commonly found in refrigeration equipment, foam, solvents, aerosols and fire extinguishers were shown in the 1970s to deplete the ozone layer (see the air chapter). Following this discovery, widespread international efforts have been made to ban and/or reduce the emission of ozone-depleting substances.

Before the introduction of controls on ozone-depleting substances, the disposal of refrigeration equipment often involved landfilling or shredding, resulting in the uncontrolled release of these substances. Since 1 January 2002, it has been a requirement for waste domestic refrigeration equipment to be collected, and disposed of in a controlled manner only once all ozone-depleting substances have been removed[WS5].

In 2004, over 43 tonnes of chlorofluorocarbons (CFCs) were removed from refrigeration equipment in Scotland (industry figures reported to the European Commission). This is equivalent to the ozone-depleting substance contents of 106,098 standard size domestic refrigeration units.

Impacts from fly tipping and litter

Fly tipping and littering blight the landscape (see Box WS1), can cause pollution and are expensive to clean up.

The Scottish Fly Tipping Forum has set up two new systems to address fly tipping:

- **Flycapture** is designed to make it easier to report and record fly tipping incidents, and to gather intelligence on fly tipping.
- The **Dumb Dumpers Stop-line (0845 2 30 40 90)** provides a single point of contact to report a fly tipping incident. The number of calls to the stop-line continues to rise and now averages 130 per month, but is known to capture only a small percentage of the number of fly tipping incidents.

Information from Flycapture for Scotland reveals that most fly-tipped waste originates from householders. This waste can include black bags, white goods, other electrical equipment and garden waste. Recent legislative changes have placed more responsibility on householders to ensure that their waste is removed only by appropriately authorised people (see www.sepa.org.uk/regulation/rocas/).

During January 2006, it cost an estimated £262,250 to clear up illegally tipped waste in Scotland based on the incidents reported in Flycapture. Actual total costs are expected to be much higher (the highest cost to any individual local authority in January 2006 was £74,614).

The success of cleaning up litter is assessed using a national performance indicator for cleanliness developed by Audit Scotland. The national cleanliness score of 70 for 2004–2005 given in the Local Environmental Audit and Management System (LEAMS) annual report[WS6] was three points above the target of 67, but much remains to be done. The report found that:

- 82% of litter is dropped by the public (e.g. cigarette ends, sweet wrappers and fast food packaging);
- the remainder arises mainly from business and domestic waste;
- 10% of all sites surveyed throughout Scotland contained a significant amount of animal faeces;
- heavily populated areas face the most difficult litter challenges due to population density and 24-hour lifestyles.

The Marine Conservation Society carries out an annual survey and clean-up of UK beaches. In 2005, the density of beach litter in Scotland was 1,748 items per kilometre surveyed at the 64 reference beaches, the highest density recorded since 2000[WS7]. The four major sources of litter recorded on beaches surveyed in Scotland were beach visitors (36%) followed by debris derived from sewage (24%), fishing (9%) and shipping (2%)[WS7].

Box WS1: Clyde litter

In 2004, Glasgow City Council began using a specialist boat, the *St Mungo*, to remove unsightly litter and other debris from the River Clyde and its estuary. Together with an accompanying barge, the *St Mungo* has proved invaluable in tackling litter problems in the Clyde. In its first year, the *St Mungo* removed 300 tonnes of litter and debris from the Clyde, filling 259 skips. The operation has been so successful that two additional smaller boats have been acquired to assist the City Council with cleaning other watercourses such as the Cart and Kelvin.

Waste minimisation

Waste producers (manufacturers, food producers, offices, shops, households, etc.) throughout Scotland are being urged to save money and benefit the environment by seeking ways to minimise their waste (see www.sepa.org.uk/wastemin/index.htm and Box WS2), reuse, recycle it and consider its potential as a source of energy.

Box WS2: Waste minimisation in Orkney and Shetland

The Business WINS (Waste Minimisation in the North of Scotland) project is helping companies to measure their resource use and come up with simple solutions to reduce waste and improve efficiency on their sites.

Between 2002 and 2005, five projects involved over 50 companies throughout the north of Scotland. Two of these were in Orkney and Shetland, where 12 companies including construction, aggregates, hotel, dairy and fish processing participated in a 'business club'.

An environmental consultant helped each company to:

- carry out an audit to establish resource use and emissions (solid, liquid and gaseous);
- develop a monitoring programme to track progress;
- put in place improvement measures over a period of 18 months.

Companies also attended club meetings to network with other participants and share best practice. Targets were set to reduce emissions to the environment and to make cost savings in the process (see table below). Savings are ongoing.

The other projects in Western Isles and Highlands are due for completion in 2006 and further projects are planned. For more information see www.sepa.org.uk/wastemin/initiatives/north/wins.htm

Benefits of WINS to participating companies

	Shetland		Orkney	
	Reduction	% reduction (compared with baseline)	Reduction	% reduction (compared with baseline)
Annual cost savings (£)	151,000	0.5 (of turnover)	63,000	0.4 (of turnover)
Reduction in energy use (kWh)	28,000	3.1	583,511	17.4
Water use (m^3)	3,845	3.1	13,129	45.5
Solid waste (tonnes)	44	7.9	34.4	2.1
Effluent volume (m^3)	3,007	3.0	10,056	56.3
Greenhouse gas emissions (carbon dioxide equivalent–tonnes)	15	0.2	Not available	Not available

The *National Waste Strategy: Scotland* provides a framework for reducing the amount of waste produced and to deal with that produced in more sustainable ways. The Strategy is being implemented through 11 Area Waste Plans (see www.sepa.org.uk/nws/guidance/awp.htm).

In the longer term, a growing lack of new resources (materials, water, energy, etc.) will require the development and use of products with less impact on the environment over their whole life cycle. The European Commission has already drafted strategies covering *The Sustainable Use of Resources and The Prevention and Recycling of Waste* (see http://ec.europa.eu/environment/newprg/strategies_en.htm) in recognition of the need to:

- conserve resources;
- increase resource efficiency;
- reduce the impacts from the use of resources;
- review current policies on the production of waste and the recovery and disposal of waste.

Forecasting impacts

In Scotland, a technique called Best Practicable Environmental Option (BPEO) is used to determine the ways of handling waste that will have the most beneficial or least detrimental impact on the environment. The BPEO principle has underpinned the development of Scotland's Area Waste Plans and the National Waste Plan for Scotland (see www.sepa.org.uk/nws/guidance/nwp.htm) Table WS2 summarises some of the beneficial environmental impacts possible if the BPEO for municipal waste is adopted.

Table WS2: Examples of the impact of adopting the BPEO for municipal waste on the environment and on resource savings

Indicator	2010 BEPO	2050 BPEO	Notes
Greenhouse gas emissions (tonnes carbon dioxide equivalent)	−2,138,000	−2,500,000	The saving in greenhouse gas emissions in 2020 is equivalent to approximately 3% of current total greenhouse gas emissions in Scotland or of taking around 700,000 cars off the road.
Air pollution Sulphur oxides (tonnes SO_2 equivalent)	−10,000	−20,000	The reduction in emissions by 2020 is of the same order as twice the current emissions from the Grangemouth petrochemical complex.
Nitrogen oxides (tonnes NO_2 equivalent)	−400	−400	The saving in nitrogen oxide emissions is equivalent to taking about 60,000–70,000 cars off the road.
Energy Non-renewable energy (10^{15} joules)	−7.5	−14	By 2020 the Scottish waste management system will be saving non-renewable energy resources sufficient to supply about 1 million average households.

Source: *National Waste Plan 2003*, Scottish Executive and SEPA

Forward look

The impact of waste on the state of the environment is expected to continue to fall as the requirements of various European Directives on waste are progressively implemented. Furthermore, as the Waste Framework Directive which is 30 years old, is under review, it is anticipated that there will be further incentives to further reduce the amount of waste produced and to raise waste recovery standards.

References

No.	Details	Available from:
WS1	*Waste Data Digest 6*, SEPA, 2006.	www.sepa.org.uk/publications/wds/index.htm
WS2	*Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the Incineration of Waste*	http://europa.eu.int/eur-lex/lex/LexUriServ/LexUriServ.do?uri=CELEX:32000L0076:EN:HTML
WS3	*National Atmospheric Emissions Inventory*	www.naei.org.uk
WS4	*A Changing Climate for Energy From Waste?* Final Report for friends of the Earth, Eunomia Research and Consulting, 2006.	www.foe.co.uk/resource/reports/changing_climate.pdf
WS5	*Guidance on the Recovery and Disposal of Controlled Substances in Refrigerators and freezers*, Environment Agency and SEPA, 2002.	www.sepa.org.uk/pdf/guidance/waste/fridge_freezers.pdf
WS6	*Local Environmental Audit and Management System Annual Report. LEAMS Benchmarking Report 2004–2005*, Keep Scotland Beautiful, 2005.	www.keepscotlandbeautiful.org/index.asp?pg=21
WS7	*Beachwatch 2005*, Marine Conservation Society, 2006.	www.adoptabeach.org.uk

Sources of further information

Topic	Source
National Waste Strategy	www.sepa.org.uk/nws/index.htm
EU waste legislation including the Waste Framework Directive	http://europa.eu.int/comm/environment/waste/legislation/index.htm
Waste minimisation	www.sepa.org.uk/wastemin/index.htm
Waste management regulations	www.sepa.org.uk/regulation/index.htm
Fly tipping	www.sepa.org.uk/flytipping/index.htm www.dumbdumpers.org
Waste Aware Scotland	www.wascot.org.uk
Keep Scotland Beautiful	www.keepscotlandbeautiful.org
Waste and Resources Action Programme (WRAP)	www.wrap.org.uk
Envirowise	www.envirowise.gov.uk

Radioactivity

Summary

Levels of man-made radioactivity in the environment have shown a general downward trend over the last decade. Concentrations in drinking water remain well below the recommended limit set to protect human health. Some instances of localised contamination from man-made radioactivity remain.

Averaged exposure to ionising radiation from man-made sources in Scotland is less than one fifth of that from natural Background radiation. Of these man-made sources, medical uses represent the predominant source of exposure, with the exposure associated with radioactive emissions to the environment being less than 0.1% compared with that associated with all sources of ionising radiation.

Overall, radioactive emissions from nuclear installations in Scotland and the UK have fallen since 1996.

This chapter provides information on radioactivity in the Scottish environment, with a focus on radioactivity introduced into the environment by man rather than radioactive substances present naturally in the environment.

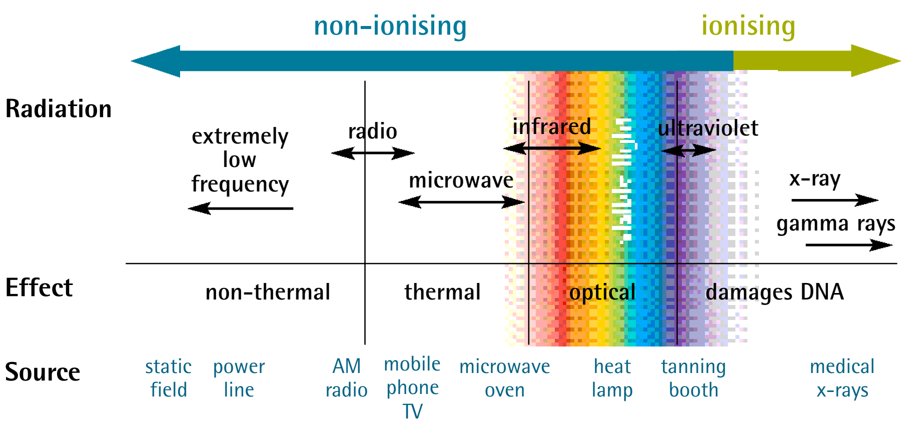
What is radiation and what is its effect?

Radiation is energy that travels in the form of waves or high-speed particles and is present throughout the environment. Figure R1 shows the many ranges of energy that form the electromagnetic spectrum. Radiation that has enough energy to cause atoms to vibrate, but not enough energy to remove electrons, is referred to as non-ionising radiation. Radiation that has sufficient energy to remove electrons from atoms is called ionising radiation. Ionising radiation creates ions in a process that may cause molecular damage. The radiation considered in this chapter is ionising radiation.

A substance which emits ionising radiation is referred to as being radioactive, with the nature of the emissions being characteristic of the specific radioactive substance, or radionuclide. Radionuclides, natural or man-made, emit one or more types of ionising radiation:

- Alpha particles
- Beta particles
- Gamma rays.

Figure R1: Bands of the electromagnetic spectrum



When living tissue is exposed to ionising radiation, some of the energy is absorbed by molecules and the tissue may become damaged. In general, the severity or type of effect is determined by the amount, type and duration of radiation exposure. It is measured as radiation dose. Different radionuclides may not deliver the same radiation dose because different radionuclides may have different biochemical and physical characteristics.

Historically, the effects of ionising radiation have been considered in terms of its ability to cause detriment to human health. This approach assumes that if human health is protected, non-human species are also adequately protected[R1]. Various organisations, including the International Commission on Radiological Protection (ICRP), are currently considering whether this assumption is valid.

Radioactive sources and exposure to ionising radiation

Ionising radiation is emitted by a wide variety of radioactive substances that have been present since the initial formation of the solar system. Some radionuclides in this category produce the radioactive gas radon, which forms the major source of radiation exposure to humans. The Earth also receives ionising radiation originating from outer space. This radiation, called cosmic radiation, penetrates the atmosphere and contributes to natural background radiation in the environment.

The human race has evolved in the presence of ionising radiation arising from radionuclides within our bodies (internal exposure) and in the natural environment (external exposure). Exposure to natural sources such as radon has increased in some areas of Scotland as a result of living in draught-proofed buildings.

Man-made radionuclides are used in a variety of situations. Their use may result in the release to the environment either through the disposal of contaminated materials or emissions to air or discharges to water. Examples of exposure include:

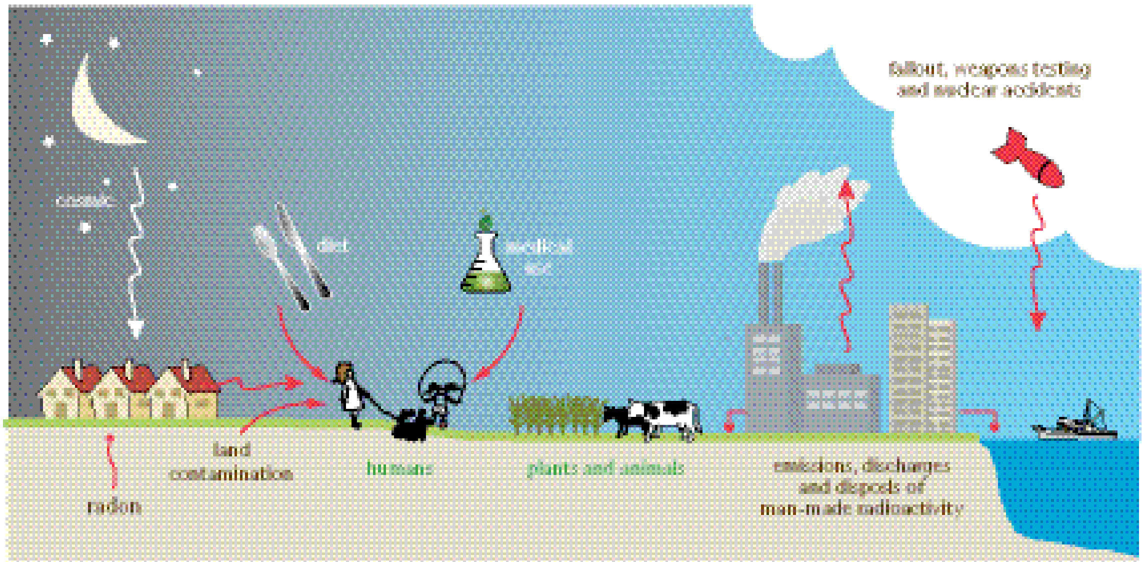
- medical uses (primarily x-rays for diagnostic procedures but also radio-pharmaceuticals and radioactive sources used in the investigation and treatment of disease);
- industrial practices for measurement and research purposes;
- consumer products (e.g. smoke detectors);
- fallout from nuclear weapons testing primarily in the early 1960s;
- nuclear accidents such as Chernobyl in 1986;
- radionuclides in the environment resulting from authorised disposals, discharges and emissions to land, water and air (primarily from nuclear installations).

Exposure to man-made ionising radiation can occur through inhalation and consumption of food and water that contain man-made radionuclides, together with direct external exposure from radioactive contamination in the environment (see Figure R2). To assess the possible implications for human health of environmental concentrations of man-made radionuclides, habit surveys are carried out near nuclear installations. To identify all routes of exposure to ionising radiation, these surveys gather information such as:

- where people live;
- what they eat;
- where their food comes from;
- what activities they do;
- how they spend their leisure time;
- their occupation.

Habit survey information, coupled with the results of monitoring programmes, allows the effective dose to the public at greatest risk of exposure to be calculated and compared with the annual limit of 1.0 milli-sievert (mSv) applicable for controlled releases of radioactivity from man-made sources[R2,R3].

Figure R2: Main routes of human exposure to sources of natural and man-made ionising radiation



Ionising radiation in Scotland

Following the Chernobyl accident in 1986, the UK Radioactive Incident Monitoring Network (RIMNET)[R4] was installed and commissioned in 1988 to:

- monitor ambient levels of radiation in the environment;
- provide early warning of potential effects on the UK of nuclear incidents occurring abroad.

The locations of the 27 monitoring sites in Scotland are shown in Figure R3. Measurements at these sites record total radiation from natural and man-made sources, and are used to assess overall dose rates across the country.

Figure R3: Location of RIMNET stations and nuclear installations in Scotland

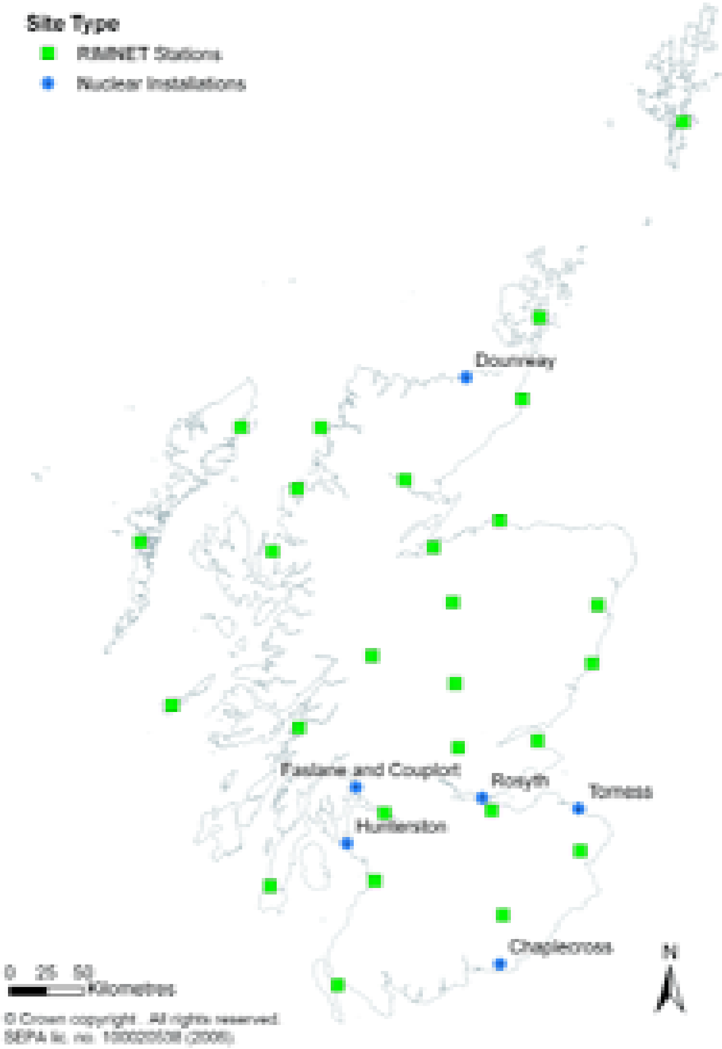
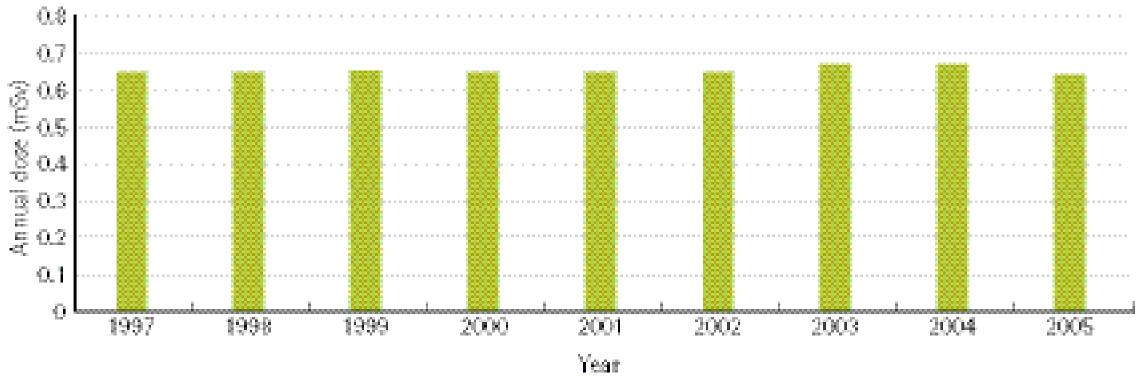


Figure R4: Annual doses for averaged data recorded at all RIMNET sites in Scotland for 1997–2005



Source: Defra e-Digest Statistics[R4]

The radiation dose rates at the RIMNET sites have been reported each year since 1997[R4]. In 2005, the average annual radiation dose for the sites in Scotland was 0.64 mSv. Average annual doses in Scotland for the period 1997–2005 have shown little variation (see Figure R4).

The radioactive gas radon, an alpha particle emitter, is produced during the decay of uranium and thorium in rocks and soils. The concentrations of radon that occur in buildings are primarily determined by:

- the uranium and thorium content of sub-foundation materials;
- the characteristics of the construction of the building and its degree of ventilation.

Measures to reduce radon in houses are typically considered when the concentration exceeds the UK radon action level of 200 becquerels per cubic metre (Bq/m^3)[R5].

Box R1: Monitoring of radioactive caesium

Caesium-137 is a radionuclide associated with a variety of sources including authorised discharges and the nuclear accident at Chernobyl in the former USSR in 1986. This radionuclide is detected throughout Scotland in a wide variety of environmental media including soil, grass and livestock.

Following the deposition of radionuclides from the Chernobyl accident, concentrations of caesium-137 in the environment have fallen steadily enabling the progressive withdrawal of restrictions on the movement, sale and slaughter of sheep above an action level of 1,000 becquerels per kilogram (Bq/kg). In 2004, monitoring of sheep in parts of the post-Chernobyl restricted upland areas in Scotland identified three farms where controls could be lifted, leaving 11 farms subject to restrictions. The results of monthly assessments of the concentrations of caesium-137 in drinking water, milk and meat indicated consistently low mean values for the period 1996 to 2004. For more information see RIFE reports 2–10 (www.sepa.org.uk/publications/rife/index.htm).

To determine general levels of man-made radionuclides in the environment, SEPA carries out a monitoring programme (see Box R1) including sampling of:

- air;
- rainwater;
- freshwater;
- seawater;
- sediment;
- soil;
- plants and animals;
- food.

The results of SEPA's annual monitoring programme are reported each year in the Radioactivity in Food and the Environment (RIFE) report series (see www.sepa.org.uk/publications/rife/index.htm).

In the most recent RIFE report (for the calendar year 2004)[R6], no major changes were found in the levels of radionuclides in food or in the environment compared with those in 2003. When the levels of radionuclides in environmental samples (including foods) are considered over the last ten years, there is an apparent downward trend.

Monitoring of air in 2004 indicated concentrations of activity typical of natural background levels[R6]. In 2004, concentrations of total alpha and total beta particle emitters in drinking water were all below World Health Organisation (WHO) screening values and made a negligible contribution to annual dose[R6]. Work carried out in 2004 suggested that surface water in Scotland was unlikely to be impacted by radioactivity[R7].

Monitoring for man-made radionuclides is focused on the area surrounding each of the seven nuclear installations in Scotland:

- Chapelcross, Hunterston and Torness nuclear power stations;
- the former Dounreay nuclear research facility;
- the defence submarine bases/naval dockyards at Faslane, Coulport and Rosyth.

The locations of these sites are shown in Figure R3.

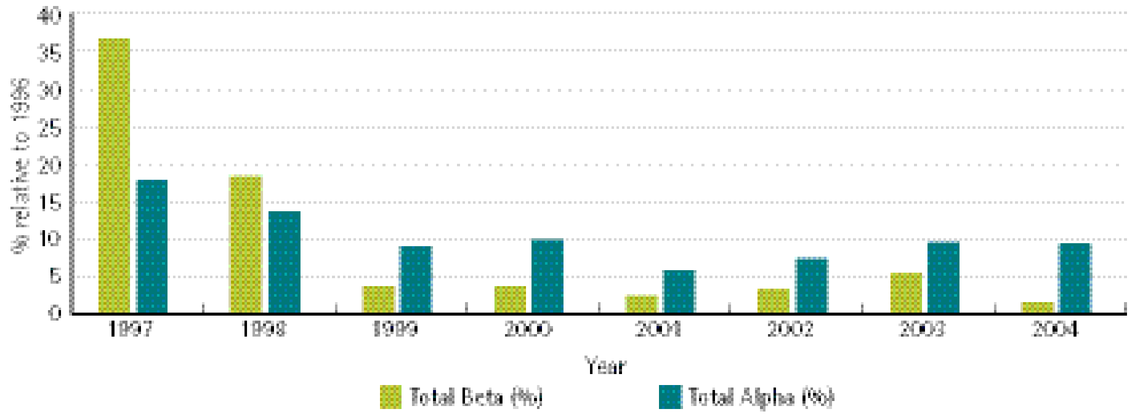
Monitoring is also carried out along the Dumfries and Galloway coastline, in the Solway Firth and further afield to assess the effects of discharges from the Sellafield fuel reprocessing plant in Cumbria, England.

In 2004, the highest exposures in Scotland from man-made radionuclides were to a group of seafood consumers on the Dumfries and Galloway coast who received an annual dose of 0.038 mSv, largely as a result of liquid discharges from Sellafield[R6]. Annual dose estimates to this group remained similar between 1996 and 2004, and are well below the regulatory limit of 1.0 mSv[R2, R3].

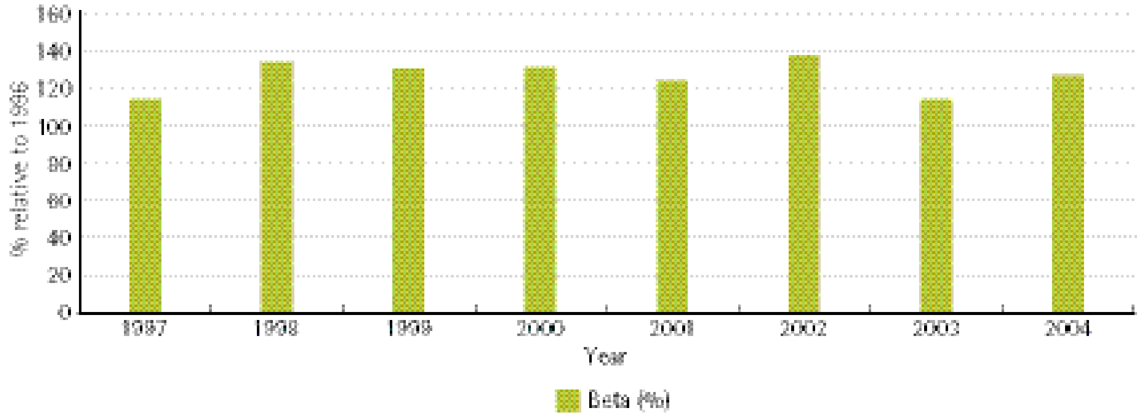
The use, disposal and release of radioactive substances are all closely controlled. Changes in operations of the nuclear installations in Scotland mean that discharges to water fell between 1996 and 2004. Emissions to air for the period 1997–2004 remained at a similar level. These trends are illustrated in Figure R5. For the UK as a whole, see www.defra.gov.uk/environment/statistics/radioact/kf/rakf11.htm

Figure R5: Radioactive discharges to (a) water and (b) emissions to air from nuclear installations in Scotland, 1997–2004

(a)



(b)



Source: RIFE Reports 3–10. Derived data excludes curium-242, argon-41 and tritium.

Some of the nuclear installations in Scotland are approaching the end of their useful operating life and radioactive waste associated with their decommissioning will have to be managed in the future. Accumulations of 'intermediate' and 'high-level' radioactive waste, already stored at some nuclear installations in Scotland, present particularly challenging issues for ensuring safe, long-term disposal. Possible management options have been considered by several organisations including the Government-appointed Committee on Radioactive Waste Management (CoRWM)[R8].

Some localised instances of elevated concentrations of radioactivity associated with historical practices have been detected at Dounreay (see Box R2) and other sites (see Box R3).

Box R2: Inputs of radionuclides into the environment from Dounreay

Following the discovery of 34 fragments of irradiated nuclear fuel on the seabed near Dounreay in 1997, an order was made under the Food and Environment Protection Act 1985 to ban the harvesting of seafood within a 2 km radius of the discharge pipeline.

Regular annual monitoring of Sandside Bay and the Dounreay foreshore has led to the discovery and removal of radioactive particles from these areas. In 2005 a radioactive particle was also found at Dunnet beach. Limited offshore monitoring has also detected hundreds of particles in the marine environment. The particles originate from the historic activities at the Dounreay plant.

A comprehensive scientific assessment showed that the overall current risk of a member of the public encountering a particle on public beaches at Sandside was low.

The Dounreay Particles Advisory Group (DPAG) was set up in 2000. The DPAG reports can be found on the SEPA website at www.sepa.org.uk/dpag

Box R3: Radioactive contamination at other sites in Scotland

At Dalgety Bay in Fife radium-226 contamination was first detected in 1990. It is believed to have originated from salvage work involving radium-coated instrumentation at a former military airfield at Dalgety Bay. Some contaminated material has been removed. Athough the most recent assessment of the radiological risk showed that there was a realistic chance of encounter, the potential effects on health were considered to be low. It also suggested that further investigation of the extent of the contamination is warranted.

Following the discovery of radioactive contamination at a former military base at Forthside in Stirling, effective action enabled the land to be returned to normal civic use.

Remedial action to deal with radium-226 contamination has been taken at a former industrial site at Balloch in Dunbartonshire.

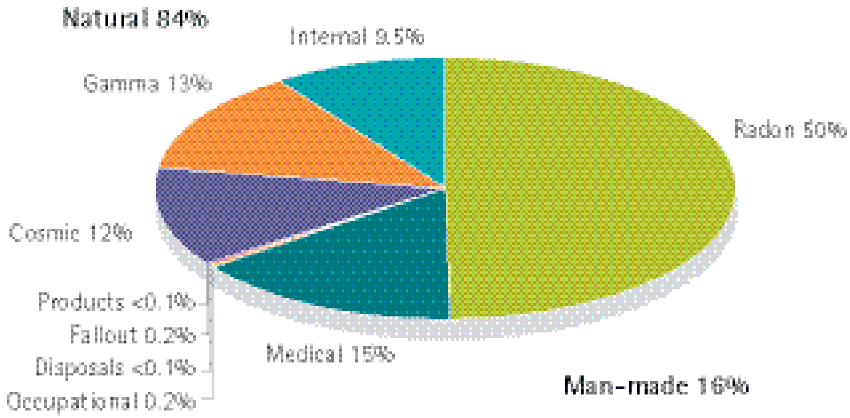
At Gowkthrapple, in North Lanarkshire, an investigation of any potential health hazards associated with radium-226 contamination at a former industrial site is currently being undertaken.

Monitoring in July 2005 confirmed the presence of radioactivity in an area of Aberdeen beach near the harbour. Sampling and analysis has been undertaken to identify potential sources of the radioactivity. Radiation exposure received by members of the public using the beach regularly was negligible.

Average annual radiation dose

Every five years, estimates are made of the average radiation dose to members of the public from all sources of ionising radiation[R9]. These estimates indicate an annual average dose in the UK of almost 2.7 mSv for 2001–2003 as a result of contributions from natural and man-made sources (see Figure R6). Using the data given in this report, it can be shown that the average population-weighted regional dose for Scotland was 2.4 mSv.

Figure R6: Sources contributing to the average annual UK ionising radiation dose



Exposure to radon contributes approximately 50% of the average annual radiation dose from ionising radiation in the UK, although radon concentrations vary significantly with geographical location. Internal exposure, mainly from naturally occurring radionuclides, contributes approximately 9.5% of the average annual radiation dose in the UK.

Estimates[R9] show that the average amount of exposure per year received by people in the UK from man-made sources of ionising radiation is around one-fifth (0.42 mSv) of that from natural sources (2.23 mSv). Most of the dose arising from man-made sources (97%) is associated with the use of x-rays in medical diagnostic procedures and is related to the exposure of a small percentage of the general population. The overall UK average annual dose for 2001–2003 is slightly higher than that estimated by the previous review in 1999. This increase is mainly due to a larger contribution from medical procedures. There has also been a slight increase in the overall dose to the population from cosmic radiation associated with greater use of air travel, as doses received from cosmic radiation increase with altitude.

Radionuclides from nuclear weapons tests and reactor accidents represent approximately 85% of the man-made radionuclides in the environment but account for only 0.2% of the average annual dose to the population. The average annual exposures associated with products and authorised emissions, discharges and disposals are all typically less than 0.1% of the exposure to all sources of ionising radiation. At these extremely low levels, they represent very small fractions of the annual dose limit for members of the public.

Forward look

Concentrations of man-made radioactivity in the environment are generally set to further reduce and our understanding of the effect that these concentrations have on ecosystems is expected to improve. The main challenge will be dealing with wastes associated with the operation and decommissioning of nuclear installations, as well as any contamination which becomes apparent in localised areas associated with historical practices. Forthcoming developments in international radiation protection principles, in European legislation and in Government policy are likely to result in an improved framework for the regulation of radioactive substances.

References

No.	Details	Available from:
R1	*1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60. Annals of the ICRP, Vol. 21, No. 1–3, ICRP, 1991.	http://intl.elsevierhealth.com/catalogue/title.cfm?ISBN=0080411444
R2	*The Radioactive Substances (Basic Safety Standards) (Scotland) Direction 2000*	www.sepa.org.uk/pdf/consultation/closed/2004/ukaea/Paper_11.pdf
R3	*European Union Council Directive 96/29/EURATOM, 1996*	http://ec.europa.eu/energy/nuclear/radioprotection/doc/legislation/9629_en.pdf
R4	Radioactive Incident Monitoring Network (RIMNET), Defra e-Digest Statistics	www.defra.gov.uk/environment/statistics/radioact/radrimnet.htm
R5	*Statement by NRPB: Limitation of Human Exposure to Radon in Homes*. Documents of the NRPB, Vol.1, No. 1, 15–16, 1990.	www.hpa.org.uk/radiation/publications/documents_of_nrpb/index.htm
R6	*Radioactivity in Food and the Environment 2004, RIFE-10*, SEPA, 2005.	www.sepa.org.uk/publications/rife/index.htm
R7	*Assessment of Pressures and Impacts on Scotland's Water Environment from Radioactive Substances*, SEPA, July 2004.	www.sepa.org.uk/pdf/publications/technical/wfd_assessment_pressures_impacts.pdf
R8	Recommendations of the Committee of Radioactive Waste Management (CoRWM)	www.corwm.org.uk/content-0
R9	*Ionising Radiation Exposure of the UK Population*, Report HPA-RPD-001, Health Protection Agency (HPA), 2005.	www.hpa.org.uk/radiation/publications/hpa_rpd_reports

Sources of further information

Topic	Source
Electromagnetic and other types of radiation	www.hpa.org.uk/radiation/understand/radiation_topics/
Dounreay Particles Advisory Group (DPAG)	www.sepa.org.uk/radioactivity/dpag/index.htm
Radioactivity in food	www.foodstandards.gov.uk

Hazardous chemicals

Summary

The state of Scotland's environment with respect to hazardous chemicals is favourable compared with the UK overall and the rest of the Europe. The use of hazardous chemicals has been reduced through legislation but, despite this, many substances continue to be used and the long-term effects are not entirely clear. Furthermore, a number of 'hotspots' of chemical contamination persist and these are often associated with past industrial practices.

Many of the environmental problems caused in the past by heavy metals and persistent organic chemicals have been reduced. Problems exist with diffuse sources of hazardous substances, for example run-off from urban areas and these continue to have ecological impacts. There is increasing concern over the rising environmental concentrations of a number of newly identified chemicals such as chlorinated paraffins, perfluorinated compounds and polybrominated flame retardants.

The focus on environmental problems associated with hazardous chemicals is changing as more subtle impacts are observed such as food chain contamination and accumulation of persistent chemicals. There may well be problems associated with chemicals in everyday use that could become more apparent as our knowledge and understanding of them grows.

Large numbers of chemicals are used every day and they bring many benefits; yet they can result in some unwanted consequences on the environment. This chapter provides information on chemicals in the environment that have the potential to cause harm. Information on chemicals which are hazardous by virtue of their radioactivity is provided in the chapter on radioactivity.

What are hazardous chemicals and why are they a problem?

Hazardous chemicals are taken here to represent chemicals that are:

- toxic – having the ability to cause harm or injury to living organisms;
- persistent – remaining in the environment for a long time;
- bioaccumulative – accumulating in living organisms (particularly those higher up the food chain) including humans;
- hormone-disrupting – altering the functioning of the hormone system;
- of an equivalent level of concern to those above.

Hazardous chemicals may cause problems depending on:

- their distribution or fate within the environment;
- their concentration and persistence in air, water, soil or sediment;
- the extent to which humans, plants or animals are exposed to them.

Monitoring of hazardous chemicals

Most monitoring of hazardous chemicals in the environment is targeted at chemicals identified in legislation as priorities for control and for which there are Environmental Quality Standards (EQSs) based on their known toxicity. Existing monitoring of the wide range of hazardous chemicals in the water environment does not provide sufficient information on potential impacts. Despite historic land contamination and the current widespread use of agricultural chemicals, there is less monitoring of hazardous chemicals in the land environment and understanding of the effects of chemicals on land is limited. More monitoring of the levels of chemicals in fish and other wildlife will be undertaken in the future to address some of the limitations of the current monitoring regime.

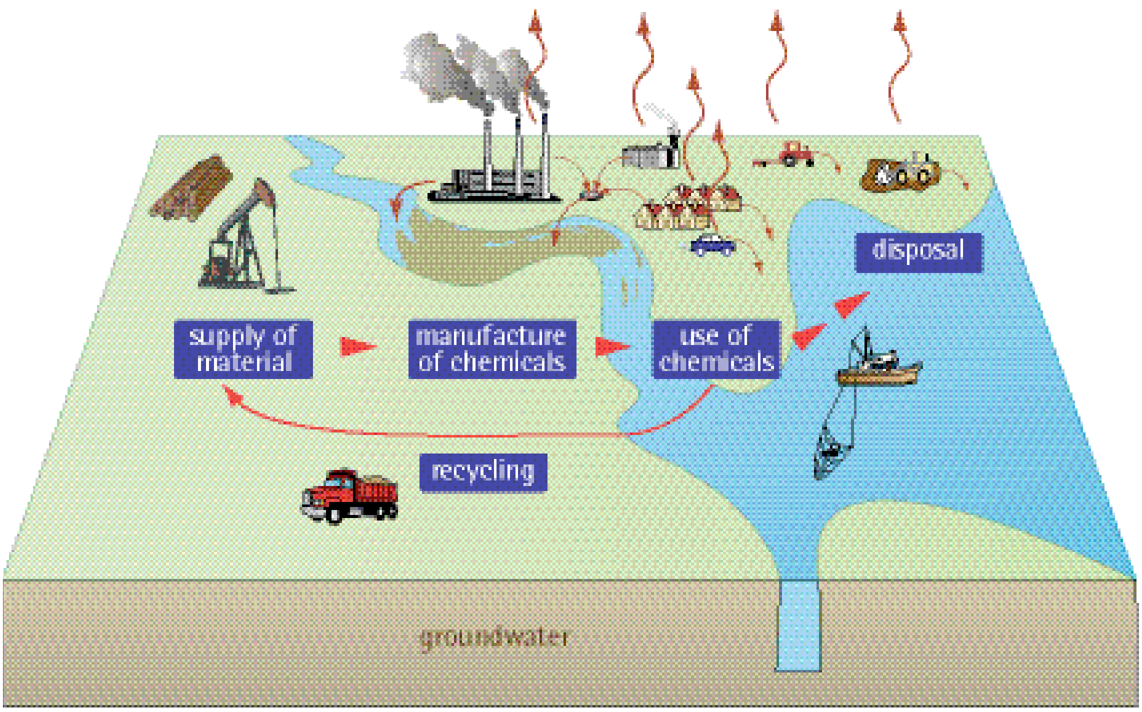
It is not possible to monitor all known pollutants so it is not known how they pass through the environment, whether they are accumulated, dispersed or transformed, and how living organisms are affected by different concentrations.

Except in a limited number of cases, the regulation of hazardous chemicals typically concentrates on individual substances. In the environment, however, chemicals are never present alone. Understanding of the effects of complex mixtures of chemicals is extremely limited and in order to address this shortfall, there is increasing interest in the development and application of specialised techniques (e.g. toxicity tests and biomarkers) for monitoring the environment.

How do harmful chemicals enter the environment?

Hazardous chemicals can enter the environment at all stages in the life cycle of a product through either accidental or deliberate release. Figure HC1 indicates some of the ways in which hazardous chemicals may be introduced into the air, land and water environments.

Figure HC1: Introduction of hazardous chemicals into the environment



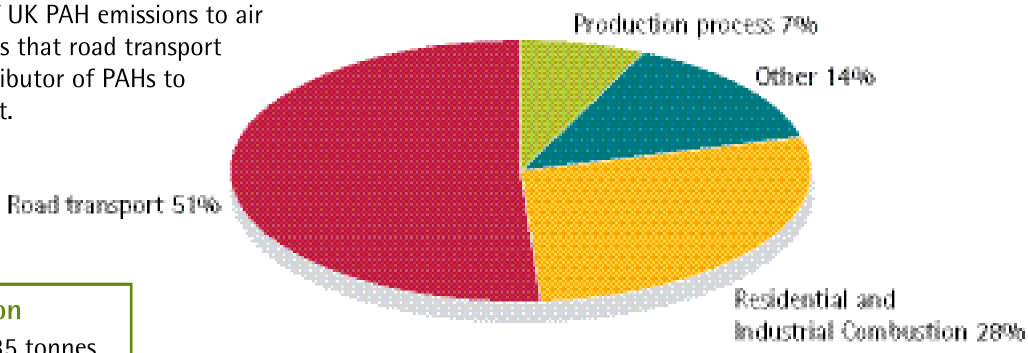
There are an estimated 30,000 chemicals on the EU market, and approximately 300 new ones being added each year (http://ecb.jrc.it). Chemical output in Europe covers a range of products such as pharmaceuticals, consumer products and plastics. Predominant industries in Scotland include agriculture, food and drink, electronics, oil and gas, chemicals and textiles. International, EU and national legislation regulates chemical releases at each stage of the chemical life cycle (see supplementary material[SHC1]).

Use of chemicals by the public can also lead to their release into the environment, for example from the use of cleaning agents in the home or from driving cars. Road traffic is of increasing concern as a source of persistent chemicals (see Box HC1). Emissions of hazardous chemicals from cars include copper, zinc, oils and polycyclic aromatic hydrocarbons (PAHs).

Box HC1: Persistent pollutants released by vehicles – UK snapshot 2002/2003

Road traffic is becoming an increasingly more important source of persistent pollutants. More than 50% of the total contribution of PAHs and copper can be attributed to car emissions. The diagram shows total annual UK emissions from vehicles in 2003[HC2].

The pie chart of UK PAH emissions to air in 2002[HC2] shows that road transport is a major contributor of PAHs to the environment.



Tyre erosion

PAHs	35 tonnes
Lead	1.0 tonnes
Copper	0.3 tonnes
Zinc	79 tonnes

Oil losses

PAHs	320 tonnes
Lead	0.02 tonnes
Copper	0.04 tonnes
Zinc	2.3 tonnes

Brake wear

Lead	1.5 tonnes
Copper	24 tonnes
Zinc	44 tonnes

Exhaust emissions

PAHs	130 tonnes
Lead	1.1 tonnes
Copper	0.4 tonnes
Zinc	1.0 tonnes

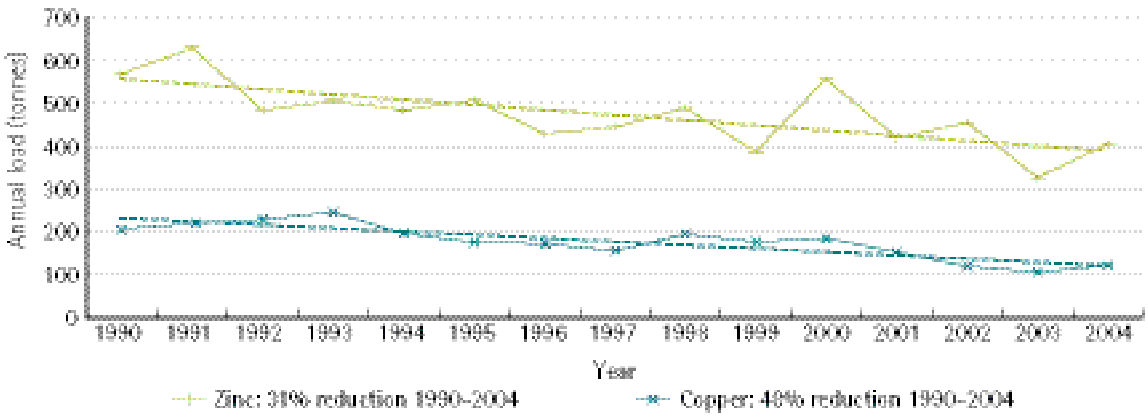
Historical contamination caused by hazardous chemicals

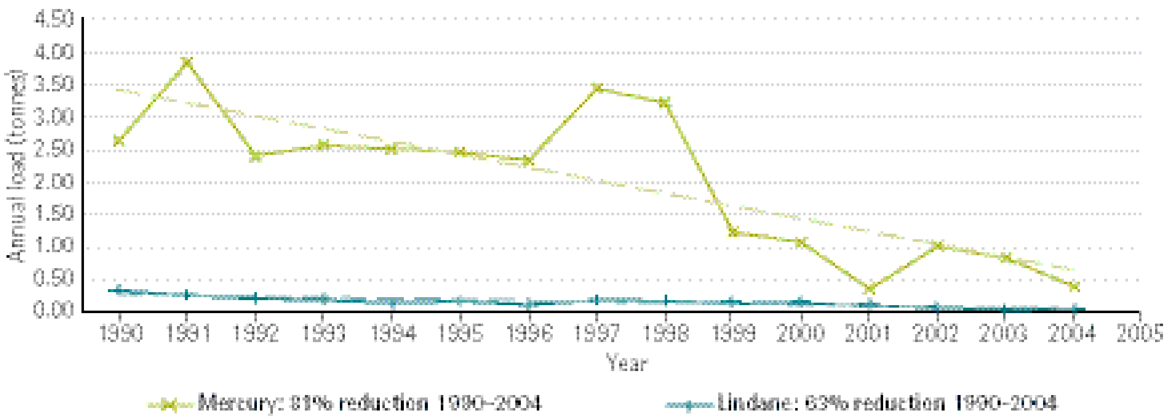
The biggest historical releases of chemicals polluting air, land and water were from industries such as steelworks, gasworks and mining. Such industries have now ceased, adopted cleaner technologies, improved operating practices or are subject to greater regulation and legislative control. Chemical releases to the environment have therefore been reduced. In some cases, however, it can take a long time for problems to become apparent and, once identified, it can take even longer to implement effective controls and achieve environmental recovery.

Concentrations of chemicals in air and water tend to decrease relatively quickly once their entry has been reduced. See Box HC2 for data on releases to Scottish coastal waters.

Box HC2: Annual loadings of chemicals to Scotland's marine environment

These graphs show the amounts of three hazardous metals (zinc, copper and mercury) and an organic compound (lindane) released into Scotland's marine environment between 1990 and 2004[HC3]. The metals are released from natural and human sources, whereas lindane is derived only from human sources. Zinc and copper (graph top, below) are released in large quantities (hundreds of tonnes per year) but are of relatively low toxicity. Although essential elements, zinc and copper may cause toxic effects in ecosystems when present at elevated concentrations. In contrast, the amounts of mercury and lindane released into the environment (graph lower, below) are much lower (a few tonnes). These are of far greater concern due to their high toxicity and persistence in the environment. Stricter legislative controls mean that the amounts entering the marine environment have fallen greatly over the past 15 years.

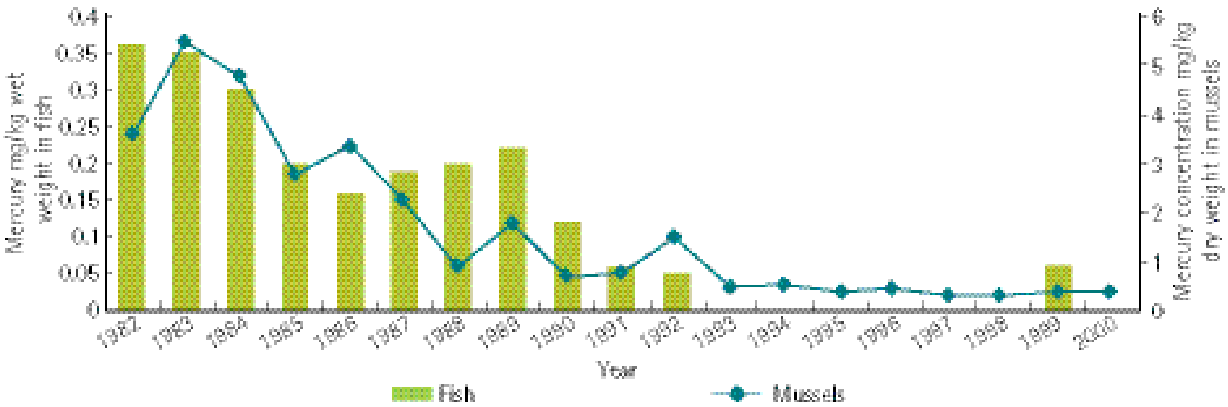




Reductions in the release of chemicals to water can also lead to reductions in levels of hazardous chemicals found in fish and mussels that reside near the discharge area (see Box HC3). However, accumulation of chemicals in sediments and soils following release to air, land and water can leave a long-term legacy of contamination. There is evidence of this in Scotland with localised land (see land chapter) and sediment contamination.

Box HC3: Metal biomonitoring in the Forth Estuary

Unlike most metals, mercury has a tendency to accumulate in food chains and can cause poisoning to predators and humans. Mercury levels in fish and mussels collected from the Forth Estuary at Grangemouth fell steadily from 1982 to 2000 following reductions in the input of the metal from a nearby industrial discharge (for species data see supplementary material[SHC2]).



In some cases, contaminants may be washed off the land causing pollution in nearby waters and remedial action may need to be taken to address such pollution. For example, run-off from land contaminated with oils at a former oil rig yard on the Cromarty Firth caused pollution in the Firth. Interception and treatment of the run-off addressed the problems in the Firth and attention is now focused on oil remaining in the soil.

Pollution from sewage and lead mining in the Clyde catchment was first noted in an official report in the late 19th century and, over 100 years later, lead and zinc contamination still affects the water quality of Glengonnar Water downstream of the old mines at Leadhills near Lanark (see www.sepa.org.uk/rqc/map.asp).

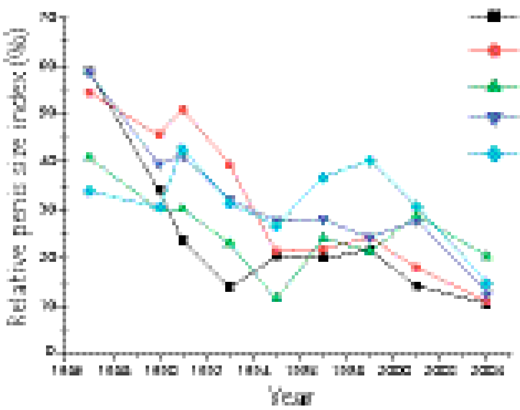
A strong correlation between dogwhelk imposex (a condition in which female dogwhelks develop male sex organs) and tributyl tin (TBT), an anti-fouling chemical, has been reported in the marine environment. This has led to restriction of the use of this chemical (see Box HC4).

Box HC4: Ecological impacts of a biocide

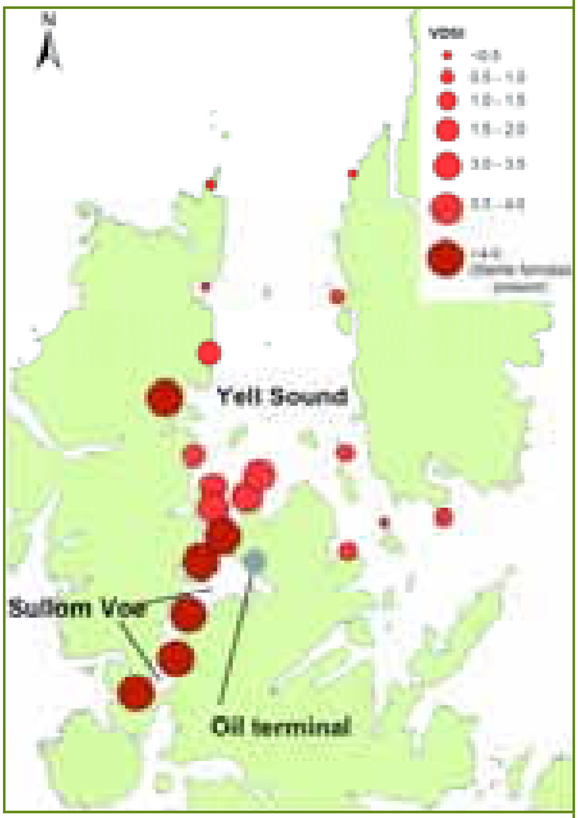
Anti-fouling paints based on TBT were used on ships as a biocide to control barnacles and algae. However, studies showed that TBT was highly toxic to shellfish such as mussels, oysters and sea snails. The use of TBT is now restricted.

Surveys have been carried out for many years at many marine sites around Scotland to characterise the extent of chemical contamination and associated biological effects. Dogwhelks and periwinkles are collected from the shore at low tide and examined for toxic effects.

Sites within Sullom Voe



Map of Sullom Voe



Since initiation of these surveys in 1987, there has been a reduction in the development of male sex characteristics (i.e. penis and/or the vas deferens) in normal female dog whelks. Imposex (development of male sex characteristics in the female dog whelk) is measured by the Vas Deferens Sequence Index (VDSI, data shown on map) and the Relative Penis Size Index (RPSI, data shown on graph). The oil terminal at Sullom Voe handles a large number of oil and gas tankers. The use of TBT on these tankers has been a source of contamination in Sullom Voe and the surrounding area for several decades. Female dog whelks from sites close to the oil terminal show the highest level of effects (larger dots on map). Female dog whelks have also become sterile at several sites within Sullom Voe (red dots). The biology of the Voe has slowly recovered since the inputs of TBT declined and the numbers of tankers visiting the terminal has fallen.

This material is reproduced with permission of Fisheries Research Services and Shetland Oil Terminal Environmental Advisory Group, monitoring funded by The Sullom Voe Association Ltd.

For further information see www.frs-scotland.gov.uk.

Current and emerging problems caused by chemicals

Increasing attention is now being paid to domestic use of chemicals. A wide variety of household and other chemicals end up in the sewerage system. Examples include hormone or endocrine disrupters such as alkyl phenols and the steroid oestrogen, ethinyl oestradiol, used in the contraceptive pill and hormone replacement therapy. A detailed investigation in England has shown that feminisation of male fish occurs downstream of many sewage works, possibly affecting fish reproduction[HC4]. With lower concentrations of treated sewage in Scottish rivers, this is expected to be less of a problem but its possible extent has not yet been fully investigated. Research is currently underway on endocrine disruption in Scottish freshwater fish.

A significant environmental impact is caused by surface water run-off from urban areas and trunk roads (see Box HC5 and supplementary material[SHC4]). The run-off of rain from roads, yards and roofs affects 1,000 km of rivers in Scotland[HC5]. Pollution from urban drainage includes oils, metals, combustion products, herbicides and chemical spillages at industrial sites. Traffic is an important source of these contaminants and represents an increasing pressure upon the water environment as road traffic increases and urban areas expand (see Box HC1).

Other groups of chemicals that have increased in importance over the last few decades include those used in:

- flame retardants, detergents, preservatives and plastics;
- agriculture and fish farming to control pests and to protect livestock.

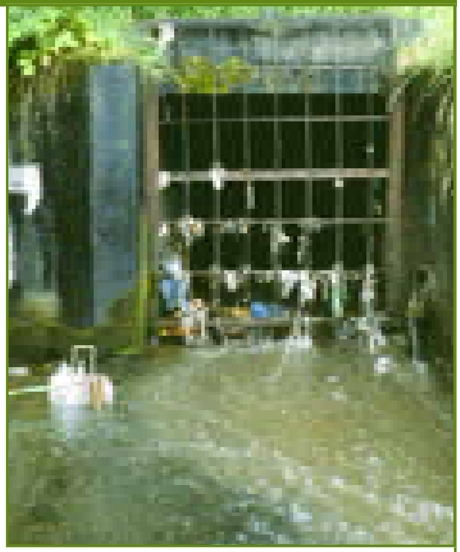
For example, organochlorine sheep dips (e.g. lindane and dieldrin) were replaced by organophosphate sheep dips which, due to human health concerns, were then replaced by synthetic pyrethroid sheep dips. Synthetic pyrethroids are significantly more toxic to aquatic life and have caused pollution in some rivers. Farmers have been encouraged to adopt good practices for the use and disposal of these products so that the chemicals do not enter watercourses.

There is monitoring of pesticides and sheep dip chemicals in surface water and groundwater (see supplementary material[SHC4]) and of pesticide residues in food (see www.food.gov.uk/science/surveillance/). The herbicide mecoprop is occasionally found in groundwaters and, in some cases, this may be due to its disposal in general waste by the public.

Various chemicals are used for medicinal purposes in marine fish farming. Monitoring of sediments from different areas of Scotland for the chemical constituents of sea lice treatments (see www.sepa.org.uk/aquaculture/index.htm) indicates that environmental damage is unlikely provided these medicines are used responsibly. This is supported by independent research[HC6] on the long-term effects of these medicines on the ecology of Scotland's marine environment. There is some evidence to show that unauthorised chemicals were used in fish farms in the past, but recent monitoring indicates that this problem has declined.

Chemical contaminants that are persistent, bioaccumulative and toxic are of particular concern (see Table HC1). In the UK, these chemicals are managed by a variety of regulations and restrictions on their use and disposal.

Box HC5: Urban run-off pollutes Red Burn



The Red Burn drains the area around Cumbernauld in the central belt between Glasgow and Edinburgh. Near to the top of its catchment, the Red Burn receives surface water run-off from a large area of housing, industrial estates and the town centre. The river downstream has very low numbers of sensitive invertebrates and virtually no fish. The river bed is covered with an oil-smelling slime. Further downstream the river receives run-off from a series of industrial sites and areas of housing. The Red Burn remains in a poor condition throughout its length and the impacts extend throughout the Bonny Water and into the River Carron for a total of 17 km.

The figureon the right illustrates that the ecology of the Burn is better where oil contamination is low (the higher the green number, the better the ecology; the smaller the purple bar, the lower the oil contamination). It also highlights that the ecology (as determined by the number of species) is better upstream than downstream of Cumbernauld. The photograph shows the Cumbernauld surface water outfall at the top of the Red Burn catchment.

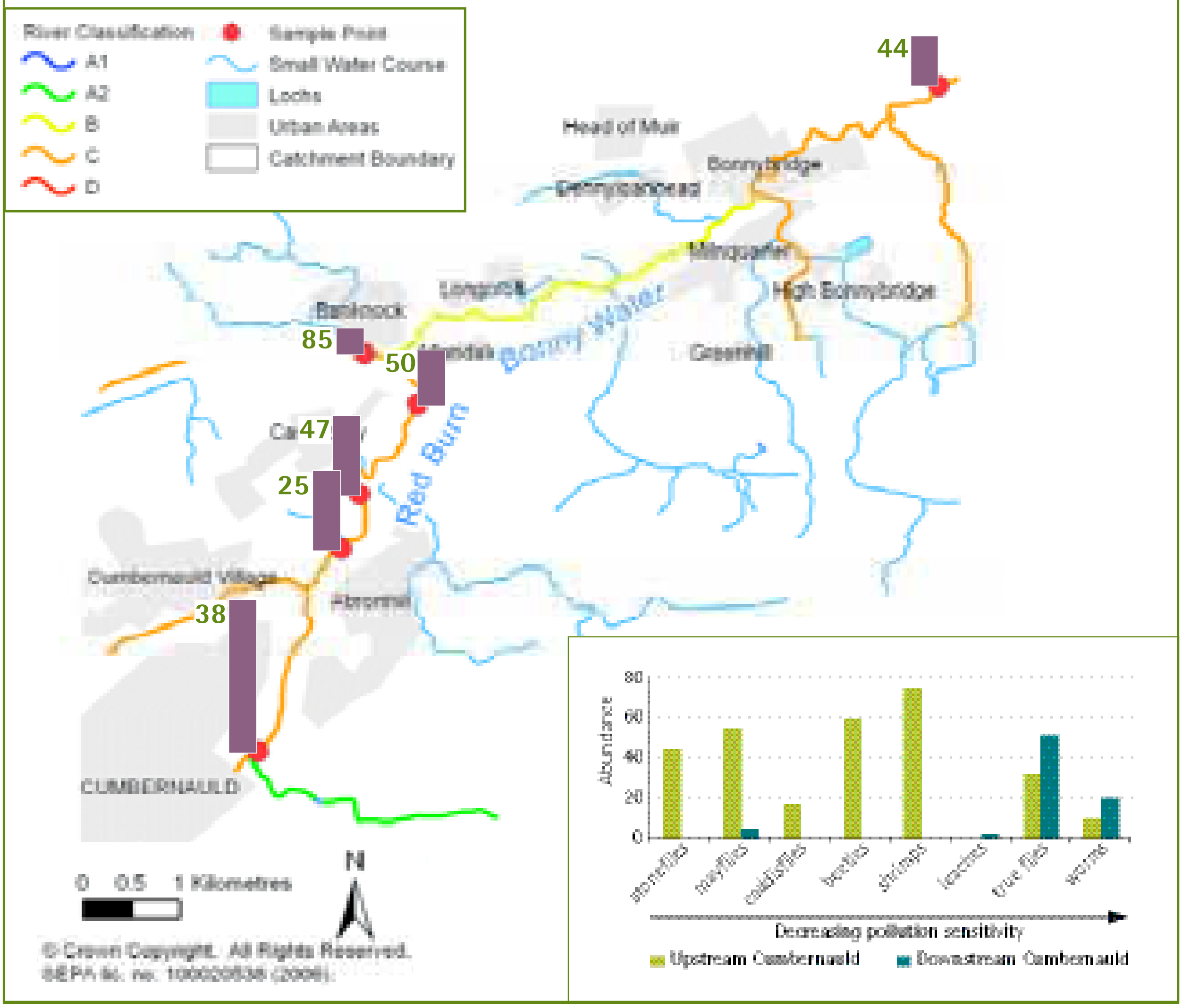


Table HC1: Chemicals of particular global concern

The contaminants tabled below are often released to the environment in very small quantities and/or may be transported over long distances from the point of emission. The very low levels of these chemicals in Scotland's environment are not currently thought to be causing undesirable effects (see Box HC6), but it is considered prudent to limit the entry of such chemicals into the environment because our understanding of their effects is limited and it may take a long time to reverse any problems that might arise.

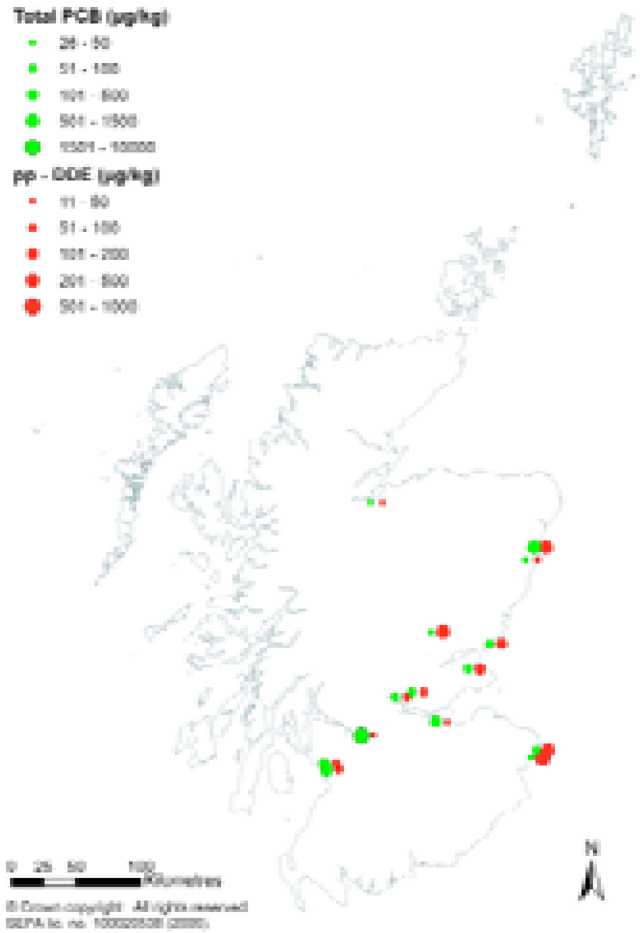
Substance name	Abbreviation	Source of release in Scotland
Polycyclic aromatic hydrocarbons	PAHs	In addition to occurring naturally in coal and crude oil, PAHs are often associated with the products of combustion of fossil fuels. See www.macaulay.ac.uk/tipss/pah.htm
Short-chain chlorinated paraffins	SCCPs	SCCPs are used as metal working fluids for a variety of engineering and metal working operations such as drilling and machining/cutting, flame-retardants in textile and rubbers, plasticisers /flame retardants in paints, coating and sealants/adhesives and fat liquoring agents in the leather industry. The European Commission has proposed a ban on the use of SCCPs in metal working and leather processing.
Polychlorinated biphenyls	PCBs	The chemical nature of PCBs leads to their accumulation in fatty tissues and hence to bioaccumulation in food chains. Their persistence and toxicity resulted in restrictions on their use in the UK during the 1970s and finally to a ban of their use. See www.macaulay.ac.uk/tipss/pcb.htm
Polychlorinated dibenzo-p-dioxins (dioxins)	PCDDs	All forms of combustion, including the burning of solid and liquid fuels (e.g. coal, oil and wood) both on a large-scale, (e.g. electricity generation) and on a small-scale (e.g. domestic stoves, coal fires, bonfires and accidental fires) and incineration of municipal, clinical and hazardous wastes.
Polybrominated diphenyl ethers (brominated flame retardants)	PBDEs	PBDEs are used as flame retardants in plastic items (e.g. casings of wic and electrical goods), printed circuit boards, textiles and in foam for furniture and cars. Some PBDEs have been banned for use in the European Union because of concerns that penta-BDE affects human health.
Perfluorooctane sulphonate	PFOS	PFOS is used in metal plating, fire fighting foams, the photographic industry, semiconductors and hydraulic fluids for the aviation industry. The UK has launched a strategy to reduce inputs of these chemicals into the environment.

Box HC6: Persistent organic pollutants in freshwater eels

Organochlorine pesticides and PCBs are extremely persistent, bioaccumulative and toxic chemicals that are found widely in the environment. The freshwater eel is a good bio-indicator species because it has a limited territorial range, a high fat content (which stores these types of chemicals) and can live for over seven years in the same stretch of river.

SEPA has monitored the concentrations of persistent organic pollutants in eel tissue at a number of locations in Scotland. Persistent organic pollutants were detected in eel tissue from all 17 locations studied, although not all of the chemicals studied were detected at all the locations. Higher levels of PCBs were found in eels from the River Clyde and River Don, whereas higher levels of DDT breakdown products were found in the Whiteadder Water and Lunan Burn (see map).

Other studies have been undertaken into the levels of these chemicals in predatory wildlife such as otters[HC7], birds of prey[HC8] and marine mammals[HC9].



Persistent organic pollutants have been targeted for international action to reduce their levels in the environment. In addition, research is being conducted on substances of emerging concern such as nanoparticles (very small particles used in sunscreens, paints and medical devices).

Despite the diversity of chemicals used in Scotland, on the whole they do not cause large-scale environmental problems. The legacy left by hazardous chemicals, which were not controlled adequately at the time, is still apparent in some parts of Scotland, especially in soils and sediments. The widespread public use of products like cosmetics and detergents and the increasing use of pharmaceuticals have meant that the environment is exposed to new pressures. Ecological damage is caused by run-off from roads and urban areas and this is likely to increase, reflecting upward trends in road traffic and urban development. Hazardous chemicals can have a variety of unwanted effects on ecosystems and, as other causes of environmental problems continue to be addressed, the more subtle effects of some chemicals in the environment may become more apparent.

Forward look

Understanding the occurrence of hazardous chemicals in Scotland will improve in the light of ongoing studies. New areas of concern may emerge, depending on the extent of use of hazardous chemicals, and whether they are used in domestic, commercial or industrial situations. The new mechanism for the control of chemicals within the European Union (REACH) is anticipated to lead to a reduction in inputs of hazardous chemicals to the environment.

References

No.	Details	Available from:
HC1	*A Review of Vehicle-related Metals and PAHs in the UK Environment*, unpublished report produced for SEPA, 2005.	Scottish Environment Protection Agency
HC2	*Emission Estimates to 2002: Emissions by Fuel Types*, National Atmospheric Emissions Inventory, 2004.	www.naei.org.uk
HC3	*Review of Scottish OSPAR Monitoring Data from the Riverine and Direct Discharges (RID) Monitoring Programme for 1990–2003*, SEPA, 2005.	Scottish Environment Protection Agency
HC4	*Causes and Consequences of Feminisation of Male Fish in English Rivers*, Environment Agency, 2004.	www.environment-agency.gov.uk/publications
HC5	*Characterisation and Impacts Analyses Required by Article 5 of the Water Framework Directive – Scotland and Solway Tweed River Basin District*, Scottish Environment Protect Agency (SEPA) 2005.	www.sepa.org.uk/publications/wfd/index.htm
HC6	*The Ecological Effects of Sea Lice Treatments in Scottish Sea Lochs*, SAMS, PML, FRS, SEAS, 2005	www.sams.ac.uk/research/coastal%20impacts/pdf/Final%20Layman.pdf
HC7	*Review of Contaminant Data for Otters in Scotland and Northern Ireland*, Project code SR(02)41. Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), 2004.	www.sniffer.org.uk
HC8	*Wildlife and Pollution: 2000/01 Annual Report*, Joint Nature Conservation Committee (JNCC) Report No. 351, JNCC, 2005.	http://pbms.ceh.ac.uk/docs/AnnualReports/jncc351_web.pdf
HC9	*Sea Mammal Research Unit: Scientific Report*, Sea Mammal Research Unit, 2004.	http://smub.st-and.ac.uk/smru%20AR.pdf
SHC1	Supplementary material on legal controls	Online version of report
SHC2	Additional data on biomonitoring in the Forth Estuary	Online version of report
SHC3	Supplementary material on hazardous chemicals in urban drainage	Online version of report
SHC4	Supplementary material on pesticide use and occurrence in water in Scotland	Online version of report

Sources of further information

Topic	Source
Persistent organic pollutants	www.pops.int/documents/guidance/beg_guide.pdf
Trends in pollution of Scottish soils	www.macaulay.ac.uk/tipss/index.html
Chemicals in soil and herbage	UK Soil and Herbage Pollutant Survey (UKSHS) – series of reports to be published by the Environment Agency
Code of practice on sheep dipping	www.scotland.gov.uk/Resource/Doc/47034/0017593.pdf
Nanotechnology	www.nanoforum.org www.cordis.europa.eu.int/nanotechnology/
Dioxins	www.scotland.gov.uk/Resource/Doc/1052/0002248.pdf
Risk reduction strategy for PFOS use in the UK	www.oztoxics.org/poprc/Library/pfos-riskstrategy.pdf
Emissions of chemicals to the environment	www.sepa.org.uk/spri www.naei.org.uk
Hazardous chemicals in and around the home	www.watersense.org.uk

Nutrient enrichment

Summary

Nutrient enrichment of rivers, lochs and groundwater is a significant problem in some areas of Scotland, particularly those with intensive agriculture or high population density, due to its potential to damage ecosystems. Effects of nutrient enrichment on estuarine and coastal waters are limited.

The area of semi-natural terrestrial habitats at risk from nitrogen deposition has declined slightly, but the potential for damage to specific habitats remains high. Agricultural production relies on the supply of nutrients to meet crop requirements, but poor application methods and oversupply of fertilisers can lead to nutrient enrichment.

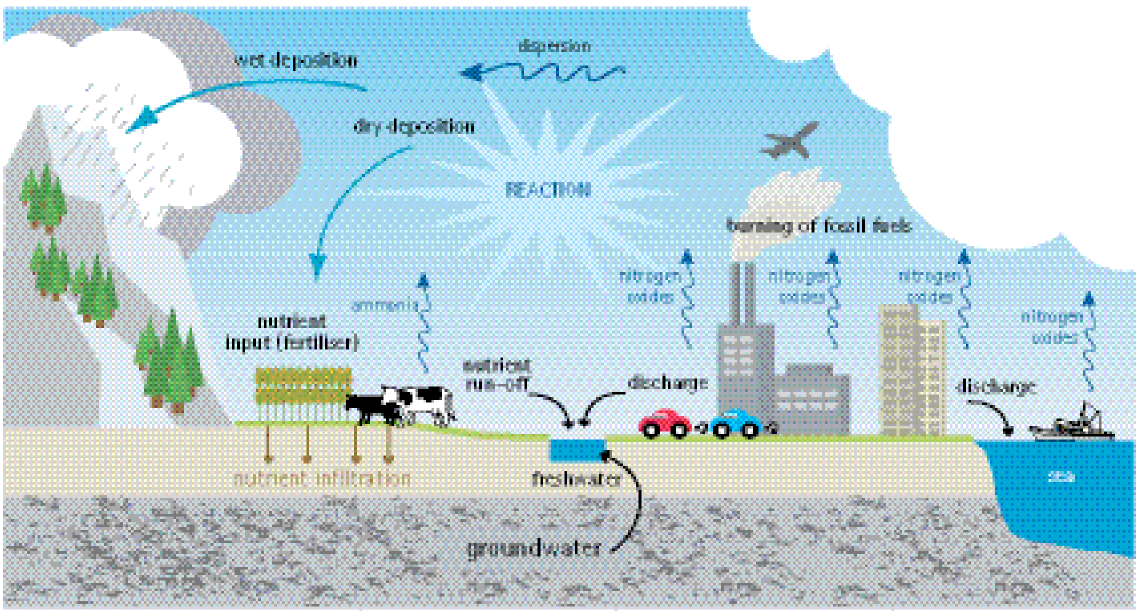
The downward trend in emissions of nitrogen oxides to air is linked to reductions in the amounts of nitrogen deposited on nutrient-sensitive plant communities. Ammonia emissions are the dominant source of nitrogen deposition and remain a major problem, particularly for nutrient-sensitive vegetation.

Better targeting and supply of nutrients in fertilisers is needed to prevent nutrient enrichment. Discharges of nutrients to water from sewage treatment works are being reduced.

Nutrients such as nitrogen and phosphorus are essential to support life and are naturally 'cycled' within the environment, but the balance of these cycles can be disturbed by the addition of extra nutrients. Poor application methods and/or the oversupply of nutrients in fertilisers (especially from livestock manures), the discharge of nutrients to water and the deposition of nitrogen compounds emitted to air result in nutrient enrichment of soil, vegetation and water (see Figure N1). Elevated levels of nitrogen and phosphorus may lead to eutrophication – process of undesirable ecological change induced by nutrient enrichment. Such change may include adverse effects on biodiversity.

Eutrophication can be particularly serious in freshwaters where the effects may interfere with recreational activities and drinking water treatment processes, as well as loss of amenity and biodiversity. The economic impact may therefore be considerable.

Figure N1: Inputs of nutrients to the environment



Nutrient enrichment of soils

Nutrient enrichment of agricultural soils is linked to the application of phosphorus and nitrogen in excess of crop demand. While nutrient deficiency can result in reduced crop yields, excessive or inappropriately timed application of nutrients can:

- produce little or no improvement in crop yields and add to costs of production;
- adversely affect organisms in the soil that are important for nutrient cycling and soil structure;
- have a detrimental effect on the quality of groundwater and surface water;
- increase emissions of ammonia, which contributes to both acidification and nutrient enrichment;
- increase emissions of nitrous oxide, a potent greenhouse gas.

Nutrients from agricultural land can reach the water environment in various forms and by different routes. This depends on the nature of the catchment and in particular upon rainfall, vegetation cover, soil type and drainage. The main losses of nutrients from farmland result from:

- surface run-off, particularly of recently spread animal manures;
- erosion of soil particles;
- land drainage;
- leaching of nutrients out of soil into groundwater (soluble nutrients are leached out of light sandy soils faster than heavy clay soils).

The impact of the nutrients on the receiving watercourses depends on:

- the inflowing load, river water flow and available dilution;
- the extent to which the nutrients become bound to sediments;
- groundwater inputs to surface water.

It is essential that agricultural nutrient inputs are managed and accounted for. Catchment sensitive farming and nutrient budgeting are useful tools that are increasingly being taken up under Land Management Contracts, as well being required within nitrate vulnerable zones (NVZ) (see groundwater section). Nutrient budgeting plans were reported as being in place under Land Management Contracts for 93,000 hectares across Scotland in 2005[N1].

An estimated 206,000 tonnes of nitrogen were applied to farmland in Scotland in 2005 from inorganic fertiliser. In addition, practically all the manure from farm animals (containing 178,000 tonnes of nitrogen) was applied to farmland. A further 1,000 tonnes of nitrogen was applied in the form of treated sewage sludge. SEPA also estimates that 30,000 tonnes of phosphorus from inorganic fertiliser were applied to farmland, plus 31,000 tonnes in manure and 530 tonnes in treated sewage sludge.

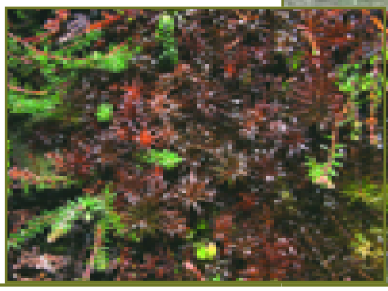
Nutrient enrichment of other terrestrial habitats

Nutrient enrichment of terrestrial habitats alters the competitive balance between different plant species, which can result in the loss of some key species important for sustaining habitat diversity (see Box N1). Habitat sensitivity to nutrient enrichment depends on habitat type and nutrient requirements. For example, upland habitats dominated by plant species adapted to naturally low levels of nitrogen availability are particularly vulnerable.

Box N1: Field experiment sites for assessing the effects of atmospheric pollution on terrestrial habitats

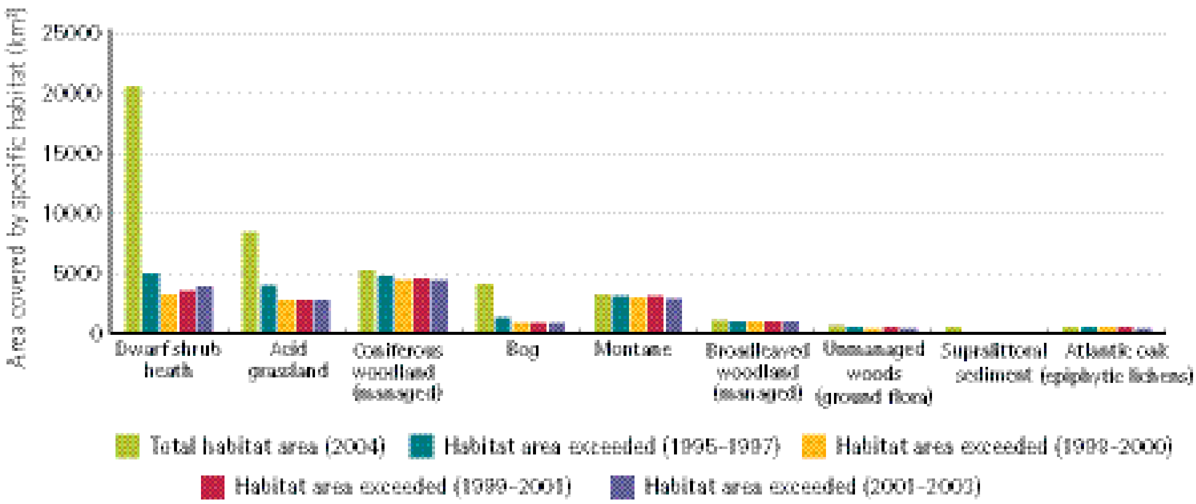
The direct effects of atmospheric pollutants on terrestrial habitats are mainly assessed through carefully managed field experiments. The Centre for Ecology and Hydrology (CEH) operates a nitrogen manipulation site on a nutrient-poor bog in southern Scotland. The semi-natural habitat is exposed to various levels of nitrogen deposition, either from rain water collected on-site and enriched with nitrogen or by direct exposure to gaseous pollutants. Applying pollutants to large plots in the field allows effects on plant communities to be assessed under near natural conditions. The large photograph shows nitrogen being applied to the site by simulating rain enrichment, while the small photograph shows the type of damage visible on moss (*Polytrichum commune*) directly exposed to enhanced ammonia concentrations.

Photographs courtesy of Centre for Ecology and Hydrology



Nutrient enrichment of semi-natural habitats, such as heathland and woodland, is linked to the deposition of nitrogen oxides (NO_X) and ammonia (NH_3) from the air. Figure N2 shows estimates of the extent to which semi-natural habitats in Scotland are thought to be at risk from nitrogen deposition. Although the total area at risk fell from 19,802 km² in 1995–1997 to 16,322 km² in 2001–2003, the potential for damage to specific habitats is still high. The level of risk varies considerably, with upland areas most vulnerable owing to the combination of sensitive habitats and higher nitrogen deposition from higher rainfall and cloud. For more information see www.nbu.ac.uk/negtap/finalreport.htm and supplementary material[SAD1].

Figure N2: Habitat area (by type) in which critical load for nitrogen was exceeded during four time periods*



Source: CEH published and unpublished data

*2004 total mapped habitat area is shown to provide context. The percentage of the area exceeded is highlighted for the most and least recent time period.

The fall in emissions of nitrogen oxides in the UK by 48% since 1970[N2] has contributed to the reduced level of nitrogen deposition across Scotland. Attention is now shifting to ammonia, the other major contributor to nitrogen deposition in the UK.

In 2002, agriculture accounted for 78% of ammonia emissions in Scotland, with livestock manures contributing the greatest part[N3]. Ammonia emissions from agriculture fell slightly between 1996 and 2002 – mainly owing to fewer cattle, sheep and pigs, coupled with improved fertiliser management. The poultry sector was the only one to emit more ammonia during this period[N3].

Nutrient enrichment of groundwater

The key source of elevated nitrate in groundwaters is agricultural land. If the total store of nitrogen in the soil exceeds that required for plant growth, some of the excess will be leached into the underlying groundwater. Some nitrate-enriched groundwater may subsequently find its way into surface waters. Groundwaters with elevated nitrate concentrations tend to be found in the more intensively farmed areas of eastern Scotland. In response to this problem, four NVZs amounting to 14% of the land area of Scotland have been designated (see Figure N3). Where an NVZ is designated, action programmes must be put in place to reduce pollution by nitrates from agricultural sources.

Figure N3: Location of nitrate vulnerable zones and catchments draining to nutrient sensitive areas in Scotland

There is monitoring of the concentration of nitrate in groundwater at around 200 sites across Scotland. Concentrations at several boreholes and springs are failing to meet the European Union standard for drinking water quality[N4] (i.e. the threshold of 50 mg/l is being exceeded for at least 5% of the time).

Monitoring since 2002 indicates a mixed picture. It is clear that the majority of sites with elevated concentrations, in both ground and surface waters, are located within the NVZs. It is also apparent that whilst the NVZ Action Programme is playing its part, it cannot be said to have reduced nitrate concentrations in either surface or ground waters to such an extent as to suggest a change in the NVZ designations. Those sites outwith NVZs that are showing elevated nitrates are being investigated by SEPA to determine the reasons. It may be that some sites are being influenced by local sources of pollution including sewage discharges or else are not representative of the groundwater.

Maps have been developed to help build understanding of the vulnerability and risks to groundwater from land use management (see www.sepa.org.uk/groundwater/tools/index.htm).

A similar eutrophication assessment of rivers based mainly on phosphorus concentrations and information on benthic diatom communities[N6] concluded that 2,184 km (8.6% of all significant watercourses in Scotland) showed evidence of being either eutrophic or potentially eutrophic. The affected rivers and streams are clustered mainly in the more populated and intensively farmed areas of the country.

All the lochs and rivers identified as being eutrophic or potentially eutrophic have been designated as sensitive areas and will be subject to targeted measures to reduce nutrient inputs. The area of Scotland affected amounts to 26% of the total land area (see Figure N3).

Nutrient enrichment of estuaries and coastal waters

Nutrient loadings to marine waters are measured, from rivers, sewage treatment works, industrial discharges and marine caged fish farms (see Table N1).

Table N1: Nitrogen and phosphorus loadings to the marine environment, 2005

Source	Nitrogen (tonnes)	Phosphorus (tonnes)
Rivers	43,100 (63%)	2,974 (37%)
Sewage treatment works	13,432 (20%)	2,543 (31%)
Industrial discharges	3,587 (5%)	1,484 (18%)
Fish farming	8,200 (12%)	1,100 (14%)
Total	68,319	8,101

Source: SEPA Oslo and Paris Conventions data and Scottish pollutant release inventory returns from fish farms

River inputs dominate the nitrogen load to Scotland's marine waters. In contrast, the contributions to the total phosphorus load are more evenly spread across the four major sources. River inputs reflect nutrient inputs from diffuse sources such as agriculture and atmospheric deposition, and these can vary widely according to the size of the river catchment and weather conditions. Few trends can be detected in nitrogen and phosphorus inputs since 1990 (see Figures N4 and N5 – waste water refers to effluent from sewage treatment works).

Figure N4: Total nitrogen loadings from industry, rivers and sewage treatment works to the marine environment, 1990–2005[N7]

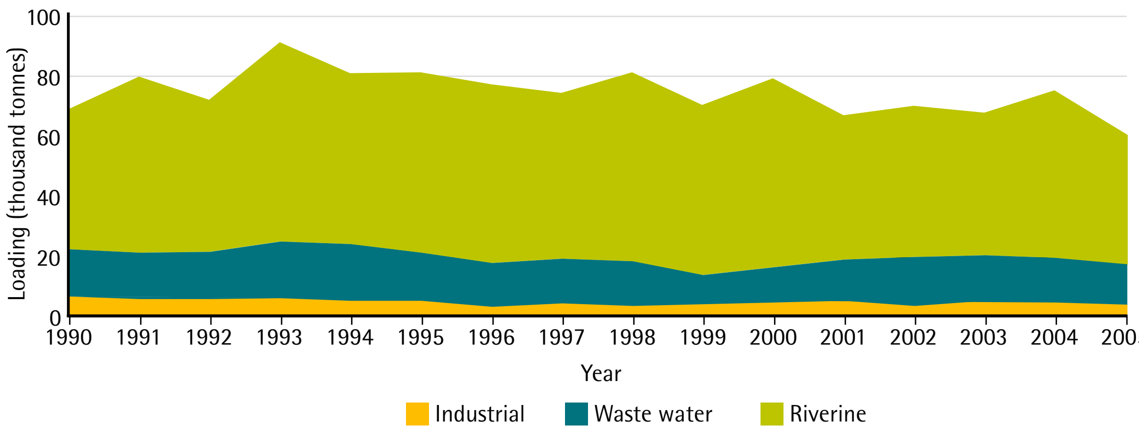
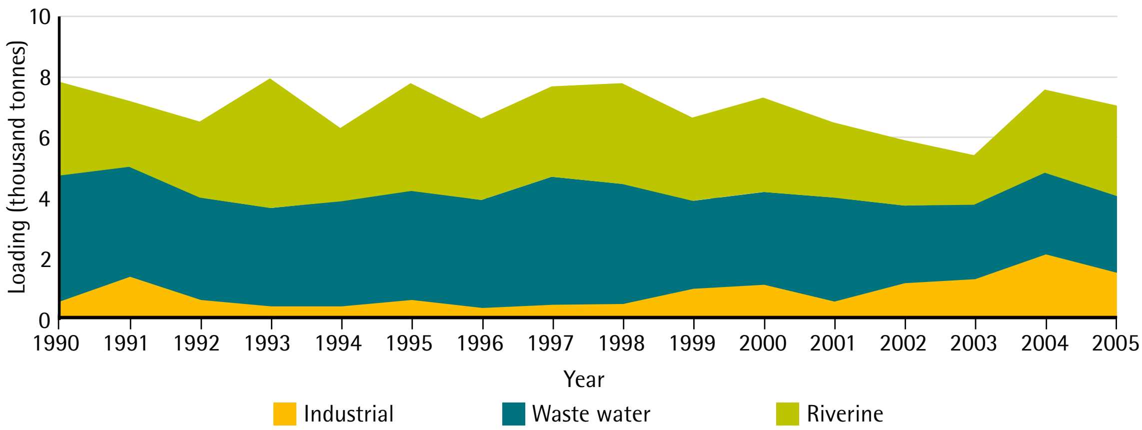


Figure N5: Phosphorus loadings from industry, rivers and sewage treatment works to the marine environment, 1990–2005 N7



Based on loadings estimates for 2005, salmon farming contributed 12% of the total nitrogen input to Scotland's waters and 14% of the phosphorus input. In some areas of the west of Scotland, particularly those with small catchment areas and low levels of human habitation, aquaculture inputs represented the majority of the total direct nutrient inputs. Direct inputs of nutrients to west coast marine waters are, however, insignificant compared with the nutrients transported to the area on oceanic and coastal currents.

A review[N8] of the occurrence of harmful algal blooms confirmed that the present level of fish farming is having only a small effect on the growth rate of phytoplankton (not a cause for concern except in a few heavily-loaded sea lochs). Additional work to review the eutrophication status of Scottish coastal waters in relation to fish farming[N9] found that neither winter nutrient concentrations nor summer chlorophyll *a* levels exceeded the assessment criteria (50% above background in any of the areas surveyed).

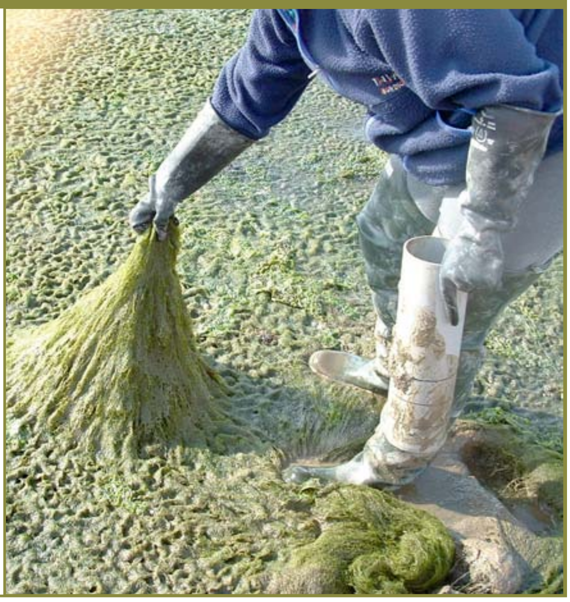
Routine surveys measure nutrient concentrations and chlorophyll levels in Scotland's estuaries and coastal waters. The results indicate that although most estuaries and coastal waters are not significantly affected by excess inputs of nutrients, there are localised impacts. For example, the Ythan estuary to the north of Aberdeen is affected by excess nitrogen draining from the catchment of the River Ythan (see Box N3).

Box N3: Eutrophication in the River Ythan and estuary

The Ythan estuary is a nationally important conservation area for various bird populations and has shown signs of eutrophication. Algal growth in the estuary (see photograph) can affect bird populations by reducing the quantity and availability of the small mud-dwelling invertebrate animals which are a prime food-source for the birds.

With EU assistance, the Ythan LIFE Project was set up in 2001 with the aim of involving local people in protecting, restoring and enhancing the Ythan catchment. Considerable work was undertaken between 2001 and 2005 to:

- raise awareness of diffuse pollution issues;
- help improve farming practices;
- carry out river restoration work.



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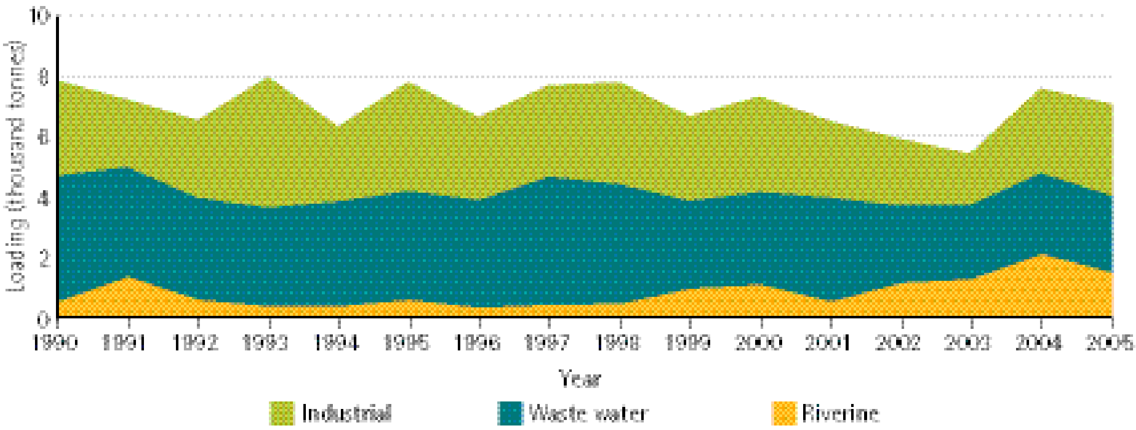

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Land use in the catchment is almost exclusively agricultural and nutrient losses through run-off and leaching from land contributes to nutrient enrichment. Nutrient removal at the sewage treatment works at Ellon has reduced inputs and further investment in wastewater treatment is planned in the catchment. One driver for this was the identification of two major tributaries in the lower part of the catchment, as well as the estuary itself, as nutrient sensitive areas under the Urban Waste Water Treatment Directive.

The River Ythan is part of the Aberdeenshire, Banff, Buchan and Moray Nitrate Vulnerable Zone (NVZ). Farms are inspected under NVZ Action Programme by the Scottish Executive; breaches can mean penalties being applied to the farmer's Single Farm Payment under Common Agricultural Policy cross-compliance introduced in 2005.

For more information on nutrient enrichment in the Ythan see supplementary material[SN3].

Look forward

Integrated measures taken under Water Framework Directive, Nitrates Directive and Urban Waste Water Treatment Directive are expected to progressively reduce nutrient enrichment of water and land. Developments in Land Management Contracts should lead to improvements in nutrient management of soils. The major challenges are likely to be tackling diffuse pollution and reducing emissions of ammonia.

References

No.	Details	Available from:
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N2	*National Atmospheric Emissions Inventory*	www.naei.org.uk
N3	*Ozone and Ammonia – Maps and Statistics for Scotland*, Centre for Ecology and Hydrology (CEH), 2005.	www.sepa.org.uk/publications
N4	Groundwater quality data, SEPA, 2001–2005.	Unpublished
N5	*Provision of a Screening Tool to Identify and Characterise Diffuse Pollution Pressures: Phase II*, Project code WFD19. Scotland and Northern Ireland Forum for Environmental research (SNIFFER) 2005.	www.sniffer.org.uk
N6	*Eutrophication Assessment of Scottish Coastal, Estuarine and Inland Waters*, SEPA, 2005.	www.sepa.org.uk/publications
N7	*Review of Scottish OSPAR monitoring data for the riverine and direct discharges (RID) monitoring programme*, SEPA, 1996–2004.	Scottish Environment Protection Agency
N8	*Review of Harmful Algal Blooms in Scottish Coastal Waters*. Report to SEPA by P Tett and V Edwards. June 2002	www.sepa.org.uk/pdf/aquaculture/projects/habs/habs_report.pdf
N9	*OSPAR Eutrophication Assessment of Aquaculture Hotspots in Scottish Coastal Waters*, Collaborative Report 07/03, Fisheries Research Services, 2003.	Fisheries Research Services
SAD1	Supplementary material on atmospheric deposition	Online version of report
SN1	Supplementary material on nutrient enrichment of Loch Lomond	Online version of report
SN2	Supplementary material on nutrient enrichment of Loch Leven	Online version of report
SN3	Supplementary material on nutrient enrichment of the River Ythan and estuary	Online version of report

Acidification

Summary

Acidification is a potential problem across large areas of upland Scotland due to its ability to damage ecosystems, but evidence of ecological damage is mainly confined to fresh waters in Galloway, smaller areas of the Cairngorms and the western and central Highlands.

Reductions in emissions of acidifying gases, means there have been significant reductions in acid deposition across the UK. Sulphur dioxide deposition declined by 52% between 1986 and 1997, while deposition of nitrogen oxides declined by 16% over the same period. The relative importance of nitrogen as a contributor to acidification has increased.

As a result of reduced acid deposition in Scotland, impacts on vegetation, soil and freshwater habitats have shown a slight decrease in some areas. There is some evidence to suggest that soils are becoming slightly less acidic. The extent of acid-sensitive vegetation affected by acidification has declined, with some areas showing signs of recovery. Some recovery is also evident in certain rivers and lochs. However, acidification is still causing other watercourses to be devoid of acid-sensitive plants, invertebrates and fish.

The recovery of soil, vegetation and water from acidification does not match the reduction in acid deposition. Recovery is predicted to take decades and some habitats may never return to their original state. Over such long timescales, recovery may be slowed or even reversed by climate change.

Some soils and freshwaters are naturally acidic due to factors such as geology, soil type, climate and land cover. These are particularly susceptible to further acidification by the deposition of certain atmospheric pollutants either in gaseous form (dry deposition) or in rain or mist (wet deposition) as illustrated in Figure AD1. Acidic wet deposition is often called 'acid rain'. These pollutants include:

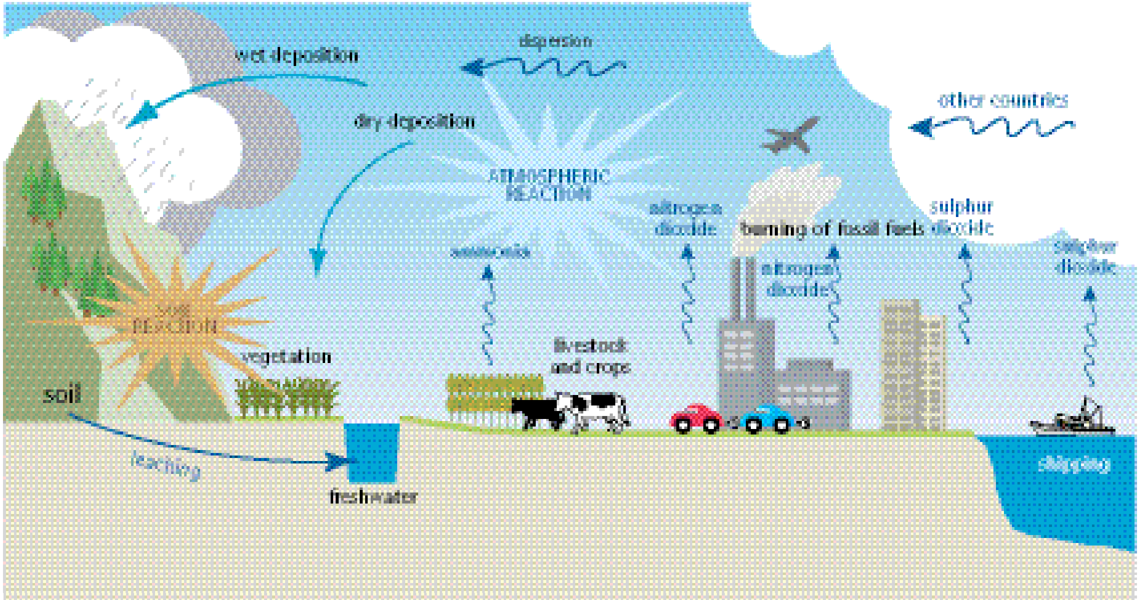
- sulphur dioxide (SO_2) and nitrogen oxides (NO_X) – chiefly derived from burning fossil fuels such as coal and oil;
- ammonia (NH_3) – arising from animal manures during their generation, storage and spreading onto land.

The deposited pollutants can increase the acidity of soils and freshwaters, adversely affecting their quality and biodiversity (nitrogen oxides and ammonia are also associated with nutrient enrichment – see previous chapter). Most soils have a natural capacity for neutralising acid inputs but, as more acid pollutants are added, this buffering capacity becomes depleted and the soils become more acidic. Acidification of the soil results in the loss of nutrients such as calcium and magnesium, thus reducing soil fertility. If acidification continues, potentially toxic metals such as aluminium are mobilised and are leached into lakes and rivers, causing damage to aquatic life.

Some areas of Scotland such as Galloway, the Trossachs and parts of the Cairngorms are particularly sensitive to acidification because:

- they receive high rates of acid deposition due to the high rainfall;
- they have been extensively planted with coniferous forest, which enhances deposition levels by virtue of the aerodynamic roughness of the canopy and the high surface area of the needles;
- they have naturally thin, acidic soils with low buffering capacity. Such soils are found in areas where the underlying geology consists of hard, slow-weathering rocks such as granite.

Figure AD1: Acidifying substances – sources of emissions, pathways and impacts



Acidification of soil

Soil acidification is of concern because of its influence on soil fertility, biodiversity (e.g. earthworms tend to be absent in excessively acidic soils), vegetation and water quality.

Many soils in Scotland, especially in upland areas, are shallow and overlie acidic geology. These soils have limited buffering capacity and are consequently sensitive to acid deposition. Sensitivity to acid inputs is measured by the critical load. The critical loads for acidity in soils were described fully in SEPA's State of the Environment Soil Quality Report[AD1]. Exceedances of the critical load were significant, particularly in the Galloway hills and the west central Highlands; overall they were exceeded across 86% of the Scottish land area for the period 1995–1997[AD1].

Elsewhere, some farming practices (e.g. high nitrogen application rates) can exacerbate acidification of agricultural soils, and farmers may carry out regular liming to reduce soil acidity and maintain its pH at the optimum level for their crops. In 2003, farmers applied 313,000 tonnes of limestone to 7.6% of the total agricultural area of Scotland[AD2]. Use of limestone to reduce soil acidification can also help to prevent water acidification.

There is no routine monitoring of soil acidification and as a result information on trends is scarce. What is known is that:

- studies in the 1980s showed that soils were acidifying. For example, peats with the highest acidity were often correlated with areas of high acid deposition. Acid deposition reduced the natural pH of Scottish peat soils by about 0.5 units[AD3];
- forest soils in the upper Dee catchment monitored over a 40-year period showed increased acidity, which was attributed to a number of factors including acid deposition[AD4];
- summary results from Countryside Survey 2000[AD5] suggest that there has been an overall decrease in soil acidity since 1978 for both Scotland and Britain as a whole. The only increase in soil acidity was recorded under coniferous woodland. Further work is required to assess the significance of these trends;
- modelled results for 2010 based on expected reductions in acid deposition indicate that the area where the critical load for acidity in soils is exceeded will decrease by about 40%[AD1].

Acidification of semi-natural terrestrial habitats

Acidification of semi-natural habitats (a result of soil acidification and direct deposition) is of concern because it causes loss of acid-sensitive species and reduced plant growth. The loss of particular plant species can in turn affect the biodiversity of other organisms higher up the food chain such as insects and birds, which rely on the affected species for survival.

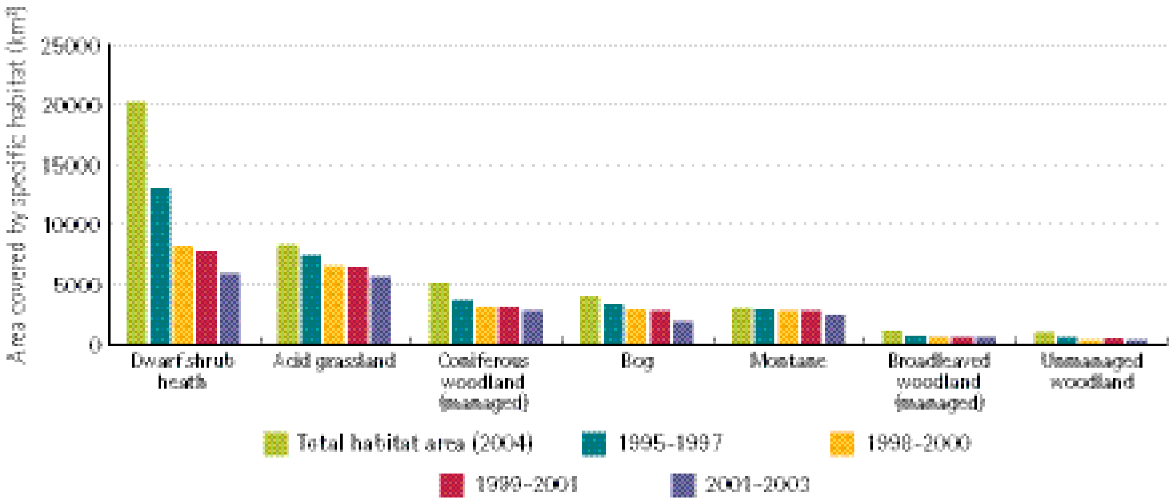
There is limited information on the actual impact of acidification on semi-natural habitats. Field surveys provide evidence of changes in plant communities, but it is difficult to isolate the effects of acidification from those of other environmental factors. For example, certain lichens are sensitive to sulphur dioxide. Mapping the distribution of lichens can therefore be used to indicate spatial or temporal changes in levels of acid deposition (see Box AD1). However, careful interpretation of the results is required due to the possible influence of confounding factors such as climatic change or other air pollutants.

Critical loads are used to assess the sensitivity of specific habitats to acidification. Exceedance of the critical load indicates the potential for damage. Figure AD2 illustrates the extent to which a broad range of terrestrial habitats in Scotland are thought to be at risk from acidification. The level of risk differs considerably, with some habitats being more susceptible to acidification than others. This is because of the combination of higher deposition and the presence of soils that offer little buffering capacity to the incoming acidity. The total area of sensitive habitats where the critical load was exceeded fell by 25% between the periods 1995–1997 (32,699 km^2 or 68% of total habitat area mapped in 2004) and 2001–2003 (20,496 km^2 or 43% of total habitat area mapped in 2004). See reference[AD6] and supplementary material[SAD1] for a breakdown of individual habitats.

While the area of habitats at risk from acidification in Scotland now appears lower, the potential for damage to specific habitats remains high. For some habitats, the critical load is still exceeded across more than half their total area. For the most sensitive habitat (montane), the critical load is exceeded across 82% of its total area in Scotland (based on 2001–2003 deposition data).

For more details see reference[AD7] and supplementary material[SAD1]. For general information on atmospheric pollutants, see www.apis.ac.uk

Figure AD2: Habitat area (by type) in which critical load for acidity was exceeded over four time periods*



Source: CEH published and unpublished data

*2004 total mapped habitat area is shown to provide context. The percentage of the area exceeded is highlighted for the most and least recent time period.

Acidification of freshwaters

Acidification of freshwaters can result in a complete loss of fish species and biodiversity in general. For example, unacidified watercourses can support as many as nine species of mayfly (*Ephemeroptera*) whereas, for most acidified watercourses, the number varies between two and zero. Impacts can be particularly severe for salmonid fisheries because both trout and salmon are sensitive – particularly in the early part of their life cycle.

Characterisation reports[AD8] provide an indication of the extent to which water is impacted by acidification. It was estimated that over 50 rivers and over 20 major lochs were at risk of failing to achieve good ecological status because of acidification. Those at risk are concentrated in the south-west area. For rivers, the estimation was based on a combination of water quality monitoring, fish monitoring, consideration of land use, local knowledge and expert judgement. For lochs, the estimation was based on water quality monitoring, studies of algal remains, modelling, local knowledge and expert judgement.

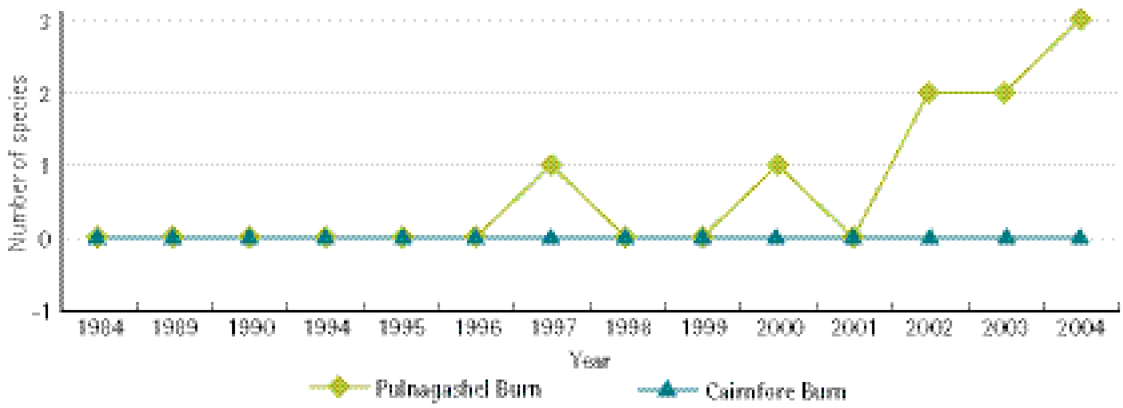
Monitoring of macroinvertebrate communities at 56 river sites (mainly in Galloway, Ayrshire, Argyll and Aberdeenshire) investigates trends in acidification. Some sites show distinct signs of improvement while others do not (see Box AD2). This difference is probably due to the interaction of a number of factors including a local reduction in acid deposition, the degree of local acidification and land use (e.g. improved forest practices, most notably in planting regime, at many sites).

Box AD1: Recolonisation of acid-sensitive lichen

The recent recolonisation of the lichen *Ramalina fraxinea* in Edinburgh's Royal Botanic Garden (RBGE) is a good example of the results of improved air quality. Though common in more rural and northern areas of Scotland, the lichen was last recorded in the capital back in 1797. This particular species is regarded as sensitive to sulphur dioxide and its return indicates that air quality in this historically polluted city has improved dramatically.

Box AD2: Acidification of the Cairnfore and Pulnagashel Burns

The Cairnfore and Pulnagashel Burns in Galloway are examples of acidified watercourses where no acid-sensitive species were detected when monitoring was first carried out. The Pulnagashel Burn, a tributary of the Water of Minnoch, has begun to show signs of recovery, with the numbers of acid-sensitive species increasing. The Cairnfore Burn, a tributary of the River Cree, shows no signs of recovery with regard to these species. For more information see supplementary material[SAD2].



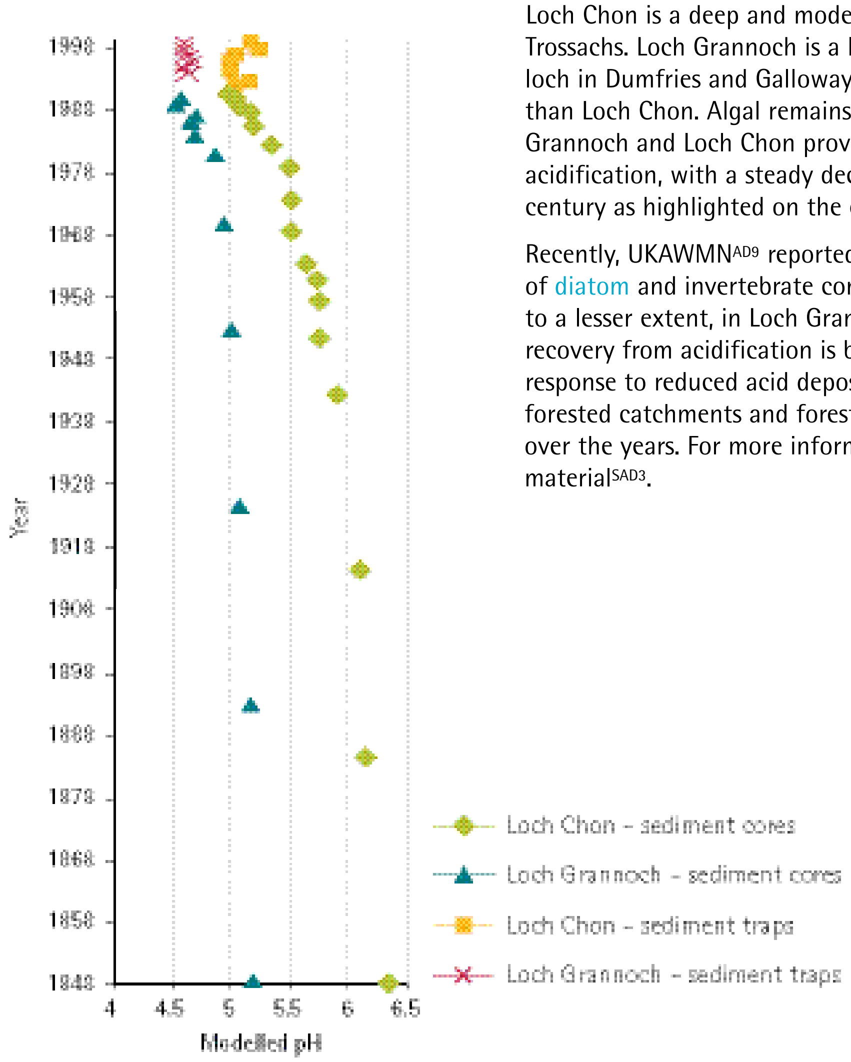
The UK Acid Waters Monitoring Network (UKAWMN) was set up in 1988 to assess the effects of acidification in sensitive waters. Of its network of 22 sites in the UK, six lochs and three streams are in Scotland; see www.ukawmn.ucl.ac.uk/map.htm for their locations and Box AD3 for information on two of the lochs. A recent review of findings over the 15 years to 2003[AD9] concluded that:

- there were significant increases in pH and alkalinity at many sites, though the trend was strongest in central and south-east England;
- there was some evidence of biological recovery at some sites;
- the overall biotic response to chemical recovery was modest.

Box AD3: Acidification of Loch Chon and Loch Grannoch

Loch Chon is a deep and moderately acidic loch in the Trossachs. Loch Grannoch is a long, deep and strongly acidic loch in Dumfries and Galloway; it is naturally more acidic than Loch Chon. Algal remains in sediments from both Loch Grannoch and Loch Chon provide clear evidence of acidification, with a steady decline in pH from the mid 19th century as highlighted on the chart below.

Recently, UKAWMN[AD9] reported changes in the composition of diatom and invertebrate communities in Loch Chon and, to a lesser extent, in Loch Grannoch. These indicate that recovery from acidification is beginning, possibly in response to reduced acid deposition. Both lochs have forested catchments and forestry practices have improved over the years. For more information see supplementary material[SAD3].



Sediment core data courtesy of SNIFFER, report number SR(00)02F
Sediment trap data courtesy of the Defra-funded UK Acid Waters Monitoring Network

Factors contributing to acidification in Scotland

Acidification in Scotland is not solely caused by emissions generated within its borders. Air pollutants such as sulphur dioxide and nitrogen oxides have a long residence time in the air and can travel great distances before being deposited to ground. Emissions of transboundary pollutants from other countries in the UK and continental Europe therefore contribute to acidification in Scotland; emissions within Scotland can also contribute to acidification in other countries.

Concerted action across Europe has resulted in reductions in emissions of acidifying gases. For example in the UK, emissions from regulated and non-regulated sources of sulphur dioxide declined by 85% and there was a 48% decrease in nitrogen dioxide between 1970 and 2003. Emissions of ammonia fell 19% over the period 1990–2003[AD10].

Reductions can be attributed to measures such as the replacement of coal with natural gas as a fuel source and the phasing out of high sulphur content in gas oil, fuel oil and diesel. Greater control is expected to lead to further reductions, but unregulated sources may become increasingly significant. For example, road transport represents the largest single source of nitrogen oxides and shipping is a significant source of sulphur dioxide.

There have been significant reductions in the deposition of sulphur dioxide across the UK (52% between 1986 and 1997) [AD7]. During the same period, deposition of nitrogen oxides across the UK declined by a much smaller amount (about 16%) and deposition of ammonium remained roughly constant. Overall, the potential for acidification from nitrogen is now significantly greater than that from sulphur[AD7].

The rate of decline in deposition has varied widely between different areas, reflecting the complex way in which pollutants behave following emission to the atmosphere. For example, reductions in south-west Scotland have been very small while the East Midlands of England have seen reductions of over 70%. Rates of decline have unfortunately tended to be smallest in areas most susceptible to damage from acidification.

Forestry can exacerbate acidification. There was extensive planting of conifer forests between 1950 and 1990 in Scotland, mainly in upland and often acid-sensitive areas, replacing heather or grass. The deposition of acidifying pollutants is enhanced at altitude because of increased rainfall and cloud cover. In conifer forests, both the aerodynamic roughness of the canopy and the high surface area of needles are effective in scavenging pollutants from the air, which are then washed off into the soil. Felling of forests can also result in a period of increased acidity. Forestry practices now place much greater emphasis on the protection of soil and water quality[AD11].

Reductions in acid deposition have resulted in improvements in the chemical quality of freshwaters and signs of biological recovery, at least in some waters[AD9]. Biological recovery may be expected to lag behind chemical recovery, particularly in rivers, where acid episodes (e.g. associated with high rainfall events) may prevent recolonisation by acid-sensitive species.

Forward look

With a continuing decline in acid deposition, at least in the short term, further recovery in soils, vegetation and freshwaters is expected, although some habitats may never return to their pre-acidification state. In the longer term, the pace of recovery may be slowed or even reversed by climate change. For example, increased rainfall could lead to an increase in acid deposition even though concentrations of acidifying gases in the atmosphere may have declined.

Emissions of substances within Europe which contribute to acidification in Scotland are set to decrease with implementation of the Large Combustion Plant Directive and the National Emission Ceilings Directive. The challenge will be achieving emission reductions from other sources, particularly if vehicle use increases at a greater rate than reductions in vehicle emissions.

References

No.	Details	Available from:
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AD9	*UK Acid Waters Monitoring Network 15-Year Report: Analysis and Interpretation of Results, April 1988–March 2003*, UK Acid Water Monitoring Network (UKAWNM), 2005.	www.ukawmn.ucl.ac.uk
AD10	*National Atmospheric Emissions Inventory*	www.naei.org.uk
AD11	*Forests & Water Guidelines*, 4th edition, Forestry Commission, 2003.	www.forestresearch.gov.uk/PDF/fcgl002.pdf/$FILE/fcgl0
SAD1	Supplementary material on atmospheric deposition	Online version of report
SAD2	Supplementary material on acidification of the Cairnfore and Pulnagashel Burns	Online version of report
SAD3	Supplementary material on acidification of Loch Chon and Loch Grannoch	Online version of report

Environmental challenges

Human health

Summary

The environment plays a significant part in the health and quality of life of individuals and communities in Scotland, but the relationship between environmental pollutants and health is complex and uncertain. Other factors also affect health and further work is required to investigate environmental impacts. There is growing evidence that environmental factors affect both our health and well-being, and contribute to environmental injustice.

Air pollutants such as nitrogen dioxide, sulphur dioxide and small particles make respiratory and cardiovascular illnesses worse and, in some circumstances, hasten death in vulnerable people.

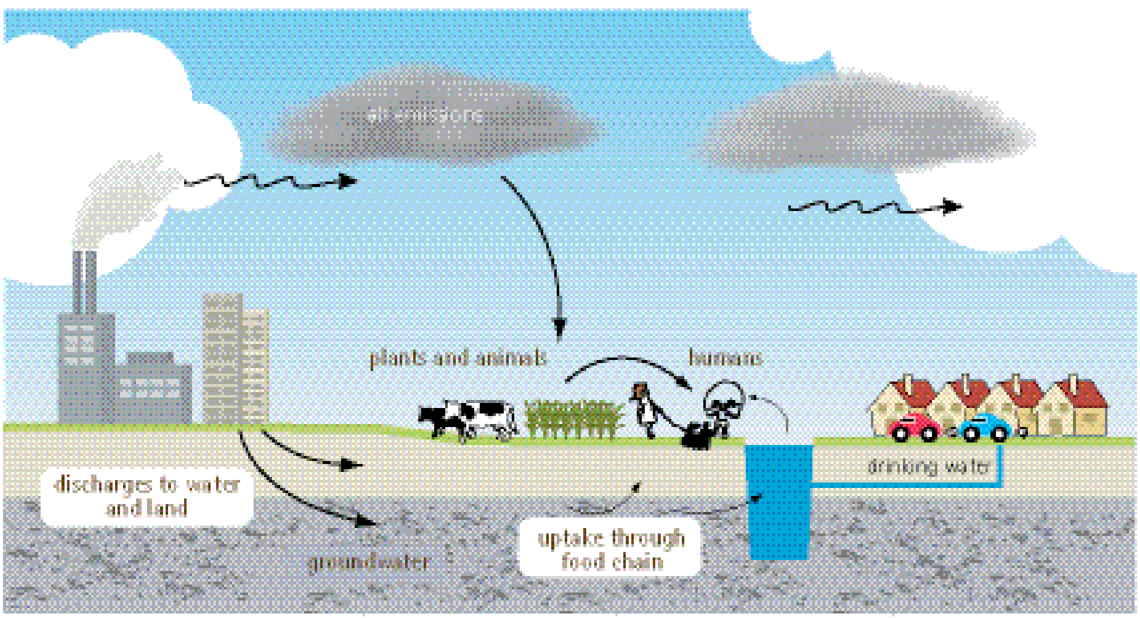
There are clear links between the environment we live in and our health (see Table HH1). Exposure to environmental pollutants can come from many different sources and routes: through the air we breathe, the food we eat, the water we drink and through our work and homes (see Figure HH1).

The focus of this chapter is the quality of our outdoor air, land and water environments. Health effects related to quality of housing, indoor air quality and use of household products are not considered.

The relationship between environmental pollutants and health is complex with high levels of uncertainty due to:

- other factors relevant to health such as lifestyle, socioeconomic circumstances, individual susceptibility and diet;
- the complexity of exposure to a mixture of chemicals and other stressors such as noise and radiation;
- the wide range of potential health impacts of pollution, ranging from specific and measurable physical conditions, through impacts on mental health (e.g. anxiety and depression) to factors which are more difficult to measure such as levels of happiness or well-being;
- a general lack of regular monitoring, in particular of air, for the range of pollutants relevant to health.

Figure HH1: Routes of exposure



Previous chapters discuss the potential health impacts of pollution. This chapter includes more details about the health impacts of air pollutants. It places the impacts in context with the state of health due to the environment, where we can measure it, and with other wider issues impacting on health.

Exposure can be difficult to assess for a variety of reasons:

- difficulties in measuring low concentrations in the environment;
- pollutant concentrations can vary with time (e.g. due to weather conditions);
- exposure can be through a variety of sources;
- exposure is affected by people's behaviour (e.g. how much time they spend outdoors);
- exposure can be acute or take place over a very long time period.

Table HH1: Examples of links between the state of the environment and human health

Aspect*	Implications for human health
Air quality	Poor air quality can aggravate existing respiratory conditions such as bronchitis and asthma and can increase the incidence of cardiovascular illness and strokes.
Land contamination	Land contamination increases the potential for chemical exposure through uptake into the food chain, direct contact with soil or contamination of water supplies. This could result in acute illness due to microbiological exposures (e.g. *Escherichia coli* type 0157) or long-term effects such as increase in cancer risk.
Land	Access to green space can improve health by providing opportunities for physical exercise, and has been shown to improve mental well-being and patient recovery time.
Water quality	Pollution can affect drinking water, recreational waters and areas where, for example, shellfish are harvested. Microbiological contamination (e.g. *Escherichia coli* type 0157 contamination of bathing waters) can give rise to gastrointestinal illness.
Waste	Poorly managed landfilling and incineration can sometimes expose people to water and air pollutants with the potential for toxic or carcinogenic effects. Landfills, composting and the application of sewage sludge to land may result in localised nuisance.
Hazardous chemicals	The accumulation in the environment of hazardous chemicals such as metals and persistent organic compounds introduces a potential threat to the food chain with implications for health (e.g. increasing risk of cancers). Lead exposure can result in neurodevelopment disorders.
Radiation	Direct exposure to radiation and accumulation of radioactivity in the food chain can increase the risk of cancer. Radon exposure from natural sources in homes is linked to increased risk of lung cancer.
Nutrient enrichment	Nitrogen and phosphorus from sources such as farming can have an adverse effect on drinking water quality and lead to toxic algal blooms. Exposure to water affected by blooms can result in gastrointestinal illness, skin irritation and liver damage.
Climate	It is predicted that climate change impacts in Scotland may in general lead to increased flood-related illness (e.g. stress, infections associated with sewage contamination), heat distress and fewer cold-related deaths.

* See the relevant chapters for detailed information about these aspects.

A number of international and regional initiatives recognise the need to develop a better understanding of the links between health and the environment[HH1, HH2, HH3].

The Scottish Executive's Strategic Framework for Environment and Health[HH4] identified cardiovascular disease/health and asthma as initial priorities. These were chosen because of their importance to Scotland's health and the extent to which environment may play an important role. Cardiovascular disease also reflects the challenge of environmental justice, in relation to inequalities in health between less well-off and more affluent areas.

The EU Environment and Health Action Plan suggests that environmental factors play a significant role in death and disease in children across the EU[HH2]. A recent report from the Health Protection Agency (HPA) suggests that about 8–9% of the total disease burden may be attributed to pollution worldwide[HH5].

In Scotland, data are available on the incidence of disease but accurate figures are not available on what percentage of that disease is due to environmental factors.

Air quality and health

The air we breathe contains varying levels of pollutants derived from vehicles, industry, housing and commercial sources – mainly produced by the combustion of fossil fuels (see air chapter). A recent consultation on air quality states that air pollution is currently estimated to reduce the life expectancy of every person in the UK by an average of eight months[HH6].

Epidemiological evidence associates air pollutants with various health effects, including illness and death from respiratory and cardiovascular diseases. The implications for human and ecosystem health vary depending on:

- type of pollutant;
- concentration exposed to (exposure to a high concentration of air pollution for a short period of time may lead to acute effects);
- the sensitivity of the receptor;
- length of time of exposure (exposure to a lower concentration of pollutants over a much longer time may lead to chronic effects).

Human health effects are associated with all particulates, but particularly those measuring 10µm or less (PM_{10}). These are small enough to penetrate the lungs where they can cause inflammation and the worsening of pre-existing heart and lung conditions. European Environment Agency research indicates that fine particles (2.5µm or less) are potentially more important in terms of human health. This is driving future air regulation.

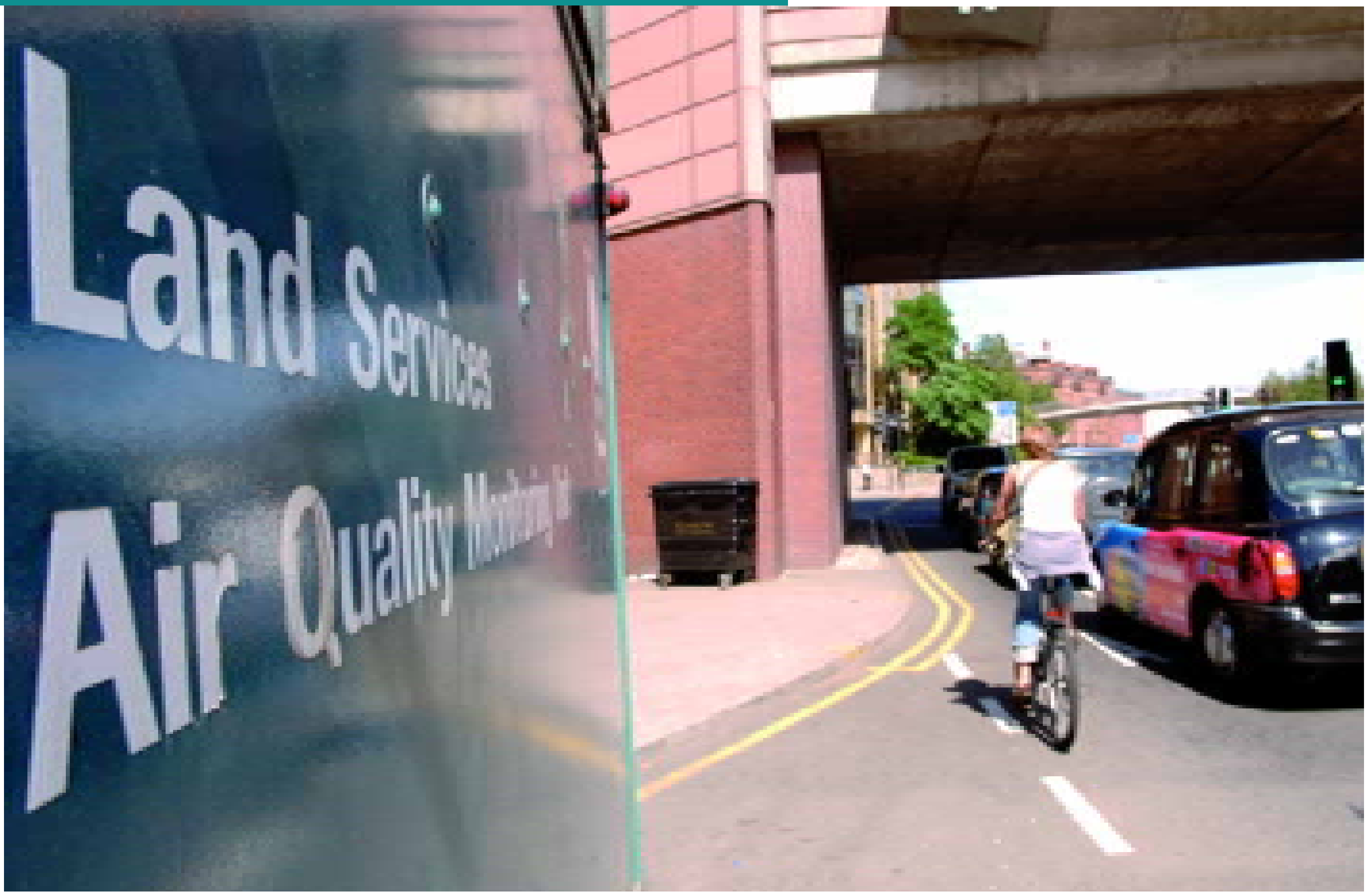
Sulphur dioxide is regarded as a potentially acidifying pollutant that, once released into the atmosphere, may be oxidised in liquid droplets leading to irritation of the respiratory tract. Sulphur dioxide pollution is considered more harmful when concentrations of particulates and other pollutants are high.

The human health effects of exposure to relatively high levels of **nitrogen oxides** can range from shortness of breath to detrimental changes in lung function under extremely high concentrations.

Volatile organic compounds play a key part in the formation of ground-level ozone, which affects human health and ecosystems. Benzene and 1,3-butadiene are of particular concern, as human exposure to these substances may increase susceptibility to cancer.

Ground-level ozone can be harmful. Short-term exposure to high concentrations can inflame airways, causing coughing, triggering asthma attacks and aggravating breathing difficulties in humans.

Stratospheric ozone forms a protective shield above the Earth's surface by absorbing harmful ultra violet radiation emitted by the sun. Depleted stratospheric ozone can result in increased amounts of harmful UV-B reaching the surface of the Earth. Prolonged exposure can affect the skin, eyes and immune system, including an increased risk of developing skin cancer and cataracts.



Health impacts

Mortality caused by coronary heart disease (CHD) has declined in Scotland over recent years, but Scotland still has comparatively very high rates. Among western European countries, Scotland had the highest rates of death from CHD for both men and women[HH7].

Scotland also has a high incidence of asthma. Reported incidence varies between 4% for all ages in Scotland, based on data from GP consultations[HH8], and up to 40% based on self-reported illness in 13–14 year olds in the UK (Scotland had the highest rate)[HH9]. Although there is no strong link between prevalence of asthma and air pollution, there is good evidence that it can worsen the condition by triggering asthma attack episodes. A 2002 US study estimated that 10–35% of acute exacerbations (worsening of the condition or triggering an attack) of childhood asthma are environmentally related[HH10].

The Committee on the Medical Effects of Air Pollutants (COMEAP) reported recently on the relationships between ill health and exposure to airborne particles[HH11]. These particles are mainly from exhaust emissions, industrial combustion and some natural sources. COMEAP estimated that, if the annual mean level of particles measuring 2.5µm or less ($PM_{2.5}$) dropped by just 1 microgram per cubic metre, the mortality rate from cardiovascular disease would fall by 0.1%.

For respiratory disease COMEAP estimated that air pollutants such as particles measuring 10µm or less (PM_{10}) and sulphur dioxide can increase the incidence of deaths and hospital admissions by affecting those who already have severe pre-existing conditions such as asthma and chronic obstructive pulmonary disease (COPD).

Chemicals and health

Chemicals bring huge benefits to society and are used in many ways. People are exposed to a wide range of chemicals at work and at home, in the food we eat, in the air we breathe and in the environment.

There is considerable uncertainty about the health effects of chemicals. Certain cancers are known to be at least partly environmental in origin. However it is difficult to estimate the contribution of chemicals in the wider environment to the incidence of cancer due to the many confounding factors, many of which are linked to individual behaviour (e.g. smoking and alcohol consumption). Occupational exposures introduce a further complication, as do exposures due to direct use of products. There is considerable uncertainty; a US expert panel concluded that environmental factors may cause at least 5–10% but less than 80–90% of the number of cancers[HH10].

Food chain and health

In general, Scotland's food supply is very safe. Fewer people are falling ill from food-borne illness than even five years ago[HH12]. Physical, microbiological and chemical agents in food are each potentially important to health. Chemicals, particularly persistent organic pollutants, can accumulate in the food chain, although levels are very low. Measurable levels of dioxins and dioxin-like polychlorinated biphenyls (PCBs) were reported recently in oily fish[HH13], but the Food Standards Agency advised that levels of these compounds were very low and the health benefits of eating oily fish would outweigh any potential health risk.

Radioactive substances can be passed through the food chain, and can result in increased risk in cancer. Levels in foodstuffs in Scotland are very low, resulting in very low exposures to the public. The results of monitoring the radioactivity in food and the environment are published annually (see www.sepa.org.uk/rife).

Health and environmental justice

Scotland's Sustainable Development Strategy[HH3] recognises that its most deprived communities are most vulnerable to the pressures of poor environments.

Quality of life and well-being are inextricably linked to our environment – be it the quality of the air we breathe or proximity to noise and odours from industrial plants. A recent report for the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) found links between social deprivation and some aspects of environment quality such as air quality, river water quality and proximity to derelict land and large industrial sites[HH14]. For example, people living in the most deprived areas are more likely to experience the poorest air quality than those living in less deprived areas.

The availability of green space can make urban neighbourhoods healthier and more attractive spaces to live. They can also provide a place for exercise which can impact tangibly on health. However, the finding[HH14] that both the least and most deprived areas in Scotland have high percentages of people living near to a local designated wildlife site suggests there is no simple relationship between deprivation and proximity to green space.

Litter, fly tipping and graffiti also tend to be more prevalent in socially deprived areas. While their impact is often dismissed as minor, links have been demonstrated between exposure to such 'street level incivilities' and the incidence of depression and anxiety, as well as self-reported general levels of health[HH15]. It is thought that a stressful external environment can cause changes in the body chemistry and affects control of the body's defence responses. Chronic stress related to our environment can make us more susceptible to disease[HH16,HH17].

Forward look

Our understanding of how the environment affects our health will improve as a result of planned studies and strategies put in place at a Scottish and European level. However, it is expected to be a long time before the links between health and the environment are fully understood due to the complexity of exposures.

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Biodiversity

Summary

Increasing intensification of land use for agriculture, forestry and industry, urbanisation and population growth within the last 250 years all led to significant and rapid declines in the previously rich and diverse biodiversity of Scotland. In 2005 nearly 32% of habitats and 18% of species identified under the UK Biodiversity Action Plan were reported as still declining in Scotland, although around 32% of habitats and 39% of species were either stable or showing signs of recovery.

The impact of climate change is already evident with some species ranges being reduced, others extended and food chains being disrupted. This threat can be expected to get worse. Some form of intervention or active management will be necessary to maintain the status of many habitats and species in Scotland. The Scottish Biodiversity Strategy published in 2004 provides a framework for biodiversity conservation and enhancement.

The state of Scotland's biodiversity is a litmus test of the state of the environment; whatever changes take place in the land, air and water environments affect biodiversity.

The Earth Summit in Rio de Janeiro, Brazil, in 1992 defined biodiversity as:

> 'the variability among living organisms from all sources, including, *inter alia*, 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'.

Biodiversity is the variety of life. It is also important for our health and well being, and as a provider of natural services. These ecosystem services sustain the environment on which we depend and mitigate impacts arising from human activity. Scottish peat bogs, for example, contribute to the purification of water and to the locking-up of carbon dioxide – a greenhouse gas and a major factor in climate change – and along with other wetland habitats can help control and mitigate the impacts of flooding. Nutrient cycling is dependent on biodiversity in soils, freshwater and the oceans, and the oxygen we breathe is released into the atmosphere as a result of plant photosynthesis.

Iconic bird species such as ospreys and sea eagles make a multi million pound contribution to the Scottish economy each year. Wildlife tourism is big business; the 5 viewing sites for ospreys alone attract 125,000 visitors who spend an additional £2.2 million each year (RSPB), whale and dolphin watching generates some £3.4 million and fishing for salmon on the Tweed is estimated to bring £12.5 million into the Borders each year[BD1]. The quality of freshwater in our streams underpins the whisky industry and Scotland's rivers and coasts, mountains and glens form the backbone for the tourist industry [BD1].

Changes in species or in habitat diversity will affect the capacity for ecosystems to recover from human intervention as well as their ability to supply the services and goods. The state of fish stocks in the North Sea dictates the fortunes of the Scottish fishing industry. Cod spawning stocks in the North Sea have declined from a peak of 250,000 tonnes in the early 1970s to less than 44,000 tonnes in 2001. It is essential that biodiversity is protected not only for its intrinsic value and cultural significance, but also for these goods and services it provides[BD2].

Scotland's biodiversity

Box BD1: Scotland's biodiversity in context

Scotland's biodiversity has developed over a relatively short period since the last ice age, which ended around 10,000 years ago. As the ice retreated, the land surface and the freshwaters began to be colonised with the arrival of species:

- dispersed by air (e.g. birds and plants where seed was carried on the wind, across the sea or by birds);
- that could reach Scotland by the sea (e.g. fish such as the eel, salmon and stickleback).

The relatively short period for the establishment of the species and habitats which make up Scotland's ecosystems means that there has been little time for new species to evolve from existing ones. The fauna and flora of Scotland are, therefore, generally characterised by species that have:

- good dispersal abilities;
- arrived from neighbouring geographical areas.

The Scottish landscape we see today consists of:

- a few remnants of the original colonising species and habitats;
- habitats derived from prehistoric human activities and species that these support;
- habitats resulting from the more recent intensification of agricultural and industrial activity, and increasing urbanisation over the last 250 years, with the species that inhabit these.

Scotland's environment supports some 90,000 species of animal, plant and microbes (Box BD2). The vast majority of these we know very little about, the focus of our knowledge being largely on birds, mammals, fish, amphibians, reptiles and vascular plants, even though together they make up less than 2% of the total. For example, there are an estimated 24,800 species of invertebrate many of which are marine and most of which have received very little attention.

These species inhabit a wide range of habitats; Scotland's climate, geology and physical landscape combining to provide a tremendous variety of natural habitats which have subsequently been altered and modified by human activity. The current landscape is a mosaic of habitats reflecting their various influences over time, from the seas and coastal waters, to rivers and lochs, farmland and forests, mountains and moorland.

Box BD2: The number of species

The estimated number of species in the taxonomic groups that occur on land and in the sea (the estimates include all land to the summit of Ben Nevis, all fresh waters and all sea out to approximately the 12 mile limit around the Scottish coast) are:

Single-celled organisms (including viruses, bacteria and protozoa	c. 44,100
Fungi (including lichens)	c. 9,140
Algae	c. 9,000
Mosses and liverworts	928
Vascular plants (ferns, conifers, flowering plants)	1,080
Invertebrate animals (including slugs and snails, sea shells, starfish, worms of all kinds, sponges, insects, spiders and mites)	c. 24,800
Fish (both freshwater and sea water)	244
Amphibians (frog, toads and newts)	6
Reptiles (lizards, snake and turtle)	4
Birds (species breeding in Scotland)	242
Mammals (including whales and dolphins)	63
Total	c. 90,000

Source : The Scottish Biodiversity Group and The Scottish Executive, Action for Scotland's Biodiversity, 2000[BD3]

Many of the habitats are internationally important – of the 159 conservation priority habitats listed in the European Habitats Directive, Scotland has 65. In terms of protected sites, the importance of these areas in a European context is recognised in the designation of around 240 Special Areas of Conservation (SACs). Habitats of international importance include:

- heather moorland;
- upland blanket bogs and lowland raised bogs;
- Atlantic oak woods;
- machair grasslands;
- freshwater and seawater lochs.

SACs have also been designated to protect a number of key species including:

- freshwater pearl mussel (Scotland holds 50% of the world population);
- otter;
- great crested newt.

Scotland's location and it's extensive coastline and wetlands makes it very important, for migrating wildfowl and for breeding populations of seabirds. Over 140 Special Protection Areas (SPAs) have been established under the EU Birds Directive to protect the breeding, feeding and roosting habitats of migrating bird species.

In addition to these European designations, Scotland also has a network of over 1450 Sites of Special Scientific Interest (SSSIs), covering some 13% of Scotland. SSSIs represent the best examples of Scotland's natural heritage and are designated by Scottish Natural Heritage (SNH) for their plants, animals or habitats, their rocks or landforms.

At a UK level, Scotland has 41 of the 45 habitats and 261 of the 391 species identified as priorities for action in the UK Biodiversity Action Plan.

In 2005 a list of species and habitats was published (www.biodiversityscotland.gov.uk) identifying those considered by Scotland's Ministers as important for biodiversity conservation in Scotland. It includes 177 terrestrial and freshwater habitats, 197 marine species and habitats, and 1806 terrestrial and freshwater species (including 61 endemic to Scotland).

The state of the natural environment

The state of the environment has a direct impact on biodiversity (see table BD1). Water, land and air quality can all influence biodiversity, often through the impact of human activity.

Table BD1: Example implications of key environmental issues for biodiversity in Scotland

Aspect*	Implications
Climate change	• Changes in abundance and distribution of species and length of growing season. • Higher temperatures less favourable for native species and habitats. • High intensity rainfall causing destruction to river habitat. • Increased erosion and siltation with consequences for fish spawning. • Disruption to food chain with potential catastrophic loss of species (e.g. island breeding seabird populations).
Water quality	• Continued increases in nitrogen and phosphorus levels in surface waters, principally from intensive agricultural practices, are driving ecological changes in plant communities in a number of rivers, lochs and estuaries in Scotland. • Certain species of flowering plants and algae thrive on the excess nutrients. The resulting prolific growth may reduce the amount of oxygen and sunlight in the water, threatening the survival of other plants, invertebrate and fish.
Water resources	• More frequent and severe river flooding leads to more dynamic river habitats, which can affect river ecology. • Increased likelihood of summer droughts, leading to river water quality problems, may have significant impacts on invertebrates and fish.
Rural land use	• Intensification of agricultural land use, particularly during the 20th century, led to declines in many traditional agricultural habitats, along with declines in their distinctive biodiversity. • Recent changes in funding support for agriculture offer significantly greater opportunities to manage farmland for the benefit of biodiversity. • Poor forestry management, causing damage to habitats, led to the introduction of guidelines covering nature conservation in 1990. • Ongoing redesign of conifer plantations is helping to improve biodiversity by creating a greater mix of tree ages, increased species and structural diversity. • Replanting of native broadleaf woodlands has increased greatly in recent years, significantly increasing the area of tree cover, particularly in lowland Scotland.
Urbanisation	• Conversion of farmland and semi-natural habitats through development for housing or industrial developments results in a loss of habitats and associated species. • Transport corridors can lead to fragmentation of habitats and isolation of populations of rare or threatened species. • Development pressure has been reduced to some extent by the use of previously developed derelict or vacant land in urban areas. Pressure for development on previously undeveloped land is still high. • Major land reclamation in former mining areas and projects such as the Central Scotland Forest and the Millennium Link restoration of the Forth and Clyde and Union Canals are improving the urban environment and increasing opportunities for linking up areas of isolated urban habitats.

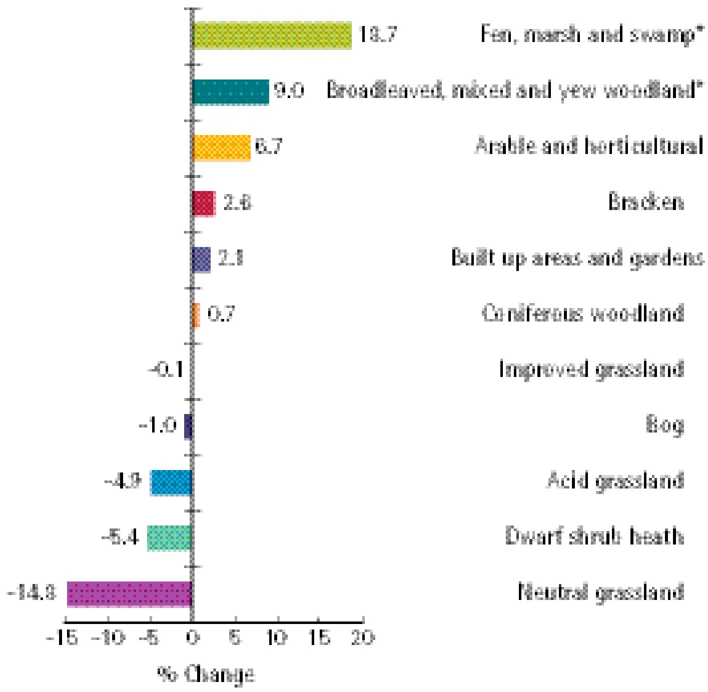
Air quality	• Scotland is currently meeting air quality objectives in relation to the protection of vegetation and ecosystems. There is, however, still the potential for contributions from these pollutants to the acidification and eutrophication of ecosystems. • In Scotland, ground-level ozone concentrations rarely attain levels high enough to induce visible symptoms on leaves, but long-term exposure to lower concentrations can reduce plant growth. Such effects could impose stresses on ecosystems and induce subtle shifts in plant species diversity.
Acidification	• Acidification is a potential problem across large areas of upland Scotland, but evidence of ecological damage is mainly confined to freshwaters in Galloway and smaller areas of the Cairngorms and the western and central Highlands. • As a result of reduced acid deposition in Scotland, the extent of acid-sensitive terrestrial vegetation affected by acidification has declined, with some areas showing signs of recovery. • Some rivers and lochs across Scotland are showing signs of recovery, but acidification is still causing others to be devoid of acid-sensitive plants, invertebrates and fish.
Nutrient enrichment of land and soils	• Nutrient enrichment of terrestrial habitats alters the competitive balance between different plant species, which can result in the loss of some key species important for sustaining habitat diversity. • Nutrient enrichment of semi-natural habitats, such as heathland and woodland, is linked to the deposition of nitrogen and ammonia from the air. • The total area at risk in Scotland fell from 19,802 km^2 in 1995–1997 to 16,322 km^2 in 2001–2003, though the potential for damage to specific habitats is still high. • Upland areas are most vulnerable owing to the combination of sensitive habitats and higher nitrogen deposition from higher rainfall and cloud mist.

*See the relevant chapters for detailed information about these aspects.

The Countryside Survey carried out in 1998 shows the latest position regarding broad habitat types (see land chapter), and changes since 1990 have been analysed by SNH[BD4]. However much of the loss of biodiversity had already occurred before 1990 – for example native Caledonian forests had been reduced to only 1% in of their previous extent by the 1970s (due to human activity) and lowland raised bogs to less than 11% of their former range.

Since 1990, the net change in broad habitat types shows a significant overall increase in area of fen, marsh and swamp habitats and in some broadleaved woodland, but loss of neutral grassland, particularly in the uplands and the islands (see Figure BD1).

Figure BD1: Net change in broad habitats, 1990–1998



* indicates significant change

Source: SNH, Natural Heritage Trends: Broad Habitats (1990 – 1998) Summary, 2004[BD4]

For species, the situation is similarly mixed. For birds which are one of the most comprehensively monitored group and focus of conservation action, numbers of corncrakes in Scotland exceeded 1,100 in 2005, the highest number recorded by the RSPB in 27 years, up from only 470 calling males in 1993. Similarly, the reintroduction of species such as the red kite and the sea eagle has been a success, as has the spread of the osprey through Scotland. However, the breeding success of many seabirds at Scottish colonies has been very poor in recent years due to reduced fish stocks. Population changes for species monitored by the Breeding Bird Survey in Scotland are also mixed, with for example, significant decreases between 1994 and 2005 for species associated with wetland habitats such as oystercatcher, lapwing and curlew, though increases for snipe. In total, of the 52 species monitored, 7 showed a significant decline, 23 a significant increase and 22 no significant trend over this time period, though all 22 decreased[BD5].

A recent report on Scottish trends in vascular plants[BD6] compared the relative change in species occurrence between 1930 – 1969 and the later period 1987 – 1999. Almost half (46%) of species studied showed little change in their frequency of occurrence, 27% of species increased and 27% decreased. This hid some important trends though, with arable weeds declining dramatically, as to a lesser extent did some upland and grassland species, where specialist species associated with nutrient poor sites fared poorly compared to generalists. Non – native species also changed to a greater extent than native species[BD6].

Results of the 2005 reporting round of the UK Biodiversity Action Plan[BD7] have not yet been fully analysed on a national basis but revealed that:

- around 32% of priority habitats and 39% of priority species in Scotland were either stable or showing signs of recovery;
- approximately 32% of habitats and 18% of species were still declining;
- a small proportion of priority species (12%) and habitats (7%) had no clear improving or declining trend in Scotland in the period 2002–2005.

A significant issue during the 2005 reporting round was the lack of sufficient data for 29% of habitat action plans and 32% of species action plans in Scotland. For many of these plans, survey work underway at the time of reporting is expected to allow improved reporting in future.

Threats to biodiversity

The Scottish Biodiversity Group's report in 2000, Action for Scotland's Biodiversity identified 7 key issues: farming, forestry and fisheries as the main three with land development, air quality, water quality and transport. In addition they recognised the importance of awareness, education and training[BD3].

Since that time, the importance of climate change has been recognised and must now rank as a dominant force in changing Scotland's biodiversity, adding to the existing threats from habitat destruction, pollution and over–fishing/harvesting. The European Environment Agency recognises that climate change will result in changes to[BD8]:

- phenology (timing of flowering, breeding, migration, length of growing season);
- species behaviour (migration routes, response to drought/flood);
- ecosystems (loss of species unable to move/adapt);
- Carbon Dioxide (CO_2) (contribution to CO_2 storage, release and sequestration).

The most recent information on the threats to priority habitats and species in Scotland is given in:

- a review of the first five years of the UK Biodiversity Action Plan (BAP) published in 2001[BD9];
- the results of the 2002 reporting round involving lead partners for BAP priority species and habitats[BD10];
- the results of the 2005 reporting round involving lead partners for BAP priority species and habitats and local biodiversity action plan officers[BD7].

At a UK level, habitat loss and degradation was the main issue identified in most published action plans as causing priority species and habitats to decline. Agricultural practices are given as the most significant cause, followed by changing management practice and infrastructure developments. Over 70% of the UK's land area is managed for arable and livestock farming. Agricultural intensification over the past 50 years led to habitat loss and fragmentation and significant pressures on wildlife[BD9].

Land and freshwater pollution (particularly nutrient enrichment) are other significant issues for biodiversity across the UK[BD3]. These issues were ranked as a higher threat to species and habitats than atmospheric pollution, which includes impacts associated with climate change. However, the consensus today is that climate change impacts on biodiversity will continue to increase in severity as will the threat from non–native invasive species.

Conserving biodiversity

To take forward the Rio convention, the EU has set an objective in its Sixth Environmental Action programme of protecting and restoring the functioning of natural systems and of halting the loss of biodiversity in the EU by 2010. This is being taken forward in Scotland through a combination of protecting sites containing species and habitats of special importance, biodiversity action plans and the Scottish Biodiversity Strategy published in 2004[BD1]. The Strategy aims to:

- halt the loss of biodiversity and continue to reverse previous losses through targeted action for species and habitats;
- increase the awareness, understanding and enjoyment of biodiversity among the people of Scotland.

Protected sites in Scotland provide a haven for wildlife, but protected habitats and species also need a healthy environment outside the boundaries of the protected sites to thrive. The conservation of the remaining near-natural habitats in Scotland will depend on protection from development or land use changes that could have a significant impact or which may contribute to piecemeal loss or degradation of habitats. Such an approach may be justified for areas including the high mountains, remote coasts and some of the remaining relatively natural rivers and lochs.

Many habitats and species found in, or previously lost from Scotland, will require some form of continued intervention or active management to maintain or restore them. The focus on this will need to be on maintenance and improvement of existing priority habitats, the restoration of degraded sites and the recreation of new habitats. Similarly for species, maintenance and expansion of numbers of existing species will need to be prioritised ahead of extensions to their range and potential reintroductions. Examples include:

- the continuation or re-establishment of traditional management practices such as traditional woodland management or burning on heather moorland;
- more direct intervention such as the re-introduction of species extinct in Scotland (e.g. as already achieved for the red kite, sea eagle and capercaillie, and as proposed for the European beaver);
- habitat creation or restoration (e.g. managed realignment to recreate or restore saltmarsh or other coastal wetlands).

Forward look

The European Union has set a challenging target of protecting and restoring the functioning of natural systems and of halting the loss of biodiversity in the EU by 2010. The Scottish Biodiversity Strategy has established a vision for the year 2030 whereby Scotland will be recognised as a world leader in biodiversity conservation. Our understanding of the situation is continuing to improve and at this stage it remains uncertain whether the target will be met. The impact of climate change is already becoming apparent, with observed changes in behaviour, phenology and species distribution, and will be a real challenge.

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BD4	*Natural Heritage Trends: Broad Habitats (1990 – 1998): Summary*, SNH, 2004	www.snh.org.uk/strategy/landcover/home.asp
BD5	*Population Changes for Species in Scotland*, Breeding Bird Survey	www.bto.org/bbs/trends/scotland/
BD6	*Scottish Trends in Vascular Plants*, SNH, 2006	Scottish Natural Heritage
BD7	*The UK Biodiversity Action Plan: Highlights from the 2005 Reporting Round*, Defra, 2006	www.ukbap.org.uk/library/Reporting2005/UKBAPReport05.pdf
BD8	Progress towards halting the loss of biodiversity by 2010, European Environment Agency, 2006	www.eea.europa.eu
BD9	*Sustaining the Variety of life: Five years of the UK Biodiversity Action Plan*, Department for Environment, Food and Rural Affairs (Defra), 2001	www.ukbap.org.uk/Library/BIODIV1.PDF
BD10	*UK Biodiversity Action Plan – Tracking Progress – results of 2002 reporting*, Joint Nature Conservation Committee (JNCC), 2002.	www.ukbap.org.uk/2002OnlineReport/mainframe.htm

Sources of further information

Topic	Source
Biodiversity in Scotland	www.biodiversityscotland.gov.uk
UK Biodiversity Action Plan	www.ukbap.org.uk
EU biodiversity policy including the Habitats and Birds Directives	http://europa.eu.int/comm/environment/nature/home.htm
Numbers of protected sites in Scotland	www.scotland.gov.uk/Topics/Statistics/15637/sesoSubject

Climate change

Summary

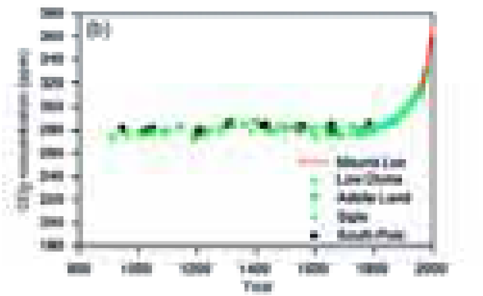
Climate change is evident in Scotland from observed trends in temperature, rainfall and snow cover. Climate change is causing changes in the growing, breeding and migration seasons, shifts in species abundance and diversity, higher river flows leading to flood risk, and sea level rise causing erosion. Left unchecked, climate change will accelerate causing damaging effects on physical, biological and chemical processes with significant consequences for Scotland's environment, economy and society.

Continued reliance on fossil fuels and growing demand for energy, for transport and for housing will escalate emissions of carbon dioxide to increasingly dangerous and potentially irreversible levels. Scotland must play its part in rapidly adopting energy conservation and efficiency measures and low carbon energy solutions. Much of the change in climate over the next 30 to 40 years is already determined by past and present emissions, so it is important that Scotland prepares itself for the inevitable impacts.

Our climate depends on the Earth's temperature. Due to rapidly increasing concentrations of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere, the temperature of the planet is rising quickly compared with relatively stable temperatures throughout the past millennium[C1].

Global carbon dioxide

Figure C1: Carbon dioxide concentration in Antarctic ice cores for the past millennium – recent atmospheric measurements (Mauna Loa) are shown for comparison[C1]

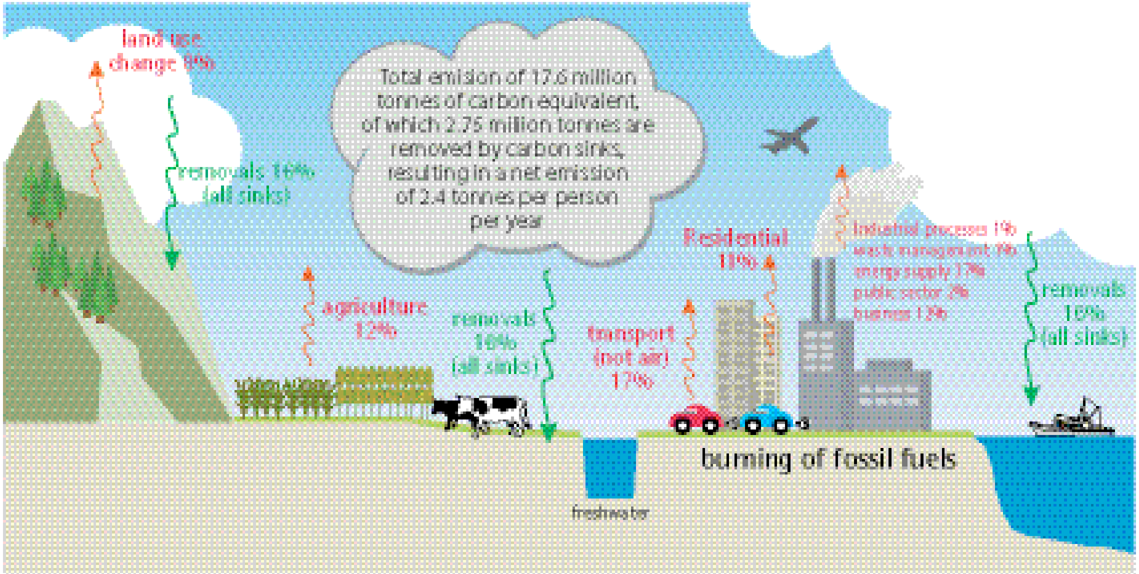


Source: IPCC (2001) Climate Change 2001: Working Group 1 - The Scientific Basis (Fig 10b)

Atmospheric carbon dioxide concentrations remained relatively constant at around 280 parts per million (ppm) for at least a thousand years, but concentrations have risen since the mid-1700s, reaching 377ppm in 2004[C1] (see Figure C1).

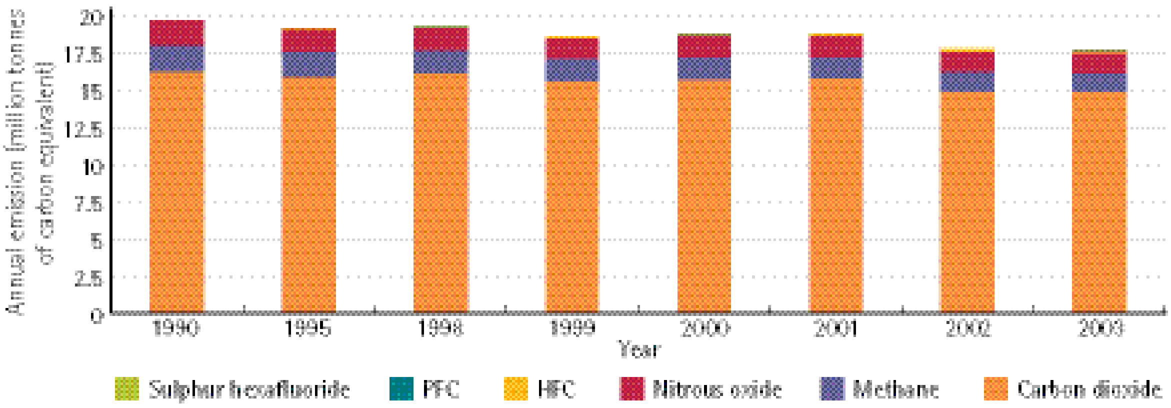
The increasing use of fossil fuels for energy generation and transport purposes means carbon dioxide is the most critical greenhouse gas. The main sources of greenhouse gases are shown in Figure C2; for further information on emissions of greenhouse gases see supplementary material[SC1].

Figure C2: Main sources and sinks of carbon emissions in Scotland[C2]



Annual emissions of the six main greenhouse gases (carbon dioxide, nitrous oxide, methane, sulphur hexafluoride, perfluorocarbons (PFC) and hydrofluorocarbons (HFC)) expressed as carbon equivalents are shown in Figure C3.

Figure C3: Scotland's greenhouse gas emissions, 1990–2003[C2]



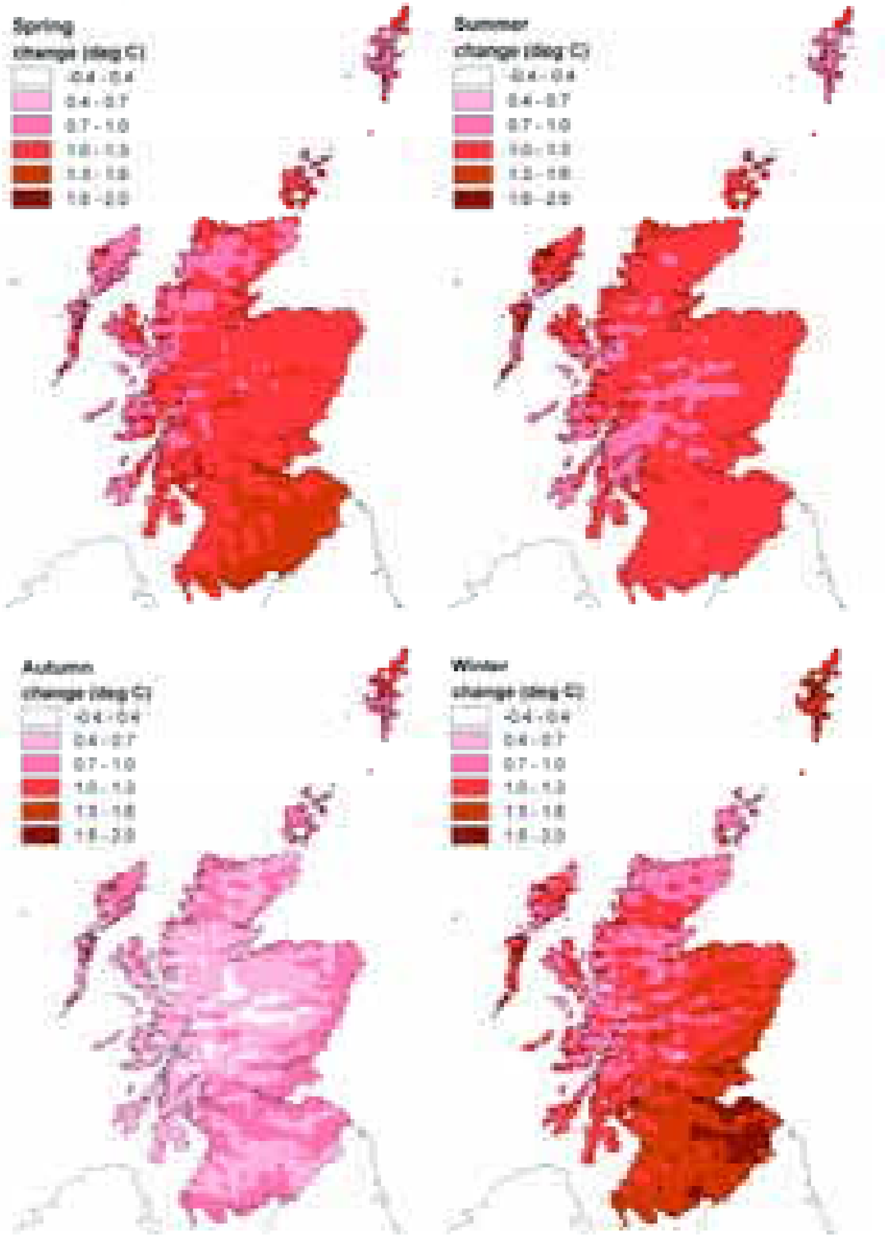
Although Scotland's carbon dioxide emissions fell by 8% between 1990 and 2003, our energy demands for transport, businesses and homes increased by over 10% during the same period[C3].

Despite methane emissions falling by 35% between 1990 and 2003[C2], significant volumes of carbon dioxide and methane could be released from soils as a result of increased temperatures or changes in land use. For example, Scotland's peat uplands are vulnerable to changes in climate and land management and, if only 0.1% is released as carbon dioxide, Scotland's emissions will double[C4].

Changing temperature

Scotland's temperature records indicate a recent and rapid warming trend; average spring, summer and winter temperatures have risen by more than 1°C since 1961[C5]. Figure C4 shows an increase in average seasonal temperatures throughout Scotland from 1961 to 2004. The largest warming trends are in south-eastern Scotland during the winter (December to February).

Figure C4: Change in mean temperature (°C) based on a linear trend, 1961–2004[C5]



Source: *Patterns of Climate Change Across Scotland: Handbook*. Project code CC03, Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), 2006.

In accordance with this general warming, frosts have occurred less frequently over the last 44 years. The annual number of days with air or ground frost has fallen by more than 25%, due largely to milder and earlier springs[C5].

Such temperature-related changes affect the plant-growing season, which compared with the 1961 baseline, now starts on average three weeks earlier and ends two weeks later[C5]. The flowering dates of some plants (particularly early spring species, such as blackthorn) have also changed and some butterflies such as the Scotch Argus have extended their range northwards while the southerly range of other species such as the Scottish Primrose is contracting[C6].

A new study of responses to climate change[C6] shows changes in the spatial distribution of plants and animals and changes in seasonal phenomena such as dormancy and migration. For example, January–February flowers such as snowdrop and wild daffodil have advanced their flowering date by three weeks since 1978.

Changing precipitation

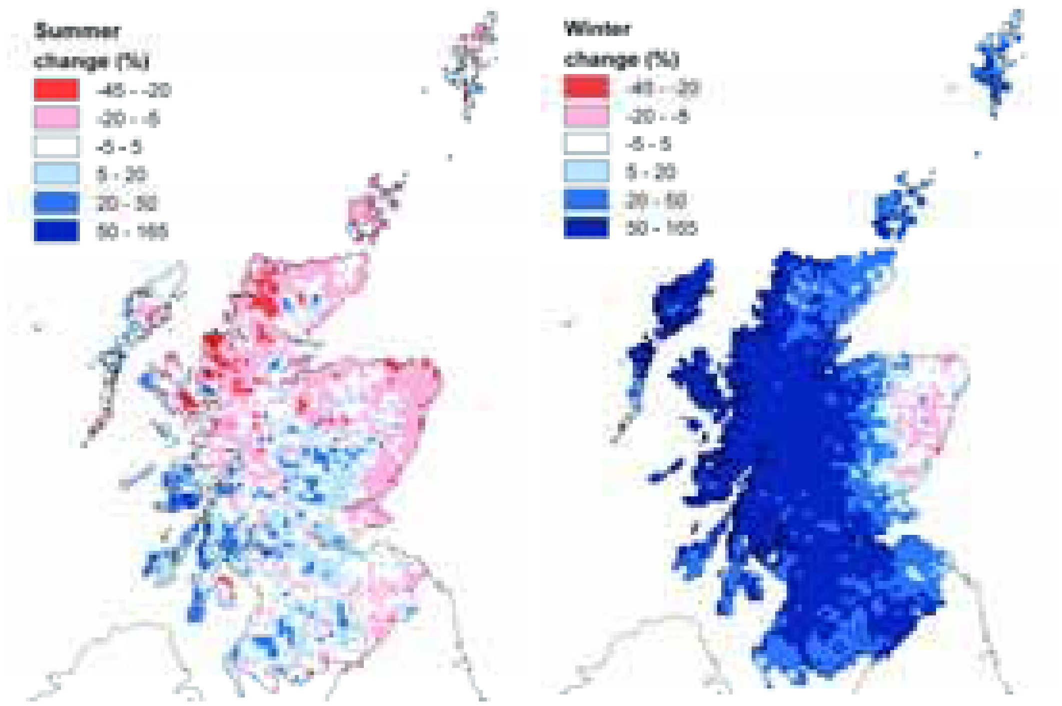
Scotland has become much wetter since 1961 with:

- an increase in average winter precipitation of almost 60% in the north and west;
- an increase in average annual precipitation of 20% for the whole country.

The increased intensity of winter precipitation across much of Scotland has implications for flooding, soil erosion (with associated implications for water quality) and landslides. Reduced rainfall in summer months, combined with more severe short duration rainfall events associated with thunder storms, could be one of the causes of an apparent increase in the frequency of landslides in Scotland[C7].

Some parts of north-west Scotland have become up to 45% drier in summer (see Figure C5).

Figure C5: Change in precipitation (%) based on a linear trend, 1961–2004[C5]

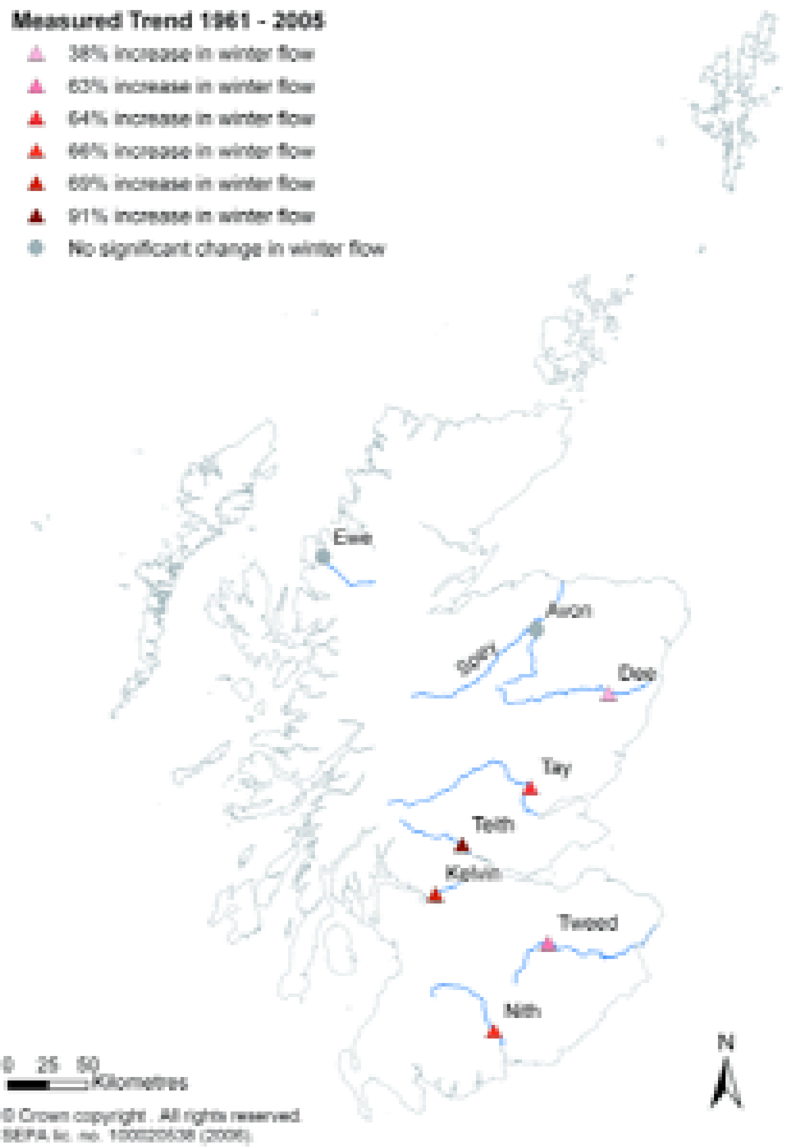


Source: *Patterns of Climate Change Across Scotland: Handbook*. Project code CC03, Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), 2006.

The period of snow cover in Scotland has decreased over the last 40 years, mainly due to snowfall occurring later in the year as a result of milder autumn and spring temperatures producing less snowfall and earlier snowmelt[C5]. Early and rapid snowmelt may increase flood risk, particularly if it coincides with high rainfall intensity.

Annual river flows show a pattern similar to rainfall trends, with no significant change for the Dee, Avon, Tweed or Ewe (trend only for 1972–2005) and about a 30% increase for the Kelvin, Nith, Tay and Teith, all of which rise in the west of Scotland. Summer flows show no significant change anywhere[C8]. Figure C6 shows substantial changes in some winter river flows.

Figure C6: Changes in winter river flows at selected locations[C8]



Analysis of Scottish river flows shows that high flow frequencies on western rivers have increased over the past two decades, while in the east values were highest in the 1950s/1960s[C8]. A cluster of extreme floods has occurred since 1988. An increase in the dominance of westerly airflows and a reduction in the days of snow cover coincide with the increased frequency of high flows. These observations appear consistent with climate change predictions.

High river flows and overloading of sewage treatment networks together with storm surges in coastal areas contribute to flooding, which is a major socioeconomic and human health issue for Scotland. Severe events can result in deaths and damage to properties. In addition to the initial shock and trauma experienced by flood victims, communities can remain affected by stress, health impacts and property blight for some considerable time[C7].

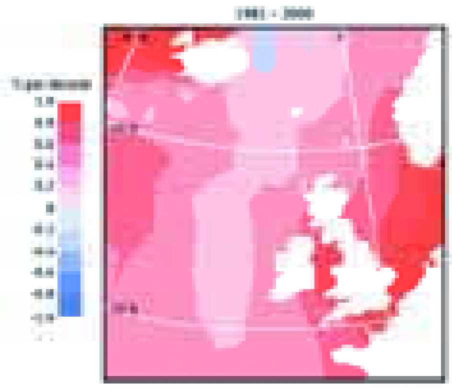
Parts of the Scottish coastline are particularly vulnerable to rising sea levels and an increase in storm surge activity, both of which are a likely consequence of climate change.

Changing marine environment

The seas around Scotland have warmed by 1°C over the last 20 years[C9] (see Figure C7). Warmer seas have prompted changes in composition, abundance and distribution of a number of marine species including plankton, fish, sea birds, whales, mammals, dolphins and porpoises[C10, C11, C12].

Warm water fish such as red mullet, sardines and anchovies have been caught off Scotland's coast since 1995[C9]. Some plankton species, which form the basis of the marine food web, have migrated north by up to 10 degrees latitude (about 700 miles)[C10]. Changes in plankton distribution and abundance have serious consequences not only for the marine ecosystem but for the ability of the oceans to absorb carbon dioxide and ultimately regulate the Earth's climate.

Figure C7: Temperature trend in degrees per decade, 1981–2000 (red shading indicates warming and blue shading indicates cooling)[C10]



Source: *Scottish Ocean Climate Status Report 2002-2003*, Fisheries Research Services, 2005.

All Scottish mainland tide gauges have recorded a sea level rise over the long term. The longest individual record indicates an average sea level rise of 0.6 mm[C11] per year at Aberdeen since 1862. Sea level rise increases the risk of flooding of coastal and estuarine towns and leads to erosion of intertidal habitats and loss of biodiversity.

Forward look

Climate change will accelerate and the impacts rapidly increase in severity if we continue with our heavy dependence on carbon-emitting energy sources. According to the latest climate change scenarios for the UK[C13], temperatures in Scotland may rise by up to 4°C by the end of the century; winters may be wetter and summers drier, winter rainfall intensity may increase and snow cover may decrease. As average global temperature increases, so does the likelihood of infrequent, high impact events. These are unlikely scenarios that could have a dramatic effect at a regional or global level. For Scotland, one of the most significant would be the slowing down and switching off of the North Atlantic deep water formation in the Artic Sea. The effect of this would be to reduce the flow of northward warm currents past the UK (popularly termed the Gulf Stream) and a reduction in our average annual temperature by up to 8°C[C14].

Table C1 summarises some of the implications for Scotland's environment and the health of its population arising from climate change. Examples are included of some of the economic consequences.

Table C1: Climate change implications for the Scottish environment, biodiversity and human health

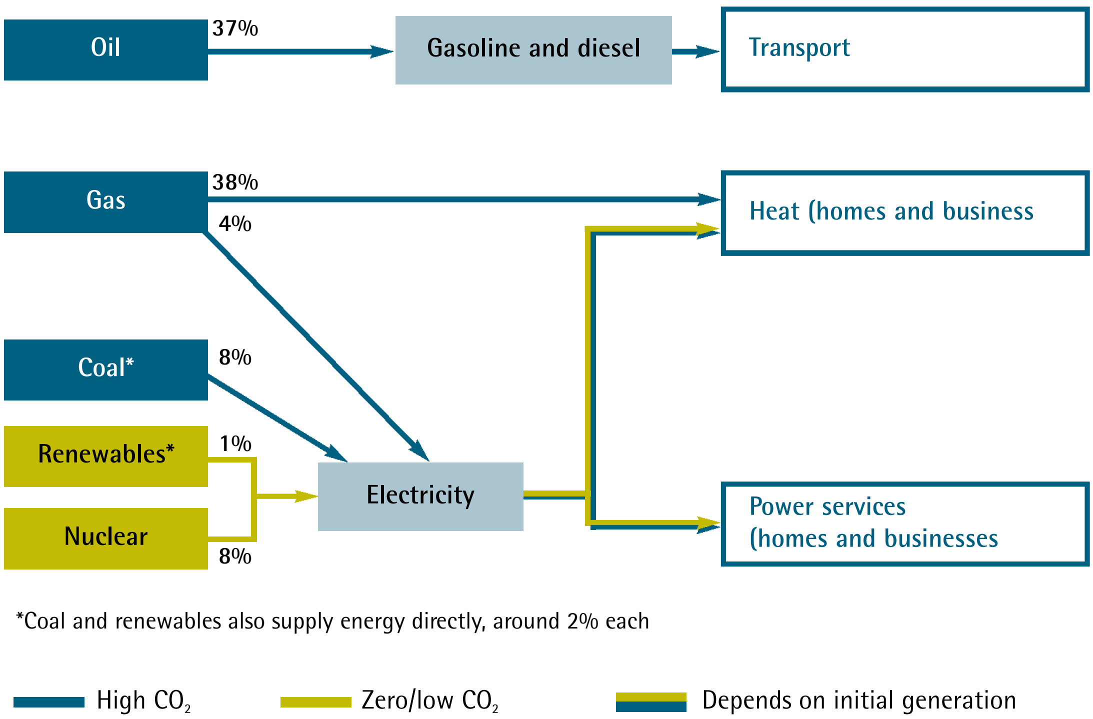
Aspect*	Implications
Water resources	• More frequent and severe river flooding, affecting 77,000 properties • Increased likelihood of summer droughts leading to river water quality problems and disruption of water supply • Limitation to abstraction practices
Biodiversity	• Changes in abundance and distribution of species and length of growing season • Higher temperatures less favourable for native species • High intensity rainfall causing destruction to river habitat • Increased erosion and siltation with consequences for fish spawning • Disruption to food chain with potential catastrophic loss of species (e.g. island breeding sea bird populations)
Marine	• More frequent and coastal flooding affecting 93,000 properties • Higher sea level, increased wave height leading to coastal erosion and loss of habitat • Loss of traditional commercial fishery
Land surface	• Drying out of soils combined with higher intensity storm events causing landslides, with potential disruption of transport links • Accelerated decomposition of peaty soils resulting in increased emissions of carbon dioxide and methane, fuelling further climate change • Increased soil loss through water and wind erosion • Changes to agricultural practice and crops (e.g. longer growing season)
Human health	• Increased flood-related stress, illness and economic costs • Increased respiratory illness and heat-related distress • Fewer cold-related deaths
Water quality	• Periods of reduced river flow providing less dilution for discharges with increased sewage treatment costs • Increased treatment costs to provide water supplies • Increased run-off impacting on bathing water quality
Air quality	• Local and regional ozone air quality goals probably more difficult to achieve in the future • An increase in summertime photochemical smog, linked to increasing temperatures and small reductions in cloud cover • Likely that the frequency of wintertime air quality pollution events will reduce
Nutrient enrichment	• Enhanced plant/algal growth due to increased temperature • Increase run-off increasing nutrient loading in water
Weather	• The weather will become more erratic and therefore less predictable, with a greater likelihood of extreme events.

*See the relevant chapters for detailed information about these aspects.

Scotland's Climate Change Programme, *Changing our Ways*[C15], sets a Scottish target to reduce annual emissions by 2.7 million tonnes of carbon by 2010. Reduction of greenhouse gas emissions requires international effort and co-operation. The European Union Emissions Trading Scheme (EU ETS) is designed to help Member States meet their greenhouse gas emissions reduction targets under the Kyoto Protocol in the most cost-effective manner (see www.dti.gov.uk/sectors/environmental/ccpo/kyotoprotocol/page20655.html). The scheme, which began on 1 January 2005, caps 45% of the UK's total carbon dioxide emissions and establishes a market for carbon trading. It will provide an important source of data to assess Scotland's future performance in reducing greenhouse gas emissions.

Box C1: The Scottish energy system

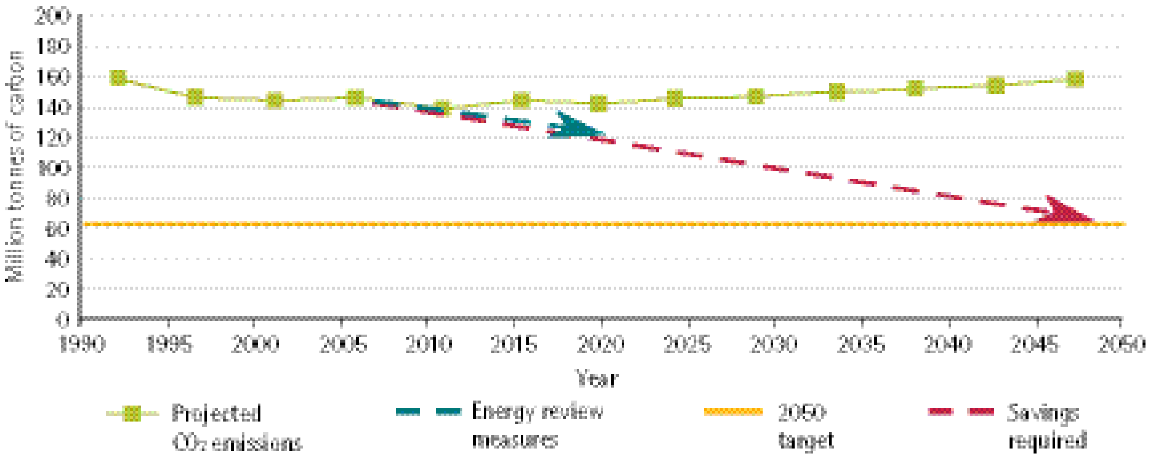
Scotland is heavily reliant on fossil fuels such as oil, coal and gas for energy and electricity generation. When burnt, fossil fuels release carbon dioxide. The figure below shows major Scottish energy flows from raw fuel to end use.



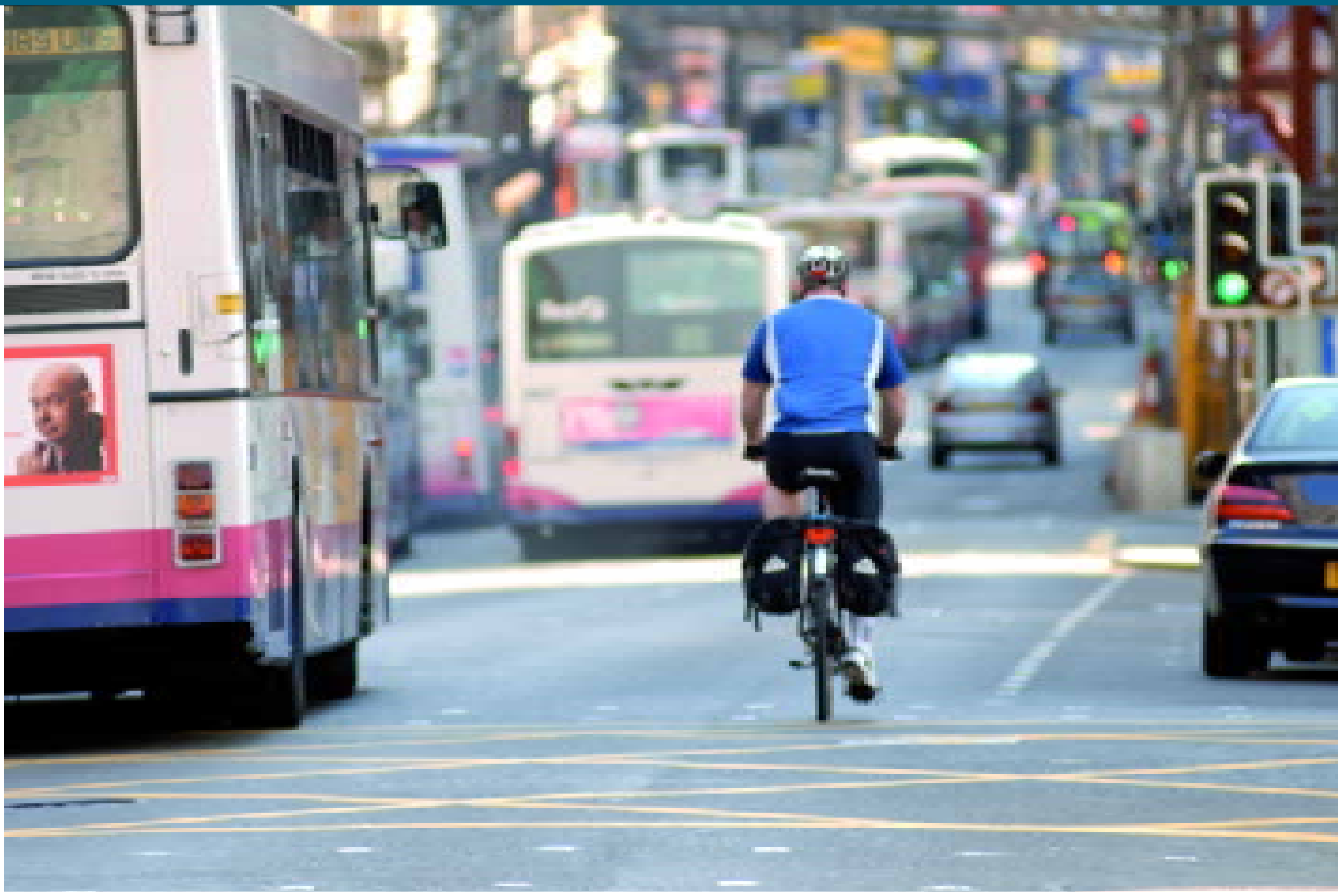
Source: Energy Review, DTI 2006 as modified using data from the Scottish Energy Study 2006

By 2010, total UK CO_2 emissions are expected to be 16.2% less than they were in 1990 due to measures contained in the 2006 UK Climate Change Programme. The 2006 UK Energy Review, published by the Department of Trade and Industry, proposed additional measures without which total emissions would have been expected to rise back to 1990 levels by 2050 due to increasing energy demand and the closure of nuclear generation plants (see www.dti.gov.uk/energy/review/index.html).

Taking account of the energy review measures, such as the renewables obligation, EU emission trading scheme, energy efficiency measures and carbon neutral developments, predicted emissions in 2020 are expected to be reduced by an additional 13% to 17% (see figure below). This figure shows projected CO_2 emissions to 2050 showing the additional effect of proposed measures in the 2006 UK Energy Review. The green dotted line illustrates how much further we have to go to achieve the UK goal of cutting CO_2 emissions by 60% from 1990 levels by 2050. There is a possibility that even more demanding targets may be required as evidence accumulates of the severity and rate of climate change.



Source: Energy Review, DTI 2006 as modified using data from the UK Energy Review 2006



Even if emissions ceased immediately, it would take decades to arrest current climate change trends due to the slow cycling rate of greenhouse gases in the atmosphere. Unless emissions are curbed sufficiently, there is an increasing risk that natural global carbon feedback processes will be thrown out of balance and further accelerate climate change. As global temperatures increase, tropical forests may start to die back and the oceans will warm and become less able to absorb carbon dioxide – both processes resulting in reduced uptake of carbon dioxide and hence higher atmospheric concentrations. Stabilisation of atmospheric concentrations of greenhouse gases at 450 parts per million by volume (ppmv) CO_2 equivalent would give a 50% chance of limiting global warming to less than 2°C above the pre-industrial era; this is considered to be the temperature above which dangerous climate change becomes likely[C16].

Scotland's greenhouse gas emissions in 2003 were comparable with the UK average of approximately 2.9 tonnes of carbon per person[C2]. The UK Government has set a goal of reducing these emissions by 60% of 1990 levels by 2050. In contrast, without urgent adoption of energy conservation, efficiency measures and low-carbon energy solutions, global carbon dioxide emissions from energy use will be expected to increase by over 60% in the next 30 years[C16]. There is clearly a need for every person in every country to work towards minimising the emissions from their lifestyle, but the deepest cuts will have to come from the most developed nations such as ours.

References

No.	Details	Available from:
C1	*Climate Change 2001: The Scientific Basis*, Third Assessment Report, Intergovernmental Panel on Climate Change (IPCC), 2001.	www.grida.no/climate/ipcc_tar/wg1/index.htm
C2	*Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland 1990-2003 Report*, National Atmospheric Emissions Inventory (NAEI) 2004.	www.naei.org.uk
C3	*Scottish Energy Study: Volume 2: A Changing Picture: Comparison of 2002 Energy Study Findings with an Earlier Study using 1990 Data*, Scottish Executive, 2006.	www.scotland.gov.uk/Publications/2006/01/19093058/0
C4	*Climate Change, Land Use and Agriculture. A Scottish Perspective*. Version: 2, Soil Association Scotland, July 2005	www.soilassociation.org/web/sa/saweb.nsf/librarytitles/64DA.HTMl
C5	*Patterns of Climate Change Across Scotland: Handbook*. Project code CC03, Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), 2006.	www.sniffer.org.uk
C6	*Natural Heritage Trends: Phenological Indicators of Climate Change*, Scottish Natural Heritage, 2006.	www.snh.org.uk/pdfs/publications/commissioned_reports/F01NB01.pdf
C7	*Technical Paper 1: Flood Risk & Insurance in England and Wales: Are there Lessons to be Learned from Scotland?* Benfield Hazard Research Centre, 2005.	www.benfieldhrc.org
C8	Analysis of unpublished SEPA hydrology data	Scottish Environment Protection Agency
C9	*Scottish Ocean Climate Status Report 2000–2001*, Fisheries Research Services, 2003.	www.marlab.ac.uk/Uploads/Documents/Ocean00_01.pdf
C10	*Scottish Ocean Climate Status Report 2002–2003*, Fisheries Research Services, 2005.	www.marlab.ac.uk/Uploads/Documents/Ocean2.pdf
C11	*Charting Progress: An Integrated Assessment of the State of UK Seas*, Department for Environment, Food and Rural Affairs (Defra), 2005.	www.defra.gov.uk/environment/water/marine/uk/stateofsea/index.htm
C12	*Natural Heritage Trends. The Marine Environment: Climate and Sea Level Changes*, Scottish Natural Heritage, 2004. *The Potential Impacts of Climate Change on Sea Levels around Scotland*, Scottish Natural Heritage, Research Survey and Monitoring Report No. 178, Scottish Natural Heritage, 2001.	www.snh.org.uk/trends/ www.shn.org.uk
C13	*Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report*, UK Climate Impacts Programme (UKCIP), 2002.	www.ukcip.org.uk/resources/publications/
C14	*Avoiding Dangerous Climate Change - Assessing the Risk of a Collapse of the Atlantic Thermohaline Circulation*, Cambridge University Press, 2006.	www.stabilisation2005.com/programme.html
C15	*Changing Our Ways: Scotland's Climate Change Programme*, Scottish Executive, 2006.	www.scotland.gov.uk/Publications/2006/03/30091039/0

C16	*Avoiding Dangerous Climate Change*. International Symposium on the Stabilisation of Greenhouse Gas Concentrations held Hadley Centre, Met Office, Exeter 1–3 February 2005. Report of the International Scientific Steering Committee, 2005.	www.stabilisation2005.com/Steering_Commitee_Report.pdf
SC1	Supplementary material on greenhouse gas emissions and removal	

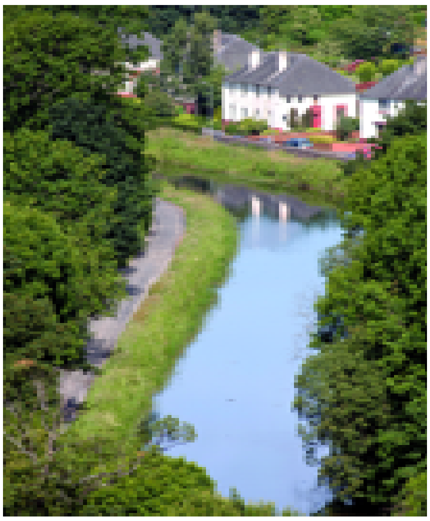
Sources of further information

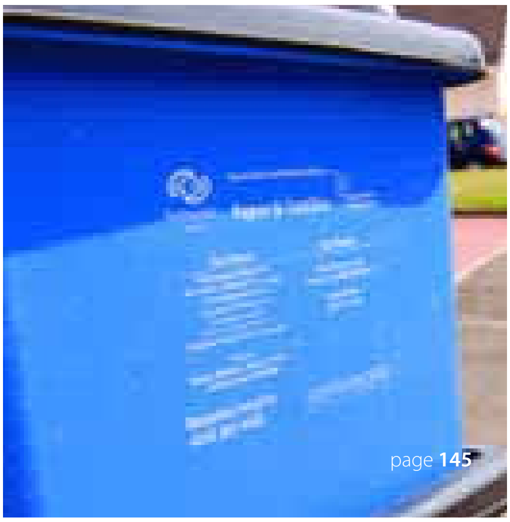
Topic	Source
Scientific issues associated with climate change	www.met-office.gov.uk/research/hadleycentre/index.html
EU ETS	www.defra.gov.uk/environment/climatechange/trading/eu/index.htm
Kyoto Protocol	http://unfccc.int/essential_background/items/2877.php
Phenology	www.phenology.org.uk

Conclusion


WALKWAY
WALKWAY


PICK YOUR OWN
FRUIT





Conclusion

The past, current and future state of Scotland's environment

One hundred years ago, foul air, filthy rivers and poor sanitation were all too common in parts of Scotland. Fifty years ago, air quality remained a problem in urban areas and rivers were polluted, but sanitation had improved significantly for most and great strides were evident in public health management. Ten years ago, SEPA was able to report that gross pollution problems had largely been dealt with, but that there were gaps in our understanding of other factors that determine the state of the environment, particularly those emanating from hidden or diffuse sources.

Today, Scottish rivers are at their cleanest for 300 years, gross air pollution from industry is declining and individual industrial sites are strictly controlled. Our understanding has improved and recently we have seen a rise in awareness of environmental issues not only by the scientific community, but also by the general public and politicians. Environmental concerns remain because we continue to consume and pollute in a manner that is not sustainable. Against this background, this report provides further information on the state of the environment in 2006. It aims to raise interest in and engagement by everyone in the debate about a sustainable future for Scotland.

The overall picture of the state of the Scottish environment is complex, with both positive and negative trends over the last decade and over longer timescales.

On the positive side:

- The legacy of industrial pollution is gradually being reduced, with land affected by contamination being identified and cleaned up;
- Most of our rivers and lochs are classified as good or excellent and support healthy populations of fish, as well as providing us with a plentiful supply of wholesome drinking water;
- There have been reductions in emissions from industrial sites of substances that cause air and water pollution or contribute to climate change, acidification and nutrient enrichment;
- The amount of waste being disposed of to landfill continues to fall as various initiatives encourage more recovery and recycling. There have also been reductions in emissions associated with landfilling;
- Man-made radioactivity levels have maintained a downward trend, with exposure associated with emissions of man-made radioactivity to the Scottish environment so small that human health can be considered as adequately protected;
- Awareness of environmental issues is rising.

On the negative side:

- Climate change is real and, if global emissions of greenhouse gases continue at current rates, there is a great risk of reaching a point whereby the change is irreversible and the consequences are potentially devastating – to human health, biodiversity, agricultural production, transport, coastal erosion and flooding;
- Increasing consumer demands and lifestyle pressures are contributing to a steady increase in resource consumption, the production of waste and our use of food, water, energy, land and transport;
- Air quality on certain days continues to present a local risk to human health in urban areas and to ecosystems in rural areas;
- Discharges to water in the form of run-off from diffuse sources in urban and rural areas remain a major source of pollution and of nutrient enrichment;
- There are aspects of our environment that contribute to ill health, jeopardise well-being and reinforce health inequalities, working against environmental justice;
- Scotland's biodiversity is under increasing threat from habitat loss, land use changes, urbanisation and the spread of non-native species, as well as climate change.

The report provides details on other areas as well, but it is clear that climate change is the greatest threat to our environment – and indeed our economic and social well-being. While generally the overall picture is one of relatively good quality, particularly in relation to many other European nations, the impacts of climate change are already beginning to be felt across all areas and aspects of Scotland's environment, and at all levels of society and economic activity.

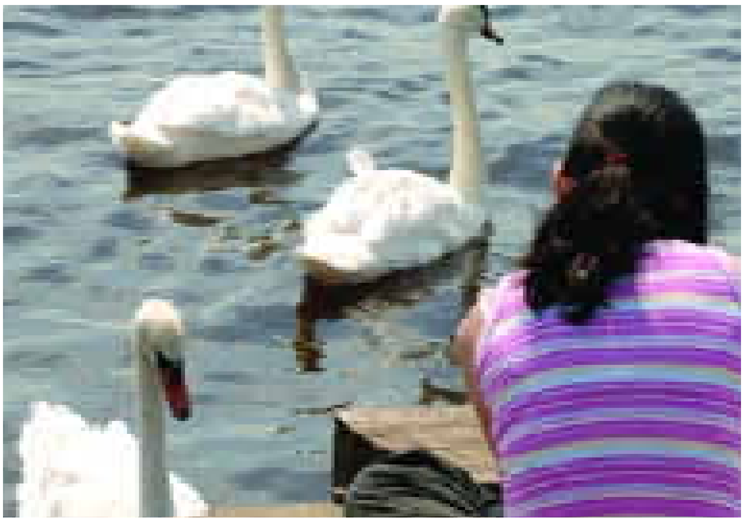
The state of Scotland's environment is largely in our hands

Although this report highlights areas where there have been and continue to be improvements in the Scottish environment, this does not mean that our current levels of consumption of natural resources and our use of materials and disposal of waste is sustainable. Action is required to maintain the current state of the environment, and further action to enhance and improve it. In doing so, we must ensure that the natural resources we consume are not at the expense of future generations but that we live within our environmental limits and ecological footprint.

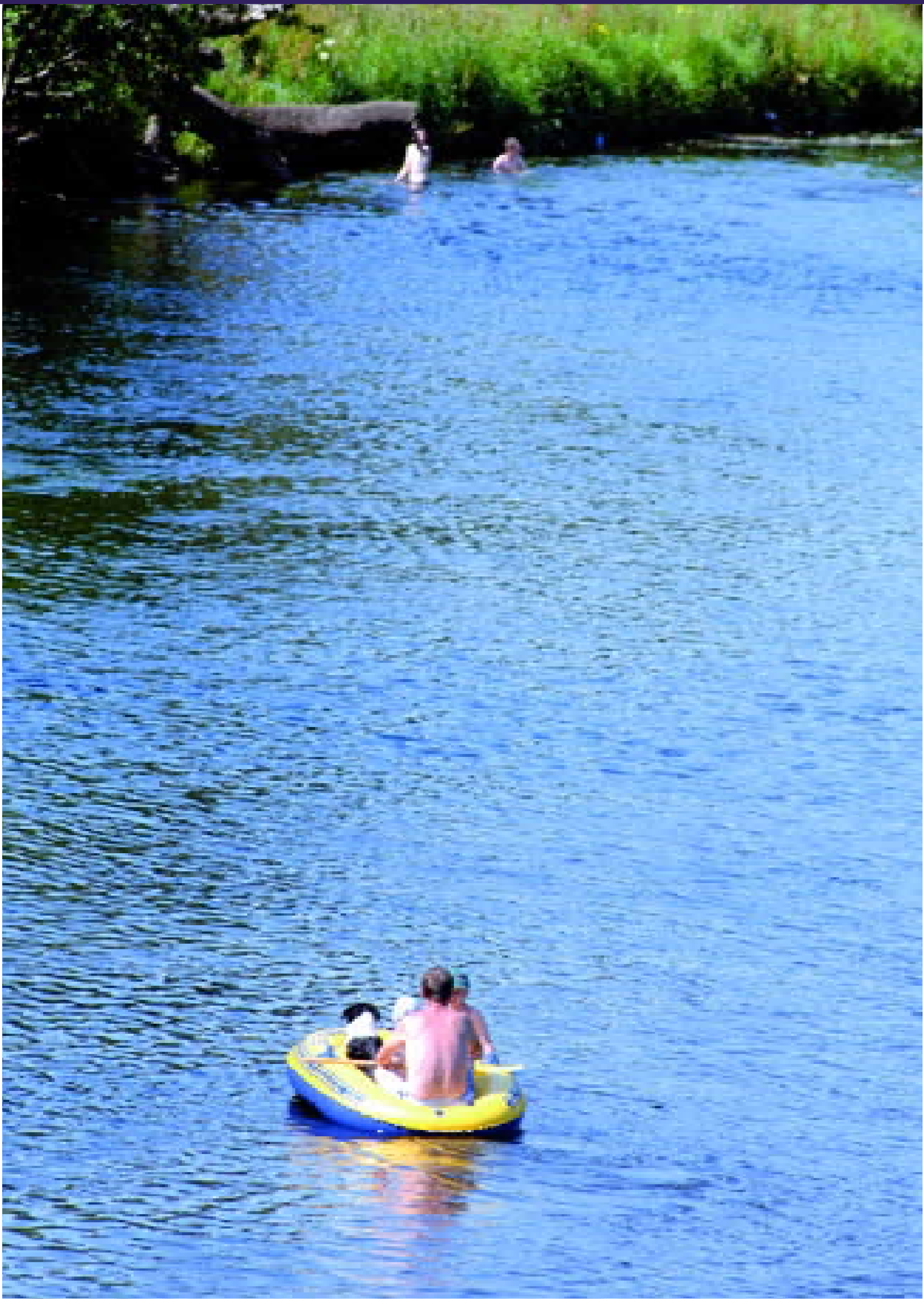
There are many challenges ahead in changing our currently unsustainable lifestyles and activities, and it is important to recognise that much of the state of Scotland's environment is largely within our own hands. Though climate change is indeed a global concern, there is still much that can and must be done 'at home'. The right decisions still need to be made within Scotland as to how our environment should be used and to what extent we shall need to change our individual behaviours to achieve this.

The underlying challenge is for all of us to make sure that our own choices of patterns of production and consumption are sustainable. These boil down to everyday choices such as: whether to walk or use public transport rather than go by car; to make more efficient use of energy in the home; to purchase locally produced seasonal food; or to recycle waste and garden rubbish. Furthermore, many of these choices have the added benefit of supporting local economies, improving our own health and saving money. We need to start making the right choices now.

Annexes



Acknowledgements



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Department of Environment, Food and Rural Affairs

Environment Agency

Environment and Heritage Service for Northern Ireland

Falkirk Council

Fisheries Research Services

Food Standards Agency

Forestry Commission

Forest Research (an agency of the Forestry Commission)

Health Protection Scotland

Joint Nature Conservation Committee

Keep Scotland Beautiful

Linking Environment And Farming

Macaulay Institute

National Society for Clean Air, Scotland

National Environment Technology Centre

Royal Society for the Protection of Birds

Scotland and Northern Ireland Forum for Environmental Research

Scottish Executive

Scottish Natural Heritage

Sullom Voe Association Limited

UK Conservation Agencies' Air Pollution Lead Co-ordination Network

United Kingdom Atomic Energy Authority

University College London - Environmental Change Research Centre

University of Abertay

Worldwide Fund for Nature

Glossary of terms

Term	Definition
A	
Abstraction	Any supply of water taken from the natural environment.
Acidification	Refers to reducing the pH of something to make it more acidic. In terms of surface waters and soils, acidification generally refers to the enhanced changes due to the deposition of sulphur and nitrogen species as a result of human activity.
Acute effect	An adverse effect on any living organism in which severe symptoms develop rapidly and often subside after the exposure stops; occurring over a short period of time; used to describe brief exposures and effects which appear promptly after exposure.
Algae	A general term for a group of photosynthetic organisms (microscopic or very large such as seaweeds), which may have bacteria-like cell structures or ones like all other organisms, containing chlorophyll *a* and a variety of other pigments, giving the organisms a range of characteristic colours.
Alpha particle	A positively charged particle consisting of two protons and two neutrons emitted by a radionuclide. These particles cannot penetrate the skin.
Ammonia	At normal environmental conditions, pure ammonia is a colourless, pungent-smelling, corrosive gas. For more information see www.apis.ac.uk/overview/pollutants/overview_NH3.htm and www.sepa.org.uk/spri/substance/sublist.aspx
Atom	The simplest unit into which a substance can be broken down while retaining its unique identity and properties. Atoms consist of a central nucleus with a net positive electrical charge, orbiting around which are small, lightweight, negatively charged particles called electrons.
Authorised disposal	Disposals (including discharges and emissions) of radioactive waste made from nuclear installations authorised under the Radioactive Substances Act 1993.
B	
Background radiation	The radiation level to which the general population is exposed. It consists of radiation from outer space and radiation from radionuclides in rocks, soil, air, food and from within the human body.
Becquerel (Bq)	The standard international unit of radioactivity, corresponding to one nuclear disintegration per second. Multiples of the becquerel such as the Megabecquerel (MBq) (1 million becquerels) are frequently used.
Best Practicable Environmental Option	The outcome of a systematic consultative and decision-making procedure which emphasises the protection and conservation of the environment across land, air and water for a given set of objectives. It is the option that provides the most benefits or least damage to the environment as a whole, at acceptable cost, in the long term as well as the short term.
Beta particle	An electron emitted by the nucleus of a radionuclide. The electric charge may be positive (positron). These particles can penetrate the skin but can be stopped by a few millimetres of metal.
Bioaccumulative	The uptake of chemicals from the environment and their concentration and retention by organisms (e.g. in fatty tissue).
Biocide	An agent that controls harmful organisms by killing them.
Biodiversity	The richness and complexity of plant and animal communities.

Biomarker	A normal metabolite that, when present in abnormal concentrations in certain body fluids, can indicate the presence of a particular disease or toxicological condition.
Borehole	Any exploratory hole drilled into the Earth or ice to gather geophysical data. Climate researchers often take ice core samples, a type of borehole, to predict atmospheric composition in earlier years.
Buffering capacity	The resistance of water or soil to changes in pH.
Buffer strip	A 1–5 metre strip of agricultural land left uncultivated alongside watercourses to minimise erosion.
C	
Carbon equivalent	A metric measure used to compare emissions of different greenhouse gases based on their global warming potential (GWP).
Catchment	An area from which surface run-off is drained away into a river.
Catchment sensitive farming	Catchment sensitive farming is a pro-active approach to reducing agricultural sources of diffuse pollution within river catchments, through land management practices.
Chlorophyll	The main green photosynthetic pigment of algae. Chlorophyll *a* is used widely as a measure of algal biomass.
Chronic effect	Long-lasting or frequently recurring.
Climate change	A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.
Commercial waste	Waste arising from premises that are used wholly or mainly for trade, business, sport, recreation or entertainment, excluding household and industrial waste (as defined in Environmental Protection Act 1990, Section 75).
Composting	The controlled biological decomposition and stabilisation of biodegradable materials (such as organic garden and kitchen wastes) under predominantly aerobic (oxygen-rich) conditions to produce a humus rich, sanitised and stabilised product that can be beneficial to soil.
Construction and demolition (C&D) waste	Arising from the construction, repair, maintenance and demolition of buildings and structures. It mostly includes brick, concrete, hardcore, subsoil and top soil, but it can also include quantities of timber, metal and plastic.
Controlled waste	Household, industrial and commercial waste or any such wastes that require a waste management licence for treatment, transfer or disposal (as defined by Environmental Protection Act 1990, Section 75).
Cosmic radiation	Ionising radiation from outer space that penetrates the Earth's atmosphere and contributes to background radiation.
Critical load	A quantitative estimate of exposure to one or more pollutants below which, according to present knowledge, significant harmful effects on sensitive elements of the environment do not occur. Ecosystems that can tolerate acidic pollution have high critical loads, while sensitive ecosystems have low critical loads.

Critical level	The concentration of a pollutant in the atmosphere above which, according to present knowledge, direct adverse effects on plants, ecosystems or materials may occur.
Cross-compliance	The conditions that a producer must respect in return for support under the Single Farm Payment Scheme i.e. maintain their land in good agricultural and environmental condition and respect regulations relating to public, animal and plant health, environmental protection and animal welfare.
Cyanobacteria	A community of largely microscopic photosynthesising organisms with bacteria-like structures, but which also contain chlorophyll *a* and pigments similar to that found in other algae. They are commonly referred to as blue-green algae although their characteristic pigments may be red, brown and purple.
D	
Debris flow	The rapid movement down slope of fragments of loose material (rock, soil, mud) produced as a result of the breakdown of minerals and rocks
Decay	The process of spontaneous transformation of a radionuclide. The decrease in activity of a radioactive substance.
Deposition	The processes by which chemical constituents move from the atmosphere to the Earth's surface. These processes include precipitation (wet deposition such as rain or cloud fog) as well as particle and gas deposition (dry deposition).
Derelict land	Land that has been so damaged by development or use that it is incapable of development for beneficial use without rehabilitation, and which is not being used for the purpose for which it is held or for a use acceptable in the local plan. Derelict land also includes unused land where known or suspected contamination could affect development. Examples of derelict land include disused mines and mineral workings, abandoned industrial areas and disused manufacturing sites.
Diatoms	A group of algae, brown and yellow in colour commonly found in waters. Their cell walls are made of polymerised silicate acting like a glass shell, which makes them readily preserved in sediments when the organic part decays.
Diffuse pollution	Pollution arising from land use activities (urban and rural) dispersed across a catchment or sub-catchment, and which does not arise as a result of the discharge of an industrial, domestic sewage, deep mine or farm effluent (this is point source pollution).
Dioxins	Dioxins and furans are families of complex chemicals containing chlorine. There are several hundred dioxin substances. They are crystalline solids which dissolve in organic (carbon-containing) solvents, fats and oils – but not in water. For more information see www.sepa.org.uk/spri/substance/sublist.aspx
Dry deposition	Direct input of atmospheric pollutants onto surfaces or uptake by plants upon contact with the ground; this pathway is important for uptake of gases and particles.
E	
Ecosystem	Living organisms (species, populations and communities of plants and animals), their physical environment (habitat) and their inter-relationship within a particular system.
Effective dose	A measure of the radiation dose to the body as a whole which takes account of the susceptibility of organs and tissues to radiation damage. The unit of measurement is the sievert (Sv).

Effluent	A discharge of pollutants into the environment, partially or completely treated or in its natural state. Generally used in regard to discharges into waters.
Electron	A negatively charged particle. Electrons make up the outer shells of an atom.
Endemic	Species native to, and restricted to, a particular geographical region.
Endocrine disruptor	A chemical that alters functions of the endocrine system, consequently harming an individual organism, its offspring or its populations.
Engineering works	These include activities such as river straightening, dredging, bank reinforcement, bridge building and gravel removal in rivers and lochs.
Environmental Quality Standard (EQS)	A regulatory value defining the maximum concentration of a potentially toxic substance which can be allowed in an environmental compartment, usually air or water, over a defined period. It can also be used to establish the allowable minimum concentration for necessary substances such as dissolved oxygen in water.
Epidemiology	The branch of medical science concerned with the occurrence, distribution, and control of diseases in populations.
Episode (pollution)	An air pollution incident in a given area caused by a concentration of atmospheric pollutants under meteorological conditions that may result in a significant increase in effects on people and ecosystems.
Erosion	Erosion consists in the removal of soil or rocks by water or wind. It is a natural phenomenon but it can be accelerated by human activities.
Eutrophication	The enrichment by nutrients, especially compounds of nitrogen and/or phosphorus, causing an increase in the growth of algae and plants that produces an undesirable disturbance to the natural balance of the ecosystem.
F	
Faecal coliforms	A specific type of coliform bacteria found only in the gut, where they can aid the digestion of food, and consequently can be found in waters suffering recent contamination with human sewage or animal faeces. The number of faecal coliform bacteria found in 100 millilitres (ml) of water is used as an indicator of pollution by faecal material.
Fertiliser	Any substance containing nitrogen or phosphorus compounds that is used on land to enhance growth of vegetation including livestock manure, sewage sludge or other organic material.
Flood plain	Any normally dry land area that is susceptible to being inundated by water from any natural source. This area is usually low land adjacent to a stream or lake.
Fluorocarbons (FCs)	Organic compounds analogous to hydrocarbons in which one or more hydrogen atoms are replaced by fluorine; was used as a propellant for domestic aerosols, now found mainly in coolants and some industrial processes. FCs containing chlorine are called chlorofluorocarbons (CFCs). They are believed to be modifying the ozone layer in the stratosphere, thereby allowing more harmful solar radiation to reach the Earth's surface.
Fly tipping	The illegal deposit of any waste onto land, i.e. waste dumped or tipped on a site without a licence to accept waste.
Fugitive emissions	Emissions not caught by a capture system. Often due to equipment leaks, evaporative processes and windblown disturbances.

G	
Gamma ray	High energy photons, without mass or charge, emitted from the nucleus of a radionuclide as an electromagnetic wave following radioactive decay. The rays are very penetrating.
Gauging station	A permanent fixture at which hydrologists measure river flows.
Global warming potential	This is a method of comparing relative radiative forcings of different greenhouse gases. A base unit of CO_2 has a nominal GWP of 1, and other gases are calculated as a ratio from the radiative forcing of 1Kg of the gas compared to 1Kg of CO_2 over a period of 100 years. For example, nitrous oxide has a GWP of 310 because per kilogram it is 310 times more "radiatively forcing" (absorbent) than CO_2. However, nitrous oxide is much less concentrated in the atmosphere. So although it has a higher GWP, the gross effect of CO_2 on the greenhouse affect is still much greater than that of nitrous oxide.
Good agricultural and environmental conditions	The standards/requirements set out in European Council (EC) Regulation 1782/2003, governing Common Agricultural Policy reform, namely: to protect the soil from erosion; to maintain organic matter levels in the soil; to maintain soil structure; and to ensure a minimum levels of maintenance for, and avoid deterioration of habitats.
Greenhouse gases	A gas that contributes to the natural greenhouse effect. The Kyoto Protocol covers a basket of six greenhouse gases (GHGs) produced by human activities: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Annex I Parties' emissions of these gases taken together are to be measured in terms of carbon dioxide equivalents on the basis of the gases' global warming potential. An important natural GHG that is not covered by the Protocol is water vapour.
Groundwater	The term groundwater refers to all water which is below the surface of the ground in the saturated zone and which is in direct contact with the ground or subsoil.
H	
Habitat	Place where an organism (e.g. human, animal, plant, micro-organism) or population of organisms live, characterised by its surroundings, both living and non-living
Hazardous waste	A term applied to those wastes that because of their chemical reactivity, toxic, explosive, corrosive, radioactive or other characteristics, cause danger, or are likely to cause danger, to health or the environment.
Household waste	Waste from domestic properties including waste from caravans, residential homes and premises forming part of an educational establishment or part of a hospital or nursing home.
Hydromorphology	A term used in the Water Framework Directive to describe a suite of morphological and hydrological attributes (quality elements) that must be protected to achieve Ecological status objectives.
Hydromorphological change	A change in any hydromorphological quality element.
I	
Imposex	A pseudo-hermaphroditic condition in female gastropods (snails) manifested by the development of a false penis.

Impoundment	Any dam, reservoir, weir or any structure which creates a barrier across a watercourse. If a structure raises the natural water level of an existing loch, this also constitutes an impoundment.
Incineration	The controlled burning of waste, either to reduce its volume or its toxicity.
Indicator	Observed value representative of a phenomenon to study. In general, indicators quantify information by aggregating different and multiple data. The resulting information is therefore synthesised.
Inert waste	Wastes that do not undergo any significant physical, chemical, or biological transformations when deposited in a landfill.
Industrial waste	Waste from a factory (within the meaning of the Factories Act 1961) or from any premises used for, or in connection with: • provision of public transport; • public supply of has, water, electricity or sewerage services; • provision to the public of postal or communication services.
Infiltration	The gradual flow or movement of water into and through (to percolate or pass through) the pores of the soil.
Inorganic	Composed of material other than plant or animal matter.
Ion	Charged particle formed when an atom loses or gains one or more electrons.
Ionising radiation	Radiation that produces ionisation in matter. Examples are alpha particles, beta particles and gamma rays.
J	
K	
L	
Land	For the purposes of this report, land consists of surface vegetation, plant material, soil and rock.
Land cover	The physical state of the land such as the quantity and type of surface vegetation, water and earth materials.
Landfill	Area of land in or on which waste is deposited. Land sealing
Land use	The human employment of the land; a change in land use at any location may involve a shift to a different type of use (e.g. from farming to residential) or a change in the intensity of use.
Land management contracts	Proposed support system, part of the Agriculture Strategy, that recognises the variation in farming across the country (see www.scotland.gov.uk/Topics/Agriculture/Agricultural-Policy).
Leaching	Process by which water removes chemicals (e.g. from soil) through chemical reactions and the downward movement of water.
Littoral	Refers to the coast or to the banks of a river, lake or estuary.
Littoral Zone	The littoral zone is defined as the area between the high water and low water marks. The littoral zone is bordered by the supra-littoral zone, also known as the "spay zone".
M	
Macroinvertebrate	Any non-vertebrate organism that is large enough to been seen without the aid of a microscope and lives in or on the bottom of a body of water.

Mesotrophic lakes	Reservoirs and lakes which contain moderate quantities of nutrients and are moderately productive in terms of aquatic animal and plant life
milli-sievert (mSv)	One thousandth of a sievert.
Moderate pollution	Concentration of a pollutant in air potentially causing mild effects, unlikely to require action, which may be noticed amongst sensitive individuals
Montane habitats	Montane habitats are found in mountain areas above the natural tree level. These alpine and sub-alpine areas represent some of the most natural and undisturbed habitats in the UK.
Morphology	Physical attributes that describe the shape, form and texture of river or loch environments, e.g. bars, sediment, riffles.
Municipal waste	Household waste and any other waste under the control of local authorities or their agents acting on their behalf.
N	
Nanoparticle	A nanoparticle is a microscopic particle whose size is measured in nanometres (nm). It is defined as a particle with at least one dimension less than 100 nm.
Nitrate Vulnerable Zone (NVZ)	An area designated in accordance with the requirements of the European Commission's Nitrates Directive 91/676/EEC, which aims to reduce water pollution caused by nitrates from agricultural sources (see www.scotland.gov.uk/Topics/Agriculture/Environment/NVZintro/NVZintr.)
Nitrogen oxides (NOx)	Oxides of nitrogen (NOx) is the term usually used to refer to nitric oxide (NO; a colourless and odourless gas) and nitrogen dioxide (NO2; a red-brown gas with a pungent smell that is soluble in water). For more information see www.apis.ac.uk/overview/pollutants/overview_NOx.htm and www.sepa.org.uk/spri/substance/sublist.aspx
O	
Organic	Containing carbon compounds.
OSPAR	The Convention for the Protection of the Marine Environment of the North East Atlantic (known as the OSPAR Convention), to which the UK is a party, agreed a strategy to 'prevent pollution of the maritime area by continuously reducing discharges, emissions and losses of hazardous chemicals with the ultimate aim of achieving concentrations in the marine environment near background values for naturally occurring chemicals and close to zero for man-made synthetic chemicals.'
Ozone	A pungent, colourless, toxic gas. Close to the Earth's surface ('tropospheric ozone'), it is produced photochemically from hydrocarbons, NOx and sunlight, and is a major component of smog. In the stratosphere, it protects the earth from harmful ultraviolet radiation. For more information see www.apis.ac.uk/overview/pollutants/overview_O3.htm
P	
Particulates	This term is used to describe particles of soot (carbon), metals or inorganic salts. They vary in size and shape and are usually classified according to size categories: typically less than or equal to 10 µm (PM_{10}); and less than or equal to 2.5 µm ($PM_{2.5}$) (1 µm = 1 millionth of a meter). For more information see www.sepa.org.uk/spri/substance/sublist.aspx

Percolation	The movement of water downward and radially through suburface soil layers, usually continuing downward to ground water. Can also involve upward movement of water.
Perfluorooctane sulphonate (PFOS)	A perfluoroalkylated substance with surface active properties used in a variety of applications including polymers.
Persistent	The ability of a chemical to remain unchanged in the environment. Persistent chemicals can become distributed worldwide, particularly in the marine environment or the atmosphere.
Pesticide	Any substance, preparation or organism prepared or used (among other uses) to: protect plants or wood or other plant products from harmful organisms; regulate the growth of plants; give protection against harmful creatures; or render such creatures harmless.
pH	A scale that denotes how acidic (<pH 7) or basic (> pH 7) a substance is based on the measurement of hydrogen ions in solution. The smaller the number on the pH scale, the more acidic the substance is.
Phenological	The science of the relations between climate and periodic biological phenomena, e.g., the fruiting of plants or the colour change of leaves.
Phytoplankton	A community of largely microscopic algae, adapted to suspension in waters, and maintained in suspension by wind-generated water currents.
Plankton	A term used to describe a community of plants and animals adapted to suspension in open water, and maintained in suspension by wind-generated water currents.
Point source pollution	Pollution caused by a discharge from a fixed installation such as the end of a pipe, stack or drain.
Pollutants	Substances which, when present in the environment under certain conditions, may become injurious to human, animal, plant or microbial life, or to property, or which may interfere with the use and enjoyment of life or property.
Polychorinated biphenyls (PCBs)	PCBs are mixtures of 209 different chemicals (cogeners) which come in various forms including oily liquids, solids and hard resins. They are very persistent in the environment, taking years to degrade. They are fat-soluble and bioaccumulate in the tissues of animals. PCBs have become worldwide pollutants due to long-distance transport on air currents.
Polycyclic aromatic hydrocarbons (PAHs)	PAHs are a group of compounds formed during the incomplete combustion of coal, oil, gas, wood, garbage or other organic substances.
Q	
R	
Radiation	The process of emitting energy as waves or particles. The energy thus radiated.
Radon	Radioactive gas formed principally during the decay of uranium and thorium.
Radioactive	Possessing the property of radioactivity.
Radioactivity	The property of radionuclides of spontaneously emitting ionising radiation.
Radionuclide	An unstable nuclide that emits ionising radiation.
Recharge	Recharge is the replenishment of groundwater. This can be from rainfall or surface water percolating down from the ground surface, or by leakage from other groundwater bodies. Recharge is largely controlled by the nature of the overlying soil and rocks as well as rainfall.

Recovery	Generating value from wastes from a wide variety of activities such as recycling, composting and energy recovery.
Recycling	Using waste materials in manufacturing other products of an identical or similar nature.
Regulated processes	A process subject to regulation by SEPA
Relative penis size index (RPSI)	Expresses the relative size of the penis between male and female dogwhelks
Reuse	Use of material again without any structural changes in materials.
Run-off	Portion of rainfall, melted snow or irrigation water that flows across the ground's surface and is eventually returned to streams. Run-off can pick up pollutants from air or land and carry them to receiving waters.
S	
Semi-natural habitat	A habitat that has been altered by human actions, but which retains significant native elements.
Soil quality	The capacity of a specific kind of soil to function within natural or managed ecosystem boundaries, sustain biological productivity, maintain environmental quality, and promote plant and animal health.
Soil organic matter	The organic fraction of the soil that includes plants and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances such as humus that are produced by the soil population.
Soil sealing	The removal of existing soil cover due to built development (roads, housing, industry, mineral workings etc). This often results in a reduction in the range of functions that soils perform but does not necessarily result in complete soil loss as the disturbed soil may either be removed and used elsewhere or built upon.
Sievert (Sv)	Unit of effective dose. The internationally recommended limit for public exposure to man-made radioactivity is 1.0 mSv per year.
Single farm payment scheme	The measure designed with the capacity to replace all of the existing direct support schemes. Part of the package of measures agreed under the heading of CAP reform
Smog	A combination of fog and smoke.
Stratosphere	The stratosphere is a layer of Earth's atmosphere that is stratified in temperature, with warmer layers higher up and cooler layers farther down. This is in contrast to the troposphere near the Earth's surface, which is cooler higher up and warmer farther down. The stratosphere is situated between about 10 km and 50 km altitude above the surface at moderate latitudes, while at the poles it starts at about 8 km altitude. The stratosphere sits directly above the troposphere and directly below the mesosphere.
Sulphur dioxide	A gas that contributes to acidification. Burning fossil fuels, such as coal, releases sulphur dioxide into the atmosphere. See www.apis.ac.uk/overview/pollutants/overview_SO2.htm and www.sepa.org.uk/spri/substance/sublist.aspx
Sustainable development	The ability to meet our needs and enjoy a better quality of life without jeopardising the quality of life of future generations.

T	
Terrestrial	A community living on the land, as opposed to in water (aquatic). Thermal treatment A broad generic term covering processes that involve the use of heat to treat waste. Incineration is the most common thermal treatment process. Pyrolysis and gasification are other high temperature processes, but there are also low temperature processes used, for example, in technologies producing refuse-derived fuel (RDF).
Transboundary Pollutants	Air pollution that travels from one jurisdiction to another, often crossing international boundaries.
Toxic	Harmfulness to living organisms. Toxicity is the capacity of a chemical to cause toxic effects to organisms or their progeny such as: reduction in survival, growth and reproduction; carcinogenicity; mutagenicity; tetragenicity; and endocrine disruption.
U	
Urban drainage	The discharge of surface water run-off from hard surfaces associated with urban areas. This includes roads, yards, car parks, roofs etc.
V	
Vacant land	Land considered by the Scottish Vacant and Derelict Land Survey (SVDLS) as land in urban settlements or within 1 km of the edge of such settlements that is unused or unsightly, or could benefit from development or improvement.
Vascular plants	Plants in the Kingdom Plantae (also called Viridiplantae) that have specialized tissues for conducting water. Vascular plants include the ferns, clubmosses, horsetails, flowering plants, conifers and other gymnosperms.
Vas deferens stage index	A measure of the degree of male sex characteristics (imposex) in the dogwhelk.
Volatile organic compounds (VOCs)	A family of highly evaporative organic materials used in a variety of industrial applications such as paints and solvents; VOCs emissions are major precursors of ground-level ozone and smog. See www.apis.ac.uk/overview/pollutants/overview_VOCs.htm and www.sepa.org.uk/spri/substance/sublist.aspx
W	
Water body	Any mass of water having definite hydrological, physical, chemical and biological characteristics and which can be employed for one or several purposes.
Watercourse	A stream, river or canal; the channel, bed or route along which this flows.
Wetlands	Areas that are inundated by surface water or groundwater with a frequency sufficient to support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth or reproduction.
Wet deposition	Removal of airborne pollutants from the atmosphere to the Earth's surface (plants, soil, materials) through precipitation (e.g. acid rain).
X	
X-rays	Radiation between ultraviolet radiation and gamma rays in the electromagnetic spectrum.
Y	
Z	

For a more widespread glossary see http://glossary.eea.eu.int/EEAGlossary

Acronyms

AQMA	Air Quality Management Area
AQS	Air Quality Strategy
BAP	biodiversity action plan
BPEO	best practicable environmental option
CEH	Centre for Ecology and Hydrology
COMEAP	Committee on the Medical Effects of Air Pollutants
Defra	Department for Environment, Food and Rural Affairs
EQS	Environmental Quality Standard
ETS	Emissions Trading Scheme
FRS	Fisheries Research Services
HPA	Health Protection Agency
NAEI	National Atmospheric Emissions Inventory
NOX	nitrogen oxides
NVZ	nitrate vulnerable zone
OSPAR	Oslo and Paris Conventions
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
ppb	parts per billion
ppm	parts per million
RIFE	Radioactivity in Food and the Environment
RIMNET	Radioactive Incident Monitoring Network
SAC	Special Area of Conservation
SEPA	Scottish Environment Protection Agency
SEERAD	Scottish Executive Environment and Rural Affairs Department
SNIFFER	Scotland and Northern Ireland Forum for Environmental Research
SPA	Special Protection Area
SPRI	Scottish pollutant release inventory
SSSI	Site of Special Scientific Interest
SUDS	sustainable urban drainage system
SVDLS	Scottish Vacant and Derelict Land Survey
TBT	tributyltin
UKAWMN	UK Acid Water Monitoring Network
UV	ultraviolet
VOC	volatile organic compound
WFD	Water Framework Directive
WHO	World Health Organization

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