Attachment P

Sampling, Analysis & Quality Plan SAQP

ARCADIS Design & Consultancy for natural and built assets

YARRALUMLA BRICKWORKS, ACT

Data Review and Gap Analysis and Sampling, Analysis and Quality Plan (SAQP)

26 JUNE 2017

Incorporating

Environmental Strategies

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REVISIONS

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V02	20/06/17	Draft for Review	RPS, CG	DJ
V03	26/06/2017	Submitted to site Auditor for review.	RPS, CG	DJ

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APPENDICES

1 INTRODUCTION

BLOC (ACT) Pty Ltd (BLOC), on behalf of Doma Group, engaged Arcadis Australia Pacific Pty Ltd (Arcadis), to prepare the following data review and gap analysis and Sampling and Analysis Quality Plan (SAQP) for the former Yarralumla Brickworks which comprises Blocks 1, 7 and 20, Section 102 Central Canberra, herein referred to as the site. The site location is shown on Figure 1, Appendix A and has an area of approximately 95,817 m^2.

The site is proposed to be redeveloped for both commercial and residential land uses. This includes the construction of a variety of residential buildings such as townhouses, apartment buildings and single dwelling houses and the reconditioning and fit out of existing brickworks buildings, where possible, for a variety of commercial uses including cafes and restaurants, retail stores, and office space.

The site is subject to a statutory audit being undertaken by Lange Jorstad of Geosyntec Consultants who is an ACT EPA approved NSW EPA Accredited Site Auditor. The site Audit is required prior to construction of the proposed development. This SAQP is required to be reviewed and endorsed by the Site Auditor prior to commencement of any sampling works.

The works being performed within this report are part of Arcadis' multi-staged approach, provided to BLOC, for the remediation of the Yarralumla Brickworks Precinct. This staged approach consists of:

- Stage 1: Data Review and Gap Analysis (Inclusive of SAQP).
- Stage 2: Infill Investigations.
- Stage 3: Preparation of a Remedial Action Plan (RAP).
- Stage 4: Monitoring and Tracking of Contaminated Material Movement.
- Stage 5: Validation Assessment.
- Stage 6: Preparation of Environmental Management Plan (EMP).

The SAQP is based by the findings of the data review and gap analysis for the forthcoming Stage 2 Targeted Site Assessment (TSA).

The purpose of the data review and gap analysis is to identify any Areas of Environmental Concern (AECs) at the site. It is noted that the previous environmental assessments for the site were completed without the proposed redevelopment's master plan. Therefore, several areas within the footprint of the proposed development have not been assessed for suitability.

The purpose of the SAQP is to present a clear and detailed description of the scope of work, data quality objectives, and criteria for which the environmental assessment would be assessed against prior to any field sampling commencing.

1.1 Background

The site is currently owned by THE DOMA GROUP (ACT) and is trading as DOMA GROUP. The site operated as the Yarralumla Brickworks intermittently since construction in 1913 through to closure in 1976. The following infrastructure is known to have been located at the site as part of the brickworks:

- Kilns for the manufacturing of bricks.
- Railway lines for the transport of bricks from the brickworks and into Canberra.
- Underground flues and subsurface workings.
- Accommodation buildings.

- Brickworks Hostel.
- Quarry.

The former brickworks buildings, for the past 23 years, are occupied by Thor's Hammer a wood recycling facility, with portions of the site remaining vacant.

Several environmental investigations have been completed on the site. The following list of reports were made available to Arcadis for review:

- Lovell Chen (2010) 'Canberra Brickworks – Denman Street, Yarralumla, Canberra - Conservation Management Plan'.
- SMEC (2014) 'Preliminary (Environmental) Site Investigation, Canberra Brickworks' (Reference: 3002219).
- Robson Environmental (2015) 'Stage 1 Environmental Site Assessment, Canberra Brickworks Remediation Project, Block 1 Section 102 Yarralumla, Canberra Central ACT' (Reference: 9623_EAR_Stage 1 ESA Report_20150312).
- SMEC (2016A) 'Canberra Brickworks: Detailed Environmental and Geotechnical Site Investigation, Canberra Brickworks Precinct, Yarralumla, ACT' (Reference: 3002523).
- SMEC (2016B) 'Canberra Brickworks: Groundwater Investigation-Addendum Report, Canberra Brickworks Precinct, Yarralumla, ACT' (Reference 3002523).

The above environmental investigations were completed without the proposed redevelopment's master plan. Therefore, several areas which are to be redeveloped have not been assessed for suitability for the intended redevelopment.

With the master plan now finalised, Arcadis intends to assess these locations which will intern direct the preparation of the Remedial Action Plan for Stage 3.

A detailed review of each historical report is provided in Section 3.

1.2 Objectives

The primary objectives of Stage 1 is as follows:

- To identify the currently understood data gaps in previous site investigations.
- To assess the land used suitability based on the data gaps identified.
- To provide the scope for Stage 2.
- To attain sufficient qualitative and quantitative information to allow for the preparation of Stage 3.

1.3 Scope of Work

The scope of work carried out in for Stage 1 included the following:

- Complete a detailed review, and provide a summary of each of the environmental investigation reports made available by BLOC.
- Perform a site visit for confirmatory purposes and understand the site layout and any potential access issues.
- Assessment of any data gaps and identification of uncertainties and issues that require further investigation to assist validation of the site as suitable for the proposed redevelopment in accordance with the master plan.
- Review the conceptual site model (CSM) and amend accordingly.

- Prepare a SAQP which presents additional sampling requirements to infill identified data gaps. The SAQP would comprise of the following details:
  - Summarise the sampling, analysis and quality objectives of the assessment program.
  - Summarise the CSM.
  - Investigation and sample methodologies.
  - Media to be sampled, sample frequency, analytes and parameters to be reported, laboratory reporting limits.
  - Summary of the field quality assurance and quality control methods.
  - Sample handling, storage and transport methods, including chain of custody procedures.
  - Summary of laboratory quality assurance procedures.

1.4 Structure

The sections within this report contain the following information:

- Section 1 – Introduction:
  - Background to the project, objectives of the works, and provides a brief overview of the DQOs.
- Section 2 –Site Conditions:
  - Site description, proposed redevelopment and master plan, summary of site conditions, and surrounding environment.
- Section 3 – Previous Environmental Investigations:
  - Summary of previous environmental investigations.
- Section 4 – Contaminants of Potential Concern:
  - Overview of the contaminants of potential concern (COPC) associated with site following a review of previous investigation findings and historical site use.
- Section 5 – Conceptual Site Model:
  - Amendment of CSM identifying areas of environmental concern (AEC) at the site potentially having been impacted by site activities, site conditions and/or specific features that could present an environmental concern with regards to potential contamination.
- Section 6 – Data Gap Analysis:
  - Discussion of the identified data gaps from previous investigations and details for additional information required to achieve the objectives of this document.
- Section 7 – Sampling and Analysis Quality Plan
  - Guidance:
    - Presents the local and national Acts, and policies with which the SAQP has been prepared in accordance with.
  - Data Quality Objectives:
    - Presents, describes, and addresses each of the seven steps of the DQO process used for each of the investigation components.
  - Assessment Criteria:

    - Investigation levels to be used to assess the field and analytical results, and includes summary tables for both soil and water investigation levels.
  - Proposed Sampling and Analytical Program:
    - Proposed sampling and analysis program to address data gaps and meet DQOs, and the Quality Assurance and Quality Control (QA/QC) requirements. Description of the proposed sampling strategy, sampling locations, and analytical suites.
  - Sampling Methodologies:
    - This section details the proposed water and soil sample collection techniques including sample preservation, storage, and handling procedures.
  - Quality Assurance / Quality Control (QA/QC):
    - QA/QC procedures used to include data quality indicators (DQIs), field logging, QA/QC sampling and frequency, and laboratory analysis specifications.
  - Reporting:
    - Preparation of report detailing the findings and any recommendations for further assessment or contingency options (if required).
- Section 8 – References:
  - References relating to this document.
- Section 9 – Limitations:
  - Statement of limitations relating to this document and proposed investigation.

2 SITE CONDITION

2.1 Site Description

The site identification details are provided in Table 2-1 below.

Table 2-1 Site Detail Summary

Site Characteristic	Detail
Street Address	Denman Street, Yarralumla, ACT
Approximate Coordinates	Latitude: 35.30855 S Longitude: 149.08741 E
Block, Section, Division	Block 1, 7, and 20 Section 102, Canberra Central
Land Zonings	CZ6 – Leisure and Accommodation. RZ1 – Suburban. PRZ2 – Restricted Access Recreation.
Historical Land use	Commercial/industrial land uses. • Yarralumla Brickworks, including: – Kilns for the manufacturing of bricks. – Railway lines for the transport of bricks from the brickworks and into Canberra. – Underground flues and subsurface workings. – Accommodation buildings. – Brickworks Hostel. – Quarry. • Thor's Hammer.
Current Land Use	Thor's Hammer.
Proposed Land Use	Commercial, open space, and residential land uses.
Site Area (approximately)	95,817 m^2

The general location is provided in Figure 1, Appendix A, while the current site boundary is shown in Figure 2, Appendix A. A figure with a surveyed site boundary will be provided within future works.

2.2 Site Condition

The site condition and surrounding environment described in previous reports is summarised in Table 2-2 below:

Table 2-2 Summary of Site Condition

Site Characteristic	Detail
Land-use	The Yarralumla Brickworks has had a disrupted operational period since it was first opened in 1913. The brickworks closed for the first time in 1931 as a result of the Depression and was reopened again in 1935. The brickworks were closed again temporarily between 1942 and 1944 as a result of World War II. After the brickworks were reopened in 1944, they operated until 1976 when the last bricks were unloaded from the kilns for the last time and the operation closed. - Infrastructure on the site has included the following: - Kilns for the manufacturing of bricks. - Railway lines for the transport of bricks from the brickworks and into Canberra. - Underground flues and subsurface workings. - Accommodation buildings. - Brickworks Hostel. - Quarry. For the past 23 years Thor's Hammer a wood recycling facility occupied the former brickworks buildings, while the remaining area of the site was left vacant. Currently Thor's Hammer still operates at the site.
Topography	The topography at the site is variable due to historical extraction works, infilling and operations at the site. However, it is noted that the generally slopes to the west north-west.
Conditions at Site Boundary	The southern and western site boundary consists of vegetated land. There is no access to the site via these boundaries. The eastern site boundary generally consists of Bentham Street, vegetated areas. and residential houses. The site is currently accessed via Denman Street. The northern site boundary is primarily fenced, and bound by a rock face, originating from quarrying works There is no access to the site via this boundary.
Visible Signs of Plant Stress	The vegetation of the Site and surrounds was characterised by areas of tree plantings (pine and deciduous trees) and open grassland (native and modified grassland). Areas within the former brickworks, former quarry and former workers accommodation contained dense grass and woody weed species (blackberry bush) with pine trees. The vegetation appeared to be in good health with no obvious signs of stress
Presence of Drums, Tanks, Wastes and Fill Material	Tanks:

Site Characteristic	Detail
	Based on information sourced from the SMEC (Sept 2016A) and Robson (2014), there are two (2) Underground storage tanks identified at the site. These are listed below: • Fuel UST, identified as AEC–7 (SMEC, 2016A) and AEC-2 (Robson 2006, 2010 - reports not provided for review) is located in the north-western portion of the site, adjacent to the Hardy Patent Kiln 2, and south of the former forklift shed. • Septic UST, identified as AEC 4 (Robson, 2015) is located within the asbestos dump. Three (3) additional locations were surveyed with ground penetrating radar (GPR) for the potential existence of USTs within SMEC (Sept 2016A). No indication of USTs, within the areas that could be accessed with GPR, were identified at these locations. Most sections that were surveyed indicated evidence of disturbance, consistent with holes that had been excavated and backfilled with debris and rubble including concrete and bricks. However, SMEC noted that GPR surveys in few locations were not successful due to access. The location of the abovementioned USTs are provided in Appendix A, Figure 3. <u>Fill Material:</u> Fill material is located across most the site, with the deepest sections located in the asbestos dump where the thickness of fill is up to approximately 4 m below ground level (m bgl). Fill material is noted to contain bricks (both whole and fragments), concrete slabs and fragments, ash, reworked material, slag, and some metal pipes. Additionally, both asbestos fibres and asbestos sheeting has been identified at the site, with the majority identified within the asbestos dump, in the north-western portion of the site. It is understood that the asbestos dump became apparent in the 1980, yet was likely initiated from the 1970s. It is furthermore likely that some of the material located within the asbestos dump came from sources external to the site. Within the asbestos dump the following quantities of fill material were identified by Robson (2015): • Known area of asbestos contaminated fill: 4,854 m^3. • Less impacted fill: 16,252 m^3. The above calculations are interpreted by Arcadis to refer to material that would be classified as asbestos waste, and material that would not. Beyond the Asbestos Dump, asbestos fibres were located within a surface sample located at TP61, which was identified as AEC-10 (SMEC, 2016A). Please refer to Appendix A, Figure 4 for a contour map, generated from historical borehole and test pit logs provided in both Robson 2015 and SMEC, 2016A. <u>Dangerous Goods Storage</u>: A dangerous goods records search was performed for the site in SMEC 2014 stated the following: A search of the Dangerous Goods Act 1975 and Dangerous Substances Act 2004 maintained by Worksafe ACT did not indicate the presence of any stored dangerous goods or underground storage tanks (USTs). The search indicated that tanks containing diesel less than 50 000 litres were not required to be licensed with Worksafe. The following COPC relating to dangerous goods have been assessed within the historical reports:

Yarralumla Brickworks, ACT

Site Characteristic	Detail
	• PCBs - Associated with buried wastes from buildings and potential transformers and associated oils. • PAHs - Derived from partially combusted organic materials, also from coal used as fuel in the kilns and ash buried across the site. • Explosives residues - Possible explosives residues in soil from historical storage on site. • Hydrocarbons - Associated with the use of fuels and lubricants and former UST. • Asbestos – Associated with historical building materials. The following locations have been identified as being historically used for the storage of dangerous goods: • Explosives store - Shed-like structure observed west of the brickworks and north of the railway line, possible location of the explosives store. Identified in 1958 aerial photograph (SMEC, 2016A), and with the location indicated on Figure 6 (Robson 2015) to be west of the Extrusion Plant. However, within Lovell Chen (2010), it is noted that the explosives store was relocated at a point in time to be 180m south of the power house. • Oil storage facility - Historical ASTs identified to be where building 34 (model railway storage shed) now resides (Lovell Chen, 2010). • Oil and coal bunkers – A former oil storage facility /coal storage bay was located at building 33 (model railway workshop). Within Lovell Chen, 2010 it is stated that the model railway workshop was constructed in 1979, utilizing the brick walls of a former oil storage facility /coal storage bay. • Substation /control room and boiler house – Located west of Down Draft Kilns 4-6 (Lovell Chen, 2010). • The power house – Located at building 3 (Lovell Chen, 2010). • Temporary Kilns - (Lovell Chen, 2010). • Asbestos Dump – located within the north-western portion of the site (Robson 2015). • UST - Fuel UST, identified as AEC–7 (SMEC, 2016A) and AEC-2 (Robson 2006, 2010 - reports not provided for review). Based on the historical reports provided for review, it is the understanding of Arcadis, that no further storage of dangerous goods exists at the site apart from those outlined above. Within SMEC 2014, a review was performed on a report by RE titled Robson Laboratories Pty Ltd (March 2006), Survey to Determine the Extent and Condition of Hazardous Building Material at Yarralumla Brickworks, Yarralumla ACT. The following Hazardous material were identified as part of this non-destructive survey are: • Friable asbestos. • Bonded asbestos. • Lead-paint. • Synthetic mineral fibre. • PCB capacitors to fluorescent light fittings. <u>Wastes</u>:

Yarralumla Brickworks, ACT

Site Characteristic	Detail
	Based on the historical information provided for review little information is known about the wastes produced at the site. However, the following wastes are expected to have been generated at the site during operation as a brickworks: • Quarry tailings. • Brick waste. • Asbestos. • Demolition waste. • Ash. • Slag waste.
Odours	It was noted during the Robson (2015) assessment of the asbestos dump that while no odours or visual observations related to putrescible waste were made, the likelihood of landfill gases to be present in the still remains a possibility until the waste has been removed. No other mention of chemical, or hydrocarbon odours were provided within the historical reports for both soil and groundwater investigations. Furthermore, field headspace measurements of soil samples using a photo-ionisation detector (PID) reported marginal readings for all historical reports.
Quality of Surface Water	Surface water at the site exists as an ephemeral water body in the former quarry. This was constructed as a 'reflection pool' after the closure of the brickworks by A R Marr Pty Ltd. Surface water, assessed within SMEC 2016B, showed the following characteristics: • pH between 3.96 and 3.99. • Relatively oxygenated. • Benzene, Toluene, Ethylbenzene, Xylenes (BTEX), Total Recoverable Hydrocarbons (TRH), Polycyclic Aromatic Hydrocarbons (PAH), Organochlorine and Organophosphate Pesticides (OCP/OPP), and Polychlorinated Biphenyls (PCB were below analytical detection limits. • zinc was the only analyte found to exceed the ASC NEPM Environmental Investigation Levels (EIL) (amended 2013) screening criteria for fresh water.
Quality of Ground Water	Groundwater was only assessed within the SMEC 2016B assessment. No comment has been made regarding and odour, colour, or sheens regarding the groundwater at the site. The following comment regarding groundwater was however made: • The variability in ground conditions and measured depth to groundwater across the site suggests that the connectivity between wells may be restricted or not be present and that depth to groundwater is reflective of ground conditions in the immediate vicinity of the monitoring wells. • pH was between 5.94 and 6.99. • Relatively oxygenated.

Yarralumla Brickworks, ACT

Site Characteristic	Detail
	• TRHs, PAHs, OCPs, OPPs, and PCBs were below analytical detection limits. • benzene above analytical detection limits at M-2 and M-7. • A number of exceedances for cadmium, copper, nickel, zinc, were recorded in the groundwater samples to exceed the ASC NEPM EIL (amended 2013) screening criteria for fresh water. • Groundwater was not intersected in M-1 and M-8.

2.3 Surrounding Land Uses

The surrounding land uses are as follows:

- North: Lane Poole Place and Bentham Street, residential properties surrounding the roads and beyond.
- East: Schomburgk Street, Woollis Street and, Bentham Street, and Denman Street with associated residential properties.
- South: vegetated land and Duntossil Drive.
- West: Vegetated land beyond which lies the Royal Canberra Golf Course to the west.

2.4 Proposed Development

The site is proposed to be re-developed for mixed use commercial, residential purposes. Based on the master plan provided to Arcadis the proposed mixed use residential and commercial development includes a variety of residential buildings are proposed across the site. This including townhouses, apartment buildings, and single dwelling houses, varying in access to surface soils. The existing brickworks buildings currently on the site will be maintained where possible and used for a variety of commercial uses including cafes and restaurants, retail stores and office space.

A key aspect to the development is the preservation of the heritage listed buildings and integration of these into the design of the new precinct such that the history of the brickworks is maintained for future generations to enjoy and explore.

2.5 Soils and Geological Setting

The Geology of Canberra 1:100,000 Sheet 8287 (1992) shows that the Canberra brickworks is underlain by calcareous and tuffaceous mudstone and siltstone of the Late Silurian Yarralumla Formation. The formation outcrops within and adjacent to the pit area of the site.

Soils encountered during the previous intrusive investigation works have been detailed in Table 2-3 below.

Table 2-3 Summary of Subsurface Conditions – Asbestos Dump

Profile	Description
ACM Fill	Average depth of 1.5m bgl, ranging from surface to 3m bgl. Consisting of Brick, concrete, ash, metal, plastic and asbestos sheeting.
Fill	No fill observed along the western side. From surface to 5.5m bgl along the northern portion. From surface to 4.5m bgl within the centre.
Natural Soil	Fill was underlain by natural sandy clay, orange to red, exhibiting medium plasticity with minor medium grained gravels or a yellow weathered granite from surface to beyond 5.5m bgl
Bedrock	Shale was identified from at 5.25 at a single location north east of the asbestos dump.

Table 2-4 Summary of Subsurface Conditions – Reminder of Site

Profile	Description
Fill	Fill generally terminated at depths less than 1m bgl, extending to beyond 3m bgl within the historical quarry. Fill consisted of reworked natural sandy to silty clays, ash, brick waste, shale with traces some glass, metal and bitumen.
Natural Soil	Natural soils were generally identified from surface to 1.0m bgl. generally comprised soft brown silty topsoils underlain by medium to stiff red-brown silty clays and clays. Variable components of sand, cobbles and weathered rock (shale and siltstone) were also identified.
Bedrock	Bedrock was identified from 0.17 to 1.9m bgl. Bedrock comprised of shale, dacite, siltstone or sandstone bedrock.

2.6 Hydrogeological Setting

Review of the 1:100,000 Hydrology of the Australian Capital Territory and Environs (1984) indicated that the groundwater beneath the Site is generally present in fractured rock. The quality tends to be variable and was described as 500 - 1,000 mg/l total dissolved solids (TDS). The yield was described as approximately 1.0 l/s.

2.6.1 Regional Bore Search

A regional bore search within a 2km radius of the site as summarised in the SMEC 2016B report, is presented in Table 2-6.

Table 2-5 Summary of Subsurface Conditions – Reminder of Site

Bore ID	Purpose	Construction Date	Depth (m)	Water Level (m)
WU36	Private	Unknown	43	35
WU105	Private	Unknown	Unknown	Unknown
WU609	Private	Unknown	Unknown	Unknown
Woden 3	Private	Unknown	Unknown	Unknown

No map or distances from the site was provided with the historic bore search. A review of the ACTmapi website identifies the closest bore to the site as being approximately 600 to 700m west by south west of the site.

2.6.2 Onsite Groundwater Wells

Groundwater monitoring bore construction details are provided in Table 2-6 below.

Table 2-6 Site Monitoring Well Construction Details

Well ID	Depth of Well (m bgl)	Zone of Screen (m bgl)	Screened Lithology	Well Elevation (TOCm AHD)	Standing Water Levels (m TOC)	Standing Water Levels (m AHD)
M1	8.5	5.5-8.5	BEDROCK	582.78	DRY	NA
M2	15.0	12.0-15.0	WEATHERED ROCK	577.40	4.091	473.31
M3	5.5	1.0-4.0	SANDY CLAY, CLAYEY SANDY GRAVEL, AND SANDY CLAY	577.61	2.741	574.67
M4	4.0	1.0-4.0	CLAY	577.95	1.198	576.75
M5	5.5	2.5-5.5	WEATHERED SILT STONE AND SILTY CLAY	584.82	1.965	582.86
M6	15	12.0-15.0	LIMESTONE	585.25	10.547	571.70
M7	14.7	11.7-14.7	ROCK	582.44	8.565	573.88
M8	15	12.0-15.0	HARD ROCK	587.43	DRY	NA

Based on the reported information in Table 2-6 above, water bearing zones were encountered within multiple zones which include:

- Limestone;
- Siltstone;
- Clays;
- Weathered bedrock.

Gauging of the monitoring wells completed by SMEC indicated that the standing water levels vary from 473.31 and 582.86m AHD. This variation may be attributed to the presence of perched water bearing units. The nature of the screened intervals of wells and the extent of connectivity of groundwater between each water bearing unit is not well understood. Arcadis notes that the monitoring well construction logs indicate that at each monitoring well, backfill sand has been used from the base of each well up to 1m bgl without consideration to the length of the screened interval. This could potentially cause preferential pathways to form between water bearing geological units and the standing water level (SWL) may not be representative of the screened interval.

Preliminary contours have been provided for groundwater in Appendix A, Figure 5. Given the variation in screened intervals the groundwater contours have been prepared for initial screening purposes only.

Regionally, groundwater is believed to flow to the north west towards Lake Burley Griffin.

Table 2-7 Groundwater Physical Parameters

Well ID	Date	pH	Temperature °C	Conductivity uS/cm	Dissolved oxygen ppm	Redox mV
M1	17/10/16			DRY		
M2	28/09/16	6.89	18.9	1923	2.25	94
M3	28/09/16	5.94	16.6	887	9.17	142
M4	17/10/16	6.60	15.5	633	2.94	115
M5	17/10/16	6.99	14.4	440	2.86	96
M6	17/10/16	6.91	15.2	2250	5.30	129
M7	17/10/16	6.50	20	455	7.83	136
M8	17/10/16			DRY		

Table 2-7 indicates the following most recent groundwater conditions across the site, however it is noted that groundwater sampling between M2 and M3 and the remainder of the monitoring wells were sampled approximately three (3) weeks apart:

- Temperature of the groundwater ranged between 14.4 and 21.6°C.
- The current pH ranged between 5.94 to 6.91 generally indicating a neutral groundwater condition.
- Dissolved oxygen in the groundwater ranged from 2.25 to 9.17 ppm indicating aerobic conditions.
- Oxidation reduction potential (ORP) levels measured from 94 to 172mV, which indicates oxidising conditions.
- Conductivity levels were between 440 and 2,250 uS/cm, indicating moderately freshwater groundwater conditions to slightly brackish conditions.

No information regarding turbidity, colour, odour, or presence of sheens were provided.

3 PREVIOUS ENVIRONMENTAL INVESTIGATIONS

3.1 SMEC (2014) 'Preliminary (Environmental) Site Investigation, Canberra Brickworks'

SMEC was commissioned by the LDA to complete a preliminary geotechnical and environmental investigation for the site. The purpose of the environmental investigation was to provide preliminary contamination data to the LDA and assess whether additional assessment work would be required. Within this report a historical summary of previous environmental investigations was performed. The historical reports assessed are listed below:

- Lester Firth & Associates Pty Ltd (June1986), Old Canberra Brickworks, Conservation Plan, June 1986.
- Connell & Wagner (February 2001), Brickworks Contamination Report, Appendix F.
- Robson Laboratories Pty Ltd (October 2006), Environmental Investigation Audit, Yarralumla Brickworks Block 1 Section 102 Yarralumla, Canberra Central, ACT.
- Robson Laboratories Pty Ltd (March 2006), Survey to Determine the Extent and Condition of Hazardous Building Material at Yarralumla Brickworks, Yarralumla ACT.
- Lovell, Chen – Architects & Heritage Consultants (March 2010), Conservation Management Plan – Canberra Brickworks, Denman Street, Yarralumla, Canberra.
- Robson Environmental Pty Ltd (May 2010), Review of Past Site Works and Indicative Costings for Further Assessment and Remediation, Yarralumla Brickworks, Yarralumla, ACT.
- Robson Environmental Pty Ltd (October 2010), Hazardous Material Survey & Management, Denman St Yarralumla Brickworks, Yarralumla ACT.
- Robson Environmental Pty Ltd (February 2012), Hazardous Material Survey & Management, Yarralumla Brickworks, Yarralumla ACT.

The sampling program was conducted at the site to provide both a preliminary geotechnical data for future development within the site (TP01 to TP13) to target previous soil data (confirmatory) or to fill data gaps (TP14 to TP28) to better inform recommendations.

Twenty-eight (28) test pits were advanced across the site and forty two (42) samples were submitted to a National Association of Testing Authorities (NATA) accredited laboratory for the analysis of the following COPCs:

• TRH	• Heavy Metals (arsenic, calcium, chromium, copper, nickel, lead, zinc, and mercury).
• BTEX	• Nutrients.
• PAH	• Herbicides.
• Creosote	• OCP/OPP.
• Explosives	• Phenols.

- Oil and Grease.
- PCB

Fill material was encountered in eighteen (18) test pits and the following observations were made:

- Brickworks and Quarry Area: fill contained brick, ash, shale with traces of anthropogenic inclusions comprising of glass, metal and bitumen. The depth of fill was up to 3m bgl which was the limit of the excavators reach. The nature of fill at depths greater than 3 m bgl was not known.
- Surrounding Areas: Sandy to silty clay which was assessed as probably reworked natural material to a depth of approximately 1 m bgl.
- Area adjacent to Cotter Road: Silty cobbles to gravelly sand with traces of brick and bitumen. Test pit TP2 refused on concrete at a depth of 2.0 m bgl

Concentrations of COPCs in samples submitted for analysis were below the adopted site criteria which are listed below:

- Health Investigation Levels (HIL) - Residential (HIL A).
- Health Safety Levels (HSL) - Low to high density residential (HSL A).
- Ecological Investigation Level (EIL) - Urban residential and public open space.

SMEC note that the sample density adopted for the assessment was less than the number of samples that would be collected for a detailed assessment. Groundwater was not assessed as a part of the preliminary investigation.

Based on the results of the investigation, SMEC stated that the potential risk to ecological receptors and human health associated with the brickworks, quarry, and former worker's accommodation was moderate to low. The remainder of the site typically comprised of natural soil grading to weathered rock. As analytical results were below the adopted site criteria, SMEC considered the potential for contamination to be present as low.

3.2 Robson Environmental (2015) 'Stage 1 Environmental Site Assessment, Canberra Brickworks Remediation Project, Block 1 Section 102 Yarralumla, Canberra Central ACT'

Robson Environmental was engaged by Capcorp Constructions Pty Ltd to complete an environmental site assessment of the Asbestos Dump located along the western boundary of the site.

The scope of the investigation comprised of the following:

- Remove vegetation across the investigation area.
- Excavation of twenty-five (25) test pits on a grid based sample pattern, of this sixteen (16) locations were within the understood boundary of the asbestos dump.
- Excavation of four (4) trenches across the Asbestos Dump.
- Analysis of soil samples for:

- TRH
- Heavy Metals.
- BTEX
- Speciated Phenols

• PAH	• OCP/OPP.
• PCB	• Asbestos

A summary of the results of the investigation is as follows:

- Asbestos sheet material was identified in five (5) test pits.
  - TP3, TP5, TP6, TP8, and TP13.
- Fibrous Asbestos and Asbestos Fines were identified in two (2) test pits.
  - TP8 and TP13.
- Concentrations of TRH and PAHs were detected at concentrations above the laboratory limit of reporting (LOR) at two (2) test pit locations.
  - TP11 and TP13.
- Concentrations of benzo(a)pyrene TEQ exceeded the site assessment criteria at one (1) test pit.
  - TP13
- Concentrations of lead and nickel were present at elevated concentrations within other sample locations, but were below the adopted commercial/industrial criteria in the event the material was disposed at the West Belconnen Resource Management Centre (WBRMC).

The primary contaminant of concern identified in the asbestos dump was asbestos sheet material. The depth of the asbestos material ranged from 0.5 m bgl to 3.2 m bgl and was generally mixed with high amounts of other anthropogenic waste including brick, tile, metal, glass, wood, ash, slag and concrete. Parts of the dump which did not have visible asbestos sheet material was noted to contain high volumes of other anthropogenic waste.

Based on the results of the investigation, Robson calculated the following volumes of waste material:

- Known area of asbestos contaminated fill: 4,854 m^3;
- Less impacted fill: 16,252 m^3.

Based on these results, Robson recommended that a Remedial Action Plan be prepared for the remediation of the asbestos dump in preparation for making the site suitable for future residential land uses.

3.3 SMEC (2016A) 'Canberra Brickworks: Detailed Environmental and Geotechnical Site Investigation, Canberra Brickworks Precinct, Yarralumla, ACT'

The LDA commissioned SMEC to complete a detailed environmental and geotechnical investigation of the Yarralumla Brickworks. The purpose of the detailed investigation was to determine the suitability of the site for the proposed land use for low to medium density housing.

The scope of the investigation was as follows:

- Excavation of sixty-three (63) test pits across the site to a maximum of 3.0 m bgl.
- Drilling of eighteen (18) soil bores to a depth of 3.0 m bgl.
- Collection of twenty (20) samples from surface locations across the site.

- Collection of three (3) sediment samples from the creek/water course in the pit area.
- Drilling, installation and sampling of eight (8) groundwater monitoring wells between 5.5 and 15 m bgl utilising wash boring methods.
- The COPCs identified for the site are:
  - TRH, BTEX, PAH, OCP/OPP, PCB, heavy metals, explosives, and asbestos.
- Samples collected were analysed for TRH, BTEX, PAH, OCP/OPP, PCB, heavy metals, and asbestos.

Results of the investigation indicated the presence of fill consisting of bricks (both whole and fragments) with concrete slabs and fragments, ash, reworked material and some metal pipes. Based on the Arcadis' interpretation of the logs, it is understood that the fill is located across the majority of the site, with the deepest sections located in the asbestos dump where the thickness of fill is up to approximately 4 m.

Bedrock occurred across the site from between 0.1 to 2.9m bgl.

The analytical criteria adopted for this assessment are listed below:

- HIL – A.
- HSL – A.
- EIL – Urban residential and public open space.
- Ecological Screening Levels (ESL) - Urban residential and public open space.
- Simpson SL, Batley GB and Chariton AA (2013). Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines. CSIRO Land and Water Science Report 08/07. CSIRO Land and Water.

Analytical results indicated that concentrations of BTEX, OPP, OCP and PCBs across the majority of the site were below the laboratory LORs.

The following contaminant concentrations were recorded above the laboratory LOR:

- Concentrations of TRH C_{15}-C_{28} and C_{29}-C_{36} were reported at concentrations above the laboratory LOR with a maximum concentration of 800 mg/kg.
- Concentrations of PAH in sixteen (16) samples were above the LOR with a maximum concentration of 6.7 mg/kg which was below the assessment criteria of 300 mg/kg. The concentration of the calculated benzo(a)pyrene TEQ was below the 3 mg/kg criteria.
- Concentrations of total phenols were detected in thirty-seven (37) samples from across the site with a maximum concentration of 47 mg/kg and were below the criteria of 3,000 mg/kg.
- Lead concentrations exceeded the HIL A criteria of 300 mg/kg at four (4) locations with exceedance concentrations ranging between 430 mg/kg and 4,300 mg/kg. These exceedances were from samples collected from the ground surface and kiln dust in the vicinity of the existing brickworks buildings.
- Concentrations of zinc were reported above the EIL criteria in three (3) samples. Other than this, all other concentrations of heavy metals were below the site acceptance criteria.

Based on the results of the assessment, SMEC identified ten (10) AECs. The AECs are summarised in Table 3-1 below along with recommendations made by SMEC.

Table 3-1: Summary of AECs and recommendations made by SMEC.

AEC	Description	Recommendation
AEC-1	Interior of Kilns around SS-4. Heavy Metals.	Further Assessment
AEC-2	Surface samples located to the west of the brickworks kilns. Heavy metals.	Further Assessment
AEC-3	Interior of Kilns around SS-10. Heavy metals, PAHs and TRH.	Further Assessment
AEC-4	Pit Area	Further Assessment
AEC-5	Areas under concrete slabs and buildings	Further Assessment
AEC-6	Areas under concrete slabs and buildings	Further Assessment
AEC-7	Underground Storage Tank	Remove tank and validation of the excavation. Groundwater water sampling may be required
AEC-8	Surface area in the vicinity of TP34A where non-friable asbestos was encountered	Further Assessment
AEC-9	Area around TP12 where elevated lead was detected	Further Assessment
AEC-10	Area around TP61 where fibres of chrysotile was detected	Further Assessment

SMEC noted that access to some areas of the site was not available and that further works should be completed to provide a comprehensive data set to allow for the LDA to make effective decisions.

Based on the results of the assessment, SMEC considered the southern portion of the site would be suitable for residential land use. The remainder of the site however would require further investigation.

3.4 SMEC (2016B) 'Canberra Brickworks: Groundwater Investigation-Addendum Report, Canberra Brickworks Precinct, Yarralumla, ACT'

As a part of the detailed environmental and geotechnical investigation that the LDA commissioned SMEC to complete, a groundwater assessment across the site was completed to determine the suitability of groundwater and surface water for the proposed residential land uses.

The scope of the groundwater and surface water assessment was as follows:

- Installation of eight (8) groundwater monitoring wells across the site.
- Sampling of groundwater wells and collection of surface water samples from ephemeral creeks.
- Analysis of water samples for TRH, BTEX, PAH, OCP/OPP, PCBs, and heavy metals.

The monitoring wells were installed to depths between 4.6 m and 15.7 m. Sampling of the monitoring wells indicated that concentrations of TRH, PAH, OCP/OPP and PCB

were below the groundwater investigation levels. Benzene concentrations were detected in two (2) monitoring wells (M-2 and M-7) but were well below the groundwater investigation level of 950 µg/L.

Based on Arcadis' review the bearing zones, in which the monitoring wells were installed, were across multiple strata. These include:

- Limestone.
- Siltstone.
- Clays.
- Weathered bedrock.

Groundwater across the site varies between 473.31 and 582.86m AHD. The extent of connectivity of groundwater between each monitoring well is uncertain. Additionally, Arcadis notes that the monitoring wells construction logs show that at each monitoring well, filter sand has been used from the base of each well up to 1m bgl irrelevant of the length of the screened interval. Furthermore, monitoring wells M-1 and M-8 are dry and did not intersect groundwater.

Concentrations of cadmium, copper, nickel and zinc exceeded the freshwater groundwater investigation levels in M-2, nickel and zinc in M-6 and M-7 and zinc in M-3 and M-7. Based on the results of the groundwater sampling, SMEC considered the concentrations of metals recorded unlikely to pose a significant environmental risk.

Concentrations of TRH, BTEX, PAH, OCP, OPP, and PCB in the samples collected from surface water were below the laboratory LORs. Concentrations of zinc were detected above the groundwater investigation levels in samples W-2 and W-3. Other than this, concentrations of other heavy metals were below the assessment criteria.

Based on the results of the surface water and groundwater assessment SMEC recommended additional surface and groundwater monitoring to further investigate the presence of benzene in water.

4 CONTAMINANTS OF POTENTIAL CONCERN

Based on a comprehensive review of the site history and previously reported soil and groundwater results, the following COPCs are considered:

- TRH;
- BTEX;
- PAH;
- OCP/OPP;
- PCB;
- Dioxins (within the kilns);
- Heavy metals;
- Asbestos both non-friable and friable.

5 CONCEPTUAL SITE MODEL

The site was historically assessed for residential land use with access to soil. This was performed prior to the proposed redevelopment's master plan having been generated. Now with the master plan the site can be divided into several sections specific to land use. These land uses are provided below and are outlined in Figure 6, Appendix A.

- Zone 1 A/B – Low density residential.
- Zone 2 – Medium density residential.
- Zone 3 A/B – High density residential.
- Zone 4 A/B – Recreational.
- Zone 5 – Commercial.

All historical samples have been reassessed in accordance with the zones that they are now located within. Analytical criteria selected for the assessment of each zone is provided in Table 7-2.

5.1 Summary of Soil and Sediment Conditions

Robson (2015):

It is noted that all samples collected within Robson (2015) are generally located in Zone 2, specifically in the north-western portion of the site.

Exceeding the NEPM 2013 HSL A – Bonded asbestos:

• TP6 0.9-1.0: - 0.06 %W/W	• TP5 1.9-2.0 – 0.12 %W/W
• TP13 0.0-0.0: – 1.17 %W/W	• TP13 0.4-0.5: – 0.42 %W/W
• TP13 1.9-2.0: – 0.64 %W/W	• TP13 2.9-3.0: – 0.30 %W/W

Exceeding the NEPM 2013 HSL A – All forms of asbestos:

• TP3 – Observed at surface	• TP8 – Observed at surface

Exceeding the NEPM 2013 HSL A – FA and AF:

- TP8 9-1.0m:
  - - 0.028 %W/W >2mm to <7mm AF/FA
- TP13 0-0.1
  - 5.7 %W/W >2mm to <7mm AF/FA
  - 0.37 %W/W <2mm AF/FA
- TP13 0.9-1.0
  - FA 0.046 %W/W >2mm to <7mm AF/
  - 0.053 %W/W <2mm AF/FA

Exceeding the NEPM 2013 HIL A – Residential:

- TP13 0-0.1
  - Benzo(a)pyrene (BaP) 9.5 mg/kg
  - Carcinogenic PAH's (As BaP TEQ) 15 mg/kg

Exceeding the NEPM 2013 EILs for urban residential fine soil:

- TP8 9-1.0m:
  - Zinc – 470mg/kg
- TP6 1.9-2m.
  - Zinc 520mg/kg.

Exceeding the NEPM 2013 ESLs for urban residential:

- TP13 0-0.1
  - Benzo(a)pyrene (BaP) 9.5 mg/kg
  - Carcinogenic PAH's (As BaP TEQ) 15 mg/kg

Concentrations of TRH and PAHs were detected at concentrations above the laboratory limit of reporting (LOR) at TP11 and TP13 but below the adopted assessment criteria.

SMEC (2016A):

<u>Zone 4B.</u>

Exceeding the NEPM 2013 HSL A – All forms of asbestos:

- Adjacent to TP-34A
  - Observed at surface

<u>Zone 1A</u>

Exceeding the NEPM 2013 HSL A – FA and AF:

- TP-61_0.2m:
  - - >0.01 %W/W <2mm AF/FA

Zone 5

At or Exceeding the NEPM 2013 HIL D – Commercial Industrial:

- SS-06 (surface) – Adjacent fan house for Kiln 1
  - Lead 4300 mg/kg
- SS-07 (surface) – Adjacent fan house for Kiln 1
  - Lead 1500 mg/kg

Exceeding the NEPM 2013 EILs for commercial industrial soil:

- SS-04 (surface)
  - Zinc 2100 mg/kg
- SS-06 (surface)
  - Lead 4300 mg/kg
  - Zinc 5400 mg/kg
- SS-07 (surface)
  - Zinc 1800 mg/kg

TRH (C_{15} -C_{28} and C_{29} -C_{36}), which was reported in ten (10) samples were below criteria. A maximum concentration of 800 mg/kg was identified in surface sample SS-10.

PAHs were reported in sixteen (16) samples and were below criteria. The maximum concentration was reported in TR-11_0.15m (6.7 mg/kg).

Total phenols were identified in thirty-seven (37) samples and were below criteria. A maximum concentration of 47 mg/kg was reported for sample SS-10.

It is noted that no sediment samples exceeded the relevant analytical criteria for the zone in which they are located.

The above mentioned COPCs have, where relevant, exceeded the Zone 1A, 2, 4B, and 5 land uses. Due to these concentrations, a number of exposure pathways are complete and pose an unacceptable risk to both human health and for the environment. Additional works are required to make these portions of the site suitable for the proposed use.

5.2 Summary of Groundwater and Surface Water Conditions

The COPCs within groundwater, which exceeded relevant Groundwater Acceptance criteria (GAC) are discussed below:

Exceeding the NEPM 2013 freshwater GIL:

- M-2
  - Cadmium 1.3 µg/L
  - Copper 4 µg/L
  - Nickel 20 µg/L
  - Zinc 67 µg/L
- M-3
  - Zinc 21 µg/L
- M-6
  - Nickel 13 µg/L
  - Zinc 18 µg/L
- M-7
  - Nickel 12 µg/L
  - Zinc 8 µg/L

The concentrations of heavy metals identified to date within groundwater across the site are not considered to represent a significant environmental risk. This is due to the concentrations of dissolved metals being considered representative of background concentrations within the screened water unit/s.

Concentrations of all other COPCs (TRH, PAH, OCP, OPP, and PCBs) were below laboratory LORs.

Benzene was identified above LORs from samples collected from wells M-2 and M-7. These concentrations were however, below the adopted GACs for the site. The low levels of benzene in groundwater are therefore not considered to represent a significant health and or environmental risk. However, the source for benzene has not yet been confirmed.

The extent of the groundwater SWLs connectivity across the site is uncertain, and has been measured between 473.31 and 582.86m AHD. Monitoring wells M1 and M8 were identified as not having intersected a water baring unit and were dry.

The most recent groundwater measurements (Table 2-6) identified that the proposed basement depths are unlikely to intersect the groundwater with the exception of the medium density residential developments located at the asbestos dump (zone 2 – north western portion of the site). Perched water between 1.9 and 4.6m bgl (Robson 2014) was measured within the asbestos dump and could potentially intersect the proposed basement of the proposed developments in this area. Furthermore, the groundwater well (MW2) adjacent to the asbestos dump shows groundwater to have been measured at 4.091m TOC (SMEC 2016B). Due to these groundwater levels, there is a potential for future basement users or construction workers to groundwater contamination. Arcadis however notes that no design has been provided for review which stipulate basement depths. The exposure pathway for direct human contact to seepage water is potentially complete yet is considered to pose a low risk to human health with the currently available data.

Arcadis notes that no groundwater monitoring wells have been installed immediately adjacent to or within the brickworks facility, or within the pit area. Therefore, the groundwater assessment to date, within these areas, is considered insufficient and that additional temporal and spatial coverage of groundwater is required.

The scope of additional groundwater assessment is provided in Section 7.4.4.

The COPCs within surface water that exceeded the GAC are discussed below:

Exceeding the NEPM 2013 freshwater GIL:

- W-1
  - Zinc 25 µg/L
- W-3
  - Zinc 22 µg/L

The concentrations of zinc identified in the onsite surface water body, exceeding the adopted GIL for freshwater are not considered to represent a significant environmental risk. This is due to:

- The onsite surface waterbody was observed as being isolated with no immediate receiving sensitive environments (e.g. wetland).
- Concentrations are considered to be representative for the background for the onsite surface water body. It is likely that the identified zinc concentrations are derived from the natural soils of the site.
- The spread of concentrations of zinc within groundwater are generally similar to those within the surface water body.

Concentrations of all other COPCs (TRH, BTEX, PAH, OCP, OPP, and PCBs) were below laboratory LORs.

Based on the proposed development layout the relevant complete exposure pathway to surface water would be through direct contact to surface water. No drinking water guidelines are available for zinc in the ASC NEPM (2013) and it is unlikely that the proposed development will use the surface water as a drinking water resource in the future. The future infrastructure regarding boardwalk or fencing for the surface water body at the site in unknown. The exposure pathway for direct human contact to surface water is potentially complete yet is considered to pose a low risk to human health.

Arcadis does not propose any further surface water assessment.

Locations of monitoring wells are provided in Appendix A, Figure 5, while the location of surface water samples are provided in Figure 7.

5.3 Assessment of the Chemical Degradation Products

Given the identified COPCs and results of historical investigations at the site degradation products are unlikely to pose an unacceptable risk to human health or the environment.

5.4 Assessment of Potential Transport Mechanisms

Transport mechanisms are the manner in which contaminants move away from the source area. Based on the proposed master plan and historical site investigations the following transport mechanism are noted.

Soils:

- Leaching and downwards migration through the soil profile into groundwater is considered potential complete. There is a potential for leaching to occur unless impacted natural soil and fill, proposed to remain onsite, is appropriately handled, disposed of offsite, and or capped. Furthermore, additional assessment is required due to the potential for an unidentified source to exist within unassessed areas of the site.

- Volatilisation of volatile contaminants originating from petroleum hydrocarbons and VOC impacted soil is considered potentially complete. Additional assessment is required due to the potential for an unidentified source to exist within unassessed areas of the site.
- Inhalation of asbestos fibres by onsite construction workers, and future site workers and residents is considered to be a complete pathway. Potential for this to occur unless impacted natural soil and fill, proposed to remain onsite, is appropriately handled, disposed of offsite, and or capped.
- Direct contact with surface and subsurface impacted soils to onsite construction workers, and future site workers and residents is considered to be a complete pathway. Furthermore, additional assessment is required due to the potential for an unidentified source to exist within unassessed areas of the site.

Groundwater:

- Migration of contaminated groundwater from potential up gradient source locations to beneath the site is not considered to be a complete pathway. This is considered unlikely after a review of historical works and land uses surrounding the site.
- Migration of groundwater to down-hydraulic gradient locations is considered a potentially complete pathway. Additional assessment is required due to the potential for an unidentified source to exist at locations previously unassessed.
- Vapours originating from petroleum hydrocarbons and VOC impacted groundwater is considered to be a potentially complete pathway. Additional assessment is required due to the potential for an unidentified source to exist at locations previously unassessed.
- Direct contact (direct or indirect) through extraction of groundwater either on or off-site is considered to be potentially complete pathway. Though considered likely it is considered to pose only a low risk to construction workers and future site residents and worker. Construction workers will be working under a site environmental management plan and basements installed within the north-western portion of Zone 2 will be sealed from seepage water.

Surface water:

- Migration of contaminated surface water from potential up gradient source locations to beneath the site is not considered to be a complete pathway. This process is considered unlikely after a review of historical works and land uses surrounding the site.
- Migration of surface water to down-hydraulic gradient location is not considered to be a complete pathway s. After a review of COPCs in surface water and that the surface water body is isolated with no immediate receiving sensitive environments it is considered to pose a low risk to the environment.
- Direct contact with the surface waterbody is considered to be a potentially complete pathway. However, after a review of COPCs it is considered to pose only a low risk to construction workers and future site residents and worker.

5.5 Assessment of Potential Exposure Routes and Exposed Populations

Exposure routes for soil, surface water, and groundwater contaminants include dermal, ingestion, and inhalation.

Exposed populations may include the following:

- Human: Workers and residents on the site, users of groundwater (actual and potential) in the local area and future site occupants.

- Ecological: plants, micro and macro invertebrates, small reptiles and small mammals.

5.6 Potential Receptors, Exposures, and Pathways

Based on the available background information, site history, site inspection, ESA works and proposed development the following conceptual site model has been developed. The AECs are sections of the site that have potentially been impacted by site activities, site conditions and/or specific features that could present an environmental concern with regards to potential contamination. The AEC and corresponding COPC are presented in Table 5-1 below.

Table 5-1 AECs and Associated COPCs

AEC	Description and Comment	COPCs
1	Sands, dust, surface areas located within site Kilns. This AEC incorporates SMEC (2016A) AEC 1 and 3. This material exceeded for and EIL for commercial/industrial guidelines for lead and zinc. A complete pathway for this material currently exists for: - Leaching to the environment and groundwater.	Heavy metals, PAHs, TRH, BTEX, and Dioxins.
2	Surface soils adjacent fan house for Kiln 1. This AEC incorporates SMEC (2016A) AEC 2. This material exceeded for HIL D and EIL commercial/industrial guidelines for lead and zinc. A complete pathway for this material currently exists for: - Direct contact to construction workers and future site workers. - Leaching to the environment. A potentially complete pathway for this material currently exists for: - Leaching to groundwater.	Heavy metals.
3	Pit area fill. No guidelines have been exceeded with historical samples. However extensive fill has been identified within this location. The extent of fill has not been delineated vertically or horizontally. Potentially complete pathways exist for leaching to the environment and groundwater from fill material.	Heavy metals, TRH, BTEX, PAHs, OCP/OPPs, PCBs, Asbestos.
4	Groundwater below the pit area. Insufficient historical assessment has been performed at this AEC. A potentially complete pathway for this material currently exists for: - Vapours originating from petroleum hydrocarbons and VOC impacted groundwater. - Migration of groundwater to down-hydraulic gradient locations.	Heavy metals, TRH, BTEX, PAHs, PCBs.

AEC	Description and Comment	COPCs
5	Soils below brickworks infrastructure. This AEC incorporates SMEC (2016A) AEC 5, 6. Insufficient historical assessment has been performed at this AEC. A potentially complete pathway for this material currently exists for: - Direct exposure to construction workers. - Leaching to the environment and groundwater. - Vapours originating from petroleum hydrocarbons and VOC impacted soils.	Heavy metals, TRH, BTEX, PAHs, PCBs, Asbestos.
6	Groundwater below brickworks infrastructure. Insufficient historical assessment has been performed at this AEC. A potentially complete pathway for this material currently exists for: - Vapours originating from petroleum hydrocarbons and VOC impacted groundwater. - Migration of groundwater to down-hydraulic gradient locations.	Heavy metals, TRH, BTEX, PAHs, PCBs.
7	UST. This AEC incorporates SMEC (2016A) AEC 7. Insufficient historical assessment has been performed at this AEC. A potentially complete pathway for this material currently exists for: - Direct exposure to construction workers. - Leaching to the environment and groundwater. - Vapours originating from petroleum hydrocarbons and VOC impacted groundwater. - Migration of groundwater to down-hydraulic gradient locations.	Lead, PAHs, TRH, and BTEX.
8	Asbestos dump. A potentially complete pathway for this material currently exists for: - Direct exposure to construction workers, future site workers and residents. - Potential for seepage water to enter basements. - Potential for leaching to groundwater.	Heavy metals, TRH, BTEX, PAHs, OCP/OPPs, PCBs, Asbestos.
9	Fill material. Extensive fill material has been identified across the site. However extensive fill has been identified across the site. Where known impacts have been identified, separate AECs have been nominated (see above). Potentially complete pathways exist for:	Heavy metals, TRH, BTEX, PAHs, OCP/OPPs, PCBs, Asbestos.

AEC	Description and Comment	COPCs
	- Leaching to the environment and groundwater from fill material. - Direct exposure to construction workers, future site workers and residents.	
10	Unassessed Footprints of low to high density residential buildings. Insufficient historical assessment has been performed at this AEC. A potentially complete pathway for this material currently exists for: - Direct exposure to construction workers, future site workers and residents. - Potential for seepage water to enter basements. Potential for leaching to groundwater.	Heavy metals, TRH, BTEX, PAHs, OCP/OPPs, PCBs, Asbestos.
11	Benzene in groundwater (M2 and M7). Temporal and spatial variation of benzene concentrations within groundwater at the site have not been fully assessed. Groundwater will need to be appropriately assessed against the relevant future land use guidelines.	BTEX.

6 DATA GAP ANALYSIS

Based on a review of the previous environmental investigations, the following data gaps were identified:

- Surface soils adjacent fan house for Kiln 1.
  - Extent of lead impact laterally and vertically within location of SS-06 and SS-07. These surface samples were in exceedance of the HIL-D guidelines for Lead and the extent of unacceptable material should be delineated.
- Pit area fill.
  - Vertical and lateral extent of fill material. Since these soils are proposed to be disturbed they will need to be appropriately assessed against the relevant future land use guidelines.
- Groundwater below the Pit area.
  - This area has not previously been assessed for the presence of COPC. Therefore, there is insufficient data with which to assess the suitability for future use.
- Soils below brickworks infrastructure.
  - This area has not previously been assessed for the presence of COPC. Therefore, there is insufficient data with which to assess the suitability for future use.
- Groundwater below brickworks infrastructure.
  - This area has not previously been assessed for the presence of COPC. Therefore, there is insufficient data with which to assess the suitability for future use.
- UST.
  - This area has not previously been assessed for the presence of COPC. Therefore, there is insufficient data with which to assess the suitability for future use.
- Asbestos dump
  - The nature of waste material in the asbestos dump has not yet been fully characterised.
- Unassessed Footprints of low to high density residential buildings.
  - This area has not previously been assessed for the presence of COPC. Therefore, there is insufficient data with which to assess the suitability for future use.
- Benzene in groundwater (M2 and M7).
  - Temporal and spatial variation of benzene concentrations within groundwater at the site have not been fully assessed. Groundwater will need to be appropriately assessed against the relevant future land use guidelines.

7 SAMPLING AND ANALYSIS QUALITY PLAN

7.1 Guidance:

The SAQP has been prepared in accordance with the following current industry best practice guidelines and standards:

- AS 4482.1-2005 Guide to the investigation and sampling of sites with potentially contaminated soil - Non-volatile substances.
- AS 4482.2-1999 Guide to the sampling and investigation of potentially contaminated soil - Volatile substances.
- ASTM D4547 – 15 Standard guide for sampling waste and soils for volatile organic compounds.
- NEPC (2013) National Environment Protection (Assessment of Site Characterisation) Measure.
- NSW EPA (1995) Guidelines for Consultants Reporting on Contaminated Sites.
- AS 5667.11-1998 Water quality - Sampling - Guidance on sampling of groundwaters.
- ASTM D6452 – 99 (2012) Standard guide for purging methods for wells used for groundwater quality investigations.
- ANZECC & ARMCANZ (2000) Australian and New Zealand guidelines for fresh and marine water quality.

7.2 Data Quality Objective

The data quality objectives (DQOs) process is a systematic planning tool based on the scientific method for establishing criteria for data quality and for developing data collection designs. The data quality objectives define the experimental process required to test a hypothesis. The DQO process was developed to ensure that efforts relating to data collection are cost effective, by eliminating unnecessary, duplicative or overly precise data whilst at the same time, ensuring the data collected is of sufficient quality and quantity to support defensible decision making.

It is recognised that the most efficient way to accomplish these goals is to establish criteria for defensible decision making before the data collection begins, and then develop a data collection design based on these criteria. By using the DQO process to plan the investigation effort, the relevant parties can improve the effectiveness, efficiency and defensibility of a decision in a resource and cost effective manner.

DQOs have been developed to detail the type of data that is needed to meet the overall objectives of this project. The DQOs presented in this document have been developed consistent with the following published guidance:

- National Environment Protection Council (1999) National Environmental Protection Measure 1999 as amended 2013 – Assessment of Site Contamination. Schedule B(2) Guideline on Site Characterisation;
- Australia Standards, AS4482.1-2005, Guide to the Investigation and Sampling of Sites with Potentially Contaminated Soil, Part 1: Non-Volatile and Semi-Volatile Compounds;
- Australia Standards, AS4482.2-1999, Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 2: Volatile Substances;
- AS 4482.1-2005 Guide to the investigation and sampling of sites with potentially contaminated soil - Non-volatile substances

- AS 4482.2-1999 Guide to the sampling and investigation of potentially contaminated soil - Volatile substances
- ASTM D4547 – 15 Standard guide for sampling waste and soils for volatile organic compounds
- NSW EPA (1995) Guidelines for Consultants Reporting on Contaminated Sites

The DQO process is a seven-step method to optimise the design of the sampling and analysis plan to ensure that all objectives of the investigation are met. The seven steps are outlined as follows:

- Step 1: State the Problem – concisely describe the problem to be studied. Review prior studies and existing information to gain a sufficient understanding to define the problem.
- Step 2: Identify the Decision – identify what questions the study will attempt to resolve, and what actions may result.
- Step 3: Identify the Inputs to the Decision – identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.
- Step 4: Define the Study Boundaries – specify the time periods and spatial area to which decisions will apply. Determine when and where data should be collected.
- Step 5: Develop a Decision Rule – define the statistical parameter of interest, specify the action level, and integrate the previous DQO outputs into a single statement that describes the logical basis for choosing among alternative actions.
- Step 6: Specify Tolerable Limits on Decision Errors – define the decision maker's tolerable decision error rates based on a consideration of the consequences of making an incorrect decision.
- Step 7: Optimise the Design – evaluate information from the previous steps and generate alternative data collection designs. Choose the most resource-effective design that meets all DQOs.

The DQOs proposed for this project are as follows:

Table 7-1 Data Quality Objectives

Item	Description
State the Problem	Insufficient characterisation of both soil and groundwater conditions has been performed in previous environmental investigations. Therefore, additional soil and groundwater assessment at several locations is required. This further assessment will allow for a statement on the extent of impact and or each areas suitability for future use.
Identify the Decision	The goal of the study is to determine: • The nature and extent (lateral and vertical) of impacts to soil and groundwater on-site. • Any potential unacceptable risks to human health and/or ecological receptors on or off-site. • Is further investigation/management required on-site or off-site to delineation the identified contamination.
Identify the Inputs to the Decision	• Inputs to the decision include: – The conceptual site model. – Current data gaps. – Analytical suite. – Assessment criteria.

	– Data acceptance criteria. – Measurements from the site.
Define the Study Boundaries	The study boundaries will be restricted to: • The cadastral boundary of the site. The study area is shown in Figure 2, Appendix A.
Develop a Decision Rule	Soil and groundwater data will be assessed with respect to the human health and ecological assessment criteria listed in Section 7.3. The requirement for further investigation/management will be triggered based on comparison of the data to the screening criteria adopted. Statistical analysis of the data may be applied in cases where minor exceedance of screening criteria is observed.
Specify Tolerable Limits on Decision Errors	The acceptable limits for samples are as follows: • Data complies with laboratory quality standards. • The following relative percentage difference (RPD) criteria will apply: – RPD of 50 % or less, for concentrations > or = 10 times estimated quantitation limit (EQL). – RPD of 75 % or less, for concentrations between 5 and 10 times the EQL. – RPD of 100 % or less, for concentrations < 5 times EQL. Where acceptable limits for field duplicates are not met, a discussion on low biased error will be provided.
Optimise the Design	The plan for obtaining representative data is provided in Section 7.4.

7.3 Assessment Criteria

Due to differing land uses, as noted within the master plan, at the site the assessment criteria will vary. Zones, identifying these areas a provided below and outlined in Figure 6, Appendix A.

- Zone 1 – Low density residential.
- Zone 2 – Medium density residential.
- Zone 3 – High density residential.
- Zone 4 – Recreational.
- Zone 5 – Commercial.

If the master plan is amended, then the zone locations will be required to be amended. Furthermore, the surveying of each of the above land uses will be require at a later date to ensure the integrity of each zone. The specific assessment criteria for each zone is provided in Table 7-2.

Due to the incomplete understanding of the sites hydraulic nature, the water bearing units, and the potential for preferential pathways between units the groundwater at the site will be assessed against the most conservative proposed land use.

All assessment criteria for the site are summarised and tabled below with additional discussion provided in the following sections.

Soil:

- ASC NEPC (2013):
  - EIL:
    - Urban residential and public open space – generated from data sourced from Robson (2015).
    - Commercial/industrial – generated from data sourced from Robson (2015).
  - ESL (fine soil texture):
    - Urban residential and public open space.
    - Commercial/industrial.
  - Management Limits (MLs) for TPH fractions F1-F4 in soil (fine soil texture):
    - Residential, parkland and public open space.
    - Commercial and industrial.
  - HSLs (Clay):
    - HSL A and HSL B – low to high density residential.
    - HSL C – recreational/open space.
    - HSL D – commercial/industrial.
  - HILs:
    - HIL A – residential – accessible soil.
    - HIL B – residential – minimum soil access.
    - HIL C – recreational.
    - HSL D – commercial/industrial.

Groundwater:

- ASC NEPC (2013):
  - Groundwater Investigation Levels (GILs) – Freshwater.
  - Health Screening levels (HSL-A Clay) for vapour intrusion based on groundwater concentrations for residential land-use with access to soil.
- ACT Department of the Environment, Climate Change, Energy and Water Environmental Guidelines for Services Station Sites and Hydrocarbon Storage, September 2011 (ACT Service Stations).
- ACT Planning and Land Authority (2009) 'Water Use and Catchment General Code' ACT Water Quality Guidelines Regulation – Aquatic habitat – Urban drains and streams (AQUA-4).

Table 7-2 Zone Appropriate Assessment Criteria

Zone	Soil	Groundwater
1 and 2	• EIL - Urban residential and public open space. • ESL - Urban residential and public open space. • MLs -residential, parkland and public open space. • HSL A and HSL B – low to high density residential. • HIL A – residential – accessible soil.	• GILs – Freshwater. • HSL-A Clay • ACT Service Stations. • AQUA-4.
3	• EIL - Urban residential and public open space. • ESL - Urban residential and public open space. • MLs -residential, parkland and public open space. • HSL A and HSL B – low to high density residential. • HIL B – residential – minimum soil access.	
4	• EIL - Urban residential and public open space. • ESL - Urban residential and public open space. • MLs – Commercial and industrial. • HSL C – recreational/open space. • HIL C – recreational.	
5	• EIL – Commercial-Industrial. • ESL - Commercial-Industrial. • MLs -residential, parkland and public open space. • HSL D – commercial/industrial. • HSL D – commercial/industrial.	

7.3.1 Rationale for Selection Soil Assessment Criteria

Both the EIL and ESL (fine grained) guidelines were selected to evaluate the risk of historical practices at and surrounding the site to terrestrial ecosystems within the initial 2m bgl. However, EILs will not be considered relevant where below sealed surfaces (e.g roadways and buildings).

EILs used within this report were generated from data sourced from the Robson (2015) report and are considered suitable for the proposed works. EIL ASC NEPM (2013) toolbox calculations are provided in Appendix B. Arcadis further notes that the EILs will be amended as additional data will be sources as part of additional intrusive investigation.

MLs have been adopted due to AEC 7 at the site, as well as other minor hydrocarbon concentrations in historical soil samples. MLs are used to consider the potential formation of light non aqueous phase liquids, fire and explosion risks and damage to

buried infrastructure. Fine grained soil was selected due to the soil types observed at the site during intrusive works.

Soil concentrations have been assessed against the ASC NEPM (2013) HILs due to the multiple proposed future uses of the site.

Soil concentrations have also been assessed against the HSLs to evaluate the risk posed from vapour intrusion. The ASC NEPM (2013) has generally adopted the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC Care) HSLs for soil with some minor deviations. The soil HSLs are based on depth of impacts, overlying soil type and land use. The selection of HSL A was based on the intended use of the site, the potential receptor/s onsite and the exposure that may be experienced. After a review of subsurface conditions the HSLs for media material will be selected once clay is considered to be the most appropriate for soils identified during intrusive works at the site. Furthermore, the HSLs for the assessment for asbestos has additionally been selected.

Soil analytical results and guideline criteria are provided below in Table 7-3.

Yarralumla Brickworks, ACT
Table 7-3 SACs mg/kg

Analyte	HSL A and B	HSL C	HSL D	HSL Depths	ML - Res	ML - Com	HIL A	HIL B	HIL C	HILD	ESL - Res	ESL - Com	EIL - Res	EIL - Com
Benzene	3	NL	4	0 to <1m	-	-	-	-	-	-	65	95	-	-
	3	NL	6	1m to <2m										
	3	NL	9	2m to <4m										
	3	NL	20	4m+										
Toluene	NL	NL	NL	0 to <1m							105	135		
	NL	NL	NL	1m to <2m										
	NL	NL	NL	2m to <4m										
	NL	NL	NL	4m+										
Ethylbenzene	NL	NL	NL	0 to <1m							125	185		
	NL	NL	NL	1m to <2m										
	NL	NL	NL	2m to <4m										
	NL	NL	NL	4m+										
Xylenes	230	NL	NL	0 to <1m							45	95		
	NL	NL	NL	1m to <2m										
	NL	NL	NL	2m to <4m										
	NL	NL	NL	4m+										
	260	NL	310	0 to <1m	800	800					120	170		

Yarralumla Brickworks, ACT

Analyte	HSL A and B	HSL C	HSL D	HSL Depths	ML - Res	ML - Com	HIL A	HIL B	HIL C	HILD	ESL - Res	ESL - Com	EIL - Res	EIL - Com
F1 (Total TRH C6-C10 less BTEX)	370	NL	480	1m to <2m										
	630	NL	NL	2m to <4m										
	NL	NL	NL	4m+										
F2 (TRH >C10-C16 less Naphthalene)	NL	NL	NL	0 to <1m	1000	1000					120	170		
	NL	NL	NL	1m to <2m										
	NL	NL	NL	2m to <4m										
	NL	NL	NL	4m+										
F3 TRH >C16-C34	-	-	-	-	3500	5000					1300	2500		
F4 TRH >C34-C40	-	-	-	-	10000	10000					5600	6600		
Naphthalene	NL	NL	NL	0 to <1m	-						-		170	370
	NL	NL	NL	1m to <2m										
	NL	NL	NL	2m to <4m										
	NL	NL	NL	4m+										
Arsenic	-						500	500	300	3000	-		100	160
Cadmium							150	150	90	900			-	-
Chromium							500	500	300	3600			380	620
Copper							30,000	30000	17000	240000			380	620
Lead							1200	1200	600	1500			1131	1800
Nickel							1200	1200	1200	6000			170	280
Zinc							60,000	60000	30000	400000			430	650

Yarralumla Brickworks, ACT

Analyte	HSL A and B	HSL C	HSL D	HSL Depths	ML - Res	ML - Com	HIL A	HIL B	HIL C	HILD	ESL - Res	ESL - Com	EIL - Res	EIL - Com
Mercury							120	120	80	730			-	-
Benzo(a)pyrene (BaP TEQ)							4	4	3	40	0.7	0.7	-	-
Total PAH							300	400	300	4000	-		-	
Asbestos % w/w FA and AF*	No visible asbestos at surface. -						-				-		-	
	0.001 to 0.04	0.02	0.05	-										
	0.01%													
DDT	-												180	640

* The screening level of 0.001% w/w asbestos in soil for FA and AF (i.e non-bonded/friable asbestos) only applies where the FA and AF are able to be quantified by gravimetric procedures. This screening level is not appropriate to free fibres. As yet there is no validated method, readily available in Australia, of reliably estimating the concentration of free fibres in soil. Soil contamination by free asbestos fibres should therefore be simply determined according to the presence or absence of fibres, in accordance with AS4964-2004.

7.3.2 Rationale for Selection of Groundwater Assessment Criteria

ASC NEPM (2013) GILs have been selected as an initial screening level as they provide concentrations which once exceeded require further investigation into points of extraction and use. With respect to use of groundwater for human purposes, the site is located within a residential area that has ready access to a potable reticulated water source. As such, the groundwater at the site, and within the immediate region, is considered unlikely to be used for drinking water. Given these factors the drinking water guidelines are not considered to be applicable to the site. The GIL for freshwater aquatic ecosystems are applicable as they apply to typically slightly too moderate disturbed systems, of which the site is located. Furthermore, as an abstraction bore is located approximately 600 to 700m west by south west of the site the GIL for irrigation is not considered to be relevant.

Hydrocarbon concentrations in groundwater (if present) have also been assessed against the HSL to evaluate the risk posed from vapour intrusion. Due to the unknown hydraulic nature the sites water bearing units and the potential for preferential pathways between units groundwater at the site will be assessed against the most conservative proposed land use. After a review of subsurface conditions the HSLs for clay are considered to be the most appropriate for soils at the site.

The ACT Service Station Hydrocarbon Guidelines provide groundwater monitoring guidelines which are relevant to the site as they are designed to achieve appropriate pollution controls to assist sites which have had underground petroleum storage systems. Furthermore, the guidelines provide criteria which once exceeded, state that notification must be provided to the ACT EPA. Due to the presence of a UST at the site this guideline is suitable for assessment.

The site is located within an urban area, the Lower Molonglo catchment and is considered a urban area. After a review of the sites location and likely discharge options, Arcadis believes the most relevant groundwater criteria for the site is Aquatic habitat – Urban drains and streams (AQUA/4). The objectives of the ACT water quality guidelines is to:

- Protect and conserve the water quality of groundwater resources of the Territory.
- Ensure that the stream flow and quality of discharges from the catchment are consistent with the protection of downstream environment values.
- Ensure that water and catchment land uses are consistent with maintaining the predominant drainage function and other values of the catchment.
- Make provision for a range of other non-drainage water uses and environmental values that are compatible with the drainage function of the catchment.
- Make provision for urban, open space and rural drainage as the predominant water use.

The adopted screening levels for groundwater criteria are tabled below in Table 7-4.

Table 7-4 GACs

Analyte	HSL A for Clay mg/L		GIL – Freshwater µg/L	AQUA 4 µg/L	ACT Service Station µg/L
Benzene	5	2 to <4m	950	300	950
	5	4m to <8m			
	5	8+			
Toluene	NL	2 to <4m	-	300	300
	NL	4m to <8m			
	NL	8+			
Ethylbenzene	NL	2 to <4m	-	140	140
	NL	4m to <8m			
	NL	8+			
Xylenes	NL	2 to <4m	200	-	350 (m &P) 200 (o)
	NL	4m to <8m			
	NL	8+			
F1 (Total TRH C_6-C_{10} less BTEX)	NL	2 to <4m	-	-	-
	NL	4m to <8m			
	NL	8+			
F2 (TRH >C_{10}-C_{16} less Naphthalene)	NL	2 to <4m	-	-	-
	NL	4m to <8m			
	NL	8+			
TRH C_{10}-C_{40}	-	-	-	-	600
Naphthalene	NL	2 to <4m	16	-	-
	NL	4m to <8m			
	NL	8+			
Arsenic	-		13	50	-
Cadmium	-		0.2	0.2	-
Chromium	-		1	2	-
Copper	-		1.4	2	-
Lead	-		3.4	1	3.4
Nickel	-		11	25	-
Zinc	-		8	5	-
Mercury	-		0.06	0.1	-
Benzo(a)pyrene (BaP TEQ)	-		-		0.7
Total PAH	-		-	3	-
DDT	-		0.006	0.001	-

7.4 Proposed Sampling and Analytical Program

7.4.1 Overview

This section of the SAQP discusses the sampling and analysis program for the proposed investigation strategy. It has been developed in accordance with the National Environment Protection (Assessment of Site Contamination) Measure 1999 as amended in 2013 (NEPC, 2013), the NSW EPA Sampling Design Guidelines (NSW EPA, 1995) and the Guidelines for Consultants Reporting on Contaminated Sites (OEH, 2011).

The sampling program will be carried out in accordance with technical procedures outlined in this section. To the extent possible all fieldwork will be performed in accordance with the Australian Standard, Guide to the Sampling and Investigation of Potentially Contaminated Soil (AS4482.1/2005).

7.4.2 Pre-Planning

Prior to intrusive works including test pitting and groundwater well installation all locations will be cleared of underground services as follows:

- Prepare occupational health and safety documentation for the proposed investigative works.
- The Dial-Before-You-Dig plans will be reviewed and will be available on site.
- Any available as-built plans will be reviewed and will be available on site.
- An experienced and suitably qualified underground service locator will mobilise to site to mark out the locations of all sub-surface infrastructure.

7.4.3 Soil Investigation

The following soil investigation scope will be performed at the site:

- Engage a suitably qualified and experienced excavation contractor to excavate/drill approximately:
    - Thirty-two (32) test pits/300mm boreholes across previously unassessed areas below proposed residential buildings. Samples would be collected from the surface, 0.5m bgl, 1.0 m bgl and then each metre thereafter until the target depth or at changes in lithology or lenses of contamination.
    - Five (5) test pits/300mm boreholes across the pit area to horizontally and vertically assess fill material. Samples would be collected from the surface, 0.5m bgl, 1.0 m bgl and then each metre thereafter until the target depth or at changes in lithology or lenses of contamination.
    - Three (3) 150mm boreholes across the footprint of the brickworks facility to assess soil conditions. These holes would be converted to groundwater monitoring wells. Samples would be collected from the surface, 0.5m bgl, 1.0 m bgl and then each metre thereafter until the target depth or at changes in lithology or lenses of contamination.
    - Five (5) test pits within the Asbestos Dump area to further characterise the nature of waste material in the dump and provide information regarding the potential bulking factor of this material.
        - As any test pits excavated into the dump area will need to consider the risk of asbestos fibres being released into the atmosphere, a licensed Asbestos Assessor would be engaged to undertake air monitoring for

airborne fibres during the excavation and sampling of test pits. The filter membranes would be analysed by a NATA accredited laboratory in accordance with the NOHSC: 3003 (2005) 'Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Dust'.

- As it is understood that that there is a clean capping layer of soil across the dump, the capping layer would be carefully removed and stockpiled separately before excavating the waste material in the dump. At the completion each test pit, the excavated material would be backfilled in reverse order with the capping material placed on top and track rolled.
- The surface of each test pit after backfilling would be inspected by a licensed asbestos assessor for fragments of ACM.

▪ Six (6) samples collected from within the kilns to assess for lead impacted soils.

- A suitably qualified and experienced environmental scientist would supervise the excavation of each test pit/borehole. Each test pit/borehole would be logged in general accordance with the Universal Soil Classification System (USCS) and samples collected at regular intervals, changes in geology or in zones of gross contamination. The coordinates of each test-pit sample location would recorded with a hand held GPS unit.
- Each test pit/hope hole will be advanced to at least 0.5m into natural material where practicable.
- Soil samples would be sent to a NATA accredited laboratory for analysis. Each sample would be analysed dependant on AEC for select COPCs as identified in Table 5-1 above.
- The COPCs selected for analysis may be subject to variation depending upon the potential risks of these contaminants being present within the sample area.
- Each test pit/borehole, where not being converted into a groundwater monitoring well will be backfilled upon completion and track rolled with the excavator or back hoe.

Sample locations are provided on Figure 8, Appendix A.

7.4.4 Groundwater Investigation

The following groundwater investigation scope will be performed at the site:

- Engage a suitably qualified and experienced drilling contractor to drill and assist with the installation of approximately:
  - Four (4) groundwater monitoring wells converted from boreholes across the footprint of the brickworks facility.
  - One (1) groundwater monitoring well converted from a borehole within the pit area.
- A suitably qualified and experienced environmental scientist would supervise the excavation of each test pit/borehole. Each test pit/borehole would be logged in general accordance with the Universal Soil Classification System (USCS) and samples collected at regular intervals, changes in geology or in zones of gross contamination.
- All five (5) of the bores will be converted to groundwater wells and developed using a stainless-steel bailer.

- A suitably qualified environmental scientist would be mobilised to the site no sooner than five (5) days after development with the appropriate equipment for collecting groundwater samples, using low flow techniques.
- Each monitoring well located on site would be gauged to measure the depth of groundwater beneath the site and allow the calculation of the groundwater flow direction.
- A suitably qualified and experienced surveying contractor will be engaged to survey in all the new monitoring wells.
- Samples would be collected from ten (10) wells across the site.
- Samples would be submitted to a NATA accredited laboratory where each sample would be analysed for:
- Existing monitoring wells (M2 to M7) – Heavy metals and BTEX
- Additional monitoring wells - Heavy metals, TRH, BTEX, PAHs, and PCBs.

Sample locations are provided on Figure 8, Appendix A.

7.5 Sampling Methodologies

7.5.1 Soil Sampling Methodology

The target depth of each test pit would be either 1.0 m bgl or where fill is encountered, the test pit would be terminated at least 0.5 m below the boundary between fill and the natural soil.

Soil samples would be collected at the surface, 0.5 m bgl, 1 m bgl and then each metre thereafter until the target depth or at changes in lithology (e.g. at the interface between capping material and landfill material) or lenses of contamination.

Soil will be removed from each test pit using an excavator or backhoe and sampled by hand from the inside of the bucket. Soil samples will be sampled by hand using new, disposable nitrile gloves.

Part of the soil sample will then be placed into snap lock plastic bags for screening with a Photo-ionisation Detector (PID). The remainder of the sample will be placed directly into a laboratory prepared 250 ml glass jar with the details of the sample, including the sample name, the job number, the date of sampling and the sample depth.

7.5.2 Groundwater Sampling Methodology

Groundwater monitoring wells will be sampled as follows:

- All wells will be gauged for depth to groundwater and depth to the base of the wells with an oil-water interface probe prior to sampling.
- Groundwater will be purged using Low-flow micro purge pumps using HDPE tubing, connected to an in-line flow cell. The in-line flow cell will house probes to measure groundwater physico-chemical parameters including pH, temperature, electrical conductivity, reducing/oxidising potential and dissolved oxygen concentration. Purging will continue at a rate of less than 0.1L/min, the rate will be adjusted to ensure the water level does not fall more than 25% of the initial standing water level.
- Purging will continue until groundwater physico-chemical parameters stabilize to within +/- 10% for three consecutive readings.

- Once the physico-chemical parameters have stabilized groundwater samples will be collected in laboratory supplied and preserved sample bottles. Samples for dissolved metals analysis will be passed through a 0.45 micron in-line filter.

7.5.3 Sampling Handling, Preservation, and Storage

Samples will be collected in accordance with standard operating procedures, based on the NEPM Australian Standard (AS4482.1-2005, AS4482.2-1999) and NSW EPA Requirements.

This will include sample logs to describe the media collected, use of chain of custody procedures, and dispatching samples with appropriate preservation. Samples will be placed in chilled containers, and refrigerated if not dispatched to the laboratory on the day of sampling. All samples will be analysed within holding times.

7.5.4 Decontamination

Where items are reused between sample locations (e.g. interphase ptobes prior to being used at the next sampling location they will be was sprayed with a mix of phosphate free detergent, scrubbed, and rinsed with potable water.

7.6 Analytical Plan

The proposed analytical plan for soil and groundwater samples collected is summarised in Table 7-5 below.

Area	Description	No Primary Samples	Analytes
AEC 1	Kiln Sand inside kilns	6	TRH, BTEX, PAH, Heavy Metals, Dioxins (2 Samples)
AEC 3	Fill in former clay pit	10	Heavy metals, TRH, BTEX, PAHs, OCP/OPPs, PCBs, Asbestos.
AEC 5	Soil beneath Brickworks infrastructure	10	Heavy metals, TRH, BTEX, PAHs, PCBs, Asbestos.
AEC 8	Asbestos Dump	Nil	No sampling Proposed
AEC 10	Infill sampling of low density and high density housing	64	Heavy metals, TRH, BTEX, PAHs, OCP/OPPs, PCBs, Asbestos.
AEC11	Groundwater	10	TRH, BTEX, PAH, Heavy Metals

7.7 Quality Assurance / Quality Control (QA/QC)

For the DQO process, the principal data quality indicators (DQIs) are precision, accuracy, representativeness, comparability and completeness. For completeness,

these DQIs are defined below. Laboratory DQOs are the acceptance thresholds for site data based on the individual DQIs for each matrix and analyte group or analyte:

- Accuracy is a measure of the agreement between an experimental determination and the true values of the parameter being measured.
- Precision is a measure of the agreement between duplicate or replicate samples.
- Representativeness is a measure of how closely the measured results reflect the actual concentration or distribution of the chemical constituent in the matrix sample.
- Comparability is a qualitative assessment made to express the confidence with which one data set may be compared with another.
- Completeness is defined as the percentage of total measurements made that are judged to be valid.

A field QA/QC program must be conducted in accordance with the NEPC (2013) and Australian Standard AS4482.1-2005 requirements to measure the precision of the field and laboratory analyses and to determine the accuracy of the analytical results. All samples will be analysed by NATA accredited laboratories. Field QA will include compliance with appropriate standard operating procedures. QC samples will be undertaken at the frequencies shown below:

Precision

- Field duplicates ≥ 5%
- Inter-laboratory duplicates ≥ 5%
- Laboratory duplicates ≥ 10%

Accuracy

- Surrogate spikes All organics by GC
- Matrix spikes ≥ 1/media type
- Laboratory control samples ≥ 1/lab batch

Representativeness

- Rinsate samples ≥ 1/field batch
- Trip blanks ≥ 1/field batch (volatiles)
- Laboratory blanks ≥ 1/lab batch

The QA/QC program will also include an assessment of comparability and completeness. No additional samples will be collected for these quality attributes, rather their assessment will focus on consideration of relevant field and laboratory factors.

Evaluation of the field DQI compared to the DQOs will be completed as follows:

Documentation completeness:

- Chain-of-custody forms completed and appropriate.

Data completeness:

- All samples received by the laboratories and analytical results reported including laboratory QA/QC.

Data comparability:

- Arcadis standard operating procedures (SOPs), Australian Standards and industry best practice followed during sediment sampling.
- Consistent field conditions and staff used during sampling.

- Standard analytical methods used by the laboratories for all analyses.
- The limits of reporting are appropriate and consistent from each laboratory.

Data representativeness:

- Rinsate samples indicate that decontamination procedures adequate.
- The frequency of laboratory blanks acceptable and the results are within specified ranges.

Precision:

- Field duplicates collected at a minimum rate of 1:20 for soil and groundwater samples. These rates are within the Australian Standard (AS1482.1 1997) and Arcadis' QA frequency ranges.
- Inter-laboratory duplicates collected at the same rate as intra-laboratory duplicates.
- Laboratory duplicates are collected at the expected rate.

Relative percent difference (RPD) between primary samples and complementary field and laboratory duplicates shall be within appropriate limits. Recoveries of laboratory surrogates, spikes and control samples shall be within appropriate limits.

The acceptable limits for sediment are as follows:

- %RPD for laboratory duplicates is less than 60%.
- Recovery of matrix spikes and surrogate spikes is as per the laboratory's Quality Assurance targets accepted under their NATA accreditation.

Precision is measured using the standard deviation 'SD' or Relative Percent Difference '%RPD'. Replicate data for field duplicates of organics is expected to be as follows:

- RPD criteria of 50% or less, for concentrations > or = 10 times PQL.
- RPD criteria of 75% or less, for concentrations between 5 and 10 times the PQL.
- RPD criteria of 100% or less, for concentrations < 5 times PQL.

Where acceptable limits for field duplicates are not met, a discussion on low biased error will be provided.

7.8 Reporting

Preparation of an assessment report detailing the following:

- Investigation and sampling methodology.
- Laboratory and field QA/QC.
- Comparison of soil and water analytical results against assessment criteria adopted for the protection of beneficial uses.
- Figures indicating sample locations.
- Discussion, conclusions and recommendations.

8 REFERENCES

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AS 4482.1-2005 Guide to the investigation and sampling of sites with potentially contaminated soil - Non-volatile substances.

AS 4482.2-1999 Guide to the sampling and investigation of potentially contaminated soil - Volatile substances.

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ASTM D4547 – 15 Standard guide for sampling waste and soils for volatile organic compounds.

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SMEC (2016A) 'Canberra Brickworks: Detailed Environmental and Geotechnical Site Investigation, Canberra Brickworks Precinct, Yarralumla, ACT' (Reference: 3002523).

SMEC (2016B) 'Canberra Brickworks: Groundwater Investigation-Addendum Report, Canberra Brickworks Precinct, Yarralumla, ACT' (Reference 3002523).

9 Limitations

The findings of this report are based on the Scope of Work described in this report. Arcadis Australia Pacific Pty Limited (Arcadis) performed the services in a manner consistent with the level of care and expertise exercised by members of the environmental profession.

No warranties, express or implied, are made. Subject to the Scope of Work, Arcadis' assessment is limited strictly to identifying typical environmental conditions associated with the subject property.

While normal assessments of data reliability have been made, Arcadis assumes no responsibility or liability for errors in any data obtained from regulatory agencies, statements from sources outside of Arcadis, or developments resulting from situations outside the scope of this project

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Information from samples collected by Arcadis personnel relating to soil, water, groundwater, waste, air or other matrix conditions in this document is considered to be accurate at the date of issue. Surface, subsurface and atmospheric conditions can vary across a particular site or region, which cannot be wholly defined by investigation. As a result, it is unlikely that the results and estimations presented in this report will represent the extremes of conditions within the site that may exist. Subsurface conditions including contaminant concentrations can change in a limited period of time and typically have a high level of spatial heterogeneity.

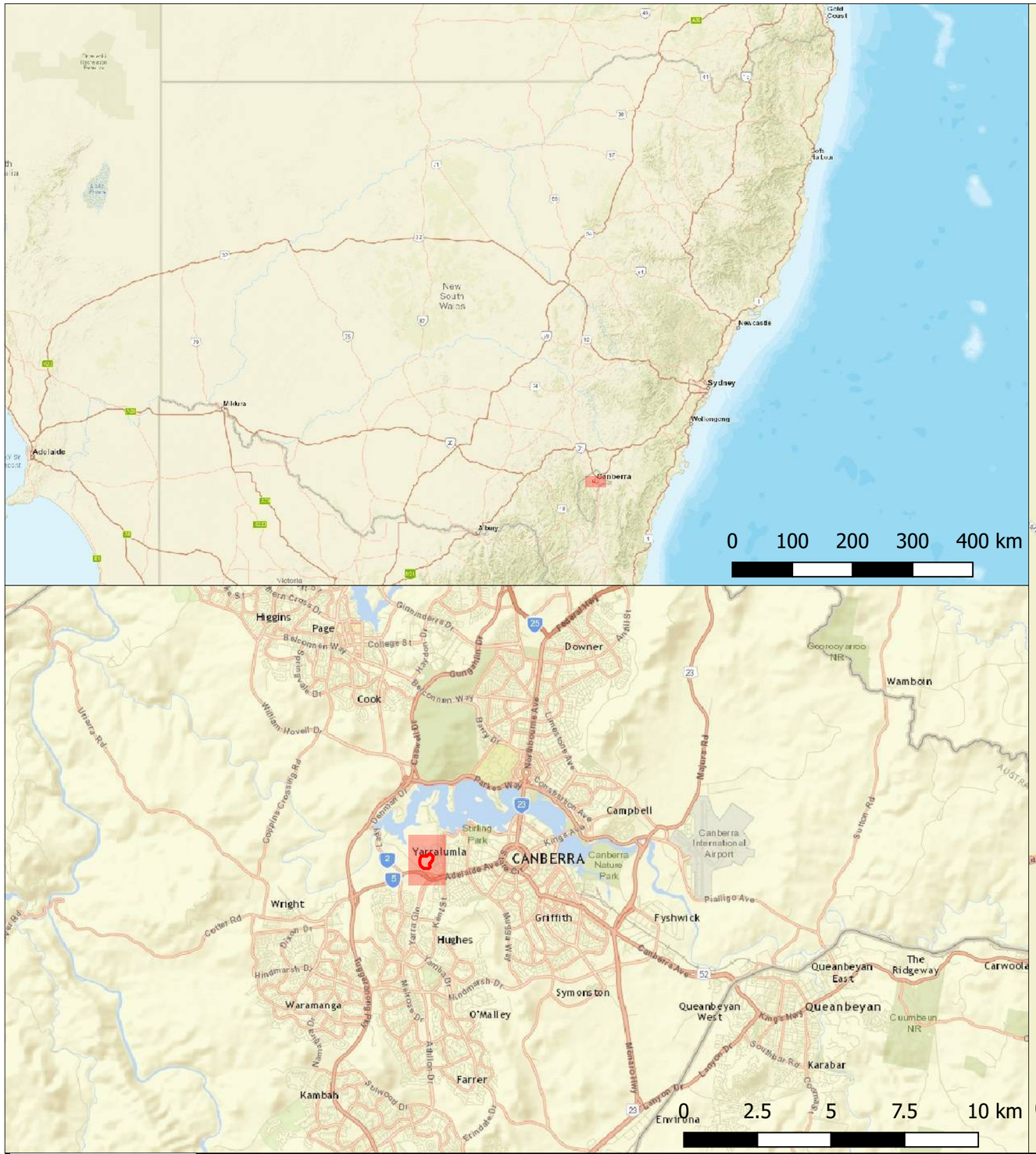
From a technical perspective, there is a high degree of uncertainty associated with the assessment of subsurface, aquatic and atmospheric environments. They are prone to be heterogeneous, complex environments, in which small subsurface features or changes in geologic conditions or other environmental anomalies can have substantial impact on water, air and chemical movement.

Arcadis' professional opinions are based upon its professional judgment, experience, and training. These opinions are also based upon data derived from the limited testing and analysis described in this report. It is possible that additional testing and analysis might produce different results and/or different opinions. Arcadis has limited its investigation(s) to the scope agreed upon with its client.

That standard of care may change and new methods and practices of exploration, testing and analysis may develop in the future, which might produce different results.

APPENDIX A

Figures



Legend

Site Boundary

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User CommunityESRI Street Maps, Near Maps 2017

N

Site Location:
Yarralumla Brickworks, 2600, ACT

17152

Figure 1:
Site Location

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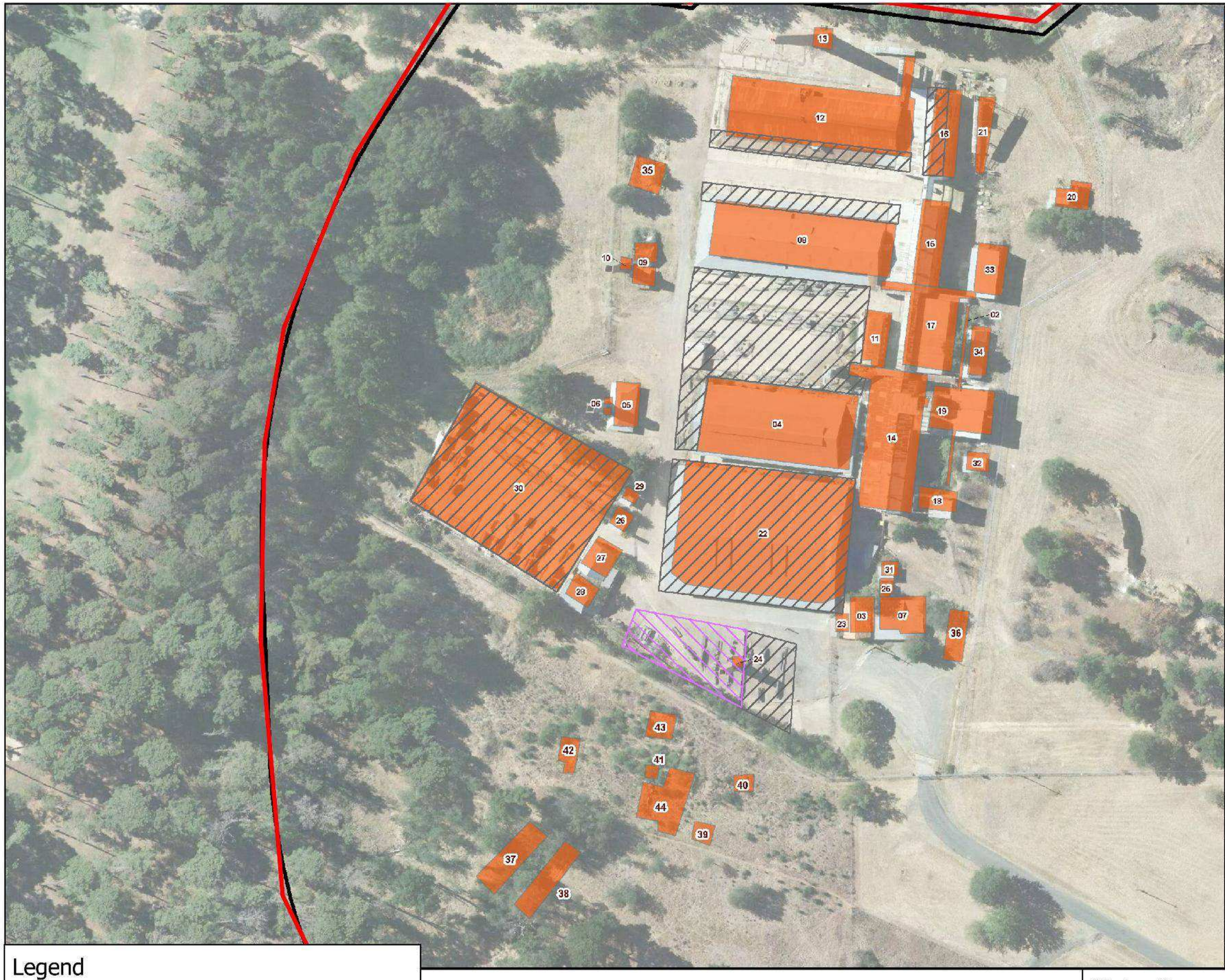

ID	Descriptio
2	Concrete Retaining Wall
3	Pow er House
4	Staffordshire Kiln (Kiln 1)
5	Fan House for Kiln 1 (Fanhouse 1)
6	Chimney Stack for Kiln 1 (Stackhouse 2)
7	Offices
8	Hardy patent Kiln (Kiln 2)
9	Fan House for Kiln 2 (Fanhouse 2)
10	Chimney Stack for Kiln 2 (Stackhouse 3)
11	Amenities Block
12	Hardy Patent Kiln (Kiln 3)
13	Chimney Stack for Kiln 3 (Stackhouse 4)
14	Machine Bay I for Kiln 1
15	Machine Bay II for Kiln 2
16	Machine Bay III for Kiln 3
17	Workshop
18	Small Crusher House (Crusher House 1)
19	Larger Crusher House (White Pan Room / Crusher House II)
20	Primary Crusher House (Crusher House III)
21	Elevator / Conveyor
22	Dow ndraft Kilns (Kiln 4 - 6)
23	Dow ndraft Kiln Control Room
24	Chimney Stack for Kilns 4 - 6 (Stackhouse 1)
25	Toilet Block
26	Amenities Block
27	Substation / Control Room
28	Boiler House
29	Ancillary Storage Building
30	Remnant of Extrusion Plant (Concrete Pad)
31	Ancillary Storage Building
32	Storage Shed
33	Model Railw ay Workshop
34	Model Railw ay Storage Shed
35	Forklight Shed (Former)
36	Weighbridge (Former)
37	Sleeping Quarters 2
38	Sleeping Quarters 2
39	Hut
40	Hut
41	Hut
42	Hut
43	Latrine
44	Kitchen and Mess Hall

Legend

- Site Boundary
- Former Brickwork
- Timber Storage
  - Unsealed Ground Surface
  - Sealed Ground Surface

N

0 25 50 75 100 m

Site Location:
Yarralumla Brickworks, 2600, ACT

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Figure 2:
Site Description

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Legend

- Site Boundary
- Proposed Sampling Locations
- Proposed GW Well
- Proposed Kiln Sample
- Proposed Asbestos Dump Test Pit

N

0 25 50 75 100 m

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User CommunityESRI Street Maps, Near Maps 2017

Site Location:
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Figure 3: Proposed Land Uses

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Legend

- Site Boundary
- Fill Contours (0.4m interval)

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User CommunityESRI Street Maps, Near Maps 2017

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Figure 4:
Fill Contours

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Legend

- SMEC_Monitoring Wells
- Site Boundary

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User CommunityESRI Street Maps, Near Maps 2017

N

0 25 50 75 100 m

Site Location: Yarralumla Brickworks, 2600, ACT	Figure 5: Groundwater Contours
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Legend

- Site Boundary
- Proposed Sampling Locations
- Proposed GW Well
- Proposed Kiln Sample
- Proposed Asbestos Dump Test Pit

N

0 25 50 75 100 m

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User CommunityESRI Street Maps, Near Maps 2017

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Figure 6:
Proposed Sampling Locations

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Legend

- Site Boundary
- SMEC_
  - SMEC_PSI
  - Trench
  - Test Pits
  - Surface Sample
  - Monitoring Wells
- Hand Auger
- Grab Sample
- Bore Holes
- Robsons_
  - Test Pits
  - Transect

N

0 25 50 75 100 m

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User CommunityESRI Street Maps, Near Maps 2017

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Figure 7:
Existing Monitoring Locations

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