British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Integrating sciences in sustainable development of natural resources and poverty alleviation – Workshop Manual, Colombo, November 2003

Ground Systems and Water Quality Programme

Commissioned Report CR/03/259N

BRITISH GEOLOGICAL SURVEY

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N S Robins

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The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

Keyworth, Nottingham NG12 5GG

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Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, 20 College Gardens, Belfast BT9 6BS

☎ 028-9066 6595 Fax 028-9066 2835

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

This manual was prepared for the Training Workshop on Integrating Sciences in Sustainable Development of Natural Resources and Poverty Alleviation in South Asia, held at Colombo, 4-6 November 2003, by the British Geological Survey (BGS).

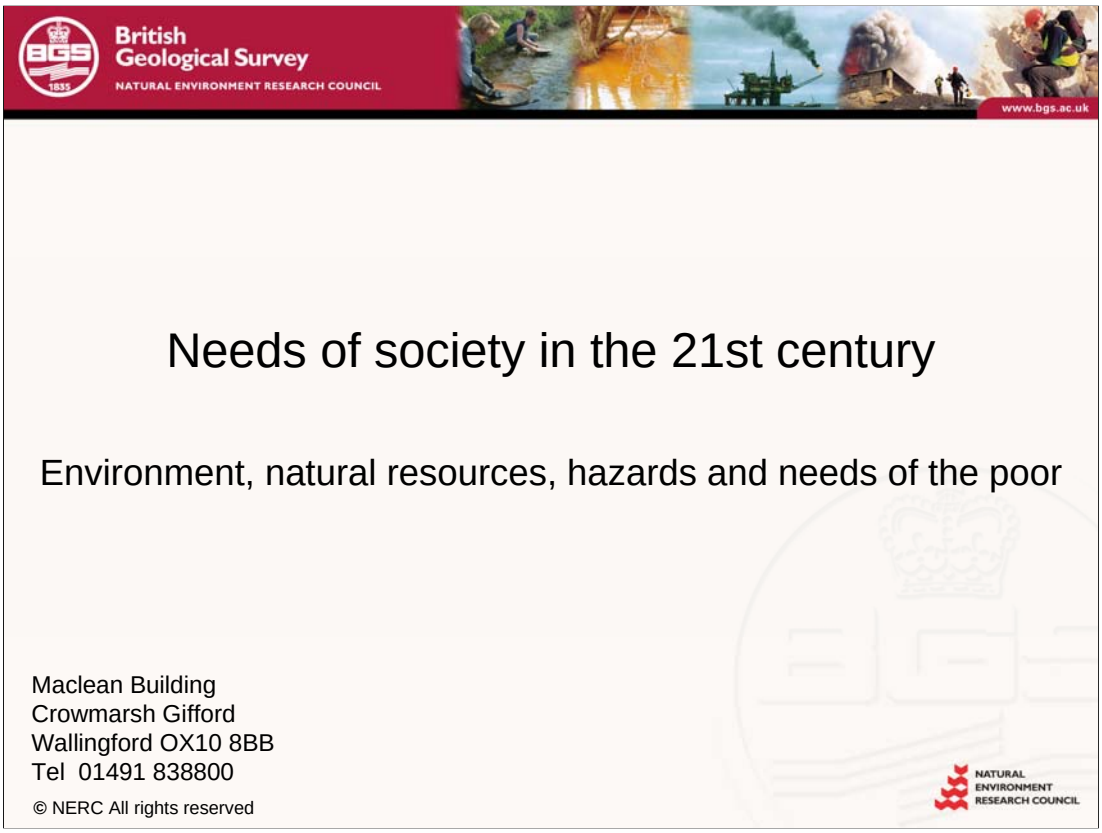
It comprises a series of six BGS presentations. The first four have been specially prepared for the Colombo workshop by Nick Robins:

1. Needs of society in the 21st century, environment, natural resources, hazards and needs of the poor
2. The role of the Geological Surveys
3. Water - the future
4.The BGS - some contributions to sustainable development

The last two are technical presentations:

5. The Bangladesh groundwater arsenic problem - prepared by David Kinniburgh and others
6. Minimising fluoride in drinking water in problem aquifers – prepared by Pauline Smedley

The four main presentations draw on two source documents, *The British Geological Survey's Responses to the Terms of Reference of the 2003 Science and Management Audit*, September 2003, and the internal BGS report of the BGS Horizon Scanning Group. Additional information is drawn from a variety of sources including the internet.



This presentation was prepared by Dr N S Robins at BGS in October 2003. If you have any queries relating to this presentation please contact the compiler on nsro@bgs.ac.uk .

These three sets of drivers inter-relate so that each succeeding summit or forum adds to the previous one. In order to appreciate the evolution of world aspirations it is best to look first at each independently.

See http://www.developmentgoals.org/ for full details of the MDGs and of the September 2000 UN Millennium Summit.

The MDGs clearly have implications for water supply and sanitation that need to be taken aboard by all practicing hydrogeologists and hydrologists. The provision of drinking water in arid and semi-arid regions relies largely on groundwater as surface waters tend to be seasonal at best.

The MDGs primarily address the individual person and their well-being.

Note that the issue of drought mitigation, i.e. reducing the hardship caused by drought, is not an explicit consideration.

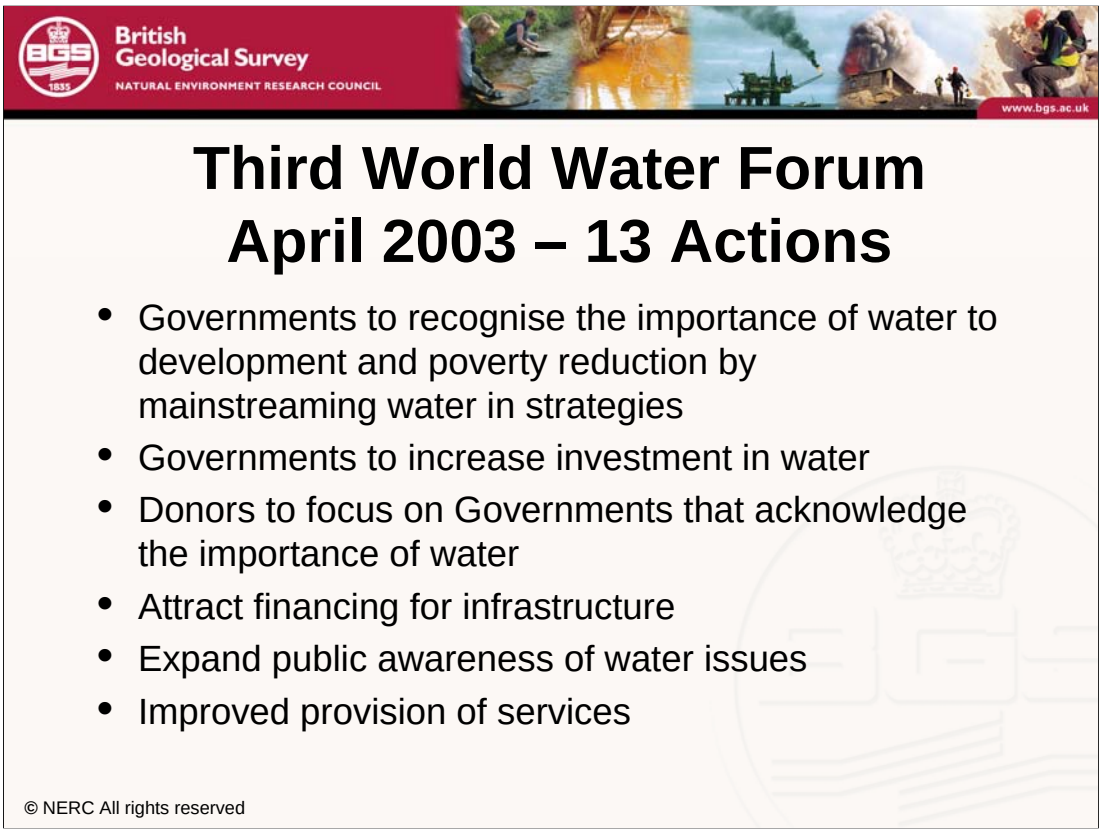
For more information go to http://www.johannesburgsummit.org/index.html .

The term poverty eradication is rarely used as it is not a practicable goal.
The Johannesburg summit started to look at sustainability and starts to consider national and global economics.

These seven issues derive from the Phnom Penh Regional Platform on Sustainable Development for Asia and the Pacific.

See http://www.johannesburgsummit.org/index.html for further information and click on Report of the WSSD.

New areas of interest include climate change and sustainable energy.

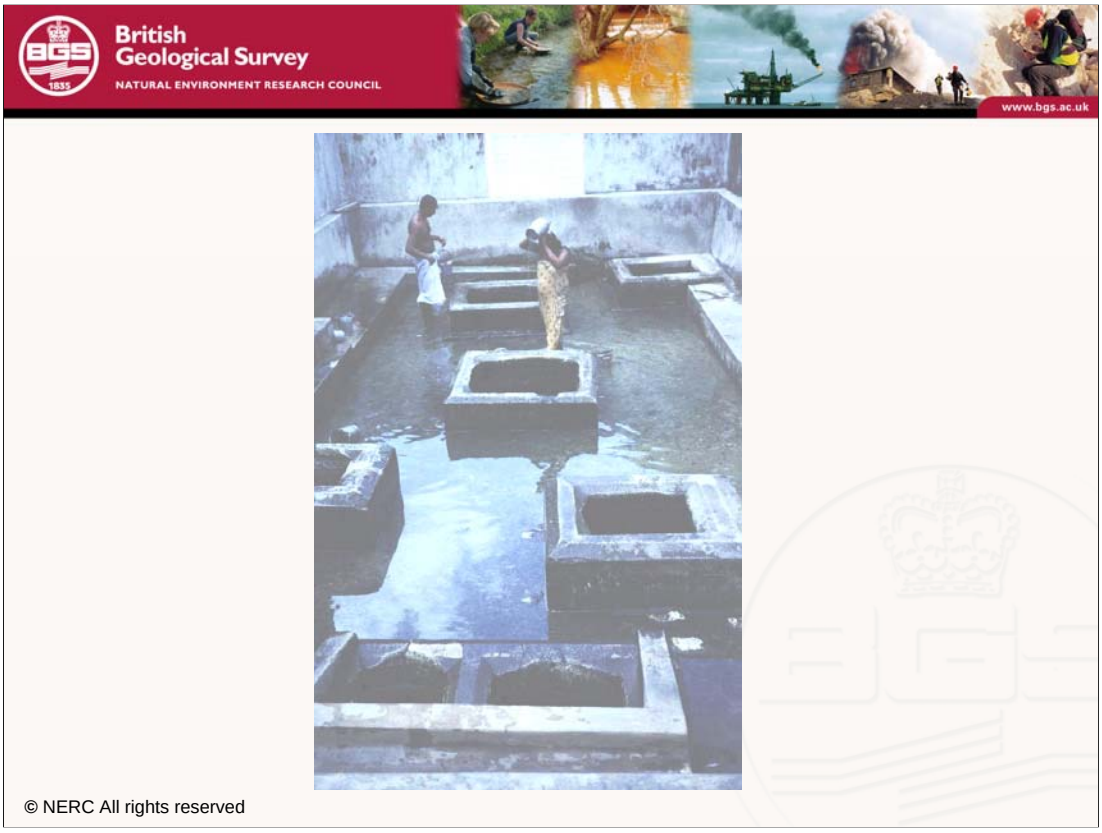


For more information see http://worldwaterforum.idrc.ca/ .

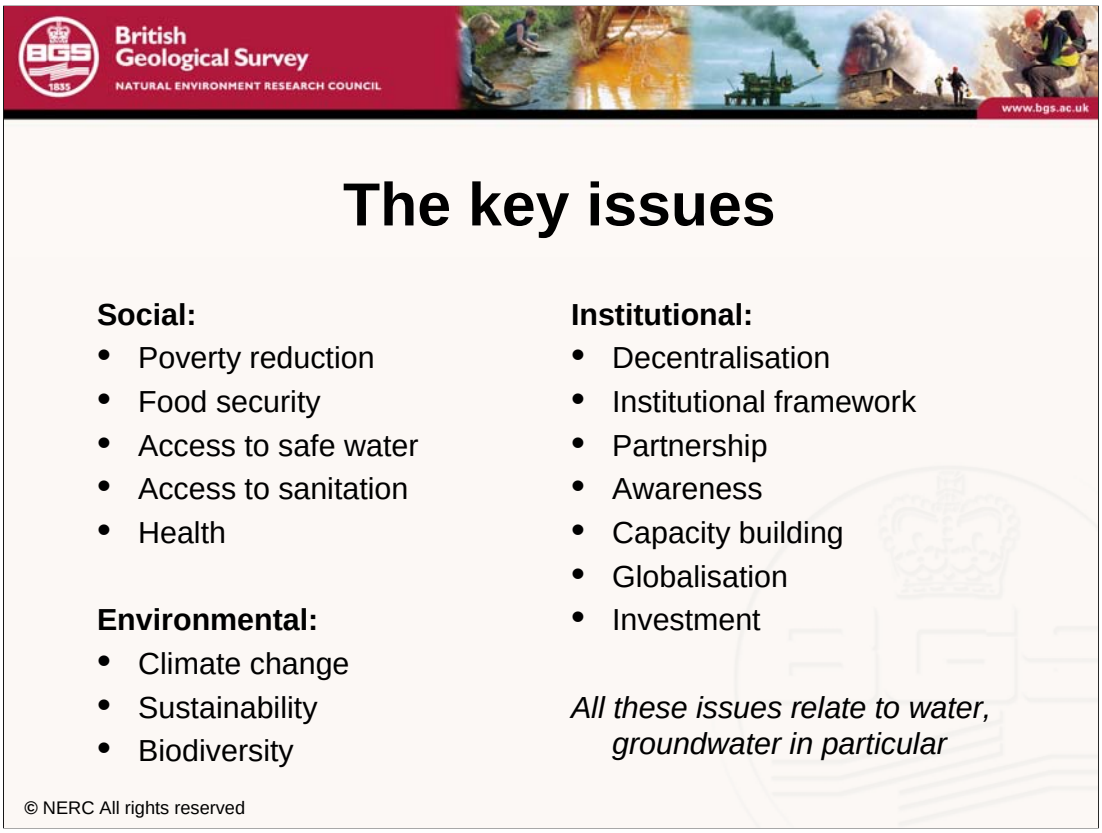
The Kyoto forum concentrated on the institutional aspects of development, including that of informing the public. It also recognised the attraction of forming global partnerships to tackle water issues, in that the problems now facing the world are too great for any one organisation to solve.

WWF-3 continued

- Capacity building for new institutions created by decentralisation
- Eradicating existing pollution and reducing future pollution
- Create partnerships for best operation
- Joint management of transboundary water resources
- Water managers to adapt to climate change and variability to avoid human suffering
- Global monitoring of resources and activities
- UN to highlight water

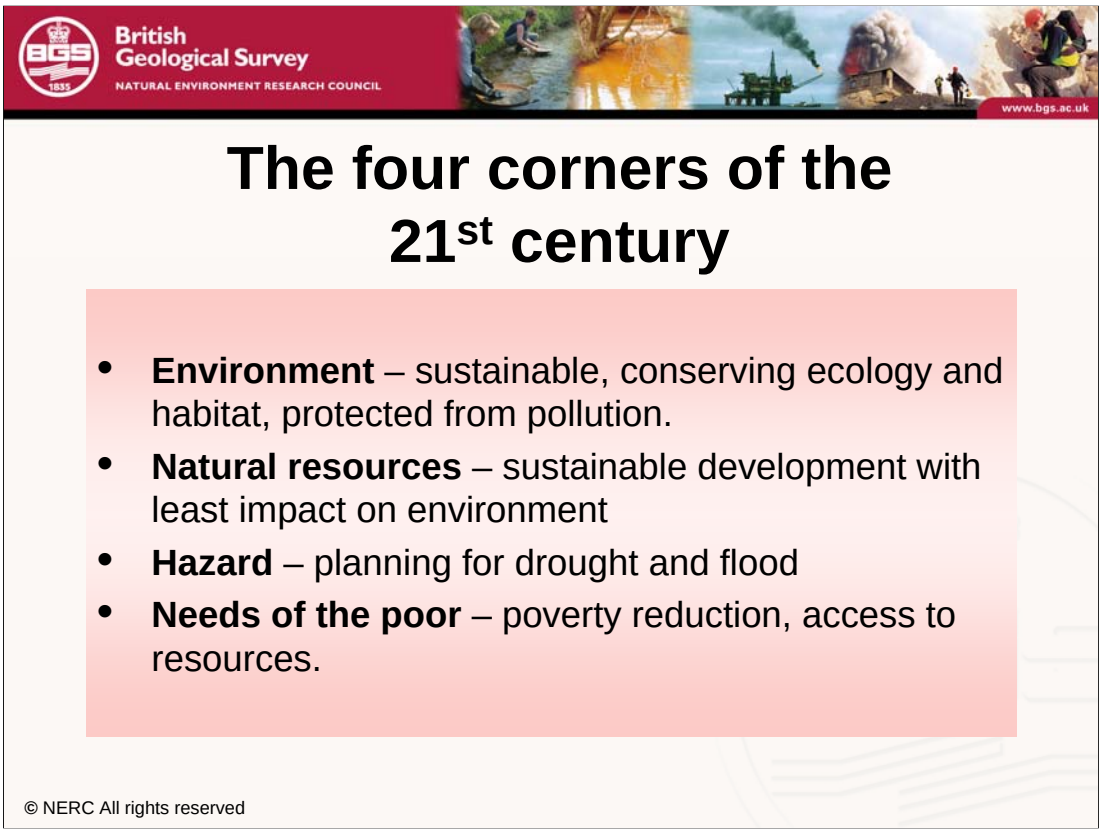


Hot springs in Sri Lanka *(Jeff Davies, BGS)*

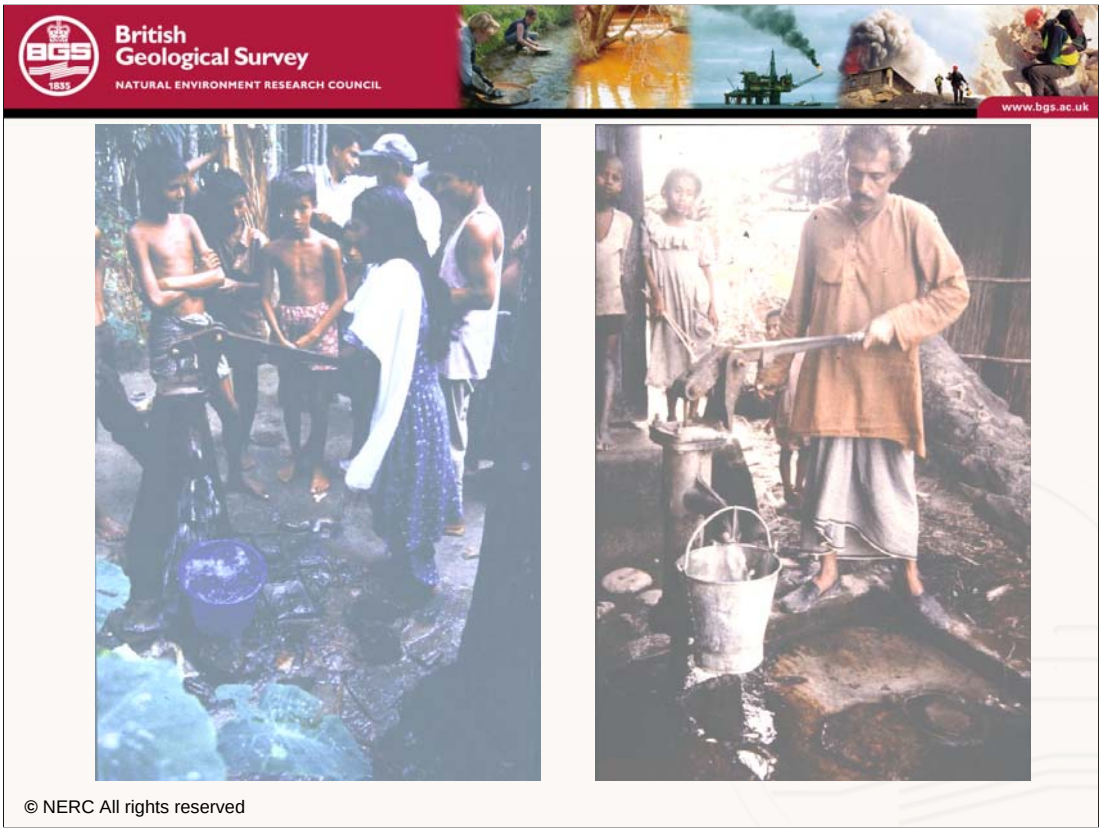


These are the issues that fall out of the MDGs, the Johannesburg Summit and Tokyo. All the social issues relate in some way to improved and sustainable development of water resources, and in arid and semi-arid areas this is very likely to be groundwater. The environmental issues are all groundwater related as well and the institutional issues also impinge on groundwater.

It is interesting that the majority of issues highlighted at these three international meetings are institutional.



These four key issues are the four that hydrogeologists should be most aware of. They should be used to guide the hydrogeologist in his activities, certainly for the next few decades.



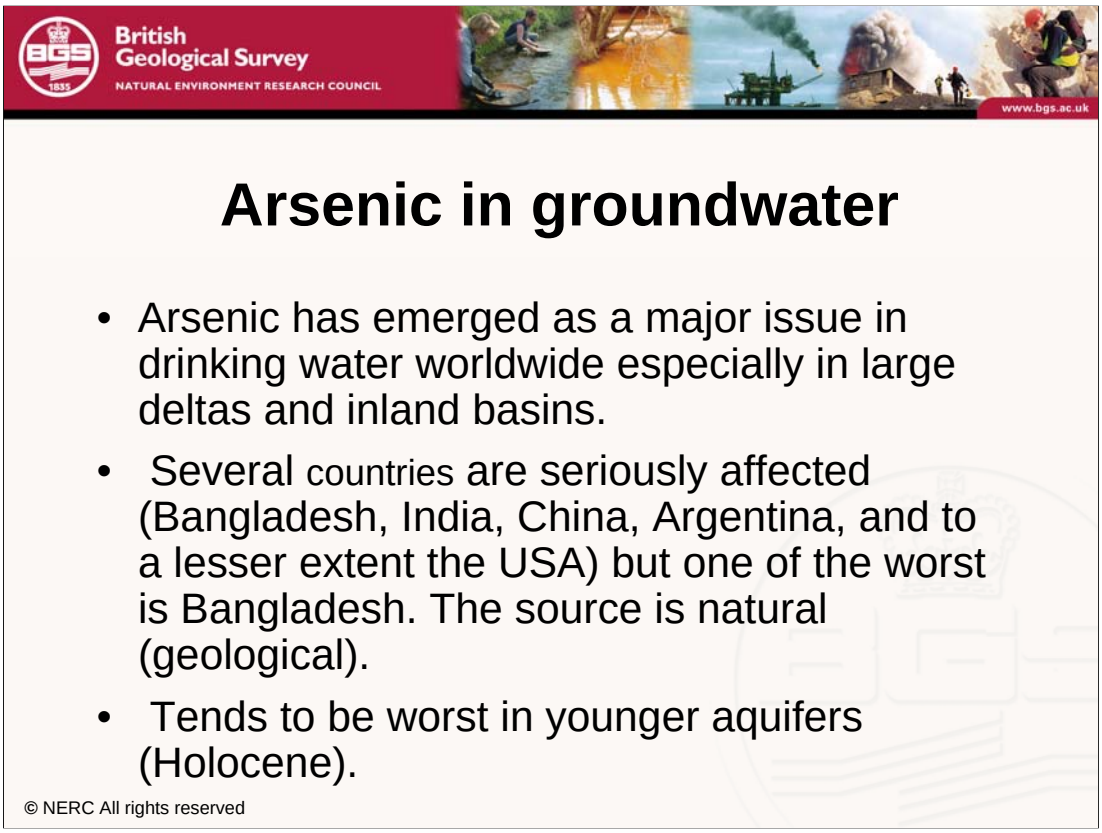
Community pumps *(Jeff Davies, BGS)*

Other social issues

Include, for example:

- Demography – occupation of marginal lands, such as the impermeable shales of West Africa; increased pressure on peri-urban and urban areas.
- Water apportionment and demand management.
- Water conservation – e.g. use of ASR, appropriate land use and management, etc
- Waste management including siting of latrines, disposal of sewage, etc.
- Education and training.
- Arsenic in groundwater

There are numerous other issues that could be listed, but these are some of the more important ones.



See also separate presentation on arsenic.

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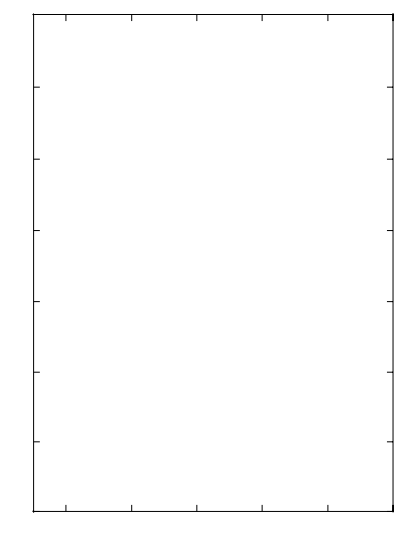
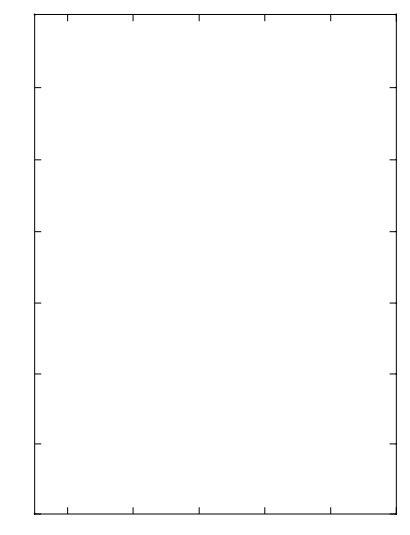
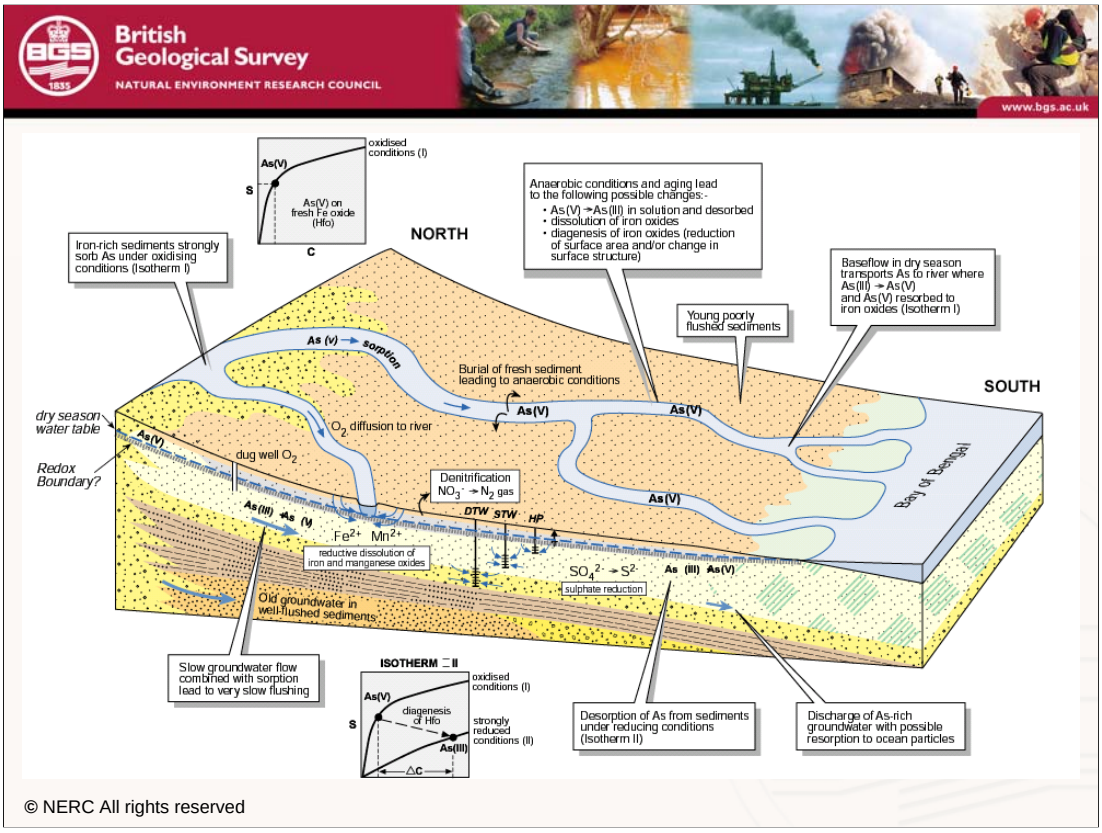
Arsenic in Bangladesh

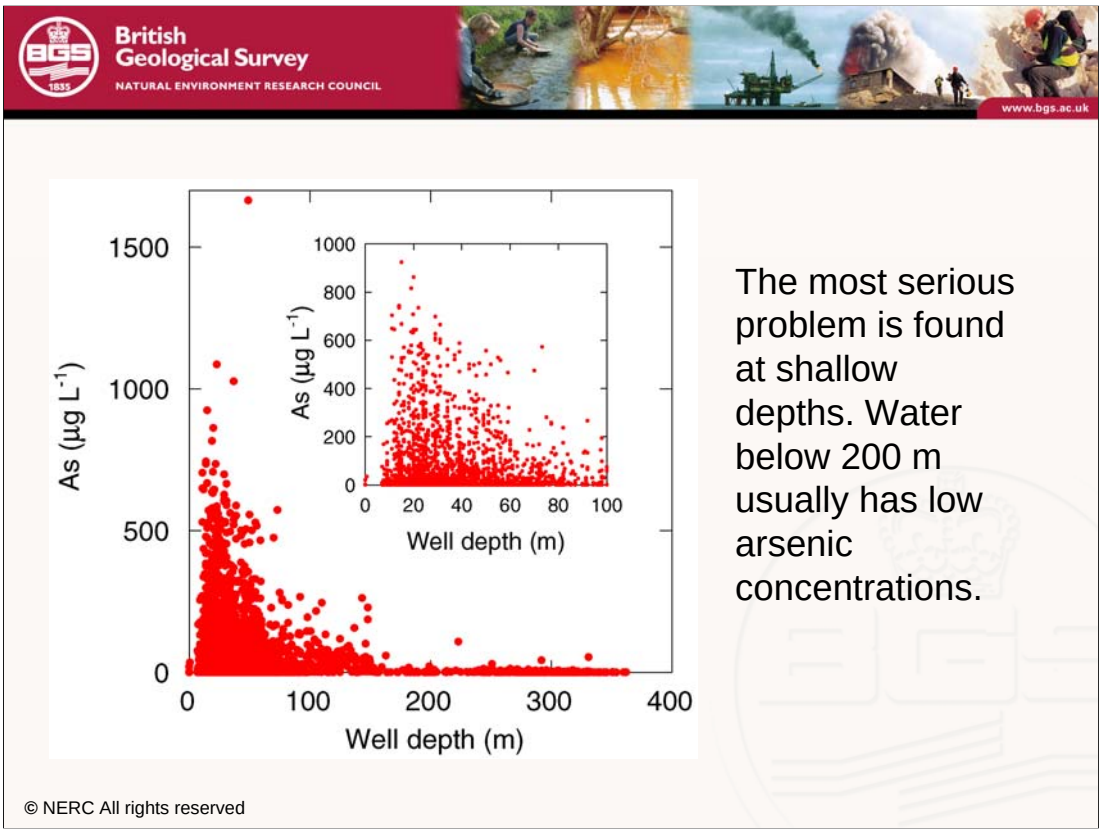




BGS in collaboration with the Government of Bangladesh undertook a comprehensive water quality survey of Bangladesh. The Bangladesh limit for arsenic in drinking water is 50 µg/L (the WHO guideline value is 10 µg/L). The problem is clearly large and often associated with high-iron waters, although the correlation is far from perfect.



This diagram schematically shows the process of arsenic generation in groundwater in a large deltaic formation. For further information see the presentation on arsenic.



These diagrams clearly show the tendency for highest arsenic concentrations in Bangladesh to cluster at depths generally below 60 m. Little if any arsenic is present below 160 m depth.

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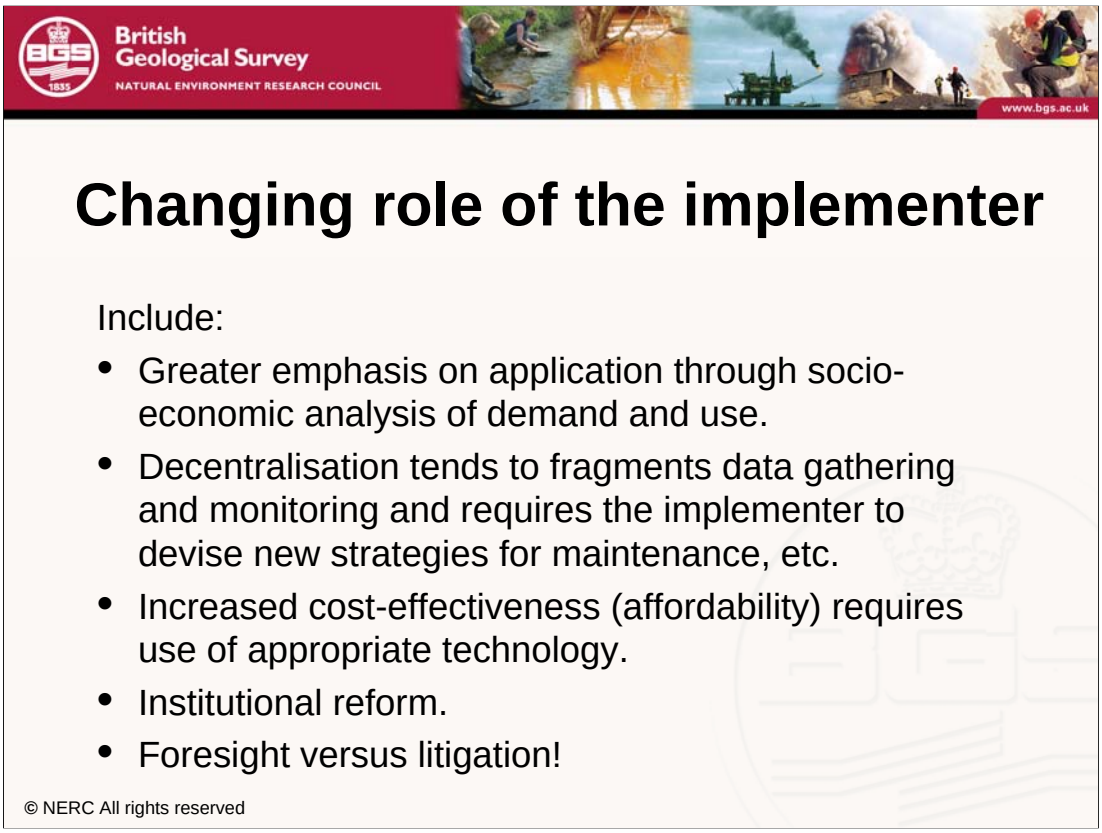
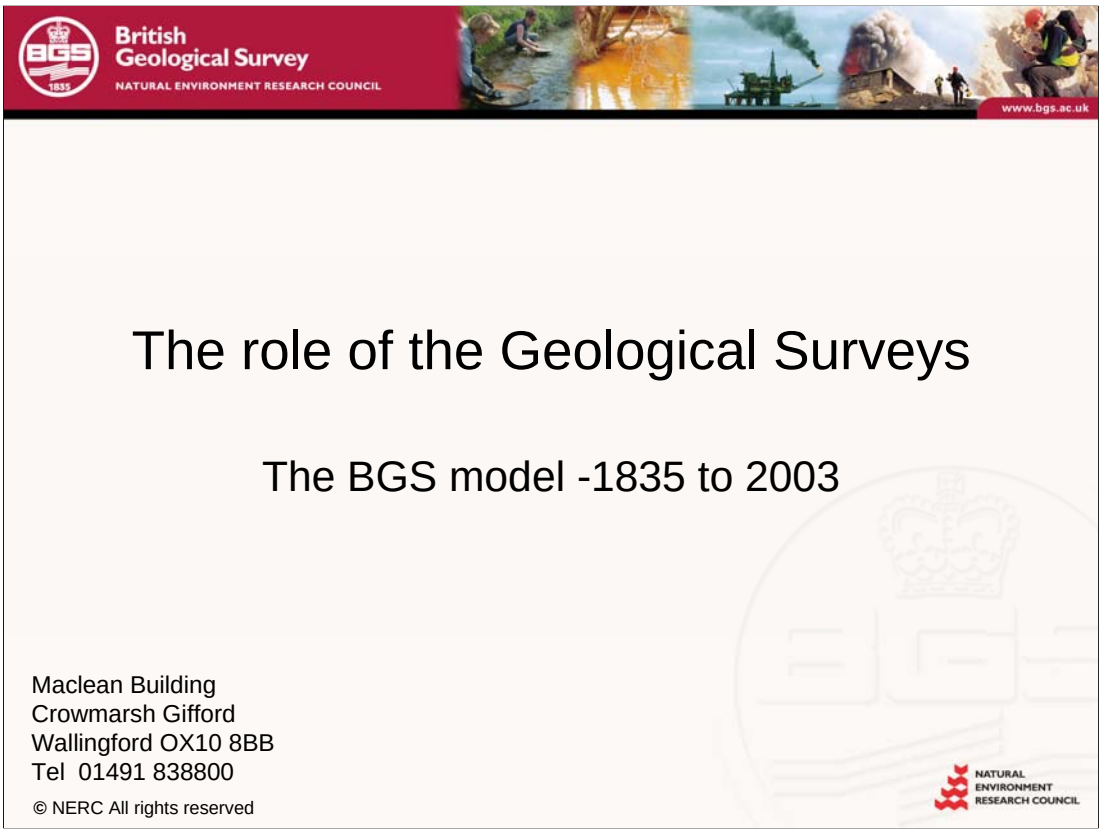
Warts on the hands and feet are an early manifestation of arsenic poisoning. Skin, bladder and lung cancer are also associated with drinking arsenic-rich water.

Bangladesh *(Dave Kinniburgh, BGS)*

Society's needs are constantly changing. In Northern Province of South Africa the question was asked what would the rural communities like best. The unanimous response was running water in each of the huts and a WC. Sadly, although there is enough water in southern Africa to satisfy this aspiration, money is not available to accomplish it.



The increased importance of social and economic analysis has been welcomed as this enables activities to focus on actual needs and demands. Decentralisation has brought a number of problems with it but the benefits are greater than the down side.

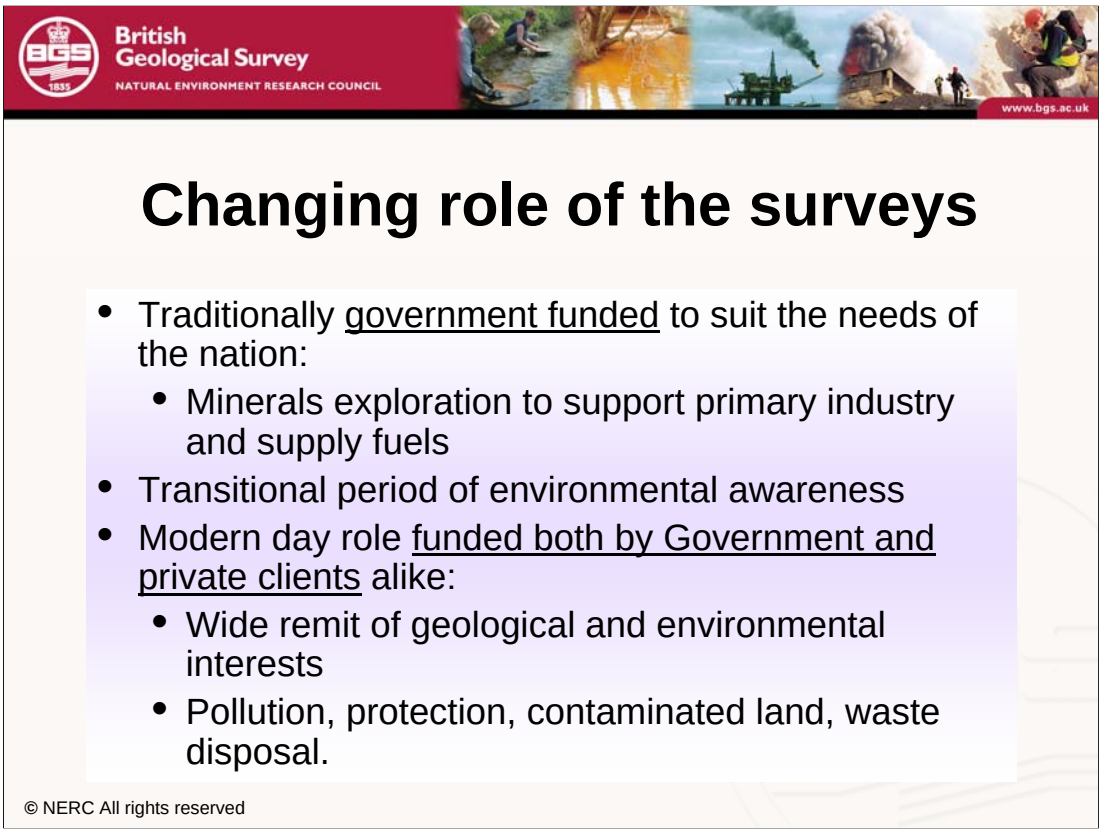


This presentation looks at the past, present and future role of the national Geological Surveys using the British Geological Survey as a model, and citing examples from elsewhere.

It is intended to help develop a programme of research and a system for developing that programme that satisfies the demands of the 21st century.

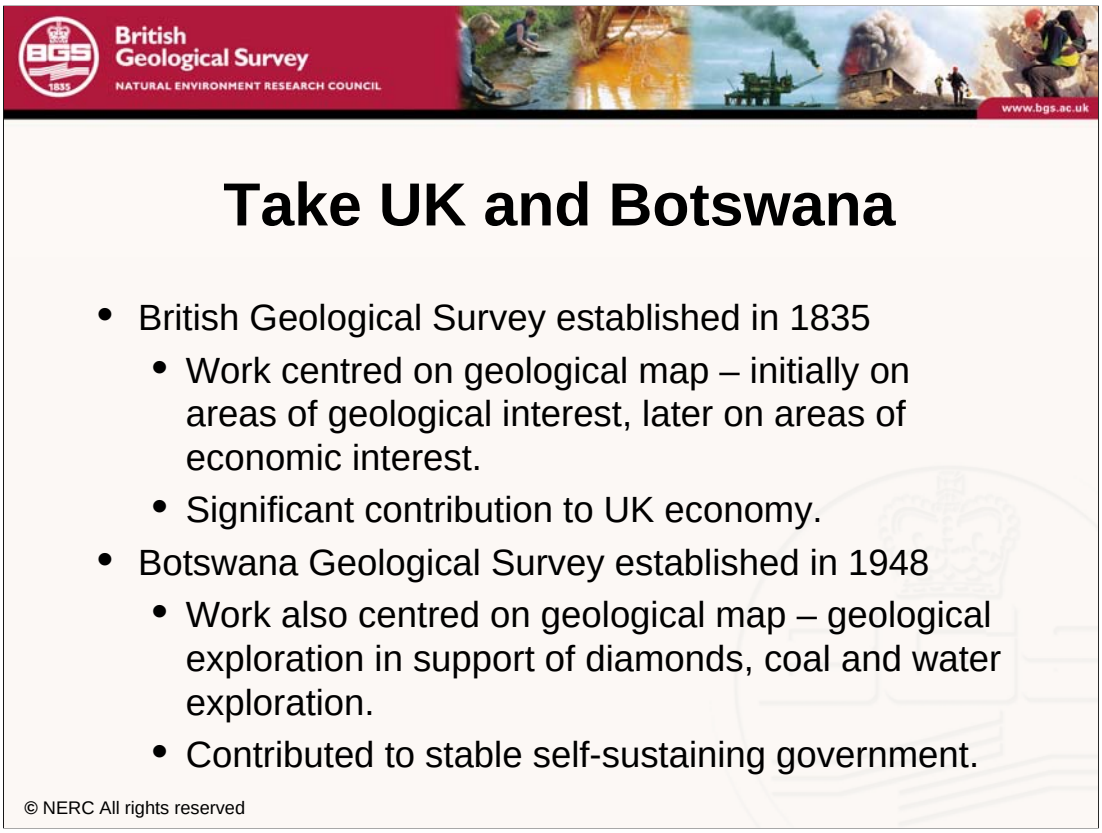
The presentation was developed by NS Robins, BGS, October 2003, and is based partly on the BGS submission to the 2003 BGS Science Management Audit team.

Nsro@bgs.ac.uk



When most of the geological surveys were first established they received direct grant aid funds from their respective governments. This money was used to provide basic geological mapping and geological understanding with which to develop mineral and fuel exploitation, to assist in transport routing and to provide information regarding hazard.

As time progressed interest turned towards the environment, and the geological surveys found that their remit had widened considerably. They also found that direct grant aid from government was no longer adequate to sustain the wide range of skills necessary to fulfil their remit. External commissions were, therefore, sought in order to provide additional funds, and to satisfy the specific requirements of agencies within government other than central government. External commissions with industry and overseas agencies are also desirable.



The British Geological Survey is the oldest established survey, although India followed in 1851. The traditional role of the BGS only changed in the last three decades when it was realised that a commissioned research programme could complement the core activities of the survey. The BGS has and does make a significant contribution to the UK economy and the well-being of its people.

The Geological Survey Department of Botswana has only recently celebrated its 50th anniversary. A major contribution made to the nation by the survey has been the exploration and development of groundwater and of diamonds supporting two key threads of the nations economy – cattle and minerals.

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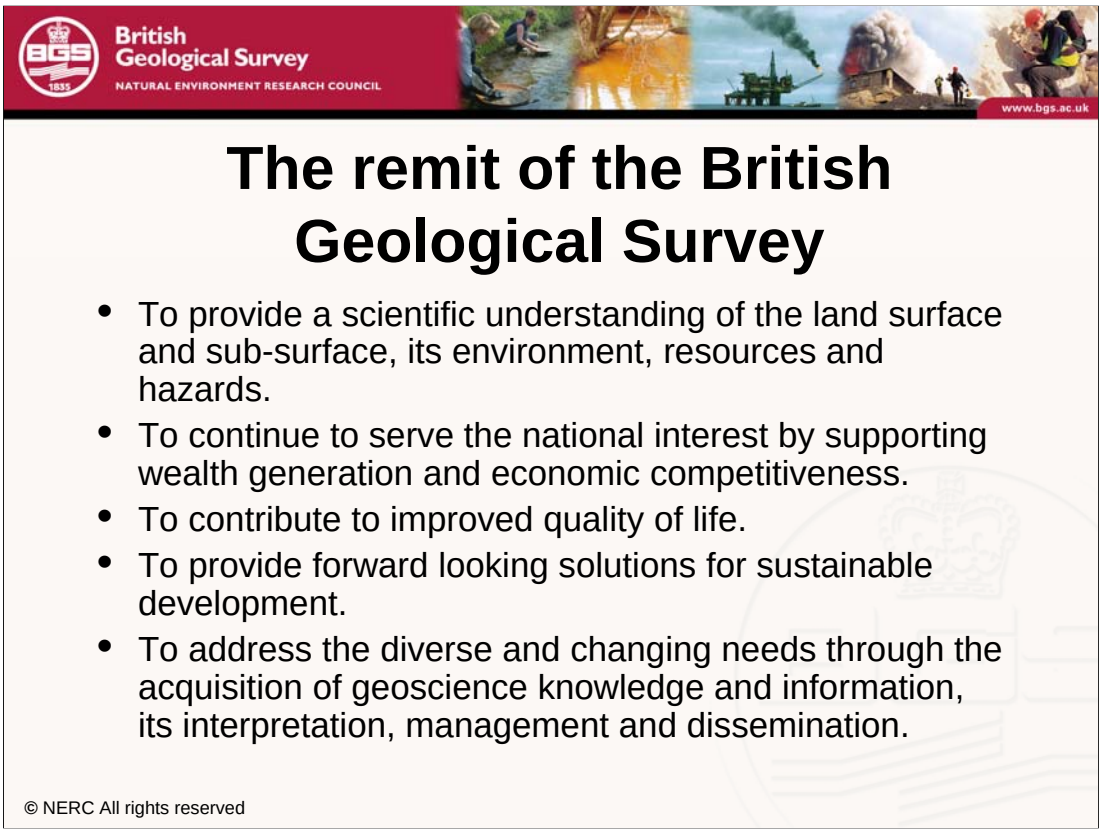
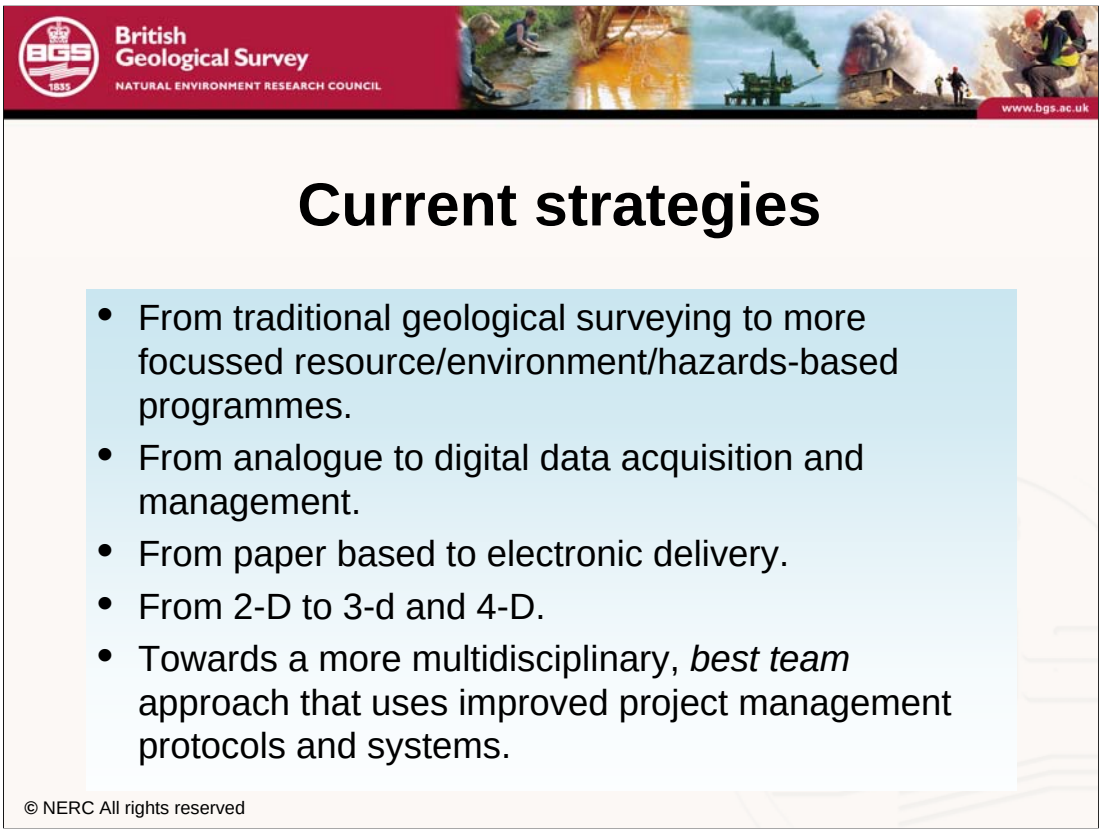
Image of the past

The Geological Surveys were staffed by strong-willed individuals with little emphasis on team work.

Archie Macgregor was typical of some of the ‘Old Boys’ in being single minded and dogged and an individualist. However, it was Archie who first turned to groundwater development in Scotland with work he did in the 1940s. Contrast the individual style of the past with the holistic and multidisciplinary needs of today.



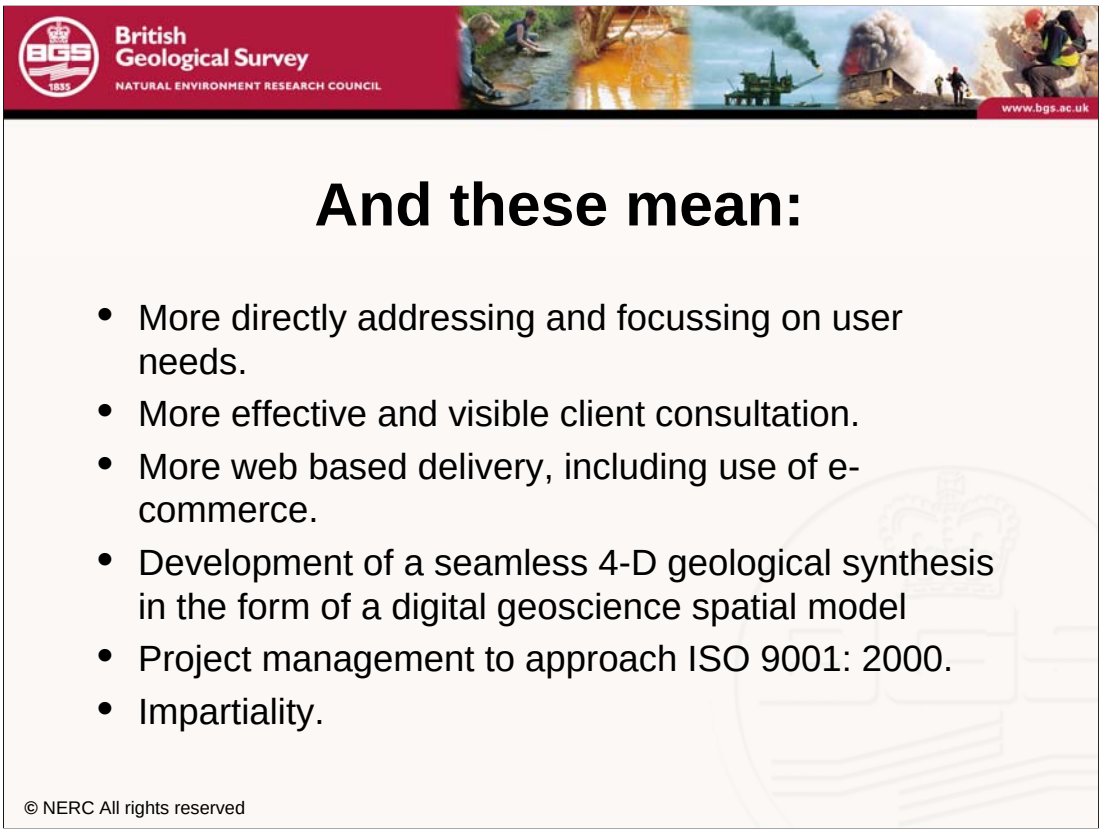
Remits for geological surveys vary from country to country. This one reflects the needs of the UK, whereas others may reflect to a greater extent the well-being of the poor and underprivileged, or specific development of mineral wealth.



Looking forward all the time to the requirements of tomorrow enables current strategies to be devised and developed. The key is that change has to be endemic and accepted by all staff. There is no room for complacency or of resistance to change.

The 2-D map is being replaced by the 3-D model (using software such as Earth Vision, Vulcan or GoCad) and the 4th dimension can be added by loading additional time dependent information into the model (such as groundwater levels or water chemistry).

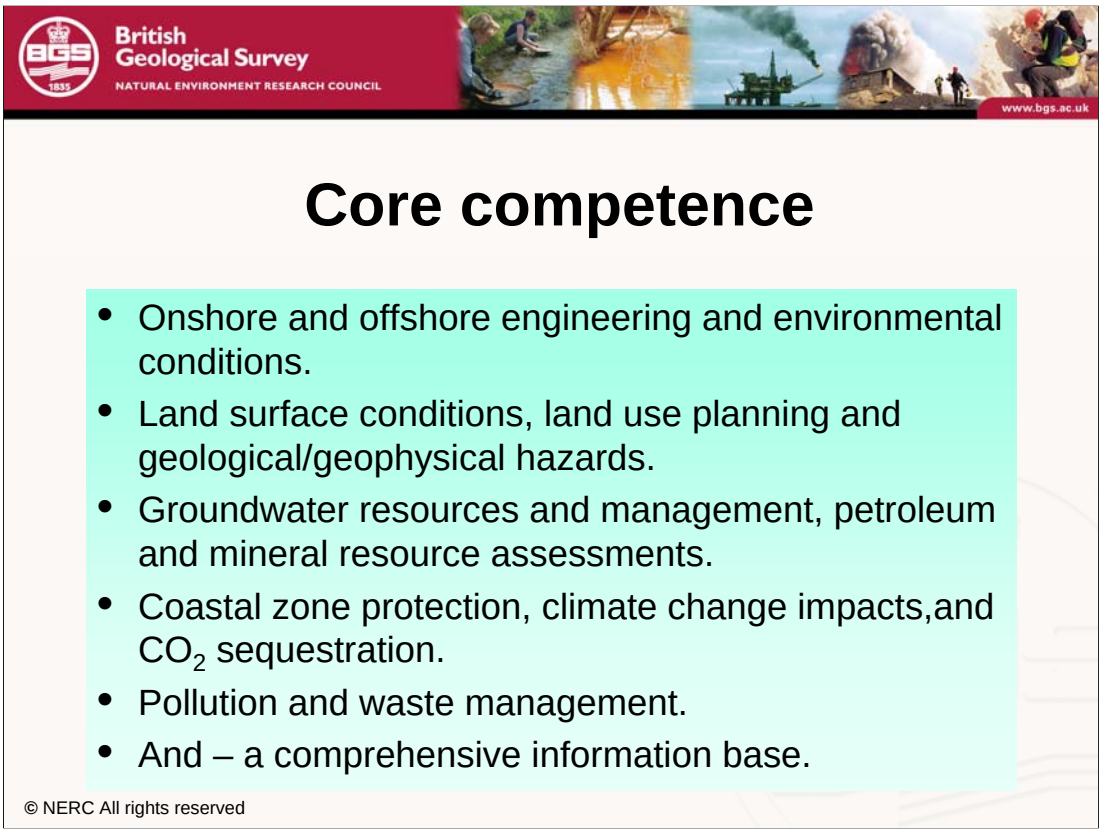
The huge opportunities that improved computer power is bringing have revolutionised the approach to Geoscience data handling and presentation. Advances in this field will continue to be made for some time yet.



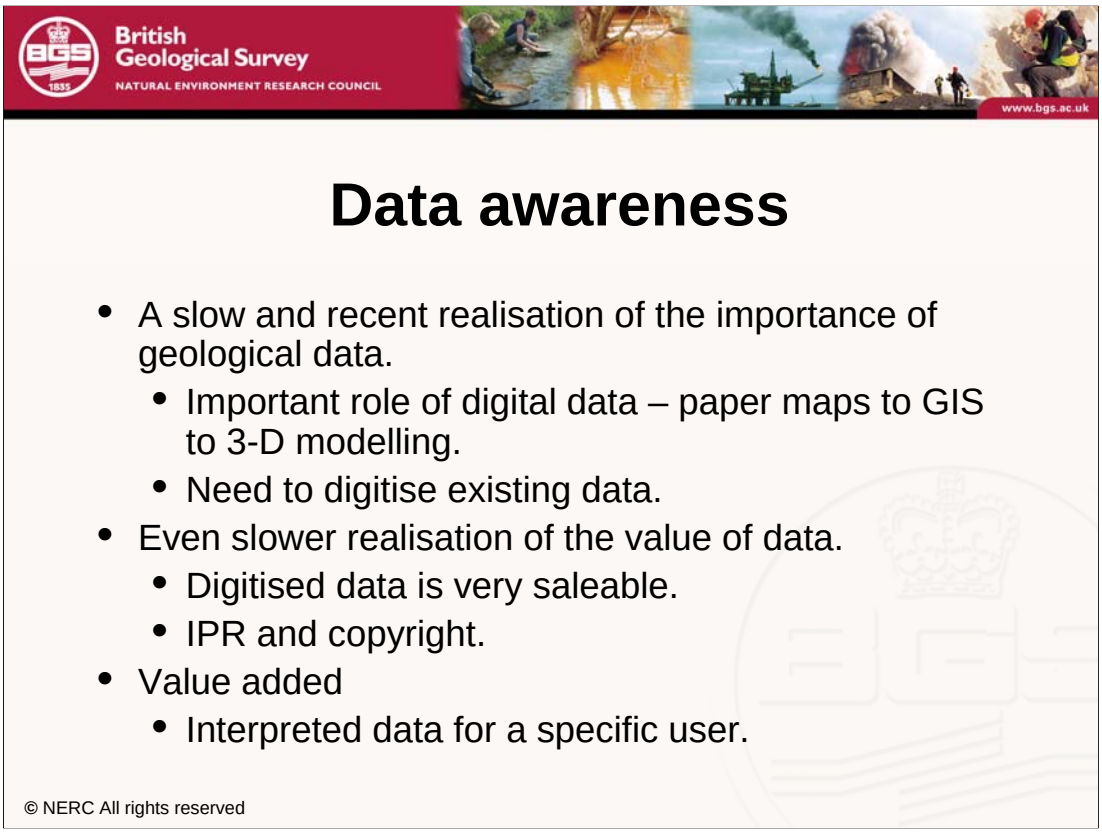
Communication is vital for survival. A continued dialogue with the client community enables the surveys to focus on user needs. In addition the geoscience information must be disseminated to the public so that the important role of the survey is realised by the nation and by its politicians.

The survey must, however, retain independence from opinion so that it can offer impartial advice and act as an arbiter should need arise.

QA is an increasingly important part of the survey job. Maintenance of an adequate paper trail enables others to validate findings. The creation of metadata is also a valuable means of support in this area.

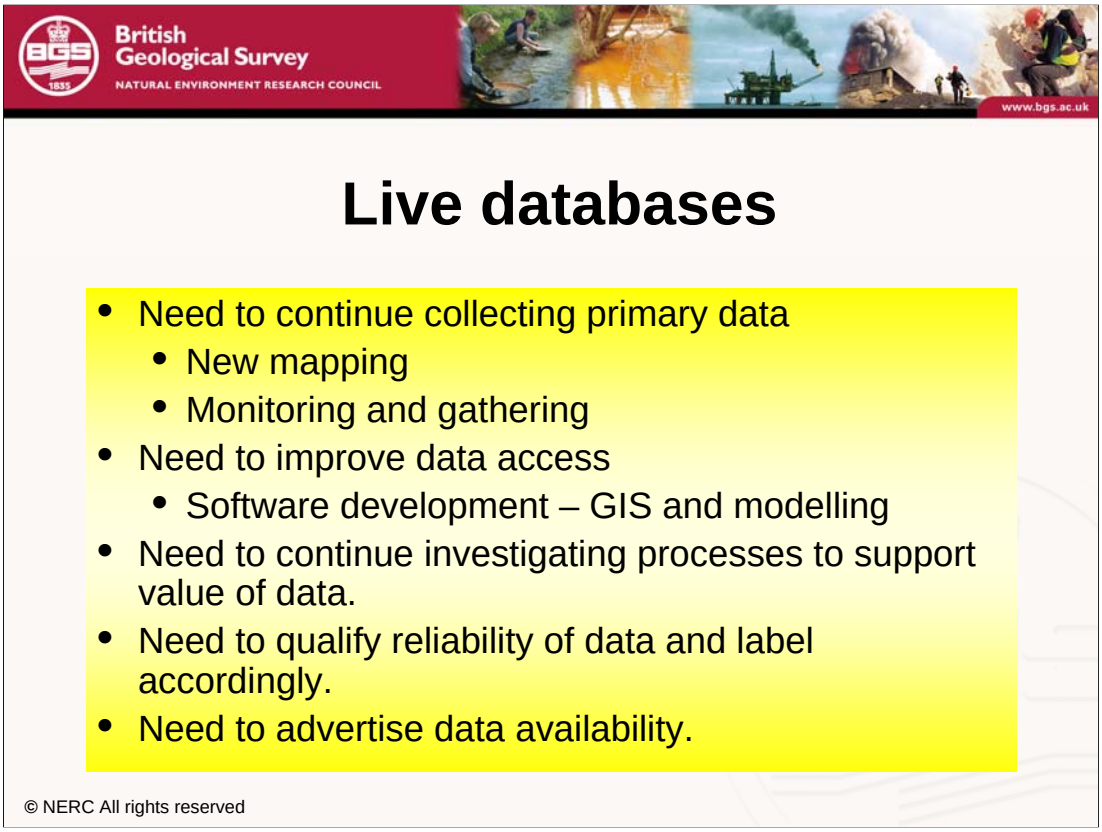


Core competence must cover the needs of each individual country, and will vary from survey to survey. These topics reflect the overall core competence of the British Geological Survey. They can be broken down into more detailed sub-topics as required. Most of the topics are, however, common to numerous geological surveys the world over.



Data is a major asset of the geological surveys. It is in many ways the family silver. Once it has been digitised and formatted ito become user friendly, it can readily be processed in a variety of ways for a variety of purposes. So long as the IPR is secure, the data can be sold or licensed time and again to provide income to support data preparation and other survey activities.

Interpreted or value added data commands a far higher price than raw data.

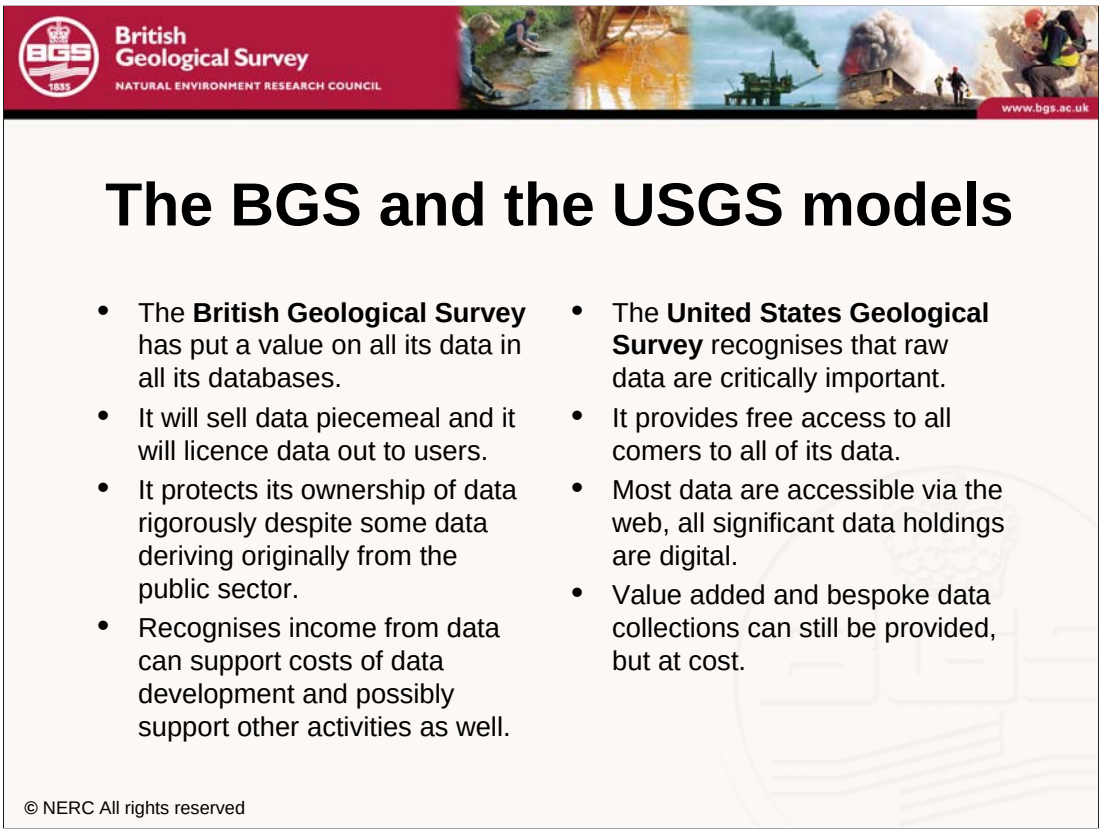


Data holdings must remain active. It is essential that the surveys continue their survey role and continue to collect primary information.

At the same time it is essential that software keeps pace with developments in IT.

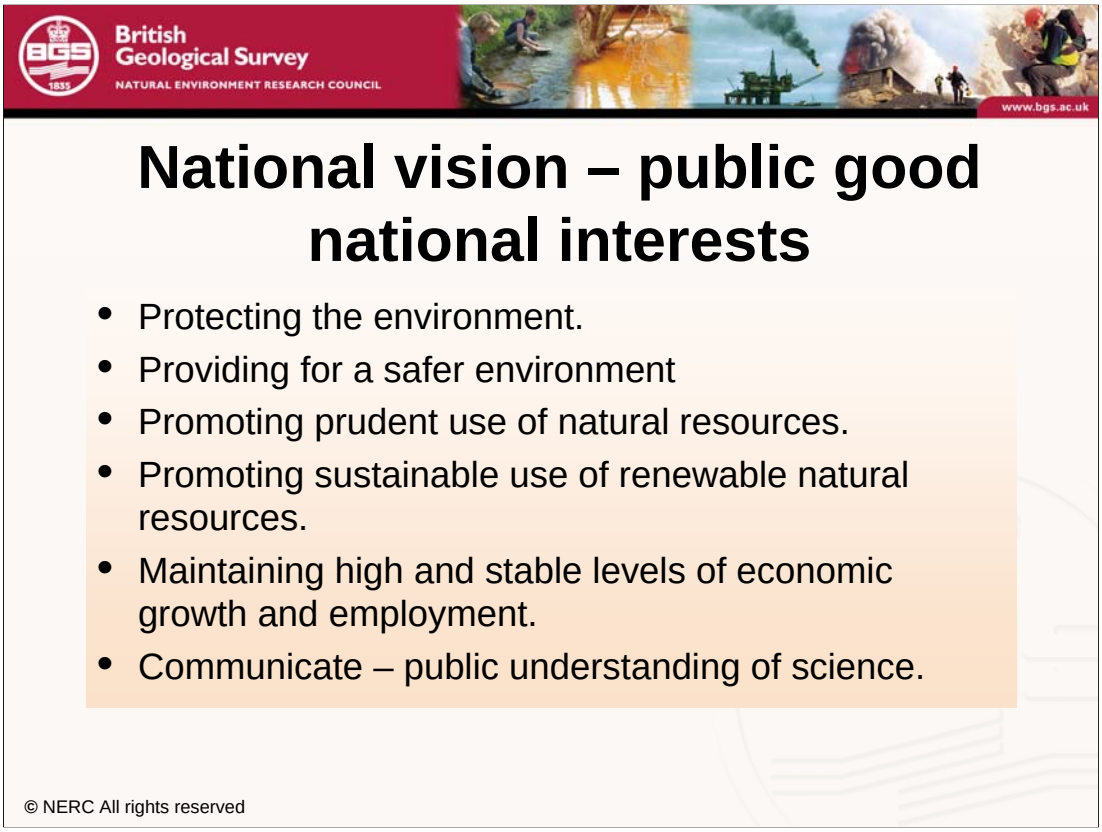
It is also essential to continue research that will investigate the processes – this understanding dictates which data are worth collecting and which are not. It also indicates the density of data points needed to be useful.

Uncertainty remains a key issue. The reliability of individual pieces of data should be assessed and the data labelled accordingly.



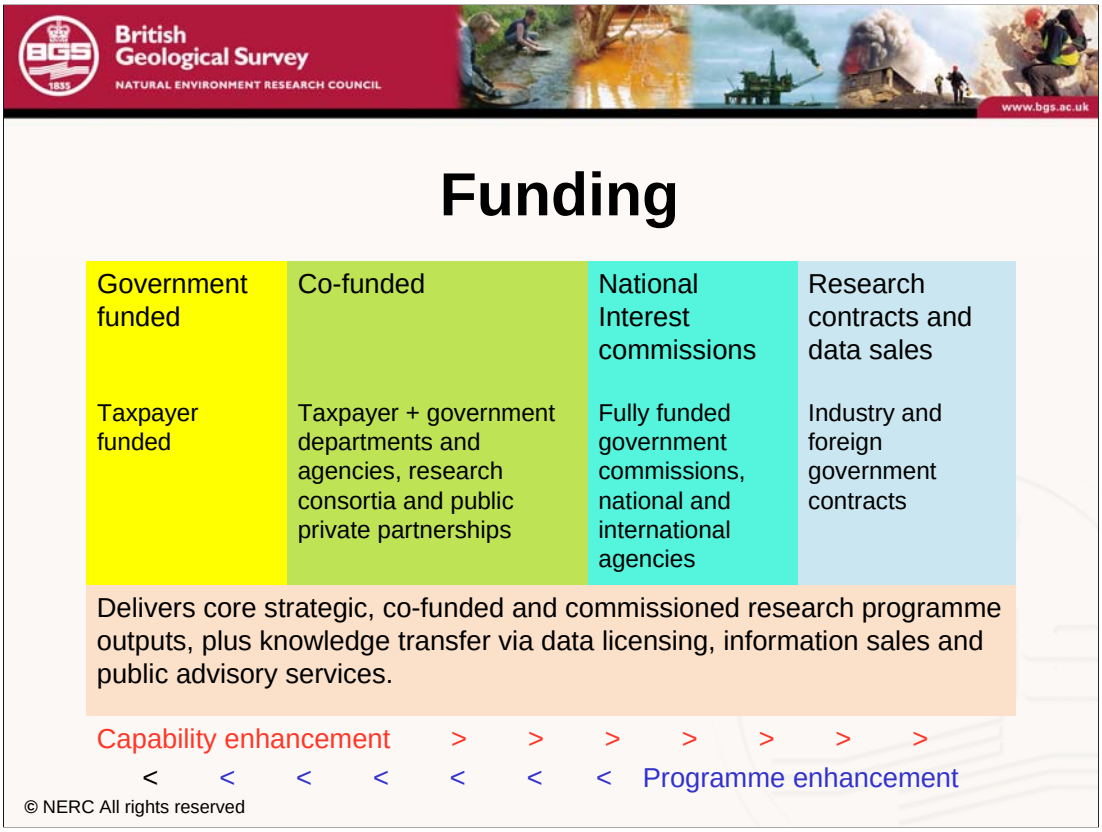
BGS has adopted the data for sale stance whereas the USGS prefer to give their data away free to everybody. The USGS model can only work in a fully government funded survey which does not have a complimentary commercial programme running alongside its core interests. There are considerable merits about giving data, but the truth is that few geological surveys can afford to do this.

The USGS is also unique in that it holds much of the responsibility of the regulator. It is, for example, responsible for environmental monitoring, a task which in Britain falls to the Environment Agency.

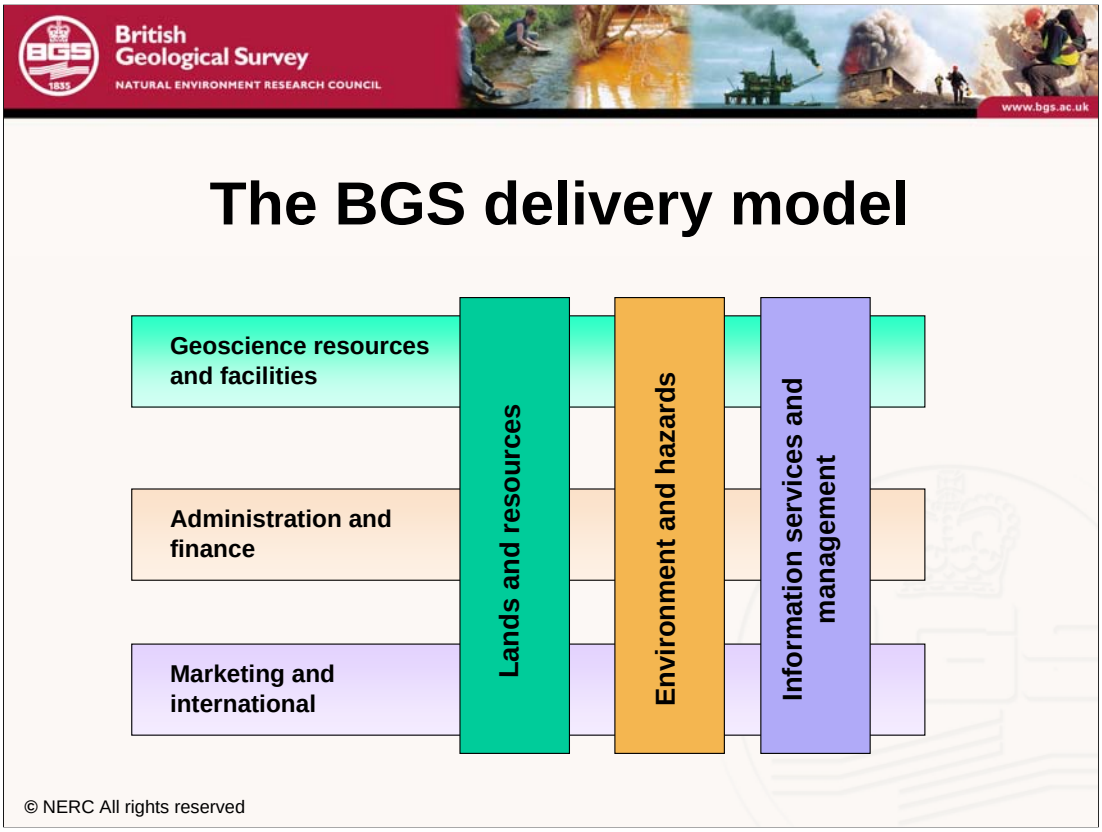


The public good national vision is a wish list that all of us would want to see put in place. At the top of the list would be lower personal taxes. The environmental vision is less selfish but is equally obvious. In some countries the vision would include wealth distribution, and support for the poor.

Provided the geological survey is careful as to what it sees as a supporting commercial programme, it will benefit from the broader vision and from the dialogue with the client, the consumer. The survey needs to realise that some tasks are better done in the private sector, the methodology might best be defined by the survey but the implementation could better be carried out by the consultants. The bottom line is that the work should have a synergy with the core programme – the core programme might just be to survey and understand the land mass.

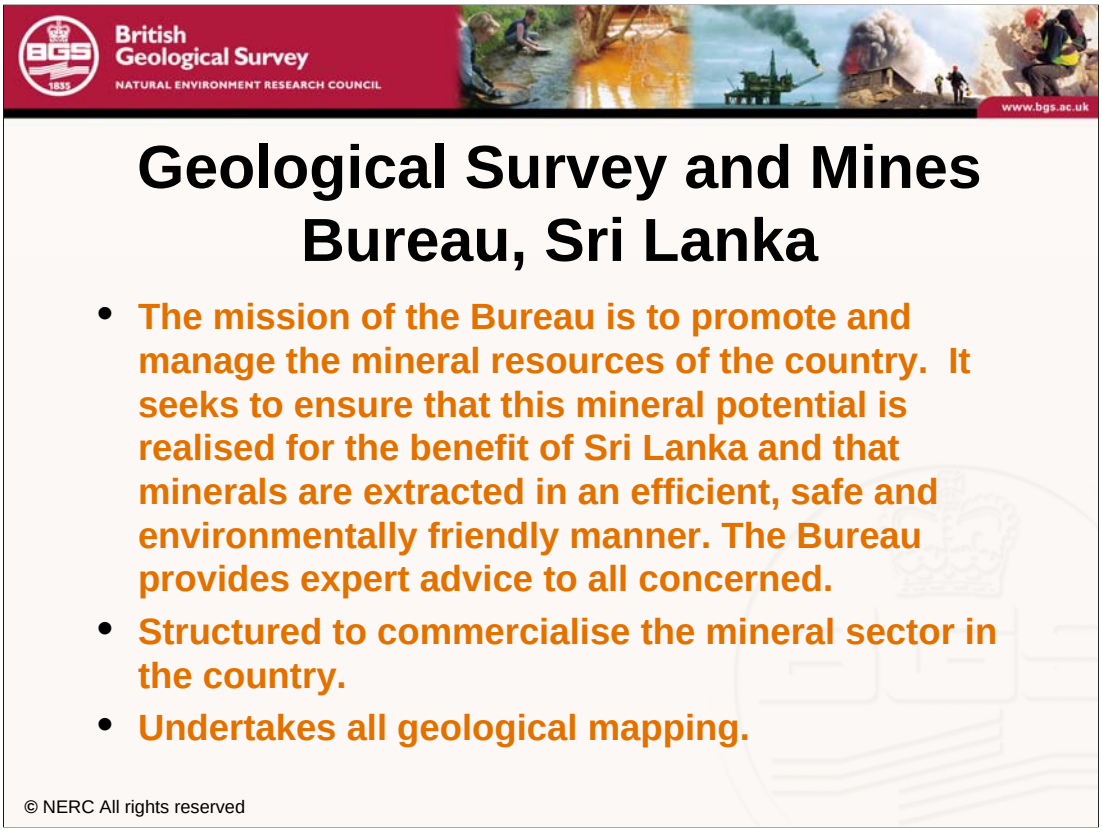


This chart shows the financial relationship between the government funded core programme and the commercial programme. It illustrates that some tasks are best funded both by government and by the stakeholder in a cofunded or partnership fashion. The combined programme promotes capability and widens the breadth of the programme. It is an essential way forward for the geological survey as tomorrow's world requires solutions specific to industry or to agencies which should in turn be paying directly for those solutions.



BGS adopted the matrix system in 1999 after many others had already disowned it. It was seen as a means of increasing corporate strength and identity and of reducing internal barriers and even internal competition. The diagram shows the horizontal thread of people and services (the resources) crosscutting and supporting the vertical programme delivery thread (the geoscience).

The matrix has been successful in improving the corporate identity within BGS. However, there are many ways of cutting a cake and the BGS model is only one of a number of successful models. The model adopted should of course, reflect the size of the survey, BGS has approximately 800 staff.



The mission of the Geological Survey and Mines Bureau is cited by way of example. It highlights the important contribution that mineral extraction makes to the economy of Sri Lanka. This is an example of a survey largely dedicated to a single purpose.

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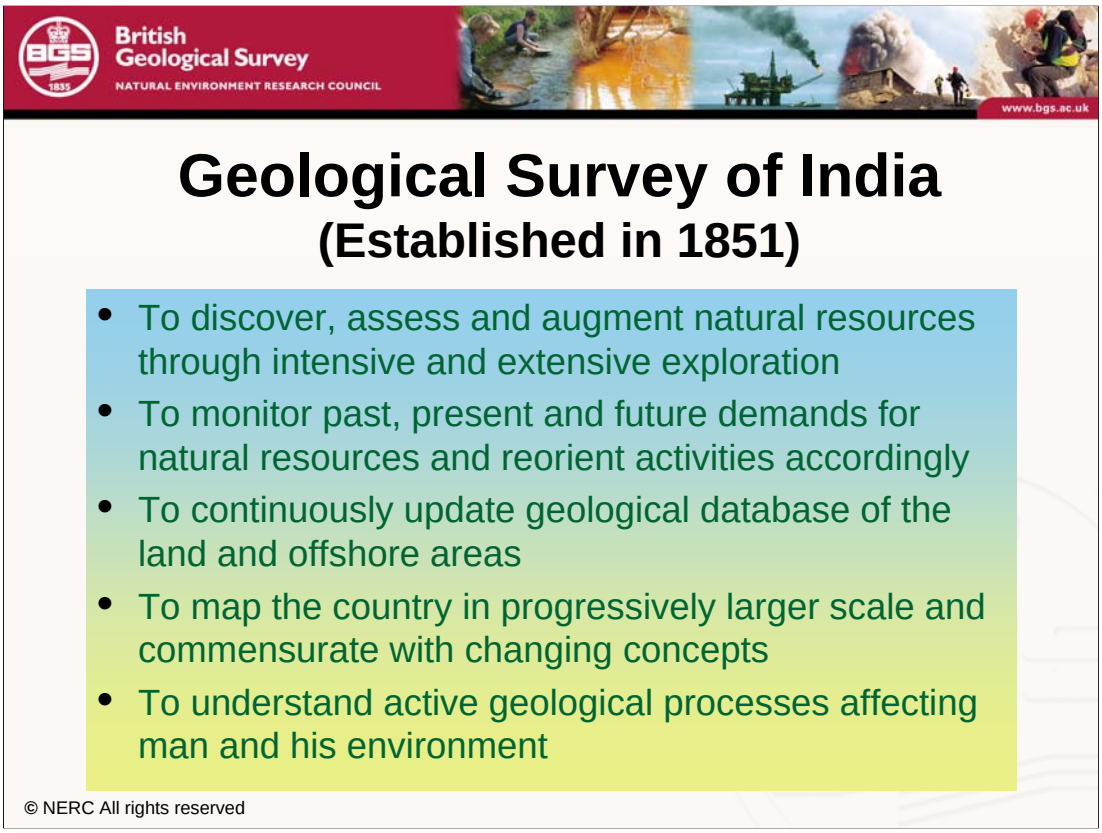
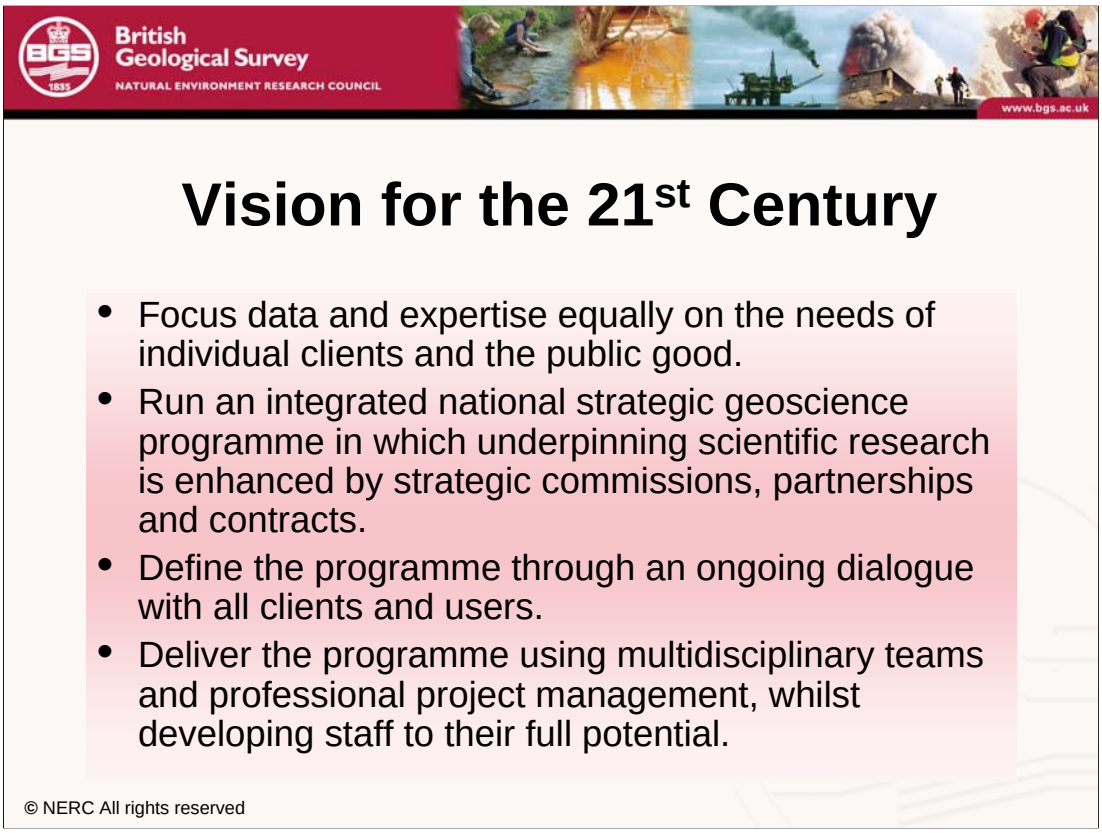


The Geological Survey of India has a much broader remit. This, however, is a much more expensive mission to satisfy than that of the survey for Sri Lanka. The Indian mission, is, however, more typical of many Asian missions and encompasses the concept of change to accommodate tomorrows needs and the need for dialogue with stakeholders.

GSI - continued

- To play proactive role in natural and anthropogenic hazard assessment and mitigation
- To render geoscientific advice for water resource, power, communication and urban development projects
- To establish and maintain a comprehensive earth science database
- To enhance interaction with the public for easy access to earth science information, maps and knowledge product
- To generate databases in the fields of environment, water resource development, natural hazards, etc.

Recognising the internal scientific drivers (which we can control) and the external drivers (which we cannot control) is essential to the geological survey in order that it may posture itself in a state of preparedness for the next challenges. Drivers include the insatiable demand for geoscience information as a key to problem solving, the protection of the environment and the maintenance of economic expectations.



This is the stated vision of the Director, BGS in his submission to the recent Science Management Audit of the survey. The vision includes statements all of which are obvious, yet few of us would have realised are key to our futures. The vision collectively looks forward to a bright, successful and useful future for geological surveys and suggests that the surveys will continue to contribute to national wealth creation and personal well-being throughout the 21st century.

Vision II

- Provide geoscience knowledge and solutions that help government, industry and individuals to make correct environmental decisions.
- Develop the maximum synergy between data and expertise through the creation of 3-D digital geoscientific spatial models.
- Raise public awareness of the impact of geoscience on sustainable development decisions by communicating with all stakeholders.
- Out sourcing selected services.

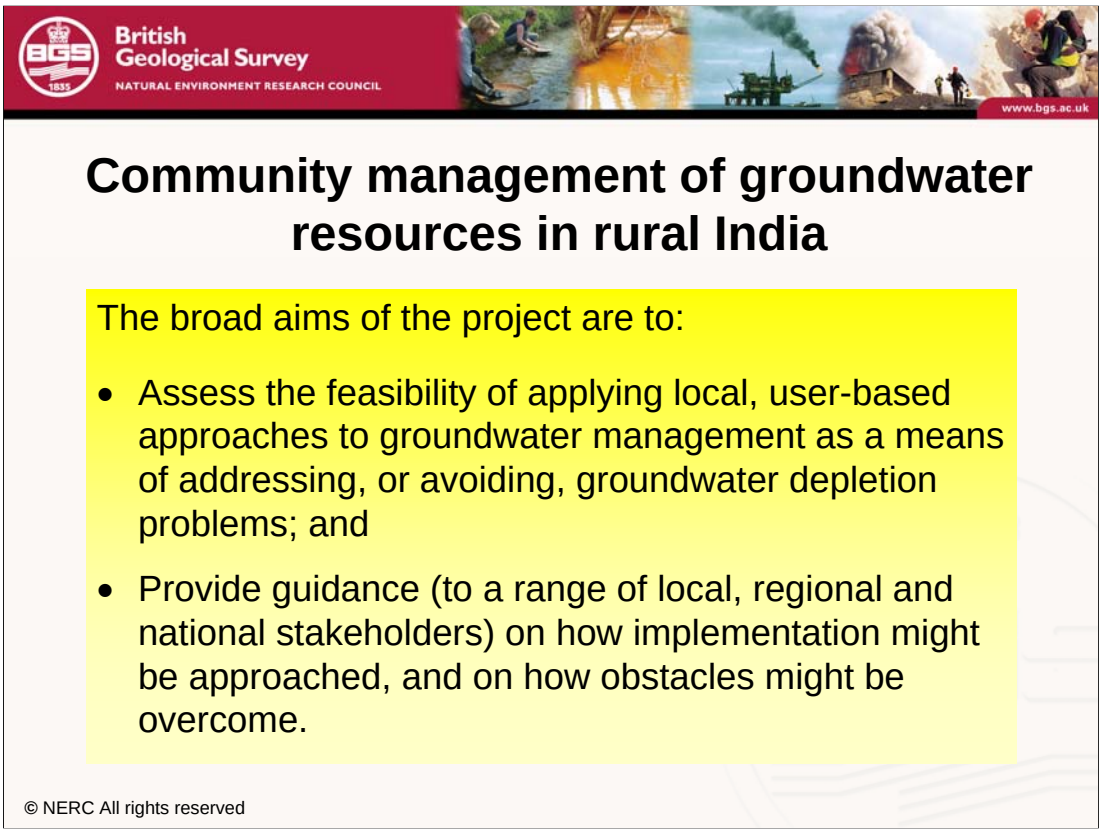
If you have any queries on this presentation please contact the author whose e-mail address is given under slide 1.

This presentation was prepared by Dr N S Robins in October 2003. Please address any enquiries to nsro@bgs.ac.uk.

Strategy towards sustainability

BGS has undertaken a number of projects in recent years specifically addressing sustainable development. In the water sector these include not only the technical aspects of groundwater development in terms of sustainable supply but also the social problems of ownership and management and the economic aspects of maintenance, spares, fuel etc.

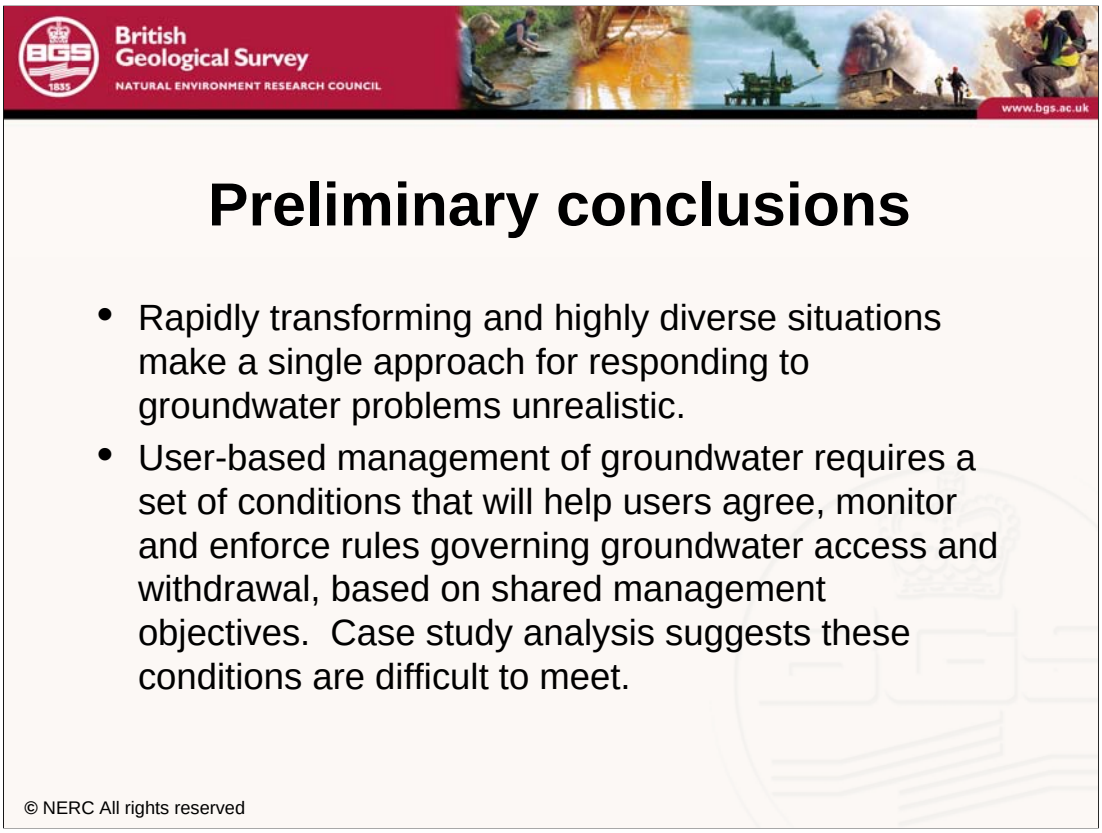
A selection of project abstracts are presented here to provide a flavour of some of this work. Most of the work has been funded by UK DfID.



This project is built around a series of case studies, with supporting desk-based reviews. The main case studies have been undertaken in the Aravilli Hills of Gujarat; the Arwari Basin, Rajasthan; Coimbatore District, Tamil Nadu; and the Pani Panchayats of Maharashtra. The case studies have allowed the impacts of and responses to declining groundwater availability to be assessed, and the potential for collective action to be explored.

The project is a collaborative project involving Indian and international organisations, including: VIKSAT, a large NGO in Gujarat; the Institute of Development Studies, Rajasthan; the Tamil Nadu Agricultural University; ACWADAM, a Maharashtra-based NGO; the Institute for Social and Environmental Transition**,** based in Nepal and the USA; the Overseas Development Institute, UK; and the British Geological Survey. It is being funded by UK DfID.

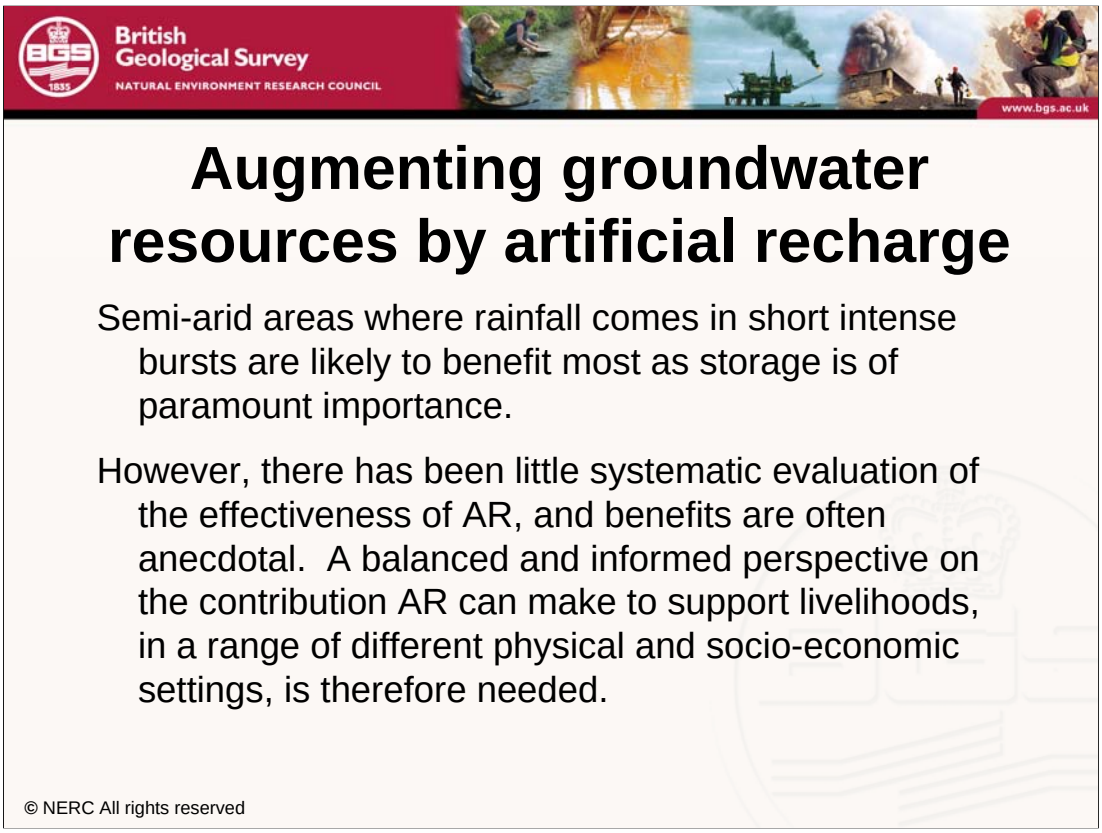
Aravilli Hills, Gujarat 2002: households sell jewellery, or go into debt, to fund speculative borehole drilling *(D Macdonald, BGS)*



In conclusion, the 'groundwater problem' is not amenable to simple diagnosis and remedy. Efforts to control groundwater use directly through top-down regulation may be feasible on key urban aquifers where management interests and scale overlap, but not beyond. In some (limited) rural circumstances, user-based management may be feasible, though unlikely without strong institutions and leadership. In many others, local initiatives building on wider economic incentives are needed to support shifts within the groundwater economy, and shifts between the farm and non-farm economies.

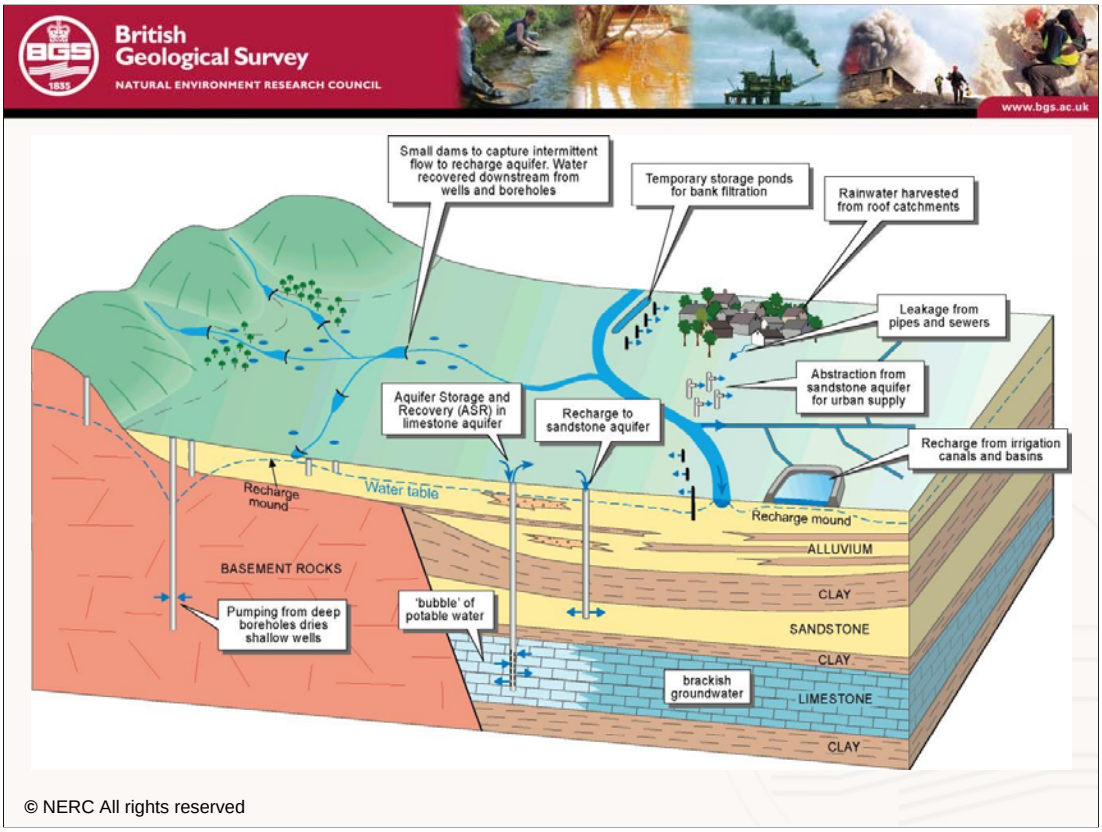
Conclusions II

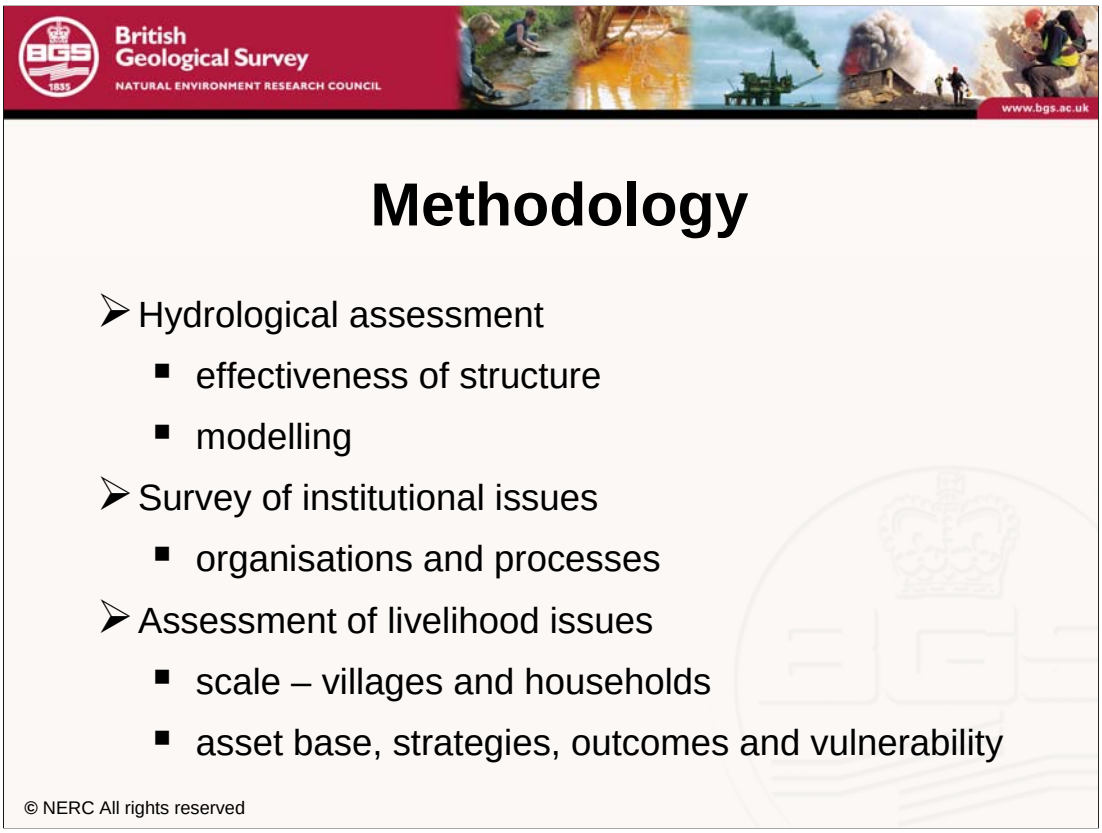
- Literature surveys and research for the case studies suggests that non-conventional (livelihoods-based) responses to emerging groundwater problems can also mitigate the impacts of such problems and may, under certain circumstances, help create the conditions for more proactive management.
- Community-level groundwater interventions (as opposed to community-based management) can, however, make a significant difference to the availability of groundwater for livelihoods and other uses under a much wider array of circumstances.



The intensity of groundwater exploitation over the last 20 years has raised concerns that groundwater use – and the livelihoods it helps support – may not be sustainable. There are many areas in the developing world where simple Aquifer Recharge technology can be used to optimise the management of scarce water resources and hence benefit the poor.

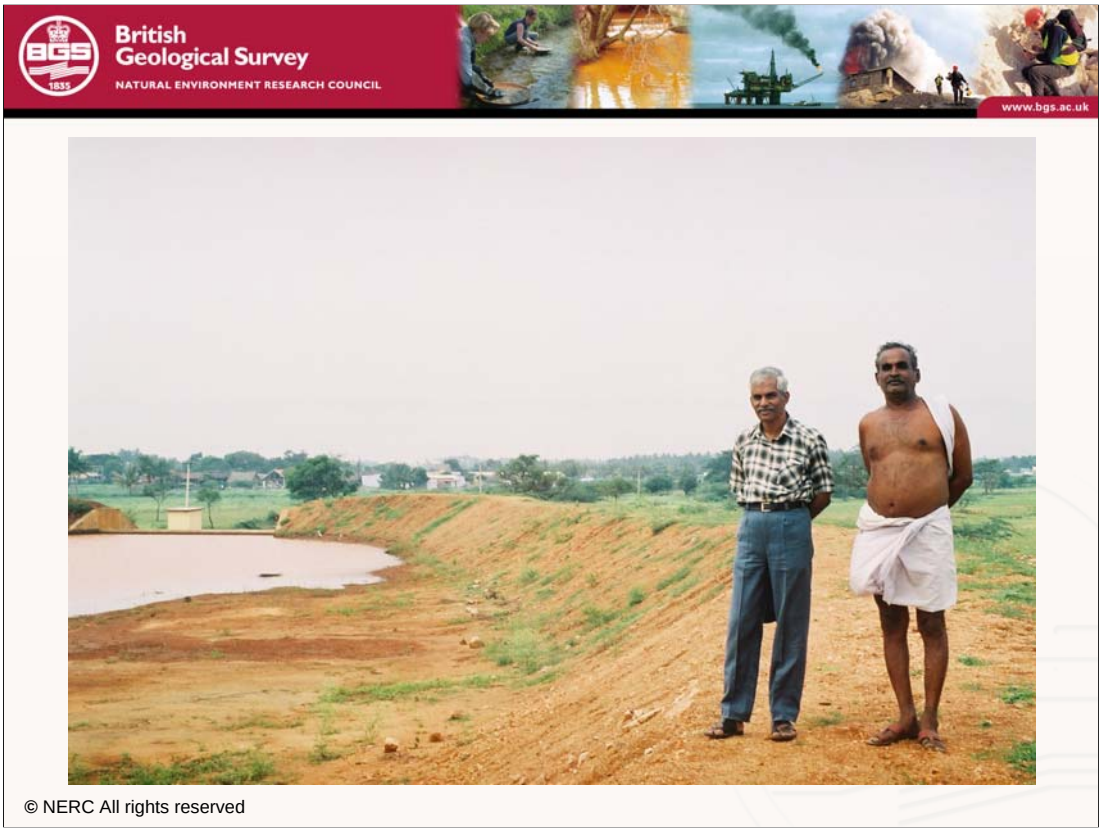
This project is funded by the UK DfID and is being carried out in India and Nepal.



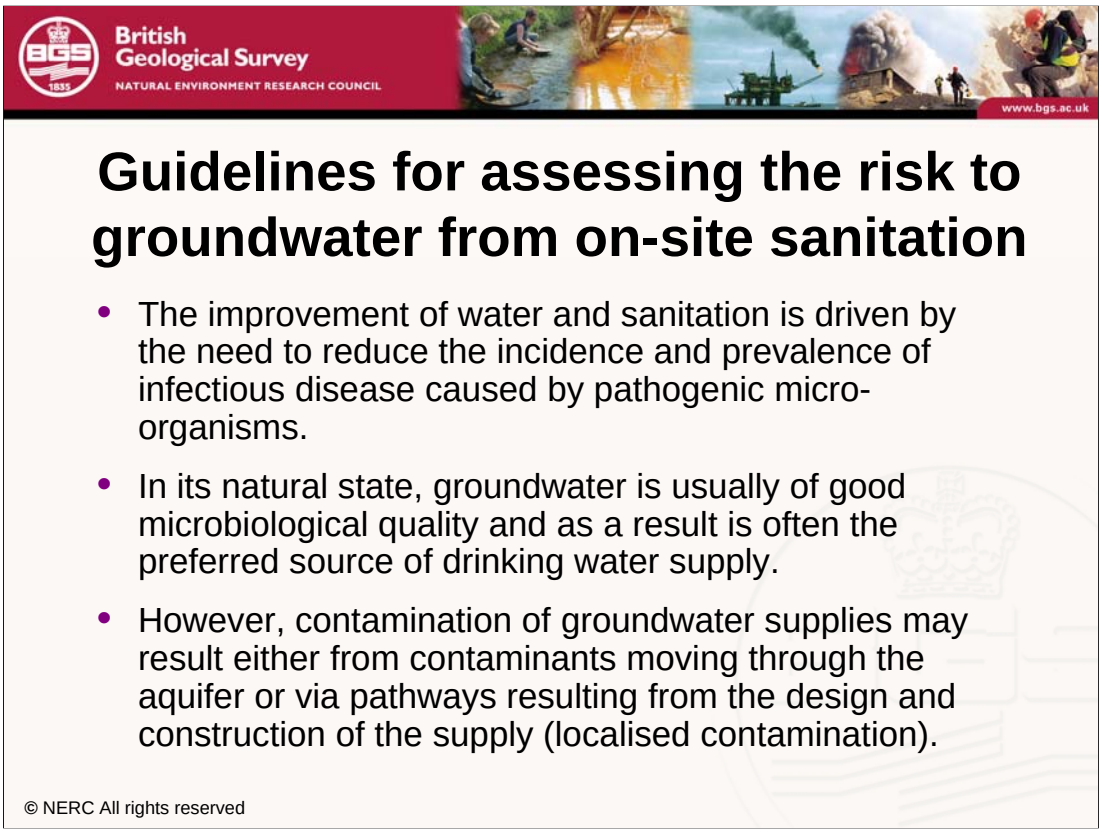


Partners

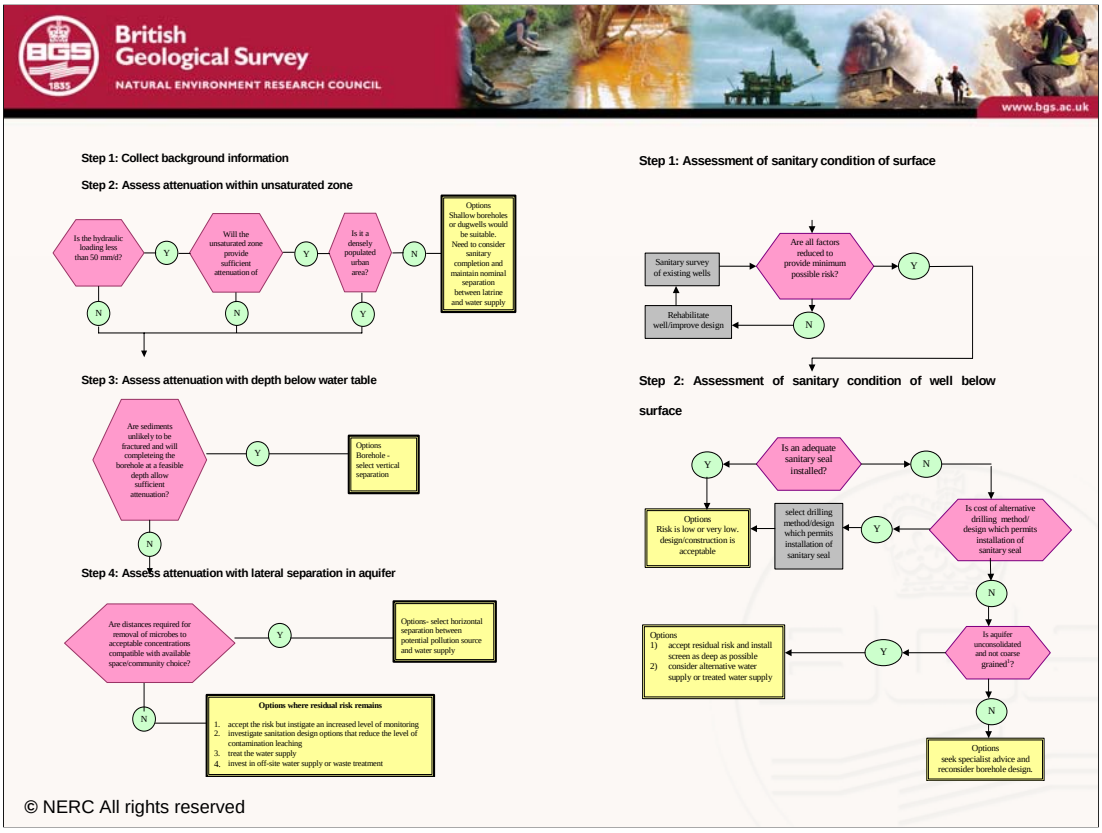
- Vikram Sarabhai Centre for Development Interaction, Ahmedabad (VIKSAT)
- Advanced Centre for Water Resources Development and Management, Pune (ACWADAM)
- Water Technology Centre – Tamil Nadu Agricultural University, Coimbatore (WTC-TNAU)
- Institute of Development Studies (IDS-Jaipur)
- Nepal Water Conservation Foundation (NWCF)
- Institute for Social and Environmental Transition (ISET), Nepal & USA.
- UNESCO, India Office



One of five research sites, this one at Coimbatore, Tamil Nadu, India. The others are at Aravalli Hills, Gujarat, India; TBS Rajasthan, India; Kolwan Valley, Maharashtra, India; and Kathmandu Valley, Nepal *(David Macdonald, BGS)*



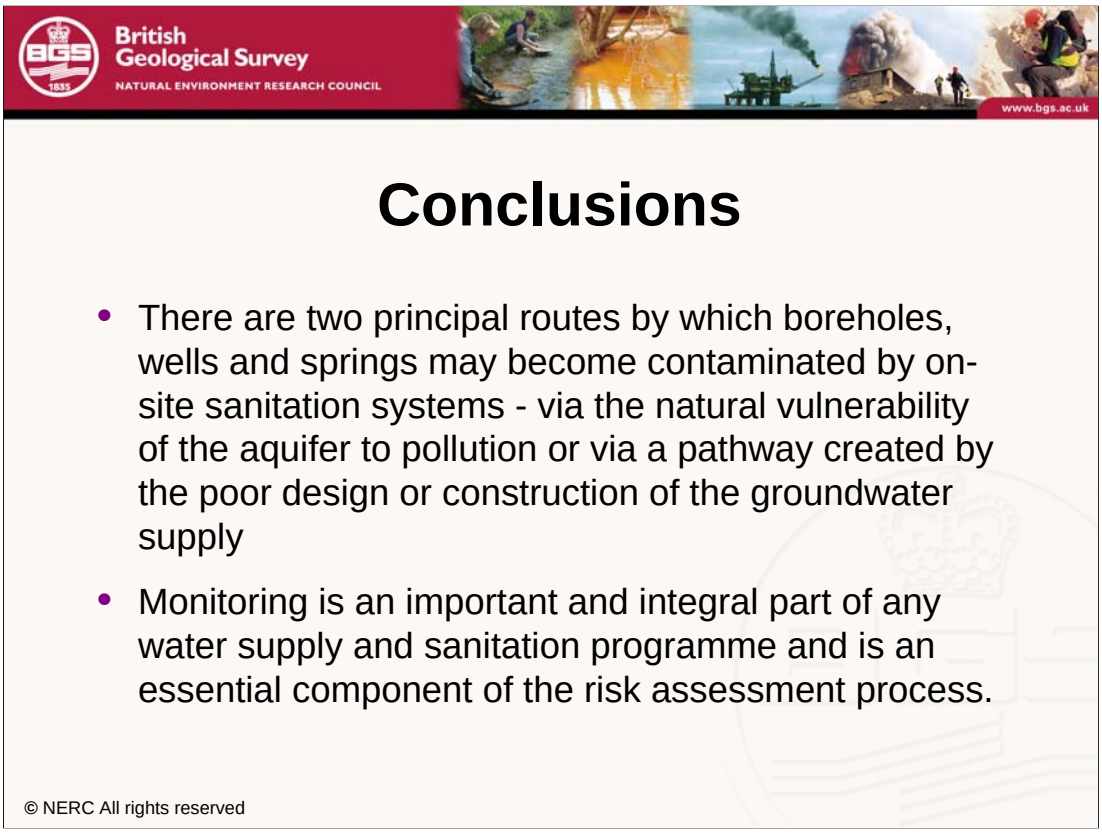
More than 1 billion people around the world still lack access to safe water supplies and more than 2.4 billion are without adequate sanitation. A substantial majority of these people live in Asia where the lack of sanitation provision is particularly acute. In Africa, over one third of the population still remains without access to safe water and sanitation, and many of these can only be served by groundwater.



Pathways will always exist in the subsurface that provide a link between the sources of contamination and the groundwater supply. However, natural (attenuation) processes in the subsurface can significantly reduce contaminants concentrations.

The key processes in the attenuation of microbiological contaminants are:

- Die-off and predation
- Adsorption
- Filtration
- Dilution/dispersion



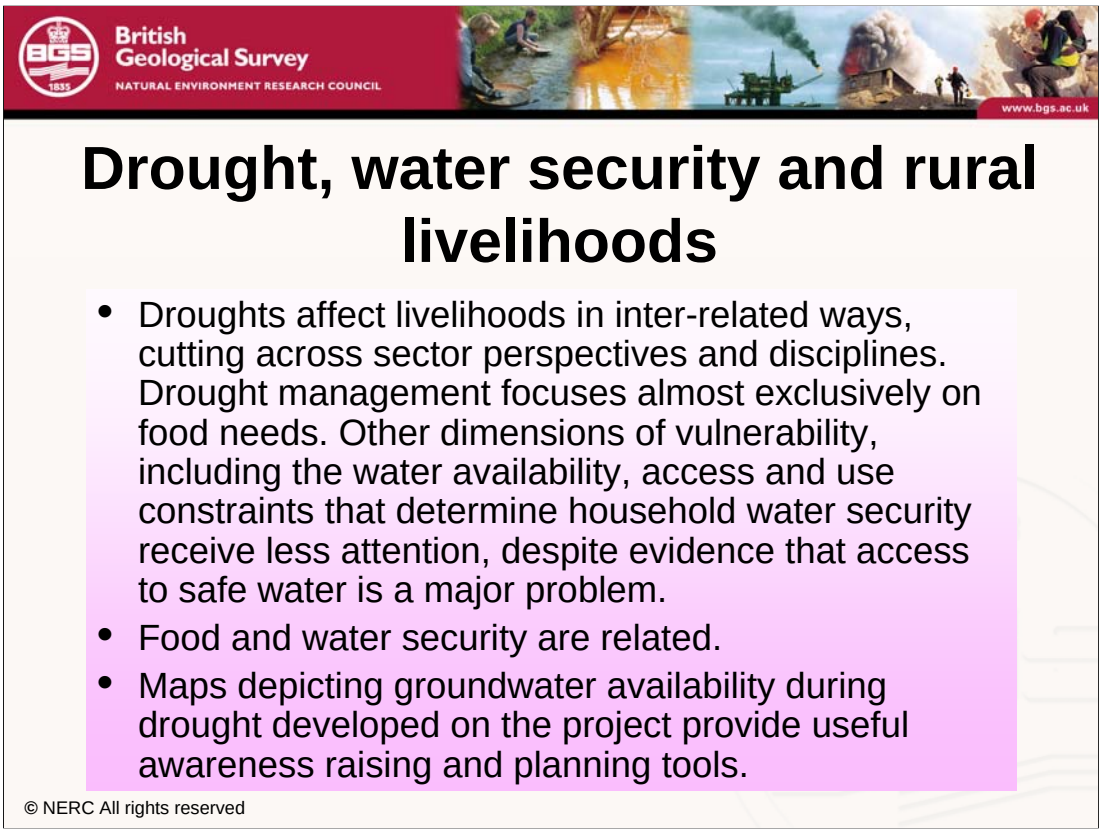
Monitoring is required to:

Provide confidence in design

Establish cause of contamination, wherever contamination is observed

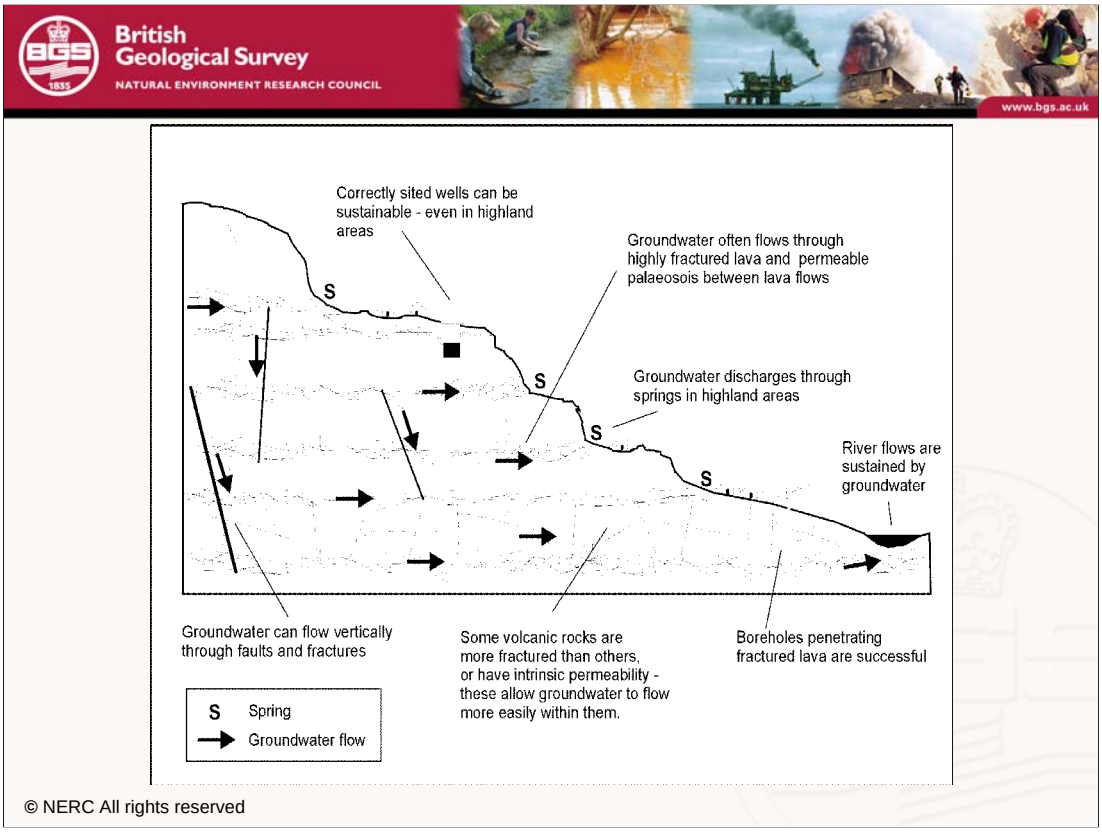
Ensure supply meets drinking water standards

Observe water quality trends with time

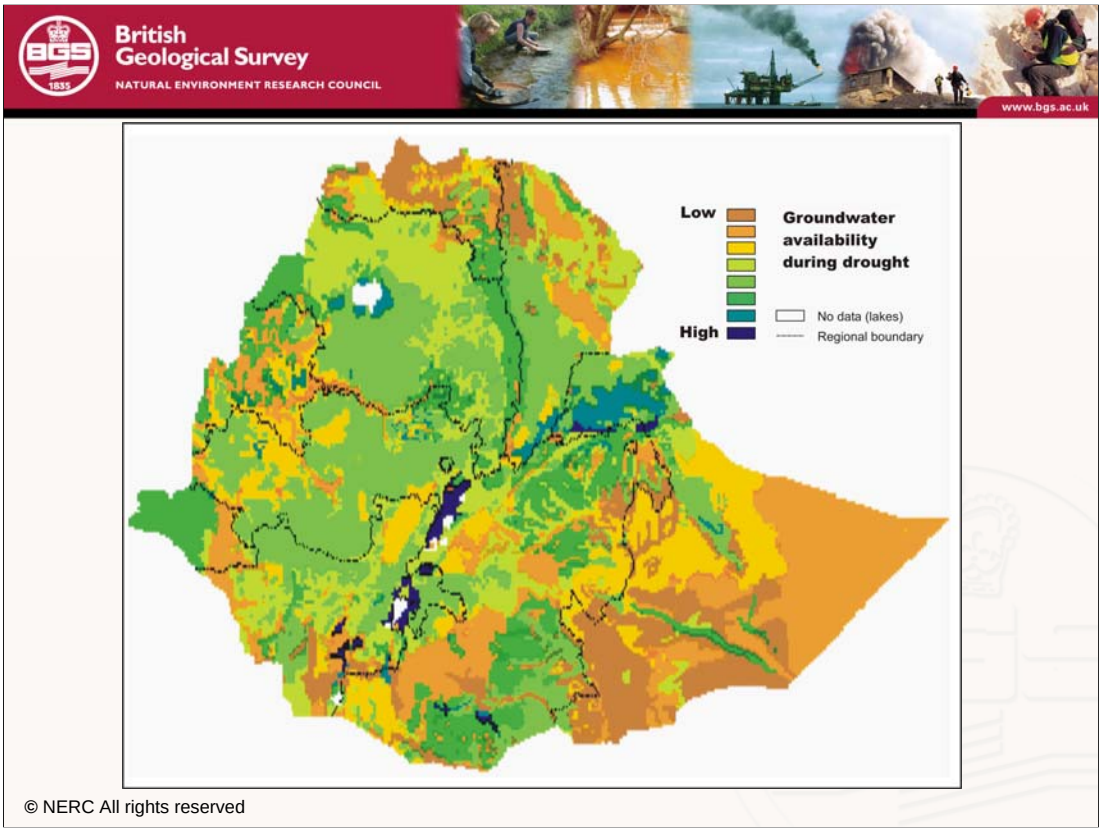


Drought is a recurring event in Africa. The current drought, affecting large swathes of eastern and southern Africa, is not exceptional. For many, drought is associated with food insecurity: rains fail; crops wither; food supplies dwindle; entitlement to food declines and people go hungry. The response, on the part of government and donors, is typically food aid 'to save lives'. Yet food insecurity is not the only concern during drought, and is not an isolated concern. One of the principal aims of this report – a synthesis of over four years research – is to show how livelihoods are affected by declining access to food *and* water, with access to both linked in a number of important ways. Implications for policy – to protect livelihoods before lives are threatened – are highlighted.

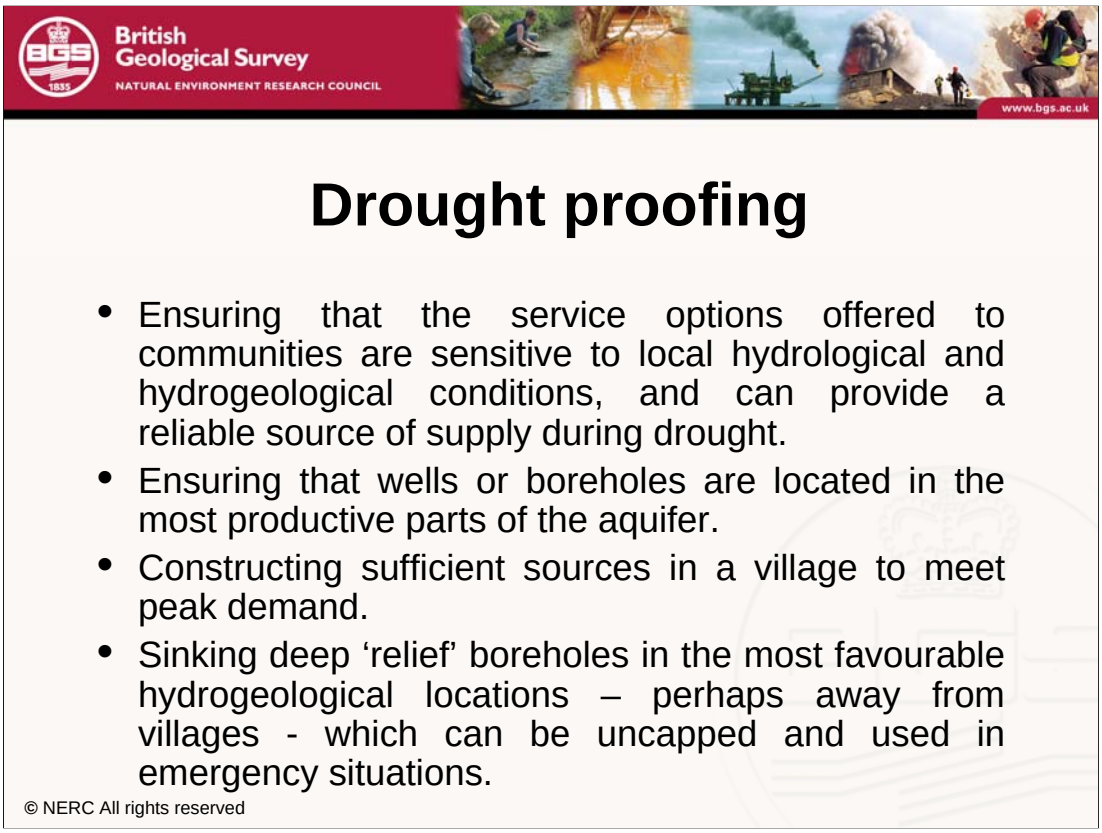
The project was funded by UK DfID and was partnered by Wateraid.



Availability of groundwater in the volcanic rocks that characterise this area of Ethiopia depends largely on the presence of fractures. The top and bottom of lava flows, particularly where they are associated with fossil soil horizons, are often highly fractured and weathered; towards the middle of the lava flows, the basalt tends to be more competent and less fractured. The interconnected fractures and cavities provide rapid, discrete flow paths, with groundwater often discharging as springs at impermeable boundaries

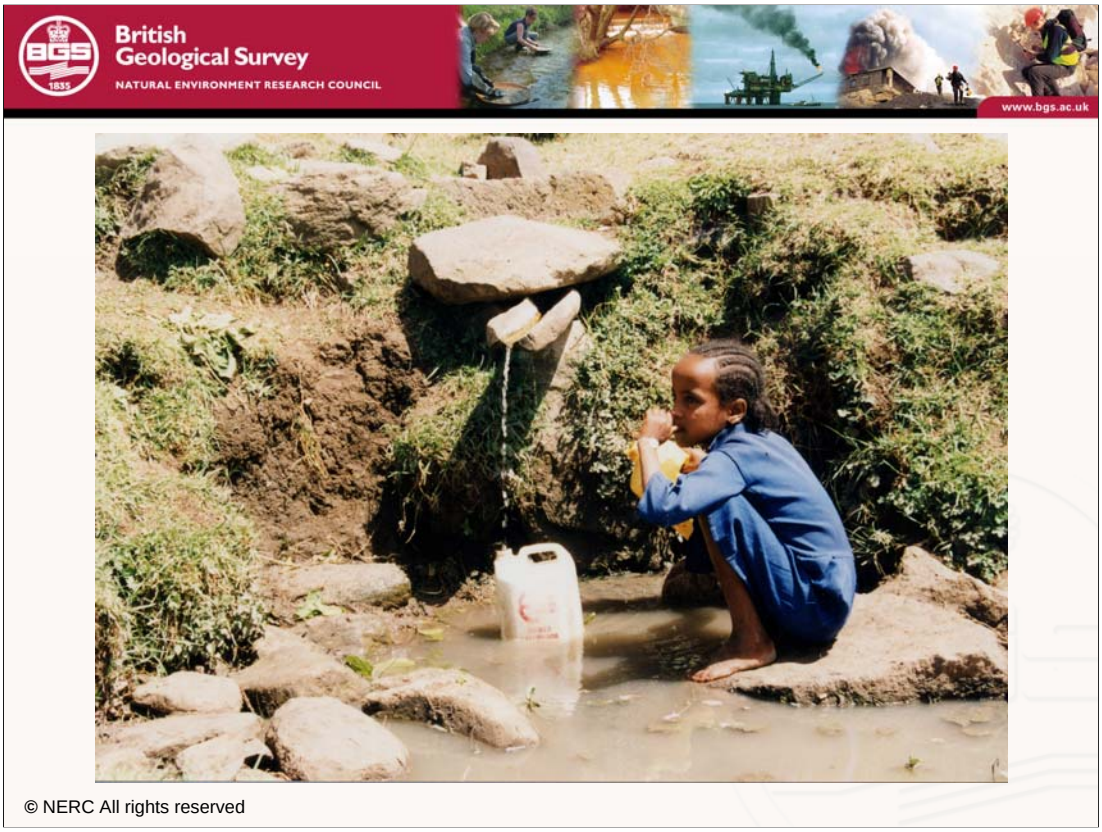


National maps, in this case, of Ethiopia, cannot be used to provide anything other than an indication of where targeting should take place, in conjunction with other tools. Regional mapping, however, could provide a much more powerful tool for targeting the kind of activities described above to water insecure areas, especially if linked to the kind of local level water security analysis described below. Investment in higher resolution maps, linked with training in the use of map information, can generate significant (and quantifiable) benefits.



The droughts of 1973, 1984/85 and 1998 were identified by communities as being particularly severe. Though the level of rainfall in 1998 was reported to be as low as that in 1984/85, impacts on communities - particularly their food security – were not as severe due to the greater preparation for food shortages by government.

Interviews with a range of informants suggested that drought is an extension and intensification of seasonal water shortages in most communities, rather than an event with its own pattern of shortage. It is, in effect, an acute version of the chronic water insecurity felt by households during dry season periods. Indicators of such stress include longer time taken to collect water (over 5 hours in some cases) due to reduced yield combined with increased demand, the use of poorer quality sources, either due to absolute unavailability of other sources or the closer proximity of poorer quality sources, and reduced consumption of water within the household. These behaviour patterns all impact on the livelihoods of households.

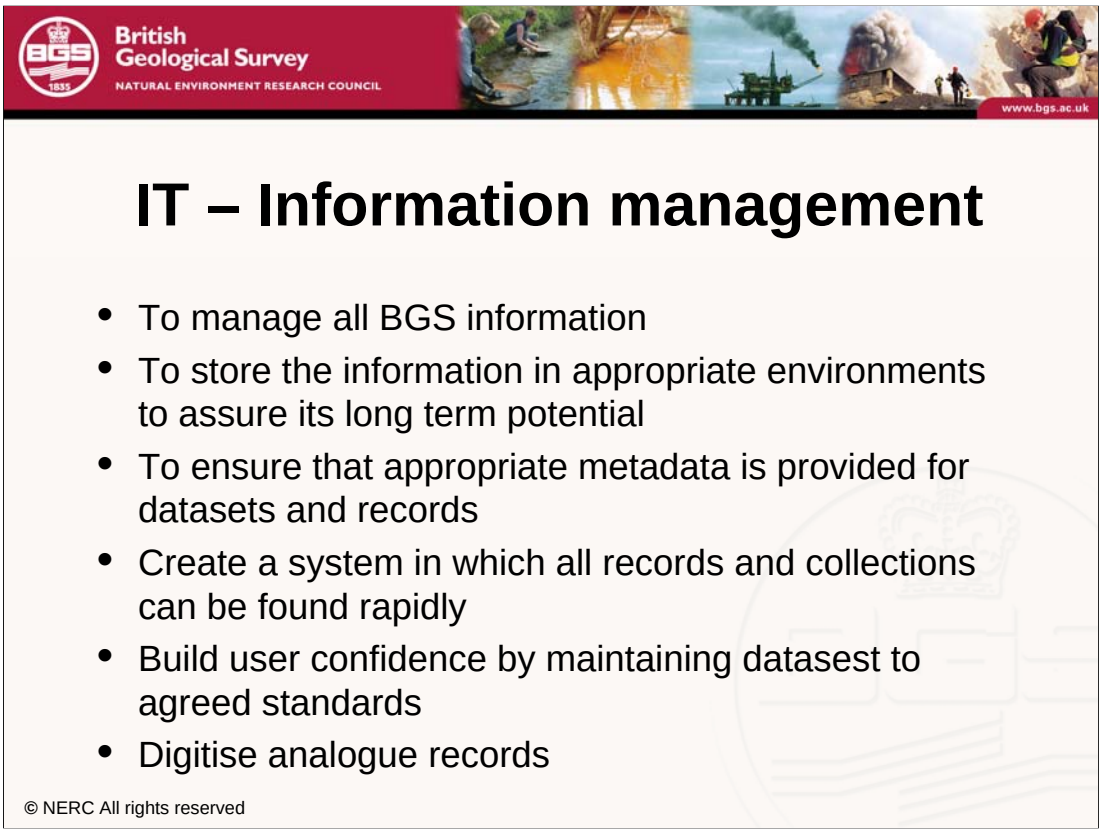


Collecting water from a spring in Ethiopia *(R Calow, BGS)*

The BGS role in other geoscience areas

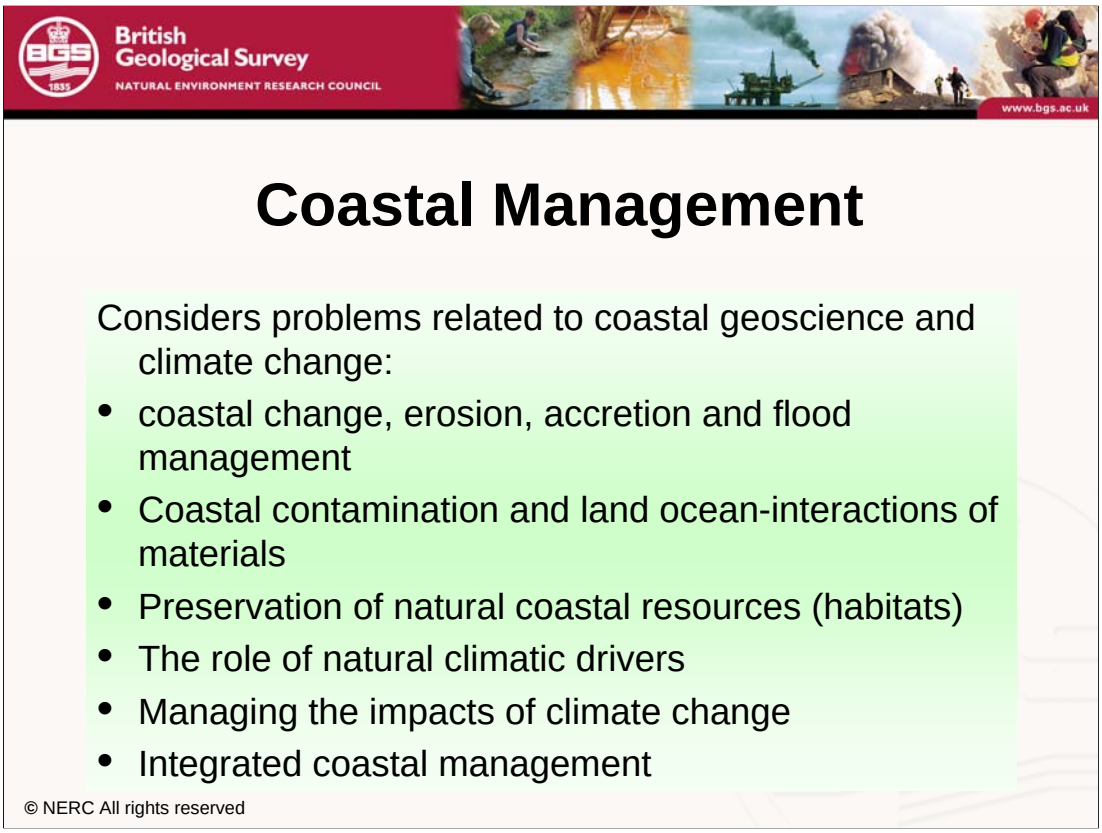
This presentation concludes with a quick review of some other geoscience initiatives using BGS as a model:

- IT
- Coastal management
- Minerals
- Energy
- Hazards and Disasters
- Human resource development

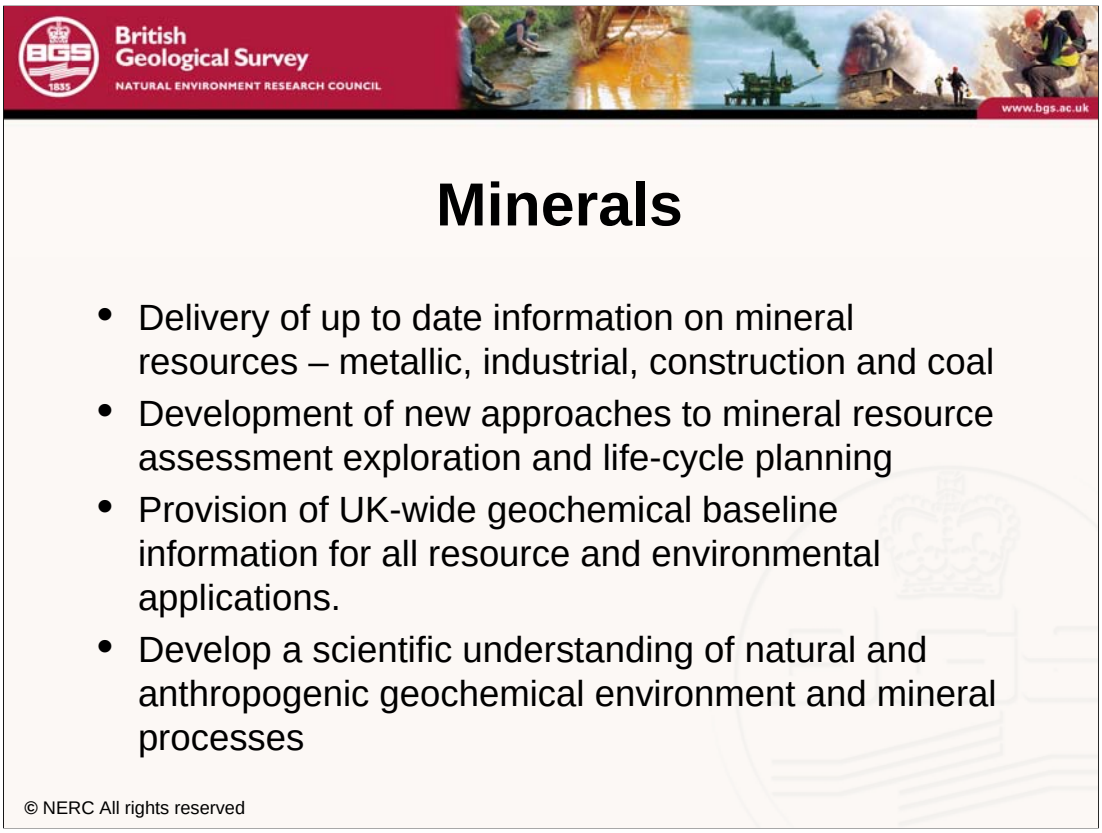


The geoscience geospatial database which is a 3-D model is a key development for which the system for integrated geospatial mapping will be the means of interrogation.

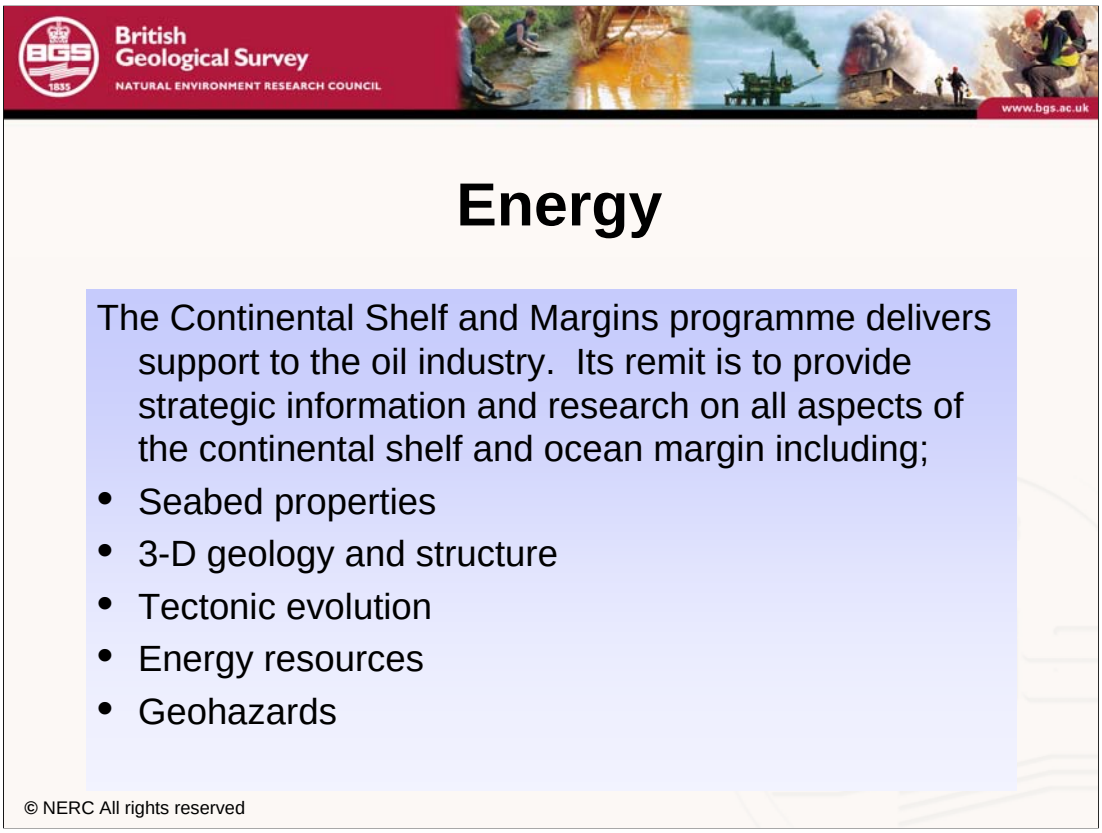
Corporate software developments include ESRI Arc8 for cartographic services, Oracle 91 portal services and B2B and B2C web services with click-pay and Virtual Private Network technologies.



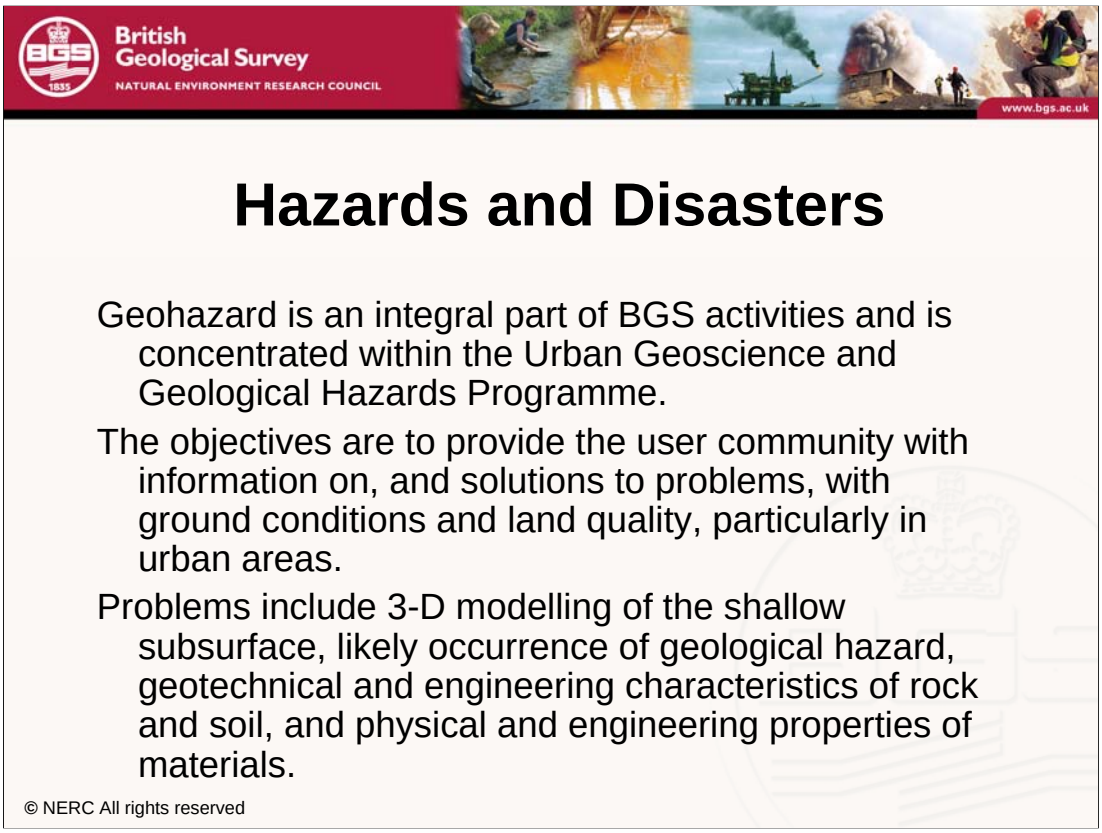
In the coming years the formulation of integrated coastal zone management through EU and other Directives may become increasingly influential. The BGS programme seeks increased involvement in integrated science programmes, a s well as initiatives with other suppliers of coastal data such as the UK Hydrographic Office.



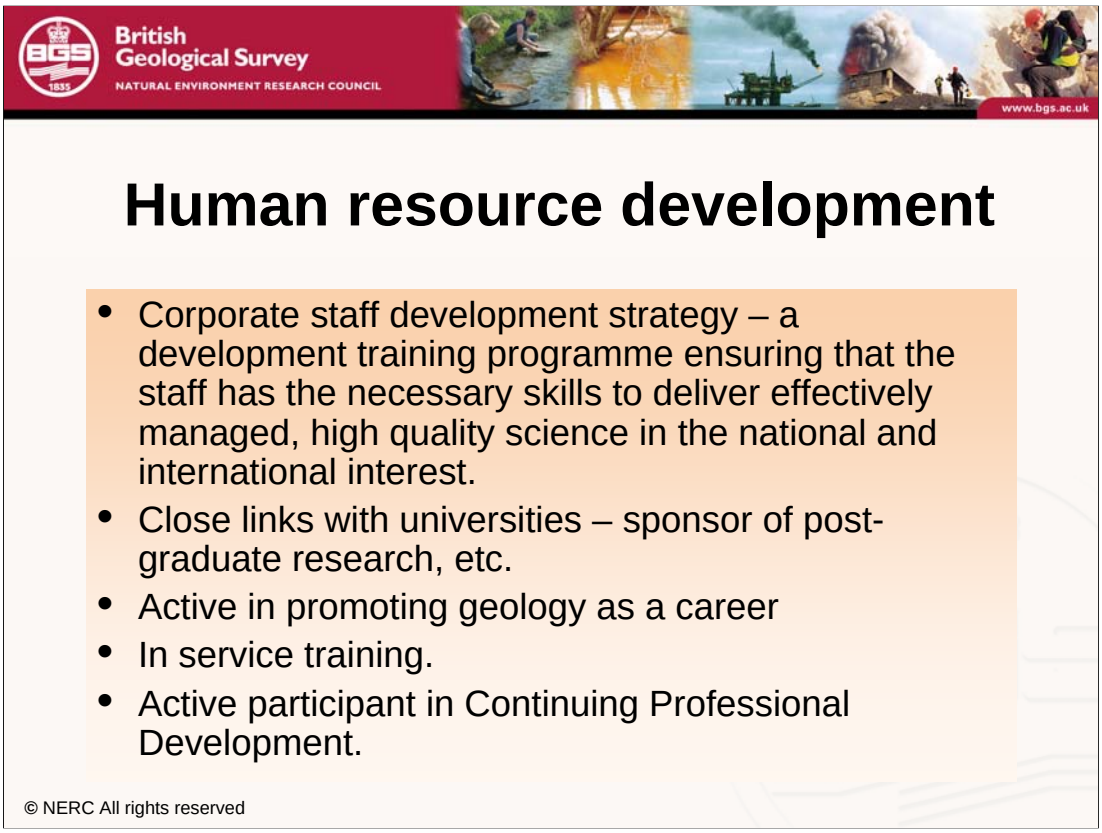
This programme has developed a wide range range of links with stakeholders keen to provide strategic solutions to key policy issues relating to land use and the supply, demand and transport of mineral commodities.



Current focus is the Atlantic margin, including 3-D structural and stratigraphic analysis, deep water sedimentary processes and geohazard. The programme has developed very strong links with the oil industry. BGS is not currently engaged in research into other facets of energy.

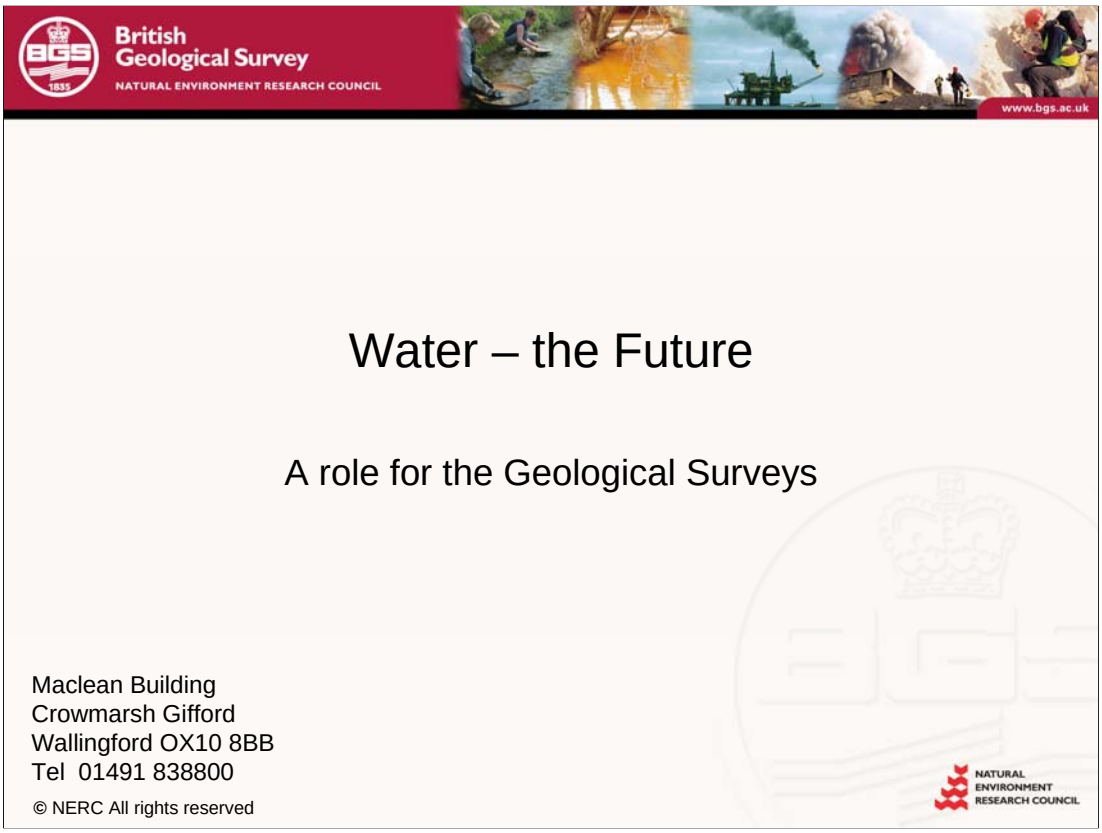


BGS rarely gets involved with disaster other than investigation into collapse or landslide.



Training and development is an important part of any Geological Survey. BGS also runs courses on a wide range of geoscience topics for both internal and external candidates,. Courses may be tailored for different audiences and are run all over the world. BGS staff are also active in providing lecture course modules to universities.

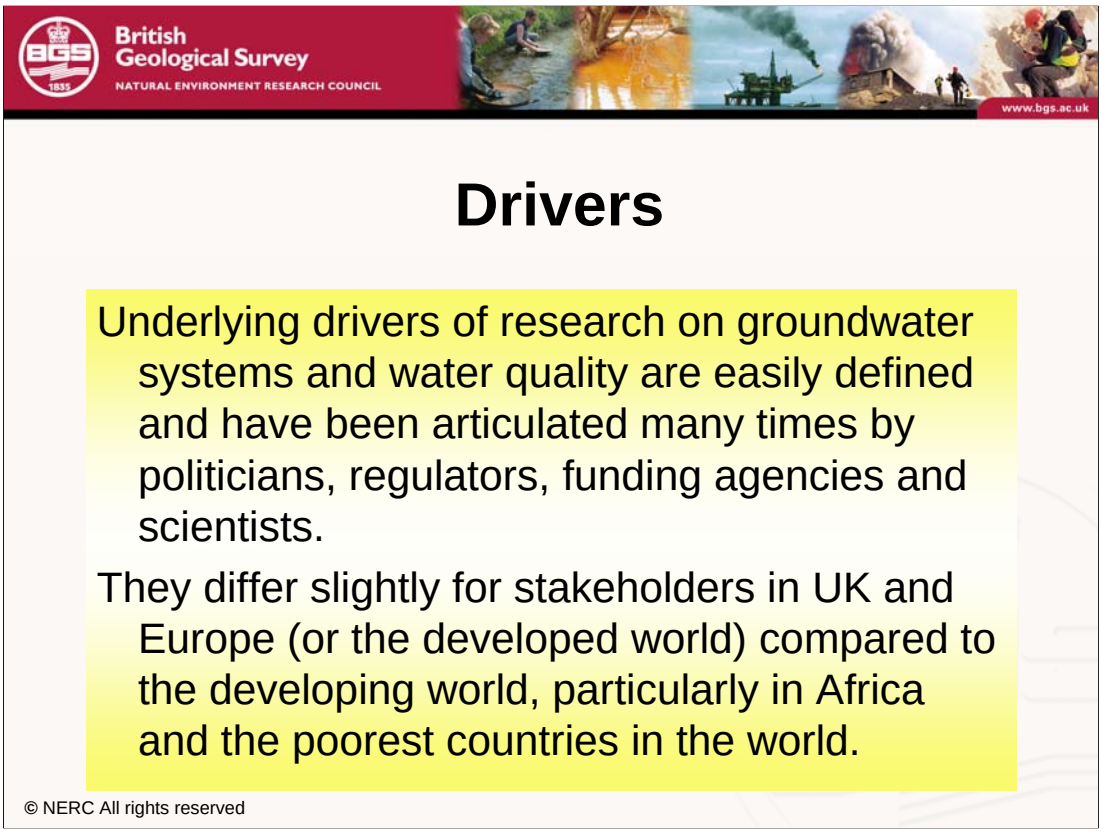
Bangladesh *(Jeff Davies, BGS)*



This presentation was prepared by Dr N S Robins at BGS. It is based partly on the water section of the BGS Horizon Scanning Report (2003) prepared by Dr D W Peach.

It included photographs by Jeff Davies taken in Sri Lanka and Bangladesh.

Any enquiries regarding this presentation should be sent to nsro@bgs.ac.uk .

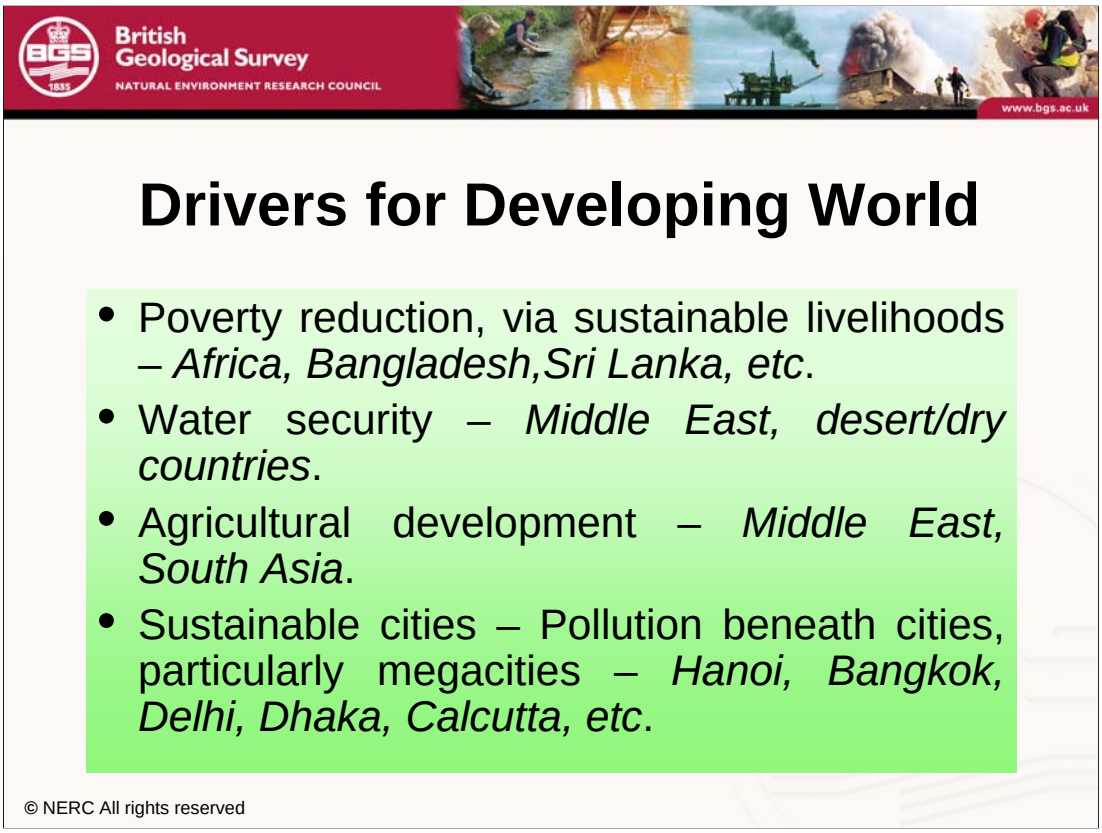


A driver may be a target like the Millennium Goals, a piece of legislation , like the European Water Framework Directive, or a global wish – poverty reduction, sustainable environment etc.

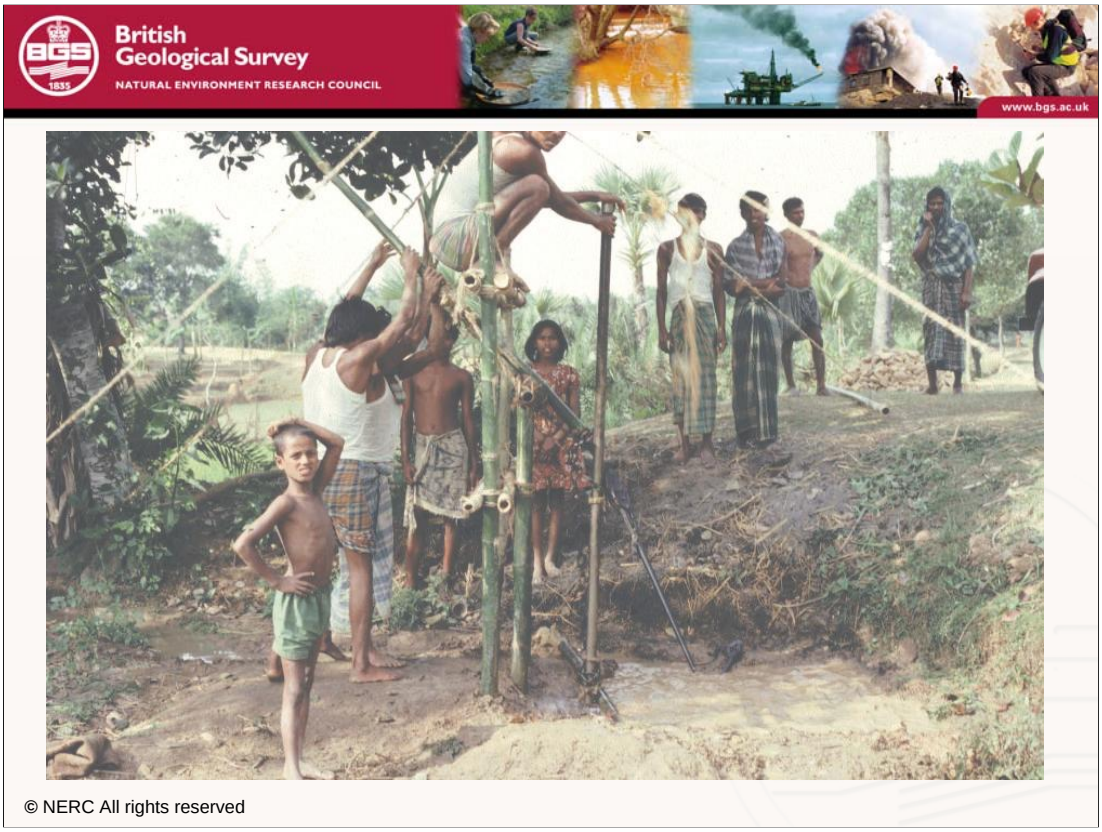
Although political drivers derive from local, regional or global politics they are, for the most part, reasonably uniform across the world.

The drivers for Europe centre around the EU Water Framework Directive which is currently being implemented by member states. It adopts a holistic catchment management approach and encompasses all the obvious political demands of the 21st century.

The Water Framework Directive will require characterisation of groundwater bodies by December 2004 and the subsequent designation of quantities and chemical status of groundwater and surface water.



Poverty reduction and water security are two key components in support of the UN Millennium Development Goals. To a large extent the two go together; safe and potable water is needed to sustain the family but additional water is needed to provide a livelihood, be it brick making, gardening or animal husbandry.



Hand drilling in Bangladesh *(Jeff Davies, BGS)*

See http://europa.eu.int/comm/environment/water/water-framework/index_en.html for more information.

Policies - Europe II

- Policies of the environmental regulators
  - To develop catchment abstraction management strategies by 2006 in England and Wales
  - Introduction of competitive trading of abstraction licenses, and time limited licensing.
- Policies of the water industry economic regulators
  - Driving down costs to the consumer.

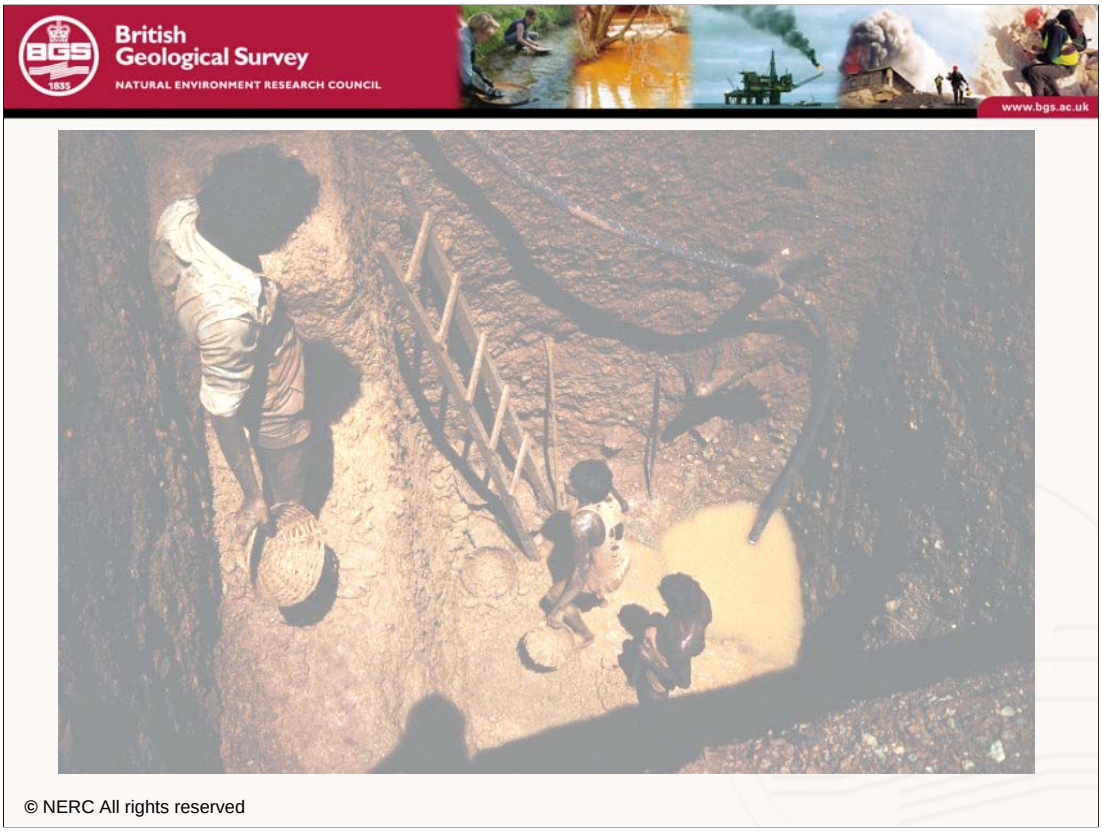
Individual regulators and the water supply industry devise their own policies in line with incoming Directives from the EU. The regulators are the recognised national implementers of the Directives, whereas the water industry needs to comply with the regulators interpretation of the Directives.

The Millennium Development Goals rely heavily on groundwater development and groundwater protection to be achieved. However, the MDGs come with no new money and require to be implemented under existing resource constraints. They remain a useful challenge for the hydrogeological community.

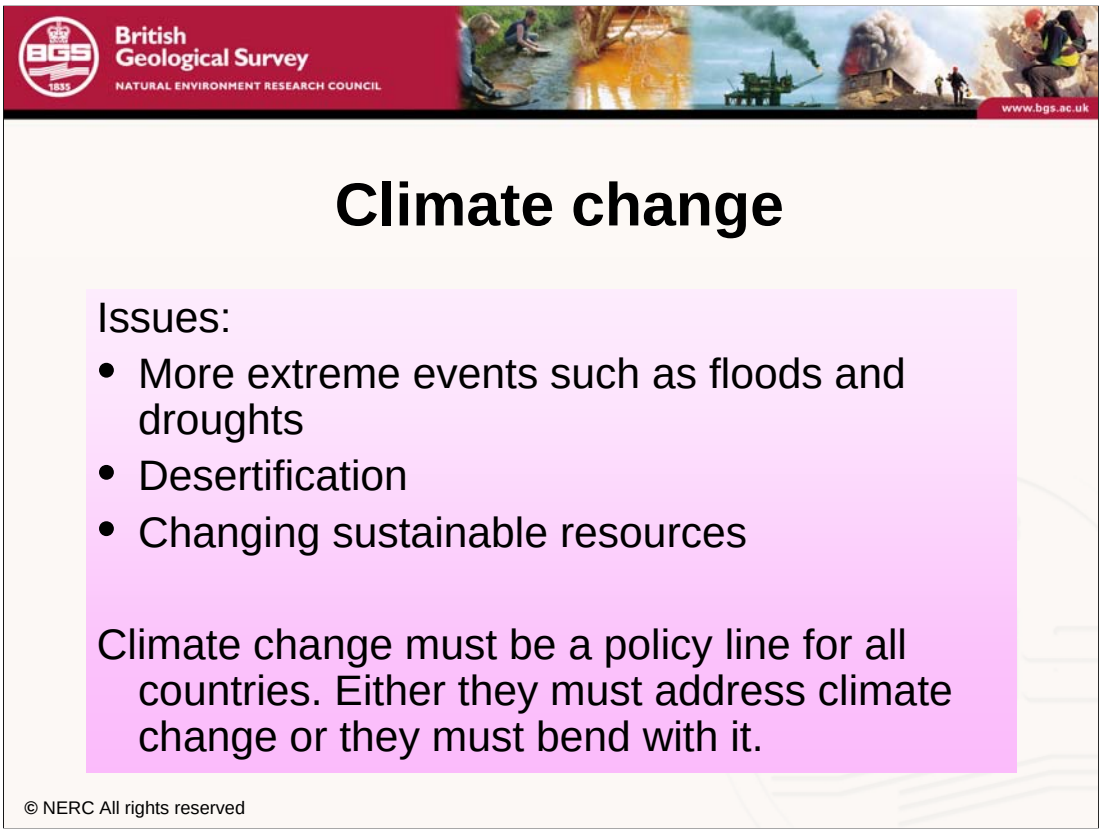
Decentralisation and community based management provide some interesting problems. Although they place ownership firmly at the door of the community, they remove the coordination that was previously possible through central or regional control. Solutions lie in the integration of the technical social and economic issues so that support can be provided at village level through a proper reporting hierarchy.

See http://www.developmentgoals.org/ for full details of the MDGs and of the September 2000 UN Millennium Summit.

The MDGs clearly have implications for water supply and sanitation that need to be taken aboard by all practicing hydrogeologists and hydrologists.

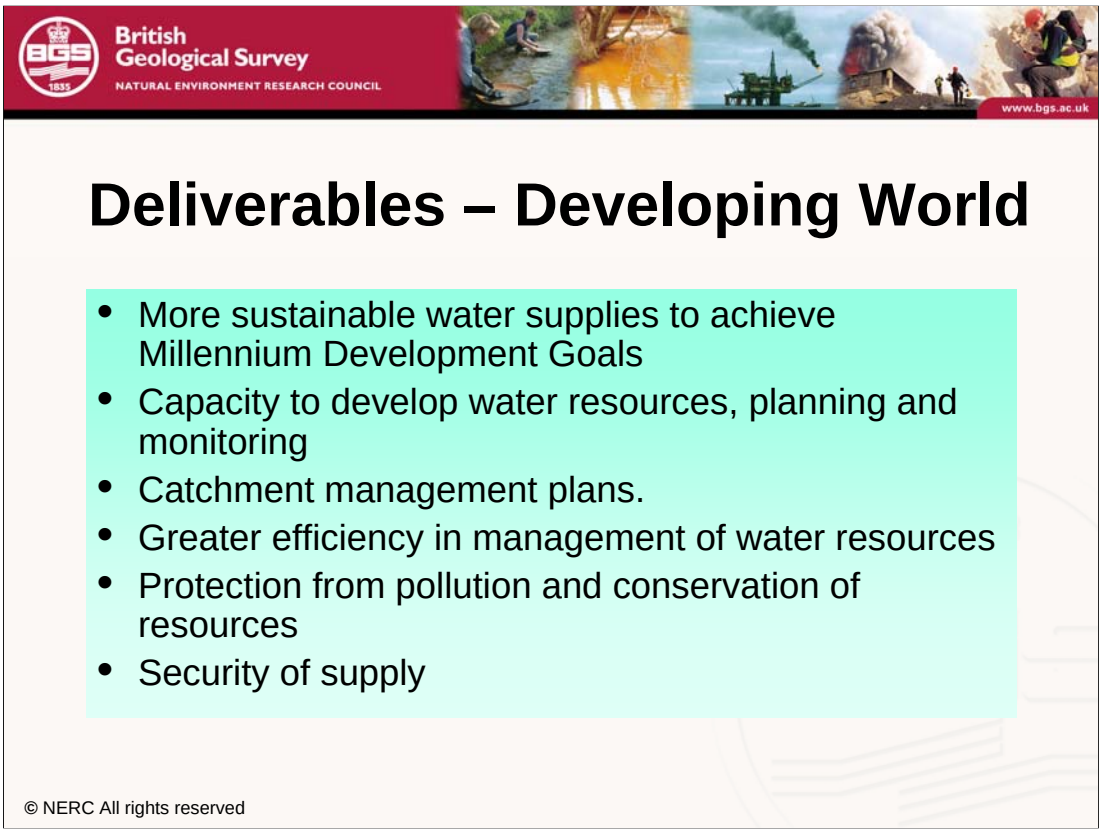


Gem pit in Sri Lanka *(Jeff Davies, BGS)*

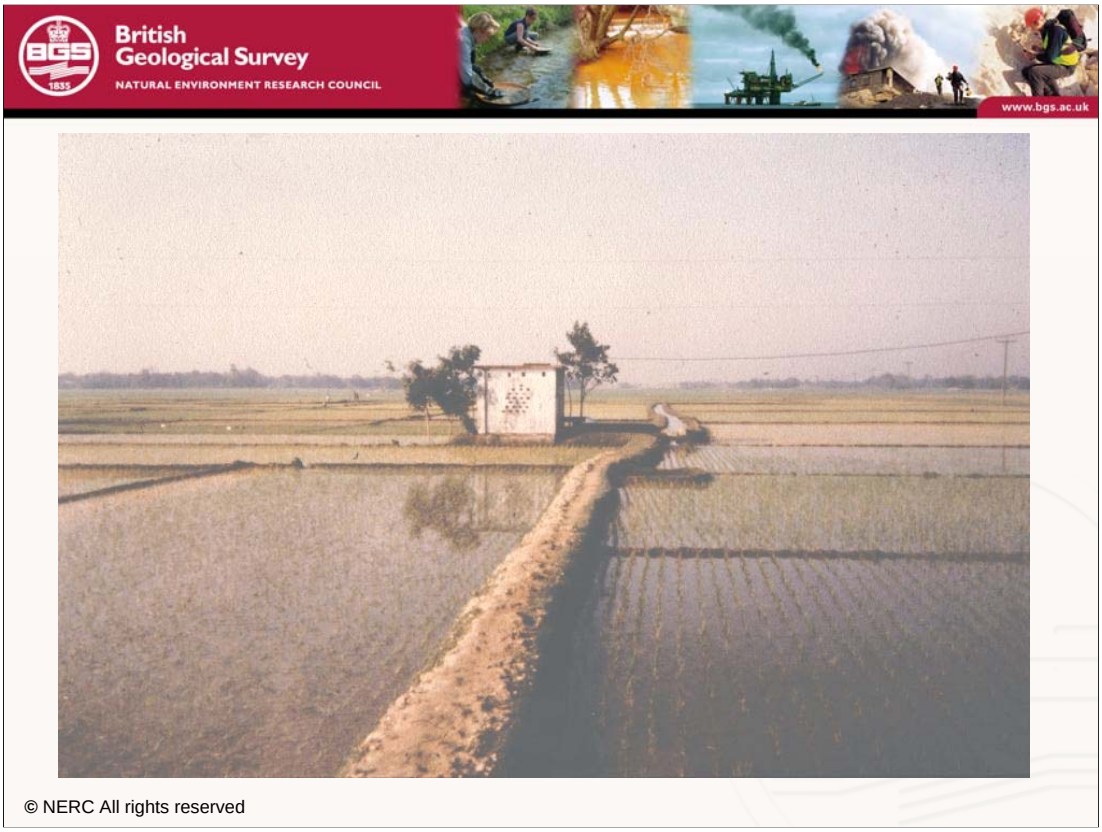


Climate change or increased climate variability is a phenomenon that is affecting us all. Consequences included changed effective rainfall, changed rainfall patterns and changed groundwater and surface water resource potential. This has clear implications for planners in countries where flood or drought events have become endemic.

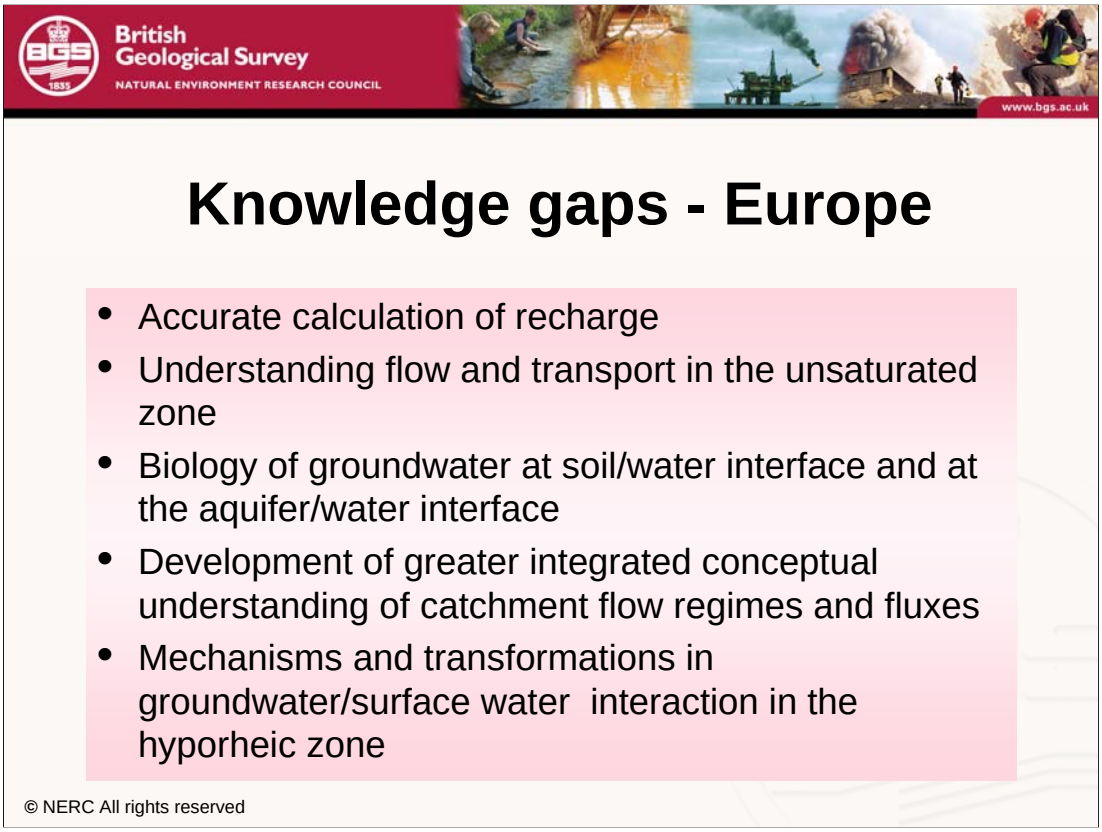
Forthcoming deliverables in Europe include those needed to satisfy the EU Water Framework Directive, but also make easy tools so that non-specialists can make technical decisions using decision support systems. The latter brings with it a culture of doming down hydrogeology. Integration of hydrogeology within a new overall science of "catchmentology" may further reduce the profile of hydrogeology.



Clare Short, UK Secretary of State for Overseas Development said at the Johannesburg Summit in September 2002 that the time for talking had finished and the time time for action was now. Key action is the delivery of sustainable safe and potable water supplies to all communities the world over. This requires planning, catchment management, efficiency of water use and protection from pollution.



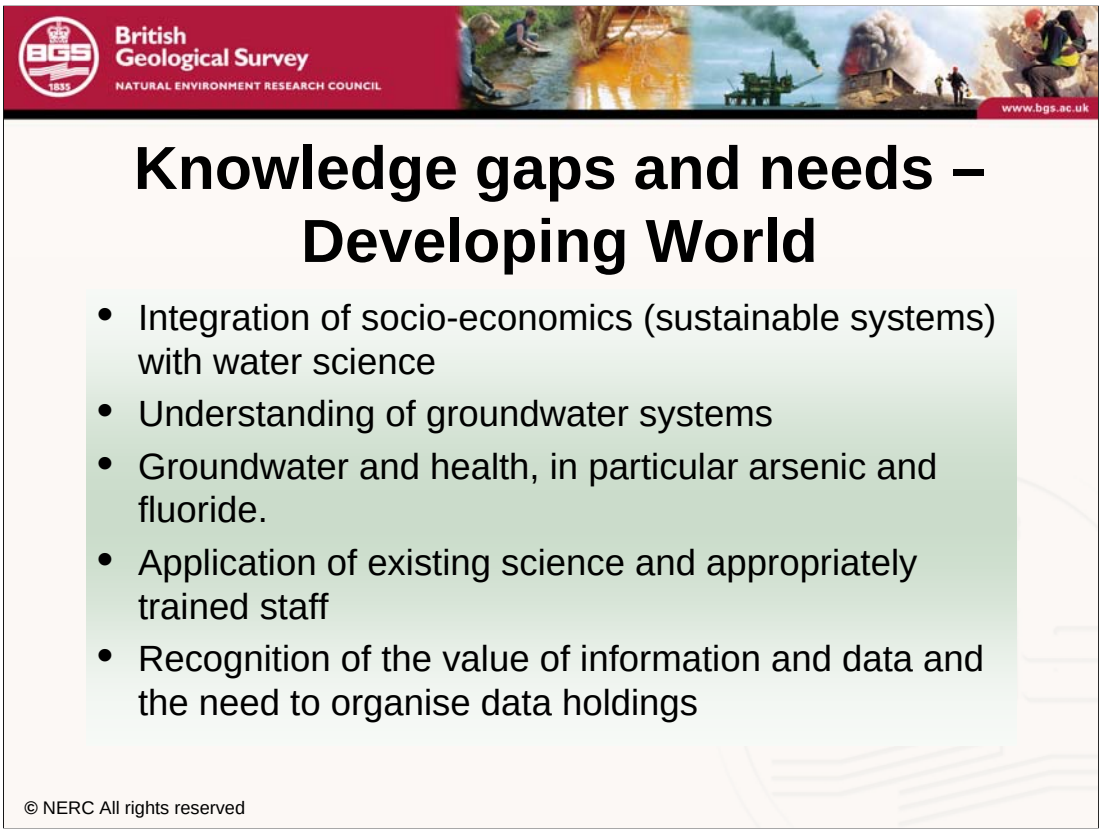
Pump house, Bangladesh *(Jeff Davies, BGS)*



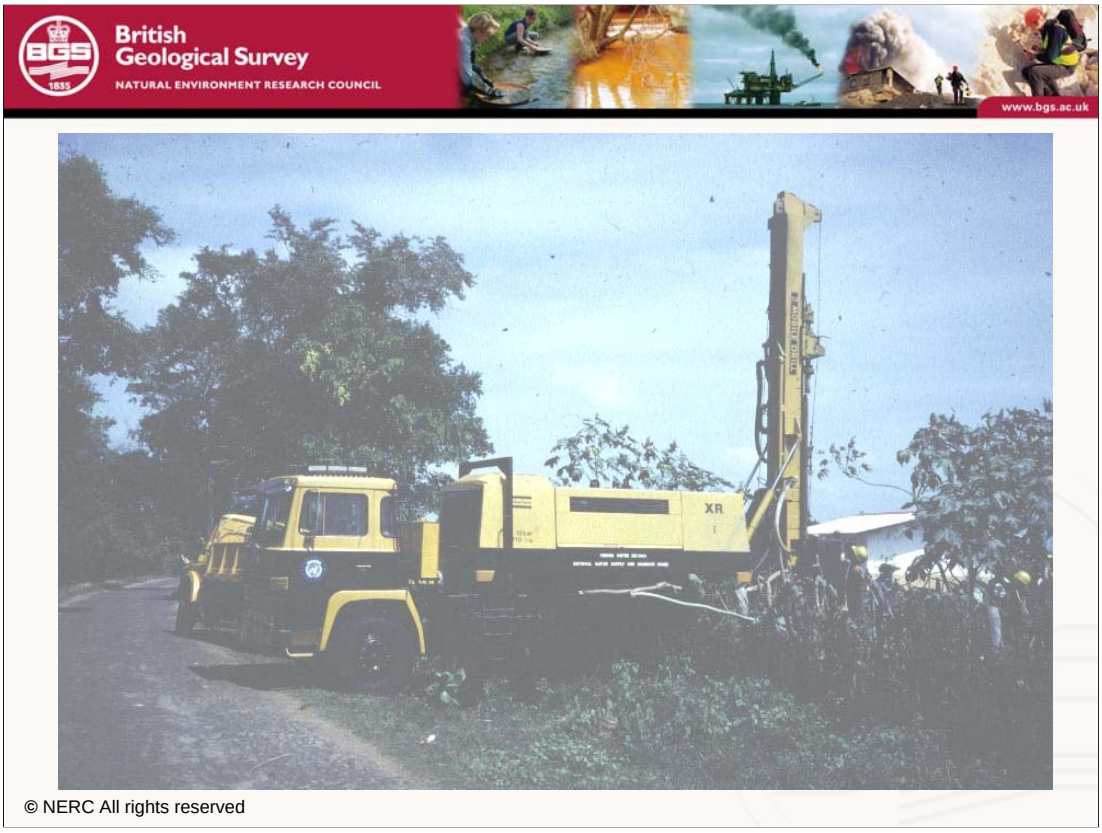
These areas of uncertainty are not unique to Europe. The first, that of recharge calculation, is a universal problem that can only usually be solved by expensive data collection, analysis and modelling.

Knowledge gaps – Europe II

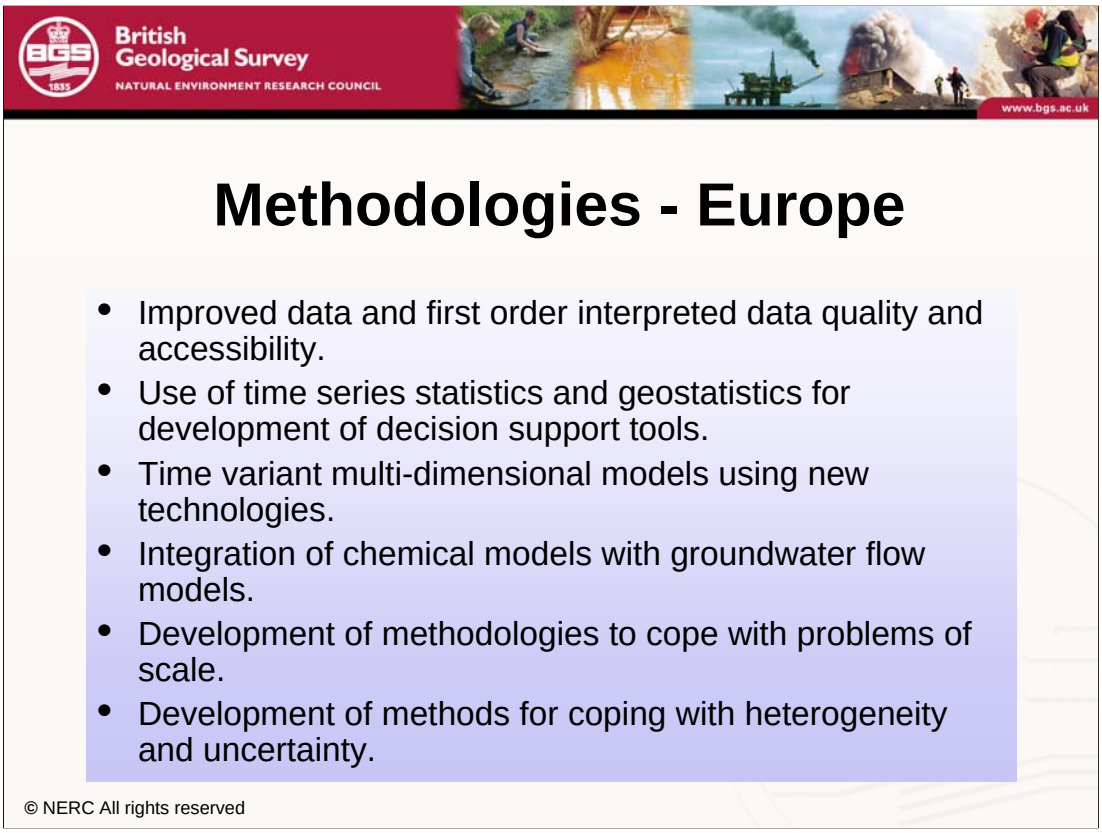
- Understanding generation of runoff and spring flows and the role of groundwater
- Groundwater flooding issues, and the role of groundwater in overland (apparently surface water) flooding
- Groundwater and health issues, including fluoride, arsenic, selenium and organics (including pesticides) and issues of ecotoxicology and groundwater.



The developing World has the same knowledge gaps as Europe. In addition it has the specific areas of uncertainty shown in this slide. The basic premise remains the application of existing technology by appropriately trained personnel.



UNICEF down-the-hole hammer drilling rig in Sri Lanka *(Jeff Davies, BGS)*

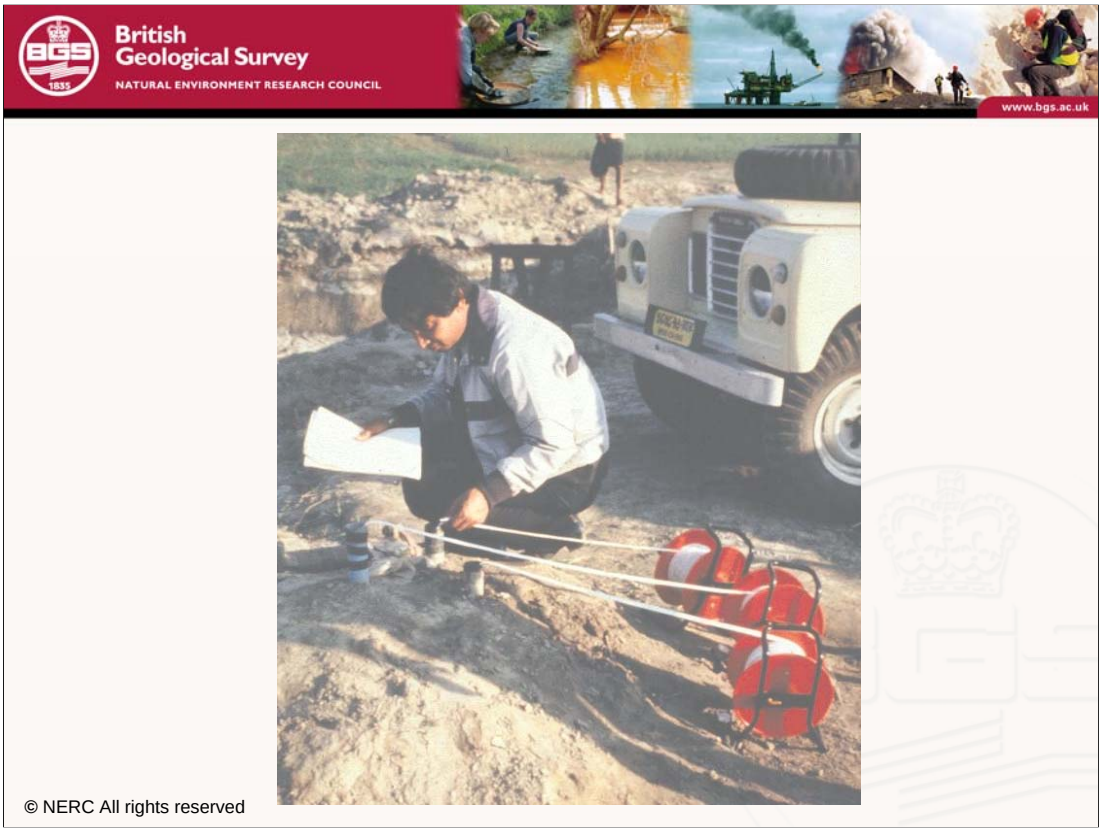


Improved data access includes data such as lithology, thickness and type of cover and soil.

New technologies for time variant multi-dimensional models include integration with stochastic approaches and new code such as object oriented code.

Problems of scale include upscaling such as fracture to catchment, and down scaling, such as years days minutes seconds.

The role of data is so often under-estimated. Data needs to be accessible and available in a user friendly form. It is commonly stored on a geospacial database such as a GIS so that useable reports can be produced on a geographic basis. If is not accessible it will not be used.



Triple piezometer observation borehole in Bangladsh *(Jeff Davies, BGS)*

Down hole geophysical tools could be developed to measure parameters used in modelling flow and transport. Examples of recent developments include chemical sondes and video scanning.

Remotely sensed monitoring could be satellite monitoring of drought conditions or of floods.

A role for the Geological Surveys

The Geological Surveys need to deliver the requirements of the 21st century. In collaboration with Departments of Water they remain the key instrument between government and the applied world to guide the development and management of groundwater resources for the satisfaction of the world's poor.

The Geological Surveys have a vital role to play in the reduction of poverty and the increased well-being of the people.

British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

The Bangladesh groundwater arsenic problem

D G Kinniburgh, P L Smedley, J Davies, C J Milne, J M Trafford, S Burden, S M I Ihtishamul Huq, N U Ahmad, K M Ahmed

Funding: UK Department for International Development

Presented at ISEG 2003, September 11th 2003, Edinburgh

Maclean Building
Crowmarsh Gifford
Wallingford OX10 8BB
Tel 01491 838800

www.bgs.ac.uk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TETULIA R.
SHAHAZPUR CHANNEL
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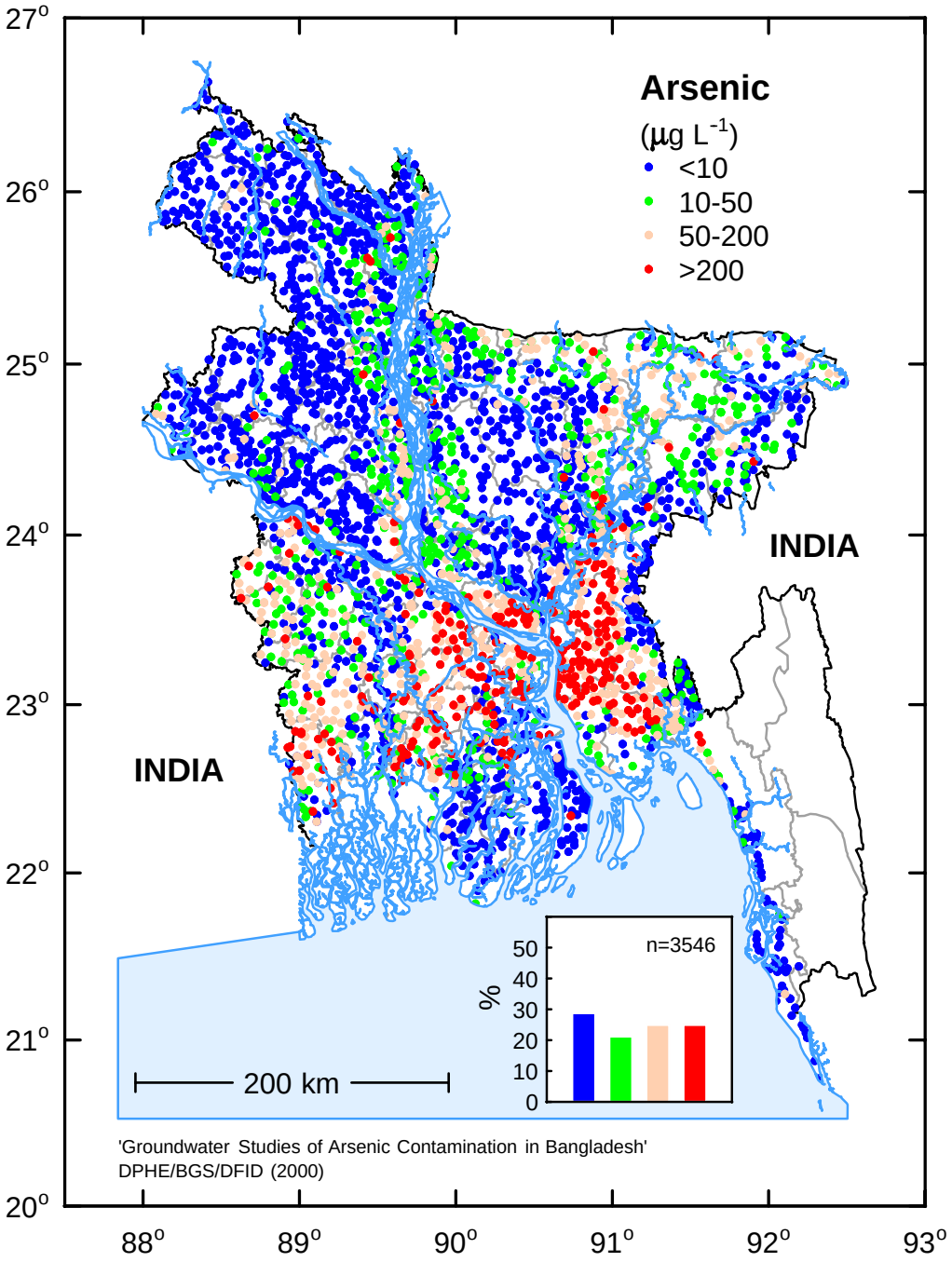
Arsenic
(µg L-1)
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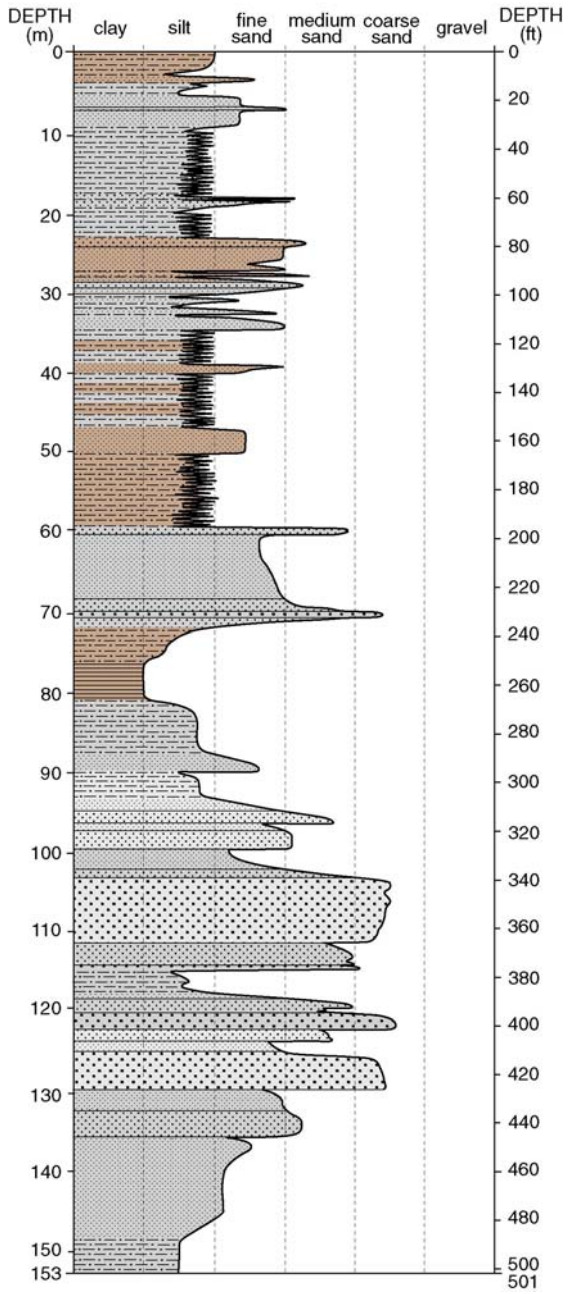
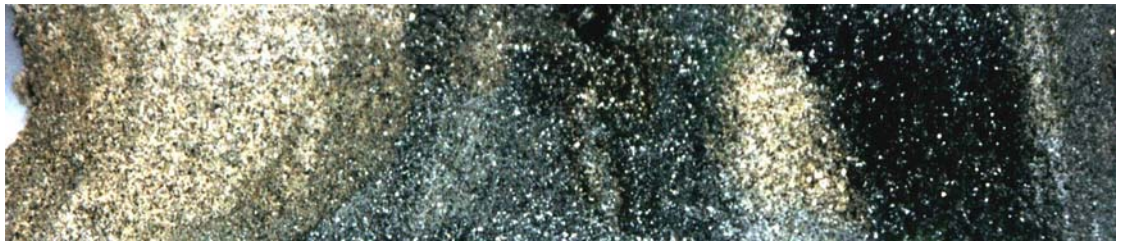
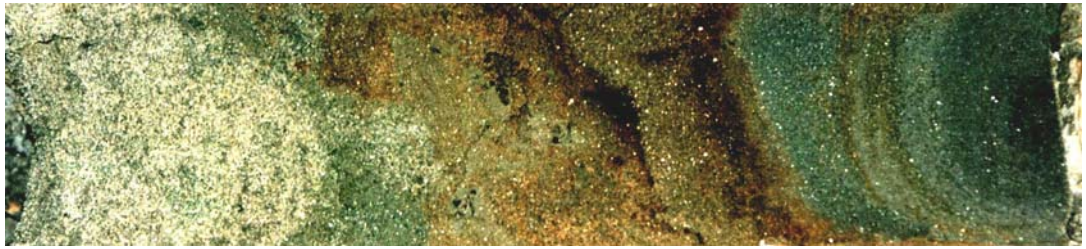
10
0
200 km
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

LAKSHMIPUR TEST BOREHOLE

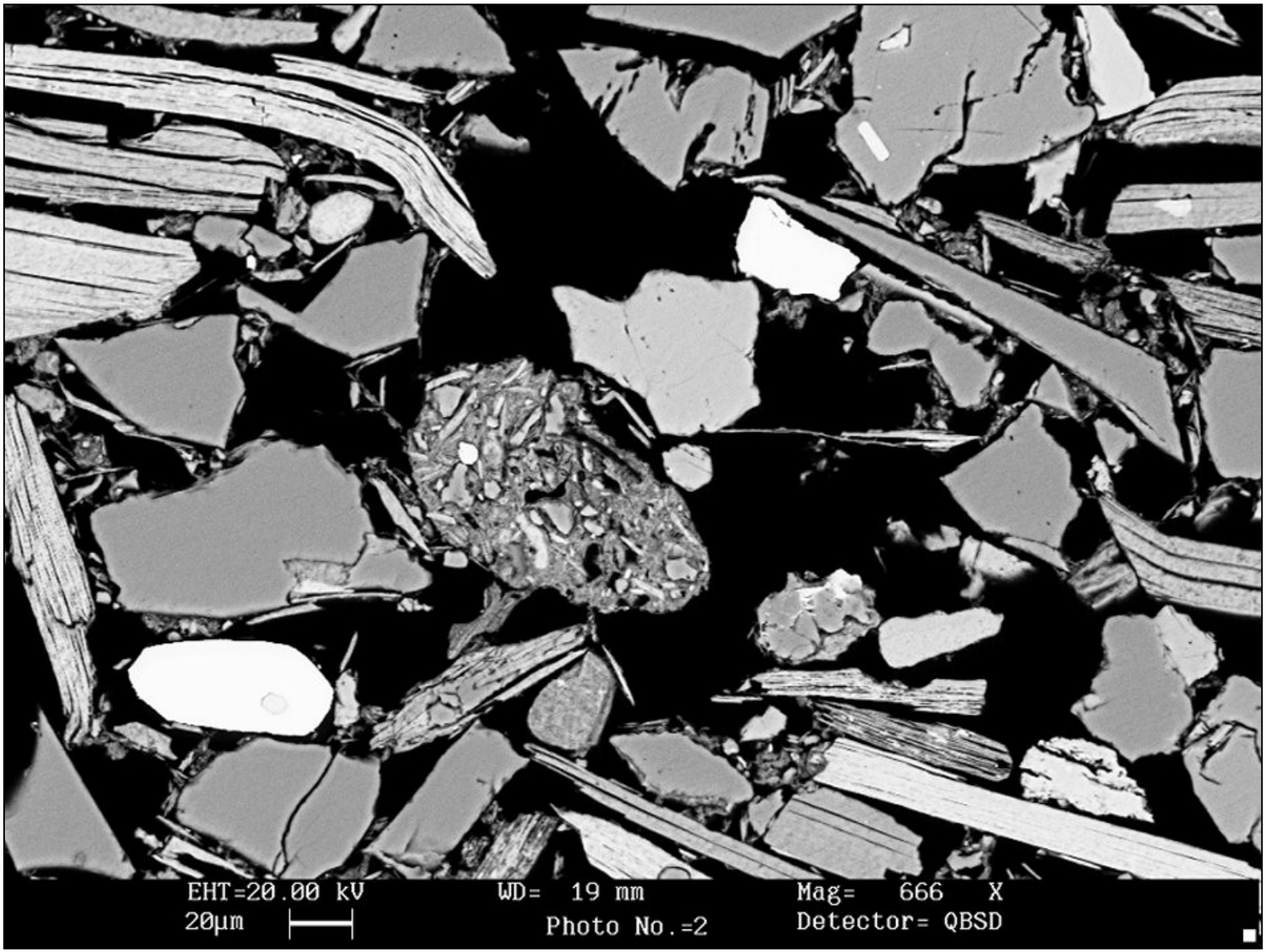




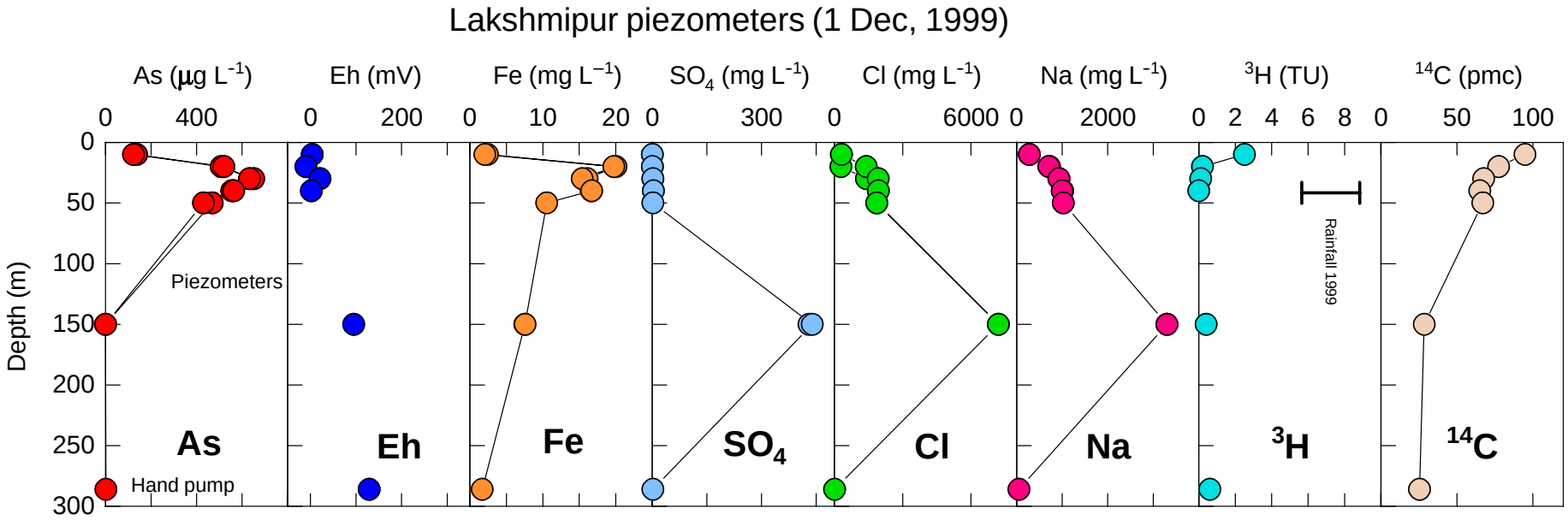


Lakshmipur

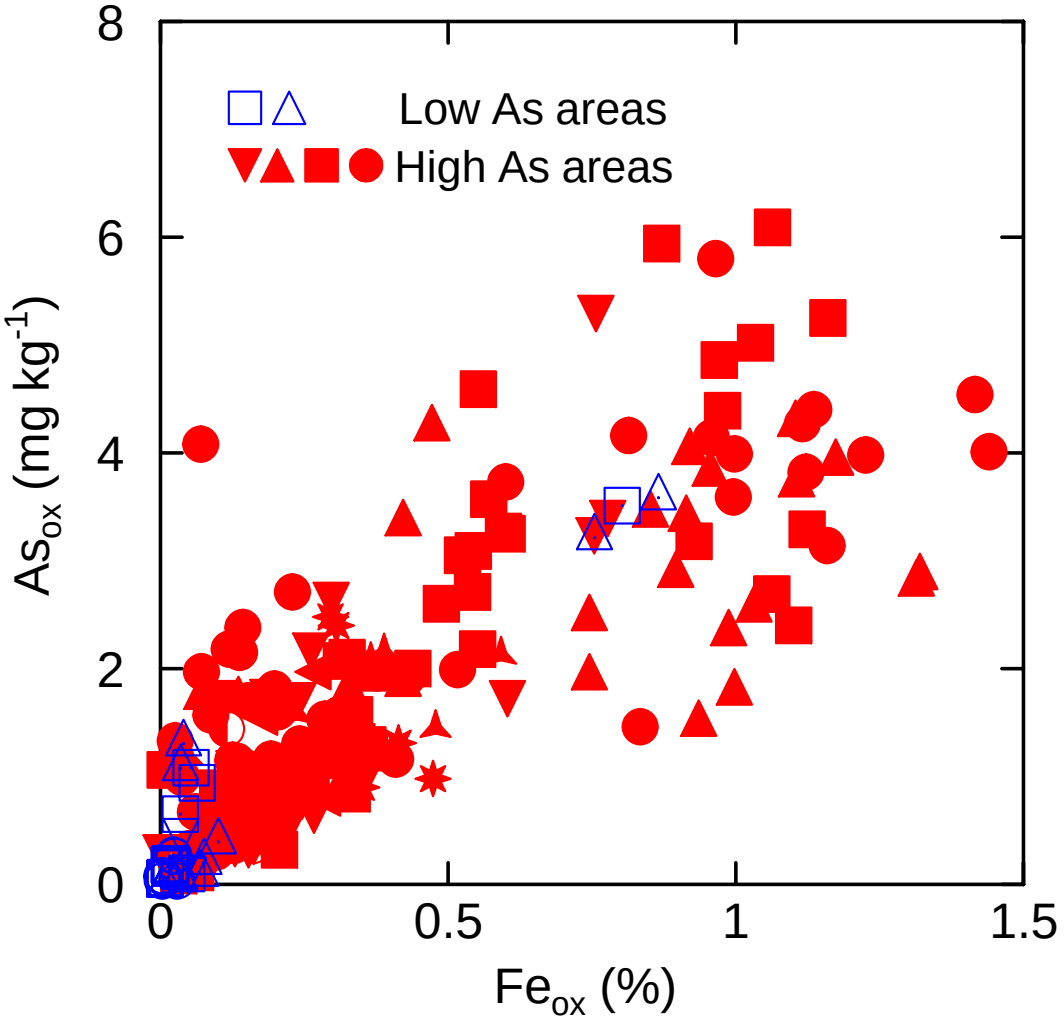
SEM




PIEZOMETER NEST-3
GROUNDWATER STUDIES FOR ARSENIC CONTAMINATION
IN BANGLADESH.
DEPARTMENT OF PUBLIC HEALTH ENGINEERING(DPHE)
TECHNICAL ASSISTANCE: BRITISH GEOLOGICAL SURVE
FUNDED BY: DEPARTMENT FOR INTERNATIONAL
DEVELOPMENT(DFID)
DPHE COMPOUND. LAKSHMIPUR SADAR.


Lakshmipur piezometers (1 Dec, 1999)
As (μg L-1)
Eh (mV)
Fe (mg L-1)
SO4 (mg L-1)
Cl (mg L-1)
Na (mg L-1)
3H (TU)
14C (pmc)
Depth (m)
Piezometers
Hand pump
Rainfall 1999
As
Eh
Fe
SO4
Cl
Na
3H
14C

Oxalate-extractable Fe and As



- 35 million people drinking water with > 50 µg/L As
- Problem worst in SE Bangladesh
- Processes leading to arsenic release and transport are not well understood quantitatively
- Short-term solutions include well switching/potable vs non-potable wells, (treatment)
- Long-term solutions include finding a low As source (rainwater, shallow dug well, deep well, treated surface water)
- No universal solution

Arsenic contamination of groundwater

Arsenic is highly toxic and carcinogenic. Groundwater is particularly vulnerable to contamination with arsenic as a result of natural geochemical processes and problems can be exacerbated by mining activity. Even natural concentrations of arsenic in groundwater can limit its suitability for drinking.

Keratosis sufferer

It is now apparent that arsenic contamination of groundwater is quite extensive. In the last eight years, BGS has undertaken a series of collaborative investigations into the arsenic contamination of groundwater in various countries. These investigations have included both 'mining-related' and 'natural' sources of arsenic contamination. Many of these have been undertaken with support from the UK Department for International Development (DFID).

DFID

Bangladesh Phase 1	**Bangladesh Phase 2**
Ghana	**Arsenic Contacts**

Bangladesh claims against the British Geological Survey

British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Minimising fluoride in drinking water in problem aquifers

DFID KaR project: R8033

Maclean Building
Crowmarsh Gifford
Wallingford OX10 8BB
Tel 01491 838800

www.bgs.ac.uk

DFID Department for International Development

Fluoride in drinking water

Project objectives

- Investigate the spatial distribution of fluoride in groundwater
- Investigate causes of high fluoride in water
- Assess degree of predictability
- Provide practical guidelines on well siting and construction to alleviate the problem
- Ultimately – improve community health

Partners

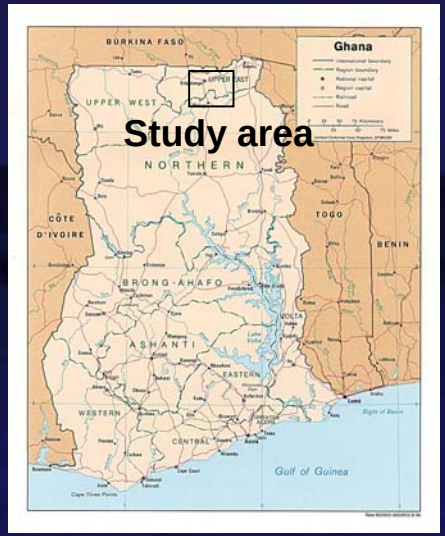
- British Geological Survey (Wallingford, Edinburgh)
- University of Dar es Salaam (Tanzania)
- University for Development Studies (Ghana)
- WaterAid (Tanzania and Ghana)

Phase I

- Aug 2001 – Dec 2002

- Collate existing fluoride data
- Carry out reconnaissance field studies of selected areas - Ghana and Tanzania
- Training of local partners including MSc student (Tanzania)
- Complete report on initial findings

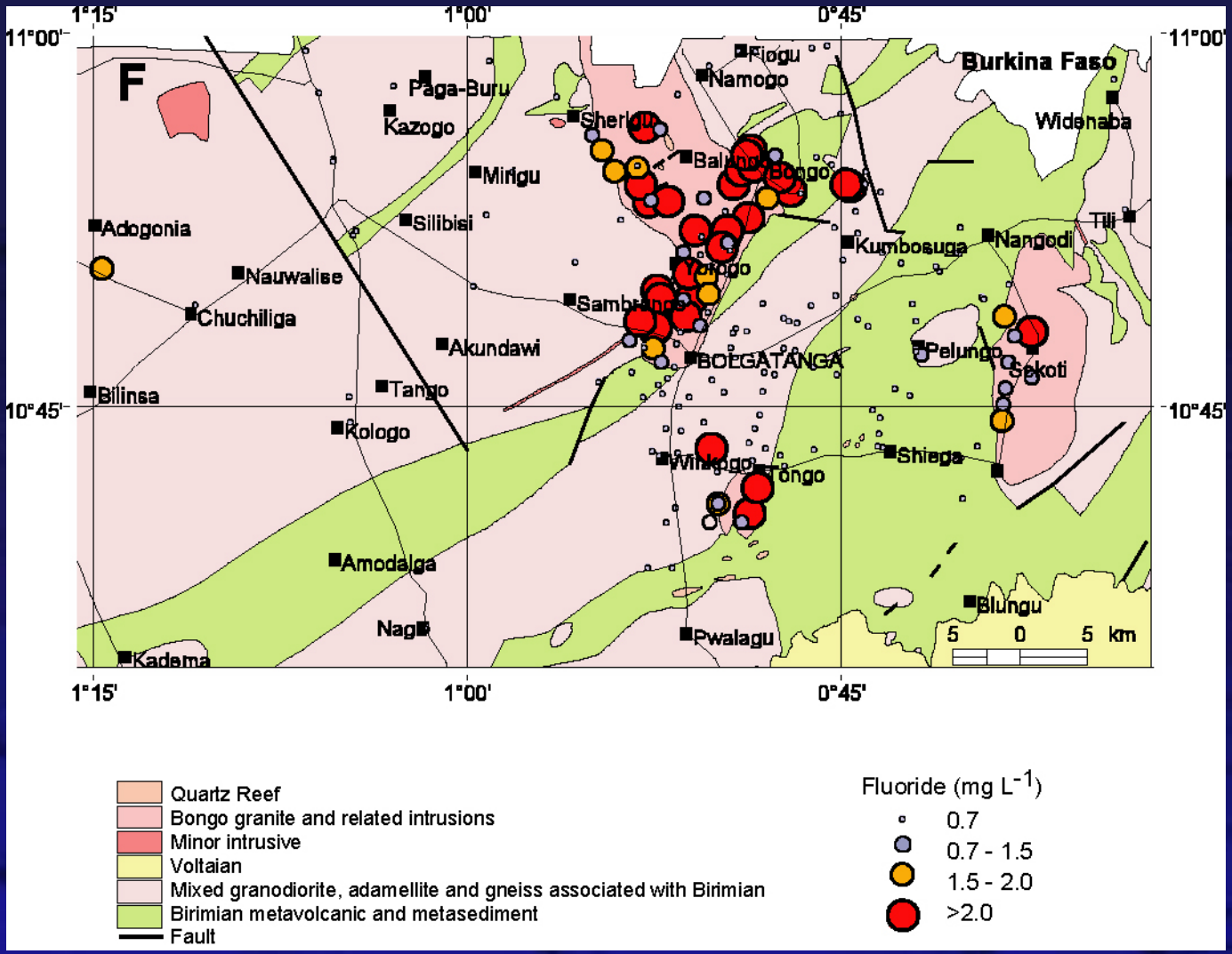
Study areas



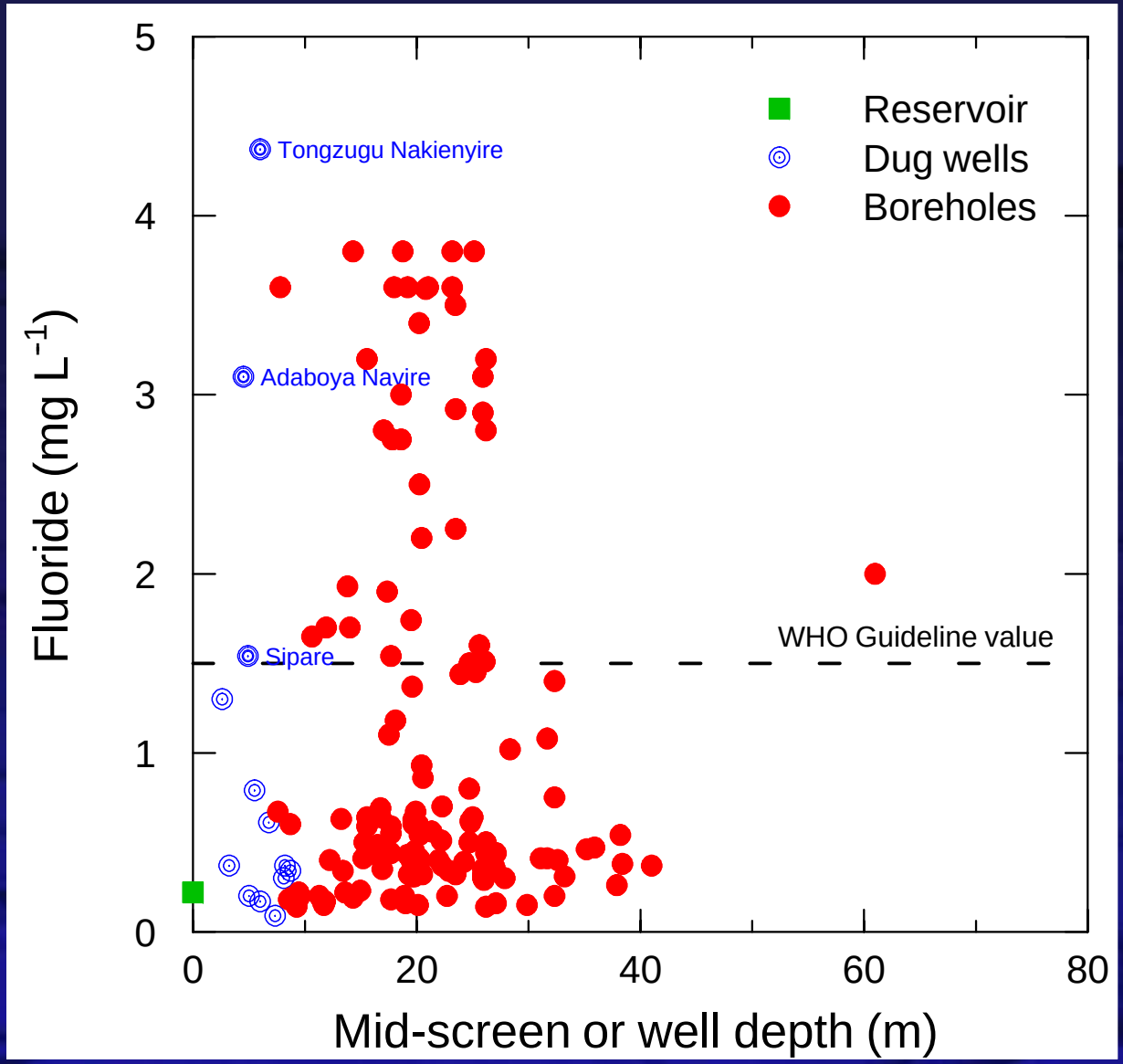
- Ghana
- Bolgatanga area, Upper East

- Semi-arid, mostly rural
- Groundwater - dominant source of water
- Dug wells, boreholes
- Hard rocks (granitic, metamorphic rocks)
- Weathered overburden

- Dental fluorosis



Fluoride in groundwater, Bolgatanga, northern Ghana



Fluoride concentration vs depth in Bolgatanga area, Ghana

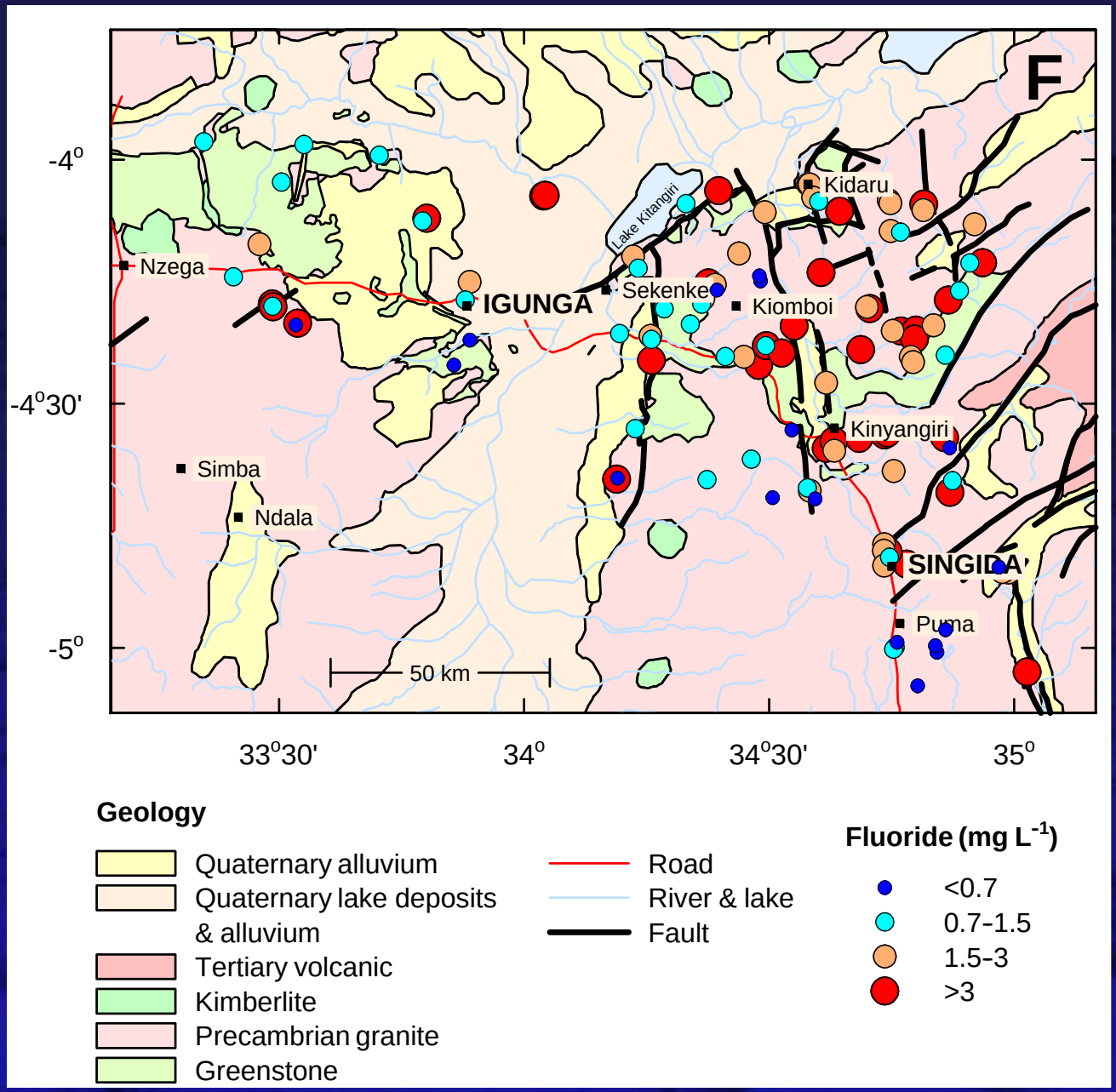
Study areas

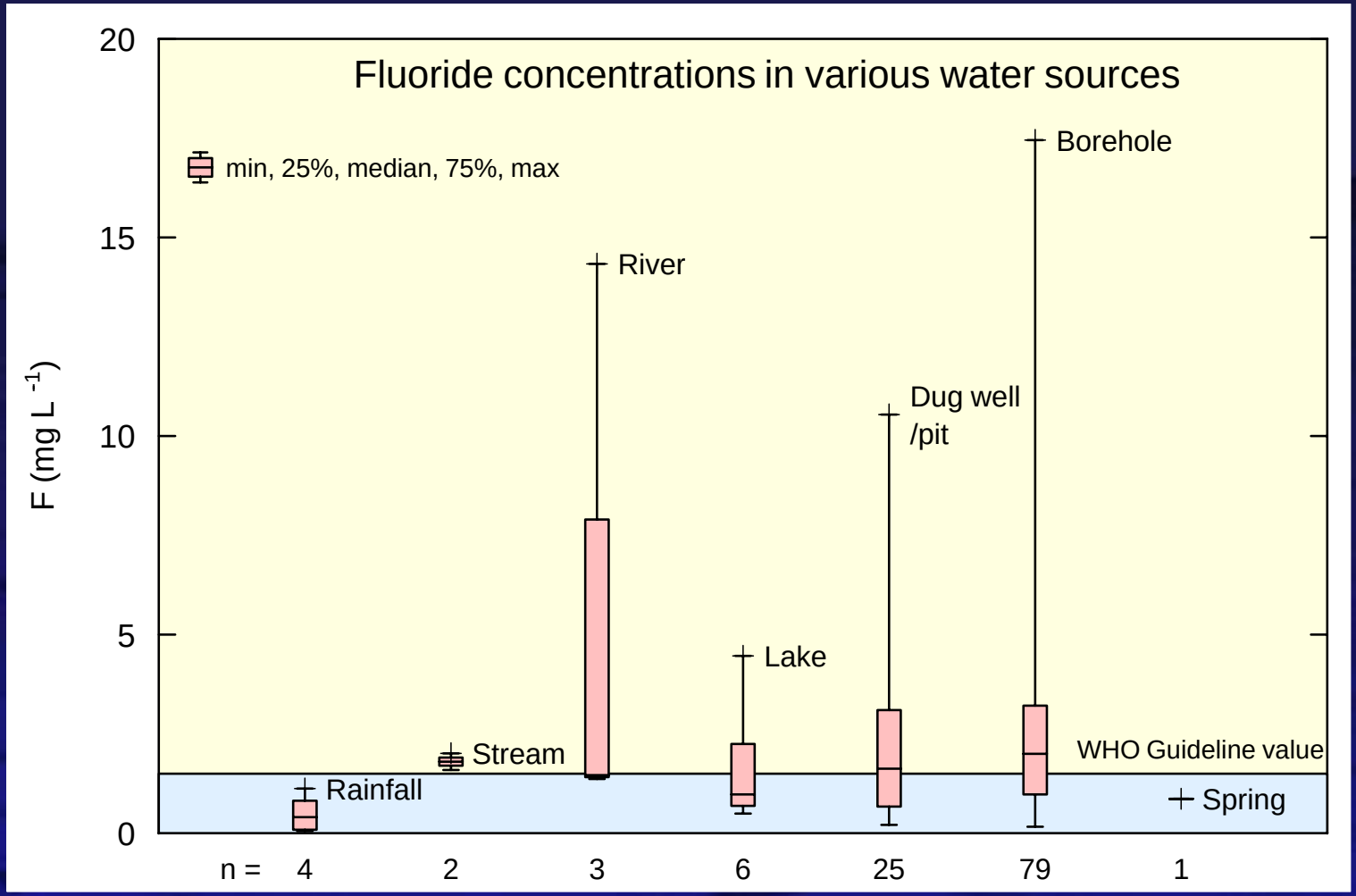
- Tanzania
- Singida-Iramba-Igunga

- Semi-arid - water scarcity
- Groundwater dominant (wells, boreholes)
- Dugouts, ponds and lakes
- WaterAid water-supply programme

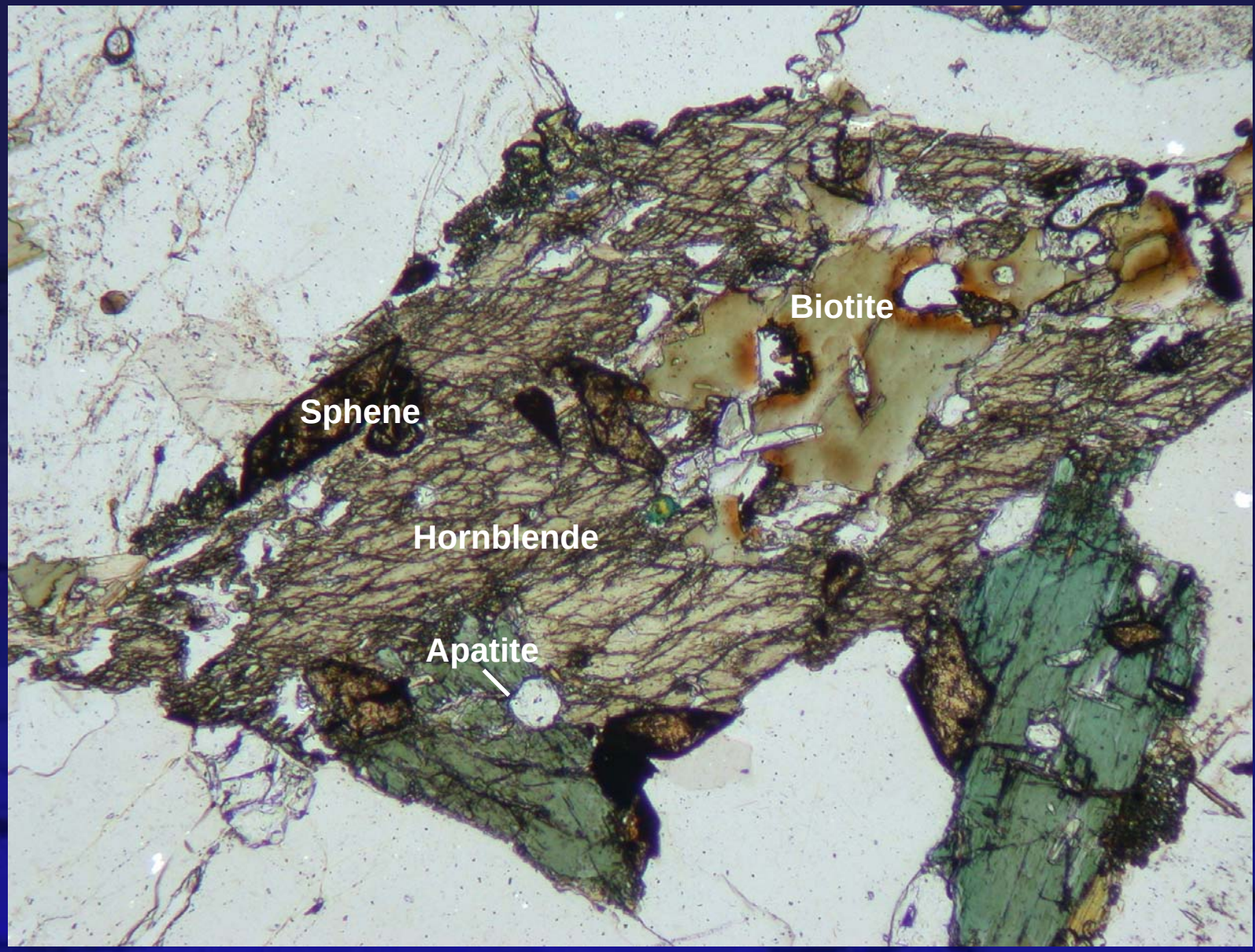
- Dental fluorosis

Fluoride in groundwater, central Tanzania

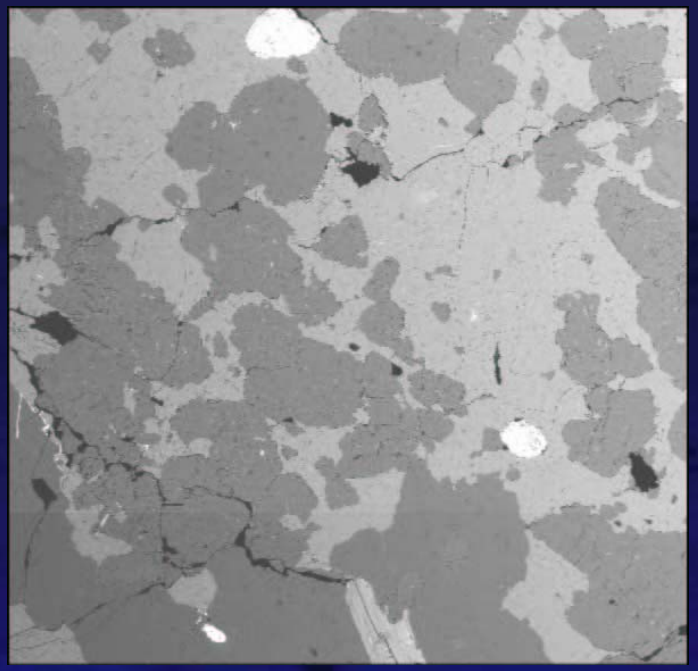


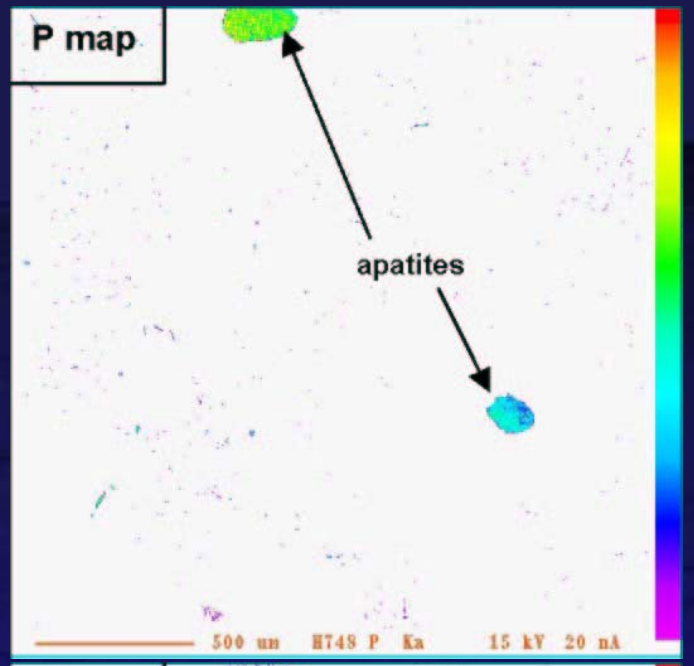


Relationship between fluoride concentration and water source, central Tanzania



Fluoride-bearing minerals in the Bongo Granite, Ghana





Fluoride-bearing apatite in granite, Tanzania

Other elements of health concern

- Ghana
  - U, NO_3, NO_2, As
  - U: 10% > WHO guideline value
- Tanzania
  - U, NO_3, Ba, As, Mn, Se, NO_2, B, Mo, Ni, Pb
  - U: 69% > WHO guideline value
  - Salinity also a common problem