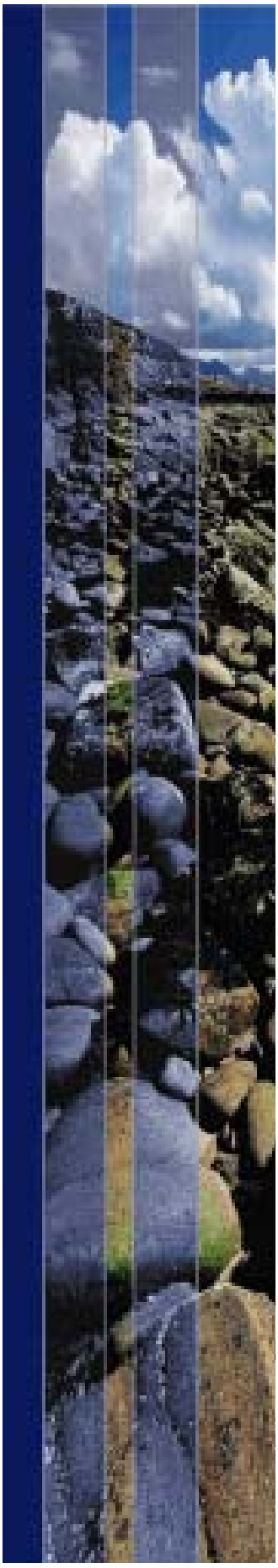


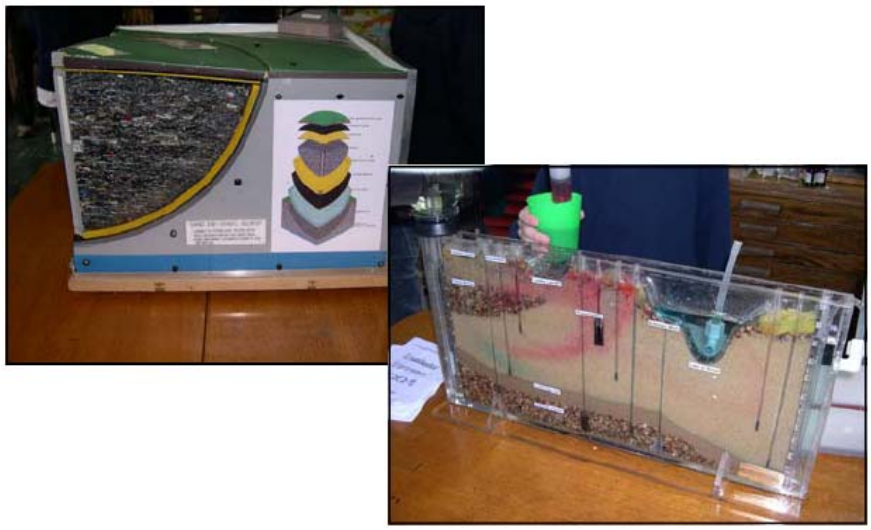
UKGroundwaterForum

A Review to Identify Options to Improve Groundwater Education in Schools

Earth Sciences Education Unit
Keele University

KEELE UNIVERSITY

EARTH SCIENCE EDUCATION UNIT



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GLOSSARY OF ABBREVIATIONS

AS/A Level	Advanced Supplementary Level & Advanced Level
ACCAC	The Qualifications, Curriculum and Assessment Authority for Wales – Awdurdod Cymwysterau, Cwricwlwm as Asesu Cymru
AQA	Assessment & Qualifications Alliance, an Awarding Body based in England
ASE	Association for Science Education
BGS	British Geological Survey
CCEA	Northern Ireland Council for Curriculum Examinations and Assessment.
CPD	Continuous Professional Development
DELLS	Department for Education, Lifelong Learning and Skills in Wales
DfES	Department for Education and Skills
EDEXCEL	An Awarding Body based in England
ELWa	Education and Learning Wales
ESEU	Earth Science Education Unit based at Keele University
ESTA	Earth Science Teachers' Association
GA	Geographical Association
GCSE	General Certificate of Secondary Education
GCE	General Certificate of Education
HMIE	Her Majesty's Inspectorate of Education
INSET	In-service training
LTS	Learning and Teaching Scotland
NDPB	Non Departmental Public Body
OCR	An Awarding Body based in England
QCA	Qualifications and Curriculum Authority – the Curriculum/Assessment body for England

SQA	Scottish Qualifications Authority
SEED	Scottish Executive Education Department
SEETLLD	Scottish Executive Enterprise, Transport and Lifelong Learning Department
WJEC	Welsh Joint Education Committee, an Awarding Body based in Wales

EXECUTIVE SUMMARY

The UK Groundwater Forum is an independent grouping of stakeholders drawn from the water industry, the environment regulators, the research community educational organisations and consultancies working in groundwater. It aims to raise the awareness of groundwater and the issues that are relevant to its use as a source of water supply and the role it plays in the environment. The Earth Science Education Unit (ESEU), based at Keele University, has been engaged by the Forum to review the current status of the teaching of groundwater and related issues in both primary and secondary education throughout the UK, with the ultimate aim of identifying areas for improvement.

The review has been divided into five tasks as follows:

- Assessment of the opportunities to teach groundwater within relevant curricula for ages 5-18 in the UK;
- Sampling teaching resources that already exist;
- Assessment by case study of how well teachers are currently able to teach groundwater;
- Assessment of activities of other organizations to provide support for teaching groundwater educational material; and
- Reporting with recommendations for promotion and a series of costed options.

The findings indicate that there is scope for increasing the focus on groundwater where aspects of water in the environment and water supply are taught. The teaching of water in the environment is not a fundamental part of the Science National Curricula in the UK. It is mainly taught through the subject of Geography, and also in Geology and Environmental Science. All students complete the 5-14 curricula requirements in Science and Geography. About 30% will take Geography at GCSE. The more specialised qualifications of AS/A Level Environmental Science and Geology are only available in some 500 institutions, and this is reflected in the low student numbers nationally. Therefore only a small minority of pupils will have been taught in any detail the below ground part of the water cycle and the significance of groundwater both in occurrence and as a resource.

Groundwater will not form a significant part of any examination question in Geography GCSE and AS/A Level exams because it is only a small element of the specifications[1]. Consequently there is not the necessity to read about and research groundwater as a separate issue. Thus a 'chicken and egg' situation occurs requiring both improved specification for groundwater and greater exposure in questions which can only be resolved in negotiation with the Awarding Bodies.

Although the groundwater content of course texts may be limited by the specifications for examined courses, there is potentially scope to include groundwater case studies to illustrate water pollution, water supply and sustainable use of groundwater at global and river basin scales. Where reference

1 The specification is the document issued annually by each awarding body for each examined course. It includes the scheme of assessment, subject content, key skills, guidance on centre assessed components, and details of awarding, grading and reporting of results.

is currently made to groundwater there is also a need to improve the rigour in terminology and explanations in some texts.

At GCSE and AS/A Level the case study information obtained through this review indicates that textbooks, videos, photographs, satellite images, CD ROMs and the internet are all used in schools. However beyond the classroom, teacher access to other suitable resources at all levels is limited by the time needed for exploration and by financial constraints.

Teachers approached through the case study assess that pupils are interested in groundwater, but some have difficulty in grasping the concepts involved. Practical work or field work, which could help with these issues, is rarely undertaken in secondary schools. At primary level experimentation, observation and trips are used to reinforce the knowledge. A small sample of teachers has some background knowledge of groundwater and related issues and is fairly confident in teaching the subject area. However, none have received professional development training in groundwater and related issues.

Other organisations provide direct education of pupils through outreach programmes and visits to water industry and field study centres. This appears to be a very effective means of conveying knowledge about water issues, but the groundwater content could be increased. These however, reach only a small proportion of the population. The uptake and success of web-based and paper-based resources is unknown. It is recommended that there is a great opportunity to build on and co-ordinate what already exists for the benefit not only of teaching about groundwater issues, but ultimately for sustainable development teaching as well.

To improve the current situation it is recommended that in the short-term the UK Groundwater Forum lobbies the National Curriculum Authorities and the Awarding Bodies and takes part in curriculum debates to:

i) give groundwater a higher profile in the Schemes of Work and Specifications;

ii) include better case studies where groundwater is relevant;

iii) include water as a resource (since in Geography specifications, water is not regarded as a resource); and

iv) integrate groundwater and its role in the environment and water supply into teaching about sustainable development.

As part of a Qualifications and Curriculum Authority review of Science at A Level, criteria for A Level Environmental Science are currently being prepared. The first draft is out for consultation and it is recommended that the UK Groundwater Forum should consider providing a response. Current specifications will be reworked to meet these new criteria for first teaching in 2008.

Such changes will need to be supported by appropriate course material (the development of which could be co-ordinated by the UK Groundwater Forum), and consultation with the publishers of course texts. Another aspect that should be taken up with the publishers is the need for more rigour in texts to eliminate errors, particularly those produced by over simplification.

It is also recommended that the UK Groundwater Forum should consult and work with other influential groups. This could include academic organisations such as the Geographical Association, the Royal Geographical Society, the Earth Science Education Forum, the Geological Society and the Royal Society to raise the profile of groundwater both nationally and internationally. Sponsorship of appropriate education-related conferences and writing of articles in teaching publications would also increase awareness.

Raising the profile within the water industry Education Forum and working with the industry education programmes is also essential. The UK Groundwater Forum should influence the water companies who already undertake extra curricula school activities, and request that groundwater is given more prominence when describing sources, occurrence and sustainable management of water supplies, in the UK and the wider world. The co-operation of the water industry will be vital in achieving longer-term goals.

It is proposed that support for the development of a national educational resource centre for promoting the teaching of an holistic understanding of all water related issues, including groundwater, should be a longer term aim for the UK Groundwater Forum. The centre could be modelled on the Earth Science Education Unit at Keele, or be developed as an extension of this organisation. The centre would catalyse activity in the water community to offer a range of services including expertise to curriculum and specification writers, expertise to textbook writers, and provision of development training to teachers and industry educator. It would also monitor and research resulting progress and developments. The Earth Science Education Unit, with hard-won expertise in these areas, remains keen to support these developments.

The teacher-development training, proposed as part of the national educational resource centre, should be carefully piloted to ensure it is well targeted. Experience shows that interactive workshops aimed at providing background knowledge, motivation and enthusiasm are very effective. There should be no financial barriers to attendance, thus securing sponsorship will be critical. A regional approach, based on existing networks, will also help to keep costs low and to limit time away from the classroom.

Indicative costings only are provided. The short-term measure costs are estimated to involve some 45 man days input per year, based on attendance of quarterly curriculum meetings, liaison with learned bodies, and meetings with publishers industry etc. For the setting up and running of a national educational resource centre for water for five years, it is envisaged that a budget of £500,000 to £1,000,000 will be required.

1. INTRODUCTION

1.1 Background

The Earth Science Education Unit (ESEU), based at Keele University, provides INSET (in-service training) to teachers across England, Scotland and Wales, through workshops for schools, teacher meetings and teacher education institutions. ESEU has been engaged by the UK Groundwater Forum to undertake a review to identify the means to improve groundwater education in schools in England, Wales, Scotland and Northern Ireland.

The UK Groundwater Forum is an independent grouping of stakeholders drawn from the water industry, regulators, research and educational organisations. It aims to raise the awareness of groundwater and the issues that are relevant to its use as a source of water supply and the role it plays in the environment. One means to help raise awareness is to improve the teaching of groundwater in schools. The aim of this approach will be to help pupils to develop a basic understanding of:

- the occurrence and use of groundwater in the UK and globally;
- groundwater as a component of the water cycle;
- the value of groundwater for drinking water, agriculture, the environment etc.;
- how groundwater is threatened by over-use, pollution, climate change, etc.; and
- the critical role of groundwater to the UK economy and infrastructure.

1.2 Review Objectives

In identifying the means to improve groundwater education this review will seek to:

1. identify the opportunities to teach groundwater within the relevant curricula for ages 5-18 in the UK;
2. identify those teaching resources that already exist;
3. assess how well teachers are currently able to teach the subject;
4. investigate the activities/plans of other organisations with a remit that could potentially include the teaching of groundwater to schoolchildren, for example water companies and the Environment Agency;
5. assess the most appropriate types of resources for teaching groundwater to the age groups identified in 1 above;
6. assess how the teaching of groundwater could be promoted within the teaching profession and what is necessary to ensure teachers are able to teach the subject effectively; and
7. outline costs for a series of options, with recommendations for ways forward for the UK Groundwater Forum.

1.3 Organisation of the Review

To meet the review objectives the project has been divided into five reportable tasks:

- Task 1: Assess the opportunities to teach groundwater within relevant curricula for ages 5-18 in the UK.

- Task 2: Sample teaching resources that already exist.

- Task 3: Assess by case study how well teachers are currently able to teach groundwater.

- Task 4: Assess activities of other organizations to provide groundwater educational material.

- Task 5: Reporting with recommendations for ways forward and a series of costed options.

These tasks are reported individually as sections 2 to 7 of this document.

2. OPPORTUNITIES TO TEACH GROUNDWATER

This section reports the results of Task 1. In this task the following actions were undertaken:

- a summary was prepared of the education administration in the UK;
- guidance on science, geography and environmental science areas for pupils aged 5-14 reviewed, as published on the QCA (the curriculum and assessment agency for England), ACCAC (the agency for Wales), CCEA (Northern Ireland) and LTS (Scotland) web sites (www.qca.org.uk, www.accac.org.uk, www.ccea.org.uk, www.ltscotland.org.uk);
- specifications for GCSE, or equivalent examinations for 16 year olds reviewed, as published on Awarding Body websites; (www.aqa.org.uk, www.ocr.org.uk, www.edexcel.org.uk, www.wjec.co.uk, www.sqa.org.uk, www.ccea.org.uk);
- specifications for AS/A Level, or equivalent examinations for 18 year olds reviewed, as published on Awarding Body websites (www.aqa.org.uk, www.ocr.org.uk, www.edexcel.org.uk, www.wjec.co.uk, www.sqa.org.uk, www.ccea.org.uk); and
- findings summarised.

Where specifications are the documents issued annually by each awarding body for each examined course. They include the scheme of assessment, subject content, key skills, guidance on centre assessed components, and details of awarding, grading and reporting of results.

2.1 Summary of Educational Administration and Awarding Bodies

Education administration under devolved government has a separate structure in England, Wales, Scotland and Northern Ireland. In each country the Parliament, Assemblies and Executives, together with the Ministries set the overall strategic framework for education administration.

2.1.1 England

The relationship in England between the Department of Education and Skills (DfES) and its non-departmental public bodies (NDPBs), including the Qualifications and Curriculum Authority (QCA) is underpinned by the legislative structure set out in the Education Act 1997, as amended by the Education Act 2002. The QCA is accountable to the Secretary of State. It has responsibilities, among others, to maintain and develop the National Curriculum and associated assessments, tests and examinations, accredit qualifications in the national qualifications framework, and regulate the public examination system. The QCA collaborates with the other national educational regulators; the Qualifications, Curriculum and Assessment Authority for Wales (ACCAC), the Northern Ireland Council for the Curriculum Examinations and Assessment (CCEA) and the Scottish Qualifications Authority (SQA).

The National Curriculum defines the knowledge, understanding and skills required by pupils in maintained schools in England. It sets the standards for children's learning from the age of 3 to 14. From 3 to 5, children experience the Foundation Stage (omitted from this review). From 5 to 14 pupils move through primary school (Key Stage 1, 5 – 7 years, Key

Stage 2, 7 – 11 years) and into the first years of secondary education (Key Stage 3, 11 – 14 years).

The National Curriculum provides a structured and assessed education through Key Stages 1 to 3. In Key Stage 4 (for 14 – 16 year olds) only four national curriculum subjects are mandatory. These core subjects are summarized in Table 1.

For each subject area 'Schemes of Work' show how the National Curriculum programme of study and attainment targets can be translated into a practical plan at Key Stages 1 – 3. The schemes are not statutory, but they are widely followed.

Table 1 English National Curriculum Core Subjects in Key Stages

Key Stage	Year Group	Core Subjects
1	1-2 (5 year olds, 6 year olds)	Core subjects: English, mathematics and science Non-core subjects: design & technology, information & communications technology, history, geography, art & design, music, physical education, personal social & health education, citizenship and religious education.
2	3-6 (7 year olds to 10 year olds)	Core subjects: English, mathematics and science Non-core subjects: design & technology, information & communications technology, history, geography, art & design, music, physical education, personal social & health education, citizenship and religious education.
3	7-9 (11 year olds to 13 year olds)	Core subjects: English, mathematics and science Non-core subjects: design & technology, information & communications technology, history, geography, art & design, music, physical education, personal social & health education, citizenship and religious education.
4	10-11 (14 year olds to 15 year olds)	Only four National Curriculum subjects are mandatory: English, mathematics, science, physical education. The majority of learners at this stage follow additional optional courses leading to external qualification, principally GCSE.

2.1.2 Wales

ACCAC is the Qualifications, Curriculum and Assessment Authority for Wales – Awdurdod Cymwysterau, Cwricwlwm as Asesu Cymru. ACCAC is a Welsh Assembly Sponsored Public Body and performs a similar role to the QCA, including:

- advising the Welsh Assembly on matters of education;
- acting as the statutory regulatory authority in Wales for qualifications outside higher education; and
- drafting the content of the National Curriculum subjects (known as National Curriculum Subject Orders) at all key stages.

In April 2006 ACCAC, Education and Learning Wales (ELWa), and the Wales Youth Agency merged with the current Department for Training and Education, creating the Department for Education, Lifelong Learning and Skills (DELLS).

In Wales the National Curriculum contains Welsh or Welsh as a second language as core subjects (Table 2).

Table 2 Welsh National Curriculum Core Subjects in Key Stages

Key Stage	Year Group	Core Subjects
1	1-2 (5 year olds, 6 year olds)	Core subjects: English, Welsh, mathematics and science. Non-core subjects: Welsh as a second language, design & technology, information technology, history, geography, art, music and physical education
2	3-6 (7 year olds to 10 year olds)	Core subjects: English, Welsh, mathematics and science. Non-core subjects: Welsh as a second language, design & technology, information technology, history, geography, art, music, physical education and religious education
3	7-9 (11 year olds to 13 year olds)	Core subjects: English, Welsh, mathematics and science. Non-core subjects: Welsh as a second language, modern foreign languages, design & technology, information technology, history, geography, art, music, physical education and religious education
4	10-11 (14 year olds to 15 year olds)	English, Welsh or Welsh as a second language, mathematics, science, physical education. The majority of learners at this stage follow optional courses leading to external qualification, principally GCSE.

2.1.3 Northern Ireland

CCEA was established on 1 April 1994 and is an NDPB reporting to the Department of Education in Northern Ireland. It is a unique education body in the UK, bringing together the three areas of curriculum, examinations and assessment. It is Northern Ireland's leading awarding body including GCSEs, GCE AS and A Levels.

The Northern Ireland Curriculum was introduced on a phased basis from 1990. It was reviewed in 1994 and the revised Northern Ireland Curriculum was introduced in September 1996. It is being continuously developed and Key Stage 4 is under review and will not have statutory effect until September 2007 and designated dates thereafter.

The curriculum is defined in terms of four key stages which cover the 12 years of compulsory schooling:

- Key Stage 1, covers school years 1–4 for pupils aged 4–8;
- Key Stage 2, covers school years 5–7 for pupils aged 8–11;
- Key Stage 3, covers school years 8–10 for pupils aged 11–14;
- Key Stage 4, covers school years 11–12 for pupils aged 14–16.

The Northern Ireland Curriculum does not constitute the whole curriculum. Schools can develop additional curriculum elements to express their particular ethos and meet pupils' individual needs and circumstances.

The curriculum for Key Stages 1, 2 and 3 includes:

- English;
- Mathematics;
- Science and Technology;
- History and Geography (known as the Environment and Society Area of Study);
- Art and Design, Music and Physical Education (known as the Creative and Expressive Area of Study);
- Irish, in Irish speaking schools only; and
- Four educational cross-curricular themes (Education for Mutual Understanding, Cultural Heritage, Health Education and Information Technology). The educational themes are not separate subjects but are woven through the main subjects of the curriculum.

Each subject in the Northern Ireland Curriculum is defined within the Programmes of Study and Attainment Targets. There may be different numbers of Attainment Targets in each subject.

2.1.4 Scotland

The First Minister for Scotland is responsible for the overall supervision and development of the education service. Day-to-day responsibility for education is delegated to the Minister for Education and Young People and the Minister for Enterprise and Lifelong Learning. They are served by the Scottish Executive Education Department (SEED) and the Scottish Executive Enterprise, Transport and Lifelong Learning Department (SEETLLD). The First Minister is advised by Her Majesty's Inspectorate of Education (HMIE) and the national bodies dealing with the development of the curriculum (Learning and Teaching Scotland - LTS) and public examinations (the Scottish Qualifications Authority - SQA). Both organisations are NDPBs.

The curriculum in Scotland is not determined by statute or regulation, but by guidance and advice from the SEED and Learning and Teaching Scotland (LTS) in various curriculum documents. At primary level, the curricular areas are language, mathematics, environmental studies, expressive arts, and religious and moral education, with personal and social development (PSD) and health education.

At lower secondary level the curriculum is divided into two stages. The first two years (S1 and S2, ages 12-14) provide a general education following the 'National 5 – 14 Programme'. Compulsory subject areas include English, a modern foreign language, mathematics, science, geography, history, home economics, technical education, art and design, music, physical education, and religious and moral education (RME). A range of optional subject areas is also available.

The third and fourth years of compulsory lower secondary education (S3 and S4, 14- to 16-year-olds) have elements of specialisation and vocational education for all. Students are expected to continue to the age of 16 with the study of English, mathematics, a science, and a social science subject. Students also have the entitlement to the continuation of a modern foreign language. In addition to these subjects, students choose from options relating to each of the following eight subject areas: language and communication, mathematical studies and applications, scientific studies and applications, social and environmental studies, technological activities and applications, creative and aesthetic activities, physical education, and religious and moral education (RME).

In November 2004, in the document 'A Curriculum for Excellence', the Scottish Executive confirmed its intention to reform and simplify the curriculum to increase student choice and make learning more stimulating. The Government has set in motion a programme of work which will be part of the process of creating a single, coherent Scottish curriculum for the three to 18 age range. The majority of measures are to be implemented from 2007.

SQA is the national body in Scotland responsible for development, accreditation, assessment and qualifications other than degrees. Its functions are set out in the Education (Scotland) Act 1996 as amended by the Scottish Qualifications Act 2002. SQA is responsible for developing and distributing 5-14 National Tests. It is also Scotland's leading awarding body for Access Level, Standard Grade, and Intermediate Grades that are the qualifications available for mainly 16 year olds Highers and Advanced Highers are

the SQA's equivalent of A/AS Level examinations. SQA produces subject-specific arrangement documents.

2.1.5 Awarding Bodies

In the UK there are six awarding bodies (exam boards) for the main school qualifications (i.e. GCSE, A/AS Levels and Scottish equivalents and a range of other vocational qualifications). These are:

- The Assessment and Qualifications Alliance (AQA);
- OCR;
- EDEXCEL;
- The Welsh Joint Education Committee (WJEC);
- The Scottish Qualifications Authority (SQA); and
- Council for the Curriculum, Examinations and Assessment (CCEA) (Northern Ireland).

There is a commonality of structure running through the different specifications based on criteria published by the QCA for the different subjects. Although these only apply directly to England, since the WJEC and CCEA want their specifications to be available to English schools, they do follow the QCA criteria. In addition there are close links between QCA, ACCAC (for Wales) and CCEA (for Northern Ireland).

The specifications for Science, Geography, Geology and Environmental Science and the relevant sections that have a bearing on groundwater are discussed below.

2.2 Review of Guidance for Pupils Aged 5-14

The Schemes of Work for Key Stages 1-4 and for the Scottish National Guidelines have been reviewed for coverage of water in the environment and related issues. The requirements for Science and Geography are summarized in Appendix 1 (Table A.1).

2.2.1 Science

In the Science Schemes of Work, for Key Stages 1-3 in England and Wales, the study of water in the environment is not a requirement, although in Unit 5D, 'Changing state', water is studied in its different physico-chemical states in relation to the movement of a droplet through the water cycle. Groundwater, however, is not included, possibly because there is no change in state.

In Key Stage 2 in the 'Rocks and Soils Unit' (Unit 3D), it is specified that the property of permeability in rocks and soils should be tested. There is no associated guidance to link this with the water cycle and therefore groundwater. In Year 9, the Key Stage 3 Science Scheme of Work includes 'Environmental Chemistry'. Section 6, entitled 'Is pollution worse now?' refers to water quality, monitoring and environmental policy. Here an extension of work could include groundwater issues.

The Northern Ireland (CCEA) Key Stage 3 course of 'Science and Technology' requires students to find out about the impact of pollution in the environment, both locally and in

the wider world. The examples of water pollution by sewage, oil and effluent from water cooling processes are likely to be applied to the surface waters of rivers and seas.

In Scotland, a more thematic approach is taken. In the Environmental Studies – 'Society, Science and Technology' guidelines, weather and climate are taught separately from physical features. So again there is apparently no holistic study of the water cycle. In the 'Earth & Space' section, in strand 'Materials from Earth', the uses and conservation of water are taught at levels A and B. At level F the student is required to explain the water cycle using an approach based on particles. This approach will give understanding of some of the physical and chemical processes involved, but will not provide a comprehensive understanding of all the inputs, outputs and stores within the cycle. Consequently, in the strand 'Resources and how they are managed' water is not recognized as a resource.

2.2.2 Geography

It would appear that in the UK the teaching of features, events and processes associated with water in the environment is consigned almost entirely to the subject of Geography. In Key Stages 1 and 2 in England, the location of water and its uses, together with ownership and economic issues are considered. In the Scheme of Work, the different types of water in the environment are not prescribed although cross reference to the water cycle is made, both of which are studied in Year 5.. Here there may be an opportunity to better define 'water' and introduce the basic concept of groundwater, linking it to the prior knowledge of permeability of rocks and soils gained in Year 3. In Year 4, the study of village settlement (Unit 9) and a village in India (Unit 10) are other topic areas where groundwater, in relation to water supply from springs, wells and boreholes could be introduced.

In Wales, Key Stage 1 does not cover water specifically in the acquisition of geographical skills and enquiry, or in the study of places. In Key Stage 2 this approach is taken to more depth, together with the exploration of themes associated with environmental change. Rivers are given as an example, but no more than this is specified.

The CCEA Key Stage 1 and 2 course, 'The World About Us', in Theme 2 – 'Materials and Change' requires the teaching of changes in state in the water cycle, and this appears to be linked to the study of weather and climate.

At Key Stage 3, water in the environment is commonly studied in relation to the water cycle and geomorphological processes. The causes and consequences of flooding are considered in Unit 4 in the English QCA Scheme of Work. There is an additional opportunity to investigate water supply issues (Unit 14: Can the Earth cope?), and groundwater could be introduced. In the Welsh (ACCAC) scheme for geography resource issues are studied in Theme 9, but water is not specifically identified.

In Scotland, as discussed above, a more thematic approach is taken and the study of Geography and Science are combined.

2.3 Review of Specifications for GCSE or Equivalent

The specifications for GCSE, which apply to England, Wales and Northern Ireland and Scottish Access, Standard and Intermediate grades have been reviewed to examine the

topics covered and potential opportunities to study groundwater. The requirements for GCSEs in Science, Environmental Science, Geology, and Geography are summarized in Appendix 1, Table A.2 and for Scottish qualifications in Table A.3.

2.3.1 Science

New GCSE Science specifications, available for teaching from September 2006, have been produced by each of the Awarding Bodies which utilize common material, use similar styles of examination questions and have a common approach to coursework assessment.
Five new exam specifications have been prepared by AQA, OCR, EDEXCEL and WJEC and they are:

- GCSE Science
- GCSE Additional Science
- GCSE Biology
- GCSE Chemistry
- GCSE Physics

Some suites also include:

- GCSE Additional Applied Science

All pupils have to do GCSE Science (which is one GCSE – replacing the old Short Course Science). Government statistics show that 92% of all 15 year olds took Science examinations in 2005 (583,100 pupils). Most pupils (71% in 2005 – 450,900) do Additional Science to make it up to 2 GCSEs. A few do Biology, Chemistry and Physics (7% in 2005 – average of 46,000 pupils) thereby covering all the work in GCSE Science and GCSE Additional Science. Some opt for GCSE Additional Applied Science – a more vocational qualification (that can be taken as a double award with some Awarding Bodies – but still has to meet the content of the QCA Science criteria). Government statistics show that, in 2005 in England, only 1% of pupils (7,600) took 'other sciences' including Environmental Science and Geology, of which 709 took Geology.

The study of water in the environment is not a fundamental part of these courses. However, there are some aspects which cover water quality. In the AQA Science A, Science B and Biology courses, the pollution of water from sewage, fertilizer or toxic chemicals is required, but the type of water is not specified. In Unit 2 of the Applied Science (Double Award) this topic is developed in the context of the 'Countryside and Environmental Management'. In the AQA GCSE Chemistry Unit 3, drinking water quality and other aspects of water quality are studied, but the water cycle is defined without reference to groundwater. In the OCR, EDEXCEL and WJEC specifications there are apparently no links to water in the environment.

In Northern Ireland the CCEA specification for Science for Foundation and Higher levels in Module 2 – 'Human Activity' requires study of the impact of the European directive on nitrate pollution, but no further details are given. In Scotland the arrangements for the SQA Standard Grade Science includes the study of water pollution from oil, sewage and industrial waste with reference to animals and plants, and therefore is unlikely to include groundwater. The Access 2 qualification studies water pollution in the context of surface water quality and testing. Intermediate level qualifications are separated as biology, chemistry and physics; these do not include water in the environment.

2.3.2 Environmental Science

There is one Environmental Science course at GCSE, and this is offered by AQA. In Theme 1: 'Air, Water and Energy' a comprehensive specification is given which specifically includes groundwater. The main stages and processes in the water cycle require study, together with the uses of water, variations in water availability, water supply (including aquifers), water treatment, and water conservation. Water pollution appears to be discussed in the context of surface water.

OCR in their Rural and Agricultural Science GCSE specification require the teaching of water pollution with reference to nitrates, but no direct mention is made of groundwater.

In Scotland the SQA offer Intermediate Grade 1 and 2 qualifications in 'Managing Environmental Resources'. In the Intermediate 1 arrangement Unit 1 'Environmental Issues', requires the study of the effects of human activity on the local environment. These include the effect of pollution from transport, industry, and agriculture on air, land, water, buildings and living things. A river study is suggested as illustrative of these processes. In Unit 3 entitled 'Land Use', part of the scope of study covers water use and water-based industry in the local economy. There is no direct mention of groundwater in this arrangement. For the Intermediate 2 qualification there is the opportunity in Unit 1 to learn about natural resources, including water. Water is classed as a renewable resource, and examples are required at local, national and global scales. In Unit 3, the study of the local environment and water use is required. Again there is no stipulation to include groundwater.

2.3.3 Geology

WJEC is the only Awarding Body to offer GCSE Geology but this is available in England, Wales and Northern Ireland. In section 4.4 water supply from groundwater sources is specified, supported by development of a case study of a groundwater scheme.

In Scotland, the Access 3 and Intermediate 1 Geology arrangements are similar in respect of the unit, 'Geology, People and Environment'. The requirements are for teaching the water cycle, to include evaporation, clouds, rain, snow and rivers. Groundwater and its features are studied, together with its main uses, the impact of pollution, variability of supply in the UK and the effects of over abstraction. Interestingly a supplementary note says that candidates should be aware of the properties of aquifers as groundwater reservoirs, but they are not expected to use the term 'aquifer'. Practical experimentation with model building is encouraged.

2.3.4 Geography

In 2005 in England, 30% of pupils took a full GCSE examination in Geography – 188,400 pupils. Meanwhile a further 2% (36,200) took a short course in GCSE Geography. There are a number of options for Geography courses with each Awarding Body from a traditional and tightly specified course to a more issues-based course. AQA offers three specifications, and a short course (worth half a GCSE) is available in each. In Geography A, 'Rocks and the landscape' are studied to understand the interactions by people with landscapes produced by different rock types including granite, Carboniferous limestone, and chalk and clay. No explicit mention of groundwater is made. In the section 'Rivers landscapes and processes' the focus is on surface waters. The section on 'Industry' looks at the factors affecting

industrial location and problems of environmental impact, particularly their contribution to land, sea and air pollution. There is no mention of water pollution. In the section on 'Managing resources' the emphasis is on energy resources. In the Geography B, course one section on 'River basin management' requires the study of the global hydrological cycle, and also the provision of water supplies for urban areas with one example of the use of groundwater at the regional scale. In the Geography C course under 'Water and food supply' the global distribution of water is studied and the impact of poor water supplies and strategies for managing and improving them. Because water has been addressed in this section it is not listed for study as a resource later in the specification.

OCR also provides A, B and C courses. In Geography A the hydrological cycle is specified as part of Unit 1, 'People and the physical world – rivers.' The inputs, flows, stores and outputs require study, but there is no specific mention of groundwater. In a later unit 'People and the environment', water pollution is taught only in relation to rivers, lakes and the sea. The Geography B course requires the study of the hydrological cycle in relation to sustainable water supply on a regional and international scale. It asks what are the main sources of freshwater and how the provision of a sustainable supply will vary throughout the world, including how these are managed at different scales. No direct mention of groundwater is made. A further section looks at variation in rainfall and water supply and its effects. Again no mention of groundwater is made. Geography C is study of people, place and themes through an issues based enquiry approach. The specification does not directly mention groundwater.

EDEXCEL offers Geography A which includes the study of river processes and landforms, but there is no link with groundwater. In the section 'People and settlements', water supply is briefly mentioned as a determining factor. An optional section looks at 'Managing the environment' and investigating damage to fragile environments caused by farming and resource exploitation. The examples given are of soil erosion, desertification, oil exploitation and lumbering. In the Geography B course there is a strong focus on sustainability, environmental responsibility and decision-making. In 'People and resources' the definitions of a renewable and a non-renewable resource are studied as well as the advantages and disadvantages of each. Groundwater is not mentioned but could be an example. In the later unit 'Use and abuse of the environment', issues affecting fresh water are taught, including groundwater as a store. Study of one large river management scheme is required together with the impact of pollution in a river or lake from a sustainable viewpoint. The short course includes investigating damage to fragile environments as in the A course.

WJEC offers an A and a B course. Only processes related to rivers and the sea are studied in the water environment in the A course. In section 1C 'Towards sustainable development of the environment', there is little opportunity for inclusion of groundwater. However, in the B course the hydrosphere is studied together with the water cycle and its components. The main sources of fresh water supply are taught together with the variability of supply around the world and at different scales. The variability of water supply, particularly the lack of it, and its impact on the environment and human activity are covered. The emphasis is on surface water, with no mention of groundwater. The short course is similar to the A course in respect of the study of water.

In Scotland the Standard Geography course does not appear to include an opportunity to study groundwater, while the Intermediate 1 and 2 courses investigate river basin

management. Details of what should be included in the study of river basin management are not specified.

The Geography specification for Northern Ireland does not directly mention groundwater even as part of Theme B in 'Physical Processes and Challenges', where river management at the national and regional scale is studied. However, a basic understanding of the significance of groundwater might be required for the generalisation No 3 'Distinctive limestone landscapes must be managed to avoid long-term damage'. Groundwater could also be considered, in Theme C 'Ecosystems and Sustainability' where the study of sensitive ecosystems and the impact of human interference are to be illustrated by peatlands. In Theme F on 'Settlements and Change', students have the opportunity to study water supply in relation to settlement development.

2.4 Review of Specifications for AS/A Level or Equivalent

A Level in England, Wales and Northern Ireland is taught over two years, normally to 16 – 18 year olds. The first year of study is called Advanced Supplementary Level (AS Level), and many students take four AS Levels in the first year of their post-16 study – with an examination at the end. Most of these then continue with three A2 Levels (second year of A Level study) in the final year. An AS and an A2 Level together give a full A Level. The equivalent examinations in Scotland are Highers and Advanced Highers.

2.4.1 Environmental Science

One specification is available for Environmental Science at AS/A Level, and this was taken by 1215 students in 2004 in England, Wales and Northern Ireland. It is offered by AQA. In the AS Module 1 'Energy, Atmosphere and Hydrosphere' water use and sources are studied including the availability of water on the surface and in aquifers, the effect of catchment use on these sources, and geologically suitable rock types and structures for aquifers. The second element of water use looks at the consequences of over abstraction. Existing and future demands on water supply, uses of water, and supply and treatment are also specified. In the A2 Module 5 'Pollution & Physical Resource Management', a global perspective is expected in the study of 'water conservation and management.' This module includes understanding the strategies for providing adequate supplies for a variety of water management schemes including aquifer water storage and recharge. Another section looks at a wide variety of water pollution mechanisms in water bodies, giving examples of coastal water and oceans.

As part of a QCA review of science at A Level, criteria for A Level Environmental Science are currently being prepared. The first draft is out for consultation. Current specifications will be reworked to meet these new criteria for first teaching in 2008.

In Scotland, 'Managing Environmental Resources' is studied at Higher and Advanced Higher level. In Unit 1 of the Higher Grade the study of natural resources includes water. The water cycle is compared to coal formation and extraction to illustrate the concepts of renewable and non-renewable resources. Later in Unit 3 land use in Scotland is studied including the development of water uses. For the Advanced Higher the water cycle is studied again. In none of the arrangements is groundwater specifically included.

2.4.2 Geology

Two specifications are available for Geology and the total entry for A Level Geology (England, Wales and Northern Ireland) was 1689 in 2004. OCR in their AS/A Level require the study of water supply commencing with the definition of terms such as porosity, permeability, hydrostatic pressure, hydraulic gradient, aquifers and water table. Description and explanation of the geological conditions necessary for the formation of springs, artesian basins and water supply from wells should be taught. Understanding of water supply in relation to rivers, reservoirs and underground sources and the advantages and disadvantages of these sources is stipulated. The careful sustainable management of water resources should also be considered.

The WJEC AS/A specification includes the study of water as a natural resource. The Key Ideas include, understanding of permeability of rocks for fluid migration, highly porous rocks acting as reservoirs, and groundwater flow controlled by geological factors. The effect of human activity is taught in relation to water supply, and the effects and control of over abstraction and contamination. Examples of saline intrusion and surface subsidence are cited. Unit GL6 includes for the investigation of the geology of local water supplies.

In Scotland the Geology Higher arrangements do not include the study of groundwater.

As above, as part of a QCA review of science at A Level, criteria for A Level Geology are also currently being prepared - for first teaching in 2008.

2.4.3 Geography

In 2005, some 28,420 students entered for A Level Geography examinations in England.

AQA offer two Geography AS/A Level courses. In Geography A, the AS Module 1 in 'Concepts in Physical Geography' studies the hydrological cycle, including inputs, outputs, flows, transfers and stores within the system. The emphasis of subsequent sections in this topic is on surface water. The A2 Module 'Challenges and Change in the Human Environment' requires the study of a reusable resource on a global scale to understand environmental impact of resource exploitation and management in the context of sustainable development. The example given is of water. The use of the term 'reusable' is not common to other specifications.

In AQA Geography B in the AS Module 1 'Dynamic Change', atmospheric, geomorphological and human processes affecting drainage basin hydrology is studied in relation to drainage basins in the British Isles. It is stated that the study should include baseflow, but otherwise there is no mention of groundwater.

OCR also offers two Geography AS/A Level courses. In the A Course, in Module 2680 'The Physical Environment' drainage basins are studied with inputs, outputs and stores. In the context of groundwater the terms recharge, baseflow, groundwater and water table are stipulated. An awareness of the influence of human activity on inputs, outputs, stores and flows is required together with the characteristics, among others, of the rocks and soils. Drainage basin studies should be illustrated by reference to actual drainage basins. In the B course drainage basins are only studied with reference to surface water. Later in Module

2692 'Issues in Sustainable Development' recommends water supply as a topic for study, but no specific reference is made to groundwater.

The EDEXCEL Geography A course also requires the study of the hydrological cycle as a system, but at the global scale. Groundwater is specified for inclusion. Later in a synoptic link the hydrological cycle is required to be studied at the regional and local scale with reasons, decisions and methods for groundwater and river management. The B course studies the global hydrological cycle with emphasis on river systems, but reference is made to inputs, stores, flows and outputs where groundwater could be considered. Water supply is studied with reference to managing environmental problems in cities, but the groundwater contribution is not specified. In an optional section 'Pollution of the environment' the hydrosphere can be studied and the example given is a river.

WJEC offers one Geography course which includes the study of the hydrology of drainage basins and selected landforms. A systems approach with inputs, flows, stores and outputs of water and sediment is required. No explicit mention of groundwater is made. In the Synoptic Unit 'Sustainable Development' water supply is studied, but groundwater is not specified. The CCEA AS/A course only requires the study of rivers, and similarly the unit 'Pollution and its Management' only cites a river as an example. In Scotland the Geography Higher includes the study of river basin management, but in the arrangements no details are supplied and the inclusion of groundwater cannot be identified.

2.5 Summary of Findings

- Under devolved government four separate educational administration systems operate in the UK.
- The national curricula for 5 – 14 year olds differ between the four systems. There is most similarity between England and Wales, while the Scottish National 5 – 14 Programme is more thematically based.
- There are six awarding bodies for the main qualifications in the UK: The Assessment and Qualifications Alliance (AQA); OCR; EDEXCEL; The Welsh Joint Education Committee (WJEC); The Scottish Qualifications Authority (SQA); and the Northern Ireland Council for the Curriculum, Examinations and Assessment (CCEA).
- The study of water in the environment, and therefore of groundwater, is not a fundamental part of the Science national curricula in England, Wales or Northern Ireland, although aspects of water pollution are considered.
- In Scotland the National 5 – 14 Programme requires the teaching of Environmental Studies which includes both Science and Geography. Weather, climate and the study of the water cycle using a particle approach are specified.
- Water in the environment is mainly taught in Geography. In England at Key Stage 2 'water' is studied through its location, uses, ownership and economic aspects. The water cycle is also studied in the Science Scheme of Work with reference to the changing states of water. In Wales Key Stage 2 studies may include rivers. The CCEA Key Stage 1 and 2 take a similar approach to the Scottish method, although at a different level, by teaching the changing states of water in the cycle and relating this to weather and climate. At Key Stage 3, water in the environment is commonly studied in relation to the water cycle and

geomorphological processes. In both Key Stages there are opportunities to include groundwater more widely in the existing Schemes of Work.

- At GCSE the teaching of water in the environment is not included in the science specifications. However, there are some aspects of water quality covered, in relation to pollution and quality testing.
- There is one specification for GCSE Environmental Science (AQA) which includes the study of groundwater and related issues – a small number of students take this exam.
- WJEC in its Geology GCSE specifies the study of water supply from groundwater sources. 709 students in England and Wales students took this examination in 2004. In the Scottish Access 3 and Intermediate 1 Geology arrangements, groundwater occurrence, use, pollution, variability of supply and effects of over abstraction are specified.
- Geography GCSE courses differ in their approach to teaching water in the environment, but in general the emphasis is on the study of features, events and processes associated with river systems. Groundwater is only specifically mentioned in relation to water supply in AQA Geography B and EDEXCEL Geography B.
- Water supply in GCSE specifications is considered separately from other resources.
- Groundwater is a component of the AS/A Environmental Science Course (AQA). The occurrence, use and over exploitation are studied together with existing needs and demands on water supply. In the second year water conservation and management, and water pollution are studied.
- In both Geology AS/A specifications (OCR and WJEC) groundwater is studied in the context of water supply. The occurrence, use and sustainable management of water supplies are taught.
- At AS/A Level a systematic approach is generally taken to the study of the hydrological cycle in Geography, and 'groundwater' is included in two of the specifications, and 'baseflow' in another. However, the emphasis remains on surface waters.
- Water supply is also a component of some of the Geography AS/A Level specifications in relation to sustainable development and exploitation by growing populations. Groundwater is not mentioned in this context.

Overall in terms of pupil numbers, most students complete the 5 – 14 curricula requirements (in Science and Geography), and fewer students (some 30%) take Geography at both GCSE and AS/A Level. At A Level the more specialised Environmental Science and Geology qualifications are only available in some 500 institutions in the whole of the UK, and this is reflected by the low student numbers nationally. Therefore there is only a small minority of pupils who will have a comprehensive understanding of the water cycle and the significance of groundwater both in occurrence and as a resource.

3. SAMPLE EXISTING TEACHING RESOURCES

Findings of research for the Government's Council for Science and Technology (CST, 2000. *Science teachers: a report on supporting and developing the profession of science teaching in primary and secondary schools*. London: Her Majesty's Stationery Office) show that secondary science teachers use textbooks as their main information source (Figure 1). The experience of the Education Department at Keele University would suggest that the situation is similar in Geography as well as other subjects. Therefore it was decided that the review of a sample of textbooks aimed at the various levels of education would provide a representative view of the resources available to teach groundwater at Key Stage 3, GCSE, AS and A Level.

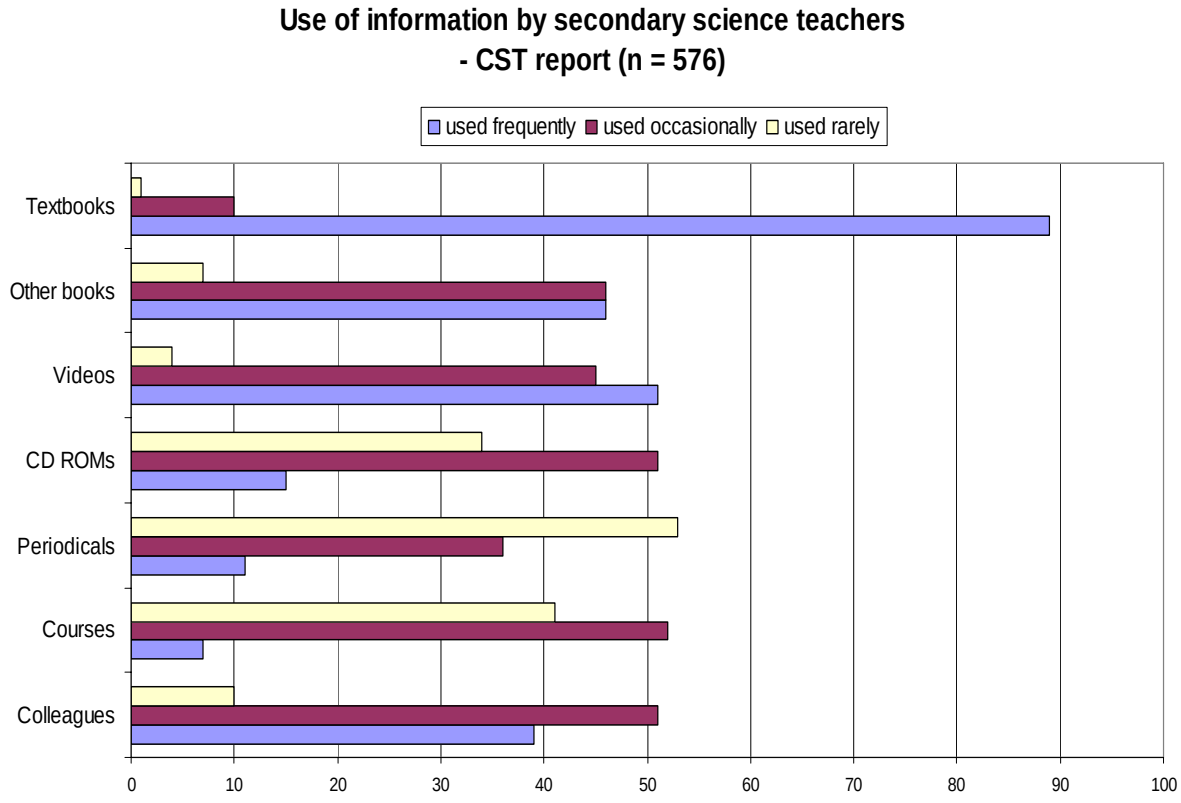

Figure 1 **Findings of use of information by secondary science teachers.**

Key Stage 1 and 2 use textbooks to a limited extent and as the case study shows primary teachers collect their own sources of information for use in the classroom. From the results of Task 1 the reviews have necessarily been limited to the subjects of Geography, Geology and Environmental Science. Based on guidance from staff at the Department of Education at Keele University, information from the case studies and the popular texts on www.amazon.co.uk, we have chosen and reviewed the following:

- 4 Key Stage 3 texts;
- 6 GCSE Geography textbooks;

- 5 AS/A Level Geography textbooks;
- 4 AS/A Level Geology textbooks; and
- 2 AS/A Level Environmental Science textbooks.

We have also reviewed resources published by the Earth Science Teachers Association (ESTA) for teaching groundwater at Key Stages 2 and 3, which contain practical activities.

3.1 Key Stage 3 Texts

Four texts that are in the same series and developed for different levels of ability and cover different Key Stage 3 skills were chosen for review.

3.1.1 Key Geography - New Foundations by David Waugh & Tony Bushell 3rd Ed. 2001. Nelson Thornes Ltd. ISBN 0 7487 6041 5

This text contains seven chapters, only one of which has relevance to groundwater. Chapter 3 is entitled 'River Flooding' and starts with an interpretation of the Water Cycle. Groundwater is defined as 'the transfer of water through the ground back to the sea'. There is no further mention of groundwater.

3.1.2 Key Geography - New Connections by David Waugh & Tony Bushell 3rd Ed. 2001.Nelson Thornes Ltd. ISBN 0 7487 6074 1

This book is arranged in six chapters, with 'Weathering, rivers and coasts' combined in the first chapter. Rivers are studied in relation to their formation by erosion transportation and deposition of material. Groundwater is not identified. The impacts of primary industries, including farming, on the environment are considered as part of the second chapter. Non-renewable and renewable resources are discussed in environmental concerns in the fourth chapter, but groundwater resources are not considered.

3.1.3 Key Geography - New Interactions by David Waugh & Tony Bushell 3rd Ed.2002.Nelson Thornes Ltd. ISBN 0 7487 6076 8.

This text starts with a chapter on 'Natural Environments', and relates features to different world climates. The emphasis appears to be on the interactions of the physical and human aspects of geography. Water related issues are not specifically identified.

3.1.4 Key Geography - New Extensions by David Waugh & Tony Bushell 2nd Ed. 1999.Nelson Thornes Ltd. ISBN 0 7487 7718 0.

This text addresses all levels of ability, and is written to stretch the more able pupils. The water cycle is discussed as part of the third chapter on 'Weather and Climate'. Four components of the water cycle are identified as evaporation, condensation, precipitation and run-off, with linkages between each component. Run-off is further defined as either over the Earth's surface (in rivers), or through the soil (as throughflow) or at deeper levels (as groundwater). 0.1% of water is identified as being stored underground in the soil and rocks. This interpretation is more complex than in the New Foundations textbook, but arguably it is also confusing for future studies by combining the concepts of groundwater and run-off. In the ninth chapter on environmental issues, water supply is discussed and hand-dug wells are cited as appropriate technology, but no linkage is made to the fact that

this is utilising groundwater. In the tenth chapter non-renewable and renewable resources are illustrated, but water is not identified as a resource.

3.2 GCSE Geography Texts

Six texts were chosen for review.

3.2.1 Key Geography for GCSE Book 1 by David Waugh 2nd Ed. 1998. Stanley Thornes. ISBN 0 7487 3603 4.

Book 1 and 2 state their purpose as providing a progression from Key Stage 3, but they do not indicate which exam specifications they are designed to cover. In the first chapter on Rivers, the hydrological cycle is illustrated and annotated. Groundwater is described as both a store in saturated soil and rock, and as a flow, or transfer, of water through the rocks and soils to the sea. A definition is also given that groundwater is 'water stored in rocks following percolation'. In the third chapter on water pollution, only surface water and sea water pollution are discussed. Although agricultural nitrates and landfills are identified as sources of pollution, rivers are identified as the main receptors. However in chapter eleven on 'Primary activities', the impact of fertiliser and farm waste are highlighted as potential pollutants of underground water supplies, but there is no further explanation about the link between groundwater, water supply as groundwater abstractions and agricultural pollution.

3.2.2 Key Geography for GCSE Book 2 by David Waugh 2nd Ed.1998. Stanley Thornes. ISBN 0 7487 3649 2.

The hydrological elements of rivers and the causes of flooding are set out in a case study of Bangladesh. Groundwater in not referred to in this text.

3.2.3 The New Wider World by David Waugh 2nd Ed. 2003. Nelson Thornes ISBN 0 17 434314 0

This text claims to be revised to match the exacting requirements of all the latest GCSE and Standard Grade specifications. The glossary defines groundwater as water stored underground in permeable rocks. In section 17 'Drainage Basins and Rivers' the hydrological cycle is introduced as a closed system and an illustration is annotated showing that 0.6% of water is stored as groundwater. A second caption is 'Runoff as groundwater'. This caption will be confusing to students. A further block diagram of a typical drainage basin shows infiltration to soil moisture storage followed by percolation transfer to groundwater storage. This stored groundwater is then transferred as groundwater flow to a river flowing to the sea. The supporting text states that 'infiltration is the downward movement of water through tiny pores in the soil'. This downward transfer will be greatest in porous rock or soil such as chalk or sand, and least in impermeable rock or soil like granite and clay. No clear definitions of 'porosity' and 'permeability' are given, resulting in this confusion of hydrogeological terms. The text goes on to describe the movement downwards as percolation, and 'percolation forms groundwater, which is water stored at a depth in rocks. Groundwater flow is the slowest form of water transfer.' Further the text states that 'the level of saturation i.e. when all the pores have been filled with water, is known as the water table.'

Water supply is briefly mentioned in section 5 on 'Urbanisation in Developing Countries' and in more detail in a section 13 case study on 'World Climate'. The case study focuses on the effects of drought. A map shows the major UK aquifers and a block diagram is presented with annotated groundwater, springs, wells and boreholes. (One of the annotations incorrectly cross-references another diagram). The supporting text refers to groundwater supplies and the demand in the south of the UK leading to water shortage by 2021. In section 16, 'Rocks and Soils', a cross-section of a chalk escarpment is shown with text describing the occurrence of springs and dry valleys. Reference is also made to falling water tables due to climate change in a case study of desertification of the Sahel.

This text is also supported by the New Wider World Teacher's Resources Book, 2nd Ed. ISBN 0 7487 7377 0.

3.2.4 Longman Geography for GCSE New Edition. John Pallister, Ann Bowen, Roger Clay, Carmela Di Landro, Olly Phillipson Pearson Education Ltd. 2001. ISBN 0582 447445.

This text has been fully updated to meet the 2001 GCSE specifications, and can also be used for Standard Grade. In Unit 2 'Rivers and the Hydrological Cycle' groundwater is mentioned in the first section on 'Rivers Systems and Processes'. In the hydrological cycle diagram (Source 1) groundwater is shown entering as infiltration and percolation into the groundwater store or aquifer. It then moves laterally as groundwater flow to a lake. The water table is not labelled in this diagram. The diagram is matched by a few lines of text. In Unit 7 'Settlement' in Source 3 a section of a chalk and clay vale landscape is shown. The text briefly discusses water supply and drainage as being significant factors affecting landscape patterns, but the example does not mention spring lines or make reference to groundwater. Water supply is mentioned in Unit 2 in section 2.11 only in relation to Kielder reservoir.

3.2.5 Tomorrow's Geography for EDEXCEL GCSE Specification A. Mike Harcourt & Steph Warren Ed. Sue Warn. Hodder & Stoughton. 2001 ISBN 034079965

This text is written by the Chief and Principal Examiners to follow the 2001 specification. The book covers the four core units: the physical world, the human world, the economic world and the natural world. It also provides information on the four options of managing the environment, hazards, tourism and urban areas. The only reference to groundwater is in relation to spring-line settlement, and an accompanying block diagram which refers to chalk as 'porous' and clay as 'impermeable'. Groundwater as a word is not used.

3.2.6 Understanding GCSE Geography. For AQA Specification A. Ann Bowen & John Pallister 2nd Ed. Heinemann Educational Publishers. 2001 ISBN 0 435 35184 2

This second edition advertises itself as meeting all the requirements of the new AQA Geography GCSE specification. In the second chapter on 'Rocks and Landscape', the development of dry valleys and bournes are discussed without reference to ground water, and spring-line settlements are shown with the example used of Fulking in Sussex. Springs are defined as forming 'at the junction of the chalk and clay; water seeping down through porous chalk meets the impermeable clay and reappears on the surface as a flow of water'.

The accompanying sectional diagram of chalk and clay vale landscape shows two alternating bands of these rocks dipping in the same direction, as opposed to an anticlinal or synclinal structure or even a chalk-clay-sandstone sequence. This is another example of erroneous oversimplification in a diagram. The term 'aquifer' as a source of water supply is introduced as an economic use of chalk. In the glossary 'aquifer' is defined as 'underground store of water in permeable or porous rock.'

3.3 AS/A Level Geography Texts

Five texts were chosen for review.

3.3.1 Cambridge Advanced Geography. Geography for AS. Ed Clive Hart. 1st Ed 2000. Cambridge University Press ISBN 0521 78609 6.

This text matches the requirements of the OCR AS GCE, Specification A (see Appendix 1). The hydrological cycle is first discussed on a global scale as a closed system, identifying shallow groundwater (<750m) as 0.30% and deep groundwater (>750m) as 0.38% of global stores of water. Shallow groundwater is highlighted as being vulnerable to pollution, whereas deep groundwater may be exploited depending on the economics. The hydrological cycle is then described at the local scale, as an open system, interacting with other drainage basins.

Infiltration and percolation are described as processes (transfers) and groundwater is identified as a store. Lateral groundwater flow is labelled as a process and called baseflow. Baseflow in the glossary is also defined as the movement of water through rocks deep underground. The term is not linked to the groundwater contribution to river flow as a hydrogeologist might expect. Groundwater is not defined in the glossary.

Each input, output and store associated with drainage basins is then described. Under 'outputs' a section on 'interbasin transfers' states that 'in nature the most common example is an escarpment where the dip of the rock encourages movement of water underground from one basin to another. Faulting of rocks might also create conditions where water from one basin is diverted to a spring in another. In well-jointed rock types which encourage underground water flow, very complex interbasin transfers can occur as water from one catchment disappears underground and re-emerges in another.' The difficult concepts in this section could be improved by explaining that groundwater catchments need not coincide with surface water catchments, and giving examples of all the circumstances mentioned.

The groundwater store is described, but the associated block diagram is small and cramped. The terms aquifer, aquiclude, water table, unsaturated and saturated zone are correctly used. Variations of groundwater levels within a drainage basin are described particularly with reference to spring flow and contribution to rivers. Where groundwater levels are declining due to over abstraction, it is stated that this is known as 'groundwater mining'. This feature is linked to causing salt-water intrusion, and in another case lowering the water table beneath London between 1950 and 1980. The more recent problem of rising groundwater levels is not referred to. However, the section ends with a discussion of integrated management of surface and groundwater resources and cites the example of the Lancashire Conjunctive Use Scheme.

Transfer processes within the drainage basin include baseflow. Water storage within porous, pervious and permeable rocks is described, and the term transmissivity is introduced. However, one statement includes the following 'The best developed water tables are found in porous rock' which is nonsense to a hydrogeologist. In relation to water supply the text goes on to say that 'underground water is the preferred water source for water companies because the volume is so large compared with a surface reservoir and water is less vulnerable to pollution.' This statement could be improved by briefly discussing the variability of groundwater availability, the economics and the environmental impact of abstraction. Finally at the end of the section it is stated that 'from a hydrological point of view the significance of baseflow is that it maintains the river flow during dry periods.' So the definition now reverts to the more accepted view and an example hydrograph from the River Itchen is used as an illustration.

Water supply is referred to in the section on 'Contemporary urban growth in MEDCs' (more economically developed countries). Water for cities is identified as coming from two main sources: fresh water and groundwater. The section goes on to say 'groundwater sources are common in US, Australian and Spanish cities', and goes on to refer to adverse consequence of over-abstraction such as:

- Aquifer depletion e.g. Tucson Arizona;
- Ground subsidence e.g. Tokyo;
- Intrusion into coastal cities e.g. San Francisco (addition of 'saline' would be helpful);
- Depletion of surface water and streams e.g. southeast England.

Later in this section schemes to reduce water demand and to re-use water are cited. The section on 'Contemporary urban growth in LEDCs' (less economically developed countries) refers to groundwater abstraction in Mexico City and the ground subsidence caused by over abstraction.

3.3.2 AS Level Geography. Ann Bowen and John Pallister. 1st Ed 2000 Heinemann Educational Publishers. ISBN 0 435 352830.

This text is a comprehensive coursebook written to meet all the requirements of AQA specification A at AS Level Geography (see Appendix 1).

'Water on the land' is the title of the first chapter. The opening section 'systems and river regimes' commences with a description of the hydrological cycle. Here it is stated that all environmental systems including the hydrological cycle are open systems. No distinction is made between global and local scale systems. However, the percentage contribution of each part of the global hydrological cycle is set out in a block diagram and groundwater is 0.62%. Groundwater is not differentiated into shallow and deep as in the previous text.

The chapter then proceeds to discuss the inputs, outputs and stores in turn. The term percolation is not used in this model, only infiltration. Once water has infiltrated into the soil and then deeper into the rocks it reaches the groundwater store 'in joints, cracks or fissures in the rocks.' No mention is made of porous strata. The flow laterally is termed groundwater flow or baseflow, but here it is linked to flow in a main river channel.

In the glossary, groundwater is defined as 'water stored in rocks, usually permeable in the saturated zone below the water table'. No definition is given for baseflow, although it is identified as a contribution in a flood hydrograph from the upper River Tees.

River basin management is addressed at the end of the first chapter and only makes passing reference to the Colorado River floodwater helping recharge groundwater supplies. A case study of Bangladesh refers to possible flood control options including lowering of the water table by groundwater abstraction in the Himalayas by tens of metres during the dry season to create underground storage capacity when the monsoon rains fall. No counter argument in terms of environmental impact or the feasibility of the scheme is given. The UK is also used in another case study to illustrate the inequality of supply and demand between the north and west and the more densely populated southeast.

3.3.3 Managing Resources. David Flint. 1st Ed 1999. Hodder & Stoughton. ISBN 0340 730889.

This book is a supporting text for AS/A Level and has a chapter devoted to 'Water and Marine Resources'. It is divided into two sections. The first concentrates on fresh water, whilst the second deals with salt water. Included in the eleven key ideas at the beginning of the chapter is the recognition that water in its various forms is one of the Earth's most important natural resources. Other key ideas include:

- some areas of the world have a surplus of freshwater, but many more have a growing deficit;
- freshwater management schemes may increase supplies, but can bring a range of environmental economic and political problems;
- demand for freshwater continues to grow rapidly worldwide, due to the growth in demand by agriculture, industry and domestic consumers; and
- strategies designed to manage growth in demand have both costs and benefits.

The chapter goes on to discuss 'water location and water disputes' with passing reference to groundwater. In the section on 'Water Availability' the significance of underground supplies is briefly discussed and the increasing use of irreplaceable 'fossil' water in the mid-west USA and Mallorca. A case study of Mallorca is presented describing over abstraction and saline intrusion due to agricultural demand in coastal areas. Restrictions on pumping were considered as a management option, but the land was sold for building of tourist complexes, and now the demand for water is even greater. Future water demand is discussed and an exercise is set to consider a series of options to balance water supply and demand on Mallorca. This leads to the final section on freshwater looking at water conservation strategies.

3.3.4 Geography for A2. Cambridge Advanced Geography. Synoptic Module. Ed Clive Hart, Jane Dove, Michael Raw, Alisdair Rogers, Kevin Stannard. 2002 Cambridge University Press ISBN 0 521 89349 6

This book advertises itself as meeting the requirements of the synoptic module 'People and Environment' options in the OCR Advanced GCE (A2) Specification A for Geography. This

single volume covers all four options offered by the module of Geographical Aspects of the European Union, Managing Urban, Rural and Hazardous Environments. In the section on urban environments reference is made to landfills as potential sources of groundwater contamination. This appears to be the only mention of groundwater in this text.

3.3.5 Collins Landmark Geography. Population, Resources and Development by Jane Chrispin and Francis Jegede. 2nd Ed. 2000. Collins Educational. ISBN 0 00 326651 6.

This book is a supporting text for AS/A Level. Surprisingly there is no mention of water as a resource or in relation to development.

3.4 AS/A Level Geology Texts

Four texts were chosen for review.

3.4.1 Holmes' Principles of Physical Geology by D Duff 4thEd 1994. Chapman Hall. ISBN 0412 40320 X

This book is recommended amongst others as a general text for the OCR Geology AS/A Level course. It is considered a classic textbook for geology. A whole chapter, Number 19, entitled 'Underground Water' is devoted to groundwater. The occurrence of groundwater is introduced in relation to the hydrological cycle. Interestingly this chapter not only considers groundwater in its liquid phase, but also in the frozen state as ice or vaporised in hot springs and geysers. This links well with the approach of science curricula to the states of water. The vertical movement of water is discussed in detail in the subsurface with reference to the unsaturated zone, the zone of intermittent saturation, the capillary fringe and the saturated zone. This section develops the concept of porosity and permeability in relation to groundwater movement through aquifers. Unconfined and confined aquifers are described together with the associated terms. A whole section with illustrations is devoted to the effects of geological structure on groundwater movement. Groundwater as a resource is dealt with in a cursory manner combining the effects of earth tides with contamination and water supply. The impacts of over abstraction and saline intrusion are discussed together, and followed by groundwater in the desert environment which is illustrated by the development of oases in an artesian basin setting. Groundwater as an erosive agent, particularly in limestone country, is used to show the development of cave structures and geomorphological surface features. Geothermal heating of groundwaters and the function of geysers and hot springs are discussed. Frozen groundwater and the formation of permafrost, patterned ground and pingos conclude the chapter.

3.4.2 Geoscience – Understanding Geological Processes. Dee Edwards and Chris King. 1999 Hodder & Stoughton Educational ISBN 0 340 68843 2

'Geoscience' provides a foundation for those studying at A Level and first year undergraduate level Geology. Groundwater is described under the heading of 'Water Resource' in Chapter 9 entitled 'Geoscience applied: resources, hazards and geotechnics.' Groundwater is identified as one of the main sources of freshwater and is set in a UK and global context. The main terms associated with groundwater are clearly defined, and a cross reference refers the reader to a description of porosity and the different types of

permeability in a previous section on sedimentary rock properties. The text is supported by clear diagrams and interesting case illustrations are given.

A theme of the book is finding interconnections between core geological concepts and emphasising their importance in human terms. For example, the artesian aquifers in Australia yield saline waters because the water has travelled very slowly through the rocks over a long period. Such waters are not suitable for drinking and produce little lather when used for washing. A further explanation of coastal saline intrusion includes the key fact that salt water is more dense, and this helps to understand the accompanying diagram. Bottled water is another illustration of where students may have used groundwater without realising, and an explanation is given about spring water taste being enhanced by water –rock interaction.

The human terms are expanded on in the section on waste disposal, which discusses very simply the dilemma of 'dilute and disperse' versus the present policy of 'concentrate and contain'. The use of different rock properties as integral to the containment design of a landfill is explored, together with the need for a thorough understanding of the hydrogeology of a site. Contaminant migration in groundwater is clearly shown in a diagram to support the text. Risk as a concept is introduced and linked to assessing sites for their suitability for waste disposal and, in the high-risk category, for radioactive waste disposal. The section ends by highlighting the fact that the recent raising of environmental protection measures for waste disposal sites has caused the cost of hiring a skip to sharply increase.

3.4.3 Geological Science. Andrew McLeish. 1986 Blackie & Sons Ltd ISBN 0216911 982

The book covers the essential requirements of the then A Level and Higher Geology syllabuses of the UK. In considering groundwater the text commences with a global view of the water cycle with 8 400 000 km^3 of water held as groundwater. Groundwater is defined as water beneath the water table. Different sources of water that contribute to groundwater are described. This is followed by a discussion of storage and flow of water in rocks with regard to the properties of porosity and permeability. Aquifers and the terms associated with the different types of aquifers are set out in the text with simple clear sectional diagrams. Springs, wells, artesian basins and oases are concisely described with examples in Australia, UK and North Africa. The book then moves to sections on water in limestone regions and looks at the features of a karst landscape, and a further section on hot springs and geysers.

3.4.4 Dynamic Earth: An Introduction to Physical Geology. Brian J. Skinner, Stephen C. Porter, Jeffrey Park. 5th Ed. 2004. John Wiley & Sons Inc. ISBN 0-471-15228-5.

This text is recommended in the OCR Geology AS/A Level reading list. It is a general text suitable for both secondary and further education. Chapter 15 is entitled 'Groundwater' and the aim of the chapter is to answer the following questions:

- What is groundwater, and where does it come from?

- What is the water table, and why is it important?
- How fast does groundwater flow? What factors control this movement?
- What causes springs?
- What are aquifers? What are the two types of aquifer?
- What factors affect the quality of groundwater used for human water supplies?
- How can water supplies be safeguarded from contamination?
- By what three processes does groundwater produce its geological effects? How do these processes work?

The definition of groundwater in the glossary is 'all the water contained in the spaces within the bedrock and regolith'. This is a wider definition than taken by the geographical texts. The questions above are answered in depth covering some twenty four pages including many clear block diagrams, maps, sections and photographs. The origin and terms associated with groundwater are first defined, then groundwater flow is discussed with a clear description of porosity and permeability. Recharge and discharge processes in a groundwater catchment are set out together with a basic understanding of Darcy's Law. Springs, wells, unconfined aquifers, confined aquifers and artesian systems are illustrated together with a case study of the Floridan aquifer. Groundwater mining and its consequences are covered with reference to lowering of the water table and subsidence of the land surface. Examples of Mexico City and the leaning tower at Pisa are given. Water quality and groundwater contamination are addressed in a further section. Pollution by sewage, toxic waste, agriculture and contamination by seawater are described, with a case study of the San Joaquin Valley. The chapter ends with looking at the processes of dissolution, cementation and replacement that are facilitated by groundwater, resulting in distinctive karstic landscapes in massive limestones.

3.5 AS/A Level Environmental Science Texts

Two texts were chosen for review.

3.5.1 Environmental Science (Bath Advanced Sciences). Kevin Byre, 1997. Nelson Thornes ISBN 01744 8243 4

This text was first published in 1997 and was designed to cover the complete A and AS Level syllabus for AEB Environment Science and to support a range of other specifications. It is now widely used for the AQA AS/A Environmental Science specification. One chapter is devoted to water resources and opens with an introduction to the hydrological cycle. Groundwater flow is marked on a sectional diagram with a flat water table running between mountains and the ocean. The sources of water are described, including groundwater. Basic terminology associated with unconfined and confined aquifers is presented. Again

a sectional diagram shows a flat water table, although arguable in this instance, it is hydraulically correct.

The problems of over abstraction are set out with examples of the London Basin (1875- 1965), subsidence in Mexico City and saline intrusions in the Middle East. The diagram illustrating saline intrusion is not very clear, and it is difficult to understand what is happening. Water treatment, managing water resources, irrigation, river management and flood control are covered in the remainder of the chapter. Artificial recharge of aquifers is given as an option under water management, and illustrated by the North London Recharge Scheme. The inter-relationship of groundwater with soil salination is discussed together with an example of control measures used in Pakistan.

Elsewhere in the book links are made with groundwater. Pollution of groundwaters is mentioned with respect to fertilisers and waste. In the chapter on energy, geothermal power is discussed with reference to the 'hot aquifer' where hot water is abstracted for power generation. An alternative approach of using 'hot dry rocks' to heat introduced water is also presented, citing the example of the Southampton City Centre scheme.

3.5.2 Environmental Science (Bath Science 16-19S) Kevin Byrne, 2nd Ed. Nelson Thornes 2001 ISBN 017448305 8.

This edition gives coverage of the AS and A GCE Environmental Science specification for AQA, and gives support for options and units in other related advanced general and vocational courses. Groundwater is defined as 'water stored within the pores, joints and fissures of rocks within the Earth.' In the chapter on 'Water Supply and Use', sources of water are described which include groundwater. The occurrence of water within aquifers is set out briefly in relation to porous and permeable strata, but no flow mechanisms are given.

The section on groundwater abstraction starts with the statement that 'In Britain the most important aquifers are sandstones,' and goes on to say 'Thus London sits above a chalk aquifer'. There is no explanation that chalk is a limestone. Diagrams of the location of the sandstone and chalk outcrop in the UK are given, and also the principal aquifers. The latter diagram also includes 'underground extensions' which are not elaborated on in the text, but are presumably the confined sections of aquifers.

The London Basin is given as an example of an artesian aquifer where the water table has fallen some 60m between 1875 and 1965. Immediately following is a sentence which states 'The two most serious side effects of over abstraction are subsidence and salt water incursions.' The reader could be forgiven for thinking these effects occur in London. However, this sentence is the introduction to two short sections, one on subsidence citing Mexico City as an example, and the other is on salt-water incursion. An example in the Middle East is given accompanied by a small and not very clear diagram.

Aquifers are also mentioned in relation to geothermal power and waste. In the subsequent chapter on 'Water resources and Management', the only reference to

groundwater involves the artificial recharge scheme in North London and reclamation of saline lands in Pakistan. This edition of the book suffers from poor editing, and through brevity has caused erroneous over simplifications with respect to groundwater.

3.6 ESTA Publications

The aim of the Earth Sciences Teachers Association (ETSA) is to encourage and support the teaching of earth sciences in schools, this includes the development of teaching resources. ESTA promote their activities and publications on their web site (www.esta-uk.org) and also at their annual conference and at teacher conferences such as those of the Association for Science Education (ASE) and the Geographical Association (GA). In addition, their work is promoted by other organisations such as the Education Committee of Geological Society and the Earth Science Education Unit at Keele University.

3.6.1 Key Stage 2

The Earth Science Teachers' Association (ESTA) has published 'Working with Rocks' for Key Stage 2. The pack contains a book 'Christina's Story' relating the story of a gravestone, together with supporting activities and worksheets. The story format allows the material to be used as part of Literacy Hour and the same themes can then be developed further in Science and Geography – in particular, relating to 'materials and properties' and 'environmental change' and the QCA Unit 3D Rocks and Soils.

Background information is supplied for teachers outlining the concept of the rock cycle, rock types, use of rocks and lists of further resources. The six activity sheets cover comparing, sorting, testing and identifying rocks. Activity 4 covers groundwater. The pupils first carry out experiments to determine porous and non-porous rocks, and their hardness. This is then linked to Worksheet E entitled 'Drilling Holes and Making Wells' in which pupils make a well in a container of gravel. They then discuss where the water has gone and the properties of chalk and sandstone in relation to water supply.

'Working with Soils' follows a similar format. A book about a worm relates the story of a family of worms, and themes are developed in six activities and accompanying worksheets. Two experiments, used to explain porosity and permeability, can be used in developing the understanding of the occurrence of groundwater.

3.6.2 Key Stage 3

ESTA published 'Water Overground and Underground' in 1992 as part of the Science of the Earth 11-14 series. It was developed to cover parts of the then Key Stage 3 Programme of Study in the National Curriculum for Science and for Geography. The details are provided at the end of the publication identifying the applicable sections, together with an analysis of skills. Three earth science problems, specifically related to groundwater issues have been used to study aspects of:

- Science
  - The application of science
  - Scientific investigation
  - Life and living
  - Materials and their properties
- Geography
  - Geographical skills
  - Physical geography
  - Environmental geography

Unfortunately ESTA report that there as been little take-up of this publication, particularly in recent years as schools have become wedded to prescribed examples in the curriculum which appear to be infrequently changed.

The publication comprises three units:

Oasis as a desert island – the permeability problem. This is a practical introduction to the importance of fluid flow through rocks and soils, and its measurement. Pupils are asked to test a new product for 'Floral Products Ltd' and are initially given the problem of ranking objects (sieve, sponge, cracked brick and undamaged brick) in order of permeability. Then they are asked to measure the permeability of green 'Oasis' and grey 'Oasis' by carrying out simple falling head tests. As a result the pupils are asked to recommend the most suitable material for flower arranging with a justification of their choice. The significance of capillary action is introduced by the teacher.

This module then requires pupils to undertake some tests on natural materials and prepare a report for 'The Sarong Water Scheme'. Pupils have to recommend the best option for transporting fresh water from the crater-lake at the centre of a volcanic island to a coastal village over a variety of mixed permeability strata.

Out of sight, out of mind? This is a laboratory simulation of water movement through rocks underground and its significance for water supply and for pollution by waste disposal. With reference to an article in the 'Observer' magazine in 1990 about Flitwick landfill, the problems associated with contamination of groundwater supplies by leachate are demonstrated. Able pupils are asked to consider the future implications of waste disposal related to a growing population, and to consider what remedial methods can be used on old sites to mitigate contamination. Although the 'Observer' article is somewhat dated the issues are just as relevant today. Local papers or the internet can be scanned to find pressure groups protesting about the impact of active and closed landfill sites in the local area.

The dam that failed. This is a problem-solving paper exercise examining the criteria for choosing a good dam site, based on a case study in South Wales. Pupils are first asked to consider the important features in the landscape that are necessary for a suitable dam location. Using maps, pupils prepare a proposal making recommendations as to the advantages and disadvantages of a dam site and whether it should be built. Finally pupils take on the role of a dam engineer to develop solutions to a leaking dam situation and argue the need for an extension to the scheme.

3.7 Summary of Findings

- The contents of textbooks and course books generally reflect the scope of the Schemes of Work and the specifications. However, a broader approach is presented in Geology where textbooks also cover the requirements of the first year of Higher Education.

- The Key Stage 3 Geography series are not required to cover groundwater, but it is mentioned in 'New Foundation', and more thoroughly discussed in 'New Extensions' aimed at more able pupils.

- The GCSE Geography texts appear to be written to cover a wide range of specifications including the Scottish Standard Grades.

- The AS/A Geography Level texts are focused on individual specifications.

- The range of textbooks recommended for AS/A Level Geology are written for a wider audience, including higher education and are therefore broader than the specifications.

- AS/A Level Environmental Science texts briefly provide a basic introduction to groundwater, but erroneous over simplification is a problem.

- The Key Stage 2 ESTA publications are very applicable to the understanding of groundwater. The Key Stage 3 publication is no longer in demand due to the changes in the National Curriculum, but still has applicability for development of generic skills in Science and Geography.

- Terminology applicable to groundwater, particularly among the geographical texts, is confused. More rigour is required.

- In some instances groundwater concepts appear to have been made to fit a model with limited explanation and so misunderstandings are likely to ensue.

- Errors and erroneous over simplifications have been noted in the texts reviewed.

- There is scope for more groundwater-related case studies, tailored to the specifications, particularly in river basin management, water supply and conservation, and in relation to development.

4. CASES STUDIES OF CURRENT TEACHERS

This section reports the findings of Task 3 where the aim was to assess teacher understanding of groundwater issues and the extent to which these are incorporated in their curriculum work. The chosen methodology was by meeting staff and completion of questionnaires. This personal communication method ensures information is collected, but is time consuming and therefore only a small number of representative schools and teachers could be contacted. The following case studies were selected:

- the Geography Department of a Secondary School which teaches both GCSE and AS/A Level Geography;
- a teacher of AS Level Environmental Sciences to students, who receive tuition by distance learning techniques; and
- the Geography co-ordinator at a Primary School where the water cycle is taught on a rolling programme for Years 3 and 4.

Three completed case study questionnaires are presented in Appendix 2. This is only a very small sample from a limited geographical area and the findings should therefore be treated as indicative. Basic information has been provided on the courses taught and the textbooks used. The primary school supplemented information by use of pictures, diagrams and ideas collected by teachers from a wide variety of sources and stored in boxes in the school.

The AS/A Level Environmental Science texts, written by Kevin Byrne and reviewed in Section 3, cover an introduction to groundwater. However, the Environmental Science teacher had to supplement the texts with information from other sources, especially by finding better diagrams. His additional information was derived from the following sources following a visit to BGS Wallingford:

1. Groundwater – our hidden asset. UK Groundwater Forum;
2. Groundwater - a valuable resource. UK Groundwater Forum Briefing Note;
3. www.bgs.ac.uk – the education section
4. http://earthguide.ucsd.edu

The feedback from the secondary school is that at GCSE and AS/A Level besides textbooks, students and teachers use videos, photographs, satellite images, CD ROMs and the internet. However, beyond the classroom, access to other suitable resources at all levels is limited by the time needed for exploration and by financial constraints.

Information from the teachers suggests that students may be introduced to groundwater at all levels (from Key Stage 2 to A/AS Level), both as part of the hydrological cycle and as one of the sources of water supply, thus conforming to the National Curriculum, Schemes of Work and specifications. An added impetus to teaching is given by the frequency of examination of the subject area. The Geography teacher suggested that, at both GCSE and AS/A Level, questions came up every 3 to 4 years that could include groundwater. However, groundwater will not form a significant part of any question because it is only a small part of the specification, and consequently there is not the necessity to read about and research groundwater as a separate issue.

The teachers at the case study schools assess that pupils are interested in the groundwater aspects, but some have difficulty in grasping the concepts involved. Where

groundwater has been taught recently to Environmental Science AS Level students it has been found that the students do not easily understand the concepts associated with porosity, permeability, saline intrusion and the timescales involved in groundwater flow. Technical parameters such as 'specific retention' and 'specific yield' are also a problem because they are taught and illustrated by the use of complex graphs. Some pupils also lack confidence in using the acquired technical terms in their written work.

The teaching of groundwater at secondary level is rarely backed up with any practical sessions which may, for example, be used to demonstrate and measure porosity and permeability. Although fieldwork is undertaken by the Geography AS/A Level students they do not look at groundwater as part of these studies. Fieldwork is not undertaken by the Environmental Science AS Level students sampled. However, in the primary school pupils look at water cycle processes outside the school building, (drying puddles showing evaporation, visiting the on-site nature reserve with a spring-fed pond), and undertake permeability experiments in Science. The primary school has also made trips, including visiting the Centre for Ecology and Hydrology during Science Week when the NERC exhibition on water was touring.

From the case studies of teaching carried out for this survey, it is found that all teachers have some background knowledge of groundwater and related issues. The teachers sampled are fairly confident in teaching the subject area. The Geography teacher enjoys teaching groundwater and feels it is an important topic to cover as does the primary school, whereas the Environmental Science tutor who has a background in Science and Chemistry, is less enthusiastic and confident. Nevertheless, he had no difficulty in obtaining additional information for a PowerPoint presentation for his students Appendix 2.

None of the teachers had received continuous professional development (CPD) training in groundwater and related issues.

5. PROVISION OF GROUNDWATER EDUCATIONAL MATERIAL BY OTHER ORGANISATIONS

This section reports the results of the assessment of activities of other organizations to provide groundwater educational material. Existing Government research (Council for Science and Technology, 2000. Science teachers: a report on supporting and developing the profession of science teaching in primary and secondary schools. London: Her Majesty's Stationery Office) already shows that science teachers make relatively little use of material published by other organisations (Figure 2). The availability of resources that focus on groundwater was examined by assessing material produced by the organisations that fund the UK Groundwater Forum to establish how uptake of these materials is measured and whether their experience was similar to the national picture for secondary school science.

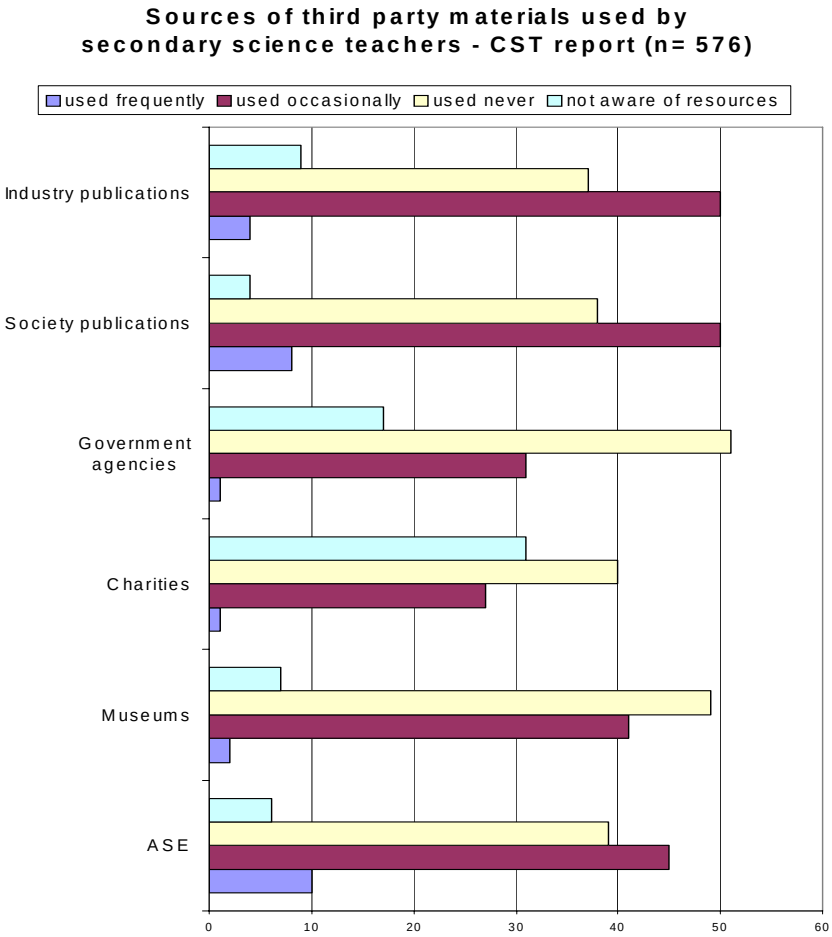

Figure 2 **Findings of use of information by secondary science teachers from research undertaken for the Council for Science and Technology (ASE = Association of Science Education).**

5.1 Water Companies

A visit was made to Ted Casey and the Education Team at the Three Valleys Water Company which is part of Veolia Water. The Environment and Education Centre is situated at the Clay Lane Pumping and Water Treatment Station at Bushey in Hertfordshire. Approximately 21,000 pupils visit the Centre each year. The Education Team aims to support teachers in providing stimulating and exciting 'hands on' experiences which will enrich curriculum work in school when pupils visit the 33 acre site. In addition, the Centre offers an outreach programme, which has steadily expanded over recent years and is now a very popular option. Many areas of study are covered (Table 3), plus free INSET courses are offered for school staff. Groundwater is mentioned as a source of water when visits are made to the treatment works, but because courses are related to curriculum work there is no major component devoted to groundwater.

Table 3 Courses offered by the Three Valleys Environment and Education Centre

Water investigations/usage	Water and Health
Rivers and river survey	Water in the Third World
Habitats	Rocks and Soils
Pond Life	Mini-beasts
Plants	Trees
Food Chains	Life Cycles
Science	Weather
Map work	Curriculum trails
Orienteering	Compass work
Recycling	Sustainability
Citizenship	SATs revision

Thames Water Utilities Limited said that their education programme is focussed on water supply, water management and water conservation. Besides their web site with dynamic news pages, at Key Stage 2, volunteers visit schools to give talks and exercises on water use and water conservation. At secondary level Thames Water has an engineering game based on getting water to customers, but this is also volunteer intensive. Groundwater was not a significant element in any of these activities. Severn Trent was the only other water company contacted, and they have 5 centres providing water based tuition to 22,000 pupils.

Ted Casey at Three Valleys and Liz Almond at Thames Water are members of the water industry Education Forum which is a regular meeting of the industry educators. The membership is listed in Table 4. Both agreed that the Education Forum would be very interested to hear the results of this review of groundwater education across the UK and recommended contact with the Forum chairperson.

The Education Forum has also generated two web sites, www.waterinschools.co.uk and www.thewaterfamily.co.uk, but again these are about water use, management and conservation and do not directly cover groundwater.

Table 4 Membership of the Education Forum for the Water Industry, May 2006

Name	Organisation	Contact Details
Anne Reed (Chair person)	Yorkshire Water	Anne.reed@yorkshirewater.co.uk
Ted Casey	Three Valleys Water Company plc	Ted.casey@3valleys.co.uk
Becky Link	Severn Trent Water plc	Rebecca.link@severntrent.co.uk
Liz Almond, Tracey Sacks	Thames Water Utilities Ltd	Tracey.sacks@thameswater.co.uk
Terry Bates	United Utilities	Terry.bates@uuplc.co.uk
Brian Nelson	Welsh Water	Brian.nelson@dwrcymru.com
Pam Lovell	Northumbrian Water	Pam.lovell@nwl.co.uk
Cath Nicholls	Wessex Water	Cath.nicholls@wessexwater.co.uk
Jim Graham	Water Aid	water@wateraid.org

5.2 Foundation for Water Research

The Foundation for Water Research (FWR) manages two websites that provide 'water and water-environment' information. The first at www.fwr.org disseminates research reports published by FWR and others, and provides information on Forums supported by FWR. These functions are largely directed at water professionals. However, FWR publishes reviews on the website which address topics of interest to the general public, but none of these directly cover groundwater.

The second website is the Water Framework Directive Information Centre at www.euwfd.com. This site provides independent information about the Water Framework Directive, including what the Directive means, how it is being implemented, who the key players are and how it is relevant to achieving and maintaining a clean and well-managed

water environment. Under the site heading 'Themes' there are a series of Information Notes that provide descriptions of key features within a river basin, and groundwater and the hydrological cycle are included. Wherever possible, links to websites have been included in these, especially resources that may be of interest to teachers. There is no information on the extent of uptake of these web services by schools.

5.3 Environment Agency

It is understand that there is no educational liaison officer role in the Environment Agency and that limited education work is undertaken. The focus of school related activities is on recruitment of suitable staff in the next five years.

5.4 British Geological Survey

BGS uses some funding of its own to publish earth science booklets, but it mainly seeks outside funding focussing on on-line resources www.bgs.ac.uk/education/home.html. BGS has a Memorandum of Understanding with ESTA to provide mutual support and expertise and to help BGS to develop appropriate potential products. BGS has also tried to influence the QCA to include more geology in A Level criteria. BGS Wallingford takes part in schools events such as the Groundwater Experience Week and National Science Week. The staff give talks on an ad-hoc basis. However, overall little emphasis has been placed on promoting groundwater in education.

5.5 Environment & Heritage Service Northern Ireland

The Environment & Heritage Service is planning a series of 13 educational factsheets that cover water management. They will be available on their web site at www.ehsni.gov.uk and are aimed at being a curriculum resource and for public information. They will also be made available at the seven heritage park sites. All are expected to be available by the end of 2006. 'Rivers and Groundwater' will be one of the factsheets. Monitoring of uptake will be by hits to the website and depletion of printed paper stock.

Expertise on education and outreach for Earth Science is currently available within the Geological Survey of Northern Ireland. A number of events have been run with older pupils on environmental issues such as assessing the potential impact from mine workings, which included consideration of groundwater. There is a local Science centre (W5) in Belfast where exhibition space is available at times. GSNI currently have a project officer based at a Geopark (Marble Arch caves) where opportunity exists for education on karstic groundwater.

5.6 UK Groundwater Forum

The UK Groundwater Forum raises awareness of groundwater through a variety of means including events, publications and its own website at www.groundwateruk.org. The website includes educational links as well as basic descriptions of groundwater, with diagrams that can be used as educational resources. The site also catalogues publications, articles, career information, other useful links, groundwater news and meetings and events. Publications include a booklet entitled 'Groundwater – Our Hidden Asset' by R. Downing published by the British Geological Survey (NERC © 1998), a video 'How Rivers Work: the Role of Groundwater' and flyers.

Uptake of these resources can be measured by website hits and depletion of publication stocks, but the actual use of these materials in schools is unknown.

5.7 Groundwater Experience Week

An example of an integrated approach among water industry organisations that enables the sharing of resources, is the 'Groundwater Experience Week'. This is an annual event organised jointly by the Hill End Field Centre of Oxfordshire County Council, the Environment Agency and the British Geological Survey. The ESEU has contributed to the associated INSET training. It is again being held in May 2006. The role-play activity is supported during the week by the enthusiasm of local hydrogeologists from the Environment Agency.

The aim of the event is to teach primary school children about the importance of groundwater. During the week about 150 Key Stage 2 pupils and their teachers attend one of the daily repeated events. Stimulating activities including a water trail, a role-play model, theatre, interactive models and water quality monitoring are undertaken. Prior to the event a training day is held for the teachers which includes a background talk by BGS, and a hands-on workshop by ESEU aimed at linking the Key Stage 2 'Rocks and Soils' unit with groundwater. The arrangements for pupils to visit to the centre are explained, and the teachers are also taken on the water trail and participate in the role-play model. This event has been very successful and gained much positive feedback.

5.8 Summary of Findings

The organisations that are represented by the UK Groundwater Forum provide resources for schools with a varying degree of success. Whilst these organisations are a small sample they indicate the following:

- The water companies support extra curricula school activities, but these are focused on water supply, conservation and management.
- The water industry has a number of regional education centres that could provide more groundwater-orientated courses.
- The Education Forum which is a regular meeting of the water industry educators would be interested to receive the findings of this report.

- The effectiveness of web-based information services for schools is not widely monitored.

- The Environment Agency effort in the educational field is focussed on recruitment of suitable staff in the next five years.

- The British Geological Survey publishes a number of booklets and supports schools science events, but overall little promotion of groundwater in education occurs.

- The Environment & Heritage Service of Northern Ireland is planning a series of 13 educational factsheets that cover water management to be available by December 2006. Groundwater is an included topic.

- The Geological Survey of Northern Ireland runs a number of events with older pupils on environmental issues that include groundwater.

- The UK Groundwater Forum provides a website, and other publications focussed on groundwater, but uptake of these in schools is not known.

- The 'Groundwater Experience Week' is an example of an integrated approach between four organisations to share the promotion of groundwater education.

Overall, it is concluded that the direct education of pupils by outreach programmes, visits to water industry and field study centres is a very effective means of conveying knowledge about water issues to a relatively small but important proportion of the population. However, the groundwater content could be increased. More information of the effectiveness of existing websites needs to be gained. It is recommended that there is a great opportunity to build on and co-ordinate what already exists for the benefit not only of teaching about groundwater issues, but ultimately for sustainable development teaching as well.

6. DISCUSSION AND CONCLUSIONS

This review has looked at the current requirements to teach groundwater in schools and the available teaching resources. As in any other subject, the main drivers for teaching are determined by the curricula and specifications, together with the frequency at which the topic comes up in examinations and assessments. Therefore to make any significant change in the degree to which groundwater is taught in schools, these drivers will need to be targeted.

6.1 Groundwater Content Drivers

Four education administration systems now operate in the UK with their own qualifications and curriculum authorities. Consequently the National Curricula differ between countries, with Scotland and Northern Ireland being more thematically based than England and Wales. Alongside and supporting this system are the six Awarding Bodies. Three are focused on England (AQA, OCR, EDEXCEL), but their specifications can be chosen in Wales and Northern Ireland. Wales (WJEC), Scotland (SQA) and Northern Ireland (CCEA) have their own awarding authorities. Therefore if the UK Groundwater Forum wishes to influence the groundwater content of the Schemes of Work and specifications a significant effort will be needed to achieve this across the UK.

The current review of the Schemes of Work and specifications shows that the study of groundwater is limited below AS/A Level. The teaching of water in the environment is not a fundamental part of the Science National Curricula in the UK. It is mainly taught through the subject of Geography. In England, water is studied at Key Stage 2 in relation to location, use, ownership and economic aspects. The inclusion of groundwater at this stage will be dependent on teacher awareness, the local water supply to schools and extra curricula activities such as events and visits arranged in conjunction with water utilities.

In Key Stage 3 Geography, water in the environment is commonly studied in relation to the water cycle and geomorphological processes. Groundwater is again not specifically mentioned in the Scheme of Work, but the word is introduced in textbooks at this level, and the secondary school case study also indicates that groundwater is briefly taught in relation to the water cycle and water supply.

At GCSE the teaching of water in the environment is not included in the Science specifications, except for some aspects of water quality related to pollution and chemical testing. GCSE Environmental Science (AQA), GCSE Geology (WJEC) and the Scottish Access 3 and Intermediate 1 Geology include the study of groundwater and related issues. Ten Geography GCSE specifications and the Scottish Intermediate Grades offer differing approaches to teaching water in the environment. In general the freshwater emphasis is on the study of features, events and processes associated with river systems. Only four GCSE specifications link the hydrological cycle with the river studies; it is in the hydrological cycle that groundwater is briefly covered. Water supply at GCSE is considered separately from other resources and only two specifications mention groundwater in relation to supply.

Groundwater occurrence, use and over-exploitation are studied at AS Environmental Science (AQA) together with the demands of water supply. This knowledge is extended in the A2 course to cover water conservation, water management and water pollution. In both Geology AS/A Levels (OCR, WJEC) groundwater use and occurrence are considered in the context of sustainable management of water supply.

At AS/A Level a systematic approach is generally taken to the hydrological cycle. The cycle is studied both at the global and the drainage basin scale. Groundwater is identified as part of the cycle, but only in EDEXCEL A course is a more developed approach to groundwater management required. Otherwise the emphasis at this level is on surface water. Water supply is a component of some Geography AS/A Levels in relation to sustainable development and exploitation by growing populations, but groundwater is not specifically mentioned in this context.

The frequency of examination of groundwater and related issues has been assessed in this review by teacher questionnaires. The feedback indicates that in Geography, at both GCSE and AS/A Level, questions come up every 3 to 4 years that could include groundwater. However, groundwater will not form a significant part of any question because it is only a small part of the specification, and consequently there is not the necessity to read about and research groundwater as a separate issue. Thus a 'chicken and egg' situation occurs requiring both improved specifications for groundwater and greater exposure in questions. This issue can only be addressed in negotiation with the Awarding Bodies.

For the UK Groundwater Forum to influence the groundwater content of the Schemes of Work and specifications requires:

- Identifying key examination committees and personnel
- Building on this current review of the existing specifications, to identify areas in which the study of groundwater could be enhanced, together with any errors and misconceptions included, and making Awarding Bodies aware of these issues
- Reviewing questions on groundwater that appear in examinations (together with any associated mark schemes) for their scope, content and accuracy and feeding back on these
- Compiling and publishing reports that include the data collected and summarise findings.

6.2 Textbooks and Other Resource Material

The contents of textbooks and course books generally reflect the scope of the Schemes of Work and specifications. Groundwater is mentioned in two Key Stage 3 Geography textbooks as part of the hydrological cycle, and this approach is continued in three out of the four GCSE texts reviewed. Linking groundwater to other topics within texts is limited to short references to, for example, fertilizer contamination, water supply from springs, wells and boreholes, and declining groundwater levels in the Sahel.

The GCSE Geography course books are written to cover a wide range of specifications, whereas the AS/A Level texts are focused on individual specifications. Again groundwater is generally referred to in the context of the hydrological cycle and to a lesser extent in relation to water supply. The textbooks recommended for AS/A Level Geology are

generally written for a wider audience, including higher education, and therefore they have a broader scope than the specifications. The AS/A Level Environmental Science texts cover a basic introduction to groundwater, and identify groundwater links to other areas of the specification. However, in the case study undertaken for this survey, the Environmental Science teacher had to supplement the information from other sources, especially in finding better diagrams.

During the review it was found that terminology applicable to groundwater, particularly among the geographical texts, is confused. In some cases this leads to errors and erroneous over simplifications. This observation is in line with research carried out by the ESEU on the earth science content of Key Stage 3 and 4 science course books, where an average of one mistake per page has been found Figure 3. (King, C., Fleming., A., Kennett, P. & Thompson, D. (2002) A report on the Earth Science content of commonly used Secondary Science Textbooks. pp 101. Keele: The Earth Science Education Unit, Keele University.)

Although the groundwater content of the geography texts may be limited by the specifications, there appears to be scope to improve the groundwater content in case studies to illustrate water pollution, water supply and sustainable use at global and river basin scales. However, it is important that agreement is reached with the awarding bodies and curriculum authorities on what examples can be used, otherwise, like the ESTA publication reviewed in Section 6, there may be little use made of such material.

At GCSE and AS/A Level the case study information indicates that besides textbooks, students and teachers use videos, photographs, satellite images, CD ROMs and the internet. However, beyond the classroom, access to other suitable resources at all levels is limited by the time needed for exploration and by financial constraints.

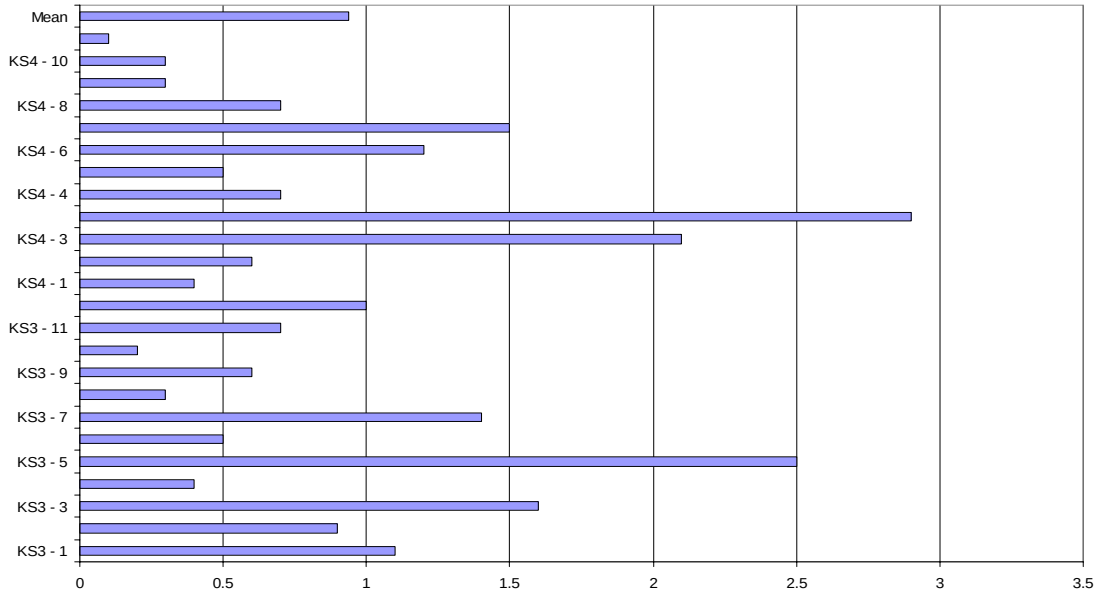

Figure 3 **ESEU research showing mean numbers of Earth Science errors per page of Science textbooks.The y-axis numbers are identifiers for the 11 KS3 and 10 KS4 texts reviewed.**

6.3 Pupils and their Needs

Information from the teacher case studies suggests that in those schools students are introduced to groundwater at all levels, both as part of the hydrological cycle and as one of the sources of water supply.

The teachers assess that pupils are interested in the groundwater aspects, but some have difficulty in grasping the concepts involved. Where groundwater has recently been taught to Environment Science AS Level students it has been found that the concepts associated with porosity, permeability, saline intrusion and the timescales involved in groundwater flow are not easy to understand. Technical parameters such as 'specific retention' and 'specific yield' are also a problem, because they are taught and illustrated by the use of complex graphs. Some pupils also lack confidence in using the acquired technical terms in their written work.

The teaching of groundwater at secondary level in the case studies is rarely backed up with any practical sessions which may, for example, be used to demonstrate and measure porosity and permeability. Although fieldwork is undertaken by the Geography AS/A Level students in the case study schools they do not look at groundwater as part of these studies, and fieldwork is not undertaken by the Environmental Science AS Level students sampled. At the case study primary school experimentation, observation and trips are used to reinforce the knowledge.

6.4 Teachers and their Needs

From the case studies of teaching, it is found that the secondary teachers have some background knowledge of groundwater and related issues. The teachers sampled are fairly confident in teaching the subject area. The Geography teacher enjoys teaching groundwater and feels it is an important topic to cover, whereas the Environmental Science tutor who has a background in Science and Chemistry, is less enthusiastic and confident. Nevertheless, he had no difficulty in obtaining additional information for a PowerPoint presentation for his students.

None of the teachers had received continuous professional development (CPD) training in groundwater and related issues. Such training is known to boost confidence and therefore enjoyment in teaching the subject, resulting in a measurable positive effect on students. Analysis of 200 studies of the effectiveness of staff development amongst teachers (Joyce and Showers Joyce, B. R., & Showers, B. (1984) Transfer of training: The contribution of coaching. In Hopkis, D., & Wideen, M. (eds.) Alternative Perspectives on School Improvement, 77 – 87. (Lewes, UK: Falmer Press).), shows that to have maximum benefit, staff coaching should enhance knowledge and skills and be backed up by practical sessions of classroom tasks. This is also illustrated by the INSET work of the ESEU in providing practical workshops to Key Stage 3 and 4 teachers to encourage improved teaching of the Earth Science element of the National Curriculum.

At Key Stage 2, where primary school teachers have little background knowledge of earth science and groundwater, the ESEU in conjunction with Oxfordshire County Council, the Environment Agency and the British Geological Survey have run annual INSET Groundwater Days. The training is used to enable class teachers to prepare their pupils for a day of

practical and field based groundwater activities. Background talks on groundwater and the objectives and organisation of the pupils' activities are given. The training incorporates a session to help teachers to look at features of rocks and soils and to describe what they see, based on the ESEU workshop of 'Spot that Rock'. This session is linked to a practical circus of experiments suitable for the primary classroom which uses material from the ESTA publications on rocks and soils. The feedback from these sessions has been very positive.

6.5 Resources Provided by Other Organisations

The organisations that are represented by the Groundwater Forum have been found to provide resources for schools with a varying degree of success. Whilst these organisations are a small sample, they show that the water companies support extra curricula school activities that are focused on water supply, conservation and management. The water industry achieves most of its education through regional education centres and outreach programmes to schools. However, the groundwater content of these activities appears limited. The Education Forum, which is a regular meeting of the water industry educators, would be interested to receive the findings of this report.

Information by the UK Groundwater Forum organisations is published in a variety of forms. Websites are produced by a number of the members, but the effectiveness of these information services for schools is not widely monitored. The British Geological Survey publishes a number of booklets and supports schools science events, but overall little promotion of groundwater in education occurs. In Northern Ireland, the Environment & Heritage Service is planning a series of 13 educational factsheets that cover water management to be available by December 2006. Groundwater is an included topic. Uptake of these will be directly monitored by how fast the stock is used.

'Hands on' science events are supported by a number of the UK Groundwater Forum members and have proved successful. The 'Groundwater Experience Week' is an example of an integrated approach between four organisations to share the promotion of groundwater education.

6.6 Conclusions

1. All students complete the 5-14 curricula requirements in Science and Geography, a few students (some 30%) take Geography at GCSE. The more specialised qualifications of AS/A Level Environmental Science and Geology are only available in some 500 institutions and this is reflected by the low student numbers nationally. Therefore only a small minority of pupils will have been taught in any detail the below ground part of the water cycle and the significance of groundwater both in occurrence and as a resource.

2. Groundwater will not form a significant part of any examination question in Geography GCSE and AS/A Level exams because it is only a small element of the specifications. Consequently there is not the necessity to read about and research groundwater as a separate issue. Thus a 'chicken and egg' situation occurs requiring both improved specification for groundwater and greater

exposure in questions which can only be resolved in negotiation with the Awarding Bodies.

3. Although the groundwater content of course texts may be limited by the specifications for examined courses, there is potentially scope to include groundwater case studies to illustrate water pollution, water supply and sustainable use of groundwater at global and river basin scales. Where reference is currently made to groundwater there is also a need to improve the rigour in terminology and explanations in some texts.

4. At GCSE and AS/A Level the case study information obtained through this review indicates that textbooks videos, photographs, satellite images, CD ROMs and the internet are used in schools. However beyond the classroom, teacher access to other suitable resources at all levels is limited by the time needed for exploration and by financial constraints.

5. The teachers approached through the case studies assess that pupils are interested in the groundwater, but some have difficulty in grasping the concepts involved.

6. The teaching of groundwater at secondary level is rarely backed up with any practical work or field work, but in the case study primary school these have been incorporated to support lessons and relevant school trips undertaken.

7. From the case studies of teaching, it is found that a small sample of teachers has some background knowledge of groundwater and related issues and is fairly confident in teaching the subject area.

8. None of the teachers surveyed had received continuous professional development (CPD) training in groundwater and related issues. Such training is known to boost confidence and therefore enjoyment in teaching the subject, resulting in a measurable positive effect on students.

9. Other organisations provide direct education of pupils through outreach programmes and visits to water industry and field study centres. This appears to be a very effective means of conveying knowledge about water issues, but the groundwater content could be increased. However, the success of web-based and paper- based resources is unknown.

10. It is recommended that there is a great opportunity to build on and co-ordinate what already exists for the benefit not only of teaching about groundwater issues, but ultimately for sustainable development teaching as well.

7. RECOMMENDATIONS

The following recommendations are made:

1. To improve groundwater education in schools it is recommended that in the short-term the UK Groundwater Forum lobbies the National Curriculum Authorities and the Awarding Bodies and takes part in curriculum debates to:

    i) give groundwater a higher profile in the Schemes of Work and Specifications;

    ii) include better case studies where groundwater is relevant;

    iii) include water as a resource (since in Geography specifications, water is not regarded as a resource); and

    iv) integrate groundwater and its role in the environment and water supply into teaching about sustainable development.

    As part of a QCA review of Science at A Level, criteria for A Level Environmental Science are currently being prepared. The first draft is out for consultation and it is recommended that the UK Groundwater Forum should consider providing a response. Current specifications will be reworked to meet these new criteria for first teaching in 2008.

2. Such changes will need to be supported by appropriate course material (the development of which could be co-ordinated by the UK Groundwater Forum), and consultation with publishers of course texts will be required. Another aspect that should be taken up with the publishers is the need for more rigour in texts to eliminate errors, particularly those produced by over simplification.

3. It is also recommended that the UK Groundwater Forum should consult and work with other influential groups. This could include academic organisations such as the Geographical Association, the Royal Geographical Society, the Earth Science Education Forum, the Geological Society and the Royal Society to raise the profile of groundwater both nationally and internationally. Sponsorship of appropriate education-related conferences and writing of articles in teaching publications would also increase awareness.

4. Raising the profile within the water industry Education Forum and working with the industry education programmes is also essential. The UK Groundwater Forum should influence the water companies who already undertake extra curricula school activities, and request that groundwater is given more prominence when describing sources, occurrence and sustainable management of water supplies, in the UK and the wider world. The co-operation of the water industry will be vital in achieving such longer-term goals.

5. It is proposed that support for the development of a national educational resource centre for promoting the teaching of an holistic understanding of all water related issues, including groundwater, should be a longer term aim for the UK Groundwater Forum. The centre could be modelled on the Earth Science Education Unit at Keele, or be developed as an extension of this organisation. The centre would catalyse activity in the water community to

offer a range of services including expertise to curriculum and specification writers, expertise to textbook writers, and provision of development training to teachers and industry educators. It would also monitor and research resulting progress and developments. The Earth Science Education Unit, with hard-won expertise in these areas, remains keen to support these developments.

6. The teacher-development training, proposed as part of the national educational resource centre, should be carefully piloted to ensure it is well targeted. Experience shows that interactive workshops aimed at providing background knowledge, motivation and enthusiasm are very effective. There should be no financial barriers to attendance, thus securing sponsorship will be critical. A regional approach, based on existing networks, will also help to keep costs low and to limit time away from the classroom.
7. Indicative costings only are provided for the short-term measures listed in no. 1 above and for the setting up and running of a national educational resource centre for water. The short term measures are estimated to involve some 45 man days input per year. For the setting up and running of a national educational resource centre for water for five years it is envisaged that a budget of £500,000 to £1,000,000 will be required.

APPENDIX 1. CURRICULA AND SPECIFICATION REVIEW

Table A.1 Review of National Curricula 5-14 years based on the content of the Schemes of Work.

(In the commentary summarized requirements are in normal text and *observations are italicised*)

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Relevant Specification Contents Sections	Commentary
Key Stage 1& 2 (Year 3)	QCA	Science			Scheme of work (non-statutory) Unit 3D	Unit 3D: Rocks and soils 1. Looking at rocks 2. Grouping rocks 3. Erosion and permeability (Here children should learn that difference in rocks can be identified by testing. So rubbing tests, and dropping droplets of water on rocks. Rank rocks according
Key Stage 1& 2 (Year 5)	QCA	Science			Scheme of work (non-statutory) Unit 5D	Unit 5D: Changing state 12. The water water cycle. T*his section focuses on changes in state with reference to a droplet of water passing through the cycle. Although no reference is made to groundwater, perhaps in part because there is no change in state,*
Key Stage 1& 2 (Year 5)	QCA	Geography			Scheme of work (non-statutory) Unit 1	Unit 1. Water. 1. Where can we find water locally? Where can we find water in the world? 2. How does water get to where it is needed? 3. Who uses water? What do they use it for? 4. Is all water useable? How can water be made useable? 5. Who owns water? Wh
Key Stage 1& 2 (Year 4)	QCA	Geography			Scheme of work (non-statutory) Unit 9	Unit 9:Village settlers.1. Where did early settlers choose to settle? *Includes water supply as a factor, but groundwater , even as springs, not specifically identified. It is an opportunity to introduce groundwater as a source of supply.*
Key Stage 1& 2 (Year 4)	QCA	Geography			Scheme of work (non-statutory) Unit 10	Unit 10: A village in India. *No reference is made to water supply although groundwater is likely to be a primary source of water. This is an opportunity to introduce water supply from wells.*
Key Stage 1& 2 (Year 4)	QCA	Geography			Scheme of work (non-statutory) Unit 1	Unit 14: Investigating rivers.1. Where does water come from. *Includes the water cycle, but no mention of groundwater. Again an opportunity to introduce the concept of groundwater and add word to vocabulary.*
Key Stage 1 & 2	CCEA	The World About Us			Theme 2	Theme 2: Materials and Change. Understanding of changes in state in the water cycle. *Appears this links with other themes about weather patterns but not the full water cycle.*

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Relevant Specification Contents Sections	Commentary
Key Stage 1 & 2	ACCAC	Geography				None
Key Stage 1 & 2	ACCAC	Science				None
National Guidelines 5-14	LTS	Environmental Studies - Society , Science and Technology		2000	Levels A-F	People and place - Strand: The Physical Environment. Levels A-D Decribe weather and climate and its impact, Identify and describe physical features. Level E-F Describe and explain weather climate and physical features. Earth & Space - Strand: Materials f
Key Stage 3 (Year 9)	QCA	Science			Scheme of work (non-statutory) Unit 9G	Unit 9G: Environmental Chemistry. 6. Is pollution worse now? *This section refers to water quality, monitoring and environmental policy. There is an opportunity to include groundwater and the impact of groundwater pollution.*
Key Stage 3 (Year 8)	QCA	Geography			Scheme of work (non-statutory) Unit 7	Unit 7: Rivers a fieldwork approach/1. What do we already know about hydrological patterns and processes? 2. What is the river section we are going to study? 3. What do we want to find out? 4. What information can we collect in the field? 5. What does our
Key Stage 3 (Year 8)	QCA	Geography			Scheme of work (non-statutory) Unit 14	Unit14: Can the Earth cope? *This studies ecosystems, pollutation and resources, and although not specifically mentioned groundwater could be introduced as part of the understanding of the significance of water supply.*
Key Stage 3	CCEA	Science & Technology			Environment f)	Environment f) Pollution find out that human activity can damage the environment, both locally and in the wider world and affect the plants and animals living there, including: water - sewage, oil, effluent from water cooling processes. *Unlikely to includ*

Table A.2 Review of GCSE Specifications

(In the commentary summarized requirements are in normal text and *observations are italicised*)

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
GCSE	AQA	Geogrpahy A	3031	2007	9.2, 9.3, 10.4, 10.5	9.2 Rocks and landscape. The interaction between people and landscapes produced by different rock types. Land uses and economic landuses of landscapes of granite, Carboniferous Limestone and chalk and clay. *No explicit mention of groundwater* . 9.3 Rivers landscapes and processes. *The focus is on surface water* .10.4 Industry: Industrial location is influenced by many factors, including problems of environmental impact, particulalry their contribution to land, sea and air pollution. A minimum of three case studies are required. *No mention of water pollution.* 10.5 Managing resources. Exploring relationship between resource use and levels of development and population growth. *Although pollution mentioned the emphasis lies with energy resources, global warming and the use of renewable energy.*
GCSE	AQA	Geogrpahy A Short	3036	2007		As Geography A
GCSE	AQA	Geogrpahy B	3032	2006	9.1	9.1River Basin Management. The hydrological cycle (Global), and also the provision of supplies for urban areas with one example of the use of **groundwater** supplies at regional scale.
GCSE	AQA	Geogrpahy B Short	3037	2006		As Geograpgy B
GCSE	AQA	Geogrpahy C	3033	2005	9.7, 9.10	9.7 Water and Food Supply: How can the availability of water and food be managed to ensure supply? a)The global distribution of water and foodsupplies. b)Look at poor water and food supplies e.g. Sahel. c) alternative strategies used to improve the availability of water and food supplies. 9.10 Resource Depletion:How can existing resources and their alternatives be managed to ensure future supplies? *Water not included here because in 9.7*
GCSE	AQA	Geogrpahy C Short	3038	2005		As Geography C
GCSE	AQA	Environmental Science	3441	2007	Theme 1, 9.2, 9.14	Theme1: Air, Water and Energy 9.2 (i)The water cycle. The main stages and processes in the watercycle including **groundwater** and the **water table**.(ii) Uses of water. The various, sometimes competing , uses of water, including industry agriculture, domestic supply, recreation, transport, energy generation and nature conservation. Candidates should study an example of a multiple use water management scheme. (iii) Variations in water availability. Seasonal variability, and some areas have water shortages while other areas have surpluses.(iv) Water Supply, including **aquifers.** (v) Water treatment (vi) Water conservation 9.14 Water Pollution. *Emphasis on surface water, and groundwater not explicitly mentione* d.

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
GCSE	AQA	Science A	4461	2007/8	Unit Biology 1b, 11.8	Unit Biology 1b Evolution and the Environment 11.8 How do humans affect the environment? Pollution of water with sewage, fertiliser or toxic chemicals.
GCSE	AQA	Science B	4462	2007/8	Unit Biology 1, 11.8	Unit Biology 1 Evolution and the Environment 11.8 How do humans affect the environment? Pollution of water with sewage, fertiliser or toxic chemicals.
GCSE	AQA	Additional Science	4463	2007/8		None
GCSE	AQA	Additional Applied Science	4863	2007/8		None
GCSE	AQA	Applied Science (Double Award)	4861	2007/8	Unit 2, 11.3	Unit 2 Science for the Needs for Society 11.3 Countryside and Environmental Management - You should be able to use data, theories and explanations to: evaluate the effect on the environment of continued use of artificial fertilisers, pesticides, herbicides and fungicides, and the effect of other factors associated with intensive farming (e.g. field size, monoculture). You should be able to assess the application and implications of science when; evaluating changes to the composition of water and air as a consequence of industrial and geological activity; and evaluating the environmental effects over time of pollution and waste disposal.
GCSE	AQA	Biology	4411	2007/8	Unit Biology 1, 11.8	Unit Biology 1 Evolution and the Environment 11.8 How do humans affect the environment? Pollution of water with sewage, fertiliser or toxic chemicals.
GCSE	AQA	Chemistry	4421	2007/8	Unit Chemistry 3- 13.3	Unit Chemistry 3 -13.3 What is in the water we drink. Consider and evaluate the environmental, social and economic aspects of water quality and hardness. *The water cycle is defined without reference to groundwater.*
GCSE	AQA	Physics	4451	2007/8		None
GCSE	OCR	21st Century Science A	J630	2005		None
GCSE	OCR	21st Century Additional Science A	J631	2005		None
GCSE	OCR	21st Century Additional Applied Science A	J632	2005		None
GCSE	OCR	21st Century Biology A	J633	2005		None
GCSE	OCR	21st Century Chemistry A	J634	2005		None
GCSE	OCR	21st Century Physics A	J635	2005		None

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
GCSE	OCR	Gateway Science B	J640	2005		None
GCSE	OCR	Gateway Additional Science B	J641	2005		None
GCSE	OCR	Gateway Biology B	J643	2005		None
GCSE	OCR	Gateway Chemistry B	J644	2005		None
GCSE	OCR	Gateway Physics B	J645	2005		None
GCSE	OCR	Geography A	none	2002	Unit 1	Unit1 People and the Physical World, Rivers (a) The hydrological cycle as a system with inputs, flows, stores and outputs.Unit 4 People and the Environment, Resource Development and the Local Environment (d) Water pollution in a river, lake or sea. *No mention of groundwater.*
GCSE	OCR	Geography A (Short Course)	none	2002	Unit 1	Unit1 People and the Physical World, Rivers (a) The hydrological cycle as a system with inputs, flows, stores and outputs.
GCSE	OCR	Geography B (Avery Hill)	none	2002	Unit 2, 2.1-2.3, 3	Unit 2 Water, Landforms and People. (2) The hydrological cycle related to provision of sustainable water supply. *Requires local and international study of water supply.* 2.1 What are the main sources of freshwater? 2.2 How does the provision of a sustainable supply of water vary in different areas of the world? 2.3 How has water management at different scales attempted to provide a sustainable supply of fresh water in different countries? (3) Variation in rainfall and water supply can cause natural and human hazards in different areas of the world. 3.3 How can a lack of rainfall and/ or water deficit cause drought and desertification? 3.4 What effect do these have on human activity? How can drought and desertification be managed? *No direct mention of groundwater.*
GCSE	OCR	Geography C (Bristol Project)	none	2002		None
GCSE	OCR	Rural and Agricultural Science	none	2002	5.6	5.6 Content Related to Rural Environment (c) What are the environmental issues? (a) Water pollution with reference to nitrate. *No direct mention of groundwater.*

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
GCSE	EDEXCEL	Geography A	1312	2000	Unit A1, 1.1Unit A2 2.3, Unit B5, 5.3	Unit A1 (core): The Physical World 1.1 River processes and landforms. *No groundwater.* Unit A2(core) The Human World 2.3 People and settlements. *Brief mention of water supply as a determining factor.* Unit B5 (option): Managing the Environment. 5.3 Fragile environments require sustainable management. Choose two forms of damage to fragile environments, one caused by farming and one by resource exploitation, one from and LEDC and one from an MEDC eg soil erosion in the Mezzogiorno or Himalyas, desertification in the Sahel or Spain, oil exploitation in ALASKA, timber in Indonesia or link to other units. *Possibility for a groundwater study.*
GCSE	EDEXCEL	Geography B	1313	2000	Unit A1, 1.4 Unit 4B, 4.1, 4.2, 4.3	Unit 1 A1 Population and resources 1.4 What are resources? *Groundwater could be an example here. Good Questions.* Unit 4B (option) Use and abuse of the environment - Water. 4.1 What issues affect fresh water? **Groundwater** *to be included in study as a freshwater store* .4.2 What happens when people try to improve their water supply? *Study required of one large river management scheme.* 4.3 How sustainable is our water? *Study pollution in one river or lake.*
GCSE	EDEXCEL	Geography Short Course	3320	2000	Unit 1, 1.3	Unit 1 Managing the environment. 1.3 Fragile environments require sustainable management. Choose two forms of damage to fragile environments, one caused by farming and one by resource exploitation, one from and LEDC and one from an MEDC eg soil erosion in the Mezzogiorno or Himalyas, desertification in the Sahel or Spain, oil exploitation in ALASKA, timber in Indonesia or link to other units. *Possibility for a groundwater study.*
GCSE	EDEXCEL	Science	2101	2005		None
GCSE	EDEXCEL	Additional Science	2103	2005		None
GCSE	EDEXCEL	Biology	2105	2005		None
GCSE	EDEXCEL	Chemistry	2107	2005		None
GCSE	EDEXCEL	Physics	2109	2005		None
GCSE	WJEC	Geography A (Mainstream) 2007/8	none	2007 & 2008	1A(4), 1C	1A (4) Only physical processes related to rivers or sea. 1C Towards sustainable development of the Environment. T*here is no good fit for groundwater issues as it is presented.*

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
GCSE	WJEC	Geography B (Avery Hill)	none	2007 & 2008	Unit 2, 1.1, 1.2, 1.3, 2.1, 2.2, 2.3, 3.3, 3.4	Unit 2: Water, Landforms and People. The Hydrospere. 1.1 What is meant by the hydrosphere? 1.2 Which systems operate in the hydrosphere? 1.3 How does the hydrological (water) cycle link the components operating within the hydrosphere? 2.1 What are the main sources of freshwater? 2.2 How does the provision of a sustainable supply of water vary in different areas of the world? 2.3 How has water management at different scales attempted to provide a sustainable supply of fresh water in different countries? 3.3 How can a lack of rainfall and/or water deficit cause drought and desertification? 3.4 What effect do these have on human activity? How can drought and desertification be managed? *Emphasis on surface waters; no mention of groundwaters.*
GCSE	WJEC	Geography (Short Course)	none	2005	A (4), C(2)	A (4) Only physical processes related to rivers or sea. C (2) Towards sustainable development of the Environment. *There is no good fit for groundwater issues as it is presented.*
GCSE	WJEC	Geology	none	2007 & 2008	4.4	4.4 Water Supply - Underground water is supplied from **aquifers** (water table, porosity, permeability, wells, springs) - study by developing a case study of a **groundwater** scheme.
GCSE	WJEC	Science	none	2007 & 2008		None
GCSE	WJEC	Additional Science	none	2007 & 2008		None
GCSE	WJEC	Biology	none	2007 & 2008		None
GCSE	WJEC	Chemistry	none	2007 & 2008		None
GCSE	WJEC	Physics	none	2007 & 2008		None
GCSE	CCEA	Science (Foundation and Higher)	DRAFT	from 2006	Module 2, 2.13 (vii)	Module 2: Human Activity 2.13 (vii) the European Directive as an attempt to reduce the levels of nitrate pollution. *This syllabus is not structured like English, Welsh and Scottish exams.*
GCSE	CCEA	Geography	3910	from 2006	Theme B, 2 & 3. Theme C, 2 and Theme F, 1.	B2 Rivers are important landscaping agents which must be managed effectively. B3 Distinctive limestones landscapes must be managed to avoid long-term damage. C2 Ecosystems are sensitive and their balance is easily upset by human interference - peatlands. F1 Settlements have developed over time - water supply. Groundwater is not specified in connection with these topics.

Table A.3 Review of Scottish Qualification Arrangements

(In the commentary summarized requirements are in normal text and *observations are italicised*)

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
Standard Grade	SQA	Science	3700 01		Topic 4, 5)	Topic 4: A study of Environments.5) Pollution . Water with reference to animals and plants from oil sewage and industrial waste. Land pollution from coal bings, in-fill sites, lead mine workings, pesticides and their impact on plant growth and the food chain.
Access 2	SQA	Science	C081 08		Unit Biology	Unit Biology , The Environment, Water Pollution. *Linked with surface water quality and testing.*
Access 3	SQA	Geology	C043 09			Unit: Geology ,People and Environment. Water cycle: evaopration, clouds, rain, snow, rivers. **Groundwater:** water table, well, spring. Lowering of water table as water is extracted. Problems of **groundwater** pollution. The main uses of water (agriculturall, industrial,domestic,recreational). Variable distribution of water reources (e.g. compare northwest Scotaland with southeast England). Drought and irrigation. Areas where **groundwater** is a significant source of supply (e.g. East Anglia, London Basin, Central Australia). Problems of over -extraction of **groundwater.** *Supplementary Notes.* candidates should be aware of the properties of aquifers as **groundwater** reservoirs. They would not be expected to use the term 'aquifer'. Experiments can be done to show how easily water runs through gravel and clay. Model wells and springs can also be made.
Intermediate 1	SQA	Geology	C043 10			Unit: Geology ,People and Environment. Water cycle: evaopration, clouds, rain, snow, rivers. **Groundwater:** water table, well, spring. Lowering of water table as water is extracted. Problems of **groundwater** pollution. The main uses of water (agriculturall, industrial,domestic,recreational). Variable distribution of water reources (e.g. compare northwest Scotaland with southeast England). Drought and irrigation. Areas where **groundwater** is a significant source of supply (e.g. East Anglia, London Basin, Central Australia). Problems of over -extraction of **groundwater.** *Supplementary Notes.* candidates should be aware of the properties of aquifers as **groundwater** reservoirs. They would not be expected to use the term 'aquifer'. Experiments can be done to show how easily water runs through gravel and clay. Model wells and springs can also be made.
Intermediate 2	SQA	Geology	C043 11			None
Higher	SQA	Geology	C043 12			None
Standard	SQA	Geography	1260 01			None
Intermediate 1	SQA	Geography	C208 10		DF44 10	DF44 10 Geography: Environmental Interactions: including study of River Basin Management.
Intermediate 2	SQA	Geography	C208 11		DF44 11	DF44 11 Geography: Environmental Interactions: including study of River Basin Management.
Higher	SQA	Geography	C208 12		DF3C 12	DF3C 12 Physical Environments (H) Lithosphere. DF44 12: Geography: Environmental interactions: including River Basin Management

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
Intermediate 1	SQA	Managing Environmental Resources	C055 10			Unit 1: Environmental Issues, Effects of human activity on the local environment. The effect of pollution from transport, industry and agriculture on air, water, buildings and living things. A river study is suggested. Unit 3: Land use. Principle features, requirements, influential factors and role in local economy of water use and water-based industry. No mention of groundwater
Intermediate 2	SQA	Managing Environmental Resources	C055 11			Unit 1: Natural Resources. 1. Resources occuring on earth including water. 2. Renewable and non-renewable resources - water as a renewable resource using local, national and global examples. Unit 3: Local Environment 4. Local land use and water use. No mention of groundwater.
Higher	SQA	Managing Environmental Resources	C055 12			Unit 1: Natural Resource Use. 1. Resources occuring on earth including water. 2. Renewable and non-renewable resources recyclable resources, including compare the water cycle and coal formation and extraction to illustrate the concepts. Unit 3: Land Use in Scotland. 1. Development of land and water uses. No mention of groundwater.
Advanced Higher	SQA	Managing Environmental Resources	C055 13			Unit: The environment and human activity. Includes study of the water cycle. No specific mention of groundwater.

Table A.4 Review of GCE AS/A Level Specifications

(In the commentary summarized requirements are in normal text and *observations are italicised*)

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
AS/ A	AQA	Environmental Science	5//6441	2006/7	AS Module 1, 10.3	AS Module 1 Energy, Atmosphere and Hydrosphere. 10.3 Water Use. Sources of Water - (i) Availability of water; surface water aquifers. (ii) The effect of landuse within the catchment area on these water sources. (iii) **Aquifers**: suitable rock types including chalk and sandstone, suitable geological structures. Consequences (i) The effects of over abstraction, including subsidence, reduced river flow, water table changes, salination and vegetation change. Demand for Water (i) Trends in water demand. (ii) The spatial and temporal mismatch of supply and demand for water in the British Isles. Future demand for water. (iii) Candidates should be aware that the lack of access to water of suitable quantity and quality is a major hindrance to development and improving the quality of life. Uses of Water and Supply and Treatment are also specified. A2 Module 5, Pollution & Physical Reource Management, Water Conservation and Management includes a global perspective or providing adequate suppiles from aquifer water storage and recharge. Water Pollution covers a wide variety of pollutants and mechanisms, but groundwater is not specifically mentioned.
AS/ A	AQA	Geography A	5//6031	2007	AS Module 1, 10.1, 14.1	AS Module 1 Core Concepts in Physical Geography. 10.1 Water on Land. Drainage Basin Systems. The concept of systems with reference to the hydrological cycle. The hydrological and atmospheric processes related to inputs, outputs, flows, transfers and stores within this system. *Emphasis of the subsequent sections in this topic is on surface water.* A2 Module 5 Challenge and Change in the Human Environment. 14.1 Population Pressure and Resource Management.Resource Exploitation. One reusable resource e.g. water must be studied on a global scale to understand the environmental impact of resource exploitation and management, in the context of sustainable development.
AS/ A	AQA	Geography B	5//6036	2007	AS Module 1, 10.1	AS Module 1 The Dynamics of Change. 10.1 Physical geography: Shorter Term and Local Change. Atmospheric, geomorphological and human processes affecting drainage basin hydrology. 10.1 should be stubied in relation to drainage basins in the British Isles. Include Baseflow.

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
AS/ A	OCR	Geology	3884/ 7884	2004	5.3.1	5.3.1 Water Supply (a) define and explain the following terms: porosity, permeability, hydrostatic pressure, hydraulic gradient, **aquifers** and water table. (b) Describe and explain the geological conditions leading to the formation of springs as a result of lithology, faults and unconformities. (c) explain the geological conditions necessary for **artesian** basins and water supply from wells. (d) Describe water supply in relation to river, reservoir and underground sources. Understand the advantages and disadvantages of surface and underground supply. Understand that water reources are both renewable and sustainable if carefully developed.
AS/ A	OCR	Geography A	3832/ 7832	Rev Ed 2005/ Assess 2007	Module 2680, 5.1.1	Module 2680: The Physical Environment 5.1.1 (a) Drainage Basins: Inputs, outputs, stores and flow; precipitation, evaopration, evapotranspiration, interception, throughfall ,stemflow,infiltration ,percolation,overland flow,throughflow, interflow, baseflow, water tables, **groundwater**, recharge. An awareness of the influences of human activity on inputs, outputs, stores and flows. Characteristics of drainage basins:size and shape, drainage density, porosity and permeability of soils, rock type, slopes, vegetation type and seasonal variations in cover, land use, human activities; their influences on flows and stores of water. These drainage basin studies should be illustrated by reference to actual drainage basins.
AS/ A	OCR	Geography B	3833/ 7833	Teaching from 2004	5.1.2, 5.6	5.1.2 Study Section B: Landforms Systems and People. Drainage basins are only studied with reference to surface water. 5.6 Module 2692: Issues in Sustainable Development. Water supply issues can be studied. *No specific reference to groundwater* .
AS/ A	EDEXCEL	Geography A	9214/ 8214	2003	Unit 1, 1.2, 1.2.1	Unit 1: Physical Environments. 1.2 Fluvial Environments 1.2.1 The hydrological cycle is a system. Global Scale. The global hydrogeological cycle (inputs, stores and flows) and the drainage basin cycle to include evapotranspiration, condensation, precipitation, surface run-off, **groundwater** flow, evaporation, transpiration, infiltration, percolation. Synoptic Link: The hydrological cycle is used and managed (Regional, Local) i) The reasons for and methods of groundwater and river management in countries at different states of development ii) Decision -making issues related to management of the hydrogeological cycle.

Stage/Qualification	Standard/ Examining Organisation	Course	Code	Year	Specification Contents Sections	Commentary
AS/ A	EDEXCEL	Geography B	9215/ 8215	2002	Unit 1, 1.1, 2.8, 5.3	Unit 1: Changing Landforms and their Manangement. River Environments. 1.1 How do fluvial systems operate within the global hydrological cycle? What impact does the hydrological cycle have on fluvial systems. Emphasis and examples are of rivers, but reference to inputs, stores, flows and outputs. 2.8 Urban Environment refers to managing environmental problems in cities inlcuding water supply. Option 5.3 The pollution of the natural environment - the hydrosphere example is a river. *Note water supply not linked to Health and Food Supply.*
AS/ A	WJEC	Geography	none	2007 & 2008	Unit GG1, 1(a),	Unit GG1Drainage Basins: hydrology and selected landforms. 1(a) The drainage basin operates as a system with inputs, flows, stores and outputs of water and sediment. Synoptic Unit GG5 Sustainable Devlopment B. Water Supply. *No explicit mention of groundwater.*
AS/ A	WJEC	Geology	none	2007 & 2008	Key Idea 3 (b), Theme 2, Key Idea 2, Key Idea 5, Unit GL6	Key Idea 3: Geologically related hazards can result from human activity(b) Water Supply. Overuse of **aquifers** can result in local exhaustion of the water supply as well as contamination (including saltwater intrusions in coastal areas), and surface subsidence. **Groundwater** pollution in developing **groundwater** resources local sources of **groundwater** pollution must be identified and controlled. (*last sentence copied as printed*). Note Unit GL5: Geological Themes, Theme 2: Geology of Natural Resources Key Idea 2: Permeable rocks offer pathways for fluid and gas migration; highly porous rocks can act as natural receptacles for underground supplies of hydrocarbon or water (c) Groundwater flow is controlled by geological factors: sources of **groundwater;** water table; springs; **aquifers; artesian** wells. Key Idea 5 Looks at rock properties such as permeability and porosity. Unit GL 6 Geological Investigations includes geology of local water supplies.
AS/ A	CCEA	Geography	3910	2004	Module 1,4	Module 1: Themes in Physical Geography - *only studies rivers* . Module 4: Physical Processes and Human Interactions. Unit C: Pollution and its Management - *only river examples given* .

APPENDIX 2. TEACHERS QUESTIONNAIRES

The teaching of groundwater-related issues

Questionnaire to teachers of Environmental Science AS/A-Level.

Teaching Group

AS Environmental Science

AS/A Level

Which specification is studied? *AQA AS Level*

Topic: Water Use

Sources of Water - Availability of water; surface water, aquifers.
- The effect of land use within the catchment area on these water sources.
- Aquifers: suitable rock types including chalk and sandstone, suitable geological structures.

Consequences - The effects of over abstraction, including subsidence, reduced river flow, water table changes, salination and vegetation change.

Demand for Water - Trends in water demand.

- The spatial and temporal mismatch of supply and demand for water in the British Isles. Future demand for water.

- Candidates should be aware that the lack of access to water of suitable quantity and quality is a major hindrance to development and improving the quality of life.

Uses of Water and Supply and Treatment are also specified. Also there is groundwater in an A2 Module.

Questions:

Which textbooks are used by the students?

Bath Advanced Science series: Environmental Science by Kevin Byrne, Nelson Thornes

Did these cover water use and groundwater sufficiently? If not what other sources were used by the students?

No

Which sources have you used to provide background information for yourself?

Visited BGS Wallingford and used:

1. *Groundwater – our hidden asset. UK groundwater Forum (BGS)*
2. *Groundwater a valuable resource (briefing note BGS)*
3. *www.bgs.ac.uk – their education section – images of groundwater and http://earthguide.ucsd.edu*

Did you have any particular difficulties in finding information?

No

What prior knowledge is assumed in the students?

The hydrological cycle – covered in Week1/2 lessons.
The topic on Groundwater was covered in Week 6.

What examples have you used, particularly with respect to groundwater, to illustrate the requirements above?

http://earthguide.ucsd.edu/earthguide/diagrams/groundwater/index.html

A power point presentation was provided which included the example of the Bath spring.

How often do exam questions occur which require an answer to incorporate groundwater and/ related issues?

Once

General

Have you received any CPD that incorporates groundwater and related issues? *No*

Will you please indicate a score for each of the following questions one of the 5 grades:

Below is the slightly revised version of the Cholsey questionnaire

	High	Moderately High	Moderate	Moderately Low	Low
What is your background knowledge of groundwater and related issues?			✕		
How confident do you feel in teaching about groundwater and related issues to pupils?			✕		
How much do you enjoy teaching about groundwater and related issues to pupils?		✕			
What do you feel is the overall importance of groundwater?		✕			
How well do you think the pupils understand the concepts associated with groundwater?			✕		

What do you feel is the level of interest of the pupils?		×			
What is the general pupil achievement in the water-related topics you teach?		×			
How much practical work is included that relates to the hydrological cycle and the understanding of groundwater?					×
How much fieldwork is included that relates to the hydrological cycle and the understanding of groundwater?					×

What are the barriers to students understanding the concept of groundwater?

Concepts such as Porous, Specific Retention, Specific Yield – Couplexgraphs, Permeable and Impermeable, timescale for water in an aquifer.

What feedback have you received from your students?

Some manage to understand ideas well, whilst other just give superficial descriptions e.g. groundwater is found in rock underground without going into the detail of the type of rock and how the water is retained. Some students are not confident enough to use permeable for example in a descriptive sentence.

Seawater incursions are understood fully by some students whilst those below average have difficulty relating the seawater to its effects on groundwater.

Are they encouraged to undertake independent reading and research in this area?

Yes

We would welcome any further comments you have on the teaching of groundwater that would aid our research.

Thank You

Geography Department Secondary School Questionnaire.

Background:

Key Stage 3

In the National Curriculum there is limited opportunity to study groundwater. Unit 7: 'Rivers, a fieldwork approach' would appear to be the only area that could be extended to cover groundwater, and the significance of baseflow contribution.

We do not study rivers at KS3.

We talk about groundwater when we do the water cycle in year 7.

In Year 8, as part of water as a resource we teach about groundwater. We look at where we get our water and different sources for water from our taps in Thames Water region.

Questions:

Do you teach the occurrence of groundwater at this stage?

Yes, see below.

Are there any other opportunities where you might introduce it?

We talk about groundwater when we do the water cycle in year 7.

In Year 8, as part of water as a resource we teach about groundwater. We look at where we get our water and different sources for water from our taps in Thames Water region.

GCSE

Questions:

What specification is studied at your school and why?

AQA. A natural transition from the old SEG syllabus we used to study. Prepares them well for our 'A' Level.

What textbooks are used?

Wider World by David Waugh
Understanding GCSE Geography by Bowen and Pallister

What resources other than textbooks do you use?

Videos, photos, satellite images, computer (internet +CD Roms) worksheets.

Do you introduce groundwater in any of the following areas?

- Rocks and landscape – *yes chalk and clay landscape.*
- Rivers landscape and processes – *yes.*
- Impact of industry – *we do not study this.*
- Managing resources – *not how we approach the syllabus at GCSE.*

What examples, if any, do you give that cover groundwater?

Chilterns – scarp and dip slope, wells.
Rivers – groundwater as a source.

How often do exam questions occur which could require an answer to incorporate groundwater and/ related issues?

Not annually, probably once every 3 or 4 years. It depends if a chalk and clay question comes up and then if it includes details about groundwater levels.

AS/A Level

Questions:

What specification is studied at your school and why?

Edexcel A

What textbooks are used?

Geography – David Waugh
Advanced Geography – Andy Palmer and Nigel Yates

What resources other than textbooks do you use?

Videos, photos, satellite images, computer (internet +CD Roms) worksheets.

How do you incorporate the teaching of groundwater into the hydrological cycle?

I do not cover that section of the syllabus.

How do you incorporate the teaching of groundwater in water supply and in relation to resource exploitation?

No answer recorded.

What examples, if any, do you give that cover groundwater?

No answer recorded.

How often do exam questions occur which require an answer to incorporate groundwater and/ related issues?

Again not often, approximately every 3 or 4 years at the most.

General

Have you received any CPD training that incorporates groundwater and related issues?

No

Will you please indicate a score for each of the following questions one of the 5 grades:

	High	Moderately High	Moderate	Moderately Low	Low
What is your background knowledge of groundwater and related issues?			×		
How confident do you feel in teaching groundwater and related issues to pupils?		×			
How much do you enjoy teaching groundwater and related issues to pupils?	×				
What do you feel is the overall importance of groundwater?	×				
How well do you think the pupils understand the concepts associated with groundwater?				×	
What do you feel is the level of interest of the pupils?		×			
What is the general pupil achievement in the topics you teach?	?	?	?	?	?
How much practical work is included that relates to the hydrological cycle and the understanding of groundwater?				×	
How much fieldwork is included that relates to the hydrological cycle and the understanding of groundwater?					×

NB: not all score markings were placed in the centre of the box. Q2 was between 'moderately high' and 'moderate', whereas Q5 was between 'moderate' and 'moderately low'.

What are the barriers to students understanding the concept of groundwater?

Access to resources beyond the classroom, money, time to explore/find suitable resources to use at the 3 different key stages.

Are they encouraged to undertake independent reading and research in this area?

Groundwater on its own is not a significant part of any question that they would have to answer at examination level and so we do not need them to read around and/or research groundwater as a separate issue.

Thank you for your help.

Please may I borrow these textbooks or come into school to undertake a quick review?

Primary School Questionnaire.

The teaching of water and groundwater-related issues
(groundwater is the water in rocks under the surface, that can be pumped out of wells for our use)

Background:

- Size of school (eg. no. pupils, no. staff)? *20*
- No. of free school meals? *5.5%*
- Is the intake selective in any way? *No*
- What do the SAT results indicate about the school? *In relation to PANDA contextual value added. Summer Date of Births for Boys and Girls declining. Above average for English and Science. In line with national average for mathematics.*
- How does the staff feel that this school is viewed in comparison with local primary schools? *Quite well, good partnership with other schools and don't 'loose' lots of children.*
-

Are any water-orientated lessons likely to be taught by 'specialist teachers' or are these lessons all taught by the normal class teacher? *Normal class teacher*

Scheme of Work Geography Unit 1: Water (*this is not compulsory)*

1. Where can we find water locally? Where can we find water in the world?
2. How does water get to where it is needed?
3. Who uses water? What do they use it for?
4. Is all water useable? How can water be made useable?
5. Who owns water? Who pays for water? What jobs are involved in providing water.
6. General.

Information on National Curriculum content provided , Key Stage 2 Year 3&4 two year rolling programme, Water Cycle content Years 3/4/5 and Geography Planning Map.

Questions:

Which Year Group is this unit taught to?

Yrs 3 & 4 Water cycle. Permanent water problems.
Year 5 Science – permeability of rocks.
Which textbooks or other resources are used by the pupils?
A variety.

Which textbooks or other resources are used by the teachers?
Oliver & Boyd/ Geography 1-4. Information boxes collated by teachers containing a variety of sources.

Do these cover the aspects of water sufficiently? If not what other sources did you use?
Internet/Expresso
Did you have any particular difficulties in finding information?
No

What prior knowledge in the pupils is assumed?

Whole class mind maps to find prior knowledge.

What examples have you used, particularly with respect to groundwater, to illustrate the requirements above?

Droughts and wells.

General

Have you received any CPD that incorporates the teaching of water and groundwater and related issues?
No

Will you please indicate a score for each of the following questions one of the 5 grades:

	High	Moderately High	Moderate	Moderately Low	Low
What is your background knowledge of groundwater and related issues?		X			
How confident do you feel in teaching about groundwater and related issues to pupils?			X		
How much do you enjoy teaching about groundwater and related issues to pupils?			X		
What do you feel is the overall importance of groundwater?		X			
How well do you think the pupils understand the concepts associated with groundwater?					X
What do you feel is the level of interest of the pupils?	X				
What is the general pupil achievement in the water-related topics you teach?		X			
How much practical work is included that relates to the hydrological cycle and the understanding of groundwater?				X	
How much fieldwork is included that relates to the hydrological cycle and the understanding of groundwater?			X		

What are the barriers to students understanding the concept of groundwater?
None – just specifically specified in the National Curriculum.

What other opportunities do you have to teach or demonstrate the occurrence and use of groundwater?
Eco-schools
Trips made by Years 5/6, for example to the Centre for Ecology and Hydrology, Wallingford.

Final comment

We would welcome any further comments you have on the teaching of water or groundwater that would aid our research.

Unit 11: Water is listed as Year 5, but Cholsey has moved it to fill the rolling programme for Years 3 & 4. It has been simplified to fit the National Curriculum objectives for that age group.

Thank You