Final Report **Project WFD18**

Valuing water use in Scotland and Northern Ireland for WFD implementation purposes

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Executive Summary

Background

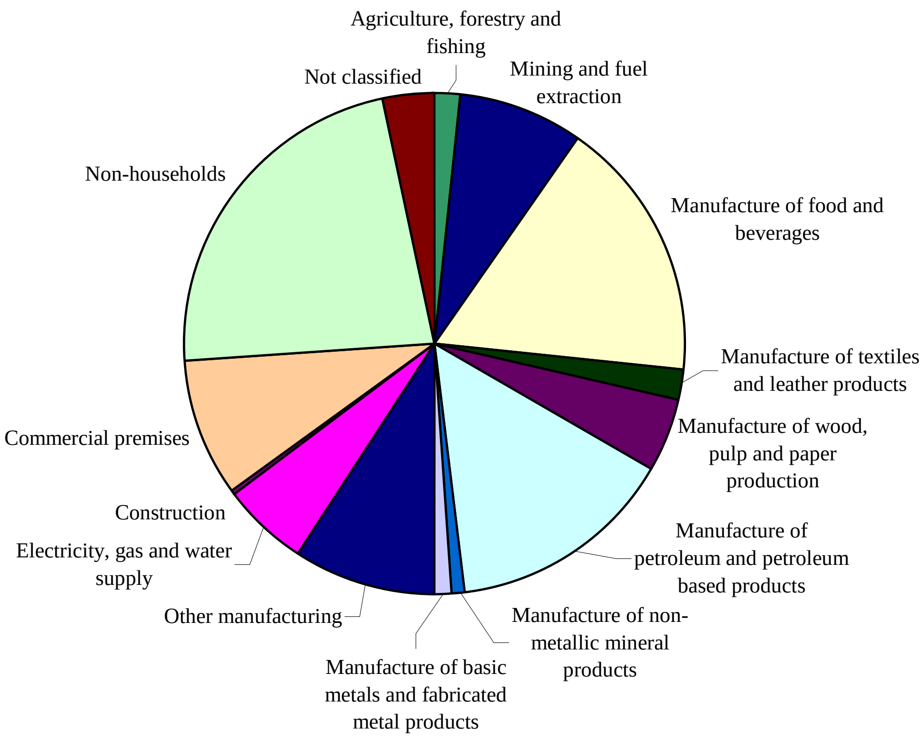
The Water Framework Directive (WFD) is a key piece of legislation regulating the water environment to improve the status of inland surface waters, transitional waters, coastal waters and groundwaters within the European Union. There are a number of economic requirements under the WFD that must be reported to the European Commission. The assessment undertaken for this project will contribute to the requirements under Article 5, which requires Member States to undertake an economic analysis of water use for each river basin district. In addition, Annex III of the Directive indicates that the economic analysis undertaken under Article 5 will also be used to contribute to requirements under Article 9 and Article 11. Article 9 requires that Member States introduce pricing policies that provide an incentive for water efficiency and contribute to the recovery of the costs of water use. Article 11 refers to applying economic tests to determine cost-effectiveness and disproportionate cost in selecting and justifying measures to meet environmental objectives.

This project was commissioned to undertake an initial study identifying how different sectors of the economy in Scotland and Northern Ireland use water and the benefits of water use for each user. Each sector uses water in different ways and for different purposes, using water from public sources and private abstractions, and discharging water after use. Therefore, the study starts with a characterisation of how water is used in different sectors (including the volume used where data is available) and the contribution that each of these sectors makes to the economy in Scotland and Northern Ireland (measured as gross value added). From this, the project aims to develop and apply a methodology to value water use, identifying gaps in understanding and potential sources of additional information. The valuation makes use of a number of techniques and methodologies, depending on the sector considered and the information available. It should be noted that the study considers the benefits of water use to the individuals and organisations in different sectors of the economy, but does not consider the costs that this use imposes on other users, the water authorities or the environment.

Water supply in Scotland

The supply of water by Scottish Water to large industrial users is shown in **Figure ES1**. Large industrial users account for 20.7% of total water supplied by Scottish Water (estimated as 1.332 million m^3 per day excluding leakage). Small metered users account for a further 19.3%; this sector is likely to include all other small industrial users and commercial premises, representing those sectors that include a large number of small organisations. The remainder of Scottish Water supplies (60.0%) is accounted for by unmetered users. Based on estimates of household water use and direct abstraction, it is likely that households account for 87.7% of unmetered water use, with the remainder supplied to small businesses. However, these estimates do not include private abstractions, which are known to be significant, particularly to some industrial users. Unfortunately, there is no comprehensive assessment of direct abstraction to all water users.

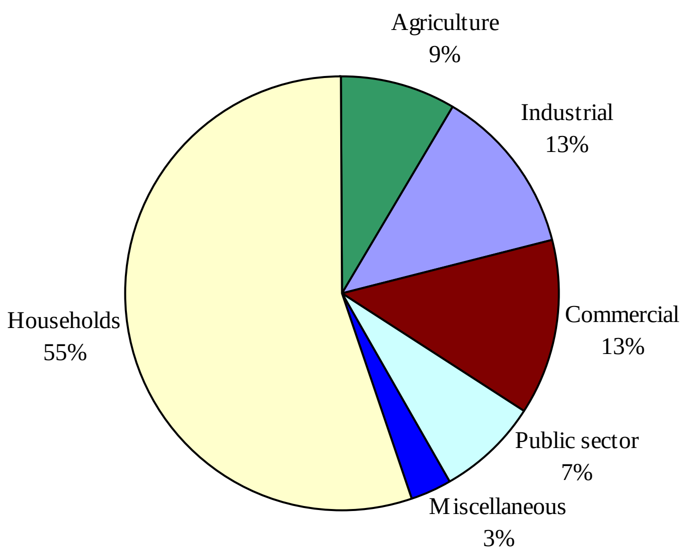
Figure ES1 Supply of water by Scottish Water to large industrial users



Water supply in Northern Ireland

Water supply in Northern Ireland has been assessed as part of the Water Resource Strategy, leading to estimates of water use for domestic and non-domestic users. This is shown in **Figure ES2**. The majority of water is supplied for domestic use, with industrial and commercial users supplied with approximately 50,000m^3 per day. Unfortunately, there is no information on direct abstractions of water; although domestic abstraction is thought to be minimal, industrial abstraction could be more significant.

Figure ES2 Water supplied by Water Service Northern Ireland



The economic significance of industrial water users

In order to assess the significance of this water use, the activities for which water is used are considered. These can be consumptive, as for production of mineral water, or non-consumptive, as for cooling of industrial facilities. The value of these processes is considered in terms of gross value added to the economy and employment. Gross value added by sector is shown in **Figure ES3** for Scotland and in **Figure ES4** for Northern Ireland.

Figure ES3 Gross value added to the Scottish economy, 2000

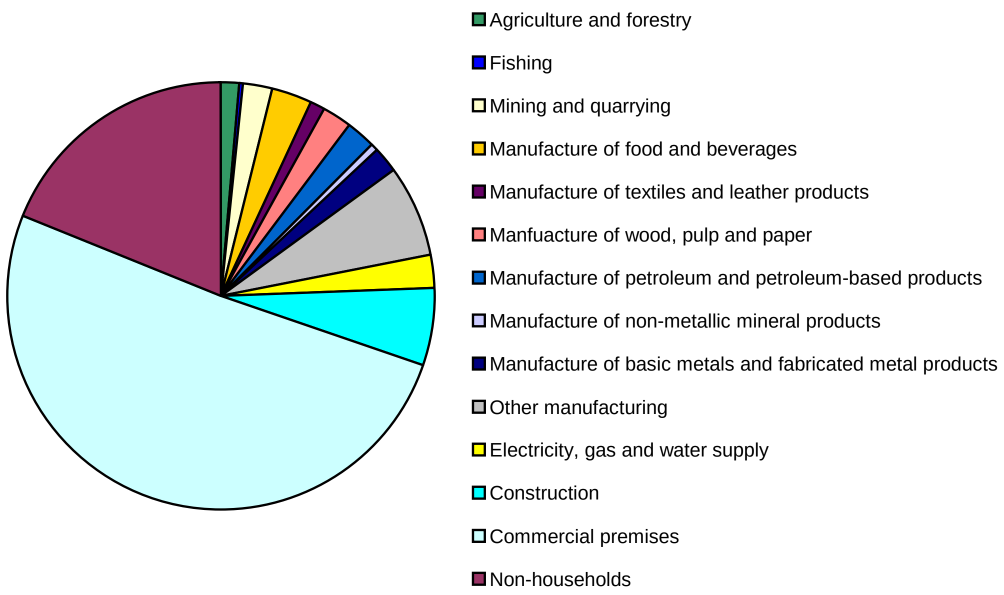
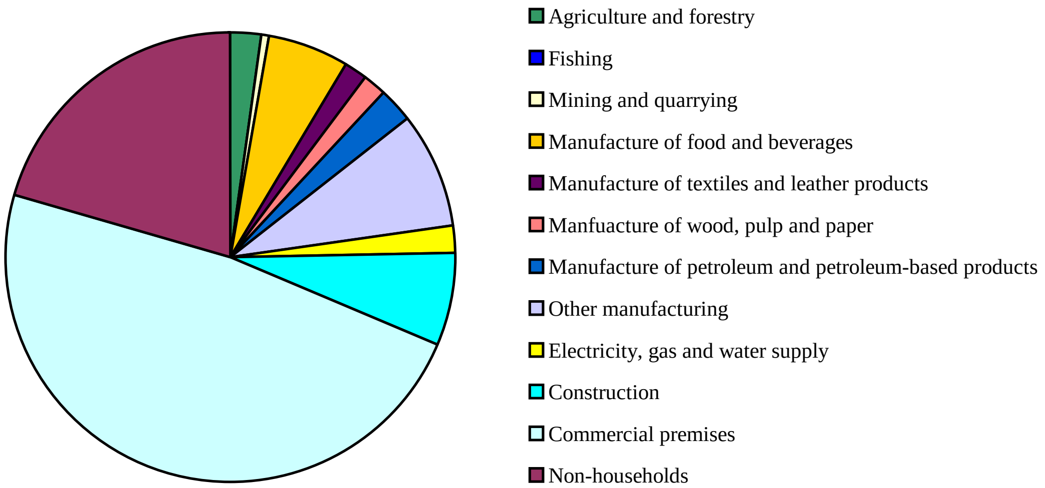


Figure ES4 Gross value added to the economy in Northern Ireland, 2000



Valuing water use

The value of water to an individual user depends on a number of features of the water use. This includes the volume of water used and the nature of use, ranging from water being used as part of the product, to use for cooling, and use for cleaning and discharge of effluent. The value also depends on the degree of necessity, reflecting the extent to which water is an intrinsic part of the product, the efficiency of water use, and the availability of alternatives. This latter characteristic will vary depending on the options available for installing technology or adapting processes to change the volume of water consumed or the processes for which water is used.

The study outlines a number of alternative methods for valuing water use drawing on a range of existing information, from market charges to environmental valuation studies, and includes consideration of the following techniques:

- The marginal productivity approach. This offers the most comprehensive analysis of the effect of water on production, but requires data on the prices and quantities of all inputs to and outputs from production;
- Net-back analysis. This technique is generally used for agricultural production and assumes that the margin of income over cost can all be attributed to use of water (from rain and irrigation);
- Assessment of avoided cost. This is based on the premise that the value of water use can be represented by the amount of money that would otherwise have had to be spent, for example by discharging rather than treating effluent;
- Direct estimates of the demand curve. This option is available where there is good information on the response of consumers to changes in price. For example, one study has estimated the demand curve for household water use;
- Stated preference techniques. These techniques use surveys to ask people how much they would be willing to pay for an increase in the amount of water that they use, or how much they would be willing to accept for a decrease. These techniques can also be used to assess the value of water quality; and
- Travel cost method. This is used to value many types of environmental asset, but in this study is useful to assess the value of rivers and lakes that may be used for recreation or angling. The method assesses the value based on how much time and money people spend in visiting a water body.

All of these techniques have been used to value water use in some situations. However, in many cases, including this study, carrying out primary research in all areas would prove too time consuming and costly. Therefore, it is possible to transfer values found in other studies for other situations to the context under consideration. This is the case for a number of the sectors in Scotland and Northern Ireland.

This report considers the value of water use for households, agricultural irrigation, aquaculture, salmon angling, industry, and hydropower. The techniques used differ for these sectors depending on information available, which restricts the comparability of the values between sectors. Comparison can be made between the industry sectors considered, and this indicates that refined petroleum and coal, primary metals, and chemicals are the highest value users assessed, while textiles, rubber and food are relatively low value. The study also includes assessment of recreational value, which cannot be linked to volumetric use, but which is of significant social and economic importance.

The values for different sectors are summarised in **Table ES1** below, although it should be noted that each value is calculated differently, and more consideration of the assumptions and limitations of different approaches are included in the main body of the technical report.

Table ES1 Summary of the valuation techniques and results for sectors considered

Sector	Valuation technique	Key assumptions and limitations	Value
Households	Gibbons' willingness to pay formula	Assumes all consumers pay volumetric charges levied to metered customers in England, Wales and Scotland Includes value of both clean and dirty water	0.102 - 0.244 p/m^3
	Benefits transfer from stated preference study	Only considers value of supply of clean water	0.067 p/m^3
Agricultural irrigation	Net-back analysis	Assumes that the West Peffer catchment is representative of other areas where potatoes are irrigated Value includes both naturally available water and water applied through irrigation	£5128 /ha
	Transfer of net-back analysis	Data from England and Scotland combined despite different agricultural support arrangements and climate	23 - 138 p/m^3
Aquaculture	Avoided cost	Costs calculated based on running costs of the largest effluent filters bought without a loan Considers water use for disposal of solid waste only Assumes filters remove all solid waste	0.126 p/m^3
Salmon angling	Benefits transfer of travel cost method study	Assumes salmon anglers in Donegal are representative of others throughout Scotland and Northern Ireland	£175 / day
Industry	Benefits transfer from marginal productivity approach study	Industrial water use in Scotland and Northern Ireland assumed to be the same as for Canada Assumes no improvements in water efficiency since 1991	0.3 - 15.7 p/m^3
Power generation	Avoided cost	Compares generation costs associated with hydropower with generation costs from other fuels and technologies	0.00 - 0.049 p/m^3 (compared to gas, nuclear and coal) 0.245 - 0.817 p/m^3 (compared to windpower)
	Avoided cost	Estimate from Scottish and Southern Energy taking account of benefit of Renewable Obligation Certificates, at most advantageous generation facilities and with greatest flexibility in markets	5.2 p/m^3

While valuation contributes to understanding the value of water use in different sectors, it does not include some features and issues that should be included in any assessment of the overall use of water in the economy. These include the following:

- The degree to which water is consumed by the process for which it is used. This varies significantly, from in-stream use (recreation, some aquaculture, etc.) to abstraction and discharge differing significantly in both time and place (e.g. bottled water manufacture, irrigation of agricultural crops, etc.);
- The degree to which water is altered by the process for which it is used, in terms of temperature, chemical and biological composition;
- The source of the water, and the sensitivity of that source to water use;
- The receptor for discharged water, and the sensitivity of that receptor to the type and volume of water discharged;
- The value of the water-using sector to the economy and society; and
- The environmental costs and benefits associated with water use and the broader environmental impacts of different sectors.

The report concludes with recommendations for improving valuation of water use in the future. This relates primarily to areas in which further data would allow a more comprehensive valuation, particularly through improved understanding of the volume of water used by different sectors and how water contributes to the costs and revenues from industrial processes.

Summary

This report contributes to the understanding of the value of water use by considering the benefits to different users. Some of the key issues related to the information in this report and the use of this information for decision making are summarised in the following bullet points.

- This report outlines how water is used, bringing together information about a wide range of sectors. This information provides a qualitative indication of how different users benefit from water use, and provides the baseline information to inform the quantitative assessment of value undertaken in the report.
- Valuation is a useful economic technique to help to reveal the importance of water in different processes. However, there are a range of valuation methods that can be used, and the different methods can lead to different values being assigned to uses that in other respects are similar.
- Different methods can be used to calculate the total, average or marginal value of water. The value of water to a user will depend on the volume used, and the value of the last unit (the marginal value) does not necessarily reflect the average value of all units. For example, households could be expected to have an extremely high value for the first unit, since this would be used for drinking, but a relatively low value for the last unit, which may be used for watering the garden.
- The value of water is calculated to take account of features of water use such as the degree of necessity and the options for alternatives. However, in considering any future changes in policy, it will be necessary for decision makers to reconsider these features individually. For example, it will be important to be clear on the different water efficiency measures undertaken by different industrial users in the past, and the scope that they have to undertake further actions in the future.

- A particular value does not indicate that a user should or will experience a particular change in their regulation or charging for water use.
- The use of the term ‘willingness to pay’ is a reflection of value in economic analysis. It does not necessarily indicate that a user would be happy to pay that amount, or that they would be able to absorb or pass on any increased cost within their business.
- Any decision making on water policy or pricing will need to include many wider considerations, including ability to respond to any changes (and ability to pay). It is not within the scope of this project to express the position of individual sectors with regard to this issue, although these comments form part of the sector reports for Scotland and are also included in considerations in Northern Ireland.
- This report provides an important first assessment of the value of water to different water users in Scotland and Northern Ireland. However, much of the information is at a relatively high level, and there are a number of gaps in the data. Therefore, it will be essential for policy makers to draw on the experience and expertise of those working in different sectors to continue to build understanding in an ongoing process, of which this report is only one part.
- This is a research report and is not a policy document. A particular value is one of a number of pieces of information to be considered as part of any decision making process considering water use. A number of other issues will also need to be included.

Contents

1. Introduction to the project

1.1 The Water Framework Directive

The Water Framework Directive (WFD) is a key piece of legislation regulating the water environment to improve the status of inland surface waters, transitional waters, coastal waters and groundwater within the European Union. The Directive (2000/60/EC), which came into force in December 2000, aims to contribute to the following objectives:

- The provision of the sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use;
- A significant reduction in pollution of groundwater;
- The protection of territorial and marine waters; and
- Achieving the objectives of relevant international agreements, including those which aim to prevent and eliminate pollution of the marine environment.

The Directive has been transposed into national law under the Water Environment and Water Services (Scotland) Bill in Scotland and the Water Environment (Water Framework Directive) Regulations (Northern Ireland) 2003 in Northern Ireland. The implementation of the Directive has been assigned to designated competent authorities, the Scottish Environmental Protection Agency in Scotland and the Environment and Heritage Service in Northern Ireland.

Within the WFD, economics plays a key role in water management and policy, using economic principles (e.g. the polluter pays principle), techniques and tools (e.g. cost effectiveness analysis), and economic instruments (e.g. incentive pricing).

There are a number of Articles within the Directive that deal with economics. In particular Article 5[1] requires an economic analysis of water use to be undertaken for each river basin district. This will form part of the river basin characterisation report to be submitted to the European Commission by December 2004. Annex III of the Directive indicates that the economic analysis undertaken under Article 5 will also be used to contribute to consideration of Article 9[2] and Article 11[3]. Article 9 requires that by 2010 member states have introduced water pricing policies that provide incentives for water efficiency and that ensure that users (disaggregated to at least agriculture, households and industry) contribute to recovery of the costs of water services. Article 11 refers to specific economic tests to determine disproportionate costs in the designation of heavily modified water bodies, and the justifications for time or objective derogation.

The requirements for 2004 are to undertake the following economic analyses:

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[1] Article 5: Characteristics of the river basin district, review of the environmental impact of human activity and economic analysis of water use

[2] Article 9: Recovery of costs for water services

[3] Article 11: Programme of measures

- Economic analysis of water use;
- Development of a baseline scenario of economic trends
- Assessment of the current levels of cost recovery for provision of water services; and
- Preparation for the cost-effectiveness analysis.

This project directly relates to the first of these requirements, but will also contribute to the other tasks for the 2004 report and beyond. In Scotland, the other elements of the economic analysis are being undertaken in complementary projects, notably the ‘Operation of the Scottish Water Market’ and ‘ Dynamics of Water Use in Scotland’.

1.2 Objectives of the study

The main objective of the project was to undertake an economic analysis of water use in Scotland and Northern Ireland that could be used to inform submissions required in December 2004 as part of the initial characterisation report. Specifically, the project had the following aims:

- To identify who benefits from (and would therefore assign value to) water use/ non-use in Scotland and Northern Ireland for Water Framework Directive characterisation purposes.
- To identify gaps in information and potential sources of additional information.
- To develop a practical methodology to value water use/ non-use in Scotland and Northern Ireland.
- To apply the methodology and fill knowledge gaps as necessary to gain a clear and robust estimation of the value of water use/ non-use in Scotland and Northern Ireland.

1.3 Scope and definitions

This study considers the value of water use to different users by looking at the benefits that different types of individual and organisation derive from water. However, the study does not consider the impacts of that water use, either through costs or benefits passed on to other users or to water authorities, or through environmental effects.

Water use is defined in the Water Framework Directive as follows:

> *‘Water use’ means water services together with any other activity identified under Article 5 and Annex II having a significant impact on the status of water.*
>
> *‘Water services’ means all services which provide, for households, public institutions or any economic activity:*
>
> *(a) abstraction, impoundment, storage, treatment and distribution of surface water or groundwater,*

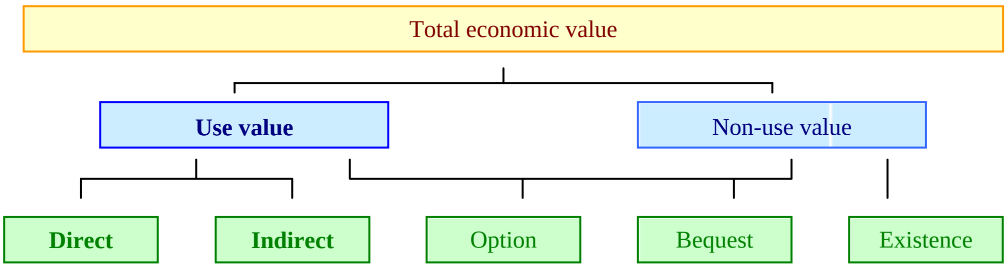
(b) *waste-water collection and treatment facilities which subsequently discharge into surface water.*

Elsewhere in the Directive, the text refers to households, agriculture and industry as water users. However, the Steering Group for this project considered that it would also be appropriate to include those activities that use water without abstraction, storage or discharge. There are a number of such activities, including angling and recreation, that are economically important but do not generally affect the status of the water.

Although these activities were initially referred to as 'non-use', it was considered that for this report it would be clearer to refer to all activities as water use. This is also more in line with the environmental economics literature, which defines non-use to include option, bequest and existence value. Option value is the value that an individual places on a resource that they do not currently use, but where they may wish to in the future. For example, an angler may never have visited the River Dee, but may value it because they would like the option of visiting in the future. Bequest value is similar, but refers to the value that an individual may place on the resource even when they have no intention of ever using it, but where they wish it to be available for use by future generations. Finally, existence value refers to the case where an individual has no expectation of using it himself or of his descendants using it, but where he feels it is valuable nonetheless.

The different types of value contributing to the total value of a resource is shown in **Figure 1.1** below (McMahon and Moran, 2000). In **Figure 1.1**, water use as defined in the Water Framework Directive (abstraction, storage and discharge) would be direct use, and the other elements considered in this project would be indirect use. Option, bequest and existence values are not considered as part of this study.

Figure 1.1 Components of total economic value



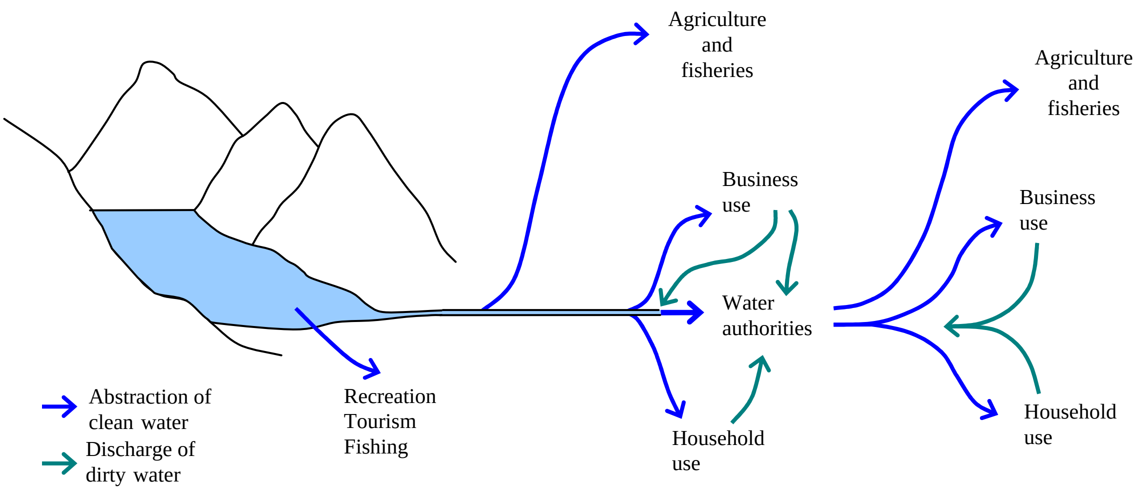
In order to facilitate comparison with other information sources, the categories used in this project were defined using Standard Industrial Classifications (SIC). These codes are the official means of classifying businesses in the UK and are used for many statistical and economic analyses. The SIC 1992 codes have recently been updated to SIC 2003 and are due to be revised again in 2007. Due to the limits of time and information availability as well as the need to focus on water use rather than only economic contribution, it was not considered appropriate to use the full detail of the SIC codes. Instead, the project used these codes as a starting point but highlighted areas where there was significant water use (in terms of volume or contribution to activity) and aggregated other categories with similar water uses. The link between the categories used in this study and the SIC codes is given in Appendix C of this report. Explanation of the choice of groupings is given where appropriate in Section 2.

1.4 Environmental economics and valuation

This project uses economic valuation techniques to indicate the importance of water use in a number of sectors in Scotland and Northern Ireland. Environmental economics considers the implicit value of environmental resources that are not sold in markets and therefore do not have a market price. Many environmental resources are not traded in markets because they display characteristics of public goods. Pure public goods are defined by three characteristics. Firstly, they are non-rival, so that if one person consumes the good it does not deny another person the chance of consuming the same good. Secondly, they are non-excludable, in that if one person consumes the good, it is not possible to prevent another person from consuming the good. Thirdly, they are non-rejectable and cannot be avoided. Therefore, consumption of (pure) public goods is not determined by individuals, but must be decided by society as a whole. The light from a lighthouse and clean air are well-cited examples.

Water is not a pure public good, but exhibits both public and private good characteristics. An aquifer may be privately owned, with water abstracted, treated and sold by a private company. However, if this is the case, the water is no longer available to support other uses or activities, which may also be important or valuable. This begins to indicate some of the unique difficulties associated with valuation of water. Water is, of course, essential for all life; however it is also a useful resource for other reasons. It can be used for a number of industrial processes, thereby encouraging economic development, or for recreation, enhancing social welfare. Water use can also affect the quantity and quality of the resource at a given point, leading to conflicts between alternative water uses. **Figure 1.2** illustrates the potential uses of water along a watercourse.

Figure 1.2 Illustration of potential water users along a watercourse



Each of these users places a value on water, because of the activities that it allows them to undertake. This value will depend on how important water is to what they do, and the value is estimated using information on the costs and benefits of water use. A discussion of economic valuation techniques is included in Section 7 of this report.

It should be noted that this idea of valuation differs from that used by surveyors in undertaking land, property and business valuations. These may be carried out for determining rates, taxation, compensation and investment, but are based on determining a value for the property or business that could be expected at sale, rather than the value to the economy or the value of an input into production. Therefore, the discussions of valuation in this report should not be confused with valuation reflecting the rateable value of businesses.

1.5 Structure of this report

This report is divided into a number of sections that examine different users of water and how to value this use. Section 2 considers the use of water in different industrial sectors, looking at the types of processes using water and the potential impacts of that use. Sections 3 and 5 build on this by considering the importance of these sectors in Scotland/Northern Ireland. Sections 4 and 6 draw together information on the volume of water used by different sectors. There has been relatively limited data for many users, and so information has been drawn from a range of sources. In order to value water use in different sectors it was necessary to narrow the focus of the project to a number of key users. Section 7 indicates which sectors have been chosen as key users, offering some justification for the choice. Section 8 outlines alternative methods for valuing water use. Although the application of different methods has in large part been dictated by available information (information gaps are identified throughout this report), it is relevant to consider the alternatives. This is useful to highlight the advantages and disadvantages of the techniques used as well as to allow other methods to be considered for use in the future. Section 8 combines information from previous sections of the report to calculate a value for water use in each of the key sectors. These values are by necessity approximate and are not directly comparable with each other since they are derived using different methods. However, they are the most accurate given current data available. Finally, Section 10 presents some recommendations and Section 11 offers some conclusions.

2. Use of water by different sectors

2.1 Introduction

As a starting point for this project, the following section considers the use of water in different sectors of the economy from a general perspective (the specific context in Scotland and Northern Ireland is considered in Section 3 and 5). The sectors are based on Standard Industrial Classification (SIC) codes, although these have been grouped and disaggregated to reflect diversity of water use. For example, within agriculture, forestry and fishing, a number of subcategories are defined to allow the difference between abstraction of water for aquaculture and use of sea water for commercial fishing to be made clear. On the other hand, an economically diverse range of commercial premises that are largely reliant on the public supply of water to provide water for drinking and sanitary services have been grouped together. The reasons for the grouping are explained in a little more detail in the text below.

In addition to industrial sectors, this project considers water use by households and by recreational users. These are considered as separate users in the assessment below.

2.2 Households

The household sector uses clean water for domestic and non-domestic purposes. Domestic purposes include washing and drinking, while non-domestic purposes include car washing and watering in the garden. Households also use water for the disposal of sewage. Some of the uses and the typical associated volumes of water are shown in **Table 2.1** (Water UK, 2004).

Table 2.1 Water use associated with household activities

Activity	Approximate water use
Taking a bath	80 litres
Taking a shower	35 litres
Flushing the toilet	7.5 - 9.5 litres
Watering the garden using a sprinkler	Up to 540 litres per hour
Using a washing machine	65 litres
Using a dishwasher	Up to 25 litres

Household water is largely supplied from public mains water, with some limited private abstractions. The vast majority of this water is disposed of into mains sewers or septic tanks where connection to the mains sewerage system is not available, with many water companies estimating that 95% of clean water supplied is returned to the public sewers.

Water from households is also discharged as runoff from driveways and gardens, and this runoff can include pollutants present in these locations. Runoff from areas of hardstanding will usually be returned to receiving waters via foul (combined) or storm drains, whilst excess water from gardens will enter receiving waters directly via the soil. The discharge of run-off through pipes has been associated with problems of increased flood risk downstream, increased contamination of waters and reduction of recharge of ground and surface waters within the urban area. Therefore, there is increasing consideration and use of Sustainable Urban Drainage Systems (SUDS), which aim to control rainwater at source.

2.3 Agriculture and forestry

2.3.1 Agriculture

At a general level, agriculture is comprised primarily of arable, horticulture and livestock enterprises, although the relative importance and the characteristics of different types of agriculture vary across regions. Although agriculture relies on water, this is largely provided by precipitation, with some additional irrigation of arable and horticultural crops. Because of the costs associated with irrigation, this is generally limited to high value crops such as potatoes, field vegetables and soft fruits and is particularly important during summer periods of low rainfall. Irrigation can help to improve yield and quality; for potatoes, irrigation not only increases yield, but also reduces the number of cracked or misshapen potatoes that cannot be sold, and lessens the incidence of potato scab (British Potato Council, 2004).

Water can be contaminated by arable farming as a result of diffuse pollution from runoff of pesticides and fertilisers. This diffuse pollution can damage biological communities in the receiving waters through, for example, eutrophication. Arable cultivation can also increase the amount of soil washed into watercourses. Pollution affects the farmer as well as the receiving water body, since nutrients or chemicals intended for the crop are washed away without effect. The water authority is also likely to incur higher treatment costs to bring it to potable quality. Other users of the water body, for example bathers or anglers, may also be affected.

Water is used for livestock farming for provision of drinking water and for washing equipment and the site. Intensive livestock farms are a potentially significant source of pollution, particularly the point source pollution from farm sheds, which has a high biological oxygen demand. Extensive livestock farming can also cause water pollution through runoff of animal excrement and through disturbance to the banks of watercourses.

Water can be supplied to farms from the mains and from private abstractions. Abstraction is used widely to provide water for irrigation and for drinking water for livestock, as well as to supply domestic water.

2.3.2 Forestry

Forestry includes managed and natural forests, and can affect water yield and flow as well as the chemical composition of water. Although forests rely on water for growth, this is largely as precipitation, and there is very little irrigation of forests except during the planting stage.

Forests intercept water in their canopy, so that less of the precipitation reaches ground and surface water bodies. This loss is expected to be greatest in wetter, upland areas of Britain, and research suggests that there may be a reduction of 1.5-2.0% in potential water yield for every

10% of a catchment planted with a mature forest (Forestry Commission, 2000). However, the loss of water yield is only likely to be a problem in those catchments where supply is being fully used, for example for hydro-electricity schemes or for impoundment for water supply. The cultivation and drainage of soils during the establishment of a forest can also increase summer base flows and peak flows during moderate rainfall events.

In terms of water quality, cultivation and drainage may also affect sedimentation and therefore the turbidity of water. This can result in disruption to water supply and water treatment plants, although it can be improved through forestry management to minimise soil disturbance. There is also concern over nutrient enrichment of soils, particularly if heavy rainfall follows the application of phosphate fertilisers or urea. Acidification of watercourses may occur in upland forests (above 300-400m) where sulphur and nitrogen is scavenged from the atmosphere. This effect is more significant in mature forests, and the concern relates principally to sulphur, which has an established role in surface water acidification.

2.4 Fishing

2.4.1 Aquaculture

The aquaculture sector includes a number of different types of production. The sector includes fresh water and marine aquaculture of finfish and shellfish. All types of aquaculture make use of water, and are therefore relevant to this study, although only some types abstract and discharge water.

Fish farms raising finfish can consist of cages situated in the sea or in fresh water lochs/loughs, or tanks and holding ponds where fish are bred and kept. For those fish farms using cages, there is no abstraction as such, although the fish farm is reliant on water held in the water body in terms of both quality and quantity. On the other hand, where fish are kept in tanks, large volumes of water are abstracted, piped through the tanks and returned to the rivers or sea. In this case, net abstraction is very low, but there can be some geographical separation between the point of abstraction and of discharge.

Both types of fish farm may affect water quality through the discharge of excretory products and veterinary treatment chemicals. The development of feed monitoring systems has reduced the discharge of uneaten food from cage fish farms to very limited levels, and the use of veterinary products is also carefully monitored. The main particulate discharge is of faecal matter, and fish farming also affects the nutrient content of the water as fish excreta consists of urea, ammonia and salts of nitrate and phosphate, which can stimulate eutrophication. However, all discharges from fish farms are carefully regulated and controlled, and many fish farmers, particularly those using tanks, claim that treatment of the discharge results in the water returning in an improved state compared to the quality of abstraction (CJC Consulting, 2002).

The issues of discharge in relation to marine finfish farms are largely similar, although there is more anecdotal evidence of effects of marine fish farms being a source of pest organisms. A Scottish study of the recovery of the benthos in marine waters that have been used for fish farming found that biological communities adjacent to cages returned to near-normal 21-24 months after farming ceased, although more research would need to be done to be certain of the conclusions (Scottish Executive, 2002a). The study also suggested that the enrichment by nutrients from marine fish farms was not sufficiently significant to exert effects on algal blooms and toxic algae, with the possible exception of a few enclosed waters.

Shellfish farms differ from finfish farms in a number of ways. Such farms are in saline lochs or marine waters and may use ropes, trays, trestles or bags to grow the shellfish. The shellfish rely on plankton in the water for food, and there are not the same potential problems with discharges as occur with finfish farms.

2.4.2 Commercial fishing

Sea fishing has little impact on the water, either through volume or discharges, although it has an important economic and social role. Commercial shell-fisheries are also economically important and water quality standards (as specified in the Shellfish Waters Directive) are maintained to support this role.

2.4.3 Angling

Recreational fishing does not involve abstraction, storage or discharge, but as with sea fishing, it can have significant impacts, particularly for local economies, and again certain water quality standards need to be maintained. Water quality standards to maintain salmonid and cyprinid fisheries are specified under the EC Freshwater Fish Directive (78/959/EEC). In time, these standards will be incorporated within the Water Framework Directive.

2.5 Mining and quarrying

Water is used in the mineral extraction industry in differing ways, depending on the mineral being mined or quarried, the degree of preparation that will be required to prepare it for its market and whether mineral is being extracted by surface or underground methods. Mineral extraction in the UK has been dominated in recent decades by coal mining, both underground and more recently opencast, together with aggregate production involving a variety of raw materials. Other minerals have also been worked (mainly quarried from the surface) to produce industrial minerals (e.g. silica sand) or building stone (e.g. certain sandstones). Metalliferrous mining has been widespread in the past, although with a few exceptions, these operations tended to be abandoned a long time ago.

Water is produced as a by-product of mining and quarrying operations, since they usually involve extracting mineral from below the groundwater table. Groundwater is therefore pumped to the surface and is often used to facilitate the mining or mineral processing operation. Surface water is also collected as part of mining operations, notably where surface mining involves the disturbance of large areas of the ground surface, either by the removal of soils or the creation of voids that will fill with surface drainage water.

The amount of water that is recycled for use in the mining or quarrying operation will be dependent on the amount available. Large and particularly deep underground mining operations of all types involve the pumping of very large volumes of water and often far more than can be utilised. As a result much of this water is discharged to surface watercourses, following treatment without being utilised as a resource by the operating company. The degree of contamination in the water will vary depending on local geology and hydrogeological conditions and particularly whether the groundwater has been abstracted from old mineral workings, where dissolved metals and other substances may be present in significant quantities. Iron and manganese are two metals that are often present (notably in the coalfield areas of Scotland) and where these emerge at the surface from previously closed mines, they are characterised by an orange coloration, resultant from the oxidation of dissolved iron as the water is exposed to air.

Water contamination, even at a low or moderate level, usually renders it unsuitable or uneconomic for use as a potable water supply. However, if not required for use by the mining company, the water can potentially represent an important source of industrial water and be sold for commercial use.

Mineral processing is undertaken as part of the surface operations at a mine and water is a key component of this operation. The separation of metals from the ore is often a complex operation and involves the use of chemicals that can lead to the serious contamination of the water, which then has to be cleaned up before it can be safely discharged to surface watercourses. The treatment process therefore often involves the large-scale storage of contaminated water in the form of tailings dams and in some cases in the past, these facilities have been abandoned on mine closure. The coal industry also utilised mineral processing to wash the coal and remove extraneous dirt. The solid waste is formed into spoil tips (called bings in Scotland), with the liquid waste being pumped via various treatment systems (thickeners etc.) to colliery slurry lagoons for final settlement and final solids removal. Aggregates preparation from quarries and opencast coal extraction is usually less water contaminating, as these products are subject to dry crushing and screening processes. Sand and gravel are subject to a more straightforward washing process, where suspended solids represent the main water contaminant.

Water is also used for other operational purposes, such as dust suppression. Examples include sprays at conveyor transfer stations (both underground at the surface) and for dampening unsurfaced surface haul roads, excavation faces etc.

2.6 Manufacturing of food and beverages

This sector includes a large variety of businesses, including food processing, maltsters, brewers, distillers and soft drinks manufacturers. These are considered in turn.

2.6.1 Food processing

Food processing businesses are highly variable in the volume of water used. In most cases, water must be of potable quality. A recent study in Scotland (CJC Consulting, 2002) found that this, combined with the small size of many of the businesses, limited the number of businesses using direct abstractions, although there was more abstraction amongst vegetable processors than milk, fish or meat processing businesses.

There is high water use in processing dairy products, with water used for plant cleaning, cooling and washing. It may also be used for lubricating and heating. Although some sites have been selected for access to low-cost water supply or discharge, all but one of the eleven respondents to CJC's study indicated that they were mains-only users.

Fish processing uses a combination of fresh and sea water. Sea water is used for the storage of pelagic fish or to artificially brine freshwater fish. Fresh water is used mainly for washing and lubricating the machinery used during filleting and freezing processes. Waste disposal has also been an issue, particularly for the pelagic fish industry (white fish is largely gutted at sea). CJC's survey indicated that changes in the costs of discharge would be more significant than changes in water prices.

In the meat processing sector, water is used for washing meat and carcasses at abattoirs, and for heating, sterilisation and domestic purposes.

Vegetable processing uses significant quantities of mains and abstracted water. The water is mainly used for rinsing and washing vegetables, particularly potatoes, but also carrots and other vegetables. Disposal of water can also be a significant cost to vegetable processing firms.

2.6.2 Production of alcoholic beverages

Maltsters use water to steep the barley grain. This occurs two or three times in order to raise the moisture level in the grain and thereby encourage germination. This water is normally required to be of potable quality, although the majority of maltsters also use direct abstractions for water supply. Most of the water used is discharged, with a small amount lost through evaporation. Although the discharge is fairly mild, it is low in oxygen. Discharge can be treated before it is released to mains sewers or natural water bodies.

Brewers also use water as a fundamental part of their process, and in some cases the quality and characteristics of the water are particularly important in giving the beer its distinctive qualities. This may be more important for small brewers selling a local or specialised product. Water is also used in brewery operations, for washing equipment, casks and bottles and for heating and cooling. The efficiency of water use varies considerably between brewers, with good practice suggesting a ratio of 4.5 litres of water per litre of beer, but with some less efficient operators closer to a ratio of 20:1 (CJC Consulting, 2002).

In contrast to maltsters and brewers, the majority of water use by distillers is for cooling. Less than 10% of water is used to form the product or by-products. However, the use of water by the sector is high and is seen as crucial to their operations (CJC Consulting, 2002).

2.6.3 Production of mineral waters and soft drinks

Mineral waters

Production of bottled water falls into a number of specific categories depending on the level of processing prior to bottling: natural mineral water; spring water; and table water. The processing allowed for each of these categories is regulated in Scotland by the Natural Mineral Water, Spring Water and Bottled Water Drinking Regulations 1999. In Northern Ireland, there are tow sets of regulations, the Natural Mineral Water, Spring Water and Bottled Drinking Water Regulations (Northern Ireland) 1999 and the Natural Mineral Water, Spring Water and Bottled Drinking Water (Amendment) Regulations (Northern Ireland) 2003. Natural mineral water is the most tightly controlled, and is not allowed to be treated in any way (although carbon dioxide may be added) and should be bottled as close as possible to the spring from which it is extracted. On the other hand, table water can be any water satisfying drinking water regulations and may be mains supplied water.

By definition, the production of mineral waters is reliant on water abstracted from private sources. The methods of production vary between different plants; for example some plants abstract water at a continuous rate, immediately discharging water above requirements, while others are able to vary their abstraction and production more readily. Water abstracted is used to fill bottles of natural spring and mineral water, but is also used for washing equipment. Water used for such processes must be of the same standard as the water sold in order that the bottled water is not contaminated.

Non-alcoholic beverages

In contrast to mineral waters, non-alcoholic beverages have less stringent water process limitations, although water must be of potable quality. Non-alcoholic beverages include flavoured mineral waters and canned soft drinks and may be produced in the same facilities as mineral waters. Therefore it is somewhat difficult to separate the production of non-alcoholic beverages and the production of mineral waters. However, in practice the use of water may differ, with the production of soft drinks tending to use mains water rather than private abstractions (CJC Consulting, 2002).

2.7 Manufacture of textiles and leather products

Textile firms vary significantly in their water use, depending on the particular type of process. Within the textile industry, it is the scouring, dyeing and wet finishing processes that use the majority of the water. However, other textile firms such as spinners and garment makers use very little water. Water is perceived as an essential resource in the textile sector, with the internationally competitive market limiting the scope for accommodating increased prices or costs. The source of water also varies within the sector, with firms relying on abstractions, mains water or a combination of both.

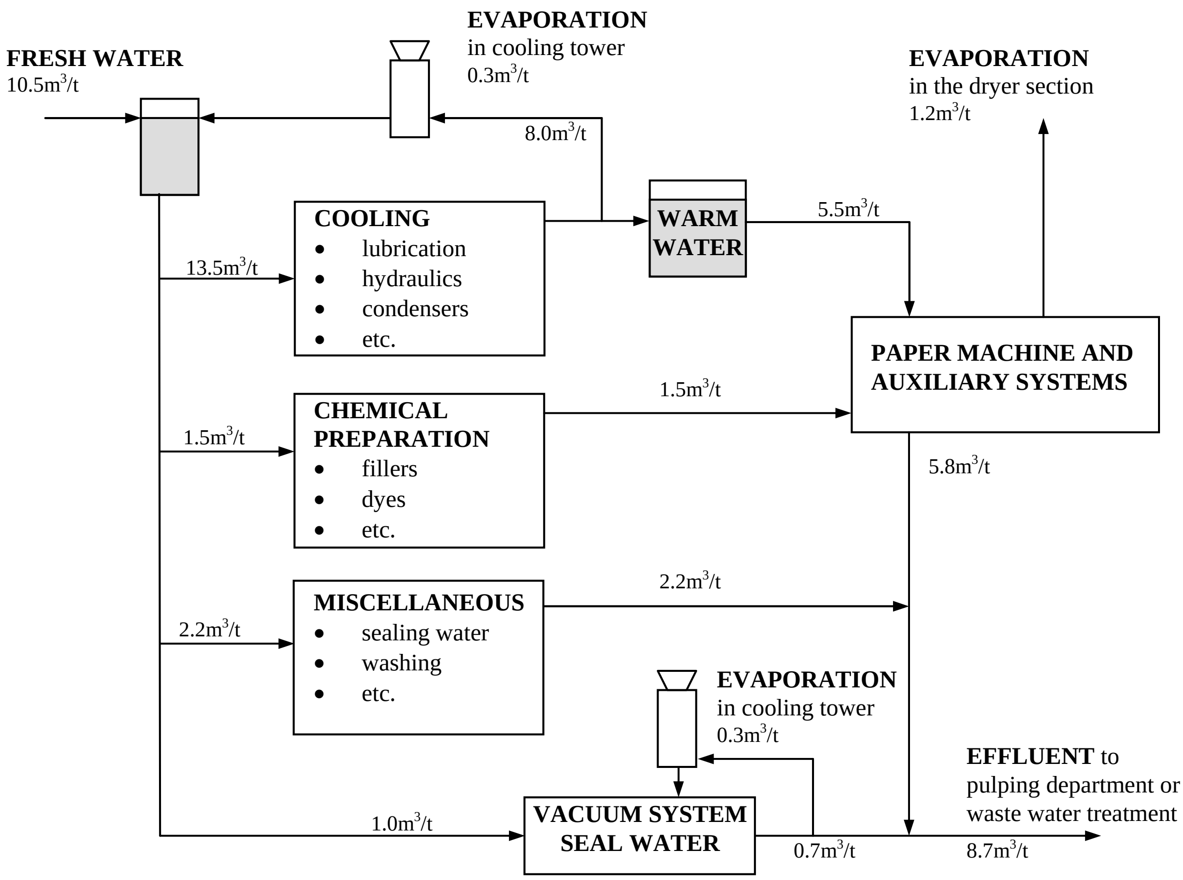
2.8 Manufacture of wood, pulp and paper products

Paper is produced from virgin fibres using chemical or mechanical means, or by repulping recycled paper. There are a number of different techniques used to produce paper pulp, the most common of which is kraft (or sulphate) processing, with the pulp used to produce paper. These processes may take place in integrated mills, producing both pulp and paper, or non-integrated mills.

Water is used in paper mills to dilute suspend the pulp fibres so that they can be pumped to form an even layer (stock preparation), to add chemicals, for cooling and for specific mechanical processes. Fresh water may be used in any of these stages, although there is also significant recirculating of the water, within the paper machine, from the paper machine into stock preparation, and after treatment back into the first stages of the process.

Figure 2.1 indicates the major areas of water use for a paper mill using 10.5m^3 of fresh water per tonne of paper produced (EIPPCB, 2001). Actual figures would depend on the paper grade produced, the nature of raw material used and the final quality level within each paper grade, and would also be influenced by whether cooling water was recycled (assumed to be the case in the diagram below). For speciality papers, for example, water use can vary between 40m^3 per tonne and 300m^3/t, with water use and recirculation determined by production technologies and quality requirements.

Figure 2.1 Illustrative use of fresh water in a paper mill



Although much of the water is re-circultated, water will be discharged with effects on biological and chemical content. This will depend on the pulp or paper used as an input and the chemicals added during processing. Used water may be treated before discharge (under Pollution Prevention and Control permits) or may be discharged to mains sewers as trade effluent. Wastewater treatment can have significant effects on the content of the discharge, as shown for a typical French paper mill (taken to be representative of European mills more widely) in **Table 2.2** below (EIPPCB, 2001).

Table 2.2 Wastewater content from paper mills before and after treatment

	Total suspended solids (kg/t)		Chemical oxygen demand (kg/t)		Biological oxygen demand (kg/t)	
	before treatment	after treatment	before treatment	after treatment	before treatment	after treatment
Woodfree printing and writing paper	12 - 25	0.3 - 2	7 - 15	1.5 - 4	4 - 8	0.4 - 0.8
Paper board	2 - 8	0.3 - 1	5 - 15	1.2 - 3	3 - 7	0.3 - 0.6
Tissue paper	2 - 30	0.3 - 3	8 - 15	1.2 - 6	5 - 7	0.3 - 2
Speciality paper	20 - 100	0.1 - 6	no data	1.5 - 8	no data	0.3 - 6

The figures for speciality paper are derived from SEPA Report 4713-2, 1997 and should represent the common emission levels to water from mills in the EU.

The upper end of the emission range for tissue mills is derived from information from the German Paper Association.

2.9 Manufacture of petroleum and petroleum-based products

2.9.1 Oil Refining

Oil and gas refining is a significant user of water, both in terms of volume used and content of the discharge. Most refineries are located close to the sea or a large river in order to satisfy the need for cooling water and also to facilitate the transport of raw materials and products. Clean water is also used in the first of the processes to refine the crude oil- desalting.

Desalting is the process by which crude oil or heavy residues are washed with water at high temperatures and pressures to dissolve and remove the salts and solids. These salts are often brought in suspended or dissolved in the oil, and can lead to the corrosion of heat exchangers and inhibit many of the catalysts used in later processes unless they are removed. This water can be fresh or recycled water. However, during the desalting process, the water becomes contaminated with dissolved hydrocarbons, free oil, dissolved salts and suspended solid, and the water must then be treated at an effluent plant prior to disposal.

Cooling of various streams is required to allow processes to take place at the right temperatures, and to cool products before storage. Some cooling is achieved through heat exchange of streams requiring cooling and those requiring heating, although it is still necessary to provide additional cooling using air and/or water. There are a number of options to achieve this cooling, including once-through systems and circulation systems. Once-through systems use river or sea water extracted from large water bodies to cool non-polluting process streams, or to cool heat exchangers in those systems using recirculated water. Circulation systems use water that is continually recycled and is cooled using ambient air. Water is also added and discharged in order to dilute the contaminants in the circulation system.

The water discharged from oil refineries consists of cooling water, process water, sanitary sewage water and storm water. Water from refinery operations can become contaminated with dissolved gases, dissolved and suspended solids and hydrocarbons. Rainwater may also come into contact with oil-polluted surfaces and occasionally, ballast water from the transporting ships may be treated at the refinery. Additionally, groundwater can become contaminated with oil from refinery operations, particularly from the storage, transfer and transport of hydrocarbons, or from water containing hydrocarbons. Within a refinery there are a number of processes to reduce the contamination of wastewater, although this depends on the refinery processes and the management of the facility.

2.9.2 Chemicals

The chemicals sector is varied, producing a wide range of different organic and inorganic chemical products. Water use within the sector is an important part of a number of processes, including as a raw material (for example industrial ethanol is manufactured from water and ethylene), as a solvent, for washing, for direct and indirect cooling and attemperation (a form of quenching), to generate steam, and for potable and domestic purposes. Water may also be used to dilute effluent, although this is not common and would require consent. Although there is a reliance on mains water, sea water is often used for cooling and there is some abstraction in the sector in Scotland (CJC Consulting, 2002). Grey water is also used for cooling in some facilities.

Water pollution can result from many of the processes involved in the manufacture of chemicals, from overflows of the storage tanks used for supplying the raw materials, through synthesis and product separation, to leakage from pipes during product storage. The types of pollutants from chemical production that may affect water bodies vary according to the type of chemical produced. Pollutants could include mixtures of oil and organic compounds in water, biodegradable organics and recalcitrant, volatile organics, heavy metals, suspended solids and heat (EIPPCB, 2003).

2.10 Other manufacturing

The companies not included in one of the sectors above have been grouped together as ‘other manufacturing’. This includes the manufacture of machinery and equipment, office machinery, electrical machinery, communication equipment, medical instruments, motor vehicles and transport equipment, and furniture, amongst other more specific manufacturing uses. Although the manufacturing sector is very diverse in terms of economics and production processes, none of these sectors appears to have significant issues in terms of water use, either through volume used or dependence of the process on water use. Additionally, many of the uses of water in these manufacturing industries have been highlighted in other sectors that use more significant volumes. These uses include as process water and for heating and cooling.

One particular sector within this category with relatively high water costs as a percentage of the total costs of inputs is the electronics sector. The use of water appears to be largely for the production of semi-conductor and printed circuit boards, which require a large volume of high quality water. Some of these plants have established additional water treatment works to further purify water supplied. However, the recent study in Scotland (CJC Consulting, 2002) found that the trade association did not identify specific concerns about changes in water regulation or costs.

2.11 Electricity, gas and water supply

Water can be used to supply energy through inland hydroelectric schemes or marine schemes. Hydropower schemes can be constructed on-line or off-line, depending on whether water is to be diverted from its original course. On-line schemes were popular some decades ago, but are no longer favoured, due to the impacts on migratory species and problems of siltation behind the structure. Off-line schemes divert the water from the watercourse, and this may have different problems, particularly due to the distance between abstraction and discharge. This may lead to low flows in a portion of the river, particularly during periods of low flow. Hydropower schemes can also use dams to create a high reservoir and increase the distance over which the water falls. The reservoir also stores water so that the flow can be regulated over periods of different rainfall and different electricity demand. Some schemes also use pumps from a low reservoir to return the water to the high reservoir, from where it can be reused during periods of high demand. The power generated from hydroelectric schemes depends on the flow of water and the height over which the water falls.

Marine schemes are much less widely used than hydropower, and currently there are only a small number of experimental schemes worldwide. Technologies differ, although those currently in operation use tidal barrages to trap the high tide in an estuary, from where it is released at low tide through turbines (Belfast Energy Agency, 2003).

In the (non-hydroelectric) power generation industry (i.e. coal, oil, gas and nuclear), freshwater or seawater is primarily used for cooling purposes and then returned to the water body. Power stations may use closed circuit or through flow systems. Closed circuit systems lose about 3% of the throughput of water in steam. Water is also used to top up the system in order to prevent concentration of salt, and the whole system is periodically purged. Through flow systems are located next to large rivers or the sea and allow water to run once through the power station. This is the case for all nuclear facilities in the UK, because of the large volume of water required for cooling. The net abstracted volumes and changes to water quality are likely to be insignificant, although the temperature of the water discharged can be noticeably raised. Water from the public supply is also used to make steam to act as the heat transfer medium and drive the turbines. This generally requires 1% of the throughput of water, and has to be of very high purity. Finally, water may also be used in fluegas desulphurisation (FGD) systems in power stations burning fossil fuels and discharged containing calcium sulphate. FGD is being introduced more widely in response to legislative changes, particularly the Revised Large Combustion Plant Directive (2001/80/EC), although there are a number of alternative FGD systems, only some of which are based on water use.

In discussions of power generation later in this report, facilities are described in terms of their installed capacity and their generation over a particular period. These figures can differ significantly. The installed capacity (in gigawatts or equivalent) gives an indication of the size of the power station. However, it does not indicate production, since this will be made as a strategic decision and will depend on the load factor of the power station. Therefore, some large stations may only operate at low load factors, and are largely kept as reserve capacity. Others will operate very intensively. Generation will also vary at different times of year depending on demand. Therefore, figures for actual generation (gigawatt hours or equivalent) are also useful.

Although this category is titled ‘electricity, gas and water supply’ in line with the Standard Industrial Classification, the value of water to the water supply industry is not considered separately in this section. The water supplied by Scottish Water and Water Service is used by the sectors considered elsewhere in this report, and therefore, to include it again here would risk double counting.

2.12 Construction

Water is used during construction for plant and wheel washing, irrigation and dust control. However, the most significant impacts on water bodies are through discharge rather than abstraction. Construction sites have historically contributed to the damage of the aquatic environment largely as a result of fuel oil spills and releases of suspended solids to water bodies. The extent to which this occurs depends on the management of the construction site as well as the size of the site, proximity to water bodies, and whether the site is contaminated or brownfield land (for further types of risk to the water body, see Entec, 2003). Suspended solids are a risk where there is significant disturbance of the site, although silt suspended in the water can result from excavations, exposed ground, stockpiles, plant and wheel washing and site roads (Environment Agency/ SEPA/ EHS, Pollution Prevention Guidelines 6). Water quality is also at risk from fuel oil spills and from contamination with concrete. Concrete is highly alkaline and can have extremely damaging effects on water bodies, particularly where there is soft water, although the risk can be controlled through suitable provision for washing concrete plant.

2.13 Commercial premises

The term ‘commercial premises’ has been defined to include industrial users who use primarily mains water for purposes similar to private households (drinking, sewage discharge and limited washing). This includes hotels, restaurants, transport and storage firms, financial firms and administrative organisations. Although the economic activities of these organisations are very different, their use of water is not as varied as other industrial sectors, and therefore they have been grouped together in this project.

2.14 Non-households

In line with the Environment Agency guidance, this study defines non-households to include a wide range of water users, who use primarily mains water for purposes similar to private households and in some cases for technical purposes specific to the institution in question. This group includes nursing homes, schools, hospitals, prisons, barracks and university halls, amongst others.

In order to indicate the water consumption associated with each type of organisation, **Table 2.3** indicates the benchmark and best practice consumption figures calculated by the Office of Government Commerce (OGC, 2003).

Table 2.3 Benchmark water use by non-households

Building category	Typical benchmark	
Office	9.3	m^3/ person/ annum
Prison with laundry	143	m^3/ prisoner/ annum
Prison without laundry	116.6	m^3/ prisoner/ annum
Primary school with pool	4.3	m^3/ pupil/ annum
Primary school without pool	3.8	m^3/ pupil/ annum
Secondary school with pool	5.1	m^3/ pupil/ annum
Secondary school without pool	3.9	m^3/ pupil/ annum
Defra laboratory	0.767	m^3/ sq. metre floor area/ annum
Large acute or teaching hospital	1.66	m^3/ sq. metre floor area/ annum
Small acute or long stay hospital without personal laundry	1.17	m^3/ sq. metre floor area/ annum
Small acute or long stay hospital with personal laundry	1.56	m^3/ sq. metre floor area/ annum
For all hospitals with central laundry facilities	Add 8.2 litres	per laundry article processed per annum
Court with catering facilities	0.54	m^3/ sq. metre floor area/ annum
Court without catering facilities	0.25	m^3/ sq. metre floor area/ annum
Museum and art gallery	0.332	m^3/ sq. metre floor area/ annum
Nursing home	80.6	m^3/ resident/ annum
College and university	0.62	m^3/ sq. metre floor area/ annum
Public lavatory	10.7	m^3/ sq. metre floor area/ annum
Police station	0.92	m^3/ sq. metre floor area/ annum
Sports centre	0.0385	m^3/ visitor/ annum
Library	0.203	m^3/ sq. metre floor area/ annum
Community centre	0.326	m^3/ sq. metre floor area/ annum
Fire station	15.08	m^3/ person/ annum
Coast guard station	12.62	m^3/ person/ annum
Vehicle Inspectorate depot	0.12	m^3/ sq. metre floor area/ annum

The potential pollution resulting from non-households is largely dependent on water management, and the risk to water bodies is minimal if water used is discharged into foul water rather than surface water drains. This applies to water used for cleaning equipment, floor and window cleaning, and that used in air conditioning and heating systems. It also includes water discharged from personal washing facilities, toilets, kitchens, laboratories, and laundries.

2.15 Amenity and recreation

There are a wide range of recreational and amenity uses of water resources. In order to consider a number of different areas, this category has been broken down into contribution to tourism and water-dependent visitor attractions, water-dependent recreation, non-water-dependent recreation, waterside amenity, and navigation.

2.15.1 Tourism and water-dependent visitor attractions

The tourists attracted to an area are influenced in part by the scenery and landscape of the area, and this is particularly the case for Scotland and Northern Ireland. This includes inland water bodies, lochs/loughs and rivers, as well as coastal waters.

There are also a small number of visitor attractions that rely on water, particularly aquariums.

2.15.2 Water-dependent recreation

There are a wide range of recreational activities that rely on water. These include activities on outdoor water bodies, such as jet-skiing, kayaking, rafting, windsurfing yachting and trips on rivers and canals, as well as activities that abstract and discharge water, in particular swimming pools. Although those taking part in many of these activities are not charged for water use, they can have an impact on the economy through spending. Angling is also a form of water-dependent recreation, although this was considered as part of the discussion of fishing, and therefore is not included again at this point.

Activities that use outdoor water bodies, either inland or coastal waters, are affected by a number of features of the water body. In particular, bathing and paddling are influenced by water quality. The blue flag standard is a symbol of environmental quality as well as sanitary and safety facilities at beaches and marinas in Europe and South Africa. Thus the award increasingly reveals more than just the quality of the bathing water, although it is imperative that water quality is compliant with the requirements of the EU Bathing Water Directive (76/160/EEC) concerning total faecal coliforms and faecal streptococci. Of the 105 blue flag beaches and 12 marinas in the UK, four beaches and one marina are in Scotland, and five beaches and three marinas are in Northern Ireland.

Since water in its liquid form is considered as a recreational resource, it is also relevant to consider the use of water as snow and ice. Skiing takes place outdoors in mountainous regions in Scotland and indoors in a small number of facilities. As with recreation on outdoor water bodies, such as yachting and water-skiing, skiing has little effect on water bodies. Although crucially dependent on precipitation falling as snow rather than rain, skiing is not affected by water quality. Similarly, there are negligible pollution effects resulting directly from skiing. Therefore, skiing and other snow sports have been excluded from the analysis.

Swimming pools are slightly different to the activities that use natural water bodies, since they abstract and discharge water, altering the chemical composition of the water between times.

Another indoor recreational activity using water is for indoor ski slopes and ice rinks. This is considered to be a relatively limited use, both in terms of the number of facilities and the volume of water used in each facility.

2.15.3 Non-water-dependent recreation and waterside amenity

Waterside amenity includes those individuals who chose to walk or spend time near to rivers, lochs/loughs or the coast because of the aquatic scenery. It also includes the higher value of property associated with a waterside location.

2.16 Navigation

Inland and coastal waters are used for navigation purposes in both Scotland and Northern Ireland. This can be for leisure (water-dependent recreation), for example on canal holidays, or for commerce, particularly for access and transport of goods and materials. Navigational trips on waterways vary in number and nature, although for some rivers and canals they are significant. Where waterways are used for navigation for commercial reasons, this links with the previous categories. For example, historically many pulp mills were situated next to rivers in order to allow logs to be floated to them, although the water is no longer used for this purpose.

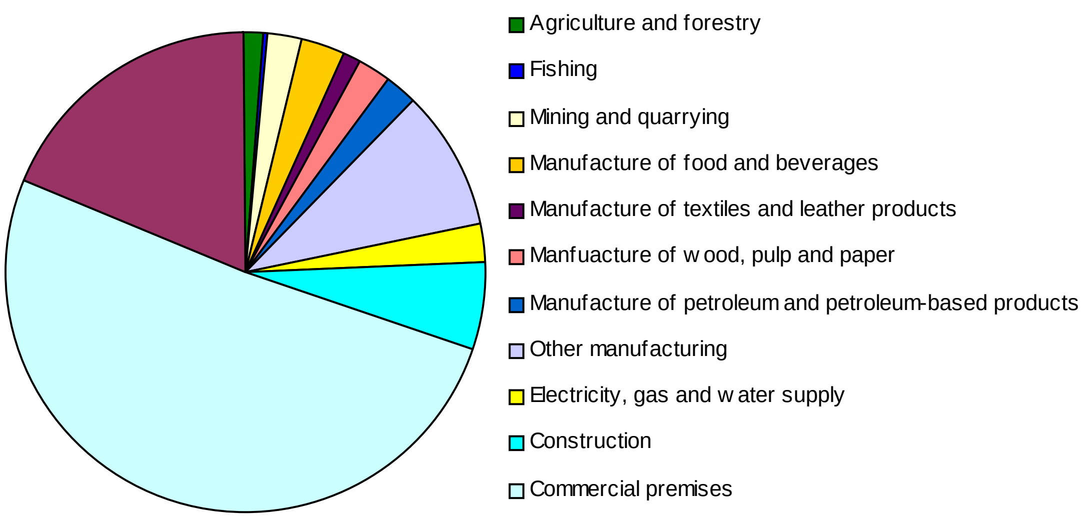
3. Use of water by sectors in Scotland

3.1 Introduction

Although a general description of sectoral water use was given in Section 2 of this report, the relevance of each sector for Scotland depends on the number of organisations in the sector and their economic importance.

The relative economic importance, in terms of gross value added to the Scottish economy, of the different industrial sectors is indicated in **Figure 3.1** (National Statistics, 2003). The most significant sectors are commercial premises and the non-household sector. This is largely due to the definitions of these sectors given in this report (discussed in Sections 2.13 and 2.14), where a large number of organisations are grouped together due to their similar use of water. Construction and manufacturing also make notable contributions to Gross Domestic Product.

Figure 3.1 Gross value added by industry group in Scotland, 2000



3.2 Households

In 2001, there were 5,062,000 people in Scotland, of whom 98.3% were living in 2,192,000 households (Scottish Executive, 2003b) (the remaining 1.7% were living in communal establishments and are therefore considered in Section 3.14). Clean water is supplied to households by Scottish Water or through private domestic abstractions. Private abstraction in Scotland has historically been unregulated, and therefore it is difficult to estimate the volume of water supplied in this way. Scottish Water supplies approximately 98% of households with clean water.

Given the lack of data on the volume of clean water supplied to Scottish households, it is necessary to make an estimate. A study in 1999 of domestic water consumption in Scotland (Environment Agency, 2001a) identified a median per capita consumption value of 139.1 l/hd/day and a mean of 143.3 l/hd/day. For the five million people living in Scotland, this would suggest a total water use of 713,000 m^3/day (five million people using a mean of 143.3 l/hd/day). However, the 1999 study found a higher mean occupancy rate than suggested by the figures above from the 2001 census (2.43 compared to 2.27). If the occupancy rate is now lower, this could increase the per capita use as some uses are replicated in each household. This figure should also be interpreted cautiously due to discrepancies highlighted in the report on the dynamics of water use (Scottish Agricultural College, forthcoming). This study points out the differences between the figure of 143.3l/hd/day reported in the 1999 study, 134l/hd/day calculated from components of household water use by SAC (SAC, forthcoming) and OFWAT reports of 153l/hd/day and 136 litres/hd/day for unmetered and metered premises respectively in England and Wales (OFWAT, 2003).

The figure of 713,000 m^3/day is based on both public and private supplies. The Drinking Water Quality Regulator (2003) has calculated that 82,019 people (1.6% of the population) relies of private supplies of drinking water, with a further 64,213 using private supplies either through use of food production facilities or as visitors to hotels, campsites, etc. However, this latter group is not included in this assessment of household consumption. The highest proportions of population using private supplies are in Aberdeenshire (13.1%), Argyll & Bute (8.88%) and Scottish Borders (6.63%). Based on an average per capita consumption of 143.3 l/hd/day, abstraction from private supplies for household use is estimated as 11,750m^3/day.

Households also produce dirty water, particularly as sewage, which is disposed of in mains sewers or is stored in private septic tanks that are emptied periodically. Scottish Water has estimated that 95% of the clean water supplied to households is returned to the sewers for disposal. Based on a supply to households of 713,000 m^3/day, this would indicate that 677,000 m^3/day are disposed of as dirty water.

3.3 Agriculture and forestry

There is a significant agricultural sector in Scotland, employing 28,645 full-time workers as well as 35,709 part-time employees and nearly 4,000 casual and seasonal workers. Agriculture and forestry account for 1.50% of gross value added to the Scottish economy. **Table 3.1** (Scottish Executive, 2003c) shows the use of land for agriculture in Scotland. In terms of land area, by far the most extensive form of agricultural land use is for rough grazing, although grass for mowing, combine harvested crops, and grass for grazing are also significant. This reflects the dominance of livestock, chiefly beef herds and sheep, although dairy enterprises are important, particularly in the south west.

Table 3.1 Agricultural land in Scotland

Agricultural land use	Area (hectares)
Combine harvested crops	474, 340
Potatoes	28, 450
Crops for stockfeeding	23, 970
Vegetables for human consumption	10, 590
Orchard fruit	40
Soft fruit	1, 650
Other crops	4, 960
Fallow	8, 070
Set-aside	90, 610
Grass for grazing	319, 770
Grass for mowing	933, 940
Rough grazing	3, 312, 900
Woodland	236, 470
Other land	74, 370
	5, 520, 130

Forestry covers 16.4% of land in Scotland, of which the majority is coniferous woodland (Forestry Commission, 2003). Other types of forestry are shown in **Table 3.2** (Forestry Commission, 2003).

Table 3.2 Forestry in Scotland

Forest type	Area (hectares)
Coniferous	888, 317
Broad-leaved	176, 519
Mixed	53, 696
Coppice	553
Coppice-w-stds	630
Wind-blow	4, 319
Felled	23, 303
Open space	134, 130
Total	**1, 281, 472**

3.4 Fishing

Fishing accounts for 0.34% of gross value added to the Scottish economy, although this does not reflect the income from angling, which is likely to have an impact on other sectors in the industrial classification.

3.4.1 Aquaculture

The lochs and rivers of Scotland are used for a large amount of commercial fish farming. The sector is spread throughout Scotland, although there are a large number of farms in the west. **Table 3.3** shows the total production of fish and shellfish in 2002 (Scottish Executive, 2003).

Table 3.3 Production of farmed fish in Scotland, 2002

	Type of fish	Production
Fish	Salmon (000 tonnes)	145.6
	Smolts (million fish)	47.2
	Rainbow trout (000 tonnes)	6.7
	Other (000 tonnes)	0.4
Shellfish	Mussels (000 tonnes)	3.2
	Other (000 tonnes)	0.3

Fish farms for finfish may consist of freshwater or marine cages within a river, loch or the sea, or may use tanks and ponds. Although water is used in both cages and tanks/ponds and both uses are therefore considered in this study, only the latter is counted as abstraction. Aquaculture was the responsible for the largest volume of abstraction considered in the CJC study of abstraction in Scotland (CJC Consulting, 2002), although hydropower was not included in the study. It was estimated that the sector abstracts 1,617 million m^3 each year, or 4.4 million m^3 per day.

Farmed fish are initially raised in freshwater environments, but seawater is used in the later stages for some breeds, including salmon. This is generally done by moving the fish to cages in sea lochs or coastal waters, although there are three sites in Scotland where seawater is abstracted and used in tanks on land. However, this is not common practice in the industry and is unlikely to represent a significant abstraction (CJC Consulting, 2002).

Of the 6,659 tonnes of trout produced in Scotland in 2002, 85% was produced in freshwater. Of freshwater production, 61% was in cages (in lochs) and 39% in ponds (FRS, 2002).

The production of shellfish, particularly mussels but also oysters and scallops, is also important, employing approximately 350 people in rural areas. In contrast to finfish production, most shellfish farms are small enterprises, producing less than 10 tonnes per year (Scottish Executive, 1999).

3.4.2 Commercial fishing

Commercial fishing in Scotland has declined over the last decade, with a fall of nearly a third in the number of people employed in the fishing industry between 1992 and 2002. However, in UK terms, it is still significant, with 65% of the UK catch landed in Scotland. Scotland's fishing industry is particularly important in the landing of pelagic fish, with 76.8% of the UK's catch of these fish landed in Scotland (236,000 tonnes). The quantity and value of commercial fishing in Scotland is shown in **Table 3.4** below (Scottish Executive, 2003).

Table 3.4 Fish landings by the UK fleet into Scotland, 2002

	Quantity ('000 tonnes)	Value (£ million)
Demersal fish	159.0	138.7
Pelagic fish	234.6	95.8
Shellfish	52.1	93.8
Total	**445.8**	**328.3**

Within Scotland, there are a number of ports where fish are landed, the most significant of which are Peterhead, Shetland (Lerwick and Scalloway), Fraserburgh, and Wick. The quantity and value at Scottish ports is shown in **Table 3.5** (Scottish Executive, 2003).

Table 3.5 Quantity and value of fish landed at Scottish ports, 2002

	Quantity ('000 tonnes)				Value (£ million)			
	Demersal	Pelagic	Shellfish	Total	Demersal	Pelagic	Shellfish	Total
Eyemouth	2,825	-	998	3,823	2,487	-	2,209	4,696
Pittenweem	80	-	942	1,021	62	-	1,836	1,898
Aberdeen	15,373	982	1,206	17,561	13,333	58	2,701	16,093
Peterhead	37,511	53,389	2,022	92,922	36,881	17,397	5,540	59,818
Fraserburgh	12,896	16,432	6,657	35,985	9,960	5,401	14,882	30,244
Buckie	1,742	17	1,191	2,950	1,730	5	2,122	3,856
Wick	16,070	94	4,886	21,051	17,555	28	6,107	23,690
Orkney	71	1	2,690	2,762	30	0	3,850	3,881
Shetland	10,719	69,116	1,137	80,971	9,769	24,860	1,695	36,323
Stornoway	593	0	3,714	4,307	412	0	8,650	9,062
Kinlochbervie	6,852	154	616	7,622	8,146	37	1,319	9,502
Lochinver	6,435	71	937	7,443	8,036	18	2,737	10,791
Ullapool	6,479	202	1,810	8,491	6,909	69	4,199	11,176
Mallaig	2,298	2,662	3,073	8,032	1,856	275	6,290	8,421
Oban	627	-	4,321	4,948	565	-	7,662	8,228
Campbeltown	245	185	4,086	4,948	208	23	7,338	7,570
Ayr	832	1	8,428	9,261	981	0	6,389	7,370
Portree	373	105	2,121	2,599	387	45	6,596	7,028
Total	**122,019**	**143,411**	**50,835**	**316,265**	**119,307**	**48,217**	**92,123**	**259,647**

3.4.3 Angling

Within Scotland, there are 36,650km of river designated under the Freshwater Fish Directive, the vast majority (36,580km) of which is designated as salmonid fisheries (Defra, 2004). Of the salmonid designated rivers, 770km failed to meet water quality requirements in 2002, with no failures of cyprinid designated rivers (Defra, 2004).

A study of angling across Scotland estimated the number of anglers and the expenditure made (Scottish Executive, 2004b). This found that most anglers visited the Highlands, North East and Central Scotland, with a total expenditure across Scotland of £112 million. Of this, salmon and sea trout anglers accounted for 65% of expenditure. Days and expenditure are shown in **Tables 3.6** and **3.7** (Radford *et.al.*, 2004).

Table 3.6 Days spent angling in Scotland, 2003

	Salmon and sea trout	Brown trout	Rainbow trout	Coarse fish	Total
Dumfries and Galloway	48,245	28,195	17,337	23,926	**117,703**
The Borders	43,000	17,884	10,942	315	**72,141**
Highlands	190,589	78,576	26,702	10,915	**306,782**
North East Scotland	190,853	54,715	108,894	11,402	**365,,864**
Central Scotland	61,646	134,391	231,615	45,581	**473,233**
Western Isles	10,715	12,606	<100	<100	**23,321**
Orkney and Shetland	<100	27,000	<100	<100	**27,000**
Total	**545,048**	**353,367**	**395,490**	**92,139**	**1,386,043**

Table 3.7 Expenditure by anglers in Scotland, £'000s, 2003

£'000	Salmon and sea trout	Brown trout	Rainbow trout	Coarse fish	Total
Dumfries and Galloway	2,962	1,186	1,206	1,397	**6,751**
The Borders	6,669	672	607	16	**7,964**
Highlands	35,408	5,088	1,752	715	**42,963**
North East Scotland	24,344	1,589	4,910	824	**31,667**
Central Scotland	3,386	5,234	10,963	1,930	**21,513**
Western Isles	719	458	<1	<1	**1,177**
Orkney and Shetland	<1	511	<1	<1	**511**
Total	**73,488**	**14,739**	**19,438**	**4,882**	**112,547**

3.5 Mining and quarrying

Mining and quarrying accounts for 1.1% of employment and 2.13% of the gross value added to the Scottish economy, with the majority of this value attributable to the mining of energy producing materials (National Statistics, 2003).

Table 3.8 indicates the production of minerals in Scotland in 2001 (Hillier *et.al.*, 2002). The most significant minerals are igneous rock, sand and gravel and coal. However, it should be noted that since these figures were produced Scotland's last deep coal mine at Longannet has been closed after a serious inrush of groundwater from areas of previously abandoned old workings. This took place in March 2002, ironically at a time where the groundwater pumped from the mine was being investigated as a potential source of industrial water.

The most significant minerals in terms of total UK production are opencast coal, with Scottish production accounting for over half of total UK output, and igneous rock (39% of total UK production). The relatively modest annual output of Scottish Talc (5000 tonnes) represented 100% of total UK production (Hillier *et.al.*, 2002).

Opencast coal mining is undertaken throughout the Central Belt of Scotland from the Ayrshire coalfield in the west to the Fife coalfield in the east, with most water usage being confined to dust suppression purposes.

Table 3.8 Production of minerals in Scotland, 2001

Mineral		Production (000 tonnes)
Coal	Deep-mined [(1)]	700
	Opencast [(1)]	8,200
Common clay and shale		839
Igneous rock		20,034
Limestone [(2)]		1,733
Sand and Gravel (land-won)		10,753
Sandstone		1,603
Fireclay		40
Peat (thousand m^3)		355
Talc		5

(1) BGS estimate
(2) including dolomite for construction purposes

Quarrying dominates the production of other minerals and therefore usage mainly relates to mineral washing and dust suppression. No figures are available for metal mining production but a number of Mines Royal Licences are held by mining companies, although these are mainly exploration related.

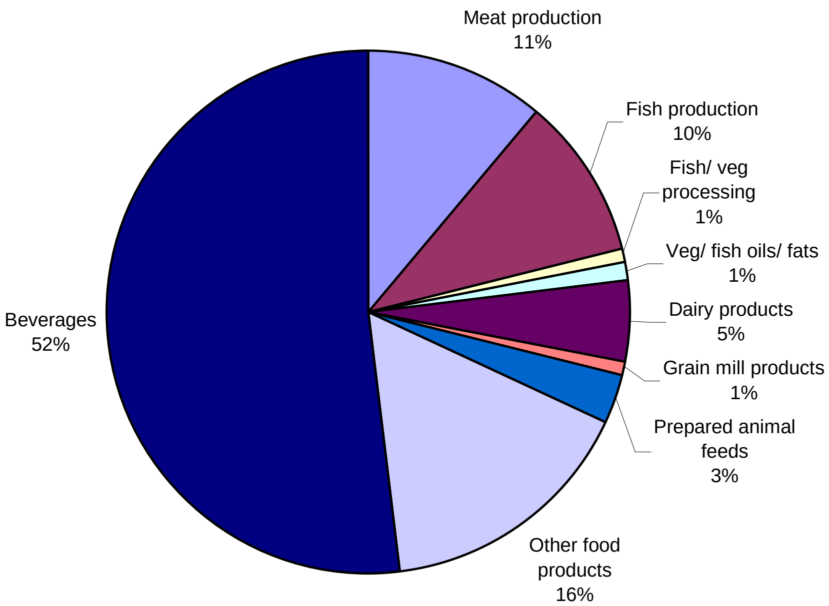
In addition to the minerals produced, Scotland acts as a focus for the production of oil and gas. None of the oil and gas fields are within 3 km and are therefore not included in the production statistics above, or within the scope of this assessment. However, the production of oil and gas is significant for the Scottish economy, and there are oil terminals at Flotta, Nigg, Sullom Voe, Grangemouth, Dalmeny and Cruden Bay, and a gas terminal at St. Fergus. These facilities provide a focus for the vast majority of oil and gas extracted from the Northern North Sea. The processing of these materials are considered in more detail in Section 3.9.

3.6 Manufacturing of food and beverages

The manufacture of food and beverages in Scotland accounts for 3.36% of gross value added in the Scottish economy.

Of production in the food and drink sector, drink accounts for just over half of gross value added, as shown in **Figure 3.2** (SEERAD, 2002a).

Figure 3.2 Gross value added in the food and drink sector, 1999



The manufacture of food and drink consumes water for a number of processes, particularly as a direct input into manufacture and for washing and cleaning equipment and facilities. Most of the sector requires potable water and Scottish Water supplies 47 million m^3 each day to the largest volume water users in the sector. In addition, direct abstractions are significant for food and beverage manufacturers. Volumes abstracted directly are estimated in the sections below.

3.6.1 Food processing

Food processing in Scotland is a diverse industry, although the main economic contribution from the sector is in meat and fish production. There is a notable lack of information on the nature, distribution and characteristics of the sector, and it has been recommended that the

Scottish Executive establish a working group in this area in the light of Pollution Prevention and Control regulations (Scottish Executive, 2002b).

The volume of water abstracted by organisations in the food processing sector was estimated as part of the study of abstraction in Scotland (CJC Consulting, 2002). This study estimated the total mean use of water as 8,000m^3 for fish processing, 49,000m^3 for vegetable processing, 63,000m^3 for meat processing and 117,000m^3 for dairy processing. Of these, direct abstraction was most common for vegetable processors, with a mean of 45,000m^3, with limited abstraction in the other sectors.

Discharge of water from food processing businesses is generally to the foul sewer, with treatment taking place at public sewage works. Yeast manufacture has a significant effect on water quality, and downgrading of quality is currently monitored by SEPA. In addition, several large creameries, chess manufacturers and an abattoir discharge effluents into coastal waters through sea outfalls (Scottish Executive, 2002b).

3.6.2 Production of alcoholic beverages

Scotland is noted for its production of Scotch whisky, and the sector is important both economically and culturally. There are just over a hundred distilleries in Scotland, spread in particular across the Highlands, and concentrated along the River Spey. Around 41,000 jobs depend on the production of whisky, with just over 9,500 employed in production itself and a further 20,000 jobs in businesses supplying goods and services (DTZ Pieda, 2003). Whisky production also supports Scottish agriculture, and uses approximately 390,000 tonnes of barley and 486,000 tonnes of other cereals each year (Scotch Whisky Association, 2002). The sector also generates over £800 million of income (principally in wages and salaries) (DTZ Pieda, 2003).

Figures from the study of abstraction (CJC Consulting, 2002) suggested that maltsters abstracted 1.566 million m^3 per year, and were supplied with a further 1.584 million m^3 from public supplies. This study suggested that malt distillers abstract 76.49 million m^3 each year. This is much higher than the estimate of abstraction included in the submission by the Malt Distillers Association of Scotland to the Scottish Parliament (Scottish Parliament, 2002b). These figures suggested that 2.6 million m^3 of water was used for mashing and 37.8 million m^3 was used for cooling in 2002. Some of this difference may be accounted for by additional distillers in other catchments (the submission to the Scottish Parliament considered six of the main catchments) and by grain distillers, although it is not expected that this would account for all of the discrepancy (Ross, pers.comm., 10th June 2004). However, the majority of the difference is likely to be accounted for by different definitions of abstraction, with the CJC estimate including all water diverted from the natural flow of a stream, and the Malt Distillers Association of Scotland estimate including only the diverted water actually used in the distillery (McLean, pers.comm., 15th September 2004). The difference in the definition of abstraction for this sector is currently under discussion between SEPA and the Malt Distillers Association of Scotland. Estimates of public supply were not available for malt distillers.

The traditional production of whisky has also encouraged production of other spirits, which rely on the same production facilities and bottling capacity. More than 70% of UK gin and vodka is now bottled in Scotland, with some whisky producers also producing other spirits (DTZ Pieda, 2003).

Table 3.9 indicates the employment and income associated with the production of spirits (whisky, gin and vodka) in Scotland (DTZ Pieda, 2003). The direct effects are associated with the income and employment in spirit production itself; the indirect effects are a result of employment and income in businesses supplying the sector, while the induced effects occur as spending filters through the economy.

Table 3.9 Economic impact of Scottish spirit production on Scotland and the UK

	Scotland	UK
Employment		
Direct	10,324	11,000
Indirect	20,583	35,403
Induced	12,192	21,640
Total	**43,099**	**68,043**
Income (£m)		
Direct	273.00	336.00
Indirect	344.58	576.22
Induced	240.25	462.60
Total	**£857.83m**	**£1,374.82m**

In addition to the value of production through sale of the product, distilleries rank amongst visitor attractions in Scotland. A study commissioned by Visit Scotland surveyed 13 distilleries, which reported 391,760 visits between January and October 2003, up 10% on the same period the previous year (Visit Scotland, 2003).

3.6.3 Production of mineral waters and soft drinks

Mineral water

The Scottish mineral water companies supply approximately 35% of the UK consumption of bottled water, which was 1.8 billion litres in 2002 (Highland Spring website). The production of mineral water in Scotland, as elsewhere, requires brands to be linked to specific springs. However, in some places more than one brand is linked to a single spring, most notably at Lennoxtown (Burnbrae Spring, Caledonian Spring, Campsie Spring, Glenburn Spring, Glencairn, Heather Spring, Lowland Glen, Scottish Mineral Water and Strathglen Spring). In such cases, the total abstraction is more significant than indicated by the economic importance of individual producers.

The production of mineral water is spread amongst a large number of companies, but is dominated by a few very large producers. **Table 3.10** is an approximate indication of order to the largest abstraction sites for the bottling of water in Scotland (Orr, pers.comm., 12th January 2004). These are based on the Food Standards Agency list (see Appendix D), and do not include bottling for alcoholic and soft drinks.

Table 3.10 Sites of most significant abstraction of water for bottling

Site	Brands
Blackford, Tayside	Highland Spring, Gleneagles, Gleneagles Maltings, Perthshire Mountain Spring
Forfar, Tayside	Strathmore Spring
Lennoxtown, Glasgow	Burnbrae Spring, Caledonian Spring, Campsie Spring, Cragganmore Spring, Glenburn Spring, Glencairn, Heather Spring, Lowland Glen, Scottish Mineral Water, Strathglen Spring
Fanellan, Highland	Lovat Spring, Sainsbury's Scottish Caledonian, Scottish Mountain Spring, Scottish Border Springs

The amount produced by different companies over time varies, particularly depending on their response to changes in demand. Some companies do not supply others in order to maintain stability of production, for example Strathmore Springs where the abstraction from the spring is not readily altered. On the other hand, companies may be able to vary output in order to respond to changing demands. This is particularly important for companies such as Highland Spring who supply water for supermarket own-label products.

Although the exact volumes of mineral water abstracted or produced are not known, there are a number of estimates that provide an indication. Based on satisfying 35% of UK consumption (Scottish Parliament, 2002a), Scottish companies produced approximately 630 million litres (630 million m^3) in 2002. Of this, it is thought that Highland Spring bottled approximately 320 million m^3 (Press and Journal, 18.12.2003). This would be consistent with the estimated sector abstraction of 687 million m^3 (CJC Consulting, 2002), since this larger figure would include process water and excess water discharged immediately.

Discharge from mineral water companies in Scotland is high quality clean water and may be either to mains sewers and directly to water courses. The study of abstraction (CJC Consulting, 2002) found that 40% of abstractors discharged to the sewer. This is preferable where no local watercourse is available; Strathmore Springs in Forfar discharge to the sewer. However, there can be significant costs associated with this discharge, and the discharge costs for the North of Scotland Water Authority area recently increased from 20p to 30p per cubic metre to reflect the difficulties associated with the clean water diluting the effluent and reducing the efficiency of sewage treatment works (Orr, pers.comm., 12th January 2004). Discharge directly to watercourses may therefore be less expensive, but can be up to 2.5km from the point of abstraction (CJC Consulting, 2002).

Non-alcoholic beverages

Distinguishing between the production of mineral waters and the production of other non-alcoholic beverages is not particularly clear because of the definition of mineral waters. Once any sweetener or flavouring is added to the mineral water, it becomes a soft drink and the production facility may become classified as a soft drinks works. This is the case for Strathmore Springs, which produces plain and flavoured mineral waters. Other works, such as that operated by Caledonian Bottlers at Mauchline, Ayrshire, combine the production of alcoholic drinks and flavoured waters.

3.7 Manufacture of textiles and leather products

Textiles and leather is a relatively small economic sector in Scotland, accounting for only 0.87% of gross value added. However, they are significant in terms of historic contribution to Scotland and also in terms of water use issues.

The textile sector is diverse and the sector is found in clusters throughout Scotland. In particular, there is a focus on knitwear in the Borders and Langholm (Dumfries and Galloway), clothing manufacturers in greater Glasgow, traditional knitwear in Shetland and Orkney, technical and industrial textiles in Dundee, and some companies in Elgin and the Highlands.

The tanning sector is based in or near the urban areas of Scotland, with four of the largest tanneries located in Glasgow. The sector is small and has declined over the past decades to seven tanneries in 2004. Survival has been helped by availability of high quality hides in the UK, local sources of soft water and a local chemical sector. The sector is an intensive water user, with approximately 20m^3 of water required to process 1 tonne of raw hide into 300kg of saleable leather. Both private and public water supplies are used. Due to the organic content of the tannery effluent (which requires treatment before discharge) and the urban location of the tanneries, primary effluent treatment is typically applied, with only one plant having a secondary/biological plant. Location, cost and space are major barriers to expansion to include biological treatment, and all effluent is discharged to mains sewers.

3.8 Manufacture of wood, pulp and paper products

Wood, paper and pulp employs 3380 people to produce approximately 1.25 million tones of paper per year (CPI, 2004), accounting for 2.31% of gross value added in Scotland (National Statistics, 2003). Although the manufacture of paper is part of a chain from forestry through to manufacture, the industry in Scotland is focused around the manufacture of paper, and most mills import treated woodpulp for raw material (only one, Caledonian Paper, produces its own pulp). There are twelve paper mills in Scotland, concentrated in the Forth/Clyde valley and around Aberdeen where they were historically situated in proximity to suppliers and markets in towns as well as close to water sources for production processes. The industry, which specialises in high quality graphics paper, is very competitive and five mills have closed since 2000 in response to changes in international economic conditions and domestic prices and regulation.

The mills rely on water abstracted from ground and surface waters for the majority of their requirements, using mains water for domestic purposes only. However, the water used for processing is required to be of high quality to ensure that the papers are not discoloured. The water is treated and discharged directly into watercourses or is disposed of into the mains sewers. Both the efficiency of water use and the quality of discharge are regulated under the Pollution Prevention and Control (Scotland) Regulations 2000, to which all mills in Scotland are permitted. The Confederation of Paper Industries estimate water abstraction as 34 million m^3 per year, with 33 million m^3 discharged (CPI, 2004). However, this is about half of the volume estimated by CJC (CJC Consulting, 2002).

3.9 Manufacture of petroleum and petroleum-based products

This sector includes petroleum refining and manufacture of chemicals and petrochemicals. Overall, the sector contributes 2.56% to the Scottish economy (using gross value added), although within this figure, the most significant contribution is made by the manufacture of chemicals (1.66% of gross value added). Manufacture of rubber and plastic products accounts for 0.69% and refining for 0.21% of gross value added. However, although overall gross value added in the chemical sector is relatively low, it is approximately 40% higher per employee than the average for the manufacturing sector (Scottish Executive, 2001b). The sector also supports jobs elsewhere within Scotland, and BP has estimated that 265,000 jobs in the UK are dependent on the oil and gas industry, with 31% of these in Scotland (BP, 2003).

There is a significant amount of extraction of oil and gas from the North Sea. The refining takes place at two locations in Scotland, oil refining at Grangemouth and specialist lubricant and bitumen refining at Dundee. For manufacture of chemicals, the largest company is operated by BP Chemicals at Grangemouth, although there are also a large number of small chemical companies.

In terms of water use, distinguishing between different parts of the sector is more difficult, particularly because of the operation of a unified site by BP Grangemouth (the largest industrial site in Scotland (BP, 2003)), incorporating both chemicals and refining activity. Scottish Water have split the sector into oil refining and chemicals, with supplies to large companies in the sector of 1,350m^3/day and 39,670m^3/day respectively (Scottish Water, 2003). However, for the BP Grangemouth site (incorporating three separately registered BP companies and a third party supplying BP), typical use of mains water is 52,000m^3/day (Forrest, pers.comm., 21st September 2004). Water is also abstracted, with CJC Consulting estimating a figure of 15,000m^3/day for chemical companies (CJC Consulting, 2002). For BP Grangemouth, approximately 980m^3/day of borehole water is used (Forrest, pers.comm., 21st September 2004).

3.10 Other manufacturing

There are a number of other sectors within manufacturing operating in Scotland, contributing 9.78% to the gross value added to the Scottish economy. Within this, the contribution of the manufacture of electrical and optical equipment is by far the most significant, accounting for almost half of the total contribution.

3.11 Electricity, gas and water supply

Installations producing electricity from fossil fuels and nuclear fuels in Scotland range in installed capacity from over 2000MW to just over 2MW. The installed capacities are shown in **Table 3.11** below (DTI, 2003). There are five major power generators, Longannet, Peterhead and Cockenzie using fossil fuels, and Torness and Hunterston B using nuclear fuels. There are a further nine small generators. In total, these facilities have an installed capacity of 7774MW. The actual generation of all of these facilities is not known, although the five largest installations supplied approximately 32,750GWh (Scottish Power, 2003, Scottish and Southern Energy, 2002, British Energy, 2003, and BNFL, 2002). This is shown in **Table 3.11** where known.

Table 3.11 Installed electricity generation capacity in nuclear and fossil fuel schemes in Scotland

Station name	Fuel	Operator	Installed capacity (MW)	Electricity supplied (GWh) 2002/3
Longannet	coal	Scottish Power	2304	10,834
Peterhead	oil/gas	SSE	1550	5,048 *
Torness	nuclear	British Energy	1250	5,700
Hunterston B	nuclear	British Energy	1190	8,930
Cockenzie	coal	Scottish Power	1152	2,223
Chapelcross	nuclear	BNFL	196	500
Lerwick	diesel/gas	SSE	67.2	137 *
Stornoway	diesel		23.5	
Kirkwall	diesel		16.2	
Loch Carnan, South Uist	diesel		11.8	
Bowmore	diesel		6	
Arnish	diesel		3	
Tiree	diesel		2.5	
Barra	diesel		2.1	

* figures relate to 2002 rather than 2002/3

These facilities are all located on the coast and are dependent on marine water to use in through flow systems for cooling. Although net abstraction is insignificant, the significant change to the water is through the increased temperature of discharge. Longannet and Cockenzie report an estimated use of river water of 1,587 million m^3 and 643.4 million m^3 respectively in 2002/3 (Scottish Power, 2003). There may also be changes in radioactive content of the water close to nuclear facilities; this is reported by British Energy (British Energy, 2003) and BNFL (BNFL, 2002). The two major nuclear facilities are estimated to use approximately half a million m^3 of water for cooling each year.

In addition to water for cooling, fresh water supplied by Scottish Water is used to create steam to drive the turbines and for site use. Longannet and Cockenzie were supplied with 2.86 million m^3 and 1.51 million m^3 respectively in 2002/3 (Scottish Power, 2003). This is equivalent to 7,836m^3 and 4,154m^3 per day. Mains water use at the two nuclear facilities was 840,000m^3 at Hunterston B and 341,000m^3 at Torness for 2002/3 (British Energy, 2003), equivalent to 2,301m^3/day and 934m^3/day respectively.

In addition to the power stations above, Scotland has a number of hydropower installations, ranging in installed capacity from 400MW to 1MW. These installations are used to provide power for specific industrial processes as well as to supply the grid. This is shown in **Table 3.12** below. Total installed capacity in hydroelectric plants in Scotland is 1993.6MW. The majority of these schemes are operated by either Scottish and Southern Energy or Scottish Power, who report power output in their annual reports. From information for Scottish and Southern Energy for 2002 (Scottish and Southern Energy, 2002) and Scottish Power for 2002/3 (Scottish Power, 2003), the overall net output of these schemes is approximately 3771GWh.

Table 3.12 Installed electricity generation capacity in hydroelectric schemes in Scotland

Scheme/ station name	Operator	Scheme/station installed capacity (MW)	Scheme/station generation (GWh), 2002	
Cruachan (pumped storage)	Scottish Power	400	-69*	A
Foyers (pumped storage)	SSE	300	44	B
Sloy/ Awe	SSE	264	456	B
Tummel	SSE	241	778	B
Affric/ Beauly	SSE	173	574	B
Conon/ Shin	SSE	139.5	674	B
Great Glen	SSE	119	450	B
Galloway	Scottish Power	109	285	A
Breadalbane	SSE	103	403	B
Lochaber	Alcan	84	Not known	C
Kinlochleven	Alcan	30	Not known	C
Lanark	Scottish Power	16	79	A
Cuileag	SSE	3	Not known	C
Loch Turret	SSE and landowner	2	Not known	C
Storr Lochs	SSE	2	8	D
Ardverikie	Ardverikie Estate	1.1	Not known	C
Gisla	SSE	1	2	D
Nostie Bridge	SSE	1	3	D
Kerry Falls	SSE	1	5	D
Morar	SSE	1	3	D
Stanley Mill	Innogy	1	Not known	C
Loch Dubh	SSE	1	4	D
Chliostair	SSE	1	3	D

Notes:

*: Pumped storage facilities may show negative generation because the energy used to pump water from below turbines to above them is greater than that generated by flow through the turbines. However, such facilities are useful to produce electricity during times of peak demand, using excess electricity for pumping during periods of low demand.

A: Source: installed capacity: J. Telfer, pers.comm., 27th February 2004, generation, Scottish Power, 2003

B: Source: installed capacity and generation: Scottish and Southern Energy, 2002

C: Source: installed capacity: Scottish Executive Renewable Energy Group, 2004

D: Source: Installed capacity and generation: Scottish and Southern Energy, 2004

Water use at the hydropower facilities operated by Scottish Power is reported in their annual environment report (Scottish Power, 2003). Cruachan used no publicly supplied water but used 3.12 million m^3 of river water. On the other hand, the remaining hydropower facilities used 7,000 m^3 of public supplies but did not use river water.

3.12 Construction

Construction employs 5.9% of the Scottish workforce (Source: Annual Business Inquiry, Office for National Statistics) and contributes 5.8% of gross value added to the economy (National Statistics, 2003). This has accompanied the steady increase in the stock of dwellings over the last decade, rising from 2,193,000 at the end of December 1991 to 2,345,000 at the end of December 2001 (Scottish Executive, 2004). Of the new dwellings completed in 2002, the vast majority (78.5%) were for the private sector, with 21.3% for housing associations and 0.2% for public authorities (Scottish Executive, 2004).

3.13 Commercial premises

The commercial sector is of enormous economic significance to the Scottish economy, employing over half of the Scottish workforce and contributing over 50% to the gross value added. Within this sector, property and the retail trade have a particular economic importance, accounting for 17.73% and 10.95% of gross value added respectively.

3.14 Non-households

Within the categories defined for this study, the non-household sector is the second most significant in terms of contribution to the Scottish economy, accounting for nearly 20% of gross value added. The sector is also responsible for a quarter of employment, equal to over 50 thousand people.

3.15 Amenity and recreation

3.15.1 Tourism and water-dependent visitor attractions

Scotland is a significant tourist destination. In 2002, tourists made over 20 million trips to Scotland, spending £4,494 million (VisitScotland). Of these visitors, 18.5 million were from the UK, although the average length of stay and expenditure was much higher from those further afield. For both UK and overseas visitors, the ‘urban’ type of tourism offered by Edinburgh and the Glasgow area comprises the main attraction. Nevertheless, the more ‘natural’ setting offered by the Highlands makes them the third more visited destination in the country. This, together with the importance of leisure activities that take place on a ‘natural’ setting (such as walking and hiking, swimming, nature study, visiting theme and activity parks, and fishing), suggests that the natural environment is a significant element of Scottish tourism. In a survey of French, Spanish and German visitors 47% of those surveyed stated that landscape, countryside and scenery was the main influence on their choice to holiday in Scotland, with 10% specifically mentioning lochs and rivers (Visit Scotland and SNH, 2002).

There are also a number of key water-dependent attractions. As part of the natural scenery, the shores of Loch Lomond were estimated to have attracted 400,000 visitors in 2002, ranking in the top ten visitor attractions with free admission (Star UK, 2003). Deep Sea World in North Queensferry also attracted a large number of visitors, 307,000 in 2002 (Star UK, 2003). The Falkirk Wheel is also an important visitor attraction, as well as forming part of canal trips through central Scotland. The visitor centre attracted 380,000 in 2003/4, with nearly 30,000 people taking a boat trip through the wheel in August 2003 (British Waterways, 2004).

3.15.2 Water-dependent recreation

The lochs, rivers, canals and coastal waters are used for a range of recreational activities, including water sports and boat trips, and are also used for coarse and game angling (see also Section 3.4.3). Spending on activity holidays, which include fishing and watersports, accounted for 28% of holiday tourist spending in Scotland in 2000, generating £657 million of income (equivalent to £243/trip or £66/night). Within this category, fishing holidays generated £52 million (£920/trip) and watersports holidays generated £62 million (£310/trip). In addition, it is likely that there is additional spending on these activities from visitors for whom fishing, boat trips or watersports was not the main purpose of their trip.

Information on the number of people involved in or days spent on all forms of water-dependent recreation is not available. However, British Waterways collects data on boats licensed on their canals. This is shown in Table 3.13 below (British Waterways, 2004).

Table 3.13 British Waterways boat licences in Scotland, 2003/4

	Under 3 months	Over 3 months	Total
Caledonian Canal	1,151	140	1,291
Lowland Canals	128	220	348
Crinan Canal	1,214	61	1,275

3.15.3 Non-water-dependent recreation and waterside amenity

Waterside amenity covers a variety of recreational activities that do not make use of the water, but for which the environment makes a positive contribution. This could include much of the wildlife tourism, with visitors coming to view sea birds, cetaceans, otters and seals for example. A report by A&M (Training and Development) (2002) estimated that 283 wildlife tourism businesses in Scotland gave full-time (seasonal or year-round) employment to over 1400 people. In addition, eleven million visits are recorded to canal towpaths in Scotland each year, for walking, cycling and fishing (Lassiere, pers.comm., 16th September 2004).

3.16 Navigation

There are a number of ports around the coast of Scotland and on the islands, with Forth, Sullom Voe, Orkney and Clyde each handling more than 10 million tonnes of freight traffic in 2001

(Scottish Executive National Statistics, 2003b). In total, 119.6 million tonnes of freight used the main ports in 2001, with crude oil (78.8 million tonnes), oil products (11.0 million tonnes), and coal (6.7 million tonnes) accounting for the greatest proportions. A much smaller amount of freight (11.4 million tonnes) was carried for part of its journey on inland waterways, of which the majority used the Forth, although others also used the Rivers Clyde and Tay, Caledonian Canal, Lochs Fyne, Leven and Linnhe, and the Moray Firth.

4. Volumetric water use in Scotland

4.1 Introduction

Volumetric data on water use in Scotland is limited, with some attempts being made by Scottish Water to combine figures from the three former Scottish water authorities. This information has been used as a starting point to assess the supply of water by Scottish Water. However, this does not include private abstractions and supplies, which is considered in the following section.

4.2 Public supply

The data from Scottish Water was compiled using the information published as part of the Water Resources Survey 2001-2002. This is the latest information publicly available, but has the added advantage of providing more detailed information on metered use by sector. The Water Resource Survey 2001-2002 defines large users as using more than 1000 cubic metres per quarter. However, that definition has been increased for the Water Resource Survey 2002-2003 to include only those users supplied with more than 100,000 cubic metres per quarter. This significantly reduces the number of users represented in the analysis and therefore reduces the information available on the sectoral use of water.

Table 4.1 indicates the supply of metered and unmetered potable water and non-potable water by Scottish Water in 2001.

Table 4.1 Water supply by Scottish Water in 2001, thousand m^3/day

Total daily demand	Potable- unmetered	Potable- metered	Non-potable	Leakage
2,408.7	799.4	522.8	9.6	1,077

Total daily demand is the total quantity put into supply to satisfy consumers plus leakage and other waste.

Leakage is calculated from figures for the three former water authorities for 2001.

Potable- unmetered includes households and non-households not metered (small commercial supplies, operational use, fire fighting, sewer cleaning, temporary supplies for construction, etc.).

Potable- metered indicates the volume used by industry and commerce charged for on a measured quantity.

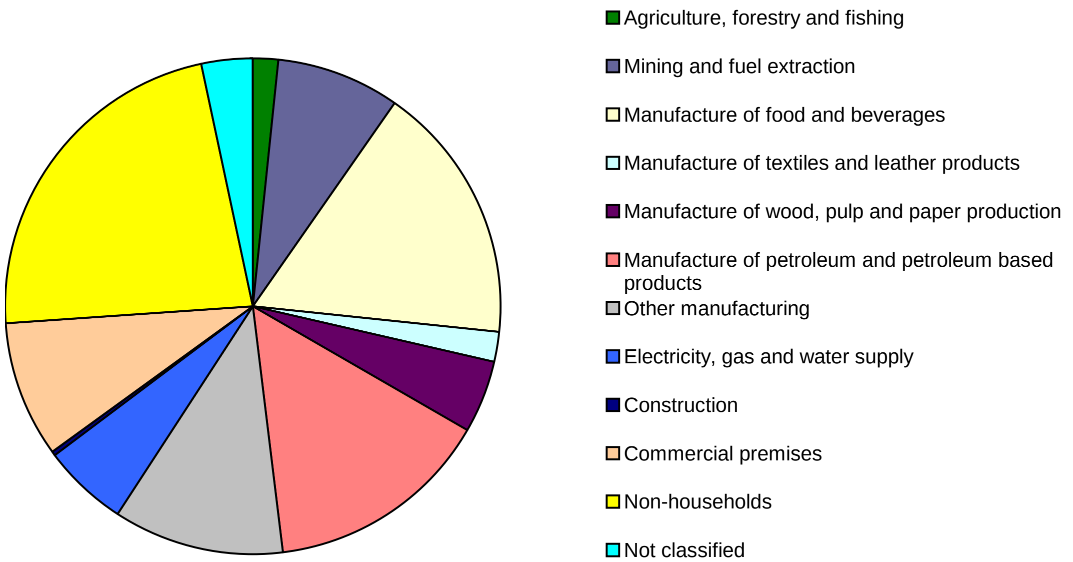
Non-potable water is used by some industries.

It is possible to identify some of the larger sectoral uses through figures collected by Scottish Water from those metered premises using more than 1000 cubic metres per quarter (Scottish Executive Environment Group, 2003). **Table 4.2** and **Figure 4.1** are divided according to the categories used in this report. However, the information available from Scottish Water does not allow for some of the divisions made here; agriculture and fishing are considered as a single group for example. There is also some difference between the non-household and commercial premises categories in this table and in the rest of the report, as these are not broken down sufficiently in the Scottish Water data to allow aggregation in exactly the same groups.

Table 4.2 Water use by large industrial users, 2001, '000 m^3/day

	Volume of water supplied by Scottish Water to large industrial users
Agriculture, forestry and fishing	4.76
Mining and fuel extraction	21.62
Manufacture of food and beverages	47.03
Manufacture of textiles and leather products	4.97
Manufacture of wood, pulp and paper production	12.88
Manufacture of petroleum and petroleum based products	41.02
Other manufacturing	30.53
Electricity, gas and water supply	14.87
Construction	1.05
Commercial premises	24.02
Non-households	62.92
Not classified	9.18
TOTAL- large metered users	**275.82**
Small metered users	256.53
TOTAL- all metered users and non-potable	**532.35**

Figure 4.1 Relative volume of water use by different large industrial users, 2001



4.3 Direct abstractions

The most relevant and up-to-date information on abstraction in Scotland forms the study of abstraction undertaken by CJC Consulting (CJC Consulting, 2002). This study considered a small number of high volume abstractors, conducting a survey of abstraction. Information on sector abstraction from this study is shown in **Table 4.3** below (CJC Consulting, 2002).

Table 4.3 Direct abstraction of water in Scotland

Sector	Estimated total sector abstraction ('000m^3/year)	Estimated total sector abstraction ('000m^3/day)	Estimated total water use ('000m^3/year)	Estimated total water use ('000m^3/day)
Food processing	2,622	7.2	12,266	33.6
Maltsters	1,566	4.3	3,150	8.6
Brewers (micro)	46	0.1	364	1.0
Mineral water	859	2.4	980	2.7
Distillers (malt)	76,490	209.6	Not available	Not available
Chemicals	5,491	15.0	29,239	80.1
Electronics	0	0	9,450	25.9
Metals	3,980	10.9	5,950	16.3
Textiles	448	1.2	957	2.6
Paper	69,281	189.8	82,667	226.5
Fish farming	1,617,350	4,431.1	1,617,350	4,431.1
Agriculture (irrigation)	8,265	22.6	8,265	22.6
Scottish Water	926,000	2,537.0	926,000	2,537.0

Note that the estimates in this table (taken from the Executive Summary of the CJC report) differ from those figures for abstraction in Table 7.3 of the CJC report for food processing, maltsters, mineral water, and distillers.

These estimates of abstraction would appear to be consistent with the figures from Scottish Water in **Table 4.3** above. In all sectors that can be readily compared, the difference between estimates of abstraction and total water use are slightly lower for the Scottish Water figures than for the CJC figures. Since the Scottish Water data related only to large volume users, this would be consistent with expectations.

For malt distilling, the figures presented by CJC (2002) differ notably from the abstraction volumes presented by the Malt Distillers Association in their submission to the Scottish Parliament in response to the Water Environment and Water Services (Scotland) Bill (Scottish Parliament, 2002b). This assessed abstraction from six of the main rivers and is presented in **Table 4.4**, deriving a figure approximately half of the figure presented by CJC.

Table 4.4 Abstraction volumes by malt whisky distillers, 2002

Catchment	Volume abstracted for mashing ('000 m^3/ year)	Volume abstracted for cooling ('000 m^3/ year)
River Spey basin	1,810	27,150
River Lossie basin	270	1,870
River Deveron basin	390	7,000
River Dee basin	7	200
River Nairn basin	40	500
River Tay basin	70	1,100
Total	**2,587**	**37,820**

The study of abstraction considered water use by Scottish Water. The figure of 2,537 thousand m^3/day in 2002 is consistent with the figure given in the Water Resources Survey (Scottish Executive Environment Group, 2003) of 2,408Ml/day in 2001. However, use of water by Scottish Water is not considered in this study as a separate element, since this water is supplied on to consumers, and to consider it in this study would risk significant double counting of the value from this water. Therefore, abstraction by Scottish Water is considered to be relevant only in the context of public supply (see Section 5.2 above).

It is likely that there is significant abstraction that has not been considered as part of the CJC study (CJC Consulting, 2002) in those sectors that were not included in the scope. This could include households and commercial users. Unfortunately however, it has not been possible to estimate the overall size of other private abstractions within this study. However, the number of people relying on private supplies for household water use has been calculated as 82,000 (Drinking Water Quality Regulator, 2003), and based on the average per capita consumption, this would suggest a total household water use from private supplies of 11,750 m^3/day. In addition to abstraction of fresh water, seawater is abstracted for industrial cooling, notably for power generation, and estimates suggest that 8,900Ml/day is abstracted for cooling at the five large power stations in Scotland.

Water is also supplied directly by British Waterways, who abstract water for canals, and have supply agreements with a small number of organisations. The quantity abstracted for use in canals depends on rainfall during the year, and figures have been estimated for drought, average and wet years (Lassiere, pers.comm., 3rd February 2004). There are estimates of volume for all feeders for the drought year scenario, except for three feeders controlled by Scottish Hydro Electric. However, there are some data gaps for average and wet year scenarios. These figures for abstraction are shown in **Tables 4.5 and 4.6**.

Table 4.5 Water abstracted by British Waterways, thousand m^3/year

	Quantity abstracted (thousand m^3/year)		
Canal	**Drought year**	**Average year**	**Wet year**
Monkland Canal	2,713	1,243	811
Forth & Clyde Canal	2,298.8	4,179.01	4,841
Union Canal	3,354	n/a	n/a
Crinan Canal	1,315.7	4,025.7	Not estimated
Caledonian Canal	56,801	Not estimated	Not estimated

Table 4.6 Water abstracted by British Waterways, thousand m^3/day

	Quantity abstracted (thousand m^3/day)		
Canal	**Drought year**	**Average year**	**Wet year**
Monkland Canal	7.4	3.4	2.2
Forth & Clyde Canal	6.3	11.4	13.3
Union Canal	9.2	n/a	n/a
Crinan Canal	3.6	11.0	Not estimated
Caledonian Canal	155.6	Not estimated	Not estimated

British Waterways have six water supply agreements in Scotland, of which four have figures available for maximum annual abstraction (Lassiere, pers.comm., 3rd February 2004). These agreements are shown in **Table 4.7**. The company name has not been identified to protect privacy, although the sector is indicated.

Table 4.7 Supply of water by British Waterways, thousand m^3/year

Sector of company	Purpose of abstraction	Max. annual abstraction ('000 m^3)
Production of alcoholic beverages (whisky)	Industrial purposes	1,363
Agriculture	Spray irrigation- crops	3
Canal balancing	Other	
Non-water-dependent recreation	Spray irrigation- sports	1
Production of alcoholic beverages	Pipe retention	377
Production of alcoholic beverages (beer)	Pipe retention	

British Waterways also have agreements with third parties where a charge is made for receiving clean surface runoff water.

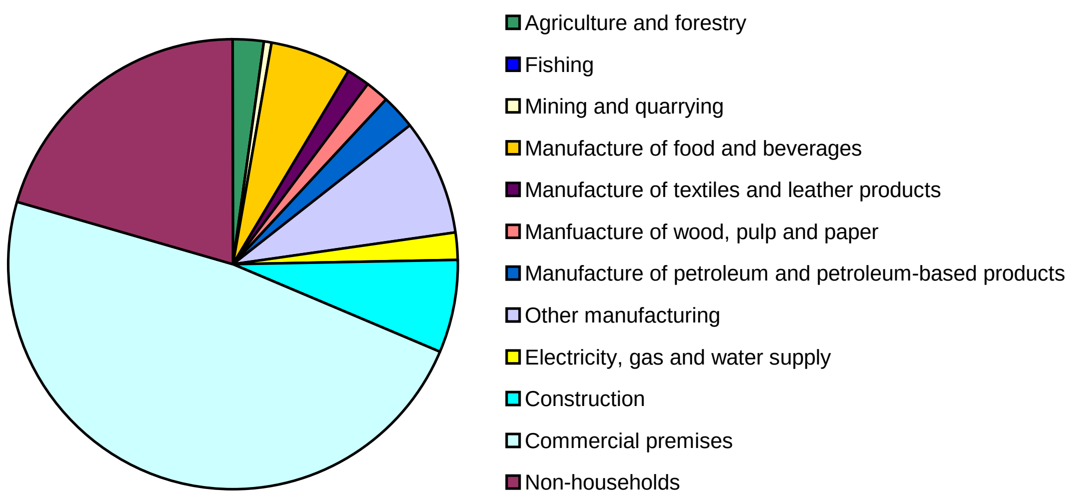
5. Use of water in Northern Ireland

5.1 Introduction

Water use in industry and households is described at a general level in Section 2 of this report. However, the importance of water use depends on the structure of the economy in Northern Ireland, and the relative importance of the different sectors.

The relative economic importance of the different industrial sectors is indicated in **Figure 5.1** (National Statistics, 2003). By far the most significant sector in the economy in terms of gross value added is the commercial premises sector, although non-households also make a significant contribution (the scope of these sectors is discussed in Sections 2.13 and 2.14). Other important sectors include the manufacture of food and beverages, other manufacturing, and construction.

Figure 5.1 Contribution of industrial sectors to gross domestic product in Northern Ireland



5.2 Households

Over 99% of households in Northern Ireland are connected to the mains for the supply of clean water (DRD, 2003). However, the remainder (approximately 15,000 people) are reliant on private sources and there may be additional use of private abstractions by those supplied with mains water. Local councils are responsible for monitoring the quality of water used for potable purposes, and the water authorities in Northern Ireland are currently working with the local councils to determine the number of groundwater sources in use. For example, Coleraine Borough Council has estimated that 600 of the households in its borough boundary are wholly or partly reliant on well or spring water (Irish News Report, 31st August 2000).

For the disposal of sewage, 83% of households are connected to the mains sewage system (DRD, 2003). The remaining households have private septic tanks, the majority of which are emptied by Water Service.

Domestic water supply in Northern Ireland is not metered, and therefore it is only possible to estimate domestic water use. **Table 5.1** shows the estimates of water consumption for different household types used to estimate consumption in the Water Resources Strategy (Ferguson McIlveen LLP, 2003). These figures represent the best estimate of consumption from a study of 80 zonal meter areas across Northern Ireland.

Table 5.1 Household consumption of water

Litres/ household/ day	Detached	Semi-detached	Terraced	Apartments
Toilet flushing *	106.15	104.73	100.31	59.16
Auto washing machine use	51.04	50.39	51.39	31.20
Twin tub use	0.23	0.07	0.21	0.18
Dishwasher use	8.36	4.41	2.01	0.88
Shower use	36.72	35.47	19.96	14.54
Power shower use	34.96	20.82	14.69	3.75
Bath use	42.50	49.77	59.75	27.83
External use- sprinkler	22.00	13.14	2.57	0.00
External use- other	2.08	1.58	0.58	0.27
Cooking and drinking	14.53	14.33	13.73	8.10
General cleaning	43.59	43.00	41.19	24.29
Personal washing	43.59	43.00	41.19	24.29
Car washing	5.00	5.00	2.50	1.00
Other miscellaneous	46.20	44.13	-10.60	18.10
Unforeseen miscellaneous	1.00	1.00	1.00	1.00
Total (l/ prop/ day)	457.94	430.87	340.47	214.59
Total (l/ hd/ day)	**157.60**	**150.30**	**124.00**	**132.50**

* This is an average, assuming that 80% of households have full flush toilets, using 9 litres per flush, 20% of households have reduced flush toilets, using 7.5 litres per flush, and a very limited number (>0.1%) of households have low flush toilets, using 6 litres per flush.

From the estimates of per capita consumption in the last line of the table, and using information on properties in Northern Ireland, the best estimate of per capita household consumption in Northern Ireland is 144.01 litres per person per day. With a population of 1,697,000 in 2002 (Northern Ireland Statistics and Research Agency, 2003), this suggests a total household consumption of 244 Ml/day. However, this figure is significantly higher than the 217Ml/day suggested in the Water Resource Strategy (Ferguson McIlveen LLP, 2003). At least some of this difference could be accounted for by metered agricultural premises, which were excluded from the lower figure, and by direct abstractions. From a figure for average domestic consumption of 0.6m^3/day in rural areas, Robins (1996) estimates that those domestic properties reliant on private sources may abstract as much as 2Ml/day in Northern Ireland.

5.3 Agriculture and forestry

Agriculture has huge historical significance in Northern Ireland, and continues to make an important contribution to the economy, society and environment of the country. The sector accounted for 2.21% of gross value added in 2000 (National Statistics, 2003), with agricultural enterprises employing 58,000 employees, 4.9% of total employment (DARD, 2001). However, employment in agriculture continues to fall, and the number employed in the sector had fallen to 54,500 by 2003. Over the last 25 years, the number of people employed on farms has fallen by a fifth, and the decline is even more significant when the move to part-time and casual labour is taken into account.

Within the sector, the majority of farms are based on livestock, particularly cattle, which are found on 84% of farms. This is shown in **Table 5.2** below (DARD, 2001).

Table 5.2 Composition of agricultural sector in Northern Ireland

% of farms with	1990	2000
Dairy cows	23	18
Beef cows	55	56
Cattle	87	84
Sheep	38	36
Pigs	9	3
Cereals	19	13

The focus on livestock is also clear from the composition of agricultural land area, of which 79.0% of total land area is grass and a further 14.2% is hill or rough land. This is shown in **Table 5.3** (DARD, 2003).

Table 5.3 Composition of agricultural land area, 2003

Land use		**Area ('000 hectares)**	
Grass		848.2	
	Under 5 years old		138.0
	Over 5 years old		710.3
Hill or rough land		152.9	
Cereals		37.8	
	Oats		2.5
	Wheat		7.3
	Barley (winter)		4.1
	Barley (spring)		23.6
	Mixed corn		0.2
Other field crops		12.0	
	Potatoes		6.0
	Arable crop silage		2.3
	Forage maize		2.1
	Other crops		1.4
Horticultural crops		3.2	
	Fruit		1.6
	Vegetables		1.5
	Ornamentals		0.1
Other land		19.6	
	Set-aside		3.5
	Woods and plantations		8.4
	Other land		7.8
Total area farmed		1073.7	

The majority of the boreholes identified in the British Geological Survey (BGS) 1992-94 survey were for agriculture or agricultural/ domestic purposes (462 of the 667 identified). A report for the BGS suggested that if the inventory had identified only two thirds of abstractions, so that there were over 600 boreholes used for agricultural purposes, with each pumping 1 litre per second for five hours, agricultural water use from boreholes could be as high as 11Ml/d (Robins, 1996). However, although the abstraction of surface water for agricultural use is uncertain, it is unlikely to be significant because of the lower percentage of land used for arable crops and the relatively high precipitation rate (Henry, pers.comm., 24th October 2003).

Agriculture accounted for 31% of the pollution incidents recorded by EHS in 2002 (Henderson, pers.comm., 4th July 2004). This primarily relates to point source pollution, although there is also a background level of diffuse agricultural pollution.

Northern Ireland has 85,000 hectares of forestry (Forestry Commission, 2003), of which approximately two thirds is owned by the Forest Service of the Department of Agriculture and Rural Development. This is equivalent to 6.5% of total land area, the lowest proportion of land used for forestry in the UK (Forestry Commission, 2003).

5.4 Fishing

Fishing, as defined in Standard Industrial Classifications, is of relatively limited significance to the economy of Northern Ireland, accounting for only 0.13% of gross value added and 0.02% of employment (DETI, 2001).

5.4.1 Aquaculture

The aquaculture sector in Northern Ireland covers all of the main types of fish farm, marine and freshwater producing fish and shellfish. The sector employs approximately 168 people, producing freshwater fish valued at £3.3 million per year and shellfish valued at over £1 million per year (DARD, 2004). The production and value of shellfish is shown in **Table 5.4** (DARD, 2004). Production of trout was 850 tonnes in 2002, with figures for the production of salmon not available because of commercial sensitivity (Hollywood, pers.comm., 18th March 2004).

Table 5.4 Production and value of shellfish farming in Northern Ireland, 2002

	Production (tonnes)	Value (£)
Oysters	342.4	751,523
Mussels	738.86	601,846
Scallops	7.04	17,911
Manila Clams	6.82	40,960

Consented discharge data held by EHS indicates that there are currently 37 fish farms in Northern Ireland using surface or groundwater sources (Henry, pers.comm., 24th October 2004). In 2000, there was 63.3% compliance with the conditions of discharge consent amongst fish farms, higher than the industrial average of 52.3%.

In addition to fish farming in fresh water, there is a growing marine industry, with fifty licensed sites covering 1,760 hectares around the coast. The most significant locations are the Carlingford and Belfast Loughs, with 16 of the sites covering 1,030 hectares. These loughs are expected to produce around 6,000 tonnes, mainly for Dutch and French markets. The production from these loughs is expected to grow to 10,000-12,000 tonnes annually over the next few years, and there are a number of additional sites currently under consideration.

5.4.2 Commercial fishing

Commercial fishing occurs off the coast of Northern Ireland for a wide variety of fish and shellfish. The quantity and value of fish landed in Northern Ireland in 2002 is shown in **Table 5.5** below (DARD, 2003). However, it should be noted that this does not correspond to the landings of fish by vessels registered in Northern Ireland.

Table 5.5 Recorded landing of fish in Northern Ireland, 2002

	Quantity (tonnes)	Value (£)
Demersal	6, 652 .04	7, 220, 689
Pelagic	6, 324 .95	1, 270, 719
Shellfish	7, 164 .14	9, 706, 061
Total	**17, 769 .66**	**18, 197, 469**

Within Northern Ireland, most of the fish is landed at Kilkeel (5,113 tonnes), Portavogie (4,462 tonnes) and Ardglass (4,804 tonnes).

5.4.3 Angling

There are a number of rivers and lakes in Northern Ireland notable for their salmonid or cyprinid fisheries (EHS, 2000). Overall, 1190km of river and 55000ha of still water have been designated under the Freshwater Fish Directive. Of these, the majority of rivers (1060km) are salmonid fisheries, while the still waters are designated as cyprinid fisheries (Defra, 2004). In particular, the Foyle catchment has a significant economic importance as a salmon and trout fishery. In addition, the River Bush, which flows from the Antrim plateau to the sea near Portballintrae, is widely recognised as one of Europe’s best salmon fisheries, although this is at risk due to sedimentation of the spawning gravels. Salmon have also been reintroduced to the River Lagan, where they successfully spawned at a number of sites. There are also a number of valuable coarse fisheries in Northern Ireland, particularly the Upper Bann (from upstream of Portadown to Lough Neagh, although there is also potential for game fishing in the middle and upper reaches).

5.5 Mining and quarrying

Mining is not economically significant in Northern Ireland, accounting for just over half a percent of gross value added to the economy. Employment in mining and quarrying accounts for just a quarter of a percent of total employment (DETI, 2001). The mining that does take place focuses on quarrying of bulk mineral products, particularly stone, but also sand and clay.

Table 5.6 shows the production of minerals in Northern Ireland in 2001 (Hillier *et.al.*, 2002). The most significant production is of natural sand, gravel and crushed rock aggregate, as well as rock for cement manufacture (DETI, 2000). The significant areas of production are spread throughout Northern Ireland, with primary production of limestone in Co. Fermanagh, sand and gravel in Co. Londonderry and Co. Tyrone, basalt and igneous rock in Co. Antrim, and sandstone in Co. Down. The only mineral that is significant in UK terms is sandstone, although this accounts for approximately 40% of total UK production (Hillier *et.al.*, 2002).

Table 5.6 Production of minerals in Northern Ireland, 2001

('000 tonnes)	Down	Antrim	Armagh	Fermanagh	Londonderry	Tyrone	Total
Limestone	.	196	470	3,336	136	608	**4,746**
Sand and gravel	110	911	220	42	2,080	2,831	**6,194**
Basalt and igneous rock	.	4,248	405	20	1,525	250	**6,448**
Sandstone	6,699	.	1,352	.	.	19	**8,070**
Others*	.	27	30	0	18	678	**753**

* Including rock salt, chalk, fireclay, granite, clay and shale, and bauxite

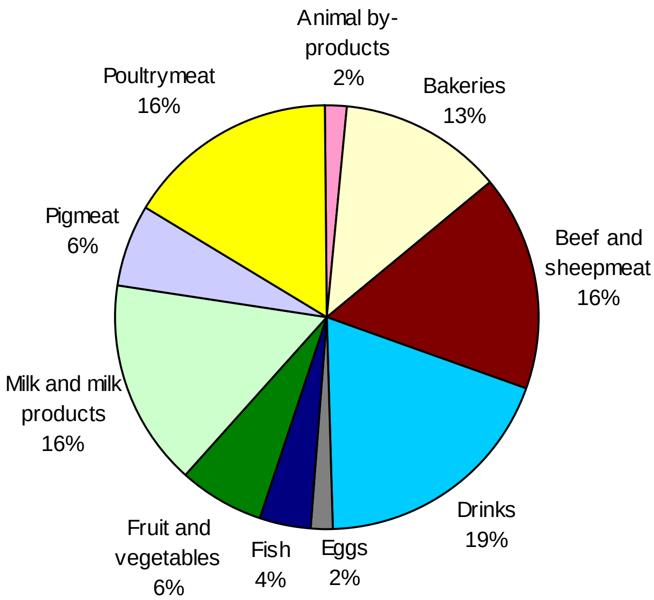
There is also one active gold mine near Omagh in Northern Ireland, and there is potential for further activity in this area.

Oil and gas is not a significant sector in Northern Ireland. Although there has been some exploration of mining potential, the geology limits the potential for production, with any gas present spread in relatively low concentrations through the sandstone areas (DETI, 2000).

5.6 Manufacturing of food and beverages

The manufacture of food and beverages accounts for 5.75% of gross value added to the economy of Northern Ireland. Within the sector, the most significant contributions to gross value added are in bakeries, manufacture of drinks, processing of beef and sheepmeat, milk and milk products, and poultrymeat. This is shown in **Figure 5.2** below (DARD, 2002). The sector employs nearly 20,000 people, 2.77% of total employment (DETI, 2001). The split of employment within the sector focuses on production of poultrymeat and bakeries (DARD, 2002).

Figure 5.2 Gross value added in the food and drink sector, 2000



The sector is dominated by a number of large companies, with the largest ten companies in the sector accounting for 38% of gross turnover, 40% of value added and 36% of total employment in the sector in 2000 (DARD, 2002).

5.6.1 Food processing

As noted in the section above, food processing focuses around the production of meat, bread and milk products. The largest company in the sector (in terms of turnover, value added and employment) in 2000 was Moy Park Ltd., which manufactures poultrymeat from its primary processing plant in Dungannon and further plants at Craigavon, Moira and Lisnaskea. Dungannon Meats, which processes beef and lamb, was the second largest company in the sector in all three areas (DARD, 2002).

Food processing has a low compliance with conditions of discharge consent, with only 30% compliance in 2000 (EHS, 2000).

5.6.2 Production of alcoholic beverages

While the production of whiskey in Ireland has been overtaken by Scotch whisky, there is still a significant amount of production, particularly for the domestic market. Much of the whiskey sold in Northern Ireland is imported from the Republic of Ireland, although there is one significant distillery at Bushmills, Co. Antrim. It is claimed that the Old Bushmills Distillery was the world's first distillery, founded in 1608, and the distillery is a notable tourist attraction on the Causeway coast.

In addition to the production of whiskey, three large organisations involved in the production of a range of beverages also manufacture alcoholic drinks in Northern Ireland, with Bass Ireland

Ltd. the Irish Bonding Co. Ltd., and Diageo in Belfast, and Diageo also operating from Mallusk to produce Baileys Irish Cream.

5.6.3 Production of mineral waters and soft drinks

Mineral waters

The production of mineral waters takes place at only three sites in Northern Ireland, as shown in **Table 5.7** below (FSA, 2003).

Table 5.7 Production of natural mineral waters in Northern Ireland

Sales description	Name of source	Place of exploitation
Classic	Classic	Edward Street, Lurgan, Craigavon, Co. Armagh
River Rock	River Rock	The Green, Lambeg, Lisburn, Co. Antrim
Rocwell Spring	Rocwell	Limehill Road, Pomeroy, Co. Tyrone

Non-alcoholic beverages

The most significant company in this sector is the Coca-Cola bottling factory at Lisburn. Coca-Cola Bottlers (Ulster) Ltd. were the third largest company in the food and drink sector in Northern Ireland in 2000 based on turnover and value added, and were fourth largest in terms of employment (DARD, 2002). This factory operates as a franchise of Coca-Cola, adding water and carbon dioxide to syrup provided. Water is used from local sources, but is tested for quality by Coca-Cola, with Coca-Cola Bottlers (Ulster) Ltd. using the same source of water for Coca Cola and River Rock mineral water.

5.7 Manufacture of textiles and leather products

The manufacture of textiles and leather contributes 1.65% to the total gross value added to the economy of Northern Ireland and accounts for 1.87% of total employment (DETI, 2001). The sector includes a small number of large firms (the largest eight employ almost half of people in the sector) and a large number of small enterprises.

Textiles have a strong heritage, particularly through the production of Irish linen, which continues to have a worldwide market. In Northern Ireland, Irish linen is focused in the Lagan and Bann valleys and Upperlands, Maghera. More modern fabrics are also manufactured in Northern Ireland, with a long established Dupont factory at Maydown producing Lycra ® and Kevlar ®. Recent developments have combined these traditions, with the launch of Irish Linen plus Lycra ® in Paris in 2002 (Dupont, 2002). However, the textiles sector in Northern Ireland has faced international pressure, and there is an ongoing trend to move low value production abroad, retaining only the high value added activities within Northern Ireland. Restructuring in response to international production has been blamed for the recent loss of jobs in the industry (BBC, 30/01/2004).

5.8 Manufacture of wood, pulp and paper products

Although forestry is of extremely limited economic significance to the economy of Northern Ireland, the manufacture of wood-based products accounts for 1.84% of gross value added (National Statistics, 2003) and 1.36% of total employment (DETI, 2001).

5.9 Manufacture of petroleum and petroleum-based products

This sector accounts for 2.42% of gross value added to the economy of Northern Ireland, particularly through the manufacture of chemicals and chemical products (National Statistics, 2003). This suggests a high value added in comparison to employment, with the sector accounting for 1.52% of total employment (DETI, 2001).

5.9.1 Oil Refining

There are no oil and gas refineries in Northern Ireland. However, oil and gas are used for electricity generation, discussed in Section 5.12 below.

5.9.2 Chemicals

Unfortunately, no information on the manufacture of chemicals in Northern Ireland was available for this study.

5.10 Other manufacturing

The rest of the manufacturing sector in Northern Ireland accounts for 8.60% of gross value added (National Statistics, 2003) and 6.92% of employment (DETI, 2001). The ‘other manufacturing’ sector is diverse, contributing to the overall manufacturing sector, which employs over 100,000 people (DETI, 2001).

Within this sector, there are a number of significant specialist areas, including electronics and life sciences. The electronics sector includes companies such as Seagate Technology (producing hard disk drive products from Springtown, Londonderry), AVX, Daewoo, TDK, SMTEK, Sanmina-Sci, and Hathaway Systems. Norbrook, based in Newry, Galen (Craigavon) and MDS Pharma Harris (Belfast) are amongst the major pharmaceutical companies located in Northern Ireland.

One of the largest single operators in the ‘other manufacturing’ sector is FG Wilson, owned and operated by Caterpillar Inc. The company is one of the largest exporters in Northern Ireland, and employs around 2,500 people at Larne, Co. Antrim and two sites in Belfast.

5.11 Electricity, gas and water supply

The production and supply of electricity, gas and water is a relatively small sector in the economy of Northern Ireland, accounting for 2.12% of gross value added. However, it is more significant through its contribution to other sectors dependent on its output.

There are three power stations operational in Northern Ireland (as at the end of May 2003, DTI, 2003), Kilroot (coal/oil) and Ballylumford (oil/gas) in Co. Antrim, and Coolkeeragh (oil) in Londonderry. These three installations are shown in **Table 5.8** and have a combined installed capacity of 1636 MW.

Table 5.8 Installed capacity for electricity generation in Northern Ireland

Station name	Fuel	Installed capacity (MW)
Kilroot	coal/oil	520
Coolkeeragh	oil	293
Ballylumford	oil/gas	823

Premier Power at Ballylumford use three of their six sea water pumps on average, with each pump abstracting 60,000 gallons (273m^3) each minute (393,000m^3 per day) for cooling. This water is returned to the sea almost immediately, although at a higher temperature and having been treated with chlorine. In addition, they use between 18,000 and 20,000 gallons (82m^3-90m^3) of raw water an hour to produce 16,000 gallons (73m^3) of demineralised water for boilers and 1,000-2,000 gallons (4.5-9m^3) an hour for service water.

Figures from Kilroot power station indicate that approximately 1,600m^3 of water are supplied each day by Water Service, with a further 230m^3 abstracted from the river (Urwin, pers.comm., 22nd January 2004). Data compiled by the power station found that between December 2002 and 2003, the station used 588,598m^3 of townswater (supplied by Water Service) and 83,934m^3 of river water. Of the 588,598m^3, 122,292m^3 was for site use, including use at the coal field for suppressing dust and conditioning coal and dust movement (69,936m^3), use for toilets and washing and use for some cooling of air compressors. The remaining 476,339m^3 (excluding 57m^3 for an old site) went to a reservoir for storage. The principal uses of this water were for demineralisation to produce steam in the boilers (226,958m^3), for service water tanks (123,390m^3) and for fire tanks and emergency cooling (87,284m^3).

Coolkeeragh power station has a lower capacity than reported by DTI because of closure, with an installed capacity of 120MW. They use approximately 2,000m^3 per month (66m^3 per day) supplied by Water Service, of which an estimated 95% is used for the steam boilers and 5% is used as domestic water. The station also uses a significant quantity of salt water, with a maximum extraction of 27,000m^3 per hour (648,000m^3 per day) of water from Lough Foyle (Quinn, pers.comm., 28th January 2004).

Table 5.9 Estimated water use for power generation in Northern Ireland

Station name	Installed capacity (MW)	Estimated water use (m^3/ day)		
		Domestic	Boilers	Cooling
Kilroot	520	143	622 (+847)	unknown
Coolkeeragh	120	3	63	648,000
Ballylumford	823	109-218	1964-2182	393,000

In addition to the fossil fuel power stations, there are nearly 30 small-scale hydroelectric sites in operation in Northern Ireland, ranging in capacity from 3kW to 0.8MW (Belfast Energy Agency, 2003).

According to Belfast Energy Agency, the potential for tidal power schemes is more limited, although there are two potential sites at Strangford and Carlingford Loughs, with a potential output of 800 gigawatt-hours per year.

5.12 Construction

Construction is a significant sector in Northern Ireland, contributing 6.86% of gross value added (National Statistics, 2003) and employing 35,000 people (5.15% of the workforce) (DETI, 2001). Although 2003 was a relatively quiet year, particularly for the construction of private housing, the private commercial sector recorded its biggest increase in demand for three years in the third quarter of the year. A recent study by the Royal Institute of Chartered Surveyors suggested that growth in the sector is expected to pick up in 2004 (BBC, 21/01/2004).

5.13 Commercial premises

The ‘commercial’ sector is by definition economically very diverse, consisting of a wide range of organisations. The sector is also very significant for the economy, accounting for almost half (48.99%) of gross value added (National Statistics, 2003) and 43.8% of employment (DETI, 2001). Of the sectors in this section, the most economically significant are public administration, social security and defence, and real estate and renting (National Statistics, 2003).

5.14 Non-households

Non-households include a range of social and community organisations (see Section 2.14), which together account for 20.95% of gross value added (National Statistics, 2003) and 27.64% of employment (DETI, 2001). Health and social work is the most economically important part of this sector (National Statistics, 2003).

5.15 Amenity and recreation

5.15.1 Tourism and water-dependent visitor attractions

There are a number of popular water dependent visitor attractions, particularly Exploris aquarium in Co. Down, which is the eighth most visited attraction, with 131,300 visitors in 2002. In addition, Portrush is well served for indoor water recreation, with the Dunluce Centre and Waterworld, which attract 76,360 and 69,416 visitors respectively.

5.15.2 Water-dependent recreation

There are a number of activities in Northern Ireland relying on the water environment, particularly angling (considered in Section 5.4.3 above) and boating. There are a large number of cruisers for hire on the loughs in Northern Ireland. However, the market has been declining, and in 2002 there were 107 boats on Lough Erne, selling 1,335.5 boat weeks, the lowest number in the last two decades (Northern Ireland Tourist Board, 2003). The largest number of weeks was sold to residents of Northern Ireland and to visitors from Germany.

Northern Ireland has significant potential for water-dependent recreation in Lough Neagh and following the successful reopening of the Shannon-Erne navigation system in the 1990s there are a number of plans for restoration of other systems. These plans include options for the Ulster Canal and the Lagan Navigation, which could ultimately link the main river systems in Northern Ireland with the navigable systems of the Republic of Ireland.

5.15.3 Non-water-dependent recreation and waterside amenity

In addition to tourism and recreation that relies on water, the aquatic environment also contributes to other activities, including wildlife tourism, and attracts visitors to natural settings. The top two visitor attractions in 2002 were the Giant's Causeway Visitor Centre (406,801 visits) and the Oxford Island Nature Reserve (220,605 visits). The characteristics of both of these centres, and a fundamental part of their appeal, relates to the sea and Lough Neagh respectively. Other visitor attractions in the top twenty include Portstewart Strand (in the care of the National Trust), and Castle Espie (a Wildfowl and Wetlands Trust property).

6. Volumetric water use in Northern Ireland

6.1 Introduction

The information available on volumes of water used in Northern Ireland is very limited. This is largely due to the historic provision of water with payment made through a mix of local rates and direct taxation. Therefore, except for a percentage of farmhouses, which are charged for the volume used by the farm, household properties are largely unmetered. Many small commercial premises are also unmetered, since the first 200Ml/year are supplied free of charge in a similar way to domestic use. However, the current system is under review as part of the Water Reform Process

6.2 Public supply

Information on water supply by Water Service is given in the Water Resource Strategy for Northern Ireland (Ferguson McIlveen LLP, 2003). As mentioned above, there is a significant problem in estimating volume supplied to households and small commercial premises, since those properties using less than 200m^3/year are charged for water as part of rates and consumption is not metered. However, the estimates made in the Water Resource Strategy to provide the baseline for future demand projections indicate the use of water at a relatively aggregated level. This is shown in **Table 6.1** below (Ferguson McIlveen LLP, 2003).

Table 6.1 Non-domestic water demand in Northern Ireland, 1999

Sector	Water demand (Ml/day)
Agriculture	32.9
Industrial	48.3
Commercial	50.1
Public sector	28.3
Miscellaneous	11.6
	171.1

Note: Figures do not add due to rounding

More disaggregated data on non-domestic water use is included in the Water Resource Strategy and is shown in **Table 6.2** below (Ferguson McIlveen LLP, 2003). The total in **Table 6.2** does not correspond with the total in **Table 6.1**, although it is assumed that the relative scale of different users can be used as indicative of their water consumption.

Table 6.2 Non-domestic water consumption in Northern Ireland, Ml/day

	Description	Ml/day	Ml/day by group
Agriculture	Domestic/agriculture	38.09	
	Cattle trough	5.17	
	Out farm	1.24	
	Intensive unit	0.45	44.95
Power generation	Power station	0.03	0.03
Industry	Industry	47.09	47.09
Commercial premises	Shops	2.11	
	Restaurant	1.29	
	Public house	2.82	
	Hotel	2.49	
	Garden centre	0.22	
	Clubs	1.99	
	Building supply	0.10	
	Stores, yard	0.91	
	Caravan site	0.56	
	Garage, etc.	1.20	
	Miscellaneous commercial	7.01	20.70
Non-households	Hospitals	5.07	
	Schools	7.03	
	Police	1.21	
	Fire authority	0.08	
	Army unit	4.91	
	Government	7.44	
	Public toilets	0.38	
	Churches, halls	0.43	
	Medical surgeries	0.23	
	Nursing home	2.40	29.18
Recreation	Leisure centre	0.82	0.82
Miscellaneous	Stand pipe	0.40	
	Others	1.34	
	Cross border	1.42	
	Test meter	6.01	
	Null entry	0.95	10.12

In addition to the supply to industry, Water Service is also responsible for supplying the majority of domestic properties in Northern Ireland. The supply of domestic water was discussed in Section 5.2 above, but is taken to be 217Ml/day for the purposes of the Water Resource Strategy (Ferguson McIlveen LLP, 2003).

6.3 Direct abstractions

There is very little understanding of the volume of water abstracted directly in Northern Ireland. However, there are a number of wells and boreholes used for private water supply. Robins (1996) suggested that 2Ml/day is abstracted in Northern Ireland for private domestic consumption.

Abstraction for agricultural purposes is relatively widespread. However, the composition of the sector in Northern Ireland would suggest that a limited volume is used for stock watering, and there is a lower impact of irrigation of arable crops than in other areas in Britain and Ireland.

In addition to domestic use, potable water is also abstracted for bottled water and food production. The Drinking Water Inspectorate of the Environment and Heritage Service currently monitor approximately 70 supplies under the Private Water Supplies Regulations (Northern Ireland) 1994, although there is limited data available on the volume abstracted through these supplies. Other industries abstracting water include laundries, distillers and creameries, as well as industrial processes using water for cooling. Although those abstracting water for industrial purposes may be using significant volumes, there is no estimate of this currently available. This is in part due to the lower concern surrounding water used that is returned to the environment relatively unchanged.

Some information is also available on water abstraction for power generation. Figures from the three power stations in Northern Ireland indicate that only Kilroot abstracts fresh water directly, taking an average of $230m^3$/day from the Kilroot River. In addition figures for seawater abstraction for cooling have been estimated for Coolkeeragh ($648,000m^3$/day) and Ballylumford ($400,000m^3$/day).

The Department of Environment is currently developing proposals for the introduction of an abstraction licensing system in Northern Ireland as part of the requirements to implement the Water Framework Directive. It is envisaged that such a system would require prior approval for new abstractions and the establishment of a register for larger abstractions.

7. Valuation of water uses

7.1 Introduction

Although there are a wide range of users of water and a high diversity of uses, water use is not as significant in all sectors. Therefore, this project focuses on a number of significant uses of water, and applies valuation to these uses. It does not attempt to produce an overall value of water use for the economy of Scotland or Northern Ireland, since this would be exacerbate the difficulties associated with reuse and recycling of water, and would be at risk of critical errors.

7.2 Choice of water users

As discussed in the introduction, water use may be significant for a number of reasons: a sector may use a large volume of water; water may be used for a valuable process; or there may be little opportunity, or only very expensive options, to substitute for the use of water. Although the multi-faceted definition of use presented above makes it less clear what uses are actually economically significant. In other words, it is unclear whether high volume users necessary impose higher benefits and cost than some low volume uses in specific geographical areas that are environmentally sensitive. For example the opportunity cost in terms of foregone environmental demand resulting from small amounts of abstraction in a particular area may be very high. In another case, a high volume use may impose minimal costs where water is abundant. It is for this reason that river basin risk assessment must accompany the economic information relating to costs and benefits in order to determine where restrictions might be appropriate. This analysis has to abstract from area specific impacts and work at some level of generality. Taking use to mean at least abstraction and discharge, we assume that there is likely to be a close correlation between volumetric use and total value, where total includes damages from discharge and opportunity cost (the foregone benefit associated with leaving water where it is).

Based on the best assessment of the volume use from public and private supplies, the study assesses the value of water for the following uses:

- Household use;
- Agricultural irrigation;
- Aquaculture;
- Salmon angling;
- Industrial use; and
- Hydropower generation.

7.2.1 Household use

Households are provided with a range of services through the use of water, both in supply of clean water and discharge of effluent. Although each user is supplied with a relatively small volume in comparison to many industrial organisations, every individual is affected by household water use. In addition, each household is able to exercise some control over the volume of water that they use, for example through their choice of activities or technologies. Because of the distinctive nature of household water use, this study considers the value of this use to those living in households in Scotland and Northern Ireland.

7.2.2 Agricultural irrigation

As a highly consumptive use of water, irrigation potentially imposes locally significant costs. Furthermore, irrigation demand is most likely to be greatest when ecological demand is greatest (Scottish Executive 2002c), i.e. when climatic variables result in low flows. The most direct cost of over-abstraction, particularly where the source is a stream or small river, might be to downstream irrigating farmers or abstractors, and to the ecological status of the source water body. Furthermore, surface or ground water sources may also to be subject to the effects of diffuse pollution, the ecological impact of which may be intensified by reduced flows.

7.2.3 Aquaculture

Aquaculture is fundamentally dependent on water for production, although management and technology choices have effects on both the abstraction and discharge of water for fish farming. Production of fish, particularly trout and salmon, in fish farms has a significant economic value with fish consumed domestically and exported. There is also a relatively small but economically valuable production of shellfish, particularly mussels in Scotland and Northern Ireland and some oysters in Northern Ireland.

7.2.4 Salmon angling

Water use for recreation differs from water use for household and industrial purposes in a number of ways. Much of recreational use does not abstract, store or discharge water, and does not have an effect on water quality through changing chemical content or temperature. However, there are a number of recreational uses that rely on water, particularly angling. This study has focused on salmon angling, which plays a significant role for local residents and tourists, and which makes a notable contribution to the economy through angler spending.

7.2.5 Industrial use

Industry is an extremely diverse sector that uses water in many different ways. Within the sector, there are some businesses that use a significant amount of water, with limited options for substituting to other technologies and contributing significantly to the economies of Scotland and Northern Ireland. On the other hand, other businesses do not have such a high value from water use. Therefore, it is most appropriate to concentrate on the former organisations. In Scotland these include production of mineral water, whisky distilling, manufacture of paper, refining and manufacture of chemicals and petrochemicals, and manufacture of textiles and leather. In Northern Ireland, these include production of mineral water, manufacture of alcoholic drinks, food processing, manufacture of paper, and manufacture of textiles and leather. However, in practice, the data requirements to value industrial water use have limited the extent to which the most significant water users in Scotland and Northern Ireland can be considered explicitly.

7.2.6 Hydropower generation in Scotland

Hydropower generation derives a significant value from water use, relying on water as a fundamental part of its process. Hydropower relies on the quantity of water and the distance over which water can fall to produce power that can be sold into the market. This power not only supplements the availability of electricity for homes and businesses, but also contributes to the government’s targets to increase the percentage of electricity from renewable sources. This sector is of limited local importance in Northern Ireland, but is much more significant in Scotland.

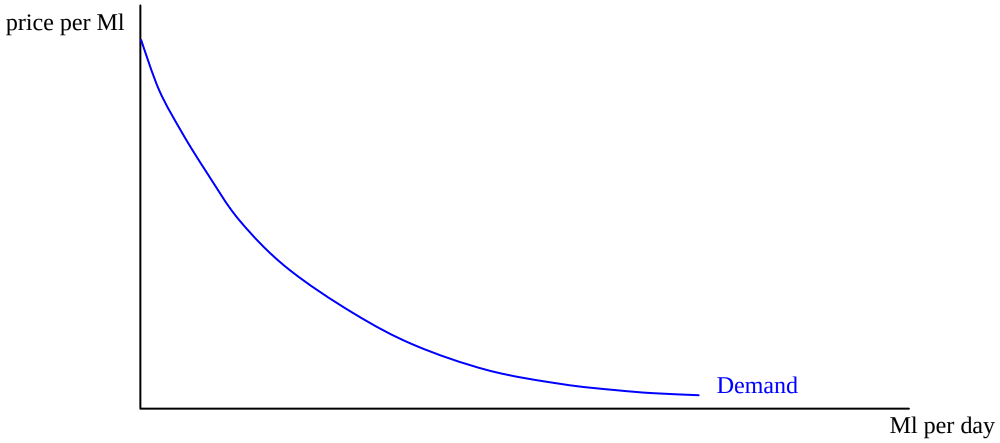
8. Methods for valuing water use

8.1 Introduction to valuation

In economic terms, the concept of value of water is almost interchangeable with the concept of demand for water. Demand is measured by willingness to pay for a commodity, where willingness to pay is the maximum that a user would spend to obtain one unit of water. This is generally shown as the demand curve. It should be noted that willingness to pay is a specific economic term that indicates the value of a good or service. It does not indicate ability to pay or offer a recommendation that the user 'should' pay.

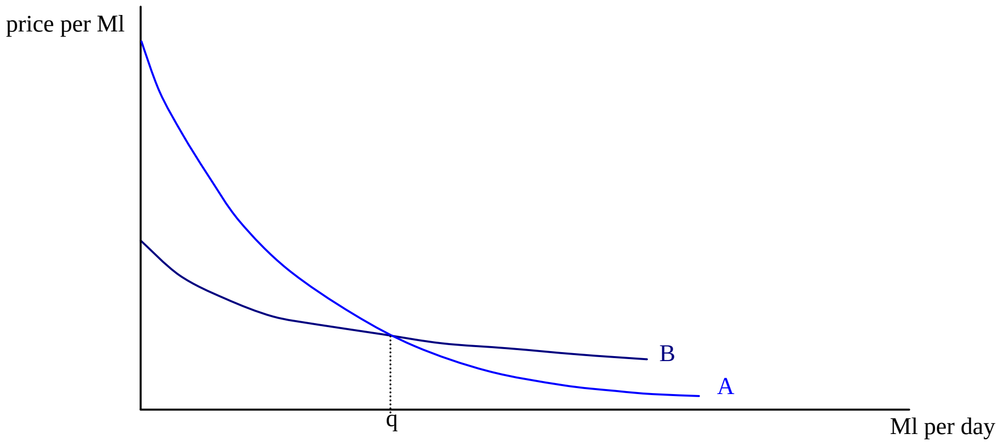
From **Figure 8.1**, it is possible to see that for the first unit (Ml) of water, an individual would be willing to pay a high price, as without any water they would not be able to use any water. As they buy more and more water, the next unit becomes less valuable, and the price that they would be willing to pay decreases.

Figure 8.1 Illustration of a demand curve



With many goods it is possible to observe how much is demanded at different prices and therefore to estimate the demand curve. However, although there is a theoretical demand curve for water, it is not possible to observe consumers' responses to changing prices, as these have been established for historic and social reasons rather than in response to market forces. Referring to **Figure 8.2**, it is possible to observe the quantity demanded, Q, but it is not possible to know whether the consumer has a demand curve such as A or one such as B.

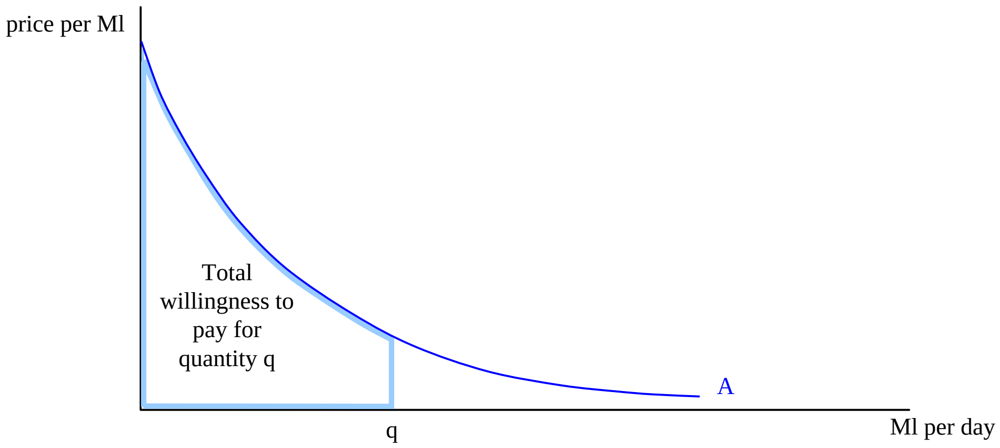
Figure 8.2 Illustration of alternative demand curves



If the water user has a demand curve such as A, any change in the price of water will cause relatively little change in the quantity demanded (they have inelastic demand). This indicates a high value for water use, since they would be willing to pay a high price to maintain their water use. On the other hand, a water use with demand curve B would prefer to reduce consumption rather than increase the price paid (it may be cheaper for them to install a new technology for example) and they have relatively elastic demand. This would indicate a relatively low value of water use. Therefore, in considering the value of water use, economists are interested in the slope of the demand curve at the quantity consumed (q). This is the marginal demand, or marginal willingness to pay, indicating the change in consumption that would occur if price was increased or decreased a fraction.

Although marginal willingness to pay is often considered to be the most useful measure of value for decision making, it is also possible to estimate total willingness to pay and average willingness to pay. Total willingness to pay is the area under the demand curve between zero and the quantity consumed (q). This is shown in **Figure 8.3** below. Average willingness to pay is calculated by dividing total demand by the quantity consumed.

Figure 8.3 Illustration of total willingness to pay



The value of water to an individual user depends on a number of features of water use, including the following:

- The types of use of water- this ranges from water being used as part of the product, to use for cooling, and use for cleaning and discharge of effluent;
- The volume of water consumed;
- The degree of necessity- this reflects the degree to which water is an intrinsic part of the product, the efficiency of water use and the availability of alternatives (below); and
- The availability of alternatives- this could be through installing technology or adapting processes to change the volume of water consumed or the processes for which water is used.

However, the value of water use does not include a number of features and issues that should be included in any assessment of the overall use of water in the economy, including the following:

- The degree to which water is consumed by the process for which it is used. This varies significantly, from in-stream use (recreation, some aquaculture, etc.) to abstraction and discharge differing significantly in both time and place (e.g. bottled water manufacture, irrigation of agricultural crops, etc.);
- The degree to which water is altered by the process for which it is used, in terms of temperature, chemical and biological composition;
- The source of the water, and the sensitivity of that source to water use;
- The receptor for discharged water, and the sensitivity of that receptor to the type and volume of water discharged;
- The value of the water-using sector to the economy and society; and
- The environmental costs and benefits associated with water use and the broader environmental impacts of different sectors.

8.2 Alternative valuation methods

In the absence of comprehensive market information, it is necessary to estimate value from the data that is available. Because of the variety of ways in which water is used, there are also a number of different methods that can be used to uncover the value of different forms of use. The discussion of estimation techniques in this section draws considerably on the work of Gibbons (Gibbons, 1986), Pearce (1999) and Renzetti (Renzetti, 2002).

Broadly speaking, it is important to distinguish between methods that use market (price) information to estimate value and those for which no market (price) information is available. In the former case, information is available from sales and purchase decisions. In the latter case there are no observable markets for specific water uses and therefore hypothetical or alternative markets must be used to gain an insight into a non-market value.

In addition to differing according to the information available and used, the methods also differ in the estimates that they make and the type of use that they consider. Some of the methods estimate the marginal value of water use. Although this is the most useful estimate of value from an economic point of view, it is also the most difficult to assess, and therefore only a small number of data intensive methods are available for this. Alternatively some methods estimate total willingness to pay for the quantity of water consumed, and divide this by the quantity to approximate an average value.

Finally, the methods may differ in the type of water use that they value. As discussed in earlier sections, each sector or organisation is likely to use water in a number of different ways. For example, they may be supplied with domestic water for their staff, they may use water as part of their product or as a medium for transport or for cooling, and they may use water to discharge effluent. Each of these types of use will have a different value, depending on the opportunity to reduce or substitute water use and the contribution that water makes to economic output. Therefore, although a method may estimate the value for one type of use, this may not be the total value to the user. Alternatively, a value for a particular user is likely to encompass a variety of values for uses within that sector. Some of the methods below are more applicable to valuing water use by sector while others are more relevant to valuing a use within a sector.

8.2.1 Methods using market information

Direct estimates of the demand curve

Where there is good demand information for different quantities and prices it is possible to calculate a demand curve, from which marginal willingness to pay can be estimated. This has been carried out for household demand, for which there is relatively comprehensive information, but as yet has not been undertaken for industrial demand.

Estimates of the impacts of water use on profits/ production

There are two main methods associated with estimating the impacts of water use on profits and production, net-back analysis and the marginal productivity approach.

Net-back analysis has been used to estimate the value of water for agricultural irrigation, but could also be applied to other sectors that are not charged for water. It can be used for any sector where there is information on the costs of inputs to production and the value of the output. The analysis is based on the idea that the maximum that a water user would be willing to pay for water would be the different between the revenue from production and the costs, i.e. total profit. Therefore, estimates produced using net-back analysis can be regarded as the upper bound of the WTP range for the particular activity.

A more comprehensive, and more ambitious, method is the marginal productivity approach. This uses detailed financial information on the costs of inputs to a process, including water, and the value of the output to form the basis of an econometric model. This model indicates how each of the inputs contributes to the value of the output. Using the coefficient on the relationship between water use and output (i.e. the change in output that would occur if input of water changed by one unit) provides an estimate of the value of water to that production process.

Estimates of the costs avoided by water use

Without actually studying demand relationships, the concept of alternative cost can also be used to value water. Using water may often be one of a range of possible production choices, but is chosen as the most convenient or least expensive. In this case, the use of water allows the organisation to avoid the costs of installing a more expensive technology. The cost of the least expensive alternative to water serves can therefore be used as a proxy for the maximum amount the user might be willing to pay for water. Depending on the manner in which this theoretical framework is implemented, the resulting water values can be average or marginal. This method can be used for water cooling and hydropower generation.

Estimates based on revealed preference

Revealed preference techniques are often used to value environmental amenities for which no market exists. Instead, they rely on the costs of associated activities. One such technique is the travel cost method, which may be used to assess the value of recreational or amenity use of a water body. The travel cost method is based on the idea that the value of water use is equivalent to the costs that the user faces in travelling to the water, including the cost of time taken to get to the water body and transport costs.

An alternative technique based on revealed preference is hedonic pricing, which may be used to estimate the landscape value of a water body. Hedonic pricing compares the cost of property local to a water body with properties not benefiting from such a location in order to estimate the marginal value of proximity.

8.2.2 Methods where no demand curve information is available

Estimates based on stated preference

In contrast to the methods mentioned above, stated preference methods attempt to place values on uses that cannot be related to direct market transactions. In this case it is normal to use a hypothetical market (contingent valuation) survey to ask people directly what value the change in water use or quality might have to them. These techniques require careful planning and can be time-consuming, but are versatile and the information can be useful to help uncover recreational use values and landscape values that are otherwise hard to estimate.

9. Application of valuation methods

9.1 Introduction

Although there are a variety of potential methods for valuing water use, as outlined in Section 8 of this report, all are not equally applicable to all economic sectors. In addition, the application of the methods is constrained by data availability. Therefore, this section of the report considers the methods most relevant for the key users identified for Scotland and Northern Ireland, and applies these methods using the data from Sections 3, 4, 5, and 6.

9.2 Household use

Households receive a range of services from water, as discussed above. In particular, these include the supply of clean water and the discharge of effluent. The following section considers the value of water to households in Scotland and Northern Ireland based on both elements of water use.

Most consumers do not chose between a range of water services at different prices, but pay the rate determined by the local water authority: they are pay the single price that is estimated to represent the average cost of supply for domestic use. Therefore, the only way to measure the marginal value of water to the individual consumer is through the use of water demand functions. The slope of the demand curve is estimated by considering a one unit increase in water supply. The willingness to pay (WTP) for this increase in water supply use is estimated using the following the formula (Gibbons, 1986, p17):

$$GWTP = \left(\frac{P.Q_2^x}{1-x}\right).\left(\frac{Q_2}{Q_2^x} - \frac{Q_1}{Q_1^x}\right)$$

where GWTP is gross willingness to pay, P is the price, Q_1 is the quantity consumed, Q_2 is the new quantity, and x = 1/e where e is the elasticity of demand (independent of sign).

For application of the formula we need:

- consumption in Ml /year /per capita;
- price per Ml measured volumetric rate; and
- an elasticity of demand. This is assumed to be -0.2, as suggested by Hoglund (Hoglund, 1997).

9.2.1 Scotland

Per capita consumption in Scotland is estimated to be 143.3l/day, or 52.3Ml/year (Environment Agency, 2001a). The cost of consumption is estimated using the charge levied by Scottish Water for those households charged by volume. The costs paid by a consumer cover both supply of clean water and discharge of foul water, with the volume discharged estimated at 95%

of the volume supplied. Therefore, the household faces a cost per megalitre that is a combination of the two charges. Scottish Water charges those households charged by volume 67p/Ml for clean water supply and 110p/Ml for discharge of foul water (Scottish Water, 2003). Therefore, the effective charge for water services is 171.5 pence per Ml supplied (67p+(0.95x110p)). Using this combination of prices requires us to assume that the elasticity of demand for supply and discharge of water is the same, but this assumption is considered to be realistic and can therefore be made in this context. Substituting these figures into the equation for gross willingness to pay generates an estimated value of 164p/Ml (0.164p/m^3).

It is also possible to consider a wider range of values obtained from different prices for water supply. Based on a combination of charges for supply and discharge as above, the charges made by the major water companies in England and Wales indicate a range of prices from 107.15p/Ml (for Northumbrian Water) to 255.59p/Ml (for South West Water). The prices charged by the companies considered are included in Appendix E. Substituting these prices into the formula for willingness to pay generates a range of values from 102.25p/Ml to 243.90p/Ml (0.102-0.244p/m^3).

9.2.2 Northern Ireland

Per capita consumption in Northern Ireland is estimated to be 144.01l/day, or 52.6Ml/year (Ferguson McIlveen LLP, 2003). However, because household water consumption is not charged by volume, it is not possible to use a local estimate of price. Therefore, an estimated range is calculated based on the charges for households in England and Wales charged by volume. Charges for ten water companies in England and Wales, and for Scottish Water, are included in Appendix E.

In estimating the value of water to the household, the cost includes both the costs of supplying clean water and discharging foul water, with the volume discharged estimated at 95% of the volume supplied. Therefore, the household faces a cost per megalitre that is a combination of the two charges. The volumetric charge for water supply ranges from 57.46p/Ml to 90.53p/Ml and for water discharge from 43.86p/Ml to 178.15p/Ml. Therefore, the effective charge for water services ranges from 107.15p/Ml (for Northumbrian Water) to 255.59p/Ml (for South West Water). Using this combination of prices requires us to assume that the elasticity of demand for supply and discharge of water is the same, but this assumption would appear to be realistic and can therefore be made in this context. Substituting these prices into the formula for willingness to pay generates a range of values from 102.27p/Ml to 243.96p/Ml (0.102-0.244p/m^3).

Household demand: stated preference approach

A different approach is to conduct a stated preference survey whereby customers are asked to indicate their willingness to pay for an improvement in service. The UK water regulatory agency conducted such a survey, though unfortunately the sample chosen was not random (Bolt, 1993). Out of the three kinds of service improvement, one related to reductions in the risk of supply interruptions. Households were willing to pay £28.8-32.7 per annum for this benefit. In 1997 price terms this is £32.40 to £36.80, or 48.6 to 55 ecu per household per year. Given an average consumption in England and Wales of about 54 Ml year, this is equivalent to 1 ecu/Ml, or £0.67/Ml (0.067p/m^3). This is significantly lower than the estimate for value using Gibbons' willingness to pay formula. This is because the results using Gibbons' formula indicate the value of the supply of clean water and discharge of dirty water. In contrast, this stated preference survey considered clean water only. If the prices for clean water are used in Gibbons' formula, the results are consistent (see Appendix E).

9.3 Agricultural irrigation

For the profit-maximising farmer, demand for irrigation water is dependent on the following components:

- area of irrigated crop;
- availability of natural soil moisture from rain and dependent on evaporative demand;
- crop yield; and
- crop price (Environment Agency, 2001b).

These factors increase or reduce total irrigation water requirement year-to-year in order to generate a constant level of yield or quality. High crop yields may decrease the price one year, causing reduced crop areas in the next as farmers respond to lowered prices. However for the estimation of willingness to pay within one year, the most influential factors on demand, once a farmer has decided his total crop area, are climatic conditions that dictate how a farmer responds to day-to-day water needs.

Water use in agriculture differs from nearly all other water uses in the economy, depending on natural climatic conditions and also on the time at which water is available. Therefore, the value of any reduction or increase in water use depends hugely on the availability of water at other times. This is highlighted in the study of the economic effects of abstraction controls (SEERAD, 2002), which finds that under some restrictions (for example, preventing abstraction when river levels fall below a certain point), the volume abstracted over the whole season increases, but the yield and revenue fall because the water was not available at the optimal point in the growing season. In the case of a ban when flows drop below the 90 percentile (the flow that is exceeded 90% of the time) modelled for the West Peffer catchment, the average volume of water applied rose from 1130m^3/ha to 1160m^3/ha, while the mean gross margin fell from £5,127/ha to £3,704/ha. However, it should be noted that this study, and the results from it that are used in the net-back analysis below, are based on modelling that assumes optimal management. In practice, the authors suggest that the effects on margins may be 25% lower, such that a 90 percentile ban would reduce gross margins in the West Peffer catchment by around £1000 (SEERAD, 2002).

9.3.1 Net-back analysis

As outlined in Section 8.2.1 of this report, net-back analysis calculates the maximum ability to pay for water use from the price of farm output and other farm costs. This allows calculation of the value of all water, including both irrigation water and naturally available water, as either pounds per hectare or pounds per tonne. The net-back value is calculated as follows (Bate and Dubourg, 1997):

$$value = (P_f \times Q_f) - C_{non-w}$$

where P_f is the market clearing price of the farm's output,

Q_f is the quantity of the farm's output, and

C_{non-w} is the farm's total non-water costs of producing quantity Q_f.

In order to apply the method to derive a willingness to pay for agricultural irrigation, it is necessary to have data on the costs associated with irrigation, yield and revenues. The only crop for which this information is currently available is for potatoes. This data comes from a survey of farmers (SAC, 2001a and SAC, 2001b) and modelling undertaken for SEERAD (2002b) looking at farms with irrigated potato crops in the West Peffer and Tyne catchments in Scotland. Although individual responses were confidential, the study reported on aggregate statistics that can be used to calculate an average willingness to pay per hectare within the relevant catchments. These calculations are shown in Appendix F.

These calculations find net-back values for water used for irrigation of potatoes ranging between £2001/ha and £8941/ha, with a mean value of £5128/ha. The value varies with potato prices and yield. However, it should be noted that the results obtained from the modelling undertaken in the SEERAD study were based on the assumption of optimal farm management. In addition, since net-back values are based on the difference between revenue and costs, they tend to represent a maximum value.

This study was necessarily location-specific due the lack of national statistics on location-specific irrigation water use and reliance on SEERAD (2002b) data. However the variation of scenarios presented in SEERAD (2002b) allowed for a relatively broad consideration of demand under varying climatic condition. This makes the average results more representative than a static analysis of average moisture availability.

Since net-back analysis considers both irrigation and naturally available water, it is not possible to calculate a value of irrigation water per cubic metre using this method. However, it is possible to extend the method to focus on irrigation water by comparing yields with and without irrigation. Irrigation can be expected to affect yield of the crop of potatoes, and may also affect the price by reducing the quality of the produce. In a small data set from a farm trial in Cambridgeshire, the fully irrigated crop yielded between 14.3% and 58.1% higher than the unirrigated crop (depending on variety). Based on these figures and assuming no price effect, the value of water for irrigation is between £0.23/m^3 and £1.38/m^3. However, these estimates are simplistic in not considering costs of abstraction licences or potato subsidies in England and the higher demand for irrigation water due to lower rainfall.

Scotland

A simple net-back analysis of potato production across Scotland using national data for price, yield and hectares grown shows great variation in net-back figures, with some negative values (Appendix F). In addition, the average value per tonne produced was significantly lower than that calculated for the West Peffer catchment, although it was not possible to calculate a comparable value per cubic metre of water used because there was no data on total water used for irrigation of potatoes across Scotland. The analysis focused on mainware potato production (excluding potatoes for seed and stock feed) since the majority of irrigation is focused on this crop to enhance quality, yield and price (SEERAD, 2002). Because irrigation data for potatoes was not available, the national level analysis should be taken as indicative only. The lower value for Scotland as a whole is in large part a reflection of the lower yields per hectare and associated lower revenue. Since irrigation costs are largely determined by costs of equipment, which does not vary significantly, the lower profit margins reduce the net-back value. This suggests that the values found in the study of the West Peffer catchment could be higher than those for Scotland as a whole.

Northern Ireland

The SEERAD study (2002b) looked at irrigation of potatoes in a specific catchment in Scotland. However, in the absence of more specific data for Northern Ireland, this provides an approximate estimate. Potatoes account for approximately 5% of agricultural land area in both Scotland and Northern Ireland, and both regions are in similar agri-climatic zone. Of those potatoes grown, approximately 10% are irrigated in Scotland, slightly higher than in Northern Ireland, where 5-6% of potatoes are irrigated.

A basic net-back analysis of mainware potato production (potatoes for seed and stock feed were not included in the analysis) across Northern Ireland using national data for price, yield and hectares grown shows great variation in net-back figures, with some negative values (Appendix F). In addition, the average value per tonne produced was significantly lower than that calculated for the West Peffer catchment, although it was not possible to calculate a comparable value per cubic metre of water used because there was no data on total water used for irrigation of potatoes across Northern Ireland. Because irrigation data for potatoes was not available, the national level analysis should be taken as indicative only. The lower value for Northern Ireland is in large part a reflection of the lower yields per hectare and associated lower revenue. Since irrigation costs are largely determined by costs of equipment, which does not vary significantly, the lower profit margins reduce the net-back value. This suggests that the values found in the study of the West Peffer catchment could be higher than those for Northern Ireland.

9.4 Aquaculture

There are a number of potential methods to value the use of water for aquaculture, including net-back analysis, cost of damages through water use and calculation of the private benefits. The calculations in this section focus on avoided costs for disposal of solid waste, since this was the only information available at the time of writing the report (Slaski, pers.comm., 18th June 2004).

As discussed earlier in Section 2.4.1, water is used in aquaculture for a number of processes, including provision of oxygen, disposal of solid waste and nitrogen, and as a medium for growth. An alternative to disposal of solid waste in water is to remove it from the effluent stream before discharge by applying settlement or filtration techniques. Some of these are used in fish farms already, in order to meet the conditions associated with discharge consents, although other technically feasible options, such as recirculation systems, are not financially viable at present. This section considers the costs of applying a standard drum filter technique to the volume of water abstracted to arrive at an estimate of avoided cost (Slaski, pers.comm., 18th June 2004).

The report on abstraction in Scotland (CJC, 2002) estimated that aquaculture abstracted 4.4 million m^3 each day. Effluent polishing recommendations from the main supplier of such filters (Hydrotech) suggest that 729 of their largest units (model 2007) would be required to treat this volume of discharge. Assuming that the filters are bought without a loan, there are two ongoing cost elements to using such filters, depreciation for having purchased and installed the filters, and electrical energy used to run them. Summing these two elements of running cost, the avoided cost for solids removal in abstracted aquaculture water is 0.126p/m^3.

This method results in a basic value for water use based on costs avoided by not removing effluent. However, there are a number of potential omissions from the calculations, which should be considered in further analysis. In particular, the value is based on all abstraction being able to use the largest filters, which may be associated with lower costs per unit volume of water than smaller filters. It also does not include extra time or costs associated with maintenance and cleaning of the filters, and it assumes that the filters are 100% efficient.

9.5 Salmon angling

The value of recreation, including angling, cannot be estimated using productivity approaches, but instead relies on methods to value non-market benefits. In addition, it is only possible to value the activity that uses water, without an estimate of value per cubic metre.

One appropriate method is the travel cost method, which considers the costs that an individual faces in travelling to the site. In the case of angling, one recent estimate of the value of angling to those taking part (rather than to the economy as a whole) was undertaken for salmon angling at a site in Co. Donegal, Republic of Ireland (Curtis, 2002). We assume that the values found in this study would be broadly transferable to Northern Ireland and Scotland since all of these countries have a good reputation for salmon fishing in particular rivers, and serve both local anglers and international visitors. No information on days spent salmon fishing was available for Northern Ireland, but in Scotland, 545,000 days were spent angling for salmon and sea trout in 2003 (see Section 3.4.3).

This paper found that the travel cost of the anglers surveyed was IR£68 (£58), of which IR£22 (£19) corresponded to travel costs, IR£14 (£12) were fishing expenses, and IR£32 (£27) was for accommodation and meals. However, the costs varied between different nationalities. Germans and other Europeans spent an average of IR£56 (£48) per day on accommodation and meals, and IR£58 (£49) per day on travel. Anglers from Northern Ireland spent the most on fishing expenses.

The value of angling also includes the consumer surplus, or the additional value that an angler would be willing to pay but in reality does not have to. The largest consumer surplus estimates were for non-Irish and older anglers, although the estimates did not vary much (from IR£115.6 to IR£161.5, or approximately £98-£137).

Total value of salmon angling is calculated by combining the estimates of travel costs and consumer surplus. This suggested a total willingness to pay of IR£206 (£175) per angler per day. The values for different nationalities surveyed are summarised in **Table 9.1** (Curtis, 2002).

Table 9.1 Mean travel costs and consumer surplus for anglers in Co. Donegal, IR£

IR£	Travel costs	Consumer surplus	Total mean willingness to pay
Northern Ireland	38.3	115.6	153.9
Republic of Ireland	48.8	145.9	194.7
Germany	132.6	161.5	294.1
Other European countries	117.6	151.7	269.3
Mean across countries	**68**	**138.6**	**IR£206**

9.6 Industrial use

Because of the complexity of many industrial processes using water, the most realistic method for valuing industrial water use is the marginal productivity approach. Although this approach is the most data intensive, it allows most comprehensive inclusion of information on the costs of other inputs to production. However, estimating the marginal product of water to industry tends to be difficult because of the low value that water tends to have relative to overall industrial costs of production and the fact that actual water intake is less than gross water use. The difference between actual and gross intake arises because of the use of recirculating water, which can be substantial in contexts where the purity of water is not the highest concern. Maximum willingness to pay for water therefore tends to approximate the marginal costs of treatment and re-use of water, or of alternative technologies that conserve water.

Unfortunately there is not sufficient data on firm's water use and non-water costs to be able to apply the model to Scotland or Northern Ireland. Therefore, it is necessary to rely on estimates made in a paper assessing the value of water use for Canadian industry (Renzetti and Dupont, 2003) and transfer the values to Scotland and Northern Ireland.

The paper by Renzetti and Dupont (2003) uses a cost minimisation function, which assumes that firms choose their inputs to production, including water, in order to minimise costs. These choices are made subject to the output to be produced and the fixed level of inputs that are not variable in the short run. Considering the problem another way, instead of minimising cost subject to a given production, a firm can maximise production subject to a constraint on cost. This way round, the production function indicates the relationship between output and inputs, including water. It is this relationship between output and the water input, with other inputs held constant, that determines a shadow price or unit willingness to pay for water based on the change in value of production that results for a unit input change.

Renzetti and Dupont (2003) estimate the value of water using cross sectional industry data for the years 1981, 1986, and 1991 (this was based on Standard Industrial Classifications, which differ from UK Standard Industrial Classifications). The results are given in **Table 9.2** and **Figure 9.1**. Inflation factors and exchange rates are applied to transfer the values to 2004 UK pounds.

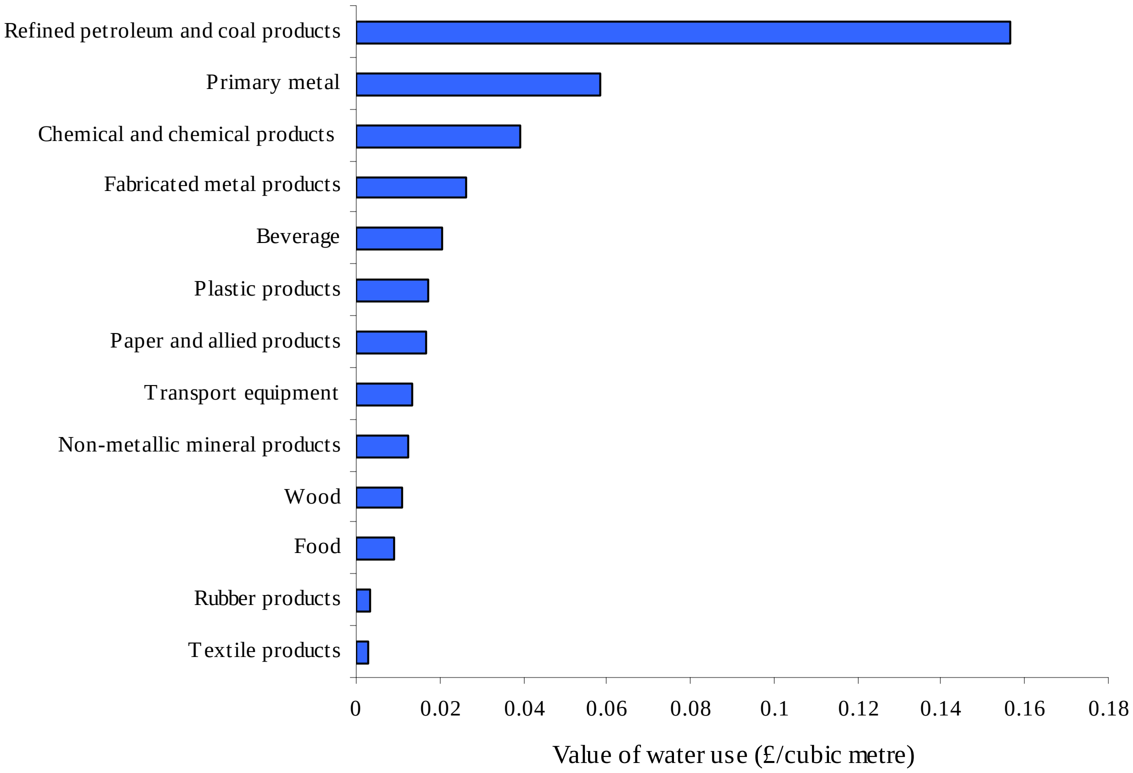
Table 9.2 Industrial value of water use

Manufacturing industry	1991 values ($Can)	2004 values ($Can)	2004 values (£UK)
Food	0.017	0.021	0.009
Beverage	0.038	0.048	0.021
Rubber product	0.006	0.008	0.003
Plastic products	0.032	0.040	0.017
Textile products	0.005	0.006	0.003
Wood	0.020	0.025	0.011
Paper and allied products	0.031	0.039	0.017
Primary metal	0.107	0.134	0.058
Fabricated metal products	0.048	0.060	0.026
Transport equipment	0.025	0.031	0.014
Non-metallic mineral products	0.023	0.029	0.013
Refined petroleum and coal products	0.288	0.362	0.157
Chemical and chemical products	0.072	0.090	0.039

Notes: inflation calculator: http://www.bankofcanada.ca/en/inflation_calc.htm

Prevailing £ -$Can exchange rate: http://www.x-rates.com/calculator.html

Figure 9.1 Value of water use in manufacturing industry



In transferring these values to Scotland and Northern Ireland, we make some strong assumptions. Perhaps the most basic assumption is that industrial water use is similar between the industries of the two countries. As OECD member states with similar GDP levels this is not an unreasonable assumption. Industrial processes are likely to be similar between internationally competitive producers. However, in applying inflation to the figures for 1991, there is an implicit assumption that there has been no change in water use in industrial processes (i.e. there have been no efficiency improvements since 1991). This is a strong assumption that is unlikely to hold in practice. For this reason in particular, the values above are only indicative of the relative value of water use between industrial sectors.

9.7 Hydropower generation in Scotland

A productivity approach to the value of water in power generation is difficult to use because of the highly distorted nature of market prices for energy, and especially due to UK government commitments to support renewable energy production through the Renewables Obligation. Therefore, an alternative means of valuation is to compare the costs of generating electricity with hydropower and the costs of alternative generation technologies. The relevance of the value per kilowatt hour (kWh) produced using alternative technologies depends on the current situation insofar as it is important to define what the most likely alternative to satisfy short term and long term supply.

Gibbons (1986) describes three methods of calculating the economic value of water used in hydropower based on the different scenarios under which a given country might use hydropower production. These are summarised in **Table 9.3** (adapted from Gibbons, 1986).

Table 9.3 Potential methods for valuing water use for hydropower

Method	Assumptions	Measurement of value	Interpretation for Scottish hydropower
Short run marginal value	All capital investment is fixed, and reduced water availability for hydropower generation displaces generation to an alternative source. Therefore, a temporary increase in alternative generation occurs, without requiring capacity increase.	Alternative source production less hydropower production costs (per kWh), not including capital outlay, depreciation or other longer-run costs.	Suited to measuring value in a context where abstraction for hydropower may be limited based on river flow rates, in order to preserve habitats or ecological health.
Long run replacement capacity value	Water availability restrictions create a need for augmentation of alternative capacity, hence the ‘replacement’ value.	The cost (per kWh) of new non-hydro capacity, less the foregone hydropower production costs.	Most suited to a situation where overall reductions in hydropower capacity are expected, for environmental or economic reasons, e.g. habitat replenishment, or avoidance of opportunity costs.
Long run average value	This represents the long-run value of water relative to alternative sources. It reflects the efficiency of hydropower generation’s dependence on water itself and available feet of head.	Difference between total costs of the non-hydropower generation, less the total costs of hydropower generation.	Relevant to long term consideration of the value of water in hydropower, relative to long term alternatives for power generation. Most relevant to situations where hydropower capacity expansion is environmentally feasible.

The choice of value depends on the alternative to generation with hydropower. The Scottish Executive (Scottish Executive, 2001a) has suggested it may be necessary to modify the operation of hydropower facilities where negative impacts need to be mitigated. Therefore, a short run marginal value might be most appropriate where there could be temporary restrictions on water management and short-term displacement to other types of generation. On the other hand, a long run average value may be more appropriate in consideration of potential new hydropower developments.

The long run average value of water for hydropower generation is assessed in a forthcoming paper (MacLeod *et.al.*, submitted). This paper estimates the volume of water flowing through hydropower turbines based on power output, efficiency, and the working head of the scheme (the distance that the water falls through the turbines). The costs associated with hydropower generation are estimated and compared to the costs of generation using other technologies (using figures from the Royal Academy of Engineering, 2004). In conjunction with figures for overall generation, this allows for calculation of the average value across all schemes in Scotland. The results are presented in **Table 9.4** (MacLeod *et.al.*, submitted).

Table 9.4 Long run average value of hydropower

	Cost of electricity (p/kWh)	Total value of water to hydro (£)	Average value of water to hydro (p/m^3)
Coal fired PF plant (no CO_2 charges)	2.5	9,907,806	0.049
Coal fired PF plant (CO_2 charges of £10/tonne)	3.3	36,402,527	0.180
Gas CCGT (no CO_2 charges)	2.2	-27,715	0.000
Gas CCGT (CO_2 charges of £10/tonne)	2.6	13,219,646	0.065
Nuclear fission plant	2.3	3,219,646	0.016
Onshore wind (no standby)	3.7	49,649,888	0.245
Onshore wind (with standby)	5.4	105,951,171	0.523
Offshore wind (no standby)	5.5	109,263,011	0.539
Offshore wind (with standby)	7.2	165,564,294	0.817

The most probable short-term alternative to hydropower would be coal or gas fired generation, or nuclear energy. The value of water for hydropower is higher when compared to onshore and offshore windpower, since these latter technologies are associated with greater capital costs. Although these costs are predicted to fall over the next 15-20 years (PIU, 2002), they are likely to remain high in comparison to other technologies. The value may also change if charges associated with emissions of carbon dioxide increase. Based on a hypothetical charge of £10/tonne of CO_2, the value of water for hydropower increases from 0.049p/m^3 to 0.180p/m^3 when compared to coal generation and from 0.000p/m^3 to 0.065p/m^3 when compared to CCGT (gas).

The experience of Scotland's largest hydropower operator Scottish and Southern Energy Group indicates a far greater range of benefits of water use in their portfolio of generation facilities. Taking account of the benefit of Renewable Obligation Certificates (ROCs) and at the most advantageous generation facilities (with the greatest head of water) and with the greatest flexibility in markets the value to them of a cubic metre (m^3) can reach as high as 5.2 pence (Donaldson, pers.comm.).

It is important to note again at this point that this report does not consider the environmental costs or benefits associated with hydropower, since it concentrates on the benefits to water users only. However, there has been significant debate about the potential positive and negative impacts of hydropower on the aquatic environment and in meeting renewable energy generation targets.

10. Recommendations

10.1 Introduction

The results of this report have necessarily been determined by the availability of information on sectors and water use in Scotland and Northern Ireland and on the availability of valuation methods developed in the economics literature. Although this has allowed us to make estimates for some of the key water users, it would be possible and desirable to improve these estimates through improving data or using more robust and comparable techniques.

Therefore, this chapter considers the ways in which estimates could be improved through future data collection and development of techniques.

10.2 Recommendations for consideration of further sectors

Section 9 of this report valued water use for a number of sectors. However, because of the lack of data and restrictions on applicability of valuation methods, it was not possible to value all the sectors making significant use of water. In particular, it may be valuable to undertake a more comprehensive analysis of the quantity and value of water use for the following sectors:

Scotland

- Livestock agriculture;
- Manufacture of mineral water;
- Manufacture of whisky;
- Manufacture of paper;
- Refining and manufacture of chemicals and petrochemicals;
- Power generation; and
- Amenity and recreation.

Northern Ireland

- Livestock agriculture;
- Manufacture of whiskey;
- Manufacture of electronic equipment;
- Power generation; and
- Amenity and recreation.

For the manufacturing sectors, valuation could involve using the marginal productivity approach. However, this would require a co-operative relationship with a number of companies in the sector considered in order to provide a cross section of data on quantity and cost of inputs and products as well as water use. It may also be possible to use the marginal productivity approach for power generation, building on the information in Sections 3.11 and 5.11, although the number of power stations may require data to be supplemented with information from England and Wales.

There have been a number of studies done in the UK and elsewhere that consider the value of different recreational activities. Although collation of these studies would require some time, it would provide a useful assessment of the value of non-abstractive water uses in Scotland and Northern Ireland.

10.3 Recommendations for improving data availability

The results of this study have in large part been determined by the availability of data. It has been particularly apparent that there is only incomplete knowledge of the volume of water used by different sectors. Although this project has been able to deliver results for the key water users based on information available, a more complete knowledge of water use would be extremely valuable for considering implementation of the Water Framework Directive.

10.3.1 Scotland

There are two areas in which the data availability for Scotland was particularly good. The first was in the Water Resources Survey (Scottish Executive Environment Group, 2003), which includes information on volumes supplied to large industrial users. However, it is understood that the number of users for which this data is recorded is expected to decrease substantially in the report for water supply in 2003, with the definition of large user being increased from those supplied with over 1000m^3/quarter to those supplied with over 100,000m^3/quarter. This will reduce the extent to which the data is able to give information on water use in the industries using the highest volume of pubic supply, exacerbating the lack of information for smaller commercial users and households.

The second area in which Scotland has gone some way towards addressing data shortages is for direct abstraction (CJC Consulting, 2002). This study has been very useful in providing an indication of those sectors using high volumes of water. However, the most noticeable gaps remaining that have come to attention during this study have been for smaller abstractors (particularly individual households and farms) and for those using marine waters (notably chemicals and power generation). With regards to use of water for cooling in power generation, this study has used information readily available from published reports by Scottish Power and Scottish and Southern Energy, and it is therefore unlikely that compiling a more comprehensive picture in this area would prove to be too difficult.

The major gap remaining in the data is the use of water by smaller industrial and commercial premises and households. Estimates of per capita household consumption have been made for Scotland and compared to other areas of the UK (Environment Agency, 2001a and OECD, 1999), and it has therefore been possible to estimate household use for Scotland (including public supply and direct abstraction). However, there has been less work considering use by smaller commercial premises and it would facilitate discussions of water use to complete information by considering this sector. This could be done by estimating volumes for the sector as a whole, or by surveying a number of organisations and applying this information to estimate sectoral water use.

There is also less complete knowledge of industrial discharges. Ideally, we would wish to identify how much water each sector was discharging, the content of this discharge, and whether it was discharged to mains sewers or to water courses. Some of this information should be available from Scottish Water, who charge for trade effluent separately from other discharge to sewers. British Waterways also hold information relating to discharges to their canals. It may also be possible to draw on information on industrial discharges held by SEPA for regulating discharge consents. Assumptions could also be made for some sectors based on their abstraction and supply of water by applying consumptiveness factors. However, it may be that more comprehensive information is available through approaching each sector. There has been some move towards this through SEPA's Economic Advisory Stakeholder Group, but it would be useful to include information on discharges in these submissions.

10.3.2 Northern Ireland

The Water Resource Strategy (Ferguson McIlveen LLP, 2003) provides the most comprehensive data on water use in Northern Ireland. However, we have faced a number of difficulties using that data, particularly for industrial users, where it is not clear which of the different figures for volume used are the most appropriate. Therefore, it would be helpful to define this, and to clarify the different groups of industrial users estimated in the Water Resource Strategy.

The most significant gap in the data on water use in Northern Ireland relates to direct abstraction. There is ongoing abstraction for both domestic use and for agricultural purposes (stock watering, washing and some irrigation). Although this gap is recognised, implementation of the Water Framework Directive will require a more accurate assessment. The Department of Environment will consider this issue when developing its proposals for the introduction of an abstraction licensing system. One option would be to carry out a study similar to that for Scotland (CJC Consulting, 2002), which identified a number of key sectors for whom abstraction was thought to be significant and sent questionnaires to businesses in those sectors.

There is also a noticeable gap in terms of discharges from different industrial premises. For industries discharging to mains sewers this information should be available from Water Service, who charge for trade effluent based on the quantity and content of the discharge. In considering discharges directly to ground or surface waters, information should be available from the Environment and Heritage Service, who regulate consents for trade and sewage effluent under the Water (Northern Ireland) Order 1999. It is anticipated that the ongoing water reform process will improve the control processes in these areas by 2006. An alternative method of assessing discharges would be to consult the industries concerned, either directly or through trade associations. This could have the advantage of picking up discharges that are not consented but are relevant in volume and could be combined with assessment of direct abstraction. However, it would risk relying on unverified information.

10.4 Recommendations for improving geographical precision

This study has considered water use for Scotland and Northern Ireland, without attempting to indicate more detail of the geographic spread of issues. However, it will be necessary to consider water use across the borders with England and the Republic of Ireland respectively in order to consider economic and environmental issues in the International River Basin Districts. This will be facilitated by an improved understanding of sectoral water use issues, including volume supplied and discharged. However, it may also be useful to use geographic information systems (GIS) to record and represent appropriate information, particularly on abstraction (by Scottish Water or privately) and discharge.

10.5 Recommendations for developing valuation methods

The most significant gap in using the valuation methods available was the lack of data to use the marginal valuation approach for industrial water use. It is expected that there are a number of sectors in Scotland and Northern Ireland who have particularly high values of water use, based on their volumetric use and product made. However, the lack of data on water use and the costs of other inputs to the industrial process restricted analysis to benefits transfer from a Canadian study. In order to carry out a marginal productivity valuation of water use in a particular sector in Scotland or Northern Ireland, it would be necessary to collect data on water use, costs of water use, costs of other inputs to the industrial process, and volume of output produced. Cross-sectional data for different companies across the sector would be necessary to provide a range of water uses. This approach requires a significant amount of data, and therefore would rely on co-operation from organisations in the sector to provide information. However, the approach would be useful in assessing the contribution of water to industrial processes for the key users outlined in Section 10.2.

11. Conclusions

11.1 Summary of the study and results

This study has considered the economic value of water use to individuals and organisations in different sectors of the economy in Scotland and Northern Ireland.

The study considered the types of water use within each sector identified, outlining information on supply, source, use and discharge where available. This showed diversity in all aspects, with some sectors, such as volume supplied by Scottish Water to large industrial users, much better understood than others, such as direct abstraction for industrial cooling. The information on water use provided a qualitative indication of how different users benefit from water use, and provided the baseline information to inform the quantitative assessment of value undertaken in the report.

The study used economic valuation techniques to help to reveal the importance of water in different processes. However, there are a number of points to note with relation to such techniques.

- Valuation is a useful economic technique to help to reveal the importance of water in different processes. However, there are a range of valuation methods that can be used, and the different methods can lead to different values being assigned to uses that in other respects are similar.
- Different methods can be used to calculate the total, average or marginal value of water. The value of water to a user will depend on the volume used, and the value of the last unit (the marginal value) does not necessarily reflect the average value of all units. For example, households could be expected to have an extremely high value for the first unit, since this would be used for drinking, but a relatively low value for the last unit, which may be used for watering the garden.
- The value of water is calculated to take account of features of water use such as the degree of necessity and the options for alternatives. However, in considering any future changes in policy, it will be necessary for decision makers to reconsider these features individually. For example, it will be important to be clear on the different water efficiency measures undertaken by different industrial users in the past, and the scope that they have to undertake further actions in the future.

The information available, in conjunction with the needs and options for this study, resulted in a focus on particular methods and users. **Table 11.1** summarises the values calculated. However, it should be noted that the values were calculated using different methods and based on different assumptions, and therefore the results for different sectors are not comparable.

Table 11.1 Summary of the valuation techniques and results for sectors considered

Sector	Valuation technique	Key assumptions	Value
Households	Gibbons' willingness to pay formula	Assumes all consumers pay volumetric charges levied to metered customers in England, Wales and Scotland Includes value of both clean and dirty water	0.102 - 0.244 p/m^3
	Benefits transfer from stated preference study	Only considers value of supply of clean water	0.067 p/m^3
Agricultural irrigation	Net-back analysis	Assumes that the West Peffer catchment is representative of other areas where potatoes are irrigated Value includes both naturally available water and water applied through irrigation	£5128 /ha
	Transfer of net-back analysis	Data from England and Scotland combined despite different agricultural support arrangements and climate	23 - 138 p/m^3
Aquaculture	Avoided cost	Costs calculated based on running costs of the largest effluent filters bought without a loan Considers water use for disposal of solid waste only Assumes filters remove all solid waste	0.126 p/m^3
Salmon angling	Benefits transfer of travel cost method study	Assumes salmon anglers in Donegal are representative of others throughout Scotland and Northern Ireland	£175 / day
Industry	Benefits transfer from marginal productivity approach study	Industrial water use in Scotland and Northern Ireland assumed to be the same as for Canada Assumes no improvements in water efficiency since 1991	0.3 - 15.7 p/m^3
Power generation	Avoided cost	Compares generation costs associated with hydropower with generation costs from other fuels and technologies	0.00 - 0.049 p/m^3 (compared to gas, nuclear and coal) 0.245 - 0.817 p/m^3 (compared to windpower)
	Avoided cost	Estimate from Scottish and Southern Energy taking account of benefit of Renewable Obligation Certificates, at most advantageous generation facilities and with greatest flexibility in markets	5.2 p/m^3

Even within specified sectors, the types of use, and the value, differ. For example, within industry, refined petroleum and coal, primary metals, and chemicals were the highest value users assessed, while textiles, rubber and food were relatively low value.

The study benefited from comments from a number of organisations and individuals. During these discussions, a number of concerns were raised over the use of the information in this report and the values suggested for different sectors. Therefore, the following points should be made clear.

- A particular value does not indicate that a user should or will experience a particular change in their regulation or charging for water use.

- The use of the term ‘willingness to pay’ is a reflection of value in economic analysis. It does not necessarily indicate that a user would be happy to pay that amount, or that they would be able to absorb or pass on any increased cost within their business.
- Any decision making on water policy or pricing will need to include many wider considerations, including ability to respond to any changes (and ability to pay). It is not within the scope of this project to express the position of individual sectors with regard to this issue, although these comments form part of the sector reports for Scotland and are also included in considerations in Northern Ireland.
- This report provides an important first assessment of the value of water to different water users in Scotland and Northern Ireland. However, much of the information is at a relatively high level, and there are a number of gaps in the data. Therefore, it will be essential for policy makers to draw on the experience and expertise of those working in different sectors to continue to build understanding in an ongoing process, of which this report is only one part.
- This is a research report and is not a policy document. A particular value is one of a number of pieces of information to be considered as part of any decision making process considering water use. A number of other issues will also need to be included.

The report presents results based on the information made available and the techniques developed at the time. However, there are a number of areas in which understanding can and should be improved. In particular, the understanding of the volume of water supplied to and discharged from different sectors could be improved. In turn, this could help to identify issues of water use at a more precise geographic level, in order to facilitate assessment of the cross-border river basin districts.

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6 Pages

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Appendix B : Conversion Factors and Glossary

4 Pages

Conversion factors

1 cubic metre = 1 m^3 = 1,000 litres

1 megalitre = 1Ml = 1,000,000 litres

1 tonne = 1 m^3

1 gallon = 4.546 litres

1MW = 1,000kW

1GW = 1,000,000 kW

Glossary

Key terms	
WFD	Water Framework Directive: Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
Environmental economics	
Bequest value	Bequest value is the value that an individual places on a resource even when they have no intention of ever using it, but where they wish it to be available for use by future generations.
Existence value	Existence value is the value that an individual places on a resource where they have no expectation of using it themselves or of their descendants using it, but where he feels it is valuable nonetheless.
Option value	Option value is the value that an individual places on a resource that they do not currently use, but where they may wish to in the future.
Public good	This is a good that is non-rival in consumption (one person's consumption does not exclude consumption by another person), non-excludable (it is not possible for one person to prevent consumption by another person) and non-rejectable (it is not possible to avoid consumption of the good). Street lighting is an oft-cited example of a public good.
Use value	The value that an individual places on a resource because they are able to make use of it, for household or industrial consumption, or for recreational activities.
Baseline information	
Gross value added	This is a measure of contribution to the Gross Domestic Product of a region. It is also used to indicate economic significance.
Market clearing price	This is the price at which all of the output of a good is sold on the market and all consumers purchase the amount that they wish to consume at that price.
Potable water	Potable water is of drinkable quality.
Private abstraction	This term has been used to relate to supplies of water taken by households or companies from ground or surface waters. Private abstraction is in contrast to public supply.

Public supply	Public supply refers to water supplied by Scottish Water or Water Service to households or industries.
Standard industrial classification (SIC)	
Sector specific terms	
Benthos	Benthos relates to the plant and animal life of the sea bottom.
Cyprinid fish	Fish of the family cyprinidae including carp, tench, roach, rudd and dace. Contrast to *salmonid fish*.
Fluegas desulphurisation (FGD)	FGD employs a sorbent, usually lime or limestone, to remove sulphur dioxide from the gases produced by burning fossil fuels.
Mainware potatoes	*Mainware potatoes* are potatoes for consumption, as opposed to seed potatoes or potatoes for stock feed.
Off-line hydro schemes	Hydropower generation schemes where infrastructure is installed away from the flow of water. At present, these tend to be preferred to *on-line hydro schemes*, which are seen as more limiting for fish migration.
On-line hydro schemes	Hydropower generation schemes where infrastructure is installed in the flow of water.
Pelagic fish	These fish live in the open sea, and are not confined to the sea bottom.
Salmonid fish	Fish of the family salmonidae, which includes all species of salmon, trout, char, whitefish and grayling. Contrast to *cyprinid fish*.
Valuation and techniques	
Average value	This is the *average value* of all units consumed, calculated as the *total value* divided by the number of units consumed.
Contingent valuation	This technique estimates the value of an environmental resource by asking direct questions about how much a consumer would be willing to pay for an increase in the environmental asset (or quality) or how much they would be willing to accept for a deterioration.
Hedonic pricing	*Hedonic pricing* is used to estimate the value of environmental attributes or services that directly affect prices, most commonly house prices. It is based on the premise that the price of a marketed good is related to its characteristics, and that it is possible to value a characteristic based on the change in price in response to a change in that characteristic.
Marginal productivity approach	This valuation technique is based on estimating the production function to identify the effect of a change to the input of water (or other inputs) to production on the output.
Marginal value	This is the value of the last unit consumed, and is calculated as the slope of the demand curve at the quantity consumed.
Net-back analysis	This is a valuation technique, often used for agricultural production, considering the value of water use to be the margin of revenue over cost divided by water used in production.
Revealed preference techniques	These type of techniques use market data or information on actual behaviour of individuals to make estimates of their preferences. Revealed preference techniques include the *travel cost method* and *hedonic pricing*.
Stated preference techniques	These techniques rely on information presented by individuals in response to particular questions. These are likely to involve questionnaires on hypothetical markets, for example, *contingent valuation* surveys.
Total value	*Total value* is the sum of marginal values for all units consumed.

Travel cost method	The travel cost method is often used to assess the value of environmental assets used for recreation (parks, lakes, rivers, etc.), where it is necessary for individuals to travel to the site to take part in these activities. The method is based on the assumption that the individual incurs costs in getting to the site, and these can be used to indicate value. However, it is limited to *use value* and does not include *bequest*, *existence* or *option value*.
Willingness to pay	(Marginal) *willingness to pay* is the maximum that an individual would be prepared to pay for one unit of a particular good.

Appendix C : Categories and SIC Codes

2 Pages

The following table indicates the links between the categories used in this report and the Standard Industrial Classification codes.

Households		
Agriculture and forestry	A	
Fishing	B	
Aquaculture	05.02	
Commercial fishing	05.01	
Angling		This is not included in the SICs.
Mining and quarrying	C	
Manufacture of food and beverages	DA	
Food processing	15.1-15.8	
Production of alcoholic beverages	15.91-15.97	
Production of mineral waters and non-alcoholic beverages	15.98	
Manufacture of textiles and leather products	DB-DC	
Manufacture of wood, pulp and paper production	DD-DE	
Manufacture of petroleum and petroleum-based products	DF-DH	
Manufacture of non-metallic mineral products	DI	
Manufacture of basic metals and fabricated metal products	DJ	
Other manufacturing	DK-DN	
Electricity, gas and water supply	E	Excluding water supply, as this would risk double counting the benefits by including this category as well as those using water supplied.
Construction	F	
Commercial premises	G-L	
Non-households	M-P	Excluding 90.01 (for similar reasons to water supply), and 92.53 and 92.6 where such activities are reliant on water or derive significant value (these are included under amenity and recreation).
Amenity and recreation		Amenity and recreation is not included in the SICs, except where this is in a commercial premise. In this case, the activity is excluded from the category above (non-households) and included in this section.
Tourism and water-dependent visitor attractions		

Water-dependent recreation

Non-water-dependent recreation

Waterside amenity

Navigation

Appendix D : Additional Information-Context

4 Pages

Natural Mineral Water in Scotland

Information taken from Food Standards Agency (2003), listing abstraction sites as at May 2003.

Sales description	Name of source	Place of exploitation
Highland Spring	Highland Spring	Blackford, Perthshire
Buchan Natural Mineral Water	Buchan	Stichen, Aberdeenshire
Burnbrae Spring	Burnbrae	Lennoxtown, Glasgow
Caledonian Spring	Caledonian	Lennoxtown, Glasgow
Campsie Spring	Campsie	Lennoxtown, Glasgow
Carnmor Spring	Clash	Braes of Glenlivet, Ballindalloch, Banffshire
Speyside Glenlivet Natural MW	Slochd Spring	Braes of Glenlivet
Cragganmore Spring	Cragganmore	Lennoxtown, Glasgow
Deeside Natural Mineral Water	Pannanich Wells	Pannanich Wells, Ballater
Findlays	Findlays Spring	Pitcox, East Lothian
Fionnar	Fionnar	Achmony Farm, Drumnadrochit, Invernessshire
Galloway	Chrichton Royal	Glencaple Road, Dumfries
Glenburn Spring	Asda	Lennoxtown, Glasgow
Glencairn	Glencairn	Lennoxtown, Glasgow
Gleneagles	Gleneagles	Blackford, Perthshire
Gleneagles Maltings	Gleneagles Maltings	Blackford, Perthshire
Glengarr	Sorn	Westown Farm, Sorn, Ayrshire
Heather Spring	Heather	Lennoxtown, Glasgow
Highland Spring	Highland Spring	Blackford, Perthshire
Islay Water	Maol Dubh	Laggan Estate, Isle of Islay
Isle of Skye Natural Mineral Water	Flodigarry Boreholes 1 & 2	Floidgarry Staffin, Isle of Skye
Lomond Spring	Hangingmyre Farm	Hangingmyre Farm, Fife
Lovat Spring	Lovat Spring	Fanellan, Kiltarlity, Beauly, Invernessshire
Lowland Glen	Lowland Glen	Lennoxtown, Glasgow

Morangie Water	Fuaran Nan Slainte	Fuaran Nan Slainte, Morangie
New Strathmore Spring	New Strathmore	126 West High Street, Forfar
Orkney Isle	St Magnus Cistern	Wellpark, Kirkwall, Orkney
Perthshire Mountain Spring	Perthshire Mountain Spring	Highland Spring, Blackford, Perthshire
Ronas Spring	Muckle Ballia Clett	Northmavine, Shetland Islands
St Ronan’s Spring	St Ronan’s	Innerleithen, Tweedale
Sainsbury’s Scottish Caledonian	Borehole 4	Lovat Pride (Mineral Water) Ltd., Fanellan, Kiltarlity, Beauly, Invernessshire
Scottish Border Springs	Purely Scottish Spring	Woollands Farm, Oldhamstocks, East Lothian
Scottish Mineral Water	Waitrose Scotland	Lennoxtown, Glasgow
Scottish Mountain Spring	Scottish Mountain	Fanellan, Kiltarlity, Beauly, Invernessshire
Springberry Scottish Mineral Water	Gallaberrry Estate	Gallaberry Estate, Kirkton, Dumfries
Strathglen Spring	Strathglen	Lennoxtown, Glasgow
Stathmore Spring	Strathmore	126 West High Street, Forfar

Blue Flag Beaches in Scotland

Category	Municipality	Beach/ Marina name
Marina	Dumfries and Galloway Council	Kirkcudbright Marina
Beach	Fife Council	Aberdour Silver Sands
Beach	Fife Council	Burntisland
Beach	Fife Council	Elie Harbour
Beach	Fife Council	St Andrews, West Sands

Blue Flag Beaches in Northern Ireland

Category	Municipality	Beach/ Marina name
Marina	Carrickfergus Borough Council	Carrickfergus Waterfront Marina
Marina	Crest Nicholson Marinas Ltd	Bangor Marina
Marina	Moyle District Council	Ballycastle Marina
Beach	Coleraine Borough Council	Portrush, West Strand
Beach	Down District Council	Tyrella
Beach	Limavady Borough Council	Benone
Beach	Newry and Mourne District Council	Cranfield, West
Beach	Moyle District Council	Ballycastle

Appendix E : Additional Information- Water Use by Households

2 Pages

The household value of water use was calculated based on the charges levied on households supplied with water. These charges only include the volumetric part of the total charge (£/m^3) and do not include any standing charges, which will also feature on a household's water bill. The following table shows the charges for supply and discharge of water for ten water companies in England and Wales, and for Scottish Water. The Water Service in Northern Ireland does not charge households based on volume used.

Volumetric charges for 2003-4 for those households in England and Wales charged by volume (p/Ml)

	Water supply	**Sewerage services (foul and surface water)**	**Sewerage services (foul water only)**
Anglian Water	87.05	109.38	109.38
Northumbrian Water	57.46	57.68	57.68
Thames Water	65.48	43.86	43.86
Scottish Water	67.0	110.0	110.0
Severn Trent Water (2004-5)	86.23	53.68	53.68
Southern Water	59.6	98.7	98.7
South West Water	86.35	178.15	154.20
United Utilities	85.4	62.7	62.7
Welsh Water	90.53	121.46	101.54
Wessex Water	90.27	98.92	98.92
Yorkshire Water	81	83.9	83.9

These figures were used in the Gibbon's willingness to pay formula to calculate value. To illustrate, the calculation is included here using figures for Scottish Water.

$$GWTP = \left(\frac{P.Q_2^x}{1-x}\right).\left(\frac{Q_2}{Q_2^x} - \frac{Q_1}{Q_1^x}\right)$$

P (p/Ml) = (1*67.0)+(0.95*110.0) = 171.5

This is based on a household being charged per megalitre supplied and based on discharge of 95% of water supplied.

Q_1 (Ml) = 52.3

This is the figure used for current consumption per person per year in Scotland- see Section 9.2.1). For Northern Ireland, Q_1 = 52.6 Ml.

Q_2 (Ml) = Q_1 + 1 = 53.3

Q_2 looks at the value of an additional unit (megalitre) to reflect the marginal value.

x = 1/e, where e = -0.2

The elasticity (e) is assumed to be -0.2, as suggested by Hoglund (1997).

$$GWTP = \left(\frac{171.5 \times 53.3^{-5}}{1--5}\right) \cdot \left(\frac{53.3}{53.3^{-5}} - \frac{52.3}{52.3^{-5}}\right)$$

= 164 *p/Ml*

If the value of household water use is considered for supply only, rather than for supply and discharge, the value falls from that discussed in Section 9.2 and illustrated above. This allows a more direct comparison with the results of the study undertaken by Bolt (1993) using a stated preference approach.

For Scotland, if price is taken to be 67p/Ml of clean water supplied (instead of 171.5p/Ml to include the charge for discharge of 95% of water supplied), the value calculated using the Gibbon's willingness to pay formula is calculated as 63.9p/Ml. Using the range of costs for water supply for the water companies, the value of water use ranges from 54.8p/Ml to 86.4p/Ml.

For Northern Ireland, the range of costs for water supply given in the table above indicate that the value of water use is estimated to lie in the range between 54.8p/Ml and 86.4p/Ml.

Appendix F : Additional Information- Water Use for Agricultural Irrigation

4 Pages

Estimated net-back value for water used for irrigation using data from the West Peffer catchment

Irrigation of potato crops serves mainly to increase revenues by increasing crop yield (t/ha) and quality (£/ha). Scabbed potatoes are not saleable as a high quality product, such as the packaged potatoes found in supermarkets, but are graded out to fetch a lower price in a market such as processing for chips or crisps. Average willingness to pay for water per hectare of crop as calculated in the equations below represents the private net benefit plus any volumetric or flat rate water charge that is levied against water abstractions.

Figures for yield (tonnes/ha), water applied to irrigated land (mm), total area irrigated, and revenue (£/t) were given in the SEERAD study of irrigation in the West Peffer catchment (SEERAD, 2002b).

The margin per tonne produced over non-irrigation costs is calculated from crop market price and yield, less costs per hectare. SEERAD (2002b) states that "[variable, non-water] costs were calculated as the sum of costs relating to the area grown (at £1253 per ha) and costs relating to yield (at £31 per tonne)". Fixed costs associated with production (e.g. capital costs for equipment) are not included in the calculations, since it is more appropriate to use only variable costs to represent marginal costs associated with production.

Non-irrigation costs (£/ha) = 1253 (£/ha) + (31 x yield (t/ha))

Margin over non-irrigation costs (£/ha) = revenue (£/ha) - non-irrigation costs (£/ha)

The water applied is given in SEERAD (2002b) in mm. This is converted into m^3 per hectare by multiplying the irrigation figure in mm by 10 (1 ha = 10,000m^2, 1mm over 10,000m^2 = 10 m^3).

Irrigation costs are calculated in SEERAD (2002b) based on annualised depreciated capital costs plus variable costs of supplying irrigation demand. The cost of irrigation depends on how the farmer distributes his extraction between potential sources (river, reservoir, borehole, etc.), unless the extent of irrigation demand is such that all capacity is required. SEERAD (2002b) converted capital costs of its surveyed farms into annual costs by annuitising over the lifespan of hosereels (the most common form of irrigation system in the UK), pipes and reservoirs over their respective lifespans, with 9% interest. The cost estimates also account for the effect of natural moisture levels on demand, in that variable costs for delivering the water via an irrigation system vary year to year. SEERAD (2002b) used weather data for the period 1989 to 1998 in combination with a potato growth and quality model to run scenarios for each year calculating (based on prices defined by likely effects of dry or wet years on crop quality and quantity) likely yield and revenue.

As discussed in Section 9.3 above, the value of irrigation water is calculated as the margin of revenue over costs.

Net-back value (£/ha) = margin over non-irrigation costs (£/ha) - irrigation costs (£/ha)

However, it should be noted that this figures assumes that there is no abstraction charge and no direct subsidies are received. Although this is the case for Scotland and Northern Ireland, care should be taken when applying these figures to other regions.

$$\text{Net-back value (£/t)} = \frac{\text{net-back value (£/ha)}}{\text{yield (t/ha)}}$$

$$\text{Net-back value (£/m}^3\text{)} = \frac{\text{net-back value (£/ha)}}{\text{water use (m}^3\text{/ha)}}$$

Calculations based on yields and prices for the West Peffer catchment

	Yield (t/ha)	Non-irrigation costs (£/ha)	Revenue (£/ha)	Margin over non-irrigation costs (£/ha)	Irrigation requirement (mm)	Water applied to irrigated land (mm)	Water applied to irrigated land (m^3/ha)	Irrigation cost (£/ha)	Margin over costs (£/ha)	Net-back value (£/ha)	Net-back value (£/t)	Net-back value (£/m^3)
1989	63.6	3215	10167	6952	170	112	1120	449	6503	6503	102.7	5.81
1990	70.8	3448	9181	5733	115	90	900	427	5306	5306	74.9	5.90
1991	61	3144	5616	2472	65	65	650	402	2070	2070	33.9	3.18
1992	67.3	3339	8127	4788	135	135	1350	472	4316	4316	64.1	3.20
1993	64.1	3240	8313	5073	105	105	1050	442	4631	4631	72.2	4.41
1994	61.2	3150	10909	7759	170	157	1570	494	7265	7265	118.7	4.63
1995	63.4	3218	11757	8539	155	130	1300	467	8072	8072	127.3	6.21
1996	69.3	3401	12839	9438	170	160	1600	497	8941	8941	129.0	5.59
1997	62.4	3187	5758	2571	55	55	550	392	2179	2179	34.9	3.96
1998	58.3	3060	5392	2332	40	25	250	331	2001	2001	34.3	8.00
Mean	**64.11**	**3240**	**8806**	**5566**	**118.00**	**103.40**	**1034**	**437.30**	**5128**	**5128**	**80.0**	**4.96**

Calculations based on yields and prices across Scotland

	Yield (t/ha)	Average market price (£/t)	Revenue (£/ha)	Non-irrigation costs (£/ha)	Margin over non-irrigation costs (£/ha)	Irrigation costs (£/ha)	Margin over all costs (£/ha)	Net-back value (£/ha)	Net-back value (£/t)
1997/98	44	76.29	3357	2617	739.76	437.3	302.46	302.46	6.87
1998/9	45	147.16	6622	2648	3974.2	437.3	3536.9	3536.9	78.60
1999/00	42	67.35	2829	2555	273.7	437.3	-163.6	-163.6	-3.90
2000/01	45	119.94	5397	2648	2749.3	437.3	2312	2312	51.38
2001/02	49	88.55	4339	2772	1566.95	437.3	1129.65	1129.65	23.05
Mean	**45**	**99.858**	**4493.6**	**2648**	**1845.61**	**437.3**	**1408.31**	**1408.31**	**31.30**

Figures of yield and price are from the British Potato Council.

Note that the prices are not in 2003 equivalent.

Calculations based on yields and prices across Northern Ireland

	Total yield (000 t)	Area (ha)	Yield (t/ha)	Average producer price (£/t)	Non-irrigation costs (£/ha)	Revenue (£/ha)	Margin over non-irrigation costs (£/ha)	Irrigation costs (£/ha)	Margin over all costs (£/ha)	Net-back value (£/ha)	Net-back value (£/t)
1997	203.7	5,894	34.57	63.94	2324.6	2210.3	-114.3	437.3	-551.6	-551.6	-15.96
1998	201.7	5,906	34.16	114.46	2311.8	3909.5	1597.7	437.3	1160.4	1160.4	33.97
1999	203.3	5,958	34.12	121.86	2310.8	4158.1	1847.3	437.3	1410.0	1410.0	41.32
2000	229.4	5,355	42.83	74.58	2580.8	3194.5	613.7	437.3	176.4	176.4	4.12
2001	187.8	5,458	34.41	98.44	2319.6	3387.1	1067.4	437.3	630.1	630.1	18.31
2002	190.4	5,469	34.82	98.70	2332.3	3436.4	1104.1	437.3	666.8	666.8	19.15
Mean	**202.7**	**5673**	**35.82**	**95.33**	**2363.3**	**3382.6**	**1019.3**	**437.3**	**582.0**	**582.0**	**16.82**

Calculations based on the effect of irrigation on yield

The following information on yields and irrigation is taken from the British Potato Council (2004).

Yields of variety Hermes

	Water applied (m^3/ha)	Yield (t/ha)	Average market price (£/t)	Revenue (£/ha)	Non-irrigation costs (£/ha)	Irrigation costs (£/ha)	Margin over all costs (£/ha)	Net-back value (£/ha)
HERMES								
Unirrigated	0	58.1	137.36	7980	3054	0	3054	4926
Fully irrigated	1940	66.4	137.36	9121	3311	437.3	3749	5372
RUSSET BURBANK								
Unirrigated	0	51.8	137.36	7115	2859	0	2859	4256
Fully irrigated	1940	81.0	137.36	11126	3764	437.3	4201	6925
SATURNA								
Unirrigated	0	41.5	137.36	5700	2540	0	2540	3161
Fully irrigated	1940	65.6	137.36	9011	3287	437.3	3724	5287

$$\frac{\text{net-back value (fully irrigated) - net-back value (unirrigated)}}{\text{water applied}} = \text{value of irrigation (£/m}^3\text{)}$$

Appendix G : Additional Information- Water Use for Aquaculture

2 Pages

Figures for the costs were provided by the British Aquaculture Federation (Slaski, pers.comm., 18th June 2004) and are provided below.

Electrical consumption

Electrical consumption of a model 2007 is 1.1 kW. Based on 729 units being required to treat 4.4 million m^3 per day, and at an assumed energy cost of £0.06/kWh, this suggests a daily energy cost of £115.34. For 4.4 million m^3, this means a unit cost of 0.026p/m^3.

Capital depreciation

The capital cost for installing the filter in question is around £33,000. For 729 units, with a 15 year depreciation schedule, the daily 'cost' would be £4394. The cost per unit volume of water would therefore be 0.10p/m^3.