Environmental sensitivity assessment of retail filling stations in selected European countries

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ABSTRACT

The environmental sensitivity of approximately 86,000 retail filling stations in 13 European countries has been assessed with regard to groundwater, surface water and ecological receptors using a source-pathway-receptor and Geographical Information System (GIS) based methodology. The information is stored in a CONCAWE database.

Across all thirteen countries the results demonstrate that, based on their location alone (i.e. irrespective of containment engineering standards which can reduce environmental risk), the percentage of retail filling stations with the potential to pose a risk to the receptors in question is small: 5% with respect to potable water (groundwater and surface water) abstractions, 8% with respect to the ecology of surface water bodies and 3% with respect to designated Natura 2000 sites (protected habitats and ecosystems).

Information in the database can be used to:

- Support a site-specific, risk-based approach to the implementation of environmental regulations and the management of groundwater contamination.
- Develop pro-active environmental risk management strategies for networks of retail filling station sites appropriate to their environmental risk profile.
- Inform decisions regarding the environmental liability potential of sites during acquisitions, divestments and site swaps.

KEYWORDS

Ecosystems, environmental sensitivity, GIS, groundwater, hydrogeology, retail filling stations, risk assessment, surface water

INTERNET

This report is available as an Adobe pdf file on the CONCAWE website (www.concawe.org).

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Nature Division of the administration of Environment, Nature, Country and Water management (AMINAL) of the department of Environment and Infrastructure (LIN) of the Ministry of the Flemish Province (MVG), Brussels

Czech Republic
Ministry of Environment of the Czech Republic - Agency for Nature Conservation and Landscape Protection, Prague
SG Geotechnika a.s, Prague

Denmark
Danish Petroleum Industry (OFR), Copenhagen
DHI Water & Environment, Hørsholm
Geological Survey of Greenland and Denmark (GEUS), Copenhagen
National Environmental Research Institute (DMU), Roskilde

Finland
AC Nielsen Company, Helsinki
The Finnish Environment Institute, Helsinki
National Land Survey of Finland, Helsinki
Ramböll Sverige AB, Gothenburg (Sweden)

France
BRGM French Geological Survey, Orléans
IGN (Institut Géographique National), Paris
MEDD (Ministere de l'Ecologie et du Developpement Durable), Paris
SANDRE (Le Service d'Administration Nationale des Données et Référentiels sur l'Eau), Limoges

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<u>Poland</u>
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IMAGIS, Warsaw
Institute of Geodasy and Cartography, Warsaw
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SUMMARY

This study has assessed the environmental sensitivity of approximately 86,000 retail filling station locations across 13 European countries, with regard to groundwater, surface water and ecological receptors, using a source-pathway-receptor and Geographical Information System (GIS) based methodology. The scale of the study allows the results to be applied and examined at a European, national, regional and site level.

The objectives of this study were to:

- Assess the scale of the risk potential posed by retail filling stations in a range of countries across Europe to groundwater, surface water and important ecosystems (that may be impacted via the groundwater migration pathway), arising from leaks and spills to land irrespective of containment engineering standards (e.g. type and age).
- Identify countries or regions of countries with high environmental risk potential.
- Enable oil companies to pro-actively develop environmental risk management strategies at retail filling stations appropriate to the environmental risk potential, as a cost effective, more sustainable alternative to “one size fits all”.
- Support a site specific, risk-based approach to management of groundwater contamination and implementation of the EU Water Framework, Groundwater and Habitats Directives.

The key findings and conclusions are as follows:

- Across all thirteen countries the results demonstrate that, based on their location alone (i.e. irrespective of containment engineering standards which can reduce environmental risk) the percentage of retail filling stations with the potential to pose a risk to the receptors in question is small: 5% with respect to potable water (groundwater and surface water) abstractions, 8% with respect to the ecology of surface water bodies and 3% with respect to designated Natura 2000 sites (protected habitats and ecosystems). As expected, there are differences between the individual countries, but in general these are not large. Whilst there is a desire to protect and improve the quality of all water bodies across Europe, the most sustainable approach to managing the potential risks to water quality from industrial facilities is to take a site-specific, risk-based approach to prevention and remediation. For example, when natural attenuation processes will be sufficiently effective reducing petroleum hydrocarbon concentrations, a remedial control approach is much more sensible when these concentrations are posing no health or environmental risks now or in the future, particularly. The alternative intrusive remediation might entail a higher environmental impact taking into account the energy required and the emissions associated with this.
- Patterns in environmental sensitivity at retail filling station locations can vary at a national, regional and local level.
- The availability, parameter definitions, quality and scale of environmental data across Europe are not consistent, meaning that inter-country comparisons should be carried out with appropriate caution.

- Groundwater protection zones (GPZ) are an important concept in protecting public water supplies in any country; however, they have also proved to be by far the most inconsistent data type used within this study. Some countries or regions of countries have yet to define GPZs.
- The variability in hydrogeology and lack of standardisation in definition of key parameters that define environmental risk potential across Europe strongly supports a national, rather than Europe-wide approach to the assessment and management of environmental risks posed by groundwater contamination and the implementation of the Water Framework and Groundwater Directives.
- The database can be used as a screening tool for ranking sites in terms of the environmental sensitivity of their location, irrespective of containment engineering standards. It can be used to identify those in the most sensitive locations for further investigation at a site-specific level, enabling resources and investment to be applied rationally (i.e. where most needed) when it comes to prevention, investigation and remediation of groundwater contamination.

1. INTRODUCTION

The EU Water Framework [1], Groundwater [2] and Habitats [3] Directives will result in greater focus from the competent authorities in Member States on groundwater and surface water quality from both a chemical and ecological perspective. Downstream oil industry facilities potentially pose potential risks to groundwater and surface water quality arising from leaks and spills to land. Surface waters and their associated ecosystems can be impacted by groundwater contamination plumes discharging as a component of base flow.

This report focuses on the environmental sensitivity of retail filling stations. Future reports may focus on refineries, terminals, depots and pipelines.

Three elements are required to manifest an environmental risk [4]. There must be a sensitive receptor, a source of contamination and a pathway by which the receptor can be exposed to the contamination. If any one of these three elements (source, pathway or receptor) is missing there can be no risk.

The environmental risk potential differs from site to site, because location plays a key role in determining the risk (e.g. proximity of potential receptors, role of geology and hydrogeology in migration and exposure pathways). The environmental risk potential of an individual facility is also a function of the integrity of its assets (potential for leaks), its operational procedures (potential for spills) and the nature and volume of products stored, all of which determine its potential to act as a source of contamination.

The most cost-effective way to assess the environmental risk profile of a network of sites is to take a tiered approach. In the first instance it is important to understand the inherent environmental risk potential due to a site's location, irrespective of the condition of the assets and the operational procedures. The latter can be factored into the risk potential profile at a higher tier assessment.

The inherent environmental risk potential of a network of sites based on location can be assessed in the first instance by a desk study exercise that covers the proximity of potential receptors and the potential for migration and exposure pathways (e.g. groundwater vulnerability assessment). Sites can be ranked according to their environmental risk potential using either a numerical scoring system or a categorisation system. Numerical scoring systems suffer from a number of drawbacks that can be overcome by using categorisation systems.

These include:

1. Potential bunching and loss of clear discrimination if more than a few parameters are used. Multiple sub-categories within major categories can overcome this.
2. Too much focus on a number losing sight of what is actually driving the environmental risk potential which is key to managing the risk. In a categorisation system the category title describes the risk.
3. False sense of accuracy based on a number.
4. Disagreements about where to draw lines between high, medium and low risk, but there are no “bright lines” in a scoring system.

In this study a very high-level categorisation system has been used to evaluate the environmental risk potential of retail filling stations in a number of countries. There is nothing to stop these high level categories being broken down into multiple sub-categories with further, more detailed, data gathering and analysis.

A GIS (geographic information system) based methodology using ESRI ArcGIS Desktop 9.3 software has been used in which the location of the retail filling stations has been overlaid on maps of aquifer type, groundwater vulnerability, groundwater protection zones, surface waters, protected ecosystems etc. All the information used in the analysis was in the public domain, although not always readily or freely available.

This report summarises the key findings of the study across Europe and interprets them. There are separate country specific reports. All the raw data are held in a GIS database. Information on specific sites or networks of sites within a country can be extracted providing the Catalist[1] number(s) of the site(s) are known. The database only represents a snapshot in time (2005–2007), however it is expected to be a valuable source of information for some time to come. Furthermore, the CONCAWE membership will decide whether expanding the database to the EU Countries not currently covered, adding additional site-specific information and updating the database in the future (e.g. 5-yearly updates) are feasible and worthwhile.

Potential uses of the results of this study include:

- Support the continuing development of a site specific, risk-based approach to the management of groundwater contamination which is coming under challenge from some governments' regulatory authorities.
- Support a practical, site specific, risk-based approach to implementation of the EU Water Framework [1], Groundwater [2] and Habitats [3] Directives that is more sustainable than a "one size fits all" approach favoured by some regulatory authorities. The latter can actually be responsible for prolonging environmental damage by not supporting environmental risk-based prioritisation of investment in site investigation, remediation and upgrading of site assets, such that sites causing real risks to the environment are not prioritised over the rest.
- Enable oil companies to pro-actively develop environmental risk management strategies at retail filling stations appropriate to the environmental risk potential posed, as a cost effective, more sustainable alternative to "one size fits all" (i.e. don't under-invest in sites with high environmental risk potential or over-invest in sites with low environmental risk potential.
- Enable the oil companies to prioritise the use of their resources to improve, as required, those locations that display the higher risk profile.
- Enable oil companies to prioritise action to comply with the Water Framework and Groundwater Directives, which require the entry of polluting substances into groundwater to be prevented or limited to prevent pollution [5].
- A source of environmental information in due diligence during acquisitions, divestments and site swaps to indicate the requirement to further assess the environmental risk potential of sites.

[1] Experian® Catalist produces commercial databases of retail filling station information in selected European countries (http://www.catalist.com)

2. OBJECTIVES

The objectives of this study were to:

- Assess the scale of the environmental risk potential posed by retail filling stations in a range of countries across Europe to groundwater, surface water and important ecosystems (that may be impacted via the groundwater migration pathway), arising from leaks and spills to land irrespective of containment engineering standards (e.g. filling station type and age).
- Identify countries or regions of countries with high environmental risk potential.
- Enable oil companies to pro-actively develop environmental risk management strategies at retail filling stations appropriate to the environmental risk potential as a cost effective, more sustainable alternative to "one size fits all".
- Support a site specific, risk-based approach to preventing and managing groundwater contamination and implementation of the EU Water Framework [1], Groundwater [2] and Habitats [3] Directives.

3. METHODOLOGY

The project has been carried out using a phased approach over a period of 3 years, as outlined below.

3.1. PHASE I – IDENTIFICATION OF COUNTRIES FOR FURTHER STUDY IN PHASE II

The objective of Phase I was to assess the feasibility of conducting environmental sensitivity assessments for selected countries in Phase II. The principal tasks required to achieve this were:

- Define hydrogeological regions across Europe.
- Collect, compile and map statistical data on groundwater use in Europe.
- Confirm the existence, availability and cost of digital environmental data and locations of retail filling stations.
- Select a set of countries and/or regions with good data availability and spread of environmental conditions representative of those found across Europe, for an environmental sensitivity assessment to best represent groundwater use in Europe.

3.1.1. Hydrogeological Units and Groundwater Use in European Countries

A total of 16 hydrogeological units were identified and defined with reference to the Hydrogeological Map of Europe [6] produced by the International Association of Hydrogeologists (IAH) and UNESCO. In addition, national, and where appropriate, regional statistics on groundwater usage were collected from published sources in each country. Subject to data availability, statistics were collated in various forms, including:

- Groundwater as a proportion of total water supply
- Groundwater as a proportion of potable water supply
- Groundwater use per capita

3.1.2. Shortlist Countries/Regions for Environmental Sensitivity Assessment

A short-list of 13 countries to undergo the Environmental Sensitivity Assessment (Phase II) was compiled through consideration of data availability, data coverage and data comparability. The thirteen countries were as follows:

- Austria	- France	- Norway
- Belgium	- Germany	- Poland
- Czech Republic	- Italy (selected regions only)	- Spain
- Denmark	- Netherlands	- United Kingdom (excl N. Ireland)
- Finland		

These countries were also selected to represent much of the diversity in the hydrogeological conditions across Europe.

The number of retail stations in these countries represent approximately 90 % of the total number of stations in the EU.

For a full report of the feasibility study see **Appendix 1**.

3.2. PHASE II – COUNTRY SPECIFIC ASSESSMENTS

For the purposes of assessing the environmental sensitivity of retail filling station locations the following was undertaken for each country included in Phase II:

- The relevant digital datasets were collated and compiled into a format which would enable the data assessment;
- The data were processed, using GIS techniques; and
- The results of the data processing were assessed for each country.

The precise methodology for assessing environmental sensitivity at retail filling station locations varied slightly for each country, dependant on the available data. The following sections explain the principles of the general method employed for all countries, whilst country specific information can be found in the individual country reports included within **Appendices 4 - 16** of this report.

3.3. DATA AVAILABILITY

In order to assess data availability as part of the Phase I activities, questionnaires, supported by explanations of the principles and objectives of the project, were sent out to project partner organisations identified by Arcadis GMI in each European country, outlining the types of data required.

For undertaking the environmental sensitivity assessment, the availability of data for the following parameters was defined as a minimum in order to allow the assessment to proceed:

- Aquifer boundaries / groundwater vulnerability
- Groundwater protection zones (GPZs)
- Surface water network
- Natura2000 ecological areas

Where groundwater protection zone data were unavailable, data on groundwater abstraction locations were requested, with a view that a series of buffer zones could be modelled around the abstractions to represent groundwater protection zones. For ecologically sensitive areas, if data relating to areas protected by national legislation were available in addition to the Natura2000 datasets, these were also requested.

There was little uniformity in data consistency and formats across the community; however, there are broad similarities across most countries. Two common issues emerged during this data evaluation stage. First, for countries with federal structures, it became apparent that it would be difficult and extremely time consuming to compile information at a national level. Secondly, although it was noted that many of the recently joined EU members were compiling information with implementation of the Water Framework Directive [5] in mind, few of these countries had established transparent procedures for accessing the information.

3.4. DATA COLLECTION

Using the contacts established during Phase I, Arcadis GMI co-ordinated the task of carrying out the digital data collection in each country. In some countries, where

Arcadis GMI had the relevant contacts and in-house knowledge, the data collection process was undertaken directly with the data suppliers. Each contact was asked to collect digital GIS data relating to groundwater, surface water, and ecologically sensitive areas and where necessary retail filling station location data.

3.5. DATA SOURCES

3.5.1. Retail Filling Station Locations

For many of the countries, details of the location of retail filling stations were obtained from Catalist Ltd (Bristol), an Experian company, and a leading source of retail forecourt information in Europe and beyond. Catalist's comprehensive database covers most of Western Europe and the information is continuously maintained by way of site visits, telephone surveys, client feedback and market intelligence. Catalist is part of Experian's Business Strategies Division, a leading provider of global retail property data, analysis and consultancy. Catalist Ltd was able to supply grid reference listings of retail filling station locations for the following countries:

- Austria	- Germany	- Norway
- Belgium	- Italy	- Spain
- France	- Netherlands	- UK (excl N. Ireland)

For those countries where the Catalist database did not hold the relevant information, data were sourced through the contacts that Arcadis GMI used to obtain the relevant environmental data in these countries. These retail filling station location lists were believed to be as complete as is reasonably practicable for the purposes of this study.

3.5.2. Potential Environmental Receptor Data

Table 1 provides details by country of the relevant organisations that supplied the environmental datasets required to complete the environmental sensitivity assessment, along with those organisations that provided retail filling station locations in the absence of Catalist data, and where applicable, the organisations that conducted the data collection process in each country.

Table 1 Project Data Suppliers

Country	**Organisation**	**Data Supplied**
Austria	Pistecky Consulting & Engineering, Vienna	Surface Water Data & *Data Collection Process*
	Austrian Federal Environment Agency, Vienna	Aquifer / Groundwater Vulnerability Data
	Provincial Governments of Austria: Lower Austria, Upper Austria, Vienna, Styria, Carinthia, Salzburg, Tyrol, and Vorarlberg	Groundwater Protection Zones & Ecologically Sensitive Areas
Belgium	ARCADIS Gedas NV, Antwerpen	*Data Collection Process (Flanders Only)*
	Nature Division of the administration of Environment, Nature, Country and Water management (AMINAL) of the department of Environment and Infrastructure (LIN) of the Ministry of the Flemish Province (MVG), Brussels	Aquifer / Groundwater Vulnerability Data, Groundwater Protection Zones, Surface Water Data & Ecologically Sensitive Areas *(Flanders Only)*
	Ministry of the Walloon Region's General Directorate of Natural Resources and the Environment (MRW-DGRNE), Namur	Aquifer / Groundwater Vulnerability Data, Groundwater Protection Zones, Surface Water Data & Ecologically Sensitive Areas *(Wallonia Only)*
Czech Republic	SG Geotechnika a.s, Prague	*Data Collection Process*
	Ministry of Environment of the Czech Republic - Agency for Nature Conservation and Landscape Protection, Prague	Aquifer / Groundwater Vulnerability Data, Groundwater Protection Zones, Surface Water Data & Ecologically Sensitive Areas
Denmark	DHI Water & Environment, Hørsholm	Aquifer / Groundwater Vulnerability Data & *Data Collection Process*
	Danish Petroleum Industry (OFR), Copenhagen	Retail Filling Station Locations
	Geological Survey of Greenland and Denmark (GEUS), Copenhagen	Groundwater Abstraction Data
	National Environmental Research Institute (DMU), Roskilde	Surface Water Data & Ecologically Sensitive Areas
Finland	Ramböll Sverige AB, Gothenburg (Sweden)	*Data Collection Process*
	AC Nielsen Company, Helsinki	Retail Filling Station Locations
	The Finnish Environment Institute, Helsinki	Groundwater Protection Zones & Ecologically Sensitive Areas
	National Land Survey of Finland, Helsinki	Surface Water Data
France	SANDRE (Le Service d'Administration Nationale des Données et Référentiels sur l'Eau), Limoges	Aquifer / Groundwater Vulnerability Data
	BRGM French Geological Survey, Orléans	Groundwater Abstraction Data
	IGN (Institut Géographique National), Paris	Surface Water Data
	MEDD (Ministere de l'Ecologie et du Developpement Durable), Paris	Ecologically Sensitive Areas
Germany	Arcadis Consult GmbH, Darmstadt	*Data Collection Process*
	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover	Aquifer / Groundwater Vulnerability Data
	Governments of the individual Federal States (15 in total, excluding Thuringia)	Groundwater Protection Zones
	Bundesamt für Kartographie und Geodäsie (BKG), Frankfurt	Surface Water Data
	Bundesamt für Naturschutz, Bonn	Ecologically Sensitive Areas
Italy	Governments of the individual Regions, Departments of Environment and Water: Emilia-Romagna, Lazio, Lombardy, Piedmont and Veneto	Aquifer / Groundwater Vulnerability Data, Groundwater Protection Zones, Groundwater Abstraction Data, Surface Water Data & Ecologically Sensitive Areas
The Netherlands	Arcadis NV, Arnhem	Aquifer / Groundwater Vulnerability Data, Groundwater Protection Zones, Surface Water Data, Ecologically Sensitive Areas & *Data Collection Process*

Country	Organisation	Data Supplied
Norway	Geological Survey of Norway (NGU), Trondheim	Aquifer / Groundwater Vulnerability Data, & Groundwater Abstraction Data
	Ugland IT Group AS, Lysaker	Surface Water Data
	Direktoratet for naturforvaltning, Trondheim	Ecologically Sensitive Areas
Poland	Arcadis Ekokonrem, Wroclaw	Aquifer / Groundwater Vulnerability Data & *Data Collection Process*
	IMAGIS, Warsaw	Retail Filling Station Locations
	Ministry of Environment of Poland -Institute of Environmental Protection, Warsaw	Groundwater Protection Zones & Ecologically Sensitive Areas
	Institute of Geodasy and Cartography, Warsaw	Surface Water Data
Spain	Instituto Geologico y Minero de Espana (IGME), Madrid	Aquifer / Groundwater Vulnerability Data & Groundwater Abstraction Data
	CEDEX Ministerio de Fomento – MMA, Madrid	Surface Water Data & Ecologically Sensitive Areas
United Kingdom	Environment Agency of England & Wales, Bristol & Scottish Environment Protection Agency, Stirling	Aquifer / Groundwater Vulnerability Data, Groundwater Protection Zones & Groundwater Abstraction Data
	eMapSite, Bracknell	Surface Water Data
	Natural England, Sheffield & Countryside Council for Wales, Bangor & Scottish Natural Heritage, Inverness	Ecologically Sensitive Areas

3.6. DATA COVERAGE

Prior to Phase II, it was clear that the geographical coverage of data in Italy was not complete. Therefore only selected regions in Northern Italy (Emilia Romagna, Lombardy, Piedmont and Veneto) along with the Lazio region were taken forward to Phase II. Likewise, in the UK, it was known that data availability for Northern Ireland was limited, and these data were therefore omitted from the UK study. However, as the project progressed, it became apparent that data availability for some regions within other study countries was also limited. After consultation it was decided that the following regions had to be omitted from the initial study until a time when the data are more accessible:

- Burgenland – Austria
- Thuringia – Germany

3.7. DATA PROCESSING

Two types of groundwater data were requested for each country:

3.7.1. Aquifer Boundaries / Groundwater Vulnerability

Each country within the study, with the exception of Finland, was able to supply a data coverage relating to either aquifer boundaries or groundwater vulnerability. The method by which each country has defined this coverage varies, but in all cases it was possible to sub divide the data to define three classes, based on definitions used in the UK (for standardisation purposes), that represent a ‘major aquifer’ class, a ‘minor aquifer’ class, and a ‘non aquifer’ class. For reference, the definitions in the UK are stated on the groundwater vulnerability maps produced by the Environment Agency of England & Wales, and are as follows:

- Major Aquifer – Highly permeable formations usually with a known or probable presence of significant fracturing. May be highly productive and able to support large abstractions for public supply and other purposes.

- Minor Aquifer – Can be fractured or potentially fractured rocks, which do not have a high primary permeability, or other formations of variable permeability including unconsolidated deposits. Although these aquifers will seldom produce large quantities of water for public water supply abstraction, they are important both for local domestic and commercial supplies and in supplying base flow to rivers.
- Non-Aquifer – Formations which are generally regarded as containing insignificant quantities of groundwater.

In Finland, almost all of the geology is classified as "locally aquiferous or practically non-aquiferous, porous or fissured rocks" on the International Hydrogeological Map of Europe [7]. As a result, it was felt that the limited extents of the groundwater protection zones were adequate to describe the overall groundwater sensitivity in Finland.

An aquifer map for each country was produced based on the three tiered classification system, from which the underlying aquifer class was assigned to each retail filling station location.

3.7.2. Groundwater Protection Zones

Data relating to GPZs varied greatly between, and even within, countries and in some cases was unavailable. The method by which each country has defined their GPZs has been described in the country reports in Appendices 4 - 16. The main principal behind the GPZ analysis in this study was to sub divide the data to define three classes of GPZ, dependent on the proximity to a groundwater abstraction. Zone 1 represents the area immediately surrounding an abstraction and in which the highest level of protection applies. Zone 3 represents the area of total catchment for public drinking water supply abstraction. In most countries, dividing GPZs into three classes was possible, however, in some regions and countries, only two categories of GPZ are designated by the relevant regulatory authority, and in these instances, no zone 3 was defined.

In countries and regions where GPZ data were unavailable (Denmark, France, Norway, Spain and certain regions of Italy), 'buffer zones' around groundwater abstractions were used. These 'buffer zones' were set at distances of 50 m (zone 1), 100 m (zone 2), and 250 m (zone 3) from the groundwater abstractions. The distances were based on experience of the travel distance of the most mobile petroleum hydrocarbons in groundwater. It is rare for petroleum hydrocarbon plumes to travel greater than 100 m from the edge of a source and most plumes are only a few tens of metres in length [8]. There are some notable exceptions to this "rule of thumb", but the objective of this project was to develop a methodology that identified 90% of sites with high risk potential. If the mesh size of a tier 1 risk assessment is set too fine it becomes a funnel rather than a sieve which is counter-productive to identifying sites with real environmental risk potential.

Although the use of 'buffer zones' as alternatives to GPZs is not ideal, given the context of the study and the available information, it was felt that building in this approach would provide a useful dataset for comparative analysis until actual GPZ data become available.

As a check, the buffer zones were calibrated against the data for several countries where GPZ data existed (see **Appendix 2**).

A GPZ map for each country was produced based on the three-tiered classification system. This was applied in the assignment of the underlying GPZ classification to each retail filling station location.

3.7.3. Surface Water Data

Surface water comprised information on lakes, reservoirs, rivers, streams and coastlines. It was collected in digital format as GIS vector files or river networks, lake outlines and coastal outlines.

The surface water data analysis was performed using a 'Spatial Join' operation within the GIS. This procedure identified from the surface water datasets the nearest surface water feature (river, lake, and coastal data) to each retail filling station location and calculated the distance to the nearest metre, which was then stored as an attribute of the retail filling station location.

For Denmark and the UK, an identical technique was applied, however the analysis was carried out by a third party. This was done to allow more detailed surface water coverage to be used, where the cost of purchasing the dataset was excessive, but the quality of alternative datasets was not suitable. In these instances, the third party was supplied with the list of retail filling station locations, and returned the same list with a distance attached to each record.

3.7.4. Ecologically Sensitive Areas Data

All the data relating to ecologically sensitive areas, including Natura2000[2] sites, within each country were merged together to create a countrywide dataset. The data comprised GIS files of polygons for each Natura2000 designated site. From this, the proximity of the retail filling station locations to the ecologically sensitive areas could be calculated within the GIS. These proximities were then recorded as an attribute of the retail filling station location data.

3.8. DATA ANALYSIS

On completion of the GIS data processing, each retail filling station location was assessed for its sensitivity with regard to groundwater, surface water, and ecologically sensitive areas. Each site was classified into one of five categories, where Category 1 was the most sensitive and Category 5 was the least sensitive. An overall environmental sensitivity was then assigned based on the most sensitive category allocated from the three individual environmental parameters. The classification scheme is outlined in **Table 2**. Cut-off distances are based on experience of travel distances of petroleum hydrocarbons dissolved in groundwater.

[2] For more information see http://ec.europa.eu/environment/nature/natura2000/index_en.htm

Table 2 Environmental Sensitivity Classification Scheme

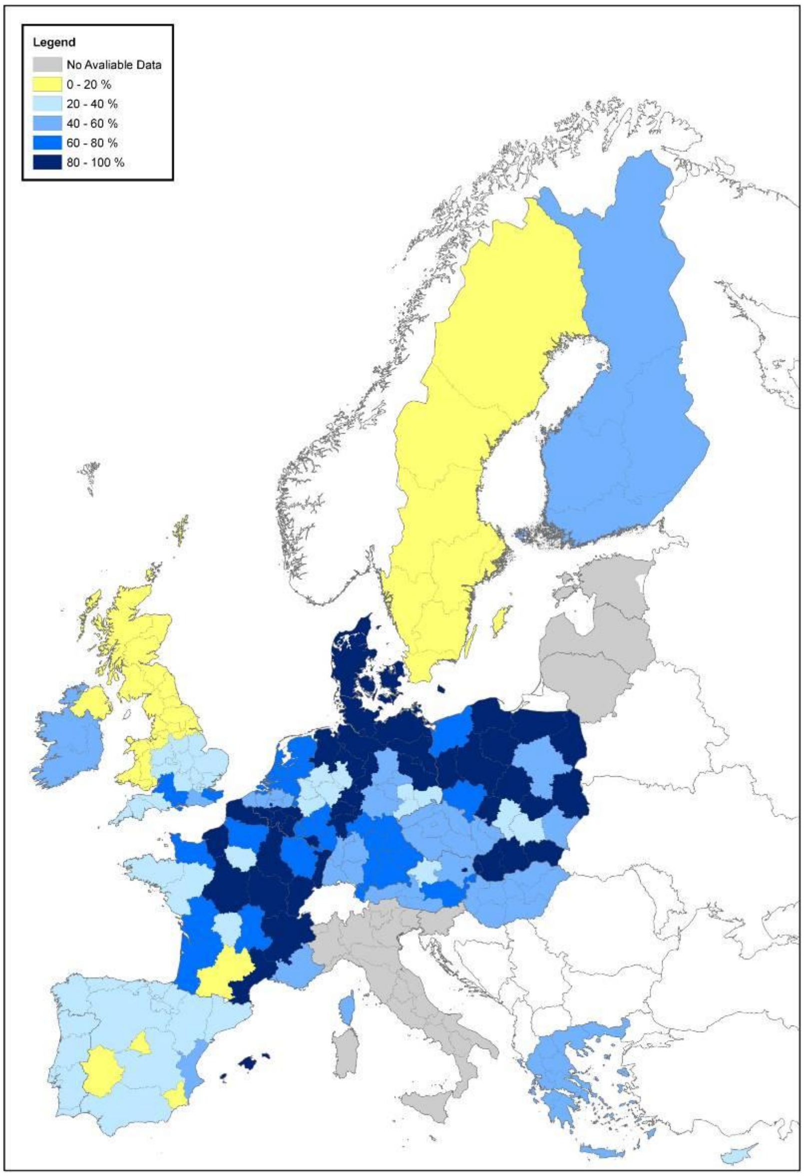
	Sensitivity Category						
	Category 1	**Category 2**	**Category 3** **a**	**b**	**c**	**Category 4**	**Category 5**
Groundwater Sensitivity	Within a GPZ1	Within 100 m of a GPZ1 GPZ2 **AND** Major Aquifer Class	Other GPZ2	GPZ3	Not in a GPZ but on, or within 100m of a Major Aquifer Class	Minor Aquifer Class **AND** not in a GPZ	Non-Aquifer Class **AND** not in GPZ
Surface Water Sensitivity	< 25 m	25-50 m	50-100 m			100-250 m	> 250 m
Ecological Sensitivity	Within	< 50 m	50-100 m			100-250 m	> 250 m
Overall Environmental Sensitivity	Defined by whichever of groundwater, surface water and ecological categories are most sensitive						

4. RESULTS

4.1. SOURCE OF DRINKING WATER ACROSS EUROPE

During Phase I of the study, a European wide assessment was undertaken to look at the importance of groundwater as a source of drinking water. Statistics were collected on a regional basis, where available, for groundwater as a percentage of potable water supplies. The results of this assessment are displayed in **Figure 1**, which highlights the variability of groundwater as a source of potable supply both across and within European countries. In particular, it highlights the importance of groundwater as a source of potable supply across Denmark, Poland and northern Germany, along with the Paris basin and sub-alpine basin regions of France. For a more detailed breakdown of the data see **Appendix 3**.

Figure 1 Groundwater Abstraction as a Percentage of Potable Water Supplies



4.2. ENVIRONMENTAL SENSITIVITY ANALYSIS

The methodology for the environmental sensitivity analysis allows the results to be broken down into the individual components of groundwater sensitivity, surface water sensitivity and ecological sensitivity. The results for overall environmental sensitivity were then assigned based on the most sensitive category allocated from the three individual environmental parameters.

4.2.1. Groundwater

The results for the analysis of groundwater sensitivity by country are presented in **Table 3**, and graphically in **Figure 2**.

4.2.2. Surface water

The results for the analysis of surface water sensitivity by country are presented in **Table 4**, and graphically in **Figure 3**.

4.2.3. Ecologically sensitive areas

The results for the analysis of ecological sensitivity by country are presented in **Table 5**, and graphically in **Figure 4**.

4.2.4. Overall environmental sensitivity

The results for the analysis of overall environmental sensitivity by country are presented in **Table 6**, and graphically in **Figure 5**.

Table 3 Groundwater Sensitivity Results

Country		**Total**	**Cat 1**	**Cat 2**	**Cat 3a**	**Cat 3b**	**Cat 3c**	**Cat 4**	**Cat 5**
Austria	Sites	2653	52	160	23	45	1664	444	265
	%age	*100%*	*2%*	*6%*	*0.9%*	*1.7%*	*63%*	*17%*	*10%*
Belgium	Sites	3528	4	20	3	41	653	2458	349
	%age	*100%*	*0.1%*	*0.6%*	*0.1%*	*1.2%*	*19%*	*70%*	*9.9%*
Czech Republic	Sites	1756	0	17	77	210	202	559	691
	%age	*100%*	*0%*	*1%*	*4.4%*	*12%*	*12%*	*32%*	*39%*
Denmark*	Sites	2260	8	24	17	170	598	980	463
	%age	*100%*	*0.4%*	*1.1%*	*0.8%*	*7.5%*	*26%*	*43%*	*20%*
Finland	Sites	2329	156	83	n/a	57	n/a	n/a	2033
	%age	*100%*	*6.7%*	*3.6%*	*n/a*	*2.4%*	*n/a*	*n/a*	*87%*
France*	Sites	14600	7	11	14	188	7030	3735	3615
	%age	*100%*	*0.05%*	*0.1%*	*0.1%*	*1.3%*	*48%*	*26%*	*25%*
Germany	Sites	15758	10	26	35	1878	6761	5520	1527
	%age	*100%*	*0.1%*	*0.2%*	*0.2%*	*12%*	*43%*	*35%*	*9.7%*
Italy* (5 Regions)	Sites	10877	151	469	135	370	2945	3830	2977
	%age	*100%*	*1.4%*	*4.3%*	*1.2%*	*3.4%*	*27%*	*35%*	*27%*
The Netherlands	Sites	4325	1	18	71	304	89	3129	713
	%age	*100%*	*0.02%*	*0.4%*	*1.6%*	*7%*	*2.1%*	*72%*	*16%*
Norway*	Sites	2176	2	0	3	20	164	149	1838
	%age	*100%*	*0.1%*	*0%*	*0.1%*	*0.9%*	*7.5%*	*6.8%*	*84%*
Poland	Sites	4520	396	907	7	n/a	1162	1164	884
	%age	*100%*	*8.8%*	*20%*	*0.2%*	*n/a*	*26%*	*26%*	*20%*
Spain*	Sites	8692	18	301	8	655	3708	1330	2672
	%age	*100%*	*0.2%*	*3.5%*	*0.1%*	*7.5%*	*43%*	*15%*	*31%*
United Kingdom	Sites	12482	227	431	287	917	1993	6189	2438
	%age	*100%*	*1.8%*	*3.5%*	*2.3%*	*7.3%*	*16%*	*50%*	*20%*
ALL COUNTRIES	Sites	85956	1032	2467	680	4855	26969	29487	20465
	%age	*100%*	*1.2%*	*2.9%*	*0.8%*	*5.6%*	*31%*	*34%*	*24%*

* GPZs were not available for these countries and have been estimated based on groundwater extraction locations
n/a not applicable based on how GPZs are defined

Figure 2 Groundwater Sensitivity Results

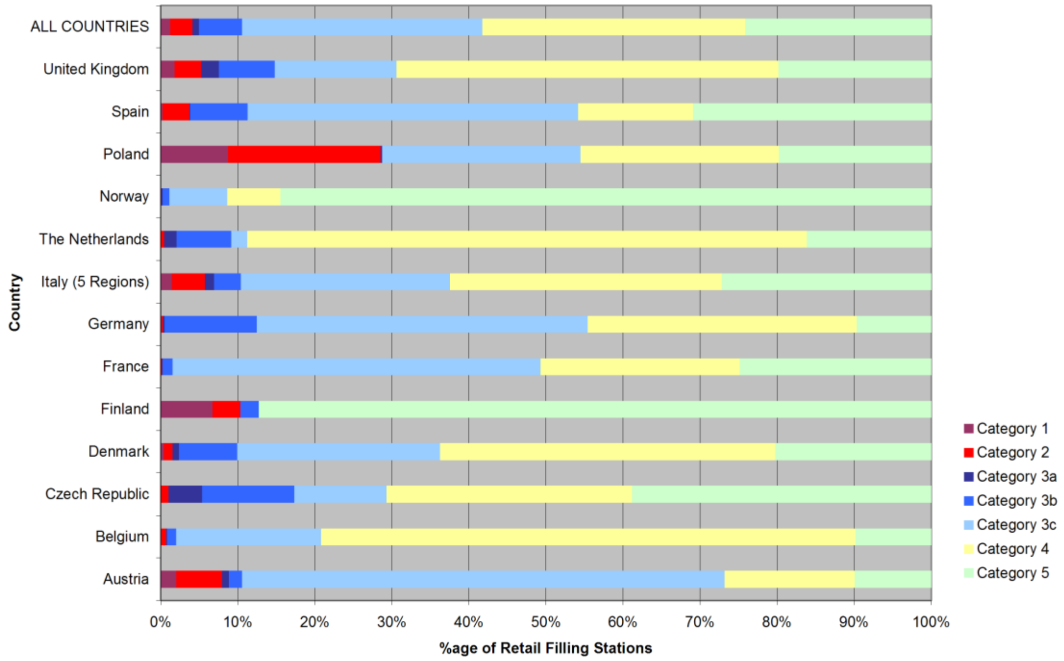


Table 4 Surface Water Sensitivity Results

Country		Total	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
Austria	Sites	2653	74	84	157	543	1795
	%age	*100%*	*2.8%*	*3.2%*	*5.9%*	*20%*	*68%*
Belgium	Sites	3528	230	210	367	914	1807
	%age	*100%*	*6.5%*	*6%*	*10%*	*26%*	*51%*
Czech Republic	Sites	1756	64	95	242	555	800
	%age	*100%*	*3.6%*	*5.4%*	*14%*	*32%*	*46%*
Denmark	Sites	2260	51	192	188	690	1139
	%age	*100%*	*2.3%*	*8.5%*	*8.3%*	*31%*	*50%*
Finland	Sites	2329	37	109	120	470	1593
	%age	*100%*	*1.6%*	*4.7%*	*5.2%*	*20%*	*68%*
France	Sites	14600	798	669	1246	2965	8922
	%age	*100%*	*5.5%*	*4.6%*	*8.5%*	*20%*	*61%*
Germany	Sites	15758	442	314	747	2632	11623
	%age	*100%*	*2.8%*	*2%*	*4.7%*	*17%*	*74%*
Italy (5 Regions)	Sites	10877	499	556	861	2065	6896
	%age	*100%*	*4.6%*	*5.1%*	*7.9%*	*19%*	*63%*
The Netherlands	Sites	4325	103	128	275	878	2941
	%age	*100%*	*2.4%*	*3%*	*6.4%*	*20%*	*68%*
Norway	Sites	2176	130	157	251	550	1088
	%age	*100%*	*6%*	*7.2%*	*12%*	*25%*	*50%*
Poland	Sites	4520	15	25	62	354	4064
	%age	*100%*	*0.3%*	*0.6%*	*1.4%*	*7.8%*	*90%*
Spain	Sites	8692	114	271	220	586	7501
	%age	*100%*	*1.3%*	*3.1%*	*2.5%*	*6.7%*	*86%*
United Kingdom	Sites	12482	533	901	1120	3361	6567
	%age	*100%*	*4.3%*	*7.2%*	*9%*	*27%*	*53%*
ALL COUNTRIES	Sites	85956	3090	3711	5856	16563	56736
	%age	*100%*	*3.6%*	*4.3%*	*6.8%*	*19%*	*66%*

Figure 3 Surface Water Sensitivity Results

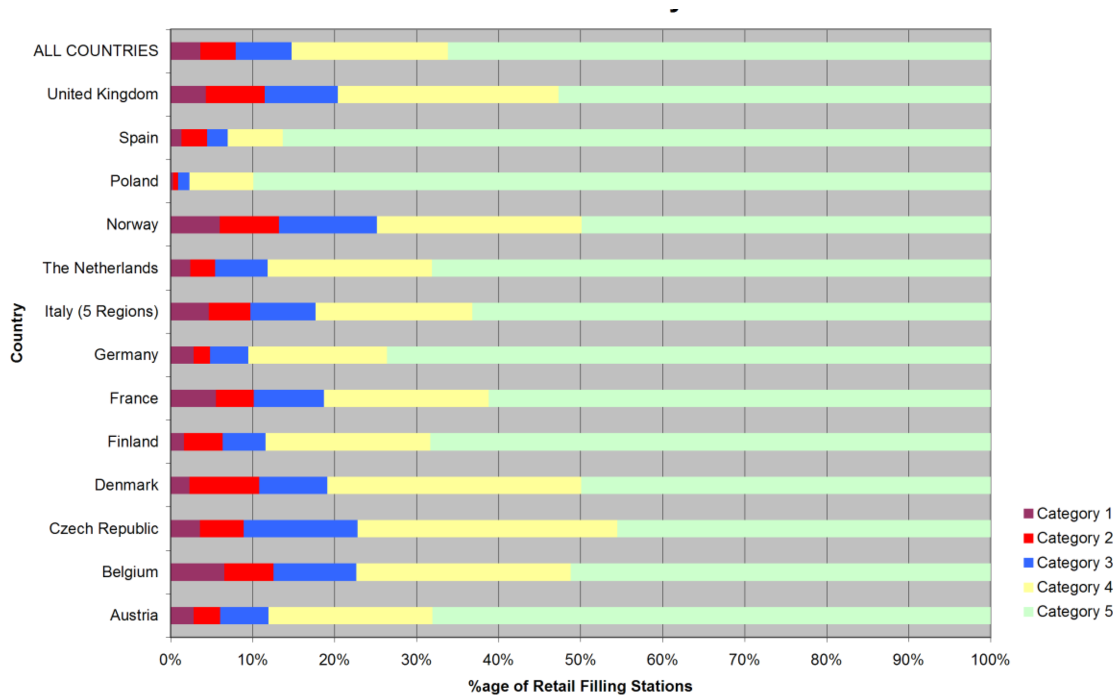


Table 5 Ecological Sensitivity Results

Country		Total	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
Austria	Sites	2653	75	39	37	101	2401
	%age	*100%*	*2.8%*	*1.5%*	*1.4%*	*3.8%*	*91%*
Belgium	Sites	3528	47	47	45	144	3245
	%age	*100%*	*1.3%*	*1.3%*	*1.3%*	*4.1%*	*92%*
Czech Republic	Sites	1756	49	15	18	43	1631
	%age	*100%*	*2.8%*	*0.9%*	*1%*	*2.4%*	*93%*
Denmark	Sites	2260	4	7	14	60	2175
	%age	*100%*	*0.2%*	*0.3%*	*0.6%*	*2.7%*	*96%*
Finland	Sites	2329	163	8	8	27	2123
	%age	*100%*	*7%*	*0.3%*	*0.3%*	*1.2%*	*91%*
France	Sites	14600	478	150	121	411	13440
	%age	*100%*	*3.3%*	*1%*	*0.8%*	*2.8%*	*92%*
Germany	Sites	15758	186	200	276	879	14217
	%age	*100%*	*1.2%*	*1.3%*	*1.8%*	*5.6%*	*90%*
Italy (5 Regions)	Sites	10877	238	81	95	277	10186
	%age	*100%*	*2.2%*	*0.7%*	*0.9%*	*2.5%*	*94%*
The Netherlands	Sites	4325	57	19	19	65	4165
	%age	*100%*	*1.3%*	*0.4%*	*0.4%*	*1.5%*	*96%*
Norway	Sites	2176	16	11	23	47	2079
	%age	*100%*	*0.7%*	*0.5%*	*1.1%*	*2.2%*	*96%*
Poland	Sites	4520	159	23	21	49	4268
	%age	*100%*	*3.5%*	*0.5%*	*0.5%*	*1.1%*	*94%*
Spain	Sites	8692	427	0	74	184	8007
	%age	*100%*	*4.9%*	*0%*	*0.9%*	*2.1%*	*92%*
United Kingdom	Sites	12482	36	80	109	358	11899
	%age	*100%*	*0.3%*	*0.6%*	*0.9%*	*2.9%*	*95%*
ALL COUNTRIES	Sites	85956	1935	680	860	2645	79836
	%age	*100%*	*2.3%*	*0.8%*	*1%*	*3.1%*	*93%*

Figure 4 Ecological Sensitivity Results

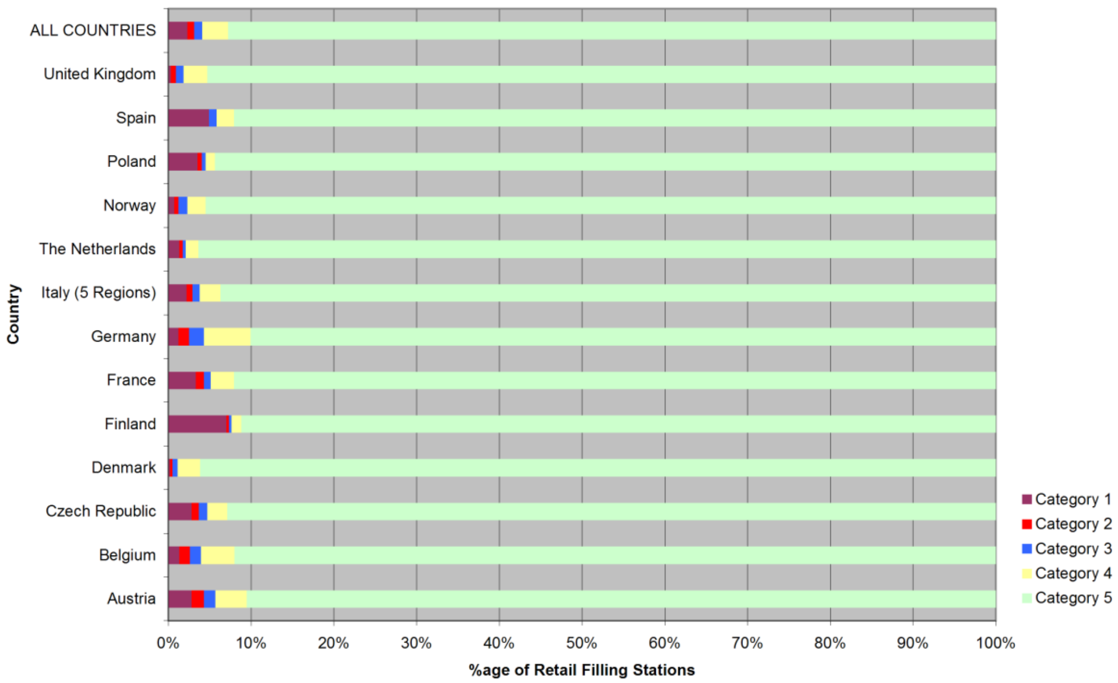
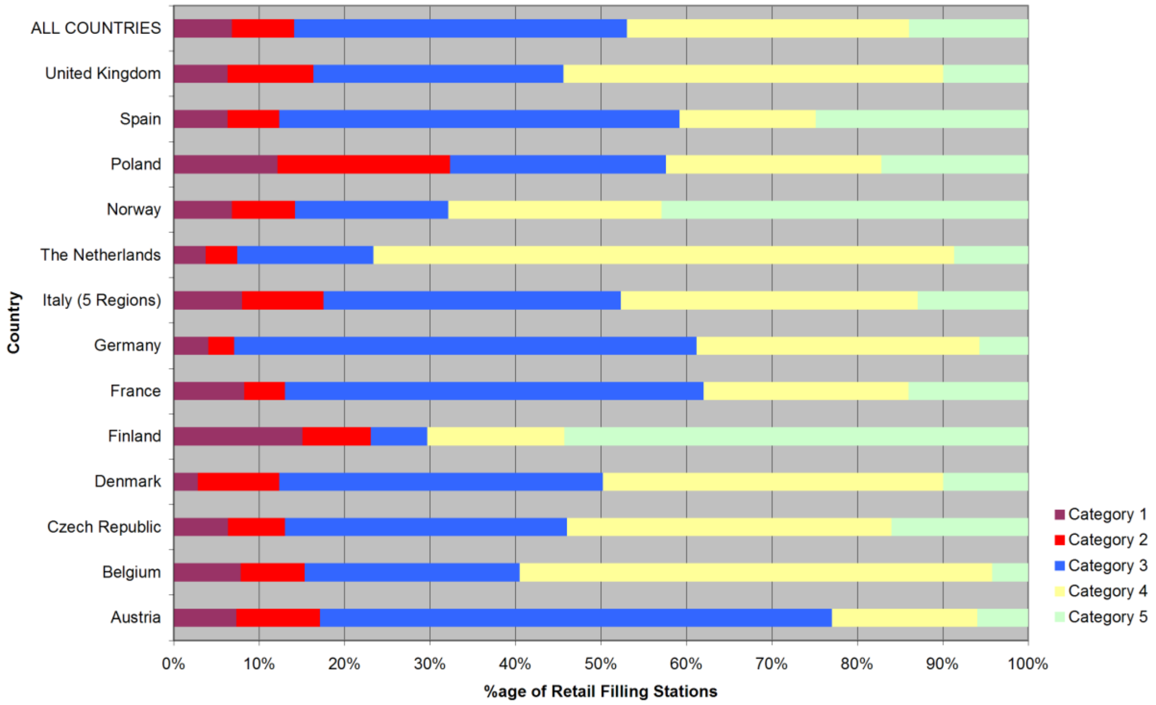


Table 6 Overall Environmental Sensitivity Results

Country		**Total**	**Cat 1**	**Cat 2**	**Cat 3**	**Cat 4**	**Cat 5**
Austria	Sites	2653	193	259	1602	441	158
	%age	*100%*	*7.3%*	*9.8%*	*60%*	*17%*	*6%*
Belgium	Sites	3528	276	262	884	1957	149
	%age	*100%*	*7.8%*	*7.4%*	*25%*	*55%*	*4.2%*
Czech Republic	Sites	1756	110	118	587	660	281
	%age	*100%*	*6.3%*	*6.7%*	*33%*	*38%*	*16%*
Denmark	Sites	2260	63	216	848	908	225
	%age	*100%*	*2.8%*	*9.6%*	*38%*	*40%*	*10%*
Finland	Sites	2329	344	184	153	382	1266
	%age	*100%*	*15%*	*7.9%*	*6.6%*	*16%*	*54%*
France	Sites	14600	1197	707	7167	3533	1996
	%age	*100%*	*8.2%*	*4.8%*	*49%*	*24%*	*14%*
Germany	Sites	15758	624	477	8510	5241	906
	%age	*100%*	*4%*	*3%*	*54%*	*33%*	*5.7%*
Italy (5 Regions)	Sites	10877	865	1040	3764	3766	1442
	%age	*100%*	*8%*	*9.6%*	*35%*	*35%*	*13%*
The Netherlands	Sites	4325	161	158	701	2928	377
	%age	*100%*	*3.7%*	*3.7%*	*16%*	*68%*	*8.7%*
Norway	Sites	2176	148	160	391	543	934
	%age	*100%*	*6.8%*	*7.4%*	*18%*	*25%*	*43%*
Poland	Sites	4520	559	905	1152	1124	780
	%age	*100%*	*12%*	*20%*	*25%*	*25%*	*17%*
Spain	Sites	8692	549	527	4069	1411	2136
	%age	*100%*	*6.3%*	*6.1%*	*47%*	*16%*	*25%*
United Kingdom	Sites	12482	773	1300	3645	5526	1238
	%age	*100%*	*6.2%*	*10%*	*29%*	*44%*	*9.9%*
ALL COUNTRIES	Sites	85956	5862	6313	33473	28420	11888
	%age	*100%*	*6.8%*	*7.3%*	*39%*	*33%*	*14%*

Figure 5 Overall Environmental Sensitivity Results



5. DATA INTERPRETATION, CONCLUSIONS AND IMPLICATIONS

5.1. DATA QUALITY AND CONSISTENCY

One of the major achievements of this study has been to bring together digital geographic datasets and retail filling station site locations from 13 European countries for the first time. However, the study has identified a number of issues relating to data consistency across, and in some cases even within, countries. This is a result of the availability, quality, format, and accessibility of datasets differing from country to country, with the structure and classification of datasets in each country reflecting their fitness for purpose for representing the way each environmental receptor is managed at a national and/or regional level. This section provides a summary of the issues encountered and addressed during the interpretation of the data within the study.

5.1.1. Groundwater data

Across Europe, the consistency of data relating to aquifer type/groundwater vulnerability and GPZs varies greatly. However, evaluating cross-border patterns, it appears that aquifer type data can be directly compared, whilst GPZ data cannot be directly compared. **Figure 6** displays the distribution of aquifers, as defined in this study, across a section of Northern Europe.

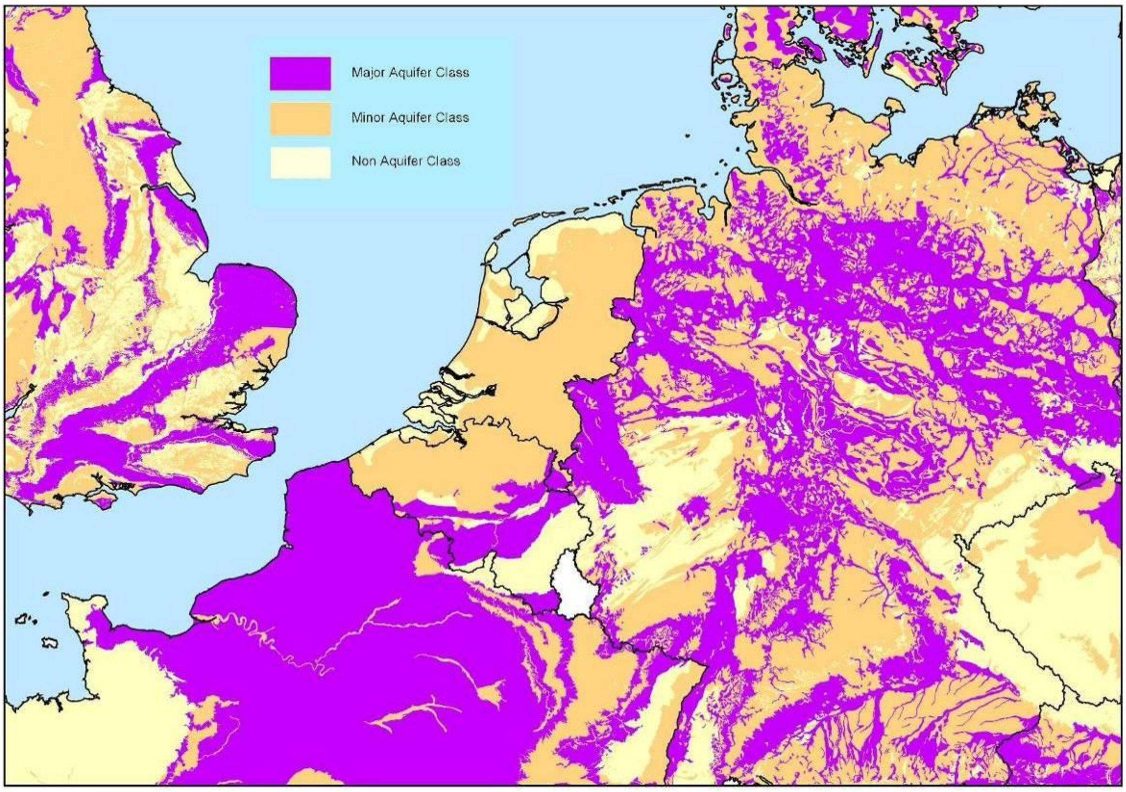
Aquifer type data were generally available as a countrywide dataset, even in those countries with a federal structure. However, the method by which each dataset had been constructed varied between countries, with a variety of methods for defining and mapping aquifers used. For example:

- By aquifer type in terms of the importance of groundwater for abstraction purposes (e.g. Denmark).
- By aquifer type in terms of the water bearing capacity of the aquifer (e.g. UK).
- By groundwater vulnerability in terms of the protection provided by overlying deposits (e.g. Poland, UK).

The mapping of an aquifer system as a 2-dimensional concept from what in reality is a 3-dimensional structure creates several limitations. Most commonly this involves the definition of which aquifer is being mapped, and whether it is shallow or deep beneath the ground surface. Unless otherwise stated in the individual country reports, it has been assumed that the aquifer being mapped is the nearest to the surface and the most likely to be impacted by a pollution event.

GPZs are a highly important concept in protecting public water supply abstractions in many countries, however, they have been the most inconsistent data type used within this study. Responsibility for groundwater protection zones varies greatly between countries and even within countries that have federal structures. For example, in some countries the regulatory authority is a government agency, whilst in others it is a private water company. In addition, the organisation responsible for mapping groundwater protection zones often differs from that regulating them. This greatly affects the quality of the mapping, and in some countries it appears that the GPZ datasets are not regularly updated or maintained.

Figure 6 Distribution of Aquifer Classes across Northern Europe



Even within countries, the way in which GPZs are defined varies, whilst in some countries and regions there is no distinction in the data between GPZs and surface water protection areas. Therefore, GPZs are not directly comparable across national borders, or in some cases within countries, due to the quality of the data available and the varying definitions used for GPZs (**Table 7**).

Table 7 Definition of Groundwater Protection Zones

Country	GPZs Defined	Regulation Basis	Digital Format	Number of GPZ Classifications	Notes
Austria	✓	Regional	✓	5	Two types of GPZ; one protects aquifers (2 Classes) and another abstractions (3 Classes)
Belgium	✓	Regional	✓	3	GPZs in Wallonia are not as established as in Flanders. No data for Brussels
Czech Republic	✓	National	✓	3	Water protection zones – not GPZs. Additional data on areas of General GW Accumulation (Natural Spring areas)
Denmark	✗	-	✗	-	Groundwater Vulnerability is focused on quality of groundwater for public supply
Finland	✓	National	✓	4	Not all GPZ have been digitally mapped to date.
France	✓	Local	✗	3	Many GPZs are yet to be designated, very few are digitally mapped. The third class of GPZ is not always defined.
Germany	✓	Regional	✓	3	Water protection zones – not GPZs. Some definitions of classes vary between regions.
Italy (5 Regions)	✓ ✗	Regional	✓ ✗	2-4	Where designated, definitions of GPZ class vary widely between regions.
The Netherlands	✓	National	✓	3	
Norway	✗	National	✗	-	
Poland	✓	National	✓	2	Spatially, GPZs are wide ranging throughout Poland.
Spain	✗	-	✗	-	
United Kingdom	✓	Regional	✓	3	GPZs only defined for England & Wales

5.1.2. Surface water data

The quality and availability of surface water data across Europe is variable. In some countries, several datasets are available at differing scales; where possible the most detailed scale of mapping was used in this study. However, in certain cases, the use of the most detailed dataset was prohibited due to cost, although, where possible, such as in Denmark and the UK, alternative methods to access the best available datasets were utilised.

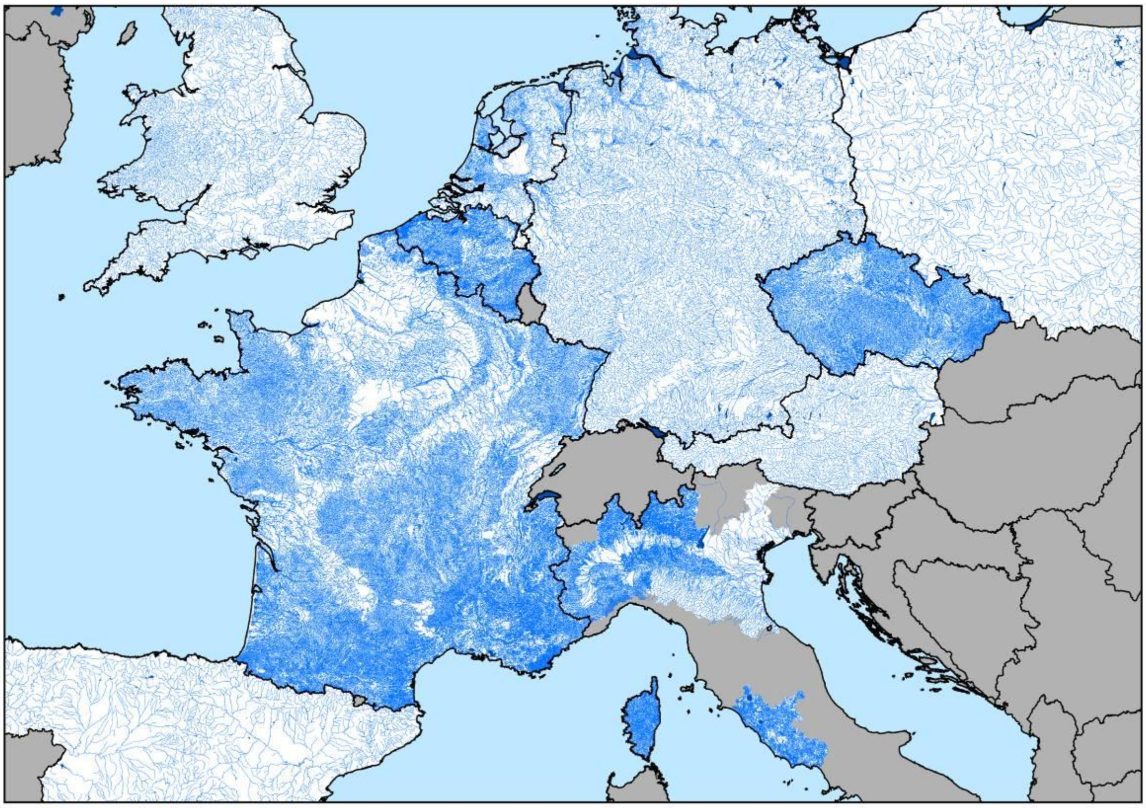
Therefore it was not possible to collate a dataset for each country using the same scale of data, and this led to initial concern about the consistency of datasets between different countries due to the variety of mapping scales. These inconsistencies were quantified according to a scale dependency exercise carried out on 2592 retail filling station locations in the UK. The study area covered the East Anglia and London regions of the UK, and represents an area where Arcadis GMI has access to surface water datasets at three different scales (1:200,000; 1:50,000; 1:1,250). Sites were assessed based on proximity to surface water features according to each of these three datasets.

The statistics generated by this study clearly suggest that the scale of the surface water data does have an effect on the apparent surface water sensitivity of retail filling station locations. Improving the scale of the data from 1:200,000 to 1:50,000 increased the number of higher sensitivity (Category 1 and 2) sites from 112 (4.3%) to 195 (7.5%) and a further increase to 247 (9.5%) was observed when the scale of the data was improved to 1:1,250. In Category 3, the number of sites increases from 58 (2.2%) to 214 (8.3%) when the scale was improved from 1:200,000 to 1:1,250 whilst in Category 4 it increased from 178 (6.9%) to 663 (26%). This pattern is not unsurprising, as it is expected that more detailed scale mapping would be more accurate, and include smaller scale surface water features such as streams and ditches. In the less detailed mapping, only larger features such as rivers and tributaries would be displayed and are likely to be more generalised in terms of the accuracy of their location.

Figure 7 displays the distribution of surface water features across a section of Northern Europe. Given the results of the scale dependency exercise, and focussing on the Czech Republic, Germany, and Poland, this figure would suggest that the surface water features are mapped at differing scales in these countries. The surface water features in the Czech Republic appear to be densely distributed suggesting a detailed mapping scale. Poland appears to have the sparsest surface water network, suggesting a less detailed scale of mapping. The actual mapping scale for the Czech Republic is 1:50,000 and is the most detailed of the three countries, whilst in Poland, the surface water features are mapped at a scale of 1:200,000. However, in Germany, the mapping scale for the surface water features is actually 1:1,000,000, yet appears more detailed than in Poland. This is due to the fact that in Poland, the surface water features mapped only include major watercourses over a certain length, whilst in Germany all tributaries and major streams are included in the data-set.

Therefore, surface water data are not directly comparable across national borders, due to the varying scales of the available data. Ultimately, the more detailed the mapping, the more likely it is that datasets from different countries can be compared, with an optimum scale of between 1:1,000 and 1:5,000 desirable. At these scales it is expected that the quality of the mapping in terms of resolution and level of accuracy to which the surface water features have been mapped would be similar from country to country. Theoretically, a scale dependency adjustment or normalisation could be made to the results to account for the variability in surface water data scales, however, this would be on the assumption that the surface water features in each country have been mapped to a set level of detail (i.e. rivers, streams, ditches, etc.) for given scales. The example given relating to Germany and Poland demonstrates that this is not the case, and highlights the fact that improving the scale of the data does not necessarily mean that the quality of the data also improves.

Figure 7 Distribution of Surface Water Features across Central Europe



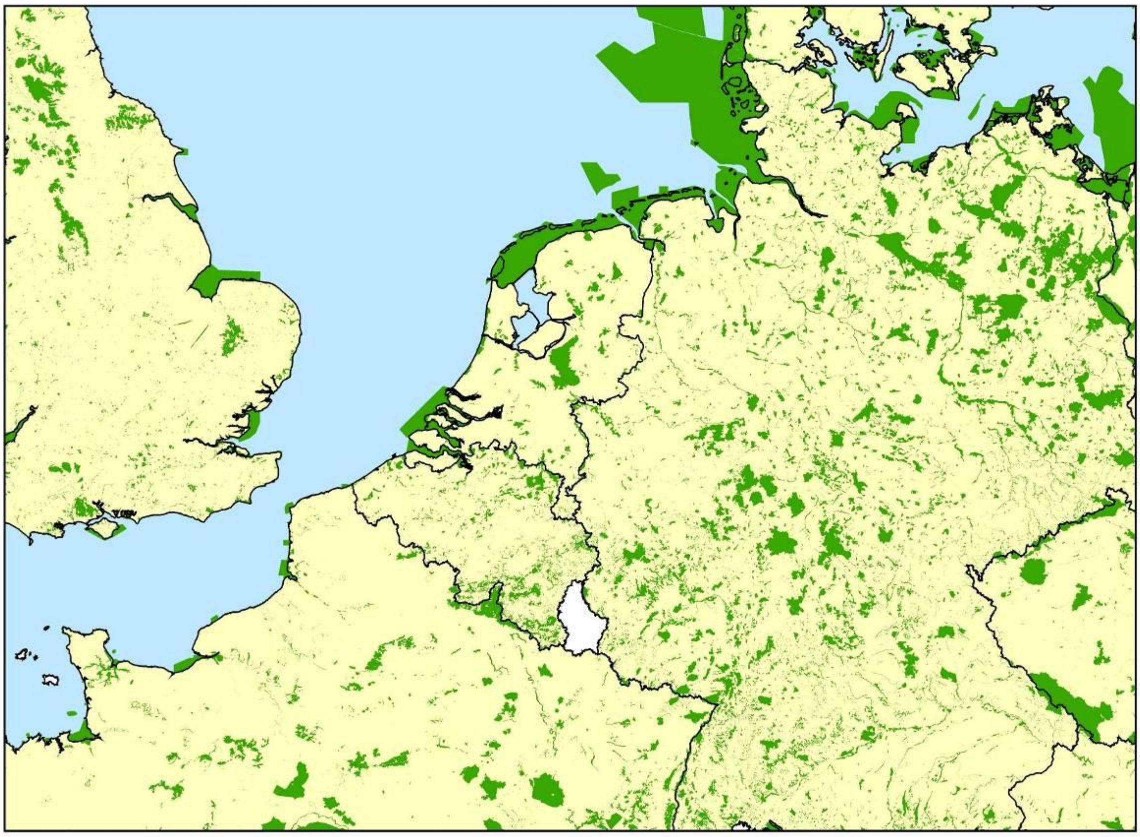
5.1.3. Ecology data

Data relating to ecologically sensitive areas were available in all countries. In most countries the ecological data was often the easiest to obtain, both in terms of accessibility and cost. The main reason for this is that the data specified for ecologically sensitive areas relates to the EU Natura2000 initiative that has been implemented on a European wide basis. One of the key drivers behind this initiative was to ensure that the data produced was easily accessible. Initially, it was anticipated that by using Natura2000 designated sites there would be consistency in the quality of the data across all countries. However this has proved not necessarily to be the case.

The overriding difficulty lies in the fact that the Natura2000 initiative is a European directive that only provides guidelines for the designation and mapping of ecologically sensitive sites. Therefore, there is generally a consistency in the quality of the data within countries, but not across countries, and largely depends on how the guidelines have been interpreted in each country. For example, under Natura2000 there might be a specific area of grassland within a much larger national park that is the habitat for a protected species; in one country the data may show the area of grassland as the Natura2000 site, whilst in another the entire national park might be designated. **Figure 8** displays the distribution of ecologically sensitive areas across a section of Northern Europe.

Therefore, data relating to ecologically sensitive areas are not directly comparable across national borders, although is generally consistent within countries. This is due to the quality of the data available and the various interpretations used to define and map Natura2000 sites.

Figure 8 Distribution of Ecologically Sensitive Areas across Northern Europe



5.2. GROUNDWATER

The distribution of aquifers across the European countries in this study highlights several notable patterns. With the exception of Finland and Norway, a significant proportion of the study area is underlain by an aquifer, either major or minor in class. However, there are also other larger areas of non-aquifer across Europe, as defined by this study. For example, the area covering central Czech Republic, eastern Germany, and northern Austria represents another larger continuous area of non aquifer, along with the Brittany region to the west and Auvergne region of south-central France, Scotland in the UK, the Alpine areas of France, Italy and southern Austria, and the slate mountains in western Germany.

Areas classified as major aquifer are mainly divided into two types; those where the underlying rock type is generally composed of carbonate (e.g. chalk and limestone) or sandstone rocks, and those where the aquifer is contained within drift deposits such as alluvium or glacial sediments, above the underlying bedrock. Aquifers that are contained within drift deposits are generally found in lowland areas and represent the majority of major aquifer areas in Poland, northern Germany, Denmark, and within the Po Basin in Italy. Smaller areas of major aquifer are found in drift deposits in mountainous areas such as in Austria and Norway, mainly attributable to the alluvial deposits found in the bottom of valleys. Bedrock aquifers tend to be larger in spatial area and more continuous in nature compared to drift aquifers, and are most noticeable in the limestone formations across France, the chalk formations of southern and eastern England, the carbonate ridges of central upland areas of Germany, and in the limestone Alps that form a belt across central Austria and southern Germany.

The distribution of GPZs across the European countries in this study is difficult to compare, as the GPZ data differs significantly from country to country. GPZ data is different to all other data types used in this study in that all the other types of data are defined based on geographical and/or natural principles, whereas groundwater protection zones are based on legislative principles. As legislation varies between countries, this results in high variability in the distribution and spatial extent of GPZs across Europe. Each country in the study extracts groundwater for public water supply from a substantial network of groundwater abstractions, with many of the countries defining groundwater protection zones surrounding these abstraction locations, generally with only a limited local spatial extent.

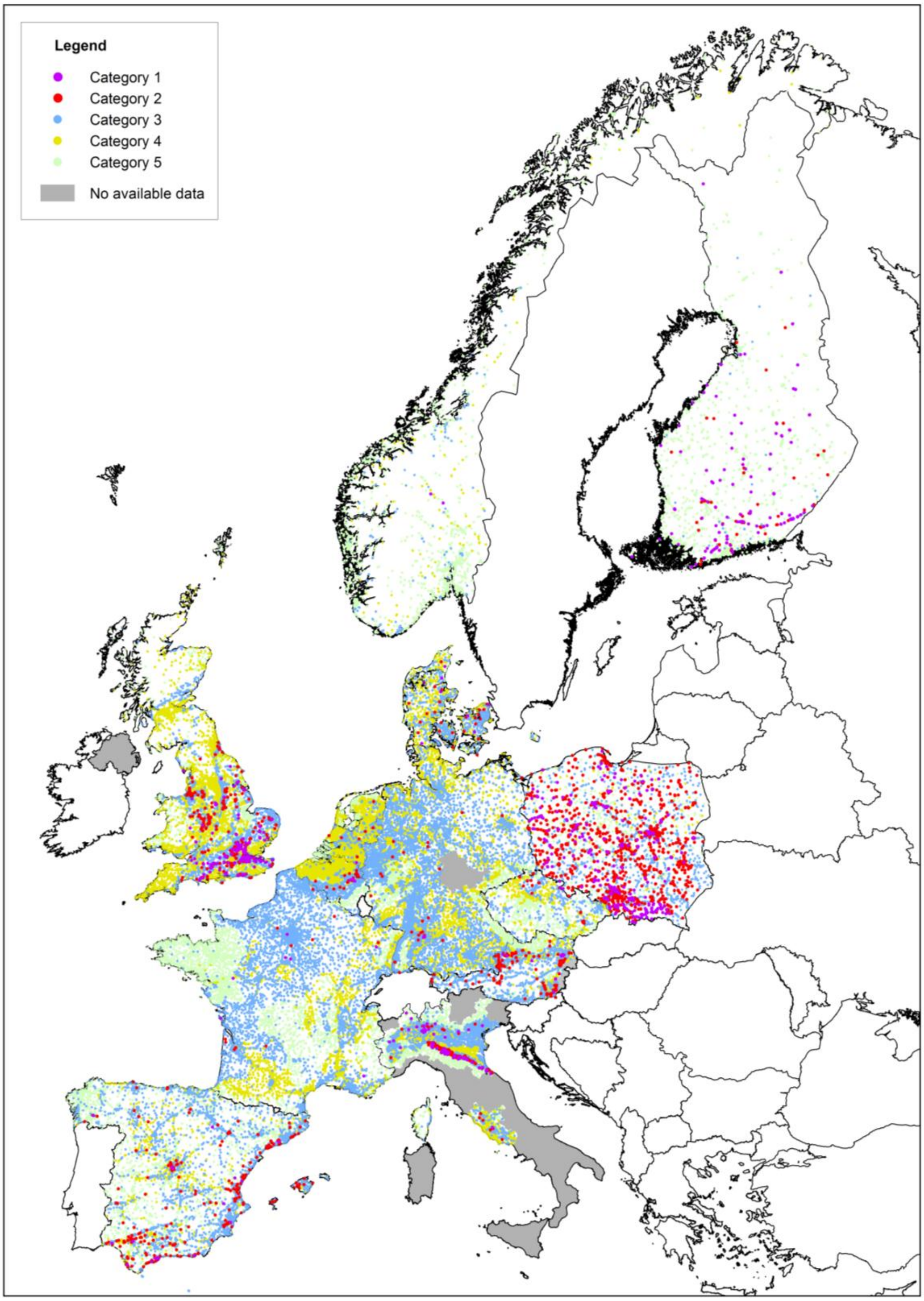
The importance of groundwater as a resource for public water supplies varies between countries and regions of the same country. In the countries studied, groundwater generally accounts for more than 50% of public water supplies, with the exception of the Czech Republic, Norway, Spain and the UK, where the reliance is lower. In particular, in Denmark, northern Germany and much of Poland and Italy, groundwater accounts for the vast majority (> 80%) of public water. However, generalisations at country level should be used with caution since there can be huge variability in reliance on groundwater in regions of the same country (e.g. 68% in the south-east of the UK, compared to < 5% in Scotland).

The groundwater sensitivity of retail filling station locations across the countries studied, as shown on **Figure 9**, is influenced mainly by aquifer type and definition of GPZs. Category 1, 2 and 3a represent sites where groundwater sensitivity is highest, and generally correspond to sites lying within a GPZ 1 or 2. Based on a knowledge of the transport of petroleum hydrocarbons in groundwater, sites located in GPZ 1 and to a lesser extent GPZs 2 and 3a are considered to be the ones that could potentially impact groundwater public water supply abstractions. Experience indicates that the frequency of impacts at public supply abstractions is low [9, 10]. The data show why this is the case. Across all the countries studied, only 1.2% of the ca 86,000 retail filling stations are located in GPZ 1, with a further 3.7% being located in GPZ 2.

Of particular note are the very low percentages of high sensitivity sites located in Germany, the Czech Republic, Flanders (Belgium) and to a lesser extent Denmark. In contrast, a larger percentage of high sensitivity sites are found in Poland. This simply reflects the larger spatial extent of GPZs in Poland compared to other countries in the study. In Finland there is also a higher than average percentage of sites found in GPZs, which is due to the retail filling stations being mainly located in valleys and low lying areas which coincides with the limited drift deposits that form the GPZs. In the UK and Italy, the distribution of higher sensitivity sites is more localised, with concentrations of these sites noted in southern England on the outcrop of the chalk aquifer and along the foothills of the Apennine Mountains in Emilia Romagna.

The vast majority (89%) of retail filling station sites across the countries studied fall into the three lowest sensitivity categories (3c, 4 and 5).

Figure 9 Groundwater Sensitivity of Retail Filling Stations across Europe



5.3. SURFACE WATER

The identified distribution of surface water features across the European countries in this study is affected by the scale and quality of the data in each country, making direct comparisons between countries difficult. However, taking these factors into account, the distribution of surface water features across the study area is generally reasonably uniform and fairly dense in nature. There are, however, some patterns that are noticeable in several countries. For example, in many of the mountainous areas, the density of the surface water network increases. The exception to this is areas of upland carbonate geology, such as in southern Germany and the chalk formations of southern England, where the surface water network becomes much sparser due to the porous nature of the underlying geology. Another observation is that in some low lying coastal areas, such as in Belgium and Germany and in poorly draining clay areas, the surface water network becomes a little denser due to the anthropogenic influence in these areas of canals and drainage channels.

The surface water sensitivity of retail filling station locations across the countries studied is displayed on **Figure 10**. Given the high density of surface water features across much of Europe the surface water sensitivity distribution is more a factor of retail filling station location density. The exception to this is in Poland and Spain, where the lower level of detail in the surface water data has led to a lower proportion of sites than in other countries being recorded as lying in close proximity to surface water features.

Based on generally low mass flux of contaminants from groundwater plumes discharging into surface waters, and potential for rapid biodegradation of petroleum hydrocarbons in sediments at the groundwater – surface water interface (known as the hyporheic zone in rivers) where anaerobic groundwater meets aerated surface water [11], sites located in sensitivity category 1 and to a lesser extent category 2 are considered to be the ones that could potentially have an impact on surface water ecosystems. Across all the countries studied, 3.6% and 4.3% of sites are in sensitivity categories 1 and 2.

The vast majority (85%) of retail filling station sites across the countries studied fall into the two lowest sensitivity categories (4 and 5).

5.4. ECOLOGICALLY SENSITIVE AREAS

Ecologically sensitive areas are widespread across all of the European countries in this study, and range in size from those having a very small spatial extent to those that cover vast areas. In terms of spatial extent, Finland contains many of the largest ecologically sensitive areas, including the largest continuous ecologically sensitive area, in northern Finland, covering thousands of square kilometres. The only ecologically sensitive areas in other countries that are of a similar size to those in Finland tend to be located in coastal regions, with the majority of their area covering offshore marine environments. Ecologically sensitive areas in Poland also tend to be larger than in other countries. The density of ecologically sensitive areas also varies between countries, with possibly the highest densities occurring in Germany and Flanders (Belgium). Looking at the distribution of ecologically sensitive areas on a European wide scale, one pattern that can be identified is the high number of ecologically sensitive areas that appear to follow river courses, particularly prevalent in Germany and Poland.

The ecological sensitivity of retail filling station locations across the countries studied is displayed on **Figure 11**.

Based on low mass flux of contaminants from groundwater plumes discharging into surface waters and potential for rapid biodegradation of petroleum hydrocarbons in the GW-SW interface and riparian wetland environments where anaerobic groundwater meets aerated surface water, sites located in sensitivity category 1 and to a lesser extent category 2 are considered to be the ones that could potentially have an impact on sensitive ecosystems via the groundwater migration pathway. Across all the countries studied, 2.3% and 0.8% of sites are in sensitivity categories 1 and 2. These tend to occur in localised clusters.

Examples of areas where these clusters of high sensitive sites occur include south-western Germany, central and northern Finland, eastern Austria, and around Rome in Italy. It is noticeable that ecological sensitivity often has a limited impact on the overall sensitivity within the countries themselves.

The vast majority of sites (93%) lie within the lowest sensitivity category (Category 5).

Figure 10 Surface Water Sensitivity of Retail Filling Stations across Europe

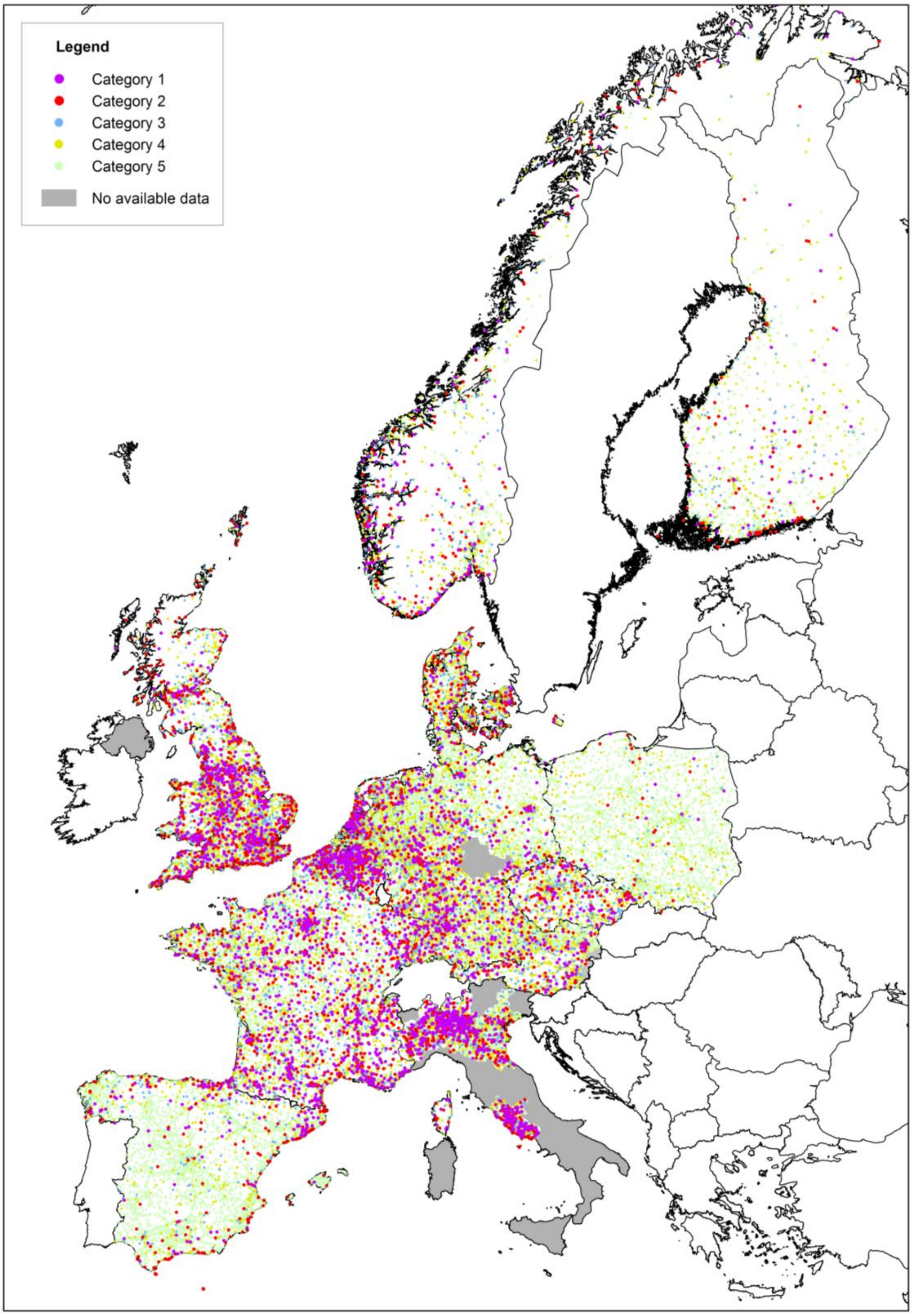
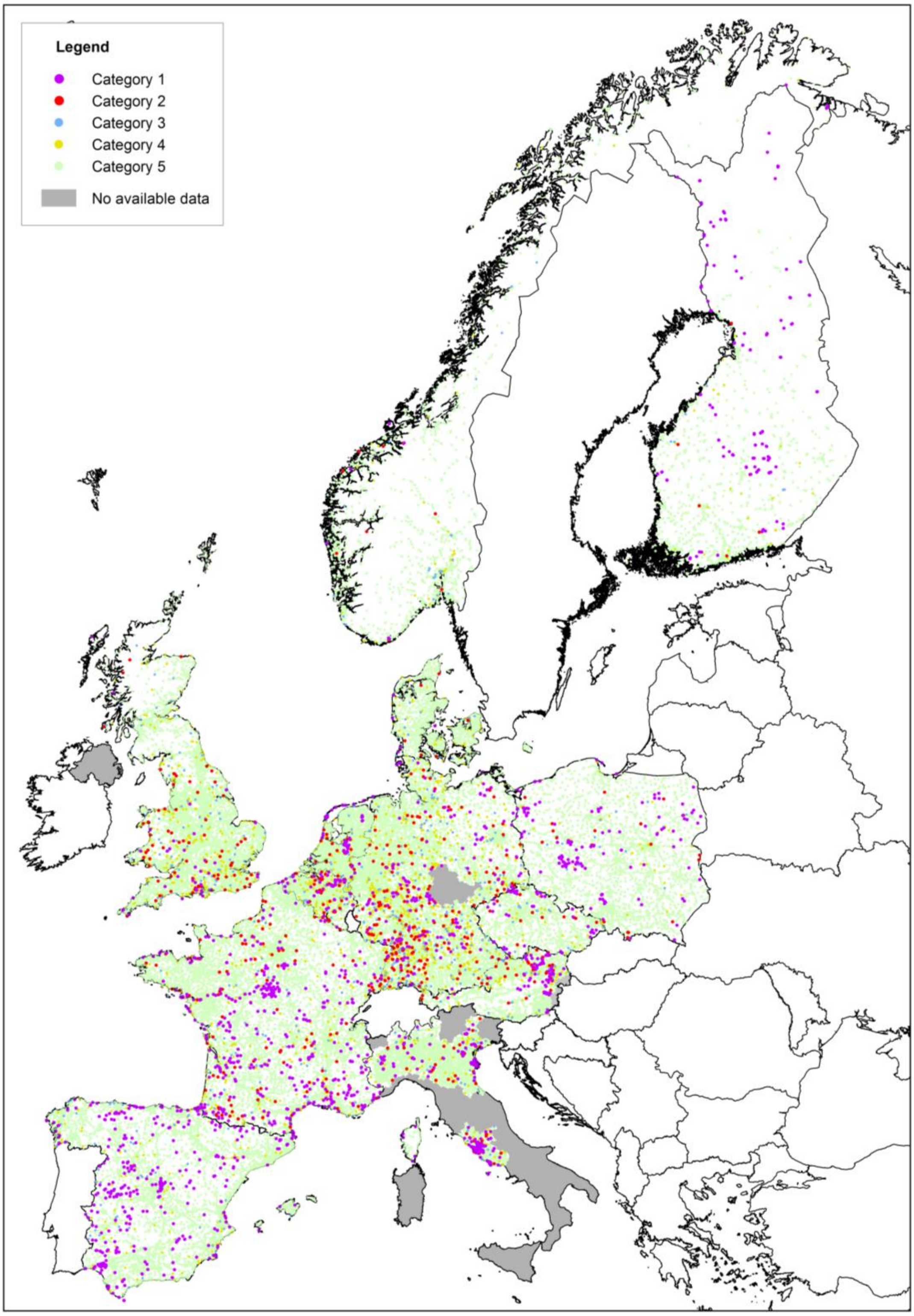


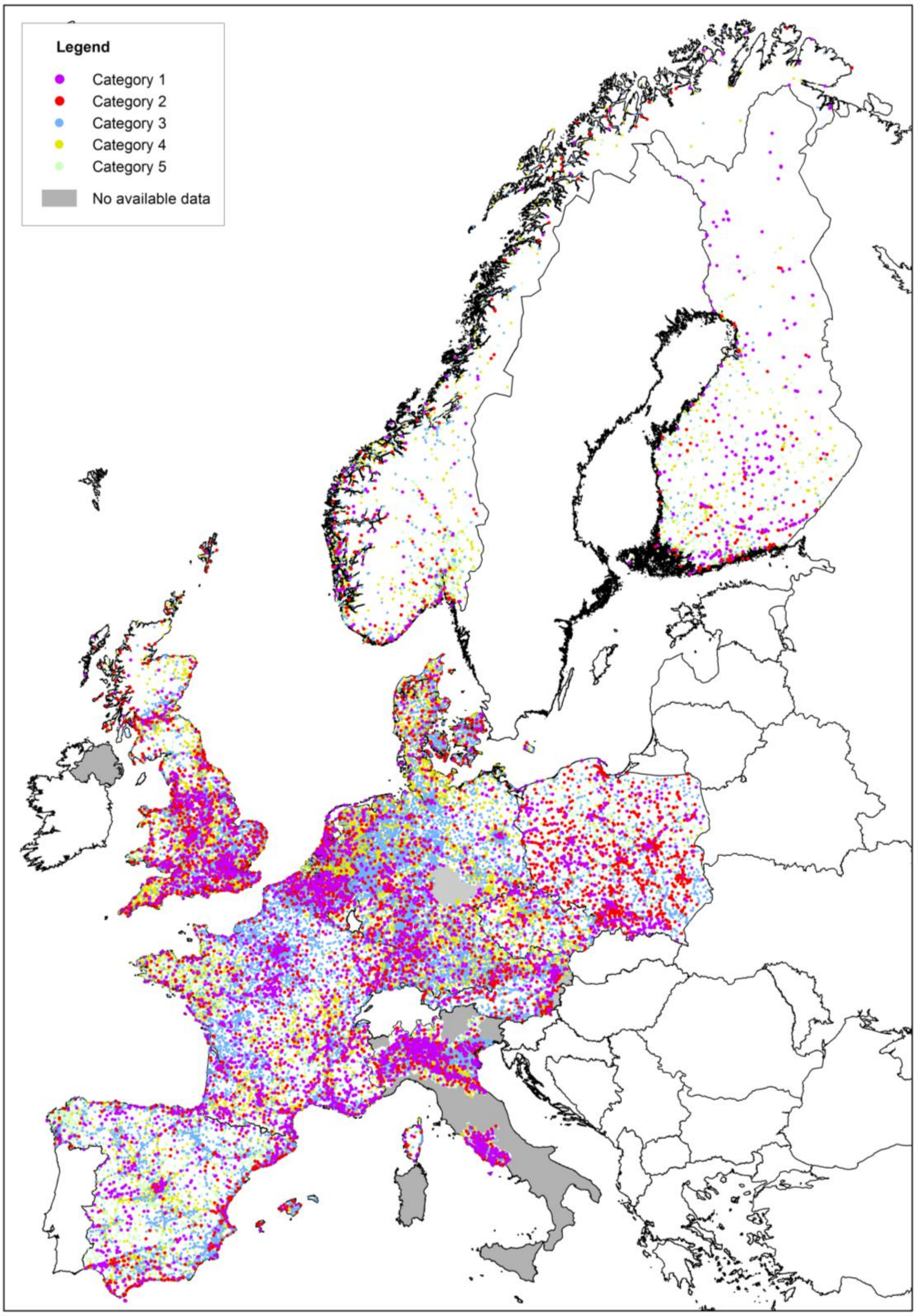
Figure 11 Ecological Sensitivity of Retail Filling Stations across Europe



5.5. OVERALL SENSITIVITY COMBINING ALL THREE CATEGORIES OF RECEPTOR

The overall assessment of the environmental sensitivity of retail filling station locations across the European countries in this study when all three receptor categories are combined shows that 14% of sites fall within one of the two highest sensitivity categories. **Figure 12** displays the overall environmental sensitivity of retail filling station locations across the European countries in this study.

Figure 12 Overall Environmental Sensitivity of Retail Filling Stations across Europe



5.6. OVERALL CONCLUSIONS AND IMPLICATIONS

This study has assessed the environmental sensitivity of approximately 86,000 retail filling station locations that are present in the Catalist databases across 13 European countries, with regard to groundwater, surface water and ecological receptors, using a Geographical Information System (GIS) based methodology.

Several problems and issues relating to data consistency across, and in some cases within, countries have been identified. In particular, GPZ, which are an important concept in protecting public water supplies in any country, have proved to be the most inconsistent data type collected within this study. Such issues have also been recognised by others and have led to the Infrastructure for Spatial Information in Europe (INSPIRE) Initiative, a European Parliament directive [12], although this is not due to be implemented until 2013.

The key conclusions from this study are as follows:

- Across all 13 countries the results demonstrate that, based on their location alone (i.e. irrespective of containment engineering standards which can reduce environmental risk) the percentage of retail filling stations with the potential to pose a risk to the receptors in question is small: 5% with respect to potable water (groundwater and surface water) abstractions, 8% with respect to the ecology of surface water bodies and 3% with respect to designated Natura 2000 sites (protected habitats and ecosystems). As expected, there are differences between the individual countries, but in general they are not large. Whilst there is a desire to protect and improve the quality of all water bodies across Europe, the most sustainable approach to managing the potential risks to water quality from industrial facilities is to take a site-specific, risk-based approach to prevention and remediation. For example, when natural attenuation processes will be sufficiently effective reducing petroleum hydrocarbon concentrations, a remedial control approach is much more sensible when these concentrations are posing no health or environmental risks now or in the future, particularly. The alternative intrusive remediation might entail a higher environmental impact taking into account the energy required and the emissions associated with this.
- Patterns in environmental sensitivity at retail filling station locations can vary at a national, regional and local level.
- The availability, parameter definitions, quality and scale of environmental data across Europe are not consistent, meaning that inter-country comparisons should be carried out with appropriate caution.
- Groundwater protection zones (GPZ) are an important concept in protecting public water supplies in any country; however, they have also proved to be by far the most inconsistent data type used within this study. Some countries or regions of countries have yet to define GPZs.
- The variability in hydrogeology and lack of standardisation in definition of key parameters that define environmental risk potential across Europe strongly supports a national, rather than Europe-wide approach to the assessment and management of environmental risks posed by groundwater contamination and the implementation of the Water Framework and Groundwater Directives.
- The database can be used as a screening tool for ranking sites in terms of the environmental sensitivity of their location, irrespective of containment engineering standards. It can be used to identify those in the most sensitive locations for further investigation at a site-specific level, enabling resources and investment to be applied rationally (i.e. where most needed) when it comes to prevention, investigation and remediation of groundwater contamination.

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GLOSSARY OF TERMS

Aquifer

For the purposes of this study, a geological unit with sufficient permeability or interconnected porosity to yield economic quantities of water when saturated.

Aquifer Boundaries

Zone of change between permeability and/or porosity of subsurface rock (usually due to a change in lithology) leading to a change in Aquifer Type.

Aquifer Type (per definition of the Environment Agency of England and Wales)

- Major Aquifer

  Highly permeable formations of subsurface rock. May be highly productive and able to support large abstractions of groundwater for portable supply on a regional scale.

- Minor Aquifer

  A permeable or porous subsurface rock that has average groundwater productivity and may be important for local water supply and supplying base flow to rivers.

- Non Aquifer

  Formations of rock which are generally regarded as containing insignificant quantities of groundwater.

Catchment Area

The area from which a surface water feature or a groundwater system derives its water (Allaby and Allaby, 1990[3]).

Ecologically Sensitive Areas

Areas defined as ecologically or geologically important including all areas relating to Natura 2000 (SPA and SAC sites), RAMSAR sites and potentially other nationally important ecological areas such as National Nature Reserves and National Parks.

Ecological Sensitivity

For the purposes of this study, the potential risk posed by retail filling stations to Ecologically Sensitive Areas.

Groundwater Sensitivity

For the purposes of this study, the potential risk posed by retail filling stations to groundwater resources, namely Aquifers and Groundwater Protection Zones.

Environmental Sensitivity Analysis

A risk assessment of a retail filling station in relation to an environmental receptor, defined within the study as an ecologically sensitive area, surface water features or groundwater with resource value.

Environmental Sensitivity Category

The resulting environmental risk category allocated to a site from the Environmental Sensitivity Analysis.

Goegraphic Information System (GIS)

A system that captures, stores, analyzes, manages, and presents data that are linked to location(s). In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology.

[3] Allaby, A and Allaby, M., 1990. Concise Dictionary of Earth Sciences. Oxford University Press.

Geology

- Solid Geology
  Consolidated subsurface rock typically deposited more than 2 million years ago.

- Drift Geology
  Unconsolidated subsurface rock typically deposited within the last 2 million years often encountered as superficial deposits above the Solid Geology.

- Hydrogeological Unit
  A subsurface rock with water bearing properties.

Groundwater
Water held in porous or permeable subsurface rock.

Groundwater Abstraction
A source of groundwater from either a spring, well or borehole.

Groundwater Protection Zone (GPZ)
A defined area associated with a groundwater abstraction or a potential groundwater resource that is protected from possible sources of contamination. Sometimes these are referred to as 'Water Protection Zone' or 'Source Protection Zone'.

Natura 2000
A network of nature protection areas established under the 1992 Habitats directive. Included are Special Protection Areas (SPAs) designated to conserve 187 bird species and sub-species and also Special Areas of Conservation (SACs) designated to conserve the 253 habitat types, 200 animal species and 434 plant species listed under the Habitats Directive.

Overall Environmental Sensitivity
As defined within this study, the combined potential risk posed by a retail filling station to any of the three environmental receptors.

Overlaying Soils
The accumulation of loose, weathered material which covers much of the land-surface of the earth to a depth ranging from a few millimeters to several meters (Whitten and Brook 1972[4])

Public Water Supply
Water abstracted from surface water or groundwater reserves, treated and supplied to the general public for domestic use. This water is not for industrial, commercial or agricultural activities.

Retail Filling Station
Retail facility that sells petroleum products mainly for use in motor vehicles.

Source Protection Zone
See Groundwater Protection Zone.

Surface Water Features
Any form of exposed water such as a stream, pond, river, lake or the sea and oceans.

Surface Water Network
The arrangement of rivers, streams, canals and lakes throughout a region or country.

[4] Whitten, D. and Brooks, J., 1972. The Penguin Dictionary of Geology. Penguin Reference.

Surface Water Sensitivity
For the purposes of this study, the potential risk posed by retail filling stations to Surface Water Features.

Travel Time
Normally referring to the period groundwater takes to pass through different types of geology, therefore indicating the period that a potential contaminant would take to move from a source to a receptor.

Water Protection Zone
See Groundwater Protection Zone.

APPENDICES

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Appendix 2:	Groundwater Protection Zone modelling
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Appendix 1 to report no. 1/11

Environmental sensitivity assessment of retail filling stations in Europe: feasibility study and country selection

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Ministry of Agriculture, Larnaca

Czech Republic
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SG Geotechnika a.s, Prague

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Estonia
Central Research Centre, Tallinn
Environmental Information Centre, Tallinn
Estonia Geological Centre, Tallinn

Finland
AC Nielsen Company, Helsinki
The Finnish Environment Institute, Helsinki
National Land Survey of Finland, Helsinki
Ramböll Sverige AB, Gothenburg (Sweden)

France
BRGM French Geological Survey, Orléans
IGN (Institut Géographique National), Paris
MEDD (Ministere de l'Ecologie et du Developpement Durable), Paris
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Latvia
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The Netherlands
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eMapSite, Bracknell
Environment Agency of England & Wales, Bristol
Natural England, Sheffield
Scottish Environment Protection Agency, Stirling
Scottish Natural Heritage, Inverness
Northern Ireland Environment Agency, formerly Environment and Heritage Service (Northern Ireland), Belfast

SUMMARY

Twenty-six European countries (Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and the UK) have been assessed for the availability and accessibility of data that would make it feasible to do an environmental sensitivity assessment of retail filling station networks with respect to groundwater, surface water and protected sites of ecological significance. These countries comprise the 25 European Union (EU) member states at the time the project was initiated, in addition to Norway, which was included at the specific request of certain CONCAWE members.

The data sought in each country included:

- Locations of retail filling stations
- Aquifer type and boundary
- Groundwater vulnerability
- Groundwater Protection Zones
- Location of public water supply wells
- Groundwater usage
- Location of surface water features
- Location of protected sites of ecological significance

To make the exercise feasible, the data had to:

- Exist
- Be available in digital format or in a format that could be easily digitised for use in a GIS (Geographic Information System)
- Be readily accessible at reasonable cost

The study identified 13 countries (Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, five regions of Italy, Netherlands, Norway, Poland, Spain and the UK) to be taken forward for environmental sensitivity assessments of retail filling station networks, the results of which form the basis of subsequent reports.

Although it was not considered feasible to do environmental sensitivity assessments for the remaining countries at the time that this project was carried out, it was apparent that most of these countries were in the process of producing the necessary data in appropriate formats such that environmental sensitivity assessments should be feasible in these countries in the future. However, the high cost (compared to the majority) of some datasets in some countries could severely restrict the use of such data.

The overall objective of this work is to promote a site-specific risk-based approach to managing soil and groundwater contamination at retail filling stations where contamination prevention and remediation measures are proportionate to the environmental risk potential of a site, as opposed to a “one size fits all” approach.

1. INTRODUCTION

The EU Water Framework [1], Groundwater Daughter [2] and Habitats [3] Directives will result in greater focus from the competent authorities in European Union Member States on groundwater and surface water quality from both a chemical and ecological perspective. Downstream oil industry facilities potentially pose risks to groundwater and surface water quality arising from leaks and spills to land. Surface waters and their associated ecosystems can be impacted by groundwater contamination plumes discharging into surface waters or by leaking drainage systems.

This report describes a preliminary study that was carried out in 2005/6 to determine the feasibility (data availability and accessibility) of assessing the environmental sensitivity of retail filling stations with respect to groundwater, surface water and protected sites of ecological significance, in 26 European countries.

Potential uses of the results of this work include:

- Support the continuing development a site specific, risk-based approach to the prevention and management of groundwater contamination which is coming under challenge from some regulatory authorities.
- Support a practical, site specific, risk-based approach to implementation of the EU Water Framework, Groundwater and Habitats Directives that is more sustainable than a “one size fits all” approach favoured by some regulatory authorities. The latter can actually be responsible for prolonging environmental damage by not supporting the environmental risk-based prioritisation of investment in site investigation, remediation and upgrading of site assets, such that sites causing real risks to the environment are not prioritised over the rest.
- Enable oil companies to pro-actively develop environmental risk management strategies at retail filling stations appropriate to the environmental risk potential posed, as a cost effective, more sustainable alternative to “one size fits all” (i.e. don’t under-invest in sites with high environmental risk potential or over-invest in sites with low environmental risk potential).
- Enable the oil companies to prioritise the use of their resources to improve, as required, those locations that display the higher risk profile.
- A source of environmental information in due diligence during acquisitions, divestments and site swaps to indicate the requirement to further assess the environmental risk potential of sites.

Three elements are required to manifest an environmental risk [4]. There must be a sensitive receptor, a source of contamination and a pathway by which the receptor can be exposed to the contamination. If any one of these three elements (source, pathway or receptor) is missing there can be no risk.

The environmental risk potential differs from site to site, because location plays a key role in determining the risk (e.g. proximity of potential receptors, role of geology and hydrogeology in migration and exposure pathways). The environmental risk potential of an individual facility is a function of the integrity of its assets (potential for leaks) and its operational procedures (potential for spills) both of which determine its potential to act as a source of contamination and the environmental setting (proximity of sensitive receptors and likelihood of an exposure pathway).

The most cost-effective way to assess the environmental risk profile of a network of sites is to take a tiered approach. In the first instance it is important to know the inherent environmental risk potential due to a site's location, irrespective of the condition of the assets and the operational procedures. The latter can be factored into the risk potential profile at a later stage.

The inherent environmental risk potential of a network of sites based on location can be assessed in the first instance by a desk study exercise that assesses the proximity of potential receptors and the potential for migration and exposure pathways (e.g. groundwater vulnerability assessment). This can be achieved using a Geographic Information System (GIS) based methodology in which the location of the retail filling stations are overlaid on maps of aquifer type, groundwater vulnerability, groundwater protection zones, surface waters, protected ecosystems etc.

2. OBJECTIVES

The objectives of the feasibility study were to:

- Gather and analyse data on the use and importance of groundwater especially as a source of drinking water on a regional basis within the 26 countries.
- Determine the existence, availability, format (digital versus hard copy) and cost of the data required for the environmental sensitivity analysis on a country by country basis such as:
  - Locations of retail filling stations,
  - Aquifer type and boundary
  - Groundwater vulnerability
  - Groundwater Protection Zone (GPZ)
  - Locations of public water supply extraction wells
  - Locations of surface water features
  - Locations of protected sites of ecological significance
- Define hydrogeological provinces for the 26 countries.
- Identify countries for which it is feasible to carry out an environmental sensitivity analysis of retail filling station networks.

3. DATA COLLECTION FOR SOURCES AND RECEPTORS

This section describes the approach adopted in collecting and collating information from across the 26 countries. Initially loosely structured questionnaires, supported by explanations of the principles and objectives underlying them, were sent out to project partners operating across Europe outlining the types of information required.

Responses indicated that there was considerable variability in the cost of datasets ranging from freely available to prohibitively expensive (tens of thousands of Euros for one environmental dataset) for research projects like this one.

It was also apparent there was a distinct lack of uniformity in data formats across the community; however, there were broad similarities across most countries. The similarities were most evident in the Member States who have joined the EU most recently where the results of action to satisfy the requirements of the Water Framework Directive (WFD) are most apparent.

Two common issues emerged during the data collection stage:

- First, for countries with federal structures data are not held at the national level. It was therefore difficult and extremely time consuming to compile information at the national level in these countries.
- Secondly, although it was noted that many of the recently joined members are compiling information with the requirements of implementing the WFD (and potentially the GDD) closely in mind, few of these countries have established transparent procedures for public access to the information.

A list of organisations holding or providing environmental data is given in **Table A1 - 1**.

3.1. GROUNDWATER USAGE DATA

There is no one single criterion that definitively describes water usage and so partners were requested to collect information on a regional basis concerning a range of parameters including (i) groundwater abstraction per capita; (ii) groundwater as a % of potable water supply; and (iii) groundwater as a % of total freshwater abstraction. Information was generally obtained from national hydrological organisations or environmental protection agencies.

Although not specifically required, a large amount of information regarding water quality and other pressures affecting the sustainability of groundwater resources was collected. A summary listing of the groundwater quality statistics collected for each country is given in **Table A1 - 2**.

3.2. SURFACE WATER DATA

Surface water networks have been converted to digital format in most countries, often by the national mapping agencies. The scale at which this information was available varied widely. In some countries, the data were available at a choice of scales. Where digital mapping was only available at a large scale then the price tended to be very high, often prohibitively so.

3.3. PROTECTED ECOSYSTEM DATA

As a result of the Natura 2000 programme initiated by the Habitats Directive, digital data on ecologically sensitive sites tended to be available in a relatively uniform format. During the data collection process, it became clear that information on two types of site, Special Protection Areas (SPA) and Special Areas of Conservation (SAC), dominate the available data sources.

Table A1 - 1 List of Organisations Holding or Providing Environmental Data

Country	Abbreviation	Organisation
Austria	UBA	Austrian Federal Environment Agency
		Pistecky Consulting Engineering
		Provincial Governments of Austria
Belgium	MRW-DGRNE	Ministry of the Walloon Region's General Directorate of Natural Resources and the Environment
	AMINAL-LIN-MVG	Nature Division of the administration of Environment, Nature, Country and Water management; Department of Environment and Infrastructure of the Ministry of the Flemish Province
Cyprus		Ministry of Agriculture
Czech Rep.		Ministry of Environment of Czech Republic
Denmark	DMU	National Environmental Research Institute
	GEUS	Geological Survey of Greenland and Denmark
	OFR	Danish Petroleum Industry Association
Estonia	EIC	Environmental Information Centre
	EGK	Geological Centre
	CRC	Central Research Centre
Finland		Finnish Environmental Institute
		National Land Survey of Finland
		AC Nielsen Company
France	BRGM	French Geological Survey
	IGN	Institut Géographique National
	MEDD	Ministere de l'Ecologie et du Developpement Durable
	SANDRE	Le Service d'Administration Nationale des Données et Référentiels sur l'Eau
Germany	BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
	BKG	Bundesamt für Kartographie und Geodäsie
		Bundesamt für Naturschutz
		Governments of the individual Federal States
Greece		Ministry of Development
		National Technical University of Athens
		National Centre of Biotope - Wetlands
Hungary		Ministry of Environment and Water
Ireland	EPA	Environmental Protection Agency
Italy		Governments of the individual Regions, Departments of Environment and Water

Country	Abbreviation	Organisation
Latvia	LEGHA	Latvian Environmental, Geological and Hydrometeorological Agency
	MoA	Ministry of Agriculture
		Nature Protection Board
Lithuania		Geological Survey of Lithuania
		Environmental Protection Agency of Lithuania
Malta	MRA	Water Directive of the Malta Resource Authority
	WSC	Water Services Corporation
Netherlands	VROM	Netherlands Ministry of Housing, Spatial Planning and the Environment
Norway		Direktoratet for naturforvaltning
	NGU	Geological Survey of Norway
		Ugland IT Group
Poland		Ministry of the Environment of Poland
		Institute Geodesy and Cartography
		IMAGIS
Portugal	INAG	Instituto da Água (Water Institute)
	LNEC	Laboratório Nacional de Engenharia Civil (Civil Engineering National Laboratory)
	DGGE	Direcção-Geral de Geologia e Energia (Geology and Energy General-Directorate)
	APDA	Associação Portuguesa de Distribuição e Drenagem de Águas (Portuguese Association of Water Distribution and Drainage)
	IA	Instituto do Ambiente (Environmental Institute)
	ICN	Instituto de Conservação da Natureza (Nature Conservation Institute)
Slovakia		The Geodetic and Cartographic Institute of Bratislava
Slovenia		Geological Survey of Slovenia
		Ministry of the Environment of the Republic of Solvenia
Spain	CEDEX - MMA	Centro de Estudios y Experimentacion de Obras Publicas
	IGME	Instituto Geológico y Minero de España
Sweden	SGU SEPA	Geological Survey of Sweden Swedish Environment Protection Agency
UK	EA	Environment Agency of England & Wales
	SEPA	Scottish Environment Protection Agency
	NIEA/EHS (NI)	Northern Ireland Environment Agency, formerly Environment and Heritage Service (Northern Ireland)
	CCW	Countryside Council for Wales
	NE	Natural England
	SNH	Scottish Natural Heritage
		Catalist
		eMapSite
		Arcadis GMI

Table A1 - 2 Summary of Groundwater Quality Statistics available by regulatory authorities

Country	Nitrate	Fertilisers	Chloride	Saline Intrusion	Pesticides	Other GW Impact Data
Austria	✓	✓ Nitrogen, Phosphate, Potassium	✗	✗	✓	Areas of Agricultural use
Belgium (excluding Brussels region)	✓	✗	✓	✗	✓ Atrazine (countrywide), Parathion, Simazine (Flanders only)	Heavy Metals (Flanders only)
Cyprus	✓	✓ Nitrate	✗	✓	✗	Area of Agricultural use
Czech Rep.	✓	✓ Nitrogen, Phosphorus, Potassium	✓	✗	✗	Contaminated GW and Soils, Environmental Burden and IPPC sources
Denmark	✓	✓ Nitrogen, Phosphorus, Potassium	✗	✗	✓ Pesticide, Herbicide, Insecticide, and others	✗
Estonia	✓	✓ Nitrogen, Phosphorus	✓	✗	✓ Fungicides, Herbicides, Seed Treatment Preparations, and others	✗
Finland	✓	✓ Nitrogen, Phosphorus	✓	✓	✓	✗
France	✓	✗	✗	✗	✓	Volatile Organic Compoundss
Germany	✓	✗	✗	✗	✓	✗
Greece	✓	✓ Nitrate	✓	✓	✗	✗
Hungary	✗	✗	✗	✗	✗	Arsenic pollution of Great Hungarian Plain
Ireland	✓	✗	✗	✗	✗	✗

Country	Nitrate	Fertilisers	Chloride	Saline Intrusion	Pesticides	Other GW Impact Data
Italy	✓✗ Statistics differ by province	✓✗ Statistics differ by province	✓✗ Statistics differ by province	✓✗ Statistics differ by province	✓✗ Statistics differ by province	✗
Latvia	✗	✓ Mineral, Organic	✗	✓	✗	✗
Lithuania	✓	✓ Ammonia	✓	✗	✓	Sulphate and Chlorine
Luxembourg	✗	✓	✗	✗	✗	✗
Malta	✓	✗	✓	✗	✓	Other pollutants
Netherlands	✓	✓ Ammonia, Potassium, Nitrates, Phosphorus	✓	✗	✗	Metals, Sulphate, pH, EC
Poland	✓	✓	✗	✗	✓	Landfill sites
Portugal	✓	✗	✗	✓	✗	Heavy metals, and Hydrocarbons
Slovakia	✓	✓ Potassium, Nitrates, Phosphorus	✓	✗	✓	Antimony (issue), and other compounds
Slovenia	✓	✓	✓	✓	✓ Atrazine	✗
Spain	✓	✗	✗	✓	✗	✗
Sweden	✗	✗	✗	✗	✗	✗
UK	✓	✓	✓	✓	✓	✓

✓ Statistical data known to exist for given compounds

✗ No statistical information on compounds sourced by this study – Statistics may exist within other regulatory bodies who were not contacted as part of this study.

3.4. RETAIL FILLING STATION LOCATION DATA

The principal source of information regarding retail filling station locations was available from the Trade Directory maintained by Catalist Ltd[1]. This is generally accepted as the most comprehensive source of retail filling station information. For historical reasons, Catalist holds complete listings for most western European

[1] Experian® Catalist produces commercial databases of retail filling station information in selected European countries (http://www.catalist.com)

countries, but at present incomplete listings and/or unqualified data in other parts of Europe. Therefore sourcing location data for filling stations was relatively easy in some countries, but a significant task in others. A summary of the numbers of filling stations by country is given in **Table A1 - 3**.

Where data from sources other than Catalist's own database was used completeness was assessed by comparing average head of population per retail filling station for these countries against those in the Catalist database. This indicated that these datasets were reasonably complete (within 10-20%).

3.5. ADMINISTRATIVE AND MAPPING UNITS

Mapping by administrative unit was achieved through a combination of maps at NUTS (Nomenclature des Unites Territoriales Statistiques) levels 1 to 3 purchased from Gfk Macon. Unfortunately mapping of the data collected could not be presented at a single NUTS level, and a number of hybrid aggregations were required. The adjustments and other factors involved in defining project mapping units for each country are described in this **Appendix**.

Table A1 - 3 Numbers of retail filling stations and sources of information by country

Country	Population (,000)	Catalist Sites	Non-Catalist Sites	All Retail Filling Station Sites	HoP / Site
Austria	8,103	2,754		2,754	2,942
Belgium	10,239	3,631		3,631	2,820
Cyprus	793	0	200	200	3,965
Czech Rep.	10,278	0	1616	1,616	6,360
Denmark	5,330	0	2218	2,218	2,403
Estonia	1,372	0	550	550	2,495
Finland	5,171	0	1603	1,603	3,226
France	58,749	14,646		14,646	4,011
Germany	82,164	16,017		16,017	5,130
Greece	10,554	0	7139	7,139	1,478
Hungary	10,043	331	1600	1,931	5,201
Ireland	3,777	2,333		2,333	1,619
Italy	57,762	22,356		22,356	2,584
Latvia	2,424	0	650	650	3,730
Lithuania	3,699	0	700	700	5,284
Luxembourg	436	241		241	1,808
Malta	374	0	80	80	4,675
Netherlands	15,864	4,345		4,345	3,651
Norway	4,805	2,176		2,176	2,208
Poland	38,644	0	6382	6,382	6,055
Portugal	10,198	2,769		2,769	3,683
Slovakia	5,399	0	750	750	7,198
Slovenia	1,988	0	450	450	4,417
Spain	39,733	8,633		8,633	4,602
Sweden	8,861	0	3690	3,690	2,401
UK	59,623	10,498		10,498	5,680
Total	**456,383**	**90,730**	**27,628**	**118,358**	**3,856**

HoP = head of population

3.5.1. Irish Province

The most important aquifers are in the Carboniferous Limestone, namely the fissured karstified limestones in the Munster synclines, the Barrow Valley and the midlands of Ireland. In Northern Ireland, Permo-Triassic sandstones are valuable aquifers at the margin of the deep Mesozoic basin.

3.5.2. North Sea and Baltic Lowlands

The Cretaceous Chalk is developed for water supply in Belgium, the Netherlands and Denmark. Cretaceous rocks, which include some chalks, are also developed for water supply in the Munster Basin of North Germany, with Cretaceous sandstones and limestones important aquifers near the margins of the Quaternary deposits. Tertiary aquifers are significant in Denmark and Belgium where marine and continental sequences of sands occur. In Denmark limestones are also exploited for supply. In the Netherlands and northern Germany, at the margin of the Quaternary deposits, Tertiary sands form aquifers, whilst Miocene and Upper Oligocene sequences in Germany also contain aquifers. Quaternary cover comprising a belt of glacial sands in Belgium, the Netherlands and Germany are important aquifers in sequences that have an average thickness of 50-100 m, along with Glacio-fluvial sands and gravels in Denmark, providing 50% of the water supply. Sub-glacial erosion channels provide prominent sources of groundwater.

In Poland the Quaternary and Tertiary sequences are the main water bearing sequences. Quaternary deposits are made up of fluvial, fluvio-glacial and alluvial sediments. Secondary and deeper aquifers include karstified rocks of the Jurassic and Cretaceous periods.

3.5.3. Uplands of Eastern France and Central and Southern Germany

The Rhine Graben (which is of considerable hydrogeological significance) dissects the western part of this province and the Hercynian massifs of the Vosges, the Black Forest and the Odenwald. The principle aquifer in this region is the Triassic Buntsandstein, a clastic formation 500-1000 m thick in Germany but decreasing to the west and southwest to less than 500 m in France. Groundwater flow is mainly via joints and fractures except in the middle section in Germany where intergranular flow is important. The Upper Jurassic limestones (200-600 m thick) represent an important intensively karstified regional aquifer in southern Germany.

3.5.4. Sub-Alpine Basin & Grands Causses, including Rhône-Saône Graben

The main aquifers in this region are in the folded and faulted Upper Jurassic limestones in the Causses du Languedoc and in the Alpes de Haute-Provence. Towards the north, in the area known as the Dauphinoise (south of Grenoble), the Lower Cretaceous Urgonian Limestone (200-400 m thick) forms extensive karstic aquifers. Quaternary alluvial deposits form significant aquifers in several parts of the sub-Alpine basin. The Rhône-Saône rift, joining the north and south of the province, contains a complex sequence of Mesozoic to Quaternary rocks, these are variable in structure and type and are intermittently water bearing.

3.5.5. Iberian Peninsula

The aquifers are highly variable because of the complex geological setting. The major La Mancha Mesozoic carbonate aquifer occurs in the central and south-western areas of the peninsula, specifically in the upper Guadiana Basin and in the headwaters of some of the smaller Mediterranean river catchments. Cenozoic sediments, up to 3000 m thick, infill the large grabens. Although of low permeability, large freshwater reserves do occur where the sequence does not include evaporites. Restricted, but thick and well-developed, Quaternary deposits along the major river systems are also important hydrogeologically. In addition, Tertiary to Quaternary clastic sediments form important aquifers in the Duero and Madrid basins.

3.5.6. Apennines and coastal areas

Triassic to Miocene Carbonate rocks form important aquifers in central and southern Italy. A series of volcanic aquifers extend along the west side of the Apennines. Deep depressions infilled with thick coarse-grained Quaternary deposits occur along the coastal margins and extend deep into the mountains. These multi-layered aquifers are highly permeable and are extensively exploited for water supply.

3.5.7. Alpine fold mountains and marginal areas including the Po Basin, the Molasse Basin and Pyrenees

The deep intermontane valleys and the widespread karst geology of the Calcareous Alps and the southern Alps are particularly interesting hydrogeologically. Throughout the Alps and marginal areas, deep glacial valleys and depressions form extensive aquifers of thick sands and gravels. Karstic systems are well developed in the Jura region north of the Molasse Basin.

The Molasse Basin, to the North of the Alps, is deeply infilled with alluvial fan and deltaic sediments, and forms the Swiss and Bavarian Plateau. Quaternary deposits form major aquifers, such as near Munich where they form one of the major groundwater sources in Germany.

The Po Basin, to the south of the Alps, has a sedimentary infill up to 1000 m thick in many areas. The entire sedimentary sequence, comprised of glacio-fluvial, fluvial and deltaic deposits, forms a single aquifer complex, becoming more permeable towards the top.

In the Pyrenees karstic features are well developed in this area, and glacial and fluvial deposits provide small but nevertheless important aquifers.

3.5.8. Upper Rhine Graben

This region is 300 km long and 30-50 km wide, covered by up to 3400 m thick sediments. The upper part, comprising Quaternary fluvial sands and gravels, is an important aquifer.

3.5.9. Hungarian Plains

This area is comprised mainly of the marine and fluvial sediments of the Carpathian Basin. The upper strata of this sequence, which are mainly Quaternary fluvial and alluvial sand and gravel deposits, provide more than three-quarters of the groundwater supply in Hungary and 56% of Slovakia's groundwater supply. The edge of the Carpathian Mountains, forming the north edge of this province, relies on sourcing groundwater from karstic carbonate aquifers.

3.5.10. Baltic States

Productive units comprise Devonian Sands and Sandstone, Silurian-Devonian karstic limestones and dolomites, and Quaternary glacio-fluvial and fluvial sands and gravels, mainly in Estonia and Latvia.

3.5.11. Scandinavian Province

Scandinavia is almost entirely composed of the Baltic (Fennoscandian) Shield, which is a mainly crystalline Precambrian rock. Local restricted aquifers occur where this basement has been sufficiently fissured and fractured by tectonically induced intense and repeated folding and thrusting. Quaternary glacial deposits also form local aquifers. To the west, the Caledonian Mountain range, comprising Cambrian and Precambrian thrusted sediments, is also only locally productive.

3.5.12. Hellenic Province

Only 15% of the water in Greece is sourced from groundwater. Mesozoic carbonate karst geology in narrow north-south belts forms the major source of this groundwater.

3.5.13. Basement Rocks and Crystalline Rocks

In Europe the basement is comprised of Precambrian and Palaeozoic rocks that have been extensively folded and faulted by the Caledonian and Hercynian (Variscan) orogenies. These are exposed across the European Lowlands and on the Iberian Peninsula. Generally the core of the more recent mountain belts is composed of low productivity crystalline rocks as can be seen in the core of the Alps and Carpathian Mountains. Both the basement and crystalline rocks can have locally productive aquifers, but on a regional scale have low or negligible productivities. However, alluvial infill sediment may be locally important in intermontane basins.

4. HYDROGEOLOGICAL PROVINCES OF EUROPE

4.1. INTRODUCTION

The geology and hydrogeology of Europe is, of course, highly complex, as shown on **Figure A1 - 1**. In order to present a Europe-wide overview and to allow a rational selection of areas for detailed analysis in later phases of the project, it was necessary to simplify and generalise the available information. Therefore a number of hydrogeological archetypes or provinces covering the whole of the European Union have been defined. The classification was based on a number of sources [5-12].

A list of the main aquifers in each country is given in **Table A1 - 4**. Summary descriptions of each hydrogeological province are given in **Table A1 - 5** and their locations are shown on **Figure A1 - 2**.

4.2. DESCRIPTION OF MAIN PROVINCES

4.2.1. Paris Basin

Carbonate rocks of Jurassic, Cretaceous and Tertiary ages form the main aquifers of the Paris Basin, although Cretaceous and Tertiary sandstones are also important. The Cretaceous Chalk is indisputably the dominant aquifer of the Paris Basin, outcropping over an area of 70,000 km^2, forming a rim around the central Tertiary outcrop.

4.2.2. Aquitaine Basin

The basin contains a geologic sequence ranging from the Jurassic to the Cretaceous, which lies at considerable depth in the north Pyrenees foredeep. They are overlain by a thick unconsolidated Cenozoic sedimentary sequence (with a maximum thickness of 10 km). On the northern and eastern margins of the basin, Middle and Upper Jurassic limestones form significant aquifers and can be more than 300 m thick. Palaeogene deposits also form complex multi-layered confined aquifers of limestone, clays and 'molassic' sands.

4.2.3. British Province

The major aquifers are the Permo-Triassic sandstones, the Jurassic limestones and the Cretaceous Chalk. The Chalk is the dominant aquifer in England and is up to 400 m thick, although the water bearing horizons are generally in the more fissured upper 50-60 m.

Figure A1 - 1 Geology of Europe

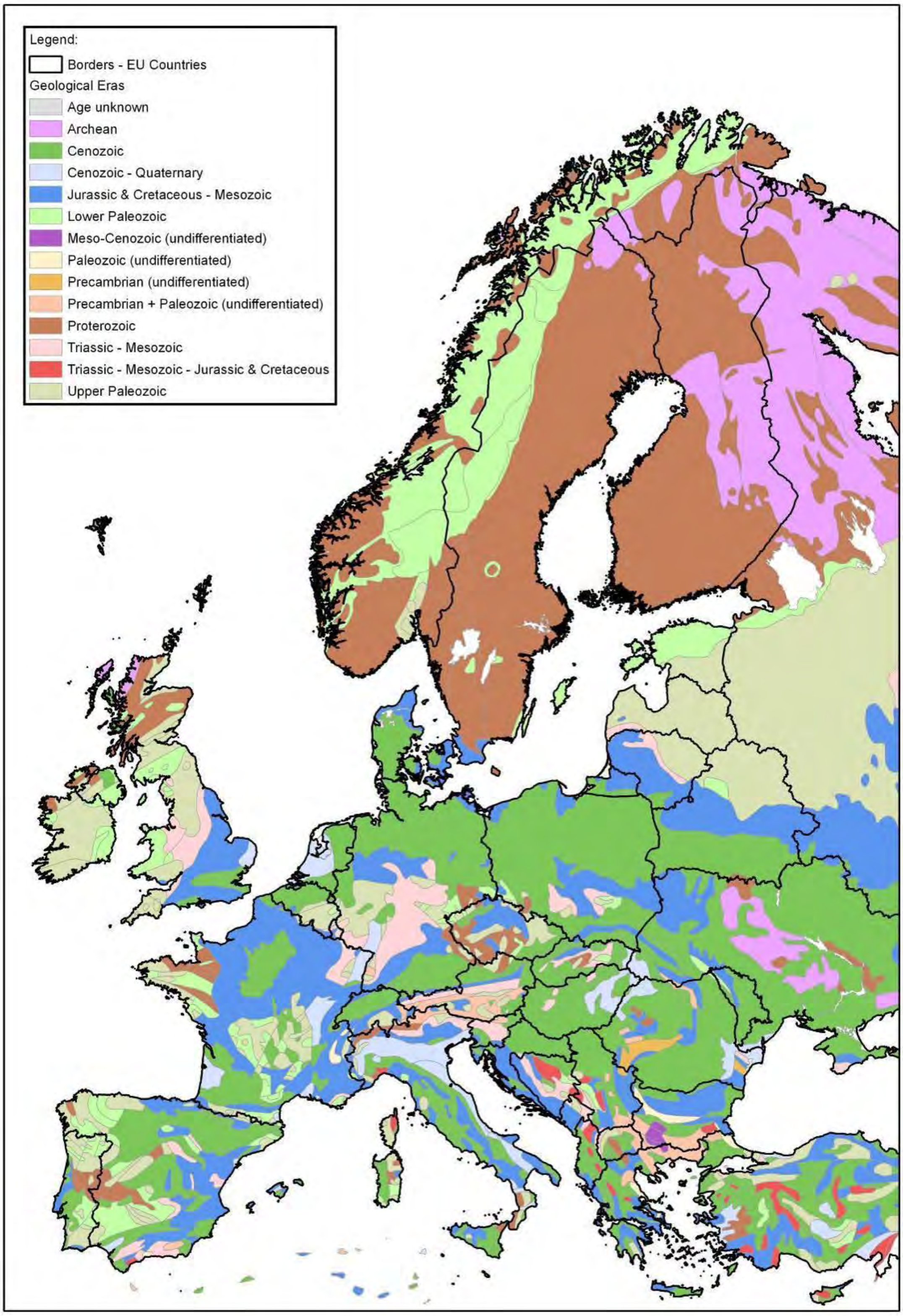


Table A1 - 4 Principal Aquifers of Europe

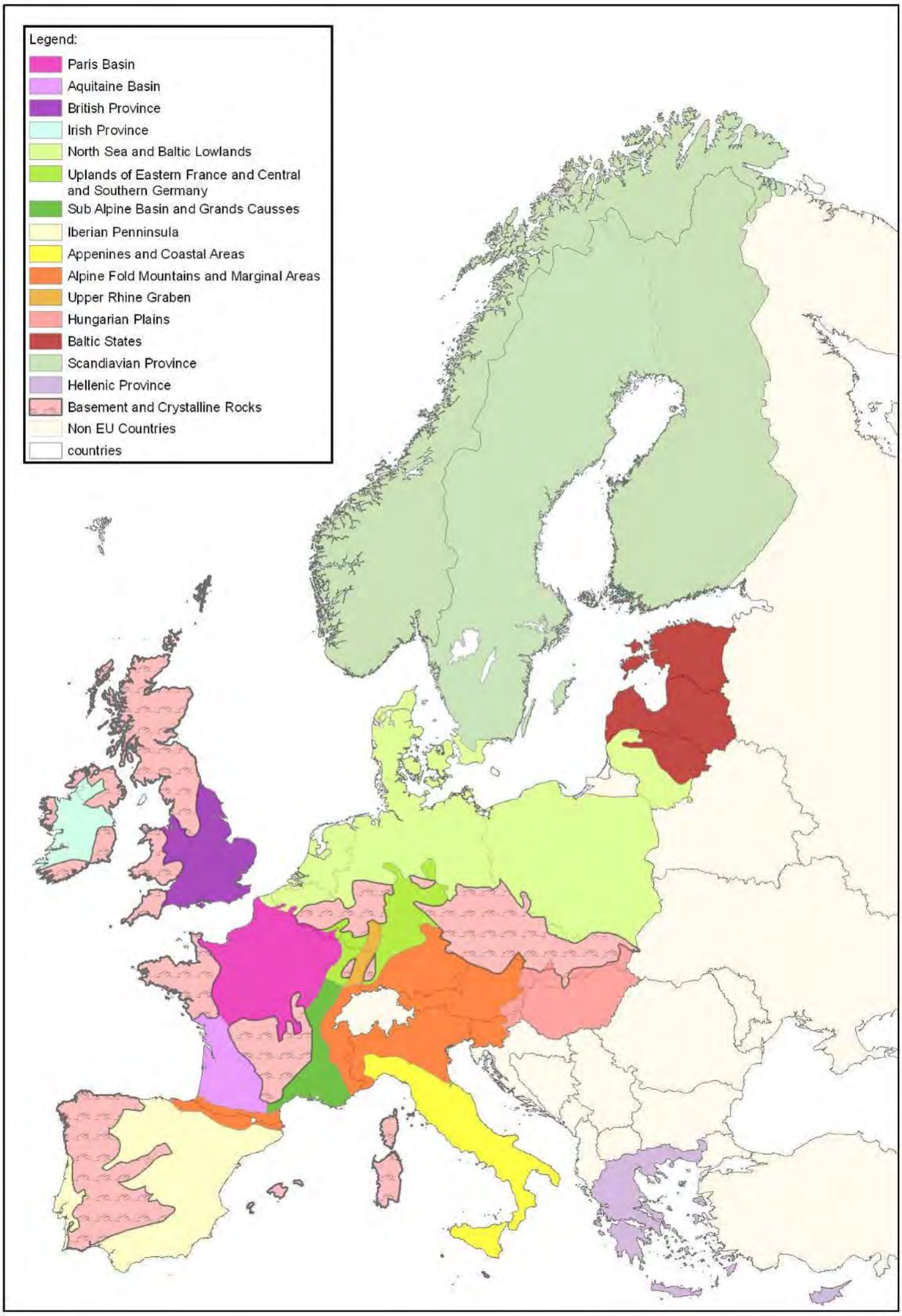
Country	**Alluvium**	**Tertiary Sediments**	**Chalk**	**Lower Cretaceous Sandstone**	**Jurassic Limestone**	**Permo-Triassic Sandstone**	**Volcanic**	**Other Sandstone**	**Other Limestone**
Austria		P							m
Belgium		I	P						
Cyprus							m		
Czech Rep.	I	m					m		I
Denmark	P	I	I						m
Estonia		I						I	I
Finland									
France	I	I	P		P			m	
Germany	I	I	m		I				I
Greece									P
Hungary	P								m
Ireland									
Italy	I	I					I		P
Latvia		I						I	I
Lithuania		m						I	I
Luxembourg								P	
Malta		P							
Netherlands		I	P						
Norway									
Poland		P			m				
Portugal		I						P	I
Slovakia	P								m
Slovenia		I							I
Spain		I						P	I
Sweden			m						
UK			P	m	m	P			

Notes:
P = Primary Aquifer
I = Intermediate Aquifer
m = Minor Aquifer

Table A1 - 5 Definition of Hydrogeological Provinces

Province	Area (km^2)	Aquifers	Countries
Paris Basin	184,155	Chalk	France, Belgium, Luxembourg
Aquitaine Basin	79,160	Mesozoic sediments	France
British Province	94,429	Chalk, P-T sandstones, Jur. limestones	England (UK)
Irish Province	45,386	Carboniferous Limestone, and P-t Sandstone	Ireland and Northern Ireland (UK)
North Sea and Baltic Lowlands	60,873	Chalk, Quaternary and Miocene S&G	France, Belgium, Netherlands, Germany, Denmark, Czech Republic, Solvakia, Poland, Lithuania, Sweden
Uplands of Eastern France and central southern Germany	76,942	Jur. – Cret. limestones	France, Germany and Belgium
Sub-Alpine Basin and Grands Causses, including Rhône-Saône Graben	66,327	Cret and U Jur limestone, Mesozoic-Quat. Seds	France
Iberian Peninsula	354,724	Complex (see text)	Spain and Portugal
Appenines and coastal areas	180,858	Mesozoic – Tertiary carbonates	Italy
Alpine fold mountains and marginal areas	312,349	Mesozoic – Tertiary carbonates and flysch	Italy, France, Spain, Germany, Austria, Slovenia, Czech Republic
Upper Rhine Graben	14,858	Alluvium	France and Germany
Hungarian Plains	122,858	Alluvium	Hungary, Austria, Slovakia
Baltic States	139,658	Dev. Sandstone, Sil-Dev carbonates Quat glacio-fluvial sands and gravels	Estonia, Latvia and Lithuania
Scandinavian Province	769,633	Minor glacial and fluvial	Norway, Sweden and Finland
Hellenic Province	142,788	Mesozoic carbonate	Greece
Basement and crystalline Rocks	790,195	PC – Pal. Metasediments, igneous and metamorphic rocks	UK, Ireland, Portugal, Spain, France, Belgium, Luxembourg, Germany, Czech Republic, Slovakia, Poland, Hungary

Figure A1 - 2 Hydrogeologic Provinces of Europe



5. EUROPEAN GROUNDWATER USAGE

5.1. DEMOGRAPHIC CONTEXT

Figures A1 - 3 and **A1- 4** display maps of population density plotted at NUTS levels 2 and 3 respectively. It is striking how unevenly distributed the population is across the Europe. Extreme densities are particularly obvious around Paris, London and Berlin. At NUTS level 2, the semi-contiguous high population densities stretching from Central England through Belgium, the Netherlands and into Germany is particularly apparent. At the opposite extreme, much of Scandinavia, and large areas of Spain, Scotland (UK), Latvia and Estonia have very low populations.

5.2. GROUNDWATER USE

Table A1 - 6 and **Figures A1 - 5 to A1 - 7** show the distribution of groundwater abstraction (mostly[2] at NUTS Level 2) in a variety of ways:

- Groundwater abstraction per capita
- Groundwater as a % of potable water supply
- Groundwater as a % of total freshwater abstraction

What is immediately clear is that not only does the extent of groundwater usage vary considerably from country to country, but also from region to region within a particular country.

Each of these provides insight into how groundwater is used. Per capita consumption tends to be greater in the Mediterranean states of Spain, Italy and Greece than those of northern Europe. This may in part reflect the lower rainfall and greater need for irrigation water for agriculture in the Mediterranean states. On the other hand, measured as a percentage of public (potable) water supply, groundwater is most important along the North German Plain and southern Baltic. However, when viewed as a percentage of total freshwater abstraction, the contribution of groundwater in many of these areas appears less important. This is presumably because in these areas, while groundwater is a preferred source of potable supply due to its lower treatment requirements, surface water is widely used in heavily industrialised areas for non-potable supply, such as industrial cooling.

[2] The adjustments made in defining project mapping units for each country were described earlier in **Table A1 -3**. Where no regional data are available for any of the three themes in Finland, Sweden and Ireland, national statistics applying to 1995 from EEA (1999) were substituted in the Figures.

Figure A1 - 3 Population Density in the Study Countries – NUTS Level 2

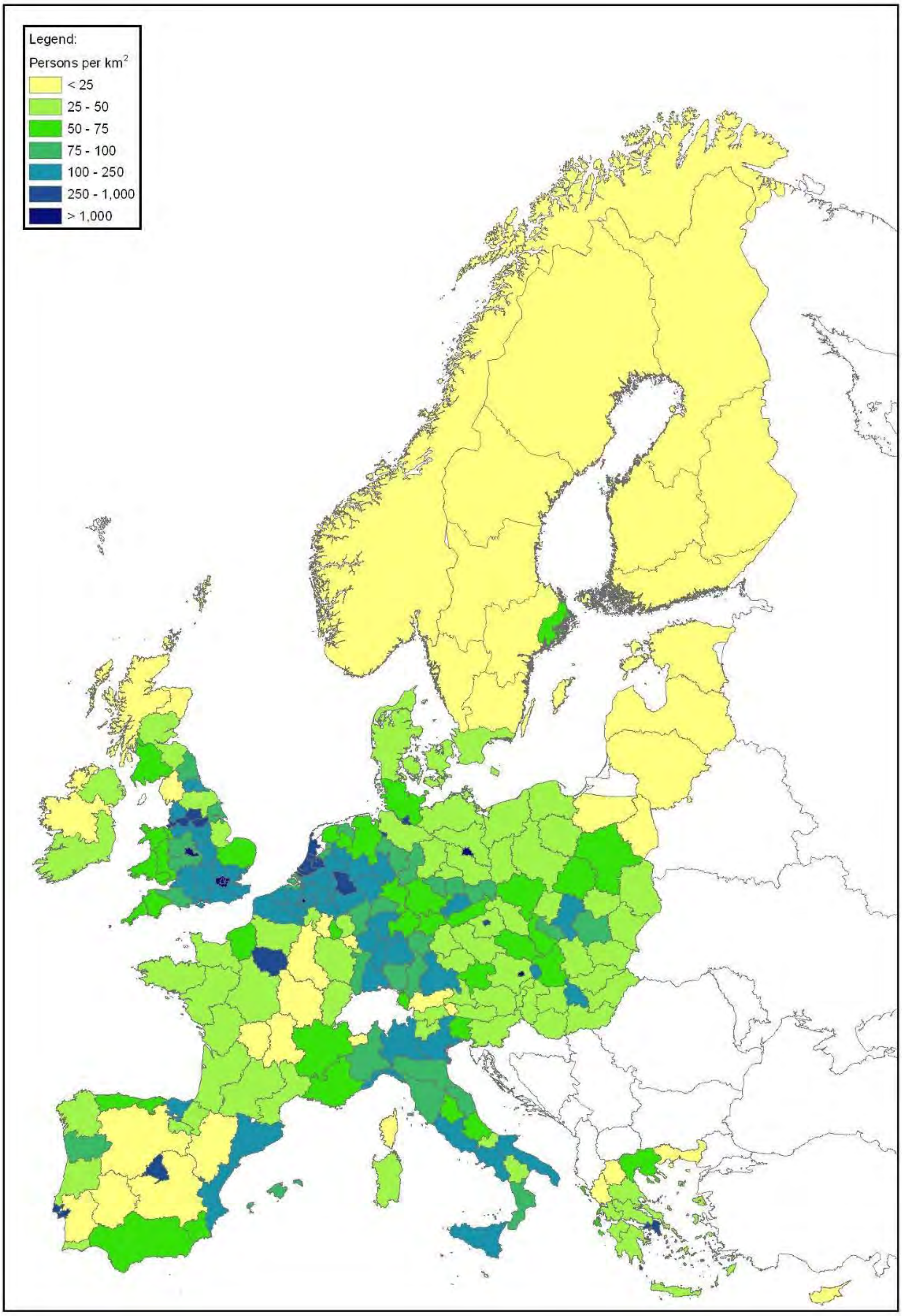


Figure A1 - 4 Population Density in the Study Countries – NUTS Level 3

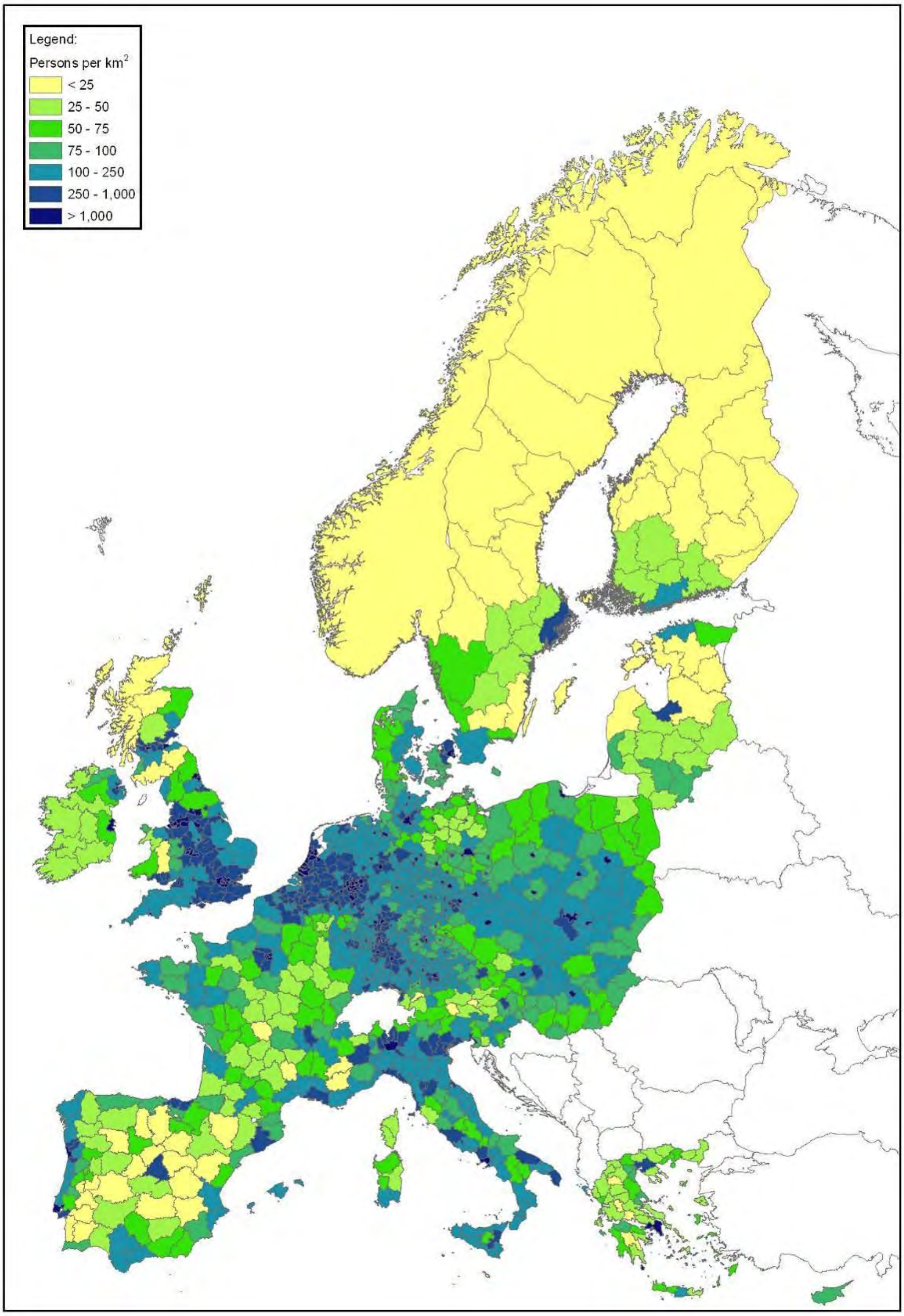


Table A1 - 6 Groundwater Use in the Study Countries by Region

Country	Region	Population (Million)	GW Abstraction per capita (m^3)	GW as % of Public Water Supply	GW as % of Freshwater Abstraction
Austria	Burgenland	0.28	66	75	
	Kärnten	0.56	38	44	
	Niederösterreich	1.54	33	42	
	Oberösterreich	1.38	13	33	
	Salzburg	0.52	27	55	
	Steiermark	1.20	44	72	
	Tirol	0.67	29	41	
	Vorarlberg	0.35	52	70	
	Wien	1.61	96	100	
Belgium	Antwerpen	1.64	49	50	16
	Brabant Wallon	0.35	90	81	59
	Hainaut	1.28	90	81	59
	Liege	1.02	90	81	59
	Limburg (B)	0.79	49	50	16
	Luxembourg (B)	0.25	90	81	59
	Namur	0.44	90	81	59
	Oost-Vlaanderen	1.36	49	50	16
	Region de Bruxelles-Capitale	0.96	90	81	59
	Vlaams-Brabant	1.01	49	50	16
	West-Vlaanderen	1.13	49	50	16
Cyprus	Kypros / Kibris	0.79	185	24	48
Czech Republic	Jihovychod	1.66	41	47	21
	Jihozapad	1.18	41	47	21
	Moravskoslezsko	1.28	41	47	21
	Praha	1.19	41	47	21
	Severovychod	1.49	41	47	21
	Severozapad	1.13	41	47	21
	Stredni Cechy	1.11	41	47	21
	Stredni Morava	1.24	41	47	21
Denmark	Danmark	5.33	129	99	98
Estonia	Eesti	1.37	39		3
Finland	Finland	5.18	46	56	10
France	Isle de France	10.98	35	32	23
	Alsace	1.75	315	98	15
	Aquitaine	2.92	157	60	44
	Auvergne	1.31	94	76	63
	Basse-Normandie	1.43	73	71	69

Country	Region	Population (Million)	GW Abstraction per capita (m^3)	GW as % of Public Water Supply	GW as % of Freshwater Abstraction
	Bourgogne	1.61	133	90	78
	Bretagne	2.92	26	25	27
	Centre	2.45	198	95	41
	Champagne-Ardenne	1.34	125	97	30
	Corse	0.26	95	55	21
	Franche-Comte	1.12	118	84	59
	Haute-Normandie	1.79	140	100	54
	Languedoc-Roussillon	2.31	135	86	25
	Limousin	0.71	26	26	19
	Lorraine	2.31	110	78	21
	Midi-Pyrenees	2.57	59	19	13
	Nord - Pas-de-Calais	4.01	87	94	65
	Pays de la Loire	3.24	56	38	12
	Picardie	1.86	138	73	67
	Poitou-Charentes	1.65	181	62	66
	Provence-Alpes-Côte d'Azur	4.53	94	46	15
	Rhône-Alpes	5.68	187	89	8
Germany	Arnsberg	3.81	39	39	16
	Berlin	3.39	67	100	75
	Brandenburg - Nordost	1.18	117	81	11
	Brandenburg - Sudwest	1.42	117	81	11
	Braunschweig	1.67	95	86	16
	Bremen	0.66	25	100	33
	Chemnitz	1.64	42	28	9
	Dusseldorf	5.26	39	39	16
	Darmstadt	3.72	74	83	19
	Dessau	0.55	75	46	9
	Detmold	2.05	39	39	16
	Dresden	1.72	42	28	9
	Freiburg	2.13	54	53	15
	Gießen	1.06	74	83	19
	Halle	0.88	75	46	9
	Hamburg	1.70	76	100	67
	Hannover	2.15	95	86	16
	Koln	4.26	39	39	16
	Karlsruhe	2.68	54	53	15
	Kassel	1.27	74	83	19
	Koblenz	1.52	73	71	14
	Luneburg	1.66	95	86	16

Country	Region	Population (Million)	GW Abstraction per capita (m^3)	GW as % of Public Water Supply	GW as % of Freshwater Abstraction
	Leipzig	1.10	42	28	9
	Munster	2.61	39	39	16
	Magdeburg	1.22	75	46	9
	Mecklenburg-Vorpommern	1.79	129	85	10
	Mittelfranken	1.68	88	74	15
	Niederbayern	1.17	88	74	15
	Oberbayern	4.03	88	74	15
	Oberfranken	1.11	88	74	15
	Oberpfalz	1.07	88	74	15
	Rheinhessen-Pfalz	2.00	73	71	14
	Saarland	0.05	76	96	27
	Schleswig-Holstein	2.78	106	100	18
	Schwaben	1.75	88	74	15
	Stuttgart	3.92	54	53	15
	Tubingen	1.76	54	53	15
	Thuringen	2.45	72	51	11
	Trier	0.51	73	71	14
	Unterfranken	1.33	88	74	15
	Weser-Ems	2.42	95	86	16
Greece	Agion Oros	0.00	159	50	27
	Anatoliki Makedonia, Thraki	0.56	212	50	27
	Attiki	3.45	14	50	27
	Dytiki Ellada	0.74	126	50	27
	Dytiki Makedonia	0.30	127	50	27
	Ionia Nisia	0.21	73	50	27
	Ipeiros	0.38	135	50	27
	Kentriki Makedonia	1.81	52	50	27
	Kriti	0.57	61	50	27
	Notio Aigaio	0.27	120	50	27
	Peloponnisos	0.67	75	50	27
	Sterea Ellada	0.66	164	50	27
	Thessalia	0.74	212	50	27
	Voreio Aigaio	0.18	24	50	27
Hungary	Del-Alfold	1.34	73	56	11
	Del-Dunantul	0.97	73	56	11
	Eszak-Alfold	1.52	73	56	11
	Eszak-Magyarorszag	1.27	73	56	11
	Kozep-Dunantul	1.11	73	56	11
	Kozep-Magyarorszag	2.84	73	56	11
	Nyugat-Dunantul	0.98	73	56	11

Country	Region	Population (Million)	GW Abstraction per capita (m^3)	GW as % of Public Water Supply	GW as % of Freshwater Abstraction
Ireland	Ireland	3.78		50	31
Italy	Abruzzo	1.28	262		99
	Basilicata	0.61	106		20
	Calabria	2.05	173		92
	Campania	5.78	156		100
	Emilia-Romagna	3.98	89		70
	Friuli-Venezia Giulia	1.19	185		98
	Lazio	5.26	192		99
	Liguria	1.63	125		69
	Lombardia	9.07	157		98
	Marche	1.46	123		89
	Molise	0.33	746		97
	Piemonte	4.29	128		90
	Provincia Autonoma Bolzano/Bozen	0.46	245		100
	Provincia Autonoma Trento	0.48	234		100
	Puglia	4.09	31		62
	Sardegna	1.65	79		43
	Sicilia	5.09	108		82
	Toscana	3.54	90		73
	Umbria	0.84	116		100
	Valle d'Aosta/Valle d'Aoste	0.12	317		100
	Veneto	4.51	129		89
Latvia	Latvija	2.42	50		45
Lithuania	Lietuva	3.70	48		3
Luxembourg	Luxembourg (Grand-Duchy)	0.44	81	67	
Malta	Malta	0.38	50		49
Netherlands	Drenthe	0.47	66	67	
	Flevoland	0.32	80	67	
	Friesland	0.62	80	67	
	Gelderland	1.92	72	67	
	Groningen	0.56	77	67	
	Limburg (NL)	1.14	71	67	
	Noord-Brabant	2.36	76	67	
	Noord-Holland	2.52	46	67	
	Overijssel	1.08	77	67	
	Utrecht	1.11	74	67	
	Zeeland	0.37	64	67	
	Zuid-Holland	3.40	38	67	
Norway	Norway	4.81	98	15	20

Country	Region	Population (Million)	GW Abstraction per capita (m^3)	GW as % of Public Water Supply	GW as % of Freshwater Abstraction
Poland	Dolnoslaskie	2.97	47	67	30
	Kujawsko-Pomorskie	2.10	51	80	43
	Lodzkie	2.64	59	87	46
	Lubelskie	2.23	48	100	34
	Lubuskie	1.02	56	92	56
	Malopolskie	3.23	20	32	7
	Mazowieckie	5.07	33	45	7
	Opolskie	1.08	56	90	47
	Podkarpackie	2.13	22	45	16
	Podlaskie	1.22	50	85	68
	Pomorskie	2.20	58	92	48
	Slaskie	4.85	32	38	28
	Swietokrzyskie	1.32	49	86	6
	Warminsko-Mazurskie	1.47	57	100	64
	Wielkopolskie	3.36	61	89	10
	Zachodniopomorskie	1.73	54	74	6
Portugal	Alentejo	0.76	29	40	50
	Algarve	0.38	15	40	76
	Centro (P)	2.38	1	40	26
	Lisboa	2.57	57	40	38
	Norte	3.63	7	40	36
	Regio Autonoma da Madeira	0.24	146	40	76
	Regio Autonoma dos Amores	0.24	100	40	97
Slovakia	Bratislavsky kraj	0.62	83	83	38
	Stredne Slovensko	1.36	83	83	38
	Vychodne Slovensko	1.55	83	83	38
	Zapadne Slovensko	1.88	83	83	38
Slovenia	Slovenija	1.99	87		97
Spain	Andalucía	7.21	152	40	
	Aragon	1.17	140	32	
	Canarias	1.66	270	100	
	Cantabria	0.53	27	21	
	Castilla y Leon	2.47	117	29	
	Castilla-La Mancha	1.71	185	24	
	Cataluña	6.14	73	23	
	Comunidad de Madrid	5.11	26	7	
	Comunidad Foral de Navarra	0.54	57	24	
	Comunidad Valenciana	4.01	336	50	
	Extremadura	1.07	141	16	

Country	Region	Population (Million)	GW Abstraction per capita (m^3)	GW as % of Public Water Supply	GW as % of Freshwater Abstraction
	Galicia	2.71	25	21	
	Illes Balears	0.78	404	95	
	La Rioja	0.26	69	25	
	País Vasco	2.06	31	21	
	Principado de Asturias	1.05	23	21	
	Region de Murcia	1.12	346	6	
Sweden	Sweden	8.86	73	20	22
UK	Bedfordshire and Hertfordshire	1.61	60	35	21
	Berks, Bucks and Oxon	2.12	136	35	21
	Cheshire	0.98	16	8	3
	Cornwall and Isles of Scilly	0.50	63	30	10
	Cumbria	0.49	90	8	3
	Derbyshire and Nottinghamshire	2.01	43	34	12
	Devon	1.08	54	30	10
	Dorset and Somerset	1.19	45	30	10
	East Anglia	2.20	80	37	12
	East Riding and North Lincolnshire	0.88	37	20	8
	East Wales	1.07	12	3	1
	Eastern Scotland	1.97	16	5	
	Essex	1.62	41	36	14
	Gloucester Wilts and N. Somerset	2.19	30	68	10
	Greater Manchester	2.58	3	8	3
	Hampshire and Isle of Wight	1.79	113	68	19
	Hereford, Worcester and Warwick	1.22	95	36	13
	Highlands and Islands	0.37	16	5	
	Inner London	2.82	6	35	27
	Kent	1.59	115	63	20
	Lancashire	1.43	14	8	3
	Leicester, Rutland and Northants	1.56	57	36	13
	Lincolnshire	0.63	132	37	12
	Merseyside	1.41	3	8	3
	North Eastern Scotland	0.44	16	5	
	North Yorkshire	0.75	80	14	7
	Northern Ireland	1.68		8	
	Northumberland, Tyne and Wear	1.42	28	14	7

Country	Region	Population (Million)	GW Abstraction per capita (m^3)	GW as % of Public Water Supply	GW as % of Freshwater Abstraction
	Outer London	4.48	14	35	26
	Shropshire and Staffordshire	1.50	74	33	11
	South Western Scotland	2.34	16	5	
	South Yorkshire	1.31	12	20	9
	Surrey, East and West Sussex	2.60	104	52	21
	Tees Valley and Durham	1.17	19	14	7
	West Midlands	2.63	7	36	13
	West Wales and The Valleys	1.87	11	3	1
	West Yorkshire	2.12	7	14	7

For countries where the percentage is given as the same for every region the data are indicative generalisations, region specific data not being available.

Population statistics sourced from EUROSTAT, the statistical office of the European Communities, and date to end of 2003.

Figure A1 - 5 Groundwater Abstraction per Capita

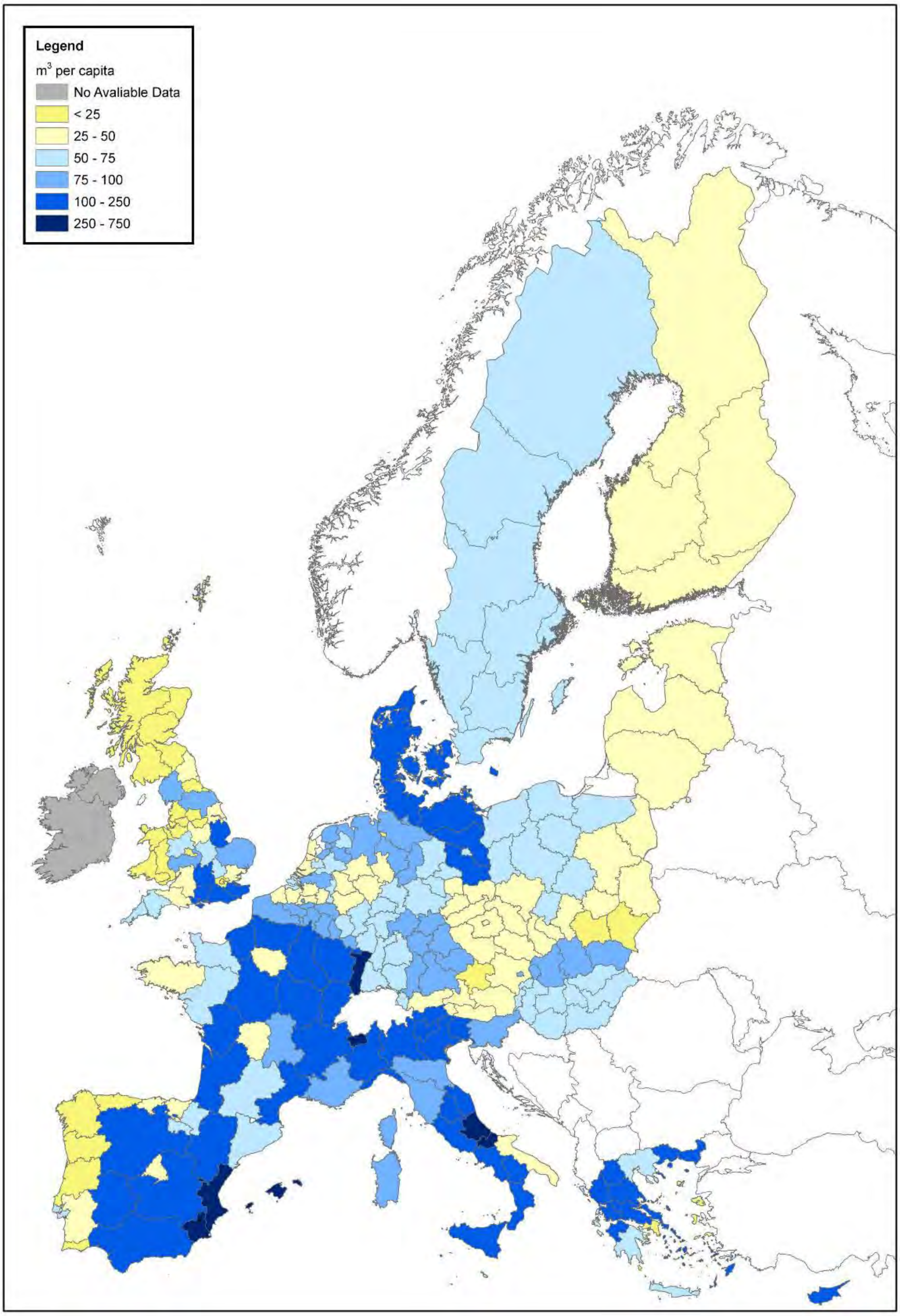


Figure A1 - 6 Groundwater Abstraction as a %age of Potable Water Supply

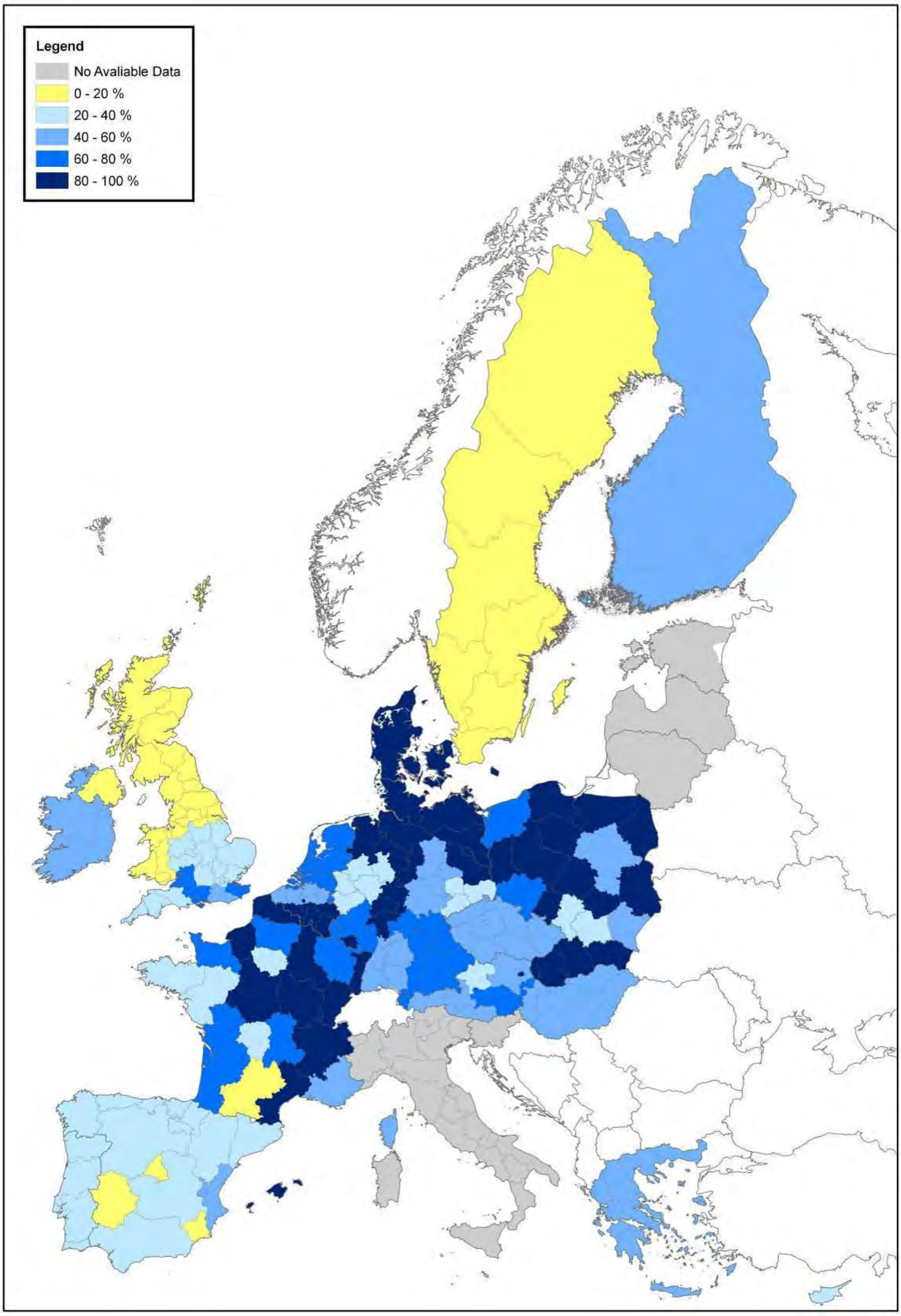
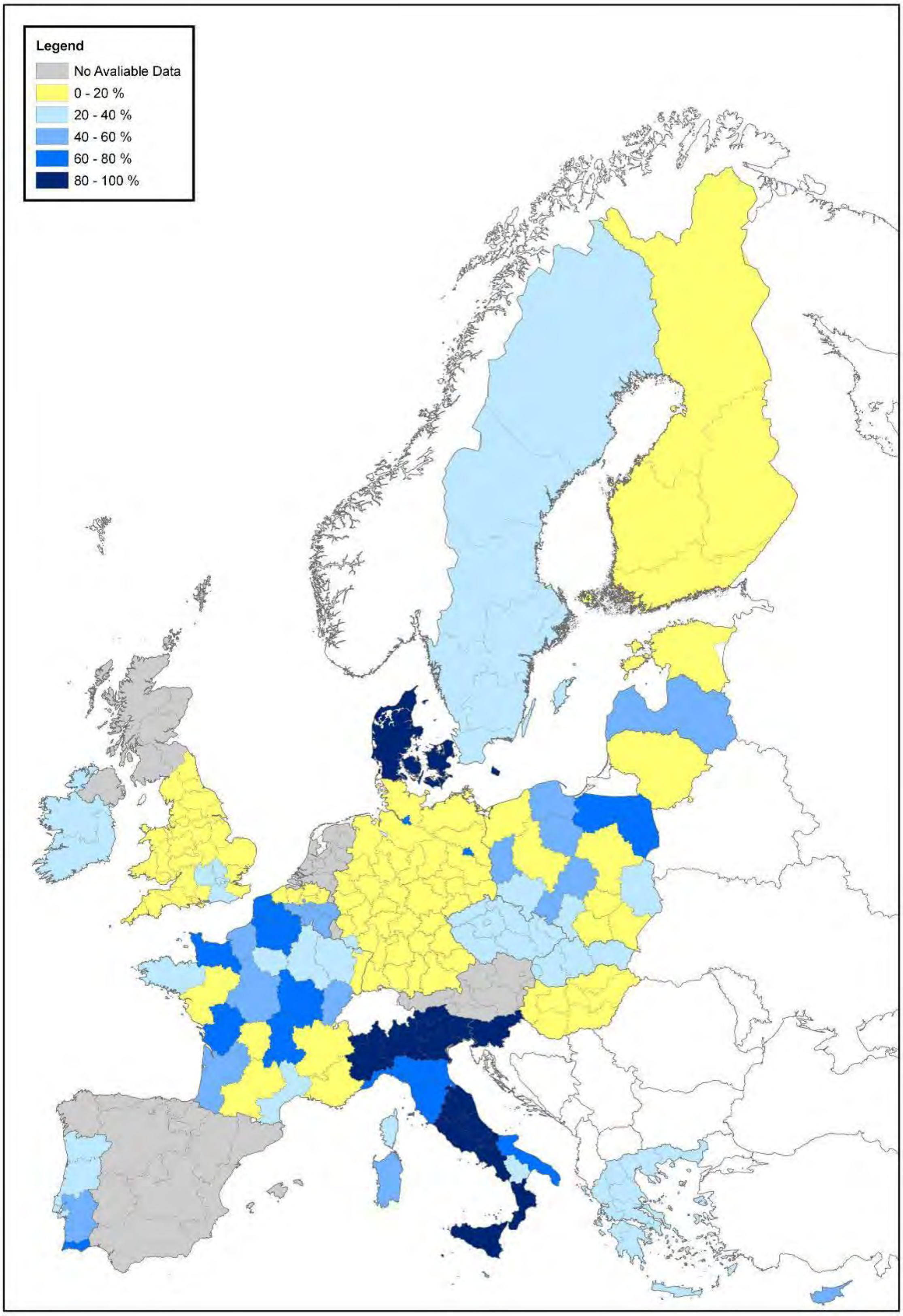


Figure A1 - 7 Groundwater Abstraction as a %age of Total Freshwater Abstraction



6. GROUNDWATER PROTECTION ZONES

Data relating to groundwater protection zones varied greatly between and even within countries, and in some cases were unavailable. The method by which each country has defined their groundwater protection zones is described in the country specific reports (**Appendices 4 – 16**) where an environmental sensitivity assessment has been carried out. The main principle behind the groundwater protection zone analysis in this study was to sub divide the data to define three classes of groundwater protection zone, dependent on the importance of the groundwater resource being protected for public drinking water supplies. Generally zone 1 represents the area of most protection or strictest legislation, with zone 3 representing the area of total catchment for public drinking water supplies. In most countries, dividing groundwater protection zones into three classes was possible, however, in some regions and countries, only two categories of groundwater protection zone are designated by the relevant regulatory authority, and in these instances, no zone 3 was defined. **Table A1 - 7** provides a summary of the definition of groundwater protection zones across the European countries.

Table A1 - 7 Definition of Groundwater Protection Zones

Country	GPZs Defined	Regulation Basis	Digital Format	Number of GPZ Classifications	Notes
Austria	✓	Regional	✓	5	Two types of GPZ; one protects aquifers (2 Classes) and another abstractions (3 Classes)
Belgium	✓	Regional	✓	3	GPZs in Wallonia are not as established as in Flanders. No data for Brussels
Cyprus	×	-	×	-	
Czech Republic	✓	National	✓	3	Water protection zones – not GPZs. Additional data on areas of General GW Accumulation (Natural Spring areas)
Denmark	×	-	×	-	Groundwater Vulnerability is focused on quality of groundwater for public supply
Estonia	✓	National	×	1	Protected zone of 50m around GW wells
Finland	✓	National	✓	4	Not all GPZ have been digitally mapped to date.
France	✓	Local	×	3	Many GPZs are yet to be designated, very few are digitally mapped. The third class of GPZ is not always defined.
Germany	✓	Regional	✓	3	Water protection zones – not GPZs. Some definitions of classes vary between regions.
Greece	×	-	×	-	
Hungary	✓	National	✓ ×	?	Little information available from Ministry of Environment and Water in Hungary.
Ireland	✓	Regional	✓ ×	3	Only 10 counties have data in a digital format.
Italy (5 Regions)	✓ ×	Regional	✓ ×	2-4	Where designated, definitions of GPZ class vary widely between regions.

Country	GPZs Defined	Regulation Basis	Digital Format	Number of GPZ Classifications	Notes
Latvia	✓	National	✓	1	Majority defined as a radius around wells based on abstraction volume (c.1200 wells) with a further 72 wells modelled more appropriately. A small number of these remain in paper format only.
Lithuania	✓	National	✓	3	Zones based on travel-time to abstraction
Luxembourg	×	-	×	-	
Malta	×	-	×	-	
The Netherlands	✓	National	✓	3	
Norway	×	National	×	-	
Poland	✓	National	✓	2	Spatially, GPZs are wide ranging throughout Poland.
Portugal	×	-	×	-	
Slovakia	×	-	×	-	
Slovenia	✓	National	✓	?	Little information available on format of GPZs from Geological Survey of Slovenia.
Spain	×	-	×	-	
Sweden	✓	National	✓	?	Little information available on format of GPZs from Geological Survey of Sweden
United Kingdom	✓	Regional	✓	3	GPZs only defined for England & Wales

7. DIGITAL DATA AVAILABILITY

The following data are required for the environmental sensitivity assessment:

- Locations of retail filling stations
- Aquifer classification boundary
- Groundwater vulnerability
- Groundwater Protection Zones (or locations of public water supply wells)
- Locations of surface water features
- Locations of protected ecosystems

The data should be available in digital format or in a format easily digitised to facilitate manipulation of large datasets

7.1. SOURCES OF INFORMATION

Information on the availability of digital data was obtained through project partners based across Europe who were given standard questionnaires to guide them. Data availability is summarised in **Table A1 - 8**.

7.2. DATA AVAILABILITY BY COUNTRY

7.2.1. Austria

Data were available for all parameters. Obtaining the relevant data from some of the provincial governments was not straight forward. In particular, data costs for the Tyrol and Upper Austria regions were only provided by the provincial governments as estimates, whilst in Burgenland the provincial government would not provide details of any costs unless a firm agreement to purchase the data was made. Given this uncertainty it was decided that Burgenland should be omitted from the study, whilst the extra data costs for the other regions were not considered significant enough to warrant their omission. It was felt that the omission of the easternmost province of Burgenland, bordering Hungary to the east, would not cause any significant problems given that it is one of the smaller provinces, containing only 130 petrol filling station locations (4.7% of the country total). An environmental sensitivity assessment was therefore feasible for most, but not all of Austria.

7.2.2. Belgium

Initial indications were that available datasets did not cover the whole of Belgium, and were restricted to the Flanders region. Following discussions with project partners it became apparent that groundwater and surface water data for Wallonia and Brussels were not publicly available. A further request was made for the data directly to the Ministry of the Walloon Region (DGRNE) who indicated that information relating to Wallonia was only available for consultation on an internet site (http://www.environnement.wallonie.be/) and that the GIS data could only be obtained for projects associated with the Walloon government. Data on ecologically sensitive areas were available for Wallonia. Therefore, the study within Belgium was initially restricted to the Flanders region only.

Since those initial discussions with the DGRNE, a regular dialogue was kept open to monitor the situation with regards to data availability. As a result, project partners were subsequently able to negotiate the release of the relevant datasets for Wallonia in this study. It therefore become practical to expand the study in Belgium to include the Walloon region.

Further information specifically for the Brussels region was unobtainable from this source, however, the Brussels region has been included by incorporating data from other sources. Using this additional information the sensitivity analysis could be expanded to include Brussels and therefore the study covered the whole of Belgium

7.2.3. Cyprus

Aquifer Boundaries and groundwater abstractions have been mapped by the Ministry of Agriculture. However, groundwater vulnerability, groundwater protection zones and ecological receptors maps were not available and the locations of petrol filling stations were not available. It was not feasible to carry out an environmental sensitivity assessment for Cyprus.

7.2.4. Czech Republic

It was assessed that the relevant digital data were available for the whole of the Czech Republic at a reasonable cost and that it was practical to take the Czech Republic forward to the more detailed sensitivity analysis stage.

7.2.5. Denmark

Obtaining the relevant data for surface water features proved challenging. The digital data for surface water features was available from several suppliers and had been produced at three different spatial scales, however data costs for these datasets was much higher than expected. The most detailed of the datasets available within the study area was that produced by DMU at a scale of 1:10,000 but this was also at the highest cost. An alternative option would have been to use a dataset produced at a scale of 1:250,000 at a lower cost, but with a potential impact on the quality of results due to the accuracy of the mapped data. However, after further discussions with data suppliers, an agreement was made to supply them with the petrol filling station locations to allow them to calculate the proximity to surface water features (lakes and rivers). This negated the need to purchase a surface water dataset, whilst still utilising the best available data at a more affordable cost.

Relevant digital data were available for other parameters at a reasonable cost. It was therefore practical to take Denmark forward to the more detailed sensitivity analysis stage.

7.2.6. Estonia

Data exists for all parameters for most parts of the country, but no routine arrangements are in place for sale and distribution. Nevertheless, the data can be accessed for non-commercial purposes, but the costs were not defined. For this reason, it was considered not appropriate to attempt an environmental sensitivity assessment for Estonia.

7.2.7. Finland

All environmental data were readily available in digital format for the whole country from the Finnish Environment Institute, apart from groundwater vulnerability. However, discussions with Finnish Environment Institute indicated that GPZ data covered most of all areas of Finland with groundwater resources and that the geology of Finland would result in the remainder of the country being classified as non-aquifer. Retail filling station locations were also available in digital format from the Nielsen Company. Although the cost of surface water data was very high, a function of the mapping scale and Finland's physiography, it was considered feasible to do an environmental sensitivity assessment for Finland.

7.2.8. France

Initial indications were that the relevant digital data were not available for the whole of France at a reasonable cost. It was also understood from discussions at that time that much of the data required to undertake the analysis was not held in a suitable digital format. Therefore France was initially not considered as a suitable country to take forward to the more detailed sensitivity analysis.

However, since those initial discussions with the relevant organisations, a regular dialogue was kept open to monitor the situation with regards data availability. As a result, project partners were made aware of new data that became available, in particular relating to groundwater resources. Therefore, a re-assessment was made and found that it was now practical to take France forward to the more detailed sensitivity analysis.

Data were available for surface water features, ecologically sensitive areas, aquifer classifications, and groundwater abstraction locations. An attempt was also made to source data on groundwater protection zones, however it became clear through consultation, that this data was not available in a digital format and is not likely to become available in the foreseeable future. Therefore, in this analysis groundwater protection zones have been modelled based upon proximity to groundwater abstractions.

7.2.9. Germany

Obtaining the relevant groundwater data proved challenging. Initially it was believed that information on groundwater protection zones had been collected as a national dataset by BKG, however, when approached for the data it emerged that this was not the case and that their data only covered the province of Brandenburg. Therefore, data for groundwater protection zones had to be collected on a province by province basis from the relevant water departments of each provincial government. This would created two main issues;

- Firstly, planned data costs increased, in particular the cost of data for Bavaria was quoted at three times the combined cost of the data for all other provinces.
- Secondly, it was not clear how many of the provinces held this data in a digital GIS format.

After consultation, the extra data costs were not considered significant enough to warrant the omission of any of the provinces. All provinces with the exception of Thuringia were able to provide the data in a digital format. In Thuringia, it emerged that the relevant data was still being digitised to the extent that only a third of the province had been completed. As such Thuringia was omitted from the study.

Relevant digital data were available for other parameters at a reasonable cost. It was therefore practical to take Germany forward to the more detailed sensitivity analysis stage

7.2.10. Greece

Neither groundwater vulnerability nor groundwater protection zone data were available in a digital format and there was doubt about the availability and coverage of retail filling station data. It was therefore considered not feasible to do an environmental sensitivity assessment for Greece.

7.2.11. Hungary

Potentially all the data types exist in digital format. Although there were some reservations about the accessibility of the data, it was considered feasible to do an environmental sensitivity assessment for Hungary.

7.2.12. Ireland

All ecological receptor datasets were available for free. Aquifer boundaries, groundwater vulnerability and groundwater protection zones were available on a county-by-county basis but only 10 counties had the data available. Groundwater abstractions and surface water features were available for the whole country. It was considered feasible to do an environmental sensitivity assessment on a contiguous block of seven counties in central Ireland.

7.2.13. Italy

It was assessed that the relevant digital data were likely to be available for five of the twenty regions of Italy at a reasonable cost, and that it was practical to take these regions forward to the more detailed environmental sensitivity analysis stage. The regions selected were Emilia Romagna, Lazio, Lombardy, Piedmont, and Veneto. The lack of digital data excluded the remaining regions from the analysis.

Obtaining the data from the various regional departments that hold the data proved challenging. The principal difficulty in obtaining the data was the levels of administration that were encountered, which led to long delays in receiving the data. In some cases, data was held by one department but owned by another, and permissions needed to be granted before data could be released.

7.2.14. Latvia

Data existed for 16 groundwater bodies in a GIS format, and abstraction locations could be converted to GIS format. Digital groundwater protection zones were incomplete. The critical issue was that retail filling station locations were held by the Latvian Environmental, Geological and Hydrometerological Agency (LEGHA) only as addresses which were not immediately convertible into coordinates and hence could not be analysed in the GIS. Given the uncertainties, it was considered not appropriate to attempt an environmental sensitivity assessment for Latvia.

7.2.15. Lithuania

Groundwater vulnerability maps existed for small parts of the country but would have required a separate project to define the rest. Groundwater source protection zones are of three types – a well-head protection zone (5- 50 m); a microbiological protection zone; and a chemical protection zone. Retail filling station coordinates were also available. However, it was not considered feasible to do an environmental sensitivity assessment for Lithuania given the incomplete groundwater vulnerability coverage.

7.2.16. Luxembourg

No suitable sources of digital data were identified and it was therefore not feasible to do an environmental sensitivity assessment for Luxembourg.

7.2.17. Malta

No suitable sources of digital data were identified and it was therefore not feasible to do an environmental sensitivity assessment for Malta.

7.2.18. Netherlands

The relevant digital data were available for the whole of The Netherlands at a reasonable cost. It was therefore practical to take The Netherlands forward to the more detailed sensitivity analysis stage.

The aquifer dataset was not as detailed as had been envisaged. In particular the dataset did not account for saline intrusion areas.

7.2.19. Norway

The initial assessment confirmed that the relevant data were available for the whole of Norway at a reasonable cost and that it was practical to take Norway forward to the more detailed environmental sensitivity analysis.

Following further discussions with the Norwegian Geological Survey (NGU) it was established that digital data relating to groundwater protection zones was unavailable. However, as an alternative, data on the locations of groundwater abstractions throughout the country were made available.

7.2.20. Poland

During the initial stage of the project it was assessed that the relevant digital data were available for the whole of Poland at a reasonable cost, and that it was practical to take Poland forward to the more detailed sensitivity analysis stage.

Following further discussions it became clear there would be a short delay in obtaining the groundwater data for Poland. The reason for this was that the data had yet to be publically released by the Ministry of Environment of Poland, as the dataset had only recently been constructed, and was being validated and verified before release. In addition, once the data had been released, it required translation from Polish into English.

7.2.21. Portugal

Groundwater Protection Zone data were not available for Portugal. Digital aquifer boundaries were available for free, but they had not been classified. Public groundwater abstractions and a proportion of private abstractions were available in Excel and Access format. Surface water features were also available in a compatible format. National Nature reserves were the only known ecological receptor that has been mapped digitally. Although it appeared technically possible to do an environmental sensitivity assessment for Portugal uncertainties over the cost of the data meant it was not recommended.

7.2.22. Slovakia

Vector maps of Slovakia were available, which could provided surface water features. A raster format of a hydrogeological map, which could provide aquifer boundaries and classifications was also available, but would require some additional processing. There was uncertainty over the availability of other groundwater data and so it was considered not feasible to do an environmental sensitivity assessment for Slovakia.

7.2.23. Slovenia

Digital data were available for all data types except groundwater abstractions for which availability was not ascertained. Aquifer boundaries, groundwater vulnerability and groundwater protection zones are maintained and provided by the Geological Survey of Slovenia. Aquifer vulnerability is based on three criteria; surface water intrusion possibility, pollutant spreading rate and purification potential. The Ministry of the Environment maintains all other databases. Locations of retail filling stations are based on the European Corine Landcover2000 database and are available in vector format, although the project team were unsure of the suitability of this method as a basis for collecting retail filling station locations. Although it appeared technically possible to do an environmental sensitivity assessment for Slovenia uncertainties over the cost of the data meant it was not recommended

7.2.24. Spain

Initially it was understood that the relevant digital data were not available for the whole of Spain at a reasonable cost. Therefore Spain was initially not considered a suitable country to take forward to the more detailed sensitivity analysis.

Since those initial discussions with the relevant organisations, a regular dialogue was kept open to monitor the situation with regards data availability. As a result, project partners were made aware of new data that became available, in particular relating to groundwater resources. Therefore a re-assessment was made and found that it was now practical to take Spain forward to the more detailed sensitivity analysis.

Following extensive correspondence, the hydrogeological data were located with the Instituto Geologico y Minero de Espana (IGME). However, justification for the release of such large datasets could not be made via email or over the telephone. Therefore a meeting was set up in Madrid involving representatives from CONCAWE and the IGME to present the project. Following this meeting, the hydrogeological data including aquifer and abstraction information were released to the project team. The datasets received covered Peninsular Spain, the Balearic Islands, Canary Islands and also the two cities of Melilla and Ceuta on the African coastline.

In Spain, no groundwater protection zones are specifically defined, and therefore none were provided. It was agreed with the IGME that as part of this project a simple modelling exercise would be carried out for groundwater protection zones in Spain on a national basis utilising the highly detailed hydrogeological and abstraction datasets provided by the IGME.

The ecological data and surface water network dataset was provided by CEDEX – MMA (Ministerio Media Ambienté). The dataset received only contained major surface water features. Further efforts to ascertain a more detailed dataset proved unsuccessful and it became apparent that no detailed national dataset was available.

7.2.25. Sweden

All the required data sets were readily available in digital format with the possible exception of retail filling stations. Data are held at two levels. National data sets are held by the Swedish Geological Survey (SGU), while subsets of the information are held by the 20 individual counties. The cost of data from SGU was prohibitively high for this project. Information from the counties is potentially cheaper but would be much more time consuming to collect. It is believed that retail filling station locations may be available free of cost. Although it was technically feasible to do an environmental sensitivity assessment for Sweden the high cost of data from SGU meant it was not practical.

7.2.26. UK

During the initial stage of the project it was assessed that the relevant digital data were available for the whole of England, Scotland and Wales at a reasonable cost, and that it was practical to take these regions of the UK forward to the more detailed environmental sensitivity analysis stage. Suitable data for Northern Ireland were not available and consequently this area was not included in this study

However, in England it was prohibitively expensive to acquire the most detailed national surface water dataset produced by the Ordnance Survey (OS), but an OS reseller was able to provide surface water proximity information for a list of grid references for the retail filling station locations. This negated the need to purchase a surface water dataset whilst still utilising the best available data at a more affordable cost.

Table A1 - 8 Available Digital Data

Country	Aquifer Data / GW Vulnerability	GW Protection Zones	GW Abstraction	Surface Water Data	Ecological Data	Retail Filling Stations
Austria	✓	✓ Except Burgenland	✓ ✗ Selected regions only	✓	✓	✓ Catalist
Belgium	✓	✓	✗	✓	✓	✓ Catalist
Cyprus	✗ Raster format only	✗	✓	✗ Raster format only	✓	✗
Czech Rep.	✓	✓	✗	✓	✓	✓ Government maintained dataset
Denmark	✓	✗	✓	✓ Analysis by 3rd Party	✓	✓ National oil association dataset
Estonia	✓	✗ Exist but not in a digital format	✓	✓	✓	✓ ✗ Unsure of completeness
Finland	✗	✓	✗	✓	✓	✓ Commercial dataset
France	✓	✗ Exist but not in a digital format	✓	✓	✓	✓ Catalist
Germany	✓	✓ Except Thuringia	✗	✓	✓	✓ Catalist
Greece	✗	✗	✓ ✗ Selected regions only	✓	✓	✓ Commercial dataset
Hungary	✓ ✗ Limited information	✓ ✗ Limited information	✓ ✗ Limited information	✓ ✗ Limited information	✓ ✗ Limited information	✓ ✗ Limited information
Ireland	✓ ✗ Selected regions only	✓ ✗ Selected regions only	✓ ✗ Selected regions only	✓	✓	✓ Catalist
Italy	✓ ✗ Selected regions only	✓ ✗ Selected regions only	✓ ✗ Selected regions only	✓ ✗ Selected regions only	✓ ✗ Selected regions only	✓ Catalist
Latvia	✓	✓ May be incomplete	✓	✓	✓	✗ Exist but not in a suitable format

Country	Aquifer Data / GW Vulnerability	GW Protection Zones	GW Abstraction	Surface Water Data	Ecological Data	Retail Filling Stations
Lithuania	× Incomplete	✓	✓	×	✓	✓ Commercial dataset
Luxembourg	×	×	×	×	×	✓ Catalist
Malta	×	×	×	×	×	✓ Commercial dataset
Netherlands	✓	✓	×	✓	✓	✓ Catalist
Norway	✓	×	✓	✓	✓	✓ Catalist
Poland	✓	✓	✓	✓ 1:200k scale only	✓	✓ Commercial dataset
Portugal	✓	×	✓	✓ 1:1million scale only	✓	✓ Catalist
Slovakia	× Raster format only	×	✓	✓	✓	✓ Commercial dataset
Slovenia	✓	✓	×	✓	✓	✓ Government maintained dataset
Spain	✓	×	✓	✓ 1:200k scale only	✓	✓ Catalist
Sweden	✓	✓	✓	✓	✓	✓ Commercial dataset
UK	✓	✓	✓	✓ Analysis by 3^{rd} Party	✓	✓ Catalist

7.3. SUMMARY

Data availability may be classified into a number of generalised groups as follows:

A. Digital data for most parameters were generally lacking for all, or major parts of the country (e.g. Cyprus, Greece).

B. Digital data existed for most parameters for all or major parts of, the country, but there were significant gaps that prevented an environmental sensitivity assessment being carried out at the time (e.g. Lithuania, Portugal).

C. Sufficient digital data apparently existed to carry out an environmental sensitivity assessment now, but there was significant uncertainty about the accessibility and cost of the data (e.g. Estonia, Latvia, Slovenia).

D. The necessary digital data to carry out an environmental sensitivity assessment existed but the cost far exceeded the available budget (e.g. Sweden).

E. The necessary digital data to carry out an environmental sensitivity assessment existed and were available at reasonable cost (e.g. Austria, Belgium, UK).

Most of the countries falling within categories A to C were in an active, and often advanced, stage of compiling the kinds of digital data required to carry out the environmental sensitivity assessments which means it should be technically feasible to address these countries in the future. However, despite minor and perhaps technically justifiable differences in data formats, there are very large and practically important differences in data costs, which in some cases will clearly constrain the use of such data.

8. COUNTRY SELECTION FOR ENVIRONMENTAL SENSITIVITY ASSESSMENTS

8.1. CRITERIA FOR SELECTING COUNTRIES

The selection of countries to be taken forward for environmental sensitivity assessments was a compromise between the following factors:

- Maximising the geographic and demographic coverage of Europe.
- Representing the diversity of hydrogeological and socio-economic conditions.
- The availability of comparable digital data at reasonable cost.

8.2. SENSITIVITY ASSESSMENT PARAMETERS

In order to compare regions, it was necessary to define parameters that are applicable to all regions. Based on the assessment of data availability a comparable sensitivity assessment could be built on the following parameters:

- Groundwater vulnerability class
- Groundwater protection zone class OR Groundwater abstraction locations
- Proximity to surface water
- Proximity to Special Protection Areas
- Proximity to Special Areas of Conservation

A critical decision was not to include both groundwater protection zones and groundwater abstractions as required datasets, as in many of the countries assessed, the availability of such data tended to be limited to either one or the other, whilst cost also prohibited the feasibility of using such datasets in some countries. For countries where both datasets were available, groundwater protection zone data would be favoured.

8.3. CONCLUSIONS

Based on the requirements listed above and the assessment of digital data availability, it was judged technically feasible to carry out environmental sensitivity assessments on all or part of the following countries:

Austria	Germany	Poland
Belgium	Hungary	Portugal
Czech Rep.	Ireland	Slovenia
Denmark	Italy	Sweden
Estonia	Latvia	UK
Finland	Netherlands	Spain
France	Norway	

However, the very high costs of certain datasets in certain countries and uncertainties over accessibility of the data meant it was not considered practicable to do environmental sensitivity assessments in: Estonia, Hungary, Latvia Portugal, Slovenia and Sweden at that time. Ireland was also excluded at that time on the basis of the small size of the retail fuel market compared to the resources required to do the assessment.

Therefore, environmental sensitivity assessments were progressed for: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Poland, Spain and the UK.

8.4. SELECTED COUNTRIES

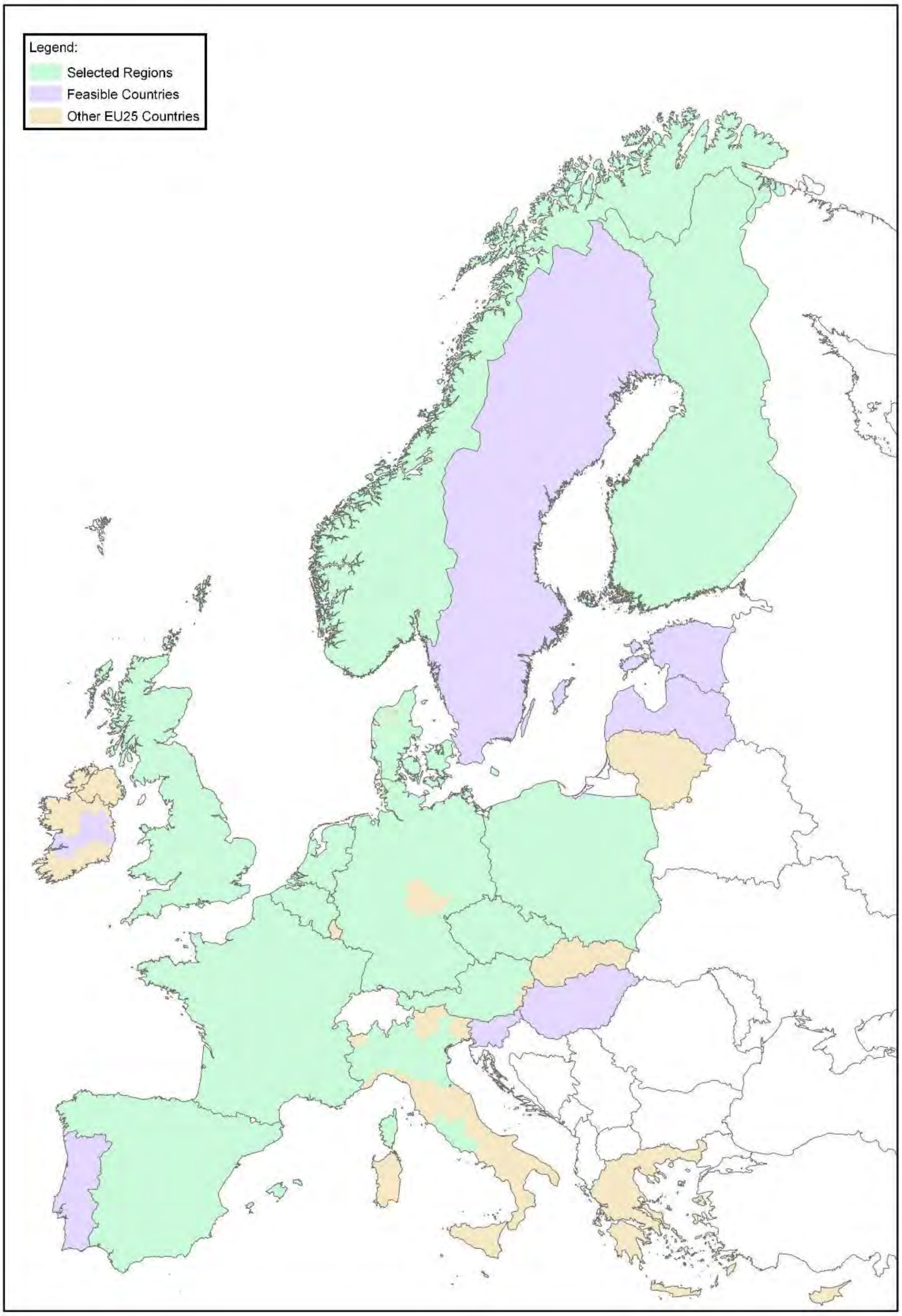
The key characteristics of the countries/regions selected for environmental sensitivity assessments are detailed in **Table A1 - 9**, with their locations shown in **Figure A1 - 8**. The proportion of each country covered depended on data availability and/or cost.

Table A1 - 9 Characteristics of selected countries for environmental sensitivity assessments

Country / Region	Study Area	Hydrogeological Province(s)	Main Aquifers	Area (km^2)	Population (M)
Austria	Whole country minus Burgenland	Hungarian Plains	Karst	79,906	8.1
Belgium	Whole country	Paris Basin, North Sea and Baltic Lowlands, Uplands of Eastern France and Central Southern Germany, Basement and Crystalline Rocks	Tertiary Sands	30,528	10.7
Czech Republic	Whole country	North Sea and Baltic Lowlands, Alpine Fold Mountains, Basement and Crystalline Rocks	Karst and Quaternary Fluvial Sediments	78,866	10.5
Denmark	Whole country	North Sea and Baltic Lowlands	Chalk, Quaternary and Miocene Sands & Gravels	43,098	5.5
Finland	Whole country	Scandinavian Province	Glacio-fluvial aquifers	338,145	5.3
France	Whole country	Paris Basin, Aquitaine Basin, Sub Alpine Basin and Grands Causses, Alpine Fold Mountains and Marginal Areas, Basement and Crystalline Rocks	Chalk, Mesozoic Sediments, Karst	674,843	65.1

Country / Region	Study Area	Hydrogeological Province(s)	Main Aquifers	Area (km^2)	Population (M)
Germany	Whole country minus Thuringia	North Sea and Baltic Lowlands, Uplands of E France and Central S Germany, Alpine Fold Mountains and Marginal Areas, Basement and Crystalline Rocks	Chalk, Quaternary and Miocene Sands & Gravels, Karst, Alluvium	340,850	79.8
Italy	5 Regions: Emilia Romagna, Piemonte, Lazio, Lombardia, Veneto	Alpine Fold Mountains and Marginal Areas, Apennines and Coastal Areas	Karst	106,983	28.9
Netherlands	Whole country	North Sea and Baltic Lowlands	Chalk, Quaternary and Miocene Sands & Gravels	41,526	16.5
Norway	Whole country	Scandinavian Province	Glacio-fluvial aquifers	385,252	4.8
Poland	Whole country	N Sea and Baltic Lowlands, basement	Quaternary and Tertiary fluvial, fluvio-glacial and alluvium	312,679	38.1
Spain	Whole country	Iberian Peninsula, Alpine Fold Mountains and Marginal Areas, Basement and Crystalline Rocks	Complex carbonate aquifers	504,030	46.2
UK	Whole country minus Northern Ireland	British Province, Basement and Crystalline Rocks	Chalk, Jurassic limestones and Triassic Sandstone	229,946	59.3
Total (for selected countries)				**3,166,652**	**378.8**
Total EU-27 (2009)				**4,456,304**	**499.0**
Total EU-27 plus Norway				**4,841,252**	**503.4**

Figure A1 - 8 Countries Selected for Environmental Sensitivity Assessments



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Appendix 2 to report no. 1/11

Calibration of Groundwater Protection Buffer Zones for countries where actual Groundwater Protection Zone data were not available

CONTENTS

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1. INTRODUCTION

1.1. BACKGROUND

For several countries included in the Stage II analysis including Denmark, France, regions of Italy (Lombardy, Piedmont, and Veneto), Spain and Norway, no data relating to Groundwater Protection Zones (GPZs) were available. This was either due to information on the extent of GPZs not being stored in a suitable digital GIS format, or simply that GPZs had not yet been defined or implemented. In these countries and regions „buffer zones" around groundwater abstractions were used. These „buffer zones" were set at distances of 50 m (zone 1), 100 m (zone 2), and 250 m (zone 3) from the groundwater abstractions based on experience of the travel distance of the most mobile petroleum hydrocarbons in groundwater. It is rare for petroleum hydrocarbons to travel greater than 100 m from the edge of a source and most plumes are only a few tens of metres in length [1]. There are some notable exceptions to this "rule of thumb", but the objective of this project was to develop a methodology that identified 90% of sites with high risk potential. If the mesh size of a tier 1 risk assessment is set too fine it becomes a funnel rather than a sieve which is counter-productive to identifying sites with real environmental risk potential.

This approach was calibrated against data from countries where GPZ data had been obtained by:

- Comparing the results for countries where both GPZ and groundwater abstraction data are available, and therefore where both methodologies are applicable.
- Using the more detailed Spain abstraction data to assess the effect of applying different distance buffers to abstractions based upon volume abstracted.
- Applying the understanding gained to other countries in the study where groundwater abstractions have been used to determine simulated GPZs based on these „buffer distances".

2. CALIBRATION OF GROUNDWATER PROTECTION BUFFER ZONES BASED ON PROXIMITY TO ABSTRACTION POINT

The analysis focussed on using the UK and The Netherlands as study countries due to the availability of both GPZ and groundwater abstraction data. In addition, the definition, implementation, and regulation of GPZs in these countries are among the most developed in Europe.

2.1. APPLYING ORIGINAL PROXIMITY BUFFERS IN THE STUDY COUNTRIES

The first step of the modelling involved calculating the number of retail filling station locations that lie within defined GPZs in the UK and The Netherlands. Then the number of retail stations that would lie within the 50 m, 100 m and 250 m buffer zones (if these had been modelled around abstractions) were determined. This enabled a comparison between the actual GPZ results and the outcome that would have been gained if no GPZ data had been available in each of the two study countries, the results of which are presented in **Table A2 - 1**.

With the exception of zone 1 in The Netherlands, the results show that more petrol filling station locations lie within the defined GPZs compared to the modelled buffer zones. In The Netherlands, there were almost 18 times as many sites located within a defined GPZ than in the modelled equivalent, whilst in the UK this rises to over 23 times as many.

This finding is probably a result of the relative sizes of the published GPZs and the modelled GPZ buffer zones derived in this report. In part the difference in size reflects assumptions on groundwater / petroleum hydrocarbon travel time and transport velocity. Published GPZs are invariably based on groundwater velocity (i.e., un-retarded flow velocity) since they are applied to a range of contaminant protection measures including both conservative (e.g. nitrate, chloride) and retarded compounds (e.g. petroleum hydrocarbons). It is interesting to note that work by Smith & Lerner (2007) on aquifer attenuation potential identified a retardation factor of $R_f \approx 20$ for benzene in a typical aquifer with organic carbon content of 2% ($f_{oc} = 0.02$), and $R_f \approx 28$ for naphthalene in an aquifer with $f_{oc} = 0.002$. These figures closely match the ratio of sites in GPZ derived on conservation / retarded transport assumptions.

These results indicate that although the buffer distances used to model GPZs for countries without relevant data reflect the extent of petroleum hydrocarbon plume transport in groundwater, they do not reflect the extent of a GPZ for a groundwater abstraction in these two countries. Therefore, in order to understand the distances that might provide a more realistic representation of the extent of the GPZs, further testing of the modelling was undertaken.

2.2. AVERAGING PROXIMITY BUFFERS BASED ON DEFINED GROUNDWATER PROTECTION ZONES

The next stage of the analysis looked at replicating the area coverage of defined GPZs as buffer zones around the abstractions. For both study countries, the total area for each zone (and accounting for any inner zones) was calculated using GIS and then divided by the total number of protected abstractions, resulting in the circular area that each zone would need to cover around each site to be distributed evenly. The radius of this circular area could then be calculated using the formula:

$$Area = \pi r^2$$

These radii were then applied as averaged buffer distances around the abstractions and the total number of retail filling station locations that lie within the zones was calculated. The results, compared to the results from using the defined GPZs, are presented in **Table A2 - 2**. There are limitations to this approach, because published GPZ are generally not circular. Indeed, the results from this analysis were variable, with the results in the UK showing that by replicating the area coverage of GPZs as buffers around groundwater abstractions the total number of retail filling station locations lying within averaged buffer distances increased by 241 sites. However, in The Netherlands, the same analysis indicated that the total number of retail filling station locations lying within averaged buffer distances fell by 158 sites.

2.3. CALIBRATING PROXIMITY BUFFERS BASED ON DEFINED GROUNDWATER PROTECTION ZONE RESULTS

Finally, an exercise was undertaken to establish the buffer distances that would be required in order to achieve the same results in terms of retail filling station numbers, compared to using the defined GPZs. This was undertaken by taking the calculated averaged buffer distance (see above) and carrying out a stepped process of increasing or decreasing the buffer distance as appropriate until the numbers of retail filling stations within the modelled buffer zones were equal to that within the defined GPZs. The results are shown in **Table A2 - 3**.

2.4. SUMMARY OF SENSITIVITY ANALYSIS

The results illustrate that in the UK and The Netherlands there is a range of distances from an abstraction that could be applicable for the purposes of simulating GPZs. For example, to represent a zone 1 as a buffer distance from an abstraction in The Netherlands, in order to achieve the same results as using defined GPZs, a buffer distance of 25m around an abstraction would be necessary. However in the UK, by replicating the area of defined zone 1 coverage as buffers around abstractions, a distance of 554m would be required. Visually comparing the defined GPZs with the two types of buffer zones modelled as part of the sensitivity testing, the extent and coverage of the defined GPZs appears much larger than for either of the modelled outcomes. **Figure A2 - 1(a-c)** illustrates these results for the eastern area of the UK, and **Figure A2 - 2(a-c)** illustrates the results for the central area of The Netherlands.

The results of the sensitivity testing indicate that the initial selection of 50 m, 100 m and 250 m as buffer zones for modelling GPZs may result in a lower estimation of the number of sites where groundwater sensitivity could be significant for contaminants that are more mobile in groundwater than petroleum hydrocarbons, as shown by **Figure A2 - 3**. From the results gained in this analysis, and by taking an approximate average from the range of distances calculated as possible buffer values for modelling GPZs, alternative buffer values were assigned, as shown below:

	Range of Distances from Analysis	**Alternative buffer Distance**
Zone 1	25 – 554 m	250 m
Zone 2	510 – 1164 m	750 m
Zone 3	844 – 1806 m	1250 m

Table A2 - 4 details the resulting numbers of retail filling station locations within each GPZ using these alternative buffer distances for those countries where proximity to groundwater abstractions has been used to model GPZs.

3. ASSESSING THE IMPACT OF GROUNDWATER ABSTRACTION USE

The sensitivity analysis suggests that by using the alternative buffer distances calculated by calibrating with data from countries with defined GPZs there would be a change in the distribution of groundwater sensitivity, and subsequently environmental sensitivity, for the sites in these countries where this estimation method was used. However, these alternative values have only been derived based upon a small study of two countries, and therefore the applicability of these distances should be considered in the context of the country to which they are to be applied. For example, much of Norway is underlain by non aquifer with groundwater occurring on a localised scale, so these larger buffer zones may not be as applicable as in a country such as Denmark where groundwater is more extensively exploited.

One of the limitations of applying the results of the calibration and sensitivity analysis to those countries where proximity to groundwater abstractions has been used in the analysis of environmental sensitivity is that apart from their location, little is known about the purpose of the abstractions. In all cases the numbers of abstractions in these countries is considered high in comparison to the number of GPZs in other countries, suggesting that the use of these abstractions is not just limited to public drinking water supply wells.

Therefore given that the calibration and sensitivity analysis was based on modelling public drinking water supply wells in the UK and the Netherlands, applying the resultant distances to all groundwater abstractions in another country, regardless of use, is likely to result in an over-estimation of the number of sites that are of higher sensitivity category with respect to groundwater.

In order to assess this, a further study has been conducted based on the Spanish datasets.

3.1. GROUNDWATER ABSTRACTIONS AND GPZS IN SPAIN

It is understood that no GPZs have been officially defined in Spain, however information was available from the Instituto Geologico y Minero de Espana (IGME) for groundwater abstractions. The detailed attribute information provided with the groundwater abstraction locations, including volume abstracted per year meant that it was possible to model GPZs in a more detailed and intuitive way than was possible for other countries where GPZ data were not available.

The specific methodology used to model the GPZs is outlined in the Spain country report (**Appendix 15**) and utilised a dataset provided by the IGME containing the locations of over 30,000 groundwater abstractions.

Although no attribute information has been provided to indicate the specific use of each abstraction, the very large range in volumes abstracted along with the high total number of abstractions in the dataset suggest that it contains abstractions for all types of use, including private supply, agricultural, industrial, and public drinking water supply.

3.2. APPLYING THE CALIBRATION AND SENSITIVITY ANALYSIS IN SPAIN

3.2.1. Applying Original Proximity Buffers

Based on the dataset of over 30,000 groundwater abstraction locations available, the original 50 m, 100 m, and 250 m proximity buffers were modelled around each abstraction to assess the number of retail filling stations that fall within each buffer zone. The results are shown below and are compared to the results gained from the detailed GPZ modelling carried out as part of the Spain country study.

	Number of Retail Filling Stations in Spain	
	Modelled GPZs	**Standard Buffer Zones**
Zone 1	18	17
Zone 2	102	90
Zone 3	731	393
Total GPZ	**851**	**500**

Although the number of sites in the modelled GPZs is greater than those that fall within the original standard buffer zones, the difference between the numbers of retail filling stations is much less when compared to the UK and The Netherlands results, especially when looking at zones 1 and 2.

3.2.2. Calibrating Proximity Buffers based on the Spain modelled GPZ Results

The buffering exercise to establish the equivalent buffer distances that would be required in order to achieve the same results in terms of retail filling station numbers, compared to using the modelled GPZs in Spain was carried out on all abstractions. The results indicate that the required distances needed to replicate the true results are 50 m for zone 1, 105 m for zone 2 and 360 m for zone 3, and are much more closely aligned with the 50 m, 100 m and 250 m standard buffer zones in comparison to the UK and The Netherlands.

3.3. ADJUSTING THE NUMBER OF ABSTRACTIONS BASED ON VOLUME

The results of the sensitivity analysis in Spain suggest that the recommended distances for modelling GPZs as buffers around abstractions is much lower than was indicated by the study in the UK and The Netherlands. However, the results for Spain include the use of all abstraction locations (over 30,000 in total) regardless of abstraction purpose, whilst the results in the UK and The Netherlands results are based on public drinking water supply abstractions (between 1,000 and 2,000 abstractions in each country).

Although no attribute information has been provided to indicate the specific use of each abstraction in Spain, information has been provided relating to the average volume that is abstracted on an annual basis. A breakdown of the numbers of abstractions by volume abstracted is provided in **Table A2 - 5**, and highlights the high number of abstractions where the annual abstracted volume is minimal. Realistically these minimal volume abstractions are unlikely to represent public drinking water supply abstractions, which are more likely to be included amongst those abstractions that abstract greater than 100,000 m^3 per annum.

In order to assess the impact that using all abstractions against just public water supply abstractions might have on the sensitivity analysis results, the analysis was repeated using the data in Spain for several scenarios, based on using abstractions of differing volumes. The results are provided in **Tables A2 - 6 and 7**, and indicate for each scenario the numbers of retail filling stations that fall into the modelled GPZs in Spain, the numbers that would fall into the standard buffer zones used in the study (50 m, 100 m, and 250 m), and the calibrated buffer distances required to match the results for the modelled GPZs in Spain.

These results indicate that as the abstractions of lower annual volumes are removed from the sensitivity analysis, the ratio between the results of the modelled GPZs in Spain and the original buffer zones, and the calibrated buffer distances both increase.

When considering only those abstractions of greater than 1,000,000 m^3 per annum, there are 326 sites in total that fall within one of the modelled GPZs in Spain, whilst when the buffer zones are applied only 8 sites in total fall within them. In addition the calibrated buffer zones have all increased by more than 100% when compared to the analysis using all abstractions.

4. CONCLUSION

This study has assessed the applicability of using buffer zones around groundwater abstractions as a way of simulating GPZs in countries where GPZ data are not available. The study has compared the results gained from using both defined GPZ and buffer zones in the UK and The Netherlands, with further analysis using data available in Spain. This has allowed an assessment to be made of reasonable distances to use.

For countries where GPZ data were unavailable, modelling GPZs as concentric rings or buffers around groundwater abstractions has already been acknowledged as having limitations within the wider study. However, given the information available, and the context of the overall study, substituting this proximity to groundwater abstraction analysis where GPZ data is unavailable has allowed more countries to be included, and provided an idea of the degree and pattern of groundwater sensitivity at retail filling stations in countries where GPZ data were not available.

Initially, a decision was made to use 50 m, 100 m, and 250 m as the buffer zone distances around groundwater abstractions for modelling GPZs in countries where data was unavailable. This was based upon experience of the travel distance of the most mobile petroleum hydrocarbons in groundwater. However, the initial calibration and sensitivity analysis study focussed on the UK and The Netherlands suggested that when compared to the defined GPZs, these buffer zones could be underestimates of GPZs for contaminants that are more mobile in groundwater than petroleum hydrocarbons. The results of this analysis indicated that buffer distances of 250 m, 750 m and 1250 m would be more appropriate for such contaminants.

However, the sensitivity analysis study was based on an analysis of public drinking water supply abstractions, whilst the groundwater abstraction data available in other countries tends to include all abstractions regardless of use. Analysis of the available groundwater data in a further country, Spain, was carried out, that allowed an assessment of scenarios based on over 35,000 abstractions of varying use, and on just the higher volume abstractions that are more likely to represent drinking water supply use. This analysis highlighted that when considering all abstractions, the resulting buffer distances were significantly lower than if only higher volume abstractions are considered, and are much more aligned to the original buffer zones used in the original analysis.

In conclusion, this study has demonstrated that the most appropriate distances to use when modelling GPZs as buffers around groundwater abstractions, will largely depend on the hydrogeology and use of the groundwater abstraction being modelled. It is felt that the use of the original buffer zones in these cases can be justified based on the findings of this study. The applicability of using these distances, however, should also be considered in the context of the country to which they are to be applied. For example, much of Norway is underlain by non aquifer with groundwater occurring on a localised scale, so larger buffer zones may not be as applicable as in Denmark where groundwater is extensively exploited.

Table A2 - 1 Comparison of number of Retail Filling Stations in actual GPZs against modelled GPZs using original Buffer Zones

	Number of Retail Filling Stations			
	United Kingdom		The Netherlands	
	Defined GPZ	Modelled buffer zones	Defined GPZ	Modelled buffer zones
Zone 1	227	6	1	3
Zone 2	695	13	84	2
Zone 3	925	61	291	16
Total Area	1847	80	376	21

Modelled Buffer Zones: Zone 1 = 50 m, Zone 2 = 100 m, Zone 3 = 250 m

Table A2 - 2 Comparison of number of Retail Filling Stations in actual GPZs against modelled GPZs using averaged Buffer Zones

	United Kingdom			(total abstractions = 1968)
	Area of defined GPZ (km^2)	Calculated averaged buffer distance (m)	Number of retail filling stations in modelled GPZ buffers	Number of retail filling stations in defined GPZs
Zone 1	1897.7	554	329	227
Zone 2	8371.4	1164	795	695
Zone 3	20170.1	1806	635	925
Total Area	20170.1	-	2088	1847

	The Netherlands			(total abstractions = 1353)
	Area of defined GPZ (km^2)	Calculated averaged buffer distance (m)	Number of retail filling stations in modelled GPZ buffers	Number of retail filling stations in defined GPZs
Zone 1	161.2	195	12	1
Zone 2	1182.4	527	77	84
Zone 3	3024.4	844	117	291
Total Area	3024.4	-	218	376

Table A2 - 3 Comparison of number of Retail Filling Stations in actual GPZs against modelled GPZs using calibrated Buffer Zones

	United Kingdom		The Netherlands	
	Calibrated buffer distance (m)	Number of retail filling stations in defined GPZ	Calibrated buffer distance (m)	Number of retail filling stations in defined GPZ
Zone 1	435	227	25	1
Zone 2	1030	695	510	84
Zone 3	1645	925	1020	291
Total Area	-	1847	-	376

Table A2 - 4 Results for Countries with Modelled Groundwater Protection Zone Buffers: comparison of original buffer zones with calibrated buffer zone distances

	Denmark		**France**	
	Retail filling stations in GPZs	Retail filling stations in GPZs using alternative calibrated buffer distances	Retail filling stations in GPZs	Retail filling stations in GPZs using alternative calibrated buffer distances
Zone 1	12	206	7	220
Zone 2	28	841	25	1244
Zone 3	166	1287	188	1752
Total Area	206	2334	220	3216

	Italy (Lombardy)		**Italy (Piedmont)**	
	Retail filling stations in GPZs	Retail filling stations in GPZs using alternative calibrated buffer distances	Retail filling stations in GPZs	Retail filling stations in GPZs using alternative calibrated buffer distances
Zone 1	21	342	6	93
Zone 2	61	1137	17	394
Zone 3	260	794	70	334
Total Area	342	2273	93	821

	Italy (Veneto)		**Norway**	
	Retail filling stations in GPZs	Retail filling stations in GPZs using alternative calibrated buffer distances	Retail filling stations in GPZs	Retail filling stations in GPZs using alternative calibrated buffer distances
Zone 1	3	47	2	25
Zone 2	3	227	3	108
Zone 3	41	223	20	148
Total Area	47	497	25	281

Table A2 -5 Number of Groundwater Abstractions by Volume in Spain

Average Annual Volume Abstracted	**Number of Groundwater Abstractions in Spain**
< 1,000 m^3 per annum	22,728
1,000 – 10,000 m^3 per annum	4,822
10,000 – 100,000 m^3 per annum	3,823
100,000 – 1,000,000 m^3 per annum	2,032
> 1,000,000 m^3 per annum	329
TOTAL	33,734

Table A2 - 6 Comparison of numbers of retail filling stations in modelled Groundwater Protection Zones based on abstraction volume against original buffer zones in Spain

	Number of Retail Filling Station Locations			
Abstraction Volume	**All Abstractions**		**>= 1,000 m^3 per annum**	
	Modelled GPZ in Spain	Original buffer zones	Modelled GPZ in Spain	Original buffer zones
Zone 1	18	17	12	8
Zone 2	102	90	102	54
Zone 3	731	393	543	184
Total Area	851	500	657	246

	Number of Retail Filling Station Locations			
Abstraction Volume	**>= 10,000 m^3 per annum**		**>= 100,000 m^3 per annum**	
	Modelled GPZ in Spain	Original buffer zones	Modelled GPZ in Spain	Original buffer zones
Zone 1	7	4	4	2
Zone 2	101	22	69	10
Zone 3	512	118	492	45
Total Area	620	144	565	57

	Number of Retail Filling Station Locations	
Abstraction Volume	**>= 1,000,000 m^3 per annum**	
	Modelled GPZ in Spain	Original buffer zones
Zone 1	7	4
Zone 2	101	22
Zone 3	512	118
Total Area	620	144

Table A2 - 7 Number of Retail Filling Stations in calibrated Groundwater Protection Zone Buffer Distances by Abstraction Volume in Spain

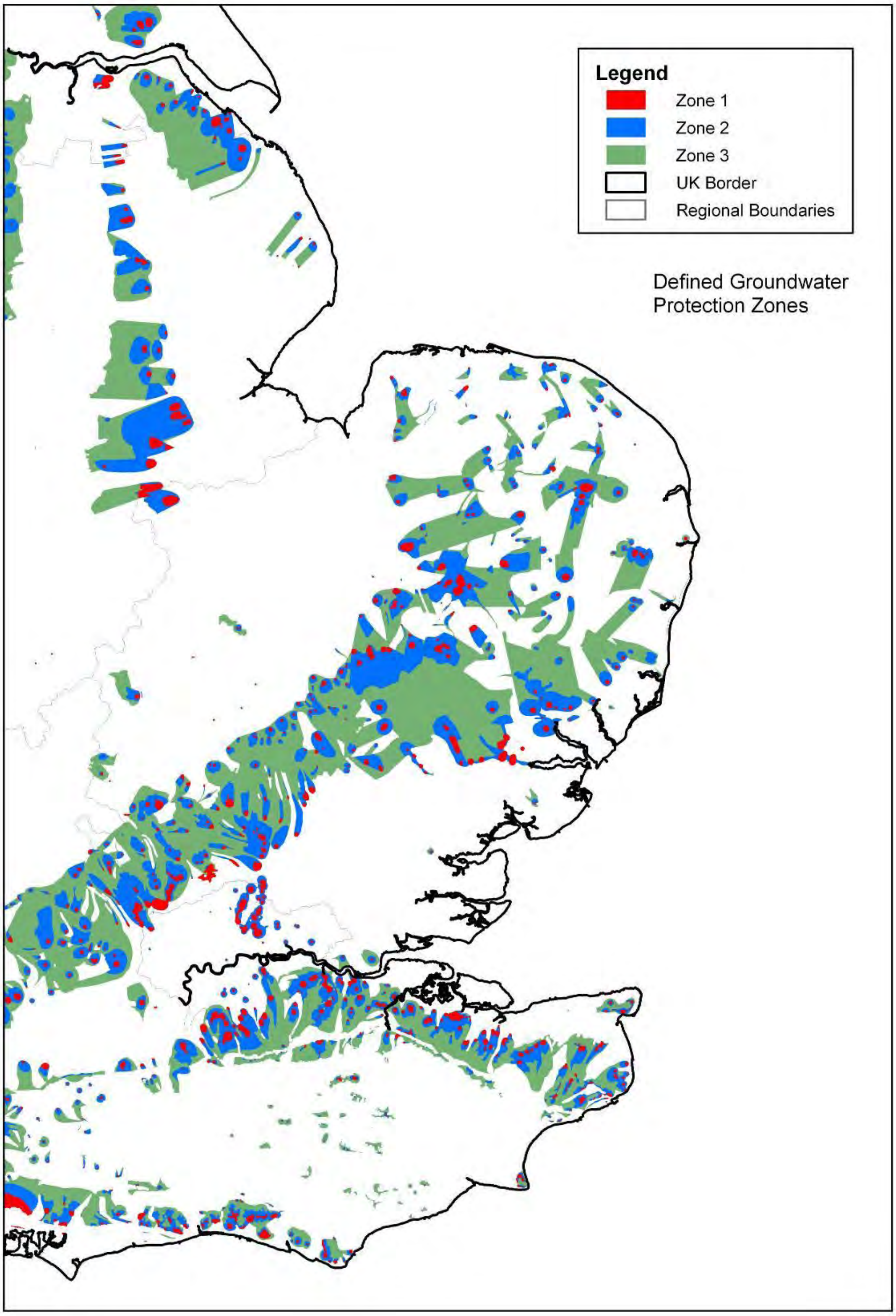
Abstraction Volume	**All Abstractions**		**>= 1,000 m^3 per annum**	
	Calibrated buffer distance (m)	Number of retail filling stations	Calibrated buffer distance (m)	Number of retail filling stations
Zone 1	50	18	58	12
Zone 2	105	102	143	102
Zone 3	360	731	519	543
Total Area	-	851	-	657

Abstraction Volume	**>= 10,000 m^3 per annum**		**>= 100,000 m^3 per annum**	
	Calibrated buffer distance (m)	Number of retail filling stations	Calibrated buffer distance (m)	Number of retail filling stations
Zone 1	67	7	70	4
Zone 2	200	101	286	69
Zone 3	646	512	1034	492
Total Area	-	620	-	565

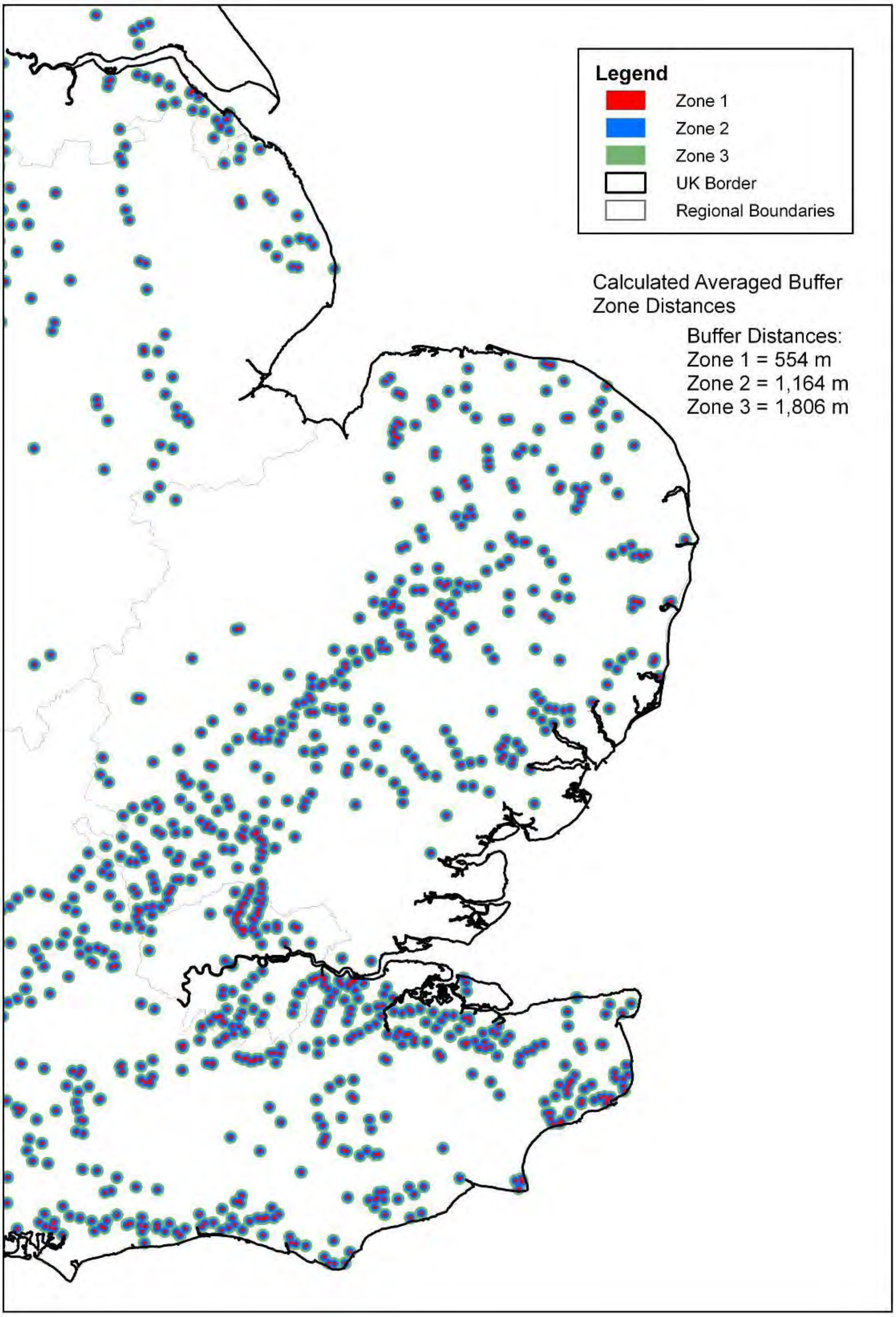
Abstraction Volume	**>= 1,000,000 m^3 per annum**	
	Calibrated buffer distance (m)	Number of retail filling stations
Zone 1	104	0
Zone 2	303	11
Zone 3	2128	315
Total Area	-	326

Figure A2 - 1 Groundwater Protection Zone Modelling for the Eastern Region of the United Kingdom

1a – Defined Groundwater Protection Zones



1b – Calculated Averaged Buffer Zone Distances



1c – Calibrated Buffer Zone Distances

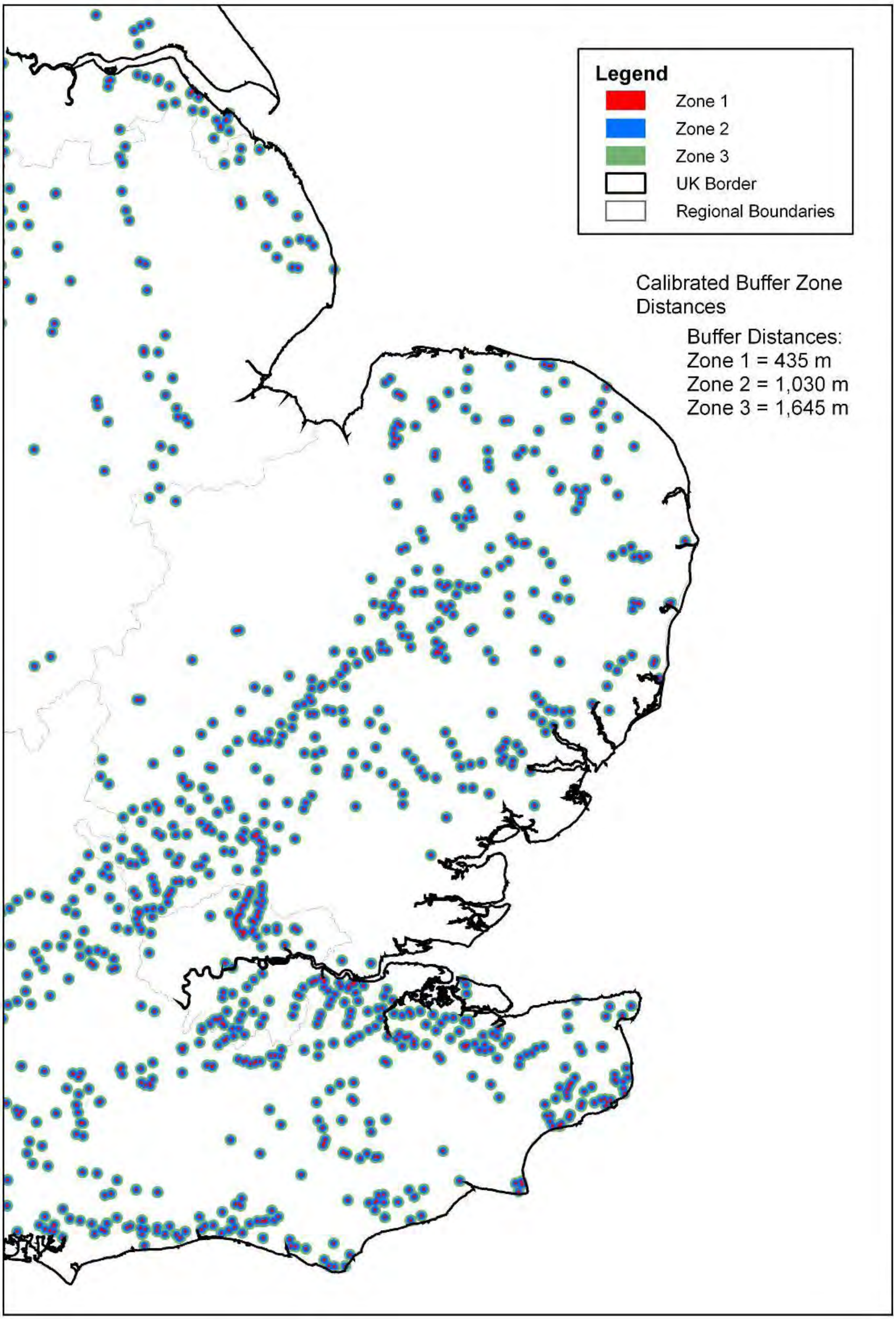
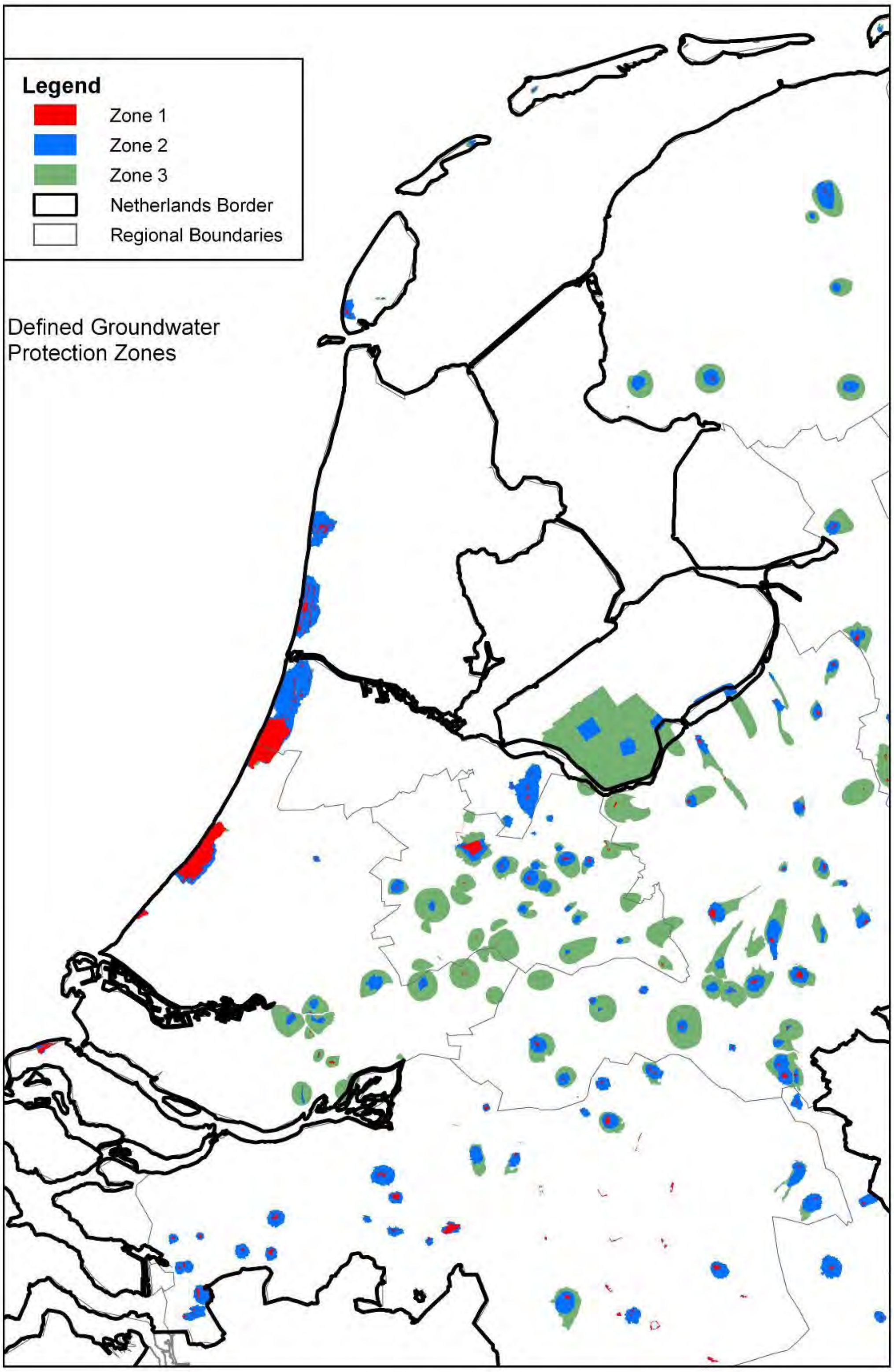
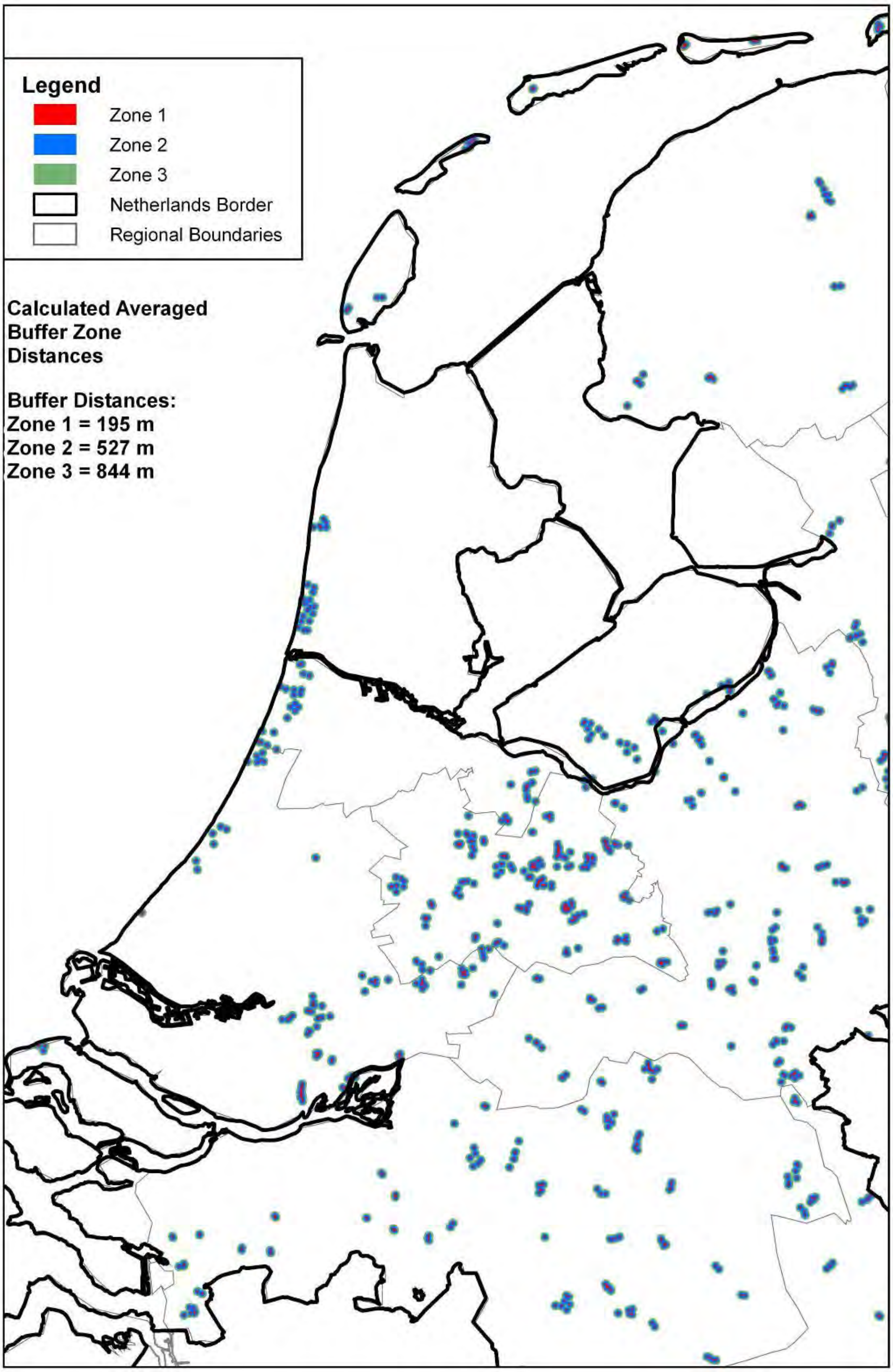


Figure A2 - 2 Groundwater Protection Zone Modelling for the Central Region of The Netherlands

2a – Defined Groundwater Protection Zones



2b – Calculated Averaged Buffer Zone Distances



2c – Calibrated Buffer Zone Distances

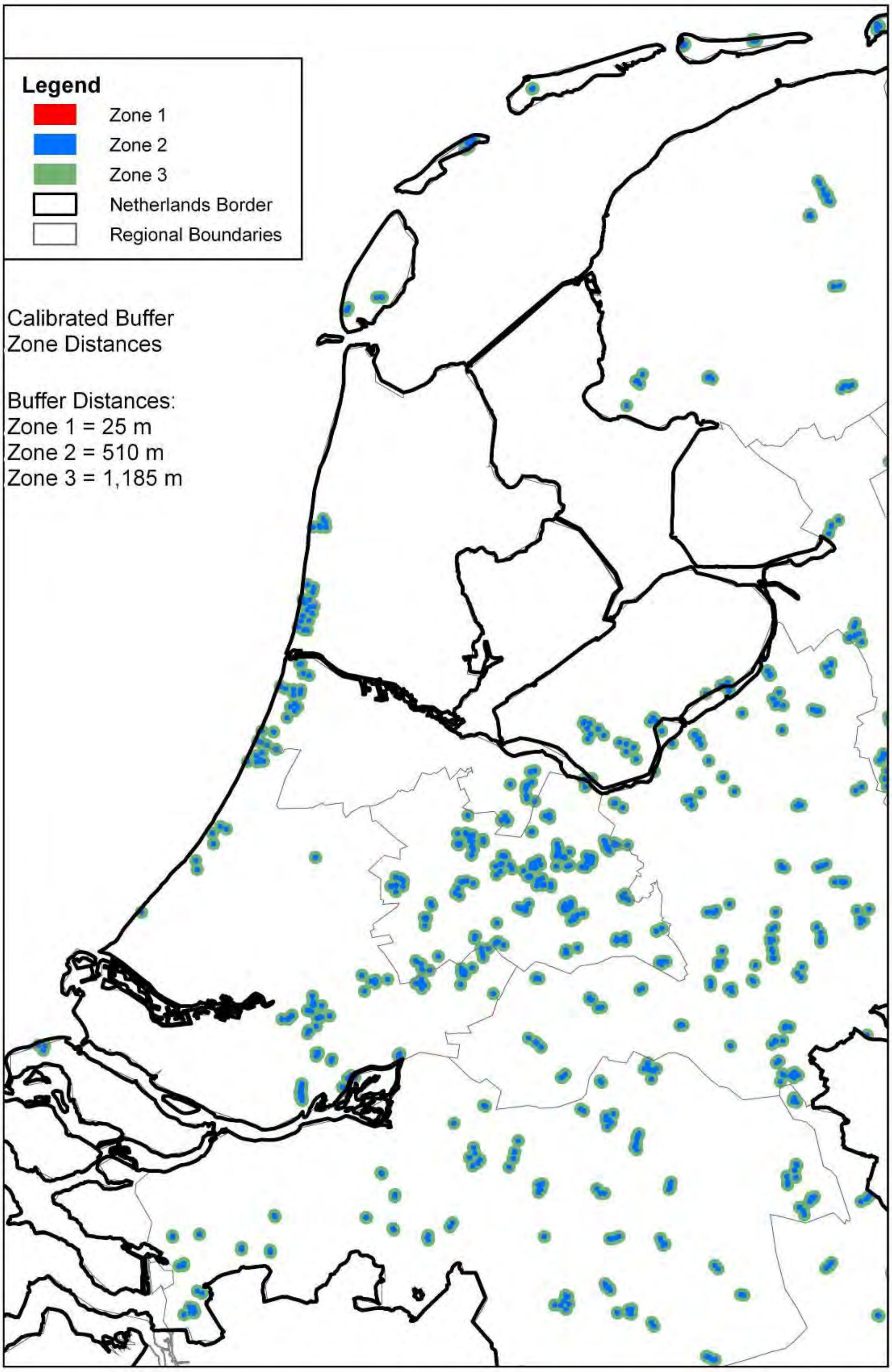
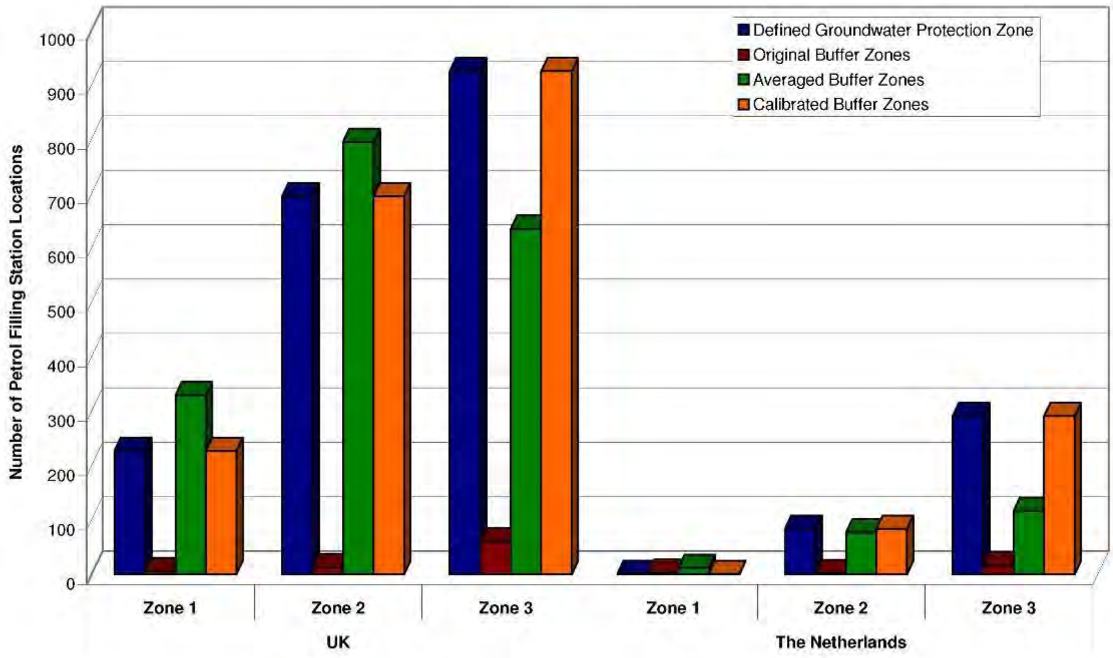


Figure A2 – 3 Groundwater Protection Zone Sensitivity Testing Study Results



5. REFERENCES

1. Newell, C.J. and Connor, J.A. (1998) Characteristics of dissolved petroleum hydrocarbon plumes. Results from four studies. API Soil and Groundwater Bulletin 8. Washington DC: American Petroleum Institute

Appendix 3 to report no. 1/11

National statistics (2005 – 2006) on use of groundwater as a source of drinking water

Country	Region	GW as % of Public Water Supply
Austria	Burgenland	75
	Kärnten	44
	Niederösterreich	42
	Oberösterreich	33
	Salzburg	55
	Steiermark	72
	Tirol	41
	Vorarlberg	70
	Wien	100
Belgium	Région de Bruxelles-Capitale	81
	Vlaams Gewest	50
	Région Wallonne	81
Cyprus	Country as whole	24
Czech Republic	Country as whole	47
Denmark	Country as whole	99
Finland	Country as whole	56
France	Ile-de-France	32
	Alsace	98
	Aquitaine	60
	Auvergne	76
	Basse-Normandie	71
	Bourgogne	90
	Bretagne	25
	Centre	95
	Champagne-Ardenne	97
	Corse	55
	Franche-Comté	84
	Haute-Normandie	100
	Languedoc-Roussillon	86
	Limousin	26
	Lorraine	78
	Midi-Pyrénées	19
	Nord-Pas de Calais	94
	Pays-de-la Loire	38
	Picardie	73
	Poitou-Charentes	62
	Provence-Alpes-Côte d'Azur	46
	Rhône-Alpes	89

Country	Region	GW as % of Public Water Supply
Germany	Baden-Württemberg	53
	Bayern	74
	Berlin	100
	Brandenburg	81
	Bremen	100
	Hamburg	100
	Hessen	83
	Mecklenburg-Vorpommern	85
	Niedersachsen	86
	Nordrhein-Westfalen	39
	Rheinland-Pfalz	71
	Saarland	96
	Sachsen	28
	Sachsen Anhalt	46
	Schleswig-Holstein	100
	Thüringen	51
Greece	Country as whole	50
Hungary	Country as whole	56
Ireland	Country as whole	50
Luxembourg	Country as whole	67
Netherlands	Country as a whole	68
Poland	Dolnośląskie	67
	Kujawsko-Pomorskie	80
	Łódzkie	87
	Lubelskie	100
	Lubuskie	92
	Małopolskie	32
	Mazowieckie	45
	Opolskie	90
	Podkarpackie	45
	Podlaskie	85
	Podmorskie	92
	Śląskie	38
	Świętokrzyskie	86
	Warmińsko-Mazurskie	100
	Wielkopolskie	89
	Zachodniopomorskie	74
Portugal	Country as whole	40
Slovakia	Country as whole	83

Country	Region	GW as % of Public Water Supply
Spain	Audalucía	40
	Aragón	32
	Cantabria	21
	Castilla y León	29
	Castilla-La Mancha	24
	Cataluña	23
	Communidad de Madrid	7
	Communidad Foral de Navarra	24
	Communidad Valenciana	50
	Extremadura	16
	Galicia	21
	Islas Baleares	95
	Islas Canarias	100
	La Rioja	25
	País Vasco	21
	Principado de Asturias	21
	Región de Murcia	6
Sweden	Country as whole	20
United Kingdom	Bedfordshire and Hertfordshire	35
	Berks, Bucks and Oxon	35
	Cheshire	8
	Cornwall and Isles of Scilly	30
	Cumbria	8
	Derbyshire and Nottinghamshire	34
	Devon	30
	Dorset and Somerset	30
	East Anglia	37
	East Riding and North Lincolnshire	20
	East Wales	3
	Eastern Scotland	5
	Essex	36
	Gloucester Wilts and N. Somerset	68
	Greater Manchester	8
	Hampshire and Isle of Wight	68
	Hereford, Worcester and Warwick	36
	Highlands and Islands	5
	Inner London	35
	Kent	63
	Lancashire	8
	Leicester, Rutland and Northants	36
	Lincolnshire	37
	Merseyside	8
	North Eastern Scotland	5

Country	Region	GW as % of Public Water Supply
	North Yorkshire	14
	Northern Ireland	8
	Northumberland, Tyne and Wear	14
	Outer London	35
	Shropshire and Staffordshire	33
	South Western Scotland	5
	South Yorkshire	20
	Surrey, East and West Sussex	52
	Tees Valley and Durham	14
	West Midlands	37
	West Wales and The Valleys	3
	West Yorkshire	14

Data from European Environment Agency (1999)[1]

Country	Surface water (%)	Groundwater (%)
Austria	0.7	99.3
Belgium (Brussels)	100	0
Belgium (Flanders)	48.5	51.5
Czech Republic	56	44
Denmark	0	100
Finland	44.4	55.6
France	43.6	56.4
Germany	28	72
Greece	50	50
Iceland	15.9	84.1
Ireland	50	50
Italy	19.7	80.3
Luxembourg	31	69
Netherlands	31.8	68.2
Norway	87	13
Portugal	20.1	79.9
Spain	77.4	21.4
Sweden	51	49
Switzerland	17.4	82.6
UK	72.6	27.4

[1] Scheidleder, A. et al (1999) Groundwater quality and quantity in Europe. Data and basic information. Technical report No. 22. Copenhagen: European Environment Agency

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