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# UK Geoenergy Observatories, Glasgow Environmental Baseline Soil Chemistry Dataset

Decarbonisation and Resource Management Programme

Open Report OR/19/062

BRITISH GEOLOGICAL SURVEY

DECARBONISATION AND RESOURCE MANAGEMENT PROGRAMME

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# UK Geoenergy Observatories, Glasgow Environmental Baseline Soil Chemistry Dataset

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# Summary

This report gives an overview of information related to the environmental baseline topsoil chemistry dataset collected as part of the United Kingdom Geoenergy Observatories (UKGEOS) project at the Glasgow Geothermal Energy Research Field Site (GGERFS) in February-March 2018 (03-18). This report accompanies the release of the GGERFS Soil Chemistry03-18 dataset.

The GGERFS facility comprises 12 environmental baseline/mine characterisation boreholes drilled into the superficial deposits and bedrock in the Cuningar Loop and Dalmarnock areas in the east of Glasgow. The aims of the facility include de-risking key technical barriers to low-temperature shallow geothermal energy from groundwater in former coal mine workings and providing environmental characterisation and monitoring to assess any change in ambient conditions.

Prior to borehole development, a study of the chemical quality of soil was carried out to aid understanding of the ground conditions and to determine the pre-development environmental baseline, against which future change can be assessed.

Ten topsoil (0 – 20 cm) samples were collected from each of the proposed GGERFS borehole sites and from two control sites with semi-natural soil in Glasgow Green and Tollcross Park. Topsoil samples were collected from 90 locations. At each location the following samples types were taken:

- A - Topsoil for inorganic and organic chemical analysis
- M-4 - Topsoil for storage at -4 °C and future geomicrobiological culture work
- M-20 – Topsoil for storage at -20 °C/ -80 °C and future geomicrobiological deoxyribonucleic acid (DNA) study

The samples collected for chemical analysis underwent laboratory testing to determine soil pH and the total concentration of 54 inorganic chemical elements and 75 organic substances including soil organic carbon, total petroleum hydrocarbon (TPH), poly-cyclic aromatic hydrocarbon (PAH) and polychlorinated biphenyl (PCB) content.

The resultant chemical data are made available in the GGERFS baseline Soil Chemistry03-18 dataset along with descriptive information about the soils, such as location, land use, presence of any contaminant material in the soil and soil texture. The data are presented in Excel® table format in the file:

***Filename: GGERFS_SoilChem0318Data_Release.xlsx***

Any use of the data should be cited to:

DOI: https://dx.doi.org/10.5285/0bfdeb32-db24-4221-9d02-f074f51edff2

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and

FORDYCE F M, SHORTER K M, VANE C H, GOWING C J B, HAMILTON E M, KIM A W, EVERETT P A, MARCHANT B P AND LISTER T R .2019. UK Geoenergy Observatories, Glasgow Environmental Baseline Soil Chemistry Dataset. Open Report, OR/19/062 (Edinburgh: British Geological Survey)

The results of the baseline survey show that topsoil from the GGERFS sites generally contains higher inorganic and organic pollutant concentrations and is more calcareous/alkaline than semi-natural topsoil collected from the two control sites in Glasgow Green and Tollcross Park.

Similarly, the maximum concentrations of the pollutants cadmium (Cd), TPH, the naphthalene and dibenzofuran PAH compounds, ∑7PCBs and tri-hepta PCB compounds reported at the GGERFS sites exceed those in pre-existing city-wide British Geological Survey (BGS) Glasgow topsoil datasets.

Whilst the current land use at all the GGERFS sites is open recreational space, these findings are a consequence of the historic land use at the GGERFS sites, all of which are underlain by building rubble, domestic rubbish and/or colliery waste.

Like many urban environments, soil quality at the GGERFS sites has been impacted adversely by the presence of these materials in the soil.

Hexavalent chromium (Cr(VI)) speciation, which is often associated with industry, was determined in the soil samples because there is a history of disposal of chromite ore processing residue (COPR) in the east of Glasgow. Results revealed that Cr(VI) concentrations in the soil were generally < 10 mg/kg, with the exception of sample G087 at site 06b where an isolated high value of 28 mg/kg was reported, probably as a result of paint fragments present in the sample.

**There is no evidence of COPR waste in the topsoil samples collected from the GGERFS sites.**

An asbestos screening assessment of a sub-set of 10 of the topsoil samples revealed that trace amounts of asbestos fibres (0.027 % wt) were found in one sample (G017) from GGERFS04 only. The amount of asbestos present was classed as 'insignificant risk' according to current industry standards. This sample was collected from outside the publicly accessible area of the Cuningar Loop Park.

Although the GGERFS sites show evidence of soil pollution, comparisons with current UK human health risk assessment land contamination generic soil guidelines for recreational open space indicate that **in general, the land would not be classed as contaminated**.

However, two soil samples G023 and G057 from site 05 do exceed the recreational open space guideline for Pb (1300 mg/kg). These were collected outside of the publicly accessible area in the Cuningar Loop. The fact that these samples exceed the guideline does not mean that the land is contaminated. Rather that further investigation would be required to determine whether there is a source-pathway-receptor linkage and any potential risk at these locations.

The Soil Chemistry03-18 dataset has established the pre-installation environmental baseline for the GGERFS facility, against which any future change in soil chemistry can be assessed.

# 1 Introduction

In 2015, the British Geological Survey (BGS) and the Natural Environment Research Council (NERC) were tasked with developing new centres for research into the sub-surface environment to aid the responsible development of new low-carbon energy technologies in the United Kingdom (UK) and internationally.

The Glasgow Geothermal Energy Research Field Site (GGERFS) in the Cuningar Loop – Dalmarnock area in the east of Glasgow is one of two United Kingdom Geoenergy Observatories (UKGEOS) project sites (Figures 1 and 2). The aims of the GGERFS facility include de-risking technical aspects of extracting/storing shallow geothermal energy in an urbanised former coal mine setting (Monaghan 2019; Monaghan et al. 2017; Monaghan et al. 2018).

The initial phase of the GGERFS project entails installing a network of boreholes into the superficial deposits and bedrock in the Cuningar Loop-Dalmarnock area of Glasgow to characterise the geological and hydrogeological setting and assess the potential for shallow geothermal energy. The borehole network is designed also for baseline monitoring to assess the environmental status before and during the lifetime of the project.

The GGERFS facility is located in the former industrial heartland of the east of Glasgow, in an urban area with extensive artificial ground. Previous work has shown that contaminants are present in the soil/artificial ground in the east of Glasgow. These have had a detrimental impact on both surface and groundwater quality in the area (Broadway et al. 2010; Farmer et al. 1999; Fordyce et al. 2004; Fordyce et al. 2012; Fordyce et al. 2017; Fordyce et al. 2019; Palumbo-Roe et al. 2017; Whalley et al. 1999).

The history and complexity of human activities (including coal mining) affecting the subsurface at the GGERFS sites mean that soil–surface-water–groundwater interactions are currently poorly understood.

Whilst the premise is that development of a mine-water geothermal facility should not instigate any material change in surface conditions, the potential for changes in sub-surface fluid flow to alter near-surface flow and soil saturation regimes (hence, soil chemistry) is unknown in such a complex environment.

The GGERFS facility provides an opportunity to monitor soil chemistry as an exemplar, to provide reassurance for similar schemes in complex settings, in the many UK urban areas, where main centres of population and fuel poverty coincide with a potential former coal mine geothermal resource.

As part of the environmental monitoring, a survey of the chemical quality of topsoil (0-20 cm depth) was carried out in February-March 2018 (03-18) at each of the proposed borehole sites to determine ground conditions and to establish the pre-development environmental baseline, against which future change can be assessed. It should be noted that the proposed borehole sites GGERFS04 and 06b were included in the facility planning applications and the soil survey; however, subsequently they were not taken forward as borehole construction sites.

The soil quality monitoring programme aimed to:

- improve the scientific understanding of the near-surface environment and interactions with the subsurface in the study areas
- support interpretation of water quality data
- provide information on ground conditions; help satisfy regulatory requirements and provide public reassurance

This report describes the methods used to carry out the topsoil survey and the initial results, as a guide to the release of the GGERFS Soil Chemistry03-18 dataset.

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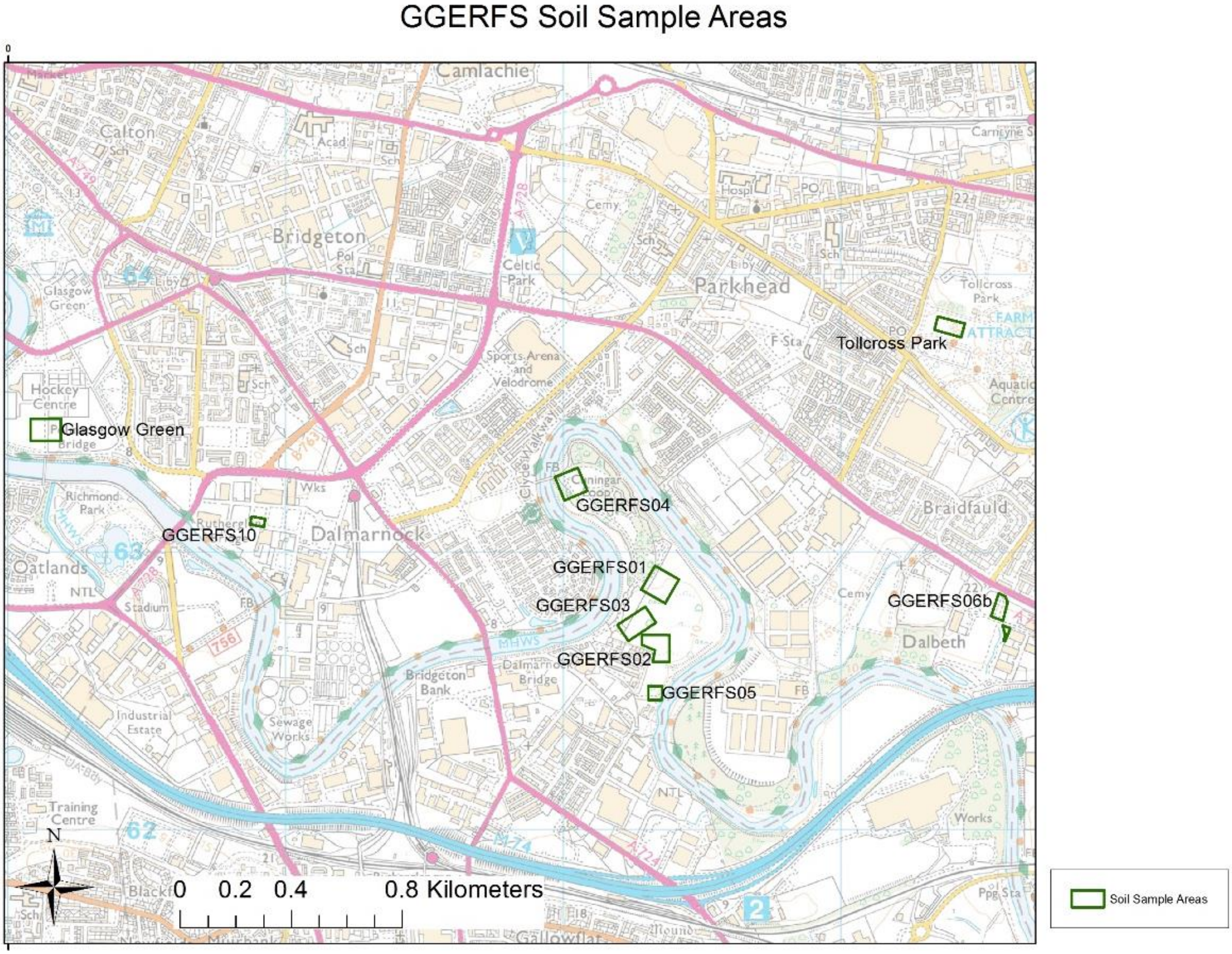
**Figure 1. Map of Great Britain, showing Glasgow, where the UK Geoenergy Observatory GGERFS facility is located.**



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Note that proposed borehole sites GGERFS04 and 06b were included in the soil survey, but subsequently were not taken forward as borehole construction sites.

**Figure 2. Map showing GGERFS and control soil sample areas in the east of Glasgow.**

# 2 Soil Chemistry Baseline Survey Rationale

## 2.1 SOIL INORGANIC AND ORGANIC CHEMISTRY

The BGS has existing soil geochemistry datasets in the surrounding area of Glasgow from the Geochemical Baseline Survey of the Environment (G-BASE) project (Fordyce et al. 2012; Fordyce et al. 2017; Fordyce et al. 2019) and a related study of organic pollutants in selected urban soil (Kim et al. 2019). The GGERFS baseline soil chemistry survey used similar methods to previous BGS studies, so that the GGERFS facility can be placed in the context of the wider environment to aid the planning of future boreholes/ developments.

Accordingly, topsoil (0-20 cm) samples were collected because:

(i) topsoil represents the zone of human interaction for public reassurance; and
(ii) this sample type is directly comparable with the existing BGS soil chemistry datasets for the area.

It was accepted that this shallow sampling strategy would not necessarily provide a complete means to aid the interpretation of the shallow groundwater chemistry data, as that would require information on the quality of artificial ground or superficial deposits at greater depth also. However, any assessment of deeper soil or Quaternary superficial deposits was deemed to be outside the scope of this study, and instead within the remit of any subsequent site investigation work.

The aim was to determine key soil quality properties such as:

(i) pH and total organic carbon (TOC) content;
(ii) persistent organic pollutants (POPs) including total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH) and polychlorinated biphenyls (PCB) content;
(iii) the total concentration of a suite of inorganic chemical elements, including key contaminants such as arsenic (As), cadmium (Cd), chromium (Cr) and lead (Pb);
(iv) In addition to total-Cr, hexavalent chromium (Cr(VI)) was determined because of a history of chromite-ore processing, and contamination of soil and surface/ground water with Cr(VI) in the area (Broadway et al. 2010; Farmer et al. 1999; Fordyce et al. 2004; Fordyce et al. 2019; Palumbo-Roe et al. 2017; Whalley et al. 1999).

## 2.2 SOIL GEOMICROBIOLOGY

The aim of the soil geomicrobiology sampling was to characterise the geomicrobiology baseline before any thermal perturbations of the system and enable predictive understanding of possible responses of the geomicrobiological system.

The GGERFS project should allow microbiologists to make use of recent developments in sampling, culturing under *in situ* conditions and biological characterisation (including high throughput genomic sequencing, bioinformatics, and 'meta-omics' techniques including transcriptomics and proteomics).

Soil samples for microbiological analysis were collected at the same time as the chemical soil samples and stored for future use. Soil gas monitoring was also carried out at the GGERFS facility at similar locations to the soil chemistry sampling. This will allow microbiologists to contribute to interpreting the causes of any measured changes in soil gas.

## 2.3 SURVEY DESIGN

A statistically-optimised approach to sampling design was adopted to strengthen the inferences that may be drawn between any changes to key environmental parameters and future activities in the area.

The soil chemistry-monitoring programme had to account for the inherent variability (in baseline) of the analytes of interest, at varied spatial scales, and over time, at key phases of the site development. This is a general challenge for environmental monitoring, which has been recognised in the development of appropriate sampling designs that address what are called 'Before and After Control/Impact (BACI)' sampling problems. For each parameter of interest, using a BACI sampling design allows the values observed after development to be compared reliably with the values before. The premise is that anthropogenic activity in the location of interest will cause a different pattern of change from before to after it starts compared with natural change in the control location (Underwood 1991). Survey design was informed by the position of boreholes and Control/Impact domains, so that any future geothermal development-related effects can be detected in the presence of overall trends that are caused by other factors.

At the time of the initial soil survey, there were seven proposed sites for borehole installation comprising GGERFS 01, 02, 03, 04, 05, 06b and 10; hence, each of these sites was surveyed (See maps in Appendix 1). However, subsequently, sites GGERFS04 and 06b were not taken forward for borehole drilling. It was anticipated that following the survey, the installation of boreholes would cause disruption and alterations to the ground surface and soil profile. It was conceivable that soil chemistry could change merely as a consequence of borehole emplacement prior to any geothermal research activity. Therefore, two areas within the nearby Glasgow Green (GG) and Tollcross Park (TC) were sampled also, to serve as 'control' sites. These were selected on the basis that the land use of these long-established (since the 1800s) parks (Appendix 1) was unlikely to change or be disturbed during the lifetime of the facility.

Ten topsoil samples were collected from each of these nine sites.

The aim of the sampling was to characterise soil chemical conditions around each of the borehole sites. The size and shape of the areas to be sampled was constrained by the locations and conditions on the ground, but extended to approximately 50 m around each proposed borehole position. The delineation of soil sampling areas also took account of anticipated losses of open ground due to access tracks to be put in place and planned developments around some of these sites that would have otherwise prevented future sampling.

The two control sites in Glasgow Green (GG), to the west of the facility and Tollcross Park (TC), to the north-east of the facility were chosen to be of a similar size to the GGERFS sampling sites, and outside the likely area of influence of the facility.

To ensure that the chemical data would be suitable for use in geostatistical approaches to future data interpretation, the majority of samples had to be relatively evenly spread across each of the nine sites, but with a proportion of closely-spaced pairs of samples to ensure that modelling short-scale variability is possible. Therefore, at each site we used a spatial simulated annealing algorithm to optimize the target location of nine samples, such that the mean distance from any point in the site to the nearest sample was minimized. Then one of these samples was selected at random and the 10th sample was located 5 m from it in a random direction. This sampling approach adheres to the rule-of-thumb suggested by Lark and Marchant (2018) for geostatistical surveys. At GGERFS sites 01, 02, 03, 04, 06b and 10, where borehole clusters were due to be emplaced, the optimization was constrained to ensure that at least four of the samples were collected in the zone adjacent to the borehole cluster at each site, so that these zones could be characterised adequately (See maps Appendix 1 soil sampling locations and proposed borehole positions at each site).

# 3 Sample Collection Methods

The soil sampling methods for the current project were based on the rigorous field-based control procedures developed by the BGS Geochemical Baseline Survey of the Environment (G-BASE) project, and were designed to minimise error (Johnson 2005; Bearcock et al. 2012).

Samples were collected in random number order but analysed in sequential order, so that any within-batch analytical instrument drift could be distinguished from genuine geographic variances (Plant 1973).

## 3.1 AVOIDING CONTAMINATION

- Jewellery was not worn during sample collection, to avoid metal contamination of the samples.
- Use of sun-cream and other skin products was avoided during sample collection.
- Gloves were worn during sample collection, for protection and to avoid contamination of the samples.
- The augers and sample bags for microbiological samples were not touched without gloves, to avoid contamination of the samples.
- The auger was cleaned between each sampling location, and the auger flight covered in a protective Rilsan® bag for transport between sites and storage.

## 3.2 SOIL COLLECTION

Samples were collected by teams of two to four BGS members of staff. Prior to fieldwork, 10 soil sampling target locations were identified via a statistically-based soil sampling design at each of the nine sites (See Section 2.3). The aim in the field was to collect samples from each of these target locations, or as close as possible to them, accepting conditions on the ground.

Samples were collected from all the target locations, with the exception of sites GGERFS10 and parts of sites GGERFS02 and GGERFS03. At GGERFS10, a shallow asphalt layer was encountered that prevented sampling at the northern edge of the site. The western edges of sites GGERFS02 and 03 also had to be revised, due to emplacement of a new access road and car park at the time of sampling. In all cases, alternative locations were selected in the field to be as close as possible to the target locations, whilst ensuring an even spread of samples across the site. Maps showing the sample locations are shown in Appendix 1.

At each sample location, a composite topsoil (0-20 cm) sample was collected, comprising five sub-samples taken from the corners and centre of a 1 x 1 m square using a stainless steel hand-held Dutch auger (Figures 3, 4, 5, 6).

Reaching a depth of 20 cm was not possible at all the sample locations. Topsoil sample G069 was collected at a depth of 10 cm because of the presence of building rubble at site GGERFS01. Similarly, it was only possible to reach a sampling depth of 15 cm over parts of site GGERFS10, because of underlying asphalt and hard-core layers, affecting samples G052, G059, G064, G066, G070 and G088.

At each sampling location, the following suite of samples was collected:

- **M4 sample**: An approximate 100 g sample in plastic self-seal bags for storage for future microbiological culture analysis. This sample-type is stored at 4 ˚C; hence, is designated M4.
- **M-20 sample**: An approximate 100 g sample in plastic self-seal bags for storage for future microbiological DNA analysis. This sample was frozen for 18 months at -20 ˚C, and then at -80 ˚C once lower temperature freezer facilities were available; hence, are designated M-20.

- **A sample**: An approximate 750 g sample in Rilsan® bags for inorganic and organic chemical analysis. These were designated ‘A’ for the A soil horizon.

The geomicrobiology samples were collected first at each location. Material from the 5 sub-sample auger-holes was mixed and homogenised in a large plastic self-seal bag and a representative amount of approximately 100 g of material placed into the two labelled small self-seal bags for M4 and M-20 samples.

The A-soil chemistry samples were collected by drilling 5 auger-holes immediately adjacent to where the geomicrobiology samples were taken. Material from each of the 5 sub-sample auger holes was placed directly into the Rilsan® sample bag.

Upon collection, any excess air was removed and the bags were sealed and stored in a cool box with ice-packs as soon as possible.

The samples were returned to the laboratory for storage in the freezer/cold store on the day of sampling.

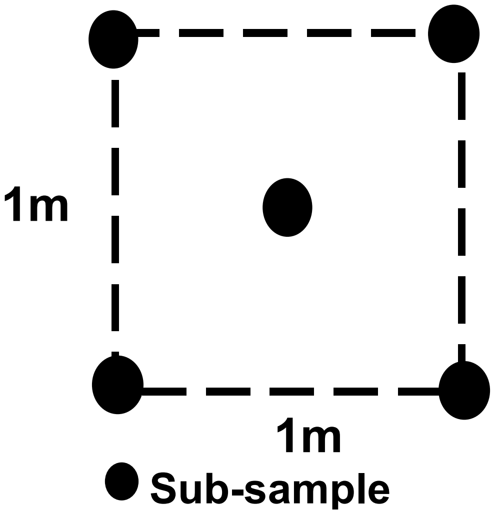


**Figure 3. Plan of auger holes for collecting a soil sample comprising a composite of five sub-samples.**

Photo © BGS NERC UKRI

At each location, microbiology soil samples were collected from one set of auger holes first.
Soil chemistry samples were collected from auger holes immediately adjacent to the microbiology sample holes

**Figure 4. Photograph showing example layout of five sub-sample auger holes in a 1 x 1 m square for soil sample G019 at site GGERFS04.**

Photos © BGS NERC UKRI

a) b)

**Figure 5. Collecting top soil samples with a hand-held Dutch stainless steel auger at a) Tollcross Park (TC) and b) GGERFS10.**

Photo © BGS NERC UKRI

**Figure 6. Collecting a topsoil sample with a hand-held Dutch stainless steel auger at site GGERFS06b.**

## 3.3 SOIL TEXTURE DETERMINATIONS

Once the geomicrobiology samples were collected, the excess material in the large self-seal bag was used to determine soil texture using the feel test, before being discarded.

Based on the BGS G-BASE methodology, eight soil texture classes were used, as outlined in Table 1. The methodologies for soil texture determination are based on those recommended by the England and Wales Soil Survey Field Handbook (Hodgson 1997) and the German equivalent field manual Bodenkundliche Kartieranleitung KA5 (BGR 2005).

- Soil texture to be estimated by "finger or feel test".
- The soil substrate is rubbed and kneaded between thumb and index finger.
- For results that are more accurate, the texture is estimated by the feel of moist soil. If the soil is dry, it must be moistened with deionised water. Main indicators for texture are the plasticity, granularity and cohesion (stickiness).

Table 1 gives a short description of the characteristics of each soil texture class and estimations on their average fractional composition. It should be mentioned, that the table is a composite summary of descriptions and values used in British and German soil science. It should be noted that the soil texture classes, sandy silt, silty sand and clayey sand do not exist in the British soil science nomenclature, instead the term loam is widely used to describe these texture types.

**Table 1. Summary description of soil texture classes, their approximate particle size composition and feel test characteristics.**

| Texture | Fraction % | | | Feel test characteristics |
|---|---|---|---|---|
| | Clay | Silt | Sand | |
| **SAND** | 0 – 5 | 0 – 10 | 85 -100 | Sand imparts a gritty feel due to the shape of the individual particles. Grains can readily be seen, no recognisable fine particles, not sticky when moist. |
| **SILT** | 0 – 8 | 80 – 100 | 0 – 20 | Sand grains barely (or not) visible. Feels soft and floury when dry, when moist it is greasy and neither sticky nor plastic. |
| **CLAY** | 65 – 100 | 0 – 35 | 0 – 35 | Only fines, high plasticity, smooth and shiny friction surface, very sticky and plastic when moist. |
| **SACL Sandy Clay** | 20 – 55 | 0 – 20 | 45 – 70 | Abundant fines with gritty feel, when moist sticky to very sticky and plastic, showing a good fingerprint. |
| **SICL Silty Clay** | 35 – 65 | 40 – 65 | 0 – 20 | Floury when dry, very sticky and plastic when moist. Rough to shiny friction surface. |
| **CLSA Clayey Sand** | 17 – 25 | 0 – 15 | 60 – 83 | Gritty feel, moderate sticky and low plastic when moist. |
| **SASI Sandy Silt** | 0 – 10 | 50 – 80 | 12 – 50 | Sand gives gritty feel to abundant fine substance, floury and sticky when wet, non-plastic. |
| **SISA Silty Sand** | 0 – 10 | 25 – 40 | 52 – 75 | Similar to SASI with greater sand component. |

(BGR 2005 and Hodgson 1997)

## 3.4 FIELD DATA RECORDING

Information about each location and soil sample was recorded on a standardised field-sheet at the time of sampling. Table 2 outlines the data recorded at each location.

Several parameters were noted, as these can affect soil properties and soil chemistry. These included soil texture, soil colour, visual qualitative assessment of soil moisture and organic matter content, the land use, the presence of any rock clasts and of contaminating materials such as metal, brick and glass fragments in the soil.

Any rainfall was noted on the day of sampling also. Longer-term local weather records for Dalmarnock monitoring station were consulted following fieldwork to assess if conditions had been dry at the field-site for at least a week before sampling (SEPA 2018).

**Table 2. Summary of information recorded at each soil sample location**

| Data Type | Description |
|---|---|
| GGERFS Site | The site name e.g. GGERFS01, GGERFS05, Tollcross Park (TC), Glasgow Green (GG) etc. |
| Soil Sample ID | G001 – G100 |
| Sample Location | 12-figure British National Grid Co-ordinates (Easting and Northing) determined using a portable global positioning system (GPS) |
| Site description | General description of the site and the sample location |
| Date | Date of sample collection |
| Land use | Categories of land use present at each soil location |
| Depth | Sample collection depth. Measured as the level of the bottom of the auger below ground surface in cm |
| Soil Texture | Determined by the feel test (See Section 3.3) |
| Soil Colour | Based on the G-BASE 8-colour classification scheme (Johnson 2005): black, dark brown, light brown, yellow, red, orange, green, grey |
| Soil Moisture Content | Based on the G-BASE qualitative visual inspection classification scheme (Johnson 2005): dry, damp, saturated |
| Soil Organic Content | Based on the G-BASE qualitative visual inspection classification scheme (Johnson 2005): low, moderate, high |
| Rock Clasts | Types of rock fragments visible in the soil |
| Contamination | Types of gross visible contamination present in the soil such as brick, metal, coal, glass, crockery fragments, plastic fragments/bags, oil, etc. |
| Rainfall | Based on the G-BASE rainfall record scheme (Johnson 2005): rainfall within categories of 12 hours, 24 hours, 48 hours, 2-7 days, 1 week, > 1 week. Noted in the field and checked against local weather records (SEPA 2018) following fieldwork |
| Photographs | Photographs were taken of each soil location |

## 3.5 DESCRIPTION OF THE SURVEY SITES

A brief description of the soil survey sites is provided in Figures 7 – 10 (Sections 3.5.1 – 3.5.4), as this has a bearing on the soil chemistry results. Building rubble and made ground materials were present at all the sites, except Glasgow Green and Tollcross Park.

### 3.5.1 Glasgow Green and Tollcross Park control sites

a) Glasgow Green

b) Tollcross Park

Photos © BGS NERC UKRI

Glasgow Green and Tollcross Park were selected as control sites because both are long-established recreational spaces within Glasgow where the land use has been consistent since at least Victorian times, and is likely to remain unchanged. Glasgow Green is the city's oldest park and was established in the 15th century. It was used variously for grazing, washing and bleaching of linen before more formal landscaping as a park during the 1800s (GCC 2019a). Topsoil samples were collected for the present study from an open area of football pitches on the north bank of the River Clyde (Figure 2 and Figure 7a).

Tollcross Park was a country estate before being purchased as a recreational park for the city in 1897 (GCC, 2019b). For this study, topsoil samples were collected from an open area of grass in the south-west of the park (Figure 2 and Figure 7b).

**Figure 7. Photos and description of a) Glasgow Green and b) Tollcross Park control sites.**

### 3.5.2 GGERFS sites 01 – 05, Cuningar Loop

a) GGERFS01

c) GGERFS03 with proximity of new car park works

b) GGERFS02

Photos © BGS NERC UKRI

d) GGERFS04 with landscaped imported topsoil with hard-core

e) GGERFS05

The GGERFS sites 01 - 05 are located within what is today a woodland park in the Cuningar Loop, a large meander on the River Clyde in the east of Glasgow (Figure 2).

Examination of historical maps reveals an interesting history. The area was first developed in the early 1800s with the installation of a water pump and holding reservoirs for the Glasgow Waterworks, at site GGERFS04 at the northern end of the Cuningar Loop. This provided water to Glasgow from the River Clyde, before the advent of the Loch Katrine water supply system in 1859. The Glasgow Waterworks closed in the mid-1800s, but the reservoirs, devoid of water, remained in place and are marked as earthworks by 1900.

From the early 1900s, sand and gravel extraction was carried out in the northern half of the Cuningar Loop particularly in proximity to sites GGERFS04 and 01, resulting in open pits and a pond, which was present in the centre of the Loop until the 1990s. The south-west of the Cuningar Loop was home to the Old Farme Colliery, which operated between 1805 and 1931 and had a mineral railway to the west of GGERFS05. Coal spoil mounds associated with the colliery were present in the area of sites GGERFS02, 03 and 05 from the 1930s.

During the 1960s, the old colliery workings, sand and gravel pits and the former Glasgow Waterworks were infilled using material that included demolition rubble from the clearance of the Gorbals and other areas of the city. The land was then moribund until the regeneration of the area as a public park in 2014. The regeneration included construction of a public footbridge across the River Clyde adjacent to GGERFS04. As part of the landscaping around the new bridge, imported topsoil was applied to the northern tip of the Cuningar Loop, including the area around GGERFS04 that contains hard-core material (Ramboll 2018b) (Figure 8d).

**Figure 8. Photos and description of soil survey sites GGERFS01-05, Cuningar Loop**

### 3.5.3 GGERFS06b, Dalbeth

a) GGERFS6b

Photos © BGS NERC UKRI

b) GGERFS6b, auger-head of sample material showing imported brown topsoil overlying sandy orange base-soil

Site GGERFS06b is located in a present-day business park in Dalbeth, that is currently under development (Figures 2 and 9a). Historic maps reveal that the area was parkland of Easterhill House country estate, with a small lodge present to the north of the site between the mid-1800s until the 1940s. Two commercial properties were located to the north of the site in the 1950s until the early 2000s, when the site was cleared to make way for the current business park. Apart from these buildings, the site remained largely undeveloped and was used as a football pitch from the 1950s. However, the site lies immediately to the north and west of the former Easterhill Colliery and Clyde Iron Works and significant piles of waste are evident on the southern segment and eastern boundary of the site from the early 20th century. The surrounding site was used as an unofficial landfill for building rubble and other waste between the 1970s and 1990s (Ramboll 2018b). As part of the recent business park development, the site has been landscaped with imported topsoil (Figure 9b), and is located on the borders of a tree-lined public footpath to the River Clyde.

**Figure 9. Photos and description of soil survey site GGERFS06b, Dalbeth**

### 3.5.4 GGERFS10, Dalmarnock

GGERFS10 showing top layer of hard-core material
Photo © BGS NERC

GGERFS10 is located in an area of cleared ground earmarked for housing development in Dalmarnock (Figure 2). Historical maps reveal that from the mid-1800s the Barrowfield Print and Dye works was located to the south of the site. The site lies on the former cotton bleaching ground associated with the dye works. The dye works were redeveloped as an iron foundry, chemical works and leather works to the south of the site before the turn of the 20th century and the site was surrounded by cotton and carpet weaving mills until the mid-20th century. The Dalmarnock gas works was located to the north of the site from the mid-1800s. However, between the end of the 1800s and the 1950s, the site itself comprised tenement housing, which was cleared in the 1950 and 60s. The area was then largely empty, apart from a hostel that was located to the north of the site during the 1980s. Within recent years, soil and shallow groundwater contamination from the former gas works and surrounding former industries has been remediated and the site has been cleared for development (Ramboll 2018a). It is currently vacant with a covering of hard-core material. Subsequent to sampling, the site has been landscaped into a green corridor and sustainable urban drainage (SUDs) road verge feature.

**Figure 10. Photos and description of soil survey site GGERFS010, Dalmarnock**

# 4 Analytical Methods

On completion of the soil survey, the geomicrobiology samples were simply stored for future work.

This report describes the methods applied to the samples collected for soil chemistry analysis as follows.

To ensure data quality, the samples were analysed where possible using methods certified by the United Kingdom Accreditation Service (UKAS). This included asbestos screening at i2 Analytical Laboratories Limited (UKAS Testing Laboratory 4041), analysis of soil pH at the BGS laboratories (UKAS Testing Laboratory 1816) and x-ray fluorescence spectrometry (XRF) determinations by Malvern Panalytical Limited (UKAS Testing Laboratory 7488). The determination of Cr(VI) in soil by the BGS laboratories is not UKAS accredited, but is an established method (Hamilton et al. 2020).

## 4.1 SOIL ASBESTOS SCREENING

Prior to borehole development, environmental desk studies were carried out by a project contractor. These revealed the possible presence of asbestos in soil at approximately 1 m depth proximal to sites GGERFS01 and 04, noted in previous site investigation reports for the area (Ramboll 2018b).

As part of laboratory Health and Safety risk assessment, a sub-set of 10 GGERFS soil samples was screened for the presence of asbestos prior to sample preparation and analysis. These included the samples closest to the areas where the potential presence of asbestos had been reported previously at sites GGERFS01 and 04; and samples containing abundant building rubble at sites 02, 03, 05, 06b and 10 (Table 3).

The samples were analysed at i2 Analytical Limited, using a combined qualitative and quantitative method that is UKAS accredited.

The quantitative method entails initial examination of the entire representative sample, then fractionation and detailed analysis of each fraction, with quantification by hand picking and weighing (Davies et al. 1996). The limit of quantification (LOQ) of this method is 0.001 % wt. The method has been validated using samples of at least 100 g, results for samples smaller than this should be interpreted with caution. In addition, the samples were analysed qualitatively for asbestos by polarising light microscope (PLM) and dispersion staining as described by the Health and Safety Executive (HSE 2006).

**Table 3. List of topsoil samples that underwent asbestos screening.**

| GGERFS Site | Sample ID |
|---|---|
| GGERFS01 | G065 |
| GGERFS01 | G099 |
| GGERFS02 | G093 |
| GGERFS03 | G049 |
| GGERFS04 | G017 |
| GGERFS04 | G019 |
| GGERFS04 | G026 |
| GGERFS05 | G071 |
| GGERFS6b | G053 |
| GGERFS10 | G060 |

## 4.2 SAMPLE PREPARATION

Following collection, the A-soil samples for chemical analysis were stored in a freezer at -20 °C and transported in cool boxes to the BGS laboratories for sample preparation and analysis.

The samples were then freeze-dried, disaggregated and sieved through a < 2 mm nylon sieve. The samples were thoroughly homogenised and cone and quartered before the following sample splits were taken:

- 10 g split for pH analysis.
- 50 g split for POPs analysis. This was milled in an agate ball mill to < 250 µm.
- 50 g split for inorganic chemical analysis. This was milled in an agate ball mill until 95% was < 53 µm.
    - From the 50g split milled to < 53 µm for inorganic analysis, the following further sample splits were taken:
        - 10 g split for Cr(VI) analysis
        - 12 g split for total element determinations by x-ray fluorescence spectrometry (XRF)

The XRF pellets were prepared by grinding the 12 g aliquot of milled material with 3 g of wax binder for 3 minutes in an agate planetary ball mill. This mixture was then pressed into a 40 mm diameter pellet at 250 kN using a Herzog (HTP-40) semi-automatic press.

As a check on sample preparation and analytical methods for the inorganic analysis, two samples were selected at random as analytical replicates (Sample A, G027 and Sample B, G039). For each of these samples, a second split of 50 g < 2 mm sample material was taken from the homogenised soil (Table 4). In addition, data quality was assured by inclusion of certified reference materials (CRM), and BGS in-house secondary reference materials (SRM) in the analytical runs. These replicates and standards were prepared in the same way as, and numbered in the same format as, the samples to appear 'blind' to the laboratories.

**Table 4. Analytical replicates prepared from samples G027 and G039.**

| **Sample Details** | **Sample A G027 from GGERFS06b** | | **Sample B G039 from GGERFS04** | |
|---|---|---|---|---|
| **Replicate Splits** | **Replicate A1** | **Replicate A2** | **Replicate B1** | **Replicate B2** |
| **Lab ID** | G027 | G010 | G039 | G075 |

## 4.3 INORGANIC ANALYSIS

### 4.3.1 Soil total element concentrations by XRF

Total concentrations of 53 chemical elements were determined by x-ray fluorescence spectrometry (XRF) by Malvern Panalytical Limited using similar methods to those deployed by the BGS G-BASE project (Ingham and Vrebos 1994; Ingham et al. 2007a; Ingham et al. 2007b). Concentrations of the major elements are expressed as oxide weight percent and for all other elements as mg/kg.

This method is UKAS accredited for the majority of elements, with the exception of aluminium ($Al_2O_3$), calcium (CaO), magnesium (MgO), potassium ($K_2O$), phosphorus ($P_2O_5$), silicon ($SiO_2$), sodium ($Na_2O$), chlorine (Cl), mercury (Hg) and sulphur (S).

Potential mineralogical and particle-size that might contribute to the overall analytical error uncertainty are minimised by fine milling of the samples prior to analysis. The calibrations were validated by analysis of reference materials and regularly corrected for instrumental drift.

The limit of quantification (LOQ) for XRF are shown in Table 5. The LOQs are theoretical values for the concentration equivalent to three standard deviations above the background count rate for the analyte in a silica matrix. High instrumental stability results in practical values for these materials approaching the theoretical detection limit.

The presence of high concentrations of certain elements in sample media can have spectral interference effects on the XRF determination of other elements. Table 6 outlines the possible interferences noted in the GGERFS dataset and these data should be treated with caution.

For XRF data quality control, CRMs were analysed twice at the start and twice at the end of the sample batch. Three internal BGS SRMs (S13B, S23B and S58S) were analysed, hidden within the batch in duplicate. These standards were the same as those analysed with the G-BASE Clyde Basin soil dataset (Fordyce et al. 2017), so that the datasets are comparable (Table 7).

The analytical results for the reference materials are reported against the certified (CRM) or accepted (SRM) values, where available, together with a summary of the precision of the analysis of each material and the analytical recovery (Tables A2.1, A2.2, Appendix 2). Precision and the robustness of the analytical methods were assessed also by comparison of the two random analytical replicate samples (Sample A and Sample B) (Table A2.3, Appendix 2).

The repeat measurements of the standards and the analytical replicate results show good precision of the data with relative standard deviation (RSD) of ≤ 15% and relative standard error (RSE) of ≤ 10% reported for the majority of elements. The exceptions are elements where concentrations are close to the LOQ, as expected (Ag, Bi, Cd, Cs, Hg, Sm, Tl and Yb) and Cr in CRM LKSD-1 (Tables A2.1 - A2.3, Appendix 2).

To assess accuracy, comparisons of measured versus certified/accepted values for the CRM and SRM standards indicate that Cr has an apparently high recovery in LKSD-1 also, that is likely to be due to poor precision. This is possibly due to potential minor inhomogeneity in the reference material affecting this particular element (Table A2.1, Appendix 2).

For the rest of the elements, the data are within the expected range of recoveries for the technique (100 ± 20%) showing good accuracy, except where element concentrations are close to or below the LOQ. The recoveries for $Na_2O$, MgO, $Al_2O_3$, $SiO_2$ and $P_2O_5$ are as expected, given analyte concentrations and the accuracy of the analytical method (Tables A2.1 and A2.2, Appendix 2).

The measured presence of Hg in GSD-6 (1.0-1.6 mg/kg) is unexpected when compared to a reference value of 0.045 mg/kg, but these values are below the LOQ, affecting the reliability of the data (Table A2.1, Appendix 2).

It is well known in geochemistry, that even when analytical instruments have been calibrated correctly, there are often identifiable shifts in the data between analytical batches as a result of recalibration events that have been necessary due to instrument breakdown or after instrument service/overhaul. The standards inserted with the GGERFS analytical runs were used to assess this type of long-term analytical drift between batches of samples. Tolerance limits arbitrarily set at the mean ± $2\sigma$ were used to assess data quality. Simple arithmetic correlations were applied to correct for this and normalise the data to the accepted CRM/SRM results. The same process is carried out on the rest of the BGS G-BASE UK geochemistry database (Lister and Johnson 2005). Thus, the GGERFS topsoil chemistry dataset is directly comparable with the surrounding BGS G-BASE Glasgow topsoil dataset, allowing the GGERFS results to be placed in context.

The correlation conditioning factors applied to the GGERFS topsoil datasets are outlined in Table 8. Factors were not applied to silver (Ag), bismuth (Bi), chlorine (Cl), germanium (Ge), mercury (Hg), iodine (I), indium (In), sulphur (S), selenium (Se), samarium (Sm), tantalum (Ta), tellurium (Te), thallium (Tl) and ytterbium (Yb), because either (i) certified/accepted values were not reported for these elements; or (ii) the majority of data, including the results for standards, were below the LOQ. Where application of the data conditioning factors resulted in an artificial negative value, these were set to zero.

**Table 5. Limits of quantification and list of inorganic parameters determined in topsoil.**

| Symbol | Parameter | Method | LOQ | Units | Lab | Accreditation |
|---|---|---|---|---|---|---|
| $Al_2O_3$ | Aluminium | XRF | 0.2 | wt% | Panalytical | None |
| CaO | Calcium | XRF | 0.05 | wt% | Panalytical | None |
| $Fe_2O_3$ | Iron | XRF | 0.01 | wt% | Panalytical | UKAS |
| $K_2O$ | Potassium | XRF | 0.01 | wt% | Panalytical | None |
| MgO | Magnesium | XRF | 0.3 | wt% | Panalytical | None |
| MnO | Manganese | XRF | 0.005 | wt% | Panalytical | UKAS |
| $Na_2O$ | Sodium | XRF | 0.3 | wt% | Panalytical | None |
| $P_2O_5$ | Phosphorus | XRF | 0.05 | wt% | Panalytical | None |
| $SiO_2$ | Silicon | XRF | 0.1 | wt% | Panalytical | None |
| $TiO_2$ | Titanium | XRF | 0.010 | wt% | Panalytical | UKAS |
| Ag | Silver | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| As | Arsenic | XRF | 0.9 | mg/kg | Panalytical | UKAS |
| Ba | Barium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Bi | Bismuth | XRF | 0.3 | mg/kg | Panalytical | UKAS |
| Br | Bromine | XRF | 0.8 | mg/kg | Panalytical | UKAS |
| Cd | Cadmium | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| Ce | Cerium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Cl | Chlorine | XRF | 200 | mg/kg | Panalytical | None |
| Co | Cobalt | XRF | 1.5 | mg/kg | Panalytical | UKAS |
| Cr | Chromium | XRF | 3.0 | mg/kg | Panalytical | UKAS |
| Cs | Caesium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Cu | Copper | XRF | 1.3 | mg/kg | Panalytical | UKAS |
| Ga | Gallium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Ge | Germanium | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| Hf | Hafnium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Hg | Mercury | XRF | 2.5 | mg/kg | Panalytical | None |
| I | Iodine | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| In | Indium | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| La | Lanthanum | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Mo | Molybdenum | XRF | 0.2 | mg/kg | Panalytical | UKAS |
| Nb | Niobium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Nd | Neodymium | XRF | 4.0 | mg/kg | Panalytical | UKAS |
| Ni | Nickel | XRF | 1.3 | mg/kg | Panalytical | UKAS |
| Pb | Lead | XRF | 1.3 | mg/kg | Panalytical | UKAS |
| Rb | Rubidium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| S | Sulphur | XRF | 1000 | mg/kg | Panalytical | None |
| Sb | Antimony | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| Sc | Scandium | XRF | 3.0 | mg/kg | Panalytical | UKAS |
| Se | Selenium | XRF | 0.2 | mg/kg | Panalytical | UKAS |
| Sm | Samarium | XRF | 3.0 | mg/kg | Panalytical | UKAS |
| Sn | Tin | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| Sr | Strontium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Ta | Tantalum | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Te | Tellurium | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| Th | Thorium | XRF | 0.7 | mg/kg | Panalytical | UKAS |
| Tl | Thallium | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| U | Uranium | XRF | 0.5 | mg/kg | Panalytical | UKAS |
| V | Vanadium | XRF | 3.0 | mg/kg | Panalytical | UKAS |
| W | Tungsten | XRF | 0.6 | mg/kg | Panalytical | UKAS |
| Y | Yttrium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Yb | Ytterbium | XRF | 1.5 | mg/kg | Panalytical | UKAS |
| Zn | Zinc | XRF | 1.3 | mg/kg | Panalytical | UKAS |
| Zr | Zirconium | XRF | 1.0 | mg/kg | Panalytical | UKAS |
| Cr(VI) | ChromiumVI | SIDMS HPLC | 0.5 | mg/kg | BGS | None |
| pH | pH | $CaCl_2$ Slurry | 0.1 | -log[H+] | BGS | UKAS |

SIDMS HPLC: Speciated isotope dilution mass spectrometry; High performance liquid chromatography
$CaCl_2$: calcium chloride

## Table 6. Reported possible spectral interferences in topsoil element concentration analysis by XRF.

| Samples containing | Will affect the results for | Comments |
|---|---|---|
| Ba > 1000 mg/kg | Sc, V, Cr, Ag, In, Sn, Sb, I, Cs, Ba, La, Ce, Nd, Sm | Data for these samples fall outside the scope of UKAS accreditation |
| Cr >1000 mg/kg | Sc, V, Cr, Cs, Ba, La, Ce, Nd, Sm data and possibly other elements | Data for these samples fall outside the scope of UKAS accreditation |
| Cu >1000 mg/kg | Sc, V, Cr, Co, Ni, Cu, Zn, Cs, Ba, La, Ce, Nd, Sm, Yb, Hf, Ta, W data and possibly other elements | Data for these samples fall outside the scope of UKAS accreditation |
| Pb > 1000 mg/kg | Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Rb, Sr, Y, Zr, Cs, Ba, La, Ce, Nd, Sm, Yb, Hf, Ta, W, Hg, Tl, Pb, Bi, Th, U data and possibly other elements | Data for these samples fall outside the scope of UKAS accreditation |
| Zn > 1000 mg/kg | Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Cs, Ba, La, Ce, Nd, Sm, Yb, Hf, Ta, W data and possibly other elements | Data for these samples fall outside the scope of UKAS accreditation |

## Table 7. List of standards included with the XRF analysis of GGERFS topsoil samples.

| CRM | Source |
|---|---|
| GSD-6 | Bulk stream sediment, National Research Centre (NRC) China |
| STSD-3 | Bulk stream sediment, Canadian Centre for Mineral and Energy Technology (CANMET) |
| LKSD-1 | Bulk lake sediment, CANMET Canada |
| LKSD-4 | Bulk lake sediment, CANMET Canada |
| **SRM** | **Source** |
| S13B | Bulk stream sediment, BGS |
| S23B | Bulk stream sediment, BGS |
| S58S | Bulk soil, BGS |

**Table 8. List of conditioning factors applied to the GGERFS topsoil XRF data to normalise to the G-BASE national topsoil dataset.**

| Element | Conditioning Factor |
|---|---|
| Al2O3 | 0.6962 x e + 4.0563 |
| CaO | 0.8518 x e + 0.3043 |
| Fe2O3 | 0.9275 x e + 0.4844 |
| K2O | 0.8864 x e + 0.2381 |
| MgO | 0.5653 x e + 0.6052 |
| MnO | 0.7614 x e + 0.0216 |
| Na2O | 0.9776 x e + 0.5947 |
| P2O5 | 0.6913 x e + 0.0794 |
| SiO2 | 0.6249 x e + 23.499 |
| TiO2 | 0.8368 x e + 0.1702 |
| As | 0.9777 x e + 1.8643 |
| Ba | 1.0366 x e + 10.244 |
| Br | 0.9742 x e + 1.2886 |
| Cd | 0.9663 x e + 0.1451 |
| Ce | 0.8123 x e + 14.223 |
| Co | 0.9124 x e - 0.3343 |
| Cr | 1.0330 x e - 4.6310 |
| Cs | 1.0791 x e - 0.3346 |
| Cu | 1.0073 x e + 4.0847 |
| Ga | 0.9268 x e + 2.4036 |
| Hf | 0.9234 x e + 1.4116 |
| La | 0.8776 x e + 7.4362 |
| Mo | 1.0071 x e + 0.2761 |
| Nb | 0.8136 x e + 4.5079 |
| Nd | 1.2478 x e - 9.2930 |
| Ni | 0.9787 x e - 1.1532 |
| Pb | 0.9786 x e - 0.1228 |
| Rb | 0.9658 x e + 5.1142 |
| Sb | 0.8805 x e + 0.1717 |
| Sc | 1.0084 x e - 1.0507 |
| Sn | 1.1811 x e - 0.0617 |
| Sr | 1.0258 x e - 9.6585 |
| Ta | 0.5543 x e + 0.9735 |
| Th | 0.974 x e + 0.5861 |
| U | 0.9885 x e + 0.3665 |
| V | 1.0034 x e + 4.3054 |
| W | 1.0128 x e - 0.4052 |
| Y | 1.1717 x e - 3.5109 |
| Zn | 1.1135 x e - 16.747 |
| Zr | 0.9190 x e + 19.892 |

where e = measured element concentration

### 4.3.2 Cr(VI) determinations by SIDMS and HPLC

The determination of Cr(VI) in soil samples was carried out using an Agilent 1260 Infinity II Bio-Inert High Performance Liquid Chromatography (HPLC) system coupled to an Agilent 8900 inductively coupled plasma mass spectrometer (ICP-MS) to perform speciated isotope dilution mass spectrometry (SIDMS), based on the methods of Hamilton et al. (2020).

The HPLC system works on the principle that the Cr(III) and Cr(VI) within a sample can be separated based on their affinity for a stationary phase (contained within an analytical column) and a mobile phase that is continuously pumped through the column. A volume of sample (typically 50 µl) is injected into the pathway of the mobile phase and introduced into the analytical column. The Cr(III) and Cr(VI) will have different retention properties on the column and will therefore exit the column into the ICP-MS for detection at different times. During this period, the ICP-MS is undertaking time resolved analysis (TRA) and will scan at a defined mass-to-charge ratio (*m/z* 52 and 53 for Cr) for a predetermined interval of time (7.5 minutes). When each species of Cr passes through the column into the instrument, a response is produced in the form of a chromatographic peak. The area of each peak is integrated using Agilent MassHunter software and exported to Microsoft Excel® for calculation of mass-bias corrected abundances and isotope ratios.

The HPLC mobile phase (40 mM ammonium nitrate ($NH_4NO_3$)/50 mM TRIS Buffer/5 mM ethylenediaminetetraacetic acid-diammonium salt ($NH_4$-EDTA), corrected to pH 7.0 with aqueous ammonia) was prepared fresh on the day of analysis. The analytical column (Hamilton® PRP-X100) was conditioned with the mobile phase at a flow rate of 1.2 ml/minute until the baseline for *m/z* 52 and 53 was stable. The outflow from the analytical column was connected directly to the nebuliser of the ICP-MS using a length of poly-ether ether ketone (PEEK) tubing.

For sample preparation, 0.2 g subsample of the dried milled material was added to a fluorocarbon polymer (PFA) microwave vessel, followed by 10 ml of 50 mM $NH_4$-EDTA (pH 10.0). The vessel was then spiked with 0.4 ml of $^{53}$Cr(VI) at a concentration sufficient to double the natural $^{53}$Cr(VI) present in the sample. The sample was then subjected to a 5 minute heating programme at 80°C (8 minute ramp time), cooled and centrifuged at 4000 revolutions/ minute for 20 minutes to separate the supernatant from the extracted solid material. Prior to chromatographic separation, the sample was diluted with ultrapure water (2-fold for samples, 10- or 100-fold for CRMs). The LOQ was 0.5 mg/kg (Table 5).

Whilst the method is not accredited to the requirements of BS EN ISO/IEC 17025:2017, data quality was verified through the use of international CRMs and internal SRMs (Table 9). To ensure data precision, repeat measurements were made on 10% of the samples.

Results for the analytical replicate samples A and B (Table A2.3, Appendix 2), for the analytical repeats (Table A2.4, Appendix 2) and for repeat measurements on the CRM and SRMs (Table A2.5, Appendix 2) show good precision of the analytical methods with RSD and RSE of < 15%. Comparison of the data with the certified/accepted values for the CRM and SRMs also show good accuracy, with recoveries 100 ± 15% (Table A2.5, Appendix 2).

**Table 9. Reference materials included with the Cr(VI )analysis of GGERFS topsoil samples**

| CRM | Source |
|---|---|
| NIST 2700 | Hexavalent chromium in contaminated soil (Low Level), National Institute of Standards and Technology (NIST), United States of America (USA) |
| NIST 2701 | Hexavalent chromium in contaminated soil (High Level), NIST, USA |

### 4.3.3 Soil pH

Soil pH was determined at the BGS laboratories (UKAS accredited) by adding 5g of <2mm sample to 12.5 ml of 0.01M $CaCl_2.2H_2O$ (calcium chloride). The mixture was shaken to form a slurry prior to analysis by pH electrode. This method of pH determination generally gives lower results (0.5 pH units) than water-based methods (Rowell 1997).

Results for the analytical replicate samples demonstrate good repeatability/precision of the data, with standard deviation (SD) of 0.03 pH unit (Table A2.3, Appendix 2).

## 4.4 ORGANIC ANALYSIS

Analyses of soil carbon, TPH, PAH and PCBs were carried out at the BGS laboratories.

The quality of PAH and PCB measurement was assessed by inclusion of the international CRM 'NIST 1941b organics in sediment' with the analytical runs. The CRM was analysed 15 times in duplicate (total 30 times) with samples interspersed throughout the analytical programme.

### 4.4.1 Soil carbon measurement

Total organic carbon (TOC) content was determined using an Elementar VarioMax C, N (carbon-nitrogen) analyser after acidification with hydrochloric acid (HCl) to remove carbonate. The LOQ for the soil carbon measurements was 0.18% (Table 10). Total carbon (TTC) was determined by direct analysis of soils (no pre-treatment other than milling) and the Total Inorganic Carbon (TIC) calculated by subtracting TOC from TTC.

### 4.4.2 Total petroleum hydrocarbons measurement

Dried soils were extracted with organic solvents and the main compound classes separated by thin layer chromatography using silica rods. The concentration of saturated, aromatic hydrocarbons as well as resin compound was determined by an Iatroscan Mk6s instrument fitted with a flame ionization detector (FID). The LOQ was 1 mg/kg (Table 10).

### 4.4.3 Polycyclic aromatic hydrocarbons (PAH) measurement

Dried soils were spiked with appropriate deuterated surrogate standards and extracted with organic solvents on an accelerated solvent extraction system (ASE). The PAH were separated by column chromatography using solid phase extraction cartridge (SPE), spiked with internal standards and analysed by gas chromatography-mass spectrometry (GC-MS). The LOQ were determined as 5 times the standard deviation of 0.6 ng injection over a 14-day analysis period for 36 PAH compounds (Table 10).

Summary data presented in Table A2.6 (Appendix 2) confirms good precision (RSD $\leq$ 25%) and an excellent fit with NIST1941b certified values across the low and medium molecular weight PAH with recoveries 100±15%. Higher RSD values are reported for concentrations close to the LOQ. Procedural blank samples of clean sand gave no quantifiable PAH.

### 4.4.4 Polychlorinated biphenyls (PCB) measurement

Dried soils were spiked with appropriate surrogate standards and extracted on an accelerated solvent extraction system (ASE). The PCBs were separated from non-halogenated moieties by column chromatography (e.g. Vane et al. 2014). The fraction containing PCB was spiked with internal standards and analysed by gas chromatography-mass spectrometry (GC-MS). Procedural blanks gave no appreciable PCB. Mean LOQ were determined as 5 times the standard deviation of 150 pg injections (n=36 over a 14 day period) (Table 11). The seven PCB congeners (PCB 28, 52, 101, 118, 153, 138, 180) that are recommended for monitoring by the International Council for the Exploration of the Sea (ICES) and the European Union Community Bureau of Reference

(EUCBR) were determined in the analytical runs. Summary data presented in Table A2.7 (Appendix 2) show good precision (RSD ≤ 20%) and a close comparison between CRM NIST1941b certified and BGS measurements for values determined above the LOQ (recoveries 100±10%).

## Table 10. Limits of quantification for topsoil carbon, petroleum hydrocarbon and PAHs

| Parameter | Symbol | LOQ | Units | Lab | Accreditation |
|---|---|---|---|---|---|
| **Soil Carbon** | | | | | |
| Total carbon (TTC) | TTC | 0.18 | % | BGS | None |
| Total organic carbon (TOC) | TOC | 0.18 | % | BGS | None |
| Total inorganic carbon (TIC) | TIC | 0.18 | % | BGS | None |
| **Petroleum Hydrocarbons** | | | | | |
| resins | | 259 | mg/kg | BGS | None |
| aromatics | | 63 | mg/kg | BGS | None |
| saturates | | 67 | mg/kg | BGS | None |
| Total petroleum hydrocarbons | TPH | 67 | mg/kg | BGS | None |
| **36 Polyaromatic Hydrocarbons** | **PAH** | | | | |
| naphthalene | | 0.05 | mg/kg | BGS | None |
| 2-methylnaphthalene | | 0.03 | mg/kg | BGS | None |
| 1-methylnaphthalene | | 0.04 | mg/kg | BGS | None |
| biphenyl | | 0.03 | mg/kg | BGS | None |
| C2-naphthalenes | | 0.04 | mg/kg | BGS | None |
| acenaphthylene | | 0.04 | mg/kg | BGS | None |
| acenaphthene | | 0.03 | mg/kg | BGS | None |
| dibenzofuran | | 0.03 | mg/kg | BGS | None |
| fluorene | | 0.02 | mg/kg | BGS | None |
| 1-methylfluorene | | 0.02 | mg/kg | BGS | None |
| dibenzothiophene | | 0.04 | mg/kg | BGS | None |
| phenanthrene | | 0.03 | mg/kg | BGS | None |
| anthracene | | 0.05 | mg/kg | BGS | None |
| 1-methylanthracene | | 0.04 | mg/kg | BGS | None |
| C1-phenanthrenes / anthracenes | | 0.04 | mg/kg | BGS | None |
| C2-phenanthrenes / anthracenes | | 0.04 | mg/kg | BGS | None |
| fluoranthene | | 0.03 | mg/kg | BGS | None |
| pyrene | | 0.03 | mg/kg | BGS | None |
| 1-methylpyrene | | 0.04 | mg/kg | BGS | None |
| C1-fluoranthenes / pyrenes | | 0.04 | mg/kg | BGS | None |
| C2-fluoranthenes / pyrenes | | 0.04 | mg/kg | BGS | None |
| benz[a]anthracene | | 0.03 | mg/kg | BGS | None |
| triphenylene | | 0.03 | mg/kg | BGS | None |
| chrysene | | 0.03 | mg/kg | BGS | None |
| C1-benz[a]anthracenes / chrysenes | | 0.06 | mg/kg | BGS | None |
| C2-benz[a]anthracenes / chrysenes | | 0.06 | mg/kg | BGS | None |
| benzo[b]fluoranthene | | 0.04 | mg/kg | BGS | None |
| benzo[k]fluoranthene | | 0.05 | mg/kg | BGS | None |
| benzo[j]fluoranthene | | 0.05 | mg/kg | BGS | None |
| benzo[a]fluoranthene | | 0.05 | mg/kg | BGS | None |
| benzo[e]pyrene | | 0.05 | mg/kg | BGS | None |
| benzo[a]pyrene | | 0.05 | mg/kg | BGS | None |
| perylene | | 0.03 | mg/kg | BGS | None |
| dibenz[a,h]anthracene | | 0.06 | mg/kg | BGS | None |
| indeno[1,2,3-cd]pyrene | | 0.04 | mg/kg | BGS | None |
| benzo[g,h,i]perylene | | 0.05 | mg/kg | BGS | None |

**Table 11. Limits of quantification for 32 PCBs in topsoil**

| PCB | LOQ | Units | Lab | Accreditation |
|---|---|---|---|---|
| PCB028 | 1.47 | µg/kg | BGS | None |
| PCB052 | 2.47 | µg/kg | BGS | None |
| PCB081 | 2.27 | µg/kg | BGS | None |
| PCB077 | 2.47 | µg/kg | BGS | None |
| PCB095 | 3.01 | µg/kg | BGS | None |
| PCB101 | 3.46 | µg/kg | BGS | None |
| PCB099 | 3.13 | µg/kg | BGS | None |
| PCB110 | 2.11 | µg/kg | BGS | None |
| PCB123 | 2.57 | µg/kg | BGS | None |
| PCB118 | 2.27 | µg/kg | BGS | None |
| PCB114 | 3.00 | µg/kg | BGS | None |
| PCB105 | 1.79 | µg/kg | BGS | None |
| PCB126 | 2.05 | µg/kg | BGS | None |
| PCB151 | 3.01 | µg/kg | BGS | None |
| PCB149 | 2.61 | µg/kg | BGS | None |
| PCB146 | 2.52 | µg/kg | BGS | None |
| PCB153 | 2.52 | µg/kg | BGS | None |
| PCB138 | 3.01 | µg/kg | BGS | None |
| PCB167 | 2.16 | µg/kg | BGS | None |
| PCB156 | 1.94 | µg/kg | BGS | None |
| PCB169 | 2.50 | µg/kg | BGS | None |
| PCB187 | 3.60 | µg/kg | BGS | None |
| PCB183 | 3.13 | µg/kg | BGS | None |
| PCB177 | 4.15 | µg/kg | BGS | None |
| PCB180 | 3.71 | µg/kg | BGS | None |
| PCB170 | 3.33 | µg/kg | BGS | None |
| PCB189 | 6.03 | µg/kg | BGS | None |
| 3-Cl | 1.47 | µg/kg | BGS | None |
| 4-Cl | 2.40 | µg/kg | BGS | None |
| 5-Cl | 2.60 | µg/kg | BGS | None |
| 6-Cl | 2.62 | µg/kg | BGS | None |
| 7-Cl | 4.12 | µg/kg | BGS | None |

# 5 Data Presentation

The GGERFS baseline Soil Chemistry03-18 dataset is presented in Excel® table format:

*Filename: GGERFS_SoilChem0318Data_Release.xlsx*

Any use of the data should be cited to:

DOI: https://dx.doi.org/10.5285/0bfdeb32-db24-4221-9d02-f074f51edff2

F M Fordyce, K M Shorter, C H Vane, C J B Gowing, E M Hamilton, A W Kim, P A Everett, B P Marchant and T R Lister. UK Geoenergy Observatories GGERFS_SoilChem03-18Data_Release

and to this report:

FORDYCE F M, SHORTER K M, VANE C H, GOWING C J B, HAMILTON E M, KIM A W, EVERETT P A, MARCHANT B P AND LISTER T R .2019. UK Geoenergy Observatories, Glasgow Environmental Baseline Soil Chemistry Dataset. Open Report, OR/19/062 (Edinburgh: British Geological Survey).

It contains the results of inorganic and organic chemical analyses for each of the 90 topsoil samples along with descriptive information about the soils, noted during sampling, such as location, land use, presence of any contaminant material in the soil and soil texture (See Table 2 for explanation).

For the chemical data, the analyte name, element chemical symbols, analytical method, units of measurement and LOQ are reported in header rows at the top of the table.

The XRF total element concentration data are reported in alphabetical order by chemical symbol as wt% oxide for the major elements, followed by minor and trace element data in parts per million (mg/kg). Data for organic substances are reported in percent for soil carbon measurements, mg/kg for TPH and PAH substances, and parts per billion (µg/kg) for PCBs.

Table 12 shows an example extract from the GGERFS baseline Soil Chemistry03-18 dataset.

Data below the LOQ are reported in two formats, depending on the analytical technique. For some analytes, data are reported as < LOQ. For other determinands, because the calculated LOQ can be higher than the detection limit of the apparatus, values can be reported that are below the LOQ.

Whilst individual results below the calculated LOQ should be treated with caution, reliable estimates of average or typical values over an area may be obtained at lower levels of concentration; meaningful relationships may thus be recognised for some elements at levels lower than the LOQ. Therefore, where detected, data below the LOQ are reported with qualifiers. A guide to the qualifiers is provided in Table 13.

For the purposes of calculating statistics and presenting example maps in this report, data below the LOQ were set to half the LOQ. Summary statistics for this report were prepared in Excel® software. Example box and whisker plots showing the 10th, 25th, 50th, 75th and 90th percentiles of the data distribution, with dots showing outliers, were generated in the Statview® software package. Maps of the sample locations and graduated symbol maps showing selected element concentrations in topsoil across the GGERFS facility were compiled in ArcGIS® software.

## Table 12. Example extract of data from the GGERFS baseline Soil Chemistry03-18 dataset.

| Sample ID | Site_No | Easting | Northing | Samp_Type | Replicate | Inorganic Analytes | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | | | | | Aluminium | Calcium | Iron | Potassium | Magnesium | Manganese | Sodium |
| Parameter | | | | | | Al2O3 | CaO | Fe2O3 | K2O | MgO | MnO | Na2O |
| Method | | | | | | XRF | XRF | XRF | XRF | XRF | XRF | XRF |
| LOQ | | | | | | 0.2 | 0.05 | 0.01 | 0.01 | 0.3 | 0.005 | 0.3 |
| Units | | | | | | wt% | wt% | wt% | wt% | wt% | wt% | wt% |
| G001 | GGERFS01 | 262363 | 662850 | Topsoil | | 11.9 | 1.33 | 5.19 | 1.29 | 1.1 | 0.1 | 1 |
| G002 | GGERFS6b | 263554 | 662774 | Topsoil | | 12.1 | 3.12 | 5.8 | 1.38 | 1.4 | 0.137 | 1.1 |
| G003 | GGERFS01 | 262319 | 662858 | Topsoil | | 13.9 | 1.12 | 5.77 | 1.53 | 1.2 | 0.107 | 0.8 |
| G004 | GGERFS01 | 262364 | 662834 | Topsoil | | 12.3 | 1.34 | 5.66 | 1.39 | 1.2 | 0.111 | 0.9 |
| G005 | GGERFS10 | 260895 | 663099 | Topsoil | | 12.8 | 3.01 | 5.12 | 1.51 | 1.3 | 0.095 | 0.9 |
| G006 | GGERFS6b | 263596 | 662713 | Topsoil | | 11.3 | 1.96 | 4.7 | 1.36 | 1.2 | 0.098 | 1 |
| G007 | GGERFS02 | 262367 | 662647 | Topsoil | | 11.1 | 1.36 | 5 | 1.31 | 1.2 | 0.08 | 1 |
| G008 | TC | 263407 | 663822 | Topsoil | | 10.8 | 0.52 | 4.58 | 1.04 | 0.9 | 0.068 | 1 |
| G009 | TC | 263431 | 663816 | Topsoil | | 11.1 | 0.53 | 4.83 | 1.06 | 0.9 | 0.054 | 1 |
| G012 | GGERFS6b | 263578 | 662831 | Topsoil | | 11.4 | 2.42 | 5.57 | 1.28 | 1.2 | 0.121 | 1.2 |
| G013 | GGERFS05 | 262326 | 662484 | Topsoil | | 13 | 1.89 | 6.3 | 1.39 | 1.5 | 0.118 | 1.2 |
| G014 | GGERFS6b | 263572 | 662770 | Topsoil | | 11.4 | 2.62 | 5.57 | 1.28 | 1.3 | 0.135 | 1.2 |
| G015 | GGERFS03 | 262227 | 662738 | Topsoil | | 10.7 | 2.02 | 5.11 | 1.31 | 1.3 | 0.086 | 1.3 |
| G016 | GGERFS04 | 262016 | 663229 | Topsoil | | 11.8 | 2.82 | 5.76 | 1.43 | 1.6 | 0.102 | 1.3 |
| G017 | GGERFS04 | 262004 | 663223 | Topsoil | | nd | nd | nd | nd | nd | nd | nd |
| G018 | GGERFS03 | 262224 | 662741 | Topsoil | | 10.7 | 1.97 | 5.15 | 1.31 | 1.3 | 0.088 | 1.3 |
| G019 | GGERFS04 | 261995 | 663262 | Topsoil | | 11.4 | 4.27 | 6.54 | 1.36 | 2.2 | 0.14 | 2 |
| G020 | GG | 260125 | 663441 | Topsoil | | 8 | 0.7 | 3.28 | 0.87 | 1.1 | 0.062 | 1.3 |
| G021 | GGERFS02 | 262365 | 662667 | Topsoil | | 11.2 | 1.49 | 7.92 | 1.21 | 1.2 | 0.133 | 1 |
| G023 | GGERFS05 | 262320 | 662478 | Topsoil | | 13.7 | 3.46 | 6.73 | 1.45 | 1.3 | 0.204 | 0.9 |
| G024 | TC | 263349 | 663812 | Topsoil | | 11.2 | 0.55 | 4.22 | 1.04 | 0.9 | 0.064 | 1.1 |
| G025 | TC | 263427 | 663791 | Topsoil | | 9.3 | 0.53 | 4.26 | 0.91 | 0.9 | 0.073 | 0.9 |
| G026 | GGERFS04 | 262063 | 663233 | Topsoil | | 16.4 | 2 | 6.24 | 1.96 | 1.6 | 0.089 | 0.7 |
| G027 | GGERFS6b | 263563 | 662791 | Topsoil | SAMPA | 12.2 | 3.23 | 5.87 | 1.37 | 1.5 | 0.129 | 1.3 |

## Table 13. Guide to data quality qualifiers in the GGERFS topsoil 03-18 dataset.

| Code | Translation | Defined as |
|---|---|---|
| > | Probably high | Not determined accurately due to interference. Probably higher. |
| < | Probably low | Not determined accurately due to interference. Probably lower. |
| * | Dubious quality | The value has a documented quality control issue such as matrix interference, treat data with caution. |
| $ | Uncertain value | Value as reported was below the lower detection limit cited by the analyst. |
| A | Estimated value | Value has been set to zero because data conditioning process created an artificial negative value. |
| nd | Not detected | |

# 6 Initial Results

Subsequent to the 03-18 baseline soil geochemical survey, the GGERFS facility was rescoped such that boreholes have not been constructed at sites GGERFS 04 and 06b. However, the soil chemistry results for these sites are presented in this report to provide wider information for the area; and in case these sites are the focus of attention in future GGERFS developments.

## 6.1 ASBESTOS RESULTS

Examination of a sub-set of 10 topsoil samples carried out as a health and safety check prior to sample preparation and handling of the samples in the laboratory revealed that only one sample contained asbestos. This was present as chrysotile in sample G017 from site GGERFS04.

Further tests revealed the asbestos content was very low (0.027 % wt) and was in the form of bonded cement, with very low presence of fibres (Table 14).

The amount of fibres present was within the Joint Industry Working Group Asbestos in Soil and Construction & Demolition Materials threshold of ‘Low’ quantities - >0.01 to <0.05 % wt, with insignificant risk (CL:AIRE 2016).

The sample was processed with additional health and safety precautions in the BGS laboratories. However, sample G017 was not accepted for XRF analysis by Panalytical Laboratories Limited.

**Any future analysis of archive material of this sample should be carried out with caution.**

**Table 14. Results of asbestos testing on topsoil sample G017 from GGERFS04**

| Sample ID | Sample Depth (cm) | Sample Weight (g) | ACM Types Detected | PLM Results | LOQ (%) | Total asbestos (%) by hand picking/weighing | Laboratory | Accreditation |
|---|---|---|---|---|---|---|---|---|
| G017 | 20 | 34 | Loose fibres & hard/cement type material | Chrysotile | 0.001 | 0.027 | i2 Analytical | ISO 17025 |
| ACM: asbestos containing material | | | | PLM: polarising light microscopy | | | | |

## 6.2 TOPSOIL CHEMISTRY

Summary statistics of parameter concentrations in the GGERFS topsoil samples are shown in Tables A3.1-A3.4 (Appendix 3). To comment on soil quality, the GGERFS results were compared to the city-wide BGS G-BASE (Fordyce et al. 2017) and organic pollutant Glasgow topsoil (Kim et al. 2019) geochemistry datasets (Tables A3.1-A3.4, Appendix 3) and to land contamination generic soil guidelines (Table A3.5, Appendix 3).

Under UK environmental legislation, the Contaminated Land Exposure Assessment (CLEA) model was established to assess potential threats to human health from soil exposure, based on a minimal level of risk (EA 2002; EA 2009). The CLEA method uses toxicological data from international studies and likely soil exposure routes and duration to derive a series of generic assessment criteria (GAC) soil guideline values (SGVs) for various land-use types as a first-pass assessment of land quality for selected parameters of potential concern. If parameter concentrations are below the GAC, the land is not considered contaminated. In England, the SGVs were subsequently updated and a suite of generic human health risk values known as category 4 screening levels (C4SL) were derived, to provide a more pragmatic approach to the identification of land that is not contaminated (DEFRA 2014). These are based on a low rather than minimal level of risk and, as such, are generally higher than the CLEA SGVs. The C4SLs have not been adopted officially in Scotland, but are widely used. Therefore, for the present study reference is made to the C4SLs (DEFRA 2014) and to current industry human health risk recommended thresholds that are typically considered as part of UK land quality assessments. These include GAC (CL:AIRE 2010; Nathanail et al. 2009); suitable for use screening levels (S4UL) (Nathanail et al. 2015) and Dutch soil target and intervention/trigger levels (VROM 2009). If parameter concentrations in soil exceed these generic guidelines, that does not mean that the land is contaminated. Rather, that further studies need to be carried out to define any source–pathway–receptor linkages for particular land-use types (EA 2009).

The results for selected parameters in topsoil are presented in box and whisker plots showing the data distribution at each of the survey sites in Figures 11 – 14.

Maps showing the concentrations of selected parameters in topsoil are shown in Appendix 4.

### 6.2.1 Comparisons with the city-wide BGS Glasgow topsoil datasets

The results for the GGERFS topsoil samples demonstrate that with the exception of Cd and $SiO_2$, the inorganic parameter contents are within the ranges reported in the city-wide BGS G-BASE urban topsoil geochemistry dataset for Glasgow (Table A3.1, Appendix 3).

By contrast, the concentrations of several organic parameters exceed those in the BGS Glasgow topsoil dataset reported by Kim et al. (2019), including total organic carbon (TOC), TPH, the naphthalene and dibenzofuran PAH compounds, and the 7 ICES/EUCBR indicator (hereafter ∑7PCBs) and tri-hepta PCB compounds (Tables A3.2 – A3.4, Appendix 3).

These and the other results are discussed in more detail as follows.

### 6.2.2 Comparisons with UK land contamination guidelines

Whilst concentrations of As, Ba, Cd, total Cr, Cr(VI), Cu, Ni, V, Zn, TPH, benzo(a)pyrene (BaP) and ∑7PCBs exceed the generic soil guidelines for allotment, garden or residential open space in several of the soil samples, they do not exceed the guidelines for recreational open space, the land use at the GGERFS sites. As such, the land would not be classed as contaminated (Table A3.5, Appendix 3; Figures 11 and 12; Figures A4.1-A4.3; A4.5-A4.8, Appendix 4).

However, topsoil Pb concentrations do exceed the category 4 screening level for recreational open space (C4SL 1300 mg/kg, DEFRA 2014) in samples G023 and G057 collected from site GGERFS05 (Figure A4.4, Appendix 4). This indicates that further investigation would be required to assess source-pathway-receptor relationships to determine any risks to human health from exposure to this soil. The highest concentrations of Ba in the GGERFS dataset (1834 and 1709 mg/kg respectively) are reported in these two samples also. This section of site GGERFS05 is characterised by extensive slag, coal fragments (possibly the waste from the Old Farme colliery) and building rubble, which likely account for the Ba and Pb pollution in these samples.

The highest As (40.4 mg/kg), Cd (18.8 mg/kg), Co (82.2 mg/kg), Hg (2.9 mg/kg), Mo (9 mg/kg), Ni (330 mg/kg), V (417 mg/kg) and Zn (11493 mg/kg) concentrations in the present study are reported in sample G069 from site GGERFS01 (Figure 11; Table A3.1, Appendix 3; Figures A4.3, A4.5 and A4.6, Appendix 4). Indeed the Cd concentration exceeds the maximum reported in the city-wide G-BASE Glasgow urban topsoil dataset (16 mg/kg; Fordyce et al. 2017). It was only possible to reach a sampling depth of 10 cm for this sample, due to the extensive presence of building rubble in this section of the GGERFS01 site. The results likely indicate greater soil pollution associated with this waste in this section of site 01. The TOC content of this sample is relatively high (14.54 %), which may be a consequence of the shallower sampling depth, as the top-most soil layer tends to be richer in decaying vegetative material (McBride 1994). Several metal pollutants are adsorbed by soil organic matter and the higher TOC content may also contribute to the elevated metal concentrations in this sample. However, none of these parameters exceed the generic soil guidelines for open recreational land use and the site would not be classed as contaminated.

### 6.2.3 Topsoil total and hexavalent chromium

Highest total-Cr concentrations (1184 - 2776 mg/kg) are reported in samples of the imported topsoil used to landscape much of site GGERFS04 (Figure 12 and Figure A4.1, Appendix 4). This material included hard-core largely comprised of dolerite. Calcium, $Fe_2O_3$, MgO, $TiO_2$ and V contents are also generally higher in GGERFS04 samples than soil from the other sites (Figure 14 and Figure A4.5, Appendix 4). Given that CaO, Cr, $Fe_2O_3$, MgO, $TiO_2$ and V are typically associated with mafic igneous rocks such as dolerite (Mielke 1979), this probably accounts for the high Cr values at this site. This is corroborated by evidence that:

(i) samples G016, G026 and G054 from outside the zone of new topsoil at GGERFS04 display much lower total-Cr concentrations (97 – 469 mg/kg) and;

(ii) the Cr(VI) concentrations are low (at or close to the limit of quantification (LOQ)) in the samples of imported topsoil, indicating that the high total-Cr contents are not associated with industrial waste (Figure 12).

Indeed, Cr(VI) concentrations in the GGERFS samples are < 10 mg/kg with the exception of sample G087 collected from GGERFS06b. This sample has the highest Cr(VI) (28.5 mg/kg) and Sb (44.7 mg/kg) contents in the GGERFS topsoil dataset. Total-Cr is high in this sample also (1751 mg/kg) (Figures 12 and A4.1, Appendix 4; Table A3.1, Appendix 4). These results indicate pollution of this soil, probably with paint fragments noted in the sample, as these elements are used in yellow pigments (Butterman and Carlin 2004; Gettens and Stout 1966). The surrounding samples collected within tens of meters of G087 at GGERFS06b have markedly lower Sb (< 2.5 mg/kg) Cr(VI) (< 1.0 mg/kg) and total-Cr (103-200 mg/kg) concentrations indicating the pollution is very isolated.

### 6.2.4 Selected topsoil pH, major element and carbon relationships

Topsoil pH values range between 3.79 and 7.86 (Table A3.1, Appendix 3). Soil samples collected from the GGERFS sites have generally higher pH values (> pH 5), with concordantly higher CaO (> 0.5 wt%), MgO (> 1 wt%) and total inorganic carbon (TIC > 1 %) concentrations than the park control sites (Figures 13 and 14). This is a result of calcareous building rubble, slag and made-ground materials noted at the GGERFS sites. These materials are known to raise the pH and CaO/MgO content of urban soil relative to natural soil in many urban environments (Birke et al. 2011; Fordyce et al. 2005; Fordyce et al. 2019).

Topsoil $SiO_2$ concentrations exceed the maximum reported in the wider G-BASE Glasgow urban topsoil dataset (82 wt%, Fordyce et al. 2017) in samples collected from Glasgow Green (Figure 14). This is not surprising as these samples were collected from football pitches on the alluvial plain of the River Clyde, where the soil was notably sandy in texture. The sandy nature of the soil accounts for the generally lower total organic carbon (TOC) content (< 2 %) in these samples than soil from the other study sites (Figure 13).

By contrast, the highest TOC value of 20% was reported in sample G051 from GGERFS05 and exceeds the maximum TOC content reported by Kim et al. (2019) in the BGS Glasgow topsoil dataset (Table A3.2, Appendix 3; Figure 13). This soil was collected from an area of extensive leaf-litter accumulation and had a peaty texture.

### 6.2.5 Comparisons between the GGERFS sites and control sites

In general, the GGERFS site soil samples contain higher metal and organic pollutant contents than the control samples collected from Glasgow Green and to a lesser extent Tollcross Park, as expected (Figures 11, 12, 14; Figures A4.1-A4.8, Appendix 4).

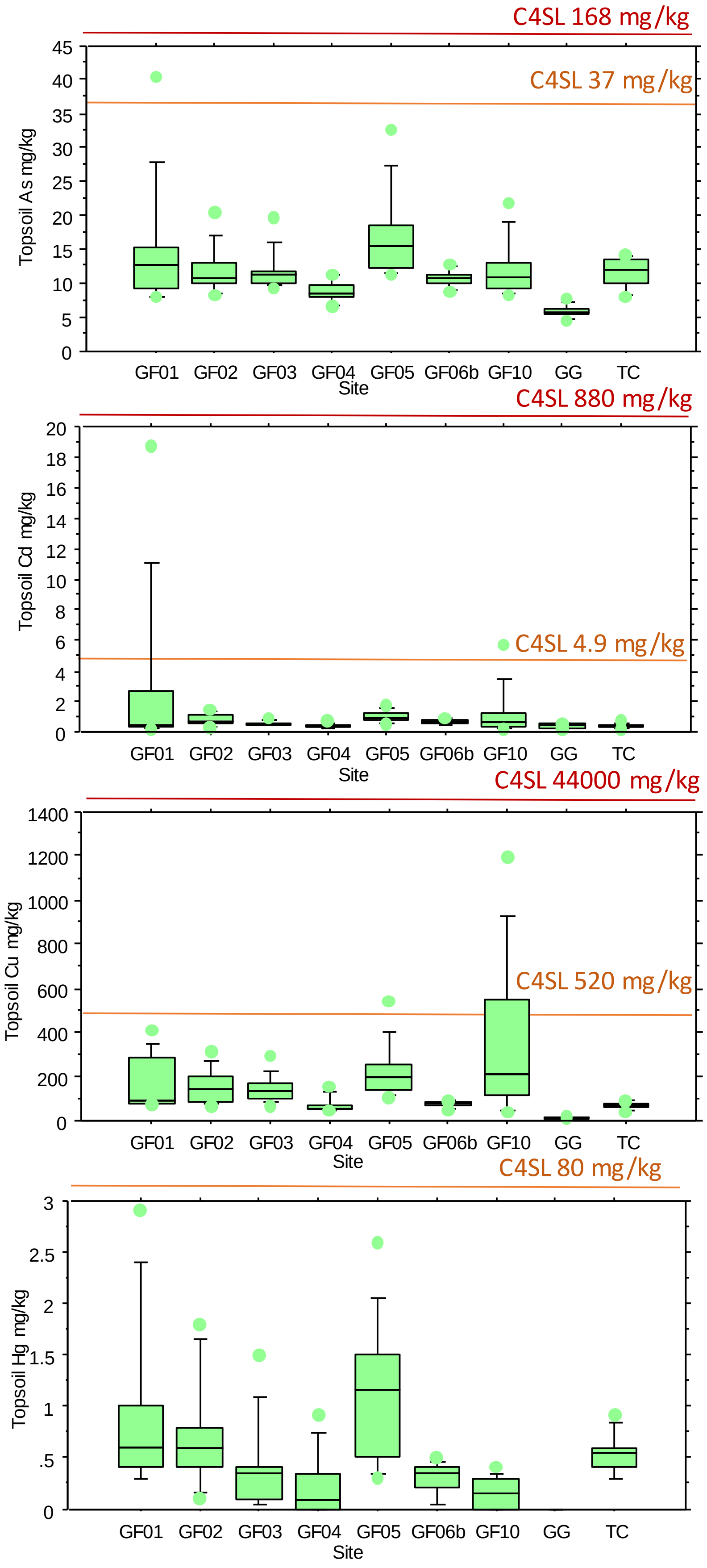
Similarly, the greater presence of building rubble, slag and made-ground materials at the GGERFS sites probably accounts for the generally higher $Fe_2O_3$ content (> 4.8 wt%) in these samples than in Glasgow Green and Tollcross Park (Figure 14).

### 6.2.6 Topsoil TPH, PAH and PCBs

Highest TPH concentrations (> 2500 mg/kg) that exceed the BGS Glasgow dataset reported by Kim et al. (2019) (Table A3.2 Appendix 3; Figure A4.7, Appendix 4) are noted in topsoil that contained hard-core from sites GGERFS04 and 10. In both cases, the hard-core included fragments of building rubble and asphalt, and the presence of asphalt probably accounts for the high TPH values. In addition, GGERFS10 is downslope from the former Dalmarnock Gas works and hydrocarbon pollution has been noted in the vicinity in the past (Ramboll 2018a). However, the area has since been remediated, and more detailed examinations of the organic chemistry dataset would be required to determine if the historic gas works is an additional source of pollution at this site.

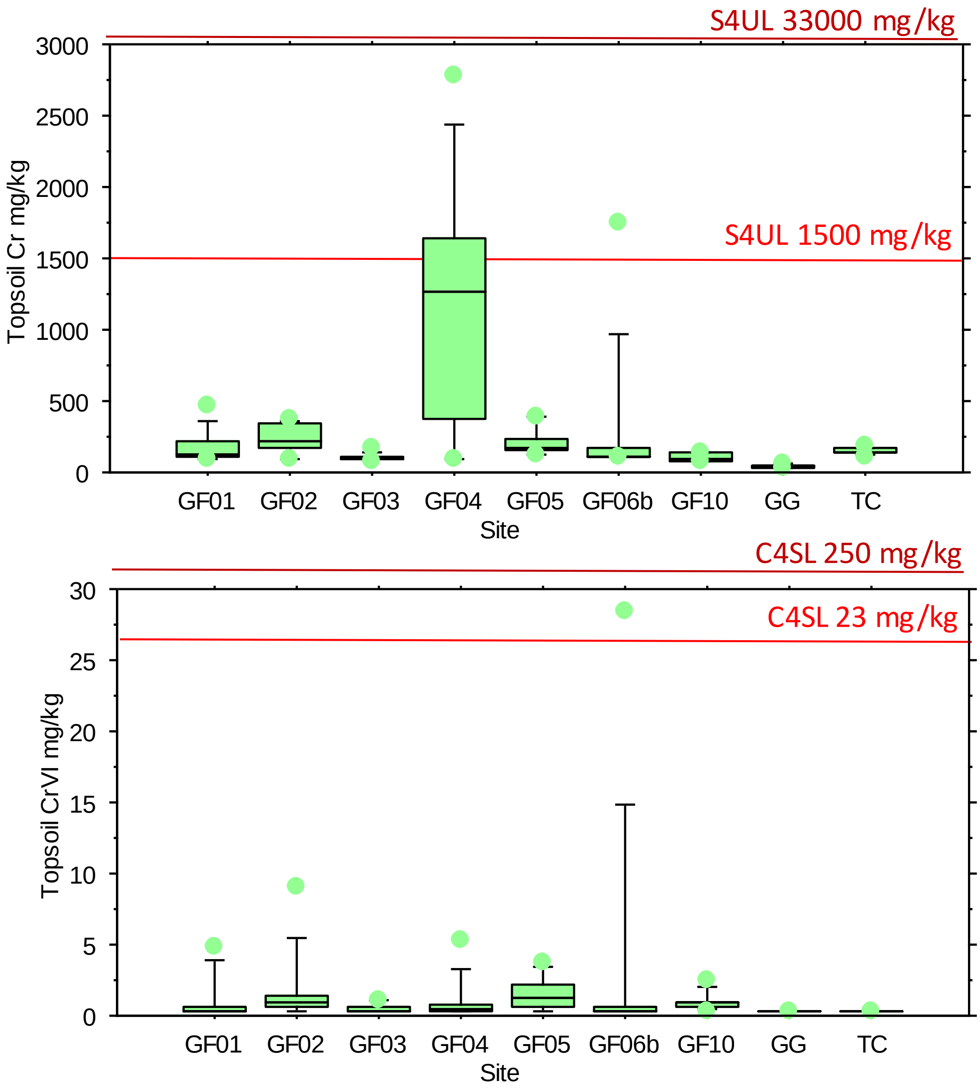
The highest naphthalene-type and dibenzofuran PAH contents in the GGERFS dataset (Table A3.3, Appendix 3) are reported from sites GGERFS01, 02 and 05 in samples G037, G097, G057 and G095, all of which were collected from areas underlain by building rubble and where slag and, coal waste were noted in the topsoil. High concentrations of organic pollutants in sample G057 at site 05 are in addition to the high Ba and Pb contents already noted. Similarly, samples G037 (site 01) and G095 (site 02) contain the highest BaP concentrations in the GGERFS dataset (17.3 and 16.5 mg/kg respectively). The soil quality guidelines for BaP tend to be the most precautionary of all the PAH compounds reflecting the toxicity of this substance. As such, BaP is often used as an indicator PAH in assessments of land quality. The GGGERFS site values do not exceed the generic soil screening level for recreational open space; hence, the land would not be considered contaminated (C4SL 21 mg/kg; DEFRA 2014).

The sum of the seven PCB congeners (PCB 28, 52, 101, 118, 153, 138, 180) as recommended by the ICES/EUCBR are typically used as an indicator of soil quality (Kim et al. 2019). The highest ∑7PCB concentrations in the GGERFS dataset, that exceed contents in the wider BGS Glasgow dataset (> 352 µg/kg; Kim et al. 2019), are reported from GGERFS 04 (sample G016) and 02 (sample G084) (Table A3.4, Appendix 3; Figure A4.8, Appendix 4). The ∑Tri-Hepta PCB contents in these two samples also exceed those reported by Kim et al. (2019) for Glasgow topsoil (> 1052 µg/kg) (Table A3.4) and likely relate to pollution from the building rubble and waste that underlie these sites. Indeed at site GGERFS04, the samples that lie to the south of the area recent landscaping (G016, G026, G054, and G017) show higher PCB contents than those collected from the area of imported topsoil in the north of the site (Figure A4.8, Appendix 4). In several of the topsoil samples from sites 01 – 05 ∑7PCB contents are above the Dutch soil target value of 20 µg/kg (for ecosystem health), but are not above the intervention/trigger value of 1000 µg/kg (VROM 2009) (Table A3.5, Appendix 3 and Figure A4.8, Appendix 4).



GG: Glasgow Green TC: Tollcross Park GF: Glasgow Facility Number of samples at each site: 10 (except 9 at 04)
C4SL: GAC screening level soil guideline for residential open space (DEFRA 2014)
C4SL: GAC screening level soil guideline for allotments (DEFRA 2014)

**Figure 11. Box and whisker plots of As, Cd, Cu, Hg concentrations in topsoil at the GGERFS sites**



GG: Glasgow Green TC: Tollcross Park GF: Glasgow Facility

Number of samples at each site: 10 (except 9 for total Cr at 04)

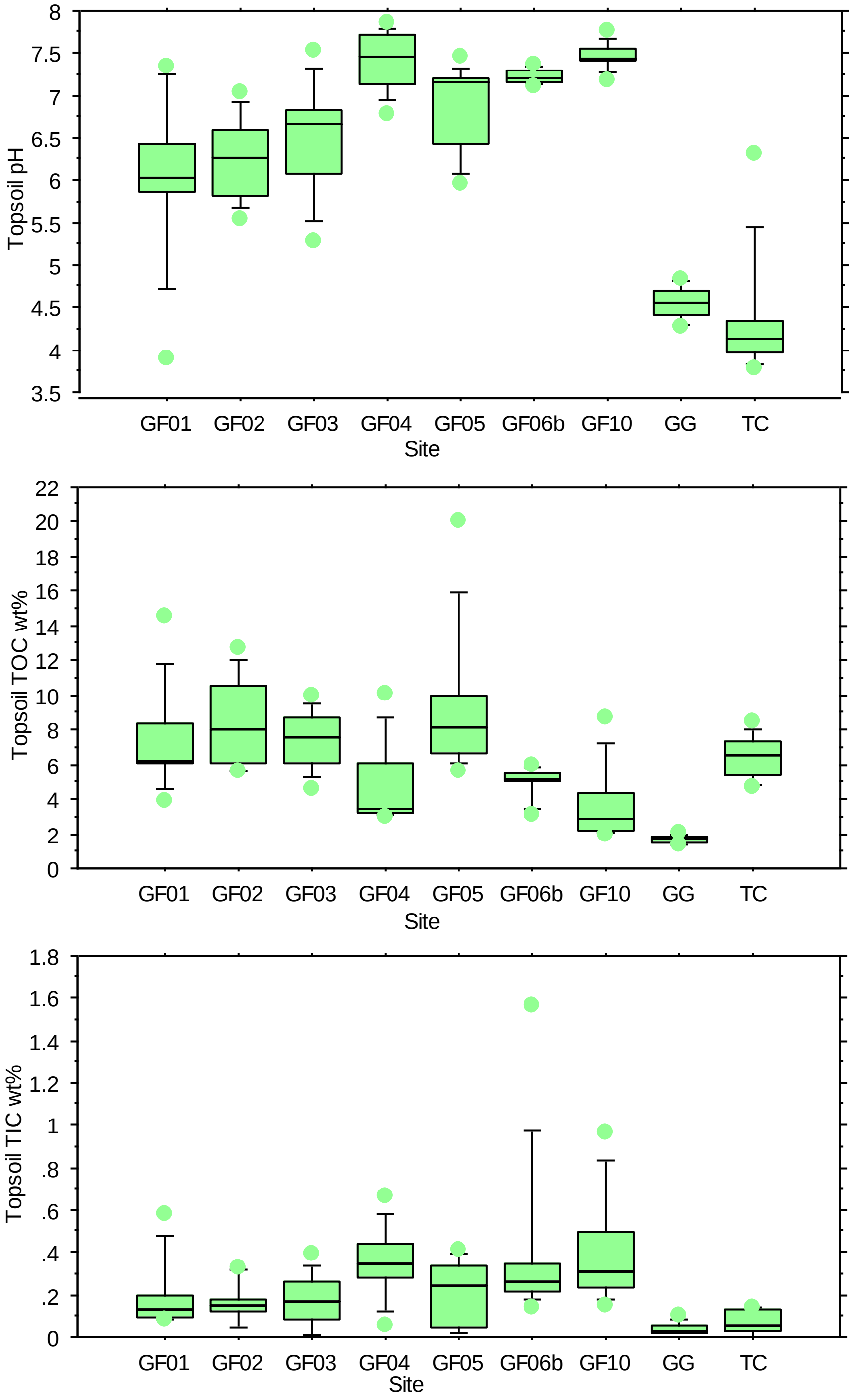
C4SL: GAC screening level soil guideline for recreational open space (DEFRA 2014)

C4SL: GAC screening level soil guideline for residential open space (DEFRA 2014)

S4UL: GAC suitable for use level soil guideline recreational open space (Nathanail et al. 2015)

S4UL: GAC suitable for use level soil guideline for residential open space (Nathanail et al. 2015)

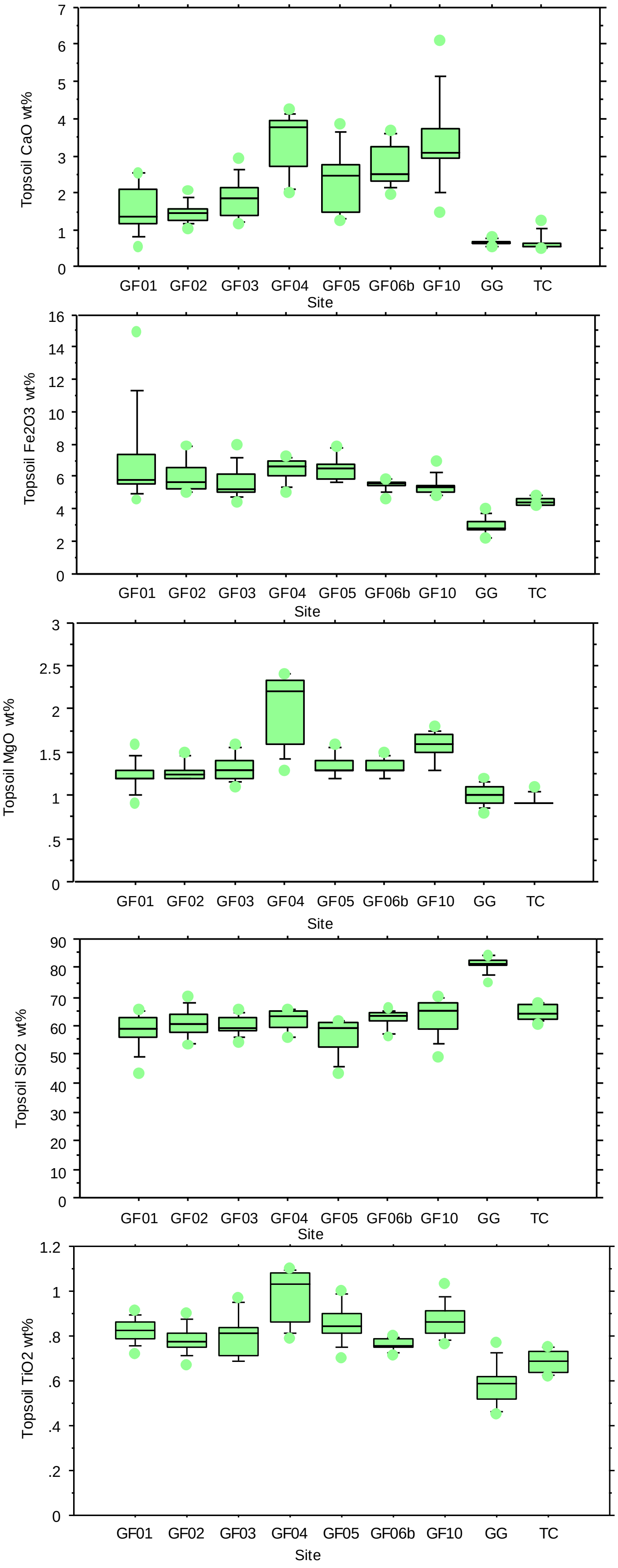
**Figure 12. Box and whisker plots of total Cr and Cr(VI) concentrations in topsoil at the GGERFS sites**



GG: Glasgow Green TC: Tollcross Park GF: Glasgow Facility

Number of samples at each site: 10

**Figure 13. Box and whisker plots of topsoil pH, total organic carbon (TIC) and total inorganic carbon (TOC) at the GGERFS sites**



GG: Glasgow Green TC: Tollcross Park GF: Glasgow Facility

Number of samples at each site = 10 (except 9 at 04)

**Figure 14. Box and whisker plots of selected major element concentrations (CaO, $Fe_2O_3$, MgO, $SiO_2$, $TiO_2$) in topsoil at the GGERFS sites**

# 7 Conclusions and Recommendations

## 7.1 CONCLUSIONS

A soil chemistry baseline survey of 90 topsoil (0 – 20 cm) samples was carried out across the seven proposed GGERFS borehole sites in the east of Glasgow during February-March 2018. In addition, two control sites were included in the survey for comparison with semi-natural soil. The control sites were situated in long-established city parks, where the land use has been stable for over 100 years: Glasgow Green and Tollcross Park.

The samples were analysed to determine soil pH and the concentrations of 54 inorganic and 75 organic soil parameters.

Initial assessments of the chemical results reveal that topsoil from the GGERFS sites generally contains higher inorganic and organic pollutant concentrations and is more calcareous/alkaline than semi-natural topsoil collected from the two control sites.

Similarly, the maximum concentrations of the pollutants Cd, TPH, the naphthalene and dibenzofuran PAH compounds, ∑7PCBs and tri-hepta PCB compounds reported at the GGERFS sites exceed those reported in pre-existing city-wide BGS Glasgow topsoil datasets.

Whilst the current land use at all the GGERFS sites is open recreational space, these findings are a consequence of the historic land use at the GGERFS sites, all of which are underlain by building rubble, domestic rubbish and/or colliery waste and, in the case of sites GGERFS04 and 10, are partially covered in hard-core material containing asphalt. Like many urban environments, soil quality at the GGERFS sites has been adversely impacted by the presence of these materials in the soil.

Both total Cr and Cr(VI) speciation were determined in the soil samples because there is a history of disposal of chromite ore processing residue (COPR) in the east of Glasgow. Whilst Cr(VI) can occur in certain natural environments, it is more typically associated with industrial activity. Results revealed that Cr(VI) concentrations in the soil were generally < 10 mg/kg, with the exception of sample G087 at site 06b where an isolated high value of 28 mg/kg was reported. However, given that Sb was also high in this sample (44.7 mg/kg) and concentrations of both these elements were low in the surrounding samples, this suggests isolated pollution probably from paint fragments that were present in the sample, as both these elements are used in pigments.

**There is no evidence of COPR waste in the topsoil samples collected from the GGERFS sites.**

An additional assessment of a sub-set of 10 of the topsoil samples revealed that trace amounts of asbestos fibres (0.027 % wt) were found in one sample (G017) from GGERFS04. This soil was collected over building rubble, outside an area of landscaped imported topsoil that has been applied to the northern section of site 04 and was not in the publicly accessible section of the Cuningar Loop. The amount of asbestos in this sample was within limits classed as 'insignificant risk'. None of the surrounding samples tested from this site contained asbestos indicating that the pollution is isolated.

Although the GGERFS sites show evidence of soil pollution, comparison with current UK human health risk assessment land contamination generic soil guidelines for recreational open space indicates that **in general, the land would not be classed as contaminated**.

However, two soil samples G023 and G057 from site 05 do exceed the recreational open space guideline for Pb (1300 mg/kg). These were collected outside of the publicly accessible area in the Cuningar Loop. The fact that these samples exceed the guideline does not mean that the land is contaminated. Rather that further investigation would be required to determine whether there is a source-pathway-receptor linkage and any potential risk at these locations.

The Soil Chemistry03-18 dataset has established the pre-installation baseline for the GGERFS facility, against which any future change in soil chemistry can be assessed.

## 7.2 RECOMMENDATIONS

Since the environmental soil chemistry baseline sampling was carried out in February-March 2018, topsoil at the GGERFS sites has undergone significant disturbance during the installation of the boreholes. Further ground disturbance will result from the planned installation of the flow experiment infrastructure. These activities are likely to alter the surface soil chemistry, before the site is fully operational. Therefore, if resources can be identified:

- It may be advisable that once the post-installation remediation is completed, a further set of topsoil samples from the disturbed areas be collected and analysed, to establish the pre-operational soil quality baseline before the facility is fully functioning, to understand the ground conditions and provide public assurance.

- Similarly, it may be advisable that soil baseline chemistry sampling be carried out again during the operational phase of the project (in 5-6 years) to provide assurance that topsoil quality has not changed significantly as a consequence of running the facility.

# Glossary

| | |
|---|---|
| ACM | asbestos containing material |
| ASE | accelerated solvent extraction system |
| BACI | before and after control/impact |
| BaP | benzo(a)pyrene |
| BGR | German Geological Survey |
| BGS | British Geological Survey |
| C, N | carbon-nitrogen |
| $CaCl_2.2H_2O$ | calcium chloride solution |
| CANMET | Canadian Centre for Mineral and Energy Technology |
| CIEH | Chartered Institute of Environmental Health |
| CL:AIRE | Contaminated Land: Applications in Real Environments |
| CLEA | contaminated land exposure assessment |
| COPR | chromite ore processing residue |
| CRM | certified reference material |
| C4SL | category four soil screening levels |
| DEFRA | Department for Environment Food and Rural Affairs |
| DNA | deoxyribonucleic acid |
| EA | Environment Agency of England and Wales |
| EDTA | ethylenediaminetetraacetic acid |
| EUCBR | European Union Community Bureau of Reference |
| FID | flame ionization detector |
| GAC | generic assessment criteria |
| G-BASE | Geochemical Baseline Survey of the Environment |
| GCC | Glasgow City Council |
| GC-MS | Gas chromatography mass spectrometry |
| GF | Glasgow Facility |
| GG | Glasgow Green |
| GGERFS | Glasgow Geothermal Energy Research Field Site |
| GIS | geographic information system |
| GPS | global positioning system |
| HCl | hydrochloric acid |
| HMSO | Her Majesty’s Stationery Office |
| HPLC | high performance liquid chromatography |
| HSE | Health and Safety Executive |
| ICES | International Council for the Exploration of the Sea |

| | |
|---|---|
| ICP-MS | inductively coupled plasma mass spectrometry |
| ID | identity number |
| LOQ | limit of quantification |
| LQM | Land Quality Management |
| NERC | Natural Environment Research Council |
| $NH_4$ | ammonium |
| $NH_4NO_3$ | ammonium nitrate |
| NIST | National Institute of Standards and Technology, USA |
| NRC | National Research Centre, China |
| PAH | polycyclic aromatic hydrocarbons |
| PCB | polychlorinated biphenyls |
| PEEK | poly-ether ether ketone |
| PFA | fluorocarbon polymer |
| PLM | polarising light microscopy |
| POPs | persistent organic pollutants |
| RSD | relative standard deviation |
| RSE | relative standard error |
| SEPA | Scottish Environment Protection Agency |
| SGV | soil guideline value |
| SIDMS | speciated isotope dilution mass spectrometry |
| SPE | solid phase extraction cartridge |
| SRM | secondary reference material |
| SUDS | sustainable urban drainage system |
| S4UL | suitable for use level |
| TC | Tollcross Park |
| TIC | total inorganic carbon |
| TOC | total organic carbon |
| TPH | total petroleum hydrocarbons |
| TRA | time resolved analysis |
| TTC | total carbon |
| UK | United Kingdom |
| UKAS | United Kingdom Accreditation Service |
| UKGEOS | United Kingdom Geoenergy Observatories project |
| USA | United States of America |
| VROM | Dutch Ministry of Housing, Spatial Planning and Environment |
| XRF | x-ray fluorescence spectrometry |

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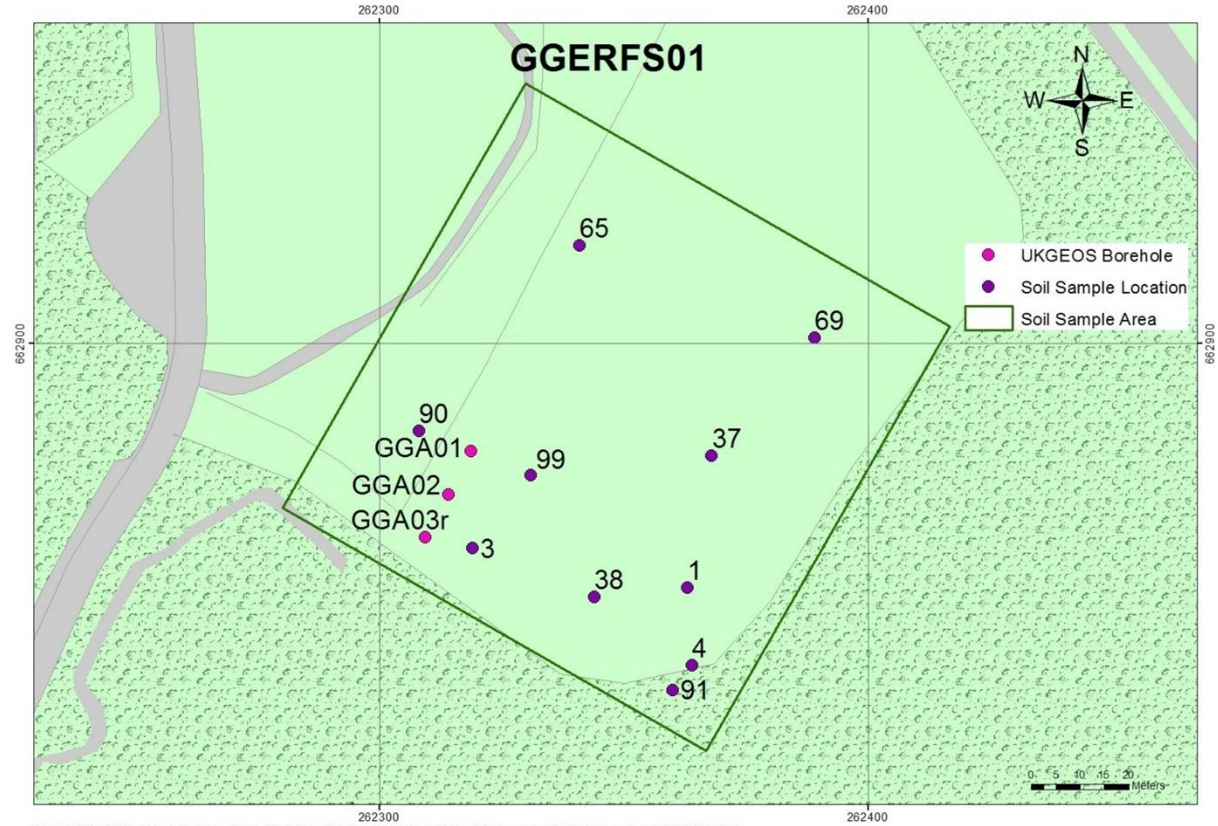
# Appendix 1 Maps of the GGERFS soil sample locations



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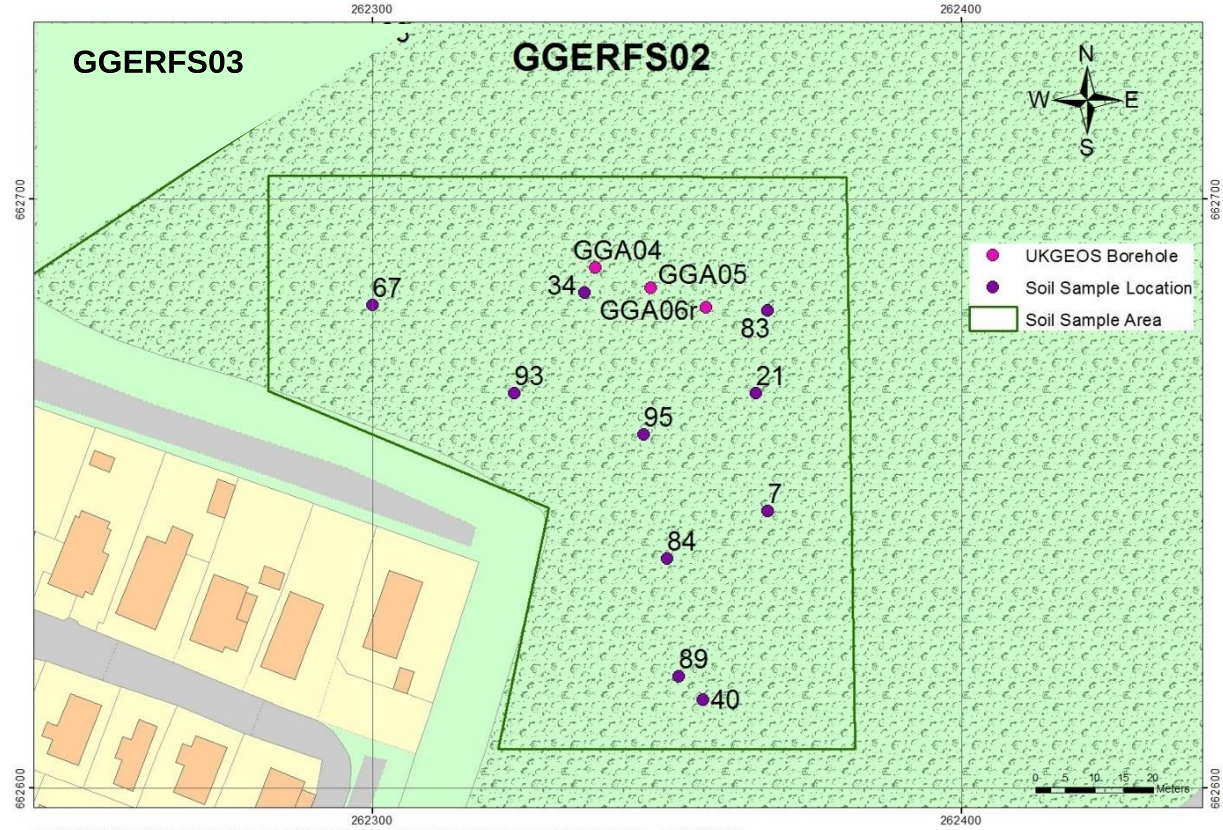
UKGEOS Borehole: proposed borehole positions, final borehole positions were subject to revision

**Figure A1.1 Map of topsoil sample locations at site GGERFS01.**



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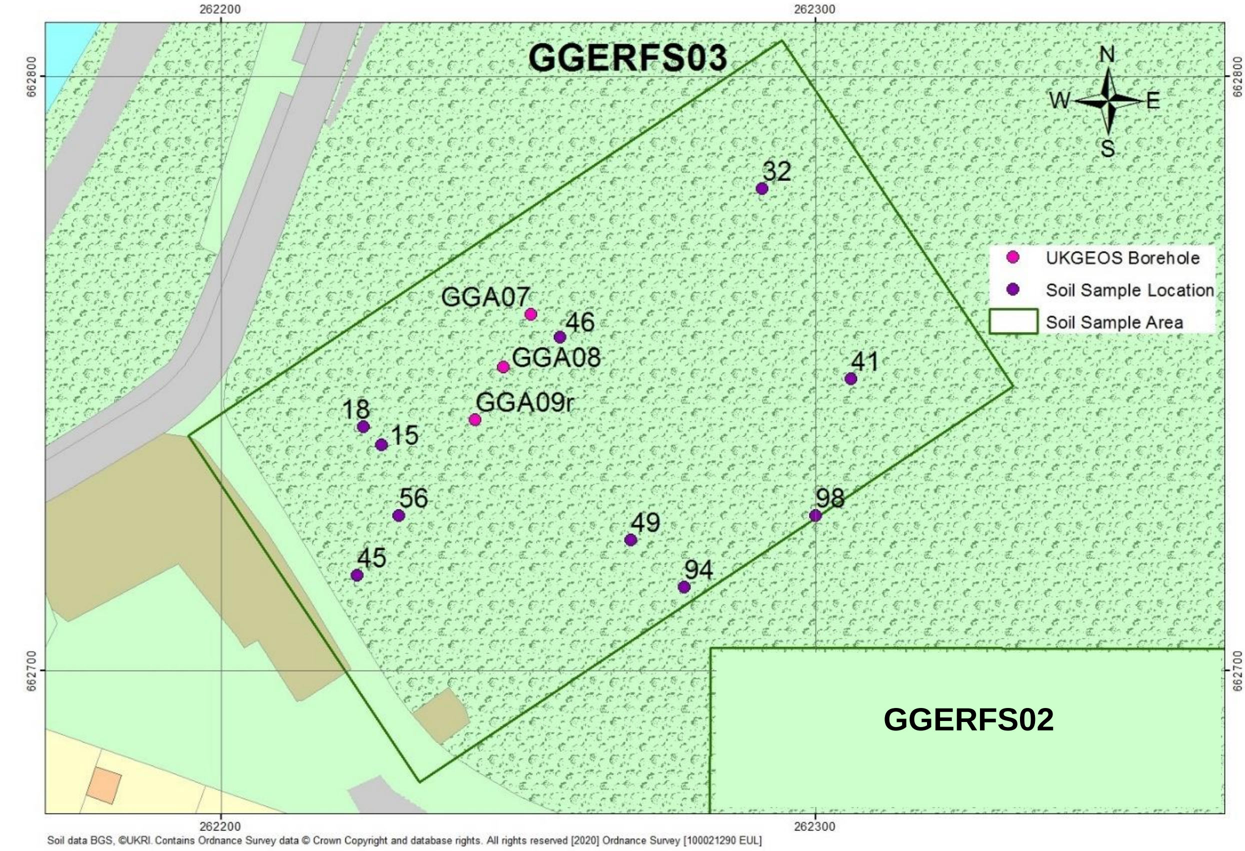
UKGEOS Borehole: proposed borehole position, final borehole positions were subject to revision

**Figure A1.2 Map of topsoil sample locations at site GGERFS02.**



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UKGEOS Borehole: proposed borehole position, final borehole positions were subject to revision

**Figure A1.3 Map of topsoil sample locations at site GGERFS03.**

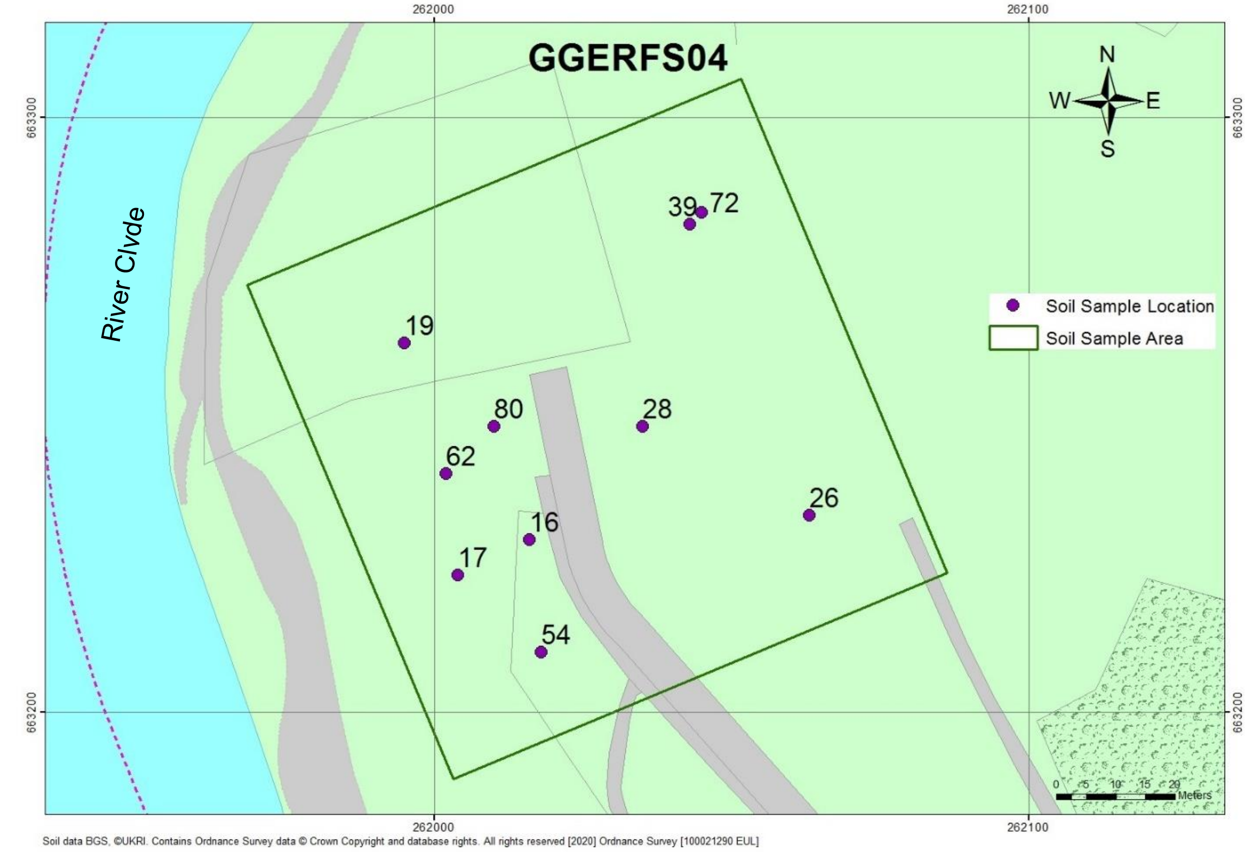

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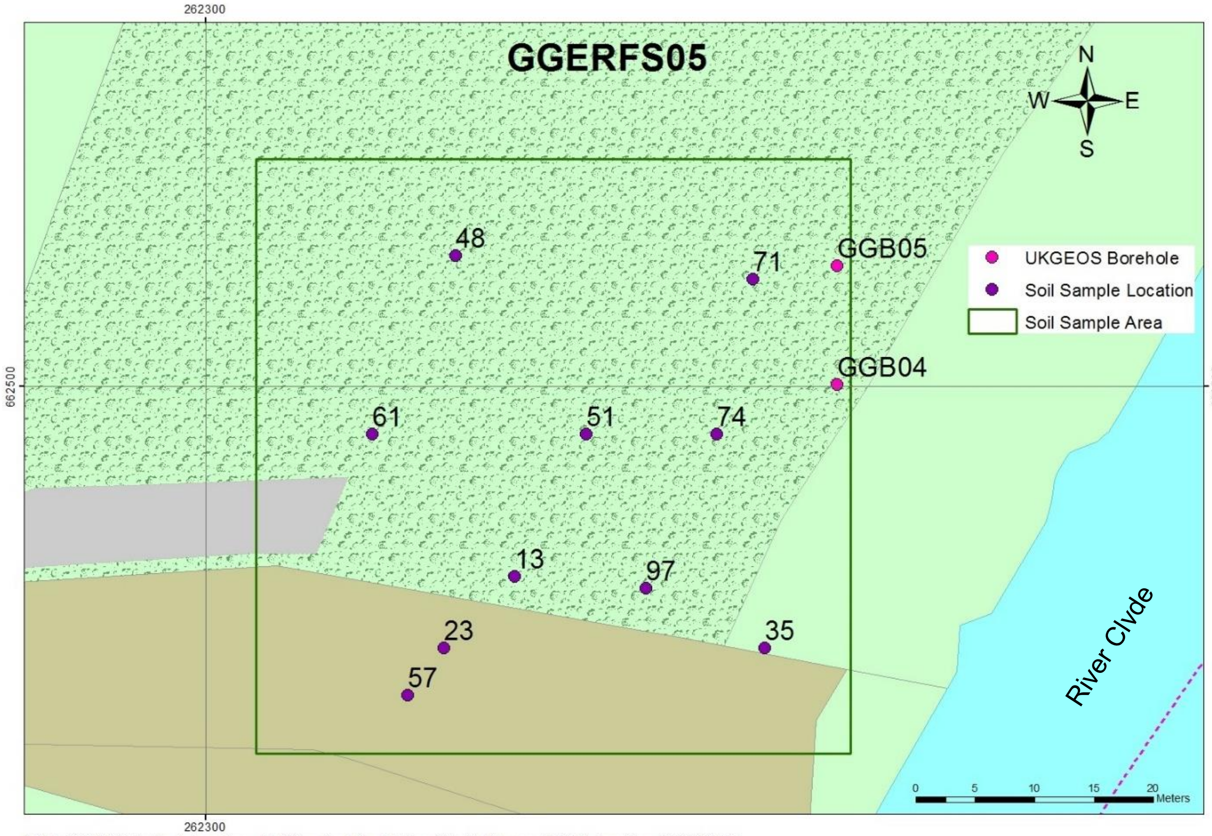
**Figure A1.4 Map of topsoil sample locations at site GGERFS04.**



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UKGEOS Borehole: proposed borehole position, final borehole positions were subject to revision

**Figure A1.5 Map of topsoil sample locations at site GGERFS05.**

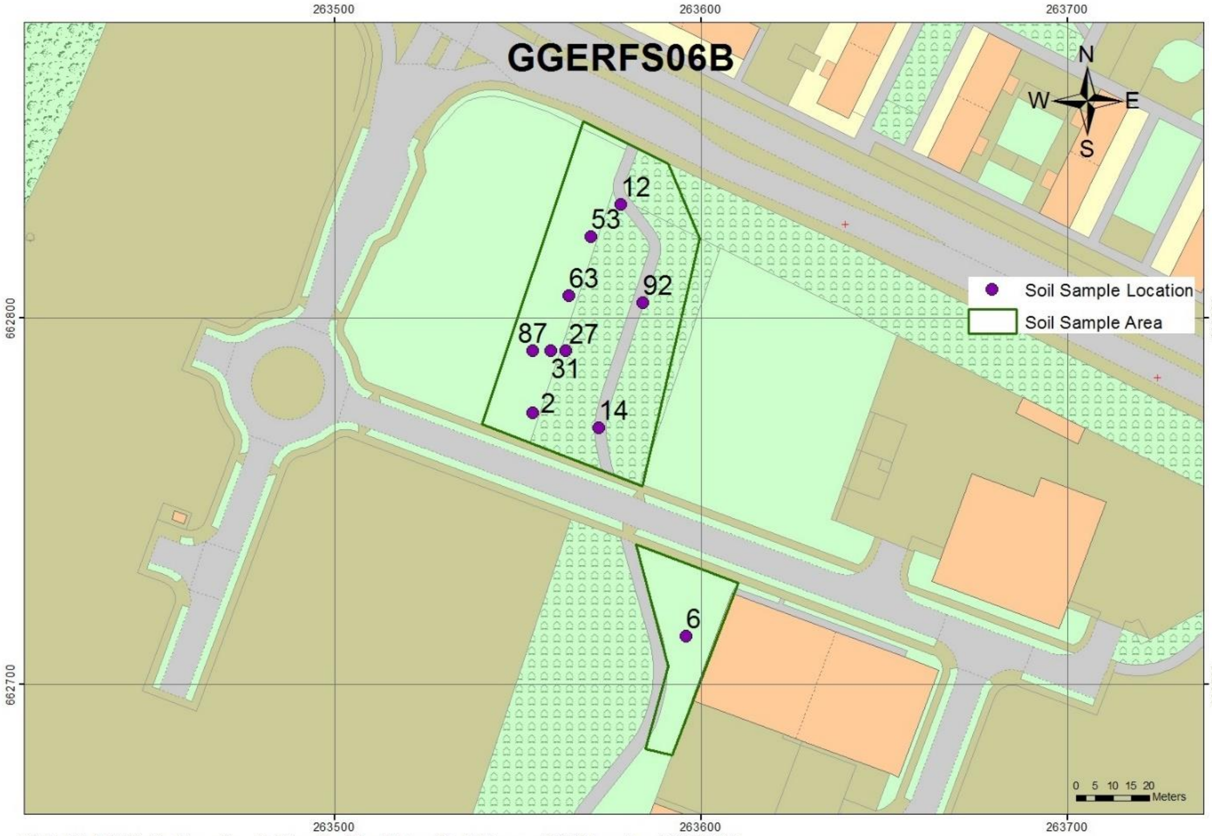

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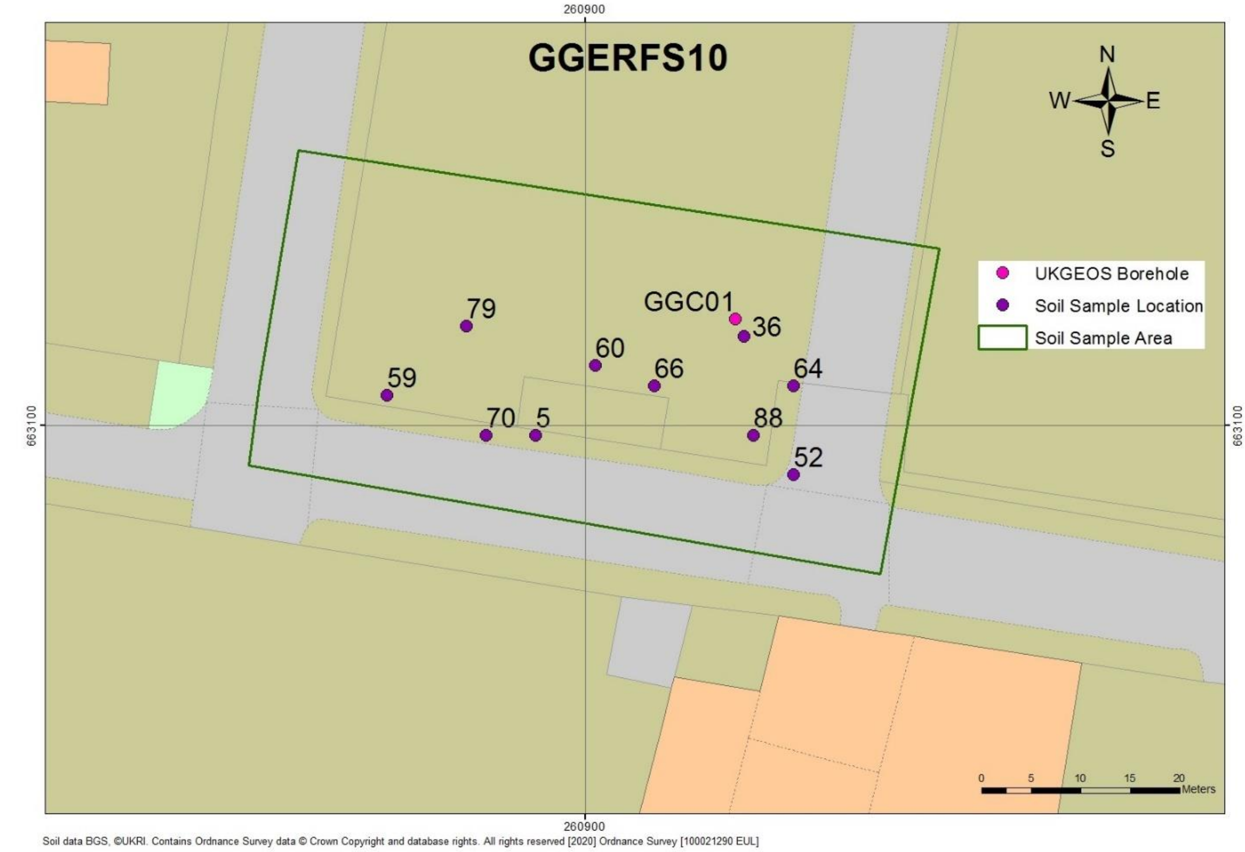
**Figure A1.6 Map of topsoil sample locations at site GGERFS06b.**



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UKGEOS Borehole: proposed borehole position, final borehole positions were subject to revision

**Figure A1.7 Map of topsoil sample locations at site GGERFS10.**

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**Figure A1.8 Map of topsoil sample locations in Glasgow Green.**

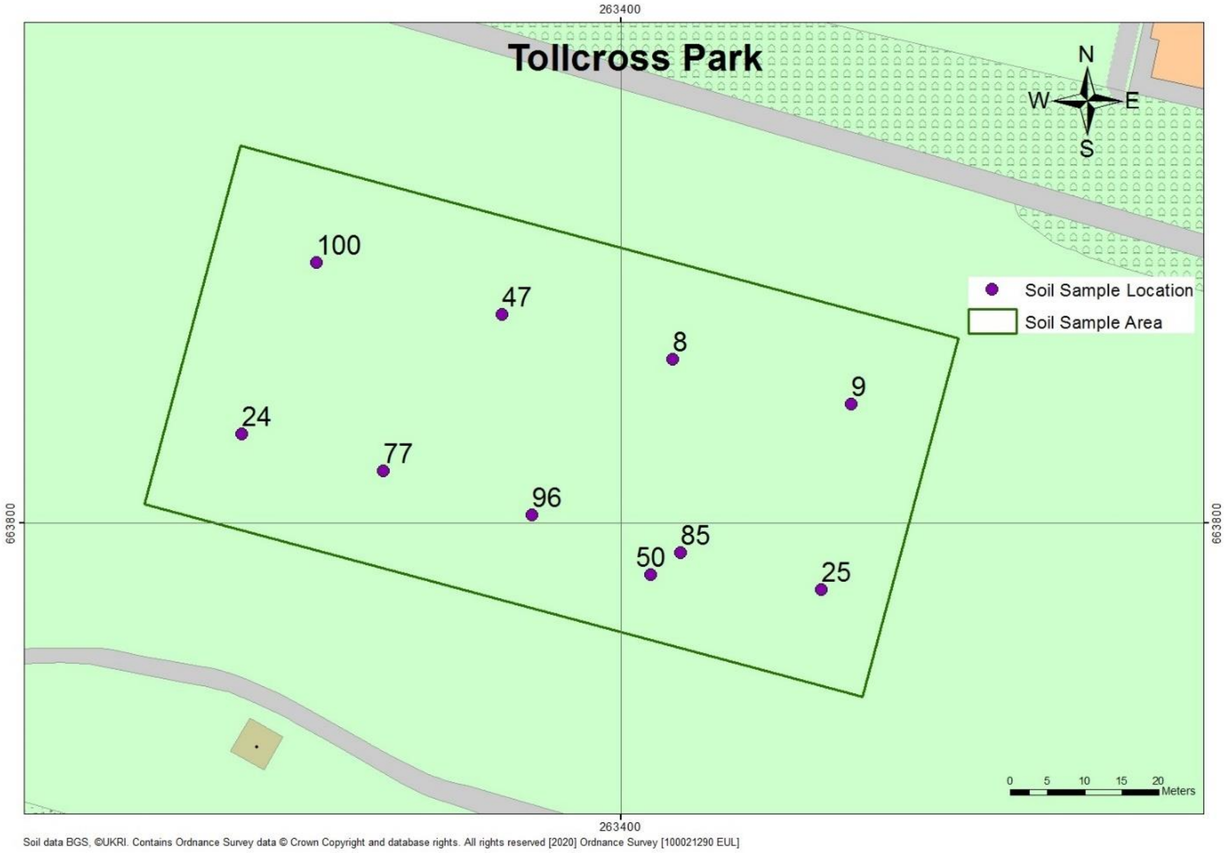

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**Figure A1.9 Map of topsoil sample locations in Tollcross Park.**

# Appendix 2 Figures of merit for GGERFS soil analysis

**Table A2.1 Results for certified reference materials included in the XRF analysis of total element concentrations in topsoil.**

| | | | GSD-6 Bulk Stream Sediment, NRC | | | | | | STSD-3 Bulk stream sediment, CANMET | | | | | | LKSD-1 Bulk lake sediment, CANMET | | | | | | | LKSD-4 Bulk lake sediment, CANMET | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Units | LOQ | CV | Mean | SD | %Recovery | RSD % | RSE % | CV | Mean | SD | %Recovery | RSD % | RSE % | CV | Mean | SD | CV | %Recovery | RSD % | RSE % | CV | Mean | SD | %Recovery | RSD % | RSE % |
| Al2O3 | wt% | 0.20 | 14.2 | 15.25 | 0.39 | 108 | 3 | 1 | 10.9 | 8.95 | 0.10 | 82 | 1 | 1 | 7.8 | 3.98 | 0.15 | 7.8 | 51 | 4 | 2 | 5.9 | 4.38 | 0.05 | 74 | 1 | 1 |
| CaO | wt% | 0.05 | 3.9 | 3.94 | 0.03 | 102 | 1 | <1 | 3.3 | 3.36 | 0.02 | 102 | 1 | <1 | 10.8 | 12.42 | 0.03 | 10.8 | 115 | <1 | <1 | 1.8 | 1.73 | 0.01 | 96 | 1 | <1 |
| Fe2O3 | wt% | 0.01 | 5.9 | 5.81 | 0.04 | 99 | 1 | <1 | 6.2 | 5.92 | 0.03 | 95 | <1 | <1 | 4.1 | 3.83 | 0.03 | 4.1 | 93 | 1 | <1 | 4.1 | 4.03 | 0.01 | 98 | <1 | <1 |
| K2O | wt% | 0.01 | 2.4 | 2.54 | 0.02 | 105 | 1 | <1 | 1.8 | 1.73 | 0.01 | 96 | 1 | <1 | 1.1 | 0.90 | 0.01 | 1.1 | 82 | 2 | 1 | 0.8 | 0.72 | 0.01 | 90 | 1 | <1 |
| MgO | wt% | 0.30 | 3.0 | 4.38 | 0.10 | 146 | 2 | 1 | 2.2 | 2.28 | 0.05 | 103 | 2 | 1 | 1.7 | 1.43 | 0.05 | 1.7 | 84 | 4 | 2 | 0.9 | 0.80 | 0.00 | 89 | <1 | <1 |
| MnO | wt% | 0.01 | 0.1 | 0.14 | 0.00 | 114 | 1 | <1 | 0.3 | 0.38 | 0.00 | 128 | 1 | <1 | 0.1 | 0.09 | 0.00 | 0.1 | 90 | 1 | 1 | 0.1 | 0.07 | 0.00 | 68 | 1 | <1 |
| Na2O | wt% | 0.30 | 2.3 | 2.00 | 0.08 | 87 | 4 | 2 | 1.5 | 0.80 | 0.00 | 53 | <1 | <1 | 2.0 | 0.83 | 0.05 | 2.0 | 41 | 6 | 3 | 0.7 | 0.20 | 0.00 | 29 | <1 | <1 |
| P2O5 | wt% | 0.05 | 0.2 | 0.25 | 0.01 | 108 | 4 | 2 | 0.4 | 0.40 | 0.01 | 99 | 2 | 1 | 0.2 | 0.13 | 0.01 | 0.2 | 64 | 8 | 4 | 0.3 | 0.33 | 0.01 | 109 | 2 | 1 |
| SiO2 | wt% | 0.10 | 61.2 | 61.30 | 1.56 | 100 | 3 | 1 | 48.6 | 39.05 | 0.31 | 80 | 1 | <1 | 40.1 | 22.30 | 0.80 | 40.1 | 56 | 4 | 2 | 41.6 | 39.53 | 0.30 | 95 | 1 | <1 |
| TiO2 | wt% | 0.01 | 0.8 | 0.71 | 0.00 | 92 | 1 | <1 | 0.7 | 0.55 | 0.01 | 79 | 1 | <1 | 0.5 | 0.38 | 0.00 | 0.5 | 76 | 1 | <1 | 0.4 | 0.28 | 0.00 | 71 | 1 | 1 |
| Ag | mg/kg | 0.50 | 0.4 | 0.23 | 0.15 | 65 | 65 | 33 | <0.5 | <0.5 | nd | nd | nd | nd | 0.6 | 0.38 | 0.13 | 0.6 | 63 | 34 | 17 | 0.2 | 0.17 | 0.06 | 83 | 35 | 17 |
| As | mg/kg | 0.90 | 13.6 | 13.13 | 0.48 | 97 | 4 | 2 | 28.0 | 24.98 | 0.39 | 89 | 2 | 1 | 40.0 | 33.58 | 0.53 | 40.0 | 84 | 2 | 1 | 16.0 | 16.60 | 0.37 | 104 | 2 | 1 |
| Ba | mg/kg | 1.00 | 330.0 | 319.25 | 2.99 | 97 | 1 | <1 | 1490.0 | 1332.25 | 9.78 | 89 | 1 | <1 | 430.0 | 378.75 | 4.19 | 430.0 | 88 | 1 | 1 | 330.0 | 251.25 | 2.22 | 76 | 1 | <1 |
| Bi | mg/kg | 0.30 | 5.0 | 4.13 | 0.61 | 83 | 15 | 7 | nr | 0.68 | 0.68 | nd | 101 | 50 | nr | 0.88 | 0.79 | nr | nd | 91 | 45 | nr | 0.27 | 0.31 | nd | 115 | 57 |
| Br | mg/kg | 0.80 | nr | 0.13 | 0.15 | nd | 115 | 57 | 24.0 | 22.68 | 0.17 | 94 | 1 | <1 | 11.0 | 9.45 | 0.31 | 11.0 | 86 | 3 | 2 | 49.0 | 49.00 | 0.63 | 100 | 1 | 1 |
| Cd | mg/kg | 0.50 | 0.4 | 0.25 | 0.06 | 58 | 23 | 12 | 1.0 | 0.70 | 0.18 | 70 | 26 | 13 | 1.2 | 1.10 | 0.12 | 1.2 | 92 | 10 | 5 | 1.9 | 1.83 | 0.30 | 96 | 16 | 8 |
| Ce | mg/kg | 1.00 | 68.0 | 70.00 | 0.82 | 103 | 1 | 1 | 63.0 | 52.00 | 0.82 | 83 | 2 | 1 | 27.0 | 24.00 | 0.82 | 27.0 | 89 | 3 | 2 | 48.0 | 35.75 | 0.50 | 74 | 1 | 1 |
| Cl | mg/kg | 200.00 | nr | <200 | nd | nd | nd | nd | nr | <200 | nd | nd | nd | nd | nr | 240.25 | 9.32 | nr | nd | 4 | 2 | nr | <200 | nd | nd | nd | nd |
| Co | mg/kg | 1.50 | 24.4 | 27.58 | 0.71 | 113 | 3 | 1 | 16.0 | 18.45 | 0.48 | 115 | 3 | 1 | 11.0 | 12.15 | 0.76 | 11.0 | 110 | 6 | 3 | 11.0 | 13.08 | 0.50 | 119 | 4 | 2 |
| Cr | mg/kg | 3.00 | 190.0 | 188.88 | 2.45 | 99 | 1 | 1 | 80.0 | 71.00 | 3.35 | 89 | 5 | 2 | 31.0 | 54.10 | 23.36 | 31.0 | 175 | 43 | 22 | 33.0 | 30.18 | 1.95 | 91 | 6 | 3 |
| Cs | mg/kg | 1.00 | 9.1 | 8.50 | 0.58 | 93 | 7 | 3 | 5.2 | 5.75 | 0.50 | 111 | 9 | 4 | 2.0 | 1.50 | 0.58 | 2.0 | 75 | 38 | 19 | 2.0 | 2.00 | 0.00 | 100 | <1 | <1 |
| Cu | mg/kg | 1.30 | 383.0 | 376.30 | 2.05 | 98 | 1 | <1 | 39.0 | 35.38 | 0.70 | 91 | 2 | 1 | 44.0 | 37.08 | 0.58 | 44.0 | 84 | 2 | 1 | 31.0 | 27.05 | 0.61 | 87 | 2 | 1 |
| Ga | mg/kg | 1.00 | 16.7 | 15.40 | 0.18 | 92 | 1 | 1 | nr | 13.18 | 0.40 | nd | 3 | 2 | nr | 8.23 | 0.38 | nr | nd | 5 | 2 | nr | 6.83 | 0.61 | nd | 9 | 4 |
| Ge | mg/kg | 0.50 | 1.3 | 0.67 | 0.29 | 51 | 43 | 22 | nr | 0.30 | 0.10 | nd | 33 | 17 | nr | <0.5 | nd | nr | nd | nd | nd | nr | 0.15 | 0.07 | nd | 47 | 24 |
| Hf | mg/kg | 1.00 | 4.9 | 3.05 | 0.31 | 62 | 10 | 5 | 5.1 | 3.60 | 0.37 | 71 | 10 | 5 | 3.6 | 2.30 | 0.41 | 3.6 | 64 | 18 | 9 | 2.8 | 1.70 | 0.22 | 61 | 13 | 6 |
| Hg | mg/kg | 2.50 | 0.0 | 1.30 | 0.24 | 2889 | 19 | 9 | 0.1 | 0.17 | 0.21 | 185 | 125 | 62 | 0.1 | 0.20 | nd | 0.1 | 182 | nd | nd | nr | 0.28 | 0.10 | nd | 35 | 17 |
| I | mg/kg | 0.50 | nr | 0.30 | 0.28 | nd | 94 | 47 | nr | 11.38 | 0.10 | nd | 1 | <1 | nr | 1.83 | 0.21 | nr | nd | 11 | 6 | nr | 9.63 | 0.39 | nd | 4 | 2 |
| In | mg/kg | 0.50 | 0.1 | 0.10 | nd | 71 | nd | nd | nr | 0.10 | nd | nd | nd | nd | nr | 0.50 | 0.14 | nr | nd | 28 | 14 | nr | 0.20 | nd | nd | nd | nd |
| La | mg/kg | 1.00 | 39.0 | 38.00 | 0.82 | 97 | 2 | 1 | 39.0 | 31.00 | 0.00 | 79 | <1 | <1 | 16.0 | 13.25 | 0.50 | 16.0 | 83 | 4 | 2 | 26.0 | 19.00 | 0.82 | 73 | 4 | 2 |
| Mo | mg/kg | 0.20 | 7.7 | 7.78 | 0.22 | 101 | 3 | 1 | 6.0 | 5.93 | 0.43 | 99 | 7 | 4 | 10.0 | 9.10 | 0.29 | 10.0 | 91 | 3 | 2 | <5 | 1.55 | 0.06 | nd | 4 | 2 |
| Nb | mg/kg | 1.00 | 12.0 | 8.83 | 0.26 | 74 | 3 | 1 | 12.0 | 10.70 | 0.36 | 89 | 3 | 2 | 7.0 | 3.60 | 0.29 | 7.0 | 51 | 8 | 4 | 9.0 | 4.25 | 0.21 | 47 | 5 | 2 |
| Nd | mg/kg | 4.00 | 33.0 | 32.03 | 1.99 | 97 | 6 | 3 | 33.0 | 38.30 | 2.76 | 116 | 7 | 4 | 16.0 | 18.65 | 2.39 | 16.0 | 117 | 13 | 6 | 25.0 | 29.03 | 2.07 | 116 | 7 | 4 |
| Ni | mg/kg | 1.30 | 78.0 | 79.03 | 1.56 | 101 | 2 | 1 | 30.0 | 31.33 | 0.41 | 104 | 1 | 1 | 16.0 | 16.13 | 0.61 | 16.0 | 101 | 4 | 2 | 31.0 | 32.75 | 0.52 | 106 | 2 | 1 |
| Pb | mg/kg | 1.30 | 27.0 | 27.73 | 0.61 | 103 | 2 | 1 | 40.0 | 45.48 | 0.94 | 114 | 2 | 1 | 82.0 | 75.78 | 0.63 | 82.0 | 92 | 1 | <1 | 91.0 | 93.90 | 0.73 | 103 | 1 | <1 |
| Rb | mg/kg | 1.00 | 107.0 | 105.35 | 1.33 | 98 | 1 | 1 | 68.0 | 61.28 | 0.43 | 90 | 1 | <1 | 24.0 | 22.05 | 0.52 | 24.0 | 92 | 2 | 1 | 28.0 | 24.08 | 0.25 | 86 | 1 | 1 |
| S | mg/kg | 1000.00 | 784.0 | 356.00 | 38.32 | 45 | 11 | 5 | 1400.0 | 1414.25 | 23.63 | 101 | 2 | 1 | 15700.0 | 9431.50 | 52.28 | 15700.0 | 60 | 1 | <1 | 999.0 | 5370.00 | 44.31 | 538 | 1 | <1 |
| Sb | mg/kg | 0.50 | 1.3 | 1.73 | 0.25 | 138 | 14 | 7 | 4.0 | 3.85 | 0.13 | 96 | 3 | 2 | 1.2 | 1.18 | 0.15 | 1.2 | 98 | 13 | 6 | 1.7 | 1.48 | 0.35 | 87 | 24 | 12 |
| Sc | mg/kg | 3.00 | 17.0 | 18.15 | 1.50 | 107 | 8 | 4 | 13.0 | 13.78 | 2.08 | 106 | 15 | 8 | 9.0 | 11.38 | 2.37 | 9.0 | 126 | 21 | 10 | 7.0 | 7.58 | 0.82 | 108 | 11 | 5 |
| Se | mg/kg | 0.20 | 0.3 | 0.13 | 0.06 | 44 | 43 | 22 | nr | 1.43 | 0.05 | nd | 4 | 2 | nr | 0.93 | 0.05 | nr | nd | 5 | 3 | nr | 2.20 | 0.08 | nd | 4 | 2 |
| Sm | mg/kg | 3.00 | 5.6 | 3.05 | 2.06 | 54 | 68 | 34 | 7.0 | 4.33 | 1.22 | 62 | 28 | 14 | 4.0 | 2.30 | 0.88 | 4.0 | 58 | 38 | 19 | 5.0 | 3.25 | 0.79 | 65 | 24 | 12 |
| Sn | mg/kg | 0.50 | 2.8 | 2.73 | 0.15 | 97 | 6 | 3 | 4.0 | 3.00 | 0.22 | 75 | 7 | 4 | 16.0 | 13.45 | 0.60 | 16.0 | 84 | 4 | 2 | 5.0 | 4.50 | 0.14 | 90 | 3 | 2 |
| Sr | mg/kg | 1.00 | 266.0 | 266.88 | 2.20 | 100 | 1 | <1 | 230.0 | 236.48 | 2.10 | 103 | 1 | <1 | 250.0 | 248.60 | 1.61 | 250.0 | 99 | 1 | <1 | 110.0 | 116.43 | 0.34 | 106 | <1 | <1 |
| Ta | mg/kg | 1.00 | 0.8 | 0.37 | 0.21 | 49 | 57 | 28 | 0.9 | 0.20 | nd | 22 | nd | nd | 0.3 | 0.20 | nd | 0.3 | 67 | nd | nd | 0.4 | <1 | nd | nd | nd | nd |
| Te | mg/kg | 0.50 | 0.1 | 0.13 | 0.06 | 103 | 43 | 22 | nr | <0.5 | nd | nd | nd | nd | nr | 0.10 | nd | nr | nd | nd | nd | nr | 0.20 | nd | nd | nd | nd |
| Th | mg/kg | 0.70 | 9.0 | 8.83 | 1.49 | 98 | 17 | 8 | 8.5 | 6.60 | 0.63 | 78 | 10 | 5 | 2.2 | 1.88 | 0.44 | 2.2 | 85 | 24 | 12 | 5.1 | 4.90 | 0.57 | 96 | 12 | 6 |
| Tl | mg/kg | 0.50 | 1.1 | 1.00 | 0.14 | 93 | 14 | 7 | nr | 0.95 | 0.30 | nd | 32 | 16 | nr | 0.80 | 0.34 | nr | nd | 42 | 21 | nr | 1.03 | 0.35 | nd | 34 | 17 |
| U | mg/kg | 0.50 | 2.4 | 2.80 | 0.28 | 117 | 10 | 5 | 10.5 | 9.43 | 0.19 | 90 | 2 | 1 | 9.7 | 9.15 | 0.19 | 9.7 | 94 | 2 | 1 | 31.0 | 30.08 | 0.22 | 97 | 1 | <1 |
| V | mg/kg | 3.00 | 142.0 | 134.88 | 1.87 | 95 | 1 | 1 | 134.0 | 124.70 | 2.56 | 93 | 2 | 1 | 50.0 | 45.13 | 1.88 | 50.0 | 90 | 4 | 2 | 49.0 | 44.33 | 0.99 | 90 | 2 | 1 |
| W | mg/kg | 0.60 | 25.0 | 23.65 | 1.27 | 95 | 5 | 3 | <4 | 3.58 | 0.45 | nd | 13 | 6 | <4 | 1.90 | 0.61 | <4 | nd | 32 | 16 | <4 | 1.60 | 0.22 | nd | 14 | 7 |
| Y | mg/kg | 1.00 | 20.0 | 20.13 | 0.60 | 101 | 3 | 1 | 36.0 | 33.23 | 0.57 | 92 | 2 | 1 | 19.0 | 19.58 | 0.25 | 19.0 | 103 | 1 | 1 | 23.0 | 21.10 | 0.39 | 92 | 2 | 1 |
| Yb | mg/kg | 1.50 | 2.1 | 0.97 | 0.49 | 46 | 51 | 26 | 3.4 | 2.03 | 0.75 | 60 | 37 | 19 | 2.0 | 1.68 | 0.29 | 2.0 | 84 | 17 | 9 | 2.0 | 1.65 | 0.39 | 83 | 23 | 12 |
| Zn | mg/kg | 1.30 | 144.0 | 142.88 | 0.67 | 99 | <1 | <1 | 204.0 | 206.20 | 1.10 | 101 | 1 | <1 | 331.0 | 308.58 | 2.21 | 331.0 | 93 | 1 | <1 | 194.0 | 186.73 | 0.80 | 96 | <1 | <1 |
| Zr | mg/kg | 1.00 | 170.0 | 167.63 | 1.46 | 99 | 1 | <1 | 196.0 | 181.38 | 3.16 | 93 | 2 | 1 | 134.0 | 119.28 | 2.07 | 134.0 | 89 | 2 | 1 | 105.0 | 95.80 | 0.54 | 91 | 1 | <1 |

Number of analyses: 4
CV: certified value
SD: standard deviation
CANMET: Canadian Centre for Mineral and Energy Technology
nr: not reported
LOQ: limit of quantification
RSE: realitve standard error
RSD: relative standard deviation
NRC: National Research Centre, China
nd: not determined

# Table A2.2 Results for secondary reference materials included in the XRF analysis of total element concentrations in topsoil.

| | | | S13B Bulk stream sediment, BGS | | | | | | S23B Bulk stream sediment, BGS | | | | | | S58S Bulk soil, BGS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Analyte** | **Units** | **LOQ** | AV | Mean | SD | %Recovery | RSD % | RSE % | AV | Mean | SD | %Recovery | RSD % | RSE % | AV | Mean | SD | %Recovery | RSD % | RSE % |
| Al2O3 | wt% | 0.20 | 18.0 | 19.30 | 0.57 | 107 | 3 | 2 | 14.1 | 14.70 | 0.00 | 105 | <1 | <1 | 16.3 | 17.85 | 0.21 | 109 | 1 | 1 |
| CaO | wt% | 0.05 | 0.7 | 0.52 | 0.01 | 78 | 3 | 2 | 1.8 | 1.85 | 0.02 | 103 | 1 | 1 | 0.9 | 0.83 | 0.01 | 92 | 2 | 1 |
| Fe2O3 | wt% | 0.01 | 6.8 | 6.77 | 0.06 | 99 | 1 | 1 | 6.4 | 6.51 | 0.01 | 102 | <1 | <1 | 6.3 | 6.39 | 0.05 | 101 | 1 | 1 |
| K2O | wt% | 0.01 | 2.3 | 2.36 | 0.01 | 102 | 1 | <1 | 3.8 | 3.98 | 0.01 | 104 | <1 | <1 | 2.1 | 2.21 | 0.01 | 103 | 1 | <1 |
| MgO | wt% | 0.30 | 1.4 | 1.60 | 0.00 | 114 | <1 | <1 | 1.8 | 2.30 | 0.00 | 128 | <1 | <1 | 1.3 | 1.50 | 0.00 | 114 | <1 | <1 |
| MnO | wt% | 0.01 | 0.1 | 0.10 | 0.00 | 92 | 3 | 2 | 0.4 | 0.42 | 0.01 | 119 | 2 | 1 | 0.1 | 0.08 | 0.00 | 89 | 1 | 1 |
| Na2O | wt% | 0.30 | 0.3 | 0.10 | nd | 30 | nd | nd | 1.9 | 1.40 | 0.00 | 72 | <1 | <1 | 0.3 | <0.3 | nd | nd | nd | nd |
| P2O5 | wt% | 0.05 | 0.2 | 0.15 | 0.01 | 85 | 5 | 3 | 0.3 | 0.39 | 0.01 | 124 | 2 | 1 | 0.1 | 0.09 | 0.01 | 65 | 8 | 6 |
| SiO2 | wt% | 0.10 | 61.8 | 59.25 | 1.91 | 96 | 3 | 2 | 57.9 | 54.45 | 0.07 | 94 | <1 | <1 | 58.5 | 52.50 | 0.85 | 90 | 2 | 1 |
| TiO2 | wt% | 0.01 | 0.8 | 0.73 | 0.00 | 94 | 1 | <1 | 0.9 | 0.95 | 0.00 | 100 | <1 | <1 | 0.9 | 0.87 | 0.00 | 99 | <1 | <1 |
| Ag | mg/kg | 0.50 | nr | 0.65 | 0.35 | nd | 54 | 38 | nr | <0.5 | nd | nd | nd | nd | nr | <0.5 | nd | nd | nd | nd |
| As | mg/kg | 0.90 | 14.1 | 14.25 | 0.21 | 101 | 1 | 1 | 93.7 | 95.30 | 0.57 | 102 | 1 | <1 | 25.2 | 24.70 | 0.42 | 98 | 2 | 1 |
| Ba | mg/kg | 1.00 | 725.0 | 846.00 | 16.97 | 117 | 2 | 1 | 657.0 | 660.00 | 7.07 | 100 | 1 | 1 | 386.0 | 338.00 | 2.83 | 88 | 1 | 1 |
| Bi | mg/kg | 0.30 | nr | 0.50 | nd | nd | nd | nd | nr | 5.75 | 0.07 | nd | 1 | 1 | nr | 0.10 | nd | nd | nd | nd |
| Br | mg/kg | 0.80 | 5.5 | 4.30 | 0.28 | 79 | 7 | 5 | 16.7 | 16.90 | 0.28 | 101 | 2 | 1 | 7.8 | 6.75 | 0.07 | 87 | 1 | 1 |
| Cd | mg/kg | 0.50 | 0.5 | 0.45 | 0.07 | 90 | 16 | 11 | 0.6 | 0.60 | 0.28 | 100 | 47 | 33 | 0.3 | <0.5 | nd | nd | nd | nd |
| Ce | mg/kg | 1.00 | 86.0 | 82.50 | 2.12 | 96 | 3 | 2 | 111.0 | 116.50 | 0.71 | 105 | 1 | <1 | 81.0 | 92.50 | 0.71 | 114 | 1 | 1 |
| Cl | mg/kg | 200.00 | nr | <200 | nd | nd | nd | nd | nr | <200 | nd | nd | nd | nd | nr | <200 | nd | nd | nd | nd |
| Co | mg/kg | 1.50 | 18.6 | 20.25 | 0.64 | 109 | 3 | 2 | 18.4 | 19.95 | 0.92 | 108 | 5 | 3 | 18.8 | 20.70 | 0.99 | 110 | 5 | 3 |
| Cr | mg/kg | 3.00 | 95.2 | 91.10 | 2.69 | 96 | 3 | 2 | 54.9 | 57.35 | 4.60 | 104 | 8 | 6 | 109.9 | 113.85 | 2.19 | 104 | 2 | 1 |
| Cs | mg/kg | 1.00 | 14.0 | 13.00 | 0.00 | 93 | <1 | <1 | 15.0 | 14.50 | 0.71 | 97 | 5 | 3 | 7.0 | 6.50 | 0.71 | 93 | 11 | 8 |
| Cu | mg/kg | 1.30 | 17.1 | 13.60 | 0.85 | 80 | 6 | 4 | 59.6 | 55.00 | 0.42 | 92 | 1 | 1 | 19.9 | 16.55 | 0.21 | 83 | 1 | 1 |
| Ga | mg/kg | 1.00 | 22.7 | 22.15 | 0.35 | 98 | 2 | 1 | 23.1 | 22.05 | 0.78 | 95 | 4 | 2 | 19.5 | 18.50 | 0.00 | 95 | <1 | <1 |
| Ge | mg/kg | 0.50 | nr | 0.65 | 0.07 | nd | 11 | 8 | nr | 0.70 | 0.28 | nd | 40 | 29 | nr | 1.15 | 0.07 | nd | 6 | 4 |
| Hf | mg/kg | 1.00 | 4.7 | 4.35 | 0.07 | 93 | 2 | 1 | 13.0 | 11.95 | 0.35 | 92 | 3 | 2 | 8.9 | 8.95 | 0.64 | 100 | 7 | 5 |
| Hg | mg/kg | 2.50 | nr | 0.15 | 0.07 | nd | 47 | 33 | nr | 2.25 | 0.07 | nd | 3 | 2 | nr | 0.10 | nd | nd | nd | nd |
| I | mg/kg | 0.50 | nr | 2.45 | 0.35 | nd | 14 | 10 | nr | 6.65 | 0.07 | nd | 1 | 1 | nr | 5.35 | 0.35 | nd | 7 | 5 |
| In | mg/kg | 0.50 | nr | <0.5 | nd | nd | nd | nd | nr | <0.5 | nd | nd | nd | nd | nr | 0.20 | nd | nd | nd | nd |
| La | mg/kg | 1.00 | 47.0 | 43.50 | 0.71 | 93 | 2 | 1 | 61.0 | 60.50 | 0.71 | 99 | 1 | 1 | 45.0 | 46.50 | 0.71 | 103 | 2 | 1 |
| Mo | mg/kg | 0.20 | 1.0 | 0.65 | 0.07 | 67 | 11 | 8 | 31.9 | 31.45 | 0.21 | 99 | 1 | <1 | 0.7 | 0.55 | 0.07 | 75 | 13 | 9 |
| Nb | mg/kg | 1.00 | 15.5 | 13.65 | 0.21 | 88 | 2 | 1 | 22.4 | 21.55 | 0.07 | 96 | <1 | <1 | 19.5 | 18.30 | 0.14 | 94 | 1 | 1 |
| Nd | mg/kg | 4.00 | 41.9 | 40.70 | 0.57 | 97 | 1 | 1 | 57.4 | 50.75 | 3.75 | 88 | 7 | 5 | 49.3 | 47.45 | 0.92 | 96 | 2 | 1 |
| Ni | mg/kg | 1.30 | 43.1 | 45.80 | 0.57 | 106 | 1 | 1 | 20.7 | 22.75 | 0.21 | 110 | 1 | 1 | 47.8 | 52.95 | 0.49 | 111 | 1 | 1 |
| Pb | mg/kg | 1.30 | 63.2 | 64.45 | 3.32 | 102 | 5 | 4 | 110.3 | 115.90 | 1.27 | 105 | 1 | 1 | 24.2 | 25.00 | 0.28 | 103 | 1 | 1 |
| Rb | mg/kg | 1.00 | 117.0 | 115.15 | 0.92 | 98 | 1 | 1 | 182.6 | 184.85 | 0.35 | 101 | <1 | <1 | 96.7 | 95.60 | 0.57 | 99 | 1 | <1 |
| S | mg/kg | 1000.00 | <1000 | 910.00 | 1.41 | nd | <1 | <1 | <1000 | 544.00 | 26.87 | nd | 5 | 3 | <1000 | 148.50 | 2.12 | nd | 1 | 1 |
| Sb | mg/kg | 0.50 | nr | 0.65 | 0.07 | nd | 11 | 8 | 2.6 | 3.25 | 0.35 | 125 | 11 | 8 | 1.0 | 0.70 | 0.28 | 70 | 40 | 29 |
| Sc | mg/kg | 3.00 | 13.5 | 14.65 | 0.49 | 109 | 3 | 2 | 12.3 | 13.90 | 0.28 | 113 | 2 | 1 | 15.1 | 14.05 | 0.35 | 93 | 3 | 2 |
| Se | mg/kg | 0.20 | nr | 0.45 | 0.07 | nd | 16 | 11 | nr | 0.35 | 0.07 | nd | 20 | 14 | nr | 0.30 | 0.00 | nd | <1 | <1 |
| Sm | mg/kg | 3.00 | 5.7 | 4.15 | 1.48 | 73 | 36 | 25 | 7.2 | 7.00 | 2.40 | 98 | 34 | 24 | 8.8 | 5.65 | 0.35 | 64 | 6 | 4 |
| Sn | mg/kg | 0.50 | 3.1 | 2.00 | 0.28 | 65 | 14 | 10 | 5.7 | 5.20 | 0.14 | 91 | 3 | 2 | 2.8 | 2.85 | 0.07 | 102 | 2 | 2 |
| Sr | mg/kg | 1.00 | 123.6 | 129.10 | 0.85 | 104 | 1 | <1 | 197.1 | 207.05 | 1.63 | 105 | 1 | 1 | 52.3 | 59.50 | 0.42 | 114 | 1 | 1 |
| Ta | mg/kg | 1.00 | 1.3 | <1 | nd | nd | nd | nd | 1.9 | 1.05 | 0.78 | 55 | 74 | 52 | 1.3 | 0.85 | 0.07 | 66 | 8 | 6 |
| Te | mg/kg | 0.50 | nr | <0.5 | nd | nd | nd | nd | nr | 0.20 | nd | nd | nd | nd | nr | 0.10 | nd | nd | nd | nd |
| Th | mg/kg | 0.70 | 11.4 | 11.45 | 0.64 | 101 | 6 | 4 | 27.6 | 27.35 | 2.05 | 99 | 7 | 5 | 13.7 | 14.30 | 1.27 | 104 | 9 | 6 |
| Tl | mg/kg | 0.50 | nr | 0.90 | 0.00 | nd | <1 | <1 | nr | 1.55 | 0.07 | nd | 5 | 3 | nr | 0.75 | 0.07 | nd | 9 | 7 |
| U | mg/kg | 0.50 | 3.1 | 2.85 | 0.21 | 92 | 7 | 5 | 37.5 | 38.50 | 0.14 | 103 | <1 | <1 | 3.3 | 3.30 | 0.00 | 99 | <1 | <1 |
| V | mg/kg | 3.00 | 90.8 | 86.25 | 2.05 | 95 | 2 | 2 | 108.3 | 109.10 | 0.28 | 101 | <1 | <1 | 157.1 | 154.30 | 3.54 | 98 | 2 | 2 |
| W | mg/kg | 0.60 | 0.6 | 1.15 | 0.21 | 192 | 18 | 13 | 39.7 | 40.40 | 0.99 | 102 | 2 | 2 | 2.0 | 2.85 | 0.21 | 143 | 7 | 5 |
| Y | mg/kg | 1.00 | 20.4 | 21.05 | 0.07 | 103 | <1 | <1 | 25.0 | 24.55 | 0.49 | 98 | 2 | 1 | 30.0 | 29.35 | 0.07 | 98 | <1 | <1 |
| Yb | mg/kg | 1.50 | 2.6 | 1.40 | 0.99 | 54 | 71 | 50 | 2.7 | 2.35 | 1.20 | 87 | 51 | 36 | 3.4 | 1.50 | 0.42 | 44 | 28 | 20 |
| Zn | mg/kg | 1.30 | 106.1 | 108.55 | 0.21 | 102 | <1 | <1 | 121.3 | 128.75 | 6.15 | 106 | 5 | 3 | 67.0 | 72.00 | 0.28 | 107 | <1 | <1 |
| Zr | mg/kg | 1.00 | 175.4 | 174.75 | 3.32 | 100 | 2 | 1 | 446.0 | 460.65 | 2.33 | 103 | 1 | <1 | 344.6 | 358.55 | 1.20 | 104 | <1 | <1 |
| Number of analyses: 2 | | | | | AV: accepted value | | | SD: standard deviation | | | | nr: not reported | | | | | | | | |
| LOQ: limit of quantification | | | | | RSE: realitve standard error | | | RSD: relative standard deviation | | | | nd: not determined | | | | | | | | |

# Table A2.3 Results for replicate Samples A and B included in the topsoil inorganic analyses.

| Analyte | Units | LOQ | Replicate A1 | Replicate A2 | Mean | SD | RSD % | RSE % | Replicate B1 | Replicate B2 | Mean | SD | RSD % | RSE % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | G010 | G027 | | | | | G039 | G075 | | | | |
| Al2O3 | wt% | 0.20 | 12.0 | 12.2 | 12.10 | 0.14 | 1 | 1 | 11.9 | 11.8 | 11.85 | 0.07 | 1 | <1 |
| CaO | wt% | 0.05 | 3.17 | 3.23 | 3.20 | 0.04 | 1 | 1 | 3.81 | 3.86 | 3.84 | 0.04 | 1 | 1 |
| Fe2O3 | wt% | 0.01 | 5.75 | 5.87 | 5.81 | 0.08 | 1 | 1 | 6.66 | 6.76 | 6.71 | 0.07 | 1 | 1 |
| K2O | wt% | 0.01 | 1.35 | 1.37 | 1.36 | 0.01 | 1 | 1 | 1.40 | 1.40 | 1.40 | 0.00 | <1 | <1 |
| MgO | wt% | 0.30 | 1.4 | 1.5 | 1.45 | 0.07 | 5 | 3 | 2.2 | 2.2 | 2.20 | 0.00 | <1 | <1 |
| MnO | wt% | 0.01 | 0.127 | 0.129 | 0.13 | 0.00 | 1 | 1 | 0.124 | 0.124 | 0.12 | 0.00 | <1 | <1 |
| Na2O | wt% | 0.30 | 1.2 | 1.3 | 1.25 | 0.07 | 6 | 4 | 2.1 | 2.1 | 2.10 | 0.00 | <1 | <1 |
| P2O5 | wt% | 0.05 | 0.22 | 0.23 | 0.23 | 0.01 | 3 | 2 | 0.28 | 0.27 | 0.28 | 0.01 | 3 | 2 |
| SiO2 | wt% | 0.10 | 63.6 | 64.4 | 64.00 | 0.57 | 1 | 1 | 65.8 | 64.6 | 65.20 | 0.85 | 1 | 1 |
| TiO2 | wt% | 0.01 | 0.803 | 0.804 | 0.80 | 0.00 | <1 | <1 | 1.036 | 1.051 | 1.04 | 0.01 | 1 | 1 |
| Ag | mg/kg | 0.50 | **0.25** | **0.1** | **0.18** | **0.11** | **61** | **43** | **0.2** | **0.4** | **0.30** | **0.14** | **47** | **33** |
| As | mg/kg | 0.90 | 10.6 | 11.1 | 10.85 | 0.35 | 3 | 2 | 8.3 | 7.6 | 7.95 | 0.49 | 6 | 4 |
| Ba | mg/kg | 1.00 | 543 | 570 | 556.50 | 19.09 | 3 | 2 | 889 | 905 | 897.00 | 11.31 | 1 | 1 |
| Bi | mg/kg | 0.30 | 0.8 | 0.5 | 0.65 | 0.21 | 33 | 23 | **<0.3** | **<0.3** | **nd** | **nd** | **nd** | **nd** |
| Br | mg/kg | 0.80 | 8.2 | 7.9 | 8.05 | 0.21 | 3 | 2 | 5.3 | 4.9 | 5.10 | 0.28 | 6 | 4 |
| Cd | mg/kg | 0.50 | 0.8 | 0.5 | 0.65 | 0.21 | None | 23 | **0.3** | **0.3** | **0.30** | **0.00** | **<1** | **<1** |
| Ce | mg/kg | 1.00 | 70 | 72 | 71.00 | 1.41 | 2 | 1 | 57 | 57 | 57.00 | 0.00 | <1 | <1 |
| Cl | mg/kg | 200.00 | **<200** | **<200** | **nd** | **nd** | **nd** | **nd** | **<200** | **<200** | **nd** | **nd** | **nd** | **nd** |
| Co | mg/kg | 1.50 | 20.7 | 20.5 | 20.60 | 0.14 | 1 | <1 | 21.1 | 22.3 | 21.70 | 0.85 | 4 | 3 |
| Cr | mg/kg | 3.00 | 109.6 | 119.6 | 114.60 | 7.07 | 6 | 4 | 1543.3 | 1370 | 1456.65 | 122.54 | 8 | 6 |
| Cs | mg/kg | 1.00 | 3 | 2 | 2.50 | 0.71 | 28 | 20 | 2 | 3 | 2.50 | 0.71 | 28 | 20 |
| Cu | mg/kg | 1.30 | 77.9 | 83.2 | 80.55 | 3.75 | 5 | 3 | 52.2 | 48.3 | 50.25 | 2.76 | 5 | 4 |
| Ga | mg/kg | 1.00 | 15.1 | 13.9 | 14.50 | 0.85 | 6 | 4 | 14 | 15.1 | 14.55 | 0.78 | 5 | 4 |
| Ge | mg/kg | 0.50 | 2.8 | 3.2 | 3.00 | 0.28 | 9 | 7 | 1.1 | 1.4 | 1.25 | 0.21 | 17 | 12 |
| Hf | mg/kg | 1.00 | 6.6 | 7 | 6.80 | 0.28 | 4 | 3 | 6.5 | 6.3 | 6.40 | 0.14 | 2 | 2 |
| Hg | mg/kg | 2.50 | 0.3 | 0.5 | 0.40 | 0.14 | 35 | 25 | **<2.5** | **<2.5** | **nd** | **nd** | **<1** | **nd** |
| I | mg/kg | 0.50 | 1.9 | 1.6 | 1.75 | 0.21 | 12 | 9 | 1.9 | 1.9 | 1.90 | 0.00 | <1 | <1 |
| In | mg/kg | 0.50 | **<0.5** | **<0.5** | **nd** | **nd** | **nd** | **nd** | **<0.5** | **<0.5** | **nd** | **nd** | **nd** | **nd** |
| La | mg/kg | 1.00 | 39 | 40 | 39.50 | 0.71 | 2 | 1 | 32 | 31 | 31.50 | 0.71 | 2 | 2 |
| Mo | mg/kg | 0.20 | 1.8 | 1.9 | 1.85 | 0.07 | 4 | 3 | 3 | 2 | 2.50 | 0.71 | 28 | 20 |
| Nb | mg/kg | 1.00 | 15.9 | 15.2 | 15.55 | 0.49 | 3 | 2 | 15.2 | 14.5 | 14.85 | 0.49 | 3 | 2 |
| Nd | mg/kg | 4.00 | 35.1 | 33.3 | 34.20 | 1.27 | 4 | 3 | 24 | 21.2 | 22.60 | 1.98 | 9 | 6 |
| Ni | mg/kg | 1.30 | 56 | 56.7 | 56.35 | 0.49 | 1 | 1 | 45.7 | 45.6 | 45.65 | 0.07 | <1 | <1 |
| Pb | mg/kg | 1.30 | 276.3 | 226.5 | 251.40 | 35.21 | 14 | 10 | 77.5 | 92.6 | 85.05 | 10.68 | 13 | 9 |
| Rb | mg/kg | 1.00 | 49.3 | 49.2 | 49.25 | 0.07 | <1 | <1 | 41.1 | 42.7 | 41.90 | 1.13 | 3 | 2 |
| S | mg/kg | 1000.00 | **549** | **556** | **552.50** | **4.95** | **1** | **1** | **810** | **793** | **801.50** | **12.02** | **1** | **1** |
| Sb | mg/kg | 0.50 | 2.4 | 2.2 | 2.30 | 0.14 | 6 | 4 | 3.2 | 4.8 | 4.00 | 1.13 | 28 | 20 |
| Sc | mg/kg | 3.00 | 11.9 | 14.2 | 13.05 | 1.63 | 12 | 9 | 11.8 | 14.8 | 13.30 | 2.12 | 16 | 11 |
| Se | mg/kg | 0.20 | 1.3 | 1.1 | 1.20 | 0.14 | 12 | 8 | 0.4 | 0.3 | 0.35 | 0.07 | 20 | 14 |
| Sm | mg/kg | 3.00 | 6.1 | 4.3 | 5.20 | 1.27 | 24 | 17 | 4 | 3.5 | 3.75 | 0.35 | 9 | 7 |
| Sn | mg/kg | 0.50 | 12.7 | 11.6 | 12.15 | 0.78 | 6 | 5 | 7.9 | 6.2 | 7.05 | 1.20 | 17 | 12 |
| Sr | mg/kg | 1.00 | 173.5 | 178.3 | 175.90 | 3.39 | 2 | 1 | 227.9 | 233.3 | 230.60 | 3.82 | 2 | 1 |
| Ta | mg/kg | 1.00 | **<1** | **<1** | **nd** | **nd** | **nd** | **nd** | **<1** | **<1** | **nd** | **nd** | **nd** | **nd** |
| Te | mg/kg | 0.50 | **<0.5** | **<0.5** | **nd** | **nd** | **nd** | **nd** | **<0.5** | **<0.5** | **nd** | **nd** | **nd** | **nd** |
| Th | mg/kg | 0.70 | 9.5 | 7.9 | 8.70 | 1.13 | 13 | 9 | 5.4 | 6.3 | 5.85 | 0.64 | 11 | 8 |
| Tl | mg/kg | 0.50 | 0.8 | 1.2 | 1.00 | 0.28 | 28 | 20 | 0.5 | **0.1** | **0.30** | **0.28** | **94** | **67** |
| U | mg/kg | 0.50 | 2.2 | 2.7 | 2.45 | 0.35 | 14 | 10 | 2 | 1.9 | 1.95 | 0.07 | 4 | 3 |
| V | mg/kg | 3.00 | 109.8 | 118 | 113.90 | 5.80 | 5 | 4 | 149.2 | 157.4 | 153.30 | 5.80 | 4 | 3 |
| W | mg/kg | 0.60 | 1.4 | 1.6 | 1.50 | 0.14 | 9 | 7 | 1.1 | 1.1 | 1.10 | 0.00 | <1 | <1 |
| Y | mg/kg | 1.00 | 26.8 | 27.8 | 27.30 | 0.71 | 3 | 2 | 22.7 | 23.6 | 23.15 | 0.64 | 3 | 2 |
| Yb | mg/kg | 1.50 | 1.5 | 1.9 | 1.70 | 0.28 | 17 | 12 | **0.9** | **0.4** | **0.65** | **0.35** | **54** | **38** |
| Zn | mg/kg | 1.30 | 340.2 | 358.4 | 349.30 | 12.87 | 4 | 3 | 174.7 | 178.7 | 176.70 | 2.83 | 2 | 1 |
| Zr | mg/kg | 1.00 | 261.5 | 266.6 | 264.05 | 3.61 | 1 | 1 | 253.6 | 249 | 251.30 | 3.25 | 1 | 1 |
| Cr(VI) | mg/kg | 0.5 | **<0.5** | **<0.5** | **<0.5** | **nd** | **nd** | **nd** | **<0.5** | **<0.5** | **<0.5** | **nd** | **nd** | **nd** |
| pH | log [H+]mol/L | 0.1 | 7.26 | 7.3 | 7.28 | 0.03 | nd | nd | 7.46 | 7.44 | 7.45 | 0.01 | nd | nd |

SD: standard deviation

SE: standard error

Bold: values below LOQ should be treated with caution

RSD: relative standard deviation

RSE: realitve standard error

LOQ: limits of quantification

nd: not determined

## Table A2.4 Results for SIDMS repeat measurements of Cr(VI) and total Cr in topsoil.

| Sample ID | Cr(VI) mg/kg | | | | | |
|---|---|---|---|---|---|---|
| | Repeat 1 | Repeat 2 | Mean | SD | RSD% | RSE % |
| G001 | <0.5 | <0.5 | <0.5 | nd | nd | nd |
| G010 | <0.5 | <0.5 | <0.5 | nd | nd | nd |
| G016 | 5.3 | 6.1 | 5.7 | 0.59 | 10 | 7 |
| G029 | <0.5 | <0.5 | <0.5 | nd | nd | nd |
| G037 | <0.5 | <0.5 | <0.5 | nd | nd | nd |
| G038 | 0.5 | 0.5 | 0.5 | 0.00 | <1 | <1 |
| G051 | <0.5 | <0.5 | <0.5 | nd | nd | nd |
| G059 | 0.6 | 0.5 | 0.5 | 0.02 | 4 | 3 |
| G073 | <0.5 | <0.5 | <0.5 | nd | nd | nd |
| G095 | 1.1 | 1.3 | 1.2 | 0.14 | 11 | 8 |

nd: not determined

## Table A2.5 Results for CRMs included in the topsoil SIDMS Cr(VI) analysis.

| CRM | Units | LOQ | Number of Measurements | Certified/ Accepted Value | | BGS Mean | RSD % | Recovery % |
|---|---|---|---|---|---|---|---|---|
| NIST2700 Cr(VI) Low Level | mg/kg | 0.5 | 8 | 14.9 | ± 1.2 | 15.3 | 7 | 102 |
| NIST2701 Cr(VI) High Level | mg/kg | 0.5 | 4 | 551.2 | ± 34.5 | 518.1 | 8 | 94 |

LOQ: limit of qualitification

## Table A2.6 Results for certified reference material NIST1941b included in the topsoil PAH analytical run.

| PAH compound | Units | LOQ | NIST1941b Certified Value | | BGS Mean | Standard Deviation | RSD % | Recovery % |
|---|---|---|---|---|---|---|---|---|
| naphthalene | mg/kg | 0.054 | 0.848 | (±0.095) | 0.87 | 0.22 | 25 | 103 |
| 2-methylnaphthalene | mg/kg | 0.033 | 0.276 | (±0.053) | 0.29 | 0.06 | 21 | 105 |
| 1-methylnaphthalene | mg/kg | 0.037 | 0.127 | (±0.014) | 0.13 | 0.03 | 22 | 102 |
| biphenyl | mg/kg | 0.030 | 0.074 | (±0.008) | 0.08 | 0.01 | 15 | 108 |
| C2-naphthalenes | mg/kg | 0.035 | 1.877 | (±0.053) | 1.97 | 0.36 | 18 | 105 |
| acenaphthylene | mg/kg | 0.036 | 0.053 | (±0.006) | 0.06 | 0.01 | 17 | 113 |
| acenaphthene | mg/kg | 0.030 | 0.038 | (±0.005) | 0.04 | 0.01 | 18 | 104 |
| dibenzofuran | mg/kg | 0.030 | nr | | 0.12 | 0.03 | 22 | nd |
| fluorene | mg/kg | 0.023 | 0.085 | (±0.015) | 0.09 | 0.01 | 13 | 106 |
| 1-methylfluorene | mg/kg | 0.023 | nr | | 0.06 | 0.01 | 18 | nd |
| dibenzothiophene | mg/kg | 0.039 | nr | | 0.05 | 0.00 | 9 | nd |
| phenanthrene | mg/kg | 0.030 | 0.406 | (±0.044) | 0.42 | 0.04 | 10 | 103 |
| anthracene | mg/kg | 0.046 | 0.184 | (±0.018) | 0.19 | 0.02 | 8 | 103 |
| 1-methylanthracene | mg/kg | 0.038 | nr | | 0.04 | 0.00 | 12 | nd |
| C1-phenanthrenes / anthracenes | mg/kg | 0.038 | 0.313 | (±0.099) | 0.33 | 0.03 | 9 | 105 |
| C2-phenanthrenes / anthracenes | mg/kg | 0.038 | 0.247 | (±0.062) | 0.26 | 0.03 | 11 | 105 |
| fluoranthene | mg/kg | 0.029 | 0.651 | (±0.050) | 0.70 | 0.06 | 8 | 108 |
| pyrene | mg/kg | 0.025 | 0.581 | (±0.039) | 0.56 | 0.05 | 9 | 96 |
| 1-methylpyrene | mg/kg | 0.037 | 0.052 | (±0.002) | 0.06 | 0.01 | 22 | 114 |
| C1-fluoranthenes / pyrenes | mg/kg | 0.037 | 0.252 | (±0.048) | 0.26 | 0.02 | 8 | 103 |
| C2-fluoranthenes / pyrenes | mg/kg | 0.037 | 0.205 | (±0.038) | 0.21 | 0.03 | 13 | 102 |
| benz[a]anthracene | mg/kg | 0.033 | 0.335 | (±0.025) | 0.35 | 0.03 | 9 | 104 |
| triphenylene | mg/kg | 0.034 | 0.108 | (±0.005) | 0.10 | 0.03 | 32 | 93 |
| chrysene | mg/kg | 0.034 | 0.291 | (±0.031) | 0.30 | 0.02 | 8 | 103 |
| C1-benz[a]anthracenes / chrysenes | mg/kg | 0.055 | 0.208 | (±0.043) | 0.22 | 0.02 | 9 | 106 |
| C2-benz[a]anthracenes / chrysenes | mg/kg | 0.055 | 0.120 | (±0.024) | 0.13 | 0.02 | 19 | 108 |
| benzo[b]fluoranthene | mg/kg | 0.035 | 0.453 | (±0.021) | 0.47 | 0.03 | 7 | 104 |
| benzo[k]fluoranthene | mg/kg | 0.053 | 0.225 | (±0.018) | 0.23 | 0.02 | 8 | 102 |
| benzo[j]fluoranthene | mg/kg | 0.053 | 0.217 | (±0.005) | 0.23 | 0.02 | 8 | 106 |
| benzo[a]fluoranthene | mg/kg | 0.053 | 0.073 | (±0.018) | 0.08 | 0.01 | 11 | 110 |
| benzo[e]pyrene | mg/kg | 0.053 | 0.325 | (±0.025) | 0.33 | 0.03 | 9 | 102 |
| benzo[a]pyrene | mg/kg | 0.048 | 0.358 | (±0.017) | 0.38 | 0.03 | 9 | 106 |
| perylene | mg/kg | 0.026 | 0.397 | (±0.045) | 0.39 | 0.03 | 8 | 98 |
| dibenz[a,h]anthracene | mg/kg | 0.055 | 0.053 | (±0.010) | 0.06 | 0.01 | 9 | 113 |
| indeno[1,2,3-cd]pyrene | mg/kg | 0.035 | 0.341 | (±0.057) | 0.36 | 0.03 | 8 | 106 |
| benzo[g,h,i]perylene | mg/kg | 0.047 | 0.307 | (±0.045) | 0.32 | 0.03 | 8 | 104 |

NIST: National Institute of Standards and Technology, USA

RSD: relative standard deviation

LOQ: limit of quantification

nr: not reported

nd: not determined

Number of analyses: 30

## Table A2.7 Results for certified reference material NIST1941b included in the topsoil PCB analytical run.

| PCB | Units | LOQ | NIST1941b | | BGS Mean | Standard Deviation | RSD % | Recovery % |
|---|---|---|---|---|---|---|---|---|
| | | | Certified Value | Range | | | | |
| PCB028 | µg/kg | 1.47 | 4.52 | 3.95 - 5.09 | 4.49 | 0.48 | 11 | 99 |
| PCB052 | µg/kg | 2.47 | 5.24 | 4.96 - 5.52 | 5.50 | 0.40 | 7 | 105 |
| PCB081 | µg/kg | 2.27 | nr | | **<2.27** | **0.10** | **233** | **nd** |
| PCB077 | µg/kg | 2.47 | 0.31 | 0.28 - 0.34 | **<2.47** | **0.28** | **27** | **nd** |
| PCB095 | µg/kg | 3.01 | 3.93 | 3.31 - 4.55 | 3.72 | 0.63 | 17 | 95 |
| PCB101 | µg/kg | 3.46 | 5.11 | 4.77 - 5.45 | 5.34 | 0.42 | 8 | 105 |
| PCB099 | µg/kg | 3.13 | 2.90 | 2.54 - 3.26 | **<3.13** | **0.92** | **34** | **nd** |
| PCB110 | µg/kg | 2.11 | 4.62 | 4.26 - 4.98 | 4.45 | 0.68 | 15 | 96 |
| PCB123 | µg/kg | 2.57 | nr | | **<2.57** | **0.19** | **95** | **nd** |
| PCB118 | µg/kg | 2.27 | 4.23 | 4.04 - 4.42 | 4.20 | 0.46 | 11 | 99 |
| PCB114 | µg/kg | 3.00 | nr | | **<3.00** | **0.04** | **583** | **nd** |
| PCB105 | µg/kg | 1.79 | 1.43 | 1.33 - 1.53 | **<1.79** | **0.64** | **39** | **nd** |
| PCB126 | µg/kg | 2.05 | nr | | **<2.05** | **0.13** | **583** | **nd** |
| PCB151 | µg/kg | 3.01 | nr | | **<3.01** | **0.19** | **15** | **nd** |
| PCB149 | µg/kg | 2.61 | 4.35 | 4.09 - 4.61 | 4.48 | 0.39 | 9 | 103 |
| PCB146 | µg/kg | 2.52 | 1.22 | 1.10 - 1.34 | **<2.52** | **0.99** | **92** | **nd** |
| PCB153 | µg/kg | 2.52 | 5.47 | 5.15 - 5.79 | 5.90 | 1.03 | 17 | 108 |
| PCB138 | µg/kg | 3.01 | 3.60 | 3.32 - 3.88 | 3.71 | 0.46 | 12 | 103 |
| PCB167 | µg/kg | 2.16 | nr | | **<2.16** | **1.16** | **83** | **nd** |
| PCB156 | µg/kg | 1.94 | 0.51 | 0.42 - 0.60 | **<1.94** | **0.28** | **93** | **nd** |
| PCB169 | µg/kg | 2.50 | nr | | **<2.50** | **0.53** | **121** | **nd** |
| PCB187 | µg/kg | 3.60 | 2.17 | 1.95 - 2.39 | **<3.60** | **0.38** | **17** | **nd** |
| PCB183 | µg/kg | 3.13 | 0.98 | 0.89 - 1.06 | **<3.13** | **0.30** | **29** | **nd** |
| PCB177 | µg/kg | 4.15 | nr | | **<4.15** | **0.26** | **25** | **nd** |
| PCB180 | µg/kg | 3.71 | 3.24 | 2.73 - 3.75 | **<3.71** | **0.65** | **18** | **nd** |
| PCB170 | µg/kg | 3.33 | 1.35 | 1.26 - 1.44 | **<3.33** | **0.35** | **27** | **nd** |
| PCB189 | µg/kg | 6.03 | nr | | **<6.03** | **0.31** | **273** | **nd** |
| 3-Cl | µg/kg | 1.47 | nr | | 9.47 | 1.64 | 17 | nd |
| 4-Cl | µg/kg | 2.40 | nr | | 42.54 | 4.15 | 10 | nd |
| 5-Cl | µg/kg | 2.60 | nr | | 31.38 | 4.70 | 15 | nd |
| 6-Cl | µg/kg | 2.62 | nr | | 24.57 | 3.54 | 14 | nd |
| 7-Cl | µg/kg | 4.12 | nr | | 13.04 | 2.24 | 17 | nd |

NIST: National Institute of Standards and Technology, USA

nr: not reported

RSD: relative standard deviation

nd: not determined

LOQ: limit of quantification

Number of analyses: 30

Bold: values below LOQ should be treated with caution

# Appendix 3 Summary statistics for the GGERFS soil chemical analysis

## Table A3.1 Summary statistics for inorganic parameters in GGERFS and BGS G-BASE Glasgow topsoil.

| **Dataset** | **$Al_2O_3$** | **CaO** | **$Fe_2O_3$** | **$K_2O$** | **MgO** | **MnO** | **$Na_2O$** | **$P_2O_5$** | **$SiO_2$** | **$TiO_2$** | **Ag** | **As** | **Ba** | **Bi** | **Br** | **Cd** | **Ce** | **Cl** | **Co** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Units** | **wt%** | **wt%** | **wt%** | **wt%** | **wt%** | **wt%** | **wt%** | **wt%** | **wt%** | **wt%** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| **GGERFS** | | | | | | | | | | | | | | | | | | | |
| Min | 6.5 | 0.52 | 2.20 | 0.66 | 0.8 | 0.041 | 0.7 | 0.18 | 43.6 | 0.454 | <0.5 | 4.5 | 130 | <0.3 | 3.6 | <0.5 | 28 | 100 | 4.4 |
| Max | 16.5 | 6.12 | 14.89 | 1.96 | 2.4 | 0.208 | 2.2 | 0.45 | **84.6** | 1.100 | 1.3 | 40.4 | 1834 | 8.7 | 28.6 | **18.8** | 132 | 100 | 82.2 |
| Median | 11.7 | 1.76 | 5.47 | 1.35 | 1.3 | 0.095 | 1.1 | 0.25 | 62.4 | 0.793 | <0.5 | 11.0 | 506 | 0.6 | 11.0 | 0.5 | 61 | 100 | 19.2 |
| Mean | 11.6 | 1.99 | 5.53 | 1.29 | 1.3 | 0.098 | 1.2 | 0.26 | 63.3 | 0.792 | <0.5 | 11.6 | 546 | 1.2 | 11.7 | 0.9 | 61 | 100 | 19.6 |
| SD | 2.0 | 1.17 | 1.62 | 0.25 | 0.3 | 0.031 | 0.3 | 0.05 | 8.3 | 0.130 | 0.2 | 5.2 | 290 | 1.6 | 6.0 | 2.0 | 15 | 0 | 9.5 |
| Count | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 |
| **G-BASE Glasgow** | | | | | | | | | | | | | | | | | | | |
| Max | 25.6 | 17.84 | 20.18 | 3.31 | 19.5 | 2.150 | 2.4 | 4.88 | 82.3 | 2.992 | 23.5 | 850.0 | 10978 | 15.9 | 129.4 | 16.0 | 1181 | 484 | 560.0 |
| Count | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 976 | 2333 |

| **Dataset** | **Cr** | **Cs** | **Cu** | **Ga** | **Ge** | **Hf** | **Hg** | **I** | **In** | **La** | **Mo** | **Nb** | **Nd** | **Ni** | **Pb** | **Rb** | **S** | **Sb** | **Sc** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Units** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| **GGERFS** | | | | | | | | | | | | | | | | | | | |
| Min | 30 | 1 | 10 | 5.3 | <0.5 | 1.3 | <2.5 | <0.5 | <0.5 | 14 | 0.2 | 10.0 | 1.7 | 11 | 11 | 17.4 | 26 | <0.5 | < 3.0 |
| Max | 2776 | 5 | 1192 | 25.7 | 21.3 | 10.4 | 2.9 | 4.0 | 0.6 | 78 | 9.0 | 19.7 | 97.6 | 330 | 1639 | 87.2 | 1525 | 44.7 | 28.0 |
| Median | 133 | 3 | 83 | 14.1 | 2.6 | 6.1 | <2.5 | 2.1 | <0.5 | 34 | 2.2 | 15.0 | 29.4 | 50 | 227 | 45.7 | 573 | 2.5 | 10.9 |
| Mean | 268 | 3 | 137 | 14.4 | 3.2 | 6.1 | <2.5 | 2.1 | <0.5 | 34 | 2.4 | 15.0 | 29.3 | 58 | 309 | 46.4 | 631 | 4.1 | 10.7 |
| SD | 450 | 1 | 164 | 3.7 | 2.8 | 1.4 | 0.6 | 1.0 | 0.1 | 9 | 1.2 | 1.8 | 13.4 | 38 | 295 | 12.8 | 338 | 5.5 | 4.4 |
| Count | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 |
| **G-BASE Glasgow** | | | | | | | | | | | | | | | | | | | |
| Max | 5334 | 25 | 3680 | 54.3 | 90.6 | 81.4 | nd | 35.8 | 0.7 | 507 | 55.7 | 61.4 | 103.5 | 1038 | 9937 | 109.3 | 5549 | 173.5 | 34.0 |
| Count | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | | 2333 | 976 | 2333 | 2333 | 2333 | 976 | 2333 | 2333 | 2333 | 976 | 2333 | 2333 |

| **Dataset** | **Se** | **Sm** | **Sn** | **Sr** | **Ta** | **Te** | **Th** | **Tl** | **U** | **V** | **W** | **Y** | **Yb** | **Zn** | **Zr** | **pH** | **Cr(VI)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Units** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **-log[H+]** | **mg/kg** |
| **GGERFS** | | | | | | | | | | | | | | | | | |
| Min | <0.2 | < 3 | 0.9 | 37 | <1.0 | <0.5 | 1.6 | <0.5 | <0.5 | 33 | <0.6 | 4.8 | <1.5 | 19 | 156 | 3.79 | <0.5 |
| Max | 5.2 | 11.1 | 204 | 465 | 1.5 | <0.5 | 13.3 | 2.5 | 6.4 | 417 | 18.2 | 65 | 4.1 | 11493 | 383 | 7.86 | 28.5 |
| Median | 1.0 | 3.4 | 15 | 134 | <1.0 | <0.5 | 7.4 | 1.0 | 2.2 | 108 | 1.6 | 23 | <1.5 | 322 | 248 | 6.75 | <0.5 |
| Mean | 1.0 | 3.4 | 31 | 139 | <1.0 | <0.5 | 7.2 | 1.0 | 2.3 | 116 | 2.4 | 23 | 1.5 | 502 | 247 | 6.31 | 1.1 |
| SD | 0.7 | 2.0 | 42 | 66 | 0.4 | 0.0 | 2.2 | 0.4 | 0.8 | 52 | 2.9 | 8 | 0.8 | 1219 | 42 | 1.21 | 3.2 |
| Count | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 90 | 90 |
| **G-BASE Glasgow** | | | | | | | | | | | | | | | | | |
| Max | 14.5 | 15.4 | 659 | 462 | 4.0 | 4.1 | 18.0 | 11.5 | 6.2 | 737 | 154.9 | 75 | 6.9 | 5086 | 2000 | 8.79 | 1485.0 |
| Count | 2333 | 976 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 2333 | 976 | 2333 | 2333 | 2331 | 27 |

nd: not determined **Bold:** GGERFS soil maximum > BGS G-BASE Glasgow soil dataset maximum

SD: standard deviation G-BASE Glasgow (Fordyce et al. 2017; Fordyce et al. 2019)

**Table A3.2 Summary statistics for soil organic carbon and total petroleum hydrocarbons in GGERFS and BGS Glasgow topsoil.**

| **Dataset** | **TOC** | **TTC** | **TIC** | **resins** | **aromatics** | **saturates** | **TPH (non-volatile)** |
|---|---|---|---|---|---|---|---|
| **Units** | **%** | **%** | **%** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| **GGERFS** | | | | | | | |
| Min | 1.38 | 1.40 | 0.00 | 262 | 32 | 34 | 90 |
| Max | **20.02** | 20.36 | 1.57 | 9488 | **3782** | **2247** | **5928** |
| Median | 5.92 | 6.21 | 0.17 | 1560 | 219 | 289 | 587 |
| Mean | 6.01 | 6.21 | 0.22 | 2194 | 482 | 454 | 937 |
| SD | 3.18 | 3.20 | 0.23 | 1917 | 719 | 465 | 1142 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | | |
| Max | 17.97 | nd | nd | nd | 1807 | 757 | 2505 |
| Count | 84 | | | | 84 | 84 | 84 |

nd: not determined **Bold:** GGERFS soil maximum > BGS Glasgow soil dataset maximum

SD: standard deviation BGS Glasgow (Kim et al. 2019)

## Table A3.3 Summary statistics for PAH in GGERFS and BGS Glasgow topsoil.

| Dataset | naphthalene | 2-methylnaphthalene | 1-methylnaphthalene | biphenyl | C2-naphthalenes | acenaphthylene |
|---|---|---|---|---|---|---|
| **Units** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| **GGERFS** | | | | | | |
| Min | 0.03 | 0.02 | 0.02 | 0.02 | 0.24 | 0.02 |
| Max | **6.63** | **2.87** | **2.00** | 0.51 | **26.50** | 0.49 |
| Median | 0.54 | 0.44 | 0.35 | 0.09 | 4.89 | 0.04 |
| Mean | 0.87 | 0.61 | 0.46 | 0.13 | 6.62 | 0.05 |
| SD | 1.13 | 0.59 | 0.42 | 0.12 | 5.64 | 0.07 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | |
| Max | 2.13 | 1.19 | 0.98 | 1.07 | 8.39 | 0.53 |
| Count | 84 | 84 | 84 | 84 | 84 | 84 |

| Dataset | acenaphthene | dibenzofuran | fluorene | 1-methylfluorene | dibenzothiophene | phenanthrene |
|---|---|---|---|---|---|---|
| **Units** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| **GGERFS** | | | | | | |
| Min | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.06 |
| Max | 3.91 | **2.26** | 4.52 | 1.08 | 0.90 | 25.52 |
| Median | 0.40 | 0.42 | 0.54 | 0.17 | 0.11 | 2.74 |
| Mean | 0.64 | 0.61 | 0.83 | 0.22 | 0.17 | 3.94 |
| SD | 0.71 | 0.55 | 0.87 | 0.20 | 0.16 | 4.32 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | |
| Max | 9.81 | 1.06 | 14.09 | 4.26 | 1.24 | 112.39 |
| Count | 84 | 84 | 84 | 84 | 84 | 84 |

| Dataset | anthracene | 1-methylanthracene | C1-phenanthrenes/ anthracenes | C2-phenanthrenes/ anthracenes | fluoranthene | pyrene |
|---|---|---|---|---|---|---|
| **Units** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| **GGERFS** | | | | | | |
| Min | 0.02 | 0.02 | 0.04 | 0.02 | 0.06 | 0.06 |
| Max | 5.82 | 0.69 | 10.96 | 5.53 | 35.14 | 28.83 |
| Median | 0.67 | 0.09 | 1.56 | 0.93 | 4.40 | 3.51 |
| Mean | 0.94 | 0.14 | 2.05 | 1.16 | 5.74 | 4.86 |
| SD | 1.02 | 0.14 | 1.98 | 1.06 | 5.84 | 5.02 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | |
| Max | 19.01 | nd | 55.72 | 8.61 | 111.79 | 112.38 |
| Count | 84 | | 84 | 84 | 84 | 84 |

nd: not determined SD: standard deviation **Bold:** GGERFS soil maximum > BGS Glasgow soil dataset maximum

BGS Glasgow (Kim et al. 2019)

Table A3.3 cont.

| Dataset | 1-methylpyrene | C1-fluoranthenes/ pyrenes | C2-fluoranthenes/ pyrenes | benz[a]anthracene | triphenylene | chrysene |
|---|---|---|---|---|---|---|
| Units | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg |
| **GGERFS** | | | | | | |
| Min | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Max | 3.41 | 9.91 | 7.01 | 14.89 | 1.62 | 12.19 |
| Median | 0.40 | 1.35 | 1.11 | 2.18 | 0.27 | 1.65 |
| Mean | 0.58 | 1.89 | 1.41 | 2.81 | 0.34 | 2.17 |
| SD | 0.60 | 1.86 | 1.38 | 2.77 | 0.30 | 2.16 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | |
| Max | nd | 15.30 | nd | 52.90 | nd | nd |
| Count | | 84 | | 84 | | |

| Dataset | C1-benz[a]anthracenes/ chrysenes | C2-benz[a]anthracenes/ chrysenes | benzo[b]fluoranthene | benzo[k]fluoranthene | benzo[j]fluoranthene | benzo[a]fluoranthene |
|---|---|---|---|---|---|---|
| Units | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg |
| **GGERFS** | | | | | | |
| Min | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 |
| Max | 5.77 | 3.14 | 10.41 | 5.42 | 5.57 | 2.11 |
| Median | 0.86 | 0.45 | 1.73 | 0.93 | 0.90 | 0.39 |
| Mean | 1.13 | 0.63 | 2.28 | 1.20 | 1.19 | 0.51 |
| SD | 1.06 | 0.63 | 2.10 | 1.13 | 1.10 | 0.46 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | |
| Max | 34.73 | nd | 37.46 | 19.62 | 19.96 | 6.87 |
| Count | 84 | | 84 | 84 | 84 | 84 |

| Dataset | benzo[e]pyrene | benzo[a]pyrene | perylene | dibenz[a,h]anthracene | indeno[1,2,3-cd]pyrene | benzo[g,h,i]perylene |
|---|---|---|---|---|---|---|
| Units | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg |
| **GGERFS** | | | | | | |
| Min | 0.03 | 0.02 | 0.01 | 0.03 | 0.02 | 0.02 |
| Max | 9.74 | 17.28 | 4.40 | 1.31 | 9.75 | 10.59 |
| Median | 1.32 | 2.38 | 0.62 | 0.20 | 1.38 | 1.40 |
| Mean | 1.73 | 3.17 | 0.82 | 0.27 | 1.84 | 1.91 |
| SD | 1.68 | 3.23 | 0.82 | 0.25 | 1.78 | 1.84 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | |
| Max | 25.48 | 50.11 | 15.52 | 3.32 | 30.45 | 31.81 |
| Count | 84 | 84 | 84 | 84 | 84 | 84 |

nd: not determined

SD: standard deviation

**Bold:** GGERFS soil maximum > BGS Glasgow soil dataset maximum

BGS Glasgow (Kim et al. 2019)

## Table A3.4 Summary statistics for PCBs in GGERFS and BGS Glasgow topsoil.

| Dataset | PCB028 | PCB052 | PCB101 | PCB118 | PCB138 | PCB153 | PCB180 | ∑7PCB | PCB077 | PCB081 | PCB105 | PCB114 | PCB123 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Units** | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg |
| **GGERFS** | | | | | | | | | | | | | |
| Min | 0.73 | 1.23 | 1.73 | 1.13 | 1.50 | 1.26 | 1.85 | 9 | 1.23 | 1.13 | 0.89 | 1.50 | 1.28 |
| Max | **53.52** | **96.95** | **218.14** | **150.35** | **142.60** | **205.88** | **164.47** | **1032** | 7.29 | 6.87 | 62.44 | 3.67 | 14.66 |
| Median | 0.73 | 1.23 | 1.73 | 1.13 | 1.50 | 1.26 | 1.85 | 9 | 1.23 | 1.13 | 0.89 | 1.50 | 1.28 |
| Mean | 1.67 | 3.08 | 5.65 | 3.85 | 5.32 | 6.16 | 5.05 | 31 | 1.34 | 1.19 | 1.99 | 1.55 | 1.49 |
| SD | 5.58 | 10.95 | 23.32 | 16.04 | 18.68 | 24.44 | 17.67 | 117 | 0.75 | 0.61 | 6.71 | 0.31 | 1.49 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | | | | | | | | |
| Max | 10.82 | 7.44 | 23.44 | 10.47 | 62.47 | 101.62 | 135.37 | 352 | nd | nd | nd | nd | nd |
| Count | 84 | 84 | 84 | 84 | 84 | 84 | 84 | | | | | | |

| Dataset | PCB126 | PCB156 | PCB167 | PCB169 | PCB189 | PCB151 | PCB149 | PCB146 | PCB095 | PCB099 | PCB110 | PCB187 | PCB183 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Units** | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg |
| **GGERFS** | | | | | | | | | | | | | |
| Min | 1.02 | 0.97 | 1.08 | 1.25 | 3.01 | 1.50 | 1.30 | 1.26 | 1.50 | 1.56 | 1.05 | 1.80 | 1.56 |
| Max | 11.43 | 14.26 | 46.69 | 4.60 | 3.01 | 24.21 | 133.07 | 18.14 | 107.35 | 76.40 | 157.63 | 101.77 | 44.96 |
| Median | 1.02 | 0.97 | 1.08 | 1.25 | 3.01 | 1.50 | 1.30 | 1.26 | 1.50 | 1.56 | 1.05 | 1.80 | 1.56 |
| Mean | 1.45 | 1.13 | 1.90 | 1.38 | 3.01 | 1.91 | 4.70 | 1.52 | 3.93 | 2.84 | 4.61 | 3.76 | 2.25 |
| SD | 1.58 | 1.41 | 5.15 | 0.55 | 0.00 | 2.53 | 17.75 | 1.91 | 12.06 | 8.04 | 17.29 | 10.76 | 4.69 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | | | | | | | | |
| Max | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Count | | | | | | | | | | | | | |

| Dataset | PCB177 | PCB170 | 3-Cl | 4-Cl | 5-Cl | 6-Cl | 7-Cl | ∑Tri-Hepta PCB |
|---|---|---|---|---|---|---|---|---|
| **Units** | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg |
| **GGERFS** | | | | | | | | |
| Min | 2.07 | 1.66 | 0.73 | 1.20 | 1.30 | 1.31 | 2.06 | 7 |
| Max | 69.58 | 71.32 | **86.39** | **325.01** | **1,084.01** | **969.63** | **861.74** | **3327** |
| Median | 2.07 | 1.66 | 0.73 | 9.56 | 10.86 | 7.43 | 2.06 | 31 |
| Mean | 3.04 | 2.81 | 3.05 | 17.17 | 36.55 | 33.45 | 19.87 | 110 |
| SD | 7.22 | 7.63 | 9.15 | 44.12 | 119.78 | 132.49 | 92.11 | 398 |
| Count | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| **BGS Glasgow** | | | | | | | | |
| Max | nd | nd | 29.74 | 84.56 | 137.90 | 382.73 | 433.14 | 1052 |
| Count | | | 84 | 84 | 84 | 84 | 84 | 84 |

nd: not determined Black: 7 PCB congeners (ICES/EUCBR) **Bold:** GGERFS soil maximum > BGS Glasgow soil dataset maximum

SD: standard deviation Purple: Tri-Hepta PCBs BGS Glasgow (Kim et al. 2019)

## Table A3.5 Summary statistics for selected parameters in GGERFS topsoil compared to land quality generic soil guidelines.

| Parameter:<br>Units: | As<br>mg/kg | Ba<br>mg/kg | Cd<br>mg/kg | Co<br>mg/kg | Cr<br>mg/kg | Cu<br>mg/kg | Hg<br>mg/kg | Mo<br>mg/kg | Ni<br>mg/kg | Pb<br>mg/kg | Sb<br>mg/kg | Se<br>mg/kg | V<br>mg/kg | Zn<br>mg/kg | Cr(VI)<br>mg/kg | TPH (non-volatile)<br>mg/kg | benzo[a]pyrene<br>mg/kg | ∑7PCB<br>µg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | 4.5 | 130 | <0.5 | 4.4 | 30 | 10 | <2.5 | 0.2 | 11 | 11.1 | <0.5 | <0.2 | 33 | 19 | <0.5 | 90 | 0.02 | 9 |
| Max | *40.4* | *1834* | *18.8* | 82.2 | **2776** | *1192* | 2.9 | 9.0 | **330** | **1639.3** | 44.7 | 5.2 | *417* | *11493* | **28.5** | **5928** | **17.28** | **1032** |
| Median | 11.0 | 506 | 0.5 | 19.2 | 133 | 83 | <2.5 | 2.2 | 50 | 226.5 | 2.5 | 1.0 | 108 | 322 | <0.5 | 587 | 2.38 | 9 |
| Mean | 11.6 | 546 | 0.9 | 19.6 | 268 | 137 | <2.5 | 2.4 | 58 | 308.7 | 4.1 | 1.0 | 116 | 502 | 1.1 | 937 | 3.17 | 31 |
| SD | 5.2 | 290 | 2.0 | 9.5 | 450 | 164 | 0.6 | 1.2 | 38 | 294.6 | 5.5 | 0.7 | 52 | 1219 | 3.2 | 1142 | 3.23 | 117 |
| Count | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 90 | 90 | 90 | 90 |
| **Generic Soil Guidelines** | * | ^ | * | ¬ | # | # | # | ~ | # | * | ~ | # | # | # | * | ^ | * | ¬ |
| A | 49 |  | 4.9 |  | 18000 | 520 | 19 |  | 53 | 80 |  | 88 | 91 | 620 | 170 |  | 5.7 |  |
| GP | 37 |  | 26 |  | 910 | 2400 | 40 |  | 130 | 200 |  | 250 | 410 | 3700 | 21 |  | 5 |  |
| G | 40 | 1300 | 149 |  | 910 | 7100 | 56 | 670 | 180 | 310 | 550 | 430 | 1200 | 4000 | 21 | 1200 | 5.3 |  |
| OR | 79 |  | 220 |  | 1500 | 12000 | 120 |  | 230 | 630 |  | 1100 | 2000 | 81000 | 23 |  | 10 |  |
| OP | 168 |  | 880 |  | 33000 | 44000 | 240 |  | 800 | 1300 |  | 1800 | 5000 | 170000 | 250 |  | 21 |  |
| All |  |  |  | 190 |  |  |  |  |  |  |  |  |  |  |  |  |  | 20/1000 |

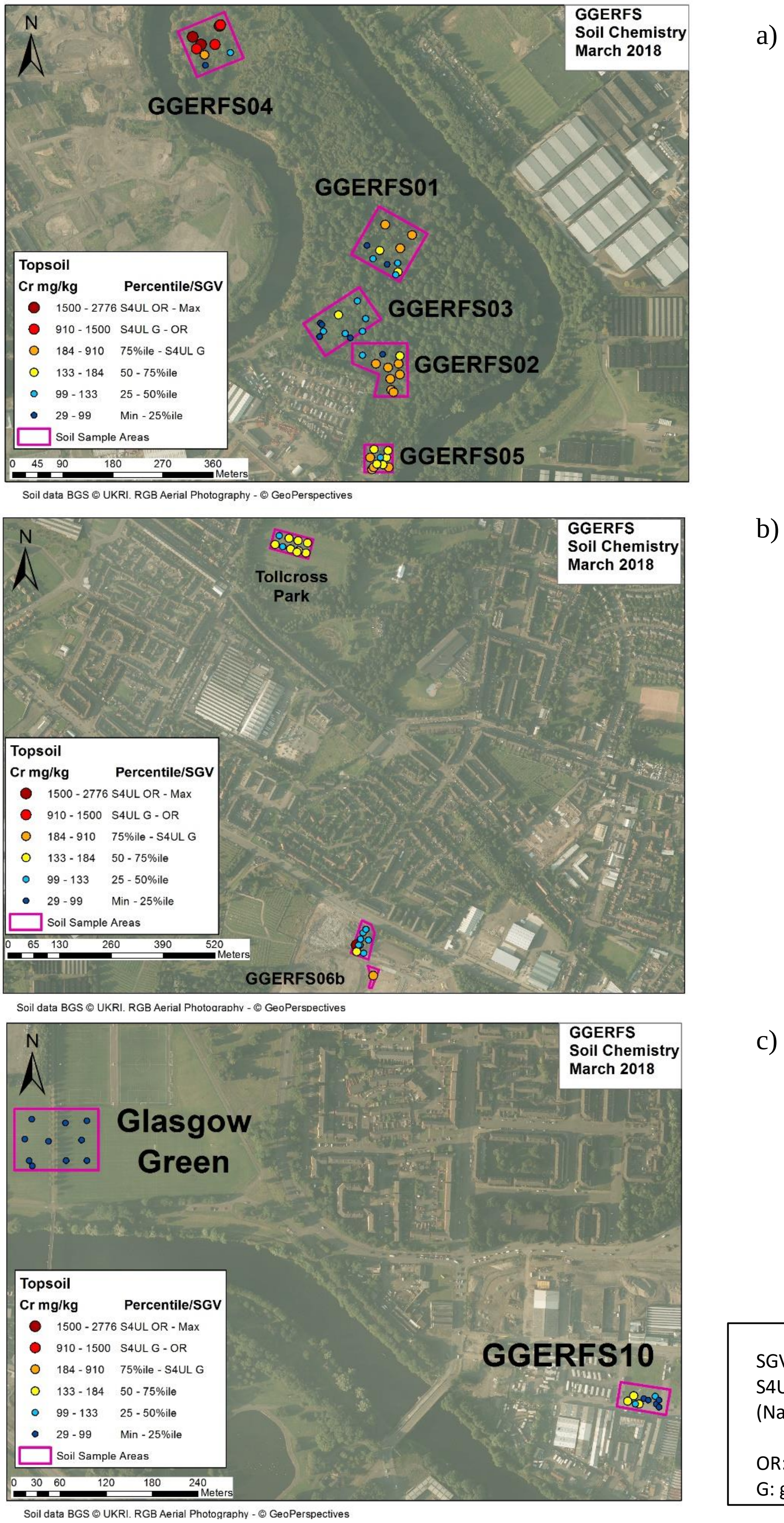
Land use:
A: allotment
GP: garden with produce
G: garden without produce
OR: residential open space
OP: recreational open space
All: any land use

* DEFRA (2014) C4SL category 4 soil screening levels
^ Nathanail et al. (2009) GAC generic assessment criteria
\# Nathanail et al. (2015) S4UL suitable for use screening levels
~ CL:AIRE (2010) GAC generic assessment criteria
¬ VROM (2009) trigger value (except Σ7PCB: target value/trigger value)

∑7PCB: Sum 7 PCB congeners (ICES/EUCBR)

*Italic* : exceeds allotment/garden generic guidelines
**Bold:** exceeds residential open space/ all land use, generic guidelines
**Bold**: exceeds recreational open space generic guidelines

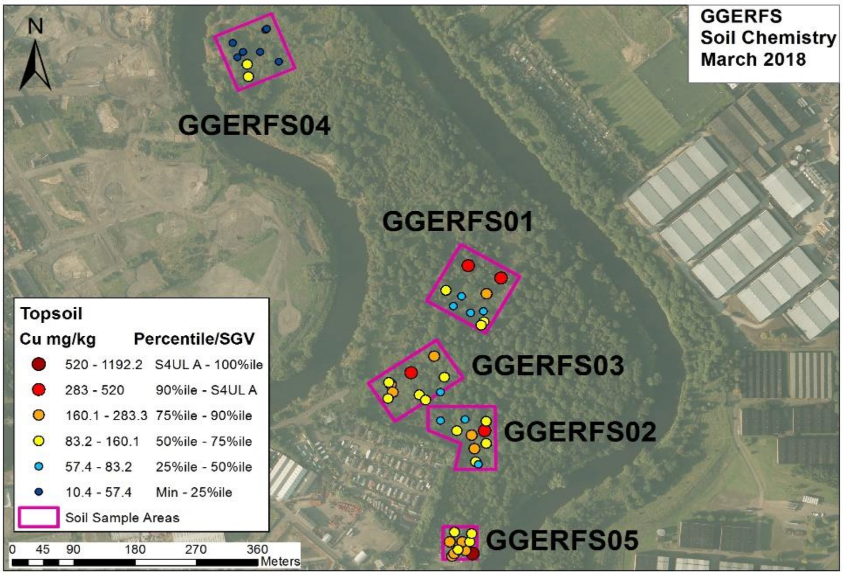
# Appendix 4 Maps showing the distribution of selected parameters in GGERFS topsoil.



SGV: soil guideline values
S4UL: suitable for use level
(Nathanail et al. 2015)

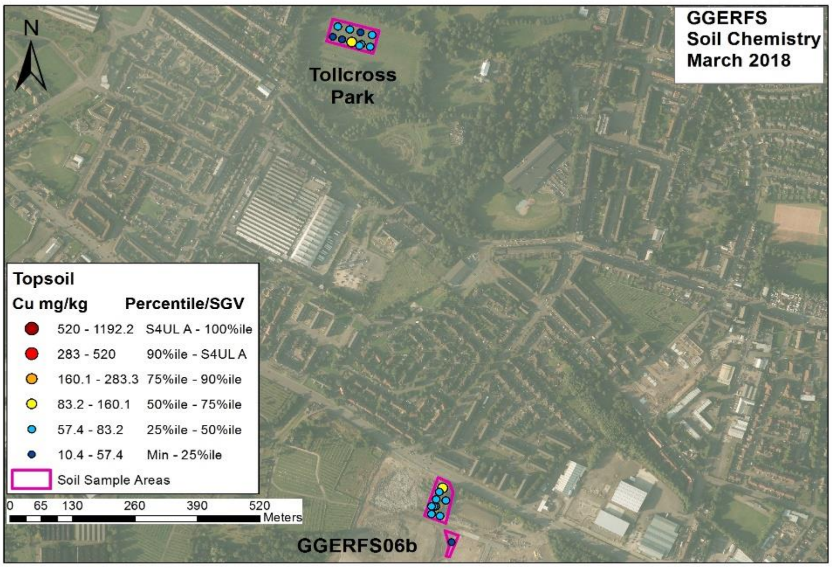
OR: open space residential
G: garden with no produce

**Figure A4.1 Maps showing total Cr concentrations in a) Cuningar Loop, b) GGERFS06b/ Tollcross Park and GGERFS10/Glasgow Green topsoil samples.**



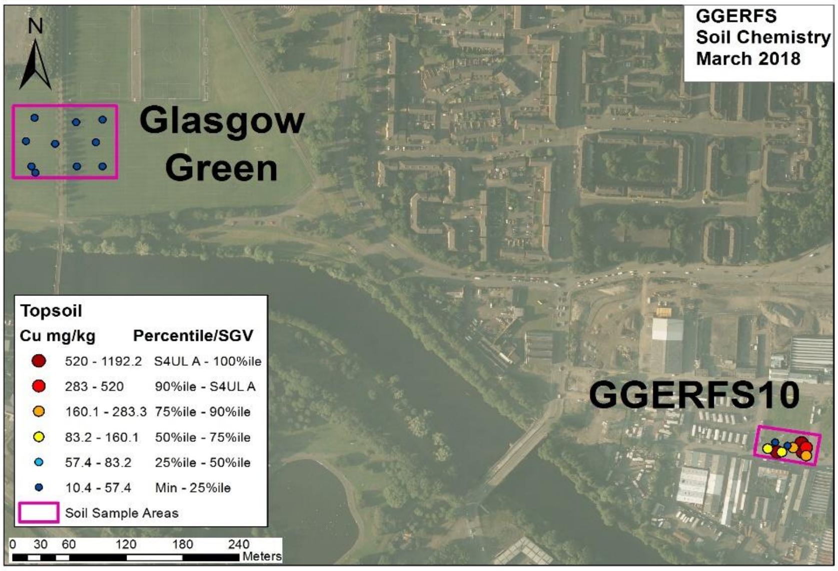
Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

a)



Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

b)



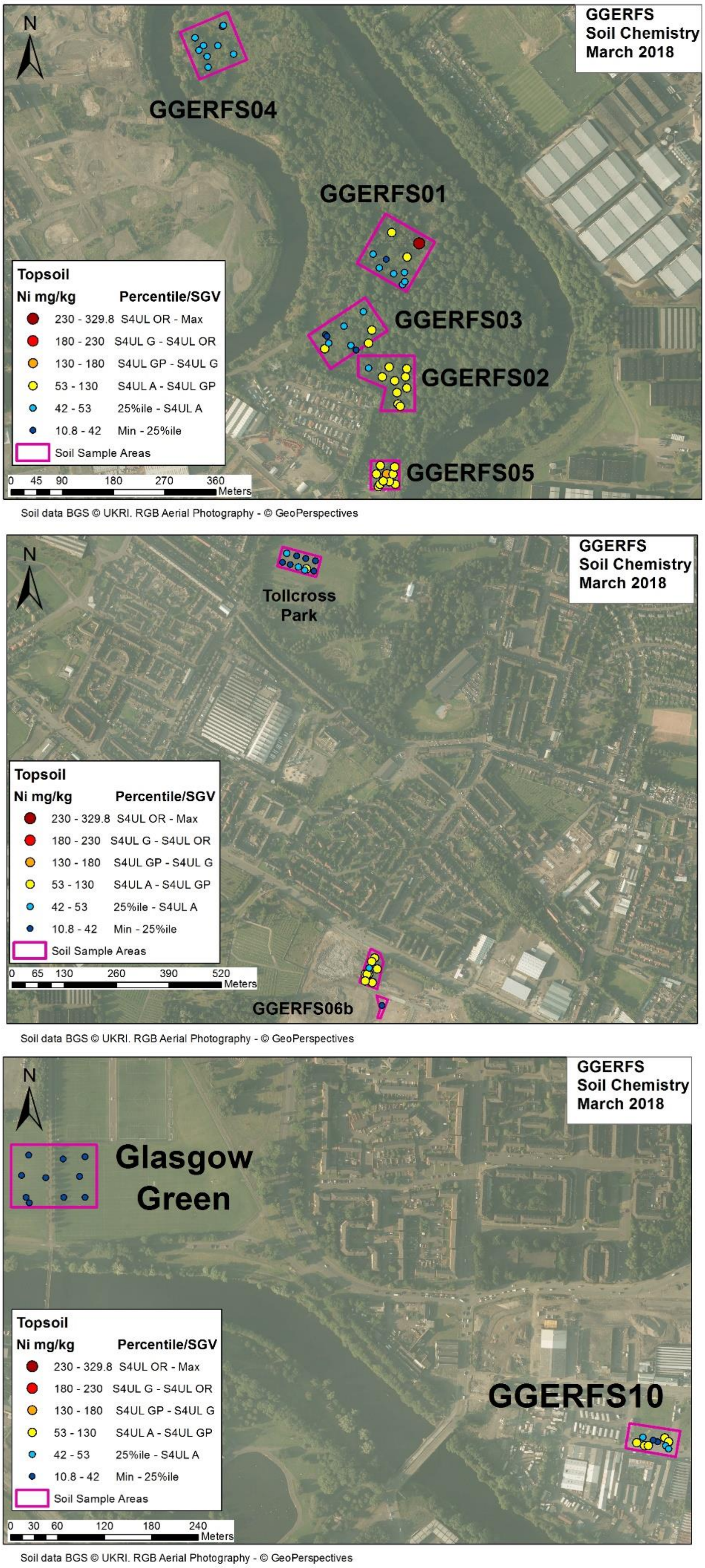
Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

c)

SGV: soil guideline values
S4UL: suitable for use level
(Nathanail et al. 2015)

A: allotment

**Figure A4.2 Maps showing Cu concentrations in a) Cuningar Loop, b) GGERFS06b/ Tollcross Park and GGERFS10/Glasgow Green topsoil samples.**



Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

a)

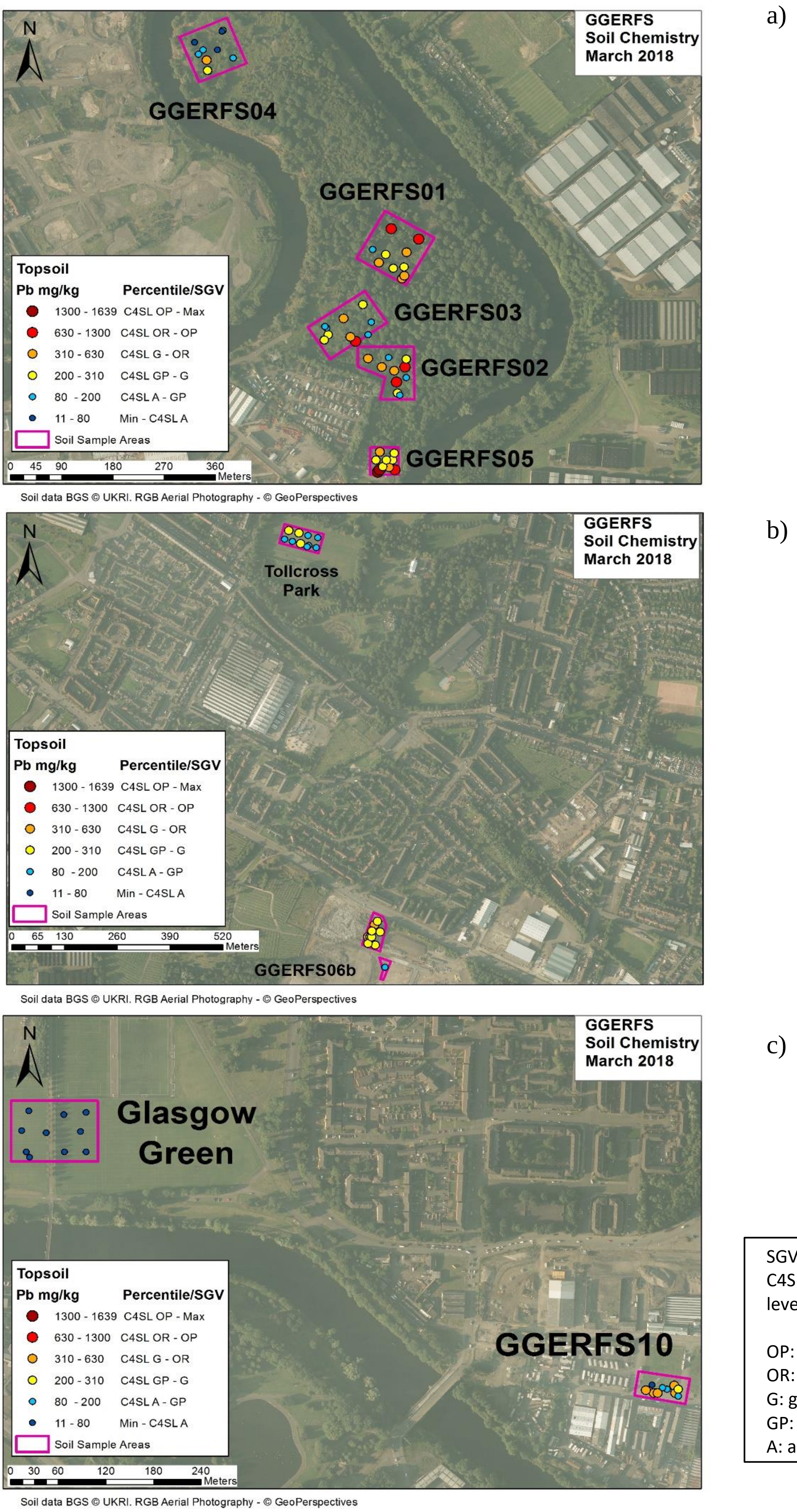
b)

c)

SGV: soil guideline values
S4UL: suitable for use level
(Nathanail et al. 2015)

OR: open space residential
G: garden with no produce
GP: garden with produce
A: allotment

**Figure A4.3 Maps showing Ni concentrations in a) Cuningar Loop, b) GGERFS06b/ Tollcross Park and GGERFS10/Glasgow Green topsoil samples.**



Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

SGV: soil guideline values
C4SL: category 4 screening level (DEFRA 2014)

OP: open space recreational
OR: open space residential
G: garden with no produce
GP: garden with produce
A: allotment

**Figure A4.4 Maps showing Pb concentrations in a) Cuningar Loop, b) GGERFS06b/ Tollcross Park and GGERFS10/Glasgow Green topsoil samples.**

Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

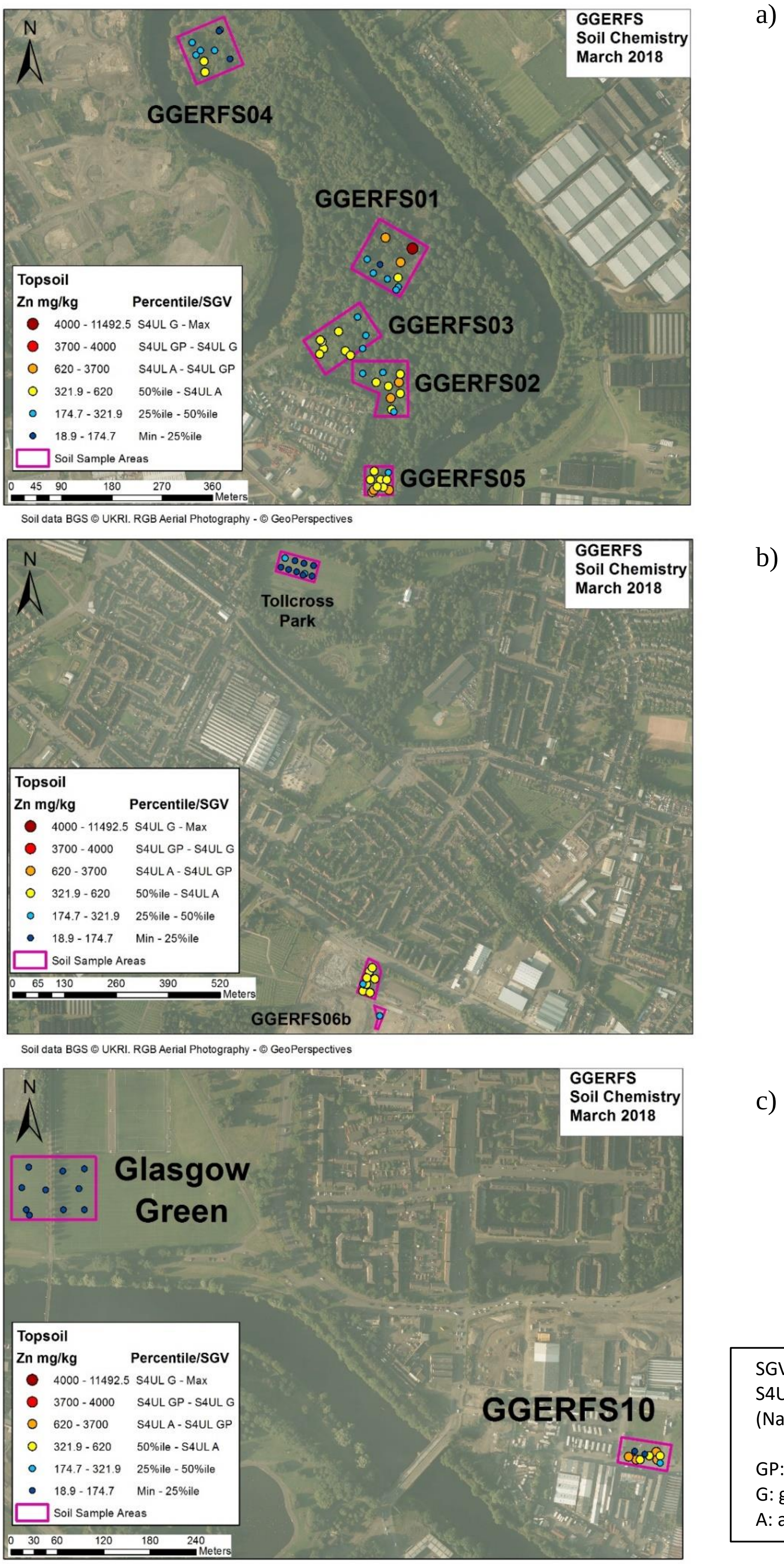
Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

SGV: soil guideline values
S4UL: suitable for use level
(Nathanail et al. 2015)

GP: garden with produce
A: allotment

**Figure A4.5 Maps showing V concentrations in a) Cuningar Loop, b) GGERFS06b/ Tollcross Park and GGERFS10/Glasgow Green topsoil samples.**



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SGV: soil guideline values
S4UL: suitable for use level
(Nathanail et al. 2015)

GP: garden with produce
G: garden with no produce
A: allotment

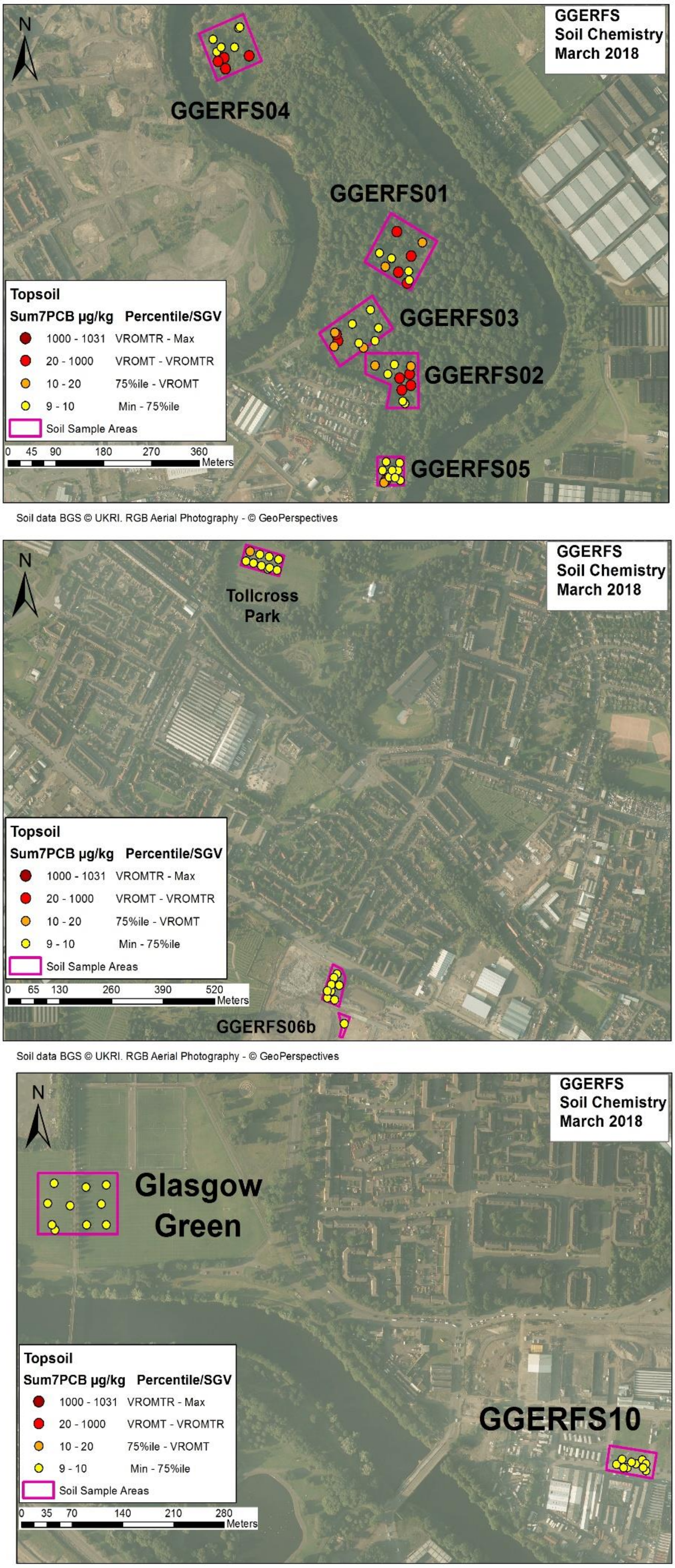
**Figure A4.6 Maps showing Zn concentrations in a) Cuningar Loop, b) GGERFS06b/ Tollcross Park and GGERFS10/Glasgow Green topsoil samples.**

Soil data BGS © UKRI. RGB Aerial Photography - © GeoPerspectives

SGV: soil guideline values
GAC: generic assessment criteria
(Nathanail et al. 2009)

G: garden with no produce

**Figure A4.7 Maps showing TPH concentrations in a) Cuningar Loop, b) GGERFS06b/ Tollcross Park and GGERFS10/Glasgow Green topsoil samples.**



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SGV: soil guideline values
TR: intervention value
T: target value
(VROM 2009)

**Figure A4.8 Maps showing ∑7PCB concentrations in a) Cuningar Loop, b) GGERFS06b/ Tollcross Park and GGERFS10/Glasgow Green topsoil samples.**