VALHALLA GAS EXPLORATION AND APPRAISAL PROGRAM – SOIL QUALITY MONITORING REPORT

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Acronyms and Abbreviations

Term	Abbreviation
AES	Australasian Environmental Solutions
BNR	Bennett Resources Pty Ltd
CoPC	Constituents of Potential Concern
DEC	Department of Energy and Conservation
DER	Department of Environment Regulation
DoH	Department of Health
EC	Electrical Conductivity
NATA	National Association of Testing Authorities
OM	Organic Matter
Proposal	Valhalla Gas Exploration and Appraisal Program
PSD	Particle Size Distribution
RSL	Regional Screening Level
TOC	Total Organic Carbon
VOC	Volatile Organic Compounds
WA	Western Australia

Units

Term	Definition
%	percentage
%w/w	Weight concentration – weight per weight
µm	micrometre
µS/cm	Microseimens per centimetre
cm	centimetre
kg	kilogram
km^2	Square kilometre
m	metre
mg/kg	milligram/kilogram
mL	millilitre
mm	millimetre
pH	Potential of Hydrogen, the pH unit

1 INTRODUCTION

Australasian Environmental Solutions Pty Ltd (AES) was contracted by Bennett Resources Pty Ltd (BNR) to undertake a baseline soil quality sampling within the Valhalla Gas Exploration and Appraisal Program's (the Proposal) Development Envelope, in accordance with the SQ1 Baseline Soil Quality Sampling Framework (no doc ID). The SQ1 framework involves the one-time sampling of sites, located in proximity to the proposed well site locations put forward in the Valhalla Proposal, to gather regional baseline soil quality data.

Baseline soil sampling was undertaken on 19 August 2021, with samples submitted to the laboratory on 25 August 2021 for analysis. Soil samples were collected from a total of six representative baseline sites located in the Exploration Permit EP 371, in the Canning Basin, Shire of Derby-West Kimberley, Western Australia (WA) (Figure 2-1). Specifically, these sites were selected for their location in different mapped soil landscape systems, and for their location in relation to the Proposal's Development Envelope and proximity to the proposed well sites.

1.1 Purpose and objectives

The purpose of this sampling report is to summarise the baseline soil sampling event, which will aid in the understanding of a local and regional soil quality assessment, as well as supporting the development of any future soil sampling and monitoring events that may occur throughout the duration of the Proposal.

The objectives of the report are to:

- Outline the sampling event
- Summarise the methodology
- Present any sampling event limitations
- Present the laboratory results
- Interpret and conclude on the baseline results.

1.2 Scope of work

The following activities were carried out as part of the scope of work for the baseline soil sampling event:

In six chosen sites:

- Measure out one 10m x 10m quadrat at each of the chosen soil locations
- Select five random locations within each quadrat, to yield one combined representative site sample
- Collect soil samples
- Submit samples to a NATA-accredited laboratory for the analysis of a comprehensive list of analytes and physical properties, and
- Prepare this report to inform on the methodology, field activities, limitations, results, interpretation and conclusions.

The results provided in this report are presented against the laboratory's limits of reporting or detection, which do not provide a comparison in terms of soil quality. A comparison against ecological and health screening levels has therefore been included to interpret the broad soil quality of the soil landscape systems sampled in the Development Envelope. Additional comparison against broader soil quality criteria is also within scope of this report.

2 SITE IDENTIFICATION

The indicative sites were firstly identified following a desktop assessment and scouting trip, undertaken in July 2021 to ascertain access to the chosen sites.

The sampling event was undertaken to assess baseline soil quality, therefore sites (Figure 2-1) were selected based upon mapped soil landscape systems within the Development Envelope, away from currently known or historically disturbed areas, such as near petroleum well sites, gravel pits and pastoral zones of influence (highly disturbed areas from cattle aggregation). The sites were selected as close as possible to certain proposed well site locations, in three different soil landscape systems (an additional system was sampled near the Mount Hardman creek given the proximity of this soil landscape system to some proposed well sites). Further detail on the sampling site justification is presented in the SQ1 Baseline Soil Quality Sampling Framework (no doc ID).

The soil sampling sites are presented in Table 4-1.

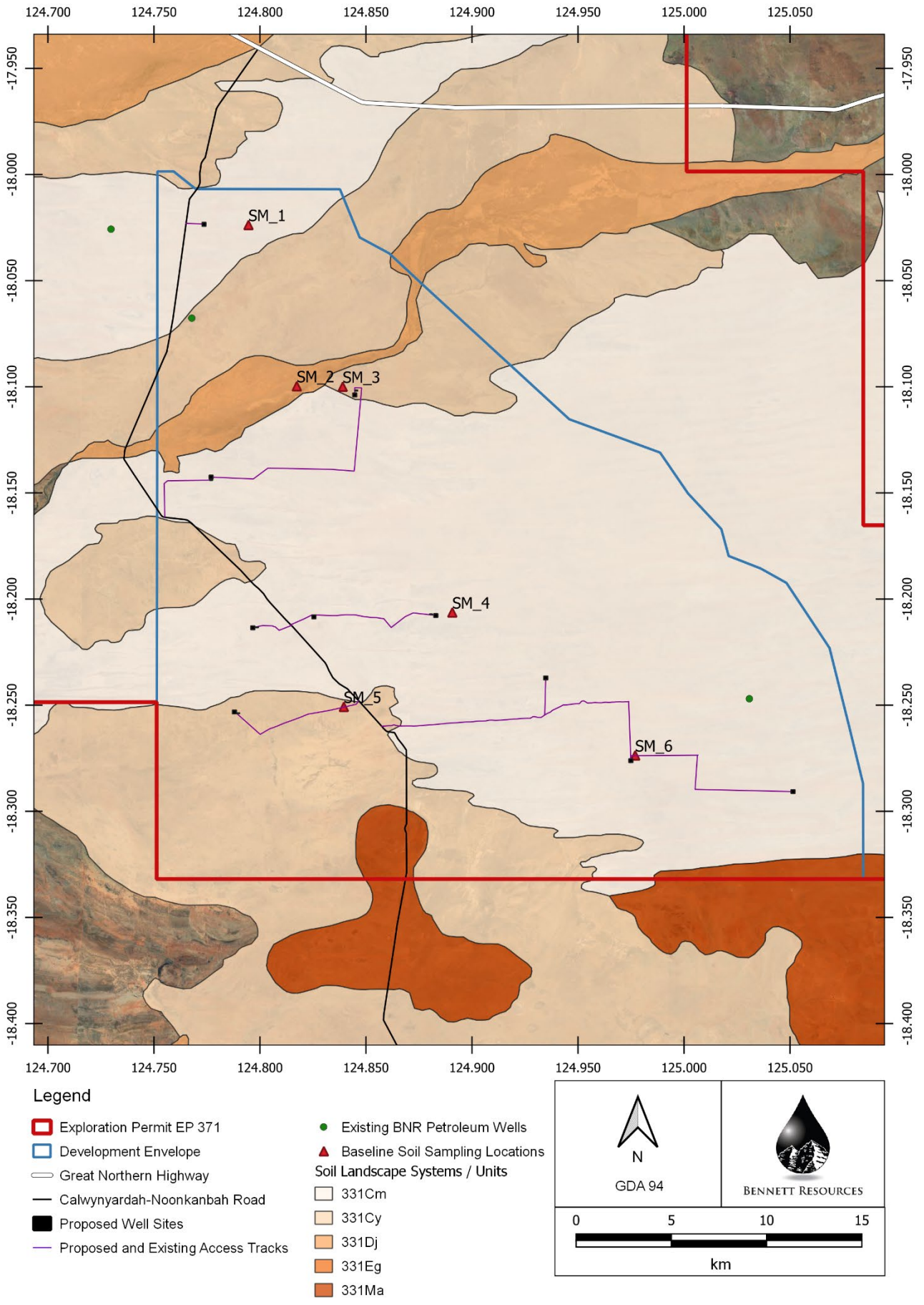

Figure 2-1: Baseline soil sampling sites

3 SUMMARY OF RECEIVING ENVIRONMENT

The Development Envelope is located within the 331 – North Fitzroy Plain Zone (soil landscape land quality zone), that covers an area of 17,925 km^2 (Tille 2006). The North Fitzroy Plain Zone is comprised of floodplains and sandplains (with alluvial plains and undulating plains) on Permian sedimentary rocks of the Canning Basin with self-mulching cracking clays, Red deep sands, Red sandy earths and Red / brown non-cracking clays. Rangeland Land Systems mapping, prepared by DPIRD, describe the biophysical characteristics of each region and separates these into land systems, which are defined as repeating patterns of topography, soil and vegetation. The Development Envelope covers four soil landscape systems (as seen in Figure 2-1), which are described as (Government of Western Australia 2021, Payne and Schoknecht 2011):

- 331Cm: Camelgooda System: Sandplains, swales and linear sand dunes supporting low pindan woodlands of acacias and low woodlands of bauhinia and bloodwood with curly spinifex and ribbon grass
- 331Cy: Calwynyardah System: Alluvial plains with scalded tracts downslope from lateritic remnants with yellowish loamy soils supporting patchy beefwood-bauhinia low woodlands with curly spinifex and ribbon grass; also minor hard spinifex grasslands
- 331Dj: Djada System: Active flood-plains with levees and levee back slopes supporting ghost gum open woodlands with frontage grasses, and cracking clay back plains supporting ribbon grass-blue grass and Mitchell grass grasslands
- 331Ma: Mamilu System: Plains and sandplains, deep red sands and yellowish loamy soils on lateritised sedimentary rocks supporting beefwood-bauhinia low woodlands and pindan acacia shrublands with curly spinifex and ribbon grass.

4 SAMPLING METHODOLOGY

Sampling was conducted as per the BNR Water and Soil Sampling Work Procedure (BNR_HSE_PR_006). The sampling methodology and analysis were reviewed using the following guideline: Department of Environmental Protection (WA): Development of Sampling and Analysis Programs (December 2001) (Department of Environmental Protection 2001).

Samples were collected by AES field staff on 19 August 2021 (Table 4-1).

Table 4-1: Valhalla baseline soil sampling sites

Site name	Soil landscape system	GPS L\location of sites (GDA 94)	Sampling date and time	Sampling depth and method
SM_1	331Cm	-18.023804 124.794597	19 Aug 2021 12:15 pm	0-40 cm mixture, soil shovel and tape measure (inappropriate soil for soil auger). 2 x 250 mL jars 1 x ~1kg soil bag
SM_2	331Dj	-18.099759 124.817378	19 Aug 2021 11:10 am	0-20 cm mixture, soil shovel and tape measure (inappropriate soil for soil auger) 2 x 250 mL jars 1 x ~1kg soil bag
SM_3	331Cy	-18.1 124.839047	19 Aug 2021 10:35 am	0-40 cm mixture, soil shovel and tape measure (inappropriate soil for soil auger) 2 x 250 mL jars 1 x ~1kg soil bag
SM_4	331Cm	-18.206345 124.890748	19 Aug 2021 09:45 am	0-40 cm mixture, soil shovel and tape measure (inappropriate soil for soil auger) 2 x 250 mL jars 1 x ~1kg soil bag
SM_5	331Cy	-18.250809 124.839569	19 Aug 2021 08:40 am	0-40 cm mixture, soil shovel and tape measure (inappropriate soil for soil auger)

				2 x 250 mL jars 1 x ~1kg soil bag
SM_6	331Cm	-18.273705 124.977	19 Aug 2021 07:30 am	0-40 cm mixture, soil shovel and tape measure (inappropriate soil for soil auger) 2 x 250 mL jars 1 x ~1kg soil bag

4.1 Sampling event limitations

As per Table 4-1, all sites were sampled. Sampling was undertaken in proximity to the indicative sites identified prior to the sampling event.

A simple soil auger was proposed to be used to sample soil to the depth of <40 cm. However, each soil site and thus landscape system was determined to be too dry, compact or difficult (e.g. loose sand or hard clay pan) to enable a reproducible, consistent and straightforward sample recovery with the auger.

As such, the auger was not used, and a small shovel was used. Sampling holes were dug to a depth of 40 cm.

The soil was too dry, compact or difficult (e.g. loose sand or hard clay pan) to obtain a suitable / consistent soil profile at each site with the equipment available. Soil depths were noted in some instances to be <5 cm prior to reaching the limit of hardpan.

All sites, with the exception of SM_2, were easily sampled given the type of soil encountered; predominantly sands and sandy soils. Samples from SM_2 were collected in the 331Dj: Djada Soil Landscape System, which consists of flood-plains with levees cracking clay back plains. This landscape system is present along the Mount Hardman Creek line and will not be encountered on the proposed well site locations for the Proposal. Samples were still collected to provide additional local background baseline data and to serve as comparison to the other soil landscape systems. Samples from SM_2 were difficult to collect with the shovel given the hard compact nature of the dry clay pan (<5 cm sample depth). Samples were required to be collected from a wider quadrat to include sandier soil near the dried creek (<20 cm sample depth), in order to submit sufficient soil matter for lab analysis.

5 CRITERIA, INVESTIGATION AND SCREENING LEVELS

Investigation and screening levels have been applied to constituents of potential concern (CoPC) to evaluate potential risks to ecosystems and human health from CoPC. Exceedance of the investigation and screening levels as presented within the adopted criteria does not necessarily infer that the substance presents a hazard or risk to human health, the environment or environmental values but that further investigation, assessment and / or risk mitigation measures are required.

5.1 References for investigation and screening levels

The following documents and guidelines addressing soil ecological and health criteria and screening levels were reviewed and applied for the interpretation of the soil sample results:

- Department of Environment and Conservation (DEC) (2010). Assessment levels for Soil, Sediment and Water. Contaminated Sites Management Series, Version 4 Revision 1, February 2010. Government of Western Australia (DEC 2010)
- Department of Environment Regulation (DER) (2014). Assessment and management of contaminated sites – Contaminated sites guidelines. December 2014. Government of Western Australia (DER 2014)
- National Environment Protection Council (NEPC) (1999). Assessment of Site Contamination) Measure (NEPM), Schedule B (1) – Guideline on the Investigation Levels for Soil and Groundwater (NEPC 1999)
- Dutch B (Indicative value for further investigation) from Moen, J.E.T., Cornet, J.P and Evers, C.W.A (1986). Soil protection and remedial actions: criteria for decision-making and standardisation of requirements, in Assink, J.W and van den Brink, W.M (1986). Contaminated Soils, First International TNO Conference on Contaminated Soil, 11-15 November 1985 (Assink and van den Brink 1986)
- ANZECC B (Environmental Investigation Levels) from ANZECC & NHMRC (1992) Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC and NHMRC 1992)

- US EPA regional screening levels (RSLs) from US EPA (2009). Regional Screening Levels, available from https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables (US EPA 2021)
- Department of Health's (DOH) letter to DEC, dated 21 April 2009 (reference 04- 06372). Contaminated Sites Management Series of Guidelines – Assessment Levels for Soils, Sediment and Water (Version 4.0) (DoH 2009).

The following definitions (NEPC 1999) have been provided to support the basis of comparison with accepted levels:

- "Ecological investigation levels have been developed for selected metals and organic substances and are applicable for assessing risk to terrestrial ecosystems. [These] depend on specific soil physicochemical properties and land use scenarios and generally apply to the top 2 m of soil"
- "Ecological screening levels have been developed for selected petroleum hydrocarbon compounds and total petroleum hydrocarbon (TPH) fractions and are applicable for assessing risk to terrestrial ecosystems. [These] broadly apply to coarse- and fine-grained soils and various land uses. They are generally applicable to the top 2 m of soil"
- "Health investigation levels have been developed for a broad range of metals and organic substances. [These] are applicable for assessing human health risk via all relevant pathways of exposure. [These] are generic to all soil types and apply generally to a depth of 3 m below the surface for residential use"
- "Health screening levels have been developed for selected petroleum compounds and fractions and are applicable to assessing human health risk via the inhalation and direct contact pathways. [These] depend on specific soil physicochemical properties, land use scenarios, and the characteristics of building structures. They apply to different soil types, and depths below surface to >4 m".

5.2 References for soil criteria and ratings

5.2.1 pH

As with many measurements on soils and sediments, pH values will vary depending on the procedure / laboratory analytical method used. pH ratings for pH extracted using deionised water ($pH_H{}^2{}_O$) at a sample solution ration of 1:5 are presented below in Table 5-1.

Table 5-1: Soil $pH_H{}^2{}_O$ ratings (Rayment and Lyons 2011) adapted from (Bruce and Rayment 2004) and (USDA-NRCS 2004)

$pH_H{}^2{}_O$ range	Rating (pH units)
1.8 – 3.4	Ultra acidic
3.5 – 4.4	Extremely acidic
4.5 – 5.0	Very strongly acidic
5.1 – 5.5	Strongly acidic
5.6 – 6.0	Moderately acidic
6.1 – 6.5	Slightly acidic
6.6 – 7.3	Circum-neutral
7.4 – 7.8	Slightly alkaline
7.9 – 8.4	Moderately alkaline
8.5 – 9.0	Strongly alkaline
9.1 – 10	Very strongly alkaline
>10	Ultra alkaline

5.2.2 Electrical conductivity

Electrical conductivity (EC) is typically measured in a 1:5 soil:water extract (EC (1:5)). Soil type must be considered when assessing soil salinity based on EC (1:5). Soil salinity ratings (based on standard CSIRO categories (Rayment and Lyons 2011) for sand, loam and clay types are presented in Table 5-2.

Table 5-2: Soil salinity rating for EC (1:5)

Salinity rating	Salinity rating based on EC (1:5) (µS/cm)

	Sand	Sandy loam	Loam	Clay loam	Light / medium clay	Heavy clay
Non-saline / very low	<130	<170	<200	<220	<250	<330
Slightly saline	130 – 260	170 – 330	200 – 400	220 – 440	250 – 500	330 – 670
Moderately saline	260 – 520	330 – 670	400 – 800	440 – 890	500 – 1,000	670 – 1,330
Very saline	520 – 1,060	670 – 1,330	800 – 1,600	890 – 1,780	1,000 – 2,000	1,330 – 2,670
Extremely saline	>1,060	>1,330	>1,600	>1,780	>2,000	>2,670

5.2.3 Organic carbon and organic matter

The general ranking of soil organic matter levels (Emerson 1991, Hazelton and Murphy 2016, Charman and Roper 2007), presented in Table 5-3 below, has been based on soils that are light-textured (sand loams, loams) and weakly structured. These soils broadly coincide with hard-setting soils.

Table 5-3: Relationship of soil organic matter to soil physical properties

Level of organic matter (%w/w)	Level of organic carbon (%w/w)	Rating	Interpretation
<0.70	<0.40	Extremely low	Subsoils or severely eroded, degraded surface soils
0.70 – 1.00	0.40 – 0.60	Very low	Very poor structural condition, very low structural stability
1.00 – 1.70	0.60 – 1.00	Low	Poor to moderate structural condition, low to moderate structural stability
1.70 – 3.00	1.00 – 1.80	Moderate	Average structural condition, average structural stability
3.00 – 5.15	1.80 – 3.00	High	Good structural condition, high structural stability
>5.15	>3.00	Very high	Good structural condition, high structural stability and soils probably water repellent

5.2.4 Major nutrients

In literature, major nutrients in WA soils are often analysed using the Mehlich 3 extraction multi-element soil test methodology to assess soils for potential nutrient deficiencies, toxicity or imbalance that may affect revegetation outcomes. However, the methodology employed by the NATA-accredited laboratory (acid extractable metals, AN-045) during this baseline soil analysis differs significantly from the Melhich 3 extraction methodology, thus comparison against other WA soil nutrient values was deemed not possible.

5.2.5 Laboratory analysed parameters

The analysis undertaken by the NATA-accredited laboratory SGS Perth is presented in the laboratory certificate of analysis in Appendix A. The results are also presented in Table 7-1 of Section 7.1, with comparison against ecological and health investigation and screening levels.

6 RESULTS AND DISCUSSION

6.1 Field observations

The weather condition on the day of sampling was sunny and hot (24-35° Celsius), with no cloud cover and a light predominantly south easterly wind. As the sampling was undertaken during the dry season of the Kimberley, the soil appeared very dry and in certain areas extremely hard and compact (dry clay pan).

The quadrat at each sampling site was set up away from the vehicle, with the engine switched off during sampling to avoid any potential contamination from exhaust fumes.

In-field description of the samples are presented in Table 6-1.

Table 6-1: Site descriptions

Site name	Soil landscape system (refer to Section 3)	Brief field description of the sites
SM_1	331Cm	On the top of a dune. Evidence of recent burning (timeframe unknown).  
SM_2	331Dj	In dry clay pan and along creek line.  
SM_3	331Cy	Evidence of cattle access. Evidence of recent burning (timeframe unknown).

		 
SM_4	331Cm	Within grasses. 
SM_5	331Cy	Within spinifex bushes. Evidence of cattle presence within the quadrat.

		 
SM_6	331Cm	Within tall grasses.  

7 RESULTS AND INTERPRETATION

Soil quality has been compared against the ecological and health levels discussed in Section 5. An interpretation of the soil chemistry is further presented in Section 7.1, following a comparison against broad soil quality ratings from literature.

Physical analysis including particle size distribution (PSD) of the soil samples is summarised in Section 7.2.

7.1 Chemical analysis

Results show that, for all soil samples, all analytes were below any of the ecological and health investigation and screening levels (Table 7-1). Overall, samples from the same soil landscape systems (SM_1, SM_4, SM_6 in 331Cm red deep sands; and SM_3, SM_5 in 331Cy yellow sandy earth) presented some differences however were within similar ranges of results. It can be inferred that the soil quality resulting from these samples are representative of the soil landscape systems present throughout the Development Envelope.

Table 7-1: Baseline soil chemical analysis and comparison against ecological and health investigation and screening levels

Analyte[1]	Units	Laboratory Limit of Reporting	Ecological Investigation and Screening Levels for Soils (mg/kg)	Health Investigation and Screening Levels for Soils (mg/kg)	Soil Sample Name (Soil Landscape System)					
					SM_1 (331Cm)	SM_2 (331Dj)	SM_3 (331Cy)	SM_4 (331Cm)	SM_5 (331Cy)	SM_6 (331Cm)
pH	pH Units	0	-	-	6.7	7.8	7.1	6.8	6.6	6.7
Conductivity of Extract (1:5 as received)	µS/cm	1	-	-	4	29	6	5	20	3
Total Dissolved Solids (by calculation)	mg/kg	5	-	-	12	87	18	15	62	10
% Moisture	%w/w	0.5	-	-	<0.5	1.6	1.0	0.9	0.9	0.9
Aluminium, Al	mg/kg	50	-	-	990	5500	2200	1300	2000	1400
Arsenic, As	mg/kg	1	20	100	<1	4	2	1	2	1
Barium, Ba	mg/kg	0.5	300	15,000	12	52	44	21	19	13
Boron, B	mg/kg	5	-	5,000	<5	<5	<5	<5	<5	<5
Cadmium, Cd	mg/kg	0.3	3	20	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Chromium, Cr	mg/kg	0.5	Cr III: 400	Cr III: 120,000	8.4	18	26	13	20	14
Hexavalent Chromium, Cr6+	mg/kg	0.5	Cr VI: 1	Cr VI: 100	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Copper, Cu	mg/kg	0.5	100	1,000	0.9	7.4	2.8	1.5	2.9	2.0
Lead, Pb	mg/kg	1	600	300	2	7	3	2	4	2
Manganese, Mn	mg/kg	1	500	1,500	47	210	150	52	160	47
Nickel, Ni	mg/kg	0.5	60	600	0.9	6.6	3.4	1.7	2.8	1.9
Selenium, Se	mg/kg	3	-	200	<3	<3	<3	<3	<3	<3
Zinc, Zn	mg/kg	2	200	7,000	<2	9	5	<2	6	<2
Silver, Ag	mg/kg	1	-	-	<1	<1	<1	<1	<1	<1

[1] Soil samples analysed at a NATA-accredited laboratory.

Analyte[1]	Units	Laboratory Limit of Reporting	Ecological Investigation and Screening Levels for Soils (mg/kg)	Health Investigation and Screening Levels for Soils (mg/kg)	Soil Sample Name (Soil Landscape System)					
					SM_1 (331Cm)	SM_2 (331Dj)	SM_3 (331Cy)	SM_4 (331Cm)	SM_5 (331Cy)	SM_6 (331Cm)
Iron, Fe	mg/kg	50	-	-	3900	13000	10000	4300	14000	6000
Strontium, Sr	mg/kg	0.5	-	-	1.3	7.4	4.2	2.9	6.2	2.3
Tin, Sn	mg/kg	3	50	47,000	<3	<3	<3	<3	<3	<3
Sodium, Na	mg/kg	10	-	-	<10	15	<10	<10	24	<10
Calcium, Ca	mg/kg	5	-	-	130	1800	250	140	250	240
Magnesium, Mg	mg/kg	10	-	-	40	820	270	120	270	73
Potassium, K	mg/kg	10	-	-	79	960	400	200	330	130
Mercury	mg/kg	0.05	1	15	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Thorium, Th	mg/kg	0.5	-	-	1.0	4.7	2.7	2.3	3.4	1.9
Uranium, U	mg/kg	0.1	-	-	<0.1	0.4	0.2	0.2	0.4	0.2
Total Organic Carbon	%w/w	0.05	-	-	0.22	0.32	0.24	0.28	0.36	0.30
Organic Matter	%w/w	0.1	-	-	0.38	0.55	0.41	0.48	0.62	0.51
Bicarbonate Alkalinity as HCO3 in Soil	mg/kg	25	-	-	<25	47	<25	<25	<25	<25
Carbonate Alkalinity as CO3 in Soil	mg/kg	25	-	-	<25	<25	<25	<25	<25	<25
Hydroxide Alkalinity as OH in Soil	mg/kg	25	-	-	<25	<25	<25	<25	<25	<25
Total Alkalinity as CaCO3 in Soil	mg/kg	25	-	-	<25	38	<25	<25	<25	<25
Water Soluble Fluoride	mg/kg	0.5	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chloride (water extractable 1:5)	mg/kg	5	-	-	38	11	51	26	51	64
Sulfate (1:5 water extractable), SO4	mg/kg	5	2,000	-	59	52	66	93	87	57

Analyte[1]	Units	Laboratory Limit of Reporting	Ecological Investigation and Screening Levels for Soils (mg/kg)	Health Investigation and Screening Levels for Soils (mg/kg)	Soil Sample Name (Soil Landscape System)					
					SM_1 (331Cm)	SM_2 (331Dj)	SM_3 (331Cy)	SM_4 (331Cm)	SM_5 (331Cy)	SM_6 (331Cm)
Water Soluble Nitrate Nitrogen, NO_3 as N	mg/kg	0.025	-	-	0.080	2.5	<0.025	0.096	0.096	<0.025
Water Soluble Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.025	-	-	0.77	2.7	0.80	0.59	0.77	0.93
Water Soluble ortho Phosphorus, P	mg/kg	0.02	2,000	-	0.27	0.16	0.45	0.28	0.40	0.51
Reactive Silica, Si	mg/kg	0.05	-	-	2.0	15	4.7	2.9	3.3	3.2
Reactive Silica, SiO_2	mg/kg	0.1	-	-	4.3	33	10	6.2	7.1	6.8
Benzene (VOC)	mg/kg	0.1	1	1.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Toluene (VOC)	mg/kg	0.1	3	520	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ethylbenzene (VOC)	mg/kg	0.1	5	230	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
m/p-xylene (VOC)	mg/kg	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
o-xylene (VOC)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Xylenes (VOC)	mg/kg	0.3	5	600	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Total BTEX (VOC)	mg/kg	0.6	-	-	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Naphthalene (VOC)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzene (F0)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TRH C6-C9	mg/kg	20	-	-	<20	<20	<20	<20	<20	<20
TRH C6-C10	mg/kg	25	-	-	<25	<25	<25	<25	<25	<25
TRH C6-C10 minus BTEX (F1)	mg/kg	25	-	-	<25	<25	<25	<25	<25	<25
TRH C10-C14	mg/kg	20	-	-	<20	<20	<20	<20	<20	<20
TRH C15-C28	mg/kg	45	-	-	<45	<45	<45	<45	<45	<45

Analyte[1]	Units	Laboratory Limit of Reporting	Ecological Investigation and Screening Levels for Soils (mg/kg)	Health Investigation and Screening Levels for Soils (mg/kg)	Soil Sample Name (Soil Landscape System)					
					SM_1 (331Cm)	SM_2 (331Dj)	SM_3 (331Cy)	SM_4 (331Cm)	SM_5 (331Cy)	SM_6 (331Cm)
TRH C29-C36	mg/kg	45	-	-	<45	<45	<45	<45	<45	<45
TRH C37-C40	mg/kg	100	-	-	<100	<100	<100	<100	<100	<100
TRH >C10-C16	mg/kg	25	-	-	<25	<25	<25	<25	<25	<25
TRH >C10-C16 - Naphthalene (F2)	mg/kg	25	-	-	<25	<25	<25	<25	<25	<25
TRH >C16-C34 (F3)	mg/kg	90	-	-	<90	<90	<90	<90	<90	<90
TRH >C34-C40 (F4)	mg/kg	120	-	-	<120	<120	<120	<120	<120	<120
TRH C10-C36 Total	mg/kg	110	-	-	<110	<110	<110	<110	<110	<110
TRH >C10-C40 Total (F bands)	mg/kg	210	-	-	<210	<210	<210	<210	<210	<210
Naphthalene (PAH)	mg/kg	0.1	5	60	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2-methylnaphthalene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1-methylnaphthalene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthylene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Fluorene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phenanthrene (PAH)	mg/kg	0.1	10	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Anthracene (PAH)	mg/kg	0.1	10	17,000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Fluoranthene (PAH)	mg/kg	0.1	10	2,300	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Pyrene (PAH)	mg/kg	0.1	10	1,700	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Analyte[1]	Units	Laboratory Limit of Reporting	Ecological Investigation and Screening Levels for Soils (mg/kg)	Health Investigation and Screening Levels for Soils (mg/kg)	Soil Sample Name (Soil Landscape System)					
					SM_1 (331Cm)	SM_2 (331Dj)	SM_3 (331Cy)	SM_4 (331Cm)	SM_5 (331Cy)	SM_6 (331Cm)
Benzo(a)anthracene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chrysene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(b&j)fluoranthene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(k)fluoranthene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(a)pyrene (PAH)	mg/kg	0.1	1	1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Indeno(1,2,3-cd)pyrene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dibenzo(ah)anthracene (PAH)	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(ghi)perylene	mg/kg	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Carcinogenic PAHs, BaP TEQ <LOR=0 (PAH)	TEQ (mg/kg)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Carcinogenic PAHs, BaP TEQ <LOR=LOR (PAH)	TEQ (mg/kg)	0.3	-	-	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Carcinogenic PAHs, BaP TEQ <LOR=LOR/2 (PAH)	TEQ (mg/kg)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total PAH (18) (PAH)	mg/kg	0.8	-	20	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
Total PAH (NEPM/WHO 16) (PAH)	mg/kg	0.8	-	-	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8

Source of assessment levels	NEPM (NEPC 1999)	Dutch B (Assink and van den Brink 1986)	DoH (DoH 2009)	US EPA RSLs (US EPA 2021)	ANZECC B (ANZECC and NHMRC 1992)

7.1.1 pH

Soil pH provides a measure of the soil acidity or alkalinity. Based on Table 7-1, overall pH values for the samples ranged between circum-neutral (pH 6.6 – 7.3) for red deep sands (331Cm) and yellow sandy earths (331Cy), and slightly alkaline (pH 7.4 – 7.8) for self-mulching cracking clays (331Dj).

7.1.2 Electrical conductivity

EC measures soluble salts in soils (soil salinity), which results from and depends on natural processes of landscape evolution, hydrological processes and rainfall (Hunt and Gilkes 1992). Based on the standard CSIRO categories (Rayment and Lyons 2011) (Table 5-2), soils with EC values generally below 130 µS/cm are considered non-saline.

Soils sampled within the Development Envelope recorded low EC values that ranged from 4 µS/cm to 29 µS/cm. All samples were therefore classed as non-saline. Deep red sands (331Cm) were found to least saline than yellow sandy earths (331Cy), with the self-mulching cracking clays having the highest non-saline rating of 29 µS/cm.

7.1.3 Organic carbon and organic matter

The organic matter content of soil, directly derived from plants and animals, is an important factor influencing many physical, chemical and biological soil characteristics. The presence of organic matter may increase water retention capacity, buffer pH and improved general soil structure. It is typically determined as a measure of the Total Organic Carbon (TOC) percentage.

By international standards, WA soils contain low concentrations of organic carbon. Organic carbon content is dependent upon soil texture and climate, with sandy soils and soils from tropical northern WA and arid central WA containing lower carbon contents (typically <1 %w/w in topsoil) compared to clay and loam soils from the temperate southwest regions of WA (MBS Environmental 2016). It is expected that organic carbon decreases with depth. Samples taken as part of this baseline soil sampling event combined all horizons (soil layers) up to <40 cm depth given specific soil profile analysis was out of scope. Thus, the distinction of organic carbon decrease with depth was not determined for this study.

In accordance with Table 5-3, all soils (mixtures of surface and subsoil) sampled within the Development Envelope recorded low levels of organic matter (OM) and TOC, with TOC ranging between 0.38 %w/w – 0.62 %w/w, and OM ranging between 0.22 %w/w – 0.36 %w/w. In general, deep red sands recorded less OM and TOC.

Interpretation of the values recorded for the sampling event and having regard for the relationship between OM and TOC suggest that the samples correspond to ‘low subsoils or severely eroded, degraded surface soils’. However, these interpretations are for reference only. Given that the baseline samples were selected within the wider untouched, natural environment, these are representative of the soil landscape systems. It is expected that other sands and earths in the region in the same vegetation systems will also record very low levels of OM and TOC.

7.1.4 Metals and major nutrients

As stated in Section 5.2.4, comparison of the soil results against other WA sites and their major nutrient values could not be undertaken due to the differences in lab methodologies at the time of sample analysis.

As anticipated, discrepancies were noted between the types of soil landscape systems. Metals (particularly chromium, manganese, iron) and minerals (calcium, magnesium, potassium) were generally lower in samples from the 331Cm red deep sands than in the 331Cy yellow sandy earths. Metals and silica in the comparative sample from the 331Dj self-mulching cracking clay (creekline soil sample) were in most cases significantly higher. The discrepancies in geochemistry are characteristic of these different types of soils.

7.1.5 Hydrocarbons

BTEX and hydrocarbon results were all below the laboratory’s limit of reporting.

7.2 Physical analysis

Soil particles will vary from fine clay to rocks, conventionally classed between coarse fragments (>2 mm) and fine earth (<2 mm). Sand and clay particles dominate in most WA soils and particularly within the Development Envelope.

Limited PSD data was available for these samples as particle sizing of soils <75 µm by hydrometer was not conducted where insufficient sample passed the 75 µm fraction. Only the sample SM_2 corresponding to self-mulching cracking clay soil could be sized through hydrometry <75 µm, confirming that the other samples comprise larger particles characteristic of sandy soils.

All laboratory quality control testing (including spikes and duplicates) were within acceptable ranges (Appendix A).

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Appendix A – Laboratory results

SGS

ANALYTICAL REPORT

ilac-MRA NATA Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	[redacted]	Manager	Kieran Hopkins
Client	BENNETT RESOURCES PTY LTD	Laboratory	SGS Perth Environmental
Address	LEVEL 9 EXCHANGE TOWER 40 THE ESPLANADE PERTH WA 6000	Address	28 Reid Rd Perth Airport WA 6105
Telephone	[redacted]	Telephone	(08) 9373 3500
Facsimile	(Not specified)	Facsimile	(08) 9373 3556
Email	[redacted]	Email	au.environmental.perth@sgs.com
Project	**Valhalla Program Soil Monitoring SM1**	SGS Reference	**PE154290 R0**
Order Number	**0064**	Date Received	25 Aug 2021
Samples	6	Date Reported	16 Sep 2021

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(898/20210).

Organics subcontracted to SGS Sydney, Unit 16 33 Maddox St Alexandria NSW 2015, NATA Accreditation Number: 2562, Site Number: 4354, SE222980.

Total Recoverable Metals: Al, Fe, Mn and Ca: Matrix spike recovery and MSD RPD failed acceptance criteria due to the presence of significant concentration of analyte (i.e. the concentration of analyte exceeds the spike level).
U, Th subcontracted to SGS Perth Minerals, 28 Reid Rd Perth Airport WA, WM209270

PSD subcontracted to SGS Cairns, 2/58 Comport St, Portsmith QLD 4870, NATA Accreditation Number: 2562, Site Number: 3146, CE154522.
Particle sizing of soils <75um by hydrometer not conducted where insufficent sample passes the 75um fraction.

SIGNATORIES

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Metals Team Leader

Louise HOPE
Laboratory Technician

Mary Ann OLA-A
Inorganics Team Leader

Murray O'NEILL
Lab Technician-Nutrients Signatory

Tommy CHENG
ICP Chemist

SGS

ANALYTICAL REPORT PE154290 R0

Parameter	Units	LOR	Sample Number: PE154290.001 Sample Matrix: Soil Sample Date: 19/8/21 12:15 Sample Name: SM_1	PE154290.002 Soil 19/8/21 11:10 SM_2	PE154290.003 Soil 19/8/21 10:35 SM_3	PE154290.004 Soil 19/8/21 9:45 SM_4
pH in soil (1:5) Method: AN101 Tested: 27/8/2021						
pH	pH Units	-	6.7	7.8	7.1	6.8
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/8/2021						
Conductivity of Extract (1:5 as received)	µS/cm	1	4	29	6	5
Total Dissolved Solids (by calculation)	mg/kg	5	12	87	18	15
Moisture Content Method: AN002 Tested: 27/8/2021						
% Moisture	%w/w	0.5	<0.5	1.6	1.0	0.9
Total Recoverable Elements in Soil by ICPOES Method: AN045/AN320 Tested: 30/8/2021						
Aluminium, Al	mg/kg	50	990	5500	2200	1300
Arsenic, As	mg/kg	1	<1	4	2	1
Barium, Ba	mg/kg	0.5	12	52	44	21
Boron, B	mg/kg	5	<5	<5	<5	<5
Cadmium, Cd	mg/kg	0.3	<0.3	<0.3	<0.3	<0.3
Chromium, Cr	mg/kg	0.5	8.4	18	26	13
Copper, Cu	mg/kg	0.5	0.9	7.4	2.8	1.5
Lead, Pb	mg/kg	1	2	7	3	2
Manganese, Mn	mg/kg	1	47	210	150	52
Nickel, Ni	mg/kg	0.5	0.9	6.6	3.4	1.7
Selenium, Se	mg/kg	3	<3	<3	<3	<3
Zinc, Zn	mg/kg	2	<2	9	5	<2
Silver, Ag*	mg/kg	1	<1	<1	<1	<1
Iron, Fe	mg/kg	50	3900	13000	10000	4300
Strontium, Sr	mg/kg	0.5	1.3	7.4	4.2	2.9
Tin, Sn	mg/kg	3	<3	<3	<3	<3
Sodium, Na	mg/kg	10	<10	15	<10	<10
Calcium, Ca	mg/kg	5	130	1800	250	140
Magnesium, Mg	mg/kg	10	40	820	270	120
Potassium, K	mg/kg	10	79	960	400	200
Mercury in Soil Method: AN312 Tested: 30/8/2021						
Mercury	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05

Parameter	Units	LOR	Sample Number: PE154290.001 Sample Matrix: Soil Sample Date: 19/8/21 12:15 Sample Name: SM_1	PE154290.002 Soil 19/8/21 11:10 SM_2	PE154290.003 Soil 19/8/21 10:35 SM_3	PE154290.004 Soil 19/8/21 9:45 SM_4
Total Recoverable Metals in Soil by ICPMS Method: AN045/IMS84V Tested: 7/9/2021						
Thorium, Th*	mg/kg	0.5	1.0	4.7	2.7	2.3
Uranium, U*	mg/kg	0.1	<0.1	0.4	0.2	0.2
Hexavalent Chromium in Soil Aquakem DA Method: AN075/AN283 Tested: 30/8/2021						
Hexavalent Chromium, Cr6+	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 2/9/2021						
Total Organic Carbon	%w/w	0.05	0.22	0.32	0.24	0.28
Organic Matter	%w/w	0.1	0.38	0.55	0.41	0.48
Alkalinity in Soil Method: AN002/AN135 Tested: 31/8/2021						
Bicarbonate Alkalinity as HCO3 in Soil*	mg/kg	25	<25	47	<25	<25
Carbonate Alkalinity as CO3 in Soil*	mg/kg	25	<25	<25	<25	<25
Hydroxide Alkalinity as OH in Soil*	mg/kg	25	<25	<25	<25	<25
Total Alkalinity as CaCO3 in Soil*	mg/kg	25	<25	38	<25	<25
Fluoride in Soil (Water Soluble 1:5 Extraction) by ISE Method: AN141 Tested: 31/8/2021						
Water Soluble Fluoride*	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5
Chloride (water extractable) Method: AN274 Tested: 2/9/2021						
Chloride (water extractable 1:5)*	mg/kg	5	38	11	51	26

Parameter	Units	LOR	Sample Number: PE154290.001 Sample Matrix: Soil Sample Date: 19/8/21 12:15 Sample Name: SM_1	Sample Number: PE154290.002 Sample Matrix: Soil Sample Date: 19/8/21 11:10 Sample Name: SM_2	Sample Number: PE154290.003 Sample Matrix: Soil Sample Date: 19/8/21 10:35 Sample Name: SM_3	Sample Number: PE154290.004 Sample Matrix: Soil Sample Date: 19/8/21 9:45 Sample Name: SM_4
Sulfate (water extractable) in Soil Method: AN275 Tested: 2/9/2021						
Sulfate (1:5 water extractable), SO4*	mg/kg	5	59	52	66	93
Total Oxidised Nitrogen NOx (Water Extract) in Soil Method: AN002/AN258 Tested: 1/9/2021						
Water Soluble Nitrate Nitrogen, NO_3 as N*	mg/kg	0.025	0.080	2.5	<0.025	0.096
Water Soluble Nitrate/Nitrite Nitrogen, NOx as N*	mg/kg	0.025	0.77	2.7	0.80	0.59
Water Soluble ortho Phosphorus in Soil Method: AN278 Tested: 2/9/2021						
Water Soluble ortho Phosphorus, P*	mg/kg	0.02	0.27	0.16	0.45	0.28
Water Soluble Reactive Silica by Aquakem Discrete Analyser Method: AN002/AN270 Tested: 2/9/2021						
Reactive Silica, Si*	mg/kg	0.05	2.0	15	4.7	2.9
Reactive Silica, SiO_2*	mg/kg	0.1	4.3	33	10	6.2
VOC's in Soil Method: AN433 Tested: 1/9/2021						
Monocyclic Aromatic Hydrocarbons						
Benzene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Toluene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
m/p-xylene	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2
o-xylene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Polycyclic VOCs						
Naphthalene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1

Parameter	Units	LOR	Sample Number: PE154290.001 Sample Matrix: Soil Sample Date: 19/8/21 12:15 Sample Name: SM_1	Sample Number: PE154290.002 Sample Matrix: Soil Sample Date: 19/8/21 11:10 Sample Name: SM_2	Sample Number: PE154290.003 Sample Matrix: Soil Sample Date: 19/8/21 10:35 Sample Name: SM_3	Sample Number: PE154290.004 Sample Matrix: Soil Sample Date: 19/8/21 9:45 Sample Name: SM_4
VOC's in Soil Method: AN433 Tested: 1/9/2021 (continued)						
Surrogates						
d4-1,2-dichloroethane (Surrogate)	%	-	117	108	109	106
d8-toluene (Surrogate)	%	-	115	109	109	105
Bromofluorobenzene (Surrogate)	%	-	104	96	97	92
Totals						
Total Xylenes*	mg/kg	0.3	<0.3	<0.3	<0.3	<0.3
Total BTEX*	mg/kg	0.6	<0.6	<0.6	<0.6	<0.6
Volatile Petroleum Hydrocarbons in Soil Method: AN433 Tested: 1/9/2021						
TRH C6-C10	mg/kg	25	<25	<25	<25	<25
TRH C6-C9	mg/kg	20	<20	<20	<20	<20
Surrogates						
d4-1,2-dichloroethane (Surrogate)	%	-	117	108	109	106
d8-toluene (Surrogate)	%	-	115	109	109	105
Bromofluorobenzene (Surrogate)	%	-	104	96	97	92
VPH F Bands						
Benzene (F0)	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
TRH C6-C10 minus BTEX (F1)	mg/kg	25	<25	<25	<25	<25
TRH (Total Recoverable Hydrocarbons) in Soil Method: AN403 Tested: 1/9/2021						
TRH C10-C14	mg/kg	20	<20	<20	<20	<20
TRH C15-C28	mg/kg	45	<45	<45	<45	<45
TRH C29-C36	mg/kg	45	<45	<45	<45	<45
TRH C37-C40	mg/kg	100	<100	<100	<100	<100
TRH C10-C36 Total	mg/kg	110	<110	<110	<110	<110
TRH >C10-C40 Total (F bands)	mg/kg	210	<210	<210	<210	<210
TRH F Bands						
TRH >C10-C16	mg/kg	25	<25	<25	<25	<25
TRH >C10-C16 - Naphthalene (F2)	mg/kg	25	<25	<25	<25	<25
TRH >C16-C34 (F3)	mg/kg	90	<90	<90	<90	<90
TRH >C34-C40 (F4)	mg/kg	120	<120	<120	<120	<120

Parameter	Units	LOR	Sample Number: PE154290.001 Sample Matrix: Soil Sample Date: 19/8/21 12:15 Sample Name: SM_1	Sample Number: PE154290.002 Sample Matrix: Soil Sample Date: 19/8/21 11:10 Sample Name: SM_2	Sample Number: PE154290.003 Sample Matrix: Soil Sample Date: 19/8/21 10:35 Sample Name: SM_3	Sample Number: PE154290.004 Sample Matrix: Soil Sample Date: 19/8/21 9:45 Sample Name: SM_4
PAH (Polynuclear Aromatic Hydrocarbons) in Soil Method: AN420 Tested: 1/9/2021						
Naphthalene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
2-methylnaphthalene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
1-methylnaphthalene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthylene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Fluorene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Phenanthrene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Anthracene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Fluoranthene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Pyrene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Benzo(a)anthracene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Chrysene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Benzo(b&j)fluoranthene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Benzo(k)fluoranthene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Benzo(a)pyrene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Indeno(1,2,3-cd)pyrene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Dibenzo(ah)anthracene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Benzo(ghi)perylene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Carcinogenic PAHs, BaP TEQ <LOR=0*	TEQ (mg/kg)	0.2	<0.2	<0.2	<0.2	<0.2
Carcinogenic PAHs, BaP TEQ <LOR=LOR*	TEQ (mg/kg)	0.3	<0.3	<0.3	<0.3	<0.3
Carcinogenic PAHs, BaP TEQ <LOR=LOR/2*	TEQ (mg/kg)	0.2	<0.2	<0.2	<0.2	<0.2
Total PAH (18)	mg/kg	0.8	<0.8	<0.8	<0.8	<0.8
Total PAH (NEPM/WHO 16)	mg/kg	0.8	<0.8	<0.8	<0.8	<0.8
Surrogates						
d5-nitrobenzene (Surrogate)	%	-	88	89	87	84
2-fluorobiphenyl (Surrogate)	%	-	81	83	83	82
d14-p-terphenyl (Surrogate)	%	-	88	92	87	90
Particle sizing of soils by sieving Method: AN005 Tested: 15/9/2021						
Passing 2.36mm	%w/w	1	100	100	100	91
Retained 2.36mm	%w/w	1	<1	<1	<1	9
Passing 600µm	%w/w	1	100	99	96	88
Retained 600µm	%w/w	1	<1	<1	4	3
Passing 300µm	%w/w	1	94	96	78	72
Retained 300µm	%w/w	1	6	3	18	17
Passing 212µm	%w/w	1	68	88	59	49
Retained 212µm	%w/w	1	27	8	20	23
Passing 75µm	%w/w	1	13	36	23	16
Retained 75µm	%w/w	1	55	52	36	33
Particle sizing of soils <75µm by hydrometer Method: AN005 Tested: 15/9/2021						
Sedimentation Diameter 1	mm	0.0001	-	0.0578	-	-
Passing Sedimentation Diameter 1	%w/w	1	-	30	-	-
Retained Sedimentation Diameter 1	%w/w	1	-	7	-	-
Sedimentation Diameter 2	mm	0.0001	-	0.0411	-	-
Passing Sedimentation Diameter 2	%w/w	1	-	28	-	-
Retained Sedimentation Diameter 2	%w/w	1	-	2	-	-
Sedimentation Diameter 3	mm	0.0001	-	0.0292	-	-
Passing Sedimentation Diameter 3	%w/w	1	-	26	-	-
Retained Sedimentation Diameter 3	%w/w	1	-	2	-	-
Sedimentation Diameter 4	mm	0.0001	-	0.0208	-	-
Passing Sedimentation Diameter 4	%w/w	1	-	24	-	-
Retained Sedimentation Diameter 4	%w/w	1	-	2	-	-
Sedimentation Diameter 5	mm	0.0001	-	0.0152	-	-
Passing Sedimentation Diameter 5	%w/w	1	-	22	-	-
Retained Sedimentation Diameter 5	%w/w	1	-	2	-	-
Sedimentation Diameter 6	mm	0.0001	-	0.0108	-	-
Passing Sedimentation Diameter 6	%w/w	1	-	22	-	-

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	PE154290.001 Soil 19/8/21 12:15 SM_1	PE154290.002 Soil 19/8/21 11:10 SM_2	PE154290.003 Soil 19/8/21 10:35 SM_3	PE154290.004 Soil 19/8/21 9:45 SM_4
Particle sizing of soils <75µm by hydrometer Method: AN005 Tested: 15/9/2021 (continued)							
Retained Sedimentation Diameter 6	%w/w	1		-	<1	-	-
Sedimentation Diameter 7	mm	0.0001		-	**0.0076**	-	-
Passing Sedimentation Diameter 7	%w/w	1		-	**22**	-	-
Retained Sedimentation Diameter 7	%w/w	1		-	<1	-	-
Sedimentation Diameter 8	mm	0.0001		-	**0.0054**	-	-
Passing Sedimentation Diameter 8	%w/w	1		-	**20**	-	-
Retained Sedimentation Diameter 8	%w/w	1		-	**2**	-	-
Sedimentation Diameter 9	mm	0.0001		-	**0.0038**	-	-
Passing Sedimentation Diameter 9	%w/w	1		-	**19**	-	-
Retained Sedimentation Diameter 9	%w/w	1		-	**1**	-	-
Sedimentation Diameter 10	mm	0.0001		-	**0.0016**	-	-
Passing Sedimentation Diameter 10	%w/w	1		-	**16**	-	-
Retained Sedimentation Diameter 10	%w/w	1		-	**3**	-	-
Sedimentation Diameter 11	mm	0.0001		-	**0.0011**	-	-
Passing Sedimentation Diameter 11	%w/w	1		-	**14**	-	-
Retained Sedimentation Diameter 11	%w/w	1		-	**2**	-	-

Parameter	Units	LOR	Sample Number: PE154290.005 Sample Matrix: Soil Sample Date: 19/8/21 8:40 Sample Name: SM_5	Sample Number: PE154290.006 Sample Matrix: Soil Sample Date: 19/8/21 7:30 Sample Name: SM_6
pH in soil (1:5) Method: AN101 Tested: 27/8/2021				
pH	pH Units	-	6.6	6.7
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/8/2021				
Conductivity of Extract (1:5 as received)	µS/cm	1	20	3
Total Dissolved Solids (by calculation)	mg/kg	5	62	10
Moisture Content Method: AN002 Tested: 27/8/2021				
% Moisture	%w/w	0.5	0.9	0.9
Total Recoverable Elements in Soil by ICPOES Method: AN045/AN320 Tested: 30/8/2021				
Aluminium, Al	mg/kg	50	2000	1400
Arsenic, As	mg/kg	1	2	1
Barium, Ba	mg/kg	0.5	19	13
Boron, B	mg/kg	5	<5	<5
Cadmium, Cd	mg/kg	0.3	<0.3	<0.3
Chromium, Cr	mg/kg	0.5	20	14
Copper, Cu	mg/kg	0.5	2.9	2.0
Lead, Pb	mg/kg	1	4	2
Manganese, Mn	mg/kg	1	160	47
Nickel, Ni	mg/kg	0.5	2.8	1.9
Selenium, Se	mg/kg	3	<3	<3
Zinc, Zn	mg/kg	2	6	<2
Silver, Ag*	mg/kg	1	<1	<1
Iron, Fe	mg/kg	50	14000	6000
Strontium, Sr	mg/kg	0.5	6.2	2.3
Tin, Sn	mg/kg	3	<3	<3
Sodium, Na	mg/kg	10	24	<10
Calcium, Ca	mg/kg	5	250	240
Magnesium, Mg	mg/kg	10	270	73
Potassium, K	mg/kg	10	330	130
Mercury in Soil Method: AN312 Tested: 30/8/2021				
Mercury	mg/kg	0.05	<0.05	<0.05

Parameter	Units	LOR	Sample Number: PE154290.005 Sample Matrix: Soil Sample Date: 19/8/21 8:40 Sample Name: SM_5	Sample Number: PE154290.006 Sample Matrix: Soil Sample Date: 19/8/21 7:30 Sample Name: SM_6
Total Recoverable Metals in Soil by ICPMS Method: AN045/IMS84V Tested: 7/9/2021				
Thorium, Th*	mg/kg	0.5	3.4	1.9
Uranium, U*	mg/kg	0.1	0.4	0.2
Hexavalent Chromium in Soil Aquakem DA Method: AN075/AN283 Tested: 30/8/2021				
Hexavalent Chromium, Cr6+	mg/kg	0.5	<0.5	<0.5
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 2/9/2021				
Total Organic Carbon	%w/w	0.05	0.36	0.30
Organic Matter	%w/w	0.1	0.62	0.51
Alkalinity in Soil Method: AN002/AN135 Tested: 31/8/2021				
Bicarbonate Alkalinity as HCO3 in Soil*	mg/kg	25	<25	<25
Carbonate Alkalinity as CO3 in Soil*	mg/kg	25	<25	<25
Hydroxide Alkalinity as OH in Soil*	mg/kg	25	<25	<25
Total Alkalinity as CaCO3 in Soil*	mg/kg	25	<25	<25
Fluoride in Soil (Water Soluble 1:5 Extraction) by ISE Method: AN141 Tested: 31/8/2021				
Water Soluble Fluoride*	mg/kg	0.5	<0.5	<0.5
Chloride (water extractable) Method: AN274 Tested: 2/9/2021				
Chloride (water extractable 1:5)*	mg/kg	5	51	64

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ANALYTICAL REPORT

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Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	PE154290.005 Soil 19/8/21 8:40 SM_5	PE154290.006 Soil 19/8/21 7:30 SM_6
Sulfate (water extractable) in Soil Method: AN275 Tested: 2/9/2021					
Sulfate (1:5 water extractable), SO4*	mg/kg	5		**87**	**57**
Total Oxidised Nitrogen NOx (Water Extract) in Soil Method: AN002/AN258 Tested: 1/9/2021					
Water Soluble Nitrate Nitrogen, NO_3 as N*	mg/kg	0.025		**0.096**	<0.025
Water Soluble Nitrate/Nitrite Nitrogen, NOx as N*	mg/kg	0.025		**0.77**	**0.93**
Water Soluble ortho Phosphorus in Soil Method: AN278 Tested: 2/9/2021					
Water Soluble ortho Phosphorus, P*	mg/kg	0.02		**0.40**	**0.51**
Water Soluble Reactive Silica by Aquakem Discrete Analyser Method: AN002/AN270 Tested: 2/9/2021					
Reactive Silica, Si*	mg/kg	0.05		**3.3**	**3.2**
Reactive Silica, SiO_2*	mg/kg	0.1		**7.1**	**6.8**
VOC's in Soil Method: AN433 Tested: 1/9/2021					
Monocyclic Aromatic Hydrocarbons					
Benzene	mg/kg	0.1		<0.1	<0.1
Toluene	mg/kg	0.1		<0.1	<0.1
Ethylbenzene	mg/kg	0.1		<0.1	<0.1
m/p-xylene	mg/kg	0.2		<0.2	<0.2
o-xylene	mg/kg	0.1		<0.1	<0.1
Polycyclic VOCs					
Naphthalene	mg/kg	0.1		<0.1	<0.1

Parameter	Units	LOR	Sample Number: PE154290.005 Sample Matrix: Soil Sample Date: 19/8/21 8:40 Sample Name: SM_5	Sample Number: PE154290.006 Sample Matrix: Soil Sample Date: 19/8/21 7:30 Sample Name: SM_6
VOC's in Soil Method: AN433 Tested: 1/9/2021 (continued)				
Surrogates				
d4-1,2-dichloroethane (Surrogate)	%	-	**108**	**109**
d8-toluene (Surrogate)	%	-	**108**	**108**
Bromofluorobenzene (Surrogate)	%	-	**94**	**96**
Totals				
Total Xylenes*	mg/kg	0.3	<0.3	<0.3
Total BTEX*	mg/kg	0.6	<0.6	<0.6
Volatile Petroleum Hydrocarbons in Soil Method: AN433 Tested: 1/9/2021				
TRH C6-C10	mg/kg	25	<25	<25
TRH C6-C9	mg/kg	20	<20	<20
Surrogates				
d4-1,2-dichloroethane (Surrogate)	%	-	**108**	**109**
d8-toluene (Surrogate)	%	-	**108**	**108**
Bromofluorobenzene (Surrogate)	%	-	**94**	**96**
VPH F Bands				
Benzene (F0)	mg/kg	0.1	<0.1	<0.1
TRH C6-C10 minus BTEX (F1)	mg/kg	25	<25	<25
TRH (Total Recoverable Hydrocarbons) in Soil Method: AN403 Tested: 1/9/2021				
TRH C10-C14	mg/kg	20	<20	<20
TRH C15-C28	mg/kg	45	<45	<45
TRH C29-C36	mg/kg	45	<45	<45
TRH C37-C40	mg/kg	100	<100	<100
TRH C10-C36 Total	mg/kg	110	<110	<110
TRH >C10-C40 Total (F bands)	mg/kg	210	<210	<210
TRH F Bands				
TRH >C10-C16	mg/kg	25	<25	<25
TRH >C10-C16 - Naphthalene (F2)	mg/kg	25	<25	<25
TRH >C16-C34 (F3)	mg/kg	90	<90	<90
TRH >C34-C40 (F4)	mg/kg	120	<120	<120

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name PE154290.005 Soil 19/8/21 8:40 SM_5	PE154290.006 Soil 19/8/21 7:30 SM_6
PAH (Polynuclear Aromatic Hydrocarbons) in Soil Method: AN420 Tested: 1/9/2021				
Naphthalene	mg/kg	0.1	<0.1	<0.1
2-methylnaphthalene	mg/kg	0.1	<0.1	<0.1
1-methylnaphthalene	mg/kg	0.1	<0.1	<0.1
Acenaphthylene	mg/kg	0.1	<0.1	<0.1
Acenaphthene	mg/kg	0.1	<0.1	<0.1
Fluorene	mg/kg	0.1	<0.1	<0.1
Phenanthrene	mg/kg	0.1	<0.1	<0.1
Anthracene	mg/kg	0.1	<0.1	<0.1
Fluoranthene	mg/kg	0.1	<0.1	<0.1
Pyrene	mg/kg	0.1	<0.1	<0.1
Benzo(a)anthracene	mg/kg	0.1	<0.1	<0.1
Chrysene	mg/kg	0.1	<0.1	<0.1
Benzo(b&j)fluoranthene	mg/kg	0.1	<0.1	<0.1
Benzo(k)fluoranthene	mg/kg	0.1	<0.1	<0.1
Benzo(a)pyrene	mg/kg	0.1	<0.1	<0.1
Indeno(1,2,3-cd)pyrene	mg/kg	0.1	<0.1	<0.1
Dibenzo(ah)anthracene	mg/kg	0.1	<0.1	<0.1
Benzo(ghi)perylene	mg/kg	0.1	<0.1	<0.1
Carcinogenic PAHs, BaP TEQ <LOR=0*	TEQ (mg/kg)	0.2	<0.2	<0.2
Carcinogenic PAHs, BaP TEQ <LOR=LOR*	TEQ (mg/kg)	0.3	<0.3	<0.3
Carcinogenic PAHs, BaP TEQ <LOR=LOR/2*	TEQ (mg/kg)	0.2	<0.2	<0.2
Total PAH (18)	mg/kg	0.8	<0.8	<0.8
Total PAH (NEPM/WHO 16)	mg/kg	0.8	<0.8	<0.8
Surrogates				
d5-nitrobenzene (Surrogate)	%	-	**83**	**85**
2-fluorobiphenyl (Surrogate)	%	-	**81**	**81**
d14-p-terphenyl (Surrogate)	%	-	**85**	**87**
Particle sizing of soils by sieving Method: AN005 Tested: 15/9/2021				
Passing 2.36mm	%w/w	1	**97**	**100**
Retained 2.36mm	%w/w	1	**3**	<1
Passing 600µm	%w/w	1	**94**	**96**
Retained 600µm	%w/w	1	**3**	**4**
Passing 300µm	%w/w	1	**80**	**61**
Retained 300µm	%w/w	1	**15**	**34**
Passing 212µm	%w/w	1	**60**	**42**
Retained 212µm	%w/w	1	**20**	**19**
Passing 75µm	%w/w	1	**23**	**19**
Retained 75µm	%w/w	1	**38**	**24**
Particle sizing of soils <75µm by hydrometer Method: AN005 Tested: 15/9/2021				
Sedimentation Diameter 1	mm	0.0001	-	-
Passing Sedimentation Diameter 1	%w/w	1	-	-
Retained Sedimentation Diameter 1	%w/w	1	-	-
Sedimentation Diameter 2	mm	0.0001	-	-
Passing Sedimentation Diameter 2	%w/w	1	-	-
Retained Sedimentation Diameter 2	%w/w	1	-	-
Sedimentation Diameter 3	mm	0.0001	-	-
Passing Sedimentation Diameter 3	%w/w	1	-	-
Retained Sedimentation Diameter 3	%w/w	1	-	-
Sedimentation Diameter 4	mm	0.0001	-	-
Passing Sedimentation Diameter 4	%w/w	1	-	-
Retained Sedimentation Diameter 4	%w/w	1	-	-
Sedimentation Diameter 5	mm	0.0001	-	-
Passing Sedimentation Diameter 5	%w/w	1	-	-
Retained Sedimentation Diameter 5	%w/w	1	-	-
Sedimentation Diameter 6	mm	0.0001	-	-

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	PE154290.005 Soil 19/8/21 8:40 SM_5	PE154290.006 Soil 19/8/21 7:30 SM_6
Particle sizing of soils <75µm by hydrometer Method: AN005 Tested: 15/9/2021 (continued)					
Passing Sedimentation Diameter 6	%w/w	1		-	-
Retained Sedimentation Diameter 6	%w/w	1		-	-
Sedimentation Diameter 7	mm	0.0001		-	-
Passing Sedimentation Diameter 7	%w/w	1		-	-
Retained Sedimentation Diameter 7	%w/w	1		-	-
Sedimentation Diameter 8	mm	0.0001		-	-
Passing Sedimentation Diameter 8	%w/w	1		-	-
Retained Sedimentation Diameter 8	%w/w	1		-	-
Sedimentation Diameter 9	mm	0.0001		-	-
Passing Sedimentation Diameter 9	%w/w	1		-	-
Retained Sedimentation Diameter 9	%w/w	1		-	-
Sedimentation Diameter 10	mm	0.0001		-	-
Passing Sedimentation Diameter 10	%w/w	1		-	-
Retained Sedimentation Diameter 10	%w/w	1		-	-
Sedimentation Diameter 11	mm	0.0001		-	-
Passing Sedimentation Diameter 11	%w/w	1		-	-
Retained Sedimentation Diameter 11	%w/w	1		-	-

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QC SUMMARY

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MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity in Soil Method: ME-(AU)-[ENV]AN002/AN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Bicarbonate Alkalinity as HCO3 in Soil*	LB187438	mg/kg	25	<25		
Carbonate Alkalinity as CO3 in Soil*	LB187438	mg/kg	25	<25		
Hydroxide Alkalinity as OH in Soil*	LB187438	mg/kg	25	<25		
Total Alkalinity as CaCO3 in Soil*	LB187438	mg/kg	25	<25	0%	NA

Chloride (water extractable) Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chloride (water extractable 1:5)*	LB187523	mg/kg	5	<5	22%	103%

Conductivity and TDS by Calculation - Soil Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity of Extract (1:5 as received)	LB187332	µS/cm	1	<1	3%	102%
Total Dissolved Solids (by calculation)	LB187332	mg/kg	5	<5	3%	102%

Fluoride in Soil (Water Soluble 1:5 Extraction) by ISE Method: ME-(AU)-[ENV]AN141

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Water Soluble Fluoride*	LB187448	mg/kg	0.5	<0.5	0%	108%

Hexavalent Chromium in Soil Aquakem DA Method: ME-(AU)-[ENV]AN075/AN283

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Hexavalent Chromium, Cr6+	LB187359	mg/kg	0.5	<0.5	0%	100%	92%

Mercury in Soil Method: ME-(AU)-[ENV]AN312

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Mercury	LB187357	mg/kg	0.05	<0.05	0%	95%	99%	1%

Moisture Content **Method: ME-(AU)-[ENV]AN002**

Parameter	QC Reference	Units	LOR	DUP %RPD
% Moisture	LB187330	%w/w	0.5	0%

pH in soil (1:5) **Method: ME-(AU)-[ENV]AN101**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH	LB187331	pH Units	-	6.2	1%	100%

Sulfate (water extractable) in Soil **Method: ME-(AU)-[ENV]AN275**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Sulfate (1:5 water extractable), SO4*	LB187523	mg/kg	5	<5	20%	106%

Total Organic Carbon by Heanes Oxidation **Method: ME-(AU)-[ENV]AN273**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Organic Carbon	LB187515	%w/w	0.05	<0.05	16%	98%
Organic Matter	LB187515	%w/w	0.1	<0.10	16%	98%

Total Oxidised Nitrogen NOx (Water Extract) in Soil **Method: ME-(AU)-[ENV]AN002/AN258**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Water Soluble Nitrate Nitrogen, NO_3 as N*	LB187464	mg/kg	0.025	<0.025		
Water Soluble Nitrate/Nitrite Nitrogen, NOx as N*	LB187464	mg/kg	0.025	<0.025	0%	100%

Total Recoverable Elements in Soil by ICPOES **Method: ME-(AU)-[ENV]AN045/AN320**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Aluminium, Al	LB187357	mg/kg	50	<50	1%	93%	12326%	2%
Arsenic, As	LB187357	mg/kg	1	<1	1%	106%	107%	9%
Barium, Ba	LB187357	mg/kg	0.5	<0.5	0%	99%	80%	9%
Boron, B	LB187357	mg/kg	5	<5	0%	NA	71%	2%
Cadmium, Cd	LB187357	mg/kg	0.3	<0.3	0%	104%	106%	4%
Chromium, Cr	LB187357	mg/kg	0.5	<0.5	1%	75%	114%	3%
Copper, Cu	LB187357	mg/kg	0.5	<0.5	9%	104%	110%	4%
Lead, Pb	LB187357	mg/kg	1	<1	11%	107%	107%	5%
Manganese, Mn	LB187357	mg/kg	1	<1	0%	104%	-15%	-113%
Nickel, Ni	LB187357	mg/kg	0.5	<0.5	14%	104%	108%	3%
Selenium, Se	LB187357	mg/kg	3	<3	0%	119%	95%	4%
Zinc, Zn	LB187357	mg/kg	2	<2	0%	102%	108%	3%
Silver, Ag*	LB187357	mg/kg	1	<1	0%	97%	103%	5%
Iron, Fe	LB187357	mg/kg	50	<50	1%	85%	2556%	401%
Strontium, Sr	LB187357	mg/kg	0.5	<0.5	2%	101%	105%	3%
Tin, Sn	LB187357	mg/kg	3	<3	0%	79%	104%	4%
Sodium, Na	LB187357	mg/kg	10	<10	0%	99%	108%	2%
Calcium, Ca	LB187357	mg/kg	5	<5	3%	100%	53%	3%
Magnesium, Mg	LB187357	mg/kg	10	<10	2%	96%	125%	4%
Potassium, K	LB187357	mg/kg	10	<10	1%	100%	128%	4%

Water Soluble ortho Phosphorus in Soil **Method: ME-(AU)-[ENV]AN278**

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery
Water Soluble ortho Phosphorus, P*	LB187534	mg/kg	0.02	<0.02	93%

Water Soluble Reactive Silica by Aquakem Discrete Analyser **Method: ME-(AU)-[ENV]AN002/AN270**

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery
Reactive Silica, Si*	LB187533	mg/kg	0.05	<0.05	NA
Reactive Silica, SiO_2*	LB187533	mg/kg	0.1	<0.10	NA

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METHOD SUMMARY

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METHOD	METHODOLOGY SUMMARY
AN002	The test is carried out by drying (at either 40°C or 105°C) a known mass of sample in a weighed evaporating basin. After fully dry the sample is re-weighed. Samples such as sludge and sediment having high percentages of moisture will take some time in a drying oven for complete removal of water.
AN002/AN135	Alkalinity (and forms of) by Titration: The sample is extracted 1to 5 in deionised water and the extract titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN002/AN270	A 1:5 sample to DI water extract is analysed for reactive silica with results reported back to the dried sample basis. Reactive forms of silicon in acid solution below pH 2 react with ammonium molybdate ions to form a yellow silicomolybdate which is then reduced with ascorbic acid to produce a blue silicomolybdate complex. Oxalic acid is added to destroy any molybdophosphoric acid. Colourimetric determination by Aquakem Discrete Analyser.
AN005	The particle size distribution of a soil is determined by wet sieving, using a maximum of 900 mL of deionised water to sieve all fractions down to 75 µm. Referenced to AS1289.3.6.1 and AS1141.11.
AN005	Following wet sieving of the sample,(particles smaller than 75 µm) a dispersing solution is added and a hydrometer is used to measure sedimentation. Soil density is determined and the percentage of each size fraction calculated. Referenced to AS1289.3.6.3.
AN040	A portion of sample is digested with Nitric acid to decompose organic matter and Hydrochloric acid to complete the digestion of metals and then filtered for analysis by ASS or ICP as per USEPA Method 200.8.
AN045	A portion of sample is digested with Nitric acid and Hydrogen Peroxide over time and then with Hydrochloric acid through several heating and cooling cycles. It provides a strong oxidising medium for bringing metal analytes into solution according to USEPA3050, after filtration the solution is presented for analysis on AAS or ICP.
AN045/AN320	Solid sample is digested with HNO3 and H2O2 and completed with addition of HCl based on USEPA Method 3050. Digest is then analysed by ICP-OES. Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference USEPA3050, USEPA6010C and APHA 3120 B.
AN045/IMS84V	Determination of elements at trace level in soil digest by ICP-MS technique, Digest analysis performed by SGS Minerals division, method IMS84V.
AN075	This method uses an alkaline digestion to solubilise both water-soluble and water-insoluble forms of hexavalent chromium in solids. The solution is then pH adjusted and the hexavalent chromium concentration in solution determined colourimetrically.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode and is calibrated against 3 buffers purchased commercially. For soils, sediments and sludges, an extract with water (or 0.01M CaCl2) is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.

METHOD	METHODOLOGY SUMMARY
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract of as received sample with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Salinity can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. Reference APHA 2510 B.
AN141	Determination of Fluoride by ISE: A fluoride ion selective electrode and reference electrode combination , in the presence of a pH/complexation buffer, is used to determine the fluoride concentration on the soil water extract. The electrode millivolt response is measured logarithmically against fluoride concentration. Reference APHA F- C.
AN258	Nitrate and Nitrite by FIA:: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Without the cadmium reduction only the original nitrite is determined. Reference APHA 4500-NO3- F.
AN273	The sample is digested in Dichromate / Sulfuric Acid to oxidise the organic carbon. The determination is completed colourimetrically by Aquakem Discrete Analyser at 600 nm. Based on Rayment & Higginson 6B1.
AN274	Chloride by Aquakem DA following 1:5 or 1:2 DI water extraction: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Results reported on dry sample basis. Reference APHA 4500Cl-
AN275	sulfate by Aquakem DA following 1:5 DI water extraction: sulfate is precipitated in an acidic medium with barium chloride. The resulting turbidity is measured photometrically at 405nm and compared with standard calibration solutions to determine the sulfate concentration in the sample. Reference APHA 4500-SO42-. Internal reference AN275.
AN278	Reactive Phosphorus in extract by DA: Orthophosphate reacts with ammonium molybdate (Mo VI) and potassium antimonyl tartrate (Sb III) in acid medium to form an antimony-phosphomolybdate complex. This complex is subsequently reduced with ascorbic acid to form a blue colour and the absorbance is read at 880 nm. The sensitivity of the automated method is 10-20 times that of the macro method. Reference APHA 4500-P G
AN283	Hexavalent Chromium via Aquakem DA: Soluble hexavalent chromium forms a red/violet colour with diphenylcarbazide in acidic solution. This procedure is very sensitive and nearly specific for Cr6+. If total chromium is also measured the trivalent form of chromium Cr3+ can be calculated from the difference (Total Cr - Cr6+). Reference APHA3500CrB.
AN312	Mercury by Cold Vapour AAS in Soils: After digestion with nitric acid, hydrogen peroxide and hydrochloric acid, mercury ions are reduced by stannous chloride reagent in acidic solution to elemental mercury. This mercury vapour is purged by nitrogen into a cold cell in an atomic absorption spectrometer or mercury analyser. Quantification is made by comparing absorbances to those of the calibration standards. Reference APHA 3112/3500
AN320	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .

METHOD	METHODOLOGY SUMMARY
AN403	Total Recoverable Hydrocarbons: Determination of Hydrocarbons by gas chromatography after a solvent extraction. Detection is by flame ionisation detector (FID) that produces an electronic signal in proportion to the combustible matter passing through it. Total Recoverable Hydrocarbons (TRH) are routinely reported as four alkane groupings based on the carbon chain length of the compounds: C6-C9, C10-C14, C15-C28 and C29-C36 and in recognition of the NEPM 1999 (2013), >C10-C16 (F2), >C16-C34 (F3) and >C34-C40 (F4). F2 is reported directly and also corrected by subtracting Naphthalene (from VOC method AN433) where available.
AN403	Additionally, the volatile C6-C9 fraction may be determined by a purge and trap technique and GC/MS because of the potential for volatiles loss. Total Recoverable Hydrocarbons - Silica (TRH-Si) follows the same method of analysis after silica gel cleanup of the solvent extract. Aliphatic/Aromatic Speciation follows the same method of analysis after fractionation of the solvent extract over silica with differential polarity of the eluent solvents .
AN403	The GC/FID method is not well suited to the analysis of refined high boiling point materials (ie lubricating oils or greases) but is particularly suited for measuring diesel, kerosene and petrol if care to control volatility is taken. This method will detect naturally occurring hydrocarbons, lipids, animal fats, phenols and PAHs if they are present at sufficient levels, dependent on the use of specific cleanup/fractionation techniques. Reference USEPA 3510B, 8015B.
AN420	(SVOCs) including OC, OP, PCB, Herbicides, PAH, Phthalates and Speciated Phenols (etc) in soils, sediments and waters are determined by GCMS/ECD technique following appropriate solvent extraction process (Based on USEPA 3500C and 8270D).
AN420	Carcinogenic PAHs may be expressed as Benzo(a)pyrene equivalents by applying the BaP toxicity equivalence factor (NEPM 1999, June 2013, B7). These can be reported as the individual PAHs and as a sum of carcinogenic PAHs. The sum is reported three ways, the first assuming all <LOR results are zero, the second assuming all < LOR results are half the LOR and the third assuming all <LOR results are the LOR.
AN433	VOCs and C6-C9 Hydrocarbons by GC-MS P&T: VOC`s are volatile organic compounds. The sample is presented to a gas chromatograph via a purge and trap (P&T) concentrator and autosampler and is detected with a Mass Spectrometer (MSD). Solid samples are initially extracted with methanol whilst liquid samples are processed directly. References: USEPA 5030B, 8020A, 8260.

SGS

FOOTNOTES

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FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
***	Indicates that both * and ** apply.	NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.