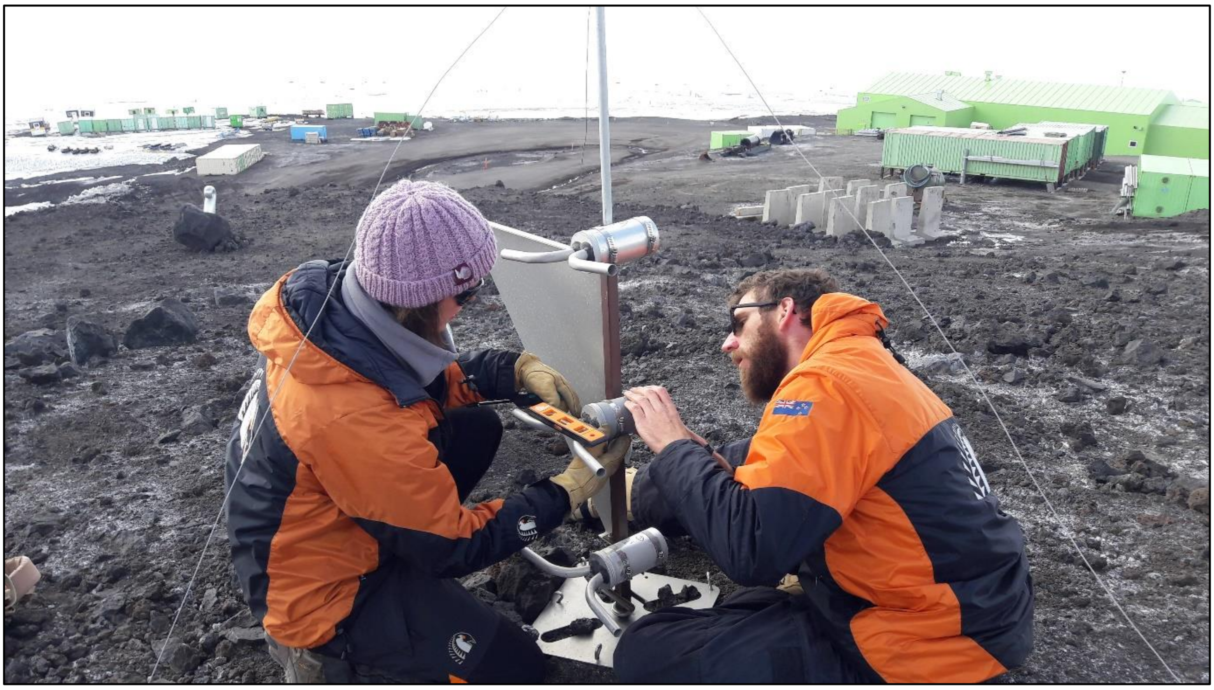
Scott Base Redevelopment CEE environmental monitoring report: Year two (December 2019 - January 2020)



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Cover picture: Annual collection of dust from MWAC passive dust collector, Scott Base operational area, Ross Island, Antarctica. Photo: Tanya O'Neill.

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1 Introduction and aims

An understanding of the soils and the underlying permafrost surrounding Scott Base is important to detect impacts of environmental change or human activities, such as the redevelopment of Scott Base, on the unique soil communities and on geomorphological processes. The Scott Base Redevelopment (SBR) is the largest project ever undertaken by New Zealand in Antarctica. It is a requirement of the Environmental Protocol to the Antarctic Treaty and New Zealand's Antarctica (Environmental Protection) Act (1994) that an environmental impact assessment be completed prior to any activity taking place in Antarctica. A Comprehensive Environmental Evaluation (CEE) of the project is being completed in order to support decision-making with an assessment of predicted environmental impacts linked with the redevelopment. A comprehensive monitoring programme was set up to verify the accuracy of the environmental impact assessment presented in the CEE and to detect unforeseen impacts or impacts that are more significant than expected.

In year one (January 2019) 25 monitoring sites were established around Scott Base to assess current levels of biodiversity and abundance of invertebrates and microbial communities, along with soil chemical characteristics, and visual characteristics within the wider redevelopment area. These monitoring plots established a baseline against which future changes can be detected. My role in year one of the project was to determine the chemical characteristics of soil from the monitoring plots, undertake visual site assessments around each monitoring plot, measure depth to ice-cement, and install 12 passive dust samplers adjacent to the monitoring plots.

In year two (December 2019 to January 2020) five control sites were established at Cape Evans, including installation of three passive dust samplers adjacent to the soil monitoring plots. Soil samples were taken and all the same parameters measured and defined in year one were replicated at the control sites.

This report is to be read in conjunction with the year one report (which gives background information on the general characteristics of Scott Base soils, including information on active layer, permafrost, soil moisture, soil organisms, and evidence of natural and human induced changes to the soil-permafrost environment; as well as sampling site selection criteria, and detailed methods). This report focusses on the results and discussion on my aspect of this multidisciplinary project, including, work undertaken at the newly established Cape Evans control sites: depth to ice-cement, visual site assessments, pXRF, and soil analysis; and new work at the Scott Base monitoring plots and environs: pXRF on surface soil at monitoring plots and target sites, melt water sampling, and particle size analysis of dust (from year 1).

2 Rationale - Cape Evans control site

In December 2019 a multidisciplinary team was deployed to establish control sites at Cape Evans, located some 25 km from Scott Base. The control sites were deemed essential to ensure any change in measured parameters at Scott Base, were not attributed solely to the redevelopment of the base, and rather to monitor any natural local environmental changes in the southern McMurdo Sound region. Cape Evans was chosen as the control site due to similarities in soil parent material (scoriaeous basaltic lava flows), soil moisture regime (subxerous), soil characteristics (Typic Haplorthels, generally shallow, loose, coarse-gravelly texture with ice-cemented permafrost), and similar local climatic conditions being so close to Scott Base, yet also far enough to not be impacted by the redevelopment project itself. For sufficient spatial coverage of the control area, five soil monitoring plots, representative of all landforms in the Cape Evans area and similar to landforms around Scott Base were selected (e.g. raised hilltop, two lowland beach ridges, wetland, and a lakeside site). Three passive dust collectors (MWACs) were installed adjacent to control sites (Figure 1).

The following reports on the results from the Cape Evans control sites, as well as new results and discussion of the Scott Base monitoring plots.

3 Methods

3.1 Cape Evans control site

At Cape Evans five representative soil monitoring plots were marked out using two orange marker poles to mark opposite ends of a 1 m^2 plot. Photos were taken of the plot area from different angles (looking inwards, from 0, 90, 180, 270 degrees), then directly above the plot with a 1 m measuring tape in place, to record current levels of vegetation, surface salts, and surrounding site characteristics. Whilst I undertook soil sampling, portable XRF, depth to ice-cement measurements, and visual site assessments, my colleague Clare Beets from Waikato University undertook an in-situ macroinvertebrate survey, took soil samples for micro-invertebrate analysis and DNA sequencing, and undertook a vegetation survey along transects. Passive dust samplers (MWACs) were installed at SMC01, SMC02, and SMC03 (Figure 1) by Pauline Sitter and Peter Taylor as per the install instruction manual by O'Neill and Sitter (2019).

3.1.1 Soil sampling and chemical analysis

Using a trowel marked with 2 cm and 5 cm depth increments, soils were sampled directly adjacent to the SMC plot (within 1 m). Two soil depths were taken, 0-2 cm and 2-5 cm, and sampling consisted of at least 10 subsamples homogenized from numerous spots adjacent to the plot to ensure a representative bulk sample (e.g. if the plot had a lot of salt efflorescence on the surface, the same adjacent soils were sampled. Alternatively if the plot appeared visibly salt-free, salt was avoided in the representative bulked sample). Approximately 400 g of soil was homogenised from two depths. These soils were analysed for pH and electrical conductivity (EC, salt) at Waikato University.

3.1.2 Depth to ice-cement or maximum thaw

Three measurements of depth to ice-cement (or maximum thaw of active layer at that point in time) were taken immediately adjacent to the control plots using small trowel, mallet and orange pole, and replicates averaged.

3.1.3 Visual site assessments

The visual site assessment (VSA) method of Campbell *et al.* (1993) was used to assess the present-day visual impacts at a representative area at each control site (Appendix 1). The VSA method is a rapid visual evaluation of terrestrial impacts and rates the extent of surface disturbance against 11 impact assessment criteria, such as extent of disturbed surface stones, evidence of boot imprints, and evidence of foreign objects, as a means of comparing disturbance severity across different sites (see Campbell et al. 1993 for full methods and illustrations). A modified version was used which included an additional six criteria: evidence of salt deposition, stratigraphic disturbance, textural disturbance, presence of rock cairns (see Kiernan and McConnell, 2001 and O'Neill *et al.* 2013a), % change in vegetative cover and evidence of exotic species; removal of 'other surface impressions' (as captured by many of the other criteria); and the modification of evidence of 'walking tracks' to include 'walking or vehicle tracks', to give a total of 16 impact assessment criteria. Criteria were rated between one and four, one being no visible impact, and four being the most severe (Appendix 1).

3.1.4 Surface soil elemental analysis using portable x-ray fluorescence

Field portable x-ray fluorescence (pXRF) is a quick method for determining the total elemental composition of surface layers of in-situ soils, and can provide semi-quantitative information about site contamination to direct and prioritise further investigations (Waikato Regional Council, 2016). In theory, x-ray fluorescence spectroscopy uses high-energy photons (x-rays) to bombard an atom and excite electrons orbiting the atom. Some of these photons have sufficient energy to eject an electron which is bound to the nucleus of the atom. When an inner orbital electron is ejected from an atom, an electron from a higher energy orbital will be transferred to the lower energy orbital. During this transition, photons (also x-rays but at lower energy than the incoming beam) may be emitted from the atom. This process is known as fluorescence, and the wavelength of the x-rays emitted from the atom will be *characteristic of that particular element* (Waikato Regional Council, 2016). Some spectral interferences can occur when an elemental spectral line for one element overlaps with another, so the user must be aware of this.

Use of the pXRF required radiation training, then further training on operation, calibration, and use of the Innov-X delta software. Before in-situ samples were measured calibration checks were performed, including analysis of a silicon dioxide blank and a standard reference material NIST2711a (soil). These calibrations were undertaken at the start and end of the day, and in between if many samples were being analysed. Detection limits vary according to the element (Appendix 2.1). The pXRF gives concentrations of elements in parts per million (ppm) (equivalent mg/kg). When concentrations were displayed lower than the detection limit the concentration is given as <LOD.

Portable XRF measurements were taken in triplicate and averaged at each soil monitoring control plot at Cape Evans. Full data is given in the excel files that accompany this report.

3.2 Scott Base soil monitoring plots and target locations

3.2.1 Dust collection, maintenance and particle size distribution

Collection of the 2018-2019 season dust samples was carried out by Pauline Sitter and Peter Taylor. Each MWAC was relocated (Appendix 3.1) and each of the three collector bottles were emptied in a systematic fashion, contents bagged and labelled, and replaced by a clean collector bottle. Each dust sample was labelled with soil monitoring plot (SM) number (1-25) (or TAE, separate MWAC), and 1 (bottom collector), 2 (middle) or 3 (top), (e.g. SM03__1 = lowest collector on the MWAC nearest to SM03).

Dust samples were transported back to Waikato University to be analysed using a Mastersizer 3000 laser diffraction particle size analyser (Appendix 3.2). Prior to analysis the dust material was dried, weighed and pre-treated with hydrogen peroxide to remove any limited organic material (which can strongly influence the soil/dust's ability to retain water and have an effect on the particle size distribution (PSD)). PSD data is given in accordance with the US Dept. of Agriculture (USDA) size fractions (most commonly used in international soil science) and the International Soil Society (ISSS) size fractions are also provided (Appendix 3.3). Data is displayed as % in each particle size range and cumulative %. Full particle size analysis data is given in Appendix 3.4.

3.2.2 Melt water sampling and analysis

Three melt water samples were taken from the vicinity of Scott Base in December 2019, including near the HFC/Cold Porch, the TAE Hut, and Front Transition (Figure 2, sites 1-3).

The HFC/Cold Porch water (site 1) was sampled from a melt pond (S77.84868, E166.7669), whereas the TAE Hut (site 2) (S77.84991, E166.76442), and Front Transition water samples (site 3) (S77.84982, E166.76929) were from running melt water. The TAE Hut water was sampled at the NW corner of the hut. There was a lot of fine sediment and flow rate was estimated at 0.1 L/second. The Front Transition sampling site had a lot of clay and silt substrate and passed through a vehicle track. Flow rate was estimated at 0.5-1.0 L/second.

Samples were stored frozen at Scott Base until transport back to New Zealand and analysed at the IANZ accredited laboratory Analytica (Hamilton, New Zealand). The following analytes were measured: suspended soils and total solids (both in g/m^3 = mg/L = ppm); pH, EC, total alkalinity ($CaCO_3$); anion/cation suite (including chloride, sulphate, nitrate, dissolved reactive phosphorus, ammonia, sodium, potassium, calcium, magnesium, iron, zinc, manganese, sum of anions, sum of cations, and EC/10*. A comprehensive suite of total metals were also measured (Appendix 4).

3.2.3 Surface soil elemental analysis using portable x-ray fluorescence

Portable XRF measurements were taken in triplicate and averaged at each soil monitoring plot at Scott Base, as well as 27 target locations around Scott Base, including the long-term storage site, truck stop, MOGAS container, hitching rail, Hanger, American plug-in, intake pipe, JP5 fuel tank, TAE Hut, waste water outflow pipe, smokers hut, and mechanics workshop entrance. Full data is given in the supplementary excel file.

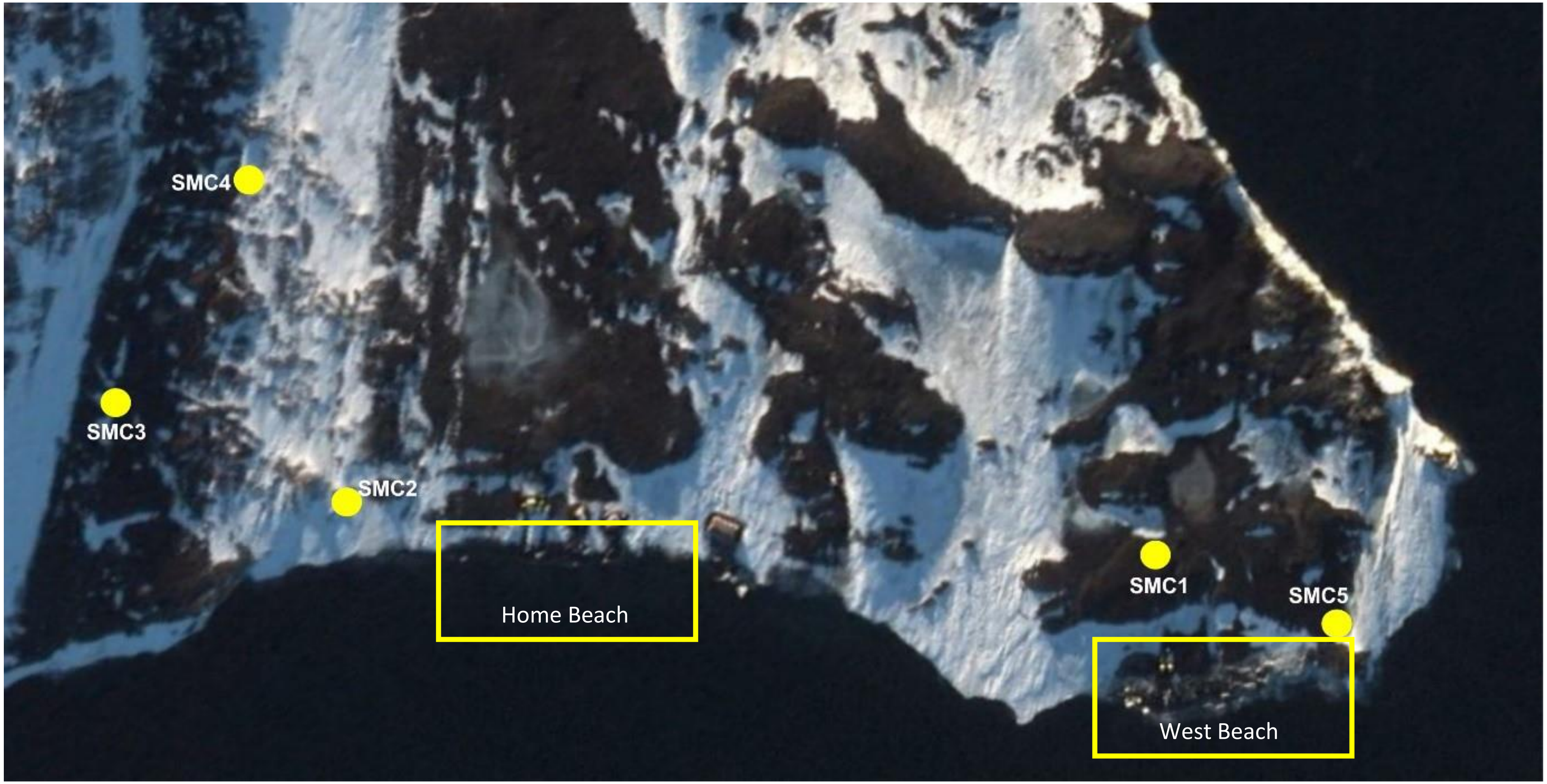

Figure 1: Map of Cape Evans control sites showing the five soil monitoring plots (SMC01-SMC05) in relation to West Beach (main helo pad) and Home Beach. MWAC passive dust samplers have been installed at SMC01, SMC02, and SMC03.

Figure 2: Map of operational area melt water sampling sites (dots): Site 1 = HFC/Cold Porch, Site 2 = TAE Hut, Site 3 = Front Transition. Map modified by Pauline Sitter.

4 Results and discussion

Results and discussion on the Cape Evans control sites are given in section 4.1. Section 4.2 gives results and discussion on pXRF measurements, particle size distribution, and melt water analysis from soil monitoring plots and target locations around Scott Base.

4.1 Cape Evans control sites

4.1.1 Soil chemical analysis

Soil pH and soil EC were measured at two depths (0-2 cm and 2-5 cm) at all control sites (Table 1). pH of the top 0-2 cm ranged from 7.38 to 8.10 and in the material beneath (2-5 cm) ranged from 7.58 to 8.30. EC varied considerably across the control sites, was always highest the top 2 cm, ranging from 272.2 to 16910.0 µS/cm in the 0-2 cm samples, to 232.5 to 8180.0 µS/cm in the 2-5 cm soil samples (Table 1). EC was higher at sites with visible surface salt (SMC01 and SMC04) (Table 1, Appendix 1). Soil moisture content in the top 5 cm (% g/g) at the control sites ranged from 0.7% g/g at SMC01 to 15.0% g/g at SMC03 (Table 1, Appendix 1).

Table 1: Soil pH, electrical conductivity, moisture content, and depth to ice-cement at soil monitoring control sites at Cape Evans. #Data are the average of duplicate samples. 1 millisiemens/centimetre (mS/cm) = 1000 microsiemens/centimetre (µS/cm). *MWAC associated with monitoring plot.

Plot	**Longitude**	**Latitude**	**Soil sample 0-2 cm#**		**Soil sample 2-5 cm#**		**Moisture content 0-5 cm**	**Depth to ice-cement**
			EC (µS/cm)	**pH**	**EC (µS/cm)**	**pH**	**(% g/g)**	**(cm)**
SMC01*	166.41034	-77.63822	16910	7.38	8180	7.58	0.72	47
SMC02*	166.42375	-77.63412	272.2	8.10	175.1	8.28	8.29	30
SMC03*	166.42976	-77.63321	747	8.10	214.3	8.30	14.95	>45
SMC04	166.43344	-77.63463	4770	7.48	460	7.96	9.59	35
SMC05	166.40596	-77.63894	442	7.70	232.5	7.89	10.21	45

4.1.2 Depth to ice-cement

Using a trowel, three measurements of depth to ice-cement (or maximum thaw of active layer at that point in time) were taken immediately adjacent to the soil monitoring plots at the control sites, and replicates averaged. SMC01 had a depth to ice-cement of 47 cm; SMC02, bedrock was encountered at 30 cm; SMC03, depth to ice-cement was >45 cm; SMC04, 35 cm; and SMC05 was 45 cm (Table 1; Appendix 1). This active layer depth varies spatially and temporally. In moist environments, such as SMC03, where there was a small stream running through the site, depth to ice-cement could not be measured, however, we would expect a significantly greater active layer depth as thermal conductivity of moist soil is greater than dry soil (Ikard *et al*. 2009; Gooseff *et al*. 2013). All soil monitoring sites have a similar low albedo due the black basaltic parent material absorbing heat, so active layer depth would be comparable in this regard (Balks et al. 2002).

4.1.3 Visual site assessments

Five site descriptions and visual site assessments were undertaken as part of the baseline survey at Cape Evans (Appendix 1).

Generally, all sites were relatively undisturbed and showed no evidence of past human disturbance. Site SMC01, located on an undisturbed hill near West Beach helo pad and refuge hut, scored one's for all VSA criteria. Site SMC02, an undisturbed site near Home Beach, showed some vegetation, and scored one's for all disturbance indicators. Site SMC03, was located in a wetland near an old 1960-1962 patterned ground experiment, at the northern end of Home Beach. The site itself showed no evidence of human disturbance. Control site SMC04 is situated on the edge of a small lake behind Skua Lake and is surrounded by skua nests. Again, no visible human disturbance was seen at this site. Finally SMC05 is located at the west end of West Beach, about 40 m from the helo pad and refuge hut. A few surface stones were disturbed at this site, likely due to the small number of visitors climbing the small hill adjacent for a view of McMurdo Sound and the basking seals (Appendix 1).

4.1.4 Surface soil elemental analysis

Average pXRF results for individual elements are shown for each soil monitoring control plot (SMC-01-SMC05) at Cape Evans, Antarctica (Table 2). Table 3 compares these average results to three soil/sediment quality guidelines:

(1) Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC 2000) which is an indicator for ecosystem health; where if the level of a trace element is less the ISQC-Low the likelihood of toxic effects on sediment-dwelling organisms is low – risks are moderate if the level of the trace element resides between the ISQC-Low and ISQC-High – and there is a high likelihood of toxic effects if the level of trace element is greater than the ISQC-High trigger value;

(2) Ministry for the Environment (MfE), Toxicological Intake Values for Priority Contaminants in Soil (NESCS) (MfE, 2011a), which measures human health risks from oral consumption (unlikely in Antarctica as hopefully no geophagists in residence); and

(3) MfE National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (MfE, 2011b), which gives an indication of threshold levels for 12 priority contaminants across five different land-uses. Although Antarctica is a unique environment, high-density residential has been deemed the most appropriate comparison as this includes a land-use scenario with limited soil contact (compared with residential or rural where home-grown consumption of produce derived from a vegetable garden is 10-25%). The health and ecosystem risks associated with the various contaminants are given in Appendix 2.2.

Antimony, cadmium, chromium and nickel are all less than the detection limit (<LOD) and do not pose a risk to human or ecosystem health (Tables 2 and 3). Copper concentrations at the control sites ranged between 10-18 mg/kg soil, lead ranged from 4-6 mg/kg of soil, zinc ranged from 65-91 mg/kg of soil, and arsenic between 5-6 mg/kg of soil, and were all lower than the ecosystem and human health trigger values, and likely to be the natural baseline levels in these undisturbed sites. Mercury ranged between 6-9 mg/kg soil, which exceeds both the ISQC-Low and ISQC-High ecosystem health guidelines and MfE oral consumption guidelines but is well less than the NESCS limit. Silver was found at 10-14 mg/kg soil, also above the ecosystem health guidelines (Table 3). It is likely that these levels of mercury and silver are natural and derived from weathering of the parent material around the Cape

Evans control sites, however may still have an impact on the microbial communities residing within the soils.

Table 2: Average portable XRF trace element concentrations at the Cape Evans monitoring sites. <LOD = less than limit of detection.

Reading	P	P +/-	S	S +/-	Cl	Cl +/-	K	K +/-	Ca	Ca +/-	Ti	Ti +/-	V	V +/-	Cr	Cr +/-	Mn	Mn +/-	Fe	Fe +/-
Cal Check																				
SiO2	-857	20	-3	10	69	11	147	7	183	6	9	1	-2	0	20	1	22	1	40	2
NIST2711a	-165	97	469	48	141	43	20197	138	22300	135	2557	21	71	2	53	4	553	6	21317	97
SMC-01	17	198	6197	215	10179	261	25651	323	17761	219	3911	54	100	5	<LOD	8	1096	17	24982	209
SMC-02	388	155	1789	102	15127	223	29504	269	20041	183	5220	50	101	4	<LOD	7	1202	13	31753	197
SMC-03	-96	149	781	86	4998	145	20970	221	19843	191	4201	45	86	4	<LOD	6	962	12	24467	165
SMC-04	247	155	2447	122	121248	913	17675	186	18855	175	3070	35	62	3	<LOD	6	886	11	21621	144
SMC-05	445	155	4435	132	28588	315	31998	265	23751	198	4767	44	94	3	<LOD	6	1109	12	31823	182
SiO2	-857	20	-3	10	69	11	147	7	183	7	9	1	-2	0	20	1	22	1	40	2
NIST2711a	-165	98	469	48	141	43	20197	138	22300	135	2557	21	71	2	53	4	553	6	21317	97

Reading	Co	Co +/-	Ni	Ni +/-	Cu	Cu +/-	Zn	Zn +/-	As	As +/-	Se	Se +/-	Rb	Rb +/-	Sr	Sr +/-	Y	Y +/-	Zr	Zr +/-
Cal Check																				
SiO2	-23	2	-93	2	-16	1	-2	1	-2	0	-2	0	1	0	-1	0	-1	0	-1	0
NIST2711a	-224	39	-16	5	101	4	316	4	86	6	1	1	96	1	125	2	18	1	151	2
SMC-01	<LOD	78	<LOD	11	11	6	78	4	6	2	<LOD	1	78	2	933	18	37	2	623	13
SMC-02	<LOD	68	<LOD	8	10	4	85	4	6	1	<LOD	1	86	2	985	15	42	2	715	11
SMC-03	<LOD	62	<LOD	8	12	4	66	3	5	1	<LOD	1	64	2	1023	16	33	2	556	9
SMC-04	<LOD	56	<LOD	8	13	4	65	3	5	1	<LOD	1	76	2	698	11	36	2	630	10
SMC-05	<LOD	63	<LOD	7	18	4	91	3	6	1	<LOD	1	92	2	993	14	42	2	769	11
SiO2	-23	1	-93	2	-16	1	-2	1	-2	0	-2	0	1	0	-1	0	-1	0	-1	0
NIST2711a	-224	39	-16	6	101	4	316	4	86	7	1	1	96	1	125	2	18	1	151	2

Reading	Mo	Mo +/-	Ag	Ag +/-	Cd	Cd +/-	Sn	Sn +/-	Sb	Sb +/-	Hg	Hg +/-	Pb	Pb +/-	Bi	Bi +/-	Th	Th +/-	U	U +/-
Cal Check																				
SiO2	-2	0	13	2	22	5	-3	5	9	3	-3	0	2	1	-10	3	-2	1	-3	0
NIST2711a	-1	1	11	3	67	7	14	7	16	5	7	1	1123	8	-2	4	5	1	-1	1
SMC-01	6	2	14	7	<LOD	16	21	17	<LOD	11	<LOD	2	6	2	<LOD	10	11	5	11	4
SMC-02	8	2	14	5	<LOD	12	34	13	<LOD	8	6	2	4	2	<LOD	8	14	5	8	3
SMC-03	5	2	14	5	<LOD	12	<LOD	13	<LOD	9	<LOD	2	5	2	<LOD	8	14	4	<LOD	3
SMC-04	6	2	14	5	<LOD	11	<LOD	12	<LOD	8	9	1	<LOD	2	<LOD	7	10	4	5	3
SMC-05	6	2	10	5	<LOD	11	23	12	<LOD	8	<LOD	1	<LOD	2	<LOD	7	14	4	<LOD	3
SiO2	-2	0	13	2	22	5	-3	5	9	3	-3	0	2	1	-10	3	-2	1	-3	0
NIST2711a	-1	1	11	3	67	7	14	7	16	5	7	1	1123	8	-2	4	5	1	-1	1

Table 3: Portable XRF trace element concentrations at the Cape Evans monitoring sites, compared against recommended sediment quality guidelines for ecosystem health (ANZECC, 2000) and human health maximum acceptable values (MfE, 2011a,b). <LOD = less than limit of detection.

Contaminant	Cape Evans	Ecosystem health		Human health	
	SMC01-SMC05 ranges (mg/kg)	ISQG-Low trigger value (mg/kg)	ISQG-High	Oral consumption (mg/kg bw/day)	High-density residential (mg/kg)
Antimony (Sb)	<LOD	2	25	-	-
Cadmium (Cd)	<LOD	1.5	10	0.8	230
Chromium (Cr)	<LOD	80	370	1500	>10000
Copper (Cu)	10-18	65	270	150	>10000
Lead (Pb)	4-6	50	220	1.9	500
Mercury (Hg)	6-9	0.15	1	2	1000
Nickel (Ni)	<LOD	21	52	-	-
Silver (Ag)	10-14	1	3.7	-	-
Zinc (Zn)	65-91	200	410	-	-
Arsenic (As)	5-6	20	70	0.0086	45

4.2 Scott Base

4.2.1 Surface soil elemental analysis

Average pXRF (based on triplicates) results for individual elements are shown for each soil monitoring plot at Scott Base (SM01-SM25) (Table 4a-c), and target locations (Tables 5 and 6a-d). Twenty-seven target sites around Scott Base were analysed and included the long-term storage site, truck stop, MOGAS container, hitching rail, Hanger, American plug-in, intake pipe, JP5 fuel tank, TAE Hut, waste water outflow pipe, smokers hut, and mechanics workshop entrance. All results were then compared to Table 3 which gives the recommended soil/sediment quality guidelines for ecosystem health (ANZECC, 2000) and human health maximum acceptable values (MfE, 2011a,b).

At the **25 soil monitoring sites**, antimony and cadmium were less than the detection limit (<LOD), and copper ranged from 19-44 mg/kg soil, lead <LOD to 16 mg/kg; all are likely the natural baseline values for these elements in these soils and do not pose a risk to human or ecosystem health (Tables 3 and 4a-c). Chromium ranged from <LOD at some sites to 139 mg/kg at site SM06, which was the only site that was higher than the ISQC-Low trigger value. At all but two sites (SM02 and SM06), mercury was <LOD, whereas at site SM02 and SM06 it was 5 mg/kg, exceeding the ISQC-High and oral consumption guidelines. At sites SM11, SM22, SM23 and SM24, nickel exceeded the ISQC-Low trigger values, and at site SM06 the concentration of nickel was 81 mg/kg which exceeds the ISQC-High trigger value. Traces of silver occurred in sites SM01, SM02, SM07, SM08, SM14, SM15, and SM17, and ranged between 10-21 mg/kg soil, exceeding the ISQC-High trigger for ecosystem health. Levels of zinc ranged from 61-300 mg/kg; 300 mg/kg found in SM02, which exceeds the ISQC-Low trigger value. And finally arsenic concentrations ranged from <LOD to 10 mg/kg (Table 4b). The detection limit for arsenic is 5 ppm, and all sites except SM04, SM06, SM07, SM16 and SM25, had greater concentrations than 5 ppm (or 5 mg/kg), and while these are less than the ISQC-Low trigger value, all exceed the oral consumption human health threshold values (Table 3). These levels are likely to be natural and a function of soil parent material. Overall, soil monitoring sites SM02 and SM06 had the highest concentrations of trace

elements. SM02 is a highly disturbed site located behind I-hut, 20 m from HFC and 15 m from sea-edge. There was some evidence of nails and wood scattered around. SM02 had high lead (16 mg/kg), mercury (5 mg/kg), zinc (300 mg/kg), and silver (21 mg/kg) concentrations. SM06 is located on a hummocky hillslope, approximately 200 m downhill of Scott Base to McMurdo road. SM06 had the high concentrations of chromium (139 mg/kg) and nickel (81 mg/kg), zinc (73 mg/kg) and mercury (5 mg/kg) (Full descriptions given in report from year 1).

Table 4a: Average portable XRF trace element concentrations (P to Fe) at the Scott Base soil monitoring sites. <LOD = less than limit of detection.

Plot	P	P +/-	S	S +/-	Cl	Cl +/-	K	K +/-	Ca	Ca +/-	Ti	Ti +/-	V	V +/-	Cr	Cr +/-	Mn	Mn +/-	Fe	Fe +/-
Cal																				
SiO2	-733	25	-6	11	53	13	84	7	294	7	7	1	-1	0	29	2	33	2	48	2
Ni2711a	-332	85	439	44	115	38	17014	117	19212	115	2163	18	59	2	40	4	475	5	17877	81
SM01	1351	344	46714	664	17212	335	12778	191	89047	822	13038	131	138	6	<LOD	10	981	15	66105	471
SM02	774	316	12147	271	34271	458	19114	299	59173	673	10486	137	120	7	<LOD	11	1000	18	54569	470
SM03	900	269	15325	270	586	130	19829	232	72177	626	13855	127	142	6	43	9	1180	15	59538	384
SM04	270	191	387	86	514	99	13081	161	49056	425	11129	101	115	4	<LOD	7	881	12	50732	314
SM05	1025	236	355	100	616	117	18614	210	60599	515	14360	127	137	6	<LOD	9	1238	15	64417	381
SM06	1226	326	1233	151	20028	356	15195	212	105744	965	19978	190	185	8	139	13	1368	18	85487	563
SM07	527	225	700	106	1711	131	15874	189	59749	503	14332	125	135	6	12	9	1059	14	65503	400
SM08	958	293	9121	254	3264	187	18494	257	61699	626	14748	155	136	7	<LOD	11	1273	19	68647	501
SM09	879	352	4862	242	3461	235	18235	306	69203	816	16559	202	155	8	<LOD	13	1263	22	75590	647
SM10	1140	296	404	124	1206	156	21210	267	76675	734	17979	179	169	7	<LOD	11	1378	19	78004	545
SM11	1153	279	1862	143	2566	158	19602	229	86124	724	19453	169	185	7	38	10	1500	18	88283	538
SM12	697	254	3553	161	23181	325	15774	187	80778	650	15201	129	136	6	<LOD	9	1171	14	69742	402
SM13	1615	336	328	137	579	165	19856	276	93862	905	21183	211	191	8	<LOD	12	1733	23	88664	627
SM14	805	283	6388	207	6845	216	18872	242	72013	667	15700	152	147	6	<LOD	11	1363	18	70510	477
SM15	688	277	1416	144	1014	153	18192	246	63569	637	16212	170	150	7	<LOD	11	1636	22	69301	516
SM16	1186	251	17014	270	22843	311	17378	212	51742	454	12404	113	131	5	<LOD	9	1085	15	62505	391
SM17	852	289	487	130	695	153	19990	265	70636	678	18498	181	170	7	<LOD	11	1435	19	79930	548
SM18	606	272	8918	240	33859	421	15186	198	75030	659	12364	116	130	6	<LOD	9	1004	14	62705	397
SM19	1225	333	8114	236	14306	296	19812	282	78553	842	16029	183	157	8	<LOD	11	1494	22	70187	542
SM20	928	258	1069	122	2635	149	19588	221	78695	647	16787	144	165	6	<LOD	9	1270	15	75696	450
SM21	1213	316	6598	226	19170	359	21183	274	86511	822	15041	155	145	7	<LOD	10	1123	17	67450	492
SM22	676	240	34751	441	75505	680	11051	137	62769	474	7869	69	90	4	<LOD	7	820	11	50571	292
SM23	1082	281	152	112	579	135	20994	244	85149	740	19102	172	173	7	<LOD	10	1450	17	85269	530
SM24	1244	239	17564	246	32240	329	17174	189	61877	494	13518	113	129	5	69	9	1205	14	70170	392
SM25	470	234	684	109	881	123	14764	197	58780	589	12039	124	120	5	<LOD	9	1048	15	54436	384
Cal																				
SiO2	-728	24	24	11	83	13	104	7	282	7	13	1	-1	0	31	2	33	2	48	3
Ni2711a	68	103	363	48	137	44	20918	144	23105	141	2648	22	72	2	47	4	576	6	22591	104

Table 4b: Average portable XRF trace element concentrations (Co to Mo) at the Scott Base soil monitoring sites. <LOD = less than limit of detection.

Plot	Co	Co +/-	Ni	Ni +/-	Cu	Cu +/-	Zn	Zn +/-	As	As +/-	Se	Se +/-	Rb	Rb +/-	Sr	Sr +/-	Y	Y +/-	Zr	Zr +/-	Mo	Mo +/-
Cal																						
SiO2	-21	2	-93	2	-16	1	-3	1	-3	0	-2	0	1	0	-1	0	-1	0	-1	0	-3	0
Ni2711	-229	34	-39	4	77	3	264	4	64	5	1	1	78	1	107	2	16	1	129	2	-2	1
SM01	<LOD	124	18	12	26	6	79	5	5	2	<LOD	1	40	2	867	17	29	2	322	8	<LOD	2
SM02	<LOD	126	<LOD	14	20	7	300	9	6	2	<LOD	1	74	2	705	15	29	2	382	9	<LOD	2
SM03	<LOD	104	<LOD	10	34	5	75	4	7	2	<LOD	1	73	2	860	14	28	2	439	8	<LOD	2
SM04	<LOD	85	<LOD	8	21	4	61	3	<LOD	1	<LOD	1	34	1	609	10	22	1	259	5	<LOD	1
SM05	<LOD	100	15	9	30	5	80	4	6	1	<LOD	1	49	1	801	13	29	2	348	6	<LOD	1
SM06	<LOD	132	81	12	36	6	73	4	<LOD	2	<LOD	1	33	2	899	17	32	2	287	7	<LOD	2
SM07	<LOD	104	<LOD	10	34	5	68	4	<LOD	2	<LOD	1	37	1	751	13	27	2	290	6	<LOD	1
SM08	<LOD	128	<LOD	12	19	6	77	4	8	2	<LOD	1	49	2	773	16	32	2	362	8	<LOD	2
SM09	<LOD	157	<LOD	16	28	8	77	6	8	2	<LOD	1	36	2	788	19	31	3	285	8	<LOD	2
SM10	<LOD	131	13	12	28	6	85	5	8	2	<LOD	1	58	2	890	17	32	2	387	8	<LOD	2
SM11	<LOD	125	50	11	39	5	76	4	6	2	<LOD	1	39	1	925	16	31	2	290	6	<LOD	1
SM12	<LOD	104	13	9	40	5	72	4	8	1	<LOD	1	44	1	768	13	29	2	289	6	<LOD	1
SM13	<LOD	144	<LOD	13	44	7	85	5	6	2	<LOD	1	40	2	958	19	33	2	341	8	<LOD	2
SM14	<LOD	122	<LOD	11	28	6	82	4	8	2	<LOD	1	60	2	828	15	31	2	368	8	<LOD	2
SM15	<LOD	129	<LOD	12	27	6	86	5	7	2	<LOD	1	47	2	698	15	29	2	271	7	<LOD	2
SM16	<LOD	105	<LOD	10	22	5	79	4	<LOD	2	<LOD	1	56	2	752	13	28	2	355	7	<LOD	2
SM17	<LOD	132	<LOD	12	24	6	82	4	7	2	<LOD	1	42	2	822	16	28	2	307	7	<LOD	2
SM18	<LOD	109	17	11	24	6	72	4	6	2	<LOD	1	39	2	751	14	28	2	283	6	<LOD	1
SM19	<LOD	135	<LOD	13	26	7	80	5	10	2	<LOD	1	51	2	964	20	30	2	362	9	<LOD	2
SM20	<LOD	112	11	10	28	5	78	4	6	2	<LOD	1	37	1	888	15	29	2	293	6	<LOD	1
SM21	<LOD	127	<LOD	12	39	7	70	4	5	2	<LOD	1	33	2	891	18	26	2	262	7	<LOD	2
SM22	<LOD	87	47	9	32	5	67	3	5	1	<LOD	1	42	1	722	11	29	2	291	6	<LOD	1
SM23	<LOD	124	29	11	39	5	89	4	7	2	<LOD	1	47	2	940	16	32	2	350	7	<LOD	2
SM24	<LOD	99	50	9	35	5	81	4	5	1	<LOD	1	48	1	687	11	29	2	313	6	<LOD	1
SM25	<LOD	98	<LOD	10	26	5	63	3	<LOD	1	<LOD	1	29	1	606	12	23	1	236	6	<LOD	1
Cal																						
SiO2	-21	2	-88	2	-15	1	-3	1	-2	0	-2	0	1	0	-1	0	-1	0	-1	0	-3	0
Ni2711a	-244	41	-11	5	112	4	344	5	77	6	2	1	104	1	183	3	34	2	223	3	1	1

Table 4c: Average portable XRF trace element concentrations (Ag to U) at the Scott Base soil monitoring sites. <LOD = less than limit of detection.

Plot	Ag	Ag +/-	Cd	Cd +/-	Sn	Sn +/-	Sb	Sb +/-	Hg	Hg +/-	Pb	Pb +/-	Bi	Bi +/-	Th	Th +/-	U	U +/-
Cal																		
SiO2	18	2	16	5	-7	5	6	3	-3	0	2	1	-7	3	-4	1	-4	0
Ni2711a	10	3	55	6	4	6	11	4	6	1	918	6	2	4	3	1	-1	1
SM01	17	7	<LOD	16	30	17	<LOD	12	<LOD	2	5	2	<LOD	9	9	5	<LOD	4
SM02	21	7	<LOD	17	33	19	<LOD	12	5	2	16	3	<LOD	10	13	5	<LOD	3
SM03	<LOD	6	<LOD	13	24	14	<LOD	9	<LOD	2	<LOD	2	<LOD	8	15	5	<LOD	3
SM04	<LOD	5	<LOD	11	<LOD	12	<LOD	8	<LOD	1	<LOD	2	<LOD	7	12	3	<LOD	2
SM05	<LOD	5	<LOD	12	<LOD	13	<LOD	9	<LOD	2	<LOD	2	<LOD	7	8	4	<LOD	3
SM06	<LOD	7	<LOD	15	22	16	<LOD	11	5	2	5	2	<LOD	8	9	4	<LOD	3
SM07	10	6	<LOD	13	<LOD	14	<LOD	9	<LOD	2	<LOD	2	<LOD	7	7	4	<LOD	3
SM08	13	7	<LOD	16	<LOD	17	<LOD	12	<LOD	2	5	2	<LOD	9	11	5	<LOD	2
SM09	<LOD	8	<LOD	20	<LOD	22	<LOD	14	<LOD	3	<LOD	3	<LOD	11	9	6	<LOD	4
SM10	<LOD	7	<LOD	15	<LOD	17	<LOD	11	<LOD	2	<LOD	2	<LOD	9	10	5	<LOD	4
SM11	<LOD	6	<LOD	14	<LOD	16	<LOD	10	<LOD	2	<LOD	2	<LOD	8	12	4	<LOD	3
SM12	<LOD	6	<LOD	13	<LOD	14	<LOD	9	<LOD	2	<LOD	2	<LOD	7	8	4	<LOD	3
SM13	<LOD	7	<LOD	17	<LOD	18	<LOD	12	<LOD	2	<LOD	2	<LOD	9	9	5	<LOD	4
SM14	12	7	<LOD	15	<LOD	16	<LOD	11	<LOD	2	<LOD	2	<LOD	8	9	4	<LOD	
SM15	11	7	<LOD	16	28	17	<LOD	11	<LOD	2	8	2	<LOD	9	11	5	<LOD	3
SM16	<LOD	6	<LOD	14	<LOD	15	<LOD	10	<LOD	2	5	2	<LOD	7	9	4	<LOD	3
SM17	11	7	<LOD	16	25	17	<LOD	11	<LOD	2	<LOD	2	<LOD	9	12	5	<LOD	3
SM18	<LOD	6	<LOD	14	<LOD	16	<LOD	10	<LOD	2	<LOD	2	<LOD	8	8	4	<LOD	3
SM19	<LOD	7	<LOD	17	<LOD	18	<LOD	12	<LOD	2	<LOD	2	<LOD	10	11	5	<LOD	4
SM20	<LOD	5	<LOD	13	<LOD	14	<LOD	9	<LOD	2	<LOD	2	<LOD	7	8	4	<LOD	2
SM21	<LOD	7	<LOD	16	<LOD	17	<LOD	11	<LOD	2	<LOD	2	<LOD	9	8	5	<LOD	4
SM22	<LOD	5	<LOD	12	<LOD	13	<LOD	9	<LOD	2	<LOD	2	<LOD	7	10	3	<LOD	3
SM23	<LOD	6	<LOD	14	23	15	<LOD	10	<LOD	2	<LOD	2	<LOD	8	16	4	<LOD	2
SM24	<LOD	5	<LOD	12	<LOD	13	<LOD	8	<LOD	2	<LOD	2	<LOD	7	8	4	<LOD	3
SM25	<LOD	6	<LOD	14	<LOD	14	<LOD	9	<LOD	1	<LOD	2	<LOD	7	10	4	<LOD	3
Cal																		
SiO2	16	2	25	5	-12	5	1	3	-2	0	1	1	-9	3	-4	1	-3	0
Ni2711a	6	3	91	8	16	8	26	5	8	1	1216	8	3	5	9	2	1	1

Table 5: Scott Base target sites for surface soil pXRF investigations

Location	Latitude	Longitude	Elevation
Long Term Storage	S77.84904	E166.76819	20 m
Outside HFC doors 1+2	S77.84817	E166.76566	13 m
Outside HFC Hagglund park	S77.84843	E166.76875	13 m
Truck stop left of HFC doors 1+2	S77.84559	E166.76825	15 m
2-stroke bowser	S77.84809	E166.77219	6 m
Outside MOGAS, next to 2-stroke	S77.84809	E166.77219	6 m
Staked barrels beside MOGAS	S77.84799	E166.77231	8 m
MOGAS bowser	S77.84785	E166.77290	6 m
Hitching rail	S77.84908	E166.77020	12 m
Back of I Hut	S77.84944	E166.77205	11 m
Front of I Hut	S77.84944	E166.77205	11 m
Hanger- seaside	S77.84956	E166.77046	1 m
Front of seaside lab	S77.84986	E166.76822	10 m
American Plug-in	S77.84986	E166.76822	10 m
Under water intake pipe	S77.84998	E166.76761	5 m
JP5 Fuel tank	S77.84918	E166.77084	7 m
Waste water outflow pipe	S77.85004	E166.76456	13 m
TAE Hut	S77.85022	E166.76514	14 m
Gully between TAE and Antennas	S77.84992	E166.76387	19 m
Near TAE MWAC	S77.85015	E166.76370	19 m
Smokers hut, bins, US plug-in	S77.84966	E166.76521	12 m
Scott Base sign	S77.84990	E166.76669	9 m
Mechanics workshop entrance	S77.84903	E166.76894	8 m
Cable	S77.84740	E166.75636	50 m
Upper staging area near ANDRILL	S77.84731	E166.84731	50 m
Near explosives	S77.84760	E166.75914	42 m
Scott Base soil climate station	S77.84820	E166.76070	30 m

Of the **27 target location sites** (Table 5), chromium ranged from <LOD to 2920 mg/kg (Table 6a). The long-term storage site had the highest chromium concentration (2920 mg/kg), exceeding ISQC-High and oral consumption human health thresholds (Table 6a) and seaside of the Hanger also had a high concentration exceeding the ISQC-High trigger values (518 mg/kg). Nickel ranged from <LOD to 149 mg/kg of soil. Nickel was found in highest concentrations at the back of the I Hut (149 mg/kg) and mechanics workshop entrance (71 mg/kg); both beyond the ISQC-High trigger value. The Hagglund park, truck stop, hitching rail, front of the I Hut, lab, American plug-in, Scott Base sign, cable, and smokers hut sites all had levels of nickel that exceeded the ISQC-Low trigger values. The likely source of nickel is stainless steel piping so higher levels around old infrastructure is typical. Zinc ranged from 86-1103 mg/kg, with the highest concentrations found at the long-term storage area (1103 mg/kg) which exceeds the ISQC-High trigger value, and hitching rail, back of the I Hut, Lab, water intake, and gully near the TAE, all at concentrations that exceed the ISQC-Low trigger value for ecosystem health. Again high levels of zinc is typical around old infrastructure due to galvanization of materials. Copper ranged from 18-70 mg/kg of soil; all sites were <LOD for cadmium and antimony, and arsenic ranged from <LOD to 14 mg/kg; all are less than ecosystem health triggers. Concentrations of silver ranged from <LOD to 31 mg/kg, and were greater than the ISQC-High trigger value at the stacked barrels beside the MOGAS hitching rail, JP5 fuel tank and TAE Hut; likely source is fuel contamination. Lead ranged from <LOD to 395

mg/kg, and the highest concentration was found near the Hanger (395 mg/kg). The water outflow and TAE Hut area also had lead concentrations that exceeded the ISQC-Low and oral consumption thresholds (Table 3). Finally in all but two sites (i.e. MWAC site near the TAE and upper staging area near the ANDRILL containers), mercury concentrations were <LOD. Both the MWAC near TAE site and ANDRILL container sites had concentrations of 5 and 6 mg/kg soil which exceed the limits for ecosystem and oral consumption (Table 6d).

Table 6a: Average portable XRF trace element (P to Cr) concentrations at target locations around Scott Base. <LOD = less than limit of detection.

Location	P	P +/-	S	S +/-	Cl	Cl +/-	K	K +/-	Ca	Ca +/-	Ti	Ti +/-	V	V +/-	Cr	Cr +/-
Cal Check																
SiO2	-279	45	-7	15	4	18	-35	11	646	13	2	2	-1	0	-12	2
Ni2711a	-649	39	88	19	85	18	4736	38	5302	35	591	6	16	1	40	2
Long Term Storage	957	263	9081	244	17495	291	15613	205	61895	568	47458	325	175	8	2920	27
Outside HFC doors 1+2	802	281	10484	272	5368	202	20198	249	70157	642	15513	148	152	7	<LOD	10
Outside HFC Hagglund park	1020	237	14304	260	5143	168	18903	202	63208	498	14760	121	141	5	71	9
Truck stop left of HFC doors 1+2	705	252	29533	398	571	115	13269	152	82226	605	11032	89	106	5	28	7
2-stroke bowser	974	290	491	126	795	149	20143	256	75912	711	18131	175	169	7	<LOD	11
Outside MOGAS, next to 2-stroke	1025	265	240	111	653	134	19974	242	66504	599	15951	149	155	6	36	11
Staked barrels beside MOGAS	731	386	4922	243	7893	295	19829	334	93854	1052	16406	218	171	9	<LOD	14
MOGAS bowser	553	249	4716	177	8484	203	17846	216	63663	554	13118	121	134	6	25	10
Hitching rail	763	262	1457	132	1080	138	18164	221	72161	628	16481	150	184	7	<LOD	10
Back of I Hut	701	328	4059	214	18013	377	18076	285	68409	758	13534	164	143	8	<LOD	14
Front of I Hut	877	266	5582	189	3961	170	17360	209	77007	654	16324	145	158	6	<LOD	9
Hanger- seaside	917	252	1676	128	2594	143	18534	215	75734	652	15076	138	135	6	518	13
Front of seaside lab	1050	251	5133	181	4123	165	22051	238	69222	574	16102	138	161	6	27	9
American Plug-in	1153	253	6242	188	6881	185	17770	199	78497	625	16515	138	151	6	<LOD	9
Under water intake pipe	805	272	6456	218	10458	254	16762	223	62515	586	15448	149	160	7	<LOD	11
JP5 Fuel tank	605	395	5175	268	11043	359	16148	317	73639	984	16035	226	167	10	<LOD	15
Cal Check																
SiO2	-171	46	-15	14	36	19	18	12	633	13	7	2	2	1	-8	2
SNi2711a	114	109	462	52	168	48	22038	154	24617	153	2844	24	75	2	67	4
Waste water outflow pipe	1404	286	2040	144	19171	284	20316	230	96744	788	16264	140	158	6	<LOD	9
TAE Hut	463	262	9669	235	3308	163	12713	177	70731	652	10998	106	123	5	<LOD	9
Gully between TAE and Antennas	1305	299	1764	153	5396	206	19990	260	76322	723	16062	159	159	7	<LOD	11
Near TAE MWAC	1222	343	3578	203	28948	459	20339	282	93777	945	19364	203	180	8	<LOD	12
Smokers hut, bins, US plug-in	1344	295	1468	146	5098	200	22524	275	77068	717	16435	159	165	7	17	11
Scott Base sign	1471	277	941	129	8881	232	23724	271	70458	641	17588	165	176	7	<LOD	10
Mechanics workshop entrance	1512	260	4876	172	14007	253	20945	218	82261	634	19506	155	176	6	49	9
Cable	1533	309	1494	159	71897	832	19215	241	88729	799	18493	173	172	7	<LOD	10
Upper staging area near ANDRILL	1291	306	2962	176	2777	178	21953	273	83896	780	18101	175	175	7	<LOD	11
Near explosives	970	248	4441	178	83227	854	20183	221	63118	534	13517	120	137	5	<LOD	8
Scott Base soil climate station	1156	313	528	137	730	162	22469	299	72697	746	17657	186	169	7	<LOD	12

Table 6b: Average portable XRF trace element (Mn to Rb) concentrations at target locations around Scott Base. <LOD = less than limit of detection.

Location	Mn	Mn +/-	Fe	Fe +/-	Co	Co +/-	Ni	Ni +/-	Cu	Cu +/-	Zn	Zn +/-	As	As +/-	Se	Se +/-	Rb	Rb +/-
Cal Check																		
SiO2	4	2	-18	4	-2	4	-54	4	-5	2	1	1	1	1	0	0	1	0
Ni2711a	154	2	10895	50	-143	24	-58	3	43	2	161	3	35	3	0	0	49	1
Long Term Storage	1001	16	58816	393	<LOD	105	<LOD	10	40	6	1103	9	9	2	<LOD	1	49	2
Outside HFC doors 1+2	1193	16	72611	486	<LOD	122	<LOD	11	35	6	102	5	6	2	<LOD	1	43	2
Outside HFC Hagglund park	1118	13	71963	411	<LOD	104	30	9	35	5	107	4	5	1	<LOD	1	43	1
Truck stop left of HFC doors 1+2	890	11	60930	337	<LOD	93	36	9	28	5	89	4	6	1	<LOD	1	42	1
2-stroke bowser	1352	18	86856	583	<LOD	136	<LOD	12	31	6	123	5	6	2	<LOD	1	39	2
Outside MOGAS, next to 2-stroke	1265	17	71628	454	<LOD	115	<LOD	10	34	5	129	5	5	2	<LOD	1	45	2
Staked barrels beside MOGAS	1282	23	73585	703	<LOD	166	<LOD	18	26	9	123	7	9	3	<LOD	1	39	2
MOGAS bowser	1158	15	62745	389	<LOD	104	17	10	22	5	96	4	6	2	<LOD	1	50	2
Hitching rail	1188	16	72101	455	<LOD	114	22	11	46	6	303	6	2	2	<LOD	1	37	1
Back of I Hut	1051	19	68360	545	<LOD	140	149	18	22	8	323	9	7	3	<LOD	1	44	2
Front of I Hut	1208	15	79390	493	<LOD	120	26	10	41	5	184	6	6	2	<LOD	1	37	1
Hanger- seaside	1197	15	65774	420	<LOD	106	<LOD	9	70	6	757	11	<LOD	4	<LOD	1	41	1
Front of seaside lab	1352	16	79093	461	<LOD	113	22	9	60	5	317	6	14	2	<LOD	1	48	2
American Plug-in	1187	14	73936	426	<LOD	107	48	10	35	5	138	4	7	2	<LOD	1	40	1
Under water intake pipe	1186	16	77451	521	<LOD	128	<LOD	12	45	6	126	5	10	2	<LOD	1	40	2
JP5 Fuel tank	1183	24	74308	723	<LOD	176	<LOD	19	18	10	205	9	8	3	<LOD	1	37	2
Cal Check																		
SiO2	10	2	-14	4	-7	4	-65	4	-4	2	1	1	0	1	-1	0	1	0
SNi2711a	615	6	24515	115	-275	44	-6	5	126	4	358	5	67	6	2	1	114	1
Waste water outflow pipe	1375	16	81136	489	<LOD	119	39	11	69	6	137	5	14	2	<LOD	1	46	2
TAE Hut	1088	15	59217	400	<LOD	110	<LOD	11	34	6	129	5	11	3	<LOD	1	34	2
Gully between TAE and Antennas	1460	19	81593	560	<LOD	134	<LOD	12	44	6	246	7	7	2	<LOD	1	56	2
Near TAE MWAC	1410	20	88989	668	<LOD	153	10	13	40	7	86	5	7	2	<LOD	1	46	2
Smokers hut, bins, US plug-in	1477	19	75944	511	<LOD	126	34	12	43	6	173	6	7	2	<LOD	1	44	2
Scott Base sign	1324	17	79848	517	<LOD	123	30	11	52	6	110	5	8	2	<LOD	1	65	2
Mechanics workshop entrance	1390	15	103607	574	<LOD	125	71	10	51	5	167	5	5	2	<LOD	1	43	1
Cable	1229	17	80886	536	<LOD	129	26	12	34	6	101	5	4	2	<LOD	1	40	2
Upper staging area near ANDRILL	1445	19	82897	561	<LOD	133	20	12	36	6	183	6	7	2	<LOD	1	45	2
Near explosives	1059	14	61454	384	<LOD	104	<LOD	10	31	5	91	4	9	2	<LOD	1	63	2
Scott Base soil climate station	1481	21	77481	573	<LOD	139	<LOD	13	26	7	101	5	6	2	<LOD	1	45	2

Table 6c: Average portable XRF trace element (Sr to Sn) concentrations at target locations around Scott Base. <LOD = less than limit of detection.

Location	Sr	Sr +/-	Y	Y +/-	Zr	Zr +/-	Nb	Nb +/-	Mo	Mo +/-	Ag	Ag +/-	Cd	Cd +/-	Sn	Sn +/-
Cal Check																
SiO2	-1	0	0	0	0	0	0	1	0	1	4	3	1	7	-3	7
Ni2711a	188	3	30	2	231	3	20	1	1	1	2	3	84	8	2	8
Long Term Storage	714	13	26	2	334	7	159	4	<LOD	2	<LOD	6	<LOD	14	<LOD	15
Outside HFC doors 1+2	797	15	30	2	309	7	117	4	<LOD	2	<LOD	6	<LOD	15	<LOD	16
Outside HFC Hagglund park	821	13	28	2	306	6	118	3	<LOD	1	<LOD	5	<LOD	12	<LOD	13
Truck stop left of HFC doors 1+2	822	13	26	2	312	5	107	3	<LOD	1	<LOD	5	<LOD	12	<LOD	13
2-stroke bowser	1029	19	30	2	356	8	120	3	5	2	<LOD	6	<LOD	15	<LOD	16
Outside MOGAS, next to 2-stroke	842	15	29	2	337	7	118	4	<LOD	2	<LOD	6	<LOD	14	<LOD	15
Staked barrels beside MOGAS	869	23	27	3	286	9	99	5	<LOD	2	11	9	<LOD	22	<LOD	24
MOGAS bowser	744	13	29	2	335	7	121	3	<LOD	1	<LOD	6	<LOD	13	<LOD	15
Hitching rail	819	14	26	2	303	6	109	3	66	3	10	6	<LOD	14	<LOD	15
Back of I Hut	764	17	29	2	298	8	109	4	<LOD	2	<LOD	8	<LOD	19	<LOD	20
Front of I Hut	891	16	29	2	316	7	111	3	<LOD	2	<LOD	6	<LOD	14	<LOD	15
Hanger- seaside	623	11	22	2	248	5	89	3	<LOD	1	<LOD	6	<LOD	13	<LOD	14
Front of seaside lab	834	14	29	2	334	6	127	3	<LOD	1	<LOD	5	<LOD	13	<LOD	14
American Plug-in	878	14	29	2	314	6	112	3	<LOD	1	<LOD	5	<LOD	13	<LOD	13
Under water intake pipe	859	16	27	2	288	7	109	3	<LOD	2	<LOD	7	<LOD	15	<LOD	16
JP5 Fuel tank	931	25	28	2	308	10	112	5	<LOD	2	23	10	<LOD	22	31	24
Cal Check																
SiO2	0	0	0	0	1	0	1	1	0	1	4	3	-11	7	6	7
SNi2711a	233	3	41	2	282	4	25	1	2	1	11	4	105	9	-2	9
Waste water outflow pipe	845	14	30	2	306	6	117	3	<LOD	1	<LOD	6	<LOD	13	<LOD	15
TAE Hut	732	14	26	2	256	6	96	3	<LOD	2	31	6	<LOD	14	<LOD	16
Gully between TAE and Antennas	813	16	29	2	393	9	146	4	<LOD	2	<LOD	7	<LOD	16	<LOD	17
Near TAE MWAC	934	20	32	2	293	8	113	4	<LOD	2	<LOD	8	<LOD	18	<LOD	19
Smokers hut, bins, US plug-in	867	16	29	2	309	7	113	3	<LOD	2	<LOD	7	<LOD	15	<LOD	17
Scott Base sign	849	16	33	2	374	8	160	4	<LOD	2	<LOD	6	<LOD	14	<LOD	16
Mechanics workshop entrance	1004	16	31	2	348	6	123	3	<LOD	1	<LOD	5	<LOD	12	<LOD	13
Cable	1062	20	33	2	355	8	132	4	<LOD	2	<LOD	6	<LOD	15	<LOD	17
Upper staging area near ANDRILL	997	19	32	2	346	8	131	4	<LOD	2	<LOD	7	<LOD	15	<LOD	17
Near explosives	870	15	32	2	394	7	159	4	<LOD	2	<LOD	6	<LOD	14	<LOD	15
Scott Base soil climate station	892	18	33	2	364	9	129	4	<LOD	2	<LOD	7	<LOD	17	<LOD	18

Table 6d: Average portable XRF trace element (Sb to U) concentrations at target locations around Scott Base. <LOD = less than limit of detection.

Location	Sb	Sb +/-	W	W +/-	Hg	Hg +/-	Pb	Pb +/-	Bi	Bi +/-	Th	Th +/-	U	U +/-
Cal Check														
SiO2	3	5	-4	2	0	1	0	1	-9	3	-2	1	-1	1
Ni2711a	16	5	-6	2	2	1	563	4	0	3	10	2	1	1
Long Term Storage	<LOD	10	31	6	<LOD	2	20	2	<LOD	8	11	4	<LOD	3
Outside HFC doors 1+2	<LOD	11	<LOD	5	<LOD	2	<LOD	2	<LOD	8	11	4	<LOD	3
Outside HFC Hagglund park	<LOD	9	<LOD	4	<LOD	2	<LOD	2	<LOD	7	11	4	<LOD	3
Truck stop left of HFC doors 1+2	<LOD	8	<LOD	4	<LOD	2	<LOD	2	<LOD	7	6	4	<LOD	3
2-stroke bowser	<LOD	11	<LOD	5	<LOD	2	5	2	<LOD	9	12	5	<LOD	3
Outside MOGAS, next to 2-stroke	<LOD	10	<LOD	5	<LOD	2	<LOD	2	<LOD	8	8	4	<LOD	3
Staked barrels beside MOGAS	<LOD	16	<LOD	8	<LOD	3	<LOD	3	<LOD	12	8	6	<LOD	5
MOGAS bowser	<LOD	9	<LOD	4	<LOD	2	10	2	<LOD	8	12	4	<LOD	3
Hitching rail	<LOD	10	14	5	<LOD	2	27	2	<LOD	8	11	4	<LOD	3
Back of I Hut	<LOD	13	<LOD	7	<LOD	2	32	3	<LOD	10	11	5	<LOD	4
Front of I Hut	<LOD	10	<LOD	5	<LOD	2	10	2	<LOD	8	8	4	<LOD	3
Hanger- seaside	<LOD	9	<LOD	6	<LOD	2	395	5	<LOD	8	7	4	<LOD	3
Front of seaside lab	<LOD	9	<LOD	5	<LOD	2	12	2	<LOD	7	6	4	<LOD	3
American Plug-in	<LOD	9	<LOD	4	<LOD	2	7	2	<LOD	7	8	4	<LOD	3
Under water intake pipe	<LOD	11	<LOD	5	<LOD	2	7	2	<LOD	8	6	4	<LOD	3
JP5 Fuel tank	<LOD	16	<LOD	8	<LOD	3	6	3	<LOD	13	11	6	<LOD	5
Cal Check														
SiO2	0	5	-1	2	-1	1	1	1	-4	3	-1	1	0	1
SNi2711a	15	6	4	4	7	1	1363	9	-2	5	9	2	2	2
Waste water outflow pipe	<LOD	10	<LOD	5	<LOD	2	51	3	<LOD	7	10	4	<LOD	3
TAE Hut	<LOD	10	<LOD	5	<LOD	2	78	3	<LOD	8	<LOD	4	<LOD	3
Gully between TAE and Antennas	<LOD	11	<LOD	5	<LOD	2	10	3	<LOD	9	8	4	<LOD	3
Near TAE MWAC	<LOD	13	<LOD	5	6	2	<LOD	2	<LOD	9	7	5	<LOD	4
Smokers hut, bins, US plug-in	<LOD	11	<LOD	5	<LOD	2	18	3	<LOD	9	12	4	<LOD	3
Scott Base sign	<LOD	11	<LOD	5	<LOD	2	7	2	<LOD	8	17	4	<LOD	3
Mechanics workshop entrance	<LOD	9	<LOD	4	<LOD	2	7	2	<LOD	7	8	4	<LOD	3
Cable	<LOD	11	<LOD	5	<LOD	2	5	2	<LOD	9	10	5	<LOD	3
Upper staging area near ANDRILL	<LOD	11	<LOD	6	5	2	<LOD	2	<LOD	9	12	5	<LOD	4
Near explosives	<LOD	10	<LOD	5	<LOD	2	<LOD	2	<LOD	8	13	4	<LOD	3
Scott Base soil climate station	<LOD	12	<LOD	5	6	2	12	3	<LOD	9	14	5	<LOD	4

4.2.2 Particle size distribution at Scott Base dust collector sites

Particle size analysis can contribute to understanding how a soil was originally formed and how it has been influenced since (such as through human activity, construction, climate change, transportation by air, water, ice, etc). In the Scott Base environment the dominate transport of particles is wind through suspension, saltation (bouncing) and creep along the ground (rolling).

In general the amount of material collected from the 12 MWACs around Scott Base was low and ranged from 0.30 g to 3.01 g of material in an approximate 11 month period (Table 7). MWAC dust collectors closest to the McMurdo to Scott Base road (e.g. SM03, SM06, SM08, SM12, SM20, and SM23) tended to have greater volumes of dust collected. It is important to consider that the ice-free area around Scott Base is only snow-free and thawed to the surface (whereby dust is able to be transported) for a short time each year and most of the year dust transport is unlikely to occur. Therefore dust collected represents approximately a 2-3 month period.

Table 7: Total weights of dust collected from MWACs associated with soil monitoring plots (SM) around Scott Base over the 2019-2020 season. 1 = lowest collector, 3 = highest collector.

MWAC id	Longitude	Latitude	Collector 1 (g)	Collector 2 (g)	Collector 3 (g)	Total (g)
SM03	166.7635	-77.8477	0.99	1.12	0.90	3.01
SM06	166.7557	-77.8465	0.53	0.34	0.17	1.04
SM08	166.7450	-77.8469	0.65	0.59	0.47	1.71
SM10	166.7614	-77.8486	0.07	0.07	0.05	0.19
SM12	166.7569	-77.8462	1.12	0.48	0.52	2.12
SM15	166.7585	-77.8485	0.06	0.17	0.07	0.30
SM17	166.7500	-77.8472	0.08	0.20	0.02	0.30
SM18	166.7587	-77.8480	-	-	-	Damaged
SM20	166.7513	-77.8458	0.23	0.37	0.28	0.88
SM23	166.7533	-77.8455	0.75	0.47	0.45	1.67
SM25	166.7589	-77.8491	0.14	0.07	0.11	0.32
TAE	166.7636	-77.8502	0.18	0.13	0.06	0.37

The average median grain size of dust ranged from 43 µm (silt) to 631 µm (coarse sand) (Table 8). MWAC dust collectors closest to the McMurdo to Scott Base road (e.g. SM03, SM06, SM08, SM12, SM20, and SM23) and in the prevailing wind direction had the finest average median grain size (~45 µm, silt), consistent with the fine silt seen blowing from the road onto the operational area and soil monitoring plots in the summer months. Very little clay-sized particles were found at the monitoring sites, consistent with the little amount of clay-sized (0.01-2 µm) material found in surface soil, and likewise, very little gravel-sized (>2000 µm) material was collected, likely due to the mass of material unable to make it into the collectors. The MWAC adjacent to SM18 was found horizontal, with very little sample collected so not analysed. Due to the lack of sample collected from each dust collector, all sample had to be analysed by the laser diffraction analyser and XRD analysis to determine silica content could not be undertaken.

Table 8: Particle size distribution (%), median particle size (µm) of MWAC passive dust collectors around Scott Base. SM = MWAC associated with soil monitoring plot; SM01-1 = lowest collector at soil monitoring plot 1; SM03-1 = highest collector at soil monitoring plot 1. Particle sizes are given as USDA size divisions, where VFS = very fine sand, FS = fine sand, MS = medium sand, CS = coarse sand and VSC = very coarse sand.

	Range in particle size (µm)									
	Clay 0.01-2 (%)	Silt 2-50	VFS 50-100	FS 100-250	MS 250-500	CS 500-1000	VCS 1000-2000	Gravel >2000	Median Dx (50) (µm)	Average (1-3) (µm)
SM03 - 1	4.01	50.80	30.77	12.83	1.59	0.00	0.00	0.00	45.50	
SM03 - 2	3.90	51.82	26.70	10.26	5.12	2.02	0.19	0.00	44.40	
SM03 - 3	3.68	53.21	29.64	10.98	2.46	0.02	0.00	0.00	43.70	44.53
SM06 - 1	3.06	48.72	26.20	12.51	6.93	2.57	0.00	0.00	48.20	
SM06 - 2	2.43	43.69	22.21	10.22	7.63	5.17	5.92	2.67	54.70	
SM06 - 3	1.99	48.61	33.37	12.75	3.26	0.02	0.00	0.00	49.50	50.80
SM08 - 1	3.01	42.00	24.43	18.39	9.29	2.87	0.00	0.00	56.60	
SM08 - 2	2.86	50.76	27.39	12.15	5.78	1.07	0.00	0.00	46.50	
SM08 - 3	2.93	55.61	27.94	11.05	2.45	0.02	0.00	0.00	42.30	48.47
SM10 - 1	1.00	26.57	26.36	24.23	9.42	1.66	7.01	3.67	88.20	
SM10 - 2	0.78	17.45	29.82	26.31	15.24	8.54	1.02	0.82	105.00	
SM10 - 3	2.01	18.30	0.00	2.80	39.56	13.29	14.73	9.11	412.00	201.73
SM12 - 1	4.08	50.50	26.11	10.95	6.04	2.32	0.00	0.00	45.30	
SM12 - 2	2.98	48.30	25.68	14.33	6.73	1.98	0.00	0.00	48.70	
SM12 - 3	3.49	64.59	25.07	5.17	1.64	0.03	0.00	0.00	36.00	43.33
SM15 - 1	1.23	32.00	29.77	28.43	8.58	0.00	0.00	0.00	71.90	
SM15 - 2	1.59	40.52	27.45	16.25	6.61	2.21	3.73	1.62	59.00	
SM15 - 3	0.97	20.90	18.83	33.19	13.59	8.21	4.32	0.00	131.00	87.30
SM17 - 1	1.02	28.11	28.36	27.32	11.69	1.91	1.56	0.03	81.30	
SM17 - 2	2.49	50.05	28.81	12.30	5.86	0.49	0.00	0.00	47.60	
SM17 - 3	0.96	29.10	36.62	19.83	6.08	5.93	1.49	0.00	69.70	66.20
SM20 - 1	1.36	42.67	31.62	15.06	8.39	0.90	0.00	0.00	55.50	
SM20 - 2	2.61	57.89	25.21	7.51	5.43	1.34	0.00	0.00	40.70	
SM20 - 3	2.21	59.18	27.95	9.09	1.57	0.00	0.00	0.00	40.40	45.53
SM23 - 1	2.55	43.59	24.63	13.86	12.50	2.86	0.00	0.00	54.60	
SM23 - 2	2.58	50.93	27.48	10.20	5.54	2.95	0.31	0.00	46.80	
SM23 - 3	2.93	59.49	29.18	8.09	0.31	0.00	0.00	0.00	40.50	47.30
SM25 - 1	0.77	18.03	22.76	32.40	20.25	4.84	0.70	0.24	128.00	
SM25 - 2	0.83	15.43	22.57	35.44	23.25	2.48	0.00	0.00	134.00	
SM25 - 3	0.85	16.19	10.45	19.75	14.40	12.15	19.44	6.65	279.00	180.33
TAE - 1	0.00	4.46	8.81	24.75	23.83	14.20	15.35	8.41	347.00	
TAE - 2	0.00	5.90	5.22	12.57	10.17	12.48	34.93	18.34	1110.00	
TAE - 3	0.00	6.96	4.86	18.90	23.28	17.94	19.68	8.21	438.00	631.67

4.2.3 Melt water analysis

Melt water samples were taken from three sites in the vicinity of Scott Base, the HFC/Cold Porch (Figure 2, Site 1), near the TAE Hut (Figure 2, Site 2), and from the Front Transition (Figure 2, Site 3). Samples were analysed by Analytica in Hamilton, New Zealand and the full suite of results are found in Appendix 4. A summary of results are given in Table 9 and compared to the maximum acceptable values (MAV) for the New Zealand drinking water (Ministry of Health, 2018) and Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC) MAV for contact recreation water activity (ANZECC, 2000).

Table 9: Total recoverable concentration of trace metals, hardness, pH, total solids, suspended solids and electrical conductivity of Scott Base meltwaters (in mg/L unless specified). HFC = HFC/Cold porch pond site, TAE = TAE meltwater stream, FT = Front transition meltwater stream. MAVs for New Zealand drinking water and recreational activity are given.

Meltwater	Scott Base sites			NZ standards	
contaminants	HFC	TAE	FT	Drinking	Recreational
		(mg/L)		(max. mg/L)	
Antimony	<LOD	0.00012	0.00022	0.02	-
Cadmium	0.000041	0.00029	0.000044	0.004	5
Chromium	0.0035	0.0049	0.0023	0.05	50
Copper	0.0078	0.019	0.0072	2	1000
Lead	0.0021	0.0103	0.0022	0.01	50
Mercury	<LOD	<LOD	<LOD	0.007	1
Nickel	0.0063	0.0084	0.0035	0.08	100
Silver	-	-	-	-	50
Zinc	0.023	0.104	0.012	1.5	5000
Arsenic	0.0014	0.0026	0.0032	0.01	50
Hardness ($CaCO_3$)	90	73.3	60	200	500000
pH	7.7	6.6	7.0	7.0-8.5	6.5-8.5
Total solids	699	507	1192	1000	1000000
Suspended soilds	79	256	73	-	-
EC (µS/cm)	852	384	1930	-	-

pH from Scott Base water samples were relatively neutral and ranged from 6.6 to 7.7, and fell within recreational guidelines. Electrical conductivities ranged from 384 µS/cm to 1930 µS/cm and largely reflected distance to coast and salt influence. Hardness ranged from 60 to 90 mg/L and suspended solids ranged from 73 to 256 mg/L. Total solids ranged from 507 to 1192 mg/L, well below the recreational limits, however the Front Transition site exceeded the MAV for drinking water (Table 9).

In all instances the total recoverable concentration of metals was below both the MAV for drinking water and contact recreational activity (Table 9, Appendix 4). This is promising as research by Sheppard et al. (1997) showed high concentrations of metals including silver (attributed to historic dumping of photographic solutions), cadmium, chromium, copper, zinc and lead (all associated with drains, leaded petrol, building materials), and mercury (historic drains), in the vicinity of Scott Base. Sheppard et al. (1997) attributed high metals in Scott Base meltwater to the low absorbance capacities of soils (due to low clay content), and thus concluded that metals were highly mobile if water was passed through contaminated soils. Note that metals can also be deposited as particulate matter from the atmosphere (e.g. lead and zinc from long-range or local sources), or via natural processes such as weathering out of the rock material from which soil is formed. At disturbed sites such as those found at Scott Base there is also likely a relationship to proximity to road, buildings, and high vehicle use areas, and total recoverable metals (in soil and meltwater), however in this study, low levels of total recoverable metals were found at the melt water sites sampled (Table 9, Appendix 4).

5 Conclusions

Five soil monitoring plots were established at Cape Evans as control sites. Three MWAC dust collectors were installed alongside SMC01, SMC02, and SMC03. Soil was analysed at two depths, 0-2 cm and 2-5 cm, for chemical characteristics such as pH and EC. pH ranged from 7.38 to 8.10 in the 0-2 cm samples, and in the material beneath (2-5 cm) ranged from 7.58 to 8.30. EC varied considerably across the control sites, and was always highest the top 2 cm, ranging from 272.2 to 16910.0 µS/cm in the 0-2 cm samples, to 232.5 to 8180.0 µS/cm in the 2-5 cm soil samples. Depth to ice-cement at the control sites ranged from 30 cm (where bedrock was encountered) to >45 cm. Moisture content ranged from 0.72 % g/g to 14.95% g/g.

Visual site assessments at Cape Evans control sites showed all five sites were relatively undisturbed, with the only site (SMC05) showing low level of disturbance; a viewpoint across McMurdo Sound that showed evidence of disturbed surface stones (low level). All control sites exhibited natural background levels of copper, lead, antimony, cadmium, chromium, zinc, arsenic and nickel, all lower than ecosystem and human health thresholds. Mercury and silver were found at elevated levels on occasion, but likely natural and weathered out of soil parent material.

Surface soil elemental analysis was undertaken at the 25 Scott Base soil monitoring plots and 27 target sites within the operational area. SM02 and SM06, showed the highest concentrations of trace elements, including high lead, mercury, zinc and silver in SM02, a highly disturbed site behind I Hut; and high concentrations of chromium, nickel, zinc, and mercury at site SM06. These values exceeded the ISQC-High trigger values for ecosystem health, and at times the oral consumption (human health) thresholds. Of the 27 target locations analysed there were a range of sites with high concentrations of certain elements. The long-term storage site exhibited very high concentrations of chromium, the back of the I Hut and mechanics workshop entrance had high levels of nickel. Zinc was also found at highest concentrations in the long-term storage area, and at lower concentrations near the hitching rail, back of the I Hut, lab, water intake and gully near the TAE; typical around infrastructure and galvanised materials. Copper, cadmium, antinomy, and arsenic were found at low or <LOD levels at all sites, and well under trigger or threshold values for ecosystem and human health. Silver contamination was found highest in areas associated with fuel or fuel storage. Lead concentrations were highest around the Hanger. Finally mercury was found in <LOD concentrations in all except two sites, near the MWAC site near the TAE/antenna field and the ANDRILL container sites, which had mercury concentrations of 5 and 6 mg/kg of soil respectively.

Dust samples were collected from the 12 MWAC dust collectors within the Scott Base operational area and analysed for particle size distribution. In total the amount of dust collected was low and ranged from 0.30 g to 3.01 g per MWAC. MWAC dust collectors closest to the McMurdo to Scott Base road (e.g. SM03, SM06, SM08, SM12, SM20, and SM23) tended to have greater volumes of dust collected. The median grain size ranged from 43 µm (silt) to 631 µm (coarse sand). MWAC dust collectors closest to the McMurdo to Scott Base road (listed above) and in the prevailing wind direction had the finest average median grain size (~45 µm, silt), consistent with the fine silt seen blowing from the road into the operational area and these soil monitoring plots.

Melt water samples were taken from three sites in the vicinity of Scott Base, the HFC/Cold Porch, near the TAE Hut, and from the Front Transition. These were analysed for a range of parameters including, total recoverable trace metals, hardness, pH, total solids, suspended solids and electrical conductivity, and compared to both recreational (contact) water quality guidelines and maximum acceptable values (MAV) for drinking water (where applicable). pH ranged between 6.6 and 7.7, hardness between 60 and 90 mg/L, and total solids ranged between 5.7 and 1192 mg/L; all within recreational guidelines. Total solids in the Front Transition site exceeded the MAV for drinking water. In all instances total recoverable metal concentrations were below both the MAV for drinking water and contact recreational activity.

Data provided in this report, the previous year one report, and from others in the greater baseline survey team, will serve as a useful and sensitive baseline against which future changes attributable to the Scott Base redevelopment can be measured. It is my recommendation that monitoring is continued at the Scott Base soil monitoring plots throughout the duration of the redevelopment of Scott Base, and at a lesser frequency, at the five soil monitoring control sites at Cape Evans.

6 References

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7 Appendix 1: Visual Site Assessments of Cape Evans control sites

Table II. Impact assessment criteria scoring system used for Visual Site Assessment (modified from Campbell *et al*. (1993), and Kiernan & McConnell (2001)).

Impact assessment criteria		Severity and extent of impacts (class)			
		1	2	3	4
A	Disturbed surface stones	none visible (0)	few (< 10)	many (10–25)	abundant (> 25)
B	Impressions of removed rocks	none visible	just visible	distinct	fresh
C	Boot imprints	none visible	just visible	distinct	fresh
D	Visibly disturbed area	< 5 m^2	5–10 m^2	20–100 m^2	> 100 m^2
E	Surface colour difference (Munsell units difference)	none visible (0)	weak contrast (-1)	moderate contrast (-2)	strong contrast (> 3)
F	Other surface impressions (e.g. hollows from backfilled excavations)	none visible	weakly visible	distinct	very fresh
G	Walking tracks	not visible	weakly defined	moderately defined	strongly defined
H	Foreign objects	none visible (0)	few (< 10)	some (10–25)	many (> 25)
I	Visible fuel spills	none visible	faintly distinguished	visible	very obvious
J	Salt deposition	none visible	faintly distinguished	visible	abundant
K	Visual biological disturbance	none visible	< 1 m^2	1–5 m^2	> 5 m^2
L	Cumulative impact	disturbance not visible	weakly evident	clearly visible	disturbed and very obvious
M	Stratigraphic disturbance	negligible	within one unit	within two units	multiple units
N	Morphological or textural change	negligible	just evident	moderate change	very obvious
O	Rock cairns	none	rare or small	moderately common	very common
P	Other disturbances (e.g. paint marks)	none	rare or small	moderately obvious	very obvious

Site: SMC01

Sampled on 29/12/19

GPS: 166.41034 -77.63822

Wind: 2kt, Cloud: 65%, Temperature: +2℃

Site description:

Undisturbed site on a hill approximately 70 m behind the West Beach helo pad and refuge huts. Soil is formed from scoriaceous basalt, gravelly, dry, and is seemingly unvegetated, with patches of visible salt. Soil has an obvious crust. pXRF undertaken. MWAC installed. Elevation = 8 m.

Soil characteristics:

Moisture content = 0.7% g/g

pH (0-2 cm) = 7.38

pH (2-5 cm) – 7.58

EC (0-2 cm) = 16910 µS/cm

EC (2-5 cm) = 8180 µS/cm

Depth to ice-cement = 47 cm

Visual site assessment:

Site	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
SMC01	1	1	1	1	1	1	1	1	4	1	1	1	1	1	1	1

Impact Assessment Criteria: A = disturbed surface stones; B = impressions of removed rocks; C = boot imprints; D = visibly disturbed area; E = surface colour difference; F = walking or vehicle tracks; G = litter; H = visible fuel spills; I = salt deposition; J = biological disturbance; K = cumulative impact; L = stratigraphic disturbance; M = textural change; N = rock cairns; O =% change in vegetation cover; P = evidence of exotic species. **Severity and Extent of Impacts**: rating of 1 is least disturbed/impacted, rating of 4 is severely disturbed/impacted.

Visual site assessment summary:

Undisturbed site, abundant salt deposition.

<u>Site</u>: SMC02

Sampled on 29/12/19

GPS: 166.42375 -77.63412

Wind: 2kt, Cloud: 65%, Temperature: +2℃

<u>Site description</u>:

Undisturbed site on the side of a mound (about 20 degrees) and near a snow bank, approximately 50 m from the Home Beach seashore. Soil is formed from scoriaceous basalt, gravelly, and has limited algae and potentially moss. SMC plot has no salt but patches of visible salt surround. Soil has no crust. pXRF undertaken. MWAC installed on mound above the SMC site. Elevation = 2 m.

<u>Soil characteristics</u>:

Moisture content = 8.3% g/g

pH (0-2 cm) = 8.10

pH (2-5 cm) – 8.28

EC (0-2 cm) = 272.2 µS/cm

EC (2-5 cm) = 175.1 µS/cm

Depth to ice-cement = bedrock at 30 cm

<u>Visual site assessment</u>:

Site	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
SMC02	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1

Impact Assessment Criteria: A = disturbed surface stones; B = impressions of removed rocks; C = boot imprints; D = visibly disturbed area; E = surface colour difference; F = walking or vehicle tracks; G = litter; H = visible fuel spills; I = salt deposition; J = biological disturbance; K = cumulative impact; L = stratigraphic disturbance; M = textural change; N = rock cairns; O =% change in vegetation cover; P = evidence of exotic species. **Severity and Extent of Impacts**: rating of 1 is least disturbed/impacted, rating of 4 is severely disturbed/impacted.

<u>Visual site assessment summary</u>:

Undisturbed site, visible salt deposition.

Site: SMC03

Sampled on 29/12/19

GPS: 166.42976 -77.63321

Wind: 2kt, Cloud: 65%, Temperature: +3℃

Site description:

Undisturbed flat in natural wetland, surrounded by patterned ground, east of Home Beach approximately 20 m from the glacier. Near RF Black patterned ground experiment (1960-1962). Soil is formed from scoriaceous basalt, gravelly, very wet, and has algae, mites and springtails. Faint salt in places but none visible in the SMC plot. Soil has no crust. pXRF undertaken. MWAC installed on a nearby mound. Approximately 300 m from Scott's Terra Nova Hut. Elevation = 10 m.

Soil characteristics:

Moisture content = 15.0% g/g

pH (0-2 cm) = 8.10

pH (2-5 cm) – 8.30

EC (0-2 cm) = 747 µS/cm

EC (2-5 cm) = 214.3 µS/cm

Depth to ice-cement = 45 cm, fills with water

Visual site assessment:

Site	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
SMC03	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1

Impact Assessment Criteria: A = disturbed surface stones; B = impressions of removed rocks; C = boot imprints; D = visibly disturbed area; E = surface colour difference; F = walking or vehicle tracks; G = litter; H = visible fuel spills; I = salt deposition; J = biological disturbance; K = cumulative impact; L = stratigraphic disturbance; M = textural change; N = rock cairns; O =% change in vegetation cover; P = evidence of exotic species. **Severity and Extent of Impacts**: rating of 1 is least disturbed/impacted, rating of 4 is severely disturbed/impacted.

Visual site assessment summary:

Undisturbed site, faint distinguished salt deposition.

Site: SMC04

Sampled on 29/12/19

GPS: 166.43344 -77.63463

Wind: 2kt, Cloud: 65%, Temperature: +2℃

Site description:

Undisturbed site on the edge of a small lake behind Skua Lake and Home Beach, directly behind SMC03. Lots of mounds surround the lake with Skua nests. Pink algae surrounds the edge of the lake, with dead grey algae further out and in the SMC and along the vegetation transect. Soil is formed from scoriaceous basalt, gravelly, wet, algae. Some salt in places in the SMC and along the transect. Soil has no crust. pXRF undertaken. Elevation = 11 m.

Soil characteristics:

Moisture content = 9.6% g/g

pH (0-2 cm) = 7.48

pH (2-5 cm) – 7.96

EC (0-2 cm) = 4770 µS/cm

EC (2-5 cm) = 460 µS/cm

Depth to ice-cement = 35 cm

Visual site assessment:

Site	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
SMC04	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1

Impact Assessment Criteria: A = disturbed surface stones; B = impressions of removed rocks; C = boot imprints; D = visibly disturbed area; E = surface colour difference; F = walking or vehicle tracks; G = litter; H = visible fuel spills; I = salt deposition; J = biological disturbance; K = cumulative impact; L = stratigraphic disturbance; M = textural change; N = rock cairns; O =% change in vegetation cover; P = evidence of exotic species. **Severity and Extent of Impacts**: rating of 1 is least disturbed/impacted, rating of 4 is severely disturbed/impacted.

Visual site assessment summary:

Undisturbed site, visible salt deposition.

Site: SMC05

Sampled on 29/12/19

GPS: 166.40596 -77.63894

Wind: 2kt, Cloud: 65%, Temperature: +2℃

Site description:

A relatively undisturbed site on the edge of hill on the west end of West Beach, about 40 m from helo pad and refuge huts. Noted a few surface stones disturbed, likely due to visitors climbing this hill as a viewpoint across the Sound. Very limited vegetation, very little cyanobacteria. SMC is on a 15 degree slope, with snow near the base. Approximately 15 m from the sea. SMC transect goes slightly upslope. Soil is formed from scoriaceous basalt, gravelly, damp in places, some salt in places along the transect. Soil has no crust. pXRF undertaken. Elevation = 2 m.

Soil characteristics:

Moisture content = 10.2% g/g

pH (0-2 cm) = 7.70

pH (2-5 cm) – 7.89

EC (0-2 cm) = 442 µS/cm

EC (2-5 cm) = 232.5 µS/cm

Depth to ice-cement = 45 cm

Visual site assessment:

Site	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**
SMC05	2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1

Impact Assessment Criteria: A = disturbed surface stones; B = impressions of removed rocks; C = boot imprints; D = visibly disturbed area; E = surface colour difference; F = walking or vehicle tracks; G = litter; H = visible fuel spills; I = salt deposition; J = biological disturbance; K = cumulative impact; L = stratigraphic disturbance; M = textural change; N = rock cairns; O =% change in vegetation cover; P = evidence of exotic species. **Severity and Extent of Impacts**: rating of 1 is least disturbed/impacted, rating of 4 is severely disturbed/impacted.

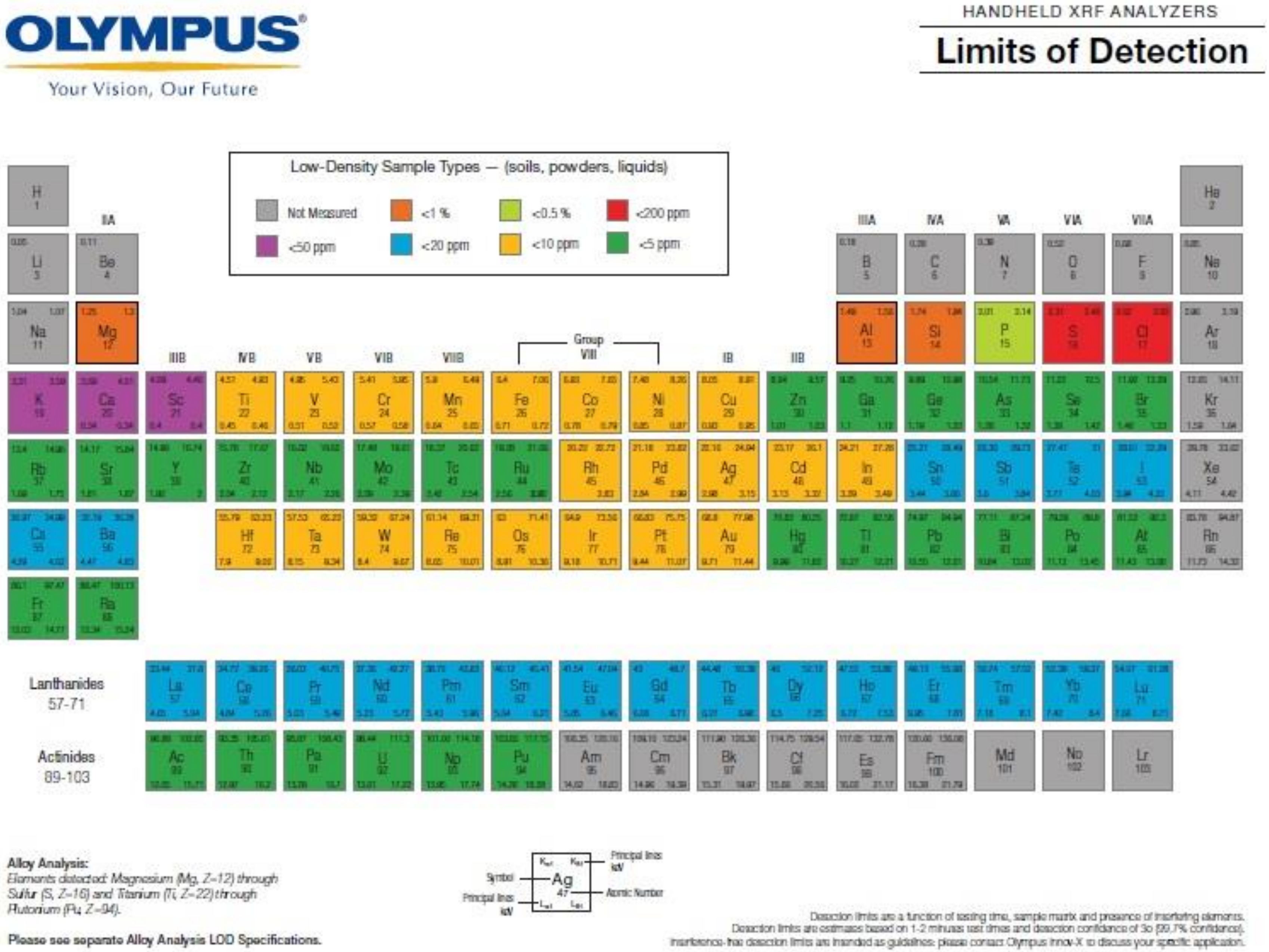
Visual site assessment summary: Relatively undisturbed site, a few disturbed surface stones, faintly distinguished salt deposition.

8 Appendix 2: Material relating to elemental analysis of surface soil using pXRF

2.1 Portable XRF detection limits

2.2 Guidelines and risks associated with certain elements

2.1 Portable XRF detection limits



2.2 Guidelines and risks associated with certain elements

Toxicological intake values and soil contaminant standards for 12 priority contaminants in oil

Source: Ministry for the Environment. 2011. Toxicological Intake Values for Priority Contaminants in Soil. Wellington: Ministry for the Environment

Toxicological intake values describe a concentration at which substances might pose no appreciable risk or minimal risk to human health depending on the substance being considered.

Specifically:

Threshold substances are those for which it is possible to identify a level of exposure at or below which they do not produce an adverse effect; toxicological intake values typically prescribe a daily level of exposure over a lifetime where there is no appreciable risk to human health.

Non-threshold substances, which include most carcinogens, pose an inherent risk at any level of exposure. For these values the toxicological intake values describe a level of exposure for which there is considered to be minimal risk. This may be determined from quantitative risk modelling for risk levels of 1 in 100,000 or application of a default factor of 10,000 to estimates of the lower 95% confidence limit ($BMDL_{10}$) of the benchmark dose that gives rise to a 10% response (BMD_{10}) and consideration of the use of allometric scaling to account for inter-species differences.

These recommendations are based on a literature review of the toxicity of contaminants, and reference health standards developed by various international agencies. Toxicological intake values for the inhalation route are not considered as inhalation will be a negligible route of exposure for non-volatile or semi-volatile contaminants. The recommended toxicological intake values and background exposures are shown in Tables S1 and S2, and Table B2 shows the soil contaminant standards for inorganic substances across five land-uses (rural, residential, high-density residential, recreation and commercial (MfE, 2011).

Table S1: Summary of toxicological intake values for threshold priority contaminants

Contaminant	Oral (µg/kg bw/day)	Skin absorption factor	Background exposure (µg/kg bw/day)	
			Child	Adult
Cadmium	0.8	0.001	0.41	0.26
Copper	150	NA	56	20
Chromium III	1500	NA	1.2	0.53
Chromium VI	3	NA	No data	No data
Lead	1.9	NA	0.97	0.41
Mercury	2	NA	0.05	0.065
Boron	200	NA	80	17
Dieldrin	0.05	0.1	0.0036	0.0014
∑DDT (complex)	0.5	0.018	0.051	0.019
Pentachlorophenol	0.3	0.24	0.02	0.02
Dioxins and dioxin-like PCBs	30 pg TEQ/kg bw/month	0.02 (PCDDs) 0.05 (PCDFs) 0.07 (PBCs)	10 pg (I-TEQ)/kg bw/month	10 pg (I-TEQ)/kg bw/month

NA – not applicable, TEQ – toxic equivalents

Table S2: Summary of toxicological intake values for non-threshold priority contaminants

Contaminant	Oral risk-specific dose (µg/kg bw/day)	Inhalation risk-specific dose (µg/kg bw/day)	Skin absorption factor
Arsenic	0.0086	NA	0.005
Benzo(a)pyrene	0.0048	NA	0.026

Table B2: Soil contaminant standards for health ($SCSs_{(health)}$) for inorganic substances

	Arsenic	Boron	Cadmium (pH 5)[1]	Chromium III	Chromium VI	Copper	Inorganic lead	Inorganic mercury
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Rural residential / lifestyle block 25% produce	17	>10,000	0.8	>10,000	290	>10,000	160	200
Residential 10% produce	20	>10,000	3	>10,000	460	>10,000	210	310
High-density residential	45	>10,000	230	>10,000	1,500	>10,000	500	1,000
Recreation	80	>10,000	400	>10,000	2,700	>10,000	880	1,800
Commercial / industrial outdoor worker (unpaved)	70	>10,000	1,300	>10,000	6,300	>10,000	3,300	4,200

Notes: All concentrations refer to dry weight (ie, mg/kg dry weight).

Arsenic (As) – Arsenic is considered to be a non-threshold contaminant with internal cancers, such as bladder and liver cancers, the most sensitive endpoints. Estimates of carcinogenic potency are primarily derived from human epidemiological data from exposure via drinking water. A daily risk-specific dose of 0.0086 micrograms per kilogram bodyweight mg/kg bw), derived from the arsenic concentration in drinking water determined to represent “negligible risk” by Canadian agencies (0.3 micrograms per litre, mg/L), is recommended. This value is based on the most current risk modelling data, and includes an external comparison population. Dermal absorption is considered to be negligible, although the skin absorption factor of 0.5% could be used as a refinement in the development of soil contaminant standards.

Cadmium (Cd) – Cadmium is considered to be a threshold contaminant, with kidney damage as a result of long-term exposure considered the most sensitive endpoint. Unlike for most other substances, toxicokinetic modelling has typically been used to estimate tolerable intakes. Given the long-term effects of cadmium, it is more appropriate to express intakes as monthly intakes. The Joint Expert Committee on Food Additives (JECFA) of the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) recommend a provisional tolerable monthly intake (PTWI) of 25 mg/kg bw and it is recommended that this value is used for the derivation of soil contaminant standards. Dermal absorption is expected to be negligible, although a dermal absorption factor of 0.0012 could be used. Dietary intake is the primary source of background exposure to cadmium and was estimated to be 12.5 mg/kg bw/month for a child (aged 1–3 years, 13 kg) and 7.9 mg/kg bw/month for an adult.

Chromium (Cr) – Chromium in its trivalent state is an essential element, but at high concentrations, and particularly in its hexavalent state, it is toxic. There is limited data on which to base tolerable daily intakes for chromium. The United States Environmental Protection Agency (US EPA) recommends a toxicological intakes of 1,500 mg Cr(III)/kg bw/day and 3 mg Cr(VI)/kg bw/day and these values are recommended for use in New Zealand. Dermal absorption of chromium (III) is expected to be a negligible route of exposure for soil contamination and is not considered relevant here. It is recommended that the adverse effects arising from dermal exposure to chromium (VI) are considered separately to those arising from oral exposure and that allergic contact dermatitis is the main effect of interest. A soil contaminant standard protective from allergic contact dermatitis could be established, but as these effects are likely to be elicited at higher concentrations than those arising from oral exposure, a soil contaminant standard protective against effects arising from oral exposure will also protect against allergic contact dermatitis. Estimates of dietary intake of chromium (III) are based on nutrient reference values for different age groups from the US Institute of Medicine (IOM) as recommended by the Australian National Health and Medical Research Council (NHMRC).

Copper (Cu) – Copper is an essential element, and adverse effects can arise both from copper deficiency and from excess copper intake. Liver damage is the critical endpoint for intake of high levels of copper in animal and human studies. The tolerable upper limit of 10 mg/day, based on liver function and converted using a 70-kg bodyweight, is used to derive a toxicological intake value of 0.15 mg/kg bw/day. Dermal absorption and inhalation are expected to be negligible routes of exposure and are not considered relevant for soil contamination. Dietary intake is the primary source of background exposure to copper. Estimated dietary intake for a child aged 5–6 years was 0.06 mg/kg bw/day and for an adult (25–44 years) was 0.02 mg/kg bw/day, which is within the recommended dietary intake for copper.

Lead (Pb) – The most significant critical effect of low concentrations of lead is considered to be reduced cognitive development and intellectual performance in children. The JECFA was the only authoritative body that had previously derived a tolerable intake for lead; the PTWI of 25 µg/kg bw/week, and the TDI derived from this, has been the value most widely used by different international agencies. However, this value has been recently withdrawn. A toxicological intake of 1.9 µg/kg bw/day is instead recommended to be used in the derivation of soil contaminant standards in New Zealand. This intake is based on dose-response modelling by JECFA and is the dietary intake at which the IQ decreases 3 points in the population. This general shift in distribution was deemed to be of concern by JECFA, although the effects were considered to be insignificant at an individual level. Exposures of individuals are more relevant in the context of contaminated sites. Inhalation exposure and dermal absorption are expected to be negligible, and could be ignored in the derivation of soil contaminant standards for contaminated land in New Zealand, as has been done by other jurisdictions. Dietary intake is the primary source of background exposure to lead and was estimated to be 0.97 µg/kg bw/day for a child and 0.41 µg/kg bw/day for an adult.

Inorganic mercury (Hg) – Inorganic mercury is considered to be a threshold contaminant, with renal effects in rats considered the most sensitive endpoint. A tolerable daily intake of 2 µg/kg bw/day is recommended as this is the value most widely used by different international agencies. Inhalation exposure is expected to be negligible on contaminated sites due to limited volatility of the forms of mercury likely to be present (mercury II). Dermal absorption is also expected to be negligible. Dietary intake, in particular seafood, and dental amalgam are the primary sources of background exposure to mercury. Dietary intakes of inorganic mercury were estimated to be 0.05 µg/kg bw/day for a child and 0.025 µg/kg bw/day for adults. Intake from dental amalgam was considered to be negligible for children and 0.04 µg/kg bw/day for adults, giving rise to a total inorganic mercury intake of 0.065 µg/kg bw/day for adults.

Boron (B) – Boron is considered to be a threshold contaminant, with foetal weight decrease in rats the most sensitive endpoint. A tolerable daily intake of 0.2 mg/kg bw, based on benchmark dose modelling in two studies by the US EPA, is recommended. Inhalation exposure and dermal absorption of boron are expected to be negligible and are not considered relevant here. Dietary intake is expected to be the primary source of background exposure to boron and, in the absence of information specific to NewZealand, it is recommended that TDIs of 0.08 mg/kg bw for children and 0.017 mg/kg bw for adults, based on international data, are used.

Drinking water standards

Source: Ministry of Health. 2018. *Drinking-water Standards for New Zealand 2005 (revised 2018)*. Wellington: Ministry of Health.

Table 2.2: Maximum acceptable values for inorganic determinands of health significance

Name	MAV (mg/L)	Remarks
antimony	0.02	
arsenic	0.01	For excess lifetime skin cancer risk of 6 x 10^{-4}. PMAV, because of analytical difficulties
barium	0.7	
boron[1]	1.4	
bromate	0.01	For excess lifetime cancer risk of 7 x 10^{-5}. PMAV
cadmium	0.004	
chlorate	0.8	PMAV. Disinfection must never be compromised. DBP (chlorine dioxide)
chlorine	5	Free available chlorine expressed in mg/L as Cl_2. ATO. Disinfection must never be compromised
chlorite	0.8	Expressed in mg/L as ClO_2. PMAV. Disinfection must never be compromised. DBP (chlorine dioxide)
chromium	0.05	PMAV. Total. Limited information on health effects
copper	2	ATO
cyanide	0.6	Total cyanides, short-term only
cyanogen chloride	0.4	Expressed in mg/L as CN total. DBP (chloramination)
fluoride[2]	1.5	
lead	0.01	
manganese	0.4	ATO
mercury	0.007	Inorganic mercury
molybdenum	0.07	
monochloramine	3	DBP (chlorination)
nickel	0.08	
nitrate, short-term[3]	50	Expressed in mg/L as NO_3. The sum of the ratio of the concentrations of nitrate and nitrite to each of their respective MAVs must not exceed one
nitrite, long-term	0.2	Expressed in mg/L as NO_2. PMAV (long term)
nitrite, short-term[3]	3	Expressed in mg/L as NO_2. The sum of the ratio of the concentrations of nitrate and nitrite to each of their respective MAVs must not exceed one
selenium	0.01	
uranium	0.02	PMAV

Notes:

Section 2.4 explains abbreviations that appear in the table.

1. The WHO guideline value (provisional) is 0.5 mg/L.
2. For oral health reasons, the Ministry of Health recommends that the fluoride content for drinking-water in New Zealand be in the range of 0.7–1.0 mg/L; this is *not* a MAV.
3. Now short-term only. The short-term exposure MAVs for nitrate and nitrite have been established to protect against methaemoglobinaemia in bottle-fed infants.

4. For information about determinands of possible health significance but which do not have a MAV, refer to the datasheets in the Guidelines.

Other determinands

Table 2.5: Guideline values for aesthetic determinands

Determinand	GV	Unit	Comments
aluminium	0.10	mg/L	Above this, complaints may arise due to depositions or discoloration
ammonia	1.5	mg/L	Odour threshold in alkaline conditions
calcium			See hardness
chloride	250	mg/L	Taste, corrosion
chlorine	0.6–1.0	mg/L	Taste and odour threshold (MAV 5 mg/L)
2-chlorophenol	0.0001	mg/L	Taste threshold
	0.01		Odour threshold
colour	10	TCU	Appearance
copper	1	mg/L	Staining of laundry and sanitary ware (MAV 2 mg/L)
1,2-dichlorobenzene	0.001	mg/L	Taste threshold
	0.002		Odour threshold (MAV 1.5 mg/L)
1,4-dichlorobenzene	0.0003	mg/L	Odour threshold
	0.006		Taste threshold (MAV 0.4 mg/L)
2,4-dichlorophenol	0.0003	mg/L	Taste threshold
	0.04		Odour threshold
ethylbenzene	0.002	mg/L	Odour threshold
	0.08		Taste threshold (MAV 0.3 mg/L)
hardness (total) (Ca + Mg) as $CaCO_3$	200	mg/L	High hardness causes scale deposition, scum formation. Low hardness (<100) may be more corrosive
	100–300		Taste threshold
hydrogen sulphide	0.05	mg/L	Taste and odour threshold
iron	0.2	mg/L	Staining of laundry and sanitary ware
magnesium			See hardness
manganese	0.04	mg/L	Staining of laundry
	0.10		Taste threshold (MAV 0.4 mg/L)
monochlorobenzene	0.01	mg/L	Taste and odour threshold
pH	7.0–8.5		Should be between 7 and 8. Most waters with a low pH have a high plumbosolvency. Waters with a high pH have a soapy taste and feel. A pH less than 8 is preferable for effective disinfection with chlorine
sodium	200	mg/L	Taste threshold
styrene	0.004	mg/L	Odour threshold (MAV 0.03 mg/L)
sulphate	250	mg/L	Taste threshold
taste and odour			Should be acceptable to most consumers
temperature			Should be acceptable to most consumers, preferably cool
toluene	0.03	mg/L	Odour

Determinand	GV	Unit	Comments
	0.04		Taste threshold (MAV 0.8 mg/L)
total dissolved solids	1000	mg/L	Taste may become unacceptable from 600–1200 mg/L
trichlorobenzenes (total)	see below		
1,2,3-trichlorobenzene	0.01	mg/L	Odour threshold
1,2,4-trichlorobenzene	0.005	mg/L	Odour threshold
1,3,5-trichlorobenzene	0.05	mg/L	Odour threshold
2,4,6-trichlorophenol	0.002	mg/L	Taste threshold
	0.3	mg/L	Odour threshold (MAV 0.2 mg/L)
turbidity	2.5	NTU	Appearance. See compliance criteria for effects on disinfection
xylene	0.02	mg/L	Odour threshold (MAV 0.6 mg/L)
zinc	1.5	mg/L	Taste threshold. May affect appearance from 3 mg/L

Notes:

1. Potable water that does not contain or exhibit any determinands that exceed these guideline values is defined as wholesome water.
2. Section 2.4 explains abbreviations that appear in the table.

Abbreviations used in tables 2.1–2.5

The following abbreviations are used in tables 2.1–2.5.

ATO Concentrations of the substance at or below the health-based guideline value that may affect the water's appearance, taste or odour: see Table 2.5

DBP Disinfection by-product. Any difficulty meeting a DBP MAV must never be a reason to compromise adequate disinfection. Trihalomethanes and haloacids are DBPs. Some DBPs may also have other sources

GV Guideline value

MAV Maximum acceptable value

MC-LR Microcystin-LR

NTU Nephelometric turbidity unit

PMAV Provisional MAV (because it is provisional in the WHO Guidelines (WHO 2017) or the WHO has no guideline value but the DWSNZ have retained a MAV or developed their own)

STXeq Saxitoxin-equivalent

TCU True colour unit. The colour after the sample has been filtered. One TCU is equivalent to 1 Hazen unit and to 1 Pt/Co unit. For more information, see Guidelines, section 18.2.1

THM Trihalomethane, of which there are four: bromoform, bromodichloromethane, chloroform and dibromochloromethane

WHO World Health Organization

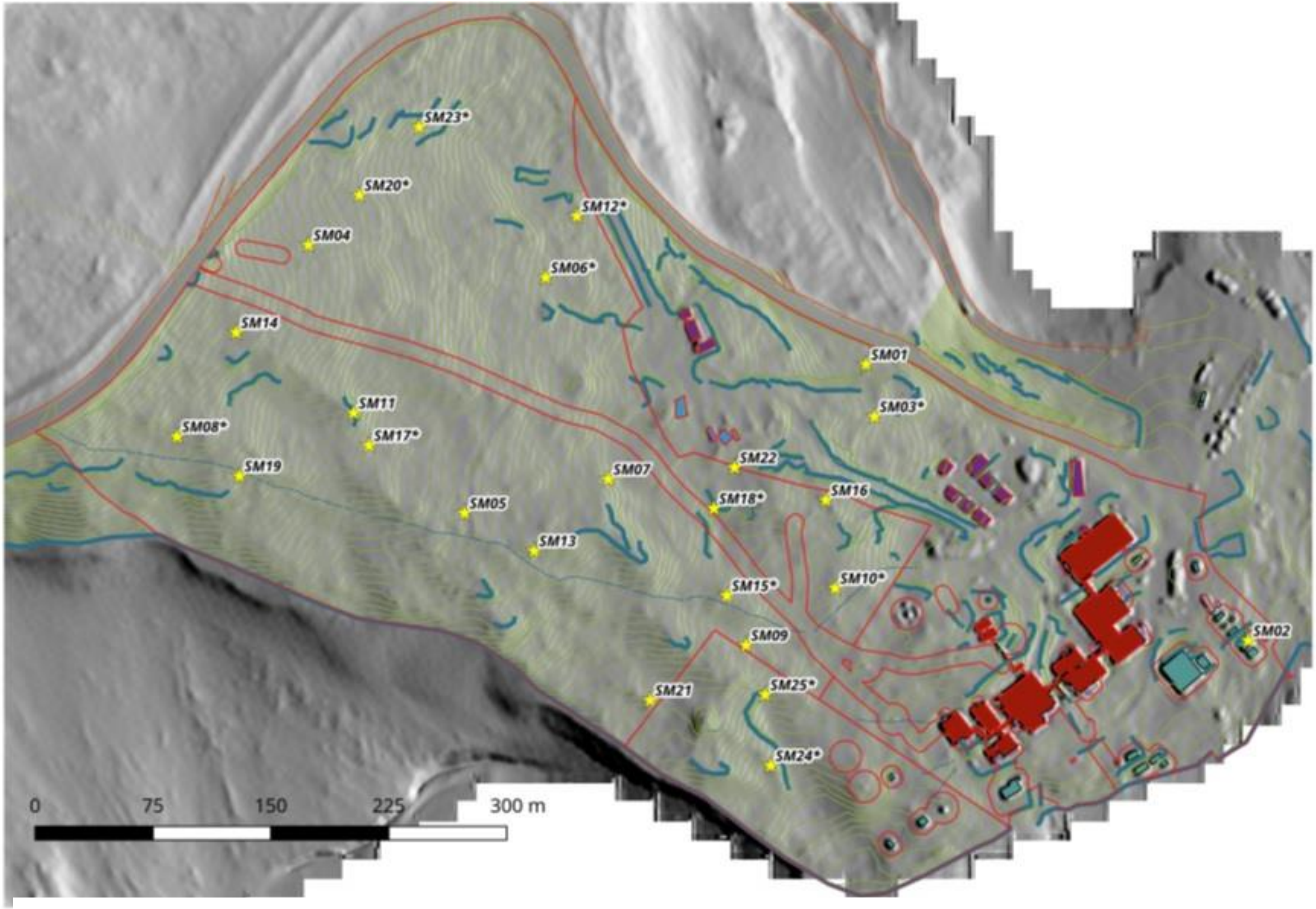
9 Appendix 3: Material relating to dust collection and analysis

3.1 Map showing Scott Base MWAC locations

3.2 Mastersizer 3000 report explanation

3.3 Soil particle size classifications – USDA and ISSS

3.4 Particle size analysis - Full data set



Appendix 3.1: Map of operational area and the 25 soil monitoring plots (provided by Pierre Roudier of Manaaki Whenua, Landcare Research. *means MWAC dust sampler is adjacent to the monitoring plot.

3.2: Explaining the Mastersizer3000 report

Sample Details

This section gives the details of sample identification, and where it can be found on the computer hosting the data, down to the run/record number in a sequence of measurements. This section also details when the sample was analysed, and the source of the data.

Obscuration: The measure of the amount of sample added to the tank. Unscattered light is focused onto the obscuration detector. If there is no sample present then the obscuration is zero. When the sample is introduced some of the light is absorbed, reflected, diffracted, scattered, etc. The optimum range of the instrument is with obscuration values between 10% and 25% - this ensures sufficient signal to noise for good measurements, but eliminates the possibility of multiple scattering. The obscuration value is also used to calculate the volume concentration.

Analysis Model: How the data is expected to be grouped. A general purpose model allows the calculation of results which may have more than one modal size, while selecting a monomodal analysis model is more accurate if you are expecting a dataset grouped on one value.

Weighted residual – Returns a number being the % residual in the comparison of the fitted and corrected data when the weighting of the detector set is factored into the calculation.

Result Statistics

Concentration: This is the calculated concentration of material in the dispersant and is based on the Beer-Lambert Law. Note that this is a derived and not a measured parameter.

Specific Surface.Area: The specific surface area is defined as the total area of the particles divided by the total weight. It is calculated using the particle density.

Mean Diameters:

D(v, 0.1) 10% of the distribution is below this value.

The v in the expression D(v, 0.1) shows that this refers to the volume distribution. This can be replaced by ***s*** for surface, ***l*** for length, or ***n*** for number distributions.

D(v, 0.5) 50% volume percentile, or median of the volume distribution.

D(v, 0.9) 90% of the distribution is below this value.

The Derived Diameters table also lists the 20% and 80% values.

D[4,3] the volume weighted mean diameter. The diameter of the sphere having the same volume as our real particle.

D[3,2] the surface weighted, or Sauter, mean diameter. The diameter of the sphere having the same surface area as our real particle.

Mode: The most likely size in the distribution, and is the size at the peak value of the frequency curve.

Span: The span gives a description of the width of the distribution which is independent of the median size. It is a dimensionless number which illustrates whether the distribution spread is narrow or wide.

Uniformity: Describes the distribution type independently of the median size, it is a measure of the absolute deviations from the median.

3.3: Soil particle size classifications – USDA and ISSS

USDA system			ISSS system		
Category	Size (µm)	Size (mm)	Category	Size (µm)	Size (mm)
Clay	0.01-2	<0.002	Clay		<0.002
Silt	2-50	0.002-0.05	Silt	2-20	0.002-0.02
Very fine sand	50-100	0.05-0.10			
Fine sand	100-250	0.10-0.25	Fine sand	20-200	0.02-0.20
Medium sand	250-500	0.25-0.50			
Coarse sand	500-1000	0.50-1.00	Coarse sand	200-2000	0.20-2.00
Very coarse sand	1000-2000	1.00-2.00			
Gravel	>2000	>2.00	Gravel	>2000	>2.00

USDA – US Dept. of Agriculture

ISSS – International Soil Science Society

9.4 Particle size analysis - Full data set

Appendix 4: Analytica report - melt water analysis