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Completion plan for the Geochemical Baseline Survey of the Environment (G-BASE)

LAND USE PLANNING AND DEVELOPMENT Programme

Internal Report IR/11/065

BRITISH GEOLOGICAL SURVEY

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Completion plan for the Geochemical Baseline Survey of the Environment (G-BASE)

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Summary

In response to NERC national capability (NC) prioritisation which seeks to end systematic regional geochemical mapping, this report contains options and recommendations for the completion of a national geochemical baseline by the G-BASE project by 31st March 2016. The plan delivers samples and analyses from southern England, an area estimated to be 35,500 km^2, approximately 7,000 km^2 of which is underlain by Chalk (and so would be unsuitable for drainage sampling).

A number of options for completing a national geochemical baseline are presented based on the current G-BASE strategy but with an overall reduced sampling density. The Panalytical arrangement for XRFS analysis until January 2016 substantially reduces the analytical budget required, and is therefore a most important criterion of the completion plan. However, the Panalytical deal should not be the sole factor that drives the strategy for finishing off G-BASE. In order to maximise the science and opportunities for collaborative research secondary options are proposed for the collection of a variety of sample media from areas of greatest environmental interest. These secondary options will require additional funding to complete the non-XRFS analyses of samples which could include contributions from external organisations.

The proposed work plan is primarily concerned with the "observe and monitor" part of NERC national capability. It excludes any proposal for the data interpretation, modelling and knowledge exchange, and adding value to current geochemical baseline tasks (*e.g.* London Earth and Clyde Basin) or anything beyond the data gathering phase of completing the geochemical mapping of southern England. It is important that the completion plan does not drive the BGS geochemistry activity into just a sample and data gathering exercise. We must continue to deliver science and information outcomes alongside completing the G-BASE baseline or we will lose the capacity to deliver any science in the future.

The preferred option involves the collection of approximately 8,200 stream sediment and water samples and 1,700 soil samples. There are nearly 1000 Mineral Reconnaissance Programme (MRP) stream sediments from SW England in NGDC and that can be incorporated into the plan and thus reduce the amount of fieldwork required for sample collection. The plan fully utilises the Panalytical quota of "G-BASE" of approximately 11,300 samples over four years (2012-16). In the overall context of team and programme planning, finishing off the G-BASE mapping should not compromise the budgets of other projects rated with a higher priority.

A programme to collect drainage and soil samples, and analyse the stream sediment and soils over four years, including data management, is estimated to be £661k (at raw costs). Trace element analysis of the stream waters would add an additional £451k over four years. Consumables and equipment over this period is estimated at £10.6k (stream sediments and soils). A further £33.8k would be needed for stream water consumables and field equipment over the same period. Whilst the sampling is done in a very cost effective manner perfected over more than 40 years, particularly with the use of unsalaried student workers, there is considerable scope for reducing the current BGS laboratory costs (sample preparation, LOI/pH determinations and water analyses). The current scheme of unit costing is inappropriate for such a large scale project and cost savings could be made and co-funding of water sample analyses should be explored. The G-BASE completion plan cannot be detached from a strategy regarding the future use of the BGS analytical chemistry laboratories. A sediment only sampling plan would utilise only the BGS sample preparation laboratories.

1 Introduction

The British Geological Survey has for several decades nurtured a national capability in systematic regional geochemical mapping through the Geochemical Baseline Survey of the Environment (G-BASE) project (Project Code NEE2095S84). This project follows on from a series of earlier regional mapping projects stretching back to the 1960s, primarily concerned with mineral exploration. The current G-BASE project and strategies for completion have been previously discussed by Johnson (2007). The aim of G-BASE has been to complete a high resolution geochemical baseline of Great Britain and Northern Ireland through a systematic survey primarily based on drainage site samples from low order *(i.e.* small) streams. In recent years resources have been diverted to focus on more strategic mapping in London (London Earth Project) and the Clyde Basin.

G-BASE is a high profile project both internally and externally that has:

- created an international reputation for BGS as one of the world's leading organisations in systematic regional and urban geochemical baseline mapping;
- over a period of 40 years through major international geochemical mapping projects generated tens of millions of pounds income for NERC;
- led to a substantial body of peer-reviewed publications and book sections;
- trained over a thousand university undergraduates in geochemical sampling methods, many of whom now work in BGS or occupy prominent positions in academia;
- underpinned many BGS and collaborative university projects through the provision of G-BASE samples and data; and
- continues (through the capability and data the project generates) to place BGS in a position to win major contracts for government departments (*e.g.* the recently awarded Defra Typical Background Concentrations of Soil Contaminant Project) in connection with government policy and implementation.

There is now a need to complete the G-BASE project and the fundamental driver for this is the Natural Environment Research Council's (NERC) national capability strategy for Earth Sciences requiring a ramp down of systematic baseline surveys over the next five years, *i.e.* completion by 31st March 2016.

"Geochemical baseline mapping will be phased out over the next five years in conjunction with outsourcing of the geochemical facilities associated with this activity." Peach (2011).

Completion of G-BASE systematic mapping is included in the project's stated delivery plan:

"G-BASE priorities [in 2011/12] will be to complete soil sampling in the Clyde basin, including sampling for organic contaminants, and to publicise and publish London Earth data. A G-BASE science strategy will be prepared, which will include a programme to complete the sampling and analysis of national systematic mapping within 5 years and the plan for transition to a longer term national capability programme of targeted high resolution geochemical investigations that will address specific science questions and fill baseline knowledge gaps."

Table 1 summarises the main areas of the BGS strategy to which completion of a national geochemical baseline is aligned. These apply to several knowledge and science areas, and give BGS a staff capability in this important area of resource and environmental sciences.

This report is the completion plan for the national systematic mapping by the end of financial year 2015-16. It is one of four component plans to be prepared by the geochemistry team to deal with the proposed phasing out geochemical baseline mapping, namely:

1. Completion Plan for G-BASE
2. Science Plan for Geochemistry
3. Business Plan for Geochemistry
4. Geochemical Information and Delivery Plan

The Geochemical Baselines and Medical Geology (GBMG) Team must continue to deliver science and information outcomes alongside completing G-BASE or BGS will lose the capacity to deliver any science in this field in the future. Capacity and skills are an important factor in completing G-BASE within five years and so this is also discussed in this report (see Section 5.1).

In this completion plan the facts and figures regarding what needs to be done to complete G-BASE are presented. Time, staff resources and available budget will dictate the options selected to complete the work. A further driver for completing the work is the availability of "free" X-ray Fluorescence Spectrometry (XRFS) analysis following the transfer of the BGS XRFS laboratories to Panalytical (see Section 4). However, to make use of these "free" analyses by completing G-BASE, BGS has to allocate budget to collect and prepare new samples. The selected options for completing G-BASE should not be driven solely by the availability of "free" analyses but by the way the work will deliver the BGS strategy (BGS, 2009) and the opportunities for delivering science value and collaborative partnerships.

Challenge	What G-BASE delivers
Challenge 1: *Acquire, interpret and enhance the UK geoscience knowledge base and make it accessible and interoperable*	G-BASE has generated a wealth of data on the distribution of chemical elements in the surface environments and this underpins many internal and external research projects. The careful custodianship of geochemical data by the G-BASE project has meant that geochemical results and samples collected over more than four decades by a great variety of analytical methods are accessible and continue to be used in many projects. Incomplete national coverage of baseline geochemical data from parts of the UK where the majority of the population lives continues to limit its applicability.
Challenge 2*: Improve the communication of geoscience knowledge so that it can better support policy and decision-making by government commerce and society*	The G-BASE project actively communicates its work through its web pages using innovative methods (*e.g.* London earth geochemistry viewer). The project continues to demonstrate its contributions to support policy and decision-making by government with involvement in contracted work to numerous government departments/agencies (*e.g.* DEFRA, HPA, EA, SEPA, DWI). The G-BASE data underpins this work, particularly regarding legislative policy (see Table 2), on safe levels of potentially hazardous elements in the surface environment.
Challenge 3: *Enhance external partnerships to improve the quality, reach and impact of our science*	The G-BASE "brand" has a high international regard and the project continues important roles in Global and European geochemical baseline mapping initiatives *e.g.* EuroGeosurveys projects/initiatives. G-BASE methodology has long been applied on major international mapping projects and BGS continues to be the client of choice for National surveys developing this capability (*e.g.* Nigerian Geological Survey Agency).
Challenge 4: *Apply a whole-systems approach to our science and improve understanding of the nature and sustainable use of natural resources and the potential impact of hazards*	G-BASE has been a very active component of multidisciplinary projects such as Tellus, Future Thames and CUSP where the geochemistry has been one of the many layers of geoscience information integrated to understand and create safer, healthier and sustainable environments (*e.g.* identification of contaminated land and protection of groundwater resources).

Table 1: A summary of the areas of the BGS strategy delivered by the completion of systematic geochemical mapping

Legislative drivers for the collection of geochemical baseline data are summarised in Table 2 and this demonstrates the Project's role in supporting policy and decision-making by government. G-BASE is one of BGS's most environmentally relevant projects.

Directive	**Summary**	**Application of baseline geochemical data**
EC Water Framework Directive (WFD) (2000/60/EC)	This requires Member States to meet a good ecological status for water quality objectives (except where deviations from the standard are justified); and to identify basic and supplementary measures to deal with point source and diffuse pollution. The directive will be managed on the basis of River Basin Districts (one or more drainage catchments).	Baseline geochemical data for stream water can provide information about surface water quality for farmers and those who manage land. Regulatory bodies and administrators can use these data to determine guideline levels for elemental concentrations.
EC Integrated Pollution Prevention and Control Directive (IPPC) (2008/1/EC), it replaces Directive 96/61/EC	It has been formulated to implement the EC Integrated Pollution Prevention and Control Directive (96/61/EC). Its objective is to control pollution from industry.	Baseline geochemical data can be used both by industry and regulators to assess the impact of polluting industries on the environment. The geochemical baseline data provide a reference point against which changes can be measured.
EC Sewage Sludge Directive (86/278/EEC)	This directive seeks to encourage the use of sewage sludge in agriculture, but regulates its use in order to protect the environment from its harmful effects.	Baseline geochemical data can be used to monitor and model the impact on the environment of sewage sludge.
Proposed EC Soil Directive	Directive under consideration. The European Union included in the 6th Environmental Action Programme the Thematic Strategy on Soil Protection that will lead in the future to an EU soil protection Directive.	Geological Surveys are the only organisations systematically sampling soil from urban areas, and can establish the urban geochemical baselines in order to assess the impact of human induced pollution. Geological Surveys are, in fact, the only organisations in Europe that have the necessary experience for carrying out continental scale geochemical mapping and monitoring projects.
EC Mine Waste Directive (2006/21/EC)	This proposed directive is seen as a supplementary measure to the WFD to minimise the adverse effects on the environment, caused by waste from the extractive industries.	Baseline geochemical data can be used to monitor and model the impact on the environment of mine waste.
EC Habitats Directive (92/43/EEC)	This directive is concerned with the conservation of natural habitats and of wild fauna and flora.	Climatic/anthropogenic changes to the geochemistry of the surface environment impacting fauna and flora can be monitored using baseline geochemical data.
EC Landfill Directive (1999/31/EC)	Landfill (England & Wales) Regulations 2002, implement the EC Landfill Directive aiming to prevent or reduce the negative environmental effects of landfill.	Baseline geochemical data can be used to monitor and model the impact on the environment of landfill.
INSPIRE Directive (2007/2/EC)	Establishing an Infrastructure for Spatial Information in the European Union for making available relevant, harmonised and quality geographic information to support formulation, implementation, monitoring and evaluation of policies and activities which have a direct or indirect impact on the environment.	Harmonised geochemical baseline data for the whole of Europe are needed in order to assess impacts on the environment.
REACH Directive (EC 1907/2006) [**R**egistration, **E**valuation, **A**uthorisation and **R**estriction of **CH**emical substances] - The law entered into force on 1 June 2007	REACH aims to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances. There is a need to fill information gaps to ensure that industry is able to assess hazards and risks of the substances, and to identify and implement the risk management measures to protect humans and the environment.	Baseline geochemical data are needed to establish the variable geochemical baseline across UK and Europe, and the local maximum threshold values, against which any changes future changes can be monitored.

Table 2: Summary of some European Commission (EC) Directives driving the demand for geochemical baseline data (after Johnson *et al*., 2011a)

2 What is meant by completion of G-BASE?

The **defining criteria** for the completion of G-BASE are:

a) Available time period, namely present to 31st March 2016 (Panalytical analyses to be complete by January 2016);
b) Area remaining to be sampled - 35,500 km^2 (see sub-section 2.1); and
c) Number of solid material G-BASE XRFS analyses available under the Panalytical deal (see Section 4).

The underpinning **G-BASE strategy** is that the geochemical mapping of the UK is *a high-resolution geochemical baseline survey using the systematic collection of soils (1 site per 2 km^2) and drainage samples (stream sediments, waters and heavy mineral concentrates) from low order (small streams) averaging 1 site per 2 km^2*.

In order to plan the completion of a geochemical baseline the following issues need to be considered:

- The only media for which G-BASE has generated UK-wide consistent samples and results are stream sediments and waters, though stream water analytes for Scotland and northern England are minimal. In the strictest sense, a complete geochemical baseline for the UK can only be achieved by finishing off southern England with stream sediment sampling.
- An estimated quarter of the remaining area cannot be covered by systematic drainage sampling - this includes urban areas and calcareous lithologies (predominantly Chalk). The average drainage sampling density for southern England will therefore be reduced.
- The remaining area of southern England could be covered by just soil sampling though a geochemical baseline for soils (England and Wales) has recently been completed with the reanalysis of the National Soil Inventory (NSI) samples, albeit at the lower density of 1 site per 25 km^2 than the G-BASE soil sampling.
- The published Wolfson Atlas (though not consistent with G-BASE sampling and analytical methodologies) provides stream sediment coverage at approximately 1site per 3 km^2 over the remaining area (not including Chalk and urban areas).
- A combination of soils and sediments would result in presentational difficulties. Soils are not a proxy for sediments and the geochemical baselines for soils and sediments are separate entities.
- The major external demand, currently, is in relation to soils and water, mainly because of legislative drivers (see Table 2). However, there is evidence to support a growing demand for stream sediment data *e.g.* in catchment management.
- There has always been a symbiotic relationship between the G-BASE project and the BGS analytical laboratories. Any reduction or cessation in the collection of soils and stream waters will impact significantly on the work load of the non-XRFS laboratories.

2.1 AREA REMAINING TO BE SAMPLED

Following the completion of the Tellus Project in Northern Ireland, southern England now remains as the only region of Great Britain and Northern Ireland without BGS geochemical information. The G-BASE geochemical baseline of the UK is defined by three types of sample media (stream sediment, stream water and soil) and progress to-date with these sample types (excluding N. Ireland) is discussed in the following sub-sections. The time and resources available mean that it will only be possible to complete a high resolution national baseline based on stream sediments. National soil geochemical baselines are available for Northern Ireland (Tellus), and England and Wales (NSI soil reanalyses), albeit for England and Wales at a much reduced sample density. G-BASE is a high resolution geochemical survey and completion should strive to maintain as high a density as practically possible taking into consideration the comments in Appendix 1 regarding how geostatistics can help formulate a plan.

2.1.1 Completed soil coverage

Figure 1 (topsoils) and Figure 2 (deep soils) show the status of G-BASE soil sampling until the end of 2010. Initially G-BASE only collected and analysed deep soil samples using the 150 µm fraction (predominantly Northeast and Northwest England). Although deep soils have continued to be collected, it is now the <2 mm fraction of topsoils that is only routinely analysed by G-BASE. For England, Scotland and Wales the Geochemistry Database currently contains 31,272 topsoils and 28,640 deep soils with analytical results. The earliest soils collected were determined by Optical Emission Spectrometry (OES) but the majority of samples have been determined by X-ray Fluorescence Spectrometry (XRFS).

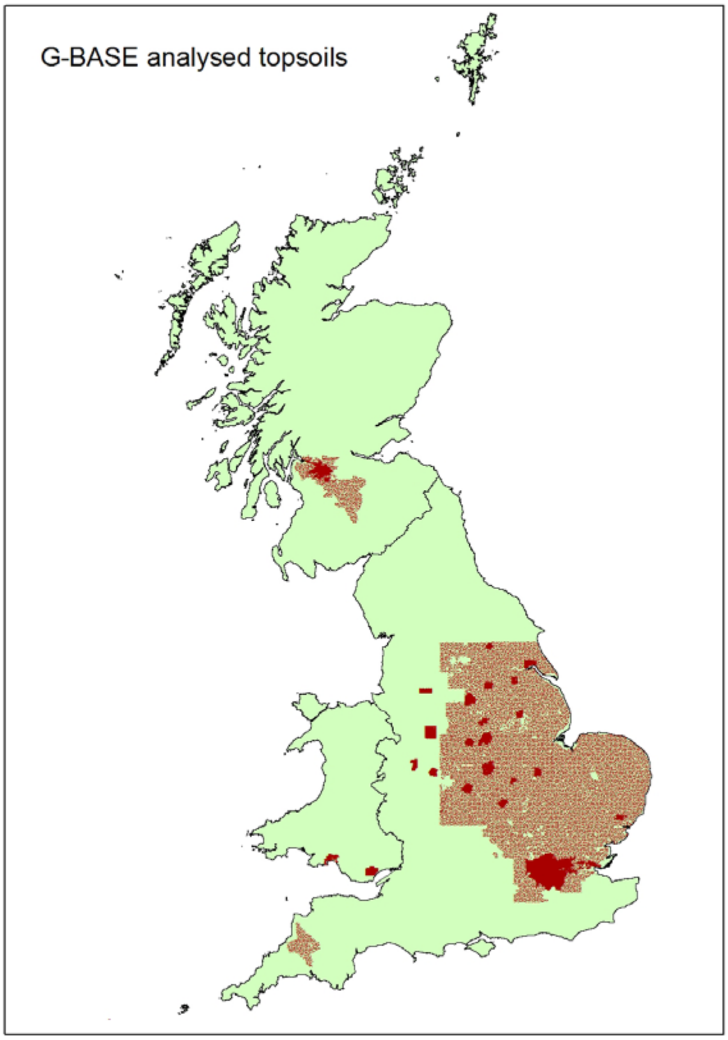

Figure 1: G-BASE topsoil sites until the end of 2010. The more dense areas of sampling represent urban areas.

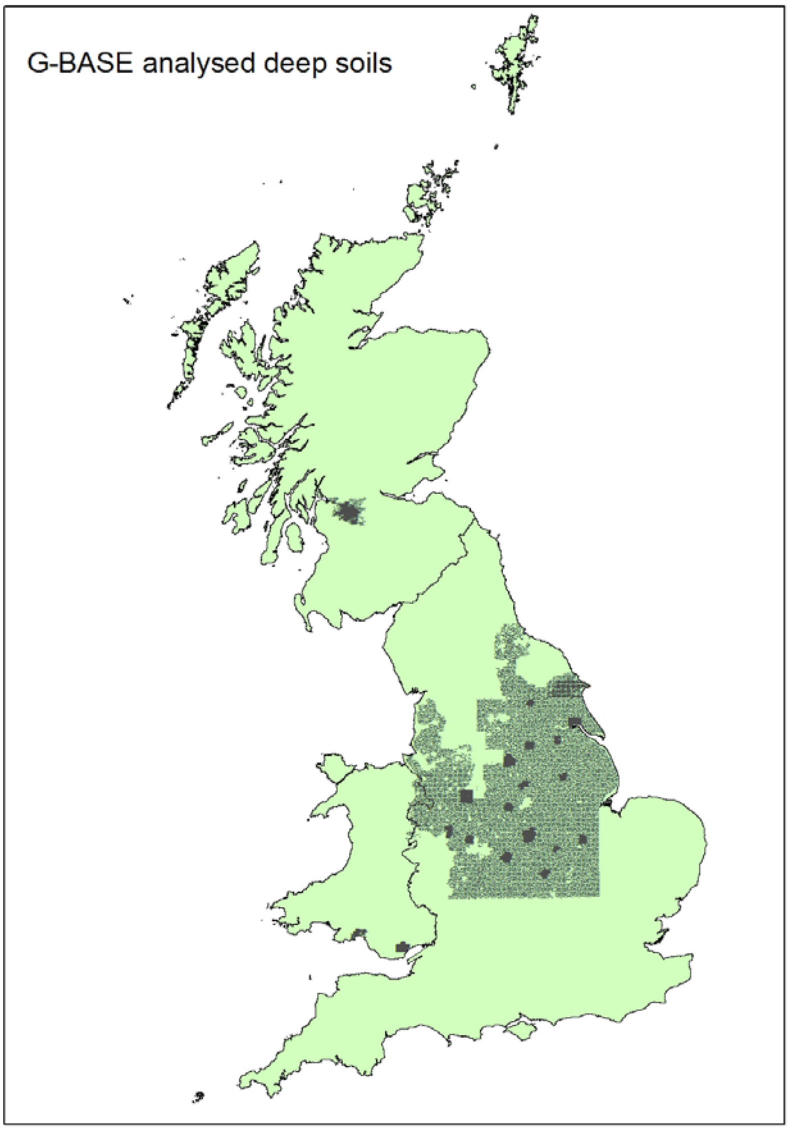

Figure 2: G-BASE deep soil sites (until the end of 2010) from which samples have been analysed. The more dense areas of sampling represent urban areas.

The London Earth topsoil data set and urban topsoil data for As, Cd, Cr, Ni and Pb are available from BGS as digital products and these are well documented (Johnson *et al*., 2011b; Appleton, 2011). Both datasets have been quality assured and levelled with respect to international certified materials. All other conditioned G-BASE soil data have been levelled to the "1990s G-BASE XRF standard" and will need to be relevelled to the "London Earth reference standard" if all soils are to be seamlessly used in a regional/national baseline. Work on Clyde Basin soils collected in 2010 and 2011 is ongoing. The raw laboratory data from the XRFS reanalysis of all urban topsoils carried out by the BGS XRFS laboratory prior to the transfer to Panalytical still requires data conditioning.

2.1.2 Completed stream water coverage

As G-BASE is a systematic survey principally based on drainage samples, stream waters are collected at every stream sediment site (if the stream is not dry). Stream water results for Scotland (apart from the Clyde Basin) are very basic (pH, conductivity, alkalinity, U and F) and it has only been since the sampling of Wales that a comprehensive range of analytes has been determined (see Figure 3 and Figure 4).

Figure 3 shows the G-BASE stream water sites showing the relatively poor coverage for Scotland. There are 58,973 G-BASE stream water samples in the Geochemistry Database with one or more analyte determinations. Much of the area of southern England still to be mapped is underlain by chalk (*c*.20% - see the next sub-section) and so is unlikely to yield many surface water samples.

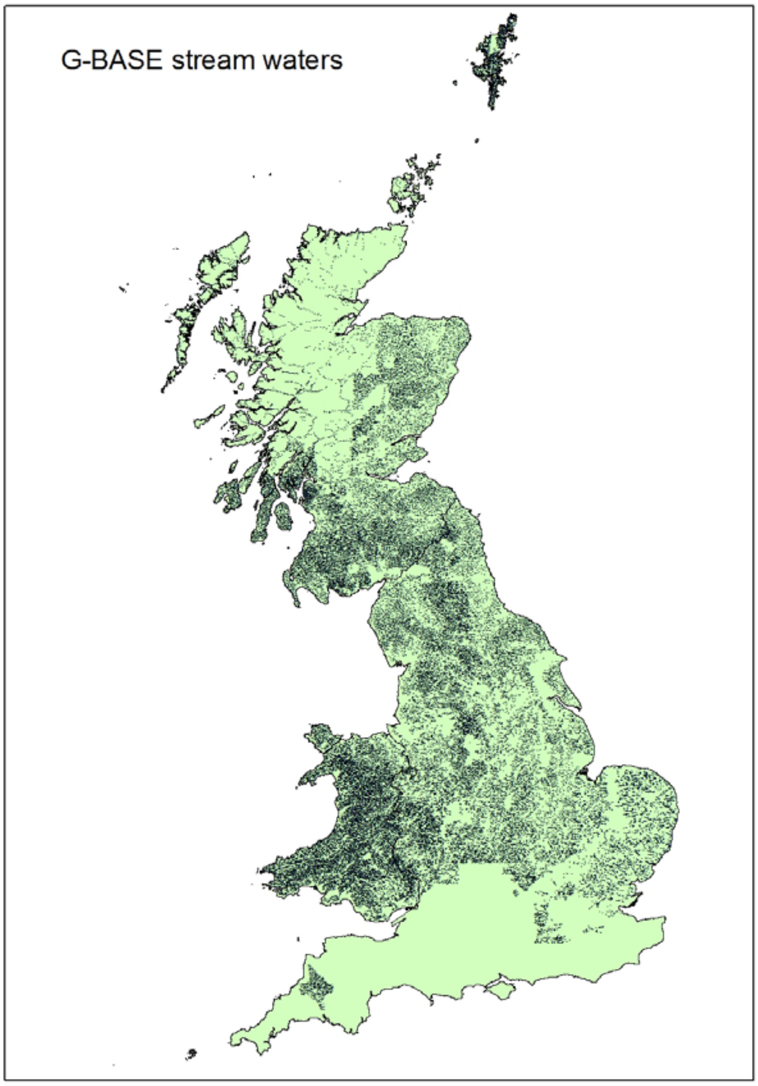

Figure 3: Map showing G-BASE stream water sites (until 2010).

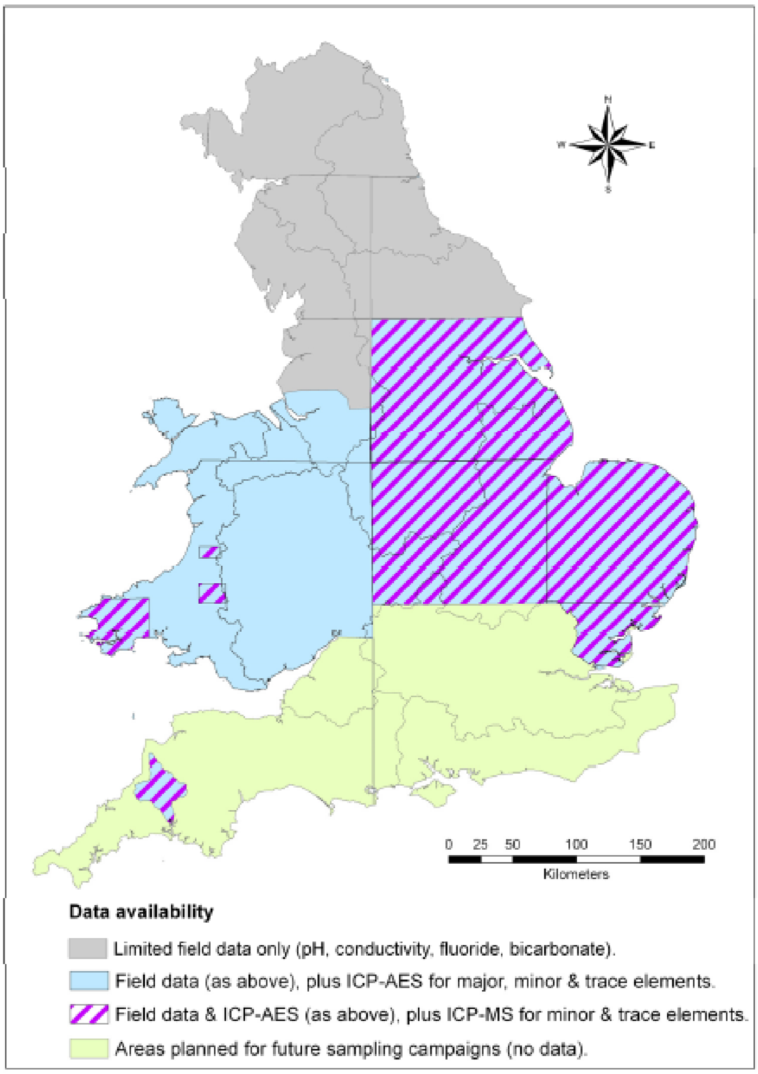

Figure 4: G-BASE stream water data availability for England and Wales (Figure 2.4, Ander and Casper, 2008)

2.1.3 Completed stream sediment coverage

Collected and analysed stream sediments form the most comprehensive and most complete geochemical baseline (Figure 5) comprising 100,138 samples. Since the 1960s there have been a variety of analytical techniques employed, so data conditioning the stream sediment results is an important part of producing seamless regional geochemical maps. The stream sediments are currently levelled to the “1990s G-BASE XRF standard”.

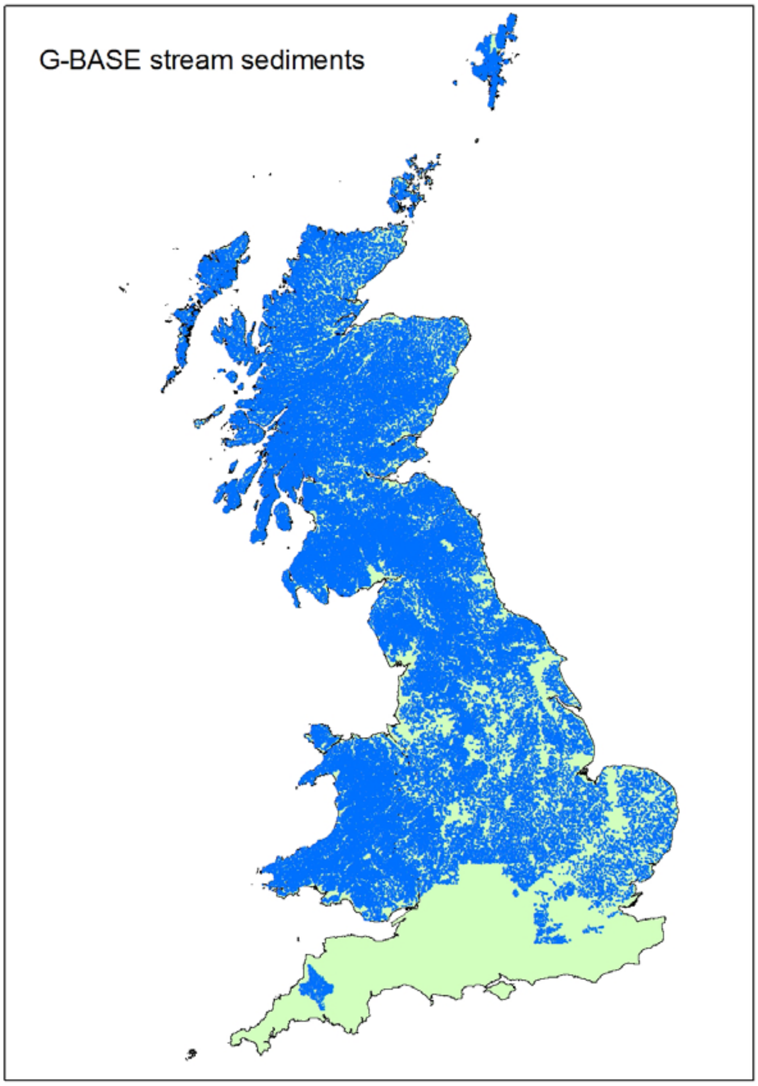

Figure 5: Map showing the G-BASE stream sediment sample sites (until 2010).

There remains an estimated 28,500 km^2 of non-Chalk and 7,000 km^2 of Chalk areas to be sampled to complete the stream sediment national coverage (see Figure 6 and Table 3). Any proposed sampling and analyses should maximise the opportunities for adding science value and collaboration opportunities. This could mean different sampling strategies being used to complete different parts of southern England, *e.g.* normal G-BASE sampling density in SW England and reduced sampling density over the remaining area.

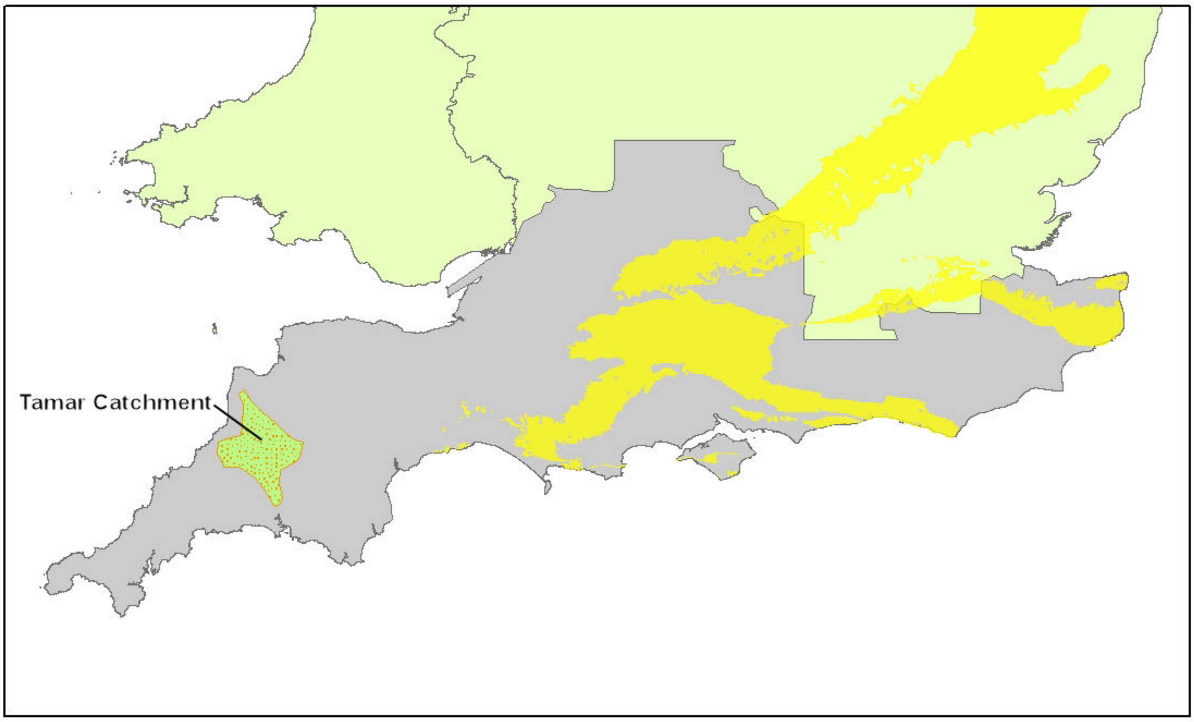

Figure 6: Area of southern England remaining to be sampled (shown in grey). The extent of the Chalk outcrop (yellow) and the area of the Tamar Catchment already sampled are also shown.

Table 3 summarises the extent of unsampled areas of southern England, also detailing the extent of chalk and limestone areas and estimates for urban areas. It should be noted that in southwest England the Tamar catchment has already been sampled (Rawlins *et al*., 2003).

	Area Description	Estimated area (km^2)	Comment
1	Unsampled southern England	37,588	Calculated in ArcGIS (grey area of Figure 6, excluding Tamar (917 km^2))
2	Area of Chalk outcrop in unsampled area	7,400	Estimated in Johnson (2007)
3	Areas not usually sampled (urban, coastal fringe, lakes/reservoirs, transport corridors, mountain peaks etc.)	1,500 (non-Chalk) 375 (Chalk areas)	Estimated as 5% of unsampled area
4	**Area of non-Chalk to be sampled**	**28,500**	**(= 1 -2 – 3 (non-Chalk)) rounded**
5	**Area of Chalk to be sampled**	**7,000**	**(= 2- 3(Chalk)) rounded**

Table 3: Summary of areas remaining to be sampled in southern England showing the estimates for non-Chalk and Chalk areas.

2.2 URBAN SAMPLING

The previous section was concerned with the G-BASE systematic regional geochemical mapping, though Figure 1 and Figure 2 do include the soils collected during the more strategic urban mapping. Figure 7 shows the urban centres mapped to-date.

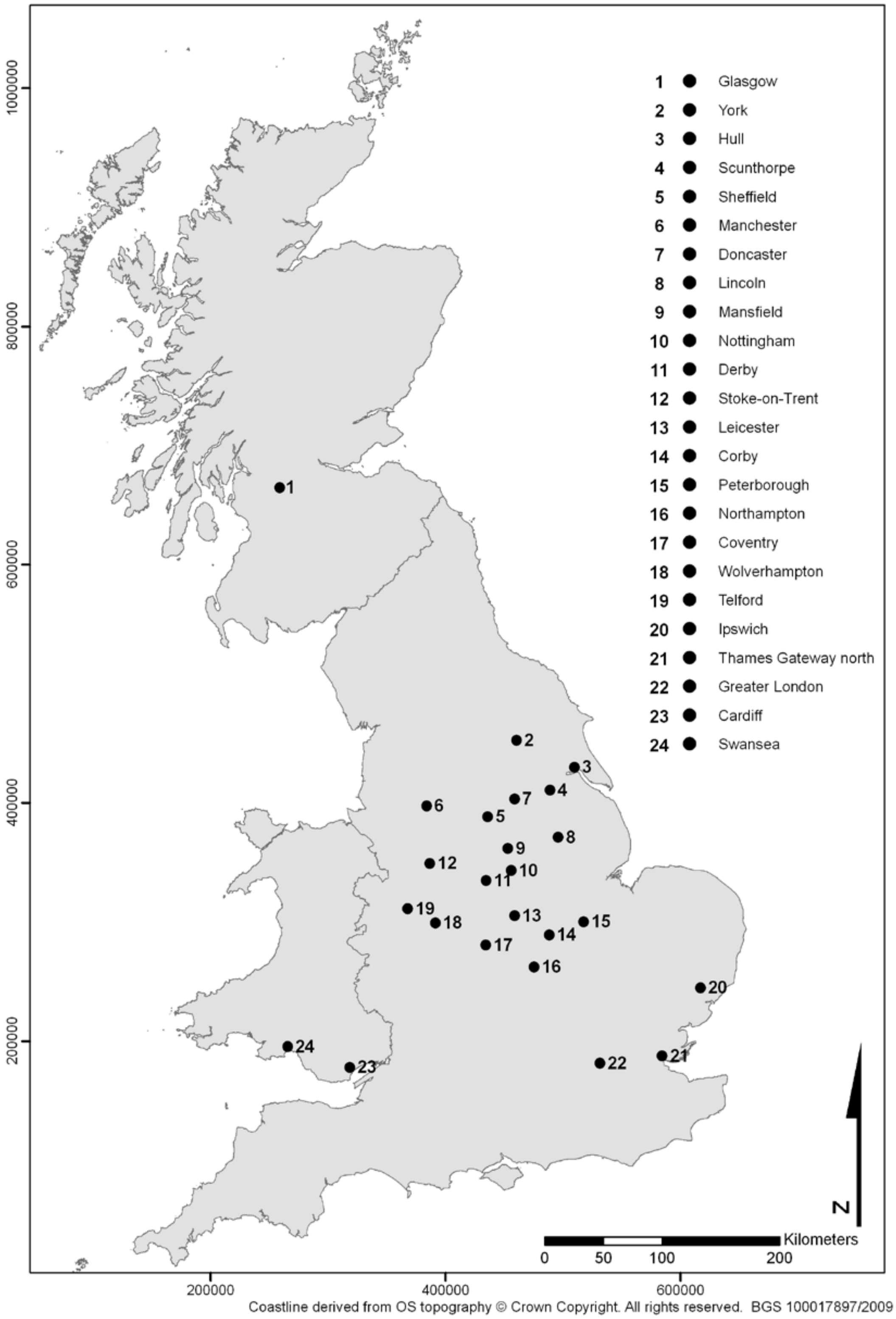

Figure 7: Map showing the urban centres mapped by G-BASE (after Flight and Scheib, 2011) (Belfast and Londonderry are not shown).

For the East Midlands and East Anglia the urban sampling projects were carried out at the same time that the regional mapping was conducted in the surrounding area making efficient use of resources. There are still some significant urban centres to be mapped (*e.g.* Birmingham, Liverpool, Newcastle) and such projects can be considered for future strategic geochemical surveys rather than as part of any systematic baseline mapping.

It should be noted that there are four major urban centres within the unsampled area of southern England, namely Portsmouth and satellite areas (88 km^2), Bristol (60 km^2), Southampton (55 km^2) and Plymouth (55 km^2) (urban areas based on polygon estimates drawn in Google Earth). An option of this completion plan should be to sample these urban centres whilst regional mapping is being conducted in the surrounding areas. Urban mapping using soils collects samples faster than drainage sampling and so any urban soil sample collection would rapidly generate samples to satisfy the Panalytical quota.

2.3 MINERAL RECONNAISSANCE PROGRAMME SAMPLES

A further important consideration is the possibility to incorporate stream sediment samples already collected in the southwest England as part of the Mineral Reconnaissance Programme (MRP) (see Figure 8).

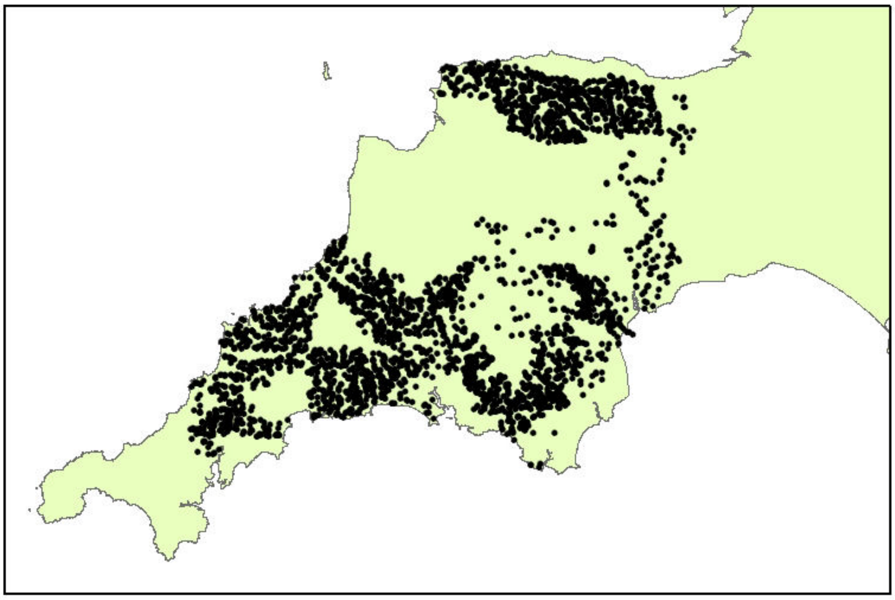

Figure 8: A map showing the sample sites for MRP stream sediments collected in SW England. There are 3,627 sites are loaded to the BGS Geochemistry Database.

During June 2011 Mick Strutt looked at the feasibility of incorporating the MRP stream sediments into the G-BASE stream sediment geochemical baseline. The MRP used similar sampling procedures and the sediments are sieved to 150 µm, the same as used for G-BASE. A search of the National Geoscience Data (NGDC) sample archive found approximately 1000 MRP sediments from the SW England with sufficient powder remaining for XRFS analysis. The distribution of these samples is shown in Figure 9. An estimated 100 of these are from the already sampled Tamar catchment so there are likely to be 900 useful MRP sediment samples. The reanalysis of MRP samples is an option included in the proposals for the stream sediment sampling option (see options 1-1 – 1-3 in Table 4).

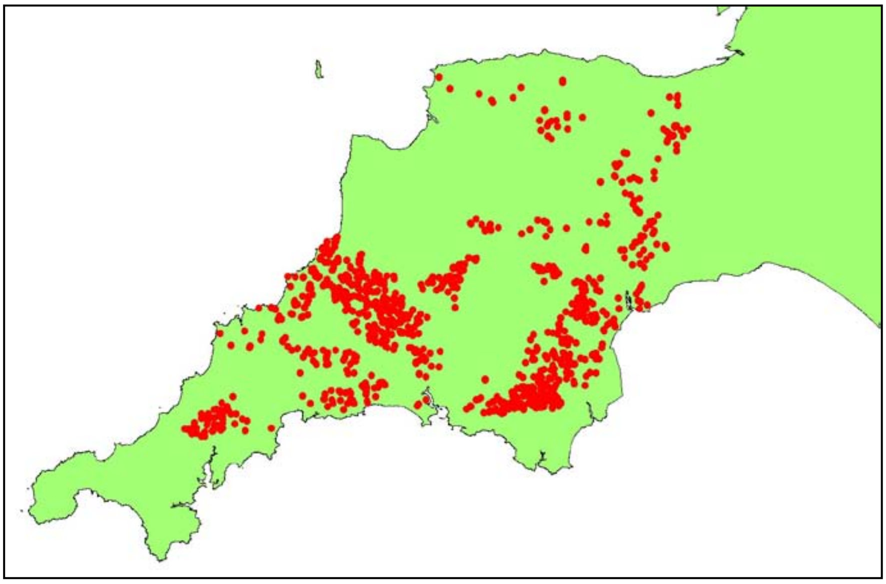

Figure 9: A map showing drainage sites in SW England where there is sufficient MRP sediment available for XRFS analysis.

3 Options available to complete G-BASE

Table 4 lists various achievable options suggested for completing G-BASE consisting of the fundamental requirement to complete baseline geochemical mapping (Options 1-x). Add-on options (Options 2-x) can be seen as adding crucial science value. The options presented are not considered to be definitive, merely a starting point in formulating the final completion plan. It would be highly desirable to fund the add-on options through collaborative projects with third parties.

	Option	Description	Comments
Fundamental requirement	1-1	Stream sediment sampling of all areas in S England at normal G-BASE sampling density. Incorporate MRP SW England sediments	Normal G-BASE field sampling strategy. Directly compatible with rest of stream sediment geochemical baseline
	1-2	Stream sediment sampling of all remaining area at reduced G-BASE sampling density. Incorporate MRP SW England sediments	Sampling strategy to be altered to account for greater distance between sites. Cost per sample site will increase. Geostatistics (see Appendix 1) will need to demonstrate validity of sampling density and problems in joining with rest of baseline. Adds complexity to the planning.
	1-3	Stream sediment sampling of Cornwall[1] and Devon[2] at normal G-BASE sampling density, remaining area at reduced G-BASE sampling density. Incorporate MRP SW England sediments	Tamar area already done at normal G-BASE density. This option gives an area of significant interest good density of coverage and gives a reasonable and achievable number of sites for S England. Drainage systems of S and SE England will yield lower sampling densities
Secondary Objectives	2-1	Targeted soil sampling, especially in urban areas (*e.g.* Bristol and Portsmouth) and over Chalk. Guided by science and strategic priorities of other BGS teams. Used to answer any deficiencies in the NSI baseline.	Sampling densities of 4 sites per km^2 in urban areas. Number of samples for XRFS analyses will be determined by Panalytical quota available once fundamental requirement option is satisfied. In addition to XRFS, pH and LOI should be determined. To be guided by the requirements of other BGS Team objectives.
	2-2	Collect suite of water samples from southern England at variable density (in conjunction with option 1-3)	Slightly increased cost to stream sediment sampling option 1-3 but budget required for water analyses – external interests? No water available from MRP sediment sites.
	2-3	Collect suite of water samples from all drainage sites sampled in southern England	Slightly increased cost to stream sediment sampling option 1-3 but substantial budget required for water analyses. No water available from MRP sediment sites.
	2-4	Collect soil samples from environmentally sensitive areas or areas of mineral interests in SW England	Can be done whilst doing the stream sediment survey in SW England without adding too much to sampling costs. Could be used to attract co-funding and collaborative research

[1] Area of Cornwall 3,563 km^2 (http://en.wikipedia.org/wiki/Geography_of_Cornwall)
[2] Area of Devon 6,707 km^2 (http://en.wikipedia.org/wiki/Devon)

Table 4: Summary of options for the completion of a national geochemical baseline.

Table 5 shows estimates of the number of samples that would arise out of each option with an estimate of the time required to collect the samples. At this point in the planning a reduced sampling density is taken to be half that of normal G-BASE densities though a more detailed plan will need to review actual densities used with a geostatistics approach (see Appendix 1).

Option	Sample Type	Sampling density (site/km^2) #	Samples collected $	Samples for prep. and analysis @	Sampling rate (samples/ team/ week) *	Total est. sampling time (weeks)
1-1	Sediment (not chalk areas)	1/2	13,350	14,962	200 (10)	67
1-2	Sediment (not chalk areas)	1/4	6,675	7,481	160 (8)	42
1-3	**Sediment (SW England)**	**1/2**	**3,538**	**4,658**	**200 (10)**	**18**
	Sediment (outside SW)	**1/4**	**4,660**	**4,893**	**160 (8)**	**29**
2-1	**Targeted soils**	**various**		**1,700**	**240 (12)**	**7**
2-2	**Stream waters (SW England only as per option 1-3) (not inc. old MRP sites)**	**1/2**	**3,538**	**3,715**	**-**	**-**
	Stream waters (outside SW England as per option 1-3)	**1/4**	**4,660**	**4,893**	**-**	**-**
2-3	Stream water (All sites) with option 1-1	1/2	14,250	14,962	-	-
	Stream water (All sites) with option 1-2	1/4	7,125	7,481	-	-

# normal G-BASE sampling density for soils and sediments c. 1 site per 2 km^2. Other densities presented here are used just to indicate impact of reduced density sampling
$ number of samples to be collected is reduced by the 900 MRP samples
@ includes control samples (additional 5%) and 900 MRP samples
*Figure in brackets gives the sampling rate per day per sampling pair. A week is 5.5 days and there are 4 sampling pairs in a sampling team. (No extra time required for sampling waters if collected at the same time as sediments).

Table 5: Estimates for the number of samples collected and the number of weeks to collect the samples. Full descriptions of options are given in Table 4.

A preferred option, and one used to guide discussion and costings in the rest of this report, is a combination of options 1-3, 2-2 with targeted soil sampling (option 2-1). The gives an achievable number of samples to be collected and submitted for analysis over four years:

- *c.*8,200 stream sediments collected to deliver a completed national baseline
- *c.*9,550 stream sediments for XRFS analyses (inc. controls and MRP sediments)
- *c.*8,608 stream waters for analyses (not inc. samples from old MRP drainage sites)
- *c.*1,700 soil samples for XRFS analyses (if Portsmouth, Southampton, Bristol and Plymouth urban areas are samples these would require *c.*1,130 soils)

The 9,550 stream sediments and 1,700 soils equate to the total number of XRFS G-BASE sample quota available in years 2-5 of the Panalytical deal (see Section 4). Further targeted soil sampling could make use of the non-G-BASE Panalytical quota, particularly if carried out for non-G-BASE projects.

The preferred option described above would require an estimated 54 weeks of fieldwork for one sampling team of four sampling pairs, i.e. 13.5 weeks per year.

A significant feature of G-BASE fieldwork over the past decade has been the “extra value” samples and observations that samplers have collected during the routine sampling for other projects. For example, tree twigs have been collected to aid the mapping of strontium isotopes in living material, and for soils the depth to the bottom of organic layers is now routinely measured. Whilst a clear focus for this completion plan must be the completion of a national geochemical baseline, other projects and teams should take advantage of this fieldwork opportunity to add more science value to the work.

4 Panalytical XRFS sample analyses

The XRFS analysis of G-BASE sediment and soil samples has underpinned the BGS systematic geochemical mapping work for the last two decades. Many of the development in the XRFS laboratory have arisen because of the symbiotic relationship between the geochemistry laboratories and the G-BASE project. With the commercialisation of the laboratories by their transfer to Panalytical this relationship is now gone, though tempered by the agreement of "free" analyses for a five year period. In reality the analyses are not "free" to the BGS as a cost per sample is involved regardless as to whether samples are submitted for analysis or not. There are some important constraints and issues regarding the submission of samples under this agreement:

- The schedule of available analyses per year is summarised in Table 6. It should be noted that the agreement commenced 14th January 2011 and so will end on 13th January 2016
- Each analysis is considered to be a standard G-BASE sample analysis. Requests for different programmes of analysis will represent an increase or decrease in the available quota. In this report each available G-BASE sample analysis is considered as "one analytical voucher"
- In Table 6 the analytical quota is sub-divided into G-BASE and non-G-BASE submissions. This is an internal BGS categorisation and there will be flexibility in transferring quotas from one category to the other depending on the science priorities determined by the BGS senior leadership team (SLT). The quotas do need revisiting as, for example, the G-BASE allocation is ramped down over the 5 years whereas the non-G-BASE allocation is not.
- The agreement does allow for 10% slippage (by mutual agreement) in between years. Furthermore, submission of samples must be according to a schedule across the year rather than bulk submission all at one time. This schedule is being reconsidered as it will be difficult to organise G-BASE sampling without student samplers whose main availability is in the summer months.

Panalytical Year	**Year 1 2011**	**Year 2 2012**	**Year 3 2013**	**Year 4 2014**	**Year 5 2015**	**TOTAL**
Total vouchers available	*4216*	*4254*	*3505*	*2748*	*2777*	*17500*
G-BASE allocation	3716	3754	3005	2248	2277	15000
Non-GASE allocation	500	500	500	500	500	2500

Table 6: A summary of available XRFS analyses from Panalytical.

At the commencement of the Panalytical agreement the G-BASE project was asked to identify samples for analysis by XRFS in order to make full use of allocations. At this time the completion of the systematic regional mapping was not a deliverable and Clyde basin samples were allocated to Year 1 of the agreement. Furthermore, a number of sample batches were carried over from the pre-commercialisation period. Table 7 shows the status regarding committed and pending XRFS analyses (as of end July 2011). It is proposed that 525 old MRP sediment samples from the SW England are submitted to bring Year 1 up to the full quota.

Sample description	Status	Number for Year 1	Number for Year 2
Remnant London Earth soils	committed	198	
Clyde topsoils carried forward from 2010	committed	1141	
Clyde stream sediments carried forward from 2010	committed	65	
Remnant peri-urban London Earth soils	committed	500	
Various PhD/collaborative project soils	submitted	21	
Clyde deep soils (2010)	reserve	(1125)	
Clyde topsoils collected summer 2011	submitted	1266	
Clyde deep soils collected summer 2011	reserve	(1266)	
MRP sediments from SW England	pending	525	375
G-BASE Southern England	*To be collected*	-	tba
TOTAL	(not inc reserve)	3716	

Table 7: A summary of samples already proposed for XRFS analyses in Years 1 and 2.

The inclusion of MRP sediments in the completion plan means that the Clyde deep soil samples will not be analysed under the Panalytical free sample quota. If these samples are to be analysed it is recommended that a scientific case for their analysis should be prepared and additional funds are sought from other (non-G-BASE) sources.

Whilst this section is primarily concerned with the Panalytical agreement the impact of this completion plan on the BGS sample preparation and analytical laboratories cannot be overlooked. The fundamental option to complete G-BASE by the collection of predominantly stream sediments will have a significant impact on the work load of the laboratories over the next four years. A sediment only option with some targeted soils will provide work essentially for only the sample preparation laboratory.

5 Resource requirements

5.1 STAFF

The G-BASE sampling strategy uses undergraduate samplers (voluntary workers or VWs) during the summer vacation deployed in sampling pairs, with four sampling pairs constituting a sampling team. The team is led by a BGS field geochemist (Team Leader) who has previous experience at working with G-BASE sampling teams. The Team Leader is assisted by an Assistant Team Leader, someone who has experience of G-BASE fieldwork, either a junior field geochemist or, as has been employed in the past, a casual appointee who has proved their worth as a G-BASE VW in previous years.

The G-BASE sampling procedures and strategy have been perfected over more than forty years to give high quality and reliable geochemical mapping, that offers undergraduates a wonderful training experience, giving a most efficient and cost effective sampling strategy. Substantial changes to the sampling strategy, *e.g.* a reduction in the sampling density, will necessitate different approaches, for example, sampling outside the summer vacation and using car based teams to move between more widely spaced samples.

In addition to the actual fieldwork, BGS staff will need time allocations for planning the work (*e.g.* access permissions and pre-plotting sample sites) and data quality control. The time required for the latter activity is usually greatly underestimated.

This plan is concerned with delivering the samples and analyses. It does not cover:

- Statistical analysis, interpretation and modelling;
- Information dissemination; and
- Adding value (*e.g.* peer-reviewed publications).

Funding the sample collection and analysis without doing any of the above fails to deliver to the stakeholder community anything of substantive value.

In Section 4 it was calculated the over the four years something like 13-14 weeks fieldwork per sampling team per year would be required (for the drainage and soil sampling options). This compares with the *c.*9 weeks operated by G-BASE in recent years. Existing BGS staff need to be committed to longer periods of fieldwork and BGS will probably need to engage short-term casual staff as team leader assistants. There are currently two competent team leaders, further team leaders who will be prepared to stay out for four weeks or more will need to be identified.

5.2 EQUIPMENT

With an emphasis on urban baseline mapping in recent years, and generally only using one team over a short period of time, field equipment for drainage sampling has generally been neglected. A plan that involves 4 years of fairly intensive drainage sampling will need to ensure stocks of equipment and consumables are adequate and in good repair. An inventory of G-BASE equipment and estimates for consumables to deliver a completed G-BASE programme are given in Appendix 3. This is estimated at £10,600 for general equipment, sediments and soils (over a 4 year sampling period) with an additional £33,800 for stream waters over the same period. Stream waters require more in the way of storage containers and consumables are required for the field tests (pH, conductivity and bicarbonate) amounting to estimated at £4 per sample. Any current end-of-year financial under-spend could be used to purchase G-BASE equipment and consumables..

The G-BASE standard wooden sieve sets and pans are the single-most costly item. It is thought that with an annual refurbishment (mainly varnishing) there are sufficient wooden sieve sets available to complete a stream sediment sampling program. The supply of Kraft sample bags is also problematic. For many years the bags that have been provided have needed to be re-glued with waterproof glue which is quite a time consuming exercise. Furthermore, the supplier of the bags ceased making them this year so a new supplier will have to be found. The Nigeria Geochemical Mapping Project bought up the entire stock of remaining large (soil) sample bags and donated what was not needed in Nigeria to the G-BASE project (*c.*15,000 bags).

5.3 FINANCIAL

Budget allocation for G-BASE sampling requires:

1. Purchase of replacement equipment and sample containers;
2. Staff time for fieldwork planning (pre-plotting sample sites, farms access database, arranging accommodation and VWs etc.);
3. Staff time during the actual fieldwork including management, training and logistical support;
4. Staff time for data collation, quality control and data levelling;
5. Accommodation in the field;
6. BGS and VW T&S costs plus BGS staff overtime;
7. An allocation to cover general field costs and consumables (*e.g.* mobile telephone top-ups);
8. Vehicle hire and fuel costs;
9. For soils, pH and LOI analytical costs; and
10. For stream waters standard G-BASE analytical package.

Item 1 is covered in the previous sub-section and analytical costs will be discussed below. Other items (2-8) represent the fieldwork costs including planning and data management. Summary fieldwork costs are reported each year in the field campaign report (*e.g.* Bearcock *et al*., 2011) though these do not include the full element of staff costs for planning and data management. Furthermore, changes to internal services (vehicles will now be completely an OR expense) and ambiguity over whether costs (staff and IS) are quoted at full economic cost (fec) mean that sampling cost per site figures are now out-dated. Indicative budgets to deliver a reduced density stream sediment sampling completion (Option 1-3), targeted soil sampling (Option 2-1) and stream water collection (Option 2-3) are given in Appendix 4. Annual budgets required for the different options are summarised in Table 8. Important points concerning the data in this table are:

1. There is no annual inflator in budget figure - costs based on 2011 data.
2. All vehicles costs entered in OR rather than IS.
3. Staff overtime (necessary for water sampling) is entered as an OR cost.
4. FEC staff costs = raw costs + 120%.
5. Staff costs include element for data management and QA.
6. It is thought that the internal services (IS) costs (all BGS analytical laboratory) could be substantially reduced by ceasing to use a unit cost pricing or seeking alternative service providers. The analytical costs are calculated as raw costs.

Stream sediment sampling	STAFF COSTS		OR	IS	Total (raw)
(option 1-3)	raw	fec			
2012-2013	£46,315	£101,893	£64,036	£27,090	£137,441
2013-2014	£46,315	£101,893	£64,036	£23,153	£133,504
2014-2015	£46,315	£101,893	£64,036	£23,153	£133,504
2015-2016	£43,681	£96,098	£59,063	£20,948	£123,691

Stream water sampling	STAFF COSTS		OR	IS	Total (raw)
(option 2-3)	raw	fec			
2012-2013	£4,180	£9,196	£4,212	£0	£8,392
2013-2014	£4,180	£9,196	£4,212	£0	£8,392
2014-2015	£4,180	£9,196	£4,212	£0	£8,392
2015-2016	£4,180	£9,196	£3,861	£0	£8,041

Targeted soil sampling	STAFF COSTS		OR	IS	Total (raw)
(option 2-1)	raw	fec			
2012-2013	£9,629	£21,185	£13,539	£12,660	£35,829
2013-2014	£9,629	£21,185	£13,539	£12,660	£35,829
2014-2015	£7,455	£16,402	£10,851	£9,980	£28,286
2015-2016					

Yearly TOTALs for all 3 options (excluding water analysis)	STAFF COSTS		OR	IS	Total (raw)
	raw	fec			
2012-2013	£60,125	£132,274	£81,787	£39,750	£181,662
2013-2014	£60,125	£132,274	£81,787	£35,813	£177,724
2014-2015	£57,951	£127,491	£79,099	£33,133	£170,182
2015-2016	£47,861	£105,294	£62,924	£20,948	£131,733
				Total	***£661,301***

G-BASE budget 2011-12	STAFF COSTS		OR	IS	Total (raw)
	raw	fec			
start year budget	£126,910	£279,200	£72,800	£60,000	£259,710

Table 8: **Summary annual budgets for the various preferred sampling options.** The current total G-BASE budget is given for reference. Stream water sampling is costed on the basis of being carried out concurrently with the stream sediment sampling, though the analysis of water samples, estimated to be £451.5k over four years at current BGS raw unit costs (see Appendix 4), are not included.

5.4 LABORATORY

Indicative costs for the non-XRFS laboratory costs are used in the detailed budget estimations of Appendix 4. Laboratory costs are represented by the IS (Internal Services) column of Table 8 (presented at raw costs). Although there are no charges to the project for XRFS analyses done under the Panalytical quota (until January 2016) sediment and soil samples collected for XRFS analyses require sample preparations. Additionally, soils will require pH and LOI determinations and any collected but unanalysed soils (*e.g.* deep soils) will require some preparation before archiving. Any stream water sampling will require a substantial budget over four years for any continued standard G-BASE analyses (>£450k).

It must be emphasised that estimated BGS analytical laboratory costs are based on what is the current pricing structure. Plans for non-XRFS G-BASE sample analyses over the next four years have to be linked in to a strategy regarding the future use of the BGS analytical chemistry facilities. In the preferred option presented here:

- A sediment only sampling option would only use the sample preparation laboratory;
- The annual number of soil samples proposed for each year represents a significant decline compared with previous years and will require only sample preparation and pH/LOI determinations;
- The budget required for the water sample analyses is highly unrealistic in the current economic climate, yet the real costs to BGS are minimal if equipment and staff are available; and
- Unit costing the pH/LOI and sample preparation gives costs that are substantially higher than when G-BASE did this work itself using undergraduates in the summer vacation. Paying staff costs directly for these tasks is likely to cost a lot less.

It seems inconceivable that G-BASE will do stream sediment sampling without collecting stream water samples. The water collection adds very little to the sampling costs and the baseline stream water data has found many applications. The science case for continued water sample collection and analysis is given in Appendix 5. However, unless there is some resolution as to how we can fund the water sample analyses there seems little point collecting samples without analysing them. There is insufficient space in the BGS cold store to store some 8,600 samples long term and there is little information on how storage will affect analyte concentrations for periods greater than 1 year. Given that our sampling and analytical methodology is designed for ultra-low concentrations of some elements it is inevitable that storage will have a significant effect on some analytes, the extent of which can only be determined by some laboratory trials.

6 Perceived threats to ongoing G-BASE work and completion

6.1 ONGOING G-BASE WORK

- A completion plan perpetuates the fact that G-BASE continues to collect samples and generate results but does not have the resources or time to publish
- Science and information outcomes have to be delivered alongside the task of completing G-BASE or we will lose the capacity to deliver any science in future. We have to continue to deliver the high impact applications of baseline geochemical data that demonstrate its importance in resource, environmental and health risk challenges
- Crucial data management tasks will continue to be under-resourced
- Staff unavailable for important follow-up work on the Clyde Basin and London Earth projects

6.2 COMPLETION PLAN

- NERC withdrawal of budget for National capability work – this happened in 2005 within six months of the G-BASE plan for completion being formulated
- Staff deployed to priority commercial work
- Access restrictions to countryside (as per foot and mouth outbreak in 2001)
- Scheduling XRFS sample submissions across the calendar year when most samples will be collected in the summer months

7 Recommendations

1. A formal completion plan based on proposals in this report is considered at senior management level so preparations can begin immediately for the completion of the systematic G-BASE geochemical mapping. The preferred option suggested in this report for the completion of a national geochemical baseline is a combination of stream sediment sampling (at normal density in the SW England and with a reduced density elsewhere) and targeted soil sampling that address some of the environmental challenges. This could include sampling the main urban areas of Portsmouth, Southampton, Bristol and Plymouth and addressing some of the gaps shown in the lower resolution NSI soil baseline.
2. The number of sediment samples collected can be reduced by approximately 1000 samples by utilising old MRP stream sediment samples from SW England that have been located in NGDC. More than 500 of these samples could be submitted before January 2012 to satisfy the Panalytical quota for the current year. The reanalysis of MRP samples forms part of the costed option to complete G-BASE.
3. A target area for a greater focus in the sampling, *e.g.* SW England, could be the next BGS cross-cutting project area. Such a project needs to be instigated now so collaborative ventures (both internal and external) can be set-up to commence in 2012-13.
4. Any completion plan will require some reduction in sampling density and some targeted soil sampling to address some of the challenges detailed in the BGS strategy. Geostatistics will be used as the basis for deciding an optimum density that will maintain the systematic mapping as a high resolution baseline compatible with the 85% of the baseline completed so far. This completion plan should consider the basic requirements for completing the systematic baseline mapping. However, other teams and projects should be invited to add science value to the fieldwork by enhancing (and resourcing) sampling plans.
5. Year 1 of the Panalytical XRFS sample analysis deal will mainly involve the analysis of Clyde Basin samples carried from 2010 and samples collected in 2011. It is very important that these samples are submitted as soon as possible so there is no carry over into Year 2. The Clyde Basin deep soils should not be analysed using the G-BASE Panalytical quota so as to maximise the "free" analyses available to finish the mapping of southern England.
6. It is estimated that the consumables and field equipment budget required to complete G-BASE is £10.6k (with an additional £33.8k if water sampling is included). A clear long-term plan for G-BASE would mean we could use any excess budget from this year to book accommodation for 2012-13 and purchase equipment and consumables.
7. Any excess OR budget from fy 2011-12 could be used to make a start on the sampling in southern England in March 2012.
8. From 2012-13 it is recommended that the task of completing the systematic baseline is identified as a specific task within the G-BASE budget. In order to support ongoing G-BASE tasks (publications, collaborative research, data management, etc.) for London Earth, Clyde Basin and other G-BASE data it is recommended that specific tasks are identified. This should be part of a strategy for sustaining BGS capability in applied geochemistry beyond the completion of G-BASE. The staff time budget allocated to sampling should not exceed 50% of the total staff allocation.
9. This completion plan needs to be considered in the context of the BGS strategy regarding the future of the BGS laboratories. A stream sediment only survey would not provide any additional work for the BGS laboratories, apart from sample preparation. Stream water analyses would provide work for the laboratories but at current costs would require a substantial budget of >£450k over four years. Stream water samples could probably be stored

for a year without too many detrimental effects on the analytes. Beyond one year the effects of long-term storage are unquantified. Ways to reduce the preparation and analytical costs need to be explored. When a completion plan is agreed collaborative projects with external organisations should be explored.

Appendix 1 : How geostatistics could help plan remaining sampling of G-BASE

Murray Lark. 14th April 2011.

1. The problem.

The general question 'how many samples are needed...?' belongs to the same class as 'how long is a piece of string?' which means that it can be answered in a straightforward way if you know the end-use of the piece of string or the sample data. A survey designed to provide national data infrastructure does not have a single end-user, and the requirements of future users cannot all be predicted. However, increased sample effort always yields diminishing marginal returns, and any rational sample planning should be done in the light of where we are on the response curve and based on the conscious decision that it is rational to spend £*x* per km^2 to achieve a precision *y* in our estimates when reducing the costs by, say, 20% would only reduce the precision by 5%. Geostatistics allows us to compute response curves for precision of predictions against sampling intensity for variables with spatially dependent variation.

2. Geostatistical approach.

The geostatistical approach, first proposed by McBratney et al (1981) and subsequently refined (*e.g.* Marchant & Lark, 2007) is based on the variogram of the variable in question. From this we can compute the expected squared error of kriging predictions (interpolations) from a sample network of particular intensity. The two graphs below were computed from variograms of Co and Ni in the Humber-Trent G-BASE soil data set. I plotted the standard error of the kriging prediction (at the centre of a grid cell, furthest from the nearest sample point) against the sample intensity (based on a square sample grid, but it could be computed for any sample array). I noted on the graph the intensities comparable to the National Soil Inventory (NSI) and G-BASE, and also fractions of the current G-BASE sample effort.

These calculations are more complex for variables that appear log-normal, but there is now a sufficiently mature body of methodology to extend the approach to cover them (*e.g.* Paul & Cressie, 2011).

These two *precision/effort curves* illustrate the diminishing returns to sample effort. If the effort in G-BASE is reduced to 2/3 of that under the current protocol for soils then the increase in the standard error is 4% for Ni and 2.7% for Co. Whether this is acceptable is a matter for discussion, but a rational process of planning sampling should surely be based on such curves, for a range of critical elements, so that we are aware of the returns that we are getting on each additional unit of field and laboratory effort.

One consequence of the geostatistical approach is that the sampling requirement to produce information of specified precision, will be different in landscapes which differ with respect to the spatial dependence of the target variables. A corollary of this is that a uniform sampling strategy would produce information that is more precise in some parts of the country and less precise elsewhere. If we have some information on a particular region then we can use this to plan a sampling scheme considering the regional precision/effort curves.

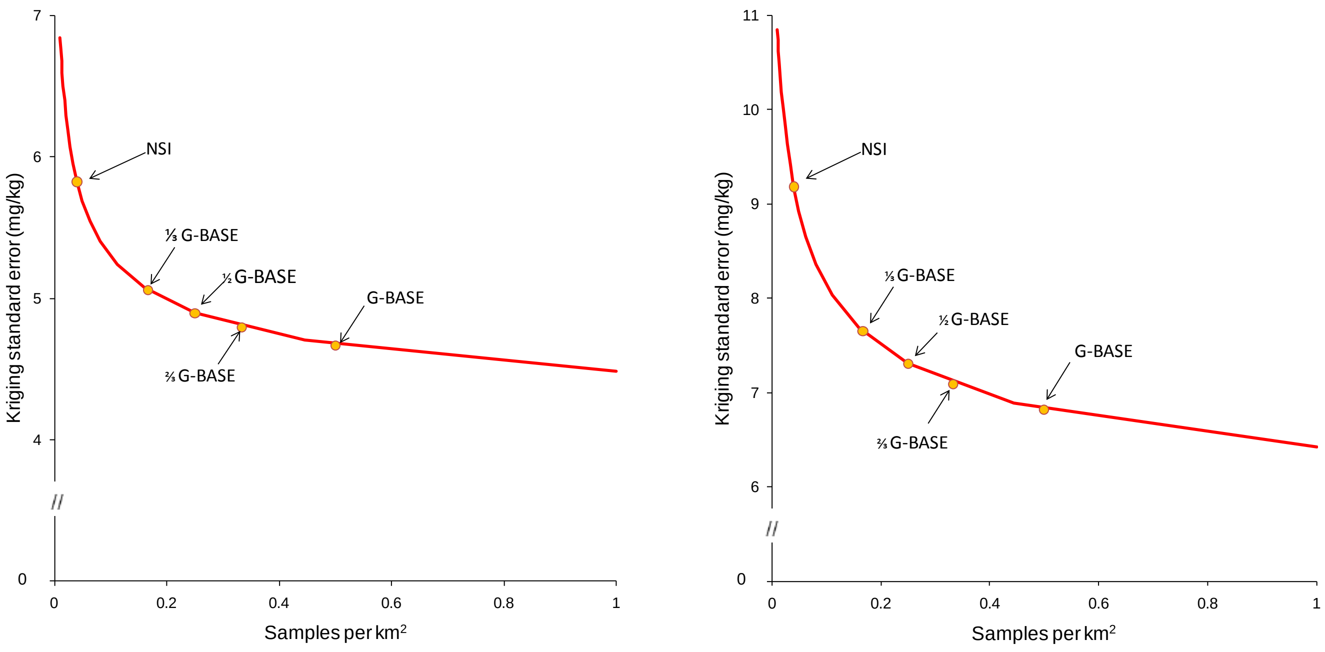

Figure 1: Precision/effort curves (kriging standard error as a function of sample effort) based on the variogram of (left) Cobalt and (right) Nickel in the Humber-Trent region

3. Proposal.

I propose that any planning of the completion of G-BASE should take account of the precision/effort curves for a range of elements from geostatistical analysis of available data on the regions still to be sampled, or analogue regions already covered. We would use data from the Tamar catchment to investigate sampling requirements in analogous regions of the South West, and newly-available data from Kent and North Surrey for the same purposes in the South East. Other available data include the NSI XRF data on soils, and possibly the Wolfson data on stream sediments. It would also be ideal if some exploratory sampling could be undertaken with a view to characterizing the spatial variability of under-represented landscapes.

The resulting precision cost curves would then be discussed with interested parties across BGS as a basis for deciding, for each remaining region, on a sample effort which is scientifically defensible as a rational use of resources.

References.

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Paul, R & Cressie, N. 2011. Lognormal block kriging for contaminated soil. *European Journal of Soil Science*, **62** (in press).

Appendix 2 : Examples of recent interest in the regional geochemistry of southern England

From: Bennett, David [mailto:david.bennett@environment-agency.gov.uk]
Sent: 13 April 2011 17:09
To: Reeves, Helen J.
Cc: Ander, Louise
Subject: GBASE

Helen

My colleague Trevor Howard and I had a very interesting meeting with Louise Ander this morning to discuss matters of mutual interest around the GBASE work.

My area of interest is radioactive substance regulation from nuclear sites (Trevor had others, that I am sure Louise will brief you on). As you may be aware we recently referred to the GBASE work when dealing with some recent (unfounded) allegations regarding large scale contamination of soils with enriched uranium around the Hinkley Point power station site in Somerset . This ability to refer to factual data from GBASE on natural levels or uranium contamination, and the extent of their variation was very useful.

Although we don't know if similar allegations will crop up again - at Hinkley Point or other nuclear sites - if they do we would probably want to refer to GBASE again. That being the case, if you are considering what factors influence priorities on where GBASE work on uranium should be extended, we would support its extension to where nuclear power station and fuel route sites are located; particularly Hinkley Point in Somerset.

Regards

David Bennett
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Dear Dr Reeves

HPA/ BGS Collaboration

I would like to express my appreciation for the hard work and professionalism of the team which delivered the initial field work on our project on arsenic and other elements in private water supplies in Cornwall.

Michael, Louise, Helen and Elliot worked seamlessly with their HPA counterparts and demonstrated huge flexibility and commitment especially in the long and anti social hours that they put in to meet the sampling targets. Their expertise was invaluable in both informing and reassuring the public about the sensitive issues of drinking water quality and we've had excellent feedback from many of the householders they visited. Preparatory work by Pauline and Louise was also noteworthy given the very short timescales and novel approach of the study

In our initial planning for the study I was quite surprised that the south west peninsula with its complex geology and long history of mineral exploitation had not been covered by the Geochemical Baseline Survey of the Environment (G-BASE) which has already been completed for most of the country north of the Midlands. This became a significant gap in our data requirements for the exposure assessment which will be a large part of both the environmental and public health assessment phases of the study.

Whilst this particular study was focussed on borehole supplies and the underlying geological formations, there are also a large number of households in Cornwall (and probably Devon and Dorset) which rely on surface water sources and the non availability of G-BASE data on streams and sediments leaves a very obvious gap in our overall population exposure assessment.

I assume that this omission will be corrected in the near future to give us a more detailed picture of the contributions of both surface and sub surface sources to the drinking water environment and I wonder if you are in a position to share with us the likely dates for availability of G-BASE data for the south west peninsula and other areas of England not currently covered.

My thanks again for the hard work and dedication of the BGS team working with us on the arsenic study in private water supplies.

Yours sincerely

Giovanni Leonardi

Dr Giovanni Leonardi
Head of Epidemiology

Appendix 3 : Inventory of G-BASE equipment and estimated costs for consumables to complete G-BASE

The following are estimates based on current costs and a rapid assessment of what is currently in the G-BASE store.

General Equipment

Based on a four year campaign across the whole of the remaining area

Item	Current Stock	Future requirement	No	Unit Cost	Total Cost
Portable computer	2	A replacement needed - use those available from SNS	0		£0
GPS	OK	Nigeria GPSs to be donated to G-BASE	0		£0
Mobile phone	OK	Suggest 4 new phones over 4 years	4	£15	£60
Mobile phone top-ups		Sample team £40 per team per 12 weeks. Staff £100 per 12 week season	4 sampling teams 2 staff	£360 per year	£1,440
First Aid Kit	OK	Provided by H&S	0		£0
Rucsacks	OK	Cost in 10 new rucksacs over 4 years	10	£60	£600
Hi-Vis jackets	OK	Provided by H&S	0		£0
Compass	OK but stocks become depleted	Cost in 8 over 4 years	8	£18	£144
Knox Protactor	OK but break easily	Cost in 12 over 4 years	12	£13	£156
Hand lens	OK but stocks become depleted	Cost in 10 over 4 years - check on quality required	10	£4	£40
Geological Hammer	OK	Plenty in store	0		£0
A5 Filofax folders	OK	Plenty in store	0		£0
Blank field cards	Soil OK. Need 10,000 drainage cards	Get new drainage cards produced internally	10,000		£708
Black Pentels and biros	Need purchasing annually	Advise against buying in bulk as pens can dry up	20 per year	£ 9.96 per 12 £3.60 per 20	£72
OS topographic maps maps (1:50k)	None for unmapped areas. Suggest 8 maps per OS area, less where small land area.	*c*.34 map sheet areas from southern England. Say 250 maps.	250	£6 per map	£1,500
A4 self-seal poly bags	Running low	Used to carry maps etc.	1000	£54.56 per 1000	£55
				Total	**£4,775**

Field cards usually printed from Science Budget print budget at no cost to project

Stream Sediments

Proposed collection of 8,200 stream sediments over 4 years

Item	Current Stock	Future requirement	No.	Unit Cost	Total Cost
Sieve set nests with pans, and funnels.	OK	Annual refurbishment (e.g. varnishing)	20	£50 per sieve	£1,000
Rubber Gauntlets	OK	Replacement gloves (sizes 8,9,10)	15	£ 8 per pair	£120
Sieve rucksac frames and bungie cords	OK	Purchase some replacement bungie cords	24	£0.95 per cord	£24
Trenching tool	OK	None	0		£0
Stream sediment Kraft bags (4" x 8")	depleted	Use remaining stock then use Kraft soil bags	0		£0
Panned concentrate Kraft bags (3" x 5")	c. 3000 remaining	Need c.6000 more. Need to check with supplier if they still have some	3000	£208 per 1000	£624
2 mm nylon sieve mesh	limited	Estimated 100 m^2 required	100 m	£18.81 per metre	£1,881
150 µm nylon sieve mesh	limited	Estimated 100 m^2 required	100 m	£12.54 per metre	£1,254
"Sedi-outer" polythene bags (6" x 17")	OK	None	0		£0
				Total	**£4,903**

Stream Waters

Proposed collection of 8,200 waters over 4 years

Item	Current Stock	Future requirement	No.	Unit Cost	Total Cost
60 ml Nalgene bottle					
30 ml Nalgene bottle					
30 ml polythene bottle (for pH)					
250 ml Nalgene bottle (alkalinity/conductivity)	OK	None			£0
Conductivity meter	OK	1 replacement	1	£456	£456
pH meter - electrode	OK	1 replacement	1	£120	£120
Ultra pure acid for acidification					
Automated pipette for acidification	1	Need 1 spare	1	£311	£311
Titrator for alkalinity	OK	1 replacement	1	£150	£150
Acid cartridges for alkalinity test plus indicator solution					
Disposal filters					
Filter syringes					
				Total	**£1,037**

Louise Ander calculates cost of consumables for waters is	£4	per sample
Total for 8,200 samples based on unit cost is	**£8,200**	

Soils

Proposed collection of 2,000 soils over 4 years

Item	Current Stock	Future requirement	No.	Unit Cost	Total Cost
1 m Dutch steel augers	OK	Allow for breakages order 10 more	10	£92	£921
Soil Kraft bags (5" x 10")	10,000+	Enough for soils and also stream sediments			£0
				Total	**£921**

Summary

Estimated equipment and consumable costs for 4 years of G-BASE fieldwork

General Equipment	£4,775
Stream sediments	£4,903
Soils	£ 921
Stream waters	£1,037 (equipment)
Stream waters	£32,800 (consumables for field testing)

Appendix 4 : Indicative Budgets 2012-2016 for G-BASE sampling

The following is a record of the data used in the budget estimates for G-BASE sampling used in summary tables within this report. All budgets are based on 2011-12 costs and do not have any annual inflation factor.

DATA

Staff costs (2011-12) (raw)		
Band	Hourly	Day
2	£74.64	£559.80
3	£56.13	£420.98
4	£45.68	£342.60
5	£34.53	£258.98
6	£26.54	£199.05
7	£21.24	£159.30
8	£16.78	£125.85
Overtime	12% of staff costs	
Daily T&S	£20	
B&B	£60	
VW costs		
Daily allowance	£30	
T&S	£100	
Other costs	£60	
Vehicles		
Minibus	£470	per week
4 x 4	£183	per week
Car	£45	per day
fuel	£200	per week
Accommodation	£1,800	full team per week
Consumables	£150	per week
Analytical costs	(raw)	calculated at 2011-12
XRFS	"free"	fec costs - 100%
Full sample prep	£10.5	
Half sample prep	£5.0	
pH and LOI	£5.5	
Water - MS cations	£22.5	
Water - IC anions	£22.5	
Water NPOC	£7.5	

SEDIMENT SAMPLING (OPTION 1-3) producing 9,550 samples for analysis

2012-13 *12 weeks field work for one team collecting 2100 sediment samples*

		Staff costs (raw)				Other recurrent (OR)	-			Internal services (raw)	
84	days	Team Leader (Band 6)	£16,720	84	days	Minibus	£5,640	2580	samples	Full samp. Prep	£27,090
84	days	Asst. Team Leader (Band 7)	£13,381	84	days	4x4 vehicle	£2,196	2580	samples	XRFS	"free"
7	days	Trainer (Band 6)	£1,393	12	days	Car	£540				
4	days	Management visit (Band 4)	£1,370	12	weeks	Fuel	£2,400				
6	days	Logistical support (Band 6)	£1,194					*includes 375 MRP samples (525 to be*			
35	days	Pre-fieldwork planning (Band 8)	£4,405	18	VW	Boot allowances	£1,080	*analysed in 2011-12)*			
10	days	Pre-fieldwork planning (Band 6)	£1,991	18	VW	Travelling costs	£1,800				
2	days	Pre-fieldwork planning (Band 4)	£685	756	days	9 VWs allowance	£22,680				
				12	weeks	Cosumables	£1,800				
				12	weeks	Team Accommodation	£21,600				
		Staff Data management				Staff T&S	-				
6	days	Field database (Band 6)	£1,194	175	days	T&S based in paid accommodation	£3,500				
20	days	management/QA/levelling (Band 6)	£3,981	10	days	T&S based on staying in B&B	£800				
		TOTAL	£46,315			**TOTAL**	£64,036			**TOTAL**	£27,090

2013-14 12 weeks field work for one team collecting 2100 sediment samples

		Staff costs (raw)				Other recurrent (OR)	-			Internal services (raw)	
84	days	Team Leader (Band 6)	£16,720	84	days	Minibus	£5,640	2205	samples	Full samp. Prep	£23,153
84	days	Asst. Team Leader (Band 7)	£13,381	84	days	4x4 vehicle	£2,196	2205	samples	XRFS	"free"
7	days	Trainer (Band 6)	£1,393	12	days	Car	£540				
4	days	Management visit (Band 4)	£1,370	12	weeks	Fuel	£2,400				
6	days	Logistical support (Band 6)	£1,194								
35	days	Pre-fieldwork planning (Band 8)	£4,405	18	VW	Boot allowances	£1,080				
10	days	Pre-fieldwork planning (Band 6)	£1,991	18	VW	Travelling costs	£1,800				
2	days	Pre-fieldwork planning (Band 4)	£685	756	days	9 VWs allowance	£22,680				
				12	weeks	Cosumables	£1,800				
				12	weeks	Team Accommodation	£21,600				
		Staff Data management				Staff T&S	-				
6	days	Field database (Band 6)	£1,194	175	days	T&S based in paid accommodation	£3,500				
20	days	management/QA/levelling (Band 6)	£3,981	10	days	T&S based on staying in B&B	£800				
		TOTAL	£46,315			**TOTAL**	£64,036			**TOTAL**	£23,153

2014-15 12 weeks field work for one team collecting 2100 sediment samples

		Staff costs (raw)				Other recurrent (OR)	-			Internal services (raw)	
84	days	Team Leader (Band 6)	£16,720	84	days	Minibus	£5,640	2205	samples	Full samp. Prep	£23,153
84	days	Asst. Team Leader (Band 7)	£13,381	84	days	4x4 vehicle	£2,196	2205	samples	XRFS	"free"
7	days	Trainer (Band 6)	£1,393	12	days	Car	£540				
4	days	Management visit (Band 4)	£1,370	12	weeks	Fuel	£2,400				
6	days	Logistical support (Band 6)	£1,194								
35	days	Pre-fieldwork planning (Band 8)	£4,405	18	VW	Boot allowances	£1,080				
10	days	Pre-fieldwork planning (Band 6)	£1,991	18	VW	Travelling costs	£1,800				
2	days	Pre-fieldwork planning (Band 4)	£685	756	days	9 VWs allowance	£22,680				
				12	weeks	Cosumables	£1,800				
				12	weeks	Team Accommodation	£21,600				
		Staff Data management				Staff T&S	-				
6	days	Field database (Band 6)	£1,194	175	days	T&S based in paid accommodation	£3,500				
20	days	management/QA/levelling (Band 6)	£3,981	10	days	T&S based on staying in B&B	£800				
		TOTAL	£46,315			**TOTAL**	£64,036			**TOTAL**	£23,153

2015-16 11 weeks field work for one team collecting 1900 sediment samples

		<u>Staff costs (raw)</u>	
77	days	Team Leader (Band 6)	£15,327
77	days	Asst. Team Leader (Band 7)	£12,266
7	days	Trainer (Band 6)	£1,393
4	days	Management visit (Band 4)	£1,370
6	days	Logistical support (Band 6)	£1,194
34	days	Pre-fieldwork planning (Band 8)	£4,279
10	days	Pre-fieldwork planning (Band 6)	£1,991
2	days	Pre-fieldwork planning (Band 4)	£685
		<u>Staff Data management</u>	
6	days	Field database (Band 6)	£1,194
20	days	management/QA/levelling (Band 6)	£3,981
		TOTAL	£43,681

		<u>Other recurrent (OR)</u>	-
77	days	Minibus	£5,170
77	days	4x4 vehicle	£2,013
12	days	Car	£540
11	weeks	Fuel	£2,200
18	VW	Boot allowances	£1,080
18	VW	Travelling costs	£1,800
693	days	9 VWs allowance	£20,790
11	weeks	Cosumables	£1,650
11	weeks	Team Accommodation	£19,800
		<u>Staff T&S</u>	-
161	days	T&S based in paid accommodation	£3,220
10	days	T&S based on staying in B&B	£800
		TOTAL	£59,063

		<u>Internal services (raw)</u>	
1995	samples	Full samp. Prep	£20,948
1995	samples	XRFS	"free"
		TOTAL	£20,948

STREAM WATER SAMPLING (OPTION 2-2) producing 8,600 samples for analysis (conducted at same time as Option 1-3)

2012-13 12 weeks field work for one team collecting 2100 water samples

		Staff costs (raw)				Other recurrent (OR)	-			Internal services (raw)	
84	days	Team Leader (Band 6)		84	days	Minibus		2205	samples	Water - MS cations	£49,613
84	days	Asst. Team Leader (Band 7)		84	days	4x4 vehicle		2205	samples	Water - IC anions	£49,613
7	days	Trainer (Band 6)		12	days	Car		2205	samples	Water NPOC	£16,538
4	days	Management visit (Band 4)		12	weeks	Fuel					
6	days	Logistical support (Band 6)									
35	days	Pre-fieldwork planning (Band 8)		18	VW	Boot allowances					
10	days	Pre-fieldwork planning (Band 6)		18	VW	Travelling costs					
2	days	Pre-fieldwork planning (Band 4)		756	days	9 VWs allowance					
				12	weeks	Consumables (field water methods)	£600				
				12	weeks	Team Accommodation					
						Staff overtime	£3,612				
		Staff Data management				Staff T&S	-				
1	days	Field database (Band 6)	£199	175	days	T&S based in paid accommodation					
20	days	management/QA/levelling (Band 6)	£3,981	10	days	T&S based on staying in B&B					
		TOTAL	£4,180			**TOTAL**	£4,212			**TOTAL**	£115,763

2013-14 12 weeks field work for one team collecting 2100 water samples

		Staff costs (raw)	
84	days	Team Leader (Band 6)	
84	days	Asst. Team Leader (Band 7)	
7	days	Trainer (Band 6)	
4	days	Management visit (Band 4)	
6	days	Logistical support (Band 6)	
35	days	Pre-fieldwork planning (Band 8)	
10	days	Pre-fieldwork planning (Band 6)	
2	days	Pre-fieldwork planning (Band 4)	
		Staff Data management	
1	days	Field database (Band 6)	£199
20	days	management/QA/levelling (Band 6)	£3,981
		TOTAL	£4,180

		Other recurrent (OR)	-
84	days	Minibus	
84	days	4x4 vehicle	
12	days	Car	
12	weeks	Fuel	
18	VW	Boot allowances	
18	VW	Travelling costs	
756	days	9 VWs allowance	
12	weeks	Consumables (field water methods)	£600
12	weeks	Team Accommodation	
		Staff overtime	£3,612
		Staff T&S	-
175	days	T&S based in paid accommodation	
10	days	T&S based on staying in B&B	
		TOTAL	£4,212

		Internal services (raw)	
2205	samples	Water - MS cations	£49,613
2205	samples	Water - IC anions	£49,613
2205	samples	Water NPOC	£16,538
		TOTAL	£115,763

2014-15 12 weeks field work for one team collecting 2100 water samples

		Staff costs (raw)				Other recurrent (OR)	-			Internal services (raw)	
84	days	Team Leader (Band 6)		84	days	Minibus		2205	samples	Water - MS cations	£49,613
84	days	Asst. Team Leader (Band 7)		84	days	4x4 vehicle		2205	samples	Water - IC anions	£49,613
7	days	Trainer (Band 6)		12	days	Car		2205	samples	Water NPOC	£16,538
4	days	Management visit (Band 4)		12	weeks	Fuel					
6	days	Logistical support (Band 6)									
35	days	Pre-fieldwork planning (Band 8)		18	VW	Boot allowances					
10	days	Pre-fieldwork planning (Band 6)		18	VW	Travelling costs					
2	days	Pre-fieldwork planning (Band 4)		756	days	9 VWs allowance					
				12	weeks	Consumables (field water methods)	£600				
				12	weeks	Team Accommodation					
						Staff overtime	£3,612				
		Staff Data management				Staff T&S	-				
1	days	Field database (Band 6)	£199	175	days	T&S based in paid accommodation					
20	days	management/QA/levelling (Band 6)	£3,981	10	days	T&S based on staying in B&B					
		TOTAL	£4,180			**TOTAL**	£4,212			**TOTAL**	£115,763

2015-16 11 weeks field work for one team collecting 1900 water samples

		<u>Staff costs (raw)</u>				<u>Other recurrent (OR)</u>	-			<u>Internal services (raw)</u>	
77	days	Team Leader (Band 6)		77	days	Minibus		1985	samples	Water - MS cations	£44,663
77	days	Asst. Team Leader (Band 7)		77	days	4x4 vehicle		1985	samples	Water - IC anions	£44,663
7	days	Trainer (Band 6)		12	days	Car		1985	samples	Water NPOC	£14,888
4	days	Management visit (Band 4)		11	weeks	Fuel					
6	days	Logistical support (Band 6)									
34	days	Pre-fieldwork planning (Band 8)		18	VW	Boot allowances					
10	days	Pre-fieldwork planning (Band 6)		18	VW	Travelling costs					
2	days	Pre-fieldwork planning (Band 4)		693	days	9 VWs allowance					
				11	weeks	Consumables (field water methods)	£550				
				11	weeks	Team Accommodation					
						Staff overtime	£3,311				
		<u>Staff Data management</u>				<u>Staff T&S</u>	-				
1	days	Field database (Band 6)	£199	161	days	T&S based in paid accommodation					
20	days	management/QA/levelling (Band 6)	£3,981	10	days	T&S based on staying in B&B					
		TOTAL	£4,180			**TOTAL**	£3,861			**TOTAL**	£104,213

SOIL SAMPLING (OPTION 2-1) producing 1700 samples for analysis

2012-13 2.5 weeks field work for one team collecting 580 soil samples

		Staff costs (raw)				Other recurrent (OR)	-			Internal services (raw)	
18	days	Team Leader (Band 6)	£3,583	18	days	Minibus	£1,209	610	samples	Full samp. Prep	£6,405
18	days	Asst. Team Leader (Band 7)	£2,867	18	days	4x4 vehicle	£471	610	samples	XRFS	"free"
2	days	Trainer (Band 6)	£398	1	days	Car	£45	610	samples	pH and LOI	£3,355
1	days	Management visit (Band 4)	£343	2.5	weeks	Fuel	£500	580	samples	Half prep	£2,900
0	days	Logistical support (Band 6)	£0								
4	days	Pre-fieldwork planning (Band 8)	£503	8	VW	Boot allowances	£480				
2	days	Pre-fieldwork planning (Band 6)	£398	8	VW	Travelling costs	£800				
1	days	Pre-fieldwork planning (Band 4)	£343	144	days	8 VWs allowance	£4,320				
				2.5	weeks	Consumables	£375				
				2.5	weeks	Team Accommodation	£4,500				
		Staff Data management				Staff T&S	-				
2	days	Field database (Band 6)	£398	38	days	T&S based in paid accommodation	£760				
4	days	management/QA/levelling (Band 6)	£796	1	days	T&S based on staying in B&B	£80				
		TOTAL	£9,629			**TOTAL**	£13,539			**TOTAL**	£12,660

2013-14 2.5 weeks field work for one team collecting 580 soil samples

		Staff costs (raw)				Other recurrent (OR)	-			Internal services (raw)	
18	days	Team Leader (Band 6)	£3,583	18	days	Minibus	£1,209	610	samples	Full samp. Prep	£6,405
18	days	Asst. Team Leader (Band 7)	£2,867	18	days	4x4 vehicle	£471	610	samples	XRFS	"free"
2	days	Trainer (Band 6)	£398	1	days	Car	£45	610	samples	pH and LOI	£3,355
1	days	Management visit (Band 4)	£343	2.5	weeks	Fuel	£500	580	samples	Half prep	£2,900
0	days	Logistical support (Band 6)	£0								
4	days	Pre-fieldwork planning (Band 8)	£503	8	VW	Boot allowances	£480				
2	days	Pre-fieldwork planning (Band 6)	£398	8	VW	Travelling costs	£800				
1	days	Pre-fieldwork planning (Band 4)	£343	144	days	8 VWs allowance	£4,320				
				2.5	weeks	Consumables	£375				
				2.5	weeks	Team Accommodation	£4,500				
		Staff Data management				Staff T&S	-				
2	days	Field database (Band 6)	£398	38	days	T&S based in paid accommodation	£760				
4	days	management/QA/levelling (Band 6)	£796	1	days	T&S based on staying in B&B	£80				
		TOTAL	£9,629			**TOTAL**	£13,539			**TOTAL**	£12,660

2014-15 2 weeks field work for one team collecting 460 soil samples

		Staff costs (raw)	
14	days	Team Leader (Band 6)	£2,787
14	days	Asst. Team Leader (Band 7)	£2,230
0	days	Trainer (Band 6)	£0
0	days	Management visit (Band 4)	£0
0	days	Logistical support (Band 6)	£0
4	days	Pre-fieldwork planning (Band 8)	£503
2	days	Pre-fieldwork planning (Band 6)	£398
1	days	Pre-fieldwork planning (Band 4)	£343
		Staff Data management	
2	days	Field database (Band 6)	£398
4	days	management/QA/levelling (Band 6)	£796
		TOTAL	£7,455

		Other recurrent (OR)	-
14	days	Minibus	£940
14	days	4x4 vehicle	£366
1	days	Car	£45
2	weeks	Fuel	£400
8	VW	Boot allowances	£480
8	VW	Travelling costs	£800
112	days	8 VWs allowance	£3,360
2	weeks	Consumables	£300
2	weeks	Team Accommodation	£3,600
		Staff T&S	-
28	days	T&S based in paid accommodation	£560
0	days	T&S based on staying in B&B	£0
		TOTAL	£10,851

		Internal services (raw)	
480	samples	Full samp. Prep	£5,040
480	samples	XRFS	"free"
480	samples	pH and LOI	£2,640
460	samples	Half prep	£2,300
		TOTAL	£9,980

Appendix 5 : Science case for continued water sample collection and analysis

Background

Stream waters have been collected and analysed since regional geochemical mapping of the UK commenced in the 1960s though the earliest stream waters were mainly determined for field measured parameters such as pH, conductivity and alkalinity. The availability of G-BASE stream water data is described by Ander and Casper (2008), and is summarised in Figure 4 of this current report. Since the geochemical mapping of Wales (1988-1994) analytical methodology has developed to determine analytes in water down to the low level of concentrations required and a stream water atlas for Wales was published in 1999 (BGS, 1999). This established stream waters as an important part of the G-BASE multi-media approach to mapping and interpreting the geochemical baseline and the science case for stream water baseline mapping was established.

Stream waters can be collected at the same time and from the same location as stream sediments with few additional resources required. These are mainly for consumables (Nalgene™ bottles, high-purity acid for acidification, filters) estimated to be £3.90 per water sample . However, the analytical costs for the stream water analyses approximately double the analysis. Below is the scientific justification for the expense.

Science Case

1. The collection and analysis of stream waters (along with sediments and soils) makes G-BASE a unique regional multi-media baseline study, an important and growing theme in environmental research. Interpretation of samples from the same location enables us to understand better and model the distribution and migration of chemical elements between the different environmental compartments. This supports integrated catchment management.
2. There are important legislative drivers that require essential information about the distribution of chemical elements in stream waters and the G-BASE stream water data have been, and will continue to be, used in support of policy decisions regarding acceptable levels of contaminants. Ander and Casper (2008) demonstrated the importance of using G-BASE stream water data to determine metal background concentrations in the context of the Water Framework Directive. Similarly, Smedley *et al*. (2008) used G-BASE stream water Mo data in a study of "Molybdenum in British drinking water". This Defra-funded project is an example of how the G-BASE stream water data could be applied to assess the implication for the UK water industry regarding potential legislative limits being imposed for drinking water.
3. The high density sampling of low order (small) streams at a regional scale complements many existing water-quality monitoring programmes undertaken on a routine basis by various regulatory authorities. The results importantly continue to demonstrate that, at a regional scale, the underlying geology is a significant factor in determining the chemical composition of the stream waters.
4. The G-BASE capability generated from the collection and analysis of waters continues to give BGS a competitive edge in winning contracted work from government departments, e.g. Tellus Project. There are many other examples to illustrate this point, often using the stream water results together with BGS groundwater data:

- “Plotting of Private Water Supply data onto simplified geology maps of east Cornwall” recently completed for the HPA (Ander *et al*., 2011)
- “A review of data on molybdenum in drinking water and a survey of molybdenum and other trace elements in drinking water”, Defra (DWI) project CEER 0604 (18 months: 2006-2008)
- “Monitoring for trace elements in drinking water”, Defra project (DWI) WD1003 (DWI 70/2/265) – a 2-year project (2011-2013) looking at non-regulated trace elements in drinking water in England & Wales.

5. The stream water work has generated peer-reviewed publications, particularly when G-BASE project resources were available for this task, and has enormous potential to continue to do so in the future. Such work has generated collaboration with academic and other research institutes. Examples of publications using the G-BASE water data:
    - Temporal and spatial variability of stream waters in Wales, the Welsh borders and part of the West Midlands, UK - 1. Major ion concentrations. M G Hutchins; B Smith; B G Rawlins; T R Lister. Water Research, 33(16), (1999): 3479.
    - Temporal and spatial variability in stream waters of Wales, the Welsh borders and part of the West Midlands, UK - 2. Alumino-silicate mineral stability, carbonate and gypsum solubility. B G Rawlins; B Smith; M G Hutchins; T R Lister. Water Research, 33(16), (1999): 3492.
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