East Dunbartonshire Council

CRAIGFOOT ALLOTMENTS, MILTON OF CAMPSIE

Supplementary Phase 2 Ground Investigation

70083065/01
JULY 2021

CONFIDENTIAL

East Dunbartonshire Council

CRAIGFOOT ALLOTMENTS, MILTON OF CAMPSIE

Supplementary Phase 2 Ground Investigation

TYPE OF DOCUMENT (VERSION) CONFIDENTIAL

PROJECT NO. 70083065

OUR REF. NO. 70083065/01

DATE: JULY 2021

WSP

110 Queen Street
Glasgow
G1 3BX

Phone: +44 141 429 3555

Fax: +44 141 429 3666

WSP.com

QUALITY CONTROL

Issue/revision	First issue	Revision 1	Revision 2	Revision 3
Remarks	Draft			
Date	July 2021			
Prepared by	Daniel Graham/ Aliyssa Glen/Jessica Layfield			
Signature				
Checked by	Stewart Browne/ Thomas Parkinson			
Signature				
Authorised by	Tony Brown/Andy Hallas			
Signature				
Project number	70083065			
Report number	70083065/01			
File reference				

CONTENTS

TABLES

FIGURES

APPENDICES

APPENDIX C

SITE INVESTIGATION INFORMATION

APPENDIX C.1

EXPLORATORY HOLE LOGS

APPENDIX C.2

LABORATORY RESULTS AND SOIL SCREEN

APPENDIX D

RISK ASSESSMENT METHODOLOGIES

EXECUTIVE SUMMARY

WSP UK Ltd was instructed by East Dunbartonshire Council to undertake supplementary ground investigations at Craigfoot Allotments, Antermony Road, Milton of Campsie following previous site investigations, with the aim of providing a site specific assessment criteria (SSAC) for lead and checking whether the loading area will be geotechnically suitable under the current design.

- Following previous site investigation works and these supplementary investigations the following was noted:
- Following bio-accessibility testing, it was not possible to produce a SSAC for lead lower than the existing GAC.
- Four lead exceedances of Human Health GAC have been identified within the shallow alluvial soils in the southern area of the site during supplementary testing. This equates to a total of eight lead exceedances in this area to date.
- No lead exceedances have been recorded for the northern area of the site (noted to comprise predominantly glaciofluvial soils versus alluvial soils).
- Lead exceedances are generally in the range of anticipated natural background concentrations based on BGS mapping data.
- While lead exceedances appear to be natural in origin (in the absence of identified anthropogenic input/source) as lead is a 'non-threshold' contaminant (i.e. on in which there is no safe dose below which an effect is not observed), then the 'ALARP' ('As Low As Reasonably Practicable') principle applies.

Previous ground investigation assessments determined that the existing levels in the south of the site are to be maintained; lead-impacted soils will may require excavation to 600mm below existing site levels, with levels to be reinstated using either soils from the northern slope or imported certified clean soils. Alternatively, further options for investigation and/or in-situ remediation are presented for consideration and discussion, which may allow avoidance of costly and unsustainable dig and dump methods.

Once development plans are advanced further, WSP recommends that a detailed remedial strategy document is developed for the site, to guide mitigation works and assist in subsequent validation, and submitted for Local Authority approval.

1 INTRODUCTION

1.1 AUTHORISATION

WSP UK Ltd (WSP) was instructed by East Dunbartonshire Council (EDC) (the Client) to undertake a supplementary geotechnical and environmental ground investigation at Craigfoot Allotments, Antermony Road, Milton of Campsie (the 'site'), in accordance with our proposal dated 11 March 2021 (ref. 70083065-BID) to support the site's redevelopment for allotment use.

1.2 BACKGROUND AND TERMS OF REFERENCE

Previous intrusive investigations in 2018 and 2020 (summarised in Section 2) carried out at the site, identified lead within shallow soils as representing potential risks to future site users. Additionally, a proposed loading area at the top of the existing slope was deemed to present a risk to its stability. Consequently, the following supplementary intrusive investigation works were recommended:

- Sampling and bio-accessibility testing in order for site specific assessment criteria (SSAC) to be produced to inform risks to future site users.
- Geotechnical sampling and testing of the slope soils to inform slope stability risks.

Full details of previous assessments may be viewed in the following reports:

- WSP UK Ltd, Ground Investigation Report, Craigfoot Allotments dated March 2018, Ref 70012724_GIR **[Ref. 1]**; and,
- WSP UK Ltd, Ground Investigation Report, Craigfoot Allotments dated January 2020, Ref 70012724_GIR/V2 **[Ref. 2].**

The site location and boundary plans are presented in Figures 1 and 2 included in **Appendix A**.

1.3 DEVELOPMENT PLANS

The site is to be developed into a series of field allotments which will be located within the flatter southern part of the site. Access to the site will be gained via a new footpath that joins Antermony Road to the north of the site, where the loading area is also proposed.

Detailed design drawings are provided in Figures 2724-WSP-SK-001 to 2724-WSP-SK-006, all included in Appendix A.

1.4 PROJECT SCOPE

The scope of the project has comprised:

- One day service clearance, goalpost set up due to overhead electricity lines, Scottish Power liaison;
- One day window sampling for 3 three boreholes to 5m depth, plus six hand pits to 0.6m depth;
- Lead and bio-accessibility testing;
- Geotechnical testing;
- Geotechnical check of current earthwork design in relation to loading area (simply stating whether it is appropriate or will need additional considerations); and,
- Update to contamination risk assessment reporting.

This report should form part of the Health and Safety File for the site.

1.5 LEGISLATIVE CONTEXT AND GUIDANCE

The assessment was undertaken in the legislative context of:

- Part 2A of The Environmental Protection Act (1990); and,
- Scottish Government Planning Advice Note 33 (PAN33).

The following good practice and statutory guidance was considered, and the assessment was undertaken in general accordance with:

- Land Contamination: Risk Management (LCRM), 8th October 2020;
- British Standard 'Investigation of Potentially Contaminated Sites – Code of Practice', BS EN 10175:2011 + A2:2017;
- Defra 'Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance', PB13735 (2012); and,
- British Standard 'Code of Practice for Ground Investigations', BS 5930:2015.

1.6 CONFIDENTIALITY STATEMENT AND LIMITATIONS

This report is addressed to and may be relied upon by the following party:

- East Dunbartonshire Council

This report was prepared in line with the WSP proposal and associated notes. This report shall not be relied upon or transferred to any other parties without the express written authorisation of WSP. No responsibility will be accepted where this report is used, either in its entirety or in part, by any other party.

Note that where this report summarises information provided from external sources, WSP cannot offer any guarantees or warranties for the completeness or accuracy of information relied upon.

General limitations of the assessment are included in **Appendix B**.

2 PREVIOUS REPORTING

Historical reporting, as summarised below, relates to previous ground investigation and tank removal works completed / reviewed by WSP as per **[Ref.1]** and **[Ref. 2].**

2.1 GROUND INVESTIGATION REPORT – MARCH 2018

Salient points are presented below. For a full understanding the reader is directed to the original reporting referenced above **[Ref. 1].**

- Ten exploratory holes were excavated, comprising five hand dug pits to maximum depths of 1.2m bgl and five mechanically excavated pits to maximum depths of 3.1m bgl;
- Made Ground was encountered to depths of up to 0.2m bgl in one location, comprising gravelly sand with glass fragments. Topsoil was encountered in the remaining locations to depths of 0.2m. Underlying natural materials comprised Alluvium and granular deposits. Bedrock of Mudstone and Sandstone was encountered in three locations.
- Chemical testing of up to 4 samples for a suite comprising heavy and phytotoxic metals, hexavalent chromium, miscellaneous inorganics (e.g. cyanide, sulphate, pH), Total Petroleum Hydrocarbons (TPH), speciated Polycyclic Aromatic Hydrocarbons (PAHs), phenols, Soil Organic Matter content (SOM), and asbestos identification;
- Soil results were screened against Generic Assessment Criteria (GAC) calculated using the Contaminated Land Exposure Assessment (CLEA) v. 1.071 model. Exceedances of lead were recorded at HP03 and HP04a in the southern part of the site;
- Lead exceedances associated with the sandy gravelly clay appeared to be naturally occurring as no obvious anthropogenic source was observed. However, despite the absence of an anthropogenic source, the sensitive allotment use dictates that the Lead GAC concentration which is permissible was exceeded, consequently additional assessments or mitigation were recommended if the Alluvium was to remain within a depth of approximately 600mm of the proposed allotment areas;
- It was understood that groundworks had been further reviewed and a requirement had been identified to increase elevations in the proposed allotment area by 500mm and provide additional topsoil thickness. It was suggested that site-won materials from the northern slope may be used for the raising of ground levels. Aside from the composite slope topsoil sample (which was analysed for a limited suite), this area had not been subject to contamination testing to confirm it is suitable for allotment use;
- It was conjectured that the slope materials may be suitable for use as the fill material and following appropriate confirmatory testing, these could then form a suitable cover system to limit exposure and plant uptake from the Lead impacts observed in HP03 and HP04b;
- Further works were recommended to obtain additional soil samples from the north of site and update the assessments presented herein. WSP estimated this could be achieved with an additional day of hand-excavated pits along with recovery and analysis of an additional 4 to 5 samples, to be analysed for a limited suite of contaminants based on the site conditions previously encountered (metals suite).

2.2 GROUND INVESTIGATION REPORT V2– JANUARY 2020

Salient points are presented below. For a full understanding the reader is directed to the original reporting referenced above **[Ref. 2].**

- Nine exploratory holes were excavated by EDC, comprising hand-dug pits to maximum depths of 0.5m bgl;
- Logs provided spanned 0.3 – 0.5m bgl only. Natural materials comprised Alluvium and granular deposits;
- Chemical testing of up to 9 samples for a suite comprising heavy and phytotoxic metals, pH and PAHs;
- Soil results were screened against Generic Assessment Criteria (GAC) calculated using the Contaminated Land Exposure Assessment (CLEA) v. 1.071 model. Exceedances of lead were recorded at CFA-8 and CFA-10 (A composite sample from CFA-1 to CFA-9 across the site). A single hexavalent chromium exceedance was recorded in CFA-6;
- A potential source was not identified for the hexavalent chromium exceedance recorded at CFA-6 based on the sample description provided by EDC. Additionally, the screen was carried out assuming hexavalent chromium, but the chromium testing by EDC was for total chromium concentrations, and it was considered likely that other more stable forms of chromium (e.g. trivalent chromium) would form the majority of the total chromium concentration recorded. On this basis it was considered unlikely that hexavalent chromium concentrations would pose a risk to future site users with no further discussion on chromium warranted;
- Lead exceedances in the southern area of the site where the allotments are proposed appeared to be associated with the sandy gravelly clay and appeared to be naturally-occurring as no obvious anthropogenic source was observed or described. Despite the absence of an anthropogenic source, the sensitive allotment use dictated that mitigation or further assessment was required;
- It had been previously suggested that site-won materials from the northern slope may be used as a cover layer in the south. Although a lead exceedance was recorded in the composite sample (CFA-10) which included materials from this area, the exceedance in CFA-10 was marginal (69mg/kg compared to GAC of 64mg/kg), and would be below the Category Four Screening Level (C4SL) for lead under allotment end use (80mg/kg). No lead exceedances were directly recorded in the north. It was therefore considered unlikely that the soils in the north would pose a risk to human health and on this basis these soils were considered suitable for use as a cover system for the proposed allotment areas in the south;
- Based on consultation with SEPA it was understood that site levels were to remain unchanged in the south. Lead-impacted soils would therefore require excavation to 600mm below existing site levels and removal off-site, with levels to be reinstated using either soils from the northern slope or imported certified clean soils;
- It was suggested that alternatively, it may be possible to avoid soil disposal costs and for soils to remain in-situ if it could be determined that the bioavailability of lead in site soils was low. The GAC applied above assume a relative bioavailability of 100% of lead in soils and therefore contributes to the dose in the GAC. Correction of the oral exposure pathway used in the GAC could be made by bio-accessibility testing. It was recommended that this testing be delivered in the south of the site to allow an updated assessment of risk, albeit it should be noted that there was no guarantee that such testing would refute risks to future allotment site users from the lead impacted soils.

3 SUPPLEMENTARY ENVIRONMENTAL GROUND INVESTIGATION

3.1 FIELD WORKS AND RATIONALE

The supplemental ground investigation was carried out on 26th and 27th April 2021 at the positions shown on **Figure 3 (Appendix A).** Exploratory hole records are included in **Appendix C**. Sample testing was scheduled and targeted to the Alluvial deposits, based on the findings of **Refs. 1 and 2**.

The investigation was carried out under the supervision of an experienced engineer from WSP.

Table 3-1 – Summary of 2021 Supplemental Ground Investigation Works Completed

Investigation Method	No.	Max Depth (m bgl)	Chemical Testing	Rationale*
Hand Pits (HP01/21 to HP06/21)	6	0.6	Lead, Bio-accessibility testing for lead	In order to determine the bioavailability of lead and, if possible, develop a site specific GAC.
Window Sample Boreholes	3	4.3	N/A	Geotechnical testing carried out to provide comment on suitability of loading area design.

Note: Samples obtained for testing were collected in 1kg plastic tubs, 250mg amber glass jars and 60g amber glass vials provided by ALS Laboratories.

3.2 CHEMICAL TESTING - SOILS

Soil samples were submitted for chemical analysis at ALS Laboratories in Hawarden. The results of the contamination testing are presented in **Appendix C**.

3.3 GROUND CONDITIONS ENCOUNTERED

A summary of ground conditions encountered is presented in Table 3-2. The lithologies and depths encountered were generally consistent with those encountered in **Ref. 1.**

Table 3-2 – Summary of Strata Encountered During 2021 Supplementary Investigation

Stratum	Depth to Base of Stratum (mbgl)	Elevation of Base of Stratum (mAOD)	Thickness (m)	Typical Description
Topsoil	0.08 to 0.36	47.82 to 42.05	0.08 to 0.36	Slightly sandy clayey silt with rare gravel
Made Ground Cohesive	0.45 to 0.45	51.44 to 51.44	0.45 to 0.45	Sandy silty clay with glass and ceramic fragments (WS01 only)
Alluvium	0.90 to 1.50	47.28 to 40.86	0.54 to 1.35	Slightly sandy slightly gravelly clayey silt, slightly sandy silty clay with rare gravel or slightly sandy gravelly silt.
Glaciofluvial Deltaic Deposits	3.20 to 3.20	48.69 to 48.69 (39.46)	2.75 to 2.75	Sandy clayey silt, silty sand and clayey gravelly sand
Glacial Till	Not proven (4.30)	Not proven (47.59)	Not proven (1.10)	Stiff sandy gravelly clay (WS01 only)

* Brackets indicate maximum unproven depth and thickness and the minimum elevation

No visual or olfactory evidence of contamination was identified during the supplementary investigations. Groundwater was recorded at the following locations summarised in Table 3-3:

Table 3-3 – Summary of Groundwater Strikes Encountered during Site Investigation

Exploratory Hole	Depth Groundwater Encountered (Strike) (mbgl)	Elevation Groundwater Encountered (Strike) (mAOD)	Depth to Groundwater after 20 mins (mbgl)	Elevation of Groundwater after 20 mins (mAOD)	Remarks
WS01	2.95	48.94	-	-	Seepage
WS03	1.50	40.86	1.50	40.86	
WS03	2.00	40.36	1.20	41.16	

4 CONTAMINATION QUANTITATIVE RISK ASSESSMENT

4.1 INTRODUCTION

Following the tiered approach which is described in LCRM, this Section provides a Generic Quantitative Risk Assessment (GQRA) of those contaminant linkages that were determined to be plausible in 2019 and identified as requiring further assessment.

4.2 HUMAN HEALTH RISK ASSESSMENT

4.2.1. Rationale

WSP has derived a set of Generic Assessment Criteria (GAC) for the CLEA generic land use scenarios using the CLEA Workbook v1.071 Excel modelling tool. Further details on the assumptions and methodologies adopted by WSP are provided in **Appendix D**.

The soil chemical data has been compared against an allotment GAC for a 6% Soil Organic Matter (SOM) content, based on an average SOM of 11.6% from two tests from the lab data in **[Ref. 1]** and **[Ref. 2].**

To support development options, human exposure to all unsaturated soils, irrespective of depth, has been assumed possible for the purpose of this assessment. This will maximise the information available to the design team on the suitability of all unsaturated material and may support with their materials management options.

4.2.2. Assessment of Risks to Future Allotment Site Users

The results of our 2021 analysis for the identified contaminants of concern in shallow soils have been compared directly to their conservative screens. Four of the six locations exceeded the allotment GAC for lead of 64mg/kg:

- HP02/21 – 132mg/kg
- HP03/21 – 131mg/kg
- HP05/21 – 105 mg/kg
- HP06/21 – 92.8 mg/kg

When compared against the Category Four Screening Level (C4SL) for lead under allotment end use (80mg/kg; indicative of low rather than minimal risk, but still strongly precautionary), all above samples would also fail.

For reference, it is also noted that the allotment GAC and C4SL are based on the following exposure assumptions:

- Critical receptor is a young female child (aged 0 to 6 years old);
- Exposure duration is 6 years;
- Exposure pathways include direct soil ingestion, consumption of homegrown produce, consumption of soil adhering to homegrown produce, skin contact with soils, and outdoor inhalation of dust and vapours;
- No building is present.

When compared to the residential with homegrown produce GAC and C4SL (134 and 200mg/kg respectively, and noted to have the same exposure parameters as allotments, with the addition of indoor inhalation of dust), it is noted that no exceedances would be recorded. The allotment screening criteria assume a higher fraction of homegrown produce is ingested by allotment holders and their families, relative to those who grow produce in their gardens.

As the conservative screens assume a relative bioavailability of 100% of lead in the soils, part of the scope of works included bio-accessibility testing in order to provide a site-specific assessment criteria (SSAC).

4.2.3. Bioavailability and Bio-accessibility

The bioavailable fraction of a chemical (also known as absolute bioavailability or ABA) is the intake dose of the chemical (e.g. via ingestion, inhalation or dermal contact) which finds its way into, and is absorbed by, the body and reaches systemic circulation unchanged, as expressed by equation 1:

$$ABA = \frac{Ds}{Di} \qquad \text{[Eq.1]}$$

Where: ABA = absolute bioavailability of a chemical in dimensionless form

Ds = absorbed dose in mg kg-1BW day^{-1}

Di = ^{int}*ake dose in mg kg-1BW day*$^{-1}$

The absolute bioavailability (ABA) of a chemical may vary between zero (if none of a chemical reaches systemic circulation intact) or 1.0 (100%) (if all of the chemical reaches the systemic circulation intact)[1]. The bioavailability of a chemical is possible to measure only using in-vivo methods and is therefore not generally measured directly for human health but is based on toxicological studies.

Relative bioavailability (or RBA) is the comparison of the extent of absorption between two or more forms of the same chemical (e.g. lead carbonate and lead chromate), or the same chemical administered in different media (e.g. soil, water), or at different doses. In the context of this report, the relative bioavailability is effectively a measure of the bioavailability of the lead in the soil versus the bioavailability of lead in the toxicological study used to derive the lead GAC (i.e. comparison of the extent of absorption between lead administered in different media):

$$RBAsoil, tox = \frac{ABAsoil}{ABAtox} \qquad \textbf{[Eq. 2]}$$

[1] CLEA Software (Version 1.05) Handbook

Where: RBAsoil,tox = bioavailability from the soil sample relative to the bioavailability from the media used in the toxicological study, in dimensionless form

ABAsoil = absolute bioavailability of the chemical in soil, in dimensionless form

ABAtox = absolute bioavailability of the chemical in the media used in the toxicological study, in dimensionless form

It is additionally noted that the bioavailability discussed herein relates to the oral pathway contribution to the GAC only (i.e. inhalation not considered).

Bioavailability is typically determined by using bio-accessibility data as a proxy. The bio-accessibility of a contaminant is the amount of a substance within the gastrointestinal tract and available for absorption. Bio-accessibility of contaminants is typically determined via the Unified Bio-accessibility Research Group of Europe (BARGE) method, an in vitro, staged leachate process which simulates the natural phases of the digestive tract.

The soil GAC that have been used herein are based upon an assumption (CLEA default) of 1.0 for relative oral bioavailability in soil (i.e. the absolute bioavailability of the chemical in the soil sample is the same as the absolute bioavailability in the media used in the relevant toxicological study). This does not necessarily mean that soil bioavailability is 100%.

The toxicological basis for the WSP soil GAC is a dietary intake that gives a geomean blood concentration of 3.5 micrograms/decilitre (ug/dL) of lead. The bioavailability of lead via dietary intake is 50%. As the relative bioavailability (WSP soil GAC, lead) is 1.0 (100%), this equates to a soil bioavailability of 50%.

For comparison, the C4SL for lead uses the same toxicological benchmark, but assumes a soil bioavailability of 30%, resulting in a relative oral bioavailability of 0.6 (60%).

The bioavailability recorded from the laboratory testing is as follows:

Table 4-1 – Summary of Bioavailability Testing

Determinand	**HP01**	**HP02**	**HP03**	**HP04**	**HP05**	**HP06**
Lead after stomach only extraction mg/kg	31.7	81.5	109	26.1	60.8	41.8
Lead after stomach and intestine extraction mg/kg	<14	22.9	26.1	<14	<14	<14
Bioaccessible lead (stomach only extraction) %	55.1	61.7	82.9	50.2	57.9	45
Bioaccessible lead (stomach and intestine extraction) %	<24.3	17.4	19.9	<27	<13.3	<15.1

It is industry best practice to use the most conservative value from bioavailability testing when undertaking soil DQRA. In this instance, this would be 82.9%. However, the CLEA model requires that we input relative bioavailability. Converting a soil bioavailability (ABAsoil) figure of 82.9% to a relative oral bioavailability (RBAsoil,tox) (toxicological study is based on dietary exposure, as explained above), results in a value of 1.658, i.e. using equation 2:

$$RBAsoil, tox = \frac{82.9}{50}$$

This would lead to a soil SSAC for lead in allotments that is higher than the existing WSP GAC.

While the exposure assumptions which underpin the current WSP GAC are conservative in nature, the bioavailability values from the soil samples as tested do not allow for a SSAC to be derived that would be lower than the existing GAC.

Full laboratory records including chemical screening data are provided in **Appendix C.**

4.2.4. Assessment

Following on-site bioavailability testing it has not been possible to derive a SSAC lower than the existing WSP GAC. Lead has therefore been noted to exceed the Human Health GAC in four of the six supplemental locations tested, with the exceedances being of the same order of magnitude as those recorded within **[Ref. 1]** and **[Ref. 2].**

Notwithstanding the above, the British Geological Survey (BGS) has derived 'normal' background concentrations for lead for England and Wales. In England the 'normal' background concentrations of lead are 180mg/kg for the 'principle' domain, 2,400mg/kg for the 'mineralisation' domain, and 820mg/kg for the 'urban' domain. Meanwhile, point data for lead concentrations in Scottish topsoil is available on a 10km grid. The closest data suggests lead concentrations of between 19 and 122.2ppm (19 and 122.2mg/kg respectively). Many of the site results reside within normal anticipated background concentrations, as anticipated given that the GAC exceedances recorded to date have been detected within shallow natural alluvial soils. It is noted that no exceedances have been reported to date within soils on the northern slope of the site; it is conjectured that this may be because the northern slopes is dominated by different lithology compared to the south of the site (i.e. mainly glaciofluvial deposits rather than alluvial deposits).

However, as lead is a 'non-threshold' substance (i.e. one in which there is no safe dose for exposure below which no adverse effects are observed), then the 'ALARP' principle ('As Low as Reasonably Practicable') is applicable.

It was understood in **[Ref. 2]** that site levels are to remain unchanged in the south and no information has been provided to the contrary at this time. Outline options for further works are presented in Section 6.0.

5 GEOTECHNICAL ASSESSMENT

5.1 GROUND CONDITIONS AND GROUND MODEL

The following ground summary is based on the preliminary ground investigation undertaken in January 2018, the supplementary ground investigation in 2019 and the works carried out in 2021 summarised in Section 3 above. The exploratory hole logs have been extracted from **[Ref. 1]** and **[Ref. 2]** and included in Appendix C.

5.1.1. Ground Conditions

In general, the recorded ground conditions in the lower southern part of the site comprise Topsoil underlain by Alluvium This is in turn underlain by either Glaciofluvial Deltaic Deposits, Glacial Till or solid geology of the Upper Limestone Formation. Made Ground is recorded underlying the topsoil in two exploratory holes.

As the site rises to the north, the Alluvium thins and is absent in the exploratory holes at the top of the slope. Here, Topsoil is recorded as being underlain by a sequence of Glaciofluvial Deltaic Deposits over cohesive Glacial Till.

A brief summary of each stratum is discussed below. For a more comprehensive description of the ground investigation and ground conditions, refer to the Ground Investigation Report **[Ref. 2]**

Topsoil

Topsoil was encountered in all exploratory holes to a maximum depth of 0.45m below ground level (bgl) [WS01].

Made Ground

Beneath the Topsoil, Made Ground was encountered in HP01 & HP04a (from the 2018 GI). In exploratory hole location HP01, the Made Ground is recorded as very soft to soft, very sandy, gravelly clay with glass fragments at 0.20m bgl. In HP04a, the Made Ground comprised gravelly clayey sand with glass fragments at 0.15m bgl. Granular components in HP01 & HP04a comprised fine to coarse angular to sub-rounded sandstone and various other lithologies.

The base of Made Ground was proven to a maximum depth of 0.20m bgl [HP01 & HP04a].

Alluvium

Alluvium is recorded in all exploratory holes, except WS01 and is generally described as "very soft to soft very sandy to sandy gravelly clay with occasional cobbles and rare boulders". However, in WS02, WS03, HP02 & TP01, soils described as "slightly clayey or silty clayey gravelly fine and medium sand" or "sandy fine and medium subangular or rounded smooth gravel" are recorded.

The maximum recorded depth to the base of the Alluvium is 2.30m bgl in TP06, with the thickest sequence (2.44m) recorded in WS02.

Glaciofluvial Deltaic Deposits

Deposits considered to represent Glaciofluvial Deltaic Deposits are recorded in WS01 – WS03, TP03, TP05 & TP06 and are described as comprising silt, sand and gravel.

The base of the Glaciofluvial Deltaic Deposits is not recorded in WS02, WS03, TP03 & TP05 (exploratory holes extend to a maximum depth of 3.10m bgl [TP03]). The base of the deposit is proven in WS01 at 3.20m bgl and in TP06 at 2.5m bgl.

Glacial Till

Deposits described as Glacial Till are recorded in WS01 & TP06 only. It is recorded from 3.20m bgl in WS01 and the base of the strata was not proven to a depth of 4.30m bgl. In TP06 Glacial Till was encountered from 2.30m bgl and the base of the strata was not proven to a depth of 2.60m bgl.

The Glacial Till is described as "stiff grey clay" or "sandy gravelly clay".

Weathered Solid Geology – The Upper Limestone Formation

Weathered Upper Limestone Formation is recorded in TP01 & TP02 as "mudstone and sandstone recovered as angular cobbles and gravel". The base of the weathered Upper Limestone Formation is not proven.

5.1.2. Groundwater

Shallow groundwater strikes were encountered in HP02, HP03, HP04a & HP04b at depths varying between 0.40m to 1.00m bgl, whilst HP01 is recorded to remain dry. In HP02, the groundwater rose from 1.00m to 0.75m bgl during a 15-minute period, whist the groundwater rose between 0.10m to 0.15m bgl in HP03, HP04a & HP04b. Groundwater seepages within TP01 & TP06 were noted at 2.00m and 1.45m bgl respectively.

In the supplementary exploratory hole locations, WS01 recorded a seepage at 2.95m bgl and WS03 recorded water strikes at 1.50m bgl and 2.00m bgl, rising to 1.20mbgl after 20 minutes. Water strikes from WS01 & WS03 were encountered in Alluvium.

5.2 SUMMARY OF STRATA

A summary of the strata recorded, based on all the available information, is presented in Table 5-1.

Table 5-1 – Material Encountered

Stratum	Range of Depth to Base of Stratum (m bgl)	Thickness (m)	Stratum Encountered in Exploratory Hole
Topsoil	0.05 – 0.45 (0.15)	0.05 – 0.45 (0.15)	All
Cohesive Made Ground	0.20	0.15	HP01 only
Granular Made Ground	0.20	0.10	HP04a only
Cohesive Alluvium	>0.40 - >2.95 (>1.06)	0.40 - >2.30 (>0.96)	All, except WS01
Granular Alluvium	0.75 – 2.60	0.60 – 0.65	HP02 & TP01
Cohesive Glaciofluvial Deltaic Deposits	1.30	0.85	WS01 only
Granular Glaciofluvial Deltaic Deposits	2.50 - >3.20 (>2.78)	0.20 - +2.70 (>1.77)	WS01, WS02, WS03, TP03, TP05 & TP06
Glacial Till	>2.60 - >4.30	>0.10 - >1.10	WS01 & TP06
The Upper Limestone Formation	>2.10 - >3.00	>0.20 - >0.40	TP01 & TP02
Note: An average value has been provided in brackets if 3 or more values are available. A Plus (+) symbol represents the base of the stratum was not proven.			

5.3 PROPOSED EARTHWORKS

Minor earthworks are required for the proposed works. Refer to 'Craigfoot Allotments Proposed Levels' drawing (drawing No.2724-WSP-SK-002) and **Appendix A** in this report for earthwork details.

5.3.1. Footpath Construction

[Ref 2] The GIR [1] notes the construction of the footpath, which traverses the slope via two switchbacks, will require regrading of the existing ground profile. In order to maintain the crossfall of the footpath as it traverses the slope, the downslope side of the footpath is to be constructed on imported fill constructed on sidelong ground. Locally, the upslope side of the footpath will be cut into the slope.

The gradient of the new embankment and cut faces is to be 1 in 3 or shallower.

The new embankments are to be constructed of imported well graded granular fill (e.g. material meeting the requirements of a Class 1A in Series 600 of the Manual of Contract Documents for Highways Works).

The site proposals show a proposed stepped access in the northwest of the site. In order to maintain an appropriate cross fall, minor cut slopes are to be formed on the upslope side of the path. Again, side slopes are to be 1 in 3 or shallower.

5.3.2. Parking / Laydown Area Construction

The proposed parking / laydown area is to be supported on an embankment with side slopes of gradient 1V:2H. The embankment reaches a maximum height of 1.2 m above the existing ground profile. The embankment is to be constructed of a similar imported well graded granular fill as the footpath.

5.4 SLOPE STABILITY ASSESSMENT

The stability analysis for the slope and proposed parking/laydown area was modelled using GeoStudio Slope W software, which uses limit equilibrium methods to allow a search for critical slope surfaces for a given slope within the confines of the slip circle search criteria specified.

For the slope stability analysis, the Morgenstern and Price method of analysis has been used as it satisfies both moment and force equilibrium as required by BS NA EN 1997-1+A1: 2013, Eurocode 7: Geotechnical Design, Part 1: General Rules.

The overall stability of the existing slope and proposed parking / laydown area has been checked in Ultimate Limit States (ULS) with design values of actions and resistances. Partial factors used are defined in BS NA EN 1990: 2002+A1: 2005 Basis of Structural Design and material parameters in accordance with BS EN 1997-1+A1: 2013.

For the modelling of the slope analysis the following calculation sequence was followed:

- The geometrical model was established based on the contours denoted in the 'Craigfoot Allotments Proposed Levels' drawing (drawing No.2724-WSP-SK-002). A copy has been provided in Appendix A for reference.
- In areas of cutting and embankment associated with the footpath, a maximum side slope of 1V:3H has been adopted. In areas of proposed embankment associated with the laydown area a slope gradient of 1V:2H has been used.
- An effective stress slope analysis was undertaken as a conservative scenario.
- Appropriate characteristic values of ground strength were selected based on geotechnical laboratory test results, empirical relationships and correlations, engineering judgement and published reputable literature.
- Design Approach 1, Combination 1 (DA1-1) and Design Approach 1, Combination 2 (DA1-2) partial factors were applied to actions, materials and resistances in accordance with BS NA EN 1990: 2002+A1: 2005 Basics of Structural Design and NA BS EN 1997-1+A1: 2013.

5.4.1. Ground Model and Geotechnical Parameters

The ground model and derived geotechnical parameters are presented in Table 5-2 and the characteristic design parameters are shown in Table 5-2. The interpreted ground model is based on the most representative material encountered.

Table 5-2 – Ground Model and Derived Geotechnical Parameters

Stratum	Ground Model		g (kN/m^2)	f' (°)	c' (kPa)
	Top of Slope (m bgl)	Bottom of Slope (m bgl)			
Granular Engineering Fill	-	-	20	3[4]	0
Cohesive Alluvium	-	0 – 1.5	18	26	0
Cohesive Glaciofluvial Deltaic Deposits	0 – 1.3	-	18	26	0
Granular Glaciofluvial Deltaic Deposits	1.3 – 3.2	1.5 – 3.0	19	30	0
Cohesive Glacial Till	3.2 – 4.3	-	20	28	0

Note: Derived geotechnical parameters for the Topsoil, Made Ground and granular Alluvium have not been derived due to the recorded thickness and distribution in the exploratory holes within /adjacent to the slope.

Unit Weight (g) is based on suggested values from Figure 1 in BS 8002: 2015 Code of Practice for Earth Retaining Structures [6].

Effective Shear Strength (f') has been derived from the equation for cohesive and granular soils in BS 8004: 2015 Code of Practice for Foundations [7] using SPT N, Atterberg Limit and Particle Size Distribution test results. The Effective Shear Strength for granular engineering fill is based on engineering judgement of Class 1A general granular fill.

Effective cohesion (c') is based on engineering judgement.

Table 5-3 – Characteristic Design Parameters

Stratum	g (kN/m^2)	DA1-1		DA1-2	
		f' (°)	c' (kPa)	f' (°)	c' (kPa)
Granular Engineering Fill	20	34	0	28	0
Cohesive Alluvium deposits	18	28	0	23	0
Cohesive Glaciofluvial Deltaic Deposits	18	26	0	21	0
Granular Glaciofluvial Deltaic Deposits	19	30	0	24	0
Cohesive Glacial Till	20	28	0	23	0
Applied surcharge – parking / laydown area (kN/m^2)		10		12.5	
Applied surcharge – temporary stockpiling (kN/m^2)		20		25	
Applied surcharge – footpath (kN/m^2)		5		6.3	
Note: The applied surcharge for the parking area is based on suggested values from Table 3 in BS 6031: 2009 Code of Practice for Earthworks and Table 7 in BS 8002: 2015 Code of Practice for Earth Retaining Structures for the footpath.					

5.4.2. Considerations and Assumptions

- Ground elevations are based on information obtained from the 'Craigfoot Allotments Proposed Levels' drawing (drawing No.2724-WSP-SK-002) in the GIR [1] and in Appendix A of this report.
- Groundwater conditions including groundwater levels have been modelled based on information in the GIR [1].
- Topsoil, Made Ground, and granular Alluvium cohesive have not been modelled due to their recorded thickness and presence in the exploratory holes.
- The embankment fill has been modelled on Class 1A Granular Engineering Fill.
- Design values for material properties are based on in-situ and laboratory tests of soil samples. Where information is limited, engineering judgement and published literature has been used.
- A factored surcharge has been used to simulate actions exerted by the proposed parking/laydown area and footpath. In the absence of more exact calculations, the nominal loads due to typical highway loading has been defined as 10kN/m2, based on Table 3 in BS 6031: 2009 Code of Practice for Earthworks [8] and 5kN/m2 for the footpath based on Table 7 in BS 8002: 2015 Code of Practice for Earth Retaining Structures [6]. For sensitivity purposes, a surcharge of 20kN/m2 has been applied to represent potential stockpiling in the laydown area.
- The Upper Limestone Formation has been modelled as an impenetrable stratum.
- The top of the Upper Limestone Formation was not confirmed and has therefore been assumed to be 5m bgl.

- The assessment does not consider any impact which temporary works might have on the slope's stability.

5.4.3. Results of Slope Stability Modelling

Two slope models were produced, the first assessing DA1-1 and the second assessing DA1-2. The slope models have been presented in Drawing 5-1 to Drawing 5-4 and a summary of the results are recorded in Table 5-4.

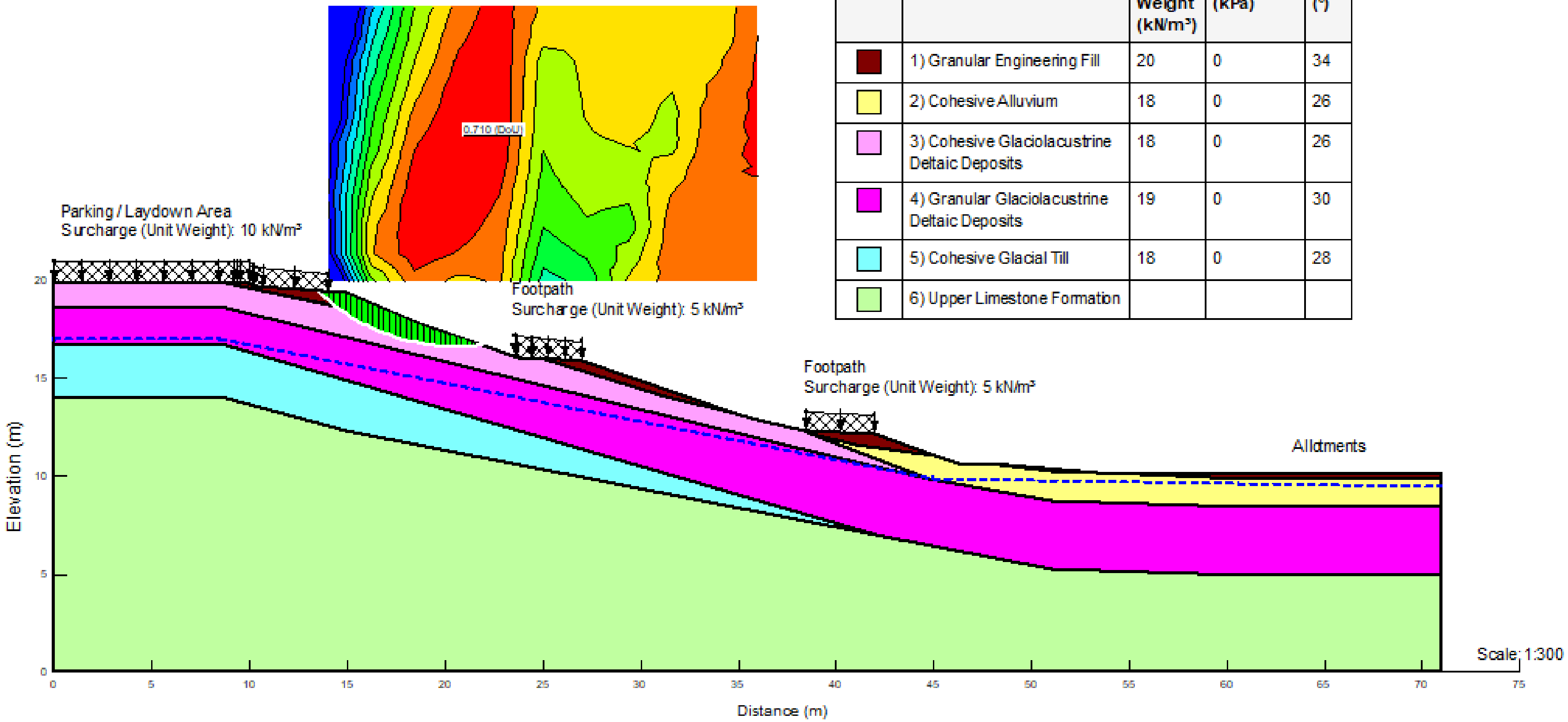
Table 5-4 – Degree of Utilisation Summary

Degree of Utilisation (DoU)	DoU in DA1-1	DoU in DA1-2
Parking / laydown area modelled with a surcharge of 10kN/m2	0.710 (see **Figure 5-1**)**Error! Reference source not found.**)	0.883 (see **Figure 5-2**)
Parking / laydown / stockpiling area modelled with a surcharge of 20kN/m2	0.743 (see **Figure 5-3**)	0.919 (see Figure 5-**4**)

The Degree of Utilisation (DoU) is t[h]e ratio of the destabilising and stabilising forces required for equilibrium:

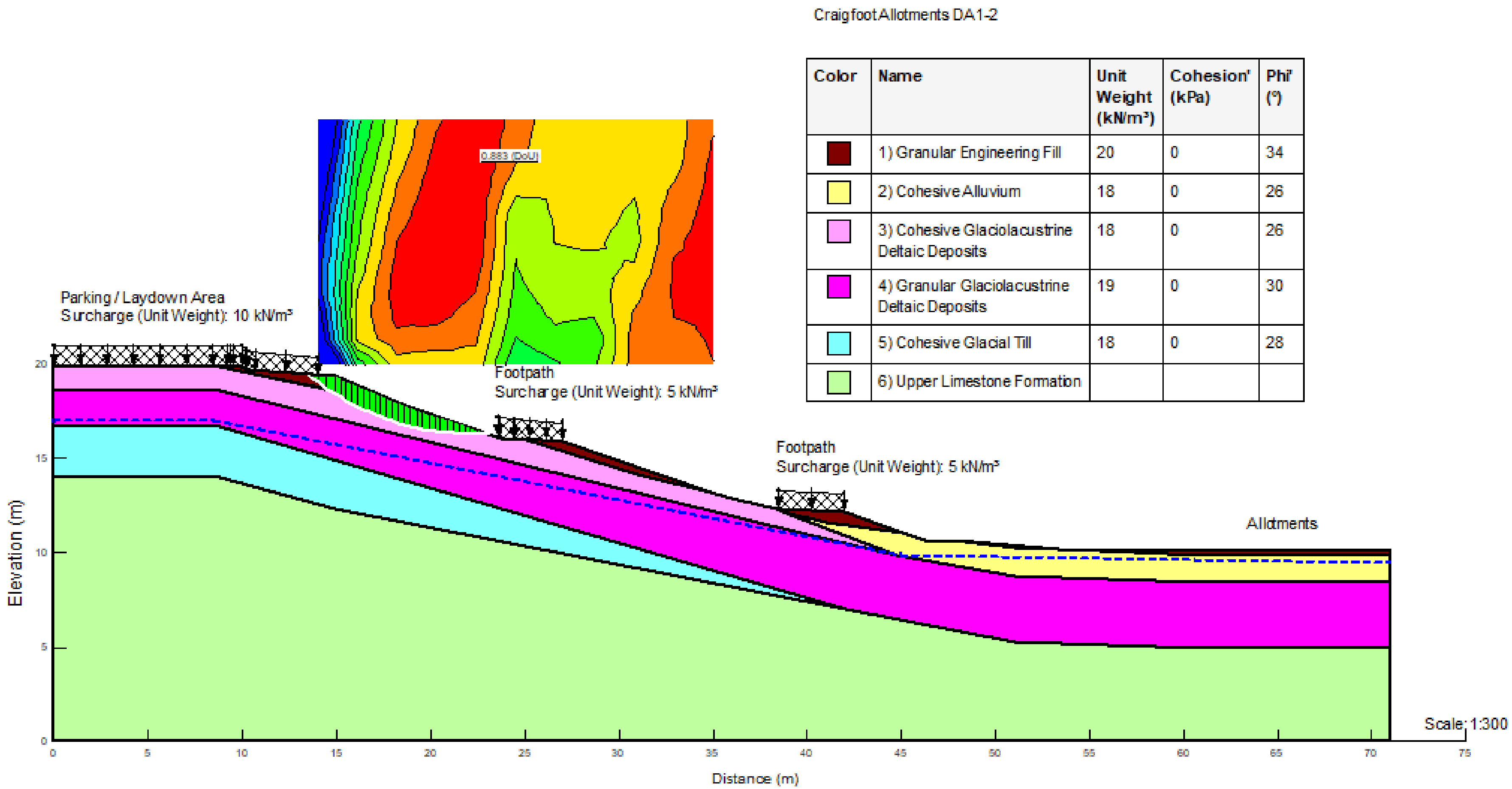
- A DoU of <1 shows that the slope has an adequate factor of safety against instability.
- A DoU of >1 shows that the slope does not have an adequate factor of safety against instability.

The model in Drawing 5-1 to Drawing 5-4 and degree of utilisation in Table 5-4 identifies the slope to have an adequate factor of safety against instability with the additional load exerted from the proposed parking/laydown area and potential stockpiling.



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	1) Granular Engineering Fill	20	0	34
	2) Cohesive Alluvium	18	0	26
	3) Cohesive Glaciolacustrine Deltaic Deposits	18	0	26
	4) Granular Glaciolacustrine Deltaic Deposits	19	0	30
	5) Cohesive Glacial Till	18	0	28
	6) Upper Limestone Formation			

Figure 5-1 - Slope Stability Analysis - DA1-1



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	1) Granular Engineering Fill	20	0	34
	2) Cohesive Alluvium	18	0	26
	3) Cohesive Glaciolacustrine Deltaic Deposits	18	0	26
	4) Granular Glaciolacustrine Deltaic Deposits	19	0	30
	5) Cohesive Glacial Till	18	0	28
	6) Upper Limestone Formation			

Figure 5-2 - Slope Stability Analysis - DA1-2

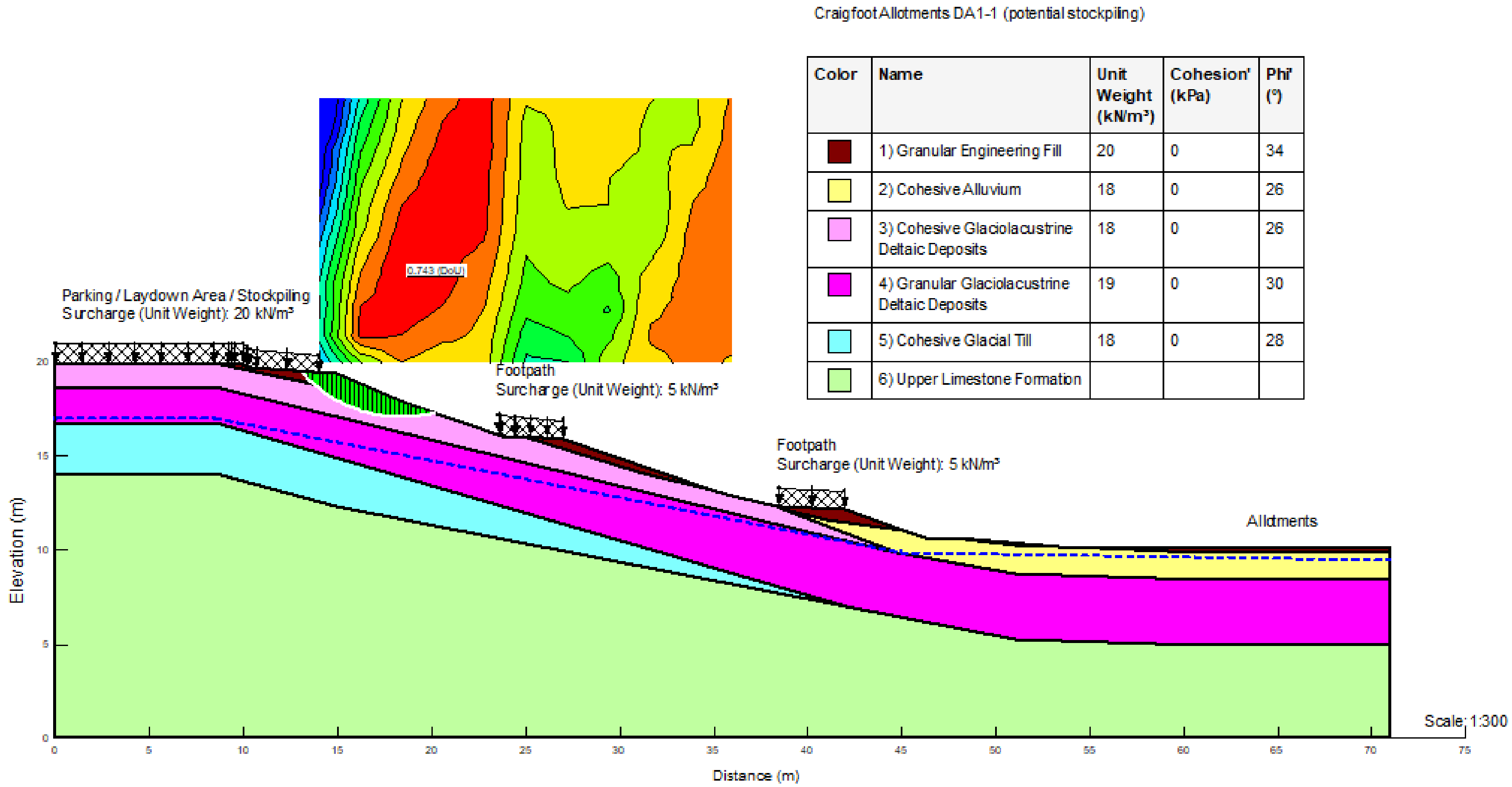


Figure 5-3 - Slope Stability Analysis - DA1-1 (sensitivity analysis)

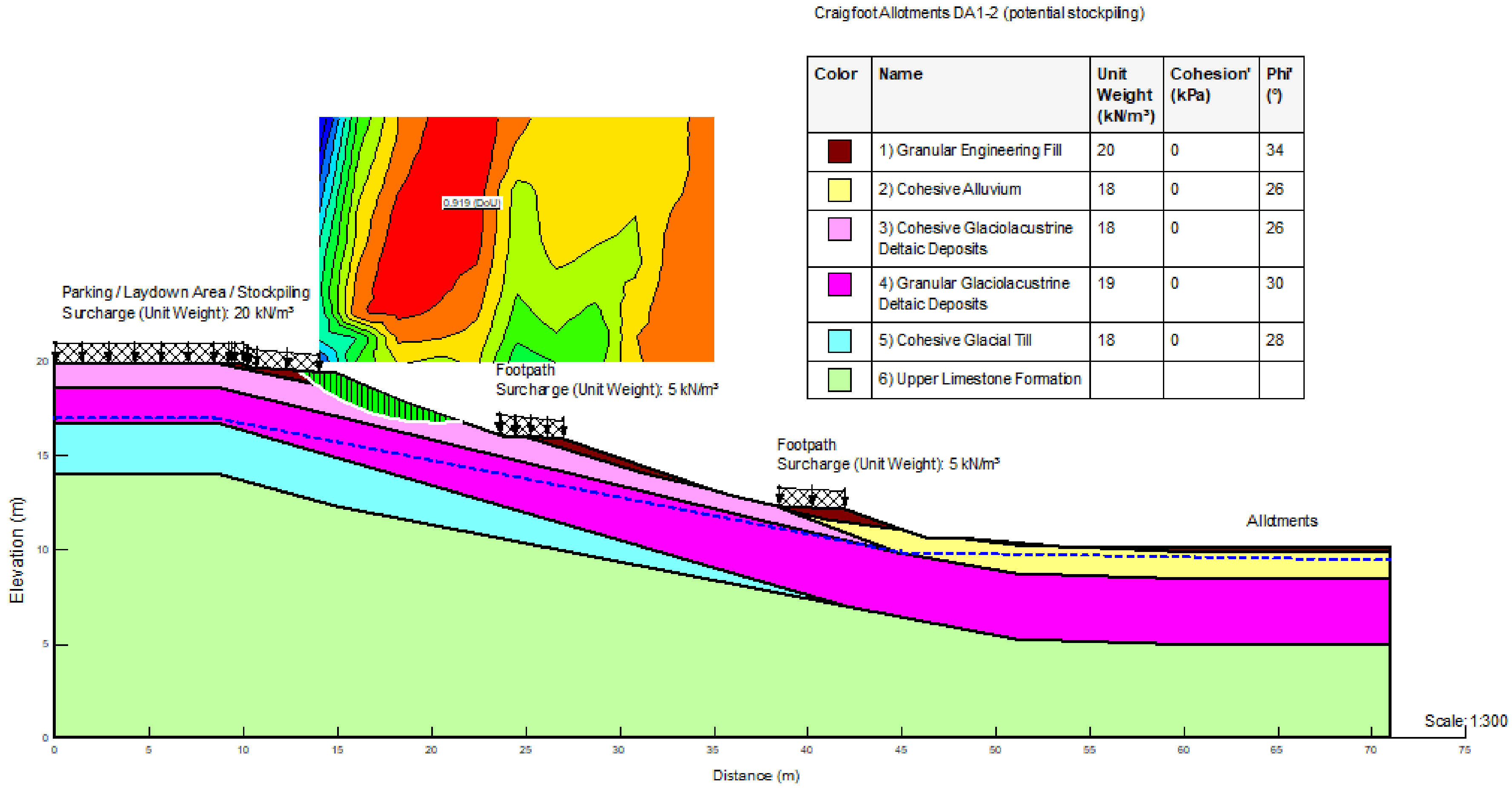


Figure 5-4 - Slope Stability Analysis - DA1-2 (sensitivity analysis)

5.5 SUMMARY

Based on the findings of the additional ground investigation and the results of slope stability analysis, the slope should remain stable with the parking / laydown area at the crest of the slope. It should be noted that the load at the crest of the slope has been limited to 20 kN/m^2. Should higher loads need to be imposed (e.g. stockpiles of soils greater than say 1 m high), additional stability analyses should be undertaken to confirm the impact on the slope.

This assessment does not consider the impact of temporary works on the stability of the slope. An appropriate temporary works design should be completed prior to works being undertaken on the slope to maintain the stability of the slope during construction.

6 CONCLUSIONS & RECOMMENDATIONS

6.1 CONCLUSIONS

Based on the proposed redevelopment of the site for use as an allotment, the following conclusions are made following 2021 supplementary investigations and assessments presented herein:

- Following bio-accessibility testing, it was not possible to produce a SSAC for lead lower than the existing GAC.
- Four lead exceedances of Human Health GAC were detected within the shallow soils in the southern area. This equates to a total of 8 lead exceedances in this area to date.
- No exceedances of lead were historically detected in the north of the site, thought to be due to the different dominant lithology in the north compared to the south (i.e. mainly glaciofluvial versus alluvial).
- Lead exceedances are in the range of anticipated natural background concentrations based on BGS mapping data and were all detected in shallow alluvial soils.
- While lead exceedances appear to be natural in origin (in the absence of identified anthropogenic input/source) as lead is a 'non-threshold' contaminant (i.e. one in which there is no safe dose below which an effect is not observed), then the 'ALARP' ('As Low As Reasonably Practicable') principle applies.
- Slope stability assessment indicted the slope to be stable with the additional load exerted from the proposed parking/laydown area.

6.2 RECOMMENDATIONS

A number of possible options now remain with respect to human health, including:

1. The site is not developed as an allotment;
2. The site is developed as an allotment using raised beds and no further testing or assessments are delivered. Such would be an economically beneficial solution, though it is understood that currently site levels need to remain at existing levels due to flooding issues so this may not be feasible at present. Notwithstanding this, it is understood the client is currently exploring the possibility of providing compensatory flood storage adjacent to the Glazert Water but upstream of the site. Consequently, this remains an option;
3. The site is developed as an allotment without raised beds, with imported clean soils used to replace the soils in the south (which would require off-site disposal). No further testing or assessments to be delivered. This would be a highly costly and unsustainable option;
4. The site is developed as an allotment without raised beds but with existing glaciofluvial soils from the northern slope (low lead concentrations) used to replace the soils in the south. Nominal validation sampling and testing would be recommended for this option;
5. Further testing and assessment is delivered to improve sample coverage for statistical purposes, and/or identify the dominant mineral forms of lead on site and which of these are contributing to the bio-accessibility. Such may allow development of the site without the need for raising levels or costly off-site disposal of impacted soils. This option, although costly, would be more economically beneficial than Option 3 (albeit there is no guarantee that further remediation may not be required after additional testing);
6. Lead in impacted soils is diluted via mixing with clean imported materials or in-situ treatment of impacted soils is delivered (e.g. application of phosphate to bind lead up as a non-labile lead

phosphate) to allow development of the site as an allotment, without the need for a change in levels. Such may require an initial feasibility study to determine the level of dilution required. For reference, phosphate is present in standard soil fertilisers;

It is currently recommended that the above options be presented for discussion with the regulator to identify a way forward.

Once the above options are narrowed down further, WSP recommends that a detailed remedial strategy document is developed for the site to guide mitigation works and assist in subsequent validation. This should also confirm the final cover layer thickness and detailed design.

To ensure that there are no significant ongoing issues with respect to human health and the wider environment, WSP recommends chemical testing for any imported soils to confirm suitability for future use in the context of human health, the water environment, and the built environment.

Appendix A

DRAWINGS

Appendix B

GENERAL LIMITATIONS

CONFIDENTIAL

Appendix C

SITE INVESTIGATION INFORMATION

Appendix C.1

EXPLORATORY HOLE LOGS

Appendix C.2

LABORATORY RESULTS AND SOIL SCREEN

Appendix D

RISK ASSESSMENT METHODOLOGIES

110 Queen Street
Glasgow
G1 3BX

wsp.com