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Geochemical Characterization and Geochemically Appropriate Levels for Soil Recovery Facilities

Geological Survey Ireland Report
2020

Geological Survey Ireland is a division of the Department of Communications, Climate Action & Environment

Geological Survey Ireland

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Reference

Glennon, M., Gallagher, V., Meehan, R. and Hodgson, J. (2020) *Geochemical Characterization and Geochemically Appropriate Levels for Soil Recovery Facilities.* Geological Survey Ireland report.

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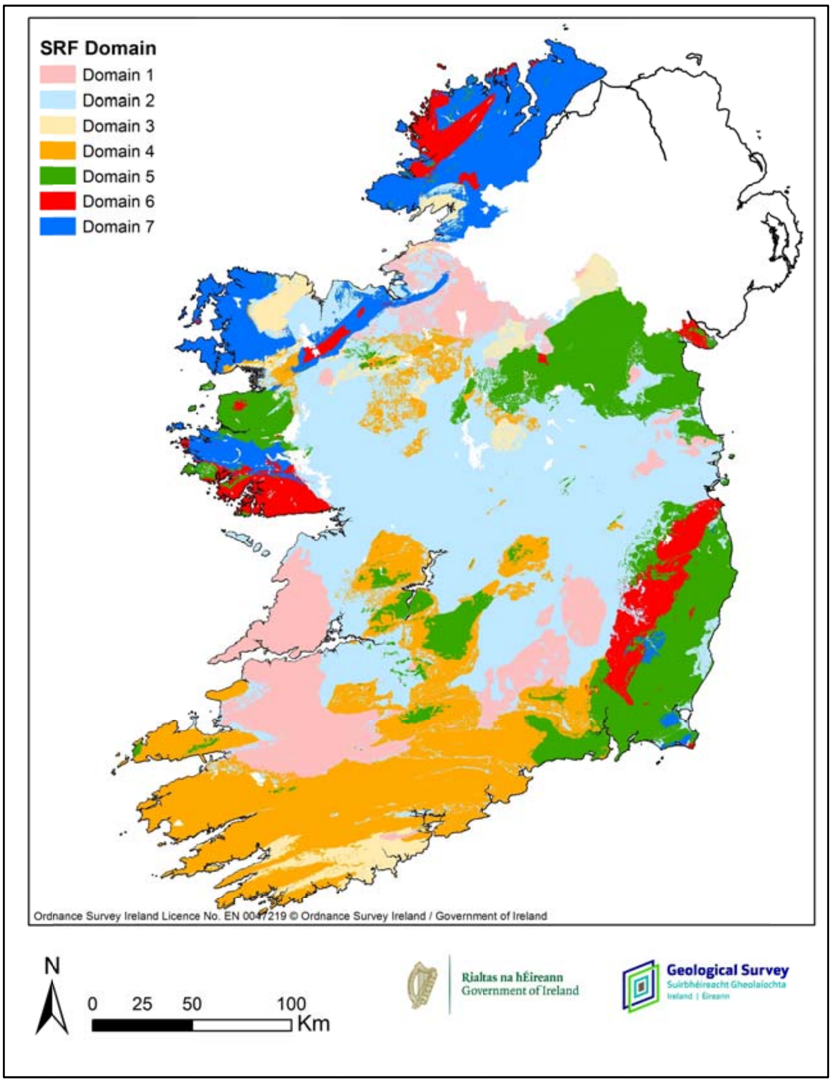
Executive summary

Geological Survey Ireland (GSI) has completed a project to inform the development of Geochemically Appropriate Levels (GALs) for Soil Recovery Facilities (SRFs) specifically in relation to metals and metalloids in uncontaminated soil and stone. A draft guidance document published by the EPA in December 2017 proposed acceptable limits for levels of chemical substances, including heavy metals and a range of organic compounds, in uncontaminated subsoil and stone to be accepted by waste-licensed SRFs (EPA, 2017). A number of submissions made to the EPA raised concerns that the proposed levels for metals were not practicable given a high degree of variation in natural metal contents of Irish subsoils.

The EPA approached GSI to assist in establishing an approach to setting appropriate trigger levels for metals for acceptance of uncontaminated soil and stone at SRFs, drawing on its expertise in the geochemistry and physical properties of natural geological materials. In response, GSI has considered the problem using the source-pathway-receptor conceptual framework, an established framework for modelling environmental risk. The placement of externally-sourced inappropriate material at SRFs poses a potential source of chemical contamination. In consultation with the EPA, the approach taken by GSI was to assume that soil and stone of a similar geochemical nature to that in the vicinity of a particular SRF can be admitted to the site with minimal risk to receptors. In terms of the source-pathway-receptor conceptual framework, this approach aims to prevent a source being introduced to the SRF and to prevent the chemical load on the receptor (down–gradient aquifer) from newly placed material exceeding the load from the original soil.

In order to understand field-scale natural geochemical variability, GSI undertook a geochemical investigation at two representative SRFs; a limestone quarry in Co. Dublin and a sand and gravel pit in Co. Kildare. Twelve boreholes were drilled using a cable percussion rig to a nominal depth of 10m within a 500m radius of each site; soils were sampled at approximately 1m intervals down-hole. 'Tellus' topsoil samples were also taken at each drilling location with a hand-auger at 0.05–0.20 m and 0.35–0.50 m depths. A total of 175 topsoil and subsoil samples were collected at the sites and analysed by ICP-MS for arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn) and separately for mercury (Hg), in both cases following *aqua regia* digestion. Particle size analysis was undertaken on a subset of 96 samples. The geochemical results were analysed within and between subsoil units, as well as down-hole and in relation to soil texture. Conceptual site models were developed from borehole logs. Results indicate that the composition of topsoils and subsoils around the SRFs are comparable. Subsoils are distinguished by several upper outliers, some with quite high concentrations of certain elements. These outliers skew the data distribution but do not affect the conclusion that topsoils and subsoils share a broadly similar geochemistry. These data support the use of topsoil data as a proxy for subsoil data, in the absence of baseline subsoil geochemical data.

GSI also undertook a geochemical domain-setting exercise, which divided the country into zones or domains based on similar geochemical signature. This was undertaken by dividing the National Soil Database (NSDB) into domains based on mapped subsoil type and bedrock type. This resulted in seven geochemical domains. Each domain is associated with a range of geochemical data, from which the 98th percentile level has been determined and set as a GAL for that domain.



The calculated GALs show wide variation among the seven domains and are generally higher than the trigger values proposed in the EPA's (2017) draft guidelines (below). The latter is to be expected given the use of the 98th percentile rather the 90th percentile of the NSDB used in the draft guidelines. However, this accounts for only some of the observed variation and the recasting of the NSDB in the context of geological domains has led to significant changes for some calculated GALs, with notably high values for As in Domain 6, Cd in Domain 2 and Hg in both Domain 3 and Domain 6.

Domain	n	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Domain 1	166	15.6	1.50	85.9	51.2	0.254	47.8	48.3	137
Domain 2	431	24.9	3.28	83.9	63.5	0.360	61.9	86.1	197
Domain 3	55	38.1	1.60	79.2	56.9	0.457	54.4	81.3	237
Domain 4	278	32.3	0.97	86.2	80.4	0.285	50.3	91.4	155
Domain 5	205	41.5	1.42	122	77.6	0.302	65.7	109	224
Domain 6	64	85.8	2.38	90.0	40.0	0.527	28.2	108	168
Domain 7	111	30.9	0.542	96.0	83.1	0.262	35.7	61.1	122
NSDB 90th percentile (Draft guidelines)	1310	16	1.3	75	35	0.2	42	48	126
NSBD 98th (all) percentile	1310	33.6	2.28	99.9	65.1	0.299	58.8	86.9	183

Calculated GALs (98th percentile) for defined geochemical domains. n = number of samples. Units are mg kg^{-1}

We recommend that the EPA considers adopting GALs as trigger levels based on the 98th percentile of the NSDB data, based on geological domains. GALs should be periodically reviewed with improved availability of baseline soil geochemistry data in Ireland, specifically, when Tellus topsoil geochemical mapping is completed nationally (projected 2028). Ideally, the approach would benefit from a national baseline subsoil geochemistry mapping exercise. We also note that large quantities of subsoil from the greater Dublin area are being moved to SRFs in the hinterland of the city. This material is likely to be mainly comprised of the Dublin Boulder Clay (DBC), which is poorly understood in terms of its geochemistry and is anecdotally known to have anomalously high levels of some metals and metalloids. Given that the NSDB did not survey Dublin soils, the GALs suggested here do not take account of the DBC. It is recommended that a geochemical characterization of the DBC is carried out in support of further refinement of this project.

1. Introduction

1.1. Aim

This document reports on the outcomes of the pilot study on the geochemical characterization of Soil Recovery Facilities (SRFs). The aim of the project was to inform the development of Geochemically Appropriate Levels (GALs) for SRFs specifically in relation to metals and metalloids, which can then be applied to these facilities as trigger levels for acceptance of waste. SRFs are facilities that are authorized licensed by the Environmental Protection Agency (EPA) to receive uncontaminated soil and stone; SRFs and which exceed the operational thresholds for Waste Facility Permitted facilities (as set out in the Third Schedule of the Waste Management (Facility Permit and Registration) Regulations 2007 (S.I. No. 821 of 2007) as amended), are authorized by the EPA, and SRFs that fall within the aforementioned thresholds, are authorized by Local Authorities.

1.2. Rationale

A draft guidance document published by the EPA in December 2017 proposed acceptable limits for levels of chemical substances, including heavy metals and a range of organic compounds, in uncontaminated subsoil and stone to be accepted by waste-licensed SRFs (EPA, 2017). A number of submissions made to the EPA raised concerns that the proposed levels for metals were not practicable given a high degree of variation in natural metal contents of Irish subsoils.

1.3. Background

In April 2018 Geological Survey Ireland (GSI) was contacted by the EPA seeking baseline geochemical information on subsoils to support the setting of appropriate trigger levels for the acceptance of waste soil and stone at SRFs. Through a series of meetings and workshops led by GSI over summer 2018, an approach was developed and scoped. Participants included personnel from GSI's Tellus geochemistry programme, Groundwater programme and Quaternary Programme; consultant Quaternary geologist Dr Robbie Meehan; Kevin Motherway (EPA Office of Environmental Enforcement), Una Fitzgerald (DCC/Eastern Midlands Regional Waste Management Office) and Graham Webb (Geosyntec/consultants to EPA). Stuart Huskisson (EPA) replaced Kevin Motherway in November 2018. A collaboration was established by way of a letter from Dr Tom Ryan, Director Office of Environmental Enforcement EPA, to Koen Verbruggen, Director GSI, on 19th November 2018.

1.4. Scope

A Project Plan was adopted on 18th January 2019 in respect of the project *Geochemical Characterization of EPA-licenced Soil Recovery Facilities.* It outlined the work GSI would undertake to assist the EPA in establishing an approach to setting appropriate trigger levels for metals for acceptance of uncontaminated soil and stone at SRFs, drawing on its expertise in the geochemistry and physical properties of natural geological materials. The agreed project had two parts:

- A detailed ground investigation at two SRF sites.
- Derivation of geochemical domains based on geostatistical analysis of relevant national geological and geochemical data.

1.5. Objectives and assumptions

Guidance issued by the EPA (EPA, 2017) outlines the rationale for setting trigger levels for the acceptance of uncontaminated soil and stone to SRFs. The guidance sets out that:

- Unlike landfills, soil recovery facilities are not required to have an engineered basal liner, nor are they required to install an engineered cap following completion of restoration or land raising.
- Because of this, it is important that precautions are taken by operators of these facilities, to ensure that only uncontaminated soil and stone is accepted in order to protect groundwater from contamination.

It is best practice to monitor incoming materials so that the licensee can determine if this material is uncontaminated and suitable for acceptance at their site. Licences granted by the EPA for soil recovery facilities may include a condition requiring the licensee to propose maximum concentrations and/or trigger levels for relevant contaminants in soil and stone proposed for acceptance at the facility from non-greenfield sources.

As described in Section 1.3 Background, EPA sought assistance from GSI to develop appropriate trigger levels for SRFs, specifically in relation to metals and metalloids. In response, GSI has used the source-pathway-receptor conceptual framework, an established framework for modelling environmental risk in their approach. The framework has been adopted for the management of groundwater contamination risk by GSI in Groundwater Protection Schemes (Department of the Environment and Local Government, EPA and Geological Survey of Ireland, 1999) and in codes of practice for contaminated land risk assessment by the EPA (EPA, 2007) and by the UK Environment Agency (Environment Agency, 2001).

The placement of externally-sourced inappropriate material at SRFs as fill poses a potential source of chemical contamination to groundwater. In consultation with the EPA, the approach taken by GSI to developing GALs for SRFs was to assume that soil and stone of a similar geochemical nature to that in the vicinity of a particular SRF can be admitted to the site with minimal risk to receptors. In terms of the source-pathway-receptor conceptual framework, this approach aims to prevent a source being introduced to the SRF and to prevent the chemical load on the receptor (down–gradient aquifer) from newly placed material exceeding the load from the original, removed soil.

A number of considerations arose during discussions of how geochemical characterization of an SRF and its environs should be undertaken:

- **Variability between SRFs.** It is understood that there is natural geochemical variation in geological materials in Ireland arising from different rock types and types of mineralization. The setting of a 'blanket' or 'universal' guideline value for the acceptance of materials into SRFs is likely to result in practical difficulties where materials contain locally naturally high levels of certain elements for example cadmium, lead, zinc and arsenic. To account for regional variability it was proposed to determine geological 'domains' where expected natural ranges of concentrations for selected elements can be set.
- **The availability of baseline subsoil geochemistry data.** There is no systematic, regional subsoil (>1 m below ground level (bgl)) geochemical data available in Ireland. Data on recorded geochemistry in subsoils is restricted to detailed, discrete projects examining mineralization within such materials as part of mining investigations (*e.g.* McCabe, 1972). Internationally, such studies have also been sparse, with only a small number listed (for full review see Shilts (1976)). There are two datasets that provide regional geochemical information on topsoil in Ireland, the National Soil Database (Teagasc/EPA) and Tellus (Geological Survey Ireland).
    - National Soil Database (Fay *et al.* 2007): Multi-element determination of topsoil (0–10 cm depth) chemistry by ICP-MS (Inductively coupled plasma mass spectrometry)

using a four-acid digest at a density of one sample per 50 km^2 (1310 samples nationwide).

- Tellus: Multi-element determination of topsoil chemistry at two depth levels (5–20 cm and 35–50 cm) at a density of one sample per 4 km^2. This NDP project is ongoing and due to be completed by 2028. Data is currently available for the border region and data for the west, midlands and east are to be published in 2019. Analysis is by ICP-MS (*aqua regia* digest) and by XRF.

A key question for the project to address was whether topsoil geochemistry is a reliable proxy for subsoil geochemistry. It is possible that a number of other factors influence subsoil chemistry that may not be reflected by topsoil geochemistry, such as parent material, ice flow direction, etc.

- **Variability within SRFs.** From a desk review of the 15 SRF sites currently licenced it was observed that there is a large degree of variation between sites with respect to subsoil type, parent material, depth to bedrock and bedrock composition. At several sites it was noted that the mapped subsoil parent material did not conform to the underlying bedrock.
- **Complex and challenging ground conditions at sand and gravel (S&G) sites.** Four of the existing licenced SRFs are sand and gravel pits with a high degree of mapped complexity and challenging ground conditions, including possible interbedding of sand, gravel and till. Such complexity suggested difficulties were likely when undertaking geochemical characterization of S&G deposits.

For these reasons it was not deemed appropriate to carry out a generalized desk-based geochemical characterization of each site using existing geochemical information. Rather, a pilot site investigation at two sites was proposed, to understand the geochemical influences on a site including *e.g.* bedrock geology, Quaternary geology, ice flow direction, wind direction, geographical setting, etc. A site investigation would also inform the domain-setting part of the project, allowing an assessment of whether site characterization match expectations of the domain in the area.

It is to be noted that this project is not to determine an approach to defining whether soil is contaminated or uncontaminated. Guidance on the usage of the terms 'contaminated' and 'uncontaminated' is given by the European Commission[1] (European Commission, 2012, p41).

[1] "The term 'contaminated soil' is not defined in the WFD or in other legal acts at Community level. A minimum criterion to be applied by competent authorities to determine whether soil is considered to be contaminated is whether it exhibits any of the 'properties of waste which render it hazardous' as per Annex III to the WFD. Furthermore, the term 'contaminated' can be clarified by comparing it to its opposite, the term 'uncontaminated soil' in Article 2(1)(c) WFD. From the wording of that provision 'uncontaminated soil and other naturally occurring material' it can be derived that uncontaminated soil essentially relates to virgin soil or soil that is equivalent to virgin soil. In the absence of EU standards, national soil legislation (where it exists) can be consulted to determine the type and level of trace contamination at which a soil might be considered equivalent to virgin soil".

2. Scope of Works

As outlined in Section 1: Introduction there were two main tasks in the GSI scope of works which were completed in parallel over a period of 25 weeks between weeks commencing 7th January 2019 and 24th June 2019:

(i) Pilot site investigation at two sites and

(ii) Geochemical domain setting.

2.1. Site investigation

2.1.1. Site selection

Initially it was decided that two sites with varying geology would be selected for detailed study, including drilling, soil/subsoil sampling, particle size and geochemical analysis and conceptual modelling of sediment stratigraphy. Ground-based geophysics was also completed at one site.

Locality A

This locality in Co. Dublin includes a Soil Recovery Facility in a limestone quarry site.

Locality B

This locality in Co. Kildare includes a Soil Recovery Facility in a sand and gravel pit.

2.1.2. Drilling works

Causeway Geotech Ltd. was appointed to carry out drilling works on 1st February 2019 following a procurement process carried out by Geosyntec Consultants on behalf of the EPA. Drilling was carried out using a Dando 2000 cable percussion rig using a 200m casing and cutting head. For coarse unconsolidated sediments a U100 sampler was used to capture loose material. Recovered material was tipped from the sampler into a wheelbarrow for bagging.

Locality A

Twelve boreholes were drilled in the vicinity of the facility at Locality A between 5th and 13th March 2019. Holes were drilled along two axes, one approximately parallel (NE-SW) and one approximately perpendicular (NE-SW) to interpreted former ice flow direction in a radius of approximately 500 m from the SRF boundary (Figure 1). Depths reached by boreholes ranged from 2.5 m to 10.0 m below ground level, reaching rockhead at depths between 2.5 m and 5.5 m in 8 of 12 boreholes. Figure 1 shows the location of boreholes with respect to the SRF, with generalized borehole profiles shown in Figure 14 and Figure 15; detailed logs of each borehole are presented in Appendix A.

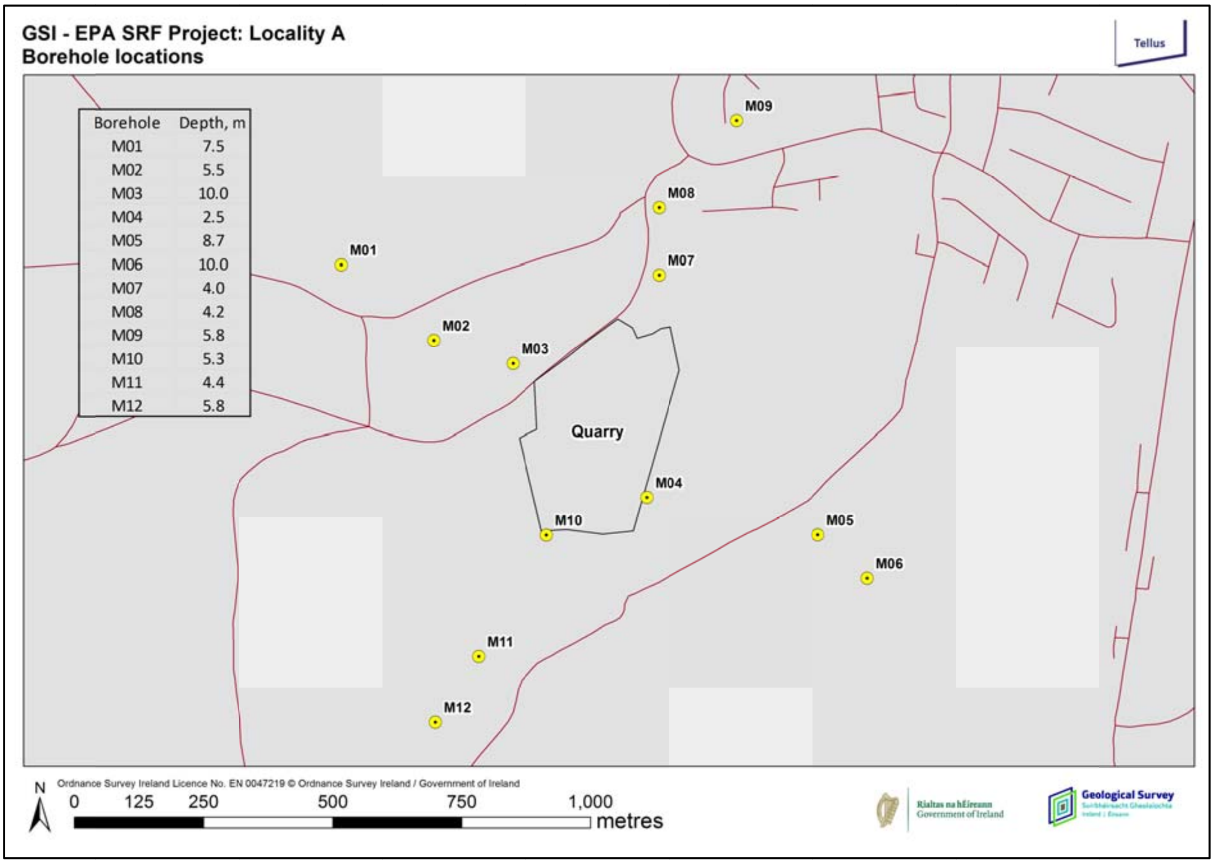


Figure 1 Locality A borehole locations in relation to the Soil Recovery Facility

Locality B

Twelve boreholes were drilled in the vicinity of the soil recovery facility at Locality B between 14th and 25th March 2019. Holes were drilled along two axes, one approximately parallel (WNW-ESE) and one approximately perpendicular (NNE-SSW) to interpreted former ice flow direction, in a radius of approximately 500 m from the SRF boundary (Figure 2). Depths reached by boreholes also ranged from 2.5 m to 10.0 m below ground level, with no boreholes interpreted as having met bedrock. Figure 2 shows the location of boreholes, with generalized borehole profiles shown in **Figure 18** and Figure 19; detailed logs are presented in Appendix B.

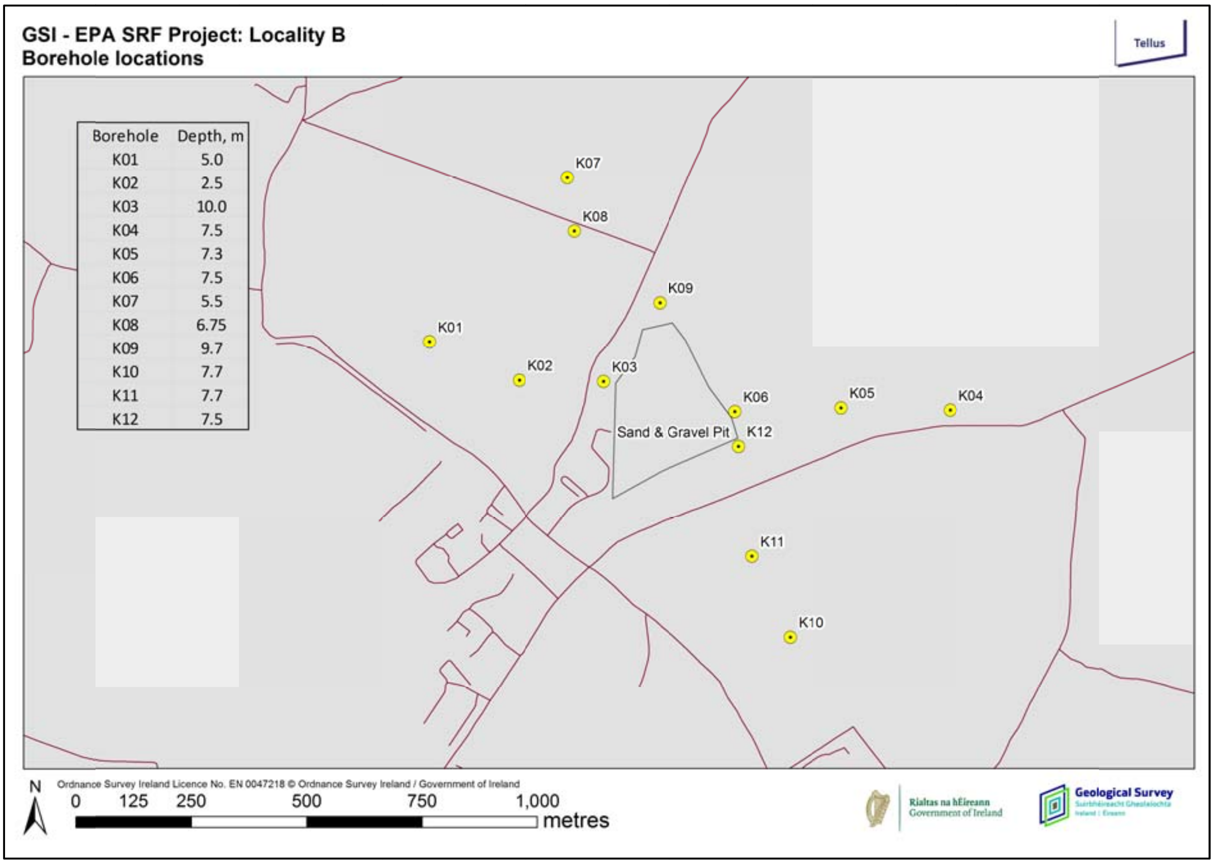


Figure 2 Locality B borehole locations in relation to the Soil Recovery Facility

2.1.3. Soil geochemical sampling

Soil geochemical sampling included two distinct sample types: topsoil samples and subsoil samples. The topsoil samples were collected according to the Tellus Project methodology and were intended to provide a direct comparison between the chemistry of Tellus-type shallow soil samples and that of true subsoil samples.

Samples were labelled in the field using a simple combination of site identifier, borehole number and sequential sample number. Thus samples taken in Locality A at the site of borehole number 6 were labelled M06-001, M06-002, etc. Samples from Locality B were labelled, *e.g.*, as K06-001, K06-002, etc. A field sample number list was created in advance of field work and sample numbers filled in sequentially. One in every twenty sample IDs was reserved for a laboratory replicate ("REP" on number list) of a specified sample ID ("DUP"). Subsequently, following sample preparation, new randomized IDs were assigned to samples and inserted reference materials prior to submission to the analytical laboratory. An example of a completed sample number list is shown in Figure 3.

Sample number list 1 **SOIL**

GSI - EPA SRF Project | SRF Name | Locality A

	Site ID	Field ID	Sample ID (randomized)	A	S	Depth Top, m	Depth Bottom, m	Samp_Std
1	M04	001	GSI-SRF-055	X		0.05	0.20	
2	M04	002	GSI-SRF-118		X	0.35	0.50	
3	M04	003	GSI-SRF-167			0.90	1.10	
4	M04	004	GSI-SRF-069			1.90	2.10	
5	M10	001	GSI-SRF-178	X		0.05	0.20	
6	M10	002	GSI-SRF-082		X	0.35	0.50	
7	M10	003	GSI-SRF-044			0.90	1.10	
8	M10	004	GSI-SRF-040			1.90	2.10	
9	M10	005	GSI-SRF-006			2.90	3.10	
10			GSI-SRF-009					STD
11	M10	006	GSI-SRF-065			3.90	4.10	
12	M10	007	GSI-SRF-152			4.90	5.10	
13	M06	001	GSI-SRF-188	X		0.05	0.20	
14	M06	002	GSI-SRF-036		X	0.35	0.50	
15	M06	003	GSI-SRF-054			0.90	1.10	
16	M06	004	GSI-SRF-068			1.90	2.10	
17	M06	005	GSI-SRF-005			2.90	3.10	
18	M06	006	GSI-SRF-046			3.90	4.10	
19	M06	007	GSI-SRF-024			4.90	5.10	
20			GSI-SRF-021					STD
21	M06	008	GSI-SRF-142			7.40	7.60	DUP
22	M06	009	GSI-SRF-075					REP
23	M06	010	GSI-SRF-098			9.90	10.10	
24	M05	001	GSI-SRF-143	X		0.05	0.20	
25	M05	002	GSI-SRF-064		X	0.35	0.50	

Batch checked in field:

Dispatch to GSI Dublin: *Dispatch to sample prep.:*

Figure 3 Completed soil sample number list

Topsoil samples were collected using a Dutch auger with a flight length of c. 0.15 m, from a 20 m x 20 m square centred close to the site of each borehole. Topsoil was sampled at two depths, the first, labelled "A", at 0.05 m to 0.20 m below ground level and the second, labelled "S", at 0.35 m to 0.50 m below ground level. Each A and S sample was a composite sample, comprised of five subsamples, one from each corner of the square and one from its centre. Sample weight was typically of the order of 0.8 to 1.0 kg. Samples were collected in 250 mm x 125 mm kraft paper bags with the respective field ID written on the bag. A full description of the Tellus sampling methodology can be found in the relevant Tellus instructional video at https://www.gsi.ie/en-ie/publications/Pages/Tellus-Geochemistry-Instructional-Videos.aspx.

Subsoil samples were taken directly from recovered borehole material, at nominal depths, as applicable, of 1.0 m, 2.0 m, 3.0 m, 4.0 m, 5.0 m, 7.5 m and 10.0 m. The recovered material was collected in a wheelbarrow directly from the drill bit. The borehole casing had an internal diameter of 0.2 m and, where intact "cores" were recovered, an approximately 0.20 m length of material was sampled to provide a sample weight of 2.0 to 3.0 kg. Samples were double-bagged in large plastic bags; a cardboard label with handwritten sample ID was placed inside a small sealable plastic bag and included with the sample. Sample labels were also handwritten on the outside of the outer plastic bag. Recorded sample depths are nominal, reflecting a degree of uncertainty in downhole sample depth measurements.

While a proportion of moist clay-rich till samples were recovered as intact “cores”, drier till samples and sand and gravel samples were typically recovered as disaggregated samples. These were collected in the wheelbarrow and sub-sampled as representatively as possible to give a total of 2–3 kg, and bagged and labelled as described above. Sand and gravel samples were commonly retrieved from depth with the aid of water added downhole and thus some loss of fine fraction is likely to have occurred in some cases.

2.1.4. Geochemical sample preparation and quality control

Geochemical samples were submitted to ALS Laboratory in Loughrea, County Galway for sample preparation. Sample preparation followed standard techniques to produce two fractions of prepared soil, < 2 mm and < 53 µm:

1. Samples were checked against supplied sample lists, logged in, assigned a laboratory ID and weighed.
2. Each sample was placed in a large aluminium-foil tray and put in a drying oven at 30°C until dry; drying typically lasted around one week.
3. When dry, each sample was placed in a large plastic bag and disaggregated by gently pounding it with a rubber mallet to break up any clumps of soil while avoiding breaking any clasts in the sample.
4. The sample was then passed through a nylon sieve with 2 mm aperture mesh size.
5. The < 2mm fraction and the > 2 mm fraction were collected and placed in labelled plastic bags.
6. Approximately 30 g of < 2 mm fraction was milled in an agate planetary ball mill to < 53 µm size (≥ 95%).
7. The < 53 µm material was split four ways into secure plastic pots for ICP analysis (5 g), loss-on-ignition (2.5 g), Hg (5 g) and excess sample (17.5. g).
8. A 10 g sample of < 2 mm material was potted for pH analysis.

Field samples designated as duplicate samples were split in two after sieving to < 2 mm. One half of the sample was assigned the ID of the original duplicate sample, the other half the ID of its replicate as indicated on the sample number list (*e.g.* on Figure 3: M06-008 and M06-009).

Samples were returned to GSI after preparation along with a batch of new empty plastic containers identical to those used for the sample splits. New randomized IDs were assigned to all samples, including quality control samples (*e.g.* Figure 3). Quality control samples were initially weighed out and potted by the British Geological Survey and supplied in their own standard secure containers. They were transferred to new containers supplied by ALS. All containers were then labelled with the new randomized IDs in GSI prior to transporting to ALS for analysis. The assignment of new randomized IDs ensured that the identities of all samples, including quality control samples, were blind to the analytical laboratory.

2.1.5. Geochemical analysis

Geochemical analyses were carried out by ALS at its laboratory in Loughrea, County Galway. All samples submitted were subjected to multi-element analysis by ICP following digestion in *aqua regia* and mercury (Hg) analysis by ICP, also following *aqua regia* digestion. Samples were additionally analysed for pH and loss-on-ignition, as is routinely the case for Tellus samples. However, these analyses have not been considered further in the context of SRF project.

2.1.4.1 Multi-element analysis by ICP-MS/AES following aqua regia extraction

Multi-element analysis by ICP (ALS code ME-MS41L) included 53 elements (Table C1, Appendix C). Analysis was by ICP-MS or ICP-AES. Table 8 (Appendix C) lists the elements analysed, their lower limits of detection and upper reporting limits. *Aqua regia* (3:1 conc. $HCl:HNO_3$) is a relatively weak acid leach that removes the more weakly bound elements from soils. It is relatively ineffective in removing elements, such as Na, K, Ti, that are contained mostly within silicate and oxide minerals.

A review of Tellus data and data for the GEMAS survey of European agricultural soils (Reimann *et al.* 2014), for which samples were analysed by both XRF ("total") and ICP *aqua regia*, suggests *average* extraction rates for *aqua regia*, indicatively calculated as ((ICP/XRF)*100), are around 75–85 % for As, Ni, Pb and Zn, somewhat higher for Cu but around 35% for Cr. No data are available for Cd and Hg. Broadly similar results were observed when unpublished Tellus ICP (*aqua regia*) data for

Certified Reference Materials were compared with their certified total element concentrations. In short, while ICP analysis following *aqua regia* extraction provides a reasonable estimate of total concentrations of As, Cu, Ni, Pb and Zn in soil samples, it appears to significantly under-report concentrations of Cr.

Note that not all of the variation observed between ICP and XRF analyses can be ascribed to the *aqua regia* extraction rate – analytical accuracy, instrumentation limitations, sample homogenization, laboratory reporting of data, etc., can all affect the measured difference between a given pair of analytical results. Moreover, it is important to emphasize that the proportion of any element extracted by *aqua regia* digestion from any given soil sample will depend on the mineralogical composition of that soil sample. Thus, extraction rates can vary significantly in line with the variation in soil composition.

A total of 20 samples of reference materials, including two certified reference materials (CRMs), TILL-3 and STSD-3, and two in-house Tellus secondary reference materials (SRM), ANTBAS and LDOWN, were analysed along with the soil samples, having been inserted blind to the analyst as described previously. Data for the RMs are provided in Table 9 (Appendix C). In general, reported results for the elements of interest, with the exception of Hg for which no useful reference material was included, were within acceptable limits.

2.1.4.2 Mercury analysis by ICP-MS following aqua regia extraction

Mercury (Hg) is recognized as posing particular problems for geochemical analysis, because of the risk of volatilization and thus loss of Hg at the relatively high temperatures frequently employed during sample preparation, *e.g.* drying, and during acid digestion prior to analysis. Cold-vapour atomic absorption spectrometry (CV-AAS) has long been the standard method for Hg analysis but advances in instrumentation in recent years have made ICP the method of choice for many applications and an increasingly viable option for Hg analysis.

Mercury is included in the multi-element suite analysed by ICP following *aqua regia* digestion. However, given its significance as a potential contaminant in soils, and the need to understand the limitations of the standard ICP *aqua regia* method, it was decided to carry out additional analysis of the samples for Hg using a single-element method (ALS code Hg-MS42), which also involves digestion by *aqua regia*. By analysing the samples separately for Hg, it was possible to include three

Hg-specific CRMs, different to those employed for the multi-element suite, thus providing useful QC for Hg analysis. The CRMs (OREAS25a, CRM-020 and PACS-3) have certified total Hg concentrations ranging from 0.1 mg kg^{-1} to 2.9 mg kg^{-1}. The results (Table 10, Appendix C) are generally acceptable estimates of Hg concentrations in the CRMs.

2.1.6. Particle size analysis

Particle size analysis (PSA) was carried out by Metlab Ltd., Ballygarvan, County Cork. PSA groups soil and subsoil particles into separate ranges of sizes to determine the relative proportion by weight of each size range. The method employs sieving and sedimentation of the soil/water/dispersant suspension to separate the particles. The sedimentation technique is based on an application of Stokes' law to a soil/water suspension and periodic measurement of the density of the suspension.

The soil and / or subsoil samples are passed through a series of sieves which range in mesh size from 125 mm to 0.063 mm, and the percentages by weight passing through each sieve recorded. Finer fractions, i.e. silt and clay, are assessed by hydrometer.

2.1.7. Geophysics

To assist in the interpretation of subsoil stratigraphy and the depth to bedrock a series electrical resistivity tomography (ERT) profiles were carried out at Locality A following the completion of the drilling programme. Site work was undertaken on 23rd and-24th May 2019 and consisted of five ERT profiles in areas of interest as identified by the drilling programme. The locations of the five profiles are shown below in Figure 4.

The survey used the GF Instruments ARES resistivity meter and a Schlumberger array with an electrode spacing of 1m for all profiles with the exception of profile 3 which used a 2m spacing setup. Profile length was limited by available space between borehole locations. Profile 4 was the longest profile using 168 electrodes and extending to 167m in length. Table 1 table below shows the profile specifications.

Profile Name	Electrode Spacing (m)	No of Electrodes	Profile length(m)
ERT 1	1	56	55
ERT 2	1	111	110
ERT 3	2	64	126
ERT 4	1	168	167
ERT 5	1	72	71

Table 1 Specifications for resistivity tomography (ERT) profiles

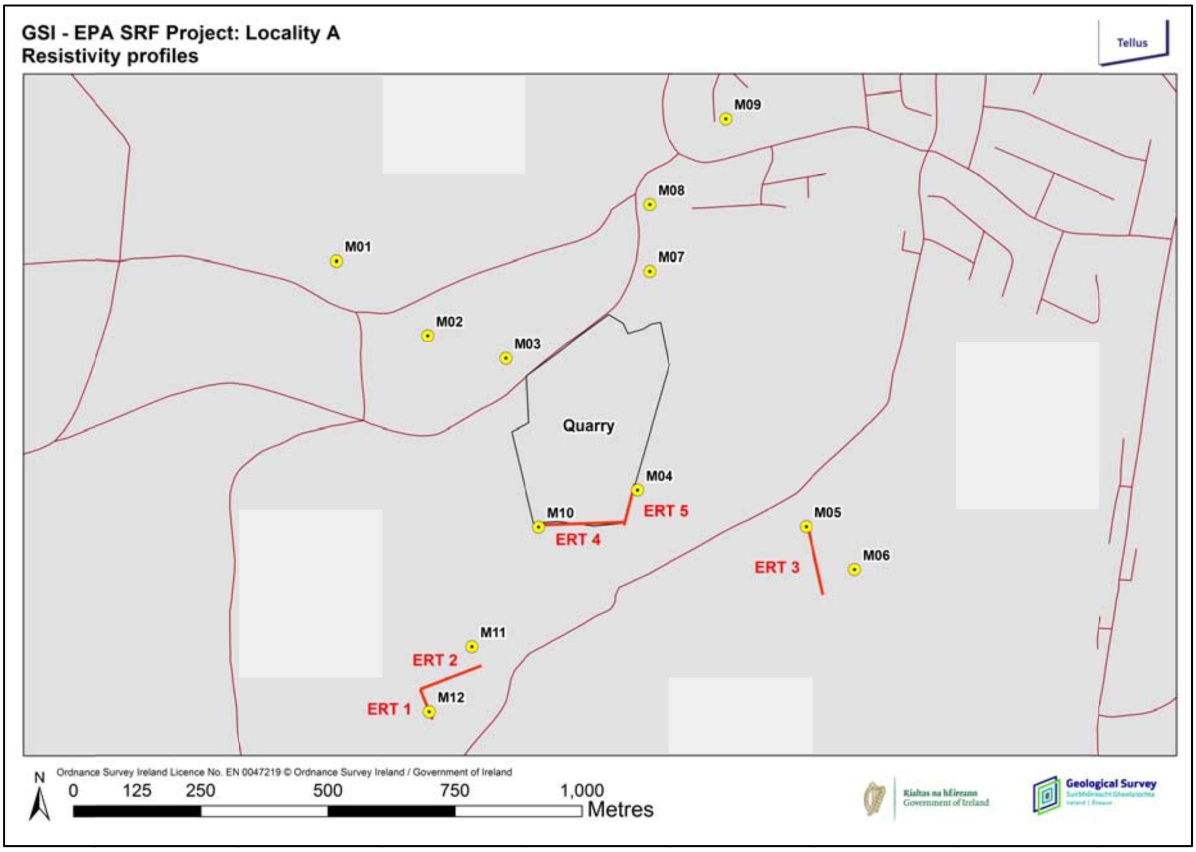


Figure 4: Geophysical Electrical Resistivity Tomography (ERT) profile locations in red. Borehole locations in yellow.

2.2. Geochemical domains

The geochemistry of soils in Ireland generally reflects the composition of the rocks from which they are derived through weathering (O'Sullivan *et al.* 2018). Transport of weathered material, *e.g.* through glacial movement, can create a soil that is derived from a parent material that differs from the bedrock that it overlies. Therefore the approach to defining domains for this study has considered both bedrock geology and subsoil geology. The perceived need to avoid unnecessary complexity in domain analysis and the lack of high-resolution or high-density soil or subsoil geochemical data that could support a more detailed subdivision led to a decision to attempt to rationalize the number of proposed domains, yet still remaining consistent with the overall bedrock and subsoil variation in the country.

2.2.1. Datasets used

The 1:40,000-scale Teagasc–EPA subsoils map of the 26 counties of Ireland (Fealy *et al.* 2009) forms the basis of the subsoil classification used in defining the subsoil domain map. Different approaches have been used in classifying subsoil material in Ireland. The GSI Quaternary map (https://www.gsi.ie/en-ie/data-and-maps/Pages/default.aspx) is classified partially according to stone counts while the Teagasc-EPA map also incorporates information, where available, regarding the matrix of the soil. In practice, there are only minor differences between the two maps but the matrix composition was considered to be relevant to a geochemistry-based domain classification, hence the decision to adopt the Teagasc–EPA map.

GSI has published three seamless national bedrock geology maps at 1:100,000, 1:500,000 and 1:1,000,000 scales (https://www.gsi.ie/en-ie/data-and-maps/Pages/default.aspx). For the purpose of generating a bedrock geology domain map, the 1:500,000 scale map was preferred as it contains sufficient detail of lithological subdivisions in the country to allow comparison with the Teagasc-EPA subsoil map, while meeting the need to avoid unnecessary complexity. The 1:100,000-scale map contains over 1100 individual lithological units and would present significant problems of reclassification in order to define SRF domains. The 1:500,000 map is, in any case, derived from the 1:100,000 map through a reclassification process informed by lithology and stratigraphy.

Soil geochemistry databases with national coverage in Ireland include the National Soils Database (NSDB) (Fay *et al.* 2007) and the low-density pan-European FOREGS and GEMAS surveys. Soil samples for the FOREGS survey (Salminen *et al.* 2005) were collected at a density of 1 sample per 5,000 km^2 while those for the GEMAS survey were collected at a sampling density of 1 sample per 2,500 km^2. Samples for the NSDB were collected at a much higher sampling density and the NSDB has thus been used as the basis for geochemical characterization of the domains defined on the basis of bedrock and subsoil geology. The NSDB comprises 1310 samples collected on a regular 10 x 10 km grid, with two samples taken per grid square, giving a nominal sampling density of one sample per 50 km^2. Composite samples were taken from a 20 x 20 m grid at each site to a depth of 0.10 m. Multielement analysis by ICP-OES/MS followed a four-acid digestion to give “total” element concentrations. Atomic fluorescence spectrometry was employed for Hg and Se analysis.

There are two main limitations to the use of the NSDB in respect of domain analysis for SRFs. Firstly, the NSDB data relates to topsoil whereas the "soil" material placed in SRFs is subsoil, generally excavated from depths exceeding 0.5 m. There have been no detailed studies of the geochemistry of subsoils in Ireland so the relationship, if any, between topsoil geochemistry and subsoil geochemistry is unknown. The site surveys carried out for this project are, in part, an attempt to increase understanding of this issue. However, until completion of national coverage by the Tellus soil geochemistry survey, at a sampling density of 1:4 km^2, the NSDB remains the only means available to establish soil geochemical domains for Ireland across all of the State.

The second main limitation of the NSDB is its relatively low sample density. As outlined below, seven geochemical domains have been defined for Ireland, based on bedrock and subsoil geology. The geological and lithogeochemical variation in the country would justify a far greater number of domains but the low sample density of the NSDB means that many of these additional domains would necessarily have very low sample numbers associated with them, severely reducing the reliability of any statistical treatment. Future availability of Tellus data will allow for a more detailed domain analysis while improving the robustness of the statistics associated with individual domains. For the seven domains defined for this study, the number of NSDB samples that fall within each domain ranges from 51 to 431.

2.2.2. Domains definition

Initial bedrock and subsoil domain maps (Figure 5 and Figure 6) were generated independently but using a similar naming scheme for the respective domains. All mapping work was carried out in ArcGIS 10.3. The first step was to create a bedrock domain map by simplifying the 1:500,000-scale bedrock map, reducing the number of units to 11 by amalgamating rock units and groups based on broad similarity of rock type and age.

The second step was to create a subsoil domain map derived from the Teagasc-EPA subsoil map. This initial subsoil domain map contained 13 classes, again created by amalgamating subsoil units based on broad similarity of parent material. In this subsoil domain map, various classes were excluded from the domain analysis, including alluvial deposits, lacustrine deposits, made ground, marine (coastal) deposits and bedrock. Moreover, the "peat" categories in the subsoil map were not assigned to a specific lithological domain.

Although the initial bedrock and subsoil domain maps are broadly similar, the larger scale of the latter gives rise to significant variation in mapped detail (Figure 7). Despite the greater mapping detail, the classification scheme in the subsoil map is considerably simpler than for the bedrock maps, comprising 67 distinct classes of which only around 40 have a specific lithological classification (Table 13, Appendix F). In contrast, the 1:500,000 map has 71 individual lithological classes across the 26 counties of Ireland (83 for the island as a whole) and is derived from the 1:100,000 map, which has over 1100 separate lithological units. There is insufficient information available to allow reclassification of the subsoil types given that the original mapping used a simplified classification scheme to start with, describing units in terms of broad lithological or lithostratigraphic characteristics, *e.g.* "tills derived chiefly from limestones", "tills derived chiefly from schist", "tills derived chiefly from Lower Palaeozoic sandstone and shale". Thus, the decision was taken to reclassify and rename the bedrock domains to follow the classifications in the subsoil domain map.

The final bedrock and subsoil domain maps were defined (Figure 8 and Figure 9) following completion of this review process. Both have seven lithological domains with the subsoil map also displaying areas classified as peat and bedrock as well as unclassified areas such as made ground.

For the final domain map (Figure 10), the bedrock and subsoil maps were unified using the geospatial analysis union tool in ArcGIS. Domains were classified according to the subsoil domain except where no subsoil domain had been assigned – these areas were classified according to the bedrock domain map. Thus, areas of peat, made ground, bedrock, etc., on the subsoil map were classified according to the corresponding bedrock domain. The single unified domain map is shown in Figure 10, with simplified class descriptors - Table 2 outlines the lithological composition of each. The GSI 1:500,000 bedrock map classes and the EPA-Teagasc subsoil map classes that correspond to the domain map classes are given in Table 12 and Table 13 (Appendix E).

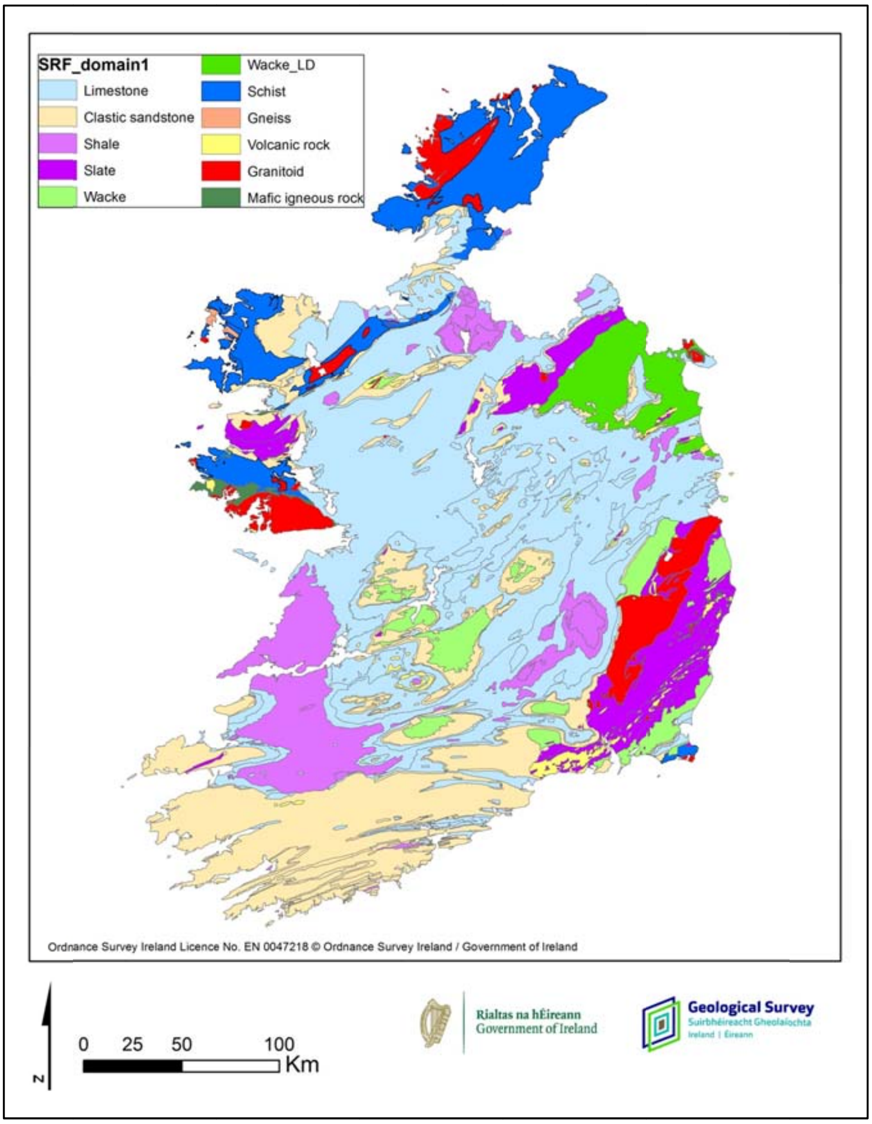


Figure 5 Initial bedrock domain map

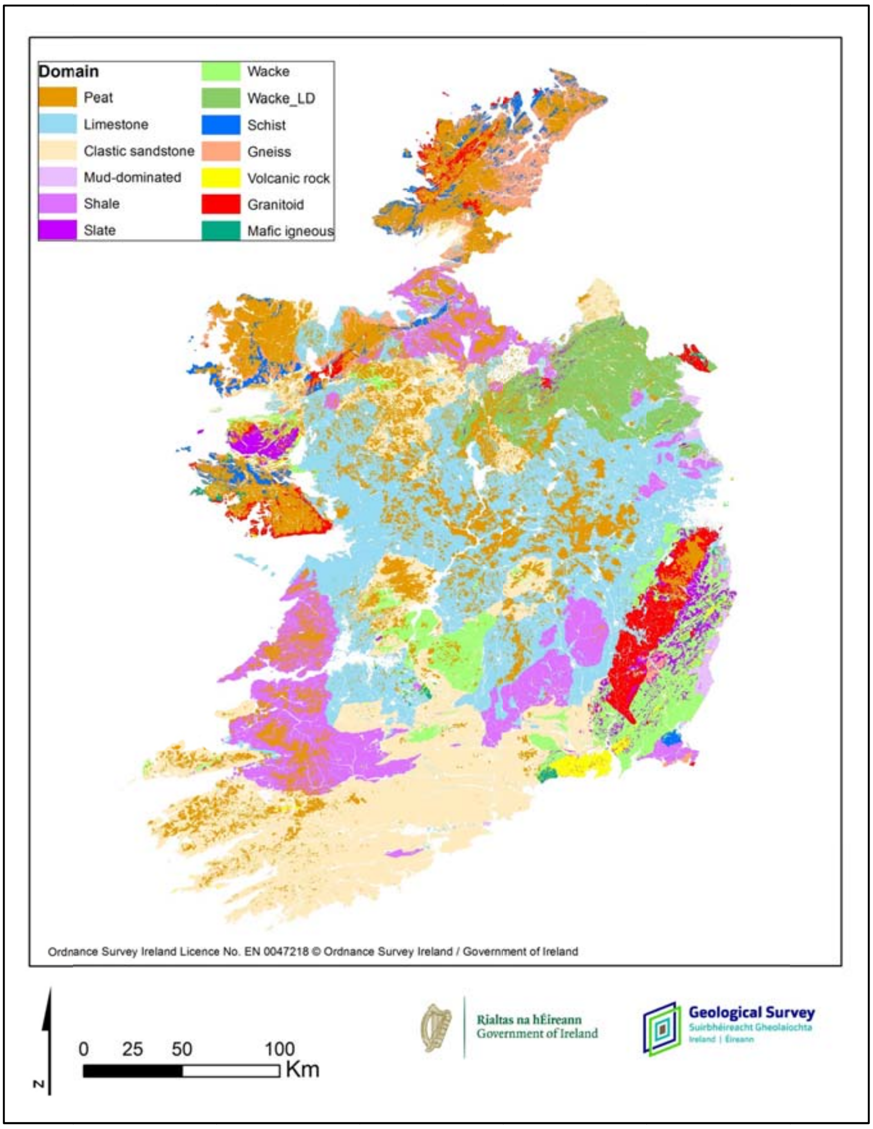
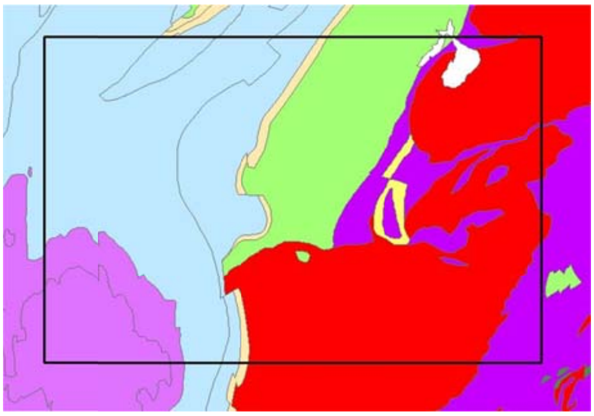
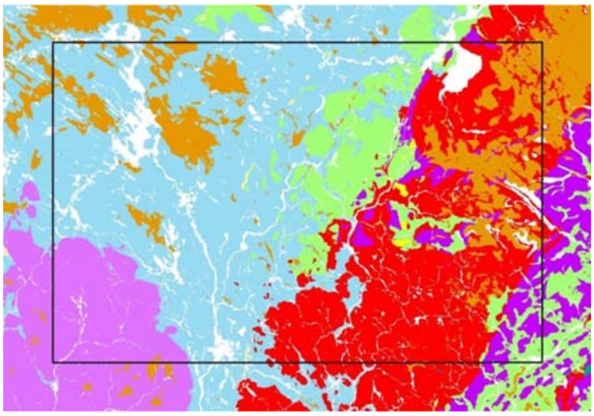


Figure 6 Initial subsoil domain map





Bedrock domain map, detail

Subsoil domain map, detail; same area

Figure 7 Detail of bedrock and subsoil domain maps showing difference arising from scale of mapping; each view c. 65 km wide; northwestrn end of Wicklow Mountains.

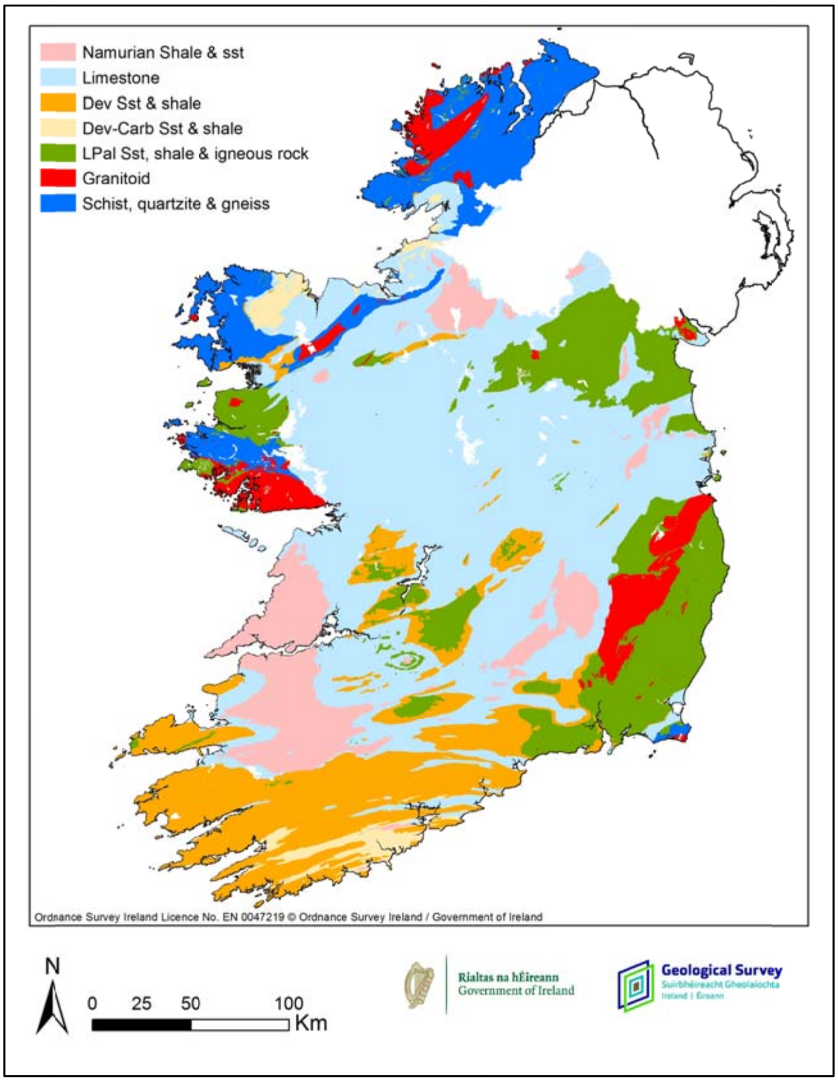


Figure 8 Final bedrock domain map

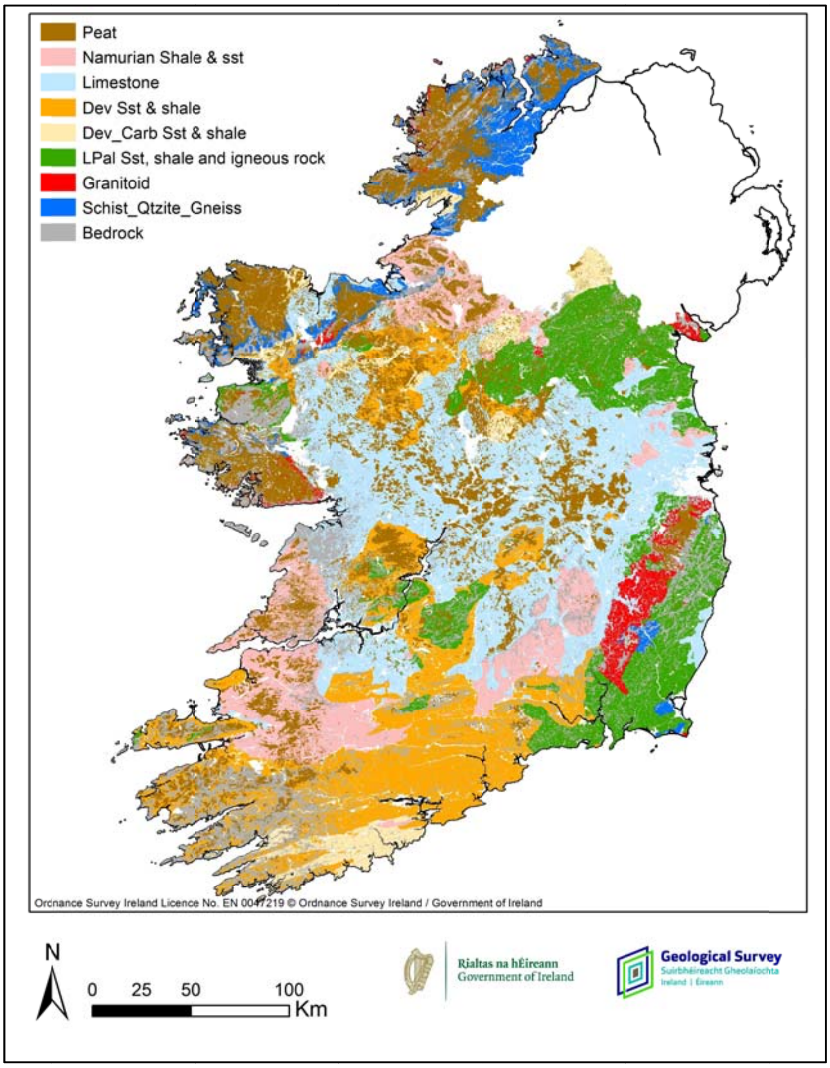


Figure 9 Final subsoil domain map

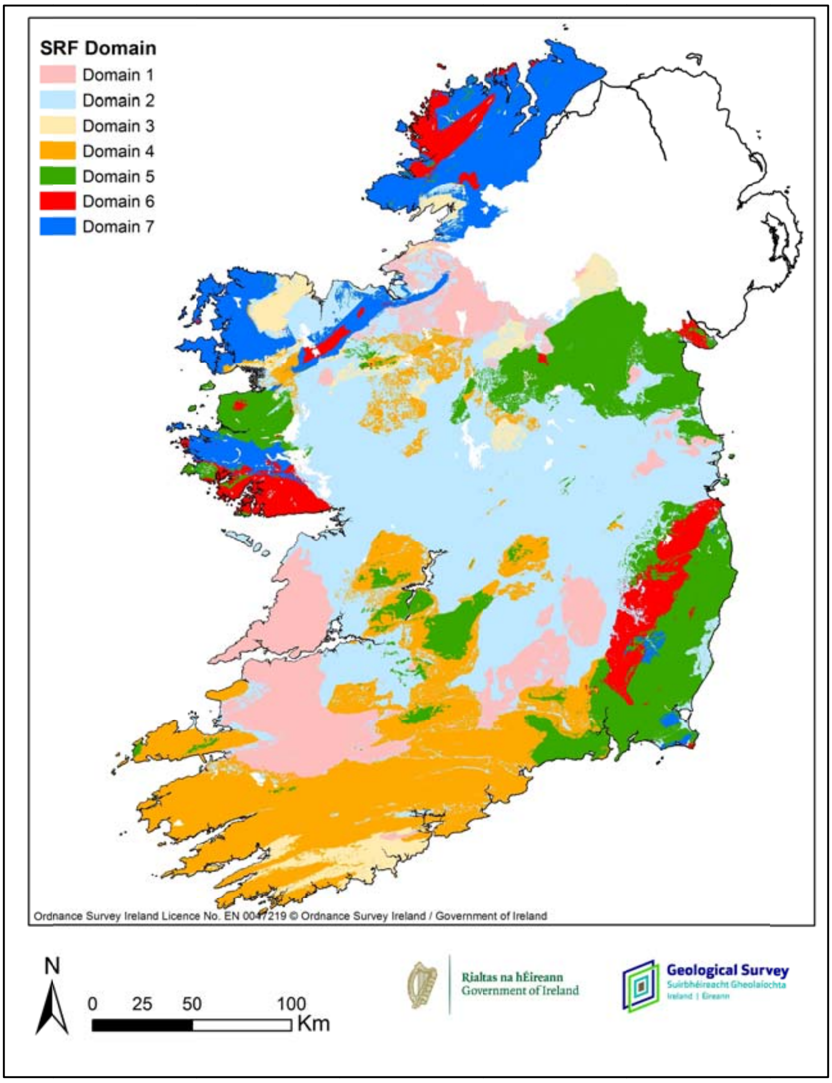


Figure 10 Final domain map

Final Domain map class	**Primary Lithology**
Domain 1	Namurian shale and sandstone
Domain 2	Carboniferous limestone and related rocks
Domain 3	Devonian to Carboniferous sandstone and shale
Domain 4	Devonian sandstone and shale
Domain 5	Lower Palaeozoic sandstone, shale and igneous rock
Domain 6	Granitic rocks
Domain 7	Schist, quartzite and gneiss

Table 2 Names and descriptions of final domain classes

2.2.3. Geochemically Appropriate Levels definition

Various approaches have been taken over the years to establishing geochemical thresholds for soil and other media (*e.g.* Reimann *et al.* 2005; Ander *et al.* 2013; McIlwaine *et al.* 2014; Reimann *et al.* 2018). In summary, the aim has been to define threshold values that mark the boundary between "normal" values and unusually high or low values in a dataset. These can be characterized as distinguishing between "background" and "anomalous" values, *e.g.* as in mineral exploration, or between "usual" and "unusual" values. In statistical terms, most approaches seek to identify a threshold above or below which outliers are present in the dataset. The original approach to identifying outliers in geochemical datasets came from the mineral exploration industry (Reimann *et al.* 2018) and involved setting the threshold equal to the mean + 2 standard deviations. This upper threshold includes around 96% of data for a normal distribution.

A key consideration when defining threshold values is the purpose to which the values will be put. For example, in the case of identifying possible mineral exploration targets or potentially contaminated sites with a view to remediation, the aim could be to identify only the uppermost outliers, limiting the number of sites to be assessed in line with budgetary and manpower constraints. In such a case, threshold values could be set at a relatively high level. Where the aim is to minimize potential risks to the environment in the context of adopting a conservative approach to environmental protection, lower threshold values may be more appropriate.

For the SRF guidelines, the purpose of developing Geochemically Appropriate Levels (GALs) is to ensure that material placed in quarries or pits licenced as SRFs does not lead to an increased geochemical load above what would be expected if the SRF contained soil similar to that existing prior to excavation of the quarry or pit. For a given SRF, the geochemical domain in which it sits, as defined from the domain map, is taken as the basis for defining GALs for that SRF. Therefore, in defining GALs for any given domain, the aim is to distinguish between the range of values considered "normal" for that domain, reflecting natural geogenic processes, including mineralization, and outlier values that may arise from anthropogenic contamination, such as industrial activity.

Geochemical data are generally skewed, i.e. are not normally distributed. Normal distributions have a typical bell-curve shape, with values distributed symmetrically about the mean. For data that are not normally distributed non-parametric statistics, i.e. those not required to fit a normal distribution, are generally employed. Typically this involves the use of ranking, *e.g.* percentiles, to classify and compare data. Tukey's boxplot (Tukey, 1977) is a common means of displaying geochemical data distribution based on percentiles. Figure 11 shows an idealized boxplot for a normal distribution. The central box spans the range from the 25th to 75th percentile, the second and third quartiles of the data, termed the interquartile range (IQR). The upper whisker value or Tukey Inner Fence (TIF) value is defined as (Q3 + 1.5 * IQR), where Q3 is 75th percentile.

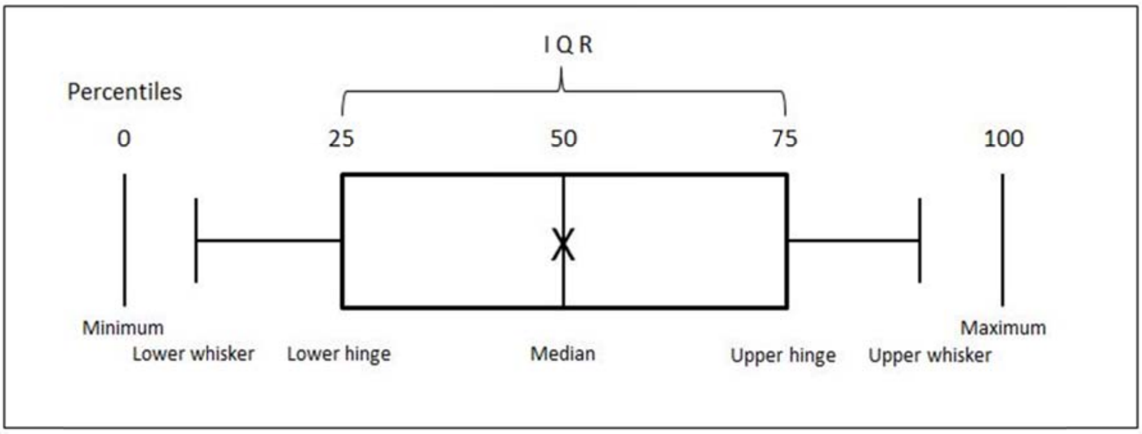


Figure 11 Tukey boxplot

Reimann *et al.* (2018) provide a detailed comparison of various threshold calculations applied to the GEMAS dataset, a pan-European geochemical survey of agricultural soils that includes over 2100 samples. A number of the options, including some outlined by Reimann *et al.* (2018), were explored for calculating SRF thresholds, including:

- Tukey Inner Fence (TIF or upper whisker)
- Cumulative Probability diagram
- 90^{th} percentile (original EPA guidance)
- 95^{th} percentile
- 98^{th} percentile

TIF was considered for raw data and for transformed data (Log10 transform and Box-Cox transform). For some elements in some domains, the TIF exceeds the maximum for the domain. This can arise where the element has a relatively narrow distribution as the TIF value is extrapolated from the inner core of the data (the IQR) (*e.g.* Reimann *et al.* 2018). However, low sample numbers and the presence of sub-populations within the data can also have a significant impact on TIF calculations, in spite of data transformation intended to "normalize" the distribution. While statistically it is not unreasonable for calculated threshold values to exceed the maximum value of the data set, the practical concern in setting such GALs for any given domain is that it may be considered an excessively permissive approach in the context of environmental protection, where a conservative approach to threshold setting may be considered more appropriate.

Breaks in the Cumulative Probability (CP) curve were also considered. Such breaks can be very useful in identifying the point at which discontinuities emerge in a dataset, including the threshold above which outliers can be identified, and are considered one of the most robust methods for identifying outliers or sub-populations (Reimann *et al.* 2018). However, use of CP curves requires expert input and involves a degree of subjectivity, making replication of the process difficult.

The 90th, 95th and 98th percentiles are defined, respectively, as the values below which 90 %, 95 % and 98 % of values in a dataset fall. The use of any percentile value to define a threshold is essentially arbitrary since it defines, in these instances, 10 %, 5 % or 2 % of values in the dataset as outliers without any interrogation of the dataset to justify this. Ander *et al.* (2013) proposed the upper 95% confidence of the 95th percentile value to define natural background concentrations (NBCs) in English soils. In its draft guidance for SRFs (EPA, 2017), the EPA has proposed the 90th percentile value of each element in the NSDB as the trigger value, a particularly conservative value that is unlikely to encompass the full extent of natural variation in soils in individual domains in Ireland.

Following a detailed assessment of all of the various methods and of the threshold values calculated from them, the 98th percentile was selected as the basis for computing trigger value for each of the defined domains. The 98th percentile value has a number of advantages:

- it is sufficiently permissive to encompass most natural geochemical variation within a given domain;
- it is essentially unaffected by the degree of skewness in the data;
- it does not require data transformation;
- it does not produce values that lie outside the existing data range for a given domain; and
- the calculation is readily understood and easily replicated.

While the concept of percentiles and the calculations underlying them are straightforward, there are different and equally valid ways of calculating percentiles. Throughout this project we have employed various statistical packages, including ioGAS, Minitab and standard functions in Excel. For the calculation of the 98th percentiles used for the GALs, we have used ioGAS. The formula for calculating the percentile is presented in Appendix G. Minitab employs the same formula whereas Excel's "percentile" function uses a different calculation. For datasets with 100+ samples, the difference in the calculated value of the 98th percentile is typically very small but for datasets with fewer than 100 samples, the divergence can be significant.

3. Results

3.1. Site investigation

3.1.1. Conceptual site models

3.1.1.1 Locality A

Desk study data suggest that bedrock at Locality A comprises calcareous shale and limestone (**Error! Reference source not found.**), which is overlain by sandstone and shale till (Lower Palaeozoic) with a matrix of Irish Sea Basin origin (Figure 13). An extensive area of glaciofluvial sands and gravels dominated by clasts of Lower Palaeozoic sandstone and shale also occurs to the east of the site.

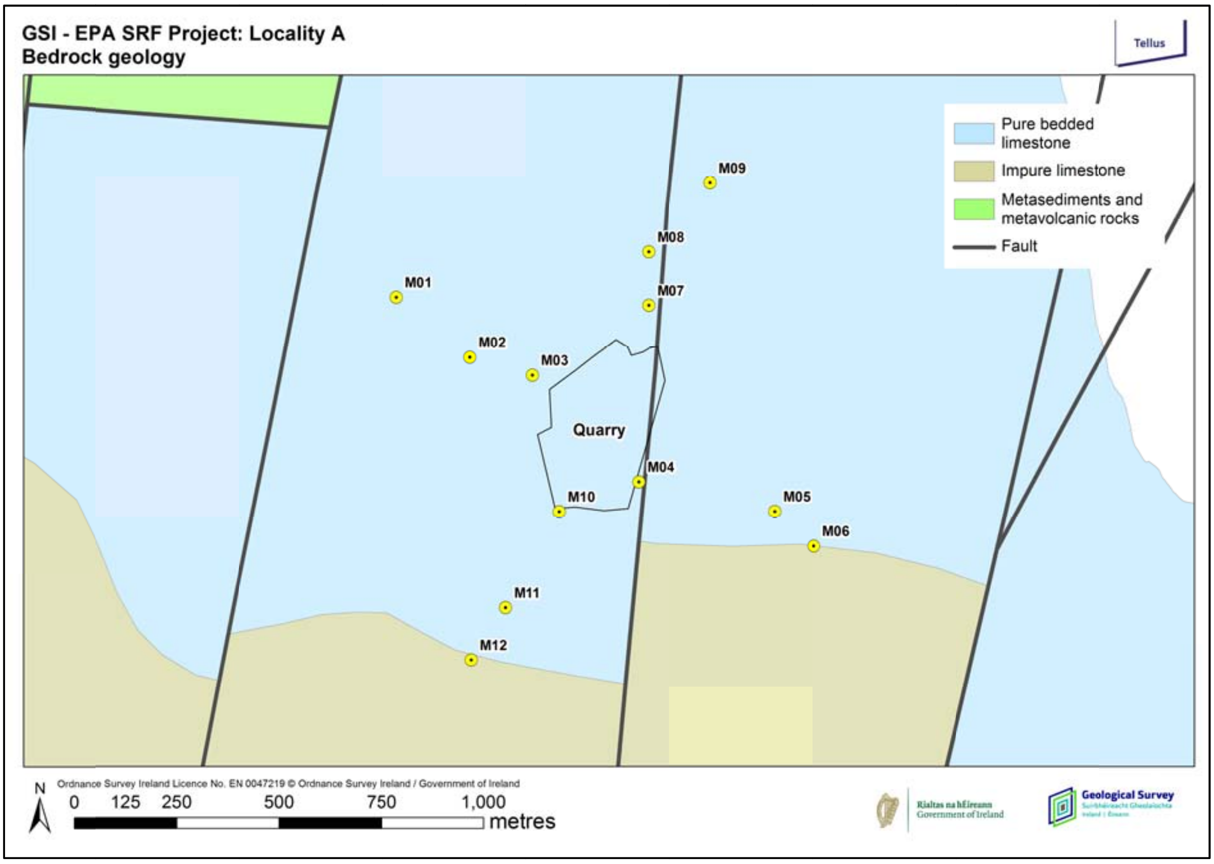


Figure 12 Mapped bedrock geology (1:100,000) of the Soil Recovery Facility site and its surrounding area at Locality A. Site investigation borehole (M01–M12) locations shown.

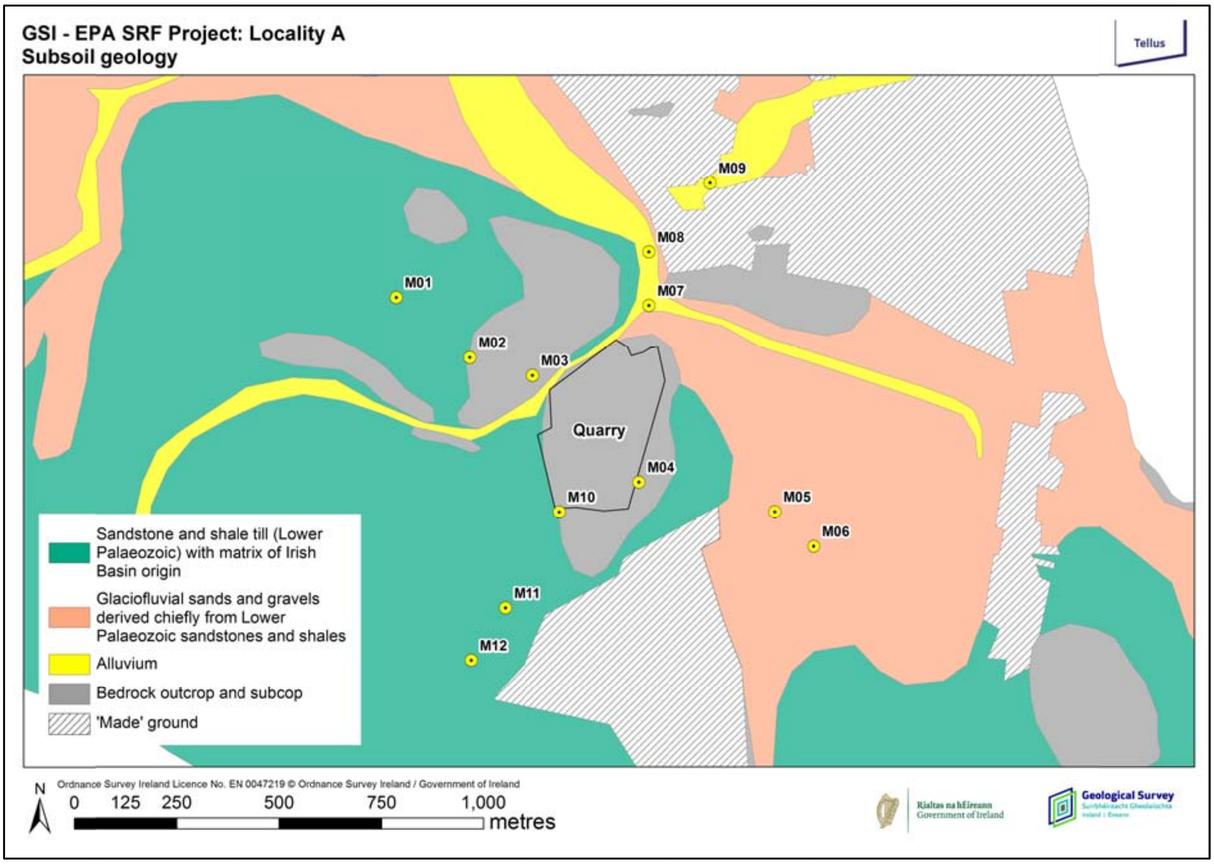


Figure 13 Mapped subsoils geology (1:40,000) of the Soil Recovery Facility site and its surrounding area at Locality A. Site investigation borehole (M01–M12) locations shown.

Alluvium subsoil is present flanking the streams around the site, as well as some 'Made' ground around the local village and in the area of a golf course to the south. Soils in this locality are shallow and calcareous where bedrock crops out in and around the SRF itself, but are deep and acidic in the wider locality, and relatively well drained on the sands and gravels.

The drilling at Locality A allowed an examination of a much more detailed and complex stratigraphy in terms of soils, subsoils and bedrock.

Along the northwest to southeast profile (Figure 14):

- 'Pure' limestone bedrock was only met definitively in one borehole (M04), but is assumed across the entire extent of the profile.
- Groundwater was met in the subsoils, and above bedrock, in five of six holes.
- Local till and sands and gravels, which occur at depth in the southeastern area of the transect, were potentially deposited during the early part of the last glaciations; the sediments at the base of borehole M06 may even be older, pre-Quaternary sediments.

- Both till and sands and gravels are overlain by 'Irish Sea Till', deposited by ice moving onshore from the Irish Sea , potentially at or during the last glacial maximum.
- Most of this transect, including the area of the quarry itself, is overlain by 'local' limestone till, deposited by an advance of lowland ice from the northwest, towards the end of the last glaciation.

Along the northeast to southwest profile at Locality A (Figure 15):

- 'Pure' limestone bedrock was not met but is assumed across the northern two-thirds of the profile; 'impure' limestone was met at the base of boreholes M11 and M12.
- Transition zone bedrock with a thickness of 1.6 m to 2.1 m was met in each of these latter two holes.
- Limestone bedrock was probably met at the base of other four holes where the cable tool refused penetration, with a broken limestone transition zone interpreted from the sequence in M07 and M08, in a mapped fault zone.
- 'Local' till and sands and gravels occur at depth in the northeastern area also, potentially deposited early in the last glaciation.
- These local deposits are also overlain in the northeast by 'Irish Sea Till', which was deposited by ice moving onshore from the Irish Sea, potentially at the last glacial maximum.
- Most of the transect, including the quarry area, is overlain by 'local' limestone till, deposited by an advance of lowland ice from the northwest, towards the end of the last glaciation.

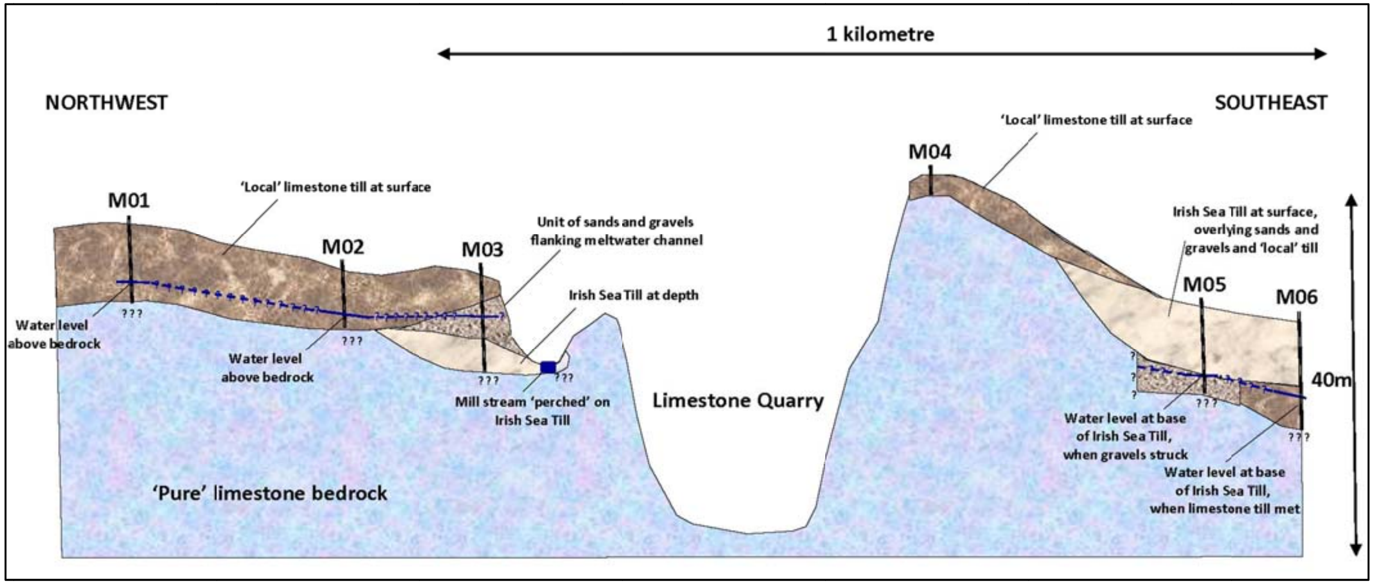


Figure 14 Northwest to southeast cross section through Locality A, from borehole M01 to borehole M06. Vertical exaggeration x 10.

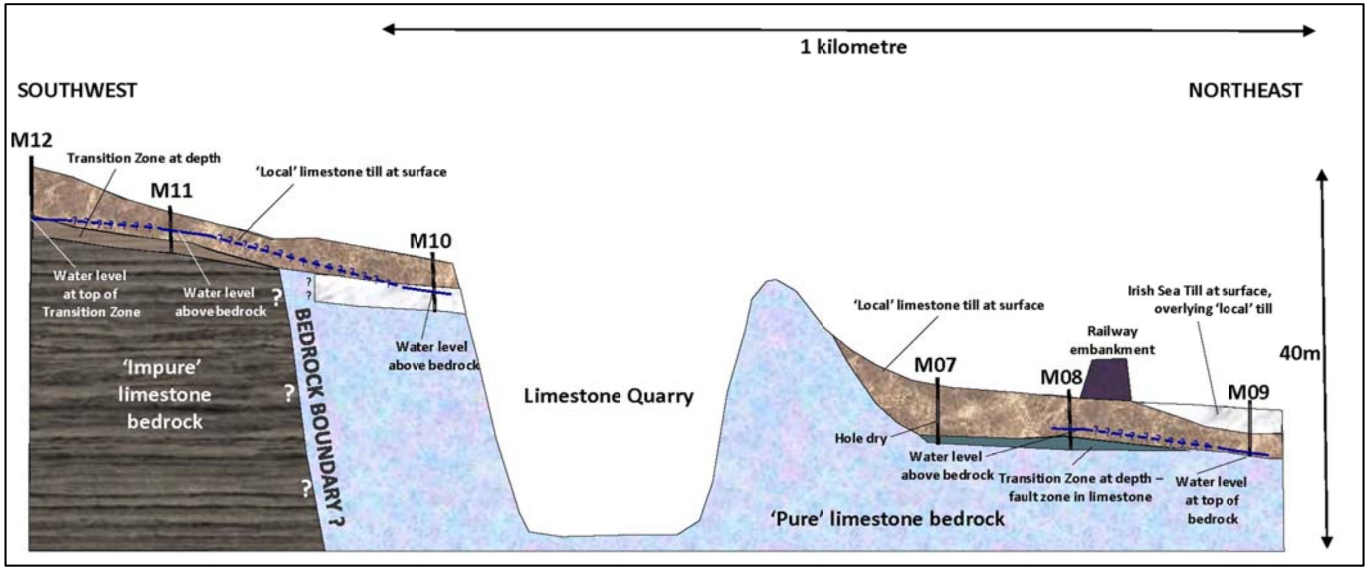


Figure 15 Southwest to northeast cross section through Locality A, from borehole M07 to borehole M12. Vertical exaggeration x 10.

3.1.1.2 Locality B

Desk study data suggest that Locality B is located in an area of Old Red Sandstone bedrock (Figure 16), which is overlain by a marked ridge comprising glaciofluvial sands and gravels derived chiefly from Lower Carboniferous limestones (Figure 17). An extensive area of till dominated by Lower Carboniferous limestone clasts also occurs around the site.

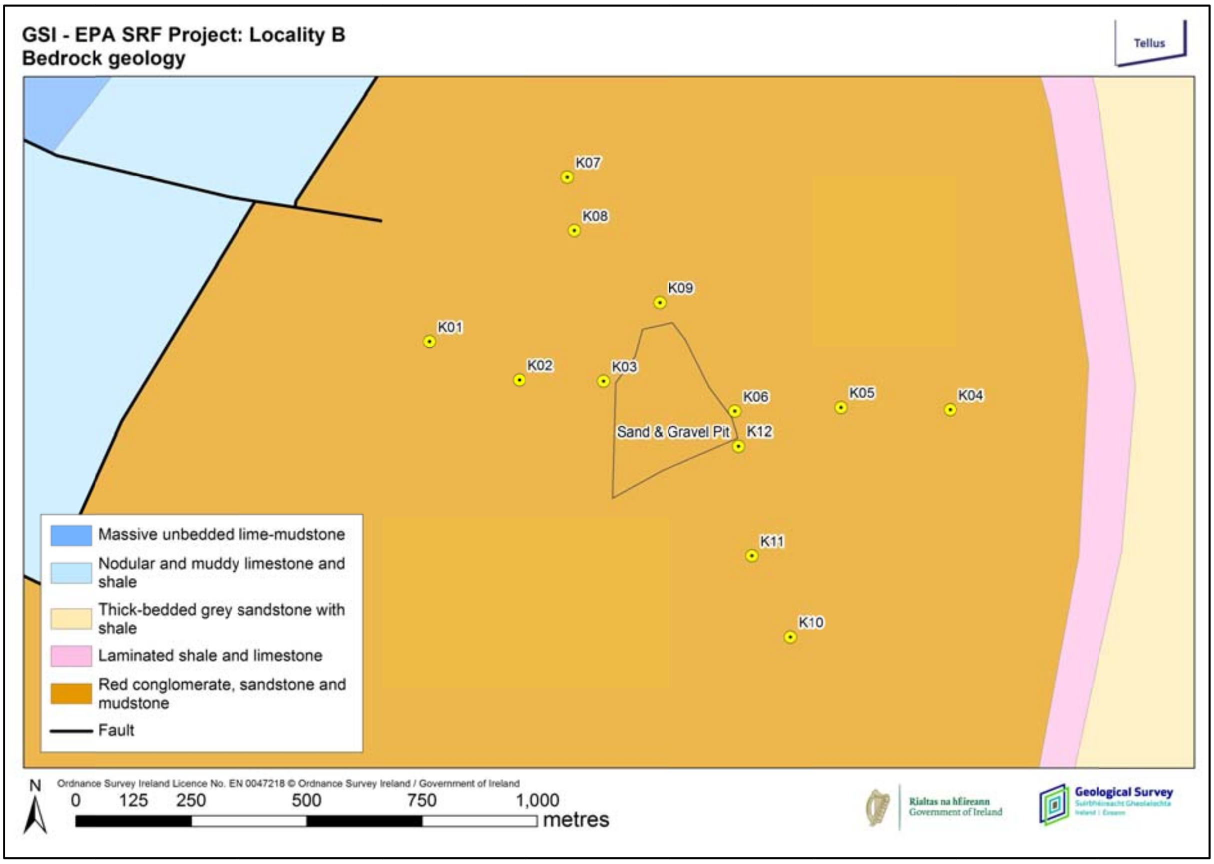


Figure 16 Mapped bedrock geology (1:100,000) of the Soil Recovery Facility site and its surrounding area at Locality B. Site investigation borehole (K01–K12) locations shown.

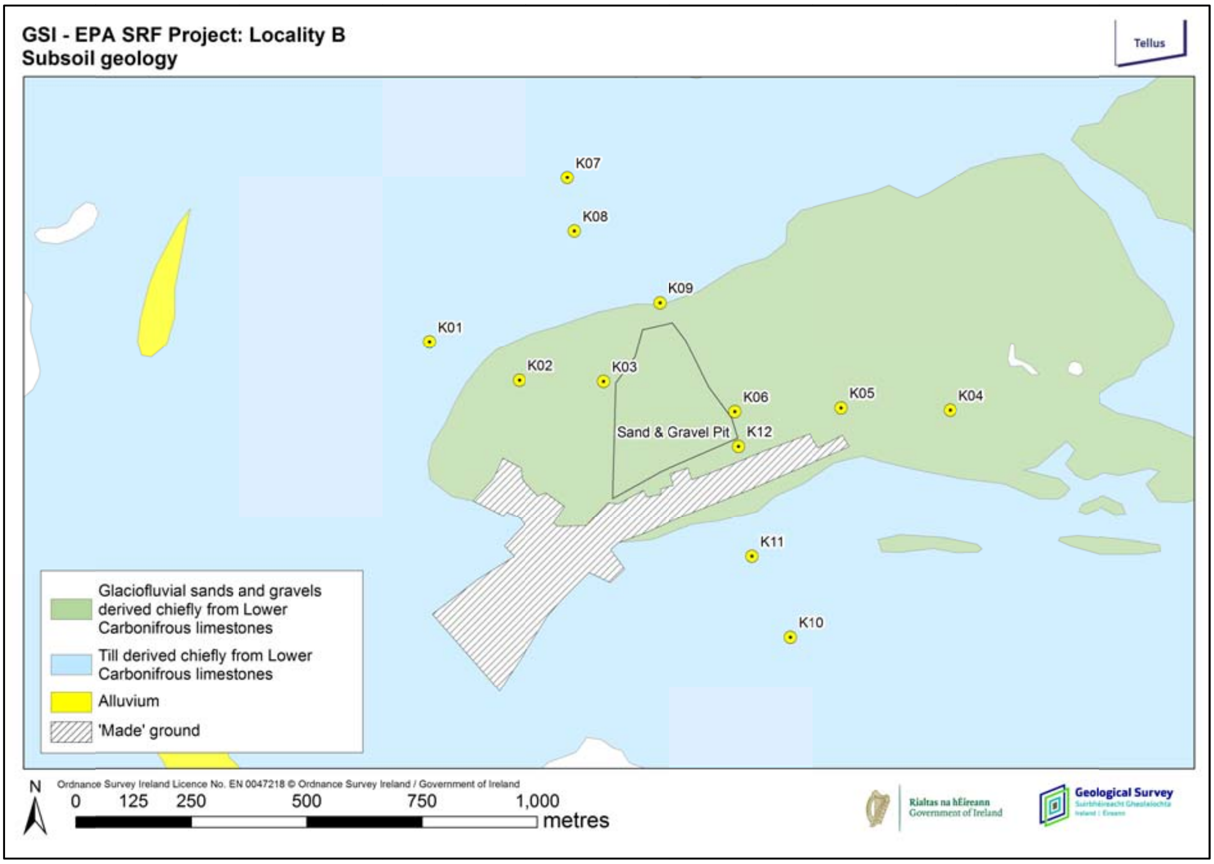


Figure 17 Mapped subsoils geology (1:40,000) of the Soil Recovery Facility site and its surrounding area at Locality B. Site investigation borehole (K01–K12) locations shown.

As at Locality A, narrow pockets of alluvium flank the streams around the Locality B SRF, and 'Made' ground covers the surface of the neighbouring village. Soils in this locality are shallow and calcareous on the sands and gravels in and around the facility itself, but are deep and calcareous in the wider locality.

Mapped sandstone bedrock is known to occur beneath the base of the pit at Locality B (20m-25m bgl) from observing and measuring the depth of subsoil faces in the pit, as well as beneath an adjacent borehole which has a groundwater level at 25m bgl. Depth to bedrock may actually be several tens of metres below ground level here, as sand and gravel has been recorded in an adjacent locality with a depth/thickness of 92m (Hydro-Environmental Services, 2016).

The drilling at Locality B allowed an examination of a much more detailed and complex soil and subsoil stratigraphy.

Along the west-northwest to east-southeast profile (**Figure 18**):

- Bedrock was not met in any of the cable tool boreholes.

- A major obstruction was met in borehole K02, possibly a large cobble or boulder. This may indicate that esker sands and cobble / boulder gravels, which are derived chiefly from limestones and which occur at depth in the sand and gravel pit faces, may also occur here.
- Limestone dominated sands and pebble gravels overlie these, dominating the substrate of the locality, all deposited during initial deglaciation.
- The glaciofluvial sands and gravels are overlain by a till which is a result of a re-advance of ice over the sands and gravels, at the very end of deglaciation.
- This readvance till is also dominated by limestone-derived material.

Along the north-northwest to east-southeast profile at Locality B (Figure 19):

- Bedrock was not met in any of these cable tool boreholes, though as groundwater was met in boreholes K10 and K11 at 5.7 m depth, bedrock may be just below this level.
- Limestone-dominated sands and gravels occur at depth, dominating the pit faces across this transect and the substrate of the locality, all deposited during initial deglaciation.
- The sands and pebble gravels are overlain by a till which is a result of a re-advance of ice over the sands and gravels, at the very end of deglaciation.
- This readvance till is also dominated by limestone-derived material.

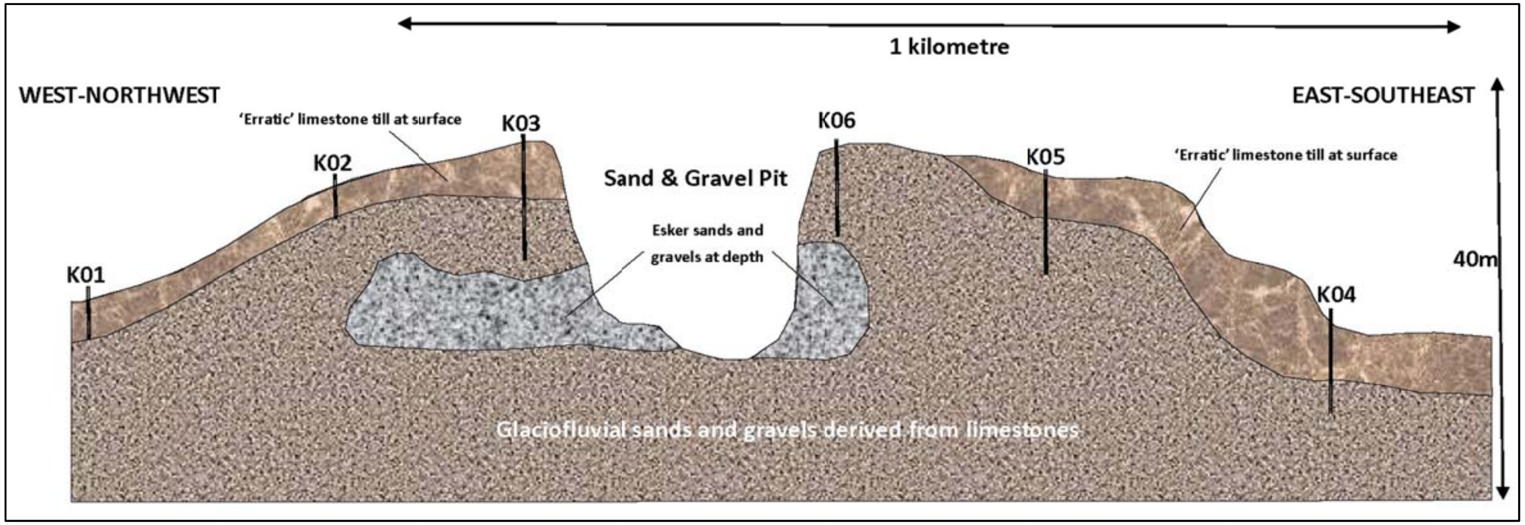


Figure 18 West-northwest to east-southeast cross section through Locality B, from borehole K01 to borehole K06. Vertical exaggeration x 10.

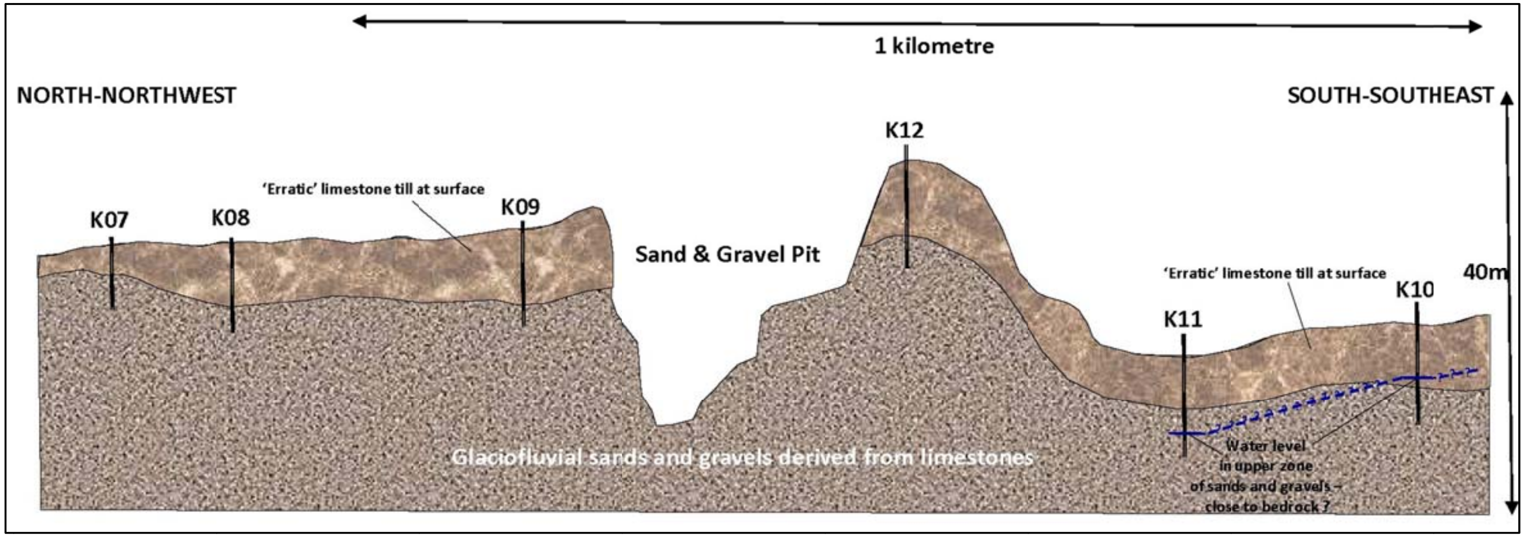


Figure 19 North-northwest to south-southeast cross section through Locality B, from borehole K07 to borehole K12. Vertical exaggeration x 10.

3.1.2. Geophysics results - Locality A

Resistivity data inversions were carried out using the Res2DIV software. The results for the five resistivity profiles are displayed in Figure 20, Figure 21, Figure 22, Figure 23 and Figure 24. Data shows apparent resistivity in ohm metres (Ω-m) with simple interpretations. The data suggest that thick subsoil occurs in places along the profiles, helping to confirm the findings from the drilling. The top of bedrock can also be mapped in places and the complex nature of the changing subsoil stratigraphy is also highlighted, particularly along profile 4.

Profile ERT 1 (Figure 20) was run south to north across a crop field close to borehole M12. Inverted data shows a thick layer of low resistivity (< 70 Ω-m), interpreted as clay rich material, i.e. subsoil. This clay rich subsoil is 3 to 4 m thick across the profile. Below this, low–medium resistivity values (100–150 Ω-m) suggest either clayey till or shale deposits. Higher resistivities (> 200 Ω-m) at depths of about 11 m bgl (30 m OD) may indicate limestone bedrock.

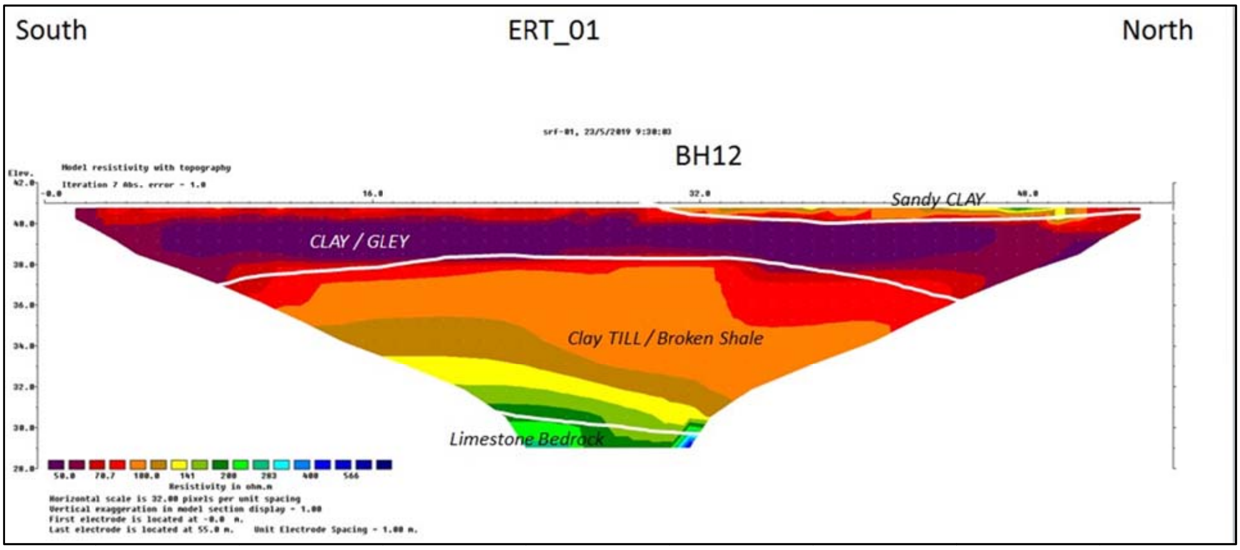


Figure 20 Interpretation of resistivity profile ERT_01

Profile ERT 2 (Figure 21) extends from the northern end of ERT 2 in an eastward direction. A top layer approximately 0.5m thick of medium resistivity values (150–200 Ω-m) would suggest a thin sand and gravelhorizon. Clay-rich deposits, to 8 m in thickness, underlie this horizon. Below, intermediate resistivities (150–300 Ω-m) over high resistivity (200 – >1000 Ohm-m) may indicate a thin shale overlying limestone bedrock. Bedrock appears to shallow towards the eastern end of the profile from about 12 to 6 m bgl.

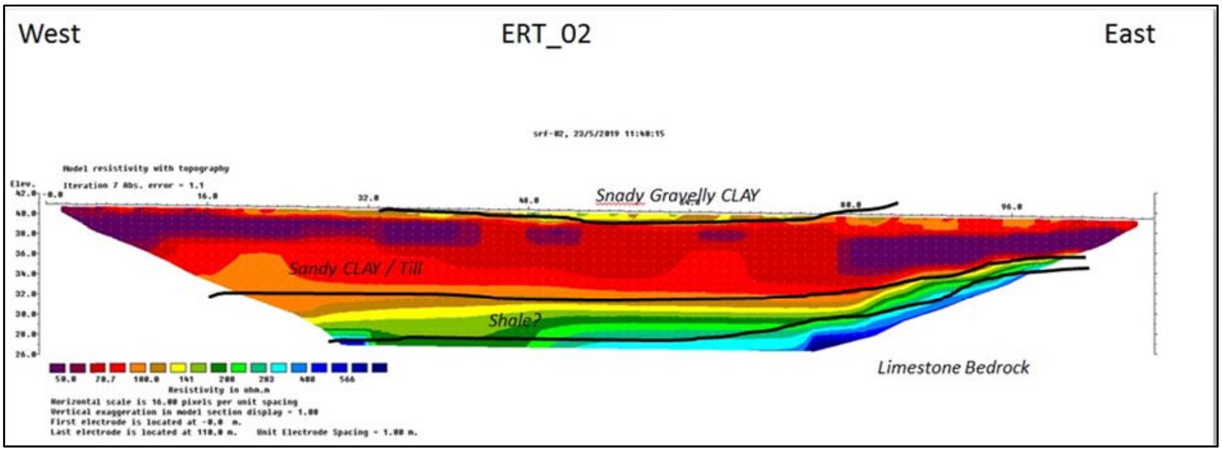


Figure 21 Interpretation of resistivity profile ERT_02

Profile ERT 3 (Figure 22**)** was carried out in the southwestern part of the site close to borehole M05 and borehole M06. The profile runs from south to north and generally shows a thick deposit of clay-rich subsoil. A thin horizon of higher resistivities at the surface towards the southern end may indicate more gravelly material. This is located close to a spring or ditch. Higher resistivities at depths of about 20 m bgl may indicate the top of bedrock.

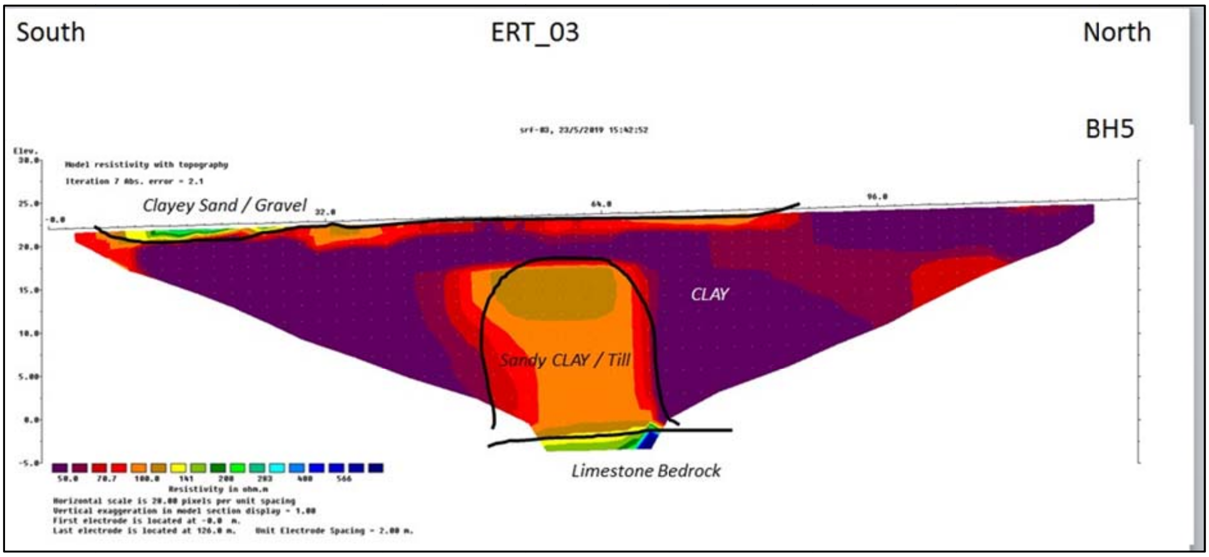


Figure 22 Interpretation of resistivity profile ERT_03

Profile ERT 4 (Figure 23**)** was located along the southern boundary of the quarry, oriented east to west. It extended for 167m, its western end close to borehole M10. High resistivity (300->1000 Ω-m) limestone bedrock is clearly shown, shallowing towards the east from a depth of about 12 m bgl to 1–2m bgl. Above the bedrock, significant variation in the subsoil can be discerned, with pockets of low resistivity (< 100 Ω-m) clay-rich material present within clayey sand and gravel horizons. Higher resistivities in this profile generally indicate a higher component of sand and gravel within the subsoil. These pockets of clay-rich material are typically 10–20 m long by 4–6m thick.

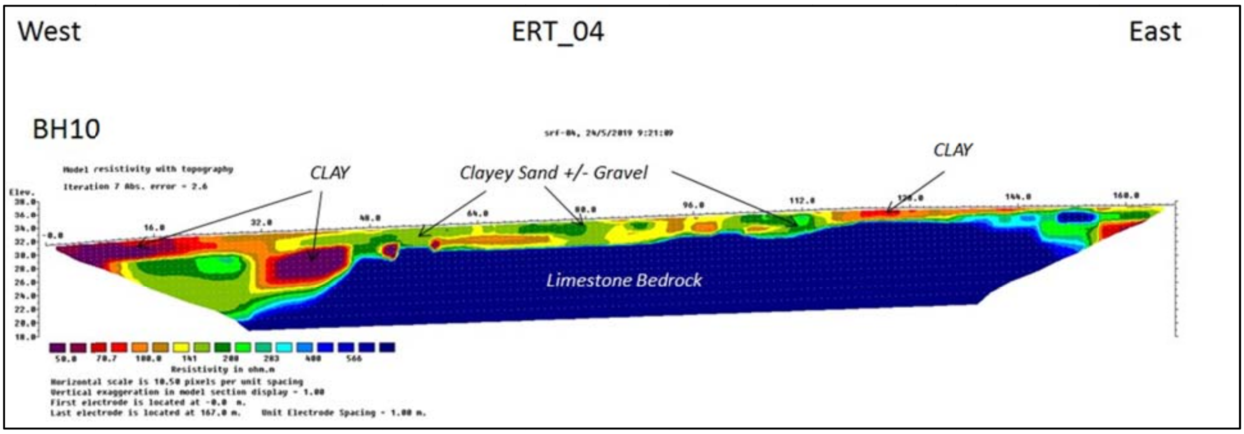


Figure 23 Interpretation of resistivity profile ERT_04

Profile ERT 5 (Figure 24) extends northwards from the eastern end of ERT 4, with its northern end close to borehole M04. Again a low resistivity layer (50-100 Ω-m) of clay-rich material is interpreted across the profile ranging in thickness from 3 to 6 m. Below this intermediate resistivity values suggest more gravelly till or weathered rock. High resistivities (300 – 1000 Ω-m) 4–14 bgl (28–38 m OD) indicate shallowing limestone bedrock to the north.

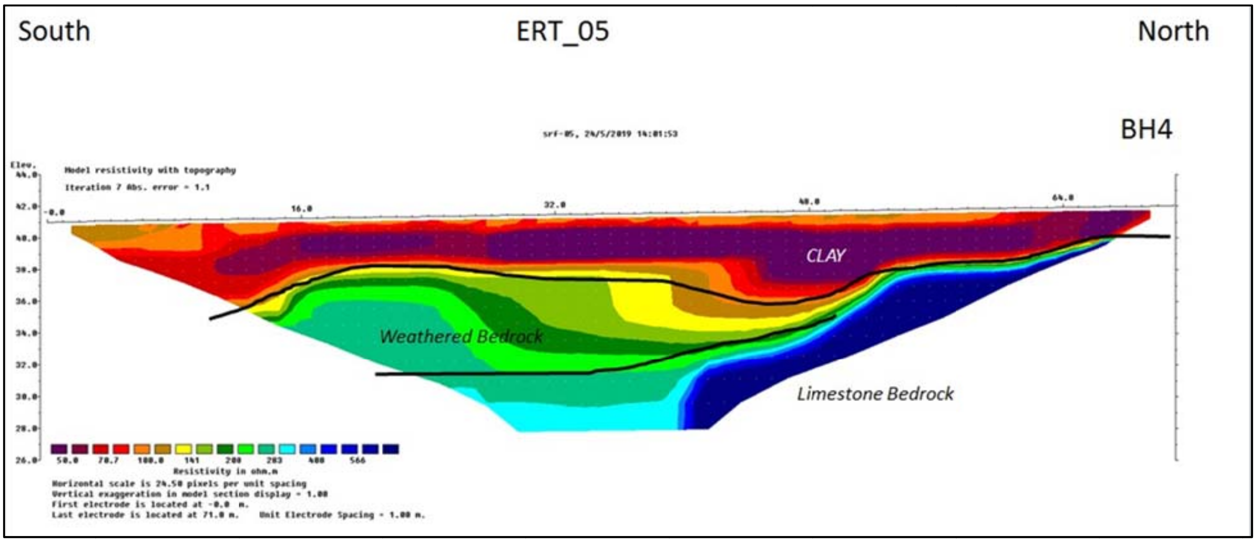


Figure 24 Interpretation of resistivity profile ERT_05

3.1.3. Particle size analysis

A total of 96 unique sediment samples from Locality A (45) and Locality B (51) were analysed for their particle size distribution (PSD), as described in Section 2.1.6. Subsoil was generally sampled from core at downhole depths of 0.5 m, 1.0 m, 3.0 m, 5.0 m and 10.0 m. In some cases, where the borehole terminated before the planned depth of 10.0 m, end-of-hole samples were taken. Table 11 (Appendix E) provides details of the samples collected and their measured proportions of sand, silt and clay.

For PSD samples collected at 1.0 m and below, geochemical samples were taken from the same section of recovered core. The PSD samples collected at 0.5 m are from core whereas geochemical samples were collected at 0.5 m from slightly different localities around the cable tool borehole, using a hand auger, and are thus not directly comparable. However, for the purposes of data exploration below, samples taken at the same nominal depth have been compiled together.

The PSD data have been compiled with the multi-element geochemical data to assess whether the sediment particle size proportions exert any control on the observed geochemical variation at Locality A and Locality B.

3.1.3.1 Locality A

A ternary plot (Figure 25) shows the variation in PSD according to subsoil classification. While the few sands and gravels samples plot towards the sand-rich end of the diagram, it is difficult to draw any conclusions concerning the remainder of the subsoil samples given the overlap of points observed.

Figure 26 shows the variation in percentages of clay content versus the eight elements of interest. In general, a moderate degree of correlation is observed between clay content percentage and element concentrations for most elements (Figure 26), with the exception of Cr, for which analytical limitations, i.e. poor extraction rates using *aqua regia* digestion, may be responsible. Pb (Pearson correlation coefficient 0.63) and As (0.54) show the strongest correlation with clay content.

Downhole logs (Figure 27, Figure 28, Figure 29 and Figure 30) compare the vertical variation in clay content to that of the elements of interest. Because the PSD samples were not taken at all the intervals sampled for geochemistry, the clay content is shown by points and a discontinuous black line. In general, the variation in percentages of clay content does show some coherence with that of the geochemistry, notably in borehole M06 where the high element concentrations at 5.0 m and below are matched by high clay content. The sediments at this basal level in borehole M06 may be older than Quaternary in age, potentially even Tertiary (see section 3.1.1.1). Given the highly weathered nature of this basal material, if the sediments are much older than those above and in the surrounding boreholes, the weathering process would mean a more intense disaggregation of compounds and potentially higher levels of certain elements (Formoso, 2006). Elsewhere, the picture is more mixed. The lack of a PSD sample at each depth sampled for geochemistry makes comparison somewhat problematic.

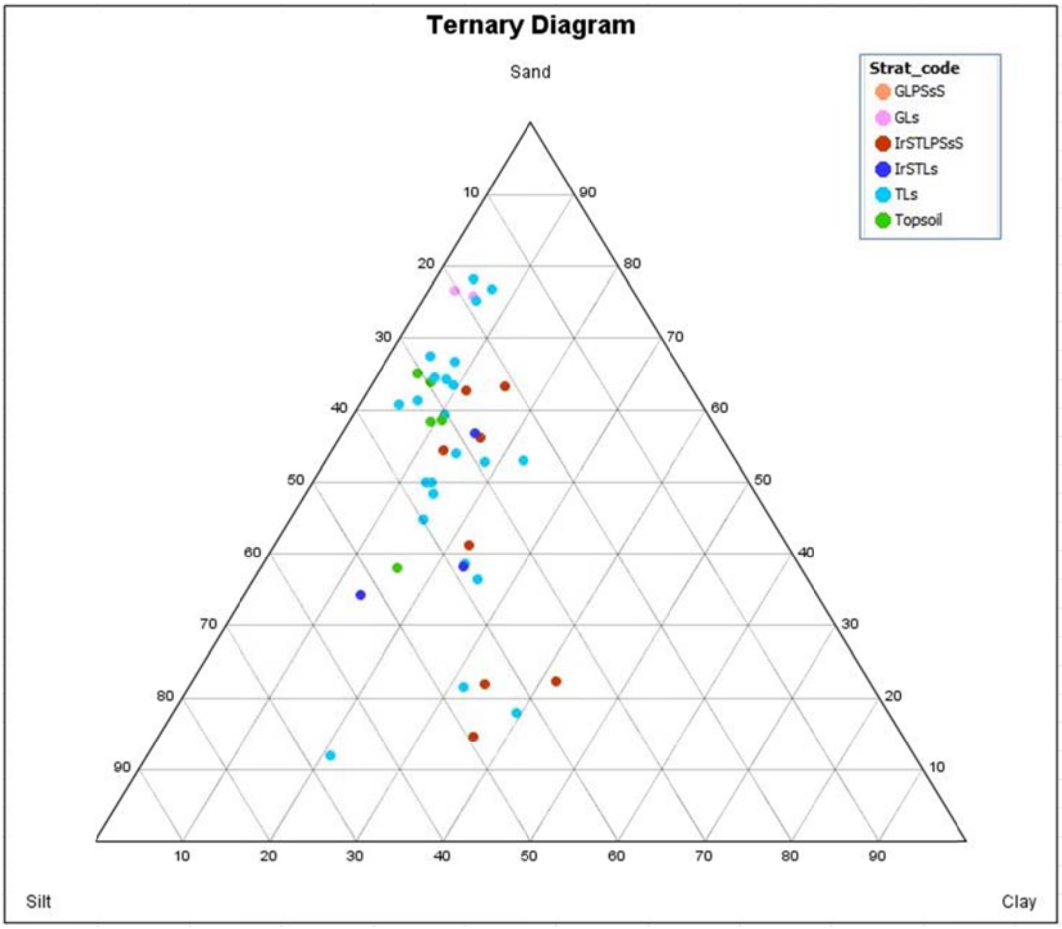


Figure 25 Ternary diagram for PSD analyses, Locality A

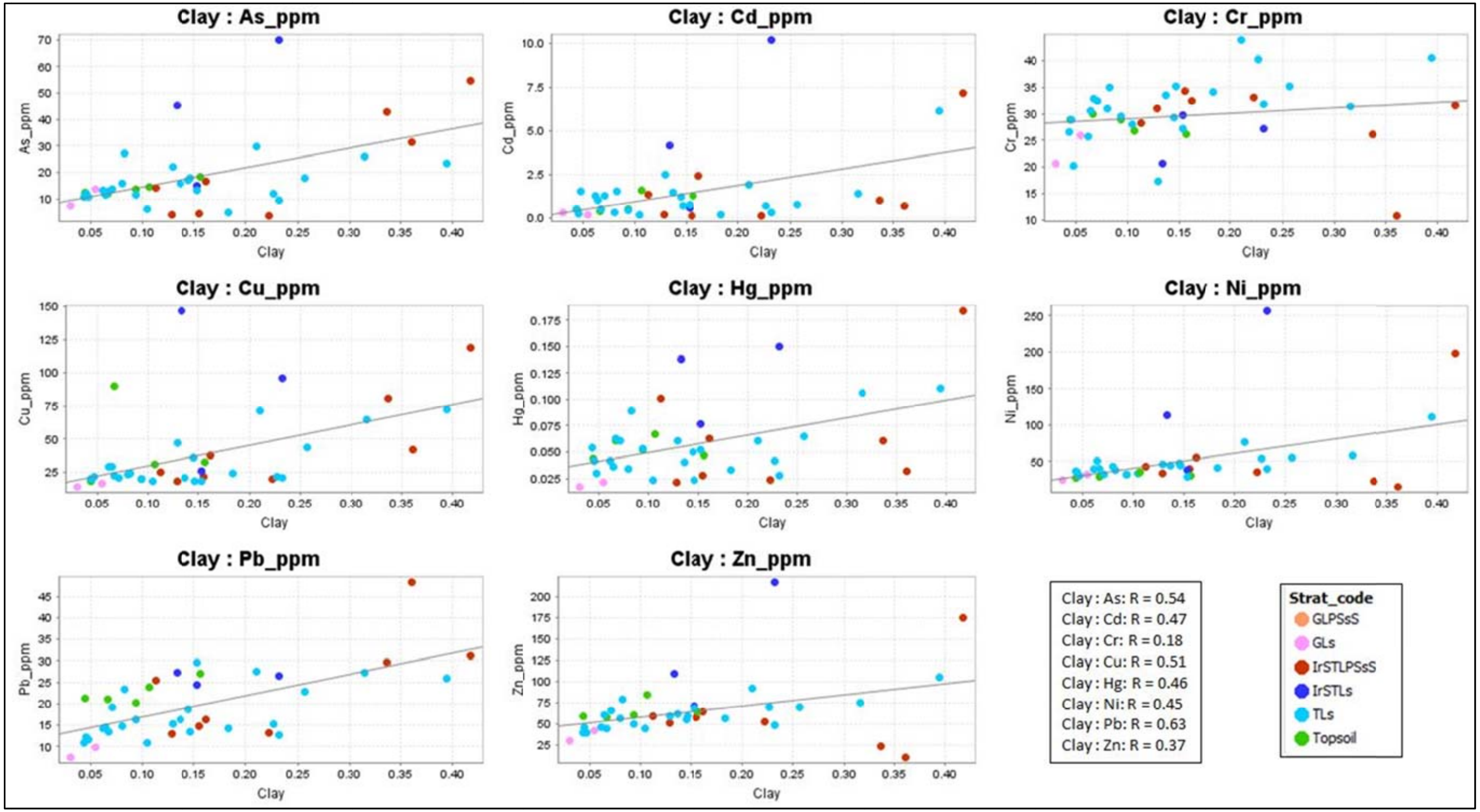


Figure 26 X-Y plots of clay content against concentrations of elements of interest, Locality A

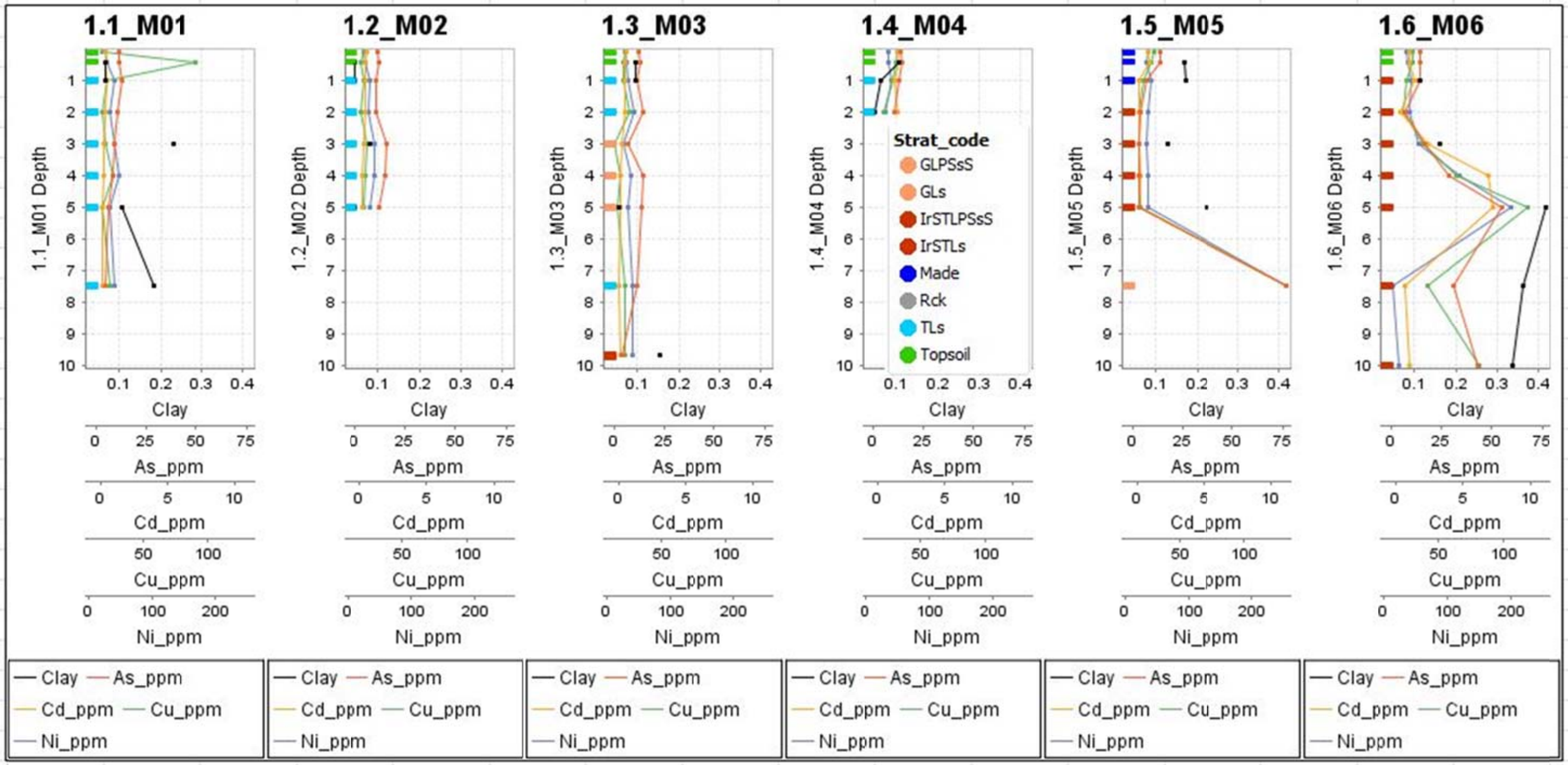


Figure 27 Down-hole PSD (clay) and geochemical variation in boreholes in the northwest–southeast traverse (Transect 1) at Locality A: As, Cd, Cu and Ni.

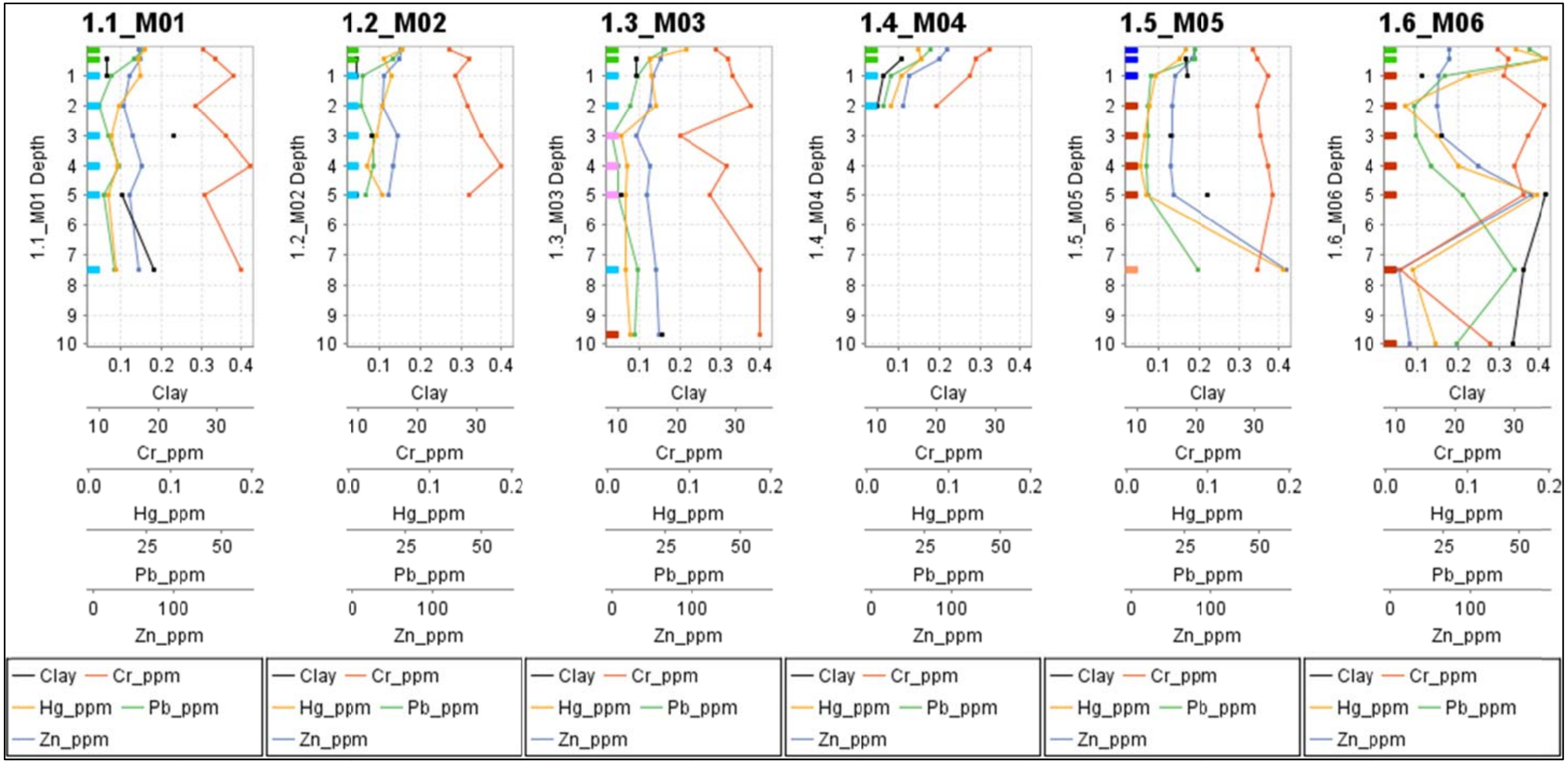


Figure 28 Down-hole PSD (clay) and geochemical variation in boreholes in the northwest–southeast traverse (Transect 1) at Locality A: Cr, Hg, Pb and Zn.

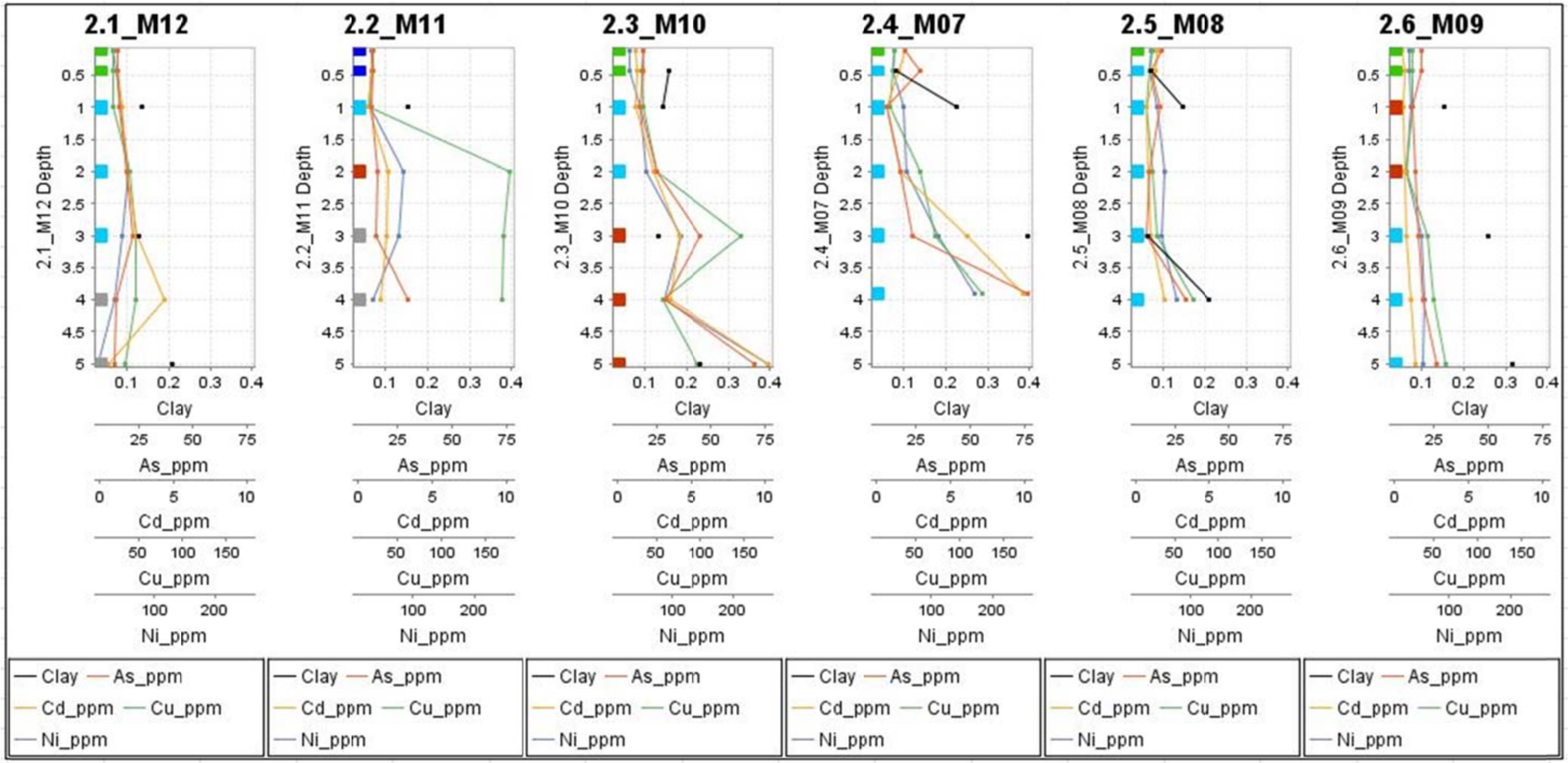


Figure 29 Down-hole PSD (clay) and geochemical variation in boreholes in the southwest–northeast traverse (Transect 2) at Locality A: As, Cd, Cu, Ni.

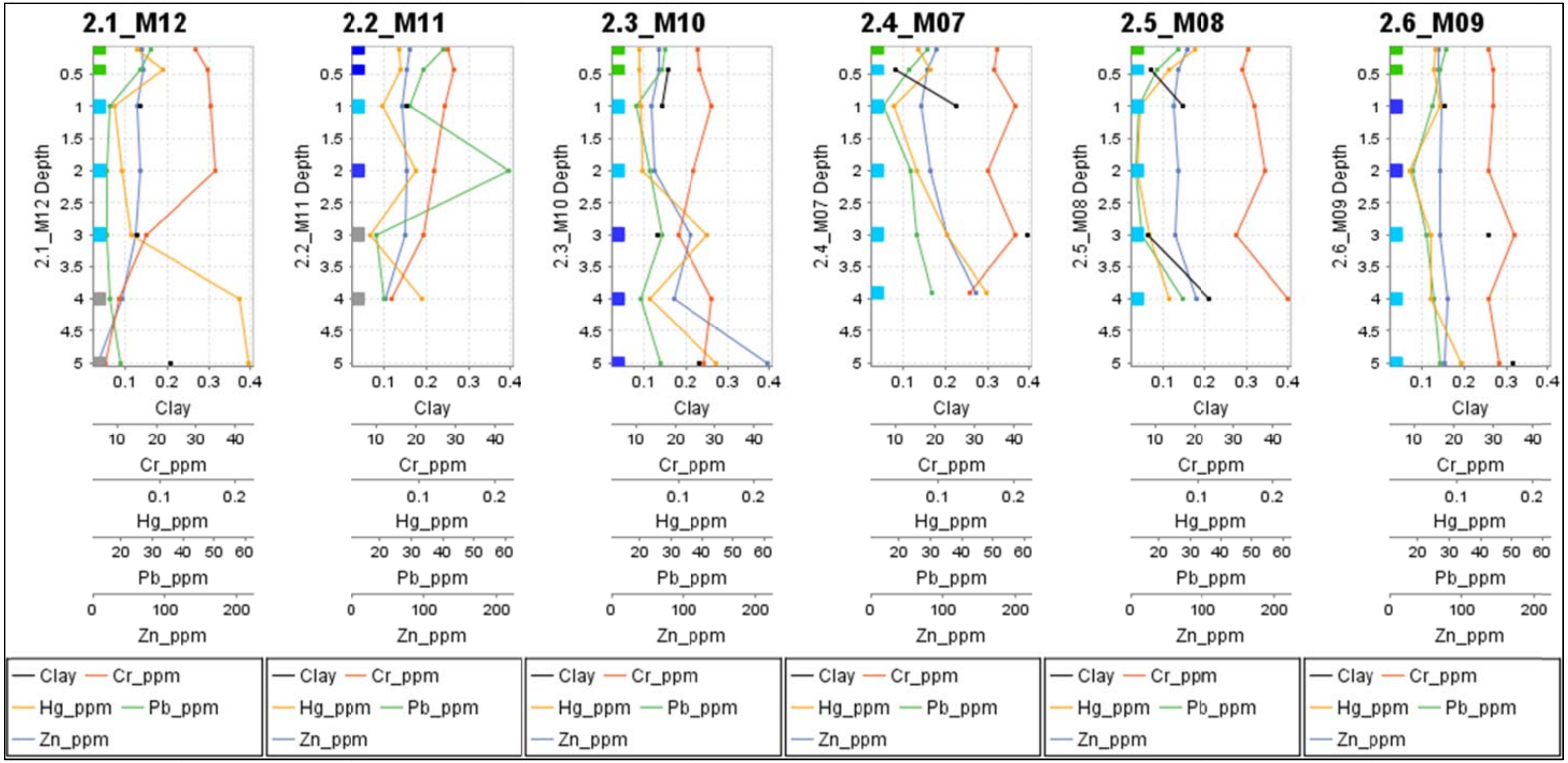


Figure 30 Down-hole PSD (clay) and geochemical variation in boreholes in the southwest–northeast traverse (Transect 2) at Locality A: Cr, Hg, Pb, Zn.

3.1.3.2 Locality B

A ternary plot (Figure 31) shows the variation in PSD according to subsoil classification, which at Locality B is considerably simpler, as sediments comprise only tills and sands and gravels. The latter plot strongly toward the sand-rich end of the diagram while till samples and topsoil samples collected by auger overlap.

Figure 32 shows the variation of clay content versus the eight elements of interest. In general, moderate-to-poor correlation is observed between clay content and element concentrations. Ni (Pearson correlation coefficient 0.55) and Cu (0.46) show the strongest correlation with clay content, while those for Pb and Zn are both negative (-0.16).

Downhole logs (Figure 33, Figure 34, Figure 35 and Figure 36) compare the vertical variation in clay content to that of the elements of interest. Because the PSD samples were not taken at all the intervals sampled for geochemistry, the clay content is shown by a discontinuous black line and points. The variation in clay content does show some coherence with that of the geochemistry, notably for some elements in samples from boreholes K02, K04, K05, K07, K08 and K10. Elsewhere, the picture is more mixed. The lack of a PSD sample at each depth sampled for geochemistry makes comparison somewhat problematic.

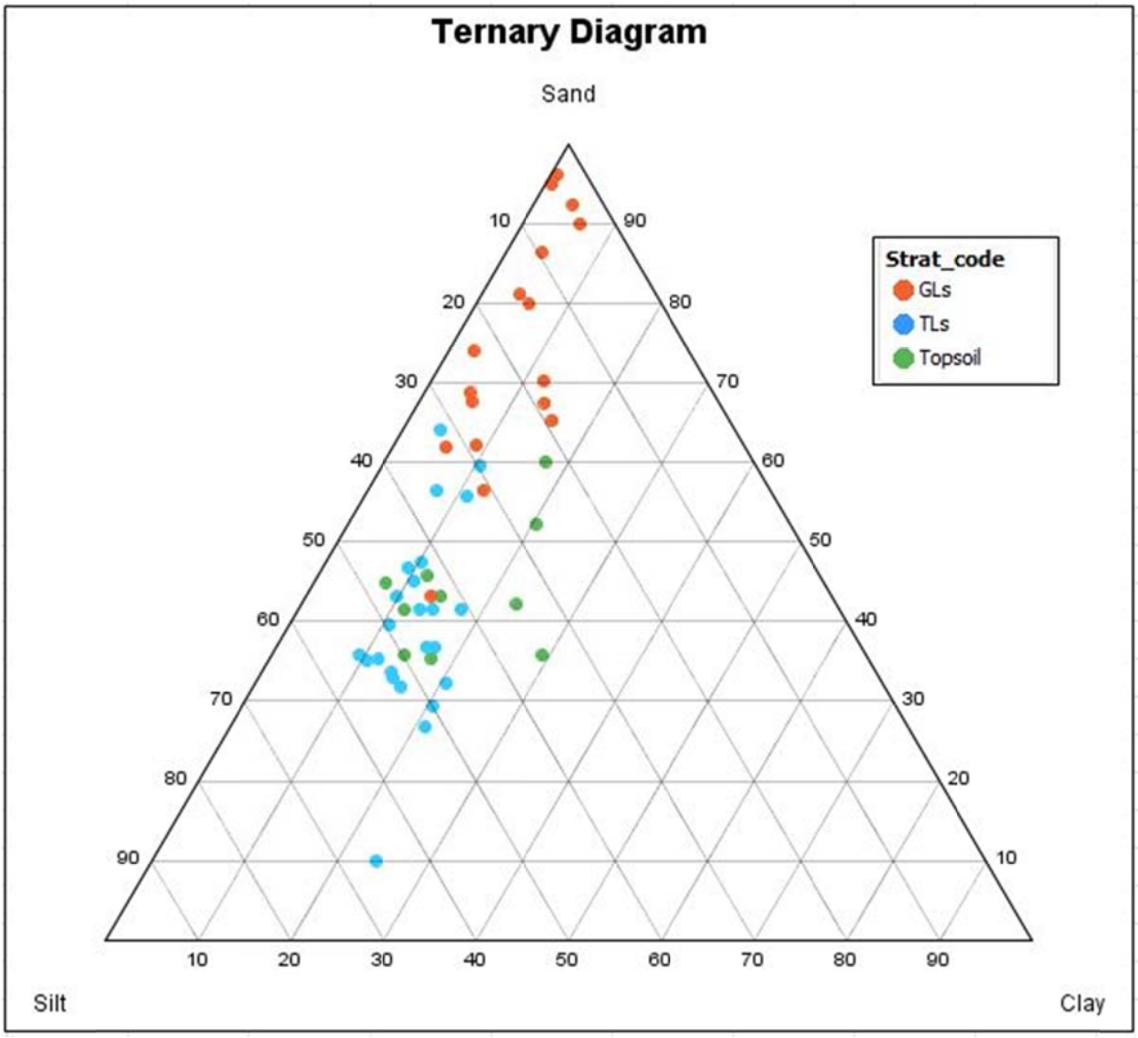


Figure 31 Ternary diagram for PSD analyses, Locality B

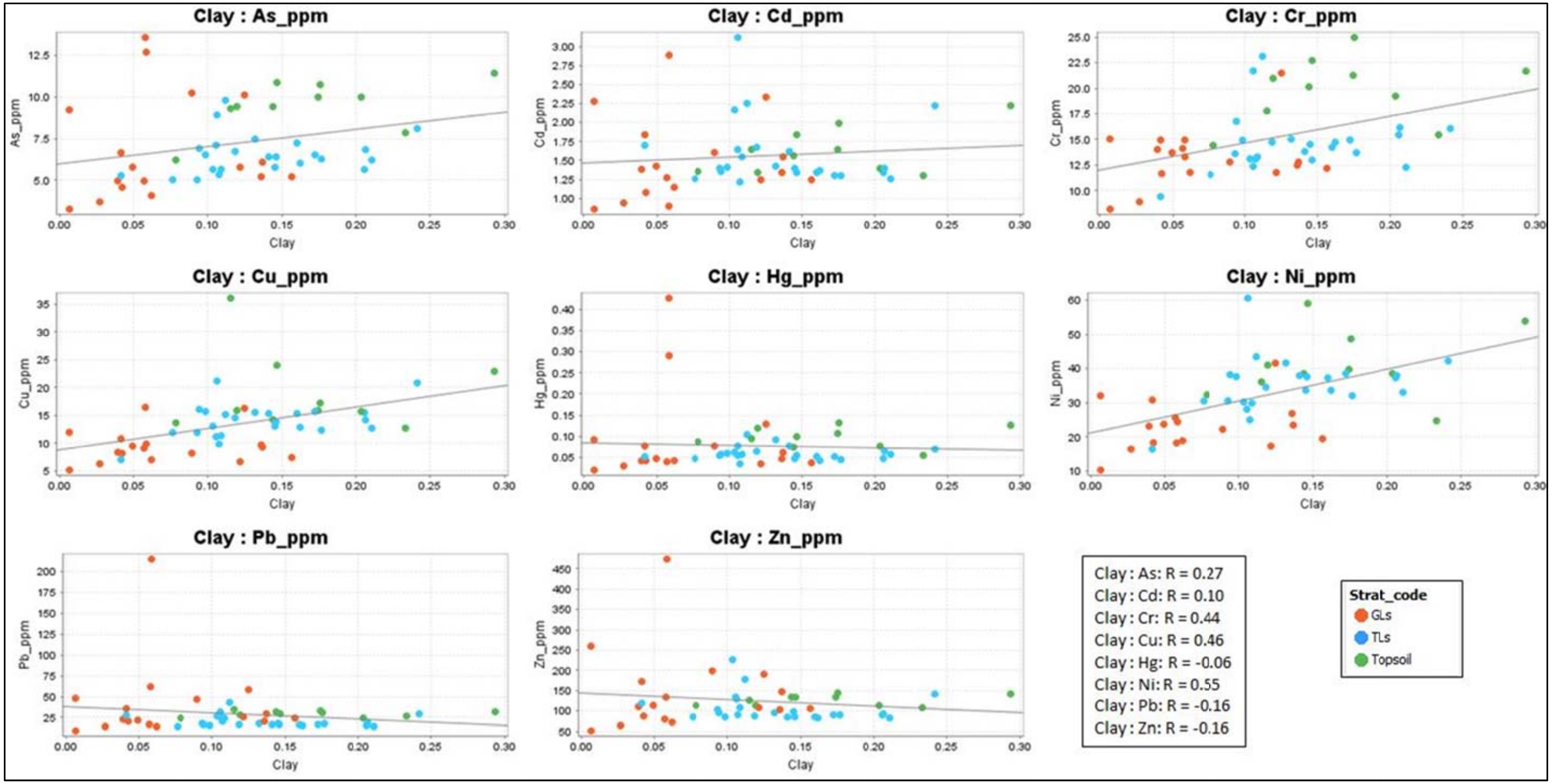


Figure 32 X-Y plots of clay content against concentrations of elements of interest, Locality B

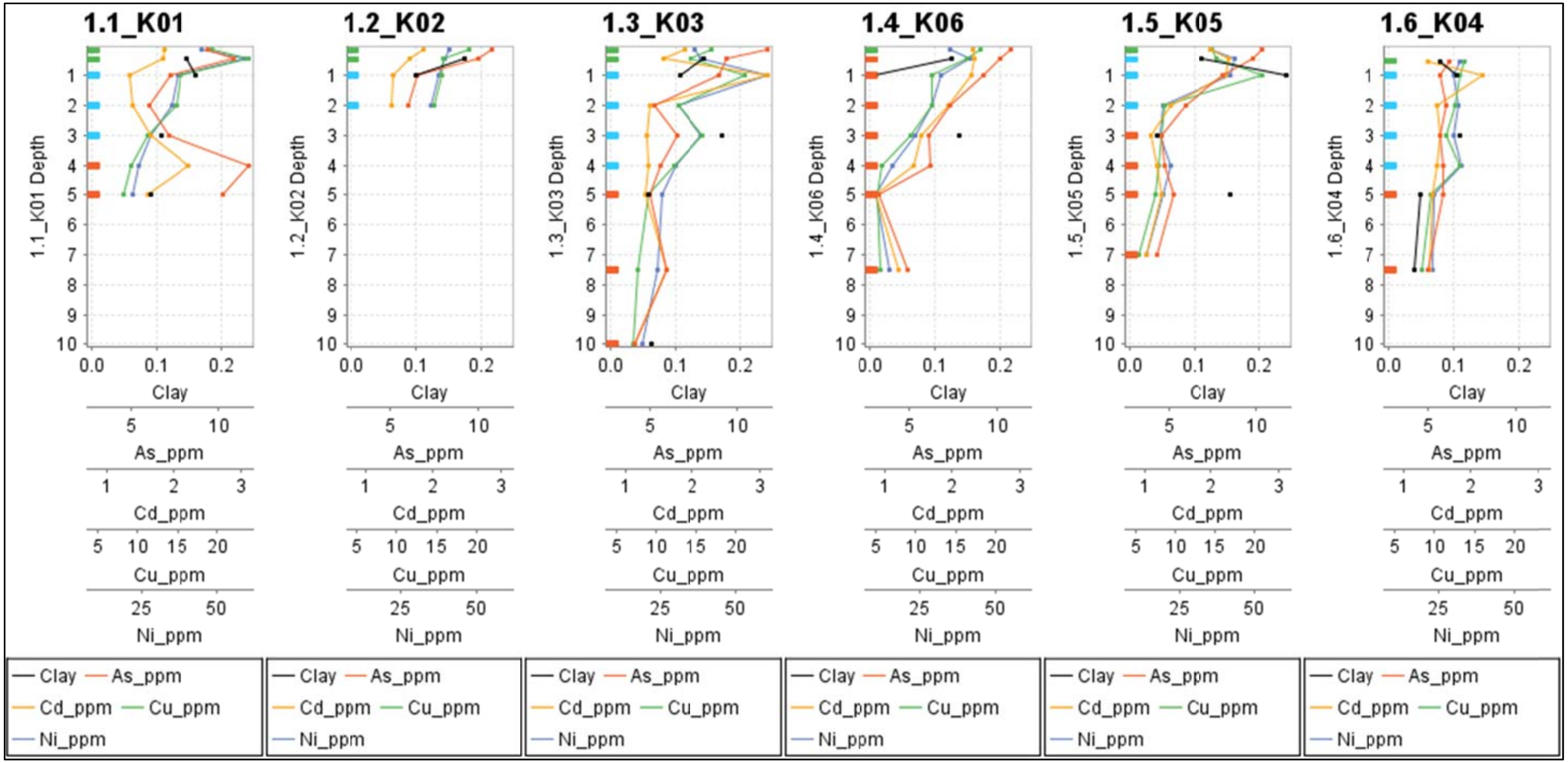


Figure 33 Down-hole PSD (clay) and geochemical variation in boreholes in the west-northwest to east-southeast traverse (Transect 1) at Locality B: As, Cd, Cu and Ni.

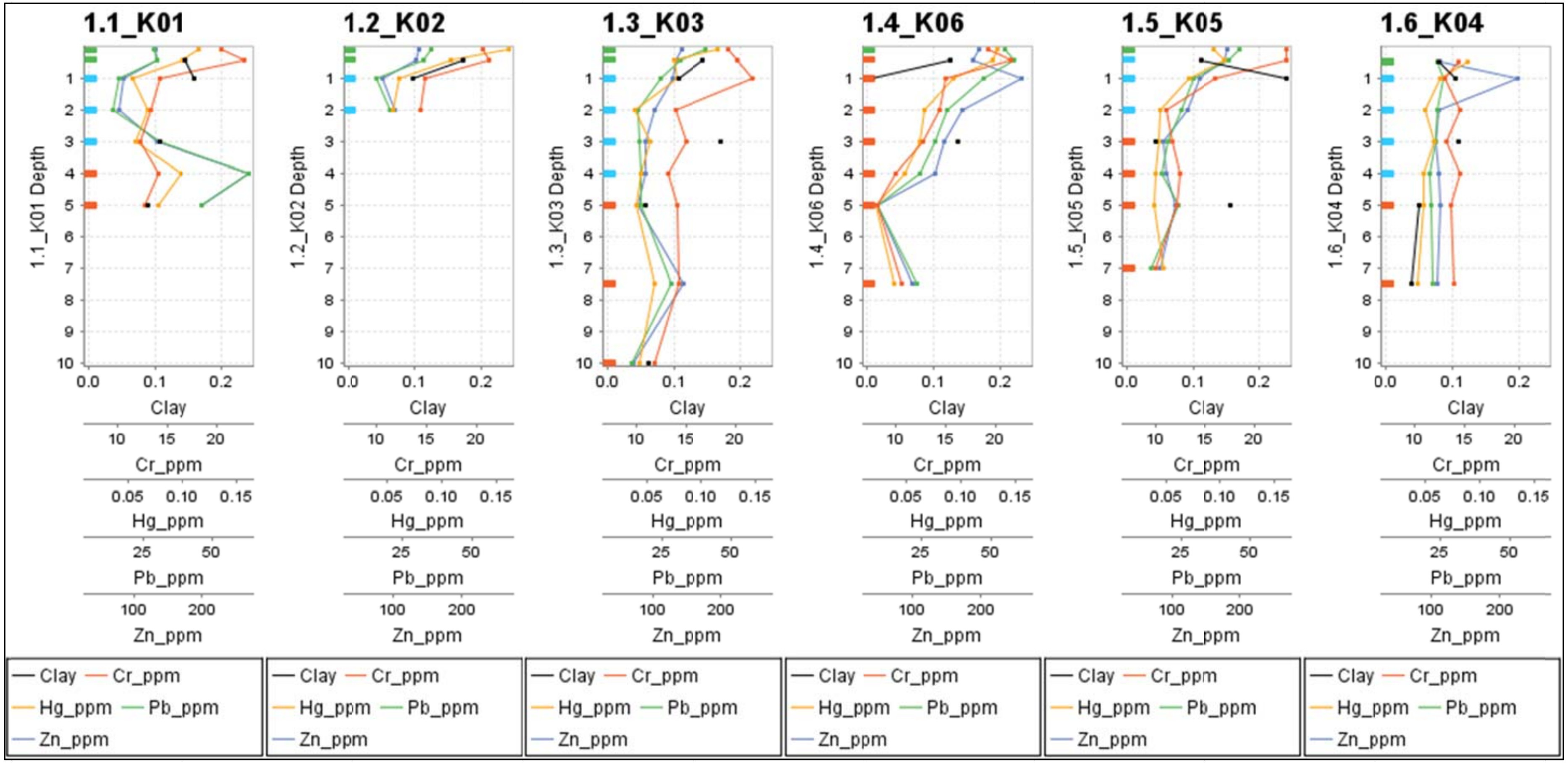


Figure 34 Down-hole PSD (clay) and geochemical variation in boreholes in the west-northwest to east-southeast traverse (Transect 1) at Locality B: Cr, Hg, Pb, Zn

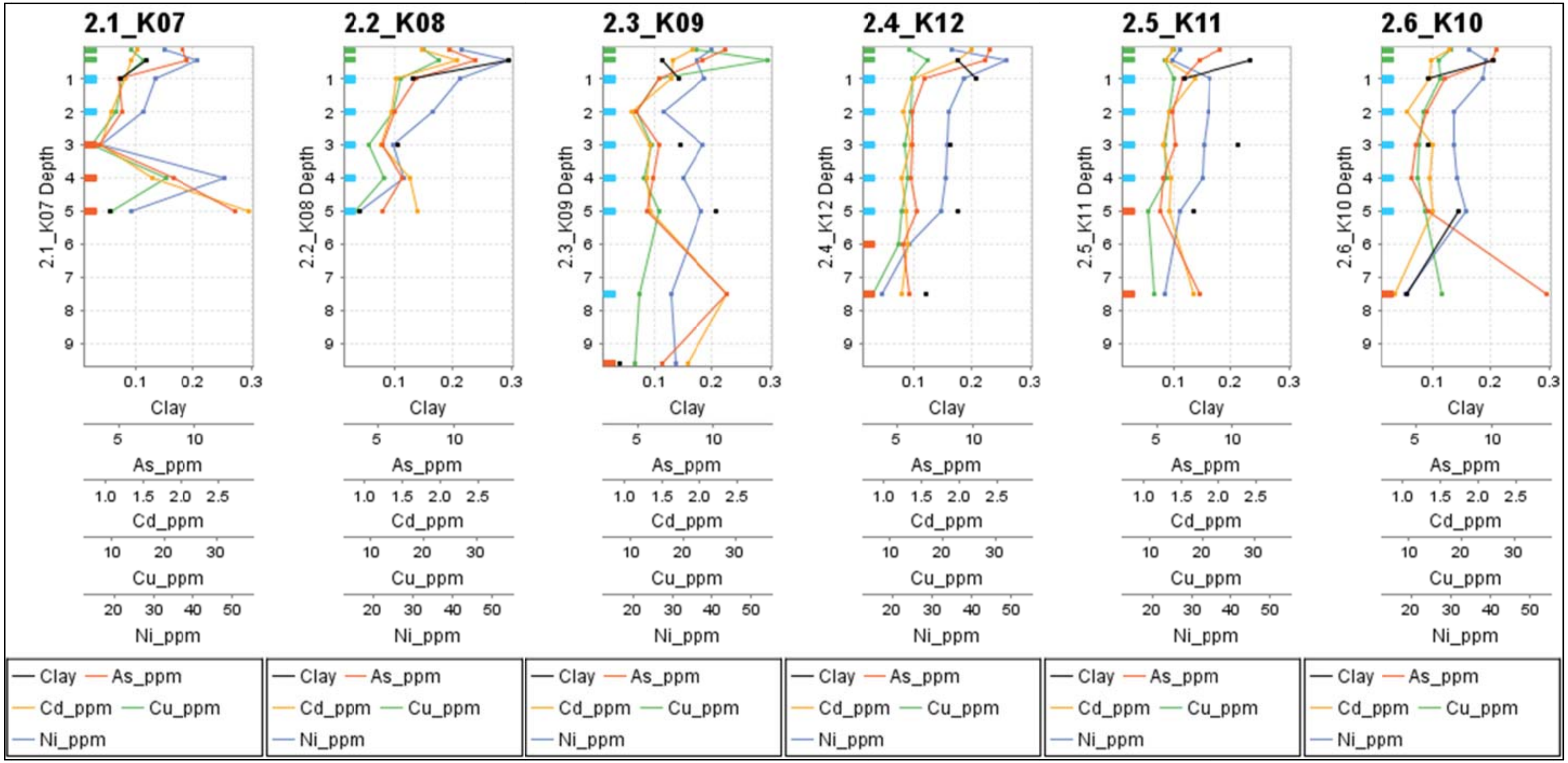


Figure 35 Down-hole PSD (clay) geochemical variation in boreholes in the north-northwest to south-southeast traverse (Transect 2) at Locality B: As, Cd, Cu and Ni.

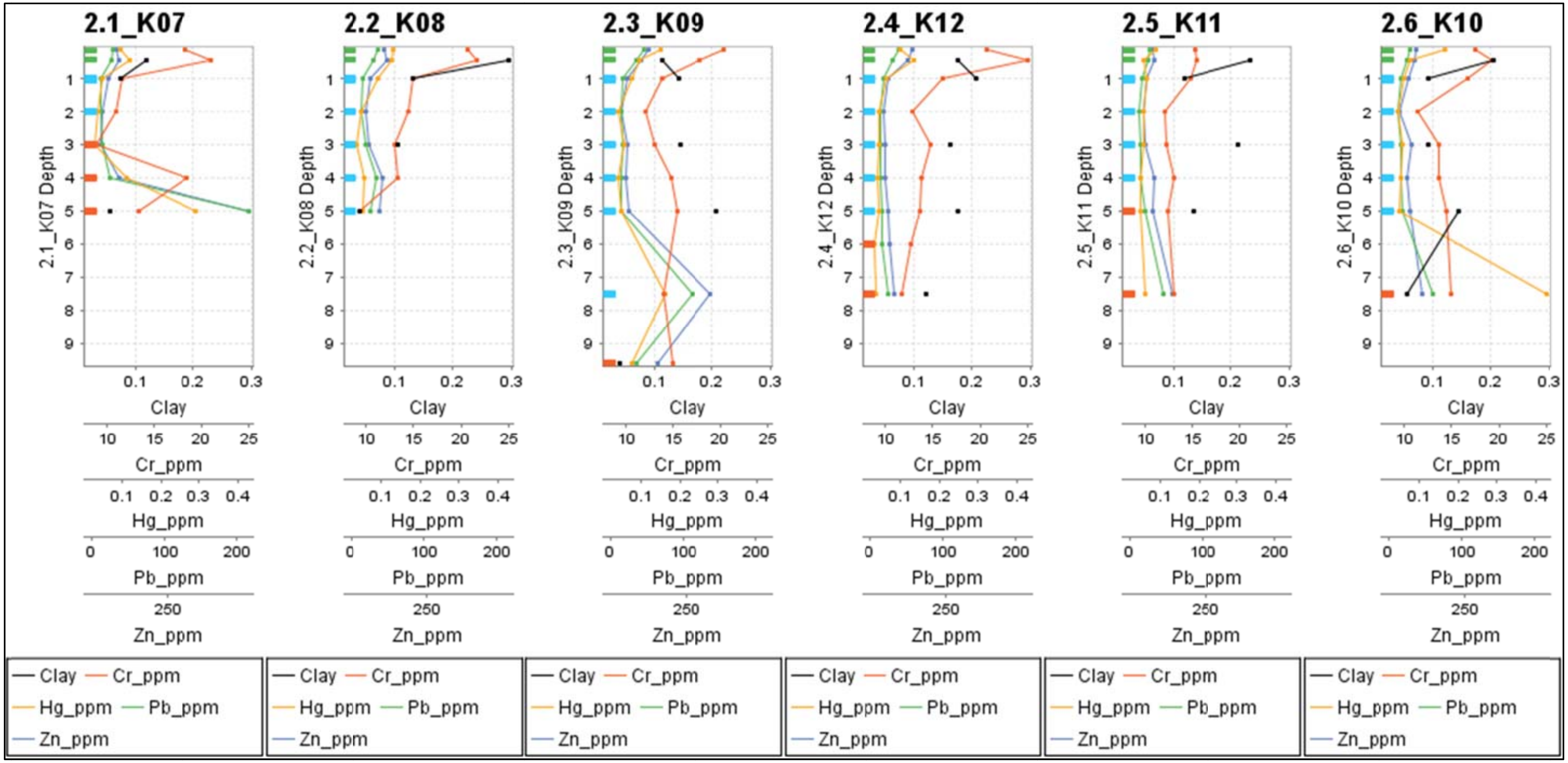


Figure 36 Down-hole PSD (clay) and geochemical variation in boreholes in the north-northwest to south-southeast traverse (Transect 2) at Locality B: Cr, Hg, Pb, Zn.

3.1.4. Geochemistry results

3.1.4.1 Locality A

A total of 84 topsoil and subsoil samples were collected at Locality A and analysed by ICP-MS for arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn) and separately for mercury (Hg), in both cases following *aqua regia* digestion. Of these, 24 samples were "Tellus" samples, topsoil samples collected at 0.05–0.20 m and 0.35–0.50 m depths from the 12 borehole sites, with the remaining 60 samples taken from core at various depths between 1 m and 10 m. Summary geochemical data are presented in Table 3.

Subsoil (n = 60)	**As**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Min	3.18	0.084	6.94	13.9	0.017	7.23	7.44	6.72
Max	76.4	11.1	43.8	176	0.218	257	60.9	217
Median	14.8	0.74	30.0	25.5	0.046	41.5	16.0	57.8
Topsoil (n = 24)								
Min	11.7	0.404	25.5	18.0	0.044	25.9	19.1	56.9
Max	27.0	1.91	35.6	90.1	0.195	38.5	58.7	94.4
Median	14.2	1.03	29.0	25.7	0.078	32.7	27.0	68.4

Table 3 Summary geochemical data for soil samples from Locality A. All concentrations in mg kg^{-1}.

The data for topsoil and subsoil samples are illustrated in boxplots (Figure 37) and histograms (Figure 38) below. In general, the bulk of both topsoil and subsoil samples, as represented by the central box in the Tukey boxplot (Figure 37) span a similar range. The topsoil data have a very narrow distribution and display few outliers. In contrast, the subsoil data are in part characterized by the presence of numerous upper outliers. This is reflected in Table 3 where the maximum subsoil concentrations are far in excess of those for topsoils for As, Cd, Cu, Ni and Zn. Nevertheless, it is clear from both boxplots and histograms that for the bulk of both topsoil and subsoil samples, concentrations of all elements in topsoils are typically as high or even higher than those in subsoils.

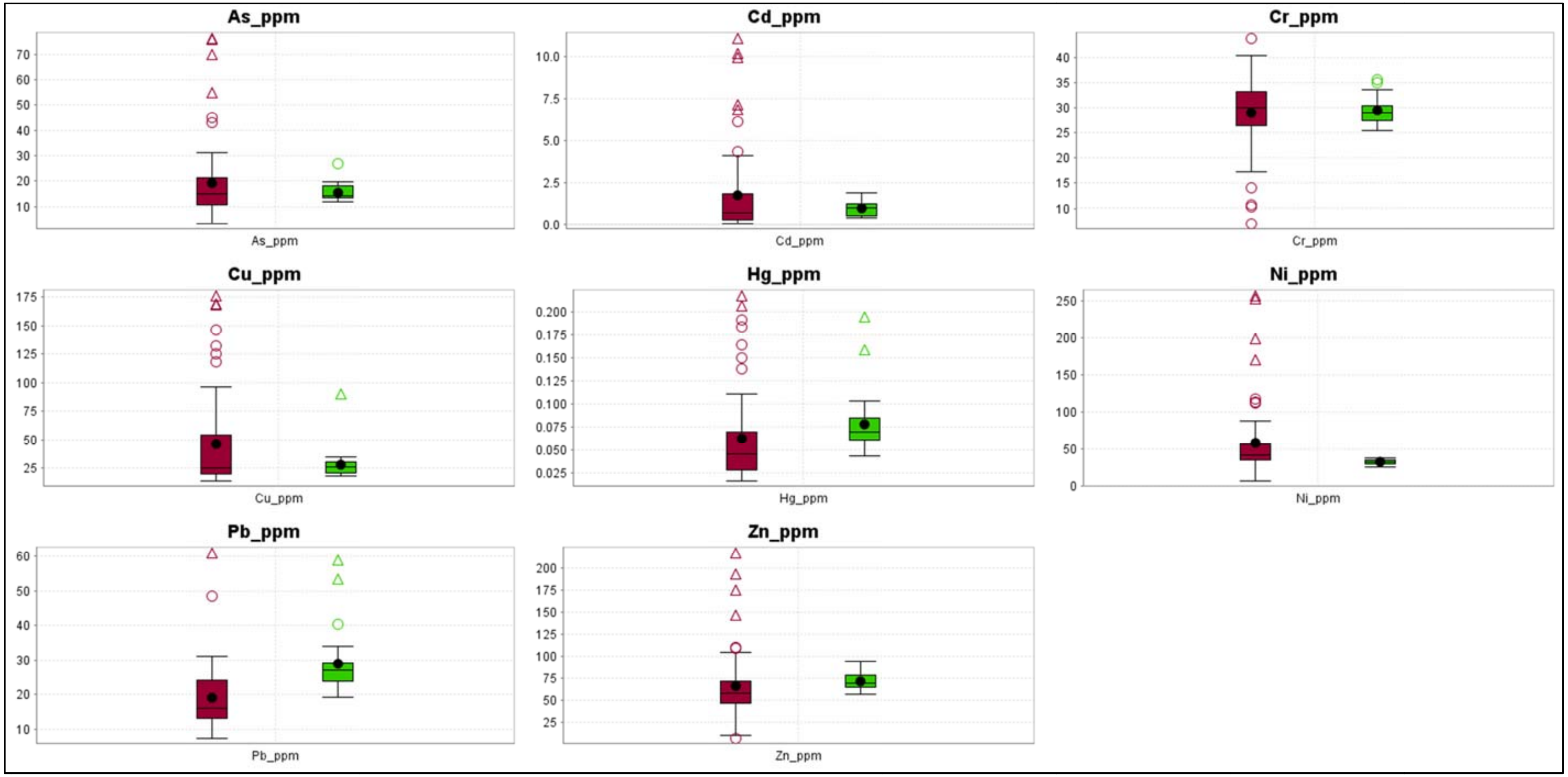
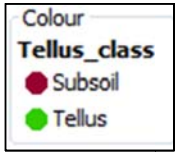


Figure 37 Tukey boxplots for topsoil ("Tellus") and subsoil geochemistry, Locality A, showing the distribution of raw (untransformed) data. The outliers are represented by O (outliers) and Δ (far outliers). Outliers are data plotting above or below the fence value (= [IQR*1.5] above the 75th percentile or below the 25th percentile). The far outliers are defined as exceeding [IQR*3] + 75th percentile.). Y axis units: mg kg^{-1}



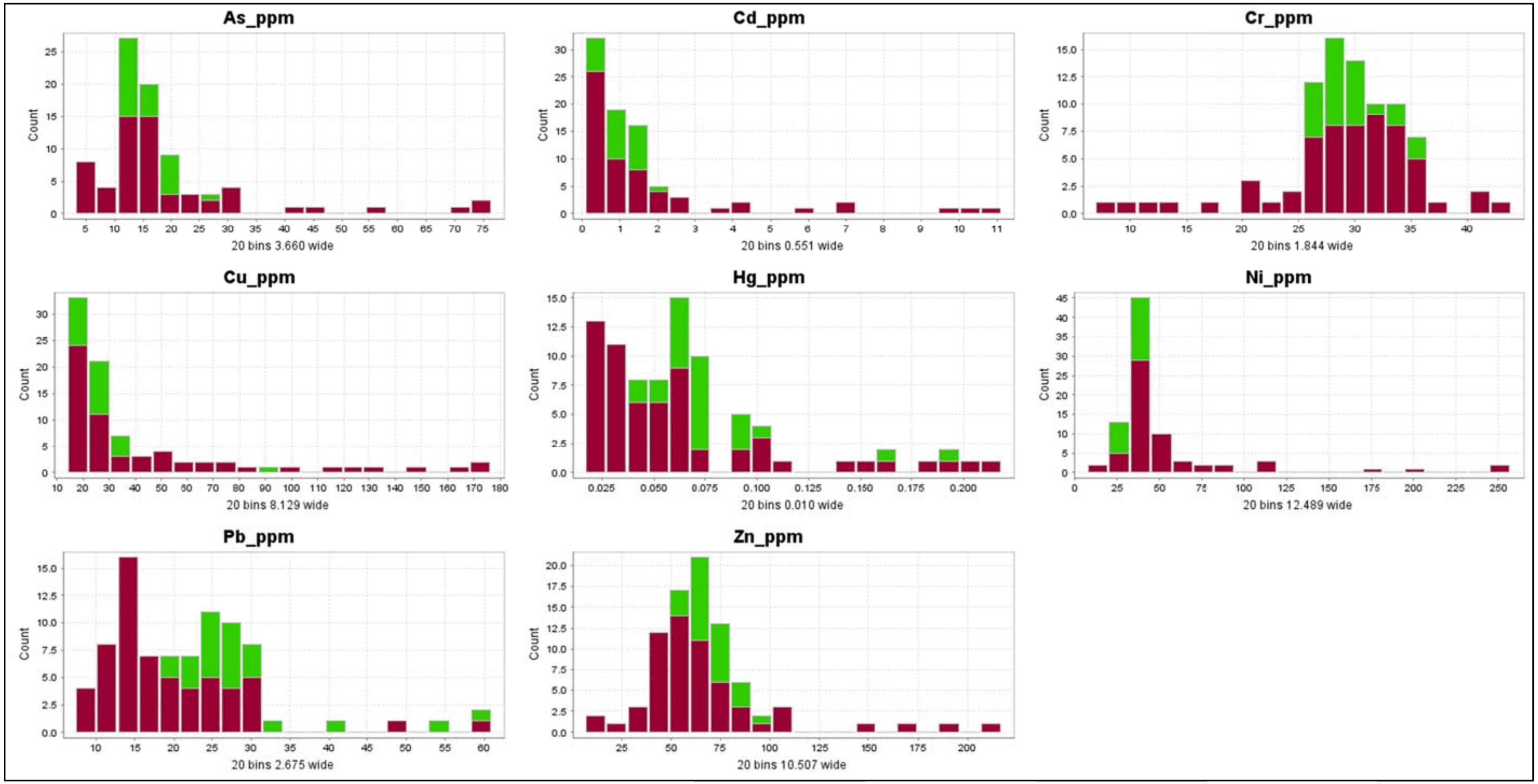


Figure 38 Histograms for topsoil (Tellus) and subsoil geochemistry, Locality A, showing the distribution of raw (untransformed) data. X axis units: mg kg^{-1}. Legend as for Figure 37.

While there is a broad correspondence between the geochemistry of topsoils and subsoils at Locality A, the presence of numerous apparent outliers in the data for subsoils is striking. Subsoils at Locality A have been classified as till derived chiefly from limestones (labelled TLs), till with a matrix of Irish Sea basin origin dominated by limestone (IrSTLs), till with a matrix of Irish Sea basin origin dominated by Lower Palaeozoic rock (IrSTLPSsS), glaciofluvial sands and gravels derived chiefly from limestone (GLs) and glaciofluvial sands and gravels derived chiefly from Lower Palaeozoic sandstone and shale (GLPSsS). In addition, in a number of boreholes a transition zone between subsoil and bedrock (Rck) was encountered and sampled. Figure 39, Figure 40 and Figure 41 illustrate the geochemical variation exhibited by the various subsoil types at Locality A. Caution is required to avoid over-interpreting these plots, given the relatively small number of samples within each subsoil class, but they do suggest that no one subsoil type can be said to be responsible for all the upper outliers observed in the subsoil data, although the samples with a matrix of Irish Sea basin origin and the glaciofluvial sands and gravels derived chiefly from Lower Palaeozoic sandstone and shale do account for most of them. For the elements As, Cd, Cu, Hg, Ni, Pb and Zn the Irish Sea till, whether dominated by limestones or Lower Palaeozoic sandstones and shale, generally has higher element concentrations than the "local" tills derived from limestone in the area. This is well illustrated in Figure 41. Summary data for the main subsoil types at Locality A are given in Table 4.

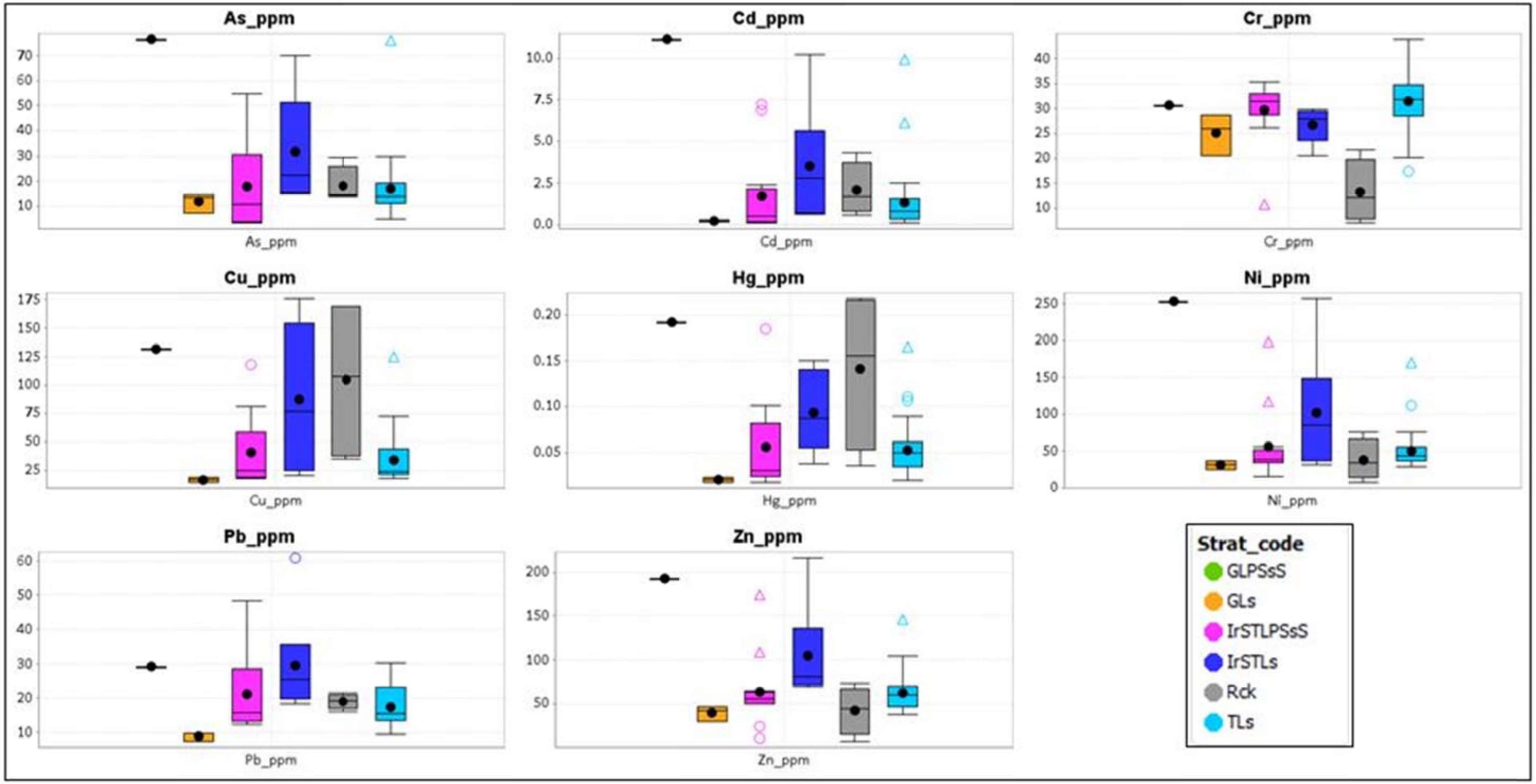


Figure 39 Tukey boxplots for subsoil geochemistry, Locality A, classified by subsoil type. Y axis units: mg kg^{-1}

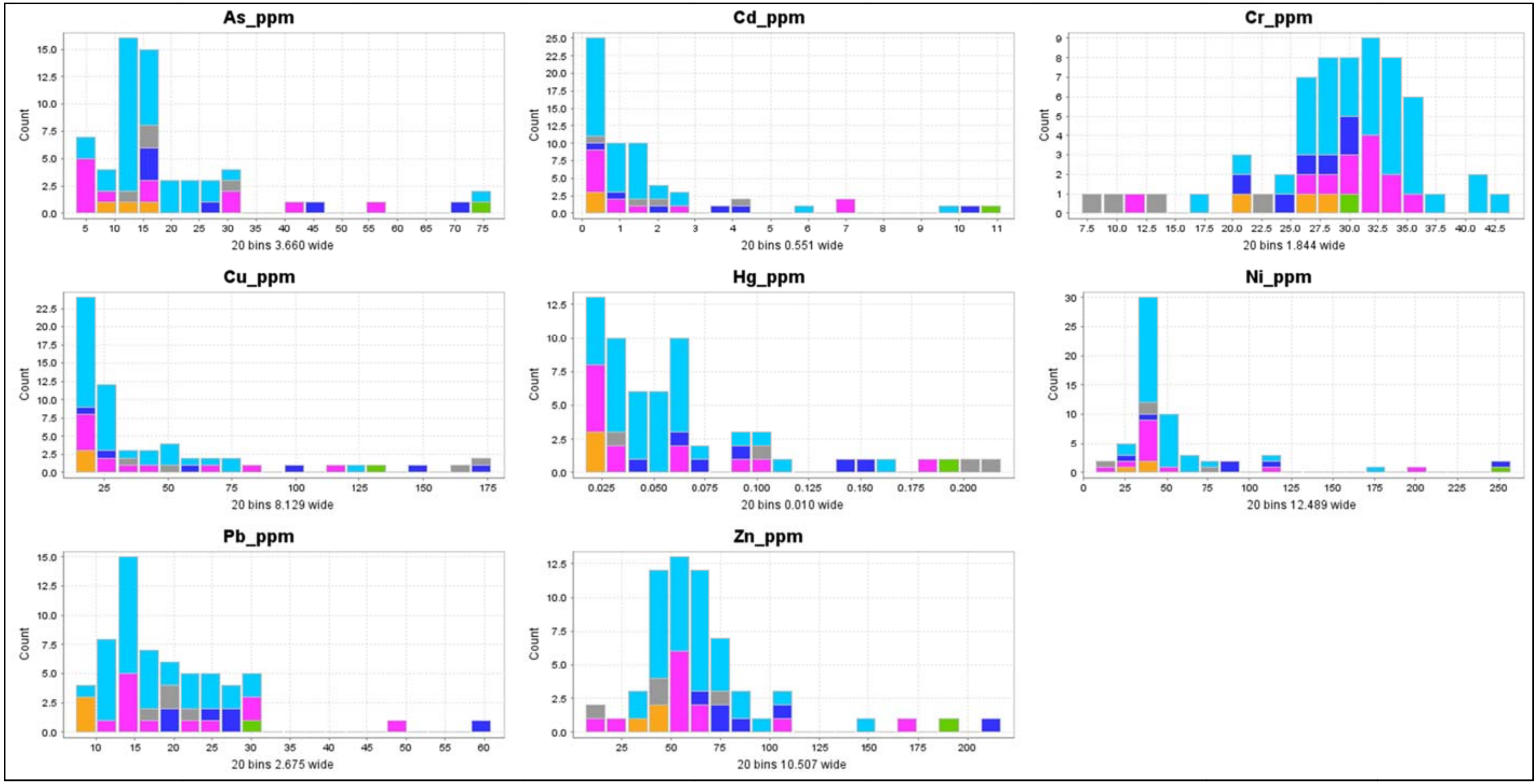


Figure 40 Histograms for subsoil geochemistry, Locality A, classified by subsoil type. Legend as for Figure 40. X axis units: mg kg^{-1}.

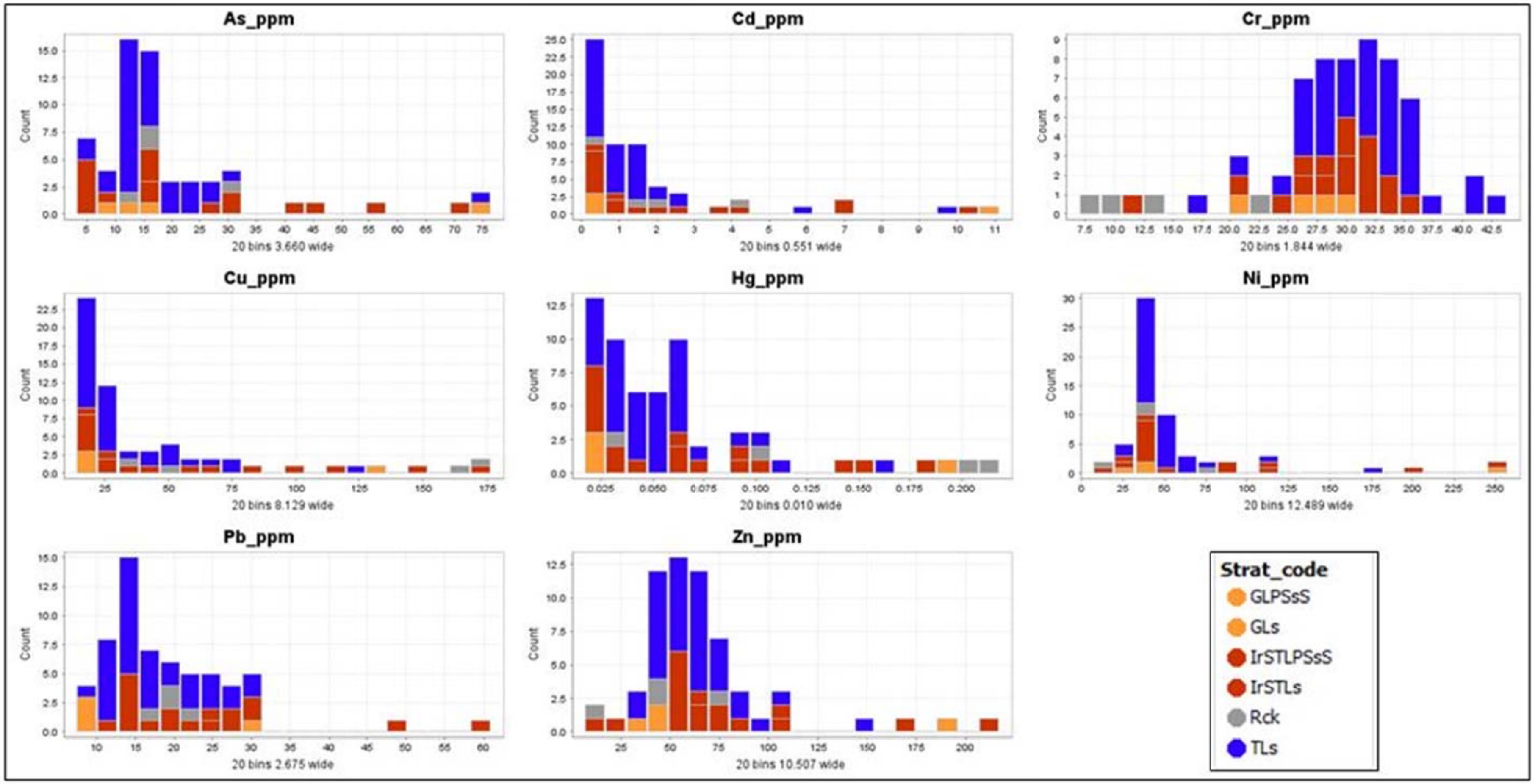


Figure 41 Histograms for subsoil geochemistry, Locality A: Irish Sea till, Limestone till and sands and gravels. X axis units: mg kg^{-1}.

Subsoils only								
Irish Sea Till (n = 18)	**As**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Min	3.18	0.122	10.7	18.0	0.017	15.2	12.5	10.4
Max	69.9	10.2	35.4	176	0.184	257	60.9	217
Median	16.1	0.857	30.0	31.8	0.061	40.5	20.5	61.7
Range	66.8	10.1	24.6	159	0.167	242	48.4	206
Limestone Till (n = 35)	**As**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Min	4.73	0.084	17.4	17.8	0.019	28.6	9.51	37.2
Max	76.0	9.93	43.8	125	0.165	170	30.3	146
Median	13.8	0.784	31.8	24.1	0.050	43.7	15.4	59.4
Range	71.2	9.85	26.5	107	0.146	141	20.8	109

Table 4 Summary geochemical data for subsoil types at Locality A. All concentrations in mg kg^{-1}.

The Locality A site is within the Domain 2 (Carboniferous limestone and related rocks) on the final domain map (Figure 10). Figure 42 compares the distribution of data using histograms for the Locality A topsoil (labelled “Tellus”) and subsoil samples and the NSDB samples in Domain 2. Note that the NSDB data are “total” concentrations, in contrast to the data for Locality A, which are based on *aqua regia* extractions. This is significant in the case of Cr, which typically has very low *aqua regia* extraction rates, much less so for other elements. The overall coherence of the Locality A data and the NSDB data in Domain 2 is noteworthy while the presence of upper outliers in the Locality A subsoil data, especially, is well displayed.

Analysis of down-hole geochemical variation provides further insight into the geochemistry of the Locality A soil samples. Data are presented below in Figure 43, Figure 44, Figure 45 and Figure 46 for the two traverses at Locality A, as illustrated by the two cross-sections above (Figure 14 and Figure 15). The first traverse includes, in sequence from northwest to southeast, boreholes M01, M02, M03, M04, M05 and M06. Holes M01 to M04, largely drilled into limestone till, show little down-hole variation for As, Cd, Cu, Ni, Pb and Zn. Indeed, if anything, element concentrations decrease from topsoils downwards into subsoils. Cr is the exception but data for this element must be considered unreliable as discussed previously. Boreholes M05 and M06, both intersecting tills with a matrix of Irish Sea basin origin, show significant increases in most elements with depth. In particular, the last sample in M05, a sand and gravel sample, has very high concentrations of most elements.

The second traverse includes, in sequence from southwest to northeast, boreholes M12, M11, M10, M07, M08 and M09. Again, for the most part the down-hole geochemical variation is modest with significant variation for most elements confined to intersections of Irish Sea till in M11 and M10.

In summary, geochemical data for samples from Locality A indicate that the composition of topsoils and subsoils around the SRF are comparable. Comparison with the data for the topsoils of the NSDB Domain 2 suggest that the data distribution displayed by the domain encompasses the bulk of the soil sampled at Locality A. The Locality A subsoils, particularly but not exclusively those classed as being dominated by a matrix of Irish Sea basin origin, are distinguished by several upper outliers, some with quite high concentrations of certain elements. These outliers skew the data distribution but do not affect the conclusion that topsoils and subsoils at Locality A share a broadly similar geochemistry.

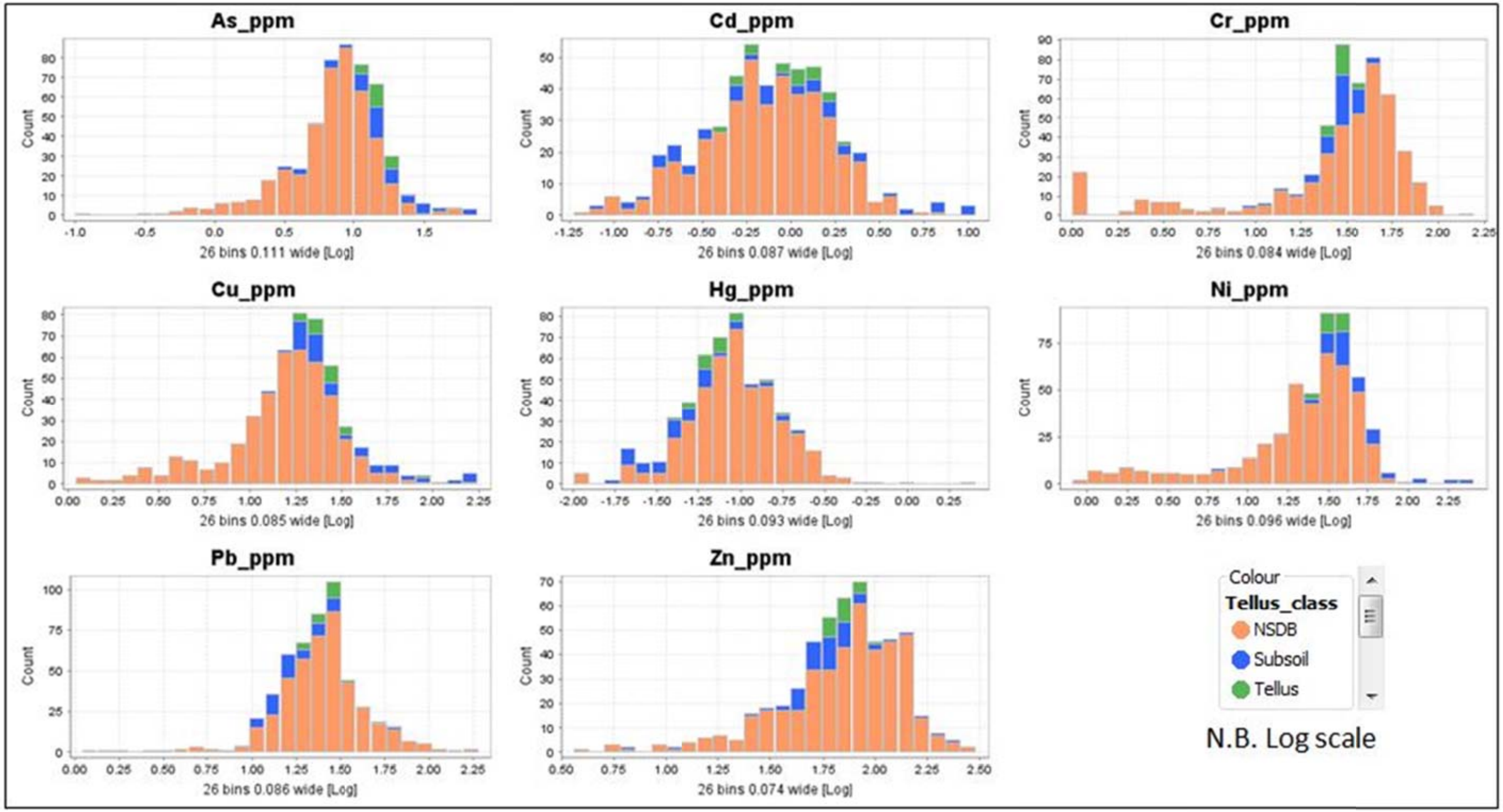


Figure 42 Histograms showing the distribution of soil geochemistry data from Locality A (subsoils and topsoils ("Tellus")) and data for NSDB Domain 2. Note use of log scale to de-skew X-axis for better visual comparison of datasets. X axis units: log mg kg^{-1}.

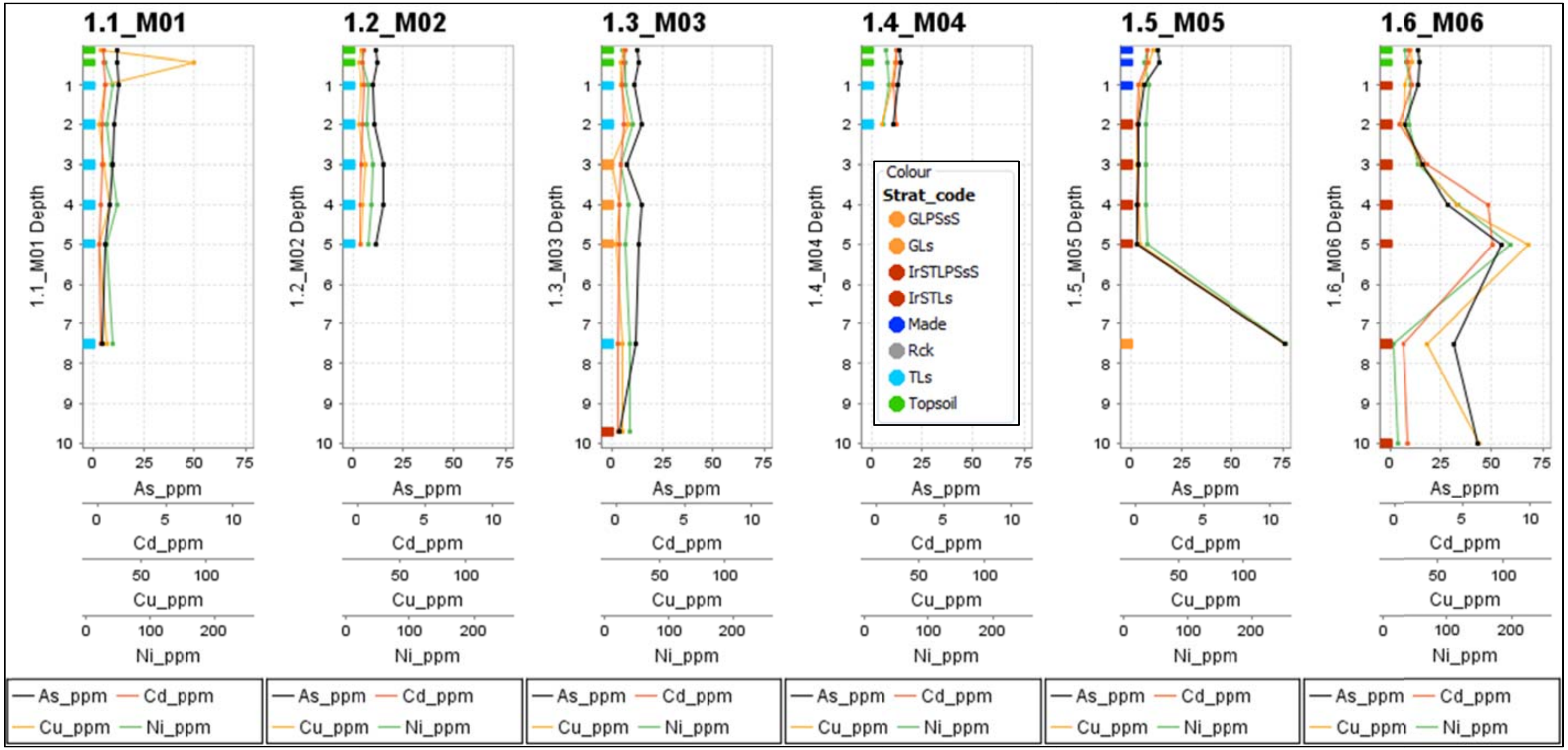


Figure 43 Down-hole geochemical variation in boreholes in the northwest–southeast traverse (Transect 1) at Locality A: As, Cd, Cu and Ni.

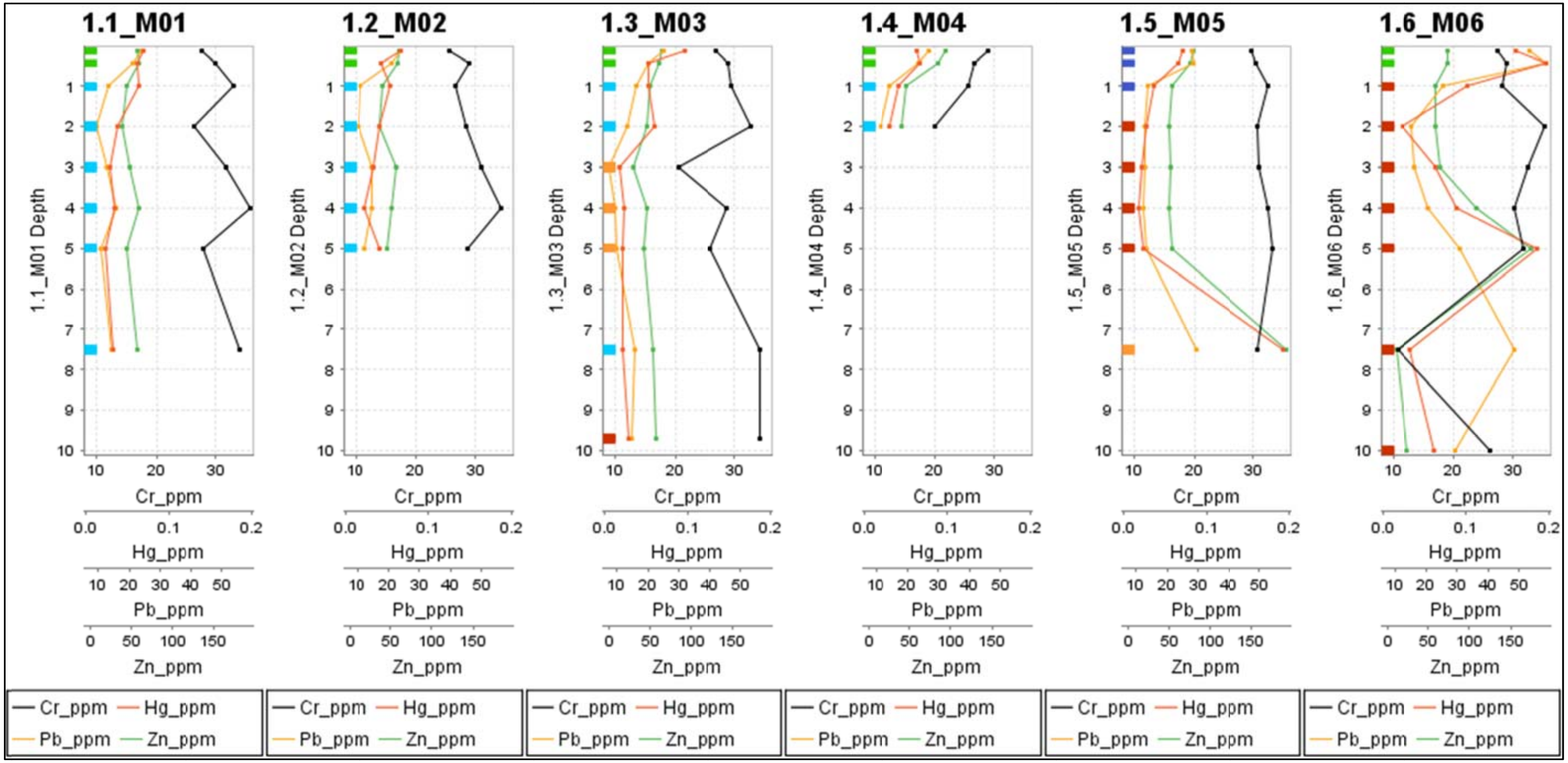


Figure 44 Down-hole geochemical variation in boreholes in the northwest–southeast traverse (Transect 1) at Locality A: Cr, Hg, Pb and Zn. Legend as for Figure 43.

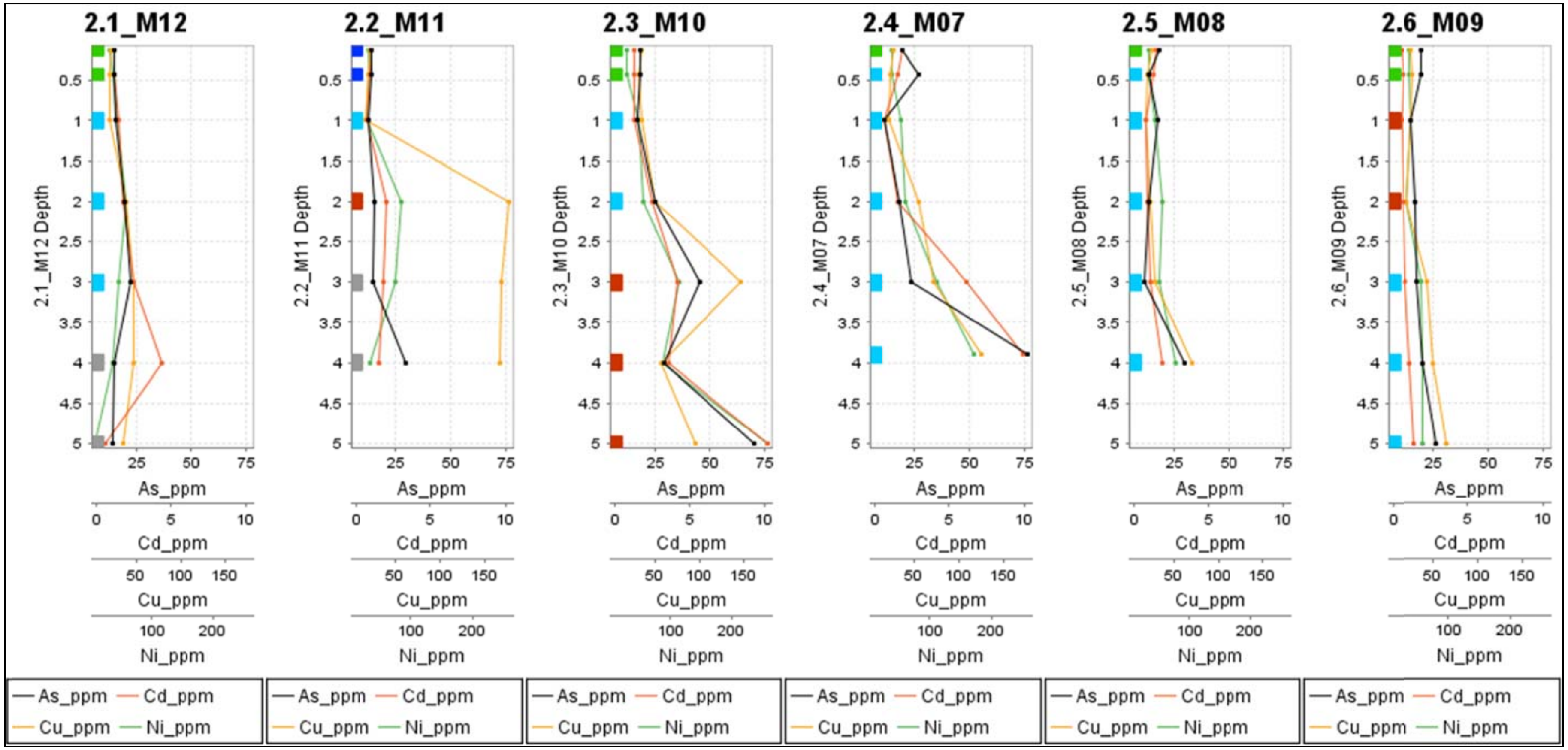


Figure 45 Down-hole geochemical variation in boreholes in the southwest–northeast traverse (Transect 2) at Locality A: As, Cd, Cu, Ni. Legend for soil types as in Figure 43.

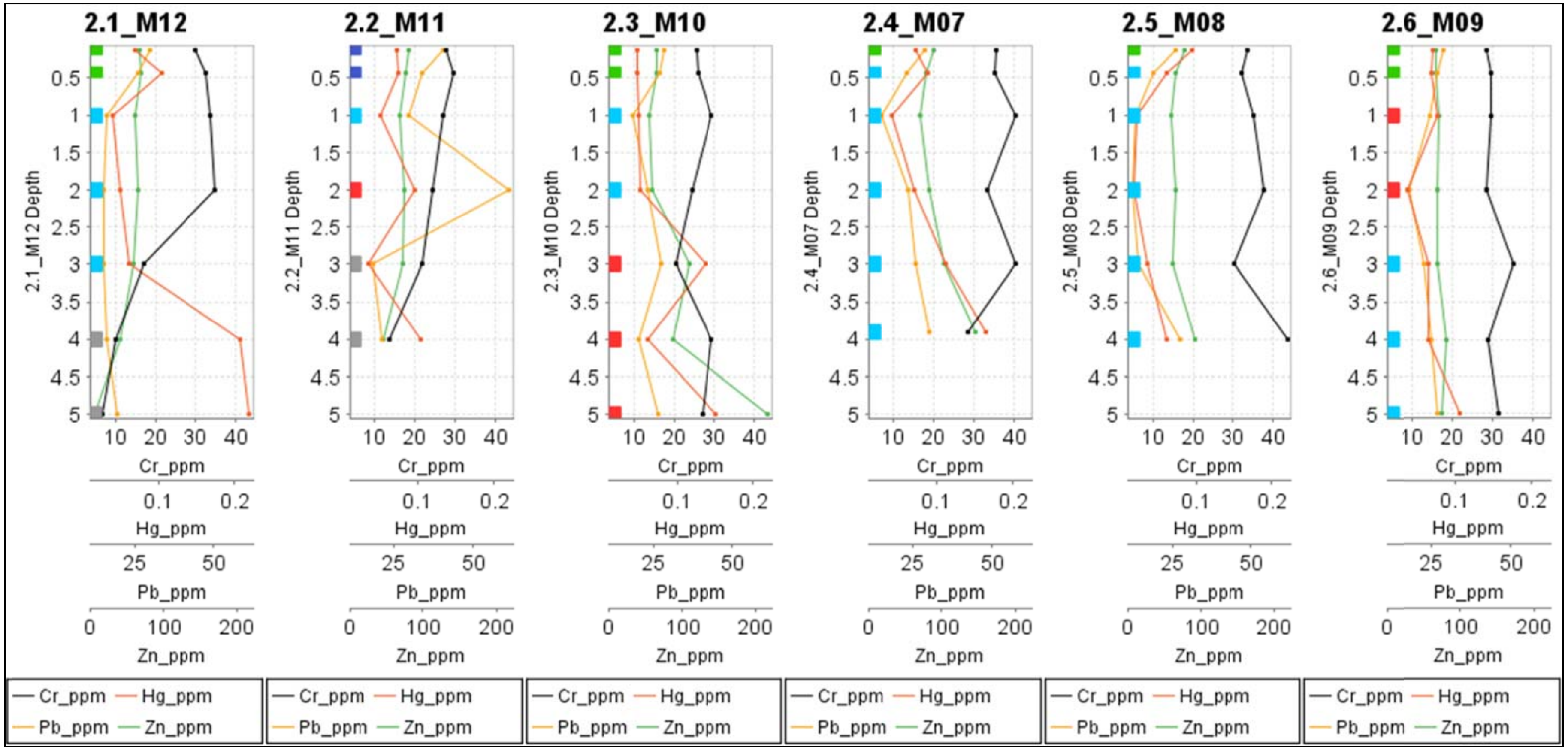


Figure 46 Down-hole geochemical variation in boreholes in the southwest–northeast traverse (Transect 2) at Locality A: Cr, Hg, Pb, Zn. Legend for soil types as in Figure 43.

3.1.2.2 Locality B

A total of 91 soil samples were collected at Locality B and analysed by ICP-MS for As, Cd, Cr, Cu, Hg, Ni, Pb and Zn as described earlier. Of these, 22 samples were "Tellus" samples, topsoil samples collected at 0.05–0.20 m and 0.35–0.50 m depths, with the remaining 69 samples taken from core at various depths between 0.5 and 10 m. Summary geochemical data are presented in Table 5.

Subsoil (n = 70)	**As**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Min	3.28	0.858	8.19	5.20	0.021	10.3	9.33	51.6
Max	13.5	3.12	23.1	21.2	0.426	60.6	215	474
Median	5.97	1.37	13.6	12.1	0.052	30.6	18.7	100
Range	10.3	2.26	14.9	16.0	0.405	50.3	206	422
Topsoil (n = 21)	**As**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Min	6.21	1.30	14.4	12.8	0.056	24.8	24.3	104
Max	11.7	2.32	25.0	36.1	0.165	58.9	55.1	196
Median	10.0	1.75	20.4	16.9	0.108	38.4	31.5	133
Range	5.47	1.02	10.6	23.3	0.109	34.1	30.9	92.0

Table 5 Summary geochemical data for soil samples from Locality B. All concentrations in mg kg^{-1}.

The data for topsoil and subsoil (till) samples are illustrated in boxplots (Figure 47) and histograms (Figure 48) below. In general, the bulk of topsoil samples, as represented by the central box in the Tukey boxplot (Figure 47), have higher element concentrations than subsoils. Both topsoil and subsoil data have quite narrow distributions. Topsoil data are associated with only a few outliers. In contrast, the subsoil data are in part characterized by the presence of numerous upper outliers, notably for As, Cd, Hg, Pb and Zn. This is reflected in Table 5 where the maximum subsoil concentrations for these elements are typically far in excess of those for topsoils. Nevertheless, for the bulk of both topsoil and subsoil samples, concentrations of all elements in topsoils are typically as high as or higher than those in subsoils.

While there is a broad correspondence between the geochemistry of topsoils and subsoils at Locality B, the presence of outliers in the subsoil data for some elements is striking. Subsoils at Locality B have been classified as either till derived chiefly from limestones (labelled TLs) or glaciofluvial sands and gravels derived chiefly from limestone (GLs). This relatively simple sub-division is in contrast to the situation observed at Locality A (section 3.1.1). Figure 50 and Figure 51 illustrate the geochemical variation exhibited by the two subsoil types at Locality B. While differences can be observed in the distribution of individual elements, *e.g.* there is some tendency toward higher concentrations of elements such as Cu and Ni in tills, caution is required to avoid over-interpreting these plots, not least because of sampling difficulties with respect to the sand and gravel material retrieved from boreholes (section 2.1.2), with the possibility of loss of fine material leading to understated concentrations of some elements. Summary data for the main subsoil types at Locality B are given in Table 6.

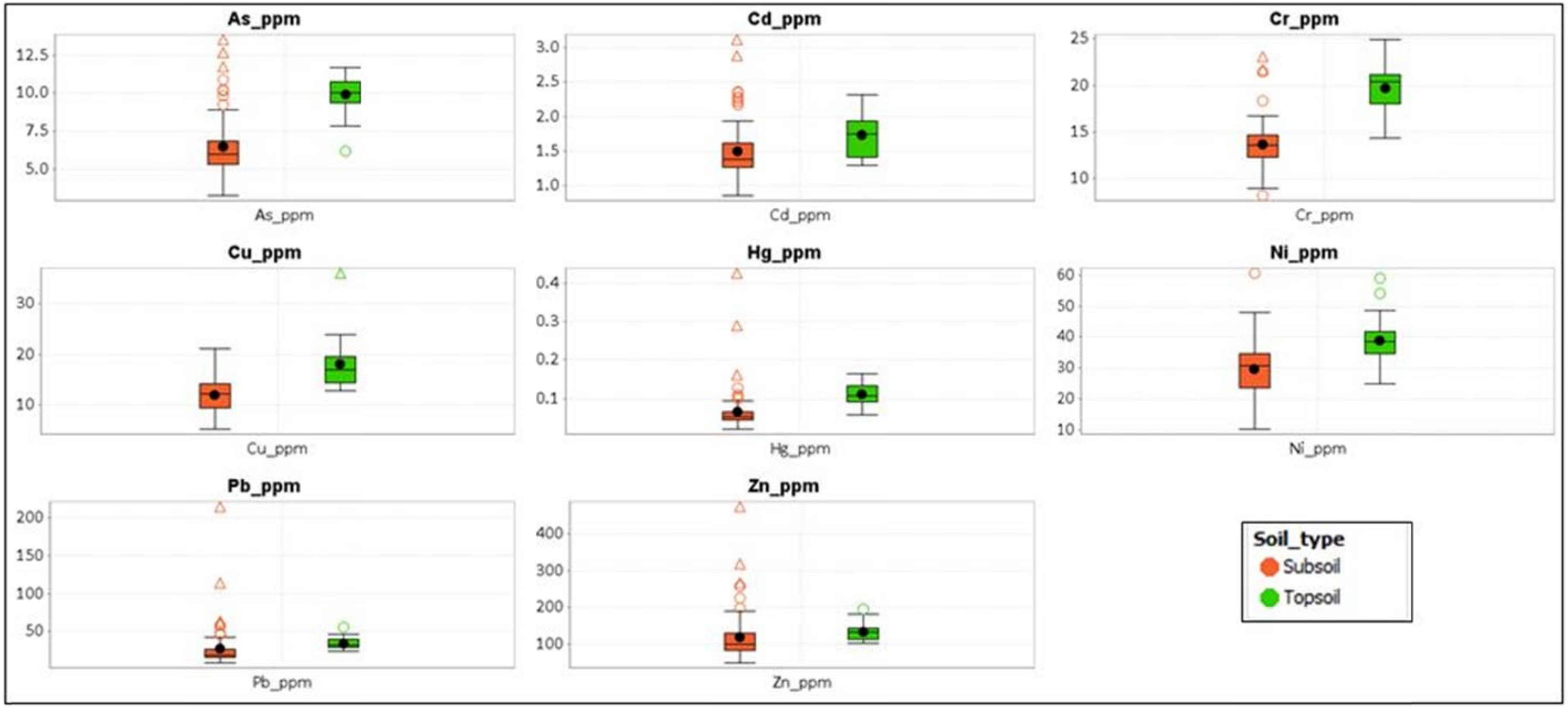


Figure 47 Tukey boxplots for topsoil and subsoil geochemistry, Locality B, showing the distribution of raw (untransformed) data. The outliers are represented by O (outliers) and Δ (far outliers). Outliers are data plotting above or below the fence value (= [IQR*1.5] above the 75th percentile or below the 25th percentile). The far outliers are defined as exceeding [IQR*3] + 75th percentile.). Y axis units: mg kg^{-1}.

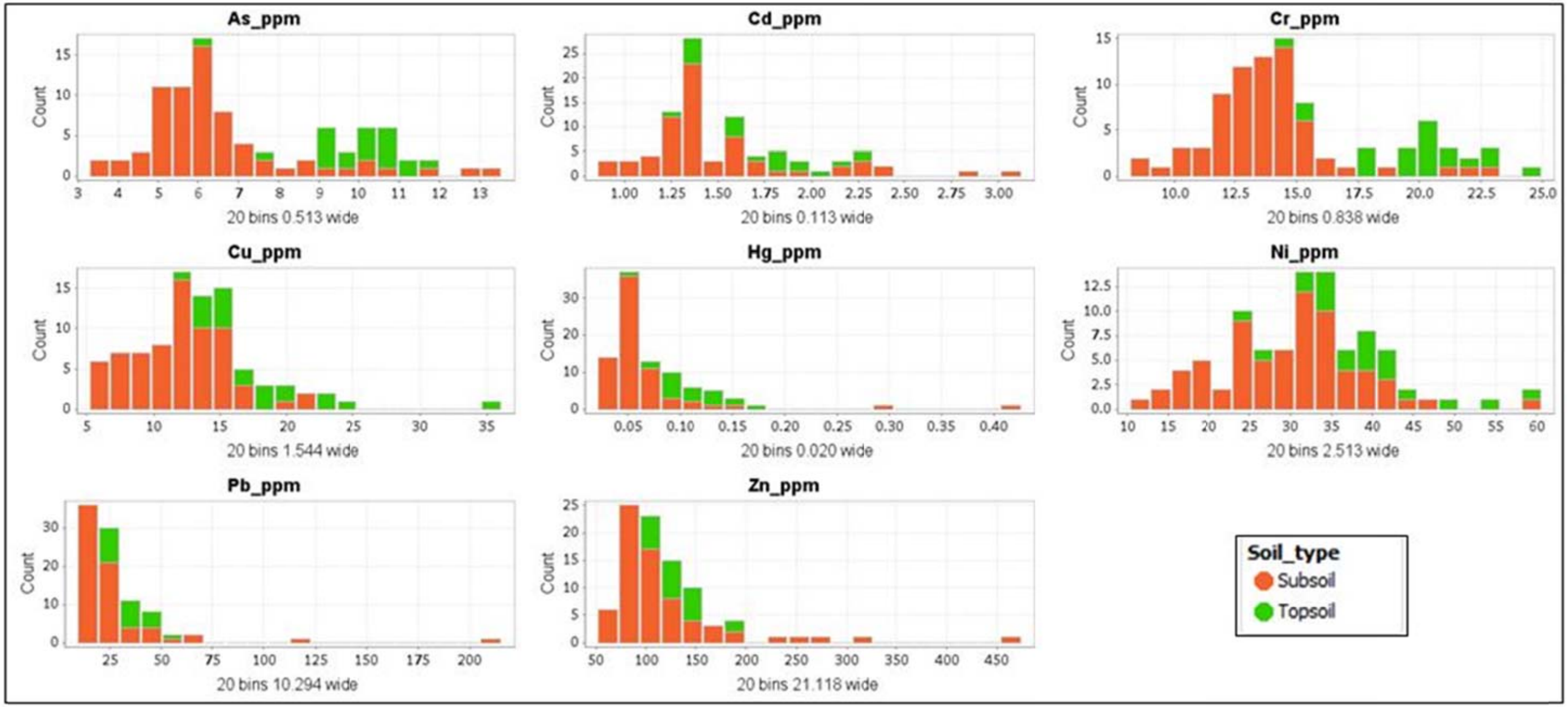


Figure 48 Histograms for topsoil and subsoil geochemistry, Locality B. X axis units: mg kg^{-1}.

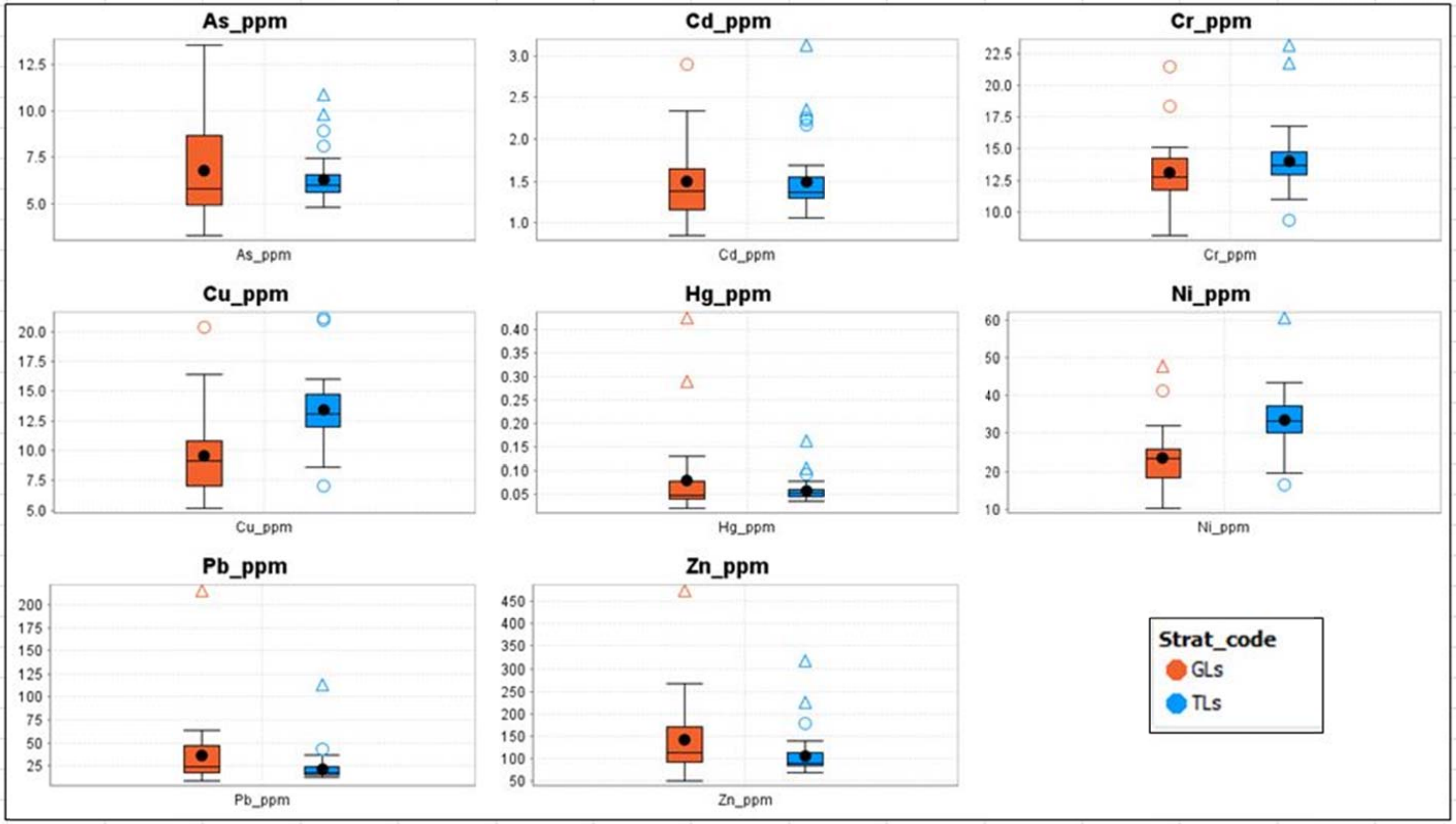


Figure 49 Tukey boxplots for subsoil geochemistry, Locality B, classified by subsoil type. Y axis units: mg kg^{-1}

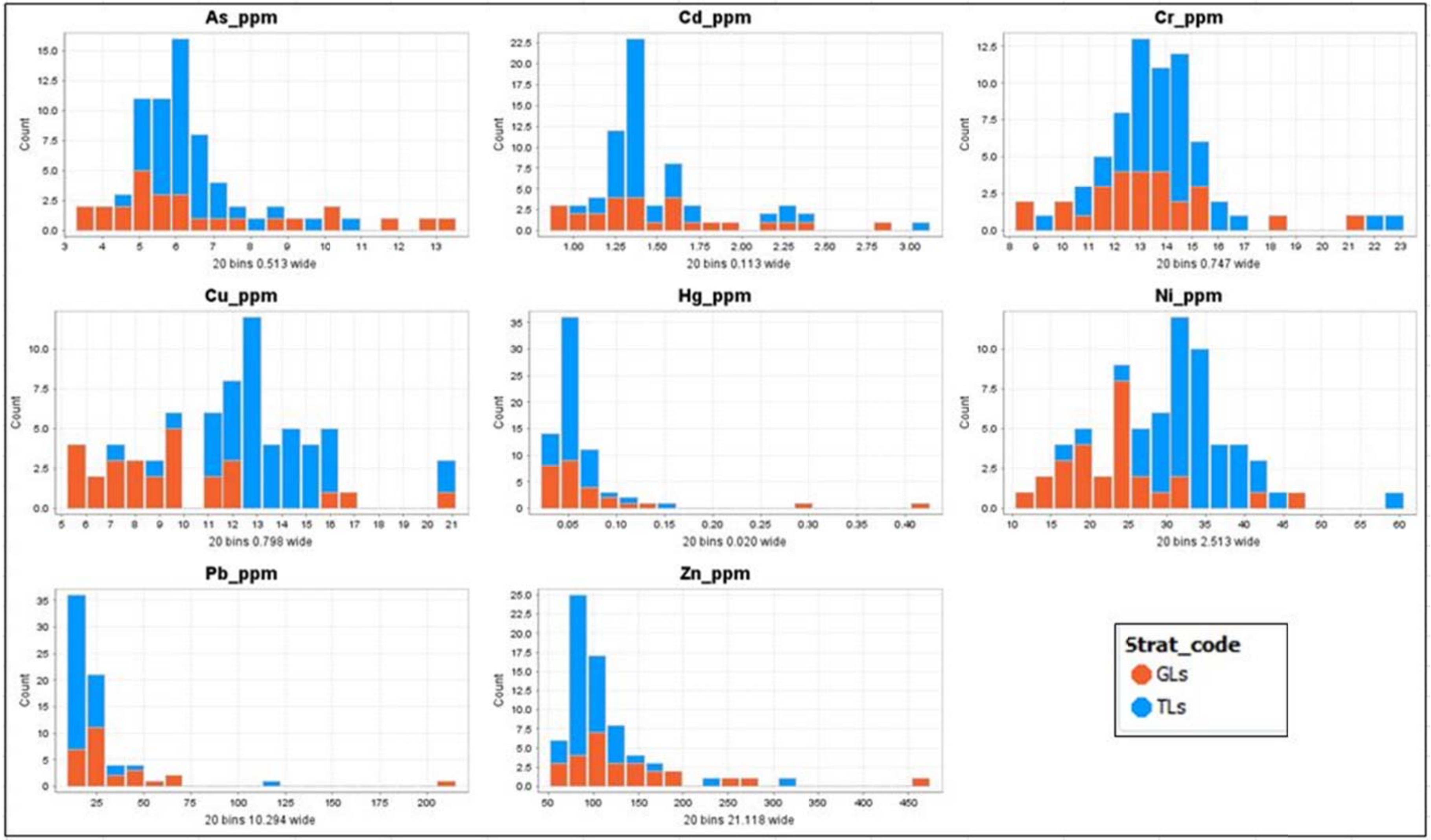


Figure 50 Histograms for subsoil geochemistry, Locality B, classified by subsoil type. X axis units: mg kg^{-1}.

Till (n = 43)	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Min	4.57	1.06	9.40	7.06	0.036	16.5	12.4	68.7
Max	10.9	3.12	23.1	21.2	0.162	60.6	113	318
Median	5.97	1.37	13.7	13.1	0.053	33.2	17.1	90.5
Range	6.31	2.06	13.7	14.1	0.126	44.1	101	249
Gravel (n = 27)	**As**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Min	3.28	0.858	8.19	5.20	0.021	10.3	9.33	51.6
Max	13.5	2.89	21.5	20.4	0.426	47.9	215	474
Median	5.81	1.39	12.8	9.07	0.048	23.2	24.4	114
Range	10.3	2.03	13.3	15.2	0.405	37.5	206	422

Table 6 Summary geochemical data for subsoil types at Locality B. All concentrations in mg kg^{-1}.

The Locality B site is within Domain 2 (Carboniferous limestone and related rocks) on the final domain map (Figure 10). Figure 51 compares the distribution of data using histograms for the Locality B topsoil and subsoil samples and the NSDB samples in Domain 2. Note that the NSDB data are "total" concentrations, in contrast to the data for Locality B, which are based on *aqua regia* extractions. This is significant in the case of Cr, which as described previously typically has very low extraction rates for *aqua regia*, much less so for other elements. Overall, the geochemistry of the Locality B soil falls within the range of that of most samples in Domain 2.

Analysis of down-hole geochemical variation provides further insight into the geochemistry of the Locality B soil samples. Data are presented below in Figure 52, Figure 53, Figure 54 and Figure 55 for the two traverses at Locality B, as illustrated by the two cross-sections above (Figure 18 and Figure 19). The first traverse includes, in sequence from west-northwest to east-southeast, boreholes K01, K02, K03, K06, K05 and K04. There is a general trend to lower values for all elements down-hole. This is consistent with the observation above that sand and gravel units generally have somewhat lower element concentrations than topsoils and tills but this trend is also observed for tills (*e.g.* K05, Figure 52). Borehole K01 is somewhat anomalous in that concentrations of some elements can be observed to increase near the base of the hole, particularly As, Cd, Zn and Pb.

The second traverse includes, in sequence from north-northwest to south-southeast, boreholes K07, K08, K09, K12, K11 and K10. Again, for the most part, element concentrations decrease down-hole. The exception is K07, at the northern end of the traverse. As with K01, which also lies on the northwestern side of the locality, concentrations of As, Cd, Zn and Pb increase toward the base of the hole. This increase in elements may to be associated with base metal mineralization, located nearby or transported by ice from the area of a known Zn-Pb deposit, c. 2 km northwest of Locality B SRF.

In summary, geochemical data for samples from Locality B indicate that the composition of topsoils and subsoils around the SRF are comparable. Comparison with data for the topsoils of the NSDB Domain 2 suggest that the data distribution displayed by the domain encompasses the bulk of the soil sampled at Locality B. Sand and gravel subsoils at Locality B have a tendency to lower element concentrations but this may be as much a reflection of sampling as any inherent geochemical signature. Subsoil at the northern extremity of the site contains a base metal signature that may be related to known mineralization to the northwest.

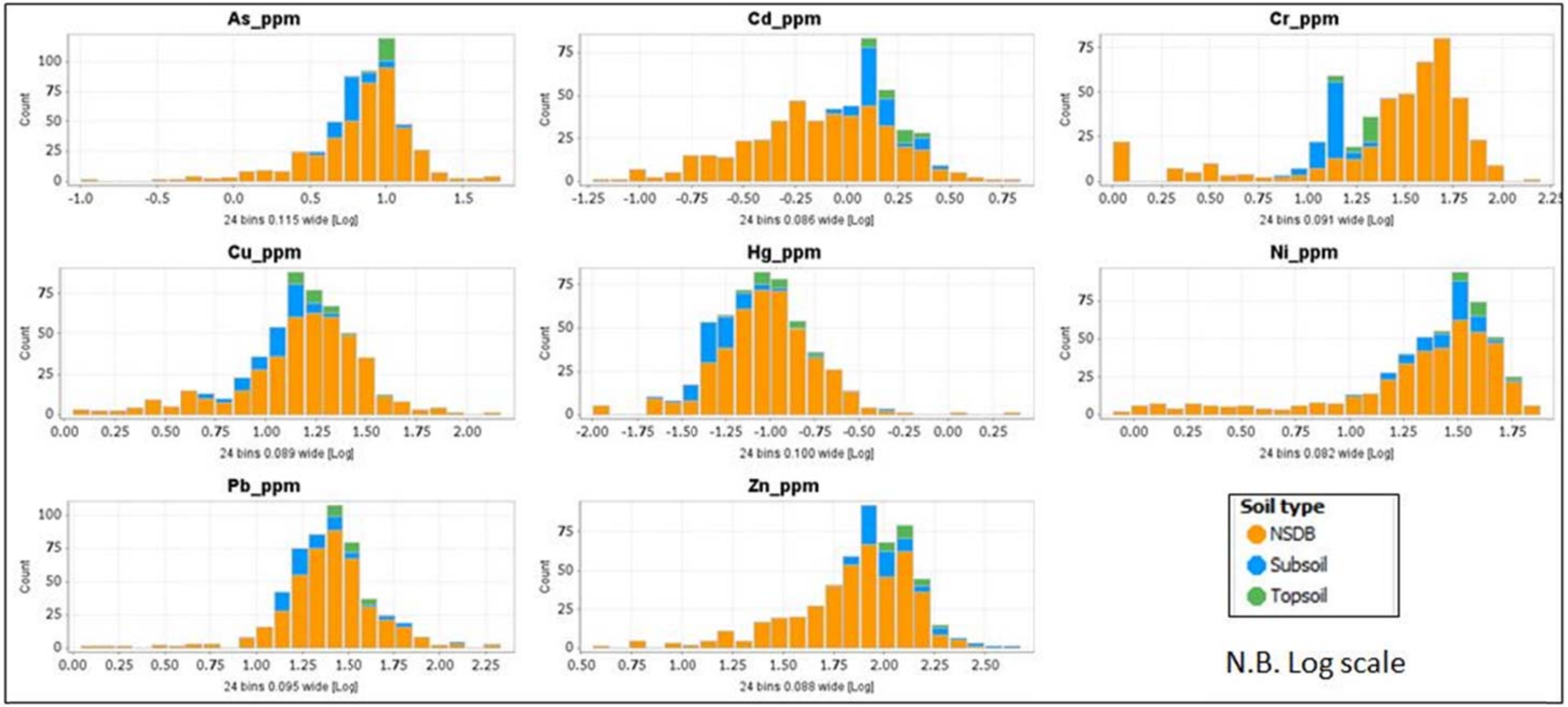


Figure 51 Histograms showing the distribution of soil geochemistry data from Locality B (subsoils and topsoils) and data for the NSDB Domain 2. Note use of log scale to de-skew X-axis for better comparison of datasets.

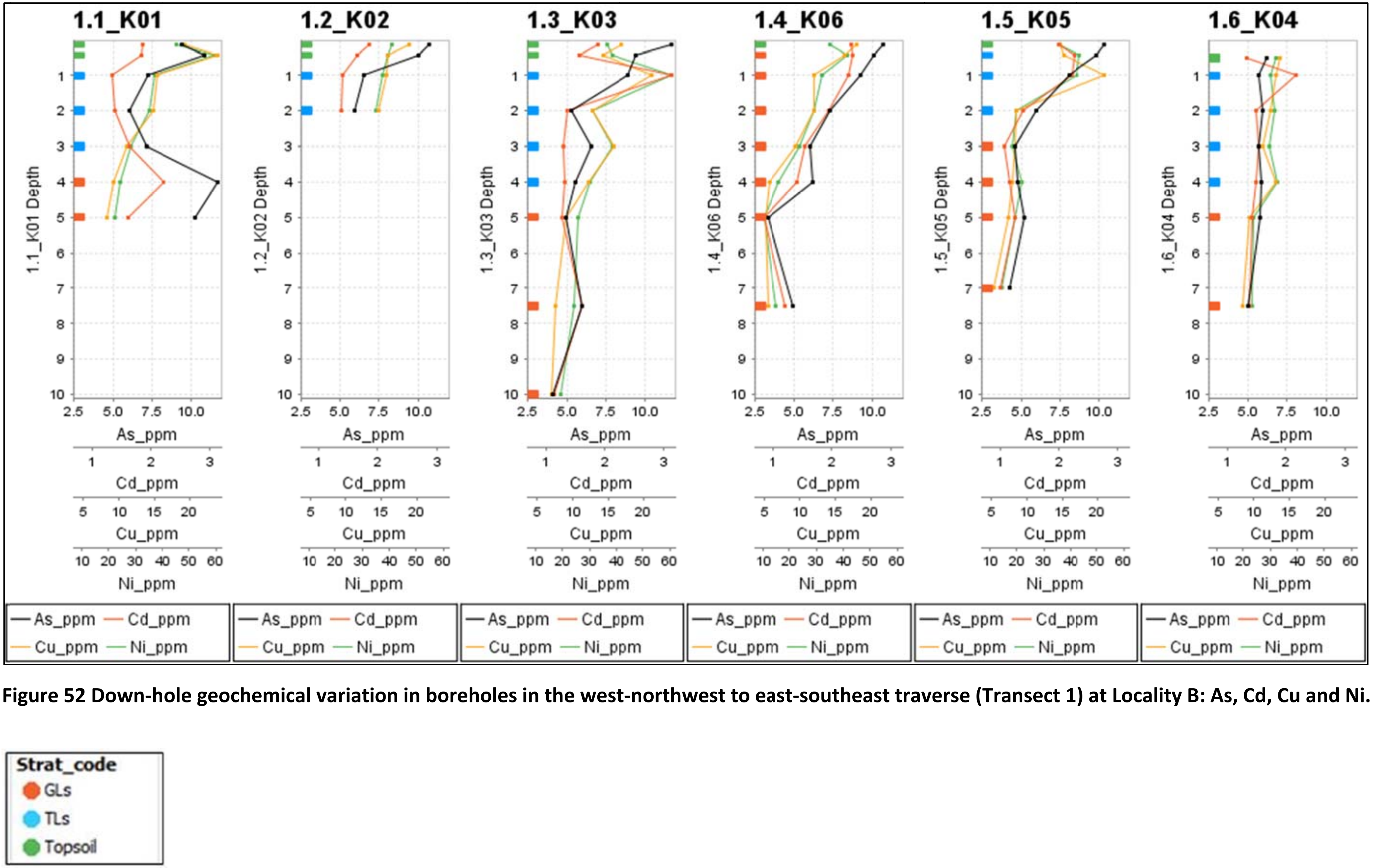


Figure 52 Down-hole geochemical variation in boreholes in the west-northwest to east-southeast traverse (Transect 1) at Locality B: As, Cd, Cu and Ni.

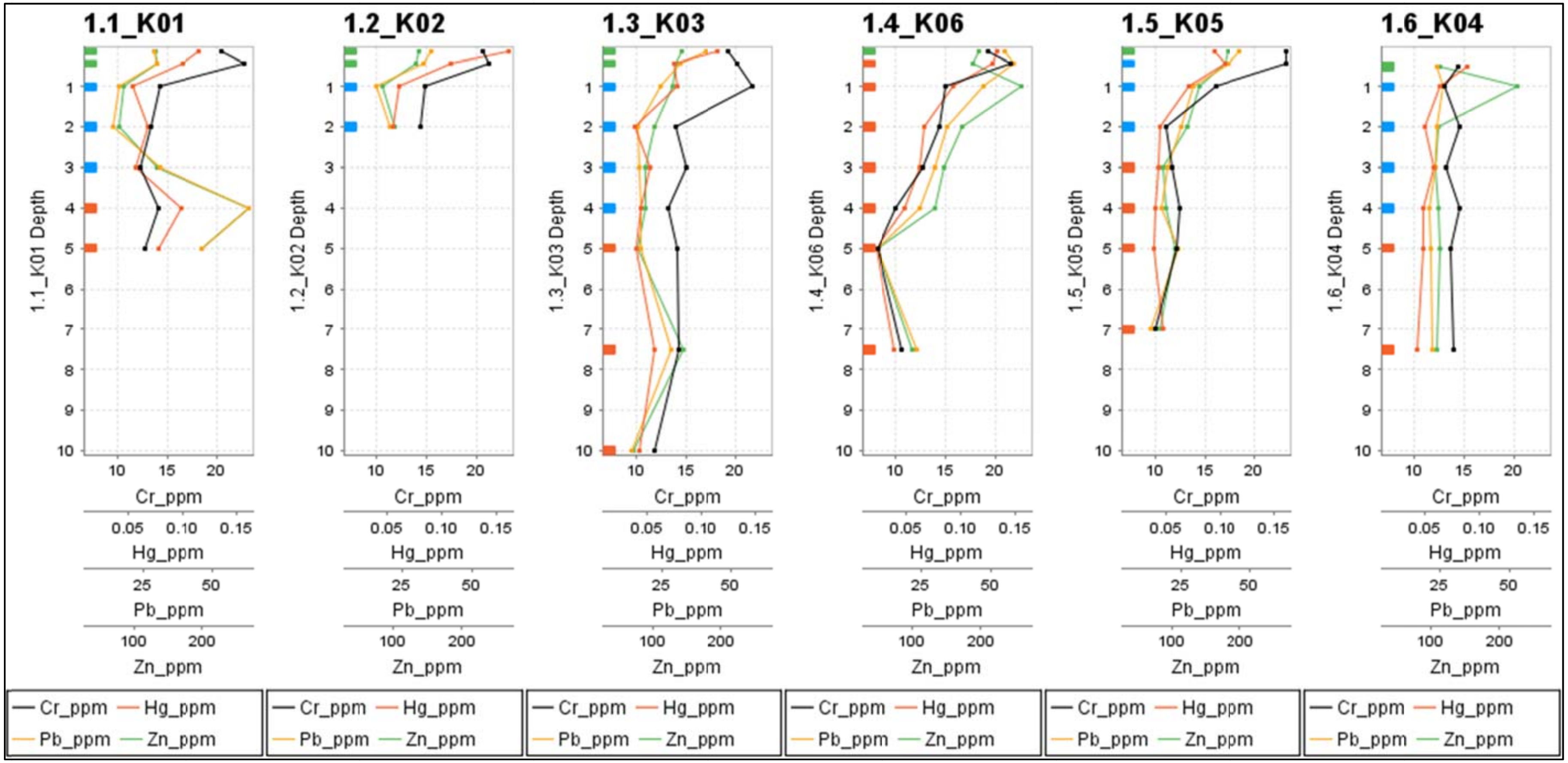


Figure 53 Down-hole geochemical variation in boreholes in the west-northwest to east-southeast traverse (Transect 1) at Locality B: Cr, Hg, Pb, Zn. Legend for soil types as in Figure 52.

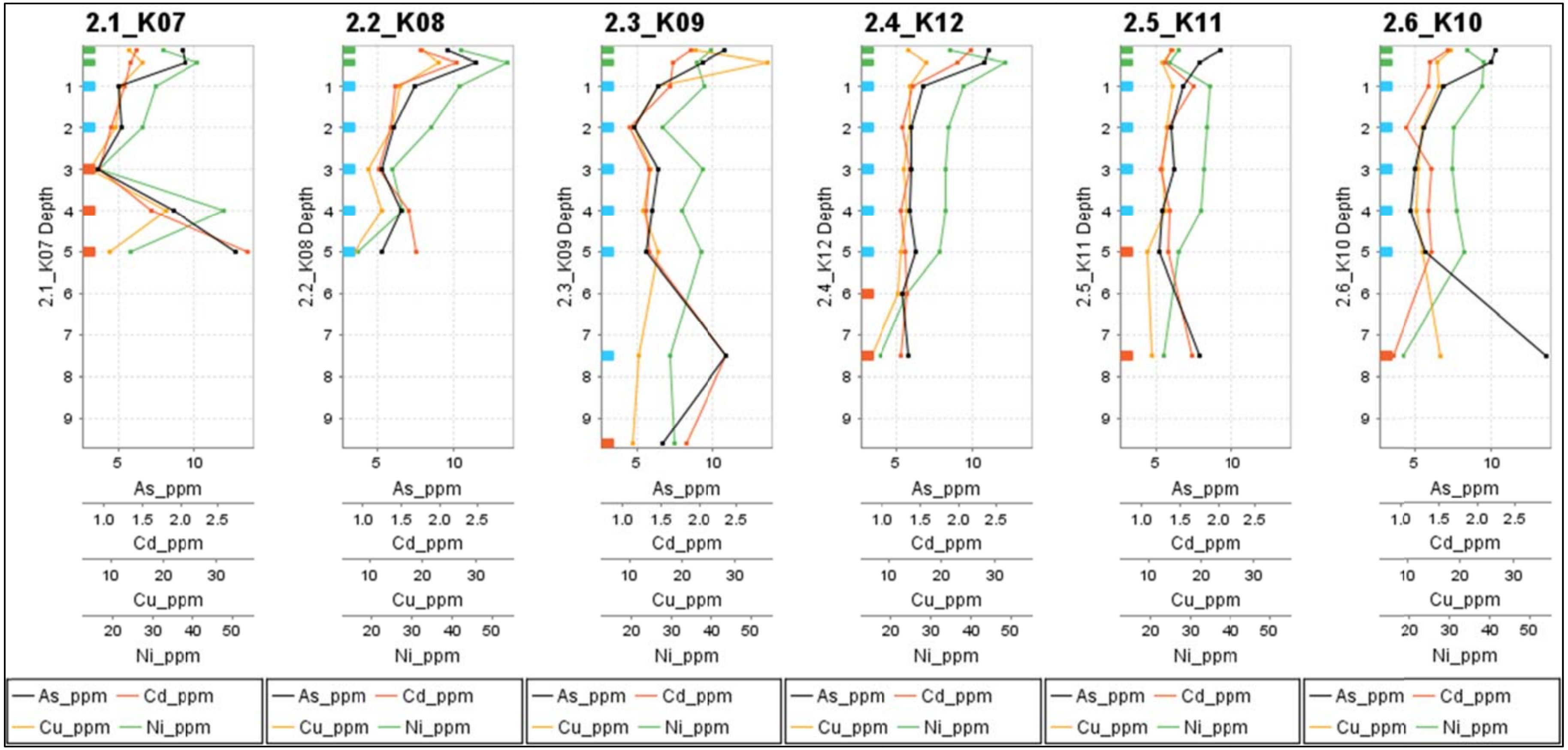


Figure 54 Down-hole geochemical variation in boreholes in the north-northwest to south-southeast traverse (Transect 2) at Locality B: As, Cd, Cu and Ni. Legend for soil types as in Figure 52.

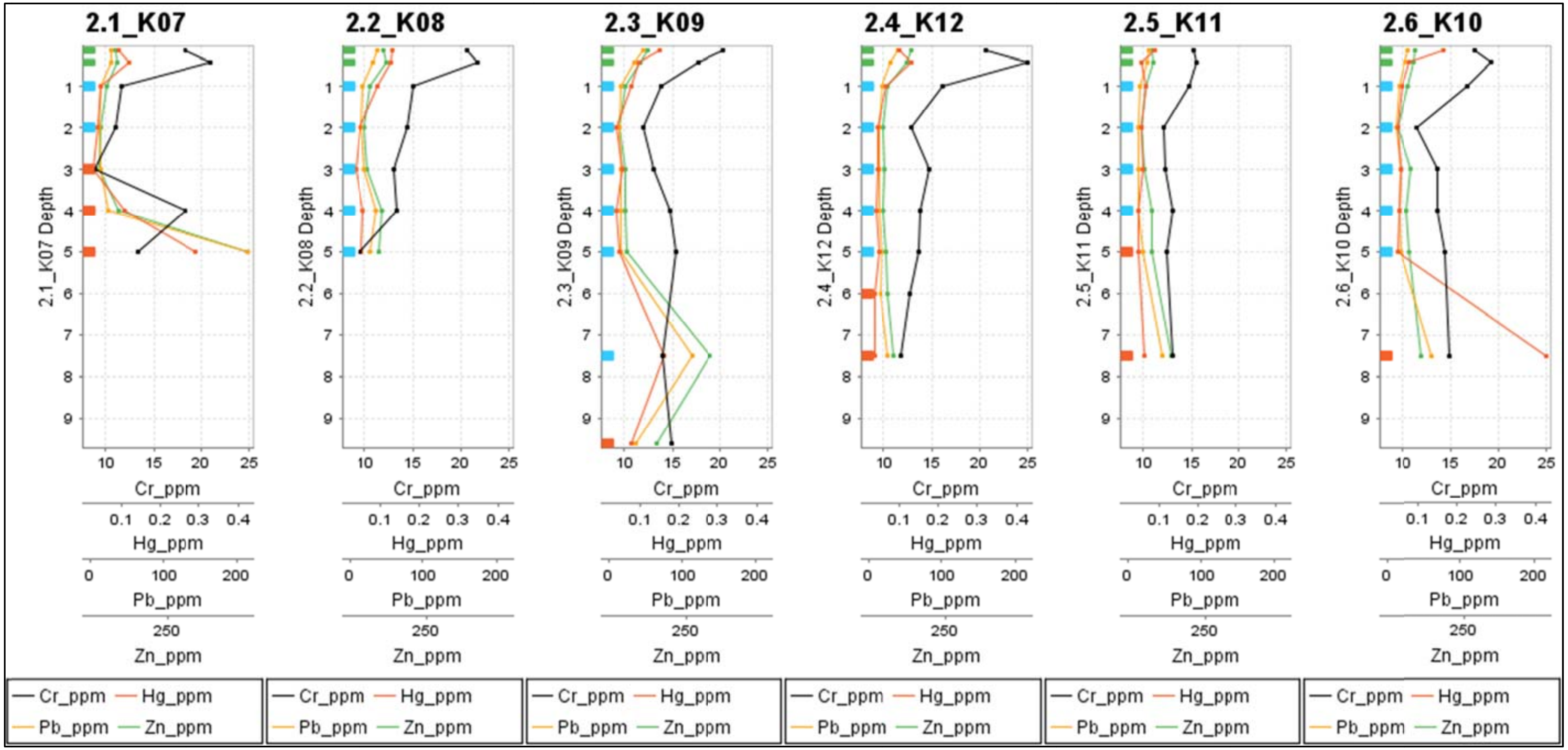


Figure 55 Down-hole geochemical variation in boreholes in the north-northwest to south-southeast traverse (Transect 2) at Locality B: Cr, Hg, Pb, Zn. Legend for soil types as in Figure 52.

3.2. Geochemical domains

3.2.1. Geochemically Appropriate Levels

Domain	n	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Domain 1	166	15.6	1.50	85.9	51.2	0.254	47.8	48.3	137
Domain 2	431	24.9	3.28	83.9	63.5	0.360	61.9	86.1	197
Domain 3	55	38.1	1.60	79.2	56.9	0.457	54.4	81.3	237
Domain 4	278	32.3	0.97	86.2	80.4	0.285	50.3	91.4	155
Domain 5	205	41.5	1.42	122	77.6	0.302	65.7	109	224
Domain 6	64	85.8	2.38	90.0	40.0	0.527	28.2	108	168
Domain 7	111	30.9	0.542	96.0	83.1	0.262	35.7	61.1	122
NSDB 90th percentile (Draft guidelines)	1310	16	1.3	75	35	0.2	42	48	126
NSBD 98th (all) percentile	1310	33.6	2.28	99.9	65.1	0.299	58.8	86.9	183

Table 7 summarizes the calculated GALs for the seven domains, as shown in Figure 10, using NSDB data and the 98th percentile as described in Section 2.2.3. The draft guideline values, i.e. the 90th percentile values as published by the EPA in 2017, are included for comparison.

Domain	n	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Domain 1	166	15.6	1.50	85.9	51.2	0.254	47.8	48.3	137
Domain 2	431	24.9	3.28	83.9	63.5	0.360	61.9	86.1	197
Domain 3	55	38.1	1.60	79.2	56.9	0.457	54.4	81.3	237
Domain 4	278	32.3	0.97	86.2	80.4	0.285	50.3	91.4	155
Domain 5	205	41.5	1.42	122	77.6	0.302	65.7	109	224
Domain 6	64	85.8	2.38	90.0	40.0	0.527	28.2	108	168
Domain 7	111	30.9	0.542	96.0	83.1	0.262	35.7	61.1	122
NSDB 90th percentile (Draft guidelines)	1310	16	1.3	75	35	0.2	42	48	126
NSBD 98th (all) percentile	1310	33.6	2.28	99.9	65.1	0.299	58.8	86.9	183

Table 7 Calculated GALs (98th percentile) for defined geochemical domains. All concentrations in mg kg^{-1}.

The calculated GALs show wide variation among the seven domains and are generally higher than those proposed as trigger values in the EPA's (2017) draft guidelines. The latter is to be expected given the use of the 98th percentile rather the 90th percentile of the NSDB used in the draft guidelines. However, this accounts for only some of the variation observed and the recasting of the NSDB in the context of geological domains has led to significant changes for some calculated GALs, with notably high values for As in Domain 6, Cd in Domain 2 and Hg in both Domain 3 and Domain 6.

3.2.2. Sampling and analytical specifications

In applying any trigger or threshold geochemical values it is important to include full specifications for sample collection, preparation and analysis. Inter-comparison of geochemical data is most reliable where samples have been collected, prepared and analysed to a uniform or at least comparable standard.

For sample collection, avoidance of any potential contamination from sampling equipment or from cross-contamination from other materials or samples is essential. This approach should be carried through the preparation stage, where use of non-metallic materials for sieving, crushing and grinding, *e.g.* agate mills, is required. Geochemical analysis generally utilizes only a small amount of material (typically between 0.5 g and 10 g). In the context of material destined for SRFs, where the requirement is to test at a rate of one per 2,000 tonne for a single source, representative sub-sampling of soil and stone for analysis is a significant challenge.

Various analytical techniques are available for testing soil samples, including multi-element and single-element techniques. A key consideration is how the reported concentrations of samples can be compared to the proposed GALs. The calculated GALs Table 7 in are based on "total" element concentrations for the NSDB, as determined following a strong acid digestion. As noted in Section 2.1.4, the weaker *aqua regia* digestion typically employed for soil analysis in various sectors and also used in this study leads to consistent under-reporting of concentrations for most elements. The degree of under-reporting depends to a large degree on the mineralogical composition of the sample and is generally within 20% for As, Cu, Ni, Pb and Zn. Analyses completed for this project suggest that *aqua regia* digestion followed by ICP-MS analysis can produce acceptable results for Hg. However, for Cr, concentrations may be routinely under-reported by as much as 60–70 % using this method. Consequently, if Cr is to be included in the list of elements for which GALs are to be specified, then Cr should be analysed by a "total" method or else a method-specific GAL should be defined. This issue is discussed further in Appendix F. As outlined therein, for samples analysed by ICP following *aqua regia* digestion, the method-specific GAL for Cr is arrived at by applying a correction factor of 0.6 to the Cr value listed in Table 7 .

3.3. Discussion

3.3.1. Locality A

At Locality A, it was previously recognized that Irish Sea Till with Lower Palaeozoic clasts and glaciofluvial sands and gravels, also with Lower Palaeozoic clasts, formed subsoil in the area. Drilling has revealed a more complex stratigraphy, with local limestone-dominated tills and sands and gravels also present in the area. The local deposits appear to have formed during the early part of the last glaciation, as evidenced by their occurrence at depth in the stratigraphy in the southeast, and are overlain by Irish Sea Till deposited by ice moving onshore from the Irish Sea, potentially at or during the last glacial maximum. However, local limestone-dominated tills were also deposited in the north and west, where they overlie Irish Sea Till, by an advance from the northwest towards the end of the last glaciation. Limestone bedrock was definitively met in only one borehole, immediately adjacent the limestone quarry, while a transition zone of broken shale or impure limestone was met in the southwest.

The bulk of both topsoil and subsoil samples at Locality A span a similar range for the eight elements of interest. While the topsoil data have a very narrow distribution and display few outliers, the subsoil data are in part characterized by the presence of numerous upper outliers. No one subsoil type can be said to be responsible for all the upper outliers observed in the subsoil data, although the Irish Sea till samples and the sand and gravel with Lower Palaeozoic clasts do account for most of them. Down-hole geochemical variation is typically modest, with most elements showing a slight decrease down-hole. The exception is for two holes in the southeast where significant increases in element concentrations are observed, notably for Irish Sea Till material. It should be noted that this variation may be owing to the fact that some of these sediments may be older than Quaternary in age and much more weathered.

Comparison with the data for the topsoils of the NSDB Domain 2 (Carboniferous limestone and related rocks) suggest that the data distribution displayed by the domain encompasses the bulk of the soil sampled at Locality A.

3.3.2. Locality B

It was previously recognized that the Locality B site is on a ridge comprising glaciofluvial sands and gravels derived chiefly from Lower Carboniferous limestones but is underlain by Old Red Sandstone bedrock. An extensive area of till dominated by Lower Carboniferous limestone clasts occurs around the site. Bedrock was not intersected in any borehole, confirming the considerable thickness of subsoils in the area. Possible esker sands and gravels were encountered north of the site. These are overlain by limestone sands and gravels that dominate the sand and gravel ridge in the centre of the area. These deposits were all formed during initial deglaciation. The sands and gravels are overlain by limestone-dominated tills that formed during a readvance at the very end of deglaciation.

In general, the bulk of topsoil samples have higher element concentrations than subsoils. Topsoil data are associated with only a few outliers. In contrast, the subsoil data are in part characterized by the presence of numerous upper outliers, notably for As, Cd, Hg, Pb and Zn. Subsoils can be divided into limestone-dominated tills and limestone-dominated sands and gravels - overall the subsoil types are geochemically very similar. There is a general trend to lower values for all elements down-hole. On the northwestern side of the site, concentrations of As, Cd, Zn and Pb increase toward the base of the hole, possibly reflecting mineralized material, located either nearby or transported by ice from a known nearby Zn-Pb deposit.

Comparison with the data for the topsoils of the NSDB Domain 2 (Carboniferous limestone and related rocks) suggest that the data distribution displayed by the domain encompasses the bulk of the soil sampled at Locality B. The investigation confirms the approach of classifying domains using subsoil map rather than bedrock map where information is available.

4. Conclusions and recommendations

A pilot geochemical investigation has been completed at two representative sites, Locality A and Locality B, in order to establish an approach to the geochemical characterization of a site and the utility of setting trigger values for acceptance based on geochemical domains.

4.1. Conclusions

4.1.1. The use of topsoil data as a proxy for subsoil data

Geochemical data for samples from two representative SRF sites indicate that the composition of topsoils and subsoils around the SRFs are comparable. Subsoils are distinguished by several upper outliers, some with quite high concentrations of certain elements. These outliers skew the data distribution but do not affect the conclusion that topsoils and subsoils share a broadly similar geochemistry. These data would support the use of topsoil data as a proxy for subsoil data, in the absence of baseline subsoil geochemical data.

4.1.2. Justification for domains approach

The recasting of the NSDB data in the context of geological domains has led to significant changes for some calculated GALs, with notably high values for As in Domain 6, Cd in Domain 2 and Hg in both Domain 3 and Domain 6. Geochemical data collected at two representative SRFs are generally within the range of values expected from their respective geochemical domains.

4.2. Recommendations

4.2.1. Trigger levels – Geochemically appropriate levels

We recommend that the EPA considers adopting 'Geochemically Appropriate Levels' (GALs), based on the NSDB data and geochemical domains, as trigger levels for the acceptance of uncontaminated soil and stone into waste-licenced SRFs.

GALs should be periodically reviewed with improved availability of baseline soil geochemistry data in Ireland, specifically, when Tellus topsoil geochemical mapping is completed nationally (projected 2028) and as GSI quaternary mapping progresses. Ideally, the approach would benefit from a national baseline subsoil geochemistry mapping exercise.

4.2.2. Chromium testing

We observe that the current industry-standard testing method, ICP following *aqua regia* digestion, performs poorly in relation to the determination of Cr because of the generally low rate of extraction of Cr using the relatively weak *aqua regia* acid mixture. Using this extraction method to test for Cr in soil will systematically underestimate the concentration of Cr in the sample. It is recommended that a 'total' (*e.g.* XRF) or 'near-total' (four-acid digest) method is employed to establish compliance with the GAL for Cr, which is based on a 'near-total' method. Alternatively, a method-specific GAL should be defined. For samples analysed by ICP following *aqua regia* digestion, the recommended method-specific GAL for Cr is arrived at by applying a correction factor of 0.6 to the Cr value listed in Table 7.

4.2.3. Dublin Boulder Clay geochemical characterization

We note that large quantities of subsoil from the greater Dublin area are being moved to SRFs in the hinterland of the city. This material is likely to be mainly comprised of the Dublin Boulder Clay (DBC). This colloquial term refers to brown and black poorly sorted, stiff lodgement till deposits which are deep and widespread across Dublin. The DBC is poorly understood in terms of its geochemistry and is anecdotally known to have anomalously high levels of some metals and metalloids. Some existing data (see the Irish Sea Till at Locality A, this study) and the Dublin Soil Urban Geochemistry project (Glennon *et al.,* 2012 and 2014) provide evidence for naturally elevated metals in certain soils in the Dublin region. Given that the NSDB did not survey Dublin soils, the GALs suggested here do not take account of the DBC. It is recommended that a geochemical characterization of the DBC is carried out in support of further refinement of this project.

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Appendix A Locality A borehole logs

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

CABLE TOOL CORE LOGS

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Geochemical sample numbers are the sample field I.D. numbers for geochemistry samples; generally taken every metre to 5m, every 2.5m thereafter.

Particle size distribution (PSD) sample numbers are the sample field I.D. numbers for particle size distribution samples, generally taken at 0.5m, 1.0m, 3.0m, 5.0m and 10.0m depths.

'Solum' refers to the soil-forming layers, comprising topsoil 'A' and 'B' horizons, developed during the Holocene Period (since 10,500 years BP).

'Facies' numbers refer to discrete units of subsoil.

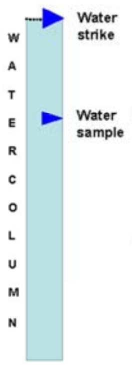
Where subsoil facies' have 'g' subscripts, this denotes gleying, or saturation, expressed as mottling therein.

Numbers after soil and subsoil colurs refer to Munsell Soil Colour charts hues and chroma

***e.g.* 3/3 (chroma), 10YR (hue)**

British Standard (BS 5930) subsoil descriptions give details of plasticity and dilatancy tests. Named subsoils in these logs only refer to those on which such tests have been completed, in the field at the time of sampling.

Symbology



Stability :

Basic data on consolidation of material drilled..

General remarks :

Information on setting of borehole locality, topographically and in t terms of land use..

Groundwater :

Data on strike depths, if any..

Sequence summary:

Short summary of soil and subsoil unit(s) sequence.

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

CABLE TOOL CORE M01

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 07/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 35.5m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	O.D. Level	Depth	Description
From 0.1m to 0.3m	Geochem	M01 001	'Solum'		35.0	0.5	TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), loam overlying very sandy gravelly SILT/CLAY. Structure seems quite blocky.
From 0.4m to 0.6m; From 0.9m to 1.1m; 1.5; From 1.9 to 2.1m	Geochem /PSD; Geochem /PSD; Geochem	003 1a; 004 1b; 005	'Limestone-dominated till' (TLs) Facies 1		33.5	2.0	SUBSOIL 'C_1' horizon: dark brown (3/3, 10YR), very sandy CLAY. Structure more massive, and material more competent. Clasts are angular to subangular, limestone-dominated. No shells present in this unit.
							GRADING INTO
2.5; From 2.9m to 3.1m; 3.5	Geochem /PSD	006 1c	'Limestone-dominated till' (TLs) Facies 2	Water strike	31.7	3.8	SUBSOIL 'C_2' horizon: brown (4/3, 10YR), gravelly, very sandy SILT with occasional cobbles. Massive and consolidated. Clasts are angular to subangular, limestone-dominated. Occasional quartz pebbles. No shells present in this unit. At base of unit, bed of medium SAND occurs.
From 3.9 to 4.1m; 4.5; From 4.9m to 5.1m; 5.5	Geochem; Geochem /PSD	007; 008 1d	'Limestone-dominated till' (TLs) Facies 3				SUBSOIL 'C_3' horizon: dark yellowish brown (4/6, 10YR), gravelly, very sandy SILT with occasional cobbles. Massive and consolidated. Clasts are angular to subangular, limestone-dominated. No shells present in this unit.

Legend:

Setting

Stability :

Material quite soft below 2.0m depth.

General remarks :

Bored on southern mid-backslope of ridge, in arable field.

Groundwater :

Groundwater strike at 3.5m bgl. Dry above this depth.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' units, more soft at depth.

CABLE TOOL CORE M01

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 07/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 35.5m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
6.0 6.5 7.0 7.5			'Limestone-dominated till' (TLs) Facies 3					SUBSOIL 'C_3' horizon (contd.): dark yellowish brown (4/6, 10YR), gravelly, very sandy SILT with occasional cobbles. Massive and consolidated. Clasts are angular to subangular, limestone-dominated. No shells present in this unit.
					28.0		7.5	**Cable tool core completed at 7.5m on stiff, overconsolidated, fissile, silt- and clay-dominated till (boulder clay, 'Irish Sea Till'?).**

Subsoil recovered

Stability :

Material continues quite soft at depth.

General remarks :

Bored on southern mid-backslope of ridge, in arable field.

Groundwater :

Groundwater below 3.5m.
Sample taken from 3.5m depth.

Sequence summary:

Grey brown podzolic topsoil over 'local', 'limestone till' units, more soft at depth.

CABLE TOOL CORE M02

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 12/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 31.0m

Samples & in-situ tests

Depth taken	Type	No	Stratum Name	Water
From 0.1m to 0.3m	Geochem	M02 001	'Solum'	
From 0.4m to 0.6m	Geochem /PSD	002 2a		
From 0.9m to 1.1m	Geochem /PSD	003 2b		
1.5			'Limestone-dominated till' (TLs) Facies 1	
From 1.9 to 2.1m	Geochem	004		
2.5				
From 2.9m to 3.1m	Geochem /PSD	005 2c		
3.5			'Limestone-dominated till' (TLs) Facies 2	
From 3.9 to 4.1m	Geochem	006		
4.5				Water sample
From 4.9m to 5.1m	Geochem /PSD	007 2d		
5.5				

Strata details

O.D. Level	Depth	Description
30.5	0.5	TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), topsoil sods overlying sandy SILT with occasional gravels (2, 3, 3 threads; 80mm, 50mm, 50mm ribbons; dilatant and raspy). Structure seems quite blocky, and material relatively soft. *GRADING INTO*
29.8	1.2	SUBSOIL 'C$_1$' horizon: dark yellowish brown (4/6, 10YR), sandy SILT with occasional gravels (2, 2, 1 threads; 50mm, 80mm, 50mm ribbons; dilatant and raspy). Structure more massive, and material more competent. Clasts are subangular to subrounded, and striated. Limestones dominant.
28.0	3.0	SUBSOIL 'C$_2$' horizon: dark yellowish brown (4/4, 10YR), silty SAND with abundant gravels (1, 0, 1 threads; 30mm, 20mm, 20mm ribbons; dilatant, very raspy). Relatively blocky structure, grading into massive material, which is heavily overconsolidated. Clasts are subangular to subrounded, and striated. Limestones dominant, with some shale content also. Most clasts <50mm across. <u>No shells</u> present in this unit. Material is dry, and well drained. *GRADING INTO*
25.5	5.5	SUBSOIL 'C$_3$' horizon: dark yellowish brown (4/6, 10YR), very sandy SILT with occasional, rare gravels (2, 3, 3 threads; 110mm, 70mm, 70mm ribbons; dilatant, very raspy). Very fissile structure, and heavily overconsolidated, with material particularly stiff from 4m depth. From 3.2m deep, recovery is as intact 'tubes' of sediment. Fissility expressed as 1mm-2mm sub-horizontal partings, with some aeration along these at 4m depth. Clasts are subangular to subrounded, and striated. Limestones dominant, with much shale content at this level. Most clasts <10mm across. <u>No shells</u> present in this unit. Material is dry, and well drained. Below 4m depth, units of very gravelly, silty SAND (0, 1, 0 threads; 30mm, 20mm, 30mm ribbons; dilatant, raspy) with occasional cobbles, are present. These units are up to 0.2m across. Becomes more soft at depth, and material is very soft, fissile and moist from 5.0m depth.
		Cable tool core completed at 5.5m on (presumed?) limestone bedrock.

Setting

Stability :

Material initially heavily overconsildated, but becomes very soft at depth.

General remarks :

Bored on northwestern mid-backslope of low rise, where slope flattens out. Bored in central area of pasture field.

Groundwater :

Groundwater not met above 5.0m bgl, where moist zone begins. Influx, and sample taken when water at 4.72m.

Sequence summary:

Grey brown podzolic topsoil over 'local', 'limestone till' units, becoming softer at depth.

CABLE TOOL CORE M03

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan   Date: 13/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 30.0m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	O.D. Level	Depth	Description
From 0.1m to 0.3m	Geochem	M03 001	'Solum'		29.5	0.5	TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), topsoil sods overlying sandy SILT/CLAY with occasional gravels (5, 4, 5 threads; 110mm, 120mm, 120mm ribbons; slightly dilatant and raspy). Material firm, and structure seems quite blocky.
From 0.4m to 0.6m	Geochem /PSD	002 3a					
From 0.9m to 1.1m	Geochem /PSD	003 3b			28.9	1.1	SUBSOIL 'C$_1$' horizon: dark brown (3/3, 10YR), sandy CLAY with occasional gravels (3, 5, 5 threads; 110mm, 90mm, 110mm ribbons; slightly dilatant and slightly raspy). Structure more massive, and fissile, and material more competent again. Clasts are subsounded and subangular limestone, up to 20mm across.
1.5			'Limestone-dominated till' (TLs) Facies 1				SUBSOIL 'C$_2$' horizon: dark yellowish brown (5/6, 10YR), sandy SILT with occasional gravels (2, 4, 3 threads; 80mm, 90mm, 90mm ribbons; dilatant and raspy). Many cobbles of subangular and subrounded, striated, limestone.
							G R A D I N G I N T O
From 1.9 to 2.1m	Geochem	004					SUBSOIL 'C$_3$' horizon: dark yellowish brown (4/6, 10YR), sandy SILT with occasional gravels (3, 3, 2 threads; 90mm, 100mm, 100mm ribbons; dilatant and raspy). Massive, heavily overconsolidated ... material recovered as intact 'tubes' of sediment. No shells present in this unit. Material is dry, and well drained.
2.5					27.3	2.7	Clasts are subangular to subrounded, and heavily striated. Limestones dominant.
From 2.9m to 3.1m	Geochem /PSD	005 3c	'Limestone-dominated sands and gravels' (GLs) Facies 2				
3.5							SUBSOIL 'C$_4$' horizon: yellowish brown (5/8, 10YR) to strong brown (5/6, 7.5R) slightly silty SAND with occasional gravels (0, 0, 0 threads; 20mm, 0mm, 0mm ribbons; cohesive, dilatant and very raspy).
From 3.9 to 4.1m	Geochem	006					Some beds of dark brown (3./3, 10YR) gravelly SAND and dark yellowish brown (4/6, 10YR) SAND with occasional gravels. Clasts are subangular to subrounded, and striated. Unit becomes more gravelly with depth. Limestones completely dominant.
4.5				►	Water sample		No shells present in this unit. Material is dry, and well drained, as far as 5.8m depth where significant water strike met.
From 4.9m to 5.1m	Geochem /PSD	007 3d					
5.5							

Legend:

Setting

Stability :

Material becomes quite soft below 2.7m depth, having been relatively stiff above this.

General remarks :

Bored just above shoulder slope of low ridge, at edge of deeply-incised meltwater channel. Bored only 5m from field boundary, at edge of pasture field.

Groundwater :

Dry - groundwater not met above 6.0m bgl.

Sequence summary:

Grey brown podzolic topsoil over 'local', 'limestone till' unit, again over sands and gravels.

Geological Survey
Suirbhéireacht Gheolaíochta
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CABLE TOOL CORE M03

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan   Date: 13/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 30.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
			'Limestone dominated sands and gravels' (GLs) – Facies 2 (contd.)	►	Water strike 24.0			**SUBSOIL 'C$_5$' horizon: yellowish brown (5/6, 10YR) sandy GRAVELS with occasional cobbles (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-cohesive, non-dilatant, very raspy). Clasts rounded and up to 0.1m across, limestone dominated.**
6.0			'Erratic dominated sands and gravels' (GLs) – Facies 3		23.8		6.0	SUBSOIL 'C$_6$' horizon: greenish grey (6/1, GLEY 1) sandy GRAVELS (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-cohesive, non-dilatant, very raspy). Clasts are of limestone, sandstones and shales, reddish brown (4/4, 2.5YR) jasper and quartz.
6.5 From 6.9m to 7.1m 7.5	Geochem /PSD	008	'Erratic-dominated till' Facies 4		22.4		6.2	**SUBSOIL 'C$_7$g' horizon: mottled strong brown (5/8, 7.5YR) and bluish grey (6/1, GLEY 2), sandy CLAY with occasional gravels (5, 5, 5 threads; 120mm, 120mm, 120mm ribbons; non-dilatant and raspy).** **Clasts of subangular and subrounded, striated, volcanics, chalk and limestone.** **No shells present in this unit.**
			'Irish Sea Till' (IrSTLPSsS) Facies 5		22.0		7.6	SUBSOIL 'C$_8$' horizon: dark brown (3/3, 10YR), sandy gravelly SILT/CLAY (4, 4, 5 threads; 110mm, 100mm, 120mm ribbons; slightly dilatant and raspy). Massive, heavily overconsolidated; clasts are angular and subangular, of sandstone and chalk. Many small shells throughout material, each 1mm, or less, across.
8.0 8.5 9.0 9.5			'Irish Sea Till' (IrSTLPSsS) Facies 6		20.0		8.0	**SUBSOIL 'C$_9$g' horizon: mottled dark grey (4/1, 7.5YR) and strong brown 6/8, 7.5YR), sandy gravelly SILT/CLAY (5, 5, 5 threads; 120mm, 110mm, 120mm ribbons; slightly dilatant and raspy).** **Massive, heavily overconsolidated ... material recovered as intact 'tubes' of sediment.** **Many small shells throughout material, each 1mm, or less, across.** **Clasts are subangular to subrounded, and heavily striated. Greenish grey (5/1, GLEY 1) sandstones dominate.**
From 9.9m to 10.1m	Geochem /PSD	009 3e					10.0	**Cable tool core completed at 10.0m on stiff, fissile, silt- and clay-dominated till (boulder clay).**

Subsoil recovered

Stability :

Material becomes very stiff below 6.2m depth, with sands and gravels having been relatively soft above this.

General remarks :

Bored just above shoulder slope of low ridge, at edge of deeply-incised meltwater channel. Bored only 5m from field boundary, at edge of pasture field.

Groundwater :

Groundwater strike at 5.8m depth. Water influx, and groundwater sample taken when water level at 4.63 mbgl.

Sequence summary:

'Irish Sea till' subsoil units beneath various units of erratic lithologies and 'local' material.

Geological Survey Suirbhéireacht Gheolaíochta Ireland | Éireann	# CABLE TOOL CORE M04
	Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities
Site: Locality A	Method and Equipment: Machine excavated, Dando 2000 shell and auger rig
	Logged by: R.Meehan Date: 05/03/2019
All dimensions on this sheet are in metres unless otherwise stated	Ground level OD: 43.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
From 0.1m to 0.3m	Geochem	M04 001	'Solum'					TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), topsoil overlying sandy SILT/CLAY with occasional gravels (4, 3, 3 threads; 110mm, 110mm, 90mm ribbons; slightly dilatant and raspy).
From 0.4m to 0.6m	Geochem /PSD	002 4a						Structure seems quite blocky, and material relatively soft.
					42.2		0.8	*G R A D I N G I N T O*
From 0.9m to 1.1m	Geochem /PSD	003 4b	'Limestone-dominated till' (TLs) Facies 1					SUBSOIL 'C_1' horizon: brown (4/3, 10YR), granular, silty SAND with occasional gravels and cobbles (0, 1, 0 threads; 30mm, 40mm, 20mm ribbons; dilatant and raspy). Clasts generally subangular, with some subrounded pebbles. Limestone dominant.
1.5					41.5		1.5	SUBSOIL 'C_2' horizon: brown (4/3, 10YR), sandy SILT with occasional gravels and cobbles (0, 2, 2 threads; 110mm, 90mm, 90mm ribbons; dilatant, raspy). Fissile structure, and heavily overconsolidated. Fissility expressed as 1mm-2mm sub-horizontal partings, with some aeration along these. Clasts are subangular to subrounded, and striated. Limestones completely dominant. Most clasts <10mm across.
From 1.9m to 2.1m	Geochem	004						No shells present in this unit. Material is dry, and well drained.
From 2.1m to 2.3m 2.5	PSD	4c			40.5		2.5	**Cable tool core completed at 2.5m on competent limestone bedrock.**

Setting

Stability :

Material initially relatively soft, but becomes consolidated below 1.2m.

General remarks :

Bored on southeastern shoulder slope of high ridge, where slope begins to steepen, just outside perimeter boundary of quarry. Bored at northern end of arable field, recently sown.

Groundwater :

Dry.

Sequence summary:

Brown earth of high base status topsoil over 'local', 'limestone till'.

CABLE TOOL CORE M05

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 06/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 27.0m

Depth taken	Type	No (M05)	Stratum Name	Water	O.D. Level	Legend	Depth	Description
From 0.1m to 0.3m	Geochem	001	'Made Ground'					IMPORTED MATERIAL, COMPRISING IN THE MAJORITY TOPSOIL, BUT WITH SOME CONCRETE SLABS, GRAVEL, VOIDS AND 'A' HORIZON SODS. Bluish grey (6/1, GLEY 2) colour.
From 0.4m to 0.6m	Geochem	002						
1.0					25.9		1.1	
From 1.4m to 1.6m	Geochem /PSD	003 5a	'Irish Sea Till' (IrSTLPSsS) Facies 1					SUBSOIL 'C_1' horizon: mottled dark yellowish brown (4/4, 10YR), light bluish grey (8/1, GLEY 2) and dark grey (3/1, 10YR), slightly sandy CLAY with occasional gravels (5, 5, 5 threads; 110mm, 120mm, 120mm ribbons; non-dilatant and slightly raspy). Occasional cobbles of subangular and subrounded, striated, limestone, with pebbles of shale also present. Becoming slightly heavier, more dense and more intensely mottled at depth. Many small shells throughout material, each 1mm, or less, across.
From 1.9 to 1.1m	Geochem /PSD	004 5b						
2.5								
From 2.9m to 3.1m	Geochem	005						G R A D I N G I N T O
3.5					23.5		3.5	
From 3.9 to 4.1m	Geochem /PSD	006 5c	'Irish Sea Till' (IrSTLPSsS) Facies 2					SUBSOIL 'C_2' horizon: very dark grey (3/1, 10YR), slightly sandy CLAY with occasional gravels (4, 5, 3 threads; 110mm, 90mm, 120mm ribbons; slightly dilatant and very raspy). Very fissile throughout, and subhorizontal fissility in evidence along 1mm wide pseudo-laminations. Clasts are of subangular and subrounded, striated, limestone, with pebbles of shale, chalk, andesite and sandstone also present. Larger cobble-sized clasts tend to be in the majority subrounded. Becoming slightly heavier, more dense and more intensely mottled at depth. Many small shells throughout material, each 1mm, or less, across.
4.5								
From 4.9m to 5.1m	Geochem	007						
5.5								

Setting

Stability :

Material becomes quite stiff below 3.2m depth.

General remarks :

Bored on middle backslope of low ridge (at lower end of higher ridge dominating the locality. Bored at the edge of farm entrance roadway, behind house, at edge of recently-ploughed, arable field.

Groundwater :

Dry - groundwater not met above 6.0m bgl.

Sequence summary:

Grey infill over over 'Irish Sea' till units, more consolidated at depth.

CABLE TOOL CORE M05

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 06/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 27.0m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	O.D. Level	Legend	Depth	Strata details: Description
From 5.9m to 6.1m	Geochem /PSD	M05 0085d	'Irish Sea Till' (IrSTLPSsS) Facies 2	Water strike	20.7		6.3	SUBSOIL 'C_2' horizon (contd.): very dark grey (3/1, 10YR), slightly sandy CLAY with occasional gravels (5, 5, 4 threads; 90mm, 110mm, 120mm ribbons; non-dilatant and slightly raspy). Many small shells throughout material, each 1mm, or less, across.
6.5			'Irish Sea Till' (IrSTLPSsS) Facies 3				6.75	SUBSOIL 'C_3' horizon: mottled bluish grey (6/1, GLEY 2) and yellowish brown (4/6, 10YR), gravelly CLAY (5, 5, 6 threads; 110mm, 100mm, 120mm ribbons; non-dilatant). Shells throughout. Clasts of subangular and subrounded, striated, volcanics, chalk and limestone.
7.0 7.5 8.0 8.5			'Erratic dominated sands and gravels' - Facies 4	Water sample	18.3		8.7	SUBSOIL 'C_4' horizon: very dark grey (3/1, 10YR) sandy GRAVEL with occasional cobbles (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-cohesive, non-dilatant, very raspy). Clasts rounded and up to 0.1m across. Erratics of jasper, breccia, dark reddish brown (3/4, 2.5YR) sandstone and metamorphics, as well as the dominant clasts of greenish grey (5/1, GLEY 1) sandstone (assumed Ordovician / Silurian).
								Cable tool core completed at 8.7m on loose, granular, sandy GRAVELS and COBBLES.

Subsoil recovered (at depth)

Stability :

Material becomes difficult to penetrate belkow 7.1m, owing to preponderance of pebbles and cobbles rolling into hole.

General remarks :

Bored on middle backslope of low ridge (at lower end of higher ridge dominating the locality. Bored at the edge of farm entrance roadway, behind house, at edge of recently-ploughed, arable field.

Groundwater :

Groundwater strike at 6.3m depth.
No rise in water level owing to gravels water sample taken at 7.48 mbgl.

Sequence summary:

'Irish Sea' till subsoil units above various units of 'erratic' lithologies.

CABLE TOOL CORE M06

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan | Date: 06/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 25.5m

Samples & in-situ tests

Depth taken	Type	No
From 0.1m to 0.3m	Geochem	M06 001
From 0.4m to 0.6m	Geochem /PSD	002 6a
From 0.9m to 1.1m	Geochem /PSD	003 6b
1.5		
From 1.9 to 2.1m	Geochem	004
2.5		
From 2.9m to 3.1m	Geochem /PSD	005 6c
3.5		
From 3.9 to 4.1m	Geochem	006
4.5		
From 4.9m to 5.1m	Geochem /PSD	007 6d
5.5		

Strata details

Stratum Name	Water	O.D. Level	Depth	Description
'Solum'	MOIST ZONE	25.0	0.5	TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), infilled, decomposed topsoil sods overlying sandy SILT/CLAY with occasional gravels (4, 4, 5 threads; 110mm, 80mm, 110mm ribbons; slightly dilatant and raspy). Structure seems quite blocky.
'Solum'	MOIST ZONE	24.8	1.2	SUBSOIL 'C_1' horizon: dark brown (3/3, 10YR), slightly sandy CLAY with occasional gravels (5, 5, 5 threads; 120mm, 120mm, 120mm ribbons; non dilatant and slightly raspy). Structure more massive, and material more competent.
'Irish Sea Till' (IrSTLPSsS) Facies 1				SUBSOIL 'C_2g' horizon: brown (4/3, 10YR), slightly sandy CLAY with occasional gravels (6, 6, 5 threads; 130mm, 120mm, 120mm ribbons; non dilatant and slightly raspy). Massive, heavily overconsolidated. GRADING INTO
'Irish Sea Till' (IrSTLPSsS) Facies 1		22.5	3.0	SUBSOIL 'C_3g' horizon: mottled dark yellowish brown (4/4, 10YR) and light bluish grey (7/1, GLEY 2), slightly sandy CLAY with occasional gravels (6, 5, 5 threads; 120mm, 120mm, 120mm ribbons; non dilatant and slightly raspy). Massive, heavily overconsolidated ... material recovered as intact 'tubes' of sediment. Many small shells throughout material, each 1mm, or less, across. Clasts are subangular to subrounded, and heavily striated. Limestones dominant, with some greenish grey sandstones and shales.
'Irish Sea Till' (IrSTLPSsS) Facies 2		22.3	3.2	SUBSOIL 'C_4' horizon: dark grey (4/1, 10YR), sandy CLAY with occasional gravels (5, 6, 6 threads; 130mm, 130mm, 130mm ribbons; non dilatant, raspy). Massive, heavily overconsolidated. GRADING INTO
'Irish Sea Till' (IrSTLPSsS) Facies 2				SUBSOIL 'C_5g' horizon: mottled dark bluish grey (4/1, GLEY 2) and dark yellowish brown (4/6, 10YR), slightly sandy gravelly SILT/CLAY (veering towards CLAY, 5, 5, 5 threads; 110mm, 120mm, 120mm ribbons; slightly dilatant and slightly raspy). Massive, yet strongly fissile, and heavily overconsolidated ... material again recovered as intact 'tubes' of sediment. Many small shells throughout material, each 1mm, or less, across. Clasts are subangular to subrounded, and heavily striated. Unit becomes more gravelly with depth. Limestones dominant, with some greenish grey sandstones, reddish yellow sandstones, and flint. Some small pods of medium SAND, each less than 0.02m across. Becomes more stiff at depth, and material is hard from 5.0m depth.

Legend:

Setting

Stability :

Material very stiff below 1.2m depth.

General remarks :

Bored on southeastern lower-backslope of ridge, where slope flattens out. Bored approximately 5m north of stable wall.

Groundwater :

Groundwater not met above 6.0m bgl. though moist zone present at 1.0m depth.

Sequence summary:

Grey brown podzolic topsoil over 'Irish Sea' till units, more stiff and clayey at depth.

Geological Survey
Suirbhéireacht Gheolaíochta
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CABLE TOOL CORE M06

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan — Date: 06/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 25.5m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	O.D. Level	Legend	Depth	Strata details: Description
6.0 6.5		M06	'Irish Sea Till' (IrSTLPSsS) Facies 2		18.8		6.7	SUBSOIL 'C_5g' horizon (contd.): mottled dark bluish grey (4/1, GLEY 2) and dark yellowish brown (4/6, 10YR), slightly sandy gravelly SILT/CLAY (veering towards CLAY, 5, 5, 5 threads; 110mm, 120mm, 120mm ribbons; slightly dilatant and slightly raspy). Massive, yet strongly fissile, and heavily overconsolidated ... material recovered as intact 'tubes' of sediment. Clasts are subangular to subrounded, and heavily striated. Unit becomes more gravelly with depth. Limestones dominant, with some greenish grey sandstones, reddish yellow sandstones, and flint. Many small shells throughout.
From 6.9m to 7.1m 7.5 8.0 8.5 9.0 9.5 From 9.9m to 10.1m	Geochem /PSD Geochem /PSD	0086e 0106f	'Local Till ?' (TLs) Facies 3	Water sample Water strike	15.5		10.0	SUBSOIL 'C_6g' horizon: mottled greenish grey (6/1, GLEY 1) and light red (7/6, 7.5YR), slightly sandy CLAY with occasional gravels (6, 6, 5 threads; 110mm, 130mm, 130mm ribbons; non-dilatant, slightly raspy). Massive, yet strongly fissile, and heavily overconsolidated ... material again recovered as perfectly intact 'tubes' of sediment. **No shells** in the material of this unit. Clasts are predominantly of small 'pea' gravels, 1mm-3mm across, and are angular. Larger clasts are more subsngular and subrounded. Only clasts above 3mm noted as striated. Limestones dominant, with many dark reddish brown to dark brown sandstones, and flint. Through 8.0m depth, greenish grey colour is almost completely dominant, and material very hard. Here, mottles are of light red colour. Unit becomes more gravelly beneath 9.0m depth, and is described as a gravelly sandy CLAY here (5, 5, 5 threads; 120mm, 130mm, 130mm, ribbons; non-dilatant, raspy). Becomes more stiff towards base of hole, with darker grey colour returning.
								Cable tool core completed at 10.0m on hard, fissile, clay-dominated till (boulder clay).

Subsoil recovered

Stability :

Material gets more stiff with depth.

General remarks :

Bored on southeastern lower-backslope of ridge, where slope flattens out. Bored approximately 5m north of stable wall.

Groundwater :

Groundwater strike at 8.7m depth. Water influx, and groundwater sample taken when water level at 7.16 mbgl.

Sequence summary:

'Irish Sea' till subsoil units over potentially 'local' till (diamict may be pre-LGM).

CABLE TOOL CORE M07

Geological Survey Suirbhéireacht Gheolaíochta Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan　　Date: 07/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 17.5m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	Strata details: O.D. Level	Legend	Depth	Description
From 0.1m to 0.3m	Geochem	M07 001	'Solum'					TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), loam overlying sandy gravelly SILT/CLAY. Structure seems blocky. Some clasts of weathered shale.
From 0.4m to 0.6m; From 0.9m to 1.1m; 1.5	Geochem /PSD; Geochem /PSD	002 7a; 003 7b	'Limestone-dominated till' (TLs) Facies 1		17.2		0.3	SUBSOIL 'C_1' horizon: brown (4/3, 10YR), sandy gravelly SILT. Structure more massive, and material more competent. Clasts are angular to subangular, limestone-dominated. No shells present in this unit.
From 1.9 to 2.1m; 2.5; From 2.9m to 3.1m; 3.5	Geochem; Geochem /PSD	004; 005 7c	'Limestone-dominated till' (TLs) Facies 2		16.0		1.5	SUBSOIL 'C_2' horizon: very dark brown (2/2, 10YR) to black (2/1, 10YR), gravelly, SILT/CLAY with occasional cobbles. Massive and heavily overconsolidated. Clasts are angular to subangular, limestone-dominated, but with occasional shales also. Occasional quartz erratics at depth. No shells present in this unit.
From 3.9 to 4.1m	Geochem	006	'Limestone-dominated till' (TLs) – Facies 3 - Potential Transition Zone		13.8		3.7	SUBSOIL 'C_3' horizon: dark yellowish brown (4/6, 10YR), slightly sandy clayey GRAVEL, with occasional cobbles. Clasts are angular to subangular, limestone-dominated. No shells present in this unit. Potential transition zone ?
					13.5		4.0	**Cable tool core completed at 4.0m on (presumed?) limestone bedrock.**

Subsoil recovered

Stability :

Material quite stiff below 1.5m depth.

General remarks :

Bored on northeastern lower-backslope of ridge, in pasture field. Gravelly unit above (presumed?) bedrock may be transition zone.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' units, potential transition zone at base

Geological Survey
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CABLE TOOL CORE M08

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 08/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 16.0m

Samples & in-situ tests

Depth taken	Type	No
From 0.1m to 0.3m	Geochem	M08 001
From 0.4m to 0.6m	Geochem /PSD	002 8a
From 0.9m to 1.1m	Geochem /PSD	003 8b
1.5		
From 1.9 to 2.1m	Geochem	004
2.5		
From 2.9m to 3.1m	Geochem /PSD	005 8c
3.5		
From 3.9 to 4.1m	Geochem	006

Strata details

Stratum Name	Water	O.D. Level	Depth	Description
'Solum'				TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), loam overlying sandy gravelly SILT/CLAY.
'Limestone-dominated till' (TLs) Facies 1		15.7	0.3	SUBSOIL 'C_1' horizon: mottled yellowish brown (5/6, 10YR) and dark bluish grey (4/1, GLEY 2), very sandy gravelly SILT. Structure massive, and material competent. Clasts are angular to subangular, limestone-dominated. No shells present in this unit. Moist throughout.
'Limestone-dominated till' (TLs) Facies 2	Water strike and sample	14.2	1.8	SUBSOIL 'C_2' horizon: mottled very dark brown (2/2, 10YR) and dark bluish grey (4/1, GLEY 2), slightly silty sandy GRAVEL with occasional cobbles. Massive and relatively soft (very moist). Clasts are angular to subangular, limestone-dominated, but with occasional sandstones and shale clasts also. Occasional quartz erratics at depth. No shells present in this unit.
'Limestone-dominated till' (TLs) – Facies 3 - Potential Transition Zone		12.5	4.0	SUBSOIL 'C_3' horizon: very dark grey (3/1, 10YR) to black (2/1, 10YR), very stiff, gravelly SILT/CLAY, with occasional cobbles. Clasts are angular to subangular, limestone-dominated. No shells present in this unit. Potential transition zone ?
		12.3	4.2	**Cable tool core completed at 4.2m on (presumed?) limestone bedrock.**

Setting

Stability :

Material quite soft below 1.8m depth, owing to saturation.

General remarks :

Bored on northeastern lower-backslope of ridge, in pasture field.
Gravelly unit above (presumed?) bedrock may be transition zone.

Groundwater :

Groundwater met at 3m depth, and sample taken at that depth.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' units, potential transition zone at base

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CABLE TOOL CORE M09

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan   Date: 11/03/2019

All dimensions on this sheet are in metres unless otherwise stated

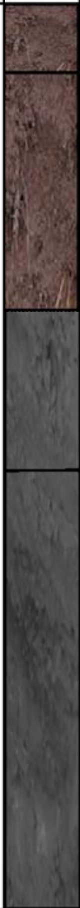
Ground level OD: 15.0m

Samples & in-situ tests

Depth taken	Type	No
From 0.1m to 0.3m	Geochem	M09 001
From 0.4m to 0.6m	Geochem /PSD	002 9a
From 0.9m to 1.1m	Geochem /PSD	003 9b
1.5		
From 1.9 to 2.1m	Geochem	004
2.5		
From 2.9m to 3.1m	Geochem /PSD	005 9c
3.5		
From 3.9 to 4.1m	Geochem	007
4.5		
From 4.9m to 5.1m	Geochem /PSD	008 9d
5.5		

Strata details

Stratum Name	Water	O.D. Level	Legend	Depth	Description
'Solum'		14.5		0.5	TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), topsoil overlying sandy SILT/CLAY with occasional gravels (5, 5, 5 threads; 100mm, 100mm, 90mm ribbons; dilatant and raspy). Shells throughout basal 0.2m, material relatively soft.
'Irish Sea Till' (IrSTLs) Facies 1		13.0		2.0	*GRADING INTO* Occasional fragments of concrete blocks at 0.8m-1.0m depth. SUBSOIL 'C₁' horizon: dark brown (3/3, 10YR), sandy SILT/CLAY with occasional gravels (4, 3, 4 threads; 110mm, 120mm, 120mm ribbons; slightly dilatant and raspy). Structure more massive, and material more competent. Clasts are subangular to subrounded, and striated. Limestones dominant, but much shale also. Shells throughout this material.
'Irish Sea Till' (IrSTLs) Facies 2		12.0		3.0	SUBSOIL 'C₂' horizon: mottled dark yellowish brown (4/6, 10YR) and light bluish grey (7/1, GLEY 2), sandy SILT/CLAY with occasional gravels (5, 5, 5 threads; 120mm, 120mm, 80mm ribbons; slightly dilatant, raspy). Shell fragments common. Very fissile structure, and heavily overconsolidated, with material particularly stiff from 3m depth. From 3.1m deep, recovery is as intact 'tubes' of sediment. Clasts are subangular to subrounded, and striated. Limestones dominant, with much shale content also at this level. Most clasts <20mm across.
'Limestone-dominated till' (TLs) Facies 3					SUBSOIL 'C₃g' horizon: mottled yellowish brown (5/6, 10YR) and light bluish grey (7/1, GLEY 2), sandy SILT with occasional gravels (3, 2, 2 threads; 80mm, 90mm, 120mm ribbons; dilatant, raspy). No shell fragments at this level. Very fissile structure, and heavily overconsolidated, with recovery is as intact 'tubes' of sediment. Fissility expressed as 1mm-2mm sub-horizontal partings, with some aeration along these at 3m-4m depth. Clasts are subangular to subrounded, and striated. Limestones dominant, with only occasional shale content at this level. Most clasts <10mm across, and subangular. Below 4m depth, colour becomes very dark grey (3/1, 10YR) predominantly. Between 4.5m and 5.0m depth, faint laminations seen in diamict material.



Setting

Stability :

Material heavily overconsolidated throughout.

General remarks :

Bored on southern mid-backslope of low rise, where slope flattens out. Bored in central area of green space at edge of housing estate, adjacent to passing stream.

Groundwater :

Groundwater not met above 5.6m bgl, where moist zone begins.

Sequence summary:

Grey brown podzolic topsoil over 'Irish Sea Till', again over local', 'limestone till' units, .

CABLE TOOL CORE M09

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 11/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 15.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
			'Limestone-dominated till' (TLs)	▶	Water strike			SUBSOIL 'C_3g' horizon: mottled yellowish brown (5/6, 10YR) and light bluish grey (7/1, GLEY 2), sandy SILT with occasional gravels (3, 2, 2 threads; 80mm, 90mm, 120mm ribbons; dilatant, raspy). No shell fragments.
6.0			Facies 3		9.2		5.8	**Cable tool core completed at 5.8m on (presumed?) limestone bedrock.**

Setting

Stability :

Material heavily overconsolidated throughout.

General remarks :

Bored on southern mid-backslope of low rise, where slope flattens out. Bored in central area of green space at edge of housing estate, adjacent to passing stream.

Groundwater :

Groundwater met at 5.8m bgl, but not in sufficient amounts to allow sample collection.

Sequence summary:

Grey brown podzolic topsoil over 'Irish Sea Till', again over local', 'limestone till' units.

CABLE TOOL CORE M10

Geological Survey
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Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan | Date: 05/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 31.5m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	O.D. Level	Depth	Strata details: Description
From 0.1m to 0.3m	Geochem	M10 001	'Solum'		31.0	0.5	TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), topsoil overlying sandy SILT/CLAY with occasional gravels (4, 4, 2 threads; 120mm, 100mm, 90mm ribbons; slightly dilatant and raspy). Material relatively soft, blocky structure, no shells.
From 0.4m to 0.6m	Geochem /PSD	002 10a					
					30.5	1.0	SUBSOIL 'C$_1$' horizon: dark brown (3/3, 10YR), sandy SILT/CLAY with occasional gravels (4, 5, 4 threads; 120mm, 100mm, 100mm ribbons; dilatant and raspy). GRADING INTO
From 0.9m to 1.1m	Geochem /PSD	003 10b	'Limestone-dominated till' (TLs) Facies 1				SUBSOIL 'C$_2$' horizon: mottled yellowish brown (5/6, 10YR) and dark bluish grey (6/1, GLEY 1), slightly sandy SILT/CLAY with occasional gravels (4, 4, 4 threads; 120mm, 120mm, 120mm ribbons; slightly dilatant and raspy). Structure more massive, and material more competent. Clasts are subangular to subrounded, and striated. Limestones dominant, but shale clasts also present. No shell fragments observed.
1.5							
From 1.9 to 2.1m	Geochem	004					
2.5					28.7	2.8	
From 2.9m to 3.1m	Geochem /PSD	005 10c	'Irish Sea Till' (IrSTLs) Facies 2				SUBSOIL 'C$_2$' horizon: mottled very dark grey (3/1, 7.5YR) and yellowish brown (5/6, 10YR), slightly sandy CLAY with occasional gravels (5, 5, 5 threads; 130mm, 120mm, 130mm ribbons; non dilatant, raspy). Shell fragments common. Very fissile structure, and heavily overconsolidated, with material particularly stiff from 3m depth. From this depth, recovery is as intact 'tubes' of sediment. Clasts are subangular to subrounded, and striated. Limestones dominant, with much shale content also. Most clasts <10mm across. Below 3.9m depth, colour becomes very dark grey (3/1, 10YR) predominantly. Between 4.5m and 5.5m depth, reddish brown (4/4, 2.5YR) clasts of sandstone occur.
3.5							
From 3.9 to 4.1m	Geochem	006		▶	Water strike		
4.5							
From 4.9m to 5.1m	Geochem /PSD	007 10d		▶	Water sample		
5.5					26.0	5.5	Cable tool core completed at 5.5m on (presumed?) limestone bedrock.

Setting

Stability :

Material heavily overconsolidated below 1.2m depth.

General remarks :

Bored on southwestern lower backslope of high ridge, where slope flattens out. Bored in northwestern corner of arable field, recently sown, just outside perimeter boundary of quarry.

Groundwater :

Groundwater met at 3.9m bgl; moist and saturated to base of hole. Water sample taken at 4.9m bgl.

Sequence summary:

Grey brown podzolic topsoil local', 'limestone till' units, again over 'Irish Sea Till'.

Geological Survey
Suirbhéireacht Gheolaíochta
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CABLE TOOL CORE M11

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 12/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 36.0m

Samples & in-situ tests: Depth taken	Type	No (M11)	Stratum Name	Water	O.D. Level	Depth	Description (Strata details)
From 0.1m to 0.3m	Geochem	001	'Made Ground'				IMPORTED MATERIAL, COMPRISING IN THE MAJORITY TOPSOIL, BUT WITH SOME TARMACADAM, CONCRETE SLABS, GRAVEL, VOIDS AND SODS. Dark brown (3/3, 10YR) colour.
From 0.4m to 0.6m	Geochem	002	'Limestone-dominated till' (TLs) Facies 1		35.5	0.5	SUBSOIL 'C$_1$' horizon: dark brown (3/3, 10YR), SILT/CLAY with occasional gravels (5, 5, 5 threads; 80mm, 80mm, 120mm ribbons; slightly dilatant and raspy). Structure blocky, and material competent. Fissility in cylindrical 'tube' shaped samples taken from core. Clasts subangular to subrounded, and striated. Limestone and shale clasts dominant, in relatively equal proportions. No shell fragments.
From 0.9m to 1.1m; 1.5	Geochem /PSD	003 11b	'Irish Sea Till' (IrSTLs) Facies 2	Water sample	35.0	1.0	SUBSOIL 'C$_2$' horizon: very dark greyish brown (3/2, 10YR), slightly sandy SILT/CLAY with occasional gravels (5, 4, 4 threads; 90mm, 100mm, 120mm ribbons; slightly dilatant and slightly raspy). Structure more massive, and material more competent. Clasts are subangular to subrounded, and striated. Limestones dominant, but shale and erratic clasts of volcanics, sandstones, quartz and metamorphics all in evidence. No shell fragments observed.
From 1.9 to 2.1m; 2.5	Geochem	004	'Erratic-dominated sands and gravels' - Facies 3	Water strike	34.0	2.0	SUBSOIL 'C$_3$' horizon: very dark greyish brown (3/2, 10YR), slightly silty, sandy GRAVEL (0, 0, 0 threads; 0mm, 10mm, 20mm ribbons; slightly dilatant, raspy). Structure granular, and material softer. Clasts are subangular to subrounded,. Limestones dominant, but shale and erratic clasts of volcanics, sandstones, quartz and metamorphics all in evidence. No shell fragments observed.
From 2.9m to 3.1m; 3.5; From 3.9 to 4.1m	Geochem /PSD; Geochem	005 11c; 006	'Transition Zone' of weathered, broken bedrock - Facies 4		33.2	2.8	BROKEN BEDROCK – TRANSITION ZONE: black (2/1, 10YR), fissile, silty,clayey GRAVEL (4, 5, 5 threads; 120mm, 120mm, 110mm ribbons; slightly dilatant). No shell fragments. Very fissile structure, and heavily overconsolidated, with penetration difficult. Recovery is as small, 1mm-10mm platelets of gravel. Bedrock material is black shale.
4.5					31.6	4.4	**Cable tool core completed at 4.4m on competent shale bedrock.**

Legend:

Setting

Stability :

Material heavily overconsolidated below 1m depth.

General remarks :

Bored on northeastern lower backslope of high ridge, where slope flattens out. Bored in southeastern corner of arable field, at edge of old farm trackway, adjacent to yard.

Groundwater :

Groundwater met at 2.1m bgl.
Water influx, and water sample taken with water at 1.7m bgl.

Sequence summary:

Topsoil over 'local' 'limestone till' unit, again over 'Irish Sea Till', overlying Transition Zone.

CABLE TOOL CORE M12

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 11/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 41.0m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	O.D. Level	Legend	Depth	Strata details: Description
From 0.1m to 0.3m	Geochem	M12 001	'Solum'		40.5		0.5	TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), topsoil overlying sandy SILT/CLAY with occasional gravels (4, 3, 3 threads; 110mm, 90mm, 90mm ribbons; slightly dilatant and raspy). Material relatively soft, blocky structure, no shells.
From 0.4m to 0.6m	Geochem /PSD	002 12a	'Limestone-dominated till' (TLs) Facies 1		40.0		1.0	SUBSOIL 'C$_1$' horizon: dark brown (3/3, 10YR), sandy SILT/CLAY with occasional gravels (4, 4, 4 threads; 120mm, 120mm, 100mm ribbons; slightly dilatant and raspy). Occasional dark grey (3/1, 10YR) mottles.
From 0.9m to 1.1m	Geochem /PSD	003 12b						
1.5			'Limestone-dominated till' (TLs) Facies 2		36.8		3.7	SUBSOIL 'C$_2$' horizon: mottled dark brown (3/3, 10YR0, bluish grey (6/1, GLEY 2) and very dark grey (3/1, 10YR) sandy SILT/CLAY with abundant gravels (6, 5, 5 threads; 120mm, 110mm, 110mm ribbons; slightly dilatant and raspy). Structure more massive, and material more competent. Becoming darker with depth. Clasts are subangular to subrounded, and striated. Limestones dominant, but shale also in evidence. Occasional lenses of sandy material below 2.5m depth. No shell fragments observed.
From 1.9 to 2.1m	Geochem	004						
2.5								
From 2.9m to 3.1m	Geochem /PSD	005 12c						
3.5								
From 3.9 to 4.1m	Geochem	006	'Transition Zone' of weathered, broken bedrock - Facies 3					BROKEN BEDROCK – TRANSITION ZONE: black (2/1, 10YR), fissile, silty,clayey GRAVEL (4, 4, 4 threads; 120mm, 120mm, 130mm ribbons; non-dilatant). No shell fragments. Very fissile structure, and heavily overconsolidated, with penetration difficult. Recovery is as small, 1mm-10mm platelets of gravel. Bedrock material is black shale.
4.5				►	Water sample			
From 4.9m to 5.1m	Geochem /PSD	007 12d		►	Water strike			
5.5								

Setting

Stability :

Material heavily overconsolidated below 2.5m depth.

General remarks :

Bored on northeastern mid-backslope of high ridge. Bored in southwestern corner of arable field, at edge of farm trackway.

Groundwater :

Groundwater met at 5.0m bgl.
Water influx, and water sample taken with water at 4.4m bgl.

Sequence summary:

Topsoil over 'local' 'limestone till' unit, again overlying Transition Zone bedrock.

CABLE TOOL CORE M12

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality A

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 11/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 41.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
			'Transition Zone' of weathered, broken bedrock Facies 3					BROKEN BEDROCK – TRANSITION ZONE: black (2/1, 10YR), fissile, silty,clayey GRAVEL. Bedrock material is black shale.
6.0					35.2		5.8	**Cable tool core completed at 5.8m on competent shale bedrock.**

Transition Zone recovery

Stability :

Material heavily overconsolidated throughout.

General remarks :

Bored on northeastern mid-backslope of high ridge. Bored in southwestern corner of arable field, at edge of farm trackway.

Groundwater :

Groundwater met at 5.0m bgl.
Water influx, and water sample taken with water at 4.4m bgl.

Sequence summary:

Topsoil over 'local' 'limestone till' unit, again overlying Transition Zone bedrock.

Appendix B Locality B borehole logs

Geological Survey
Suirbhéireacht Gheolaíochta
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CABLE TOOL CORE LOGS

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Geochemical sample numbers are the sample field I.D. numbers for geochemistry samples; generally taken every metre to 5m, every 2.5m thereafter.

Particle size distribution (PSD) sample numbers are the sample field I.D. numbers for particle size distribution samples, generally taken at 0.5m, 1.0m, 3.0m, 5.0m and 10.0m depths.

'Solum' refers to the soil-forming layers, comprising topsoil 'A' and 'B' horizons, developed during the Holocene Period (since 10,500 years BP).

'Facies' numbers refer to discrete units of subsoil.

Where subsoil facies' have 'g' subscripts, this denotes gleying, or saturation, expressed as mottling therein.

Numbers after soil and subsoil colurs refer to Munsell Soil Colour charts hues and chroma

***e.g.* 3/3 (chroma), 10YR (hue)**

British Standard (BS 5930) subsoil descriptions give details of plasticity and dilatancy tests. Named subsoils in these logs only refer to those on which such tests have been completed, in the field at the time of sampling.

Symbology

WATER COLUMN

Water strike

Water sample

Stability :

Basic data on consolidation of material drilled..

General remarks :

Information on setting of borehole locality, topographically and in t terms of land use..

Groundwater :

Data on strike depths, if any..

Sequence summary:

Short summary of soil and subsoil unit(s) sequence.

CABLE TOOL CORE K01

Geological Survey | Suirbhéireacht Gheolaíochta | Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 25/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 110.0m

Depth taken	Type	No	Stratum Name	Water	O.D. Level	Legend	Depth	Description
From 0.1m to 0.3m	Geochem	K01 001	'Solum'					TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), loam overlying very sandy SILT/CLAY with occasional gravels (4, 4, 5 threads; 110mm, 100mm, 80mm ribbons; slightly dilatant and raspy).
From 0.4m to 0.6m	Geochem /PSD	003 1a			109.2		0.8	Structure seems quite blocky, and material soft.
From 0.9m to 1.1m	Geochem /PSD	004 1b	'Limestone-dominated till' (TLs) Facies 1					SUBSOIL 'C_1' horizon: very dark greyish brown (3/2, 10YR), gravelly sandy SILT with occasional cobbles (1, 1, 2 threads; 80mm, 60mm, 60mm ribbons; dilatant and raspy).
1.5								Structure more massive, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <50mm across. Limestones dominant. No shells present.
From 1.9 to 2.1m	Geochem	005						Relatively blocky structure, grading into massive material, which is heavily overconsolidated.
2.5								Sample at 2.9m is a very dark greyish brown (3/2, 10YR), gravelly, very sandy SILT with occasional cobbles (2, 1, 1 threads; 90mm, 60mm, 60mm ribbons; dilatant and raspy).
From 2.9m to 3.1m	Geochem /PSD	006 1c			107.0		3.0	GRADING INTO
			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2					SUBSOIL 'C_2' horizon: grey (5/1, 10YR), gravelly SAND (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant and very raspy).
3.5								Granular and slightly consolidated.
From 3.9 to 4.1m	Geochem	007						Clasts are rounded and subrounded, limestone-dominated. Occasional quartz pebbles.
								Pods of sandy GRAVEL present in this unit. 0.1m across.
4.5					105.5		4.5	GRADING INTO
								SUBSOIL 'C_3' horizon: dark reddish brown (3/4, 5YR), gravelly, slightly silty SAND (0, 1, 0 threads; 40mm, 60mm, 60mm ribbons; dilatant and very raspy). .
From 4.9m to 5.1m	Geochem /PSD	008 1d			105.0		5.0	Granular and slightly consolidated.
5.5								**Cable tool core completed at 5.0m on soft, granular, sorted sands and gravels (glaciofluvial).**

Setting

Stability :

Material quite soft below 2.8m depth.

General remarks :

Bored on northwestern footslope of ridge, in arable field.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

Geological Survey
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CABLE TOOL CORE K02

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 25/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 120.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
		K02						
From 0.1m to 0.3m	Geochem	001	'Solum'					TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), sandy loam topsoil overlying very sandy gravelly SILT (2, 1, 2 threads; 90mm, 70mm, 70mm ribbons; dilatant and raspy).
From 0.4m to 0.6m	Geochem /PSD	002 2a			119.3		0.7	Structure seems quite blocky, and material relatively soft.
From 0.9m to 1.1m	Geochem /PSD	003 2b	'Limestone-dominated till' (TLs)					SUBSOIL 'C$_1$' horizon: dark yellowish brown (4/6, 10YR), very sandy gravelly SILT with occasional cobbles (2, 2, 2 threads; 80mm, 110mm, 90mm ribbons; dilatant and raspy).
1.5								Relatively blocky structure, grading into massive material, which is quite consolidated.
From 1.9 to 2.1m	Geochem	004	Facies 1					Clasts are subangular to subrounded, and striated. Limestones dominant, with some shale content also. Most clasts <50mm across.
								No shells present in this unit. Material is dry, and well drained.
2.5					117.5		2.5	**Cable tool core completed at 2.5m on obstruction (presumed large boulder?).**

Setting

Stability :

Material initially relatively soft, but becomes more consolidated at depth.

General remarks :

Bored on northwestern mid-backslope of ridge, at southern extreme of arable field. Refusal at 2.3m initially, then moved a few metres, refusal again at 2.5m. Difficult to drill through basal 0.8m.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'local', 'limestone till' unit.

CABLE TOOL CORE K03

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan   Date: 15/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 124.0m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	O.D. Level	Legend	Depth	Description
From 0.1m to 0.3m	Geochem	K03 001	'Solum'					TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), loam overlying sandy SILT/CLAY with occasional gravels (5, 5, 4 threads; 90mm, 100mm, 100mm ribbons; dilatant and raspy). Structure seems quite blocky, and material soft.
From 0.4m to 0.6m	Geochem /PSD	002 3a			123.5		0.5	
From 0.9m to 1.1m	Geochem /PSD	003 3b	'Limestone-dominated till' (TLs) Facies 1					SUBSOIL 'C$_1$' horizon: very dark greyish brown (3/2, 10YR), sandy gravelly SILT (3, 2, 3 threads; 120mm, 90mm, 80mm ribbons; dilatant and raspy).
1.5								
From 1.9 to 2.1m	Geochem	004						Structure more massive, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <70mm across. Limestones dominant. No shells present.
2.5								
From 2.9m to 3.1m	Geochem /PSD	005 3c						Relatively blocky structure, with subhorizontal fissility, expressed as 5mm 'partings' in recovered subsoil. This grades into massive material at depth, which is heavily overconsolidated.
3.5								
From 3.9 to 4.1m	Geochem	006						
4.5					119.3		4.7	
From 4.9m to 5.1m	Geochem /PSD	007 3d	'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2					SUBSOIL 'C$_2$' horizon: dark brown (3/3, 10YR), silty sandy GRAVEL (0, 0, 0 threads; 20mm, 30mm, 20mm ribbons; dilatant, cohesive and very raspy). . Granular and slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. . Pods of silty gravelly SAND present in this unit. Maximum 0.15m across.
5.5								

Setting

Stability :

Material becomes more consolidated at depth from 1m - 4.7m, but quite soft below 4.7m depth.

General remarks :

Bored on northwestern shoulder slope of ridge, in pasture field, adjacent to gravel pit (only approx. 40m from western face of pit).

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

Geological Survey
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CABLE TOOL CORE K03

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 15/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 124.0m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	Strata details: O.D. Level	Legend	Depth	Description
6.0 6.5		K03	'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2		117.2		6.8	SUBSOIL 'C_2' horizon: dark brown (3/3, 10YR), silty sandy GRAVEL (0, 0, 0 threads; 10mm, 0mm, 30mm ribbons; dilatant, cohesive and very raspy). Granular and slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. . Pods of silty gravelly SAND present in this unit. Maximum 0.15m across.
7.0			'SILT' Facies 3		117.1		6.9	SUBSOIL 'C_3' horizon: yelllowish brown (5/6, 10YR), SILT (2, 2, 3 threads; 90mm, 80mm, 50mm ribbons; dilatant and very slightly raspy). Massive and overconsolidated.
7.5 8.0 8.5 9.0 9.5			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 4					SUBSOIL 'C_4' horizon: dark brown (3/3, 10YR), sandy GRAVEL (0, 0, 0 threads; 0mm, 0mm, 20mm ribbons; dilatant and very raspy). Granular and slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. Much fine sand, with increasing proportions at depth.
From 9.9m to 10.1m	Geochem /PSD	0083e			114.0		10.0	**Cable tool core completed at 10.0m on soft, granular, sorted sands and gravels (glaciofluvial).**

Subsoil recovered

Stability :

Material consistently soft below 4.7m depth.

General remarks :

Bored on northwestern shoulder slope of ridge, in pasture field, adjacent to gravel pit (only approx. 40m from western face of pit).

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

CABLE TOOL CORE K04

Geological Survey
Suirbhéireacht Gheolaíochta
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Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Site: Locality B

Logged by: R.Meehan | Date: 22/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 106.0m

Depth taken	Type	No	Stratum Name	Water	O.D. Level	Depth	Description
From 0.1m to 0.3m	Geochem	K04 001	'Made Ground'		105.75	0.25	IMPORTED GRAVEL FILL, VOIDS AND 'A' HORIZON SODS. Bluish grey (6/1, GLEY 2) colour.
From 0.4m to 0.6m	Geochem /PSD	002 4a	'Solum'		105.5	0.5	TOPSOIL 'A'/'B' horizons: dark yellowish brown (4/6, 10YR), gravelly sandy SILT (2, 2, 3 threads; 110mm, 80mm, 80mm ribbons; dilatant and raspy).
							G R A D I N G I N T O
From 0.9m to 1.1m	Geochem /PSD	003 4b	'Limestone-dominated till' (TLs) Facies 1				
1.5							SUBSOIL 'C$_1$' horizon: dark yellowish brown (4/6, 10YR) to brown (4/3, 10YR), sandy gravelly SILT (1, 1, 2 threads; 80mm, 70mm, 60mm ribbons; dilatant and raspy).
From 1.9 to 2.1m	Geochem	004					
2.5							Structure more massive, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <50mm across. Limestones dominant. No shells present.
From 2.9m to 3.1m	Geochem /PSD	005 4c					Relatively blocky structure, with subhorizontal fissility, expressed as 5mm 'partings' in recovered subsoil. This grades into massive material at depth, which is heavily overconsolidated.
3.5							
From 3.9 to 4.1m	Geochem	006					
4.5					101.3	4.7	
From 4.9m to 5.1m	Geochem /PSD	007 4d	'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2				SUBSOIL 'C$_2$' horizon: dark yellowish brown (3/4, 10YR), gravelly, slightly silty SAND (0, 0, 0 threads; 20mm, 0mm, 0mm ribbons; slightly dilatant, slightly cohesive and very raspy). Granular and slightly consolidated. Clasts are rounded and subrounded, limestone-dominated.
5.5							Grades into SAND at depth.

Setting

Stability :

Material becomes more consolidated at depth from 0.8m - 4.7m, but quite soft below 4.7m depth.

General remarks :

Bored on low rise on southeastern mid-backslope of ridge, in hardstand area among stand of mature coniferous forestry.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

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CABLE TOOL CORE K04

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan   Date: 22/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 106.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
6.0 6.5 7.0			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2					SUBSOIL 'C$_2$' horizon: dark yellowish brown (3/4, 10YR), SAND with occasional gravels (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, non-cohesive and very raspy). . Granular and slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. .
From 7.3m to 7.5m	Geochem /PSD	0084e			98.5		7.5	**Cable tool core completed at 7.5m on soft, granular, sorted sands and gravels (glaciofluvial).**

Subsoil recovery

Stability :

Material becomes more consolidated at depth from 0.8m - 4.7m, but quite soft below 4.7m depth.

General remarks :

Bored on low rise on southeastern mid-backslope of ridge, in hardstand area among stand of mature coniferous forestry.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

Geological Survey
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CABLE TOOL CORE K05

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan   Date: 20/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 121.0m

Samples & in-situ tests: Depth taken	Type	No (K05)	Stratum Name	Water	O.D. Level	Legend	Depth	Strata details: Description
From 0.1m to 0.3m	Geochem	001	'Solum'		120.6		0.4	TOPSOIL 'A'/'B' horizons: very dark brown (2/2, 10YR), sandy loam with occasional gravels. Structure crumb to blocky, and material soft.
								G R A D I N G I N T O
From 0.4m to 0.6m	Geochem /PSD	002 5a	'Limestone-dominated till' (TLs) Facies 1					
From 0.9m to 1.1m	Geochem /PSD	003 5b						SUBSOIL 'C$_1$' horizon: dark yellowish brown (4/4, 10YR) to very dark greyish brown (3/2, 10YR), very sandy gravelly SILT (1, 0, 1 threads; 50mm, 40mm, 60mm ribbons; dilatant and raspy).
1.5								Structure massive, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <50mm across. Limestones dominant, with occasional sandstones. No shells present.
From 1.9 to 2.1m	Geochem	004						
2.5								
From 2.9m to 3.1m	Geochem /PSD	005 5c			118.0		3.0	
3.5			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2					SUBSOIL 'C$_2$' horizon: very dark greyish brown (3/2, 10YR), very sandy GRAVEL (0, 0, 0 threads; 10mm, 20mm, 0mm ribbons; non-dilatant, non-cohesive and very raspy). .
From 3.9 to 4.1m	Geochem	006						Granular and slightly consolidated.
4.5								Clasts are rounded and subrounded, limestone-dominated. . Some greenish grey sandstone clasts.
From 4.9m to 5.1m	Geochem /PSD	007 5d						At 4.5m-5.0m depth, some shallow lenses of dark yellowish brown (4/6, 10YR), laminated SILT (2, 1, 1 threads; 50mm, 40mm, 50mm ribbons; slightly dilatant, non-raspy), which are no more than 0.05m across.
5.5								

Setting

Stability :

Material becomes more consolidated at depth initially, from 0.8m – 2.8m, but soft below 3.0m depth.

General remarks :

Bored on southeastern shoulder slope of ridge, in pasture field.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

CABLE TOOL CORE K05

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan | Date: 20/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 121.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
6.0 6.5 7.0			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2		113.7		7.3	SUBSOIL 'C$_2$' horizon: dark yellowish brown (3/4, 10YR), becoming dark grey (4/1, 10YR) at 5.7m depth, sandy GRAVEL (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, non-cohesive and very raspy). . Granular and slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. Clast of oolithic limestone recovered near base of borehole.
7.5								**Cable tool core completed at 7.3m on soft, granular, sorted sands and gravels (glaciofluvial).**

Subsoil recovery

Stability :

Material soft below 3.0m depth.

General remarks :

Bored on southeastern shoulder slope of ridge, in pasture field.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

Geological Survey / Suirbhéireacht Gheolaíochta / Ireland | Éireann	# CABLE TOOL CORE K06
	Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities
Site: Locality B	Method and Equipment: Machine excavated, Dando 2000 shell and auger rig
	Logged by: R.Meehan — Date: 20/03/2019
All dimensions on this sheet are in metres unless otherwise stated	Ground level OD: 124.0m

Samples & in-situ tests: Depth taken	Type	No (K06)	Stratum Name	Water	O.D. Level	Legend	Depth	Strata details: Description
From 0.1m to 0.3m	Geochem	001	'Solum'		123.7		0.3	TOPSOIL 'A'/'B' horizons: very dark brown (2/2, 10YR), sandy loam with occasional gravels. Structure crumb to blocky, and material soft.
From 0.4m to 0.6m	Geochem /PSD	002 6a			123.5		0.5	SUBSOIL 'C_1' horizon: dark yellowish brown (4/4, 10YR), SAND (0, 0, 0 threads; 0mm, 10mm, 10mm ribbons; non-dilatant, raspy).
					123.3		0.7	SUBSOIL 'C_2g' horizon: mottled dark grey (4/1, 10YR) and strong brown (4/6, 7.5YR) gravelly SAND (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, raspy). G R A D I N G I N T O
From 0.9m to 1.1m	Geochem /PSD	003 6b	'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 1					SUBSOIL 'C_3' horizon: very dark greyish brown (3/2, 10YR), sandy GRAVEL (0, 0, 1 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, raspy). Structure granular, and material only slightly competent. Clasts are subangular to subrounded, and striated. Most clasts <20mm across. Limestones dominant, with occasional greenish grey sandstones. No shells present.
1.5								
From 1.9 to 2.1m	Geochem	004						
2.5								
From 2.9m to 3.1m	Geochem /PSD	005 6c						
3.5								
From 3.9 to 4.1m	Geochem	006						
4.5								
From 4.9m to 5.1m	Geochem /PSD	007 6d						
5.5								

Setting

Stability :

Material becomes more difficult to drill from 1.4m depth, yet matrix is soft below 1.0m depth.

General remarks :

Bored on low rise on southern upper backslope of ridge, in pasture field Drilled adjacent to ponded area.

Groundwater :

Dry.

Sequence summary:

Brown earth of high base status topsoil, over sorted sands and gravels.

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

CABLE TOOL CORE K06

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 20/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 124.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
6.0 6.5 7.0 7.5			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 1		116.5		7.5	SUBSOIL 'C_2' horizon: dark yellowish brown (4/4, 10YR), becoming dark grey (4/1, 10YR) at 5.9m depth, sandy GRAVEL (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, non-cohesive and very raspy). . Granular and slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. Units slightly silty in places.
								Cable tool core completed at 7.5m on soft, granular, sorted sands and gravels (glaciofluvial).

Subsoil recovery

Stability :

Material very cobbly towards base of hole, from 6.0m depth.

General remarks :

Bored on low rise on southern upper backslope of ridge, in pasture field Drilled adjacent to ponded area.

Groundwater :

Dry.

Sequence summary:

Brown earth of high base status topsoil, over sorted sands and gravels.

Geological Survey
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CABLE TOOL CORE K07

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 26/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 112.0m

Samples & in-situ tests: Depth taken	Type	No (K07)	Stratum Name	Water	O.D. Level	Depth	Strata details: Description
From 0.1m to 0.3m	Geochem	001	'Solum'				TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), sandy loam overlying sandy SILT/CLAY with occasional gravels (4, 4, 4 threads; 100mm, 100mm, 80mm ribbons; slightly dilatant and raspy). Structure seems blocky, and material soft.
From 0.4m to 0.6m	Geochem /PSD	002 7a			111.5	0.5	
From 0.9m to 1.1m	Geochem /PSD	003 7b	'Limestone-dominated till' (TLs) Facies 1				SUBSOIL 'C$_1$' horizon: very dark greyish brown (3/2, 10YR) to light grey (6/1, 10YR), silty gravelly SAND with occasional cobbles (0, 1, 1 threads; 40mm, 40mm, 20mm ribbons; dilatant, very raspy, cohesive). Structure massive, and material competent. Clasts are subangular to subrounded, and striated. Most clasts <30mm across. Limestones dominant. No shells present. Pods of sorted SAND within, up to 0.05m across.
1.5							G R A D I N G I N T O
From 1.9 to 2.1m	Geochem	004			110.0	2.0	
2.5							SUBSOIL 'C$_2$' horizon: grey (5/1, 10YR), gravelly slightly silty SAND (0, 0, 1 threads; 20mm, 20mm, 30mm ribbons; non-dilatant and very raspy).
From 2.9m to 3.1m	Geochem /PSD	005 7c	'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2				Granular and slightly consolidated.
3.5							Clasts are rounded and subrounded, limestone-dominated. . Some greenish grey sandstone clasts.
From 3.9 to 4.1m	Geochem	006					At 4.0m-5.5m depth, some shallow lenses of dark yellowish brown (4/6, 10YR), laminated gravelly SILT (2, 2, 2 threads; 50mm, 40mm, 50mm ribbons; slightly dilatant, non-raspy), which are no more than 0.1m across.
4.5							Pods of sandy GRAVEL present in this unit. 0.1m across.
From 4.9m to 5.1m	Geochem /PSD	007 7d			106.5	5.5	
							Cable tool core completed at 5.5m on soft, granular, sorted sands and gravels (glaciofluvial).

Legend:

Setting

Stability :

Material quite soft throughout.

General remarks :

Bored on small rise on northwestern footslope of ridge, at edge of site where house under construction, set within arable field.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

Geological Survey Suirbhéireacht Gheolaíochta Ireland | Éireann	CABLE TOOL CORE K08
	Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities
Site: Locality B	Method and Equipment: Machine excavated, Dando 2000 shell and auger rig
	Logged by: R.Meehan Date: 26/03/2019
All dimensions on this sheet are in metres unless otherwise stated	Ground level OD: 112.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
From 0.1m to 0.3m	Geochem	K08 001	'Solum'					TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), sandy loam with occasional gravels.
From 0.4m to 0.6m	Geochem /PSD	002 8a			111.5		0.5	Structure crumb to blocky, and material soft.
								G R A D I N G I N T O
From 0.9m to 1.1m	Geochem /PSD	003 8b						
1.5								SUBSOIL 'C$_1$' horizon: very dark greyish brown (3/2, 10YR), very sandy gravelly SILT (2, 2, 1 threads; 90mm, 50mm, 90mm ribbons; dilatant, raspy).
From 1.9 to 2.1m	Geochem	004	'Limestone-dominated till' (TLs)					Structure massive, yet strongly fissile, and heavily overconsolidated ... material recovered as intact 'tubes' of sediment.
2.5								Clasts are subangular to subrounded, and striated. Most clasts <20mm across.
From 2.9m to 3.1m	Geochem /PSD	005 8c	Facies 1					Limestones dominant, with occasional greenish grey sandstones. No shells present.
3.5								Many narrow lenses of SAND, from 1.4m depth.
From 3.9 to 4.1m	Geochem	006						
								Begins to grade into silty SAND-dominated material from 4.2m depth (0, 1, 1 threads; 40mm, 30mm, 50mm ribbons; slightly dilatant, cohesive, raspy).
4.5								
From 4.9m to 5.1m	Geochem /PSD	007 8d			106.8		5.2	
5.5			'Limestone-dominated till'(TLs) Facies 2					SUBSOIL 'C$_2$' horizon: dark reddish brown (3/3, 5YR), very sandy gravelly SILT (2, 3, 3 threads; 110mm, 70mm, 70mm ribbons; dilatant, raspy). Material consolidated, subrounded and subangular, limestone dominated, striated clasts. G R A D I N G I N T O

Setting

Stability :

Material becomes more difficult to drill from 1.0m depth, and heavilty overconsolidated from 3.5m depth.

General remarks :

Bored on low rise on northwestern lower backslope of ridge, in arable field. Drilled adjacent to entrance trackway.

Groundwater :

Dry.

Sequence summary:

Brown earth of high base status topsoil, over 'limestone till' units, again over sorted sands/gravels.

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

CABLE TOOL CORE K08

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

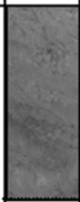
Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Site: Locality B

Logged by: R.Meehan   Date: 26/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 112.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
6.0 6.5			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 3		105.25		6.75	SUBSOIL 'C_2' horizon: dark reddish brown (3/3, 5YR), becoming dark grey (4/1, 10YR) at 6.0m depth, sandy GRAVEL (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, non-cohesive and very raspy). . Granular and slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. Units slightly silty in places.
7.0								**Cable tool core completed at 6.75m on soft, granular, sorted sands and gravels (glaciofluvial).**

Subsoil recovery

Stability :

Material very cobbly towards base of hole, from 5.9m depth.

General remarks :

Bored on low rise on northwestern lower backslope of ridge, in arable field. Drilled adjacent to entrance trackway

Groundwater :

Dry.

Sequence summary:

Brown earth of high base status topsoil, over 'limestone till' units, again over sorted sands/gravels

CABLE TOOL CORE K09

Geological Survey
Suirbhéireacht Gheolaíochta
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Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan — Date: 19/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 115.5m

Depth taken	Type	No	Stratum Name	Water	O.D. Level	Depth	Description
From 0.1m to 0.3m	Geochem	K09 001	'Solum'				TOPSOIL 'A'/'B' horizons: dark brown (3/3, 10YR), loam overlying sandy SILT/CLAY with occasional gravels (4, 5, 4 threads; 120mm, 100mm, 100mm ribbons; slightly dilatant and raspy). Structure seems quite blocky, and material soft.
From 0.4m to 0.6m	Geochem /PSD	002 9a			115.0	0.5	
From 0.9m to 1.1m	Geochem /PSD	003 9b	'Limestone-dominated till' (TLs) Facies 1				SUBSOIL 'C$_1$' horizon: dark yellowish brown (5/6, 10YR), sandy SILT with abundant gravels (2, 2, 1 threads; 100mm, 100mm, 80mm ribbons; dilatant and raspy).
1.5							Structure massive, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <30mm across.
From 1.9 to 2.1m	Geochem	004					Limestones dominant. No shells present.
2.5							At depth, relatively blocky structure, with subhorizontal fissility, expressed as 5mm 'partings' in recovered subsoil. This grades into massive material at depth, which is heavily overconsolidated.
From 2.9m to 3.1m	Geochem /PSD	005 9c					From 3m depth, (Old Red?) sandstone clasts (4/3, 5YR, reddish brown) present in till.
3.5							
From 3.9 to 4.1m	Geochem	006					
4.5							
From 4.9m to 5.1m	Geochem /PSD	007 9d					
5.5							

Legend:

Setting

Stability :

Material becomes more consolidated from 1m depth.

General remarks :

Bored on northwestern mid-backslope of ridge, in pasture field, adjacent to old shed.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit.

CABLE TOOL CORE K09

Geological Survey
Suirbhéireacht Gheolaíochta
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Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 19/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 115.5m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
6.0 6.5			'Limestone-dominated till' (TLs) Facies 1		109.0		6.5	SUBSOIL 'C_1' horizon (contd.): dark yellowish brown (5/6, 10YR), sandy SILT with abundant gravels (2, 4, 3 threads; 110mm, 110mm, 110mm ribbons; dilatant and raspy). Structure massive, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <30mm across. Limestones dominant, with sandstones also common. No shells present. Relatively massive structure, with subhorizontal fissility, expressed as 5mm 'partings' in recovered subsoil. Heavily overconsolidated.
7.0 7.5			'Limestone-dominated till' (TLs) Facies 2		108.0		7.5	SUBSOIL 'C_2' horizon: strong brown (4/6, 7.5YR), sandy SILT/CLAY with occasional gravels (4, 5, 5 threads; 120mm, 110mm, 100mm ribbons; slightly dilatant and very raspy). Massive and heavily overconsolidated. Limestones dominant, no sandstones observed at this depth. Subrounded and subangular pebble clasts. No shells present.
8.0			'Limestone-dominated till' (TLs) Facies 3		107.1		8.4	SUBSOIL 'C_3' horizon: brown (4/3, 10YR), gravelly very sandy SILT (1, 1, 0 threads; 50mm, 40mm, 40mm ribbons; dilatant and very raspy). Softer material, only slightly consolidated. Clasts are subangular and subrounded, limestone-dominated. .Again, no sandstones at this depth. Very gritty and sand-dominated throughout.
8.5 9.0 9.5			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 4		114.8		9.7	SUBSOIL 'C_4' horizon: very dark greyish brown (3/2, 10YR), gravelly SAND (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant and very raspy). Granular and slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. Occasional, small, sandstone pebbles. Pods of sandy GRAVEL present in this unit, up to 0.15m across.
								Cable tool core completed at 9.7m on soft, granular, sorted sands and gravels (glaciofluvial).

Subsoil recovered

Stability :

Material consistently soft below 7.5m depth.

General remarks :

Bored on northwestern mid-backslope of ridge, in pasture field, adjacent to old shed.

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' units, again over sorted sands and gravels.

Geological Survey
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CABLE TOOL CORE K10

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 21/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 105.5m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	O.D. Level	Legend	Depth	Description
From 0.1m to 0.3m	Geochem	K10 001	'Solum'					TOPSOIL 'A'/'B' horizons: strong brown (4/6, 7.5YR), sandy loam overlying sandy SILT with occasional gravels (3, 3, 2 threads; 120mm, 120mm, 100mm ribbons; dilatant and very raspy). Structure seems crumbly, and material soft.
From 0.4m to 0.6m	Geochem /PSD	002 10a			105.0		0.5	SUBSOIL 'C$_1$' horizon: yellowish red (5/6, 5YR), sandy gravelly SILT (2, 1, 2 threads; 80mm, 60mm, 70mm ribbons; dilatant, raspy). Structure massive, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <30mm across. Limestones dominant, with some sandstones. No shells present.
From 0.9m to 1.1m	Geochem /PSD	003 10b	'Limestone-dominated till' (TLs) Facies 1		104.5		1.0	G R A D I N G I N T O
1.5								
From 1.9 to 2.1m	Geochem	004						SUBSOIL 'C$_2$' horizon: brown (5/3, 10YR), sandy SILT with abundant gravels (2, 2, 1 threads; 80mm, 80mm, 60mm ribbons; dilatant, raspy).
2.5								Structure massive, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <40mm across.
From 2.9m to 3.1m	Geochem /PSD	005 10c						Limestones dominant. No shells present.
3.5								At depth, relatively blocky structure, with subhorizontal fissility, expressed as 5mm 'partings' in recovered subsoil. This grades into massive material at depth, which is heavily overconsolidated.
From 3.9 to 4.1m	Geochem	006						From 4m depth, (Old Red?) sandstone clasts (4/3, 5YR, reddish brown) present in till.
4.5								
From 4.9m to 5.1m	Geochem /PSD	007 10d		▶	Water strike			At 5m, material is a sandy gravelly SILT (2, 2, 2 threads; 100mm, 120mm, 100mm ribbons; dilatant, raspy). Following water strike here, material grades into softer diamicton.
5.5				▶	Water sample			

Setting

Stability :

Material becomes more consolidated from 1.3m depth.

General remarks :

Bored on northwestern lower backslope of low ridge, which is to the south of the main ridge of the Waste Recovery Facility and the majority of the other boreholes, in a pasture field.

Groundwater :

Groundwater met at 5.0m bgl, where moist zone begins. Influx, and sample taken when water at 5.7m.

Sequence summary:

Grey brown podzolic topsoil over 'local', 'limestone till' units, becoming softer at depth.

CABLE TOOL CORE K10

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 21/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 105.5m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
6.0			'Limestone-dominated till' (TLs) Facies 1		99.3		6.2	SUBSOIL 'C$_2$' horizon (contd.): brown (5/3, 10YR), sandy gravelly SILT (2, 2, 2 threads; 100mm, 120mm, 100mm ribbons; dilatant, raspy). Structure massive, and material relatively soft. Clasts are subangular to subrounded, and striated. Most clasts <30mm across. Limestones dominant. No shells present.
6.5 7.0 From 7.4 to 7.6m	Geochem /PSD	008 10e	'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2		97.8		7.7	SUBSOIL 'C$_3$' horizon: yellowish red (4/6, 5YR), sandy GRAVEL (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, non-cohesive and very raspy). Granular and only slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. The majority of the clasts less than 20mm across are sandstone pebbles. Pods of gravelly SAND present in this unit, up to 0.15m across.
8.0								**Cable tool core completed at 7.7m on soft, granular, sorted sands and gravels (glaciofluvial).**

Subsoil recovery (note reddish colour)

Stability :

Material becomes quite loose, with little recovery, from 6.2m depth.

General remarks :

Bored on northwestern lower backslope of low ridge, which is to the south of the main ridge of the Waste Recovery Facility and the majority of the other boreholes, in a pasture field.

Groundwater :

Groundwater met at 5.0m bgl, where moist zone begins. Influx, and sample taken when water at 5.7m.

Sequence summary:

Grey brown podzolic topsoil over 'local', 'limestone till' units, over sorted sands and gravels.

CABLE TOOL CORE K11

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan | Date: 21/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 103.0m

Samples & in-situ tests: Depth taken	Type	No	Stratum Name	Water	O.D. Level	Legend	Depth	Strata details: Description
From 0.1m to 0.3m	Geochem	K11 001	'Solum'					TOPSOIL 'A'/'B' horizons: very dark brown (2/2, 10YR), sandy loam overlying sandy SILT with occasional gravels (2, 1, 2 threads; 50mm, 40mm, 80mm ribbons; dilatant and very raspy). Structure seems crumbly, and material soft.
From 0.4m to 0.6m	Geochem /PSD	002 11a			102.5		0.5	SUBSOIL 'C₁' horizon: brown (5/3, 5YR), sandy gravelly SILT with occasional cobbles (2, 2, 2 threads; 80mm, 80mm, 80mm ribbons; dilatant, raspy). Structure massive, yet fissile, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <30mm across. Limestones dominant.
From 0.9m to 1.1m	Geochem /PSD	003 11b			102.0		1.0	G R A D I N G I N T O
1.5								SUBSOIL 'C₂' horizon: brown (5/3, 10YR), sandy gravelly SILT with occasional cobbles (2, 1, 1 threads; 80mm, 90mm, 100mm ribbons; dilatant, raspy).
From 1.9 to 2.1m	Geochem	004	'Limestone-dominated till' (TLs) Facies 1					Structure massive, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <40mm across.
2.5								Limestones dominant. Many sandstone clasts beneath 1.5m depth, especially those <20mm across. No shells present.
From 2.9m to 3.1m	Geochem /PSD	005 11c						At depth, relatively blocky structure, with subhorizontal fissility, expressed as 5mm 'partings' in recovered subsoil. This grades into massive material at depth, which is heavily overconsolidated.
3.5								
From 3.9 to 4.1m	Geochem	006			98.9		4.1	G R A D I N G I N T O
4.5			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2					SUBSOIL 'C₃' horizon: yellowish brown (5/6, 5YR), sandy GRAVEL (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, non-cohesive and very raspy). . Granular and only slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. The majority of the clasts less than 20mm across are sandstone pebbles.
From 4.9m to 5.1m	Geochem /PSD	007 11d			97.9		5.1	Pods of gravelly SAND present in this unit, up to 0.1m across. G R A D I N G I N T O
5.5			'Limestone-dominated till' (TLs) Facies 3					SUBSOIL 'C₄' horizon: brown (5/3, 10YR), gravelly, very sandy SILT (2, 1, 2 threads; 80mm, 80mm, 70mm ribbons; dilatant, very raspy). Structure massive, and material competent. Clasts subangular to subrounded, and striated. Most clasts <30mm across. Limestones dominant. Many sandstone clasts.

Setting

Stability :

Material becomes more consolidated from 1.5 depth.

General remarks :

Bored on northwestern footslope of low ridge, which is to the south of the main ridge of the Waste Recovery Facility and the majority of the other boreholes, in a pasture field.

Groundwater :

Dry to 5.7m bgl.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' and gravels, becoming softer at depth.

CABLE TOOL CORE K11

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Geological Survey Suirbhéireacht Gheolaíochta Ireland | Éireann

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan — Date: 21/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 103.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
6.0 6.5 7.0 From 7.4 to 7.6m	Geochem /PSD	008 10e	'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 4		Water strike Water sample 95.3		7.7	SUBSOIL 'Cg' horizon: dark brown (3/3, 10YR), silty sandy GRAVEL (0, 2, 1 threads; 20mm, 10mm, 20mm ribbons; slightly dilatant, cohesive, raspy). . Granular and only slightly consolidated. Clasts are rounded and subrounded, limestone-dominated. The majority of the clasts less than 20mm across are sandstone pebbles. Pods of gravelly SAND present in this unit, up to 0.3m across.
8.0								**Cable tool core completed at 7.7m on soft, granular, sorted sands and gravels (glaciofluvial).**

Subsoil recovery

Stability :

Material becomes quite loose, with little recovery, from 7.0m depth.

General remarks :

Bored on northwestern footslope of low ridge, which is to the south of the main ridge of the Waste Recovery Facility and the majority of the other boreholes, in a pasture field.

Groundwater :

Groundwater met at 7.2m bgl, where moist zone begins. Some influx, and sample taken when water at 7.5m.

Sequence summary:

Grey brown podzolic topsoil over 'local', 'limestone till' units, over sorted sands and gravels.

CABLE TOOL CORE K12

Geological Survey
Suirbhéireacht Gheolaíochta
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Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 14/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 120.0m

Depth taken	Type	No	Stratum Name	Water	O.D. Level	Depth	Description
From 0.1m to 0.3m	Geochem	K12 001	'Solum'		119.5	0.5	TOPSOIL 'A'/'B' horizons: very dark brown (2/2, 10YR), loam overlying very sandy SILT with abundant gravels (2, 1, 2 threads; 80mm, 50mm, 50mm ribbons; dilatant and very raspy). Structure seems quite blocky, and material soft.
From 0.4m to 0.6m	Geochem /PSD	002 12a	'Limestone-dominated till' (TLs) Facies 1				SUBSOIL 'C$_1$' horizon: very dark greyish brown (3/2, 10YR), sandy SILT with abundant gravels (2, 2, 1 threads; 80mm, 80mm, 90mm ribbons; dilatant and raspy).
From 0.9m to 1.1m	Geochem /PSD	003 12b					Becomes more brown (4/3, 10YR) from 1.2m depth.
1.5							Structure more massive at depth, and material more competent. Clasts are subangular to subrounded, and striated. Most clasts <70mm across. Limestones dominant, but with common sandstones also. No shells present.
From 1.9 to 2.1m	Geochem	004					Relatively blocky structure, with subhorizontal fissility, expressed as 5mm 'partings' in recovered subsoil at depth. This grades into massive material at depth also, which is heavily overconsolidated.
2.5							
From 2.9m to 3.1m	Geochem /PSD	005 12c					
3.5							
From 3.9 to 4.1m	Geochem	006					
4.5			'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2				
From 4.9m to 5.1m	Geochem /PSD	007 12d					SUBSOIL 'C$_2$' horizon: grey (5/1, 10YR), gravelly SAND (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, non-cohesive and very raspy). . Granular and only slightly consolidated. Clasts are rounded and subrounded, limestone-dominated., with occasional sandstones and quartz clasts.
5.5					114.3	5.7	

Legend:

Setting

Stability :

Material becomes more consolidated at depth from 1m – 5.5m, but quite soft below 5.5m depth.

General remarks :

Bored on southeastern shoulder slope of ridge, in strip of pasture at edge of gravel pit (only approx. 20m from southern face of pit).

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

Geological Survey
Suirbhéireacht Gheolaíochta
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CABLE TOOL CORE K12

Project: Geochemical Characterisation of EPA-licenced Soil Recovery Facilities

Site: Locality B

Method and Equipment: Machine excavated, Dando 2000 shell and auger rig

Logged by: R.Meehan Date: 14/03/2019

All dimensions on this sheet are in metres unless otherwise stated

Ground level OD: 120.0m

Samples & in-situ tests			Stratum Name	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
		K12	'Limestone-dominated, glaciofluvial sands and gravels' (GLs) Facies 2					SUBSOIL 'C$_2$' horizon: grey (5/1, 10YR), gravelly SAND (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, cohesive and very raspy) interbedded with sandy GRAVEL with common cobbles (0, 0, 0 threads; 0mm, 0mm, 0mm ribbons; non-dilatant, non-cohesive and very raspy).
6.0								Granular and only slightly consolidated.
6.5								Clasts are rounded and subrounded, limestone-dominated., with occasional sandstones and quartz clasts.
7.0								
From 7.4m to 7.6m	Geochem /PSD	008 12e			112.5		7.5	
								Cable tool core completed at 7.5m on soft, granular, sorted sands and gravels (glaciofluvial).

Subsoil recovered

Stability :

Material consistently soft below 5.7m depth. Progress slow in basal 1.5m owing to preponderance of cobbles.

General remarks :

Bored on southeastern shoulder slope of ridge, in strip of pasture at edge of gravel pit (only approx. 20m from southern face of pit).

Groundwater :

Dry.

Sequence summary:

Grey brown podzolic topsoil over 'limestone till' unit, again over sorted sands and gravels.

Appendix C Geochemical analytical data

Summary of elements analysed by ICP-MS, their lower limits of detection and upper reporting limits; summary of analytical results for inserted reference materials for multielement and Hg analyses.

Element	Units	LLD	URL		Element	Units	LLD	URL
Ag	mg/kg	0.001	100		Na	wt %	0.001	10
Al	wt %	0.01	25		Nb	mg/kg	0.002	500
As	mg/kg	0.01	10000		Ni	mg/kg	0.04	10000
Au	mg/kg	0.0002	25		P	wt %	0.001	1
B	mg/kg	10	10000		Pb	mg/kg	0.005	10000
Ba	mg/kg	0.5	10000		Pd	mg/kg	0.001	25
Be	mg/kg	0.01	1000		Pt	mg/kg	0.002	25
Bi	mg/kg	0.001	10000		Rb	mg/kg	0.005	10000
Ca	wt %	0.01	25		Re	mg/kg	0.001	50
Cd	mg/kg	0.001	1000		S	wt %	0.01	10
Ce	mg/kg	0.003	500		Sb	mg/kg	0.005	10000
Co	mg/kg	0.001	10000		Sc	mg/kg	0.005	10000
Cr	mg/kg	0.01	10000		Se	mg/kg	0.1	1000
Cs	mg/kg	0.005	500		Sn	mg/kg	0.01	500
Cu	mg/kg	0.01	10000		Sr	mg/kg	0.01	10000
Fe	wt %	0.001	50		Ta	mg/kg	0.005	500
Ga	mg/kg	0.004	10000		Te	mg/kg	0.01	500
Ge	mg/kg	0.005	500		Th	mg/kg	0.002	10000
Hf	mg/kg	0.002	500		Ti	wt %	0.001	10
Hg	mg/kg	0.004	10000		Tl	mg/kg	0.002	10000
In	mg/kg	0.005	500		U	mg/kg	0.005	10000
K	wt %	0.01	10		V	mg/kg	0.1	10000
La	mg/kg	0.002	10000		W	mg/kg	0.001	10000
li	mg/kg	0.1	10000		Y	mg/kg	0.003	500
Mg	wt %	0.01	25		Zn	mg/kg	0.1	10000
Mn	mg/kg	0.1	50000		Zr	mg/kg	0.01	500
Mo	mg/kg	0.01	10000					

Table 8 Multielement ICP (*aqua regia*) analysis: lists of analytes, lower limits of detection (LLD) and upper reporting limits (URL)

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
STSD-3								
Cert ("Total")	28		80	39		30	40	204
Cert (aqua regia)	22	1	34	38	0.09	25	39	192
Mean (n=5)	25.0	1.15	29.7	36.7	0.071	26.8	40.9	190
TILL-3								
Cert ("Total")	87		123	22		39	26	56
Cert (aqua regia)	84	<0.2	73	23	0.107	32	16	43
Mean (n=5)	86.2	0.101	61.2	20.7	0.095	30.9	17.0	41.6
ANTBAS								
Mean Tellus ICP		0.809	0.162	192	97.9	0.042	172	6.09
Mean (n=5)		0.679	0.158	191	101	0.039	174	6.20
LDOWN								
Mean Tellus ICP		10.9	0.388	48.4	38.1	0.085	59.8	36.4
Mean (n=5)		11.2	0.390	50.7	40.4	0.074	63.5	38.1

Table 9 Summary data for ICP (aqua regia) analyses of reference materials. Certified values are given for CRMs STSD-3 and TILL-3; means of previous Tellus ICP analyses of SRMs ANTBAS and LDOWN are provided for comparison.

RM	Mean	Min	Max	n	Cert values
OREAS25a	0.061	0.052	0.08	6	0.053
CRM-020	1.454	1.315	1.56	7	1.12
PACS-3	2.353	2.24	2.51	7	2.98

Table 10: CRM data for Hg analyses

Appendix D Particle size distribution data

Table 11 Results for particle size analyses of Locality A and Locality B subsoil samples

Site	Hole ID	Unit_name	Field ID	Sample ID	Sand	Silt	Clay	Nominal Depth, m
Locality A	M01	Topsoil	1a	M01A	0.64	0.30	0.07	0.5
Locality A	M01	Till, limestone-dominated	1b	M01B	0.65	0.29	0.07	1.0
Locality A	M01	Till, limestone-dominated	1c	M01C	0.39	0.38	0.23	3.0
Locality A	M01	Till, limestone-dominated	1d	M01D	0.59	0.30	0.10	5.0
Locality A	M01	Till, limestone-dominated		M01E	0.53	0.29	0.18	7.5
Locality A	M02	Topsoil	2a	M02A	0.65	0.31	0.04	0.5
Locality A	M02	Till, limestone-dominated	2b	M02B	0.78	0.17	0.04	1.0
Locality A	M02	Till, limestone-dominated	2c	M02C	0.67	0.25	0.08	3.0
Locality A	M02	Till, limestone-dominated	2d	M02D	0.61	0.35	0.05	5.0
Locality A	M03	Topsoil	3a	M03A	0.58	0.32	0.09	0.5
Locality A	M03	Till, limestone-dominated	3b	M03B	0.63	0.27	0.09	1.0
Locality A	M03	Sands and gravels, limestone-dominated	3c	M03C	0.77	0.20	0.03	3.0
Locality A	M03	Sands and gravels, limestone-dominated	3d	M03D	0.76	0.19	0.05	5.0
Locality A	M03	Irish Sea Till	3e	M03E	0.63	0.21	0.15	10.0
Locality A	M04	Topsoil	4a	M04A	0.59	0.31	0.11	0.5
Locality A	M04	Till, limestone-dominated	4b	M04B	0.75	0.19	0.06	1.0
Locality A	M04	Till, limestone-dominated	4c	M04C	0.67	0.28	0.05	2.0
Locality A	M05	Made ground	5a	M05A	0.47	0.36	0.17	0.5
Locality A	M05	Made ground	5b	M05B	0.49	0.34	0.17	1.0
Locality A	M05	Irish Sea Till	5c	M05C	0.54	0.33	0.13	3.0
Locality A	M05	Irish Sea Till	5d	M05D	0.41	0.36	0.22	5.0

Site	Hole ID	Unit_name	Field ID	Sample ID	Sand	Silt	Clay	Nominal Depth, m
Locality A	M06	Irish Sea Till	6b	M06B	0.63	0.26	0.11	1.0
Locality A	M06	Irish Sea Till	6c	M06C	0.56	0.28	0.16	3.0
Locality A	M06	Irish Sea Till	6d	M06D	0.22	0.36	0.42	5.0
Locality A	M06	Irish Sea Till	6e	M06E	0.15	0.49	0.36	7.5
Locality A	M06	Irish Sea Till	6f	M06F	0.22	0.44	0.34	10.0
Locality A	M07	Till, limestone-dominated	7a	M07A	0.64	0.28	0.08	0.5
Locality A	M07	Till, limestone-dominated	7b	M07B	0.53	0.24	0.23	1.0
Locality A	M07	Till, limestone-dominated	7c	M07C	0.18	0.43	0.39	3.0
Locality A	M08	Till, limestone-dominated	8a	M08A	0.77	0.16	0.07	0.5
Locality A	M08	Till, limestone-dominated	8b	M08B	0.48	0.37	0.15	1.0
Locality A	M08	Till, limestone-dominated	8c	M08C	0.61	0.32	0.06	3.0
Locality A	M08	Till, limestone-dominated		M08D	0.12	0.67	0.21	4.0
Locality A	M09	Irish Sea Till	9b	M09B	0.57	0.28	0.15	1.0
Locality A	M09	Till, limestone-dominated	9c	M09C	0.36	0.38	0.26	3.0
Locality A	M09	Till, limestone-dominated	9d	M09D	0.22	0.47	0.32	5.0
Locality A	M10	Topsoil	10a	M10A	0.38	0.46	0.16	0.5
Locality A	M10	Till, limestone-dominated	10b	M10B	0.54	0.32	0.14	1.0
Locality A	M10	Irish Sea Till	10c	M10C	0.34	0.52	0.13	3.0
Locality A	M10	Irish Sea Till	10d	M10D	0.38	0.39	0.23	5.0
Locality A	M11	Till, limestone-dominated	11b	M11B	0.45	0.40	0.15	1.0
Locality A	M11	Transition zone, weathered, broken bedrock	11c	M11C	0.75	0.22	0.04	3.0
Locality A	M12	Till, limestone-dominated	12b	M12B	0.50	0.36	0.14	1.0
Locality A	M12	Till, limestone-dominated	12c	M12C	0.50	0.37	0.13	3.0
Locality A	M12	Transition zone, weathered, broken bedrock	12d	M12D	0.43	0.37	0.21	5.0
Locality B	K01	Topsoil	1a	K01A	0.43	0.42	0.15	0.5
Locality B	K01	Till, limestone-dominated	1b	K01B	0.32	0.52	0.16	1.0

Site	Hole ID	Unit_name	Field ID	Sample ID	Sand	Silt	Clay	Nominal Depth, m
Locality B	K01	Till, limestone-dominated	1c	K01C	0.60	0.30	0.11	3.0
Locality B	K01	Glaciofluvial sands and gravels, limestone-dominated	1d	K01D	0.62	0.29	0.09	5.0
Locality B	K02	Topsoil	2a	K02A	0.60	0.22	0.17	0.5
Locality B	K02	Till, limestone-dominated	2b	K02B	0.43	0.47	0.10	1.0
Locality B	K03	Topsoil	3a	K03A	0.36	0.50	0.14	0.5
Locality B	K03	Till, limestone-dominated	3b	K03B	0.35	0.54	0.11	1.0
Locality B	K03	Till, limestone-dominated	3c	K03C	0.37	0.46	0.17	3.0
Locality B	K03	Glaciofluvial sands and gravels, limestone-dominated	3d	K03D	0.68	0.27	0.06	5.0
Locality B	K03	Glaciofluvial sands and gravels, limestone-dominated	3e	K03E	0.90	0.04	0.06	10.0
Locality B	K04	Topsoil	4a	K04A	0.45	0.47	0.08	0.5
Locality B	K04	Till, limestone-dominated	4b	K04B	0.47	0.42	0.10	1.0
Locality B	K04	Till, limestone-dominated	4c	K04C	0.40	0.50	0.11	3.0
Locality B	K04	Glaciofluvial sands and gravels, limestone-dominated	4d	K04D	0.69	0.26	0.05	5.0
Locality B	K04	Glaciofluvial sands and gravels, limestone-dominated	4e	K04E	0.86	0.10	0.04	7.5
Locality B	K05	Till, limestone-dominated	5a	K05A	0.56	0.33	0.11	0.5
Locality B	K05	Till, limestone-dominated	5b	K05B	0.10	0.66	0.24	1.0
Locality B	K05	Till, limestone-dominated	5c	K05C	0.92	0.03	0.04	3.0
Locality B	K05	Glaciofluvial sands and gravels, limestone-dominated	5d	K05D	0.65	0.19	0.16	5.0
Locality B	K06	Glaciofluvial sands and gravels, limestone-dominated	6a	K06A	0.57	0.31	0.12	0.5
Locality B	K06	Glaciofluvial sands and gravels, limestone-dominated	6b	K06B	0.96	0.03	0.01	1.0
Locality B	K06	Glaciofluvial sands and gravels, limestone-dominated	6c	K06C	0.68	0.19	0.14	3.0
Locality B	K06	Glaciofluvial sands and gravels, limestone-dominated	6d	K06D	0.95	0.04	0.01	5.0
Locality B	K07	Topsoil	7a	K07A	0.46	0.42	0.12	0.5
Locality B	K07	Till, limestone-dominated	7b	K07B	0.56	0.36	0.08	1.0
Locality B	K07	Glaciofluvial sands and gravels, limestone-dominated	7c	K07C	0.74	0.23	0.03	3.0
Locality B	K07	Glaciofluvial sands and gravels, limestone-dominated	7d	K07D	0.62	0.32	0.06	5.0
Locality B	K08	Topsoil	8a	K08A	0.36	0.35	0.29	0.5

Site	Hole ID	Unit_name	Field ID	Sample ID	Sand	Silt	Clay	Nominal Depth, m
Locality B	K08	Till, limestone-dominated	8b	K08B	0.42	0.45	0.13	1.0
Locality B	K08	Till, limestone-dominated	8c	K08C	0.45	0.44	0.11	3.0
Locality B	K08	Till, limestone-dominated	8d	K08D	0.64	0.32	0.04	5.0
Locality B	K09	Topsoil	9a	K09A	0.41	0.47	0.12	0.5
Locality B	K09	Till, limestone-dominated	9b	K09B	0.34	0.52	0.14	1.0
Locality B	K09	Till, limestone-dominated	9c	K09C	0.33	0.52	0.15	3.0
Locality B	K09	Till, limestone-dominated	9d	K09D	0.29	0.50	0.21	5.0
Locality B	K09	Till, limestone-dominated		K09E	0.81	0.15	0.04	7.5
Locality B	K10	Topsoil	10a	K10A	0.52	0.27	0.20	0.5
Locality B	K10	Till, limestone-dominated	10b	K10B	0.36	0.55	0.09	1.0
Locality B	K10	Till, limestone-dominated	10c	K10C	0.47	0.44	0.09	3.0
Locality B	K10	Till, limestone-dominated	10d	K10D	0.42	0.44	0.15	5.0
Locality B	K10	Glaciofluvial sands and gravels, limestone-dominated	10e	K10E	0.80	0.14	0.06	7.5
Locality B	K11	Topsoil	11a	K11A	0.42	0.35	0.23	0.5
Locality B	K11	Till, limestone-dominated	11b	K11B	0.35	0.53	0.12	1.0
Locality B	K11	Till, limestone-dominated	11c	K11C	0.27	0.52	0.21	3.0
Locality B	K11	Glaciofluvial sands and gravels, limestone-dominated	11d	K11D	0.43	0.43	0.14	5.0
Locality B	K12	Topsoil	12a	K12A	0.35	0.47	0.18	0.5
Locality B	K12	Till, limestone-dominated	12b	K12B	0.32	0.47	0.21	1.0
Locality B	K12	Till, limestone-dominated	12c	K12C	0.37	0.47	0.16	3.0
Locality B	K12	Till, limestone-dominated	12d	K12D	0.42	0.41	0.18	5.0
Locality B	K12	Glaciofluvial sands and gravels, limestone-dominated	12e	K12E	0.70	0.18	0.12	7.5

Appendix E Domains: reclassification tables

Table 12 Bedrock domains – reclassification of GSI 1:500,000 bedrock geology map base

Unit Name	SRF Domain
1, Meta-dolerite, meta-gabbro	Domain 5
2, Serpentinite, Neoproterozoic (NE Ox Mts) & Lower Ordovician (Clew Bay, Carnew)	Domain 5
3, Orthogneiss suite, mainly quartz diorite (Connemara)	Domain 6
4, Granodiorite, tonalite, dacite, granite	Domain 6
5, Gabbro, dolerite & diorite	Domain 5
6, Microgranite & porphyry	Domain 6
7, Appinite Suite	Domain 5
8, Granite, granodiorite	Domain 6
9, Granite, granophyre	Domain 6
11, Dolerite & gabbro	Domain 5
13, Mullet Gneiss; Granitic orthogneiss	Domain 7
14, Cross Point Gneiss; Granitic orthogneiss	Domain 7
15, Doolough Gneiss & Granite; Granitic orthogneiss & granite	Domain 7
16, Kilmore Quay Group; Paragneiss, schist	Domain 7
17, Greenore Point Group; Schistose amphibolite	Domain 7
19, Slishwood Division; Quartzo-feldspathic paragneiss	Domain 7
20, Inishkea Division (possibly Dalradian); Psammitic & pelitic schist	Domain 7
21, Grampian Group; Psammitic & pelitic schist	Domain 7
22, Appin Group; Quartzite	Domain 7
23, Appin Group; Psammitic & pelitic schist & marble	Domain 7
24, Argyll Group; Paragneiss & migmatite	Domain 7
25, Argyll Group; Amphibolite & amphibolitic schist	Domain 7
26, Argyll Group; Quartzite	Domain 7
27, Argyll Group; Psammitic & pelitic schist, marble, amphibolite, diamictite	Domain 7

Unit Name	SRF Domain
28, Southern Highland Group; (Epidote-)amphibolitic schist & tuff	Domain 7
29, Southern Highland Group; Pelitic & psammitic schist, phyllite & marble	Domain 7
30, Marine; Quartzite & minor slate	Domain 5
31, Marine; Slate	Domain 5
32, Marine; Greywacke & shale	Domain 5
33, Basalt - andesite, tuff & shale	Domain 5
34, Rhyolite and rhyolitic tuff	Domain 5
35, Deep marine; Slate, schist & minor greywacke	Domain 5
36, Deep marine; Greywacke, shale, sandstone & conglomerate	Domain 5
37, Basalt - andesite, tuff, slate & mudstone	Domain 5
38, Rhyolite, rhyolitic tuff & slate	Domain 5
39, Deep marine; Slate, shale, minor sandstone & siltstone	Domain 5
40, Marine to fluvial; Greywacke, shale, sandstone & conglomerate	Domain 5
41, Melange (Ordovician or Silurian); Greywacke, sandstone & conglomerate	Domain 5
42, "Moffat shale" facies (Ordovician - Silurian); Shale & greywacke	Domain 5
43, Shallow marine (Dunquin Group, Dingle); Siltstone, sandstone, tuff, limestone	Domain 5
44, Rhyolitic tuff, basalt & andesite (in Dunquin Group)	Domain 5
45, Shallow marine (Croagh Patrick Succession); Sandstone, siltstone, conglomerate	Domain 5
46, Quartzite (in Croagh Patrick Succession)	Domain 5
47, Alluvial - playa (Louisburgh - Clare Island Succession); Sandstone, siltstone, conglomerate	Domain 5
48, Transgression - regression sequence (Killary Hbr - Joyces Country Succ.); Sandstone, conglomerate, greywacke, mudstone, tuff	Domain 5
49, Deep marine turbidite sequence; Mudstone, greywacke & conglomerate	Domain 5
50, Basalt, andesite, basaltic & andesitic tuff	Domain 5
51, Rhyolite & rhyolitic tuff	Domain 5
52, Continental redbed facies; Sandstone, siltstone & mudstone (base of Dingle Group is in the Upper Silurian)	Domain 4
53, Continental redbed facies; Sandstone, siltstone & mudstone	Domain 4
54, Continental redbed facies; Sandstone, conglomerate & siltstone (in places extends into the Carboniferous)	Domain 4
55, Shallow marine, (Cork Group, Old Head Sandstone Fm); Sandstone & mudstone	Domain 4
56, Basalt, trachyte, syenite & tuff	Domain 5

Unit Name	SRF Domain
57, Marine (Cork Group) (extends into the Visean); Mudstone, sandstone & thin limestone	Domain 3
58, Shallow marine ("Lower Limestone Shale"); Shale, sandstone & thin limestone	Domain 2
59, Shallow marine & coastal plain (basal clastics); Sandstone, mudstone & conglomerate	Domain 2
60, Shallow & marginal marine (Navan Group); Dark-grey limestone, mudstone, sandstone, minor evaporite	Domain 2
61, Marine shelf & ramp facies; Argillaceous dark-grey bioclastic limestone, subsidiary shale	Domain 2
62, Waulsortian mudbank; Pale-grey massive limestone	Domain 2
63, Shallow marine & coastal plain (Basal Clastics); Sandstone, mudstone & conglomerate	Domain 2
64, Marine shelf facies; Limestone & calcareous shale	Domain 2
65, Marine basinal facies (Tobercolleen & Lucan Fms - "Calp"); Dark-grey argillaceous & cherty limestone & shale	Domain 2
66, Marginal marine (Mullaghmore, Downpatrick & Clogher Valley Fms); Sandstone, mudstone & evaporite	Domain 3
68, Marginal marine (Meenymore Formation); Mudstone, sandstone & evaporite	Domain 1
71, Fluvio-deltaic & basinal marine (Turbiditic); Shale, sandstone, siltstone & coal	Domain 1
72, Fluvio-deltaic & shallow marine; Shale, sandstone & siltstone with coal	Domain 1
73, Continental redbed facies & shallow marine; Sandstone, conglomerate, magnesian limestone, marl, evaporite	Domain 2
74, Continental redbed facies (Permo-Triassic, Wexford); Sandstone, conglomerate & siltstone	Domain 2
75, Continental redbed facies, lagoonal & shallow marine; Sandstone & mudstone with evaporite	Domain 2
77, Shallow marine (Upper Cretaceous); Chalk, flint, glauconitic sandstone& chalk breccia	Domain 1
78, Undifferentiated minor volcanic rocks	Domain 5

Table 13 Domain classification of Teagasc subsoil map (see Figure 9)

Description	Parent Material	SRF Domain
Alluvium	A	Various
Alluvium (clayey)	Ac	Various
Alluvium (gravelly)	Ag	Various
Alluvium (silty)	Asi	Various
Acidic Esker sands and gravels	AcEsk	Various
Basic Esker sands and gravels	BasEsk	Domain 2
Basic igneous gravels	GBi	Domain 5
Chert sands and gravels	GCh	Domain 2
Sandstone and shale sands and gravels (Cambrian/Precambrian)	GCSsS	Domain 5
Sandstone sands and gravels (Devonian/Carboniferous)	GDCSs	Domain 3
Sandstone sands and gravels (Devonian)	GDSs	Domain 4
Granite sands and gravels	GGr	Domain 6
Sandstone sands and gravels (Lower Palaeozoic/Devonian)	GLPDSs	Domain 4
Shale sands and gravels (Lower Palaeozoic)	GLPS	Domain 5
Sandstone sands and gravels (Lower Palaeozoic)	GLPSs	Domain 5
Sandstone and shale sands and gravels (Lower Palaeozoic)	GLPSsS	Domain 5
Limestone sands and gravels (Carboniferous)	GLs	Domain 2
Metamorphic sands and gravels	GMp	Domain 7
Shales and sandstones sands and gravels (Namurian)	GNSSs	Domain 1
Quartzite sands and gravels	GQz	Domain 7
Volcanic rock till with matrix of Irish Sea Basin origin	IrSTAv	Domain 5
Sandstone and shale till (Cambrian/Precambrian) with matrix of Irish Sea Basin origin	IrSTCSsS	Domain 5
Sandstone till (Devonian) with matrix of Irish Sea Basin origin	IrSTDSs	Domain 4
Sandstone and shale till (Lower Palaeozoic) with matrix of Irish Sea Basin origin	IrSTLPSsS	Domain 5
Limestone till (Carboniferous) with matrix of Irish Sea Basin origin	IrSTLs	Domain 2
Acid volcanic till	TAv	Domain 5
Basic igneous till	TBi	Domain 5

Description	Parent Material	SRF Domain
Chert till	TCh	Domain 2
Sandstone and chert till (Carboniferous)	TCSsCh	Domain 3
Sandstone and shale till (Cambrian/Precambrian)	TCSsS	Domain 5
Sandstone till (Devonian/Carboniferous)	TDCSs	Domain 3
Sandstone and shales till (Devonian/Carboniferous)	TDCSsS	Domain 3
Tidal marsh	TdlMr	Various
Sandstone till (Devonian)	TDSs	Domain 4
Granite till	TGr	Domain 6
Sandstone till (Lower Palaeozoic/Devonian)	TLPDSs	Domain 4
Shale till (Lower Palaeozoic)	TLPS	Domain 5
Sandstone till (Lower Palaeozoic)	TLPSs	Domain 5
Sandstone and shale till (Lower Palaeozoic)	TLPSsS	Domain 5
Limestone till (Carboniferous)	TLs	Domain 2
Metamorphic till	TMp	Domain 7
Shales & sandstones till (Namurian/Carboniferous)	TNCSSs	Domain 1
Shales and sandstones till (Namurian)	TNSSs	Domain 1
Quartzite till	TQz	Domain 7
Aeolian Sediments undifferentiated	Aeo	Various
Lacustrine	L, Lc, Ls, Lsi	Various
Blanket peat	BktPt	Various
Cutover peat	Cut	Various
Fen peat	FenPt	Various
Raised peat	RsPt	Various
Karstified limestone bedrock at surface	KaRck	Various (mainly Domain 2)
Bedrock outcrop/subcrop	Rck	Various
Scree	Scree	Various
Marsh	Marsh	Domain 4
Beach/raised beach sand	Mbs	Various
Marine clays	Mc	Various

Description	Parent Material	SRF Domain
Estuarine sediments (silts/clays)	Mesc	Various
Marine sands and gravels	MGs	Various
Marl (Shell)	Mrl	Domain 2
Marine silts	Msi	Various
Made ground	Made	Various
Water	Water	Various
Blown sand	Ws	Various
Blown sand in dunes	Wsd	Various

Appendix F Chromium extraction rates

Chromium extraction rates in aqua regia and calculation of trigger values

Soil analyses carried out in the course of environmental testing in Ireland and the U.K. typically employ an *aqua regia* or comparable weak acid digestion. This can be expected to result in a partial extraction of elements from a sample and a degree of under-reporting of concentrations for most metals.

Data for the Tellus survey (GSI) and the GEMAS European Agricultural Soil survey (Reimann *et al.* 2014) have been examined to assess the rates of extraction for each element in *aqua regia*. Comparison of ICP-MS data for soils extracted with *aqua regia* with data for soils analysed by XRF allows an extraction rate to be calculated for each element for each sample: assuming that the XRF analysis yields a total (100 %) element concentration, the extraction rate is calculated as the ratio of the concentration measured using an aqua regia digest to that measured by XRF, expressed as a percentage [($conc_{\textit{aqua regia}}$/$conc_{XRF}$)*100].

Aqua regia is effective at extracting relatively loosely bound elements in soils, such as those in sulphides and bound to organic matter and to clays, but it has limited effect on minerals such as feldspars and pyroxenes and on oxides such as spinels. As elements can be hosted by a variety of minerals, the extraction rate for any element in soil samples will vary depending on the mineralogy of the sample. Tellus and GEMAS data suggest that for the seven of the eight elements listed in the guidance (Hg is excluded as XRF data are not available), extraction rates for all except Cr typically exceed 80 - 90 %. In contrast, extraction rates for Cr are typically relatively low, averaging around 35 %. This reflects the fact that the main host minerals to Cr, including spinels such as chromite ($FeCr_2O_4$), are generally difficult to digest using weaker acids.

Data for 4,131 GEMAS agricultural soil samples from grazing land (Gr) and arable land (Ap) and for 11,381 Tellus regional A and S soil samples were compiled and extraction rates for Cr calculated for each sample. Samples for which Cr was below the analytical detection limit were excluded as were samples for which the computed extraction rate exceeded 100 %, leaving 4,120 GEMAS samples and 9,629 Tellus samples. Histograms of the Cr extraction rate data are presented below. The similarity in the data distribution for the two datasets as displayed by the histograms is striking. The median extraction rate for the GEMAS data is 33.8%, that for the Tellus data 36.9%; mean values are very similar (35.5 % and 37.8 %, respectively).

For the purpose of setting trigger values for SRF domains, it is necessary to derive a correction factor for Cr analysed following *aqua regia* digestion. Otherwise analyses of backfill material will consistently under-report Cr concentrations. One option would be to select the median or mean extraction rate for the data, c. 35 %. Thus Cr trigger values computed for each domain, based on the "total" Cr analyses in the NSDB, would be multiplied by 0.35. However, as shown by the histograms below, extraction rates for a significant proportion of samples are much higher. In order to ensure trigger values for Cr adequately reflect the full range of variation in extraction rates, an upper bound to the computed extraction rate data equal to the 95th percentile has been selected as the correction factor. For the GEMAS data, the 95th percentile is 59.3%, for Tellus 61.2 %. The upper bound for the Cr extraction rate in *aqua regia* is therefore taken to be 60 % and the correction factor applied to the trigger value for each domain is 0.6.

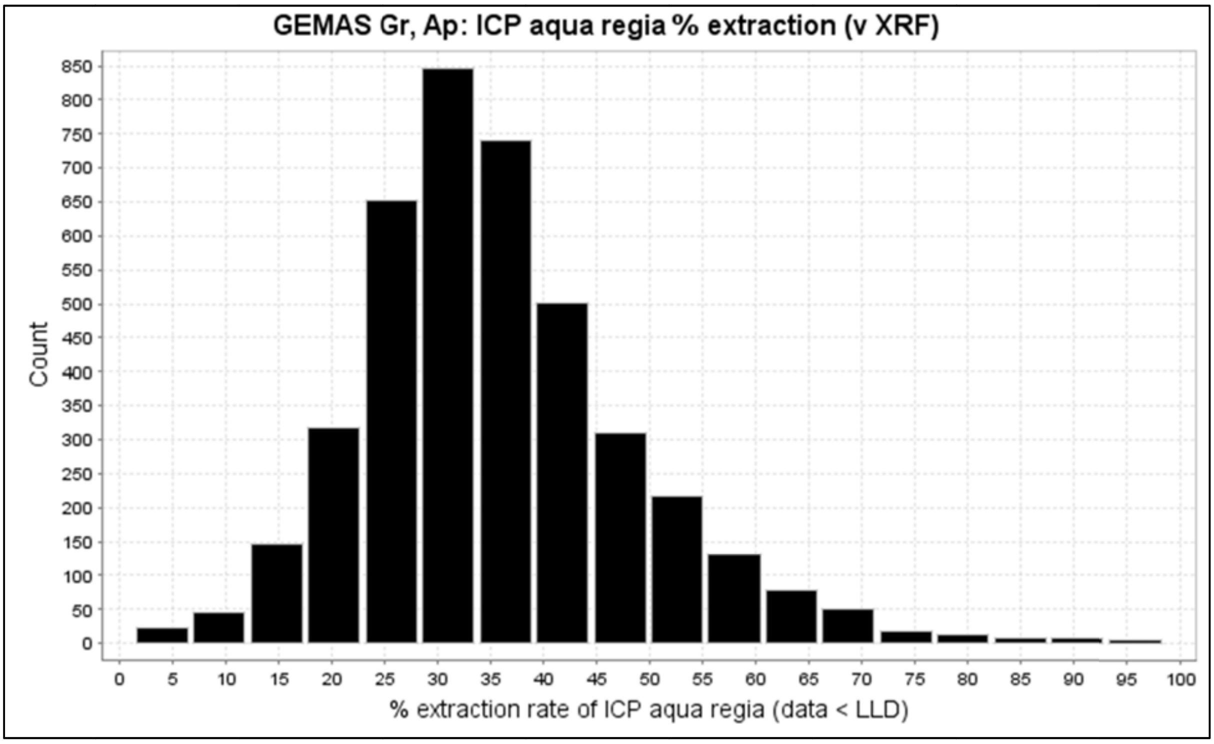

Figure 56 Histogram of computed extraction rates for Cr in GEMAS soil samples. Computed rate > 100% excluded.

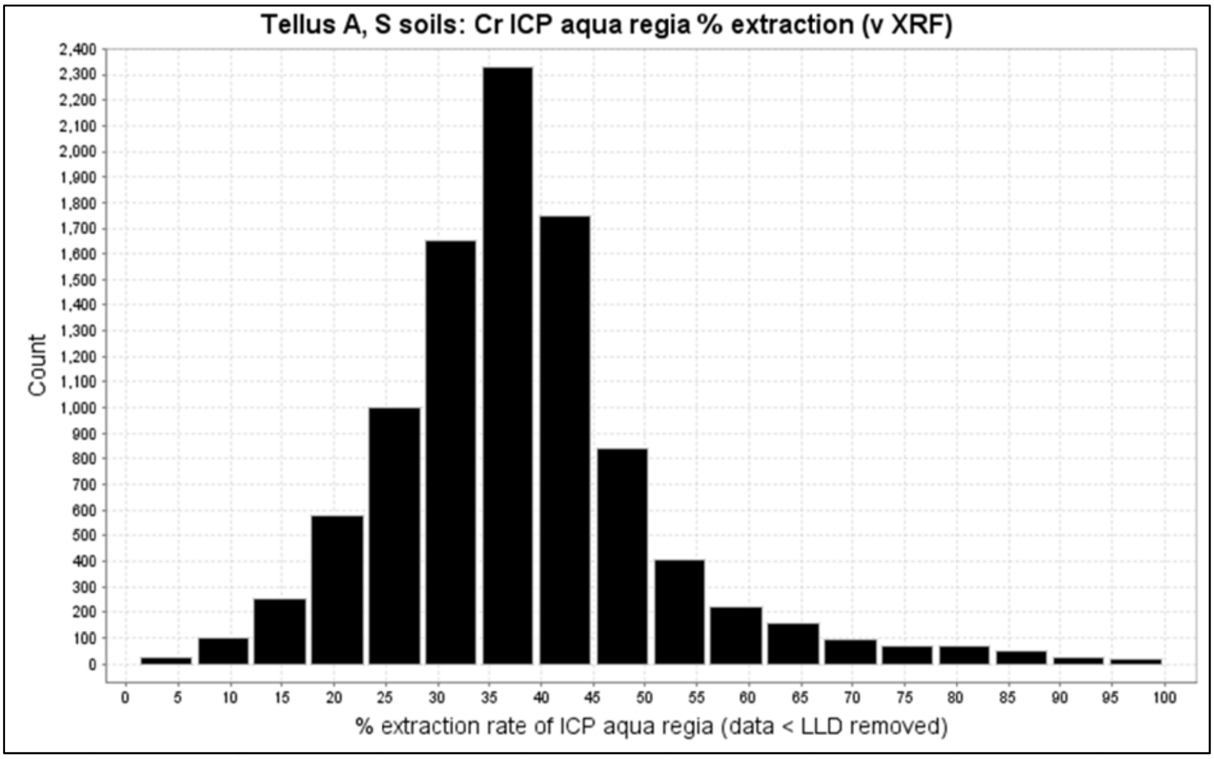

Figure 57 Histogram of computed extraction rates for Cr in Tellus soil samples. Computed rate > 100% excluded.

Appendix G Calculation of percentiles

Calculation of Percentiles: outline of method, as employed by ioGAS and used for SRF project

Various methods are commonly used to calculate percentiles. The method employed in this project, as incorporated into the ioGAS programme, utilizes weighted averages similar to the method described online by David M. Lane (http://onlinestatbook.com/2/introduction/percentiles.html) and labelled the "Third Definition". The following is an abbreviated version David M. Lane's description of the methodology.

TWO SIMPLE DEFINITIONS OF PERCENTILE

There is no universally accepted definition of a percentile. Using the 65th percentile as an example, the 65th percentile can be defined as the lowest score that is greater than 65% of the scores. This is the way we defined it above and we will call this "Definition 1." The 65th percentile can also be defined as the smallest score that is greater than or equal to 65% of the scores. This we will call "Definition 2." Unfortunately, these two definitions can lead to dramatically different results, especially when there is relatively little data. Moreover, neither of these definitions is explicit about how to handle rounding. For instance, what rank is required to be higher than 65% of the scores when the total number of scores is 50? This is tricky because 65% of 50 is 32.5. How do we find the lowest number that is higher than 32.5 of the scores? A third way to compute percentiles (presented below) is a weighted average of the percentiles computed according to the first two definitions. This third definition handles rounding more gracefully than the other two and has the advantage that it allows the median to be defined conveniently as the 50th percentile.

THIRD DEFINITION

Unless otherwise specified, when we refer to "percentile," we will be referring to this third definition of percentiles. Let's begin with an example. Consider the 25th percentile for the 8 numbers in the table below. Notice the numbers are given ranks ranging from 1 for the lowest number to 8 for the highest number.

Table: Test Scores.

Number	Rank
3	1
5	2
7	3
8	4
9	5
11	6
13	7
15	8

The first step is to compute the rank (R) of the 25th percentile. This is done using the following formula:

$$R = P/100 \times (N + 1)$$

where P is the desired percentile (25 in this case) and N is the number of numbers (8 in this case). Therefore,

$$R = 25/100 \times (8 + 1) = 9/4 = 2.25.$$

If R is an integer, the Pth percentile is the number with rank R. When R is not an integer, we compute the Pth percentile by interpolation as follows:

1. Define IR as the integer portion of R (the number to the left of the decimal point). For this example, IR = 2.
2. Define FR as the fractional portion of R. For this example, FR = 0.25.
3. Find the scores with Rank I_R and with Rank $I_R + 1$. For this example, this means the score with Rank 2 and the score with Rank 3. The scores are 5 and 7.
4. Interpolate by multiplying the difference between the scores by F_R and add the result to the lower score. For these data, this is (0.25)(7 - 5) + 5 = 5.5.

Therefore, the 25th percentile is 5.5. If we had used the first definition (the smallest score greater than 25% of the scores), the 25th percentile would have been 7. If we had used the second definition (the smallest score greater than or equal to 25% of the scores), the 25th percentile would have been 5.

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