Environment Agency

Evidence

Delivering sustainable river basin management: plausible future scenarios for the water environment to 2030 and 2050

Report C: Implications

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We can't do this alone. We work with government, local councils, businesses, civil society groups and communities to make our environment a better place for people and wildlife.

This report is the result of research commissioned and funded by Defra Futures Partnership[1].

Published by:
Environment Agency, Horizon House, Deanery Road, Bristol, BS1 5AH

http://www.gov.uk/government/organisations/environment-agency

ISBN: 978-1-84911-402-8

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Dissemination status:
Publicly available

Keywords:
Alternative scenarios, futures, river basin management, water framework directive, water, 2030, 2050, consequences, pressures, catchments, water users.

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[1]The work was carried out through a Defra led partnership by the Centre for Environmental Risks and Futures (CERF) (now Cranfield Institute of Resilient Futures) at the University of Cranfield. The partnership included the Environment Agency, Defra, Natural England, Forestry Commission England, Marine Management Organisation, CAMERAS, Natural Environment Research Council, Scottish Government and Welsh Government.

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Professor Doug Wilson
Director, Research, Analysis and Evaluation

Executive summary

This project elaborated existing socioeconomic scenarios developed by the Environment Agency and Defra for application to river basin management. Five scenarios are presented:

- uncontrolled demand
- innovation
- sustainable behaviour
- local resilience
- reference

This report develops and explores the implications of these 5 scenarios for water, the water environment, and its uses and users. A drivers, pressures, status and impacts (DPSI) framework is used to understand water management issues in 2050 under the 5 contrasting scenarios. Nine indicators of significant water management issues, or exposure pressures, are used:

- phosphorus
- nitrogen
- sanitary pollutants
- chemicals and metals
- faecal organisms
- abstraction and flow
- physical modification
- sediments
- invasive non-native species

The first part of this report identifies the scenario source pressures that affect these indicators and explores how each unique combination of pressures is reflected in a change of exposure pressures for a given indicator. The implications for the water environment and water users (impacts) are explored for illustrative purposes.

The second part of the report presents 2 illustrative case studies designed to explore the impacts of changing social, economic and environmental conditions on different generic illustrative catchment types and key sectors of society. The case studies outline the impacts on catchments and sectors, providing additional information to support strategic thinking and decision-making.

In the first case study, 4 generic catchment types that captured the diversity of topographies, climate, dominant land use and water resources across England and Wales were used to illustrate how the pressures and impacts may vary under the 5 scenarios. The generic catchment types selected were:

- uplands
- lowland grassland
- lowland arable

- lowland urban

The second case study focuses on those sectors most affected by catchment environment conditions, their management and associated regulations. The key sectors studied were:

- general public
- manufacturing industries
- leisure industries
- utilities (water and energy companies)
- farming and fisheries

This report is one of 3 reports produced by the project. The other 2 present an overview of the scenarios and describe the scenarios in detail, respectively.

Note that the scenarios and the environmental consequences described in these reports reflect the collective views of a set of stakeholders at the time the work was undertaken (2012 to 2014).

The project was led by the Environment Agency and delivered through joint working with Defra and its arm's length bodies (Environment Agency, Natural England, Forestry Commission England) and the Scottish Environment Protection Agency and Natural Resources Wales through the Defra Futures Partnership initiative, led by Cranfield University.

Acknowledgements

The Cranfield Centre for Environmental Risk and Futures (CERF) (now called the Cranfield Institute for Resilient Futures (CIRF)) Futures Partnership is a futures research organisation hosted by Cranfield University which comprises organisations including Defra, the Scottish and Welsh Governments, Department for Energy and Climate Change, Department for Transport, Natural England, Forestry Commission, Environment Agency, Scottish Environment Protection Agency, Marine Management Organisation, Food Standards Agency and the Natural Environment Research Council.

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1 Introduction

This is the third in a series of reports produced for this project (Table 1.1). It develops and explores the implications of elaborated scenarios for water, the water environment, and its uses and users. The 5 scenarios, which are described in detail in the second report in the series (Report B), are:

- Uncontrolled demand (UD)
- Innovation (INN)
- Sustainable behaviour (SB)
- Local resilience (LR)
- Reference (REF)

Table 1.1 Outline of the reports produced for this project

Report	Description
Report A: Overview	This report presents an overview of the scenarios and key outputs of the analysis, looking at the consequences for the water and the water environment and its management. It is not intended as a summary of the scenarios and the overall analysis.
Report B: Full scenarios	This report explains the scenarios in detail. It describes the process of their development, documents the progression from current day to 2030 and from 2030 to 2050, and illustrates how the main drivers develop.
Report C: Consequences for water and the water environment **THIS REPORT**	This report examines the implications of each scenario for the water environment, and for water users. It describes the implications of the scenarios for different generic types of catchments representing contrasting parts of England and Wales and across a range of sectors including the general public, manufacturing industries, leisure industries, utilities (water and energy companies), and farming and fisheries.

1.1 Structure of the report

This report has 2 parts. Part I focuses on the pressures on, and impacts of, indicators of significant water management issues at a national scale. Part II consists of 2 illustrative case studies:

- Case study 1 illustrates the contrast across different types of catchments intended to represent dominant types, in particular geographical areas
- Case study 2 explores the implications for key sectors of society

1.1.1 Part I

A ‘systems’ framework based on the European Environment Agency drivers, pressures, state, impacts and response (DPSIR) framework (EEA 1999) is used to understand water management issues in 2050 under the 5 contrasting scenarios. The framework used in this study (see Report B, Figure 3.2) includes:

- drivers and activities
- source pressures
- exposure pressures and impacts

In line with the Environment's Agency's 'Challenges and Choices' consultation document (Environment Agency 2013), a total of 9 indicators of significant water management issues, or exposure pressures, are used:

- phosphorus
- nitrogen
- sanitary pollutants
- chemicals and metals
- faecal organisms
- abstraction and flow
- physical modification
- sediments
- invasive non-native species

The drivers, activities and source pressures described in Report B for each scenario affect each of the 9 indicators differently. The first part of this report identifies the scenario source pressures that affect these indicators and explores how each unique combination of pressures is reflected in a change of exposure pressures for a given indicator. The impacts on the environment and on water users are explored for illustrative purposes.

1.1.2 Part II

Illustrative 'virtual' case studies were developed to explore the impacts of changing social, economic and environmental conditions on different generic illustrative catchment types and key sectors of society. The aim is to learn, through these case studies, what the emerging strategic, political and management implications for different types of generic river catchments and associated sectors might be under a range of socioeconomic contexts. The case studies outline the impacts on catchments and sectors, providing additional information to support strategic thinking and decision-making.

Four generic catchment types were selected for case study 1, capturing the diversity of topographies, climate, dominant land use and water resources to illustrate how the pressures and impacts may vary across England and Wales under the scenarios. The generic catchment types selected are 'uplands', 'lowland grassland', 'lowland arable' and 'lowland urban'.

The case studies provide details on the relevant water and environmental issues and offer insights into the future state of catchments with different dominant land cover make-up and associated economic, social and cultural activities. Source pressures, exposure pressures and impacts on indicators of significant water management issues are also explored.

Case study 2 highlights the implications for key sectors under each scenario. The focus is on sectors most affected by catchment environment conditions, their management and associated regulations. These include:

- manufacturing industries
- leisure industries
- utilities (water and energy companies)
- farming and fisheries
- general public

2 Part I: Analysis of pressures and impacts

2.1 Analysis of environmental source and exposure pressures

This section presents a comparative analysis of the source and exposure pressures on, and impacts of, the 9 indicators of significant water management issues.

2.1.1 Nutrients: phosphorus and nitrogen

Under the **UD** and **LR** scenarios, the loading of nutrients such as phosphorus (Table 2.1) and nitrogen (Table 2.2) increases significantly from agricultural and urban sources. Agricultural practices include:

- conversion of arable land
- incorrect fertiliser applications by unskilled farmers
- occasional deterioration of silage/manure storage facilities in livestock farms due to lack of maintenance

Urban sources include:

- population growth
- sewer overflows
- leaking and misconnected drains
- reduced efficiency of nutrient removal at sewage treatment works (STWs)
- direct discharge of effluents

Contrastingly, under the **INN** scenario there is a significant improvement in agricultural and urban practices as nutrient efficiencies increase and fewer nutrients are applied, respectively. For instance, the European Union bans phosphorus in laundry products, closed loop agricultural systems reduce the need for fertiliser application and the use of genetically modified crops that can fix their own nitrogen is under trial. Moreover, measures are also implemented to prevent nutrients from reaching the water environment. Examples include:

- recovery of phosphorus in STWs using novel techniques
- improving urban wastewater infrastructure and drainage systems
- agricultural practices that reduce soil compaction and erosion, such as a combination of miniaturisation of farming equipment (for example, tractors) and equipment built from new lighter materials and low impact tyres (for example, large low-inflation pressure tyres)

Some of these measures mitigate the impacts of climate change on nutrient transport by reducing run-off and erosion.

Under the **SB** and **REF** scenarios, there is a small change in environmental risk with opposing contributions from urban and agricultural sources. Under the **SB** scenario, integrated farming systems plan efficient nutrient use and management of crops, soil, livestock and manure. The benefits of reducing nutrients in water bodies are offset, or partially offset, by rising levels of nutrients in STW effluents due to low energy wastewater treatment processes. STWs make a higher contribution than livestock to average phosphorus loads going into national water bodies and therefore reductions from agriculture only partially offset the increased load of phosphorus from STWs. Contrastingly, agriculture is the major contributor to nitrogen loads and therefore there is environmental improvement as a result of overall nitrogen reductions. Conversely, under the **REF** scenario reduced loads of phosphorus from urban sources are partially offset, while nitrogen from similar sources is fully offset by the use of unsustainable agricultural practices to grow food and energy crops.

Table 2.1 Phosphorus: comparison of source and exposure pressures across the 5 scenarios

Source pressures	Scenario				
	UD	INN	SB	LR	REF
Expansion of household, industrial and commercial areas	red	red	white	white	red
Occurrence of sewer overflows, incidents and misconnected drains	red	green	green	red	green
Strictness of discharge consents	red	green	red	red	green
Occurrence of direct discharge of effluents	red	green	green	red	white
Legislation on the use of phosphates in domestic and commercial products	red	green	green	red	white
Expansion of arable/horticultural land	red	white	red	red	red
Livestock production	white	red	green	white	white
Significance of farm environmental regulations and guidance	red	green	green	red	red
Soil management practices	red	green	green	red	red
Appropriate application of fertiliser, sewage sludge and slurry/manure	red	green	green	red	red
Management of livestock and manure	red	green	green	red	red
Climate change induced run-off and erosion	red	red	red	red	red
Exposure pressures	↓↓↓	↑↑	↓	↓↓↓	↑

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Significance of source pressures is indicated by positive (green), negative (red) or no (white) direction of change.
Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down), while the extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

Table 2.2 Nitrogen: comparison of source and exposure pressures across the 5 scenarios

Source pressures	Scenario				
	UD	INN	SB	LR	REF
Expansion of household, industrial and commercial areas	■ (red)	■ (red)	□ (white)	□ (white)	■ (red)
Occurrence of sewer overflows, incidents and misconnected drains	■ (red)	■ (green)	■ (green)	■ (red)	■ (green)
Strictness of discharge consents	■ (red)	■ (green)	■ (red)	■ (red)	■ (green)
Occurrence of direct discharge of effluents	■ (red)	■ (green)	■ (green)	■ (red)	□ (white)
Expansion of arable/horticultural land	■ (red)	□ (white)	■ (red)	■ (red)	■ (red)
Significance of farm environmental regulations and guidance	■ (red)	■ (green)	■ (green)	■ (red)	■ (red)
Soil and crop management practices	■ (red)	■ (green)	■ (green)	■ (red)	■ (red)
Appropriate application of fertiliser, sewage sludge and slurry/manure	■ (red)	■ (green)	■ (green)	■ (red)	■ (red)
Management of livestock and manure	■ (red)	■ (green)	■ (green)	■ (red)	■ (red)
Climate change induced run-off events	■ (red)	■ (red)	■ (red)	■ (red)	■ (red)
Exposure pressures	↓↓↓ (red)	↑↑ (green)	↑ (green)	↓↓↓ (red)	↓ (red)

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Significance of source pressures is indicated by positive (green), negative (red) or no (white) direction of change.
Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down), while the extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

2.1.2 Sanitary pollutants and faecal indicators

Sanitary pollutants encompass ammonia, dissolved oxygen and biochemical oxygen demand (BOD). There are 2 major sources of sanitary pollutants (Table 2.3) and faecal indicators (Table 2.4). These sources are:

- wastewater from urban areas and livestock farms (point sources)
- run-off from arable land (diffuse sources) in agricultural areas

Across all 5 scenarios, climate change will contribute to increased pollutant loads. Heavy rainfall causes failure of sewerage infrastructure, failure of combined sewer overflows, failure of slurry manure or silage storage facilities on farms, and run-off from land where fertilisers, sludge or slurry/manure have been spread. Climate change also adversely alters temperature and river flows, favouring the formation of un-ionised ammonia, the spread of eutrophication and a further reduction in the dissolved oxygen of the receiving water bodies.

Both urban and agricultural sources will cause a significant deterioration in the water environment under the **UD** and **LR** scenarios. For example, under the **UD** scenario, livestock is allowed access to watercourses leading to reduced microbiological water quality as a result of direct excretion. Under the **LR** scenario**,** there is increased domestic animal husbandry and increased application of manure/slurry and sewage sludge on agricultural fields.

Contrastingly, under the **INN** scenario, sanitary pollutants in wastewater have been significantly reduced and microbiological water quality is improved through advances in technology including aerobic biological treatment, activated sludge treatment and tertiary treatment. This is combined with improved wastewater infrastructure and management such as sustainable drainage systems (SUDS) that prevent wastewater incidents. Improved agricultural practices are also achieved; for instance, factory type intensive production of livestock reduces waste run-off incidents into water bodies.

Under the **SB** scenario, good practice for sewage sludge and slurry/manure application become very common as well as improved waste management due to declining livestock production. These sustainable practices are offset by reduced wastewater treatment processes, imposed by a low carbon agenda and the impacts of climate change. The best available low carbon technologies achieve levels of 5mg/l for BOD and 1mg/l for ammonia; however, most treatment is not to this high standard.

Under the **REF** scenario, no change in the load of sanitary pollutants and microbiological water quality is observed. Significant improvements in sewage treatment, infrastructure and management are achieved despite increasing pollution from agricultural practices.

Table 2.3 Sanitary pollutants: comparison of source and exposure pressures across the 5 scenarios

Source pressures	Scenario				
	UD	**INN**	**SB**	**LR**	**REF**
Expansion of household, industrial and commercial areas	Red	Red	□	□	Red
Occurrence of sewer overflows, incidents and misconnected drains	Red	Green	Green	Red	Green
Strictness of discharge consents	Red	Green	Red	Red	Green
Occurrence of direct discharge of effluents	Red	Green	Green	Red	□
Expansion of land used for livestock production	Red	□	Red	Red	Red
Significance of farm environmental regulations and guidance	Red	Green	Green	Red	Red
Soil management practices	Red	Green	Green	Red	Red
Appropriate application of fertiliser, sewage sludge and slurry/manure	Red	Green	Green	Red	Red
Management of livestock and manure	Red	Green	Green	Red	Red
Climate change	Red	Red	Red	Red	Red
Exposure pressures	↓↓↓	↑↑↑	↓	↓↓↓	No change

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference

Ammonia, BOD and dissolved oxygen are analysed conjunctively.
Significance of source pressures is indicated by positive (green), negative (red) or no (white) direction of change.
Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down), while the extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

Table 2.4 Faecal indicators: comparison of source and exposure pressures across the 5 scenarios

Source pressures	Scenario				
	UD	INN	SB	LR	REF
Expansion of household, industrial and commercial areas	red	red	white	white	red
Occurrence of sewer overflows, incidents and misconnected drains	red	green	green	red	green
Strictness of discharge consents	red	green	red	red	green
Occurrence of direct discharge of effluents	red	green	green	red	white
Livestock production	white	red	green	white	white
Significance of farm environmental regulations and guidance	red	green	green	red	red
Soil management practices	red	green	green	red	red
Appropriate application of sewage sludge and slurry/manure	red	green	green	red	red
Management of livestock and manure	red	green	green	red	red
Climate change	red	red	red	red	red
Exposure pressures	↓↓↓	↑↑↑	↓	↓↓	No change

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Significance of source pressures is indicated by positive (green), negative (red) or no (white) direction of change.
Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down), while the extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

2.1.3 Chemicals and metals

The temporal and spatial trends of chemical and metal pollution (Table 2.5) are dictated by risk behaviours intrinsic to each scenario. Under the **UD** scenario, pollution incidents are frequent as there is weak regulation of human toxicological risk assessment for new chemicals entering the market. Under the **INN** scenario, the risk consists of rare events with very high impacts. Occasional potentially hazardous incidents occur when new chemicals are adopted under a process relaxed by EU legislation before their potential impacts are truly understood. Nevertheless, more stringent standards for biota are in place, relating to bioaccumulation of chemicals in living organisms and metal bioavailability.

Under the remaining scenarios, **SB**, **LR** and **REF**, there is restricted adoption of new substances when the health and environmental hazards are unknown or unclear; however, exceptions occur under the **LR** scenario when this is seen to constrain economic growth. Under the **SB** and **LR** scenarios, the frequency of pollution incidents depends on the region in question, its associated land use risks and the wealth to mitigate those risks. Under the **REF** scenario, there are periods of environmental standard relaxation and associated degradation that usually correspond to economic recessions.

Pollution from chemicals and metals increases under the **UD** and **LR** scenarios but reduces under the **INN** and **SB** scenarios and, to a lesser extent, the **REF** scenario. Sources of chemicals and metals include:

- domestic and industrial effluents
- transport
- urban and agricultural run-off
- mine water

The overall level of pollution depends on the relative contributions from each source and impacts are exacerbated by climate change. At one extreme, peak flows flush toxic substances into water bodies and flood landfill sites; at the other, low flows reduce the dilution of a substance, augmenting its impact on the environment.

Urban pollution significantly reduces under the **INN** and **SB** scenarios and, to a smaller extent, the **REF** scenario as SUDS are commonly used and there is a reduction in the number of traditional cars powered by fossil fuels in favour of green transport alternatives. Moreover, under the **INN** scenario, wastewater treatment processes are improved to remove chemicals (for example, pharmaceuticals such as triclosan) and metals from effluent more efficiently, as prescribed by legislation, often using novel processes. Under the **UD** scenario, there is a reduction in nitrogen oxides and sulphur dioxide due to an increase in the electrification of private vehicles and a shift towards nuclear energy. Under the **LR** scenario, urban pollution is a concern where coal-fired stations run with locally mined coal and is aggravated by a lack of maintenance of private and public vehicles. Under the **UD** and **LR** scenario, sewer overflows and incidents are frequent, as is STW overloading due to urban growth.

There is significant rise in industrial activities under the **UD** and **INN** scenarios with opposing consequences for the aquatic environment. Under the **UD** scenario, there is increasing concern about the pollution of land and water by hazardous substances, namely heavy metal pollution from the nanotechnology sector. Contrastingly, the environment is protected under the **INN** scenario as a result of tight regulation on the use and release of substances as well as the industrial operation of closed loop systems that allow the reuse of chemicals and metals. Under the **SB** scenario, there is a decline in manufacturing and heavy industry, and a reduction in imported chemicals. Businesses invest in reuse technologies to avoid the burdens of environmental regulation and tax. Regulation is tight, but industrial discharge consents are relaxed in order to comply with the carbon agenda. The population acting as a watchdog plays an important role in reducing industrial pollution. Equally, under the **LR** scenario, concerned communities reduce the occurrence of pollution incidents, but in this case it is limited to visible pollution events in their own communities.

Agriculture is a major diffuse source of chemicals. Under the **UD**, **LR** and **REF** scenarios, there is increased use of pesticides and herbicides for subsistence agriculture (for example, slug pellets and weedkillers) and for intensive agriculture (for example, metaldehyde, cypremethrin, diazinon, diuron, permethrin and hexachlorocyclohexane), including the use of previously banned chemicals under the

LR scenario. Under the **UD** scenario, there is also increased use of veterinary products to improve livestock growth performance and control parasites. The **INN** scenario brings novel pesticides and herbicides with reduced environmental impacts, while integrated farming methods practised under the **SB** scenario use fewer pesticides. The ‘green’ scenarios, **INN** and **SB**, regulate the growth of crops for non-food use (for example, energy crops) to restrict the chemicals applied, and stricter regulation is passed to reduce or ban the use of chemicals with environmental impacts above defined thresholds.

The scenarios depict futures with different degrees of renewable energy use. Coal is no longer in use, except under the **LR** scenario where coal-fired power stations operate in those regions with active coal mines. The **INN** scenario goes further by improving treatment processes for mine drainage water. The electrification of transport occurs under the **UD, INN** and **SB** scenarios, and to a lesser extent the **REF** scenario, and there is a consequent reduction in urban pollution. Under the **LR** scenario, this is also achieved as mobility has fallen. Reduced urban pollution improves problems arising from acid and nitrogen deposition.

Table 2.5 Chemicals and metals: comparison of source and exposure pressures across the 5 scenarios

Source pressures	**Scenario**				
	UD	**INN**	**SB**	**LR**	**REF**
Expansion of household, industrial and commercial areas	Red	Red	White	White	Red
Sustainable urban drainage systems	Red	Green	Green	Red	White
Occurrence of sewer overflows, incidents and misconnected drains	Red	Green	Green	Red	Green
Pollution from vehicles	Red	Green	Green	Red	White
Strictness of STW and industrial discharge consents	Red	Green	Red	Red	Green
Chemicals and metals used in manufacturing/heavy industry (quantities and hazardous)	Red	Green	Green	Red	Green
Watchdog controlling industrial pollution	Red	White	Green	Green	White
Expansion of arable/horticultural land and livestock production	Red	White	Red	Red	Red
Chemicals used in agriculture(quantities and hazardous)	Red	Green	Green	Red	Red
Mine drainage water from coal mines	Green	Green	Green	White	Green
Climate change	Red	Red	Red	Red	Red
Exposure pressures	↓↓↓ (red)	↑↑ (green)	↑↑ (green)	↓↓ (red)	↑ (green)

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Significance of source pressures is indicated by positive (green), negative (red) or no (white) direction of change.

Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down), while the extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

2.1.4 Abstraction and flow regulation

Across all 5 scenarios, climate change increases the risk of drought, reduces water availability and alters the hydrological patterns. A changed rainfall pattern also affects flow quantity and dynamics, and groundwater recharge. Under the **UD** and **INN** scenarios, a national strategy is used to augment water supply in the form of increased reservoir storage capacity, inter-basin raw water transfer and desalination plants. River flow is therefore significantly regulated (Table 2.6). Impounding structures alter the flow, and water is released back into the system at a different location (for example, further downstream or in a different catchment) which affects the water quality and quantity of the receiving water body. Although flows are highly regulated under the **INN** scenario, water is a valued resource. Water demand is managed and abstraction is maintained within sustainable levels, protecting low flows and flow variability.

Contrastingly, under the **UD** scenario, there is increased water demand across all sectors and a lack of environmental concern. Regulation leads to abstractions that typically occur beyond sustainable levels in summer, and increased tensions between different water users. Some areas are sacrificed to preserve healthy aquatic ecosystems for the benefit of the most wealthy. Altered flows cause significant problems for river ecology and fisheries. Under the **UD** scenario in particular, anthropogenic factors have a negative impact on catchment hydrology, which is reflected in altered river flows; examples include extended impermeable paving in urban areas, compacted soils in agricultural fields and poached river banks.

Under the **SB** and **LR** scenarios, the majority of water supply measures exploit local resources. Water storage reservoirs significantly regulate the flows. Under the **LR** scenario, with high consumptive and non-consumptive water demands, abstractions are unsustainable and catchments are over-abstracted, particularly in periods of drought. Contrastingly, under the **SB** scenario, water is allocated to the environment and society fairly. In summer, abstraction increases to be used for efficient agricultural irrigation and, in areas of water scarcity, the population dramatically reduces water consumption and accepts occasional interruptions to the water supplies. Furthermore, changes in woodland practices enhance local water availability; examples include replacement of fast growing tree species with native species.

Under the **REF** scenario, water is used efficiently and abstraction from local and neighbouring sources is generally sustainable, except in periods of drought when demand is higher.

Table 2.6 Abstraction and flow regulation: comparison of source and exposure pressures across the 5 scenarios

Source pressures	Scenario				
	UD	INN	SB	LR	REF
Total consumptive water demand	Red	Blank	Green	Blank	Blank
Freshwater demand for power generation	Red	Blank	Green	Green	Green
Large-scale water transfers	Red	Red	Green	Green	Red
Impounding structures	Red	Red	Green	Red	Red

Source pressures	Scenario				
	UD	INN	SB	LR	REF
Sustainability of abstractions	Red	Green	Green	Red	Green
Environmental regulation	Red	Green	Green	Red	Green
Enforcement of abstraction licences and limits	Red	Green	Green	Red	White
Run-off from urban and rural catchments	Red	Green	Green	Red	White
Commercial forestry	Red	Red	Green	Red	Red
Climate change	Red	Red	Red	Red	Red
Exposure pressures	↓↓↓	↑↑	↑↑↑	↓↓	↓

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Significance of source pressures is indicated by positive (green), negative (red) or no (white) direction of change.
Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down), while the extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

2.1.5 Physical modification

Physical modification of rivers, lakes and transitional/coastal waters (Table 2.7) results predominantly from pressures from the urban sector (for example, impounding structures, flood control, culverts, recreation and re-sectioning), bringing changes in land use activities such as land drainage, tree removal, land reclamation and poaching.

Under the **UD** and **INN** scenarios, there is a significant deterioration in natural hydromorphology. Droughts and floods, which are exacerbated by climate change, are tackled with heavy engineering solutions causing physical modification. Increased reservoir storage capacity includes the conversion of natural lakes into reservoirs close to highly populated areas. Flood alleviation measures focus on embankments, bank and shoreline reinforcements, and dredging measures in densely urbanised areas and high-value agricultural and industrial land. Under the **LR** scenario, physical habitat also suffers significantly deteriorated due to anthropogenic modification, although the magnitude of change depends on the vulnerability of the local area. Measures to cope with floods and droughts contribute to the deterioration to a smaller extent (for example, impounding structures are small to deal with local water needs), but there is the development of small-scale hydroelectric stations to produce energy locally.

Contrastingly, under the **SB** scenario, there are improvements to river morphology: riparian areas and vegetation are well managed, natural processes for controlling river flows are used (for example, wetlands) and river restoration initiatives enhancing water ecology are widespread.

Under the **REF** scenario, there is a minor deterioration in the natural hydromorphology. Small- and medium-scale water storage reservoirs are built to enhance the resilience of regional water supplies. Flood protection includes:

- a combination of hard engineering defences where the population is high and activities generate high income

- natural mechanisms of flood management in areas that become abandoned

Table 2.7 Physical modification: comparison of source and exposure pressures across the 5 scenarios

Source pressures	Scenario				
	UD	INN	SB	LR	REF
Expansion of household, industrial and commercial areas	■ red	■ red	□ white	□ white	■ red
Impounding structures	■ red	■ red	■ green	■ red	■ red
Heavy engineering flood alleviation measures	■ red	■ red	■ green	■ red	□ white
Small-scale hydroelectric stations	□ white	□ white	■ red	■ red	□ white
Environmental regulation	■ red	■ green	■ green	■ red	■ green
River restoration initiatives	■ red	□ white	■ green	■ red	□ white
Climate change	■ red	■ red	■ red	■ red	■ red
Exposure pressures	↓↓↓ (red)	↓↓ (red)	↑↑ (green)	↓↓ (red)	↓ (red)

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Significance of source pressures is indicated by positive (green), negative (red) or no (white) direction of change.
Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down), while the extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

2.1.6 Sediments

Agricultural and rural land management are the principal causes of changes to sediment regimes (Table 2.8), with small contributions from urban areas and the transport sector (for example, the sewer network and SUDS). Under the **UD** scenario and, to a lesser extent the **LR** scenario, erosion from intensive agricultural practices is a significant cause of sedimentation in lakes and rivers. It results from:

- soil and crop mismanagement practices (for example, growing crops on inappropriate land, incorrect timing of agricultural practices and lack of ground cover in winter months)
- inappropriate livestock management (for example, poaching of river banks and overstocking)
- removal or poor management of riparian vegetation, buffer strips and trees which is exacerbated by increased rainfall intensity and flash floods

Contrastingly, under the **SB** scenario there is a significant improvement in sediment load due to improvements in the causes of erosion (see above) and widespread river restoration initiatives.

Under the **INN** and **REF** scenarios, there are minor changes from current conditions. Under the **INN** scenario, significant improvements in sediment issues are achieved through enhanced agricultural and rural land management practices. However, these improvements are offset by the creation of new large-scale reservoirs that have a detrimental impact on sediment build-up and transport.

Table 2.8 Sediments: comparison of source and exposure pressures across the 5 scenarios

Source pressures	Scenario				
	UD	**INN**	**SB**	**LR**	**REF**
Impounding structures	Red	Red	Green	Red	Red
Environmental regulation	Red	Green	Green	Red	Green
River restoration initiatives	Red	White	Green	Red	White
Expansion of arable/horticultural land	Red	White	Red	Red	Red
Livestock production	White	Red	Green	White	White
Significance of farm environmental regulations and guidance	Red	Green	Green	Red	Red
Soil and crop management practices	Red	Green	Green	Red	Red
Management of livestock	Red	Green	Green	Red	Red
Climate change	Red	Red	Red	Red	Red
Exposure pressures	↓↓↓	↓	↑↑	↓↓	No change

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Significance of source pressures is indicated by positive (green), negative (red) or no (white) direction of change.
Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down), while the extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

2.1.7 Invasive non-native species

Invasive non-native species (INNS) (Table 2.9) become widespread and establish in riparian areas, freshwater, and coastal and transitional waters under the **UD** scenario and, to a lesser extent, the **LR** scenario. This causes significant deterioration in these water bodies. Two distinct paths lead to this status, which is exacerbated by characteristics common to both scenarios.

Under the **UD** scenario, there is an increase in the human activities that spread INNS and bring new arrivals. Examples include:

- transport of agricultural products
- freight
- trade in commodities and goods by post and courier services
- aquaculture
- ballast water from ships
- movement of travellers

A short-term focus in government has led to a lack of monitoring and management of INNS. Their prevalence is becoming costly to the national economy due to structural damage to infrastructure and production losses.

Contrastingly, under the **LR** scenario there is reduced movement of people and goods both nationally and internationally. However, reduced investment in maintenance, monitoring, infrastructure upgrades and pro-active management has allowed INNS to become widespread, particularly those that do not pose health risks or which bring economic benefits (for example, edible fish). Those INNS perceived as threats are tackled by local communities that run initiatives, but actions are usually unsuccessful as they are taken in isolation without being part of a co-ordinated regional or national effort.

The increased eutrophic conditions of the **UD** and **LR** scenarios help some INNS to become dominant. This is because growth and spread are not limited by nutrient availability and control of one non-native species may just allow another species to dominate if nutrients are high. The development of woodland areas for commercial forestry using fast growing non-native species is another pressure on autochthonous species. These woodlands have a shorter harvesting cycle, with detrimental changes to habitat conditions of existing fauna and flora. Moreover, the cyclic harvesting does not support the development of native tree species.

Climate change equally affects all the scenarios and increases the spread and impact of INNS. These spread quicker in milder winters, where already stressed fauna and flora cannot compete and increased flooding provides a pathway. Moreover, as average temperatures rise, INNS migrate northwards from Europe. At the same time, species that are already present in England and Wales, but benignly, may become invasive in the 2050s. If native species are put under increasing pressure by climate change, then the relative impact of INNS on these increases.

Under the **INN** scenario, INNS proliferate in certain areas. This is assisted by human activities (as under the **UD** scenario) and climate change. However, prescriptive legislation emerges to reduce the risks (for example, tighter regulatory standards on the emptying of ship's ballast tanks and compulsory sterilisation of the water). Nevertheless, INNS that provide economic benefits are intentionally supported. Examples include edible species and those providing a commercial or beneficial function such as fast nutrient removal from waters or the remediation of eutrophic water bodies. Legislative tools are combined with control and eradication measures where INNS are not desired; biological, chemical and mechanical measures are used but these often have unintentional impacts on the water environment. These measures are conducted successfully in a co-ordinated fashion at the national level when economically viable. These measures are expensive, but the annual cost of unwanted invasive species to the economy is higher.

Under the **SB** scenario, INNS are a minor concern. The human activities that spread these species and bring new arrivals are minimised due to local/regional governance, prescriptive regulation and improved education (for example, INNS are banned from aquaculture). Public action and preventive, pro-active management have controlled the spread and establishment of INNS. This is more successful and cost-effective than control and eradication measures. Local communities start initiatives to slow the spread (for example, 'check, clean, dry' and 'bio-control' campaigns). Raising public awareness, changing behaviour and voluntary manual removal are popular initiatives. On some occasions, actions are unsuccessful as they are taken in isolation without being part of a co-ordinated national or regional effort.

Under the **REF** scenario, there is a marginal increase in INNS. There is no significant change from current conditions as the impacts of climate change and the human activities that cause proliferation of INNS are reduced by a combination of pro-active and reactive measures.

Table 2.9 INNS: comparison of source and exposure pressures across the 5 scenarios

Source pressures	Scenario				
	UD	INN	SB	LR	REF
Societal and political environmental concern and public education	■ (red)	■ (green)	■ (green)	■ (red)	□ (white)
National and/or regional co-ordination at political level to control INNS (if applicable)	Not applicable	■ (green)	■ (red)	■ (red)	■ (green)
Practice of human activities that spread INNS and bring new arrivals	■ (red)	■ (red)	■ (green)	■ (green)	■ (red)
Prescriptive legislation to control INNS	■ (red)	■ (green)	■ (green)	■ (red)	□ (white)
Eutrophication of water bodies	■ (red)	■ (green)	■ (green)	■ (red)	□ (white)
Commercial forestry	■ (red)	■ (red)	■ (green)	■ (red)	■ (red)
Climate change	■ (red)	■ (red)	■ (red)	■ (red)	■ (red)
Exposure pressures	↓↓↓	↓	↑	↓↓	↓

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Significance of source pressures is indicated by positive (green), negative (red) or no (white) direction of change.
Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down), while the extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

2.1.8 Summary of exposure pressures

Table 2.10 presents a summary of the exposure pressures under the 5 scenarios for England and Wales as a whole.

Table 2.10 Summary of change in environmental risk for each scenario

	UD	INN	SB	LR	REF
Phosphorus	↓↓↓	↑↑	↓	↓↓↓	↑
Nitrate	↓↓↓	↑↑	↑	↓↓↓	↓
Sanitary pollutants	↓↓↓	↑↑↑	↓	↓↓↓	No change
Chemicals and metals	↓↓↓	↑↑	↑↑	↓↓	↑
Faecal indicator organisms	↓↓↓	↑↑↑	↓	↓↓	No change
Abstraction and flow	↓↓↓	↑↑	↑↑↑	↓↓	↓
Physical modification	↓↓↓	↓↓	↑↑	↓↓	↓

	UD	INN	SB	LR	REF
Sediments	↓↓↓	↓	↑↑	↓↓	No change
INNS	↓↓↓	↓	↑	↓↓	↓

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Change in exposure pressures is characterised as an improvement (green arrow up) or degradation (red arrow down)
The extent of change is characterised as weak (one arrow), moderate (2 arrows) or strong (3 arrows).

2.2 Implications for the water environment and water users (impacts)

2.2.1 Eutrophication

Under the **UD** and **LR** scenarios, eutrophication is an important water management issue. It occurs as a result of increased loads of nutrients, where phosphorus is usually the limiting nutrient, combined with reduced river flows, low dissolved oxygen, high BOD and raised temperatures. Eutrophication adversely affects aquatic ecosystems, degrading the balance and causing the loss of sensitive species. This heightens the potential for invasion and spread of more resistant INNS. Moreover, there is an impact on navigation where channels are blocked. In coastal and transitional waters, nitrogen can cause eutrophication leading to increased number of shellfish harvesting beds that are periodically closed to diarrhetic shellfish poisoning and paralytic shellfish poisoning. Toxic algal blooms also deteriorate the water quality, which is not suitable for abstraction and recreational activities such as bathing. Those wishing to partake in water-based recreation use home testing kits to assess the water quality. This is more common under the **UD** scenario, as under the **LR** scenario few people travel for recreation. Under the **UD** scenario, eutrophication is a particular concern as illegal water abstraction and fishing from affected water bodies cause a rise in health incidents among the poorest in society.

Under the **INN** scenario, there is reduced occurrence of eutrophication with benefits for public health, the aquatic environment and navigation. Eutrophication is generally restricted to high alkalinity river systems, particularly in lowland rivers.

Under the **SB** and **REF** scenarios, there are negligible changes in the overall eutrophication levels of the water bodies. Under the **SB** scenario, however, there is an increase in STW discharges to the coast, increasing health scares from the consumption of shellfish contaminated with bio-toxins.

2.2.2 Nitrogen and acid deposition

Rainfall chemistry can be affected by the pollutants produced from the combustion of fossil fuels for energy production, livestock farming and intensive fertiliser use. Under the **UD** scenario, and to a smaller extent the **LR** scenario, these activities have resulted in further acidification of soils and waters in acid-sensitive areas such as many upland habitats. They have also contributed to nitrogen enrichment (eutrophication) in nutrient-poor communities (for example, upland heath). A change in the pH of water affects populations of fish, invertebrates and water plant communities. Soil acidification affects the breakdown of organic matter and soil nutrient balance, and increases the solubility of some elements that can be toxic to the roots of the plants.

Under the **INN** and **SB** scenarios, there is a significant recovery of affected rivers, wetlands and natural habitats. There is no significant modification in the **REF** scenario.

2.2.3 Water quality

Water quality varies across the scenarios. Under the **UD** and **LR** scenarios, it deteriorates significantly with severe implications for the water environment and water users. However, it improves under the **INN** scenario, with minor changes under the **SB** and **REF** scenarios. Examples of pollutants include:

- bio-toxins (see Section 2.2.1)
- un-ionised ammonia
- nitrates
- faecal indicators
- sediments

Un-ionised ammonia (under the **UD** and **LR** scenarios) is hazardous due to its toxic and sub-lethal impacts on fish and macroinvertebrates.

Nitrates are a concern under all scenarios, particularly under **UD** and **LR**. Impacts under the **LR** scenario are not as extreme, as Nitrate Vulnerable Zones are protected when the water resources of a given community are directly affected. High nitrate concentrations in drinking water (exceeding the current Drinking Water Directive limit of 50mg/l) can cause methemoglobinemia (blue baby syndrome) – an inability to use oxygen in infants that could be fatal. Despite the reduction in agricultural diffuse pollution, nitrate remains a concern under the **INN**, **SB** and **REF** scenarios, namely in chalk aquifers where a nitrate peak takes 60 years to arrive (Wang et al*.* 2011).

The presence of faecal indicators under the **UD** and **LR** scenarios causes public health issues. Rivers and lakes are not suitable for bathing and there are increased gastrointestinal illnesses associated with *Escherichia coli* and *Cryptosporidium* in shellfish. Moreover, under the **UD** scenario, the illegal abstraction of water for drinking purposes exposes the poorest in society to further health risks when control measures are not taken such as boiling water or using chlorine tablets.

In the **SB** and **REF** scenarios, there is negligible overall change from current conditions. Under the **SB** scenario, some rivers downstream of STWs are not suitable for bathing and increases in STW discharges to the coast increase human health scares, although human health is not actually compromised. Contrastingly, under the **INN** scenario there is enhanced use of water bodies for recreational activities throughout the year and a drastic reduction in human health incidents.

Increased levels of sediment under the **UD** and **LR** scenarios have an impact on freshwater ecosystems where chalk streams are particularly vulnerable. Sediment is harmful to fish and can cause reduced visibility, asphyxiation and illness if swallowed. Sedimentation of gravel riverbeds has a detrimental effect on salmonid species such as salmon and trout. Deposited sediment can smother whole streambeds and reduce the variation of habitats and flows. High levels of sediment can completely fill in deep pools, destroying the entire habitat for some species. Lakebed substrates are also adversely affected by increased sediment loading, suffering from changes to the structure and substrate of the lakebed, reduction of lake depth and changes to lakeshore. Sediments increase turbidity, affecting the photosynthesis rate of aquatic plants. Moreover, sediments increase the concentration of nutrients or toxic substances that are attached to the sediment particles. Sediments also have a detrimental impact on water users. Siltation of rivers causes loss of space for water, increasing flood risk and increased displacement and removal of the substratum by dredging, particularly in estuaries with heavy boat traffic. Higher turbidity means poorer water quality for abstraction and drinking water colour problems that can only be solved using refined water treatment processes.

Under the **SB** scenario, there is a significant improvement in the sediment regime; this is reflected in healthier aquatic ecosystems and improved fisheries.

Under the **INN** and **REF** scenarios, there are no significant changes from current conditions.

The deterioration of water quality, particularly under the **UD** and **LR** scenarios, requires expansion of the water treatment infrastructure and the introduction of more sophisticated water treatment processes to protect public health when it is not possible or sufficient to blend with cleaner water. This further increases the price of water and contributes to greenhouse gas emissions as water treatment is an energy-intensive process.

2.2.4 Chemical pollution

Pollution by chemicals and heavy metals increases under the **UD** and **LR** scenarios. Bioaccumulation in fish, shellfish and benthic organisms poses a risk to aquatic ecosystems and human health. Increased levels of chemicals are particularly harmful when there is low dilution capacity during drought periods; this will become more frequent due to climate change. Water abstraction is restricted in some areas and during specific times of the year. The risks of this type of pollution are high and uncertain, particularly under the **UD** scenario where the population is exposed to new chemicals. Moreover, poorer sections of society who grow crops illegally on contaminated land and abstract contaminated drinking water are particularly at risk.

Chemical pollution reduces under the **INN** and **SB** scenarios despite rare incidents occurring under the former. Consequently there is a better environment for aquatic ecosystems and reduced levels of treatment required at water treatment works.

2.2.5 Physical habitat

Under most of the scenarios (**UD**, **INN** and **LR**), river hydromorphology and aesthetic values deteriorate. This has consequences for the water environment such as:

- interference with fish population movements
- physical disturbance of transitional habitats
- change in-river flows
- alteration of natural sediment dynamics – leading to loss of continuity
- loss of faunal nursery, refuge and feeding areas
- loss of riparian zone and/or marginal habitat
- bank erosion
- adverse impacts on the water quality of the downstream river
- INNS transfer

Under the **UD** and **LR** scenarios, there is a higher impact on fisheries due to a lack of public funding and local requirements for the development of improved fish passages.

Contrastingly, river hydromorphology improves under the **SB** scenario with new habitats such as meadows and wetlands being created, thus benefiting aquatic ecosystems, providing improved recreational value and increasing storage capacity for floodwaters.

2.2.6 Water quantity

Low flows and flow variability are impacted under the **UD** and **LR** scenarios with consequences for the water environment and water users. Dried out wetlands and increased lengths of ephemeral chalk streams during periods of drought have impacts on aquatic ecosystems, tourism and leisure activities. Reduced water flows, lower flow velocities and reduced depth limit ecological status in surface water bodies. Restricted or low flows lead to higher residence times, which combined with higher concentrations of nutrients, result in eutrophication. Flow variability is important to trigger the migration of fish. More natural flow dynamics help to maintain a sediment regime beneficial to the ecology. Reduced flows can increase sedimentation rates affecting species sensitive to sediment loadings. Under the **UD** scenario, there is also a significant alteration in natural flows, particularly where water travels large distances or between catchments from the point of abstraction to its return to the environment. Examples of such areas include those supplied by large reservoirs, water transfers or desalination plants.

Furthermore, intrusion of saltwater into groundwater sources and upstream migration of saltwater tidal limits deteriorates the quality of water supplies under the **UD** and **LR** scenarios. Sinking water tables further reduce low river flows and significantly deplete wells. Under the **UD** scenario, the poorest in society with no access to drinking water are particularly affected, as they are unable to afford the price of water. Under the **LR** scenario, supplies are interrupted where water availability is low.

Under the **INN** and **SB** scenarios, there is generally a good ecological status of water bodies and reduced tensions over water allocations for the different users. Under the **INN** scenario there is an alteration of natural flows, where water travels large distances or between catchments.

2.2.7 INNS

Under the **UD** and **LR** scenario, INNS cause environmental impacts. INNS alter the natural balance in an ecosystem (for example, by displacing native species preying or competing for resources) and interbreed with native species changing the genetic pool.

Under the **INN** scenario, chemical, biological and mechanical control and eradication measures have side effects on aquatic ecosystems, despite INNS not having a direct impact on the environment.

INNS also have consequences for water users. Under the **UD** and **LR** scenarios, public health concerns arise as INNS are often vectors of exotic diseases. Widespread INNS cause structural damage to infrastructure and loss of production. Examples include:

- blocked channels causing problems for navigation, fishing and flood defences
- where the burrowing of some INNS undermine structures including those for monitoring and flood defences

For example, the Chinese mitten crab causes considerable damage to riverbanks along the Thames through burrowing that increases erosion and affects flood defences.

Certain INNS provide economic benefits (for example, edible fish, fast nutrient removal or the remediation of water bodies suffering from eutrophication), which are explored under the **UD**, **LR**, **INN** and **REF** scenarios. Under the **SB** scenario, the ecological status of water bodies improves and the economic costs associated with past control and eradication measures, public health, structural damage to infrastructure and loss of production are reduced.

2.2.8 Summary of consequences to the water environment and water users (Impacts)

Table 2.11 presents the major water management issues identified for the 5 scenarios, while Table 2.12 shows the Water Framework Directive water status under them. The consequences for the water environment and for water users are presented, for illustrative purposes, in Table 2.13 and Table 2.14 respectively.

Table 2.11 Major water management challenges under the 5 scenarios

Water management challenges	Scenario				
	UD	INN	SB	LR	REF
Eutrophication	Red	Green	White	Red	White
Acid and nitrogen deposition	Red	Green	Green	Red	White
Un-ionised ammonia	Red	Green	White	Red	White
Nitrate in drinking water	Red	White	White	Red	White
Microbiological contamination	Red	Green	White	Red	White
Sediments	Red	White	Green	Red	White
Chemical pollution	Red	Green	Green	Red	White
Hydromorphological alterations	Red	Red	Green	Red	White
Water quantity	Red	Green	Green	Red	White
INNS	Red	White	White	Red	White

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Significance is indicated by positive (green), negative (red) or no (white) direction of change.

Table 2.12 Water Framework Directive water status under the 5 scenarios

Water Framework Directive water status	UD	INN	SB	LR	REF
Good ecological status	Red	Red	Green	Red	White
Good chemical status	Red	Green	Green	Red	White

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
This is an integrated – one out, all out measure.
Significance is indicated by positive (green), negative (red) or no (white) direction of change.

Table 2.13 Impacts on the water environment under the 5 scenarios

Impacts on the water environment	UD	INN	SB	LR	REF
Loss of sensitive species	red	green	white	red	white
Invasion and spread of non-native species	red	white	white	red	white
Acidification of soils and waters	red	green	green	red	white
Toxic and sub-lethal impacts on fish and macroinvertebrates	red	green	green	red	white
Obstacles to fish passage	red	white	green	red	white
Detrimental impact on aquatic plants	red	green	green	red	white
Dried out wetlands and ephemeral chalk streams	red	green	green	red	white
Reduced water flows, lower flow velocities and reduced depth	red	green	green	red	white
Alteration of natural flow variability	red	green	green	red	white
Intrusion of saltwater into groundwater	red	green	green	red	white

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
This list of impacts is not comprehensive and only for illustration purposes.
Significance is indicated by positive (green), negative (red) or no (white) direction of change.

Table 2.14 Impacts on water users under the 5 scenarios

Impacts on water users	UD	INN	SB	LR	REF
Public health					
Shellfish poisoning (chemicals, toxins and microorganisms)	red	green	red	red	white
Unsuitable bathing water (chemicals, toxins and microorganisms)	red	green	white	red	white
Unsuitable drinking water (chemicals, toxins and microorganisms)	red	green	white	white	white
Contaminated food crops (chemicals, toxins and microorganisms)	red	green	green	white	white
INNS as vectors of exotic diseases	red	white	white	red	white
Methemoglobinemia	red	white	white	red	white
Gastrointestinal illness	red	green	white	white	white

Impacts on water users	UD	INN	SB	LR	REF
Navigation					
Blocked channels	red	green	white	red	white
Need for dredging in estuaries	red	white	green	red	white
Recreation and tourism					
Recreational opportunities	red	green	green	red	white
Aesthetic value of water bodies	red	red	green	red	white
Water companies					
Water treatment processes and cost (drinking water)	red	green	green	red	white
Restricted abstraction due to contamination of supplies	red	green	green	red	white
Flood risk	red	white	green	red	white

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
This list of impacts is not comprehensive and only for illustration purposes.
Significance is indicated by positive (green), negative (red) or no (white) direction of change.

3 Part II: Case studies

3.1 Case study 1: Catchment types

This section highlights how the main drivers of change may play out differently across the country in different generic types of catchments. Four catchment types, typical of different parts of England and Wales, are intended to illustrate this contrast. The major drivers of change, which include climate change impacts and change in land use and population, are likely to develop differently in different parts of the country. The scenarios tell a different story depending on the catchment in question.

Different socioeconomic pressures affect different catchments. In upland catchments there are mainly pressures from:

- land use change (for forest and woodlands, for livestock production and in peat lands)
- protection of water reserves and amenity value

In lowland catchments dominated by grassland, there are pressures from urbanisation and agriculture both in terms of land use change and the environmental impacts of these practices. Lowland catchments dominated by arable suffer from pressures in agriculture and protection of water supplies, while lowland urban catchments are mainly affected by changes in urbanisation.

Climate change plays an important role across all the scenarios, often exacerbating the impacts of socioeconomic changes. For example upland catchments suffer from flash floods, arable areas from increased water demand for irrigation, urbanised areas from eutrophication, and grasslands from droughts affecting wetland ecosystems.

3.1.1 Upland catchments

Why this catchment

'Upland catchments' predominate in the rural west (for example, Wales, the Pennines and Dartmoor). They currently have a low population density, with agricultural grasslands (for extensive sheep and beef production) and non-agricultural uplands (for example, peat bogs, heather moorland) as the dominant land cover. The predominant source of water is surface water (Table 3.1). The exposure pressures for the indicators of significant water management issues in 2050 are summarised in Table 3.2.

Table 3.1 Characteristics of generic upland catchments under current conditions

Uplands	Dominant land cover	Population density	Water sources
For example, Wales	Grass and unmanaged	Low	Surface water

Protection of water resources

Upland catchments provide one of the strategic water reserves of England and Wales. Under current conditions, 70% of the UK's drinking water is collected from upland catchments (Natural England, no date). The value of upland catchments for their water resources is even more cherished in the future, regardless of the scenario considered, with reduced availability of water resources as a result of climate change.

Where supplies are augmented within a national strategy to satisfy water demand (**UD** and **INN** scenarios), heavy engineering is used to develop high capacity water storage reservoirs and a network for water to be transferred across catchments. This includes the creation of new upland reservoirs by flooding valleys. Thus, there is a significant amount of physical modification of the rivers in upland catchments under these scenarios.

Where the local population is mainly supplied with local water (**SB** and **LR** scenarios), uplands partially lose their strategic role as water reserves. The level of modification in upland catchments does not increase. Under the **LR** scenario, existing reservoirs continue being operated to satisfy the water demand in the catchment. Under the **SB** scenario, with reduced water demand, abstractions are sustainable – respecting flow variability and impacts on sensitive areas; in wealthier regions, river restoration projects reduce the impact of river modification works carried out in the past.

Under the **REF** scenario, no new large-scale water transfers occur, but water is transferred across neighbouring catchments and small-scale reservoirs are built to cope with high water demand during periods of water stress. Abstractions are sustainable, but exceptions occur during drought periods (as permitted by law) and when significant economic benefits can be obtained during recession periods.

Expansion of forest and woodlands

Traditionally upland areas have been exploited for timber production. Under the **UD** scenario, commercial forests increase in upland areas; upland areas are where land is less favourable for the expansion of urban and agricultural areas, which have greater impacts on the water environment. Under the **LR** scenario, commercial forests in wetter areas are vital to the local economy. Commercial forestry increases the soil erosion associated with periods of afforestation and deforestation. Conversion of grassland into forest in upland areas may lead to significant reduction in annual stream flows of 10–15% (CEH, no date) and the replacement of native tree species for fast growing non-natives also influences river flows. Moreover, afforestation with conifer plantations may have a detrimental impact on aquatic ecosystems, exacerbating surface water acidification, which is toxic to juvenile salmonids (Puhr et al. 2000) and severely affects salmonid fisheries traditionally important in upland catchments.

A strategic move for carbon sequestration under the **INN**, **SB** and **REF** scenarios causes afforestation of non-peat upland areas (see below), which has a negative impact on river flows.

Livestock production

Uplands have long been subject to livestock grazing. Under the **INN** and **SB** scenario, livestock grazing declines in upland areas. In the **INN** scenario, synthetic meat is widely consumed and factory type intensive production of livestock predominates in the lowlands. In the **SB** scenario, society eats a more vegetarian diet, but livestock production is still extensive as it is an important niche market and has value as a global export, where England and Wales participate as a sustainable producer.

Under the remaining scenarios, measures are implemented with greater regard for the consequences on water resources. Under the **UD** and **REF** scenarios, there is an increase in livestock production in upland areas where possible. Under the **REF** scenario, controls are put in place to limit livestock density in riparian areas and to manage slurry, avoiding deterioration of water quality (for example, microbiological indicators and sediments).

Under the **LR** scenario, there is no significant change in livestock production at a regional level, but the area dedicated to livestock production in upland areas may increase as lowland livestock production is being replaced by arable, depending on the topography and soil conditions. Measures are implemented to avoid deterioration of local water quality, although the impacts on downstream communities are often ignored.

Land use change in peat lands

The run-off regime in upland catchments is very flashy, with high flood discharge and low baseflow as a result of high rainfall, low evapotranspiration and the low permeability of soils (for example, impermeable rocks, thin or waterlogged soils, peaty soils). Rapid erosion and high sediment yields are often associated with periods of rainfall and high run-off, and periods of drought; this is further exacerbated by climate change.

Peat soils, which are mostly found in the uplands, are the largest carbon store in England and are severely affected by climate change; evidence suggests that peat lands will shift from net sinks to net sources of carbon. Under the **UD** scenario, land use change that alters upland vegetation cover and rising pressures of acid rain further degrades peat lands, which are subject to erosion and carbon loss. This has negative impacts on biodiversity, carbon storage and water quality (House et al. 2010). Under the **LR** scenario, the situation is very similar with peat lands being used for agriculture in order to satisfy the food demand of the local communities.

Under the **SB** and **INN** scenarios, and to a lesser extent the **REF** scenario, carbon is high on the political agenda and priority is given to carbon sequestration and measures that reduce greenhouse gas emissions. Upland areas are therefore areas of concern; researchers, policymakers and land managers work collaboratively towards developing best management practices for carbon retention, for example, through grip-blocking, identifying vegetation type/height and related grazing regimes.

Preservation of amenity value

The uplands are beautiful landscapes, supporting wildlife and providing enjoyment and solace opportunities for people. The uplands continue to have amenity value in the future though the nature of this may change, where for example, pristine landscapes may lose their special appeal. The only exception is under the **LR** scenario, where there is less demand for a good quality environment for recreation as people do not travel around the country for recreation and leisure time is increasingly given over to pastimes that are productive such as animal husbandry and gardening.

Under the **INN** and **UD** scenarios, the infrastructure built to augment water supplies often reduces the aesthetic value of upland areas, but these are not perceived to have a major environmental impact. In the **UD** scenario, uplands are the preferred areas for the wealthiest of society to live or to have a second home. New reservoirs are generally used for recreational purposes (for example, leisure and bathing water) by those who can afford to pay for these services.

Under the **SB** scenario, rivers are restored to their natural conditions in wealthier regions where river engineering works have been conducted in the past. These catchments are associated with tourism, recreation activities and habitat creation.

Under the **REF** scenario, there are only small changes from current conditions.

Table 3.2 Summary of change in environmental risk for upland catchments (2050)

Indicator	UD	INN	SB	LR	REF
Phosphorus	No change	↑↑↑	↑	↓↓↓	↑
Nitrate	No change	↑↑↑	↑↑	↓↓↓	↑
Sanitary pollutants	No change	↑↑↑	↑	↓↓↓	↑
Chemicals and metals	↑	↑↑↑	↑↑	↓↓	↑
Faecal indicator organisms	↓↓	↑↑↑	↑	↓↓	↑
Abstraction and flow	↓↓↓	↓	↑↑↑	↓	↓
Physical modification	↓↓↓	↓↓↓	↑↑↑	No change	↓
Sediment	↓↓	↓	↑↑↑	↓	No change
INNS	↓↓	No change	↑↑	↓	No change

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Change is characterised as an improvement (green arrow up) or degradation (red arrow down). The extent of change is characterised as weak (1 arrow), moderate (2 arrows) or strong (3 arrows).

3.1.2 Lowland catchments (grassland)

Why this catchment

'Lowland grassland catchments' represent, for example, the rural south-west where there is currently a low to medium population density. These catchments have grasslands for intensive ruminant livestock production, and dairy as the dominant land cover (Table 3.3). The exposure pressures for the indicators of significant water management issues in 2050 are summarised in Table 3.4.

Table 3.3 Characteristics of generic lowland grassland catchments under current conditions

Lowlands (grassland)	Dominant land cover	Population density	Water sources
For example, south-west	Grass and marginal land	Low to medium	Surface and groundwater

Urbanisation

The extent to which lowland grassland habitats are affected depends largely on their location. Lowland catchments are further urbanised near urban areas in all scenarios. This is particularly true under the **LR** scenario, enabling the government to minimise investment in transport and communication as small urban centres expand. Under this scenario, there is increased urban run-off due to minimum improvement to existing infrastructure that is at the end of its life. Population growth places additional stress on existing sewage and water infrastructure that is poorly maintained and vulnerable to extra pressures.

In the **UD** scenario, rural areas in lowland catchments are associated with the proliferation of poor quality ‘affordable’ housing. These new developments are not connected to sewerage systems, but rely on septic tank systems and the installation of poor quality drainage and ‘inadvertent’ connections into surface water systems. The receiving water bodies are of poor quality. Those on low incomes, who cannot afford water charges, often resort to consuming illegally abstracted water from hand-dug wells or boreholes, rather than risk drinking water directly from rivers. Similarly, high food prices mean alternative forms of food production are sought, creating pockets of subsistence agriculture, occasionally on contaminated land, and livestock can be seen feeding on riparian areas further deteriorating water quality.

Under the **INN** scenario and, to a lesser extent the **REF** scenario**,** lowland grassland catchments can also be prone to the expansion of urban areas. New developments use the best technological solutions, such as SUDS and combined water and wastewater treatment works, minimising the impact of urbanisation on the water environment.

Under the **SB** scenario, lowland grasslands near urban areas also suffer from an expansion of urban development, but to a lesser extent than in the **INN** and **REF** scenarios. This is because the population is comparatively smaller in size, and a small but significant proportion moves to agricultural areas that offer job opportunities in sustainable agriculture. This expansion has detrimental effects on water bodies. New developments incorporate SUDS, but wastewater treatment processes are not as efficient as the current ones in order to reduce the carbon footprint; coastal waters are particularly affected by a reduced quality of effluents.

Agriculture

Given the high competition for land under the **UD** scenario, grasslands are used for intensive agriculture for potatoes and horticulture. Increased livestock production causes further deterioration of the receiving water bodies as a consequence of run-off from farms that typically lack proper storage of slurry/manure. Conversion into arable lands is associated with high fertiliser application. Grasslands are agriculturally improved, that is, they are either permanently uncultivated or are part of an arable rotation that has been modified for agriculture or recreation, resulting in a loss of significant diversity of highly specialised plant and animal species.

Under the **LR** scenario, grasslands are converted into arable and horticultural lands to satisfy the increasing demand for local produce, resulting in a deterioration of local water quality despite the fact that water is used efficiently for irrigation. Equally, under the **REF** scenario, grasslands are used for intensive agriculture generally in the form of very large farms; however, the environmental impacts of prescriptively regulated agricultural practices on the water environment are significantly lower than those under the **UD** and **LR** scenarios.

Contrastingly, under the **INN** scenario, healthy grasslands are protected to provide essential services such as habitats for pollinators, flood prevention and carbon storage. Equally, under the **SB** scenario this habitat is a priority for nature conservation and wetlands are specially protected for their carbon storage properties. A greater number of lowland grassland habitats are listed under the EU Habitats Directive and the UK Biodiversity Action Plan. Under the **SB** scenario, however, extensive agriculture causes agricultural land expansion and parts of lowland catchments (grasslands) are converted into arable and horticultural land. The environmental consequences of integrated agriculture systems are minor.

Table 3.4 Summary of change in environmental risk for lowland catchments dominated by grassland and marginal land (2050)

Indicator	UD	INN	SB	LR	REF
Phosphorus	↓↓↓	↑↑	↓↓	↓↓↓	No change
Nitrate	↓↓↓	↑↑	↓	↓↓↓	↓↓
Sanitary pollutants	↓↓↓	↑↑↑	↓↓	↓↓↓	↓
Chemicals and metals	↓↓↓	↑↑	No change	↓↓↓	No change
Faecal indicator organisms	↓↓↓	↑↑↑	↓↓	↓↓↓	↓
Abstraction and flow	↓↓	↑↑	↑↑	↓↓	↓
Physical modification	↓↓	↓↓	↑↑	↓↓	No change
Sediments	↓↓↓	↓	↑	↓↓	No change
INNS	↓↓↓	↓	↑	↓↓	↓

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Change is characterised as an improvement (green arrow up) or degradation (red arrow down). The extent of change is characterised as weak (1 arrow), moderate (2 arrows) or strong (3 arrows).

3.1.3 Lowland catchments (arable)

Why this catchment

Lowland arable catchments represent the rural east (for example, East Anglia). The catchments currently with low to medium population density and arable land as the dominant land cover; the predominant source of water is groundwater (Table 3.5). The exposure pressures for the indicators of significant water management issues in 2050 are summarised in Table 3.6.

Table 3.5 Characteristics of generic lowland (arable) catchment under current conditions

Lowlands (arable)	Dominant land cover	Population density	Water sources
For example, East Anglia	Arable land	Low to medium	Groundwater

Agriculture

Arable catchments are considered by the government to be of strategic national interest for food production under the **UD, REF** and **INN** scenarios. Under the **UD** and **REF** scenarios, there is an expansion of farmland for intensive agriculture, for the REF scenario in the form of corporately owned large-scale farm units. There are several options to expand farmland in arable catchments including:

- removal of environmental buffer strips (implemented for Entry Level Stewardship funding)
- conversion of grasslands into arable land
- conversion of arable land to grow potatoes and horticultural crops

Under both the **UD** and **REF** scenarios, flood protection infrastructure safeguards those agricultural areas that generate higher incomes. However, the impact on the water environment differs greatly between the **UD** scenario and the **REF** scenario. Under the **UD** scenario, there is very high demand for irrigation and water quality suffers severe deterioration due to agricultural intensification that uses more fertilisers, pesticides and unsustainable soil management practices indiscriminately as a result of the relaxation of environmental legislation and a lack of environmental awareness. Contrastingly, under the **REF** scenario, intensive agricultural practices are highly regulated in order to protect the water environment; less water-intensive crops are grown in water-scarce areas and irrigation is efficient.

Under the **INN** scenario, there is a sustainable intensification of agriculture. Arable catchments do not see an increase in the proportion of agricultural land. Agriculture has less impact on the environment as a result of tighter regulations and improved agricultural practices and techniques as well as enhanced chemicals and fertilisers.

Under the **SB** scenario, agricultural areas mostly supply the local population and some flood-prone farmlands are being transformed into seasonally flooded water meadows. Integrated agricultural systems are used with minimal impact on the environment and legislation has banned the use of chemicals that cause environmental deterioration.

Farmers select crops that fit the local availability of resources; irrigated crops increase only in areas where water is available and farmers select less water-intensive crops in other areas. Rural communities have grown as more jobs are created in sustainable agriculture. Rural and more isolated areas become more populated. SUDS and STW are constructed in new developments. In smaller urban areas, the number of small wastewater treatment plants increases, some of which are private plants making use of reed beds.

Under the **LR** scenario, arable lands reduce as they now solely supply the local population. Agriculture practised by first generation inexperienced farmers has detrimental effects on the water environment. There is a move away from pure arable lands to mixed farming; slurry/manure provides a source of local and cheap nutrients to supplement the soil. The yields become more vulnerable to droughts and floods, which are accepted by farming communities. Flood defences are too costly to protect agricultural land and farmers increasingly build on-farm storage reservoirs in order to cope with periods of drought. Given the limited investment in research and development, agricultural practices rely on the use of chemicals (some of which had been banned in the past) to control pests and diseases.

Protection of water supplies

Chalk aquifers are an important groundwater reserve in lowland catchments. Under the **UD** scenario, current Nitrate Vulnerable Zones in recharge zones where water is at risk of exceeding the nitrate concentration limit are largely ignored. Farming practices increase nitrate leaching and the public water supply sources have high nitrate concentrations. Consequently, treatment works have been installed at many groundwater sources and, while these are effective at reducing nitrate concentrations to protect public health, they are costly.

Under the **LR** scenario, the situation is similar, but not as extreme as Nitrate Vulnerable Zones are protected when the water resources of that community are directly affected.

Under the **INN, SB** and **REF** scenarios, there is no further increase in the concentration of nitrate in the groundwater in lowland arable areas as a result of sustainable agricultural practices, namely in aquifer recharge areas. However, treatment of groundwater is necessary due to past nitrate pollution. Nitrate concentrations in the unconfined aquifer have increased in the past, whereas the confined aquifer has been penetrated by modern groundwater with high nitrate concentrations. Thus raw groundwater frequently poses a risk to public health.

Table 3.6 Summary of change in environmental risk for lowland catchments dominated by arable land (2050)

Indicator	UD	INN	SB	LR	REF
Phosphorus	↓↓↓	↑↑	↑	↓↓↓	↑
Nitrate	↓↓↓	↑↑	↑↑	↓↓↓	↓
Sanitary pollutants	↓↓↓	↑↑↑	↑	↓↓↓	↑
Chemicals and metals	↓↓↓	↑↑↑	↑↑↑	↓↓↓	↑
Faecal indicator organisms	↓↓↓	↑↑↑	↑	↓↓↓	↑
Abstraction and flow	↓↓↓	↑↑	↑↑	↓↓	↓
Physical modification	↓↓	↓↓↓	↑↑	↓↓	↓
Sediments	↓↓↓	↓↓	↑↑	↓↓↓	No change
INNS	↓↓↓	↓	↑	↓↓	↓

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Change is characterised as an improvement (green arrow up) or degradation (red arrow down). The extent of change is characterised as weak (1 arrow), moderate (2 arrows) or strong (3 arrows).

3.1.4 Lowland catchments (urban)

Why this catchment

'Lowland urban catchments' represent, for instance, the urban Midlands with a high population density and urbanised land as the dominant land cover; the predominant source of water is surface water (Table 3.7). There are very few truly urban catchments, but urban catchments may receive pressures from upstream rural catchments. The exposure pressures for the indicators of significant water management issues in 2050 are summarised n Table 3.8.

Table 3.7 Characterisation of generic lowland (urban) catchment under current conditions

Lowlands (urban)	Dominant land cover	Population density	Water sources
For example, Midlands	Urban areas	High	Surface water

Urbanisation

In catchments with large urban areas, there is an expansion of urban land to accommodate a growing population and an industrialisation of such catchments. Under the **UD** scenario, the water environment – already affected by pressures from upstream rural catchments – often deteriorates beyond the point of recovery. Sewage infrastructure often fails due to a lack of investment, and relaxation of regulation causes a reduction in the standards for wastewater treatment and industrial effluents. Rivers are modified to accommodate an expanding urban area and to protect from flooding those areas that generate more income; flooding have a severe impact on the more deprived sections of society who live in floodplain areas.

Under the **REF** scenario, there is an expansion of urban areas. Old areas have an ageing water and wastewater infrastructure, while new developments incorporate SUDS as required by law. Overall, urban run-off reduces, which coupled with stringent effluent discharge consents for industrial plants and STWs, leads to an improvement in the urban water environment. Flood protection is built in the most vulnerable urban areas that generate income, with the remainder being gradually abandoned and transformed into floodplain areas that provide a natural attenuation of peak flows. Urban areas are supplied mostly by renewable energies and transport runs on biofuel.

Under the **LR** scenario, increased household occupancy and ageing water and wastewater infrastructure, coupled with relaxed effluent discharge consents, leads to the deterioration of the receiving water bodies. However, measures are implemented to ensure public health protection (for example, efficient water treatment processes or community action when the impacts of pollution are visible). The number of vehicles running is significantly reduced due to their associated costs, but the lack of maintenance of those vehicles contributes to increased air pollution. Urban subsistence farming increases hugely with allotments, school plots and gardens being used to provide a staple diet. Industrial activities central to the communities' subsistence are allowed to operate under relaxed environmental standards.

The picture is very different under the **INN** scenario. Urban areas operate as closed loop systems and provide a pleasant place to live. Public vehicles run on biogas produced from sewage sludge and energy self-sufficient buildings are common. SUDS are widely incorporated, reducing the impacts of flash floods and sediments in the receiving water bodies. The quality of urban effluents is drastically improved and the quantity reduced, as a result of tighter controls and enhanced treatment processes that allow the use of wastewater as a source of potable water.

Under the **SB** scenario, urban areas increase to accommodate a growing population and become greener. Cities own considerable amounts of natural land, and ecological networks are created and strengthened within and between urban centres in the same region. Examples include ecologically improved waterways, tree corridors and green connections between open spaces, providing recreational areas for people and good and healthy urban habitats for fauna and flora. To compensate for any loss of green space taken by an expansion of buildings, green roofs are quickly adopted. Water quality is a concern with urban water bodies having poor quality relative to non-urban parts of the country. Due to the lower standards of discharge consents, the quality of urban effluents is poor, especially where wastewater is discharged in coastal areas. Wealthier catchments are less affected as low energy technology is available to perform wastewater treatment processes at higher standards, but at a greater cost.

Table 3.8 Summary of change in environmental risk for lowland catchments dominated by urban land (2050)

	UD	INN	SB	LR	REF
Phosphorus	↓↓↓	↑↑	↓↓	↓↓↓	No change
Nitrate	↓↓↓	↑↑	↓	↓↓↓	↓↓
Sanitary pollutants	↓↓↓	↑↑↑	↓↓	↓↓↓	↓
Chemicals and metals	↓↓↓	↑↑	↓	↓↓↓	No change
Faecal indicator organisms	↓↓↓	↑↑↑	↓↓	↓↓↓	↓
Abstraction and flow	↓↓	↑↑↑	↑↑↑	↓↓	↓↓
Physical modification	↓↓↓	↓↓↓	No change	↓↓	↓↓
Sediments	↓↓↓	↓↓	↑↑	↓↓↓	↓
INNS	↓↓↓	↓↓	No change	↓↓↓	↓↓

Notes: UD = Uncontrolled demand; INN = Innovation; SB = Sustainable behaviour; LR = Local resilience; REF = Reference
Change is characterised as an improvement (green arrow up) or degradation (red arrow down). The extent of change is characterised as weak (1 arrow), moderate (2 arrows) or strong (3 arrows).

3.2 Case study 2: Implications for key sectors

Each scenario affects the various sectors of society differently. This second case study explores the implications for a number of sectors, which have a dependence on water and the water environment, a role in its management and/or are general users. The aim was to carry out an analysis of the impacts of environmental change on the sector and the impacts of the sector on the environment. The 5 sectors discussed are:

- general public
- manufacturing industries
- leisure industries
- utility companies (water and energy)
- farming and fisheries

This case study does not aim to be a comprehensive assessment of all sectors and is intended to be illustrative to stimulate further discussion and analysis. In particular, it became evident during this project that further research would be required for the general public and manufacturing industries' sectors. The implications for these key sectors under each of the 5 scenarios are summarised in Table 5.1 in Report A.

3.2.1 Why these key sectors?

General public

The general public are dependent on all the services provided by the other sectors listed above. Managing water resources to adequately supply good quality potable water is vital for numerous household activities such as:

- drinking
- cooking and food preparation
- bathing and washing
- laundry and cleaning
- flushing toilets and septic tank systems
- heating systems
- lawns and gardens
- car washing
- swimming pools
- ponds

The water environment is also of primary importance to the general public, providing opportunities for:

- boating and canoeing
- angling
- swimming
- surfing
- sub-aqua
- artistic activities
- social activities
- physical exercise
- informal near stream bankside recreation or picnicking
- bird watching
- cultural heritage interest
- walking and hiking

Changes in water quality, water quantity and physical habitat (for example, those associated with climate change impacts) are projected to change total annual river flows by approximately ±20% in 2050 (Jackson 2012). The impacts of this change on the wider water environment have significant consequences on the activities and services provided by water resources and the water environment for the general public. This could result in consequences for public health (physical and mental) and general well-being. With population growth these consequences could be acute, particularly in areas where growth is higher.

Manufacturing industries

Water and the water environment are essential for the functioning of the manufacturing industries. Most manufacturing industries are dependent on resources obtained from the water environment for their production systems. Poor water quality or limited/unreliable access to water means higher costs for businesses and consumers. Moreover, industries also rely on watercourses to dispose of wastes, some of which are, to some extent, treated by natural processes in the receiving environment.

Vast amounts of water are used by the manufacture of food and drink, chemicals, pharmaceuticals and paper. Water is an important element in many products such as chemicals, drugs, lotions, shampoos, cosmetics, cleaners and beverages. Technology and communication industries depend on water for manufacturing and for effective operation, for example, in cooling large computer servers. Manufacturing industries are also dependent on other raw materials such as crops and wood, which are reliant on water and functioning ecosystems.

Water bodies are being damaged by abstraction (Environment Agency 2011a) and pollution from manufacturing industries in some places. The siting of manufacturing plants near watercourses can also lead to morphological impacts on aquatic ecosystems.

For various reasons, the manufacturing industry in England and Wales has been in decline. Future environmental pressures and changes in water availability may further impact this sector. For instance, water usage was seen in a food industry survey as becoming a food security issue (Allegra Strategies 2012).

Leisure industries

Many leisure activities and the industries associated with them are dependent on the water environment. For instance, water sports such as fishing and canoeing require adequate water in the natural environment to take place. Other activities such as hiking, dog walking, and art and craft are dependent on the aesthetics of these environments.

According to statistics from Visit Britain, the number of tourist visits to Britain increased by 11 million between 2002 and 2012. Projections indicate that there will be steady growth in visits between now and 2020, with the symbolically important 40 million threshold being reached by 2020 (Visit Britain 2012). This is likely to increase demand for water and have an impact on the environment.

Future environmental pressures may reduce water availability for abstraction to service tourism industries. Additionally, these pressures may have an impact on the natural environments that much of England and Wales' tourism relies on. Low flows in some aquatic environments and changes in water quality could potentially have detrimental impacts on water-based leisure activities.

Water demand and shortage issues associated with tourism in other countries appears to have serious effects on surrounding communities and natural habitats, as well as on the tourism sector itself; it also undermines the sustainable development of destinations (Tapper et al. 2011). Often tourism develops in already water-stressed areas such as coastal locations.

Utility companies (water and energy)

Many utility companies are dependent on good quality water supplies and the services provided by the water environment. The water industry has a significant role in ensuring their water supply and wastewater services have minimal environmental impacts. Six and a half billion cubic metres of water are abstracted each year to be put into the public water supply system. Water companies abstract almost half of the total amount taken from non-tidal waters in England and Wales, but return over 70% as treated effluent which, unless it is discharged to the marine environment, augments river flows (Environment Agency 2008).

The industries that light homes, offices and streets and which provide energy for heating, cooking and running modern appliances use considerable amounts of water for cooling processes, although most of this is returned directly to the local environment (Environment Agency 2011a).

The annual amount abstracted for public water supply in England and Wales did not vary much between 2000 and 2012 (Defra 2013). However, household water demand has increased since the 1950s due to population growth and changes in behaviours, and is now more than half of all public water supplied (Defra 2008). In contrast, water abstraction from freshwater sources to support electricity generation (for example, hydropower and power station cooling water) increased between 2000 and 2012 by 13% (Defra 2013).

The population of England and Wales is expected to grow significantly in the future. This growth may be focused on particular parts of the country such as the south-east. This implies increased water demand for households, but also for schools and shops and for electricity generation.

Farming and fisheries

Agricultural and horticultural industries rely on water for irrigating crops, watering animals and general agricultural activities. Fishery industries need adequate supplies of clean water regardless of whether the activity is performed within the water environment or through aquaculture farms.

Water for spray irrigation is required in the summer when water resources are most scarce.

This sector is likely to be challenged in the future with overall water demand predicted to increase (Environment Agency 2011a). Changes in water demand, and agricultural and land management practices, will significantly affect water resources and the water environment.

3.2.2 General public: impacts under the scenarios

Uncontrolled demand

Social achievement and financial stability epitomise the goals of individuals in society.

In the **UD** scenario, the majority of people residing in urban areas have low environmental awareness and concerns around the cost and availability of resources (that is, water, energy and food). The poorest of society live in urban areas that are environmentally degraded and vulnerable to flooding, where water resources are heavily polluted. They struggle to make ends meet; because water bills are high, they resort to illegal abstraction of often contaminated water, which poses serious public health issues. Personal aspirations include securing basic needs and more long-term ambitions such as moving to a well-off community and securing a better lifestyle.

Conversely, the affluent of society that have properties in these well-off communities can afford to pay for good environmental services such as recreational activities in tributary sub-catchments or upland catchments and the good quality potable water provided in these areas.

Innovation

Society meets its needs, achieving environmental protection without change in consumer behaviour.

Under the **INN** scenario, society is aware of the value of the environment but is unwilling to change lifestyles to preserve it. The government provides innovative solutions to protect the environment. Technology eases pressure on energy, land and water resources. Houses are retrofitted for resource efficiency (for example, metering, aerated showerheads and toilet flushing technologies that reduce water use).

There is greater equity between the richest and poorest of society. Social values are superseded by demonstrations of wealth, including owning the latest gadgets, acquiring the latest fashionable clothes and eating out at gourmet restaurants.

Sustainable behaviour

Individual and community behaviours ensure environmental protection.

In the **SB** scenario, a more ‘green’ conscious society is aware of the need to protect the environment for its cultural and provisioning services. The population has the ability to meet their basic needs. Goods are more expensive as the price of externalities, such as virtual water, are passed on to the consumer. Those products with low environmental and social costs remain affordable to the majority of society on middle class incomes. Water is affordable to all despite its price being high.

Individuals compete to be ‘greener’ than their neighbours and demand ready access and the opportunity to enjoy the natural environment. Society has ownership of water and ecosystem problems, and the role of the public as a watchdog helps to ensure compliance with environmental regulation. There is a shift towards increasing personal accountability, which ensures the population remains sustainable in their practices and consumer choices. Domestic water recycling in homes is the norm and there are tight controls over housing development, business permissions, and public energy and water infrastructure.

Local resilience

Society struggles to meet basic needs, relying on local community support for subsistence.

Under the **LR** scenario, the population focuses on protecting the environment as the source of their survival and are heavily engaged in community life. Individuals share the burdens and rewards of the community together, where those in need often benefit from resources in the community, accessed through social support networks. Individuals work hard to maintain a ‘comfortable’ lifestyle in which their basic needs are met, and to build a strong and supportive community that is comparatively better off than neighbouring communities.

Society reduces consumption of food, water and energy. The cost of resources varies significantly between years and seasons. Technology is rarely used as it increases prices. Individuals aim to reduce the amount of waste produced and water consumed in order to minimise costs. Houses have been adapted to become more efficient, significantly reducing water consumption and maximising the use of rainwater and greywater; often individuals retrofit their own homes making use of their DIY skills. In addition, increased household occupancy also means higher resource efficiency.

Short-term management and protection of environmental resources are conducted locally and not at a catchment scale, disregarding longer term environmental interests and downstream communities. When regulation and management systems fail to protect local resources, efforts to control (visible) pollution events tend to be driven by community anger.

Reference

Individuals aspire to relocate to the countryside to elevate their social status in society.

As the price of agricultural land increases, only the affluent in society can afford to live in rural areas in the **REF** scenario; the remaining population reside in urban areas. Individuals are capable of meeting their basic needs but strive to attain a higher standard of living. Individuals are only concerned about local environmental impacts as it relates to their quality of life. Increasingly, the price of goods causes sporadic events of public outcry. This results in reduced consumption of water and energy, predominantly among price-conscious consumers.

3.2.3 Manufacturing industries: impacts under the scenarios

Uncontrolled demand

Industry flourishes as profit margins are maximised, unhindered by environmental regulation.

Under the **UD** scenario, industry thrives as less stringent environmental regulation reduces barriers to profit maximisation and ensures the sector can compete on price in international markets. The UK's manufacturing industry performs well, producing high-end goods and services for export, and cheap products for national consumption. Industry moves to regions where cheap land is available. Urban centres are now heavily industrialised, further affecting receiving water bodies.

Water-intensive manufacturing processes are common in areas where supplies are available. In industries where profit margins are low, there is reduced investment in water-saving technologies or measures, and those are only implemented if economic benefits are achievable in the short term. The increasing price of water is reflected in the cost of products.

There is a significant increase in the quantity of chemicals imported for manufacturing, and pollution by hazardous substances and priority hazardous substances (specified in the Water Framework Directive) are of increased concern. Poorly regulated and widespread nanotechnology is particularly alarming, causing heavy metal pollution. The most advanced manufacturers begin to reuse materials if this provides short-term economic advantages, but industrial treatment technologies are slow to advance.

Innovation

Investment in research and development provides a good business model and opportunity for industry to operate within environmental standards.

Under the **INN** scenario, manufacturing industries operate within the limits set by strict regulation and tight environmental standards. Environmental incentives and the increased accountability of businesses for environmental externalities are also in place to promote investment in innovative technologies. These enhance the efficiency of processes, namely reducing the carbon footprint of end-of-pipe solutions and developing closed loop systems that promote the valuation of resources, waste minimisation, and the reuse of byproducts and waste. Hi-tech manufacturing causes the expansion of industrial areas. An overall increase in water demand from this sector is seen.

A variety of novel chemicals with reduced environmental impacts are available and quickly adopted by manufacturing industries. On occasion, this leads to unexpected environmental impacts. New types of pollution are a concern; for instance, the evolution of nanotechnologies and synthetics for textiles, pharmaceutical, beauty and energy industries. Regulations are gradually updated to control new pollutants.

Sustainable behaviour

Environmental legislation and social pressure prompt green manufacturing.

Under the **SB** scenario, the government requests that all environmental and social costs included in a product’s lifecycle to be made available to consumers to enable them to make more informed purchasing decisions. Products with high total costs are heavily taxed while the remaining products remain affordable. This results in widespread adoption of technologies that optimise production and minimise environmental impacts (for example, water saving, low carbon technologies and green energy). New technologies are adopted given proven reliability, cost-efficiency and a low risk of unexpected impacts. Older technology is often retrofitted or maintained when this is more economical and/or sustainable than replacing it.

Remediation measures are generally more costly than preventive measures. Product legislation banned substances responsible for environmental impacts and health hazards (for example, general chemicals and pharmaceuticals). The public acts as a ‘watchdog’ for industrial malpractice, protecting the environment.

Local resilience

Environmental standards are traded off against economic growth.

In the **LR** scenario, manufacturing industries operate in challenging local and national markets, and struggle to maintain profit margins. Finance for investments in new infrastructure and equipment is limited with companies running outdated technologies. The implementation and enforcement of environmental policies varies widely across the regions. Industries avoid the deterioration of local environmental resources that have a direct impact on human health, such as protecting the water quality of their local water bodies. Selfish community behaviour is evident, with little regard to downstream impacts. The magnitude of the environmental impacts considered acceptable by the local community depends on the services and products in question. Companies that are essential to the local economy are allowed to negotiate some level of non-compliance, while for the remainder, non-compliance results in forced shutdown.

Reference

Minimal compliance with environmental standards is pursued to reduce financial pressures.

In the **REF** scenario, manufacturing industries operate in an international market that goes through cycles of prosperity and recession. The increasing cost of resources leads to slow investment in resource-efficient technologies and management systems. New technologies such as those for water saving are embraced if they are reliable and provide short- to medium-term economic gains.

The manufacturing sector has seen an improvement in compliance levels alongside marginally higher standards, resulting in low concentrations of chemicals in industrial effluent. Compliance with environmental standards is pursued to avoid the costs associated with penalties and reputational damage. Pollution by hazardous substances and priority hazardous substances is of less a concern, as the EU has banned the use of chemicals with high environmental impacts and has a risk-based approach for approval of new chemicals. The most advanced manufacturers reuse materials if it provides short-term economic advantage.

3.2.4 Leisure industries: impacts under the scenarios

Uncontrolled demand

A dichotomy of services exists where the 'natural water environment' is offered on an exclusive basis, while the 'artificial water environment' is considered mainstream.

In the **UD** scenario, mainstream leisure services that provide access to water-related environments and activities move away from the natural environment such as lakes and beaches, adopting artificial water environments such as swimming pools and aquatic parks. Tourism and leisure activities that utilise the natural environment are advertised as exclusive services, typically targeting the affluent in society. The 'pristine' catchments and private beaches with good bathing water quality and healthy ecosystems are offered at high cost. Good environmental management that achieves the desired water quality is costly and carried out mostly by private initiatives, as the environment has a low priority on the political agenda. Nevertheless, these areas are also subject to a high level of physical modification of rivers (for example, with newly built big storage reservoirs), but this infrastructure is not perceived to have a major environmental or aesthetic impact.

Innovation

The leisure industry capitalises on changing notions of aesthetics, providing new leisure services.

In the **INN** scenario, the leisure industry benefits from improvements in water quality across the country, with an expansion in sport and leisure infrastructure associated with the water environment (for example, wave gardens, sailing clubs and water skiing), which is affordable for all. New notions of aesthetics in agricultural areas and expanding household areas are further explored by the leisure industry such as vineyards and rural vacations.

Sustainable behaviour

The leisure industry provides opportunities to maximise the outdoor experience.

Under the **SB** scenario, the population has free access to the environment. As a result, tourism and leisure industries are limited to providing the facilities and equipment that maximise the outdoor experience (for example, camping, equipment rental and guided tours).

Travelling abroad is considered unsustainable by most. Society is willing to pay to improve and protect their environment especially in wealthier regions, which have greater disposable income. Heavily modified river reaches are restored, mainly in regions with wealthier communities, improving the opportunities for recreation, biodiversity and the attractiveness of the landscape as well as contributing to increased natural storage capacity of flows. River restoration includes:

- remeandering
- creating 'green' natural riverbanks where previously banks were encased in concrete
- fish passages that enable the migration of fish past sluices and other obstacles

Local resilience

Leisure industries decline and are restricted to services provided at a local community scale.

In the **LR** scenario, the leisure industry is one of the sectors most affected by the challenging markets in an era of protectionism. The majority of the population focuses on making ends meet and tends not to venture out of their community for recreational or leisure activities. Leisure time is increasingly given over to pastimes that are productive, such as animal husbandry and gardening. In communities where river and streams are contaminated, the population does not have the option of water-related leisure activities. High-end holiday destinations are accessible only to a small minority.

Reference

Growing confidence in water quality increases demand for leisure services.

In the **REF** scenario, leisure services that provide access to the water environment benefit from improvements in water quality, which prompts the expansion of water bodies where leisure activities are permitted. Growing confidence in water quality is matched by an increasing demand for water-related leisure activities. Society has a level of environmental concern, and interest groups strongly defend their interests in aid of environmental protection.

3.2.5 Utility companies (water and energy): impacts under the scenarios

Uncontrolled demand

Profit is prioritised in a society where water resources are scarce.

In the **UD** scenario, water and energy companies are faring well, producing high profits for shareholders. Degradation of water quality and reduced water availability prompt investment in storage and in technologies for water treatment processes. Similarly, there is investment in storage in the energy sector. Water and energy demand rise and the high price of water and energy is the only factor restraining their consumption, given the lack of public environmental awareness and demand control measures incentivised by the profit seeking industry. Upland catchments become protected national water resources and a strategy to augment supplies is implemented by the water industry. This involves large-scale water transfers, high capacity reservoirs and desalination plants. Water is frequently over-abstracted.

Low environmental standards allow for reduced investment in operational management (for example, leakage reduction and wastewater treatment processes) and there is increased impact on water resources and the water environment. Water quality deteriorates as a result of the relaxation of discharge consents and secondary treatment becomes the norm. Moreover, discharge consents are often not complied with due to the weak enforcement of environmental regulations and deteriorating monitoring systems. Reduced investment in sewage infrastructure, combined with climate change, results in frequent sewage overflow incidents. Sophisticated water treatment processes are used to ensure water is potable.

Energy companies move away from coal and use the existing coal plants to produce biofuels from agricultural residues. Other sources of energy include nuclear, wind and shale gas. Utility companies ensure high income areas are provided with a secure supply of water and energy. In gated communities, backup energy generators are usually found as well as resilient and interconnected water supply networks distributing very good quality water. These areas are charged a higher cost for maximum profit.

Innovation

Investment in infrastructure and technology improves services with reduced environmental impact.

Under the **INN** scenario, water and wastewater services remain privatised, but are provided by several competing multinational companies which exploit the individual elements of the business processes that have been split out (for example, abstraction, treatment, distribution network and billing). Customers' demand for good water quality and the tightening of drinking water standards has driven tighter environmental standards. Water and wastewater treatment has advanced so much that, in many areas, wastewater and water treatment have merged into one plant. Wastewater is not discharged to the environment as it is now used as a source of potable water. Customers choose the greenest and most efficient companies driving further innovation across the industry.

A twin track approach is used by the water industry to balance water supply and demand. Supplies are augmented based on large-scale water transfers coupled with reservoirs, groundwater recharge and less energy-intensive desalination plants. Per capita household demand is reduced by retrofitting appliances in most dwellings (for example, smart meters, rainwater harvesting and greywater reuse). There is also a substantial reduction of leakage, which is strongly regulated through improvements in materials, techniques, repair solutions and metering.

The major sources of energy are gas, nuclear and solar. Energy generation is less affected by water availability as fossil fuels are partly substituted by non-water using renewable sources of energy (for example, solar generation and second generation biofuels such as those manufactured from residues of food crops). Ceasing production at coal-fired power plants reduces the byproducts of combustion and allows the decommissioning of the remaining coalmines. Water is no longer abstracted for cooling towers, increasing the river flows (where typically 33% is lost on evaporation) and putting an end to thermic pollution issues and fish kills when water is drawn into the coal power plant.

Sustainable behaviour

The drive for sustainability reforms the water industry.

Under the **SB** scenario, the water industry operates under local regulations and protects water and the water environment as much as possible without compromising their carbon footprint. Water companies invest in maintaining infrastructure and monitoring systems, and in reducing leakage losses. Water resources are carefully protected for future generations and sustainable abstraction guarantees reduced impacts during low flow periods and on sensitive water bodies and habitats. In water-stressed areas, interruptions such as hosepipe bans are common and accepted by the population as necessary measures to cope with climate change. Local water is used to supply the local population when possible and water trading within the region becomes the norm. Water transfers across the regions are considered a low priority measure and only in areas with high water deficit.

Low energy-intensive wastewater treatment processes are used to reduce the carbon footprint (for example, tertiary treatment in reed beds). These processes are generally not as efficient, even though the flow entering the sewage system has decreased in volume and load. Locally led regulation has relaxed discharge consents, particularly into coastal water environments, ensuring high compliance with environmental water quality standards. Despite increased urban density, sewer blockages and sewer overflows incidents are less common.

Mutualisation of the water industry implies a significant temporal and spatial change (depending on who is in charge) of the impacts of discharges on receiving water bodies and on public health scares. However, investment in water quality monitoring is locally led to ensure compliance with water quality standards, for instance, in catchment sensitive areas and in bathing waters. In wealthier regions, low energy technology is available to perform wastewater treatment processes at higher standards, albeit at a higher cost.

Rural and more isolated areas become more populated, and the number of small wastewater treatment plants using very simple treatment processes increases; some of these are private plants.

Efforts to lower the carbon footprint drive investment and the development of energy from renewable sources. The use of wind and carbon capture storage gas, associated with campaigns by the energy utilities to reduce demand, drive significant environmental improvements. A small number of power plants operate but these have been relocated to the coast to take advantage of available water for cooling.

Local resilience

Companies provide services locally and struggle to operate.

In the **LR** scenario, water and energy companies operate on a local scale as a local monopoly. Poor economic conditions mean funds are limited for operational and capital investments, with infrastructure used beyond their useful life. Utility services are unreliable with interrupted water and energy supply, frequent environmental incidents (for example, sewage overflows) and leakage losses. Regions with strong local leadership and available funds have maintained their own infrastructure, improving the standards and reliability of the service. 'Energy islands' emerge with well-developed local energy generation attracting migration.

Water abstraction is determined by local needs. Where water is scarce, the water price is high and supplies are unreliable; in periods of stress, water is abstracted beyond sustainable levels. Standards for effluent and environmental water quality are set by local authorities and are less stringent than earlier in the century, particularly in coastal areas or in downstream community areas. Exceptions exist where stricter standards are set, including at upstream abstraction points and fisheries, to protect the local community from public health issues. As communities are unable to control upstream discharges, they have to treat the water they abstract to a higher level. Public health scares associated with a contaminated water environment (for example, microorganism, heavy metals and chemicals) are more frequent, though the severity is low.

Energy generation is regionalised, being sourced from wind and gas from waste and landfill sites. There is an increased number of coal-fired power stations with locally mined coal. The re-activation of coal mines offers local employment. Energy shortages and rationing have become a way of life and many communities invest in small generation units. New sources include wind farms limited to small-scale plants, as communities have few funds available. Small-scale generators powered by fossil fuels are used as backup for these renewable energy sources.

Reference

Periodic reviews support improved water resource management.

In the **REF** scenario, the water industry operates under the instruction of shareholders to maximise profits. During periods of economic growth, Periodic Reviews set high water prices allowing companies to improve existing water infrastructure and its resilience to climate change and to reduce leakage losses.

Water supply and wastewater treatment services are restricted by prescriptive environmental regulations. However, the security of public water supplies has a higher priority than the protection of the aquatic environment. Water companies are permitted to over-abstract during periods of drought, which are increasingly frequent as a result of climate change. Further water treatment of abstracted surface water is usually required in periods when low dilution capacity from rivers means that water is often contaminated (for example, with heavy metals and chemicals). Regulation of wastewater released into the environment is tight and the level of compliance high. Moreover, there is a reduction in the number of sewage incidents.

Investment in renewable sources of energy, gas and biofuel means there is less pressure on the water resources associated with energy production.

3.2.6 Farming and fisheries: impacts under the scenarios

Uncontrolled demand

Production systems are defined by the quality of environmental resources.

Under the **UD** scenario, farming is segregated into intensive large-scale and corporate type farms, high-end quality farms and subsistence farming. Intensive farming practices that dominate the agricultural landscape use lower quality water sources and rely on treatment systems to ensure compliance with food standards.

Production costs are minimised as a result of low environmental standards. A smaller proportion of farms produce more expensive, high-end goods. These practices are concentrated in areas with high quality water and soil. The environment benefits from chemical-free production services (for example, low doses of antibiotics and pesticides).

Subsistence agriculture is practised as a means of supplementing a deficient diet. These practices occur on the periphery of urban areas in contaminated soils, often using illegal and contaminated water, which poses risks to public health.

Intensive agriculture covers most of the available productive land where hedgerows are removed. This enables increased yields using increased quantities of water, fertiliser/sewage sludge and pesticides at the expense of environmental degradation (for example, eutrophication arising from diffuse pollution or soil saturated with heavy metals). Equally, fish farming increases the use of nutrients and medicines to increase production. Livestock production causes greater levels of erosion and water pollution (for example, deterioration in slurry/manure storage or reduced usage of riverside livestock fencing), occasionally raising public health issues. The small margins of profit generated from the sale of cheap goods leads to reduced investment in technology or measures to reduce the environmental impacts of production. The resulting environmental degradation is made possible due to relaxed legislative environmental requirements with a politically motivated low level of enforcement.

The capture of wild fish also increases, especially by the poorest of society who struggle to meet their basic needs. Overfishing occurs in some areas, further affecting fish species such as salmon, shads and lampreys, which are already under stress. Stress factors affecting these fish species include water pollution and the presence of INNS. In addition, there is a lack of public funds and omissions in local development planning for removing in-river obstacles to fish migration and maintaining or installing new fish passages.

Innovation

Efficient production systems rely on technology to maintain competitiveness and to comply with environmental standards.

In the **INN** scenario, increased agricultural production to feed a growing population consumes more resources, but is more efficient due to technological innovation. There is a rising demand for food, and technology has been revolutionised to optimise resources (for example, area of land, fertilisers and water) and increase crop yields. Farming is mainly run on large-scale holdings using precision farming, but there is widespread use of vertical farms, hydroponics, aquaponics and other hi-tech urban agriculture. Water is used more efficiently, including the use of smart irrigation systems, greywater recycling and the selection of water-efficient genetically modified crops. Genetically modified crops that require less water and fertilisers have boomed, particularly for producing animal feed, and have been implemented with consumer support. Synthetic meat uses less water than livestock production and is the reason why meat remains affordable for most and is still consumed in vast amounts. Farming and fishery practices are more environmentally friendly; for example, less harmful pesticides are used, and manure and slurry are used to generate energy. Furthermore, these activities are subject to strict regulations and high environmental standards.

Fisheries provide economic benefits and therefore water bodies that contain economically significant species are protected. Examples include shellfish and watercress, but also commercial inland fishing and sport fishing for leisure.

Sustainable behaviour

There is high demand for locally grown and seasonal produce grown sustainably.

Under the **SB** scenario, England and Wales play a small role in the global food market as a sustainable producer with an emphasis on fresh vegetables. There is also high demand for sustainably and locally grown food, with a relaxation of aesthetic expectations of produce. Extensive sustainable agriculture that integrates environmental sustainability into the production system becomes the norm, with a subsequent increase in land allocated for agriculture. Soil is nurtured and the application of chemicals is reduced, as farmers invest in biological processes and environmentally harmful substances are banned. There is a significant decline in diffuse pollution arising from sustainable agricultural practices. More water is used to irrigate crops as a result of climate change and an increase in the proportion of vegetable crops that require irrigation, but water is used more efficiently.

There is a reduction in livestock production as society eats a more vegetarian diet and the cost of meat rises (for example, because of the cost of externalities such as methane emissions). Livestock and the storage of slurry and manure are managed effectively, reducing impacts on the water environment. The public acts as a ‘watchdog’ for agricultural malpractice, protecting the environment.

Some floodplains are used for agriculture (for example, grazing cattle), despite the increased risk of flooding posed by climate change. Farmers accept the higher risk associated with crop losses. There is an increase in pockets of organic farming and domestic agriculture driven by a cultural movement.

Local resilience

Local food production increases to achieve self-subsistence.

In the **LR** scenario, there is an increase in food produced locally, especially in those regions struggling most to meet the demands of their population. Intensive agriculture is supported by subsistence agriculture that becomes widespread in allotments and gardens in both rural and urban areas.

Reduced investment in research and development means that technology is old and agricultural practices cause environmental harm (for example, pests are resistant and banned pesticides are reintroduced in the market). Moreover, agriculture is practised by first generation unskilled farmers, leading to poor soil management and agricultural practices contributing to increased diffuse pollution. This is exacerbated by practices to optimise yields/livestock production under relaxed environmental regulations. There has been a transition to mixed farming to enable the use of slurry/manure. Water-saving technologies are perceived to be expensive and farmers choose crops suitable to the water availability in their area, minimising irrigation costs.

Farmers’ groups are established in order to collectively tackle the challenges they face. In many instances individuals and communities implement their own measures such as building on-farm reservoirs or drilling boreholes for irrigation (as permitted by local authorities) to deal with periods of water scarcity.

Farmers are more vulnerable to climate change as a result of a lack of funding for adaptation and mitigation options. Urban farmers collect and use rainwater, but many commercial farmers have to accept frequent production losses. Also, where seasonal sewer overflows are frequent, farmers prefer to irrigate their crops with groundwater and avoid using potentially contaminated water from their winter storage reservoirs. Communities invest in arable crops (wheat, corn) that can be stored, providing buffers to deal with fluctuating levels of production.

Reference

Market-driven intensive agriculture is dominated by big corporations.

Under the **REF** scenario, there is increasing pressure on agricultural land, primarily due to competition for land to be used to grow food crops and energy crops. Land value has increased for prime arable land. Big farms and big corporate farmers benefit from economies of scale while smaller enterprises struggle.

The EU, supported by its Member States, has removed agricultural subsidies. This has forced farmers to optimise their practices, including a reduction in fertiliser and pesticide applications. Agricultural production is specialised and conditioned by local characteristics such as soil type, water availability and the sensitivity of the receiving water environment. Farmers select crops that generate higher profits and require fewer resources (for example, land and water).

Nevertheless, agriculture has an impact on the environment including:

- a reduction in the funding allocated for agricultural research
- a greater share of irrigated crops due to pressures for higher yields and raised temperatures
- soil erosion and compaction issues arising from unsustainable practices

References

ALLEGRA STRATEGIES, 2012. *Taste of the Future. A look to the future of foodservice 2012–2015.* Foodservice Consultants Society International UK & Ireland (FCSI).

CEH, no date. *Why monitor upland catchments?* [online]. Wallingford, Oxfordshire: Centre for Ecology and Hydrology. Available from: https://www.ceh.ac.uk/why-monitor-upland-catchments [Accessed 16 May 2017].

DEFRA, 2008. *Future Water. The government's water strategy for England*. CM7319. Norwich: HMSO.

DEFRA, 2013. *Estimated abstractions from all surface and groundwaters by purpose and Environment Agency region: 2000 – 2012*. London: Department for Environment, Food and Rural Affairs. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266829/v2iwtb23a-ab-purpose-EA-201313_all_surface_and_gw.csv/preview [Accessed 7 July 2014].

EEA, 1999. *Environmental indicators: Typology and overview.* Technical Report No 25. Copenhagen: European Environment Agency.

ENVIRONMENT AGENCY, 2008. Water resources in England and Wales – Current state and future pressures. Report: GEHO1208BPAS-E-E. Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2011a. *The case for change – current and future water availability*. Report – GEHO1111BVEP-E-E. Bristol: Environment Agency. Available from: http://webarchive.nationalarchives.gov.uk/20140328084622/http://cdn.environment-agency.gov.uk/geho1111bvep-e-e.pdf [Accessed 11 May 2017].

ENVIRONMENT AGENCY, 2013. *England's waters: Challenges and choices*. *Summary of significant water management issues.* Consultation paper. Bristol: Environment Agency.

HOUSE, J.I., ORR, H.G., CLARK, J.M., GALLEGO-SALA, A.V., FREEMAN, C., PRENTICE, I.C. AND SMITH, P., 2010. Climate change and the British Uplands: evidence for decision-making. *Climate Research*, 45 (1), 3-12.

JACKSON, C.R., 2012. *Future flows and groundwater levels: R-Groundwater model summary*. Science Report/Project Note – SC090016/PN6. Kegworth, Nottinghamshire: British Geological Survey. Available from: http://nora.nerc.ac.uk/20778/ [Accessed 16 May 2017].

NATURAL ENGLAND, no date. *Natural England: a review of upland evidence* [online]. Natural England. Available from: http://webarchive.nationalarchives.gov.uk/20140605090108/http://www.naturalengland.org.uk/ourwork/uplands/default.aspx [Accessed 15 May 2017].

PUHR, C.B., DONOGHUE, D.N.M., STEPHEN, A.B., TERVET, D.J. AND SINCLAIR, C., 2010. Regional patterns of streamwater acidity and catchment afforestation in Galloway, SW Scotland. *Water Air and Soil Pollution*, 120 (1-2), 47-70.

TAPPER, R., HADJIKAKOU, M., NOBLE, R. AND JENKINSON, J., 2011. *The impact of the tourism industry on freshwater resources in countries in the Caribbean, Mediterranean, North Africa and other regions*. Research project for the Travel Foundation, UK.

VISIT BRITAIN, 2012. *Foresight Issue 100*. London: VisitBritain. Available from: https://www.visitbritain.org/sites/default/files/vb-corporate/Documents-Library/documents/2012-2%20Inbound%20Tourism%20Growth%20Potential.pdf [Accessed 11 May 2017].

WANG, L., STUART, M.E., BLOOMFIELD, J.P., BUTCHER, A.S., GOODDY, D.C., MCKENZIE, A.A., LEWIS, M.A. AND WILLIAMS, A.T.. 2011. Prediction of the arrival of peak nitrate concentrations at the water table at the regional scale in Great Britain. *Hydrological Processes*, 26 (2), 226-239.

Bibliography

BRAUNGART, M., MCDONOUGH, W. AND BOLLINGER, A., 2007. Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design. *Journal of Cleaner Production*, 15 (13-14), 1337-1348.

CHARRON, D.F., THOMAS, M.K., WALTNER-TOEWS, D., ARAMINI, J.J., EDGE, T., KENT, R.A., MAAROUF, A.R. AND WILSON, J., 2004. Vulnerability of waterborne diseases to climate change in Canada: a review. *Journal of Toxicology and Environmental Health, Part A: Current Issues*, 67 (20-22), 1667-1677.

CHAVE, P., 2001. *The EU Water Framework Directive: An Introduction*. London: IWA Publishing.

CHINABUT, S., 2006. Problems associated with shellfish farming. *Revue Scientific et Technique (International Office of Epizootics)*, 25 (2), 627-635.

COOPER, J., LOMBARDI, R., BOARDMAN, D. AND CARLIELL-MARQUET, C., 2011. The future distribution and production of global phosphate rock reserves resources. *Conservation and Recycling*, 57: 78-86.

CORDELL, D., DRANGERT, J. AND WHITE, S., 2009. The story of phosphorus: Global food security and food for thought. *Global Environmental Change*, 19 (2), 292-305.

DEFRA, 2006. *Rural Development Programme for England 2007–2013: Consultation*. London: Department for Environment, Food and Rural Affairs.

DEFRA, 2010. *Fertiliser Manual (RB209),* 8th edition. London: Department for Environment, Food and Rural Affairs.

DEFRA, 2011a. *Protecting our water, soil and air: a code of good agricultural practice for farmers, growers and land managers*. London: Department for Environment, Food and Rural Affairs.

DEFRA, 2012a. *Standards of Good Agricultural and Environmental Condition* [online]. London: Department for Environment, Food and Rural Affairs. Available from: https://www.gov.uk/standards-of-good-agricultural-and-environmental-condition [Accessed 11 May 2017].

DEFRA, 2012b. *Waste water treatment in the United Kingdom – 2012. Implementation of the European Union Urban Waste Water Treatment Directive – 91/271/EEC*. PB13811. London: Department for Environment, Food and Rural Affairs. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69592/pb13811-waste-water-2012.pdf [Accessed 11 May 2017].

DEFRA, 2012c. *Water use by industry* [online]. London: Department for Environment, Food and Rural Affairs. Available from: http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/statistics/environment/green-economy/scptb10-wateruse/ [Accessed 11 May 2017].

EEA, 2009. *Water resources across Europe – confronting water scarcity and drought.* Copenhagen: European Environment Agency.

ENVIRONMENT AGENCY, 2009a. *Response to Defra consultation on new regulatory order to address the passage of fish (for Water Framework Directive and EU Eel Regulation).* Bristol: Environment Agency. Available from: http://webarchive.nationalarchives.gov.uk/20140328084622/http://www.environm ent-agency.gov.uk/research/library/consultations/106537.aspx [Accessed 11 May 2017].

ENVIRONMENT AGENCY, 2009b. *Water resources strategy for England and Wales*. Bristol: Environment Agency. Available from: http://webarchive.nationalarchives.gov.uk/20140328084622/http:/www.environment-agency.gov.uk/research/library/publications/40731.aspx [Accessed 10 May 2017].

ENVIRONMENT AGENCY, 2011b. *Water: Planning ahead for an uncertain future. Water in the 2050s*. Briefing note. Bristol: Environment Agency. Available from: https://data.gov.uk/data/contracts-finder-archive/download/815282/b5bb574c-3fae-4942-ba2e-a169200af3b6 [Accessed 11 May 2017].

ENVIRONMENT AGENCY, 2011c. *Catchment Flood Management Plans: Annual Report 2011*. Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2011d. *River basin management guide to hydromorphology no.6*. Bristol: Environment Agency. Available from: http://webarchive.nationalarchives.gov.uk/20140328084622/http://www.environment-agency.gov.uk/static/documents/Research/River_basin_management_guide_to_hydromorphology_no._6.pdf [Accessed 15 May 2017].

EUROPEAN COMMISSION, 2007. *Positive and negative effects of nanotechnology on the environment.* DG Environment News Alert Service, 26 July 2007. Brussels: European Commission.

EUROPEAN COMMISSION, 2012a. *River Basin Management Plans: Report on the Implementation of the Water Framework Directive (2000/60/EC).* COM(2012) 670 final. Brussels: European Commission. Available from: http://ec.europa.eu/environment/water/water-framework/impl_reports.htm#third [Accessed 11 May 2017].

EUROPEAN COMMISSION, 2012b. *The UWWT Directive lays down four main principle obligations* [online]. Brussels: European Commission. Available from: http://ec.europa.eu/environment/water/water-urbanwaste/directiveprinciples/index_en.htm#regulation [Accessed 11 May 2017].

GARNETT, T. AND GODFRAY, C., 2012. *Sustainable intensification in agriculture. Navigating a course through competing food system priorities*. Oxford: Food Climate Research Network and the Oxford Martin Programme on the Future of Food, University of Oxford.

GRAHAM, A., DAY, J., BRAY, B. AND MACKENZIE, S., 2012. *Sustainable drainage systems. Maximising the potential for people and wildlife. A guide for local authorities.* Sandy, Bedfordshire: RSPB; Slimbridge, Gloucestershire: Wildfowl & Wetlands Trust.

HODGE, I. AND RENWICK, A., 2006. *Business as usual projections of agricultural activities for the Water Framework Directive: Phase 2*. Report prepared for Defra project WT03035. Cambridge: Rural Business Unit, University of Cambridge; Edinburgh: Land Economy Group, Scottish Agricultural College.

HOODA, P.S., EDWARDS, A.C. AND MILLER, A., 2000. A review of water quality concerns in livestock farming areas. *Science of the Total Environment*, 250 (1-3), 143-167.

HOWARD, D.C., WADSWORTH, R.A., WHITAKER, J.A., HUGHES, N. AND BUNCE, R.G.H., 2009. The impact of sustainable energy production on land use in Britain through to 2050. *Land Use Policy*, 26 (Suppl. 1), S284-S292.

INMAN, A., 2006. *Soil erosion in England and Wales: causes, consequences and policy options for dealing with the problem*. Discussion paper prepared for WWF. Godalming, Surrey: WWF-UK.

IPCC, 2007. *Climate Change 2007: Synthesis Report*. Geneva: Intergovernmental Panel on Climate Change. Available from: http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms3.html [Accessed 11 may 2017].

KNOX, J., DACCACHE, A., WEATHERHEAD, K., GROVES, S. AND HULIN, A., 2013. *Assessing climate and land use impacts on water demand for agriculture and opportunities for adaptation*. R&D Technical Report FFG1129/TR. London: Department for Environment, Food and Rural Affairs. Available from: http://randd.defra.gov.uk/Document.aspx?Document=11705_DefraFFG1129_Cranfield_PhaseIFinal_05.12.13.pdf [Accessed 11 May 2017].

KOWALSKI, M., WAYLEN, C., CLIST, S., WILCOX, S., LYNN, S. AND GARROW, D., 2011. *Freshwater availability and use in the United Kingdom. A review of freshwater availability and non-household (consumptive) use in the UK.* RSC014-001 for WRAP. Banbury: Waste and Resources Action Programme.

NATIONAL GRID, 2011. *UK Future Energy Scenarios. UK gas and electricity transmission*. Warwick: National Grid. Available from: http://www.nationalgrid.com/NR/rdonlyres/86C815F5-0EAD-46B5-A580-A0A516562B3E/50819/10312_1_NG_Futureenergyscenarios_WEB1.pdf [Accessed 11 May 2017].

ONS, 2012. Annual mid-year population estimates for England and Wales, Mid 2011. London: Office for National Statistics. Available from: http://www.ons.gov.uk/ons/dcp171778_277794.pdf [Accessed 11 May 2017].

PRUDHOMME, C., CROOKS, S., JACKSON, C., KELVIN, J., YOUNG, A., 2012. *Final technical report*. Science Report/Project Note – SC090016/PN9. Wallingford, Oxfordshire: NERC/Centre for Ecology & Hydrology.

RESTORING EUROPE'S RIVERS, 2008. *River restoration, what is river restoration?* [online]. Available from: http://www.restorerivers.eu [Accessed 10 July 2013].

THE FUTURES COMPANY, 2012. *Socio-economic scenarios for water to 2050.* Unpublished report prepared for the Environment Agency.

THE FUTURES COMPANY, 2013. *Building electricity generation scenarios to identify water demand impacts.* Unpublished report prepared for the Environment Agency.

UK NATIONAL ECOSYSTEM ASSESSMENT, 2011. The UK National Ecosystem Assessment: Synthesis of the Key Findings. Cambridge: UNEP-WCMC. Available from: http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx [Accessed 11 May 2017].

UKTAG, 2003. *Guidance on morphological alterations and the pressures and impacts analyses. Final working paper*. TAG2003WP7c (01). Edinburgh: SNIFF. Available from: http://www.wfduk.org/resources%20/morphological-alterations-and-pressures-and-impacts-analyses [Accessed 11 May 2017].

US EIA, 2012. *Annual energy outlook 2012 with projections to 2035.* DOE/EIA-0383(2012). Washington DC: US Energy Information Administration.

WWF, 2006. *Illegal water use in Spain. Causes, effects and solutions.* Madrid: WWF-Spain. Available from: http://wwf.panda.org/what_we_do/how_we_work/policy/wwf_europe_environment

/news/index.cfm?68900/Spain-sucked-dry-by-illegal-water-use [Accessed 11 May 2017].

List of abbreviations

BOD	biochemical oxygen demand
INN	Innovation [scenario]
INNS	invasive non-native species
LR	Local resilience [scenario]
REF	Reference [scenario]
SB	Sustainable behaviour [scenario]
STW	sewage treatment works
SUDS	sustainable drainage systems
UD	Uncontrolled demand [scenario]

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