Radiation Consultancy & Training Services

Health Physics Report on

Radiological Assessment of Fill Materials at No. 11 Nelson Parade, Hunters Hill

For State Property Authority NSW

28th November 2011

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REPORT DETAILS

Title: **Radiological Assessment of Fill Materials at No. 11 Nelson Parade, Hunters Hill**

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Reference: **0073K-1-3-93**

REVISION / CHECKING HISTORY

REVISION NUMBER	DATE	REVIEWED BY	APPROVED FOR ISSUE	DISTRIBUTION – NUMBER OF COPIES		
				Client	Site Auditor	ANSTO File
1.0	14.11.2011	R Blackley	n	--	--	1(e)
1.1	15.11.2011	S McIntosh	y	1(e + h)	1(e)	1(e)
1.2	28.11.2011	R Blackley	y	1(e + h)	1(e)	

Table Notes: *(e) – electronic copy*
(h) – hard copy

Executive Summary

The Australian Nuclear Science and Technology Organisation (ANSTO) was approached by the NSW State Property Authority (SPA) to undertake a radiological and chemical assessment of fill materials present at certain parts of the property located at No. 11 Nelson Parade, Hunters Hill, NSW, for the purpose of assessing the materials for potential hazards or requirements for remediation.

Review of historical land use and related recent studies undertaken in the area indicate that some areas adjacent to the property at No. 11 Nelson Parade have been impacted by radioactive residues from the processing of uranium bearing ore for extraction of radium by the Radium Hill Company up until 1915.

The radiological and chemical assessment of the fill material is required to be undertaken to assist in future decision making prior to the commencement of remediation activities on adjacent properties.

Analysis of the site indicates background levels of naturally occurring radioactive material for the majority of the building footprint, with some smaller areas under the driveway, pool and patio having slightly elevated levels of radioactivity.

If these areas of slightly elevated radioactivity were to undergo remediation and the arising material be disposed of, the material would be classified as *Restricted Solid Waste* in accordance with the NSW waste classification system.

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Abbreviations	
ACM	Asbestos Containing Material
ANSTO	Australian Nuclear Science and Technology Organisation
BaP	Benzo(a)Pyrene
Bq	Becquerel
BTEX	Benzene, Toluene, Ethylbenzene and Toluene
CoC	Chain of Custody
COPC	Contaminants of Potential Concern
CT	Contaminant Threshold
DECC	Department of Environmental and Climate Change
mbgl	Metres below ground level
PID	Photoionisation Detector

GHD	GHD Pty Ltd
LG	Location Grouping
LLD	Lower Limit of Detection
LOR	Laboratory Limit of Reporting
mg/kg	Milligrams per kilogram
mSv	millisievert
NORM	Naturally Occurring Radioactive Material
OCP	Organochlorine Pesticides
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
SCC	Specific Contaminant Concentration
SOP	Standard Operating Procedure
TCLP	Toxicity Characteristic Leaching Procedure
TPH	Total Petroleum Hydrocarbon
UCL	Upper Confidence Limit
µg/L	Micrograms per litre
µSv/hr	Microsievert per hour
WCR	Waste Classification Report

1. Introduction

1.1 General

The Australian Nuclear Science and Technology Organisation (ANSTO) was approached by the NSW State Property Authority (SPA) to undertake a radiological and chemical assessment of fill materials present at certain parts of the property located at No. 11 Nelson Parade, Hunters Hill, NSW, for the purpose of assessing the materials for potential radiological or chemical hazards or requirements for remediation.

Review of historical land use and related recent studies undertaken in the area indicate that some adjacent areas surrounding the property at No. 11 Nelson Parade have been impacted by radioactive residues from the processing of uranium bearing ore for extraction of radium by the Radium Hill Company up until 1915. Subsequent to the adjacent area being vacated by the Radium Hill Company, the area was landscaped and filled with materials of unidentified origin. As a result, there is potential for non-uniform distribution of radiological and chemical materials in the soil.

The radiological and chemical assessment of the fill material is required to be undertaken to assist in future decision making prior to the commencement of remediation activities on adjacent properties.

1.2 Objectives

The radiological assessment is being undertaken to provide suitable data to enable decisions to be made regarding the future management of fill material underneath the building footprint of No. 11 Nelson Parade.

The objective of the program is to assess the radiological content of fill material below the building footprint and surrounding areas and compare this against natural levels of background radiation in the surrounding environment.

This radiological assessment is designed to complement previous assessments undertaken on adjacent properties.

The radiological and chemical contaminants of concern in the fill material during the analysis are based upon a historical assessment of the site.

1.3 Scope of Work

The scope of work is to suitably assess the property at No. 11 Nelson Parade and compare the results for significance against natural background levels. Further assessment of areas of elevated levels of radioactivity may be undertaken, for both radiological and chemical contaminants, in order to classify the material (in situ) that may undergo remediation if required, in accordance with the NSW waste classification.

1.4 Limitations

This radiological assessment is given strictly in accordance with, and subject to, the following limitations:

- The assessment was prepared for the SPA (“the Client”) in accordance with the scope of work agreed between ANSTO and the Client.

- ANSTO assumes no responsibility for conditions it was not authorised and directed by the Client to investigate.
- This report is based, in part, on unverified information supplied to ANSTO from several sources during the project research. Therefore, ANSTO does not guarantee its completeness or accuracy, and assumes no responsibility for errors or omissions related to this externally supplied information.
- This report should not be altered, amended or abbreviated, issued in part or issued incomplete in any way without the prior written consent of ANSTO. ANSTO accepts no responsibility for any circumstances that arise from the issue of a modified report without the permission of ANSTO.

2. Site Information

2.1 Site Identification and Description

The site consists of the following parcel of land in the residential suburb of Hunters Hill, Sydney, as shown in Figure 1;

- No. 11 Nelson Parade, Hunters Hill, including under the residential building footprint;

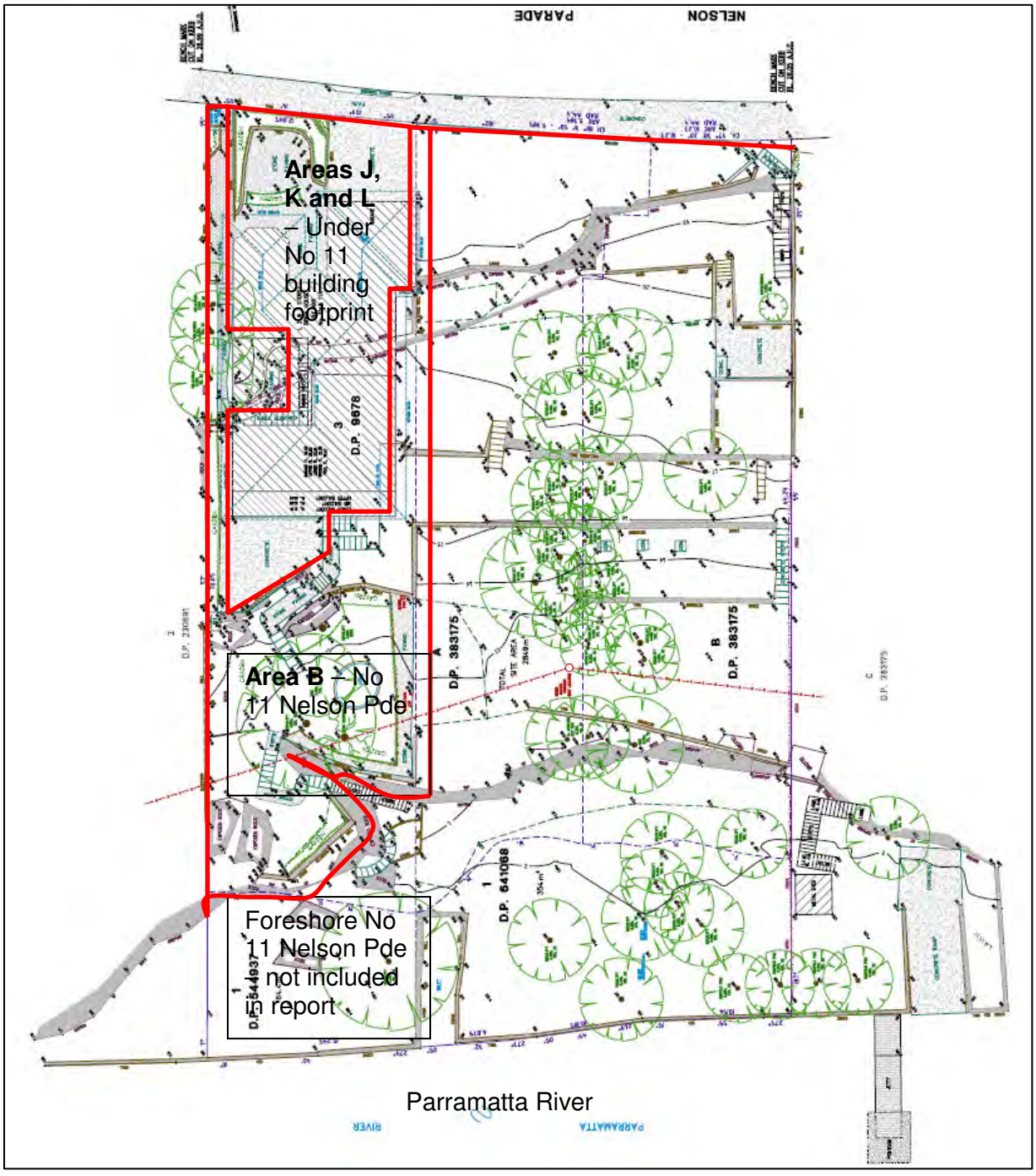
The area in its pre-remediated state generally is a series of sloping terraces from the northern perimeter and high point at Nelson Parade, sloping southward towards the Parramatta River. The southern boundary of the study area is the cliff line separating the upper section of the property from the foreshore area beside the Parramatta River.

The soil appears generally shallow in terms of loose sediment deposits to a depth of 1m below ground level (BGL) in much of the area, with regions of rocky outcropping and retaining walls that have been backfilled that contribute to the terracing. Mature trees are scattered around the site. No 11 contains a functional dwelling, located on the upper section of the property.

Photo 1. Backyard of property at No. 11 Nelson Parade

Photo 2. Building on No. 11 Nelson Parade (from the backyard)

Figure 1. The locations of the soil materials classified and type of analysis undertaken



2.2 Site History

In the early part of last century, the Radium Hill Company established a processing works in the area of Nelson Parade at Hunters Hill in NSW for the purposes of extracting radium from uranium-bearing ore for medical and other uses. The uranium came from Radium Hill in South Australia and was shipped to the site in Hunters Hill. A report by Sinclair Knight and Partners in 1987 described the ores processed at the plant as being a mixture of ilmenite, magnetite and rutile in association with black mica and carnotite. Historically the process has incorrectly been described as being a smelting process; however, as described by Ratcliff (1914), the extraction process was a chemical process. During the processing of the concentrates, a number of solid and liquid waste streams were generated and disposed of on the site. The Radium Hill Company went bankrupt and the plant was closed in June 1915, leaving some residual materials containing isotopes of the uranium decay chain.

In addition to the radium extraction plant, from 1895 until 1966 a tin smelter operated on what is now Kelly's Bush Reserve, which borders Nelson Parade at Hunters Hill. The smelter processed tin ore that contained thorium-bearing and uranium-bearing monazite minerals. Low levels of these radiological contaminants remained in the resultant tin slag produced by the smelter.

A carbolic acid plant also operated on reclaimed land on the lower portion of Lot 7 Nelson Parade from the late 1880's until 1900. The disposal of chemical contaminants from this plant is not known, however chemical contaminants including hydrocarbons and metals are suspected to be present in the area as a result.

When the potential hazards from the residual materials from the radium extraction plant were recognised in the 1950's, the soil and associated material was relocated to one area, predominately the current Lots 7 and 9 on Nelson Parade. Extensive soil relocation has occurred on the properties adjacent to the study area during the construction of walls, terraces and swimming pools.

Following a Parliamentary Inquiry in 2008, the NSW Department of Health engaged the Australian Nuclear Science and Technology Organisation (ANSTO) to carry out an extensive radiological survey and characterisation of the area on and surrounding Nelson Parade, Hunters Hill, including in the Parramatta River immediately adjacent to the site.

2.3 Site Setting

This section provides an overview of the site area, topographical, hydrogeological and geological setting.

2.3.1 Site Area and Condition

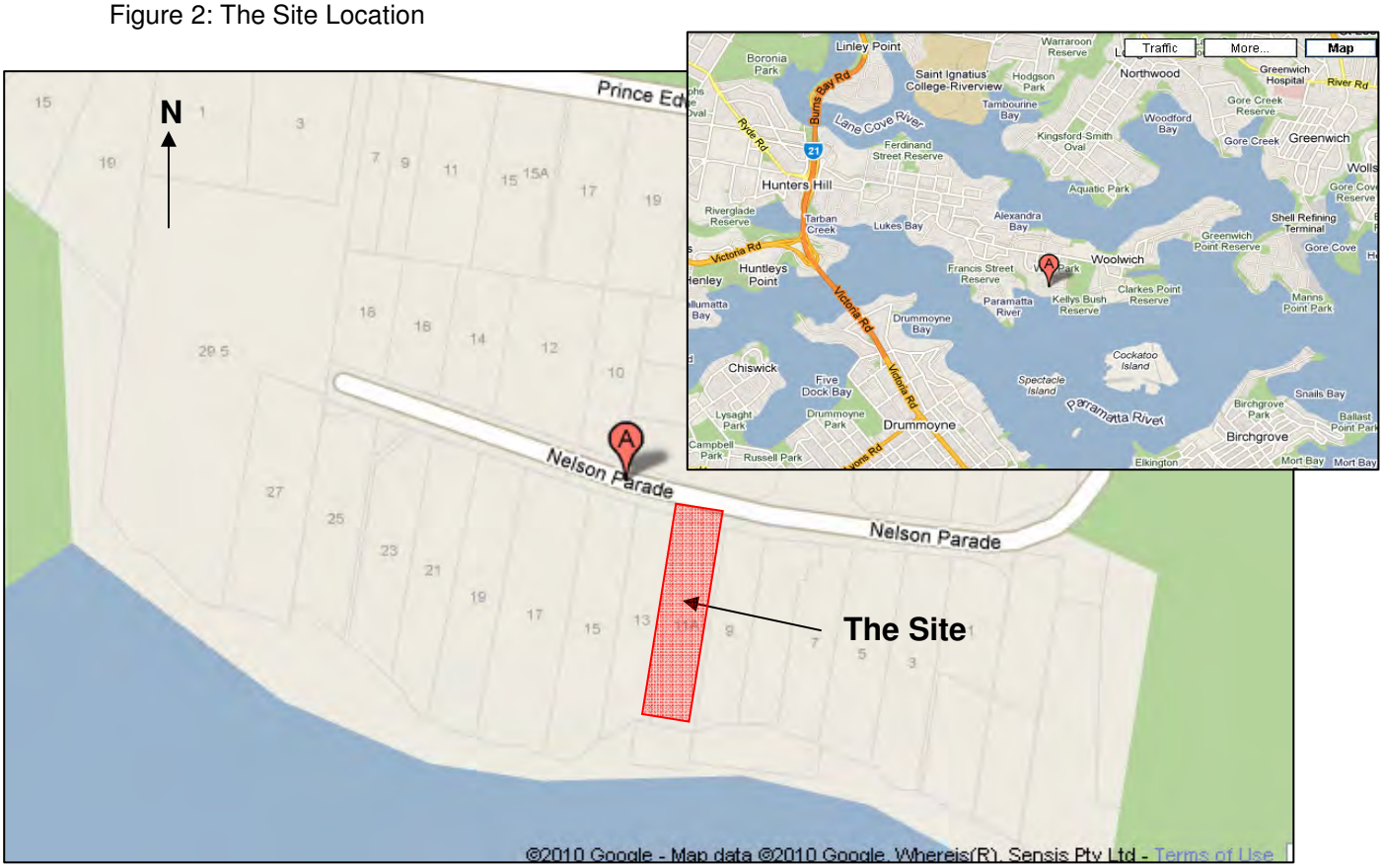
The land being assessed comprises of a single block of land, comprising of the building footprint of the dwelling on No. 11 Nelson Parade and its surrounding grounds, as shown in Figures 1 and 2.

The dwelling on No.11 Nelson Parade is a four storey residential dwelling on the upper terraced section of the block, built in 1968 on previously vacant land.

The block of land is not currently privately owned and there is nobody currently residing on this land.

The entire site is currently surrounded by a secure fence to prevent access to the area.

Figure 2: The Site Location



2.3.2 Geology, Topography and Hydrogeology

The 1:100,000 Soil Landscape Series (1993) map of Sydney identifies the localised landscape as '*undulating to rolling low hills on Hawkesbury sandstone and discontinuous earthy sands'*. Similarly, the 1:100,000 Geological Series Sheet (1983) of Sydney shows the underlying bedrock to be Triassic Hawkesbury sandstone, which is described as '*medium to coarse-grained quartz sandstone with very minor shale and laminate lenses'*.

The Site is situated on a Hawkesbury sandstone outcrop on the banks of the Parramatta River. The topography of foreshore land between Nelson Parade and the water's edge drops off sharply due to the outcropping sandstone and cutting activities undertaken during development of the Site.

Due to the proximity of the Site to the Parramatta River, groundwater is expected to infiltrate into the sandstone bedrock and flow in a southerly direction towards the river. However, due to the steep topographical change from Nelson Parade to the river, it is expected that only the immediate foreshore area of the Site would be affected by groundwater infiltration.

Observations during the field investigation identified a silty sand fill layer over natural sandstone bedrock. The depth of the fill layer varied from 0.00 m to 1.70 m. Refer to **Section 5.1** and **Appendix F** for detailed descriptions of the lithology.

2.4 Previous Investigations

The following previous relevant investigations have been undertaken at or around the Site:

- Radiation Branch of the Department of Health, 1966.
- Scott, B. W., *Investigation of Radioactive contamination at Nelson Parade Woolwich*, September 1977.
- Sinclair Knight and Partners, *Radium waste clean up Nelson Parade, Hunters Hill, Review of Environmental Factors*, August 1987.
- Environmental Resources Management Australia, *Radiological Contamination Assessment 11 Nelson Parade, Hunters Hill, NSW, Australia*, August 2008.
- GHD Pty Ltd (GHD), *Contamination Investigation of Foreshore Land Fronting 5 and 13 Nelson Parade, Hunters Hill*, June 2009.
- ANSTO, *Radiological survey of Nelson Parade, Hunters Hill – Stages 1 and 2,* June 2009.
- ANSTO, *Waste Classification of Fill Materials at Nelson Parade, Hunters Hill*, September 2011.

A review of these reports has been undertaken by ANSTO and CH2MHILL, with summaries provided in the following section.

2.4.1 Radiation Branch of the Department of Health (1966)

Between September 1965 and May 1966 a radiological investigation was conducted by officers of the Radiation Branch of the Department of Health. The investigation included analysis of soil surveys for radium, dose rates inside private residential buildings (including the then existing buildings on Nos 7 and 9 Nelson Parade) and analysis of plants for radium content. The report concluded that although localised areas of higher dose rates were observed, the average dose rates at the site did not constitute a significant health hazard.

2.4.2 Scott, W. B, Radiological Investigation (1977)

At the request of the then Health Commission of NSW, Mr B W Scott undertook a comprehensive radiological assessment of the former site of the radium extraction plant and surrounding blocks of land, including monitoring for radon and radon decay products inside the private residences of No.5, No.7, No.9 and No.11 Nelson Parade. Elevated readings of radon were detected inside No.7 Nelson Parade, only. The residential building on No.7 was subsequently vacated and demolished in 1983 (it is unclear when No. 9 was demolished, but some time after No. 7).

2.4.3 Sinclair Knight and Partners (1987)

Sinclair Knight and Partners undertook an extensive radiological investigation of the former site of the radium extraction plant and surrounding blocks of land in 1987. The findings of the report are summarised as:

- 70% of the samples collected at the site contain more than 2 Bqg^{-1} of radium-226, with an average of 4 Bqg^{-1} of radium-226 for the site. Some more elevated levels were measured on No.9 and to a lesser extent on No.7 and No.11. The

spread of material was consistent with its use as fill behind retaining walls and over rock shelves.

- The levels of activity were not higher than those typically encountered in uranium mining and milling.

A detailed map of the distribution of radium-226 radioactivity across the site was included in the report.

2.4.4 Environmental Resources Management Australia Assessment (2008)

Environmental Resources Management Australia (ERM) was commissioned by Henry York Davis to undertake a radiological assessment of the property at No. 11 Nelson Parade on behalf of the then private owners of the property. Australian Radiation Services (ARS) undertook external dose rate monitoring across the backyard (only) of No.11, where elevated dose rates of up to 1.49 µGy/h were detected, predominately along the eastern boundary immediately adjacent to the property at No.9 Nelson Parade. Soil samples were taken along this eastern boundary of the property and analysed against a single background sample. Activities of up to 9 Bq/g of Ra-226 were detected in the backyard of the property. Radon monitoring inside the dwelling indicated levels at or close to natural background levels.

2.4.5 GHD Contamination Investigation (2009)

GHD was commissioned by the NSW Department of Commerce (DoC) to undertake a contamination assessment of foreshore land fronting Nos 5 and 13 Nelson Parade, Hunters Hill. A review of historical land use records undertaken by GHD indicated that both properties could be contaminated through the presence of residual radioactive materials from the extraction of uranium ore by the Radium Hill Company between 1911 and 1916. Numerous filling and reclamation activities were reported to have been undertaken on the lower foreshore lands.

In order to characterise the foreshore fill material, a total of six soil borings were completed using a hand auger. Two samples were collected from each boring location and submitted for both chemical and radiological analysis. In addition, a gamma radiation field survey was undertaken at each property using a SE Inspector EXP handheld radiation detector unit.

Fill materials observed at the foreshore of each property were described as follows:

- **No. 5 Nelson Parade foreshore:** brown to tan fine-grained fill sands with crushed sandstone, brick fragments, ash, charcoal and glassy black gravels.
- **No. 13 Nelson Parade foreshore:** dark brown sandy topsoil underlain by orange / tan and white sands.

Asbestos containing material (ACM) was not observed on either property and a PID screen at each sample interval indicated low (< 1.7 parts per million) readings. Contaminants of potential concern (CoPC) that were identified at No. 5 and No. 13 Nelson Parade at concentrations exceeding the adopted human health investigation (HIL – Residential [A]) or phytotoxicity assessment criteria included:

- **No. 5 Nelson Parade foreshore:** Lead, arsenic, mercury, zinc and PAH

- **No. 13 Nelson Parade foreshore:** Lead and arsenic

Lead concentrations above the HIL A criteria (300 mg/kg) were reported in one sample collected at No. 5 Nelson Parade foreshore and two samples collected from No. 13 Nelson Parade foreshore. The maximum lead concentration was 570 mg/kg. A total of four samples exceeded the HIL A criteria for arsenic (100 mg/kg). Two of the arsenic exceedances were from No. 5 Nelson Parade foreshore and two were from No. 13 Nelson Parade foreshore. The maximum arsenic concentration was 470 mg/kg.

The following Provisional Phytotoxicity Investigation Level (PBIL) exceedances were reported for arsenic, mercury and zinc:

- Arsenic: Two exceedances of the associated PBIL (20 mg/kg) in samples collected at No. 5 Nelson Parade foreshore and two exceedances for samples collected at No. 13 Nelson Parade
- Mercury: Four exceedances of the PBIL (1 mg/kg) in samples collected at No.5 Nelson Parade foreshore
- Zinc: Two exceedances of the PBIL (200 mg/kg) in samples collected at No.5 Nelson Parade foreshore

Total petroleum hydrocarbon (TPH) concentrations were reported above the laboratory limit of reporting (LOR) in all samples collected from No. 5 Nelson Parade foreshore and a single sample collected from No.13 Nelson Parade foreshore. The maximum TPH (C_{10}-C_{36}) concentration was 940 mg/kg (sample 5HA1), less than the adopted criteria of 1000 mg/kg.

Total polycyclic aromatic hydrocarbon (PAH) concentrations were detected above the adopted HIL A criteria (20 mg/kg) in all samples collected at No. 5 Nelson Parade foreshore. The maximum PAH concentration was reported to be 216.9 mg/kg in the near surface (0.1 metres below ground level [mbgl]) sample. Similarly, concentrations of Benzo(a)pyrene (BaP) in all samples from No.5 Nelson Parade foreshore exceeded the adopted HIL A criteria (1 mg/kg), with a maximum concentration of 16 mg/kg. All samples analysed from No.13 Nelson Parade foreshore reported concentrations of total PAH and BaP below the HIL A criteria.

Concentrations of benzene, toluene, ethylbenzene and xylene (BTEX), organochlorine pesticides (OCP) and polychlorinated biphenyls (PCB) in all samples analysed were less than the laboratory LOR.

GHD attributed the elevated concentrations of PAH, lead, arsenic, mercury, zinc and PAH at No.5 Nelson Parade foreshore to the presence of ash and charcoal observed within the fill materials.

Radiological analytical results were reported below the adopted site criterion for all samples. The gamma ray field survey indicated a greater level of activity at the foreshore of No. 13 Nelson Parade than No.5 Nelson Parade, with 12 out of 26 surveyed locations exceeding the assessment criterion of 0.7 microgray per hour (µGy/hr).

All measured Toxicity Characteristic Leaching Potential (TCLP) results were below the laboratory LOR.

GHD concluded that fill materials at No. 5 Nelson Parade foreshore could be disposed of off-site under the general immobilisation approval (1999/05). The immobilisation approval allows for waste classification of materials impacted by PAH using TCLP values only.

Due to the elevated levels of gamma radiation in fill material at No.13 Nelson Parade foreshore, GHD concluded that the material would require disposal as *Restricted Solid Waste* at a suitable registered facility and subject to NSW DECCW approval.

2.4.6 ANSTO Radiological Survey of Nelson Parade (2009)

ANSTO was commissioned by the NSW Department of Health and the NSW DECC to undertake a radiological survey of the areas surrounding the properties covered by this report. Surveys were not undertaken on the Lots No's 5, 7, 9 and 11 Nelson Parade.

Surveys were completed in the yards and houses of residents in Nelson Parade adjacent to the properties of No's 5, 7, 9 and 11. The survey results within the survey area varied significantly, depending upon their location. Most areas indicated nil or negligible presence of radioactivity above natural background levels. The areas of the highest radiological activity measured were from roadways in Hunters Hill; however this was assessed to be a result of the inclusion of thorium-bearing slag from the tin smelter formerly located in nearby Kelly's Bush. The other areas of highest radiological readings were from properties immediately adjacent to the former radium extraction plant site in Nelson Parade.

The report details the areas surveyed, the methodology used and the potential exposure levels arising from external gamma radiation and the internal exposure from potential inhalation of radioactive dusts and radon, and the ingestion of particles and foodstuffs. It also provides guidance on the spatial and vertical distribution of contamination and the level of uranium and thorium in the soil.

The exposures from ingestion, dust inhalation and external exposure pathways were analysed, with the total exposure assessed to be less than 1 mSv per year.

Indicative radon concentrations were measured inside targeted dwellings, with all results being below the recommended action level for possible remediation action. However, in one dwelling elevated radon levels which were just below this action level were measured. Core samples were taken in the areas of elevated radioactivity and the cores analysed. From the activity screening and analysis, the maximum activities were calculated, the radionuclide ratios identified and the vertical extent of the contamination estimated at each site. Elevated radiological results were detected on properties immediately adjacent to the radium extraction plant site, including in the backyards of No's 13 and 15 Nelson Parade.

2.4.7 ANSTO Waste Classification of Fill Materials at Nelson Parade, Hunters Hill (2011)

ANSTO was commissioned by the NSW State Property Authority to undertake an in situ radiological and chemical waste classification of the fill materials located on the former site of the radium extraction plant, namely the properties at No's. 7 and 9, the backyard of No. 11 and the entire foreshore area fronting No's. 5, 7, 9, 11 and 13 Nelson Parade.

The report identified that the nature of the fill materials across the site appeared to be consistent. Field observations indicated that the only visual chemical contamination was attributed to pockets of ash, charcoal and suspected coking waste. Chemical results showed that elevated concentrations of heavy metals, BaP and Total PAH tended to correlate with these isolated pockets of visually contaminated material. The nature of the fill materials with regard to radiological content was variable across the site. Localised concentrations of elevated radioactivity were present on the site, often where historical back-filling behind walls had occurred. The average total radioactivity across the site was 40 Bq/g (median activity of 13 Bq/g) with a 95% UCL value of 97 Bq/g, which is below the criteria for *Restricted Solid Waste* (100 Bq/g). This figure is primarily due to the high standard deviation of 66 Bq/g.

The following waste classifications were determined:

Chemical

- **No's. 11, 13, 15 and Foreshore areas** = *General Solid Waste*
- **No's. 7 and 9 Nelson Pde** = Material from one area was classified as *Restricted Solid Waste*. The remaining material in the area was classified as *General Solid Waste.*

Radiological

- **No's. 11 (excluding building footprint), 13, 15 and Foreshore areas** = *Restricted Solid Waste*

No's. 7 and 9 had previously been classified as Restricted Solid Waste on a radiological basis by the Site Auditor, based upon the results of the 1987 Sinclair Knight and Partners report.

3. Contaminants of Concern and Investigation Criteria

3.1 Contamination Sources

Reviews of historical land use and related recent studies undertaken in the area indicate that some of the area may be impacted by radioactive residues from the processing of uranium bearing ore for extraction of radium by the Radium Hill Company up until 1915. In addition the area may also be impacted by chemical residues from the carbolic acid plant. Subsequent to the adjacent properties being vacated by the carbolic acid plant and Radium Hill Company, the study area was landscaped and filled with materials of unidentified origin. As a result, there is potential for non-uniform distribution of radiological materials and also the potential for chemical impact on the soil.

The assessment is designed to complement previous assessments undertaken on adjacent properties and to provide a suitable level of information to guide future decisions on the management of the property.

3.1.1 Radiological

Radioactive material exists naturally within soils. These are due to the presence of isotopes from the uranium, thorium and actinium decay chains, and from potassium-40. Due to the transportation of uranium-bearing ores from the Radium Hill mines in South Australia to the site at Hunters Hill and the subsequent processing for extraction of radium-226, there is potential for elevated levels of radioactive material from the uranium decay chain. No evidence exists to indicate the presence of significant amounts of other isotopes. Therefore the radiological contaminants of concern are the isotopes of the uranium-238, thorium-232 and uranium-235 decay chains. These are summarised in Table 1 below, including the limits of reporting for the preferred laboratory assessment methodology.

Table 1: ANSTO laboratory methods for proposed isotopic analysis and Limits of Reporting

Radionuclide	Lab Method	Lab Limit of Detection (mg/kg)
Th-234	VP-2747	2.9
Pa-234m	VP-2747	22
Th-230	VP-2747	14
Pb-214	VP-2747	0.3
Bi-214	VP-2747	0.3
Pb-210	VP-2747	5.4
Ac-228	VP-2747	0.7
Th-228	VP-2747	30
Ra-224	VP-2747	2.4
Pb-212	VP-2747	0.2
Bi-212	VP-2747	1.9
Tl-208	VP-2747	0.2

U-235	VP-2747	0.6
Th-227	VP-2747	0.8
K-40	VP-2747	6.0

3.1.2 Chemical

A carbolic acid plant was located on the foreshore area of No7 Nelson Parade. Due to the subsequent relocation of soil around the site, and the potential contaminants from the radium extraction plant and carbolic acid plant on surrounding properties, the following broad range of analyte groups are the main chemical contaminants of concern, as summarised in Table 2 below. CH2M Hill was contracted by ANSTO to undertake the chemical analysis of material.

Table 2. Accredited laboratory methods for proposed chemical analytical suites and Limits of Reporting

Analyte Group	Lab Method	Lab Limit of Reporting (mg/kg)
Heavy Metals (As, Cd, Cr, Cu, Pb, Ni, Zn)	EG005T	1-5
Mercury	EG035T	0.1
Polycyclic Aromatic Hydrocarbons (PAH)	EP075 (SIM) B	0.5
Total Petroleum Hydrocarbons (TPH)	EP080/071	10-100
Organochlorine Pesticides (OCP)	EP068A	0.05 – 0.2
Asbestos	AS 4964	--
Total Polychlorinated Biphenyls (PCB)	EP066	0.1
Total Characteristic Leaching Procedures (TCLP) – Heavy Metals	EG005C	0.1 mg/L
Total Characteristic Leaching Procedures (TCLP) – PAH	EP075 (SIM) B	0.5 – 1 µg/L

3.1.3 Asbestos

Although none was identified during previous investigations and from the historical review, there does exist the possibility that asbestos from either former buildings or from unknown fill materials used on adjacent properties may be present. However, no direct evidence exists to indicate that asbestos is present. Asbestos is included in the decision-making process only if visible asbestos-containing material is identified during the site assessment.

3.2 Contaminants of Potential Concern

The predominant radiological contaminants of concern are from the uranium-238 decay chain, and to a lesser extent uranium-235 and the thorium-232 decay chains, all of which are present at some level as a result of the activities undertaken on the adjacent properties. As the ores containing these isotopes have been processed, it is unknown if these decay chains are currently in a status of secular equilibrium. Therefore isotopes from different parts of each of

the decay chains were analysed to determine the ratios between each isotope. This eliminated the potential underestimation or overestimation of the total radioactivity present on the site if the decay chains are not in secular equilibrium and only a single isotope is analysed.

The exact chemical contaminants that may be present on the site are not known. However, from analysis of the historical uses of the site, particularly from the carbolic acid plant, and from previous chemical assessments of the site, a broad range of chemical contaminants were chosen for analysis, as listed in Table 2. There is no evidence which would suggest a need to analyse for any other specific chemical contaminants.

3.3 Comparison of Fill Material to Natural Background Levels

Isotopes in the U-238, U-235 and Th-232 decay chains exist naturally in the environment. Radiological contaminants from the radium extraction plant are also exclusively from the U-238, U-235 and Th-232 decay chains. Unlike artificial radiological material which generally does not occur in nature, the measured levels of radioactivity cannot be measured as total activity without consideration of natural background levels. In addition, as the levels of radioactivity that naturally occur can vary considerably, even within a small area, there is a need to determine if measured levels are in excess of, or just a result of, this natural variability.

Initial survey results indicated minimal elevation in levels of radioactivity under the building footprint at No.11 Nelson Parade when compared to natural background levels of radioactivity. Therefore initial assessments were completed undertaken to determine if measured levels were distinguishable from background levels.

The methodology for determining if radioactivity is indistinguishable from background, contained in *MARSSIM (2000)* and the *U.S. Nuclear Regulatory Commission NUREG-1505 Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys (1998)*, is known as 'Scenario B'. The Null Hypothesis in Scenario B is that 'Measurements in the survey area are indistinguishable from those in the background samples'.

For areas where levels of radioactivity in fill material were distinguishable from background levels, further assessment was undertaken of the material and guidance provided on the waste classification of the material, if future management of the site included disposal of fill material.

3.4 Waste Classification Criteria

The waste classification of fill materials is included in this report to provide additional guidance, only, if any future decisions are made to remediate any part of the site. This inclusion does not imply that remediation of any part of the site is required.

3.4.1 Soil – Radiological

The DECC Guideline *'Waste Classification Guidelines, Part 3: Waste Containing Radioactive Material'* (October 2008) defines how to classify wastes containing radioactive material. Samples were analysed for the ^{238}U decay chain, ^{232}Th decay chain and ^{235}U decay chain and assessed against the protocol outlined in NSW DECC (2008) '*Waste Classification Guidelines, Part 3: Waste Containing Radioactive Material'.*

The Guideline states that 'liquid or non-liquid wastes with:

- A Specific Activity of 100 Bq/g^{-1} AND;
- Consist of, or containing more than, the prescribed activity of a radioactive element in Schedule 1 of the Radiation Control Regulation 2003 whether natural or artificial;

must be classified as *hazardous waste'*.

For material containing radionuclides in the U-238, Th-232 and U-235 decay chain, the Total Specific Activity should be used, which is the sum of radioactivity for each radionuclide present.

For material containing a total specific activity of less than 1 Bq/g^{-1}, the material can be classified as *General Solid Waste*, in accordance with the guidelines.

Material containing a total specific activity of between 1 Bq/g^{-1} and 100 Bq/g^{-1} can be classified as *Restricted Solid Waste*, in accordance with the guidelines.

3.4.2 Soil – Chemical

Chemical analytical results were used to determine the potential waste classification of the material in accordance with the NSW DECC, *Waste Classification Guidelines*, 2008. Contaminant threshold (CT) values for waste classification without completion of leaching tests have been adopted from Table 1 of NSW DECC (2008). Maximum values for leachable concentrations (TCLP) and total concentrations (SCC) when used together have been adopted from Table 2 of the NSW DECC (2008).

Table 3 summarises the adopted criteria for the CoPC associated with the Site.

Table 3

Waste Classification Criteria

Waste Classification Report

Analyte	General Solid Waste			Restricted Solid Waste		
	CT1 (mg/kg)	TCLP1 (mg/L)	SCC1 (mg/kg)	CT2 (mg/kg)	TCLP2 (mg/L)	SCC2 (mg/kg)
Monocyclic Aromatic Hydrocarbons						
Benzene	10	0.5	18	40	2	72
Toluene	288	14.4	518	1152	57.6	2,073
Ethylbenzene	600	30	1080	2400	120	4,320
Xylene	1000	50	1800	4000	200	7,200
Total Petroleum Hydrocarbons						
TPH (C_6-C_9)	—	—	650	—	—	2,600
TPH (C_{10}-C_{36})	—	—	10,000	—	—	40,000
Polycyclic Aromatic Hydrocarbons						
Benzo(a)pyrene	0.8	0.04	10	3.2	0.16	23
PAH Total	—	—	200	—	—	800
Polychlorinated Biphenyls						
Total PCB	—	—	< 50	—	—	< 50
Organochlorine Pesticides						
Aldrin + Dieldrin	—	—	250	—	—	1,000
DDT	—	—	< 50	—	—	< 50
DDD	—	—	< 50	—	—	< 50
DDE	—	—	< 50	—	—	< 50
Heavy Metals						
Arsenic	100	5	500	400	20	2,000
Cadmium	20	1	100	80	4	400
Chromium (VI)	100	5	1,900	400	20	7,600
Lead	100	5	1,500	400	20	6,000
Mercury (inorganic)	4	0.2	50	16	0.8	200
Nickel	40	2	1,050	160	8	4,200

3.4.3 Soil – Asbestos

As noted above, asbestos was to be included in the assessment only if visible asbestos containing materials (ACM) was identified during the field investigation. NSW DECC (2008) states that if asbestos is detected in the sample collected, the material should be designated as *Special Waste – Asbestos* and disposed of at a suitable waste receiving facility.

3.5 Comparison of Analytical Data

The methodology, known as 'Scenario B', for determining if radioactivity is indistinguishable from background is contained in *MARSSIM (2000)* and the *U.S. Nuclear Regulatory Commission NUREG-1505 Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys (1998)*. This methodology utilises the Wilcoxon Rank Sum Test followed by the Quantile Test. The Null Hypothesis in Scenario B is that 'Measurements in the survey area are indistinguishable from those in the background samples', which is rejected if the data fails either of the above mentioned statistical tests.

The statistical methodology used for the comparison of the analytical concentrations to the adopted waste classification criteria is based on the methods referred to in the NSW EPA, *Contaminated Sites: Sampling Design Guidelines*, 1995 and National Environment Protection Council (NEPC), *National Environment (Assessment of Site Contamination) Protection Measure (NEPM)*, 1999, namely:

- comparison of the 95% upper confidence limit of the arithmetic mean concentration (95% UCL) values of each contaminant (with the exception of asbestos) to the nominated site criterion;
- comparison of the calculated standard deviations to a value of 50% of the nominated site criteria; and
- determination of the required number of samples (Procedure B) to allow calculation of an average concentration.

4. Assessment Methodology

4.1 Scope of Fieldwork

All fieldwork was conducted in accordance with ANSTO's Quality Management system, CH2M Hill's standard operating procedures, and relevant State regulations. Each separate area of the survey was slightly different. However the following general methodology was used:

1. Radiological mapping of the areas using 2 inch NaI detectors and Geiger-Muller detectors mounted on a tripod at a distance of 1 metre above the ground for a count time of 300 seconds each count;
2. A continuous 'walk-over' survey technique using 2 inch NaI detectors at a height of 5 centimetres above the ground along spatial lines at a nominal separation of 1 m, but with allowance for inaccessible areas. The radiological mapping assisted in determining the spatial distribution of radiological materials and reduction when determining the critical size of radiological hotspots;
3. Soil sampling at regular intervals using a hand auger;
4. Laboratory analysis of soil samples for radiological and chemical impacts; and
5. Data interpretation and reporting.

4.2 Data Quality Objectives (DQOs) Process

The Data Quality Objectives (DQOs) process is a seven step planning approach used to prepare plans for environmental data collection activities. The purpose of establishing Data Quality Objectives (DQO) is to ensure that the field investigations and subsequent analyses are undertaken in a way that ensures the reporting of data is reliable.

As identified in Appendix IV of the *Guidelines for the NSW Site Auditor Scheme (2nd Edition)*[1] a series of steps are involved in the DQO process. They are:

1. State the problem
2. Identify the decision
3. Identify inputs to the decision
4. Define the study boundaries
5. Develop a decision rule
6. Specify limits on decision errors
7. Optimise the design for obtaining data

4.2.1 Step 1 – State the Problem

The radiological and chemical assessment is being undertaken to provide suitable data to enable decisions to be made regarding the future management of fill material underneath the building footprint of No. 11 Nelson Parade and the remainder of the surrounding property.

[1] NSW DEC 2006, Contaminated Sites: Guidelines for NSW Site Auditors Scheme

The objective of the program is to assess the radiological and chemical content of fill material below the building footprint and surrounding areas and compare this against natural levels of background radiation in the surrounding environment and against radiological and chemical waste classification guidelines.

4.2.2 Step 2 – Identify the Decision

The key decisions to be made as a result of the assessment are:

- Is the radiological content of the soil distinguishable from natural background levels; and
- What are the radiological and chemical classifications of the soil with respect to the relevant NSW waste classification guidelines?

4.2.3 Step 3 – Identify Inputs to the Decision

A number of inputs were required in the decision making process. These included:

- Historical information gained from previous related reports and historical records of the area;
- Identification of elevated levels of radiological materials via direct probe monitoring;
- Intrusive sampling of soil to a depth of 2 m or bedrock;
- Quantitative data obtained from intrusive soil sampling and analytical investigation; and
- Comparison of data with appropriate screening level criteria.

4.2.4 Step 4 – Define the Study Boundaries

The lateral boundaries of the survey area are described in the Introduction and viewed in Figure 1.

The vertical boundaries of the survey were to a depth of 2 metres of soil or to bedrock. Previous studies of adjacent areas indicated no clearly defined stratification of radiological materials within the vertical profile.

4.2.5 Step 5 – Develop a Decision Rule

Project data collected were compared to the radiological data from the background samples to determine if statistically the results are indistinguishable from background levels.

If the results of sampling areas are distinguishable above background levels, project data collected from these areas were compared to the appropriate NSW DECC guidance material for classification of chemical and radiological waste materials.

The classification of the soil in terms of potential waste was determined against the DECC *Waste classification guidelines, Part 1: Classifying Waste* (2009) and *Part 3: Waste Containing Radioactive Material* (2008)

Asbestos was reported only if it is visible on the site, and as either presence or absence of friable and bonded asbestos. If friable or bonded asbestos were present, then this would

have been quantified and reported in terms of volume and location and its presence assessed to allow for appropriate classification of the waste.

4.2.6 Step 6 – Specify the Limits on Decision Errors

Two primary decision errors may have occurred due to uncertainties or limitations in data:

- Type A error: An investigation area may have been assessed to pose no unacceptable risk when in reality it did (a false negative). This may be due to limitations in the sampling plan or unreliable data sets.
- Type B error: An investigation area may have been assessed to pose an unacceptable risk when in reality it didn't (a false positive). This may be due to inappropriate sampling, sample handling or analytical procedures.

The reliability of both the field and laboratory programs were assessed in terms of the Data Quality Indicators (DQIs - precision, accuracy, representativeness, completeness and comparability), as set out in Appendix V of NSW DEC (2006).*Guidelines for the NSW Site Auditor Scheme (2nd edition)*. The laboratory program for analysis of radiological and chemical impacts is separate, as the DQI's for precision and accuracy are addressed separately.

Precision

Precision is a measure of agreement among replicate measurements of the same property, under prescribed similar conditions[2].

Precision of Radiological data is achieved by collection and analysis of duplicate samples. Blind duplicate samples are collected at a rate of not less than one per 20 (i.e. 5%) soil samples and are assessed by comparing the relative percentage difference in activity between the anonymous samples. Samples were mixed and homogenised on site before being split into duplicates.

Precision of Chemical data is achieved by collection of Blind (one per 20 samples) and Split (one per 20) duplicate samples. Analysis of samples for chemical impacts was undertaken at NATA accredited laboratories for both Primary and Secondary samples.

Accuracy

Accuracy is a measure of the trueness of a measuring system, which is determined by the closeness of measurements of standards compared to their known true value.

Accuracy of Radiological data was achieved by using ANSTO Building 21 Gamma Ray Spectrometer in compliance with ANSTO procedure VP-2747 for sample preparation, system operation and quality maintenance. This includes calibration of the instrument against reference standards. The Gamma Ray Spectrometer system also scored 'A' under annual International Atomic Energy Agency (IAEA), Worldwide Proficiency Testing for 'trueness' and 'precision'.

Accuracy of Chemical data was achieved by using laboratory methodologies in accordance with those stipulated by NATA accreditation scheme.

[2] Multi Agency Radiation Survey and Site Investigation Manual (MARSSIM) 2000, Rev.1

Representativeness

Representativeness is a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point.

Representativeness of data was achieved by collecting samples and data in an appropriate pattern across the site and by collecting a suitable number of samples to characterise the site. This soil sampling program complied with the NSW EPA *Sampling Design Guidelines*[3].

A systematic sampling pattern was used, as specified in Section 2.6 of the guidance material *MARSSIM (2000).* Samples were collected every 10 metres external to the building footprint and every 2.5 metres inside the building footprint, at a greater population than the above mentioned NSW EPA, *Sampling Design Guidelines* recommends.

Completeness

Completeness is a measure of valid data obtained, expressed as a percentage of the total measurements made.

Sufficient valid data was generated during the study.

Comparability

Comparability is a qualitative term expressing the confidence with which subsequent data sets within a study may be compared, specifically with respect to field, laboratory and interpretation.

Comparability was achieved through maintaining a level of consistency in sampling techniques, sample handling techniques, analytical laboratory techniques and reporting methodology.

4.2.7 Step 7 – Optimise the Design

To determine the most resource-effective sampling and analysis program, a sampling and analysis plan was prepared. ANSTO and CH2M Hill conducted fieldwork in accordance with their quality management system which specifies field techniques, sample collection, analytical sample counting and assessment, and sample management (chain of custody). The program was also prepared with guidance from *MARSSIM (2000).* The general methodology is outlined in the 'Methodology' above.

4.3 Fieldwork Methodology

A continuous radiological survey was undertaken across the entire site using 2 inch NaI detectors at a distance of approximately 5 centimetres above the ground, in lines 1 metre apart across the site. Areas where access was not possible were omitted from the continuous survey. Results were recorded manually at intervals of 1 metre on a map of the site. Additional results were recorded if an area of significantly elevated radioactivity was detected, to identify the boundaries of the elevated activity. All detectors were checked in accordance with ANSTO Instruction S-ROH-I-006 *Operational Checks – Health Physics Contamination Monitors* prior to use. All detectors performed satisfactorily during the radiological survey.

[3] NSW EPA (1995), Contaminated Sites: Sampling Design Guidelines

Soil borings were advanced across the site using a concrete drill (if required) and hand auger to a maximum depth of two mbgl or until refusal. Each soil boring was backfilled with the material removed and each boring through the floor was capped with a steel plate.

Photo 3. Bore hole locations in pool area of the building

Photo 4. Bore hole through concrete floor slab, and soil sample inside the building

Sample locations were based on a systematic grid pattern. A site plan indicating the boring locations is provided on **Appendix B**.

Soil samples were collected from every boring at a frequency of one sample per 0.5 mbgl or if visual or olfactory signs of contamination were observed. Samples scheduled for analysis for volatile compounds were collected directly from the auger head to minimise disturbance of the sample and the potential loss of volatile contaminants. The remaining soil was then transferred to a stainless steel container to allow homogenisation of the sample prior to collection. In addition, material for radiological analysis was collected in a laboratory-supplied

plastic jar. Samples for confirming the presence and / or absence of asbestos were placed in laboratory-supplied re-sealable sample bags.

Photo 5. Capped bore holes in pathway beside the building

A soil boring log was completed at each location. It includes a description of the lithology observed, details of the samples collected and any observations of visual or olfactory signs of contamination (**Appendix F**).

All soil samples collected were screened in the field during sample collection for volatile organic compounds with a photoionisation detector (PID). The reported PID readings for each sample were noted on the corresponding boring log (**Appendix F**). Between each reading, the PID was allowed to stabilise to normal background air quality conditions.

Table 4 summarises the number of soil borings per area of the Site.

Table 4

Summary of Soil Borings

Waste Classification Report

Area Identification	Total No. of Soil Borings	Maximum Depth Achieved (mbgl)
B	6 (B1, B2, B3, B4, B6, B8)	1.00
J	13 (J1, J2, J4, J6, J7, J8, J9, J10 , J12, J14, J15, J16, J17)	1.10
K	1 (K1)	0.30
L	15 (L1, L2, L4, L5, L7, L8, L9, L10, L11, L12, L13, L14, L15, L16, L17)	1.30

4.3.1 Service Clearance

All sample locations were cleared for services using Dial-before-you-dig information and an electromagnetic sweep by an accredited service locator. If services were identified at a proposed sample location, the sample location was relocated to the nearest safe location.

In addition a radiological survey was undertaken of the site prior to the collection of samples, as specified in the risk assessment for the sampling program.

4.3.2 Sampling and Analytical Program

Radiological

Soil samples collected for radiological analysis were analysed at ANSTO's environmental analysis gamma spectroscopy laboratories in Sydney for the analysis listed in **Table 1**.

Chemical

Soil samples collected for chemical analysis were submitted to ALS Laboratory Group (ALS) in Sydney for the analysis listed in **Table 2**

ALS Laboratory Group was used as the primary laboratory and Envirolab Services (Envirolab) was used as the secondary laboratory.

4.3.3 Sample Handling and Transport Methods

All samples were labelled with a unique identifier consisting of the sample location (i.e. K1_1), date collected and sampler. A field worksheet was completed for each sample including depth of sample, required analysis, time of sample collection and signature of the sampler.

Samples for analysis of volatile compounds (i.e. BTEX and TPH (C_6-C_9)) were placed in 150 mL laboratory prepared and supplied glass jars. Samples for the analysis of heavy metals, TPH (C_{10}-C_{36}), PAH, OCP and PCB were placed in 250 mL glass jars.

Soil samples collected for chemical analysis were kept cool in eskies containing ice and sent on the day they were collected via courier to ALS. Each sample shipment had accompanying chain of custody (CoC) documentation.

Samples of no less than 200g for analysis of radiological activity were placed in air-tight sealable 1L plastic containers. As the radiological activity of the samples does not degrade with temperature, there is no requirement to transport the samples for radiological analysis packed in ice. Upon receipt of the samples for radiological analysis, the samples were prepared by being crushed, large pieces of organic material removed and then dried in an oven to reduce the moisture content of the sample. The 100g samples were then weighed and re-sealed in their screw capped containers using a silicone sealant for a period of at least 3 weeks to allow the in-growth of the radon decay products present in each of the decay chains. Samples were then counted on the calibrated gamma spectroscopy system for a period of 24 hours each sample.

4.3.4 Field Equipment Calibration

The PID used by CH2M HILL to screen for the presence of volatile contaminants was calibrated on a daily basis using an isobutylene calibration gas and according to the manufacturer's instructions. Certificates recording the daily calibration results are included in **Appendix G**.

Each of the radiological monitoring devices and electronic personal dosimeters was calibrated and recorded on an annual basis in accordance with ANSTO Instrument Calibration quality procedure S-RIC-P-001 against known standards.

Instruments underwent a daily instrument response check against natural background radiation.

4.3.5 Decontamination Methods

The decontamination of personnel, personal protective equipment (PPE) and sampling equipment was performed in accordance with the procedures outlined in CH2M HILL's standard operating procedures (SOP), to minimise risks to health and safety and prevent cross-contamination of contaminants.

At each sample location a new set of disposable nitrile gloves was used to collect the soil sample. Between each sample location, all soil sampling equipment was decontaminated using a scrubbing brush and a solution of Decon90 and tap water to remove soil material, followed by a rinse in deionised water. A rinsate sample was collected by pouring deionised water over the decontaminated hand auger. This rinsate sample was submitted for analysis to assess potential cross contamination which may have occurred between sampling locations.

At the conclusion of each day of fieldwork, disposable sampling equipment and PPE, including coveralls, gloves, PID bags and dust masks, were collected and scanned with a radiation contamination monitor to determine whether any residual radiological contamination was present. After the scan, the equipment was secured in a rubbish bag and stored at the Site awaiting later disposal. In addition, to prevent potential exposure to the courier driver, the samples that were to be dispatched to the laboratory were scanned to ensure that residual radiological contamination was not present outside the sample jars or on the outside of the esky.

4.3.6 Field Quality Control / Quality Assurance

In addition to the sampling program specified in **Section 4.3.2,** QA/QC samples were also collected. **Table 5** summarises the QA/QC samples collected and the analysis scheduled.

Table 5

QA/QC Sample Frequency

Waste Classification Report

QA/QC Sample Type	Frequency of Collection	Analysis Scheduled
Inter-lab duplicate samples	5% of primary samples	Analysis for CoPC
Intra-lab duplicate samples	5% of primary samples	Analysis for CoPC and total radioactivity
Trip spike and trip blank samples	One trip spike and trip blank per sample shipment for analysis of volatile compound loss and potential cross contamination	BTEX, volatile contaminants
Rinsate samples	Four rinsate samples collected over one week sampling period	Analysis for CoPC

4.3.7 Chain of Custody Documentation

Refer to **Appendix H** for copies of the CoC documentation.

5. Investigation Results

The fieldwork undertaken as part of this investigation was completed between 23 and 27 August 2010. The location of each of the soil borings are shown in **Appendix B**. The following sections describe the findings of the waste classification investigation at the Site.

5.1 Field Observations

The lithology encountered during the advancement of the soil borings was consistent across the areas investigated. Fill materials consisted of orange / brown silt and sand topsoil with frequent inclusions of angular sandstone fragments. Fill material was underlain by Hawkesbury sandstone that outcrops along the banks of the Parramatta River.

PID readings reported during the investigation were low (< 2.3 ppm) and there were no olfactory signs of chemical contamination observed. Infrequent glass, brick fragments and gravel were identified in fill materials. Potential ACM was not identified at the locations investigated or observed on the surface of the Site.

5.2 Analytical Results

The following sub-sections provide an assessment of the radiological and chemical results against different adopted assessment criteria.

For the purpose of the results discussion, the areas of the site investigated have been combined into the following location groupings (LG) based upon their property boundaries and usage:

- LG2 – Outdoor area of No. 11 Nelson Parade (Area B), excluding foreshore.
- LG3 – Building footprint of No. 11 Nelson Parade (Areas J, K and L)

Area LG3 was sub-divided into two sub –areas:

- LG3.1 – Reduced Building footprint of No. 11 Nelson Parade (from Areas J, K and L), see Figures 3 to 8;
- LG3.2 – Remainder of building footprint on No. 11 Nelson Parade including the pool area, veranda and driveway (from Areas J and L), see Figures 3 to 8.

5.2.1 Assessment of Building Footprint Against Background

As discussed previously, isotopes in the U-238, U-235 and Th-232 decay chains exist naturally in the environment. The material underneath the building footprint of No.11 Nelson Parade was assessed to determine if the isotopes present are at levels significantly above natural background levels, i.e. are the concentrations distinguishable from background?

The methodology, known as ‘Scenario B’, for determining if radioactivity is indistinguishable from background contained in *MARSSIM (2000)* and the *U.S. Nuclear Regulatory Commission NUREG-1505 Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys (1998)* was used in the assessment.

The Null Hypothesis in Scenario B is that ‘Measurements in the survey area are indistinguishable from those in the background samples’.

Five background samples were taken from an area adjacent to the site at Nelson Parade and suburbs near Hunters Hill (Five Dock, Huntley's Cove, Padstow and Ryde – See Table 23). These background samples were grouped into two groups, with the two samples in closest geographical proximity grouped together and the remaining three samples from surrounding suburbs grouped together during comparisons.

A walk over radiation survey was conducted inside the building and underneath any accessible areas under the building footprint. Variations in readings were detected inside the building, however, due to the shielding of the fill material offered by the thick concrete floor slab, less reliance could be placed upon these results than in the unshielded areas such as in the yard of the property. In general, higher readings were detected on the eastern side of the building; however after completing further investigation this was determined to likely be a result of ambient dose rates from the previously identified radiological material on the adjacent property, No. 9 Nelson Parade.

Soil samples were taken at an increased population (every 2.5 metres) through holes drilled through the floor slab inside the building and through the driveway. Samples were only taken at locations where bedrock or fill material were directly beneath the floor level. As a result no sample locations were identified on Level 2 of the building.

A number of samples were unable to be analysed because that part of the building resided on bedrock with no or insufficient amounts of loose fill material present (see Key in Figures 3, 4 and 5).

Samples were analysed using gamma spectroscopy, with the radiological results of different isotopes within the same decay chain analysed to determine the ratios of isotopes and assess if the decay chains were in a state of secular equilibrium. From this the total activity for all of the isotopes in the U-238, U-235 and Th-232 decay chains were calculated and used as the predominate driver in the assessments. The results are summarised in **Appendix D**.

The locations of the soil samples collected within the footprint of the building on each floor of the building are shown in Figures 3, 4 and 5.

Each of the samples collected within the footprint of the building including the driveway area and rear patio were analysed to determine if the levels of radioactivity were distinguishable from the naturally occurring radioactivity present in the environment using both the Wilcoxon Rank Sum (WRS) Test and the Quantile Test.

Analysis of all of the 35 samples in the footprint area (LG3.1 and LG3.2) indicated above, compared against the background samples, resulted in the footprint passing the WRS test, as the Rank Sum of 659 was below the Critical Value of 765. The results were also tested against the Quantile Test and passed. As the null hypothesis was not rejected in either test, the fill material beneath the building footprint (Areas 3.1 and 3.2 combined) is proven to be indistinguishable from background.

The highest total radioactivity measured under the building footprint was from samples taken from the driveway and pool area (LG3.2). Although not required, in order to provide additional information on the spatial distribution and concentration of the radiological material, further analysis of the samples was undertaken. Sections of the building footprint which were more accessible such as the rear patio, the pool area and the driveway were excluded from the analysis, as shown in Figures 6, 7 and 8.

Analysis of the remaining 14 (L1, L2, L2.2, L4, L4.2, L4.3, L5, L7, L10, L14, L15, K1, J6 and J9) samples in the reduced footprint (LG3.1), directly beneath the main section of the building, were tested using the WRS test and passed, as the Rank Sum of 105 was below the Critical Value of 161, as shown in **Appendix I**. The results were also tested against the Quantile Test and passed. As the null hypothesis was not rejected in either test, as expected, the fill material beneath the reduced building footprint (Area LG3.1) is proven to be indistinguishable from background.

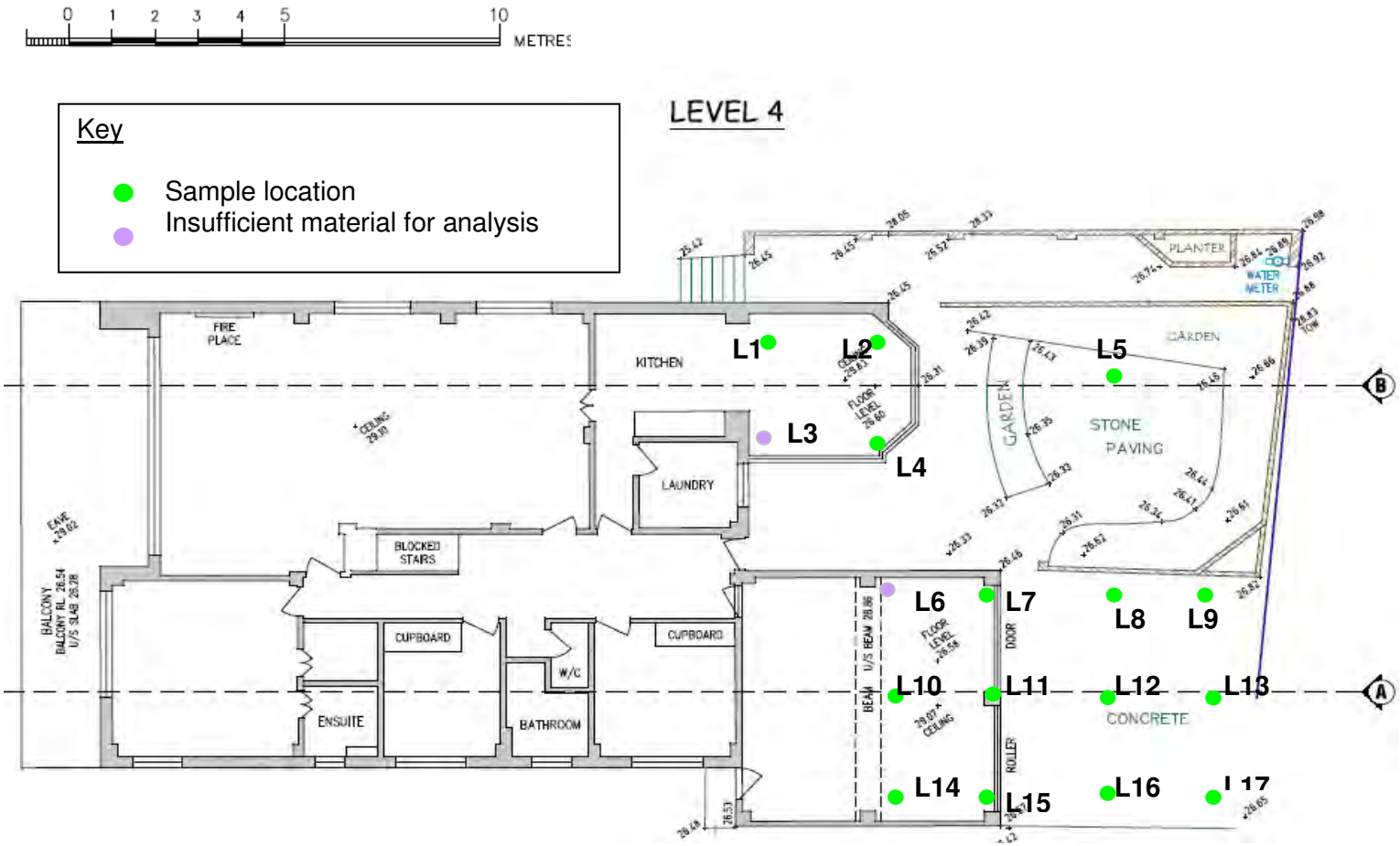


Figure 3. Borehole locations on Level 4 (top level) of the building footprint (LG 3.1 and LG 3.2)

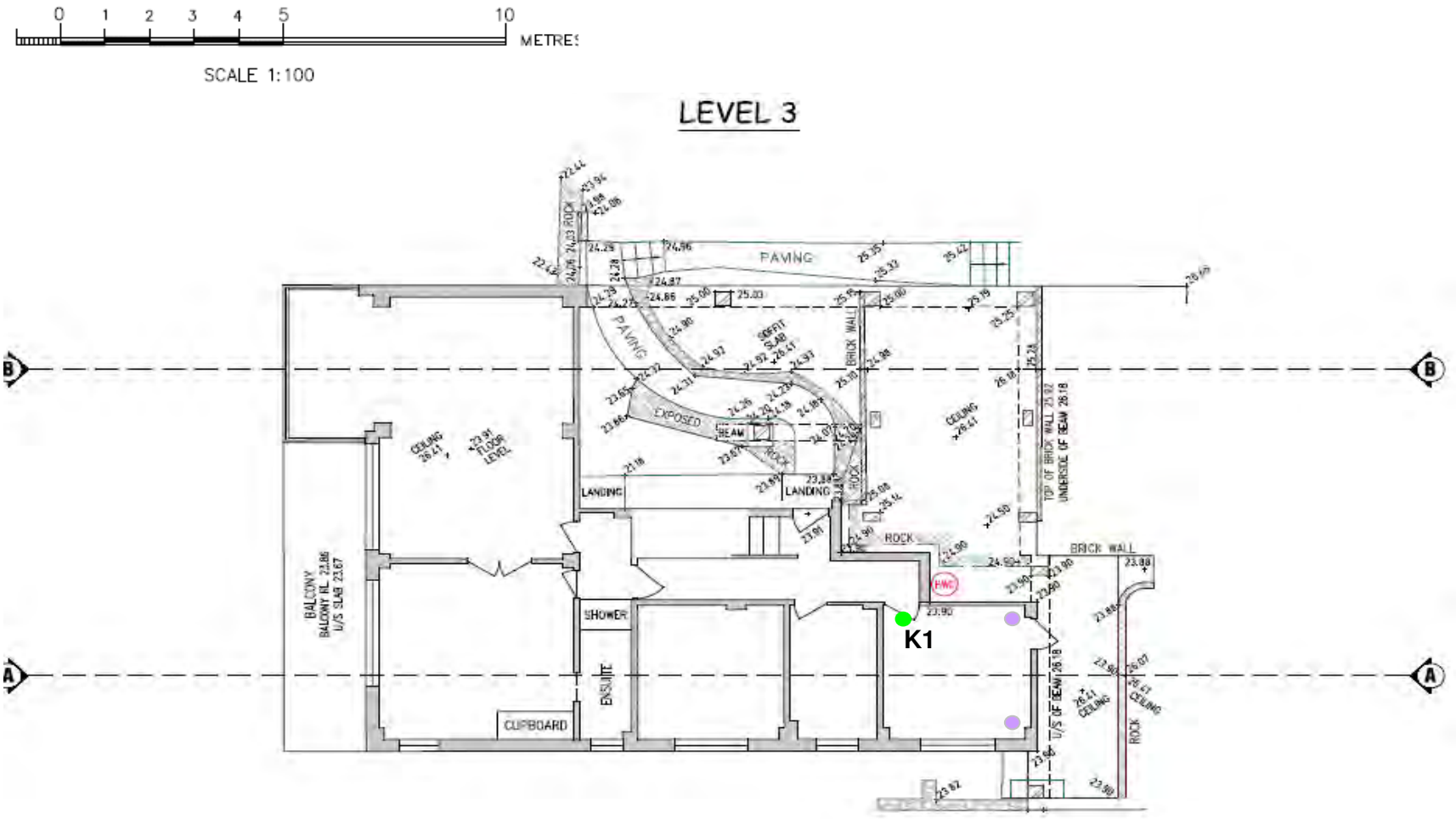


Figure 4. Borehole locations on Level 3 (middle level) of the building footprint (LG 3.1 and LG 3.2)

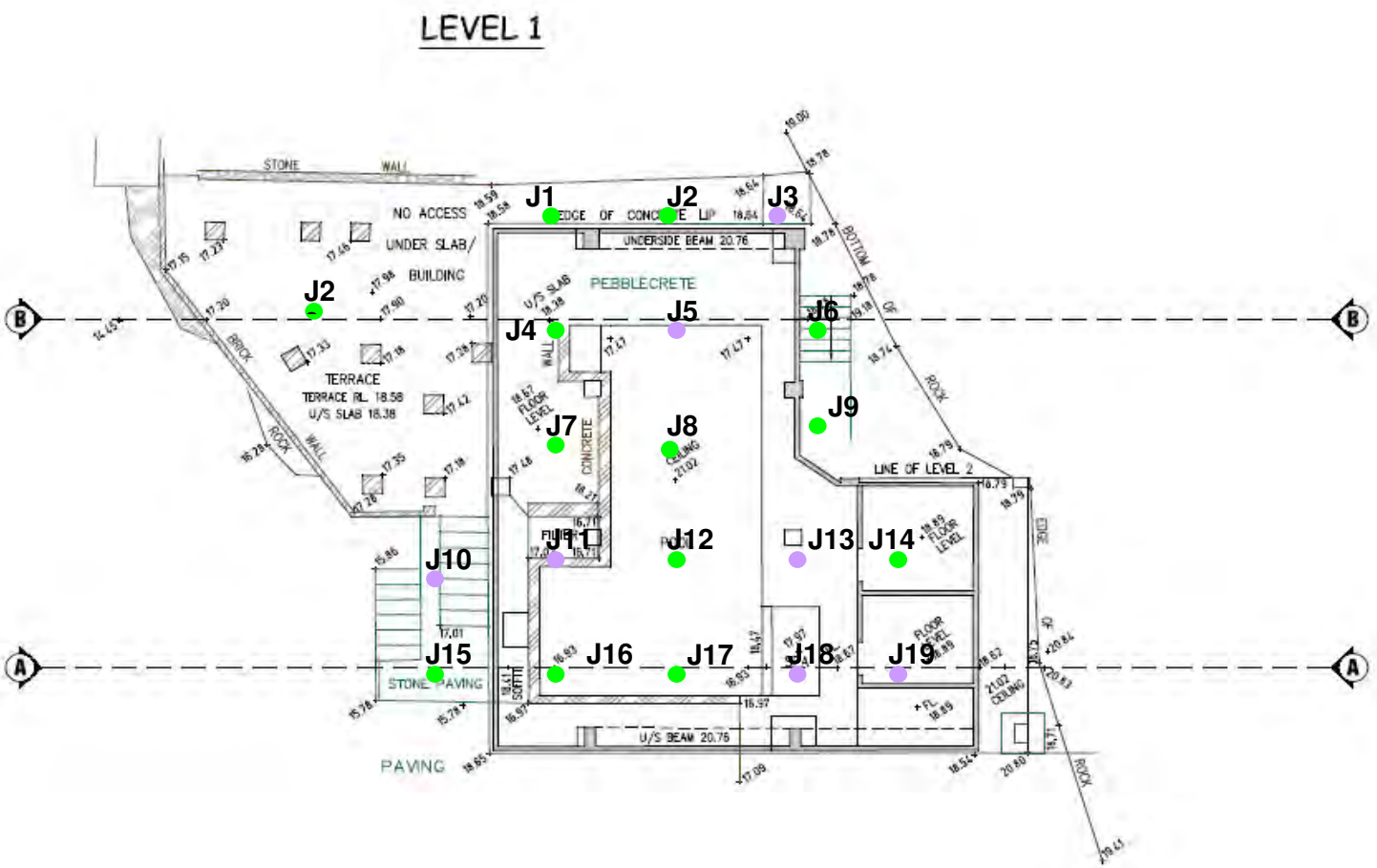


Figure 5. Borehole locations on Level 1 (lower level) of the building footprint (LG 3.1 and LG 3.2)

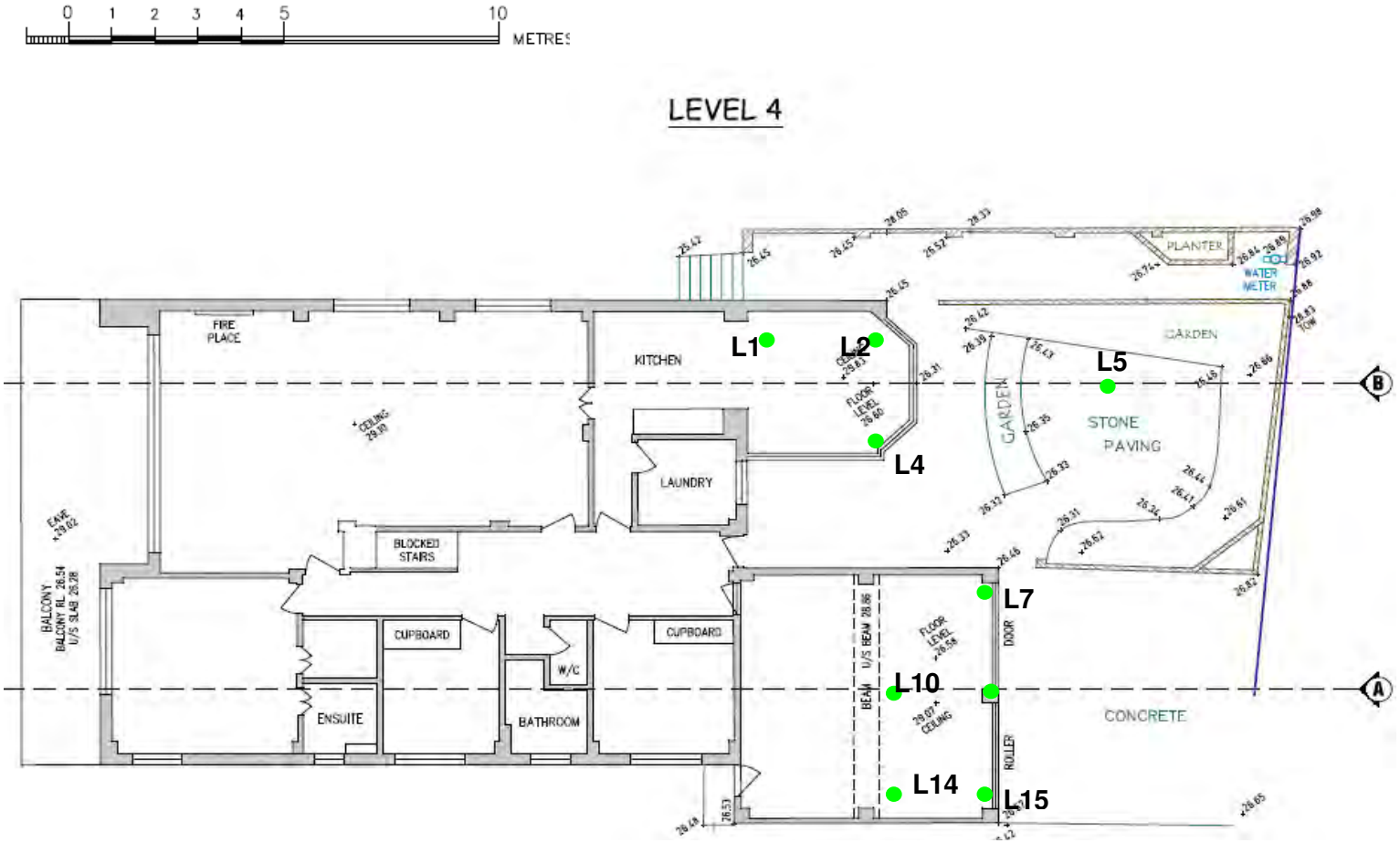


Figure 6. Samples on Level 4 (upper level) included in reduced footprint assessment (LG 3.1)

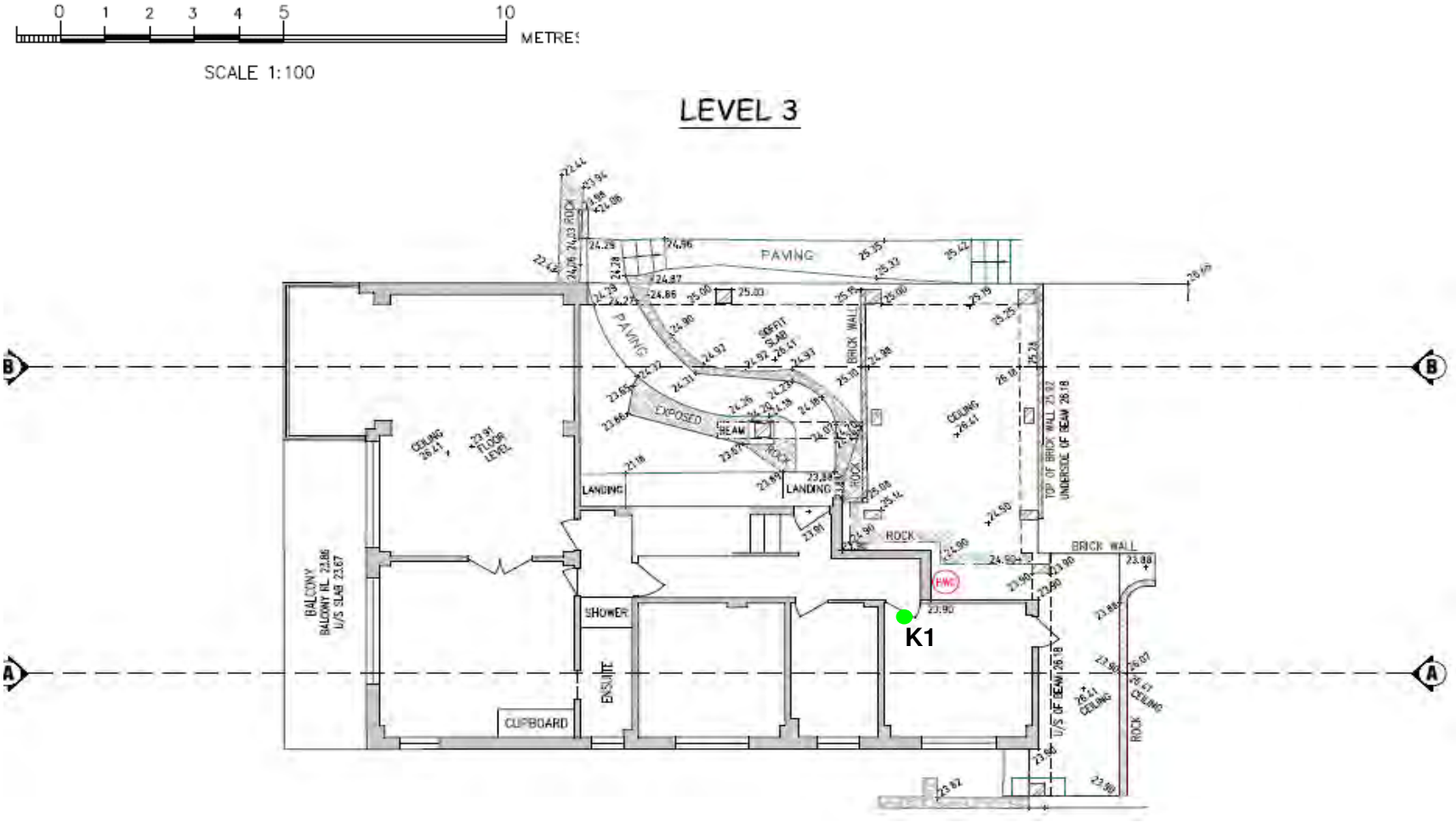


Figure 7. Samples on Level 3 (middle level) included in reduced footprint assessment (LG 3.1)

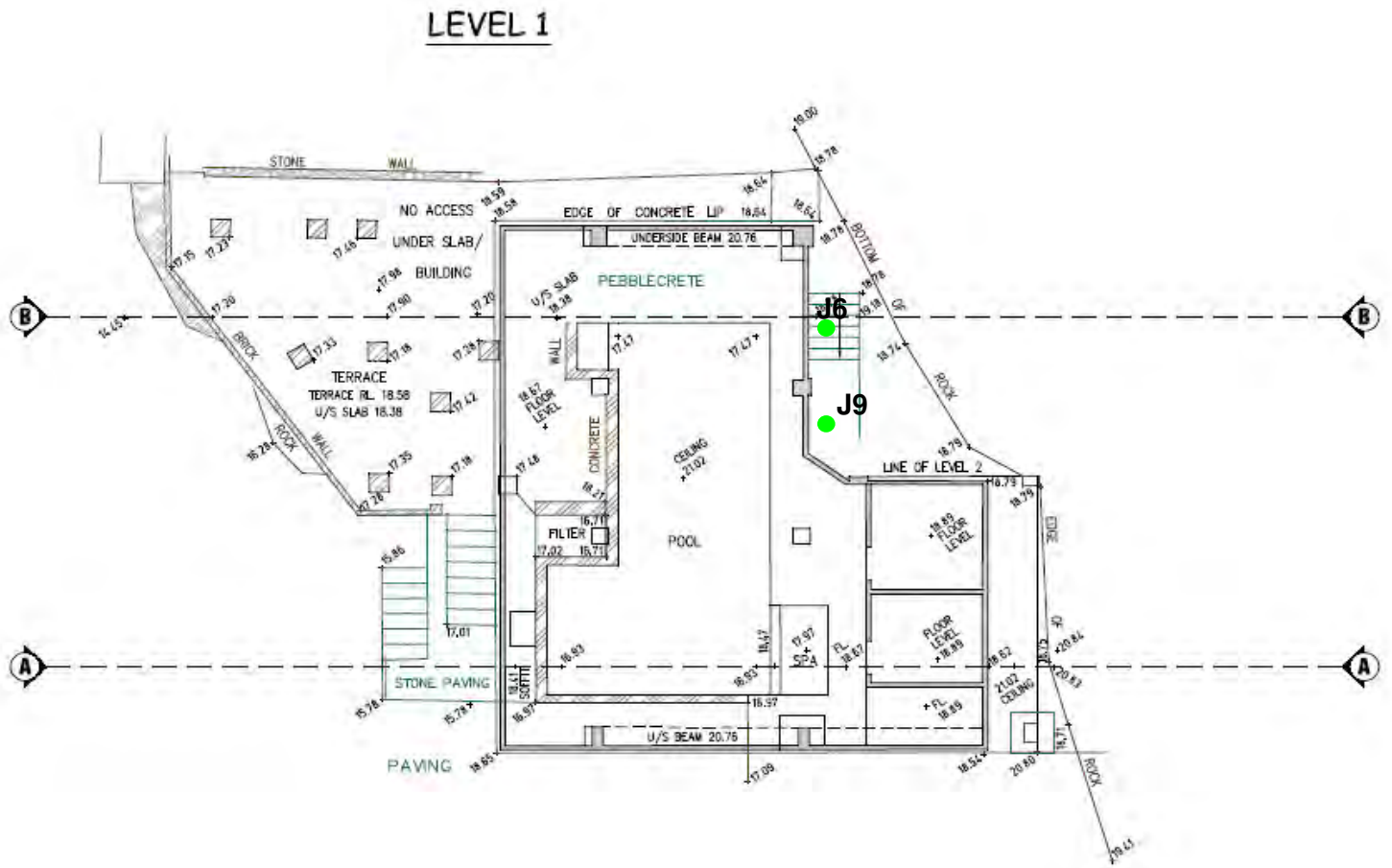


Figure 8. Samples on Level 1 (lower level) included in reduced footprint assessment (LG 3.1)

The remainder of the property (Area LG2) external to the building footprint was assessed to determine if the radioactivity in the fill material was indistinguishable from natural background levels using both the Wilcoxon Rank Sum (WRS) Test and the Quantile Test.

Analysis of all of the 8 samples in the area external to the building footprint (Area LG2), compared against the background samples, resulted in the footprint failing the WRS test, as the Rank Sum of 71 was above the Critical Value of 69. As the results failed the WRS Test, they were not tested against the Quantile Test. As the null hypothesis was rejected by the WRS test, the fill material beneath the building footprint is not indistinguishable from background.

5.2.2 Assessment of the Building Footprint and the Remainder of the Property against Waste Classification Guidelines

To provide a suitable level of information to enable decisions to be made regarding the management of this area, the reduced building footprint (LG3.1), the excluded sections of the reduced building footprint (LG3.2) and the remainder of the site (LG2) were analysed and compared against the State guidelines on classification of the material for disposal. The following sub-sections provide an assessment of both the chemical and radiological results against the adopted assessment criteria for each of the three areas. The waste classification of fill materials is included in this report to provide additional guidance, only, if any future decisions are made to remediate any part of the site. This inclusion does not imply that remediation of any part of the site is required.

Chemical results were initially compared to Contaminant Threshold (CT) values for general and restricted solid waste, prior to an assessment based on representative TCLP concentrations. It is noted that some contaminants, such as total PAH, do not have an associated CT value. In those cases, the Specific Contaminant Concentrations (SCC) were therefore adopted as the most appropriate assessment value.

Based upon the walk over radiation survey results of the areas and previous survey results, slightly elevated levels of activity were detected across the rear yard of No. 11 Nelson Parade.

Radiological results of different isotopes within the same decay chain were analysed to determine the ratios of isotopes and assess if the decay chains were in a state of secular equilibrium.

From this analysis the total radioactivity of the samples were calculated and compared against the Contaminant Threshold values for general and restricted solid waste.

5.2.3 Radiological Results – Waste classification

Spatial Distribution

As described in the methodology above, radiological mapping was undertaken of all of the areas surrounding the building footprint using 2 inch NaI detectors and Geiger-Muller detectors, and a continuous ‘walk-over’ survey technique at a distance of approximately 5cm above the ground along lines at a nominal separation of 1 m, but with allowance for inaccessible areas. These results provided an increased representation of the spatial distribution of radioactive material across the site. This allowed for significantly increased identification of contaminant ‘hotspots’ and aided in ensuring that samples were representative of the entire site. These results have been plotted and presented in **Appendix A** in units of relative levels of radioactivity (counts per second, cps). It should be noted that due to the shielding offered by

the concrete suspended floor slab the relative levels of radioactivity within the building were measured but were not mapped.

As can be seen by the plot, the radioactivity is not distributed homogeneously across the site. However it did provide additional confidence that the location of the soil sample sites provided a suitable representation of the radiological contaminants present outside of the building footprint. It also allowed the identification of the location and extent of any radiological 'hotspots' which did not fall in a soil sample site.

Secular Equilibrium

Due to the history of the site, the predominant radiological contaminants of concern were isotopes from the uranium-238 decay chain, and to a lesser extent isotopes from the thorium-232 and uranium-235 decay chains.

If undisturbed for a suitable period of time, these decay chains will be in a state of secular equilibrium, where the ratios between each isotope in the decay chain are the same. However if the material has been processed it is probable that the equilibrium of the decay chain has been disturbed. This can have a significant influence over the total activity of the sample being analysed and the total activity of the sample at a later time period.

Soil samples collected were analysed for a number of isotopes from different parts of each of the decay chains. This allowed a comparison of the ratios of the isotopes in a chain to determine if they are in secular equilibrium and if not, where the decay chain has been disrupted.

In the analysis of the samples by gamma spectroscopy, to determine the total activity of the samples, the following assumptions were made:

- The concentration of Th-234 was assumed to be representative of U-238, Pa-234, U-234 and Th-230 in the U-238 decay chain (Pa-234 and Th-230 were also measured).
- The concentration of Pb-210 was assumed to be representative of Rn-222, Po-218, Pb-214, Bi-214, Po-214, Bi-210 and Po-210 in the U-238 decay chain.
- As Bi-214 and Pb-214 have very short half lives, they were comparable to Pb-210 measured activities (Pb-210, Bi-214 and Pb-214 were all measured) to confirm or reject the above assumption in the U-238 decay chain.
- The concentration of Ra-224 was assumed to be representative of Th-232, Ra-228, Ac-228 and Th-228 in the Th-232 decay chain (Th-228 was measured but had a high lower limit of detection on the gamma spectrometer).
- As Th-228 and Ac-228 have relatively short half lives, they were comparable to Ra-224 measured activities (Ac-228, Th-228 and Ra-224 were all measured) to confirm or reject the above assumption in the Th-232 decay chain.
- The concentration of B-212 was assumed to be representative of Rn-220, Po-216, Pb-212, Bi-212, Po-212 (64%) and Tl-208 (36%) in the Th-232 decay chain.
- As Pb-212 and Tl-208 have relatively short half lives, they were comparable to Bi-212 measured activities (Pb-212, Bi-212 and Tl-208 were all measured) to confirm or reject the above assumption in the Th-232 decay chain.

Therefore, comparison of the Th-234 activity (upper part of the U-238 decay chain) against the Pb-210 activity (lower part of the U-238 decay chain), and the Ra-224 activity (upper part of the Th-232 decay chain) against the Bi-212 activity (lower part of the Th-232 decay chain) provided some indication of the level of secular equilibrium of the U-238 and Th-232 decay chains.

A number of the results were reported as 'less than' figures due to the lower limit of detection of the detectors. Where possible, if a 'less than' figure was reported, another suitable isotope was used for comparison, based on the above assumptions (See Table 27). Analysis of the 43 samples resulted in 16 samples from the U-238 decay chain and 4 samples from the Th-232 decay chain having the key isotopes reported as 'less than' figures. The 27 samples from the U-238 decay chain and 39 samples from the Th-232 decay chain were therefore able to be compared.

The average RPD% for the U-238 decay chain was 41% for samples where the upper part of the decay chain was a higher ratio than the lower portion, and 50% where the lower part was a higher ratio than the upper portion. On average the RPD% was 23%. The average RPD% for the Th-232 decay chain was 13% for samples where the upper part of the decay chain was a higher ratio than the lower portion, and 19% where the lower part was a higher ratio than the upper portion. On average the RPD% was 12%.

Analysis suggests that the radioactive material from each of the decay chains is not quite in secular equilibrium but in many cases is close. In general the majority of samples indicated a slightly higher activity for the isotopes in the lower part of the decay chains than the upper part.

The total radioactivity of the sample from the different decay chains can be calculated by the multiplication of an isotope's activity by the number of isotopes present in the decay chain. In the case of the U-238 decay chain the total activity is a multiplication of the Pb-210 activity, and in the case of the Th-232 decay chain the total activity is a multiplication of the Bi-212 activity.

As the results indicate that the samples are close to a state of secular equilibrium, the total activity of the samples, and as a consequence the results of the assessment, will not vary significantly due to in-growth of decay products over time.

Where there is significant disequilibrium, overall there is a slight increase in the measured activities of isotopes in the lower part of the decay chain in most samples. With regard to change in activity over time due to ingrowth, this would only lead to a slight over-estimation of total radioactivity of each sample, and not under-estimation.

Vertical Distribution

Across the site there existed no clear stratification of radiological material deposition. In some sample locations stratification of material did exist; however this was generally localised and not consistent across the site. Where a variation in activity was detected in a single borehole, multiple samples were taken at differing depths and analysed separately. To represent the material from a single bore hole being homogenised prior to assessment, the individual results from samples taken at different depths in a single borehole were averaged. As the samples containing the highest activity and second highest activities in each borehole were analysed, this methodology would result in a slightly higher activity being reported than if all of the samples from a single borehole were homogenised prior to analysis. However it did provide additional information on the highest activities present on the site.

Radioactivity Results

The total activity of the soil samples was calculated by summing the total activity of isotopes from the uranium-238, thorium-232 and uranium-235 decay chains. These were compared against the total activity limits for classification as General Solid Waste and Restricted Solid Waste. The results are reported as total activity and **do not** subtract background readings.

The total number of samples collected, as reported in **Table 7** below, represents the total number of boreholes sampled. The total number of samples analysed, including where multiple samples were analysed for a single borehole are indicated in parenthesises in *italics*.

Table 7

Summary of Total Activity Exceedances

Waste Classification Report

Total Activity Limit (gross)	Location	No. of Samples Collected	No. of Criteria Exceedances	Maximum Concentration (Bq/g)
>1 Bq/g				
	LG2	6, *(8)*	5, *(7)*	115 (B6-1)
	LG3	29 *(35)*	7 *(7)*	4 (J20-1)
	Total	**25 *(34)***	**22 *(31)***	
>100 Bq/g				
	LG2	6, *(8)*	1, *(1)*	115 (B6-1)
	LG3	29 *(35)*	0 *(0)*	4 (J20-1)
	Total	**25 *(34)***	**4 *(5)***	

Note: The location(s) of the maximum concentration is indicated in the last column in parenthesises

5.2.4 Chemical Results – Waste Classification

Heavy Metals

Heavy metals that exceeded the CT1 and CT2 adopted assessment criteria included arsenic, lead and mercury. All other heavy metals were below the respective criterion. A summary of the number of exceedances and the maximum concentration detected in each of the LGs is provided in **Table 8**.

Table 8

Summary of Heavy Metal Exceedances

Waste Classification Report

Analyte [CT1 Value]	Location Grouping	No. of Samples Collected	No. of Criteria Exceedances	Maximum Concentration (mg/kg)*
Arsenic [100 mg/kg]				
	LG2	8	1	106 (B6-1)
	LG3	35	0	16 (J20-1)
Lead [100 mg/kg]				
	LG2	8	2	361 (B6-1)
	LG3	35	0	92 (J1-1)
Mercury [4 mg/kg]				
	LG2	8	0	0.2 (B6-1 & B8-1)
	LG3	35	0	0.4 (L7-1)

*Table Notes: * - Sample location/s at which maximum concentration was detected is shown in parenthesises.*

Organics

Organic contaminants in exceedance of the adopted waste classification criteria were limited to BaP and total PAH. A summary of the number of exceedances and the maximum concentration detected in each of the LGs is provided in **Table 9**.

Table 9

Summary of total PAH and Benzo(a)pyrene Exceedances

Waste Classification Report

Analyte [CT1 Value	Location Grouping	No. of Samples Collected	No. of Criteria Exceedances	Maximum Concentration (mg/kg)
Benzo(a)pyrene [0.8 mg/kg]				
	LG2	8	2	1.6 (B8-1)
	LG3	35	5	7.7 (L12-2)
Total PAH [200 mg/kg]*				
	LG2	8	0	20.6 (B8-1)
	LG3	35	0	117.9 (J16-1)

Table Notes: *Samples in which the maximum concentration was detected are shown in parenthesises.*
** No CT1 exists for Total PAH. Value shown is the associated SCC1 value.*

Asbestos

Potential ACM was not observed at any of the sample locations or on the surface of the Site.

5.2.5 Toxicity Characteristic Leaching Procedure Results

Field observations and analytical results for each LG were reviewed with reference to the NSW DECC (2008) guidelines. Analytical results reporting detections of contaminants in excess of the laboratory LOR were compared against the respective CT criteria. Contaminants with concentrations exceeding the CT criteria for *General Solid Waste* were considered to be the CoPC likely to drive the waste classification process. TCLP analysis was scheduled for samples with elevated contaminant concentrations in each LG to determine the leaching potential of the contaminants. TCLP analysis was scheduled for each LG where there were exceedances.

Samples identified for TCLP analysis included those with elevated concentrations of arsenic, lead, mercury and BaP. TCLP results are presented in **Appendix I** attached to this report. A summary of the TCLP analysis scheduled for each LG is provided in **Table 10.**

Table 10

Summary of Scheduled TCLP Analysis

Waste Classification Report

Location Grouping	Sample Location	Sample ID	TCLP Analysis
LG2	B6	B6-1	Arsenic, Lead
	B8	B8-1	Lead, BaP

Table 10

Summary of Scheduled TCLP Analysis

Waste Classification Report

Location Grouping	Sample Location	Sample ID	TCLP Analysis
LG3	J1	J1-1	BaP
	J16	J16-1	BaP

TCLP results were reported less than the TCLP1 criteria for *General Solid Waste* as specified in Table 2 of the NSW DECC (2008) guidelines. Further discussion in relation to the TCLP results and influence upon the overall waste classification of material in each LG is provided in **Section 5.6**.

5.3 Comparison of Statistical Data to Site Assessment Criteria

Chemical

For each LG with samples exceeding the relevant *General Solid Waste* criteria, statistical assessment was performed where six or more primary samples were analysed. A statistical assessment of chemical data was undertaken for LG2 and LG3 using the United States Environmental Protection Agency (USEPA) software package ProUCL Version 4.0.

In accordance with NSW EPA (1995), the dataset was initially assessed to determine if it represented a normal, log normal or non-parametric distribution, with the appropriate method for determining the 95 % UCL value applied. Normal distribution provides a representative description of data that is centred on the mean. It is the preferred distribution due to the high probability that the statistical result represents the actual data. Log-normal distribution is a probability distribution where the logarithm of the distribution is normal. Log-normal distribution routinely includes variable results as multiples of the mean. Non-parametric data does not fit any parameterised distribution, such as normal or log-normal, as is common when heterogeneous fill material is assessed. Non-parametric data does not invalidate any statistical analysis, but rather requires that a degree of caution to be attached to the results.

Summary tables presenting the statistical assessment for each LG reporting criteria exceedances are including in **Appendix I.**

5.3.1 LG2 – Statistical Data Assessment – Chemical Waste Classification

The statistical data assessment for CoPCs that exceeded the adopted criteria for samples collected within LG2 is summarised below:

Arsenic – The dataset has a normal distribution with a 95% UCL of 56.96 mg/kg, less than the SCC1 criterion for *General Solid Waste* (500 mg/kg). The standard deviation is less than 50% of the criterion.

Lead – The dataset has a log normal distribution due to a coefficient of variation (1.3) greater than 1.2. This marginal exceedance is not considered to affect the validity of the dataset and the Chebyshev method was used to calculate the 95% UCL value of 283.2 mg/kg. This value is less than the SCC1 criterion for *General Solid Waste* (1,500 mg/kg). The standard deviation is less than 50% of the criterion.

BaP – The dataset has a normal distribution with a 95% UCL of 1.0 mg/kg, less than the SCC1 criterion for *General Solid Waste* (10 mg/kg). The standard deviation is less than 50% of the criterion.

5.3.2 LG3 – Statistical Assessment – Chemical Waste Classification

The statistical data assessment for the CoPCs that exceeded the adopted criteria for samples collected within LG3 is summarised below:

BaP – The dataset is considered to have a non-parametric distribution, with a maximum BaP concentraton of 7.7 mg/kg reported for sample L12-2. The Chebyshev method was utilised to calculate the 95% UCL of 2.13 mg/kg, which is below the SCC1 criterion for *General Solid Waste* (10 mg/kg). The standard deviation is less than 50% of the criterion.

5.3.3 Asbestos Results

During the waste classification assessment no visible asbestos containing materials was identified on the site. Therefore no classification of the material as *Special Waste – Asbestos* is required.

5.4 Comparison of Statistical Data to Site Assessment Criteria

Radiological

In accordance with NSW EPA (1995), the dataset was initially assessed to determine if it represented a normal, log normal or non-parametric distribution, with the appropriate method for determining the 95% UCL value applied. Normal distribution provides a representative description of data that is centred on the mean. It is the preferred distribution due to the high probability that the statistical result represents the actual data. Log-normal distribution is a probability distribution where the logarithm of the distribution is normal. Log-normal distribution routinely includes variable results as multiples of the mean. Non-parametric data does not fit any parameterised distribution, such as normal or log-normal, as is common when heterogeneous fill material is assessed. Non-parametric data does not invalidate any statistical analysis, but rather requires that a degree of caution to be attached to the results.

Summary tables presenting the statistical assessment for the site reporting criteria exceedances are including in **Appendix I.**

5.4.1 LG2 – Statistical Data Assessment – Radiological

A statistical data assessment for total activity that exceeded the adopted assessment criteria for samples collected within the site is summarised below:

Total Activity – The dataset is non-parametric due to the heterogeneous fill material being assessed. The highest result (Sample B6, total activity115 Bq/g) was significantly higher than the other results obtained for the total activity within the site. All other results were below the limit of classification as *Restricted Solid Waste*.

Due to non-parametric distribution of the data, resulting from inclusion of these samples, the Chebyshev method was used to calculate the 95% UCL value of 85 Bq/g, which is

below the criteria for *Restricted Solid Waste* (100 Bq/g). This figure is primarily due to the high standard deviation of 39 Bq/g against the median activity of 11 Bq/g (average activity 26 Bq/g) as a result of the inclusion of this sample.

As the identification and a reduction in the potential size of the radiological hotspots on the area comprising of heterogeneously distributed fill material can be achieved by the continuous walk over radiological survey of the site (unlike in chemical analysis), the statistical Sign Test as outlined in MARSSIM was also utilised during the analysis of the data.

Statistical analysis using the Sign Test (α=0.05) was utilised. Of the 8 samples from the collective site, 7 of the samples were less than the criteria limit for *Restricted Solid Waste*, which meets the requirements of the Sign Test. This, coupled with the results of the continuous walk over radiological survey, indicates that the hot spots are relatively small in area and when consideration is given to the total volume of soil present, the collective site meets the requirements of the *Restricted Solid Waste* classification.

5.4.2 LG3 (LG3.1 and LG3.2) – Statistical Data Assessment – Radiological

A statistical data assessment for total activity that exceeded the adopted assessment criteria for samples collected within the entire building footprint is summarised below:

Total Activity (LG3.1 + LG3.2) – The dataset is non-parametric due to the radioactivities discussed above. The highest results are significantly higher than the other results obtained for the total activity within the areas. All other results were below the limit of classification as *General Solid Waste*.

Due to non-parametric distribution of the data, the Chebyshev method was used to calculate the 95% UCL value of 1.6 Bq/g, which is below the criteria for *Restricted Solid Waste* (100 Bq/g). This figure is primarily due to the standard deviation of 0.8 Bq/g against the median activity of 0.8 Bq/g (average activity 1.0 Bq/g).

If background readings are subtracted from the samples, the 95% UCL value would be 0.6 Bq/g, which is below the criteria for *General Solid Waste* (1 Bq/g).

In accordance with MARSSIM, statistical analysis using the Sign Test was utilised. Of the 35 samples from the collective site, 28 of the samples were less than the criteria limit for *General Solid Waste*, which meets the requirements of the Sign Test. This, coupled with the results of the continuous walk over radiological survey, indicates that the hot spots are relatively small in area and when consideration is given to the total volume of soil present and the subtraction of background levels, the collective building footprint meets the requirements of *General Solid Waste* classification.

Total Activity (LG3.1 only) – The average activity of the reduced footprint (Area LG3.1 only) is 0.6 Bq/g (inclusive of background) with a standard deviation of 0.3 Bq/g. All of the samples are below the level for *General Solid Waste,* as is anticipated from analysis of the material against background levels in Section 5.2.1. Therefore no further statistical analysis is required.

Total Activity (LG3.2 only) – The dataset of the areas excluded from the reduced building footprint (Area LG3.2, see Section 5.2.1) is non-parametric due to the radioactivities discussed above. The highest results are significantly higher than the other results obtained for the total activity within the area. All other results were below the limit of classification as *General Solid Waste*.

Due to non-parametric distribution of the data, the Chebyshev method was used to calculate the 95% UCL value of 2.1 Bq/g (inclusive of background), which is below the criteria for *Restricted Solid Waste* (100 Bq/g). This figure is primarily due to the standard deviation of 0.9 Bq/g against the median activity of 1.0 Bq/g (average activity 1.3 Bq/g).

5.5 Data Quality Assessment

Data Quality Indicators (DQIs) were developed as part of the DQO process to provide goals for the quality of data required to achieve the objectives of the assessment. Details on the DQIs and data quality assessment adopted for the chemical and radiological analytical results are provided in **Appendix E**.

An assessment of the quality of the chemical data against data quality indicators (DQIs) indicated that although there were a small number of non-conformances, the majority of the DQIs were achieved. Based on the conclusions of the quality review, CH2M HILL considers that the chemical data supplied for the Site meets the objectives of the Precision, Accuracy, Representativeness, Completeness and Comparability (PARCC) criteria. Therefore, CH2M HILL and ANSTO consider that the chemical data set is of acceptable quality to meet the objectives of this waste classification program.

An assessment of the quality of the radiological data against data quality indicators (DQIs) indicated that although there were a small number of non-conformances, the majority of the DQIs were achieved. Based on the conclusions of the quality review, ANSTO considers that the radiological data supplied for the Site meets the objectives of the Precision, Accuracy, Representativeness, Completeness and Comparability (PARCC) criteria. Therefore, ANSTO considers that the radiological data set is of acceptable quality to meet the objectives of this assessment.

5.6 Summary of Chemical Waste Classification

The waste classification of the material in each LG is based on chemical results and is discussed in the following sections.

5.6.1 LG2 – Chemical Waste Classification

CoPCs detected at concentrations greater than the CT values specified in **Section 3.4.2** included arsenic, lead and BaP. Samples representative of the LG2 area indicate no exceedances of the maximum allowable leachate concentration (TCLP1) or specific contaminant concentrations (SCC1) for *General Solid Waste*. Therefore the material in LG2 is classified as *General Solid Waste*.

5.6.2 LG3 – Chemical Waste Classification

The only CoPC detected at a level greater than the CT values specified in **Section 3.4.2** was BaP. Samples representative of the LG3 area indicate no exceedances of the maximum allowable leachate concentration (TCLP1) or specific contaminant concentrations (SCC1) for *General Solid Waste*. Therefore the material in LG3 is classified as *General Solid Waste*.

5.7 Summary of Radiological Waste Classification

The waste classification of the material for the site collectively is based on radiological results and is discussed in the following sections.

5.7.1 LG2 – Radiological Waste Classification

Radioactive material was detected at varying concentrations across the area. Of the 8 samples collected, 7 of the samples exceeded the criteria for classification as *General Solid Waste* and 1 of the samples exceeded the criteria for *Restricted Solid Waste* specified in **Section 3.3.1**.

Statistical assessment of the data resulted in a 95% UCL value less than the criterion of 100 Bq/g total activity. Therefore, the material in the collective area is classified as *Restricted Solid Waste*.

5.7.2 LG3.1 – Radiological Waste Classification

Radioactive material was indistinguishable from background levels within the reduced building footprint.

Therefore, the material in the reduced building footprint is classified as *General Solid Waste*.

5.7.3 LG3.2 – Radiological Waste Classification

Radioactive material was detected at varying concentrations across the areas excluded from the reduced building footprint. Of the 21 samples collected, 7 of the samples exceeded the criteria for classification as *General Solid Waste*. None of the samples exceeded the criteria for *Restricted Solid Waste* specified in **Section 3.3.1**.

Statistical assessment of the data resulted in a 95% UCL value less than the criterion of 100 Bq/g total activity. Therefore, the material in the collective area is classified as *Restricted Solid Waste*.

6. Conclusions and Recommendations

The following conclusions and recommendations are provided based on the chemical and radiological results reported in this investigation.

The fill material underneath the building footprint of No. 11 Nelson Parade is indistinguishable from natural background levels of radioactivity.

The fill material in the property surrounding the building is elevated above natural background radiation levels.

To provide a suitable level of information to enable decisions to be made with regard to the management of this area, the site was analysed and compared against the State guidelines on classification of the material for disposal. The following sub-sections provide summaries of both the chemical and radiological results against the adopted assessment criteria for each of the three areas. The waste classification of fill materials is included in this report to provide additional guidance, only, if any future decisions are made to remediate any part of the site. This inclusion does not imply that remediation of any part of the site is required.

6.1.1 Chemical Waste Classification

The nature of the fill materials across the Site appears to be consistent. Field observations indicated that the only visual contamination is attributed to pockets of ash, charcoal and suspected coking waste. Chemical results show that elevated concentrations of heavy metals, BaP and Total PAH tend to correlate with these isolated pockets of visually contaminated material.

Through an assessment of both total contaminant concentrations and TCLP results and consideration of the DECC *1999/05 General Approval of the Immobilisation of Contaminants in Waste,* 1999, the following waste classifications have been determined:

- **LG2 and LG3** = *General Solid Waste*

6.1.2 Radiological Waste Classification

The nature of the fill materials across the site with regard to radiological content is variable across the site. Localised concentrations of elevated radioactivity are present on the site, often where historical back-filling behind walls has occurred. The spatial extent of these hot spots has been qualified by the use of continuous walk over radiological surveying. Through an assessment of total radioactive concentrations, the following waste classifications have been determined:

- **LG2** = *Restricted Solid Waste*
- **LG3 (combined)** = *General Solid Waste*
  - **LG3.1 (only)** = *General Solid Waste*
  - **LG3.2 (only)** = *Restricted Solid Waste*

7. References

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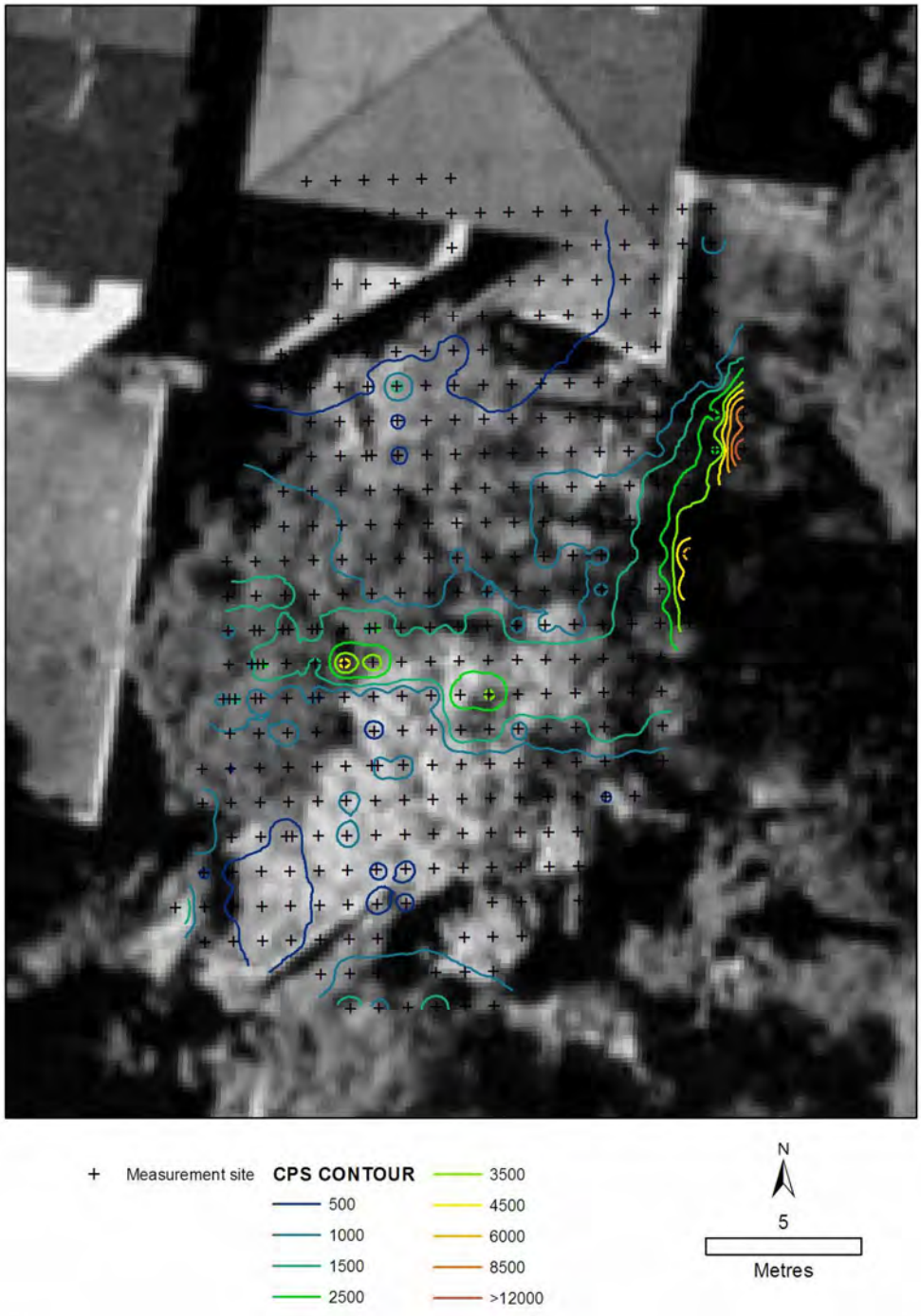
Sinclair Knight and Partners, *Radium waste clean up Nelson Parade, Hunters Hill, Review of Environmental Factors*, August 1987

US EPA, *Calculating Upper Confidence Levels for Exposure Point Concentrations at Hazardous Waste Sites*, December 2002

U.S. Nuclear Regulatory Commission, *A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys, NUREG-1505, Rev. 1*, 1998

8. Appendix A – Spatial Distribution of radioactive material

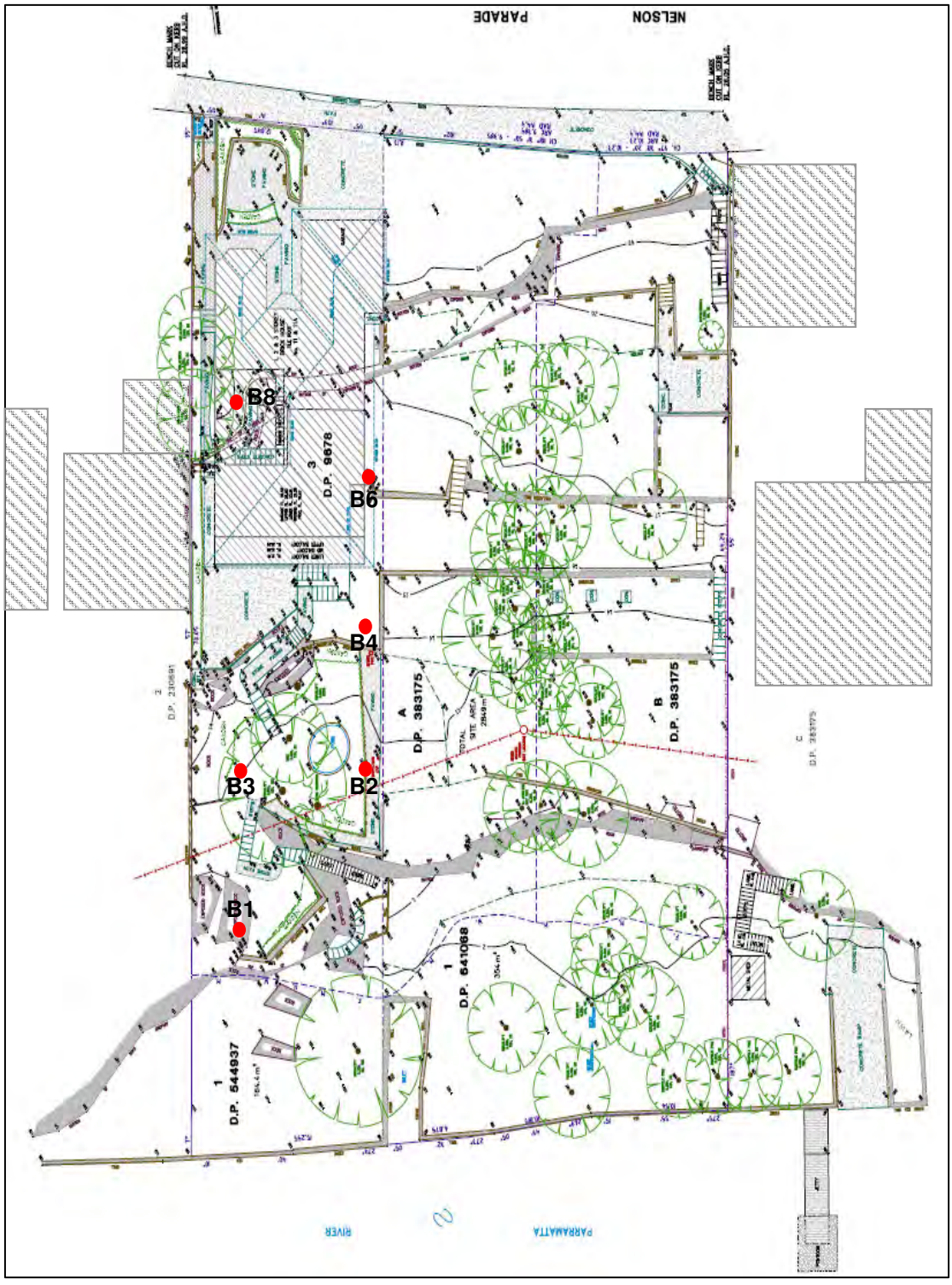
Area B: No11 Nelson Parade Backyard



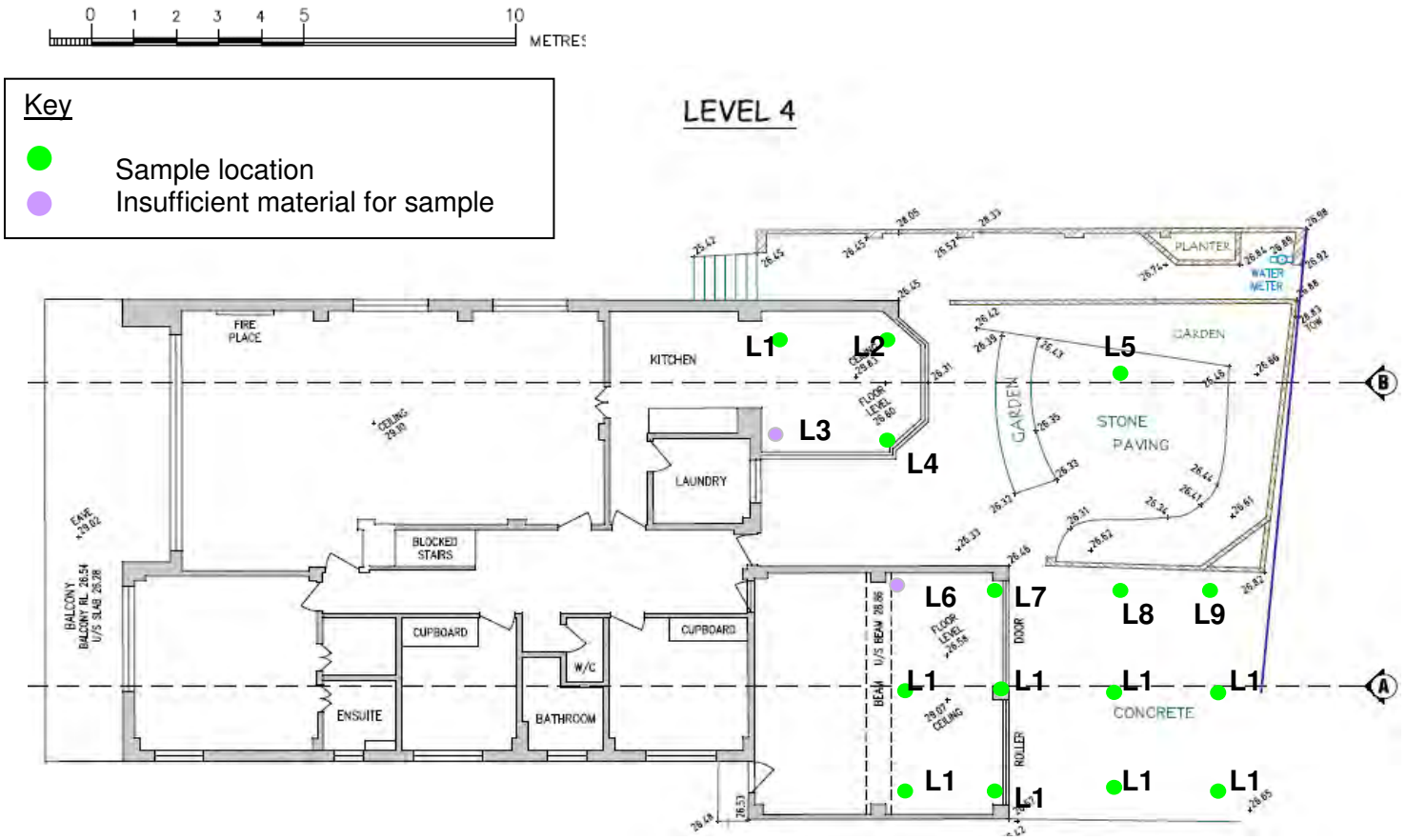
Note: Contour scaling customised for this map to highlight variations in relative activity

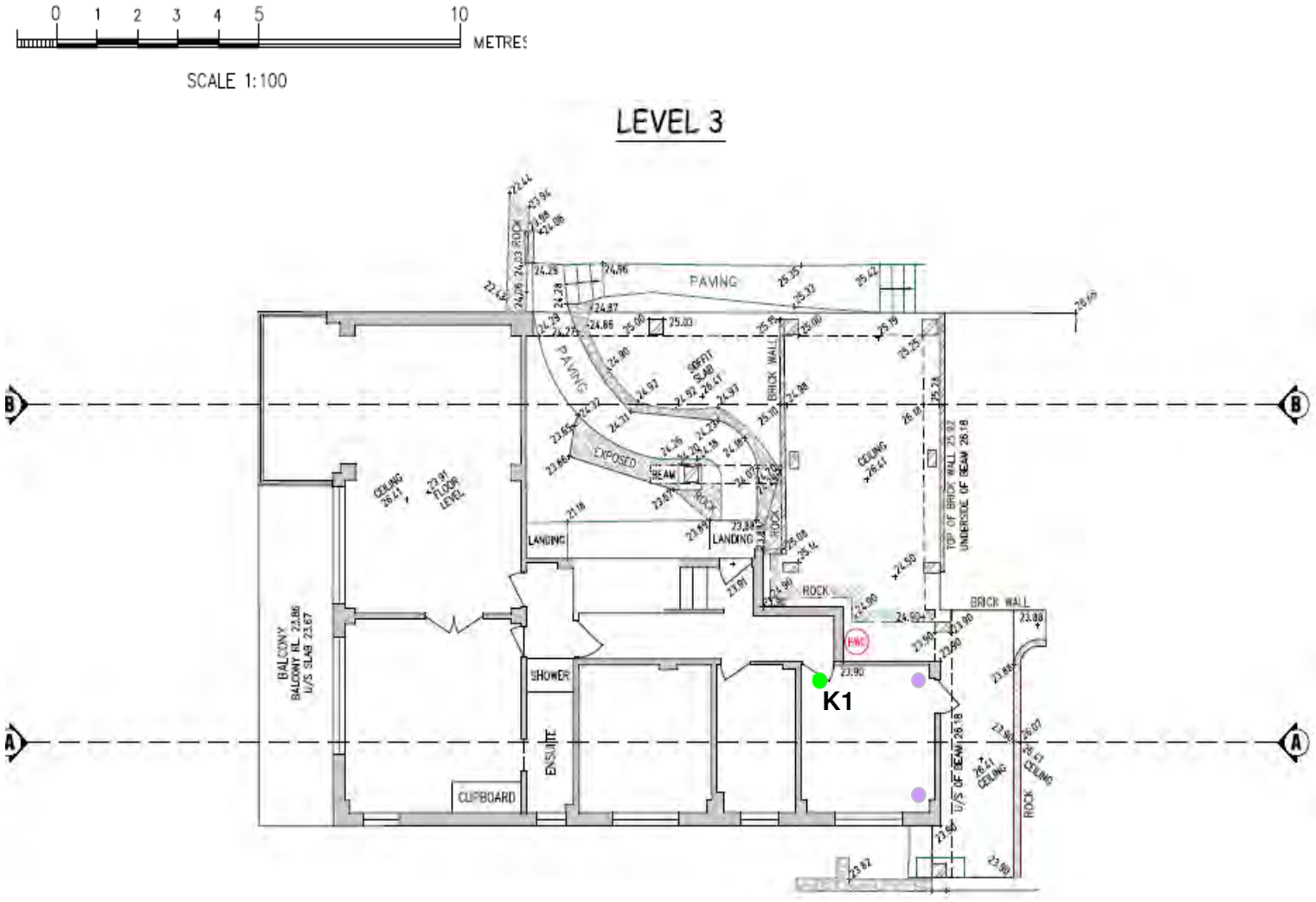
9. Appendix B – Borehole Locations

Borehole locations No 11 Nelson Pde Exterior

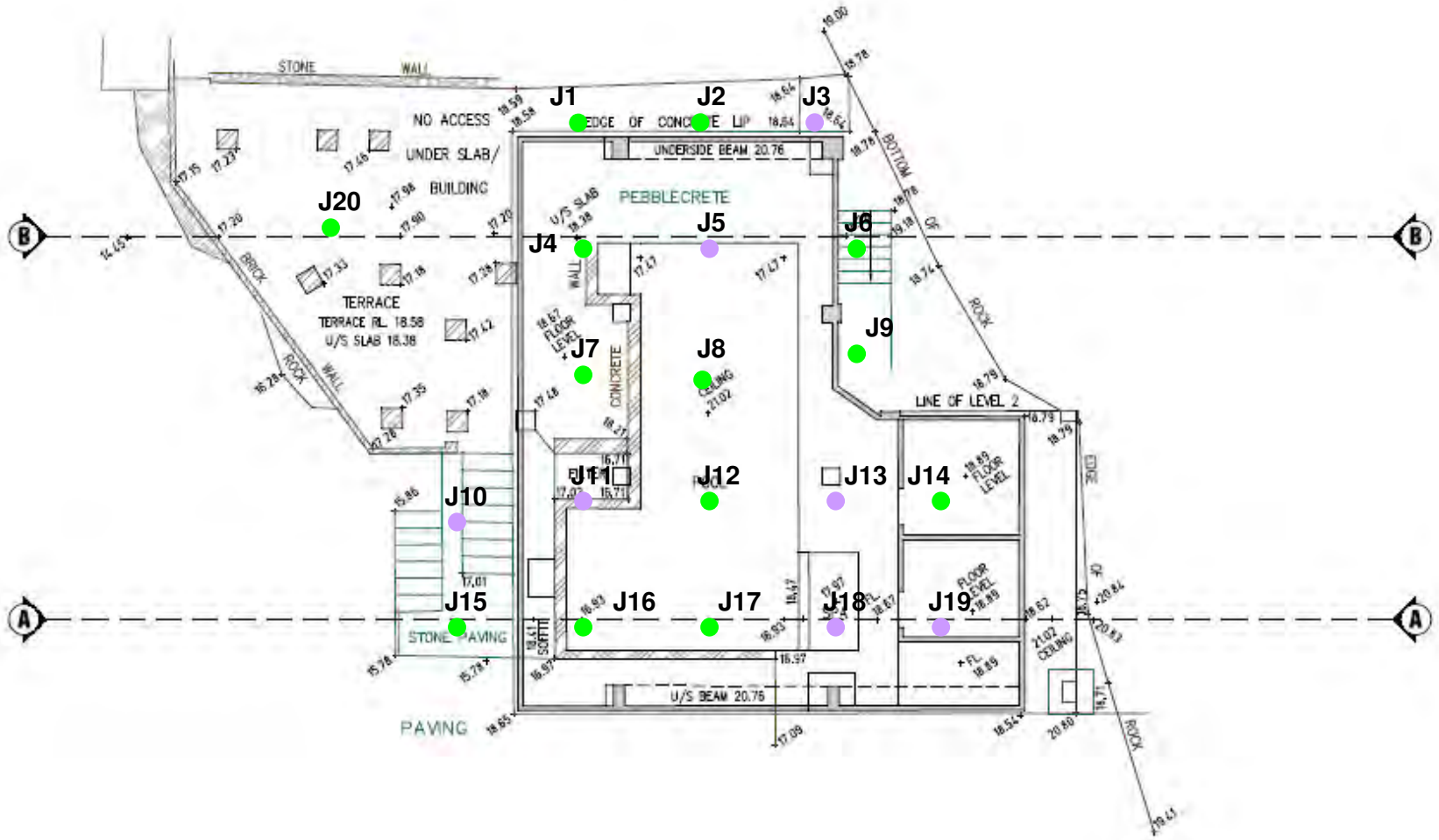


Borehole locations No 11 Nelson Parade Interior




0 1 2 3 4 5 10
METRES
SCALE 1:100
LEVEL 3
PAVING
PAVING
SOFFIT SLAB
BRICK WALL
EXPOSED BEAM
CEILING
FLOOR LEVEL
LANDING
LANDING
ROCK
ROCK
TOP OF BRICK WALL 25.92
UNDERSIDE OF BEAM 26.18
BRICK WALL
BALCONY
BALCONY RL 23.86
U/S SLAB 23.67
SHOWER
ENSUITE
CUPBOARD
U/S OF BEAM 26.18
CEILING
ROCK
K1
A
B

LEVEL 1


J1
J2
J3
J4
J5
J6
J7
J8
J9
J10
J11
J12
J13
J14
J15
J16
J17
J18
J19
J20
STONE WALL
NO ACCESS
UNDER SLAB/
BUILDING
EDGE OF CONCRETE LIP
UNDERSIDE BEAM 20.76
PEBBLECRETE
U/S SLAB
TERRACE
TERRACE RL 18.58
U/S SLAB 18.38
BRICK WALL
ROCK WALL
CONCRETE WALL
FLOOR LEVEL
CEILING 21.02
LINE OF LEVEL 2
STONE PAVING
U/S BEAM 20.75
PAVING
BOTTOM OF ROCK
A
B

10. Appendix C – Field Instruments Used

The Health Physics measurements, analysis and survey work was conducted using a number of different systems to measure the different types of radiation emissions. These detection systems are calibrated annually at ANSTO's dedicated instrument calibration facility. These calibrations are traceable to primary and secondary standards. The following table details the instruments used by ANSTO for the work.

Instrument	MTE / Serial No.	Detector	Use
Eberline E-600	2904 Calibration Due 2/3/2012	SSPA-3 High sensitivity γ detector, 2 x 2" NaI(Tl) detector	High sensitivity gamma measurements, for identifying localised elevated areas in the γ energy range from 60 keV to 2 MeV
Eberline E-600	2568 Calibration Due 25/5/2011	SSPA-3 High sensitivity γ detector, 2 x 2" NaI(Tl) detector	High sensitivity gamma measurements, for identifying localised elevated areas in the γ energy range from 60 keV to 2 MeV
Eberline E-600	2903 Calibration Due 2/3/2012	SSPA-3 High sensitivity γ detector, 2 x 2" NaI(Tl) detector	High sensitivity gamma measurements, for identifying localised elevated areas in the γ energy range from 60 keV to 2 MeV
NE Electra	1971 Calibration Due 1/3/2012	DP2/R4-A Scintillation detector - calibrated in cps	Contamination monitoring and for detecting a wide range of radiations. Used to initially identify areas of interest above background and for self monitoring for loose particles
Rotem R-200	2591 Calibration due 1/3/2012	GM type	Measures ionising radiation, (including X-Rays) from 30keV to 2 MeV, over the range of 0.1μSv/h to 1000mSv/h
Mini Instruments	2386 Calibration due 14/3/2012	GM Environmental probe	Environmental dose rate meter sensitive to γ energy with extendable count time
Eurisys Mesures Radiagem 2	1755 Calibration Due 3/11/2012	G.M. type (small tube-good for high intensity beams)	Measures ionising radiation, (including X-RAYS) from 30keV to 2 MeV, over the range of 0.1μSv/h to 100mSv/h
Target Identifier	2327 Calibration due 1/3/2012	1" NaI detector and GM tube	Analysing gamma energies for comparison against internal libraries to determine radionuclide identity. Effective from 30keV to 1.5MeV
Sv Bleeper	3041 Calibration due 4/1/2012	GM Tube	Used for recording real time radiation exposures to staff, and early warning of hazardous levels.
Sv Bleeper	3036 Calibration	GM Tube	Used for recording real time radiation exposures Calibration due, and early

	due 4/1/2012		warning of hazardous levels.
Sv Bleeper	3038 Calibration due 4/1/2012	GM Tube	Used for recording real time radiation exposures to staff, and early warning of hazardous levels.
Sv Bleeper	3033 Calibration due 1/3/2012	GM Tube	Used for recording real time radiation exposures to staff, and early warning of hazardous levels.
Sv Bleeper	3042 Calibration due 1/3/2012	GM Tube	Used for recording real time radiation exposures to staff, and early warning of hazardous levels.
Sv Bleeper	3039 Calibration due 4/1/2012	GM Tube	Used for recording real time radiation exposures to staff, and early warning of hazardous levels.

11. Appendix D – Sample Analysis Results

12. Appendix E – QA/QC Assessment

13. Appendix F – Soil Borehole Logs

14. Appendix G – Calibration Certificates

15. Appendix H – CoC and Laboratory Reports

16. Appendix I – Statistical Assessment